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Surface cleaning and preparation: choosing the best option

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Summary

Good surface preparation is essential in the efficient production of high-quality engineering products. However, costs are often higher than expected due to the inefficient use of resources (materials and utilities) and the cost of waste disposal. Stringent legislation (environmental, health and safety) adds to the cost and the complexity.

This Good Practice Guide is intended to help surface engineering and other engineering companies to:

- reduce operating costs, volatile organic compound (VOC) emissions, solvent consumption and waste by improving the management of their pretreatment and surface cleaning processes;
- choose the most appropriate cleaning method for their needs;
- work towards the requirements of the Solvent Emissions Directive and deal with the consequences of the reclassification of trichloroethylene (trike) as a category 2 carcinogen.

Companies can reduce costs, improve working conditions, reduce their impact on the environment and gain a competitive advantage by undertaking a systematic review of the need for cleaning, adopting good practice and selecting the most appropriate cleaning agents and processes. The Guide covers:

- legislative and cost drivers for change;
- how to prevent and reduce waste;
- factors affecting the choice of cleaning method;
- mechanical cleaning;
- organic solvent cleaning;
- aqueous cleaning;
- biological cleaning;
- conversion coating (including combined cleaning and conversion);
- good practice in surface cleaning.

The Guide emphasises the benefits of adopting good practice and improving solvent management before considering alternative cleaning methods. An evaluation matrix is provided to give companies a framework within which to undertake a systematic appraisal of possible changes to their cleaning process.

The industry examples in the pocket at the back of the Guide describe how five companies have achieved cost, environmental and safety benefits from optimising their surface preparation systems.

Contents

Introduction

This Good Practice Guide explains how surface engineering and other engineering companies can save money and improve their environmental performance by implementing cleaner technology and improving their management of pretreatment and surface cleaning processes. Systematically reviewing the need for cleaning, identifying alternative methods of surface preparation and adopting good practice will help companies to reduce their impact on the environment. By describing good practice, the Guide aims to encourage companies to implement new techniques that can save them money and give them a competitive advantage.

1.1 Stricter legislation governing solvent use

Engineering companies use large quantities of organic solvents for cleaning metal components both during manufacture and for maintenance purposes. Some of these solvents have been shown to contribute to ozone depletion in the upper atmosphere and some contribute substantially to volatile organic compound (VOC) emissions to atmosphere. Many are classed as flammable and/or toxic.

In the last five years, solvent consumption for vapour degreasing in the UK has fallen by 35% in response to increasing concerns about health and safety and a desire to reduce costs. *Reducing solvent use for vapour degreasing in the metal finishing industry* (BG334)[1] describes how many companies have implemented simple measures to reduce their solvent consumption, leading to significant cost savings and environmental benefits.

However, new legislative drivers are forcing companies to implement stricter controls on solvent use and to consider the upgrading/replacement of traditional vapour degreasing plant.

- The **Solvent Emissions Directive** (SED), which is being incorporated into UK legislation, specifies stricter VOC emission limits. The Directive covers any surface cleaning activity using more than 1 tonne/year of a VOC classed as a carcinogen, mutagen or as toxic to reproduction, and any halogenated VOCs with possible irreversible effects. The Directive also covers any activity using more than 2 tonnes/year of any other VOC. Under the Directive, companies will be required to reduce solvent consumption, or reduce the solvent content of cleaning materials to below stated thresholds, or meet emission limits for waste gases and fugitive emissions. Process authorisations will be revised to take account of the Directive's additional requirements. New activities, new abatement equipment and substantial changes to existing activities will have to meet the requirements immediately. Existing activities need to meet the requirements for risk phrase compounds within the shortest possible time. Other existing authorised activities have until 31 October 2007.
- **Reclassification of trichloroethylene as a category 2 carcinogen** by the European Union in June 2001[2] means that this solvent (commonly known as trike) will automatically be treated as a carcinogen under the Control of Substances Hazardous to Health (COSHH) Regulations and the SED. Under COSHH, companies will be required to introduce tighter controls to reduce workers' exposure to trike. Companies will also be encouraged to use alternative solvents (thus eliminating the need to use trike altogether), provided this reduces the overall risk to health, safety and the environment.

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1 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

2 Trichloroethylene was previously classed as a category 3 carcinogen.

These legislative changes will force companies to minimise emissions from degreasing operations. The first step is to adopt best practice and then review cleaning strategies.

The Health and Safety Executive's Engineering Information Sheet No 34 *Surface cleaning: solvent update including the reclassification of trichloroethylene*[3] gives basic advice on proposed changes affecting heath, safety and environmental controls on the use of solvents (particularly halogenated solvents). See appendix 1 of this Guide for a summary of key existing legislation and future developments.

For the latest advice on environmental legislation affecting your operations, contact the Environment and Energy Helpline on freephone 0800 585794 (www.envirowise.gov.uk). For information on health and safety issues, phone the HSE InfoLine on 08701 545500 (www.hse.gov.uk).

1.2 Resource management

Changes to surface cleaning practices and processes will enable companies to achieve cost savings and improve their environmental performance. By optimising their cleaning processes, companies from all sectors of the surface engineering and engineering industry can:

- achieve significant cost savings;
- improve efficiency;
- eliminate waste at source.

This approach to eliminating and minimising waste is often referred to as waste minimisation, but resource efficiency is a more accurate description. A systematic approach to waste minimisation (see section 2) involves identifying resource use at the process level.

1.3 Scope of this Guide

This Guide updates and replaces *Vapour degreasing* (GG15) and *Cost-effective paint and powder coating: surface preparation* (GG51), published by the then Environmental Technology Best Practice Programme (now Envirowise) in 1996 and 1997 respectively. GG15 and GG51 focused on vapour degreasing and provided only an overview of alternative cleaning technologies. This Guide describes best practice and provides more detailed information on the various methods of surface preparation.

The surface engineering industry covers a wide range of processes dealing with the treatment and coating of metal surfaces including electroplating, anodising, phosphating, galvanising, thermal spraying, heat treatment, painting and powder coating. Most of these processes relate to the finishing operations that treat metal components to prevent corrosion and degradation, as well as improving their aesthetic appearance. However, this Guide covers surface pretreatment and surface cleaning only - it does not cover finishing (galvanising, painting, powder coating, etc).

Surface preparation to remove grease, oil, contamination and rust prior to machining and finishing is essential to ensure that metals are clean and adequately prepared for subsequent working. This Guide is, therefore, relevant to any company that carries out any of the following processes either before component manufacture or as a core part of its business activity:

[3] Available from HSE Books, Tel: 01787 881165 (www.hsebooks.co.uk).

- mechanical surface preparation, eg sanding and blasting;
- solvent cleaning;
- aqueous cleaning;
- biological cleaning;
- conversion coating;
- combined cleaning and conversion.

1.3.1 Guide structure

Section 2 explains how waste minimisation can be used to make immediate savings from simple measures to eliminate and reduce the need for cleaning. The main advantages and disadvantages of the four main cleaning methods and the factors affecting their cost are summarised in section 3.

Descriptions and advice on best practice for the four main cleaning options are given in colour-coded sections as follows:

- section 4 - mechanical cleaning;
- section 5 - organic solvent cleaning;
- section 6 - aqueous cleaning;
- section 7 - biological cleaning.

Best practice for conversion coating is described in section 8, while section 9 presents an action plan and a framework for evaluating options for change.

The industry examples in the pocket at the back of the Guide illustrate the cost savings and other benefits achieved by five companies that have optimised their pretreatment and cleaning operations.

Preventing and reducing waste

Engineering companies can achieve significant cost savings without the need for major investment by:

- identifying how and why wastes are arising;
- taking into account the true cost of waste;
- adopting simple no-cost and low-cost measures to prevent, reduce, re-use and recycle waste and thus move up the resource management hierarchy (see Fig 1).

Reducing solvent use for vapour degreasing in the metal finishing industry (BG334)[4] describes the changes in the patterns of solvent use since 1996 and the various ways in which companies have reduced solvent consumption.

Your company may be faced with the decision to invest in cleaner technology, eg switching from solvent degreasing. Section 3 introduces the range of cleaning techniques available and summarises their main advantages and disadvantages. Section 9 contains a simple framework to help you evaluate possible cleaning options for your company. The industry examples in the pocket at the back of the Guide describe the changes made by five surface engineering companies.

To reduce solvent waste and costs, start by improving your solvent management and then think about alternative cleaning methods (see sections 4 - 8).

2.1 Sources of waste

Good surface preparation is essential to obtain a quality finish with a long service life. However, surface preparation is often overlooked when upgrading processes. Traditional methods may work well, but their true cost is often higher than expected if waste disposal and utility (gas, electricity and water) costs are taken into account.

Wastes that arise during surface preparation include:

- spent surface preparation agents, eg worn-out brushes, contaminated solvents and spent acid;
- solutions and spent blasting media;
- direct loss of surface preparation agents from the process, eg solvent losses from degreasers and the loss to drain of metallic compounds from conversion baths;
- inefficient or excessive use of water in rinse baths and in cooling process tanks;
- poor quality work giving rise to the need for rework;
- energy losses during the heating of process tanks;
- overuse and leaks of compressed air used for agitating baths and with air knives;
- wasted effort.

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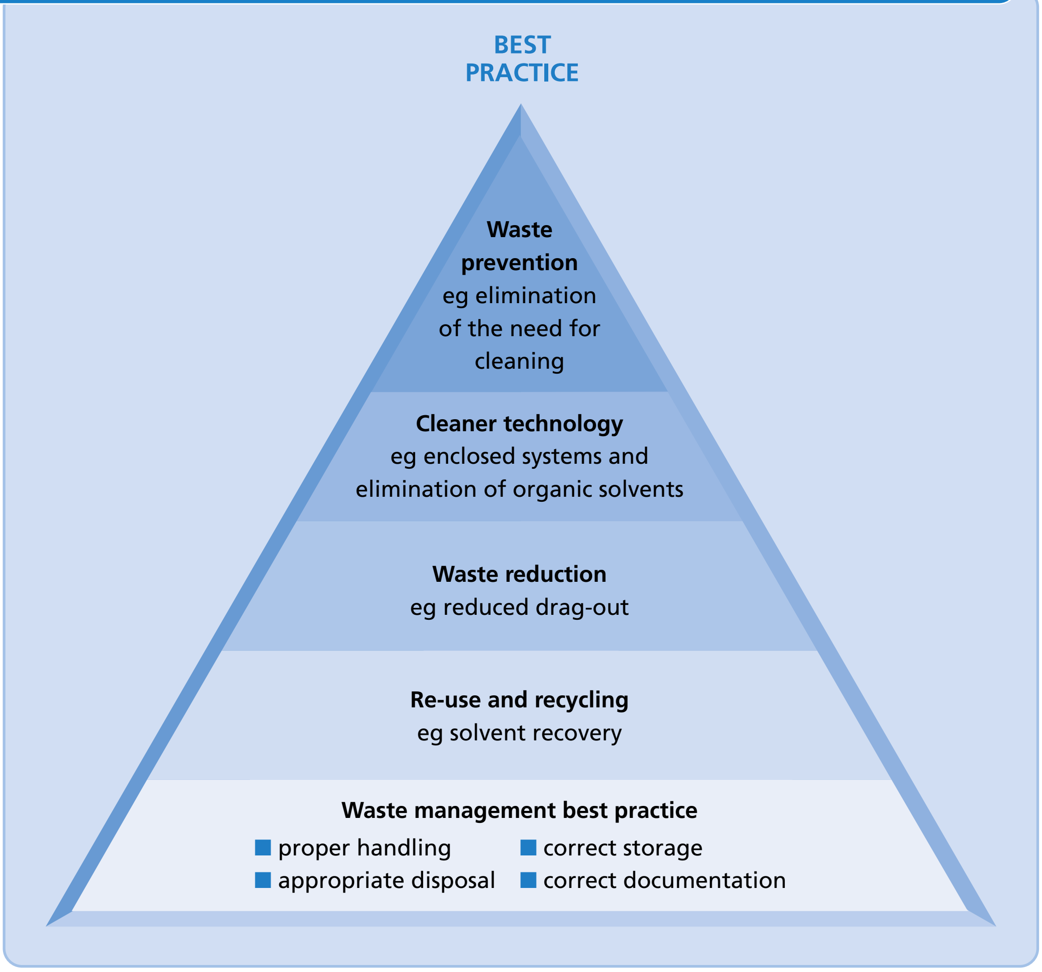
4 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

2.2 Cost savings from moving up the waste hierarchy

Extensive use of vapour degreasing over many years may lead operators to assume that 'nothing else will do' and that existing practices cannot be improved. Although this assumption may sometimes be true, it is always worth examining.

The hierarchy shown in Fig 1 provides a framework to help companies make better use of resources and reduce waste.

Fig 1 Resource management hierarchy as applicable to pretreatment and surface cleaning



Waste minimisation is based upon a systematic approach to resource management as shown in Fig 1. The aim is to move up the hierarchy to:

- reduce the amount of waste generated;
- increase the efficiency of operations through improved process controls;
- make the greatest cost savings.

The true cost of waste is not just the cost of waste disposal, but also the cost of the resources, time and overheads going into the wasted material. For example, moving to an enclosed system will enable a company to reduce its VOC emissions and save the value of the raw material that used to evaporate from its open tanks. If the company can eliminate the use of the organic solvents giving rise to these VOC emissions by moving to aqueous-based cleaning systems, there may be substantial savings due to:

- the use of cheaper raw materials;

- reduced waste disposal costs;
- reduced management time in ensuring compliance with health, safety and environmental legislation.

2.3 Waste prevention: eliminating the need for cleaning

Components are cleaned to remove substances on their surface which are detrimental or harmful to:

- subsequent coating or assembly operations;
- performance in service;
- people handling the parts.

A variety of substances or soils are removed by surface cleaning including:

- oils, greases and waxes;
- some lacquers, paints and dyes;
- particulate matter and metallic swarf.

Surface cleaning can fulfil these tasks well; the equipment is simple to operate, compact and can be efficient in its use of materials and energy. However, regulations are increasing the cost of some aspects of the process. This not only increases the importance of good practice, but may also make alternative cleaning processes more attractive.

Waste prevention is the first priority. There are material, energy, waste disposal and labour costs associated with all cleaning methods. Any opportunity to reduce the amount of cleaning or even eliminate it - without compromising product quality - will reduce costs.

Prevent waste by considering:

- changes to working methods to eliminate the need to clean between processes;
- improvements to handling procedures to prevent soiling between operations;
- application of a temporary protective coating (with the aim of avoiding subsequent cleaning);
- use of sealed containers (to control the air in contact with the components);
- use of absorbents such as silica gel to remove moisture (thus preventing corrosion occurring);
- protection of components between operations by wrapping them in VPI paper;
- impregnation with chemicals such as amines;
- prevention of unauthorised cleaning.

The need for surface preparation can be eliminated or minimised by looking at the reasons why the process is used and addressing each reason in turn.

- Reducing the length of time taken for surface preparation and improving stock handling conditions can:
  - reduce the amount of surface preparation required;
  - prolong the life of surface treatment agents;
  - remove the need for a particular surface treatment agent.

- Keeping items clean and in a dry atmosphere both during and after manufacture may eliminate the need to degrease and/or shot blast before coating.
- Discussions with suppliers about component specifications and the use of alternative ways of protecting metals other than with oils and greases may eliminate the need to undertake pretreatment in the first place.

2.4 Cleaner technology

Cleaner technology[5] options are mainly related to substituting hazardous substances with less hazardous substances, eg replacing trike with less hazardous solvents, biocleaners or aqueous cleaning.

Several alternative materials and techniques for surface preparation have been developed in response to regulatory pressures relating to the use of certain surface preparation chemicals, eg chlorinated solvents used for degreasing. These materials and techniques are described in later sections of this Guide.

When comparing your current system with alternative methods, do not forget to take the cost of rework and customer returns into account. Section 9 contains a framework to help you evaluate possible options for change.

2.5 Waste reduction

Reducing the need to clean is the next priority. Avoid excessive cleaning by:

- Spinning-off excess oil prior to degreasing.
- Talking to component manufacturers about the level of protective greasing needed during shipping. Over-greasing necessitates greater cleaning and results in higher costs. Better communication with manufacturers can help to save both time and money.

Even if you are not considering changing the materials or methods used for surface preparation, you may still be able to identify ways of improving efficiency and, hence, reduce costs.

While waste is often inevitable, the amount can generally be reduced. Examples of waste reduction include:

- optimising processes to increase yield;
- increasing transfer time to reduce drag-out;
- lower solution concentrations (thus reducing the quantity of raw materials required);
- avoiding rework;
- using countercurrent rinsing[6].

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5 *Cleaner technology: an essential guide for industry* (GG288) provides an overview of cleaner technology in general. Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

6 See *Minimising chemical and water waste in the metal finishing industry* (GG160), available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

2.6 Re-use and recycling

Waste can be minimised through the re-use of raw materials in the cleaning process, eg:

- water used to cool trike can be re-used in rinsing processes;
- re-use of dry blast media for mechanical cleaning.

Recycling is the next best option when considering ways to optimise the performance of existing plant. Examples include:

- using spent alkaline cleaners to adjust the pH of acidic wastewaters prior to treatment;
- recovering spent solvent;
- using treated cleaning water on-site.

Practical advice from Envirowise

For practical advice on minimising waste, see the following free publications from Envirowise:

- *Minimising chemical and water waste in the metal finishing industry* (GG160)
- *Cost-effective solvent management* (GG13)
- *Good housekeeping measures for solvents* (GG28)
- *Support for the engineering industry* (EN335)

Free, confidential on-site waste reviews (called *Fast*Track visits) from independent Envirowise advisors are available to companies with fewer than 250 employees. To find out more, contact the Environment and Energy Helpline on freephone 0800 585794 or visit the Envirowise website (www.envirowise.gov.uk).

Factors affecting the choice of cleaning method

Once cleaning has been avoided or minimised wherever possible, residual contamination can be removed by a variety of methods. The choice of a particular application depends on a number of factors, including:

- cost;
- the amount and type of contamination to be removed;
- the materials to be cleaned;
- product specifications;
- subsequent finishing operations;
- space constraints;
- the existence of waste or effluent treatment facilities;
- health and safety issues.

Selection of the most appropriate cleaning technology is a complex process, which varies for different types of component, contamination and operational setting. Where a number of components require cleaning, it is necessary to balance the benefits and costs of selecting a more flexible cleaning process against a need for multiple dedicated processes.

Table 1 overleaf summarises the main advantages and disadvantages for each of the main methods reviewed in this Guide. These four methods are considered in sections 4 - 7. Another option, conversion coating, is described in section 8.

Table 1 Main advantages and disadvantages of principal cleaning techniques

Cleaning method	Advantages	Disadvantages	Section
Mechanical	■ Low cost, particularly if using brushes rather than fully enclosed systems. ■ May avoid the need for solvents.	■ Only line-of-sight is cleaned. ■ Waste disposal costs may be high. ■ Difficult to re-use media when removing oil or grease. ■ May affect the component surface.	4
Organic solvent	■ Effective at dissolving oils and greases. ■ All parts of the component are cleaned. ■ Load is dry on leaving plant.	■ Risks to health, safety and the environment. ■ Governed by strict legislation. ■ Special waste generated, which is expensive to dispose of. ■ Solvent losses may occur through evaporation. ■ Plant needs to be maintained and cleaned regularly.	5
Aqueous	■ Lower operating costs than vapour degreasing. ■ All parts of the component are cleaned. ■ Water can often be re-used or recycled. ■ Less hazardous to human health and the environment than organic solvent cleaning.	■ Effluent treatment costs may be high. ■ Components may be wet and require drying on completion. This may increase costs. ■ Certain chemicals may corrode machinery and components.	6
Biological	■ Low operating temperature means lower operating costs than vapour degreasing. ■ All parts of the component are cleaned. ■ Solution can be disposed of directly to sewer. ■ Biological surfactants, which make use of micro-organisms, do not need replacing. ■ Less hazardous to human health and the environment than organic solvent cleaning.	■ Only suitable for hydrocarbon contamination. ■ May take longer than traditional degreasing techniques. ■ Enzyme cleaners require replenishing. ■ Components may be wet and require drying on completion. This may increase costs.	7

3.1 Capital and operating costs

Possible costs to be considered when comparing different cleaning methods are summarised in Table 2.

Table 2 Cost items for surface pretreatment and cleaning

Category	Typical cost items
Capital	Cleaning system (eg tanks) and control unit
Installation	Labour (depends on the size and complexity of the plant)
Operational	Labour Consumables
Maintenance	Labour Consumables
Raw materials	Cleaning media, eg solvents, water and detergents
Energy	Electricity/gas/fuel oil
Waste management	Solid waste disposal Wastewater discharge Special waste disposal Effluent treatment and sludge disposal
Regulatory	Permits, authorisations and consents as required

The costs in Table 2 are direct costs for standard plant. Costs may be higher for customised plant, eg additional ultrasonic cleaning equipment.

Indirect additional costs, which also need to be taken into account when considering new plant or equipment, include:

- reliability;
- manufacturing yield;
- training;
- emissions monitoring;
- management time dealing with technical and/or regulatory issues.

3.2 Opportunities for savings

Maximum savings are obtained by eliminating the need for surface cleaning, eg through re-specification of the product with alternative surface protection.

However, you can achieve significant savings through improved practices with existing systems, eg waste reduction, recycling and resource re-use (see section 2).

Changes to your process, eg moving from open-top to closed-top degreasing, will probably require capital investment. However, as part of the decision-making process it is important to determine the lowest cost option by identifying the costs and savings associated with different techniques. Table 3 overleaf lists some typical potential cost reductions with the different cleaning methods featured in this Guide.

Table 3 Typical savings opportunities for different cleaning processes

Cleaning process	Potential saving opportunities
Mechanical	Recycling of blast medium and reduced consumption of water/detergents/solvent
Enclosed degreasing	Reduced solvent consumption compared with open-top degreasing
	Reduced energy use for heating solvent tank
	Increased production efficiency
Aqueous	Reduced solvent consumption
Biological	Reduced energy consumption
	Reduced special waste disposal costs

A framework for evaluating possible cleaning options is provided in section 9. More detailed advice on financial appraisal is given in *Investing to increase profits and reduce wastes* (GG82)[7].

3.3 Implementing change

When changing or improving your process, the first step is to identify:

- what is required from the system in terms of surface finish quality for subsequent operations;
- the true costs of running existing equipment.

Improvements to the surface preparation process can be divided into:

- changing the material(s) used for surface preparation, eg ‘drop-in’ alternatives;
- introducing a new preparation technique - this may include a change of material.

The different surface preparation methods described in this Guide are not suitable for all situations. When deciding which method is best for your particular application, it is important to consider:

- the character of the part, eg size, shape and composition;
- the nature of the contamination, eg oil, grease, scale or swarf;
- the subsequent coating process;
- the finish quality requirements.

Before making a final decision, ask suppliers of the different technologies to carry out trials on components used in your processes. Try to have trials performed using typical components and the heaviest normal contamination. You may also find it helpful to talk to users of similar systems to obtain their views on how well the system works and to discuss any problems. Check which product may be subject to reclassification in future.

[7] Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

Enclosed degreasing plant reduces trike consumption by over 50%

Pendle Polymer Engineering produces rubber-metal bonded components whose reliability depends on the strength of the rubber-metal bond. Cleaning of the metal parts prior to the bonding process is, therefore, critical and vapour degreasing is seen as the only option capable of guaranteeing a sufficiently high quality finish. To improve working conditions and reduce the company's impact on the environment, Pendle Polymer Engineering installed an enclosed vapour degreasing plant in place of its elderly open top degreaser. Trike consumption has fallen by over 50% despite a doubling of throughput since the enclosed plant was installed.

For more details, see the industry example in the back pocket of the Guide.

Mechanical cleaning

Abrasive cleaning is often used to:

- remove oil, swarf, grease and rust from metallic surfaces;
- provide a good surface for paint adhesion.

The main waste produced by mechanical treatments is spent abrasive. However, inadequate cleaning leads to rework, which wastes both time and materials.

A variety of mechanical treatment techniques are available ranging from simple brushing to shot blasting.

4.1 Brushing

This is an effective technique for removing scale, rust, paint and other tightly adhering contaminants. It is not suitable for removing fluids.

The final finish is determined by the quality and cleanliness of the brushes.

- Knock, scrape or wash brushes regularly to remove built-up materials.

4.2 Blasting

Blast cleaning relies on the mechanical forces obtained by directing and 'blasting' a suitable medium towards the surface to remove the surface coating/contamination and thus clean it. Blasting can be wet (where the medium is propelled within a water jet) or dry (where the medium is propelled without water).

The choice of blast medium and cleaning method depends on:

- the nature of the coating being removed;
- the material of the component being cleaned.

Most blasting systems have a closed circuit and thus allow the abrasive medium to be re-used. They range in size from blast cabinets to whole rooms designed for treating larger surfaces.

The line-of-sight nature of blast cleaning means that only those surfaces that can be impacted by the blast spray are cleaned effectively. This restricts the extent to which blasting can be used to clean components with blind holes and spaces.

Abrasive cleaning reduces the need to use solvent cleaners for some processes. However, it generates solid or aqueous wastes that are contaminated with the removed surface coating. This waste must be managed effectively.

The range of blasting techniques are summarised in Table 4, together with their advantages and disadvantages.

Table 4 Blast cleaning methods: applicability, advantages and disadvantages

Process	General comments	Applicability/advantages	Disadvantages
Dry blasting	Most shot blasting systems can use a range of materials. Traditional abrasives include: ■ metal particles; ■ plastic pellets; ■ organic substances such as crushed walnut shells. Use of sand or materials containing free silica is not permitted for shot blasting. Abrasive cleaning processes have been developed that use: ■ carbon dioxide pellets which evaporate leaving only the contaminant to be disposed of; ■ wheat starch which can be disposed of by incineration; ■ sodium bicarbonate which leaves an aqueous effluent.	■ Applications range from particulate removal to deburring and removing cured paints and rust or oxides. ■ Blasting is usually the preferred method for removing heavy scale and paint from large surfaces. ■ It can also be used to remove heavy coatings from hard components.	■ Re-use of the blast medium is difficult when used to remove grease or oil as blasting merely projects the contamination back to the surface together with the medium. ■ For some components, the impact from the blasting medium can affect surface texture or the shape of thin parts.

Table 4 Blast cleaning methods: applicability, advantages and disadvantages (continued)

Process	General comments	Applicability/advantages	Disadvantages
Wet blasting	Uses compressed air to blast media in a liquid suspension (slurry) onto the surface to be cleaned. The medium generally has a small diameter to ensure effective suspension. Thickeners are sometimes used to allow heavier medium to be suspended.	■ Removes a wider range of coatings than dry systems. ■ Can be used prior to dry blasting to remove oils and greases (to avoid fouling the blast medium and thus making it difficult to recycle). ■ Some components may require liquid cleaning after using some abrasive media. This is because residues from the media may cause corrosion.	■ Generates wastewater that requires disposal.
Air blasting	Two methods are used: ■ suction; ■ pressure.	■ Best suited for use with lighter media that respond well to air acceleration.	■ Tends not to be used with heavy media.
Wheel blasting	Uses a bladed wheel revolving at high speeds to deliver the medium to the surface being blasted. The medium is delivered to the wheel where it is accelerated centrifugally toward the surface.	■ Can operate with almost any type of medium, but is more efficient when using heavy media and shot.	■ Tends not to be used with lighter media.

4.3 Mechanical cleaning good practice

- **Improvements to existing plant.** Where possible, replace silica and silicate materials with synthetic materials based on aluminium oxide.

- **Waste minimisation and cleaner technology.** Preventing the need for cleaning reduces the need for mass mechanical cleaning of components.

  - Consider use of modern manufacturing techniques.

  - Identify the root causes of rust or other surface contamination and then implement measures that prevent the contamination in the first place. If necessary, talk to your supplier or customer.

- **Re-use and recycling.** Remove dust and contaminants from dry blast media using filters or a cyclone. The media can then be re-used several times.

  The use of cyclones enables blast media to be sorted so that the fine 'spent' fraction is removed and only particles of the correct size are used. This provides a more consistent cleaning action.

  An extraction system removes and filters dust-laden air from the blast cabinet; undersized particles are collected in a dust collector bin, which can be removed for emptying.

  A cyclone reclamator improves and maintains process conditions by separating fractured media and dust from re-usable media, which are then recirculated.

- **Waste disposal.** Disposal options for waste media depend on the types of contaminant present. Ensure that the waste is disposed of responsibly (it is usually special waste) and that the appropriate consignment notes are retained for a minimum of three years. A discharge consent may be required for your effluent.

Organic solvent cleaning

Chemical cleaning agents break down the contamination (soil) or coating through a number of processes (see Table 5).

Table 5 Action of chemical cleaning agents

Process	Purpose
Solvency	Dissolves and removes the contamination or coating.
Detergency	Facilitates the wetting of the component surface and washing off the contamination or coating.
Chemical action	Acidic or alkaline chemicals can be used to break down contamination or coatings.

To enhance their cleaning action, chemical cleaners are normally applied using an active process involving heat, physical agitation, spraying or ultrasonics.

The two main groups of chemical cleaners are:

- solvent-based cleaners;
- aqueous cleaners.

Co-solvent cleaners (emulsions of solvents in water) are used for some cleaning processes.

5.1 Cleaning technologies

Solvent cleaners are effective in dissolving and removing organic materials such as oils and grease, or other contaminants that are soluble in the given solvent. The choice of solvent is critical and depends on the type of contamination and compatibility with the component material.

Solvent-based cleaning can be carried out using a range or combination of process types, including:

- vapour degreasing;
- immersion cleaning;
- spray cleaning;
- ultrasonic cleaning.

These cleaning processes can be carried out in open baths, semi-open baths or in closed plant. Table 6 shows the range of technologies applicable to chemical cleaning.

Table 6 Solvent-based surface cleaning methods: applicability, advantages and disadvantages

Process	Applicability	Advantages	Disadvantages	Comments
Wipe cleaning	■ Spot cleaning or occasional use.	■ Reduces solvent use when used to clean small areas of a large item instead of cleaning the whole item, eg when finishing off an item that has already been cleaned.	■ Tends to generate more waste per unit area cleaned than other processes. ■ Cloth becomes loaded with the cleaning chemical and contaminant, and has to be changed frequently.	■ Possible health or fire risks. Precautions depend on the solvent used. ■ High exposures can occur if ventilation is inadequate.
Vapour degreasing	■ Virtually any cleaning/ degreasing application.	■ Proven technique. ■ Load is dry when it leaves the plant and free from residual surface contamination. ■ Solvents used are non-flammable.	■ Numerous potential sources of waste and solvent loss. ■ Tends to use trike and other hazardous solvents.	■ Subject to increased regulation.
Conveyorised tunnel systems	■ Degreasing agent is sprayed onto parts suspended on jigs or flight bars.	■ Economic in medium to high-volume coating operations.	■ Careful design needed to avoid solvent losses.	
Immersion cleaning	■ Effective in removing soluble fluids and contaminants.	■ Least aggressive form of wet cleaning. ■ Solvent losses from dip baths due to evaporation can be lower than from some vapour-phase degreasers.	■ Immersion tanks can become heavily loaded with contaminants in a short time.	■ Separation and filtration systems may help if contaminant loads are high. ■ A pre-wash station can increase the time between solution changes. ■ Suitable for use with some of the newer cleaning materials. ■ Consider using alternatives to chlorinated solvents.

Table 6 Solvent-based surface cleaning methods: applicability, advantages and disadvantages (continued)

Process	Applicability	Advantages	Disadvantages	Comments
Ultrasonic cleaning	■ Effective in removing many contaminants.	■ Relatively cheap and effective. ■ All sides of the submerged parts are cleaned.	■ Can cause erosion of the metal surface.	■ Initial trials should be performed to check for possible erosion. ■ Aqueous or organic systems can be used. ■ Can be retrofitted to existing tanks.
Megasonic cleaning	■ Line-of-sight operation.	■ Less danger of surface damage and erosion than ultrasonic cleaning.	■ Not as aggressive as ultrasonic cleaning.	■ Contaminant removal depends on the solution chemistry in the tank.
Spray cleaning (high pressure)	■ Line-of-sight process.	■ Applicable to many contaminants, but particularly to removing particles.		■ Proper safety precautions (eg fire suppression systems or inert gas blanketing) must be available when flammable or combustible liquids are used. ■ High pressure spraying is usually performed in a glove box or other enclosed space. ■ Use of detergents with low foaming characteristics is recommended.
Spray cleaning (low pressure)	■ Dissolves contaminants that are soluble in the spray liquid. ■ Used for rinsing parts or removing contaminants loosened by another process.	■ Can produce all levels of cleanliness.	■ Ineffective for tightly adhered particles.	■ Proper safety precautions (eg fire suppression systems or inert gas blanketing) must be available when flammable or combustible liquids are used. ■ Use of detergents with low foaming characteristics is recommended.

Table 6 Solvent-based surface cleaning methods: applicability, advantages and disadvantages (continued)

Process	Applicability	Advantages	Disadvantages	Comments
Power wash cleaning	■ Combines techniques such as immersion, sprays and ultrasonics in an automated machine.	■ Less floor space is needed than for equivalent linear systems. ■ Controlled use of materials. ■ Lower labour costs.		■ Washing, rinsing and drying cycles can be performed in one tank. ■ Machines can incorporate a custom-spray system to clean blind holes.
Steam cleaning	■ Removes water-soluble contaminants, oils/greases and other heavy contaminants.	■ Steam-generating equipment can be portable and usually requires little floor space. ■ Useful for infrequent cleaning of large objects.		■ Often carried out manually. ■ Additives such as alkaline detergents or rust inhibitors can be used.
Supercritical fluid cleaning (SFC)	■ Effective for liquid contaminants including silicone oils, hydrocarbon oils and machining fluids.	■ Supercritical carbon dioxide is an excellent solvent, capable of penetrating into tiny cracks. ■ Effective for cleaning complex parts with tight tolerances.	■ SFC is not effective in removing particles and salts.	
Carbon dioxide 'snow' cleaning	■ Most suited for line-of-sight cleaning.	■ Effective in removing particles, thin fluid layers, flux and fingerprints.	■ Not suitable for removing rust, paint, grease or heavy oil layers.	
Ultraviolet cleaning	■ Depends on line-of-sight exposure to UV radiation. ■ Best for cleaning simple, flat surfaces.	■ Removes very thin organic films. ■ Produces high cleanliness levels.	■ Particles or salts are not removed. ■ Some metals may be oxidised by the UV radiation.	■ Thicker contaminant layers take longer to clean.

5.2 Vapour degreasing: selecting the right plant

Vapour degreasing is still widely used, especially where the quality of the cleaned product needs to be very high, eg prior to polishing operations. However, alternative cleaning techniques and processes tend to be used for lower quality work. Solvent cleaners are now often used only for heat treatment where heavy oils need to be removed from the product surfaces.

Although the payback period is sometimes quite long, the use of fully enclosed degreasers is increasing. Companies are investing in new plant with sealed units because of:

- the significant reduction in the amount of solvent needed to operate such plant;
- the reduction in occupational exposure levels;
- higher productivity;
- the longer working life of these plants.

Retrofitting lids on open-top degreasers is a popular option as it reduces VOC emissions and solvent costs. Although it is significantly cheaper to retrofit than to buy a new enclosed degreaser, life expectancy and efficiency are both lower.

Once vapour degreasing has been confirmed as the preferred cleaning method, it is well worth:

- examining the benefits of using modern plant (see section 5.4);
- looking at ways of improving existing plant (see section 5.5);
- adopting operational good practice (see section 5.6).

When drawing up the specification for a vapour degreasing plant with an emphasis on waste minimisation, it helps to be familiar with both the principles of the process and the chemicals to be used.

New enclosed system significantly reduces solvent use

Avon Ames, a manufacturer of aluminium copier rollers, used to use methyl chloroform (1,1,1-trichloroethane) to clean the rollers in an open system. Solvent consumption has fallen by 80% since the company installed a new enclosed cleaning system, which achieves high standards of cleanliness and leaves the rollers dry at the end of cleaning. The new cleaner replaced four open cleaners, thus freeing their operators for other duties.

5.3 Principles of vapour degreasing

When a ‘dirty’ component is placed in the vapour layer formed above a boiling liquid, the vapour condenses on the cold surface of the component and dissolves any soluble contaminants present. As the vapour condenses, the liquid drains back into the boiling liquid below, carrying some of the soil with it. Further cleaning occurs as more vapour condenses on the component. Once the temperature of the component reaches that of the vapour, condensation ceases and the cleaning process stops. The component is withdrawn slowly and allowed to cool to room temperature.

Some solids and non-soluble material are washed away during this process. However, particulate matter may remain in ‘blind’ holes and upward-facing, cup-like features. The removal of particulate matter usually requires boiling liquid, spraying or even ultrasonic treatment. Tumbling is required to remove solvent from cup-like features.

Vapour degreasing is most effective with solid, thick components with a high heat capacity. Thin sections may not be cleaned as effectively because they heat up faster, thus reducing the amount of solvent condensing on the surface. Spraying of boiling liquid may be needed to clean thin metal parts.

5.3.1 Vapour control

Any vapour above a boiling liquid will escape to atmosphere unless prevented from doing so. Uncontrolled discharge cannot be permitted because:

- the vapour will affect the environment;
- the vapour may be harmful to operators and other staff;
- excessive solvent loss would make the process uneconomic.

5.3.2 Which solvents are used?

Trike remains the most popular solvent for vapour degreasing, but concern about its health and safety aspects has increased interest in the use of alternatives and substitutes. Many companies have reduced or ceased use of trike, and trike consumption in Western Europe fell by an estimated 29% between 1995 and 2000[8].

Trike and the two other chlorinated solvents used for vapour degreasing (methylene chloride and perchloroethylene) are essentially non-flammable, though they can be ignited by high energy ignition sources (such as a welding torch) at certain concentrations in air.

Trichloroethylene (trike)

Trike is sold under trade names such as Altene, Hi-tri, Neu-tri, Tavoxene, Trielena, Triklone, Tristabil and Vorclin. Trike is popular because of its flexibility in cleaning a number of material types and its efficiency in soil removal. Its properties include:

- strong solvent action;
- medium boiling point (87°C);
- high vapour density.

However, trike is a classified carcinogen and has a Maximum Exposure Limit (MEL) of 100 ppm. Because of its occupational exposure limit, trike is not considered suitable for cold or wipe cleaning. As with other chlorinated solvents, trike is unstable in a welding arc, where it can break down to harmful products such as phosgene.

Exposure with properly operated and maintained open-top baths can be controlled to less than 20 ppm (measured as an eight-hour time-weighted average) and exposure can be even lower with fully enclosed baths. However, trike's reclassification as a category 2 carcinogen means that there is a greater emphasis on substitution. You should, therefore, consider whether you can substitute trike with an alternative that provides a lower overall impact to health, safety and the environment. This needs careful consideration and you should also consider how you can control exposure by better management of your existing process. You should only move to an alternative if there is sufficient evidence that it is better for health, safety and the environment. You should also re-assess your process and ensure you are managing the risks from the new substance. Any substance can present a risk to health if badly managed.

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[8] See *Reducing solvent use for vapour degreasing in the metal finishing industry* (BG334), available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

The stricter legislation now applicable to trike (see section 1.1) is stimulating many solvent users to consider:

- their volume of solvent use;
- solvent emissions from cleaning processes;
- alternatives to using solvents (particularly chlorinated ones);
- occupational exposure to solvents (mainly dermal or inhalation routes; see section 5.6.7).

Alternatives to trike

An increasing number of alternatives are now available. Tables 7 and 8 list some of the main alternative chlorinated and non-chlorinated solvents and their potential applicability. However, these alternative solvents can also be hazardous to health, and without appropriate solvent management, a switch from trike to these solvents may simply expose operators to different dangers. The use of alternatives should be properly assessed, taking into account all considerations.

It is not sufficient just to change the solvent if the degreasing tank is in a poor state and working practices are poor. Using a substitute solvent in a badly maintained plant and/or continuing to follow poor working practices may even increase the risks by exposing operators to high levels of a different hazardous substance.

Alternative solvents will only reduce operator exposure and costs if good practice is followed.

- Changing to a different solvent may introduce new health, safety or environmental problems. Evaluate your process and check that you are not replacing one hazard with another. The aim is to reduce the overall risk to health, safety and the environment.
- When switching solvent cleaners, it is important to adjust the bath's settings (thermostatic controls, pH, etc) to suit the requirements of the new solvent. For example, thermostats will need re-setting if changing from trike to perchloroethylene, and changing to methylene chloride requires less heat input.
- Changing from trike to an alternative solvent constitutes a relevant change[9] under the Environmental Protection Act 1990. Section 11 requires operators to apply to their local authority for a variation of conditions and to pay the relevant fee.
- Where it is necessary to continue to use trike, then emission levels can be reduced by:
  - improved solvent management;
  - adopting good practice, eg maintaining and using baths correctly (see section 5.6);
  - improving existing plant (see section 5.5).

Alternative solvent reduces energy and solvent use by 50%

To reduce operator exposure and solvent use, Budenberg Gauge decided to convert its open degreasers to use methylene chloride rather than trike. The conversion, which included increased space for condensing coils, cost less than £1 000 and reduced solvent use by 50% from 4 tonnes/year to 2 tonnes/year. Methylene chloride's lower boiling point also led to a 50% reduction in heat input. Occupational exposure is now about 30 ppm (eight-hour time-weighted average).

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[9] Section 11(11) of the 1990 Act states that 'a relevant change in a prescribed process is a change in the manner of carrying on the process which is capable of altering the substances released from the process or of affecting the amount of any other characteristic of any substance so released.'

Table 7 Alternative chlorinated solvents

	Methylene chloride	Perchloroethylene
*Trade names**	Aerothene, Methoklone, Propulsol, Solvaclene, Striptron, Ukalene, Ukatronic	Dowper, Perklone, Perstabil, Pertene, Soltene, Vors
Contaminants removed	■ Soils ■ Oils ■ Greases ■ Buffing compounds	■ High melting point waxes. ■ Components with low heat capacity, eg thin sections.
Applicability	■ Has low boiling point (40°C) and better cleaning power than trike and perchloroethylene. ■ Good for cleaning: - temperature-sensitive components; - components that must leave the degreaser cool enough to handle; - components where an aggressive solvent is required.	■ Has higher boiling point (121°C) than trike or methylene chloride and, therefore, a greater washing action.
Disadvantages	■ Has lower latent heat of evaporation than trike and perchloroethylene. This means that less solvent condenses onto component and washing action is reduced.	■ Less powerful cleaning solvent than trike. ■ May produce harmful breakdown products if welding activities are carried out in vicinity of degreasing equipment.

* The list is not exhaustive and has been compiled from information currently available to Envirowise. The listing of a product does not constitute an endorsement by Envirowise of either the product or its effectiveness, and neither does the omission of a product discriminate against its effectiveness.

Table 8 Alternative non-chlorinated solvents

Cleaning agent	Contaminants removed	Applicability and comments
n-propyl bromide (nPB)	■ Soils ■ Oils ■ Greases ■ Buffing compounds	■ Can be used instead of chlorinated solvents. ■ Can be used in existing vapour degreasers with relatively little or no retrofitting of current apparatus. ■ The Health and Safety Executive (HSE) has reviewed the possible harmful effects of nPB. Chemical Hazard Alert Notice (CHAN) No 26 is available free from the HSE InfoLine on 08701 545500 or the website (www.hse.gov.uk/pubns/chindex.htm). It may be reclassified as risk phrase R60 Category II reproductive toxicity and its ozone depletion potential is not resolved.
Hydrofluoroethers (HFEs)	■ Lighter oils can be removed with a 100% HFE cleaning agent.	■ Can be used as either the cleaning or rinsing agent in a co-solvent process. ■ HFE cleaners have been used effectively in ultrasonic solvent and co-solvent processes where the low solvent use and precise control reduces running costs. ■ To increase solubility of medium-weight oils, commonly used as an azeotrope with another organic solvent. It is important to consider the environmental and toxicity effects of the azeotrope. ■ HFEs are non-toxic, non-flammable and not ozone-depleting and have a low global warming potential relative to chlorofluorocarbon (CFC) alternatives.
Alcohols	■ Rosin fluxes ■ Fingerprints ■ Light oils ■ Plasticisers	■ Used for handwipe processes, cold dip tanks and heated tanks (provided proper safety precautions are taken). ■ Often used to dry parts after water-based cleaning and as cleaners in precision applications. ■ Mainly ethanol and isopropyl alcohol (IPA). Both are highly volatile and flammable and must be handled accordingly. Extensive safety precautions required. ■ Often blended with other solvents to increase cleaning effectiveness.

Table 8 Alternative non-chlorinated solvents (continued)

Cleaning agent	Contaminants removed	Applicability and comments
Dibasic esters (DBE)	■ Paint residues	■ Commonly used as a paint stripper and as a solvent in semi-aqueous processes. ■ Mixture of methyl esters of adipic, glutaric and succinic acids. Pure DBE has a very low vapour pressure. ■ Used either undiluted or mixed with other chemicals such as N-methylpyrrolidone.
Ethyl lactate	■ Silicone oils and greases ■ Machining coolants ■ Sulphur-based trapping oils ■ Lithium grease ■ Layout inks ■ Fingerprints	■ Components cleaned with ethyl lactate can be rinsed with ethyl lactate itself, water or an alcohol. ■ Combustible with a flash point of about 49°C, depending on its purity.
Glycol ethers	■ Flux ■ Solder paste ■ Inks ■ Greases ■ Oils	■ Also used to strip photoresist in the semi-conductor industry. ■ Often blended with other solvents for specific cleaning applications. ■ Tend to emulsify well and separate easily during recovery. ■ Many different glycols are used for cleaning. They are volatile, combustible or flammable compounds and must be handled accordingly. Glycol ethers must be selected carefully to avoid those which are potentially harmful to health.

Table 8 Alternative non-chlorinated solvents (continued)

Cleaning agent	Contaminants removed	Applicability and comments
N-methylpyrrolidone (NMP)	■ Paints and other coatings, including polyurethanes, printing inks, epoxy resins, polyamidimide-based wire enamels and water-based coatings ■ Plastics, including polystyrene, polyesters and PVC	■ Used for stripping paint, dissolving coatings and plastics, removing heavy oil and carbon deposits from engine parts. ■ Used in both immersion and ultrasonic processes. ■ Also used with a water rinse in semi-aqueous processes. ■ Has a low vapour pressure and is combustible, with a flash point of 93°C. ■ After cleaning, the oils can be removed by lowering the solvent temperature (many oils are only soluble in NMP above 63°C). The solvent can then be re-used and the oil recycled.
Petroleum distillates	■ Heavy oil and grease ■ Tar ■ Waxes	■ Used in immersion or handwipe processes. ■ Used as the organic component of some semi-aqueous systems. ■ Low surface tension allows them to penetrate and clean small spaces. ■ Flammable hydrocarbons produced by refining crude oil. ■ Proprietary blends are available that are formulated to be relatively harmless to health. Many have low volatilities to reduce fire risk and VOC emissions.
Silicones	■ Fingerprints ■ Greases ■ Oils	■ Not suitable for use as vapour degreasing agents. ■ Can be used as immersion cleaners with ultrasonics and some heating. ■ Have low toxicity, no odour and low surface tension. Are combustible and can be extremely volatile.
Terpenes	■ Rosin fluxes ■ Fingerprints ■ Heavy petroleum greases and oils	■ Used in immersion and ultrasonic systems (often work well at room temperature). ■ Used either as a component of a semi-aqueous cleaning system or by themselves. ■ When used in the former, the terpene can often be separated and re-used. ■ Strong solvents derived from natural sources such as pine trees or citrus fruit. They are flammable or combustible and tend to have strong odours. Can produce explosive mists when sprayed.

5.4 Vapour degreasing: key design features of modern plant

Modern vapour degreasers can typically be divided into three categories:

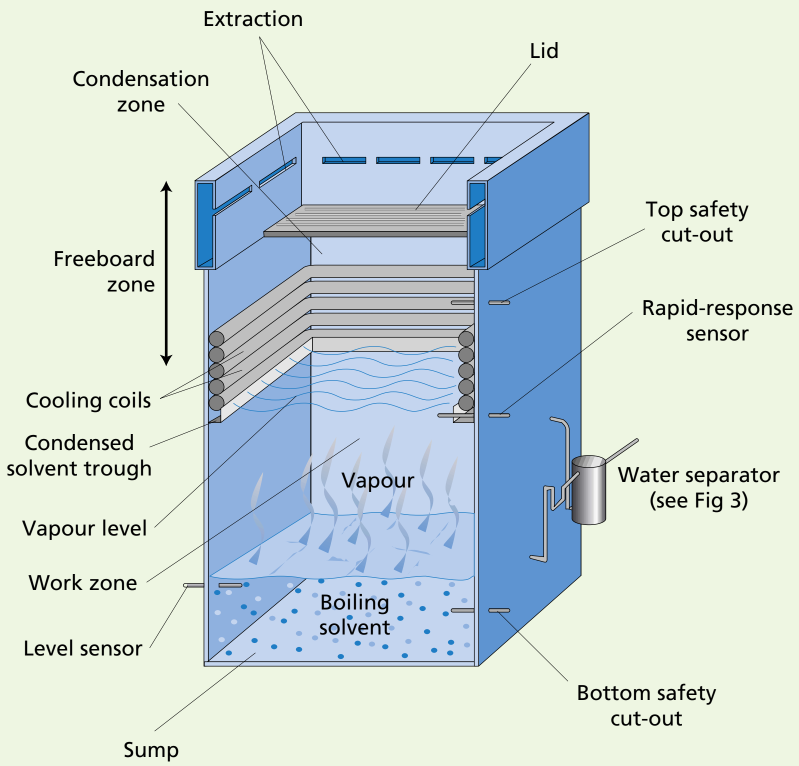
- conventional top-loading;
- top-loading with multiple doors;
- totally sealed end-loading.

The first category is used widely; the second and third categories have lower levels of solvent loss and may be suitable where compliance with environmental regulations is more difficult to achieve. These types of plant also result in lower occupational exposure than many conventional open-top degreasers.

5.4.1 Conventional top-loading unit

Fig 2 shows a basic vapour degreasing unit.

Fig 2 Conventional top-loading vapour degreaser



Sump

The sump contains solvent which is heated by electricity, steam or thermal fluid transfer media. The use of gas is not recommended for new plant. Sump heating controls, which are vital for the safe and efficient operation of the plant, consist of:

- A **bottom safety cut-out**. This safety device is set to limit the temperature of the solvent to prevent overheating and the risk of fire when the solvent becomes heavily contaminated with oil and grease. The cut-out may be adjustable, allowing the use of different solvents (provided the plant is otherwise suitable).

- A **level sensing device**. This device stops operation with insufficient liquid solvent in the sump and is intended to prevent fire or damage to the plant. The bottom safety cut-out will not protect against low solvent levels and both controls are recommended for safe operation of degreasing plant.

Work zone

This area becomes filled with clean vapour rising from the vigorously boiling liquid in the sump to the condensation zone. 'Cold' work entering the work zone causes the vapour level to fall. The vapour then rises as heat is transferred to the work from the condensing vapour. Vapour reaches the condensation zone only when the temperatures of the component and the solvent vapour have equalised.

A **rapid-response sensor** may be installed just below the condensation zone as an energy-saving device. This sensor responds to the temperature of the vapour by switching the heat input to the sump to approximately one-fifth of the value required to boil the liquid in the sump vigorously. This condition is maintained until a new load is placed in the unit, when the cooling effect caused by the drop in vapour level reactivates the main heating system.

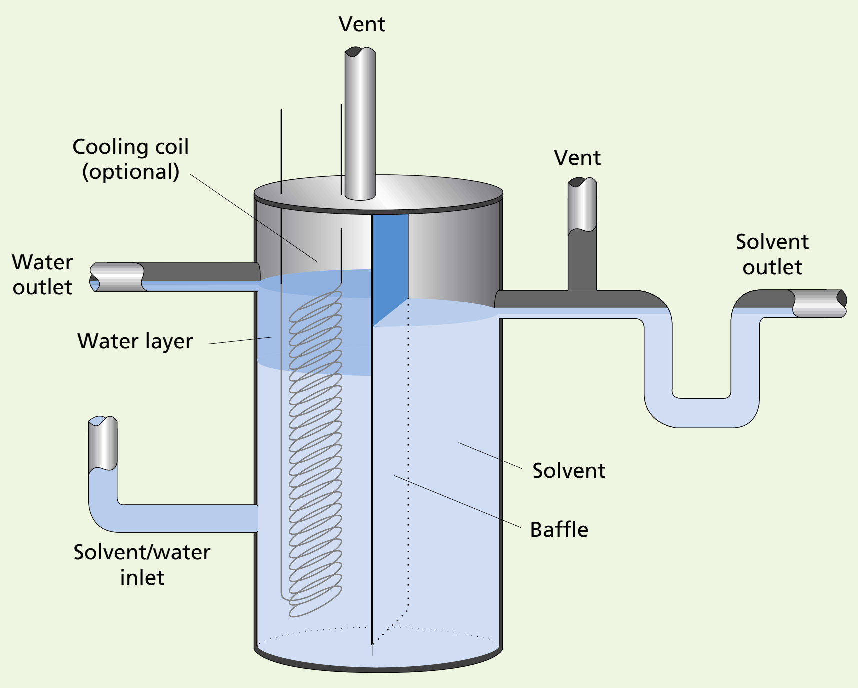
Condensation zone

This zone is where the vapour cools, condenses and returns via a pipe to the sump. A bank of water-cooled or refrigerated coils, which are sometimes finned, maintain a cold zone above the solvent vapour causing it to condense and return to the sump. When methylene chloride is used as the solvent, the condensation coils are often connected to a refrigeration system as this lower boiling point solvent requires more effective cooling.

Vapour condensing on the coils is collected and allowed to flow through a pipe to the **water separator** (see Fig 3). Water, which becomes entrapped in the solvent vapour, separates and floats on the surface of the collected solvent. The solvent is returned to the sump, while the water layer is drawn off and treated to prevent residual solvent entering the sewerage system.

The outlet to the water separator provides a convenient point from which to divert the flow of clean solvent to a separate container to empty the plant. This procedure is necessary during maintenance.

Fig 3 Schematic diagram of a typical water separator



Freeboard zone

This zone, which allows residual liquid to evaporate from the component and minimises solvent loss to the surrounding air, extends from the mid-point of the condensation coils to the rim extraction level near the top of the degreaser. The purpose of the freeboard zone is to:

- minimise the effects of draughts on the vapour zone;
- provide a holding space to give a 'flash-off' time for solvent residues to evaporate from the components;
- enable work to be turned, to drain liquid from cup-like areas.

The **top safety cut-out** is fitted within the freeboard zone immediately above the cooling coils. Should vapour reach this important safety device, the heat source in the sump will switch off, thus preventing solvent loss to the environment. The top safety cut-out should be designed and positioned to make weekly inspection and testing easy.

The continued effective functioning of the top safety cut-out is critical to economic plant operation, operator safety and compliance with environmental regulations.

Lids

Lids, which range from lift-out panels to automated roller shutters (see section 5.5), are essential to prevent excessive vapour loss. They should be fitted within the freeboard zone, below the rim extraction vents (see below). Lids or any other covers should not be placed over these vents as this causes solvent vapour to be drawn from the unit through the vents and discharged to the atmosphere. This is not only wasteful, but it increases the risk of the sump emptying and the residual oil and grease igniting.

Lids are intended to minimise solvent losses while the plant is heating up, idling, cooling and switched off.

Rim extraction vents

Vents (to one, two or four sides) ducted to a suitable point outside the building are intended to minimise operator exposure to solvent vapour. Rim extraction draws the air/solvent mixture away from the plant opening, through ducting, to the air outside the building. Excessively high extraction rates result in a substantial loss of solvent; control is, therefore, important.

The air/solvent mixture is either discharged directly to the air outside the building, or passed through adsorption media (eg activated carbon) before discharge to the atmosphere (to comply with environmental legislation).

The concentration of solvent in the air reaching the vents is significantly minimised by operational good practice (see section 5.6).

Load/unload system

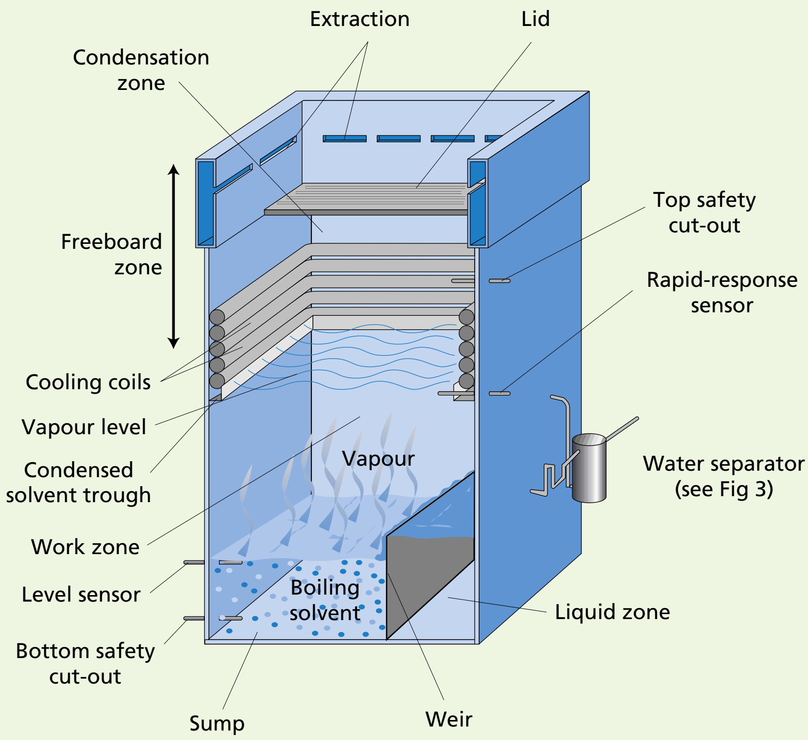
A motorised component load/unload system is recommended for all vapour degreasing plants. Such a system allows the speed of entry/exit of the work to be controlled (see section 5.6.2).

Additional modifications

Some conventional, top loading degreasing units are fitted with additional features to make them more effective.

Sub-dividing the work zone into two compartments (one compartment contains hot solvent and the other vapour) allows a combined boiling liquid/vapour process (see Fig 4 overleaf). This two-compartment system improves the removal of particulate and non-soluble matter. Clean solvent from the water separator is diverted to the liquid solvent zone; the excess flows over the weir into the sump. Components pass through the vapour zone before entering and after leaving the liquid zone.

Fig 4 Modified vapour degreaser incorporating boiling liquid/vapour



A further enhancement involves adding ultrasound to the liquid compartment to improve the cleaning process. It is also possible to add spray lances to this type of plant to help remove stubborn particulate matter. To avoid excessive solvent loss and unnecessary operator exposure, spraying should take place low down in the degreaser below the cooling coils.

5.4.2 Top-loading unit with double doors

The basic top-loading design can be modified to reduce emissions of solvent vapour into the working environment by adding extra doors (see Fig 5) and other features.

Automatically operated lid

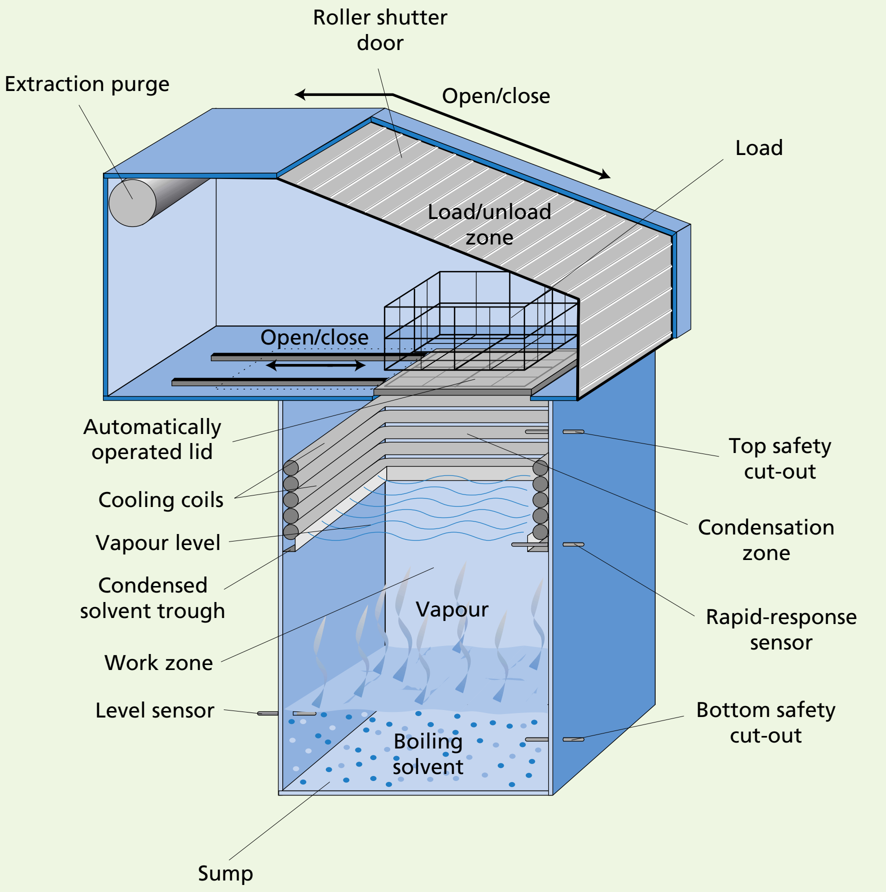
An automatically operated lid ensures that the degreaser is closed during idling periods.

Load/unload zone

Components are placed into this sealed zone, which has a roller shutter door, in baskets, jigs or fixtures supported by a table or frame. Once the roller door is closed and the cleaning cycle initiated, an interlock device prevents the door being opened until the cleaning cycle is completed. The cleaning cycle is controlled either manually according to timers fitted to the unit, or by internal sensors that detect when each cleaning stage is completed. The load/unload zone is intended to be free from solvent whenever the roller doors are open.

Sensors are particularly useful in jobbing situations when work characteristics (quantity, size, shape) can vary significantly. A rapid response temperature measurement and switching device installed immediately below the cooling coils will help to achieve better control. When the vapour level rises above the sensing point, the device signals that the solvent is no longer condensing on the load, and the unload cycle can commence.

Fig 5 Multiple door vapour degreaser



Extraction purge

This system, which removes the air/solvent mixture from the load/unload zone, operates immediately before the unload cycle. It operates only when the automatic lid is sealed and the solvent-containing zone isolated. When all traces of solvent have been removed, the roller door interlock is deactivated. The door can then be opened, the work removed and new work added.

Advantages of multiple doors

These additional features can be supplied either as a complete plant or as a retrofit option to some designs of conventional open-top degreasers. Considerable savings in solvent consumption compared with conventional plant are possible; some operators claim to have achieved savings of up to 80%. Another benefit is improved work scheduling due to the more predictable nature of the load/unload cycle.

A further advantage of this type of totally sealed plant is the potential to add liquid spraying nozzles to the vapour zone. This additional feature, which operates intermittently, can improve the removal of particulate and other non-soluble matter.

Many operators of conventional degreasing plants have found that top loaders with multiple doors can help them to comply with controls on VOC emissions. For example, companies just above the current threshold for registration with their local authority (see appendix 1) may be able to reduce their solvent consumption to below the threshold level. Companies that are well above the threshold for registration may have to consider fitting adsorption equipment to the extraction system to comply with emission limits.

5.4.3 Totally sealed end-loading unit

These units, which are designed specifically for the bulk treatment of small parts, operate a virtually closed loop with complete re-use of all solvent. A typical unit is shown in Fig 6. Such units are usually equipped with a side entry/exit, together with protected load/unload zones. They are designed to wash the parts first by immersion in liquid solvent and then by vapour cleaning. The solvent's cleaning power is improved by:

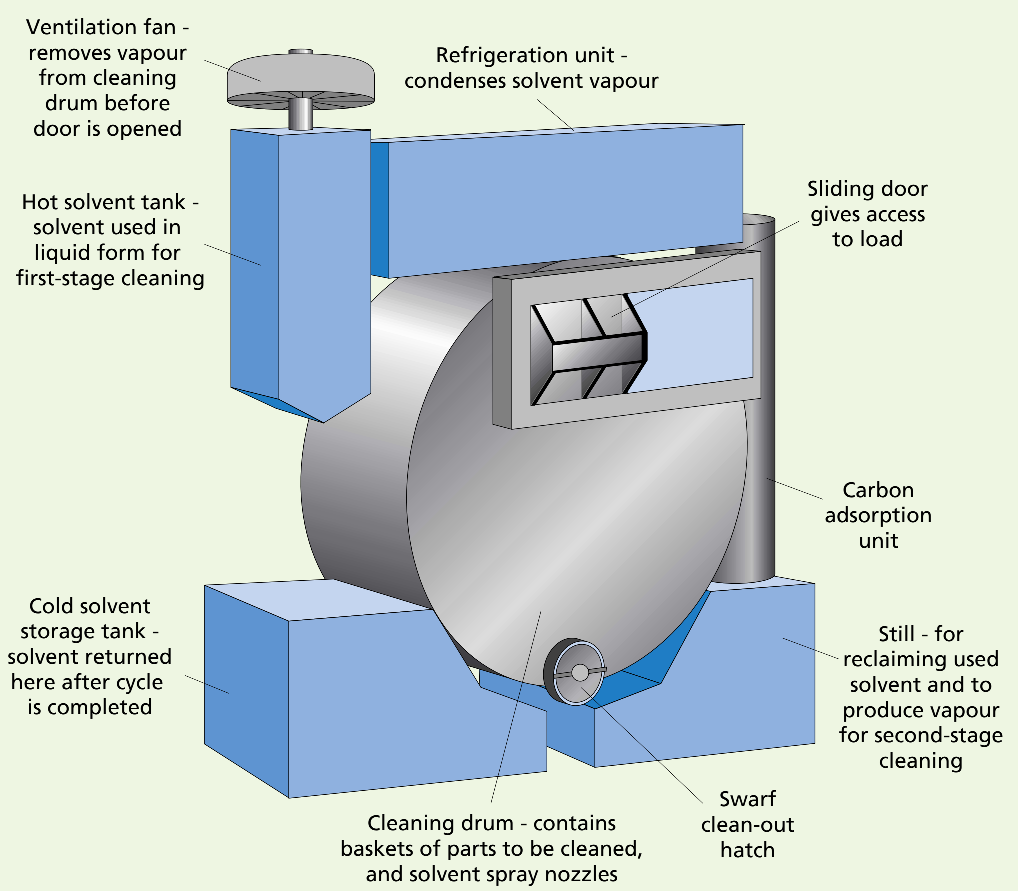
- tumbling;
- pulsed agitation;
- ultrasound.

These additional features are used to remove stubborn soluble/non-soluble particulate matter and swarf.

When solvent washing is complete, the solvent drains away and additional solvent vapour enters the cleaning chamber. Vapour cleaning removes residual contaminated liquid. The vapour is then withdrawn from the cleaning chamber, condensed and returned to the bulk clean solvent. The contaminated liquid is passed through fine strainers to remove particulate matter before it is distilled and returned to the clean solvent tank.

During the load/unload operation, extractors within the cleaning chamber create a positive airflow through the door into the unit and prevent solvent loss through the doors. The extracted air passes through activated carbon filters before being discharged to atmosphere. The advantage of this type of unit is that solvent consumption is dramatically reduced, potentially requiring no more than 100 litres/year of make-up solvent for a typical sized plant. Solvent vapour around the plant is reduced to low or negligible levels, and emissions are well within the regulatory limits.

Fig 6 Totally sealed end-loading plant



5.5 Vapour degreasing: improvements to existing plant

Where practicable, cleaning fluids which do not contain organic solvents, or cleaning fluids with significantly less volatile organic solvents, should be used. HSE guidance should be sought prior to any substitution of existing cleaning fluids.

Most degreasing plants operating in the UK contain only basic features. While it is often not cost-effective to invest in a new state-of-the-art degreaser, there are many no-cost and low-cost ways of improving existing plant performance and reducing running costs by making changes to both plant design and operating procedures. This section describes ways of improving existing plant design, while good practice for the operation of vapour degreasing plants is summarised in section 5.6. All open-top machines using risk phrase VOCs must be enclosed within the shortest possible time, as agreed with the regulator. Open-top machines using VOCs are unlikely to comply with the SED. Where practicable, cleaning should be carried out in enclosed cleaning systems, which should be sealed to prevent emissions in operation. If this is not practicable, emissions should be contained and vented to abatement equipment where necessary.

Common problems with the design of degreasing plant include:

- unsuitable lid or no lid at all;
- inadequate rim ventilation;
- hoist speed too fast;
- sited in potential draughts;
- inadequate topping-up method;
- inadequate freeboard ratio.

All of these problems result in more solvent being used than necessary. This, in turn, leads to increased costs, and environmental and safety problems.

The following practical solutions to these problems can be applied to existing plant and to equipment of all ages. In some cases, they can be designed and constructed in-house. In other cases, you will need help from external suppliers.

5.5.1 Fit and use appropriate lids

- Avoid using covers on conventional open-top degreasers that:
  - Cause vapour drag-out when lifted.
  - Are made of unsuitable material.
  - Are incorrectly fitted above the rim ventilation slot. Fitting a lid above the extraction vents can allow the extraction system to pump the degreaser dry. This not only wastes large quantities of solvent, but also presents a fire hazard as residual oil and grease in the plant are exposed to direct heat from the sump.
- Design lids to fit within the freeboard zone, below the extraction vents.
- Retrofit lids to conventional plant. The lids separating the enclosure from the solvent tank should provide a hermetic seal, thereby minimising emissions during operation.
- Use lids of a roller or slide design rather than lift-out panels. Automatic or motorised lids with horizontal movement maintain the most effective control and are a more convenient way of covering the plant while it is in use. They are also a more practical way of reducing the effect of draughts and other factors, eg contamination of the solvent with water.

- Fit segmented lids on long degreasing units, as they allow partial opening when processing work with shorter dimensions. Lift-out lids increase the chance of 'dragging out' solvent vapour if they are removed quickly. Roller shutters or sliding panels that move horizontally do not have this disadvantage and are generally recommended.
- A complete new double-door system can be designed to fit on top of certain existing degreasing units. This approach overcomes the effects of draughts and increases the operator's protection from solvent vapour inhalation. Tests have shown that such equipment can reduce solvent consumption by up to 80%. However, carbon adsorption of the exhaust gases may be required as plant equipped with double doors is unlikely to be within the required solvent emission limits.
- Where an enclosure is retrofitted to an open-top degreasing vessel, the door separating the enclosure from the external environment should be interlocked with the ventilation system and hermetic sealing lid separating the enclosure from the solvent chamber, thus ensuring that the outer doors are closed and the ventilation is off before the sealing lid can be opened to degrease workpieces. Emissions must comply with the regulations.

5.5.2 Improve rim ventilation

Adequate rim ventilation (lip extraction) is essential to prevent the operator from being exposed to unacceptable levels of solvent vapour. It is important to remember that the ventilation controls vapour emissions, it does not eliminate them. The extraction should be interlocked with the hermetic sealing lid. The lid separates the enclosure from the solvent chamber to contain vapours during degreasing, thus, with the lid sealed, solvent-laden air can be removed and cleaned in a controlled manner.

- Install ventilation on at least two sides of the tank rim unless the plant is less than 350 mm wide, in which case single-sided ventilation is generally adequate. Four-sided rim ventilation is often installed on modern degreasers.
- Use an extraction rate of 640 - 915 m^3/hour per m^2 of bath surface. While it is important that extraction rates are high enough to protect operators, excessive extraction results in unnecessary solvent consumption. However, emissions must comply with the regulations.
- A rim vent slot velocity will be specified for any degreaser with a specific rim vent slot design, extract fan specification and ductwork configuration. Some users may find it easier to check this measurement rather than the total volume of air extracted. Ask your supplier for the appropriate figure.

5.5.3 Fit power-operated hoist and lifts

- Use a power-operated hoist to control the speed of entry/exit of workpieces.
- Set the speed so that it cannot exceed 3 m/min. Higher entry speeds will result in vapour spilling over into the workplace or excessive extraction to the atmosphere via the rim vents.

5.5.4 Improve siting

- Avoid air turbulence in the plant area as this can cause serious solvent losses.
- Features that create air currents, and thus disturb the vapour in degreasing units, include:
  - doors;
  - windows;
  - heating and ventilation systems;
  - busy passages.

- Ensure that degreasers are:
  - sited away from draughts;
  - shielded if necessary;
  - isolated from naked flames, hot surfaces and welding operations;
  - in a no smoking area.

5.5.5 Install fixed pipework for topping-up

- Pump new solvent directly from the container using fixed pipework connected to the sump. Topping-up the degreaser by pouring in solvent from a drum or bucket increases operator exposure and the risk of spillage.
- Avoid spills in the interests of both operator safety and solvent consumption. Spillage can also result in solvent soaking into the floor, with the potential risk of contaminated land problems. Spillages also increase the risk of watercourses being contaminated by solvent and the company being prosecuted.

5.5.6 Raise the freeboard ratio

The freeboard ratio is defined as the freeboard height divided by the width of the tank. The higher this ratio, the less chance there is of solvent vapour leaving the plant and entering the workplace.

- A relatively deep freeboard zone:
  - reduces the effects of draughts on the vapour zone;
  - increases the holding space (thus allowing solvent to evaporate from the load);
  - enlarges the zone where work may be turned to drain off solvent.
- Use a freeboard ratio of at least 0.75:1 and preferably 1:1. A freeboard ratio of less than 0.75:1 is likely to lead to unnecessarily high employee exposure.

5.5.7 Install support frames within the condensation zone

- Fit frames within the condensation zone to allow workpieces mounted on jigs to be supported while degreasing is in progress. This enables the lifting device to be raised and the lid closed over the work during the degreasing process, thus minimising vapour loss. Although a simple measure, support frames have the potential to significantly reduce solvent waste and operator exposure. Carefully designed frames can also prevent damage to parts of the plant, eg cooling coils and fins, and thus reduce maintenance costs.

5.5.8 Fit a time controller/alarm and an idling cut-out

- Avoid excessive cleaning as it wastes time, energy and solvent. Once load conditions and effective cleaning times have been established, control the duration of the cleaning process using timers and alarms.
- Use appropriate lid designs and fit interlock devices to prevent poor operation and minimise solvent loss.
- Install a rapid-response sensor immediately below the condensation zone to control energy consumption. The sensor cuts the heat input to the sump in response to the vapour temperature. The cooling effect of a new load being placed in the unit reactivates the main heating system. This will minimise emissions during non-process periods.

5.5.9 Add extraction to the clean-out hatch in the sump

- Fit an extraction system at the clean-out hatch. This safety feature, which is particularly important if the degreasing unit is set in a pit, helps to minimise operator exposure to solvent fumes during cleaning out. However, it does not make entry to the degreaser safe.

5.5.10 Prioritising plant modifications

The modifications described above can be applied to most existing vapour degreasing plants. The ease with which the modifications can be made and the subsequent benefits will vary according to the type of modification and the plant.

Table 9 indicates the 'typical' level of costs and benefits associated with the various modifications.

Table 9 Relative benefits of plant modifications

Modification	Cost	Cost savings	Environmental benefits	Health and safety benefits	Action
Use lids provided	None	Medium	High	Medium	Do
Isolate from draughts	Low	Medium	Medium	High	Do
Install support frames	Low	Medium	Medium	Medium/high	Do
Install powered hoist	Medium	High	High	High	Do
Time indicator/ controller and alarms	Medium	Medium/high	High	Medium	Do
Install roller or slide lid	Medium	Medium	High	Medium	Do
Idling cut-out on heater	Medium	High	Medium	Low	Do
Fixed pipework at sump	Low	Low/medium	Medium	High	Do
Increase freeboard height	Medium	Medium	Medium	Medium/high	Consider
Install double doors	High	Medium/high	High	High	Consider
Install extraction to clean-out hatch	Low	None	Low	High	Consider

5.6 Vapour degreasing good practice

The efficiency of any degreasing plant depends on how well it is operated. This section suggests ways in which you can get the best out of your plant through operational good practice. Organic solvent losses can be identified and minimised by operational controls and good operational practice. A programme to monitor and record consumption of organic solvent/organic solvent-containing cleaners should be used to minimise the amount of excess solvent used.

Operational features that often need improvement include:

- monitoring of cooling water, solvent levels in air, top safety cut-out and rim ventilation;
- control of cleaning out;
- training for maintenance and operation;
- use of covers;
- provision of information.

Poor operational control invariably leads to:

- wasted solvent;
- increased costs;
- increased risks to the health and safety of operators;
- a greater environmental impact.

Company benefits from switching to an enclosed vapour degreasing system

High solvent consumption and the need to comply with environmental legislation prompted Revill Industrial Finishes to review its cleaning operations and consider alternatives to its inefficient open-top plant. After investigating three options, the company selected an enclosed degreasing system with an automated cleaning cycle. Trike is still used as the cleaning agent, but consumption has fallen by 30% mainly because evaporative losses from the solvent tank have been eliminated. Health and safety risks have improved significantly because operators are no longer exposed to solvent.

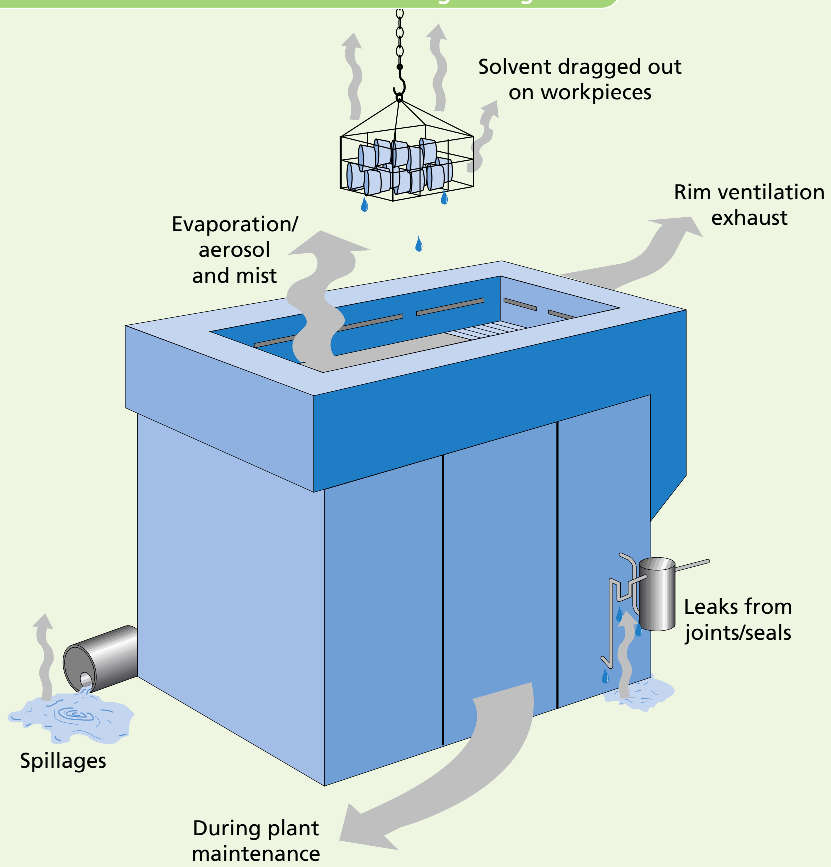
For more details, see the industry example in the pocket at the back of the Guide.

5.6.1 Good housekeeping

Adopting good housekeeping measures and implementing simple low-cost or no-cost improvements can help companies to get the best out of their degreasing plant. Keeping a check on how the plant is running also provides opportunities for improving performance and reducing costs.

The ways in which solvent can escape from a degreaser are limited (see Fig 7) and can be minimised by attention to good housekeeping during operation, plant maintenance and waste disposal.

Fig 7 Potential routes for solvent loss from a degreasing unit



5.6.2 Operation

Solvent is lost - as a vapour, aerosol, mist or liquid - from a degreaser in a number of ways, including:

- through the plant's open top;
- via the rim extraction mechanism;
- dragged out on work removed from the plant.

Solvent losses can be minimised by:

- **Positioning tanks to avoid draughts and uncontrolled air movements.** Draughts are often the cause of excessive solvent loss. To avoid unnecessary operator exposure to high levels of VOCs:
  - be aware of draughts (use smoke tapers or anemometers to isolate the source of any draughts);
  - enclose or surround tanks, if necessary, with metal, wood or plastic screens;
  - fit baffles to keep air streams from extraction fans, heating ducts and refrigeration-cooled chillers away from the tank;
  - seal windows to prevent them being opened;
  - lock doors (if possible) or fit with flexible plastic screens.
- **Use the lids provided.** Using lids is essential, particularly when the plant is starting up, closing down or idling.
  - Use the lid whenever workpieces are inside the unit. Only remove lids temporarily during loading and unloading.
  - Open sectional lids or roller shutters (where fitted) only as far as is needed for loading or unloading.
- **Load/unload the plant at the correct speed.** Allow the workpieces to pass slowly through the freeboard zone during loading and unloading. Avoid too high an entry speed as this will cause vapour to spill over the sides of the unit due to the so-called 'piston effect'. This leads to excessive solvent losses. Vapour disturbance will also increase solvent loss via the rim extraction vents.
  - Ensure loading and unloading speeds are less than 3 m/min.
  - When degreasing is complete (ie condensation on the workpieces has ceased), remove them slowly. An excessive lifting speed will draw vapour from the tank into the extraction zone.
  - Ensure workpieces pass slowly through the condensation zone and then wait in the freeboard zone for the load to dry. The time needed for drying to be completed depends on the load characteristics; simple shapes dry rapidly, while complex components or baskets containing large numbers of small parts need much longer.
- **Use mechanical handling for all loads.** This will help to ensure that the operator waits for the load to dry before removing it. Without handling equipment there is a danger that operators, perhaps to avoid fatigue, will not allow sufficient time and rush the procedure. Conversely, operators may remain standing over the plant for longer than necessary, thereby increasing their exposure to the solvent significantly. Manual loading also encourages operators to lean on the extraction box or even hang workpieces from it. These practices can damage the plant and, by closing the slot in the extraction vent, make extraction ineffective.
  - Train operators to use loading/unloading equipment for **all** loads and not just those that are too heavy or awkward for easy lifting. This will reduce their exposure to solvent and ensure that the correct loading and unloading speed is always used.

- If mechanical handling is not practicable, provide suitable hooks so that baskets of components may be hung up to drain and dry properly in the freeboard zone.

- **Turn the workpieces in the freeboard zone.** This action minimises solvent drag-out on loads with cupped areas or blind holes. Plants with a deep freeboard zone facilitate turning.

- **Jig the work appropriately.** Jigging the workpieces, such that any solvent-retaining holes drain freely, may remove the need to turn the workpieces. Careful consideration of the component may improve the efficiency of cleaning and will reduce solvent loss due to the piston effect.

- **Use a tank of the correct size.** Ensure that the area of the base of the load does not exceed 50% of the surface area of the degreasing tank to avoid aggravating the piston effect.

Jig redesign improves plant performance

A company in the Midlands degreased flat, plate-like components by loading them horizontally in a single layer in a shallow basket. The components had to be sprayed using a lance for effective cleaning. By redesigning the jig so that the components were loaded in a near vertical position, the company was able to achieve an almost three-fold increase in the load of components, eliminate the lance and significantly reduce the piston effect when loading the degreaser.

- **Use emission-free transfer systems when charging the degreasing plant and pumping out waste totally contained.** Charging the bath can be by pump or gravity-fed methods. The point at which the solvent discharges into the degreasing plant should, where practicable, be below the liquid level in the sump. If the discharge point is above the liquid level, the plant must cool before introducing solvent. Condensing and ventilation systems must be in operation when transferring solvent.

5.6.3 Plant maintenance

Degreasing plants require routine maintenance and cleaning if they are to continue to perform effectively. Cleaning operations should be reviewed periodically to identify steps that can be eliminated as cleaning operations give rise to fugitive emissions of VOCs.

Regular maintenance
Scheduled maintenance is designed to ensure that systems and controls function correctly and that the plant is safe.

- Safe operation depends on the correct operation of the sensors controlling:
  - sump level;
  - sump temperature;
  - vapour temperature;
  - freeboard zone temperature.

  Check these controls during preventive maintenance to ensure that they are working correctly. This normally involves disconnecting the relevant control and waiting for the sensing unit to respond. However, the method relies on the person carrying out the inspection knowing what should happen.

- Do not leave plant unattended during checks and ensure that two people are always present.

- Allow only properly qualified and experienced staff to reconnect control devices.

- Set the top safety cut-out in the freeboard zone to turn off the heat input to the sump when the appropriate temperature for the solvent is reached (check with your solvent supplier). This cut-out is particularly important as it prevents excessive solvent loss in the event of reduced coolant flow. Such solvent loss could lead to very high exposure levels in the area around the plant.

- Record the results of control tests/measurements on simple charts posted either on or near the plant. Table 10 lists the plant characteristics that operators are advised to measure and the suggested frequency for testing.
- Encourage operators to investigate any unusual trends immediately. For example, recording the temperature of the output water from the cooling coils will, over a period of time, reveal trends which will enable cause and effect to be established. Significant variations may be related to excessive or unusual solvent use. Once a cause is established, optimum control values for the degreasing unit can be determined. A business operating more than one degreaser may find that each unit needs different values. In addition to providing useful data, this approach can generate a feeling of 'ownership' in operators.

Table 10 Plant control monitoring

Characteristic	Frequency	Method
Cooling water volume/flow	Daily	Flow meter.
Cooling water temperature	Daily	Stainless steel sheathed probe and digital thermometer.
Solvent sump level	Daily	Visual at start-up.
Solvent sump temperature	Weekly	Stainless steel sheathed probe and digital thermometer.
Bottom safety cut-out	Weekly	Slowly reduce thermostat setting until heater cuts out. Reset.
Top safety cut-out	Weekly	Turn off coolant and note that a rise in vapour level cuts out heater. Turn coolant back on.
Acid acceptance value:		
enclosed/automatic plant	Daily	Titration kit from solvent supplier.
open top plant	Monthly	Titration kit from solvent supplier.
Low-level device	At clean-out	Allow solvent to evaporate to this probe. Check heater cuts out.
Rim ventilation	Every three months*	Measure airflow rate using anemometer.

* COSHH regulations require checks to be carried out every 14 months.

Major and periodic maintenance

The need for periodic maintenance will vary with the work and soil input to the plant. Signs that indicate action is required include:

- the sump boiling temperature reaches the limit (check with your solvent supplier);
- inadequate component cleaning or component corrosion;
- bad odour;
- failure of plant controls.

Carry out major cleaning at least once a year. In many cases, more frequent cleaning may be appropriate.

Precautions during major cleaning

Provided degreasers are cleaned sufficiently often, entry into the plant for cleaning purposes will not generally be necessary. A major cleaning programme that involves emptying all the solvent and sludge out of the plant presents serious risks. It must be performed only by trained personnel following an established and enforced safe system for work.

For specific information on a particular solvent, refer to the manufacturer's data sheet. For detailed advice, contact the HSE InfoLine on 08701 545500 or visit the HSE website (www.hse.gov.uk).

5.6.4 Waste management

Good waste management practice is essential because degreasing plant wastes are hazardous to health. Failure to comply with the duties placed on plant operators to ensure that the wastes are properly handled may lead to prosecution.

- Do not mix different waste solvents.
- Store different waste solvents separately and label them clearly.
- Efficient handling may lead to cost savings from solvent recovery.

All organic solvent-contaminated waste should be stored in closed containers.

Contamination indicators

Degreasing solvents cannot be used if they are grossly contaminated with oils, greases, waxes and metallic swarf. Contamination causes the boiling point of the sump liquid to rise to a level above that of the uncontaminated solvent. The extent of this increase gives an indication of the usefulness of the sump contents.

- Do not use sump liquors (ie the combined residual solvent and the accumulated contaminants) above the maximum boiling point. Set the sump safety cut-out to this temperature.

At the maximum allowable sump temperature, the waste contains 45 - 65% solvent by volume. Some wastes become acidic due either to the type of work treated or to misuse. These wastes may contain higher levels of solvent.

On-site solvent recovery

Solvent in the waste can be recovered and recycled on-site by distilling the sump contents while in the degreaser. The condensate from the distillation is collected by diverting the flow from the water separator into another container. If the bottom safety cut-out operates, no more recovery is possible.

Clean-out is normally needed at a solvent level of 50% by volume. This is typically 5 - 10°C below the cut-out temperature. Companies operating numerous degreasers may opt for separate, dedicated distillation plant.

In some cases, the recovered material is not re-usable or reclaim may be uneconomic because:

- the solvent concentration is too low;
- the solvent is a mixture which is difficult to separate.

Check recovered solvent for acidity and, if necessary, add stabiliser to correct this. It is essential to follow the data sheets and other information provided by the supplier at all times.

Specialist solvent recovery
After distillation, the residual material in the sump may still contain up to 30% of solvent by volume. These residues have commercial value and should not be discarded as waste.

Arrange for such residues to be transported by a licensed waste carrier to a specialist recycling company. Once the recycler has extracted the solvent content, the final unusable material is incinerated.

Specialist solvent recovery is a worthwhile operation as it may reduce both solvent purchase costs and disposal costs. The volume of reclaimable solvent is also allowed against annual use for the purposes of Local Air Pollution Control (LAPC) (see appendix 1).

Some leading solvent manufacturers and distributors offer specialist reclaim programmes to their customers.

Waste disposal
If further solvent recovery is not practicable, follow the correct procedure for disposing of final waste.

- Segregate, package and label all spent solvents properly.
- Allow only trained personnel to handle and store spent solvent.
- Adopt correct handling procedures.
- Document and record movements of both spent solvent for reclaim and final waste.

Final waste must only be disposed of via an authorised licensed waste disposal contractor. The Duty of Care Regulations 1991 demand careful management and documentation at all stages.

The final waste after internal and/or external processing should contain minimal levels of chlorinated solvents. Where the level of residual chlorinated solvent is less than 1 - 2% of the final waste, it can often be incinerated in a conventional incinerator. Wastes containing higher levels of chlorinated solvents can only be incinerated in a specially designed thermal oxidation plant operating at around 1 200°C and fitted with air pollution control equipment.

Landfill is no longer an environmentally acceptable disposal route for these wastes.

5.6.5 Training

Plant operators are crucial to the efficient operation of degreasing plant. Effective operators have to be trained.

Operators of simple open-top degreasers will benefit from a broad, well-structured training programme with a minimum of 4 - 6 hours of instruction. Such a programme should also be sufficient for the basic operation of automatic machines.

Areas to be covered include:

- theory of operation;
- health and safety;
- legal requirements;
- good practice.

Maintenance personnel require additional training in, for example, the programming of plant control equipment. A useful checklist of the main points to be reviewed in a training programme is given in Table 11.

Table 11 Training checklist

Subject	Topics	
Theory	Reasons for degreasing	
Basic plant operation	Start-up procedures Checking cooling Jigging workpieces Timing Delays in freeboard zone Handling	Checking cut-outs Checking solvent condition Loading workpieces Unloading workpieces Workpiece cooling
Health and safety	Toxicity Protective equipment Handling	Hazard and risk Legal framework
Environmental regulations	Legal framework	
Record-keeping	Solvent acidity Solvent additions Safety cut-outs Airflow (extraction)	Plant use Water flow Instrument calibration Clean-out frequency

5.6.6 Assessing progress

To achieve continual improvement, it is important to appreciate what effect your actions have had in reducing solvent use and costs. This enables decisions on further action to be taken and makes it easier to target the most cost-effective improvements. To achieve this understanding, you need to measure solvent use and monitor cleaning costs.

Remember:
If you don't measure it, you can't manage it.

Managing solvent use

Various tools are available to help companies manage solvent use. These include formal environmental management systems, solvent management plans, and monitoring and targeting procedures. These tools can be used as stand-alone activities or as part of a broader waste minimisation programme.

This Guide outlines some of the basic requirements for measuring solvent consumption. Further practical advice is given in *Cost-effective solvent management* (GG13) and other Envirowise publications[10]. *Reduce costs by tracking solvents* (GG114) provides a simple computer-based spreadsheet to help companies compile a solvent inventory and prepare a mass balance of their solvent use.

Measuring solvent consumption

Under LAPC and its successor, Local Air Pollution Prevention and Control (LAPPC) (see appendix 1), companies operating prescribed coating processes using more than a certain amount of solvent each year must obtain an authorisation from their local authority. This requirement applies to coating companies operating vapour degreasing plants.

[10] Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

Local authorities require information on solvent consumption and solvent loss - or mass balance - at six-monthly intervals. It is also good management practice to collect this information as part of a solvent management plan.

Companies are advised to record:

- The information required to complete the example solvent management record shown in Table 12.
- The number of hours the plant is turned on and the number of hours spent degreasing. Use a daily log sheet like the one shown in appendix 2 to obtain this information.

The number of hours that the plant is turned on but not degreasing represents wasted solvent, energy and cooling water. Fitting a rapid response sensor significantly reduces energy consumption when the plant is not degreasing.

This information provides useful plant management data and an indication of the degreaser's operating costs. Another framework is provided in the updated Process Guidance Note for Surface Cleaning which will aid compliance with the SED.

Table 12 Example solvent management record

Management action	Annual volume	Annual weight	Unit price	Annual cost
(a) Solvent purchased*				
(b) Solvent recovered				
(c) Solvent disposed of				
(d) Residual solvent content of waste disposed of				
Then (a) – {(b) + (c) + (d)} = loss or fugitive emissions				

* If solvent is taken into stock and subsequently issued for use, item (a) becomes 'solvent issued' rather than 'solvent purchased'.

Measuring the cost of cleaning

Cleaning costs are either direct or indirect (see Table 13). Direct costs are easier to quantify, while indirect costs can only be estimated if you have a good working knowledge of your overall production process.

Table 13 Typical degreasing plant costs

Direct costs	Indirect costs
Capital cost of plant	Product reliability
Plant installation costs	Product manufacturing yield
Material costs, eg solvent and cooling water	Training (if process changes)
Labour	Air emissions monitoring
Energy	
Waste treatment and disposal	
Maintenance	
Local authority registration fees	

Inexpensive monitoring can bring big savings

A small metal finishing company in the Midlands carried out an audit of its solvent use, including some simple air monitoring. Surprised by the large amount of solvent being lost from the degreasing plant - even when it was not in use - the company decided to implement a solvent reduction plan. Improved practices and some minor modifications to the degreasing plant resulted in a reduction in solvent use of around 25%.

5.6.7 Health and safety monitoring

Companies that follow the advice in this Guide are likely to have made significant steps towards controlling exposure. However, monitoring may still be necessary to demonstrate that a healthy and safe working environment is maintained.

Even though the solvents used tend to have strong and characteristic odours, the threshold of smell is not an adequate method of assessing vapour in air levels. Nevertheless, if a solvent can be detected by its smell other than occasionally and for short periods, then immediate investigation is needed to determine the cause and remedial action taken.

Even when emissions are well controlled, you are always likely to be able to smell trike when near the cleaning bath. If you think the smell of trike has increased, this may suggest something is wrong. However, operators get used to the smell. It is more effective to check the bath condition and to ensure that good practice is being followed.

For specific information on a particular solvent, refer to the manufacturer's data sheet. For detailed advice, contact the HSE InfoLine on 08701 545500 or visit the HSE website (www.hse.gov.uk).

5.7 Cold cleaning

Direct application of cold solvent followed by removal of the soil by wiping or brushing is a long-standing alternative or complement to vapour degreasing. Residual contamination can be removed by one or more rinses in progressively cleaner solvent.

A wide range of solvent cleaners is now available as alternatives to chlorinated solvents (see Table 8 on pages 26-28). They include hydrocarbons, oxygenated hydrocarbons and terpene-based cleaners. Most of the proprietary formulations have relatively high flash points and can require longer drying times than the more volatile chlorinated solvents they are replacing.

The use of low flash point solvents is not normally recommended unless there are particular reasons why certain formulations should be used. If they are used, stringent precautions need to be taken to control the risk of ignition and fire. Solvents and formulations with a flash point below 32°C (and, therefore, subject to the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972) should not normally be used. Most commercial formulations have a flash point above 45°C to allow a significant margin of safety above ambient temperatures.

A mixture of solvents is used with emulsifiers such as fatty alcohols to form an emulsion. The concentrate is sprayed onto the article to be cleaned and then rinsed off with water. Alternatively, the concentrate is mixed with a specified volume of water to give a cleaning emulsion. Components are normally dried using hot air. The oil film produced during drying also prevents corrosion, eg during temporary storage.

5.8 Ultrasonic cleaning

Ultrasonic cleaners are mainly used for:

- precision cleaning of water-sensitive components or assemblies;
- those applications where solvent cleaning provides improved process performance.

With these cleaners, minimising solvent use is essential to ensure compliance with environmental and safety legislation, and to optimise running costs.

The amount of solvent in the cleaning bath is measured precisely, it is added automatically from a reservoir to maintain the correct level. This enables close control of solvent use and the recording of detailed information on solvent use. The ultrasonic tank is maintained at a controlled level of cleanliness by filtering and distilling the solvent.

5.9 Action plan for improvement

Ask yourself:

- How can I meet the requirements for risk phrase compounds within the shortest possible time?
- How well is the vapour from the degreasing plant controlled?
- Can I improve my solvent management?
- Can I improve the performance of existing plant by making simple and cheap modifications (as described in section 5.5)?
- Can I reduce solvent use and VOC emissions by adopting operational good practice (as described in section 5.6)?
- Am I using the optimum solvent for the application? Remember that you may need to alter the specification when changing to a different solvent.
- Can a conventional top loader fitted with appropriate cut-out and sensors do the job effectively and safely?
- Could I reduce vapour emissions by adding extra doors? Top loading units with double doors have:
    - automatically operated lids;
    - a sealed load/unload zone;
    - an extraction zone to purge solvent from the load/unload zone.
- Am I treating small parts in bulk? A totally sealed end-loading unit may be the answer.
- Do I need to fit air pollution control equipment?

Practical advice from Envirowise

For free advice and publications on improving your solvent management, contact the Environment and Energy Helpline on freephone 0800 585794 or visit the Envirowise website (www.envirowise.gov.uk). Companies with fewer than 250 employees can request a free *Fast*Track or counselling visit from an independent Envirowise consultant.

Useful publications include:

- *Cost-effective solvent management* (GG13)
- *Reduce costs by tracking solvents* (GG114) - includes spreadsheets on disk
- *Environmental management systems workbook for metal finishers* (GG118)
- *Environmental management systems workbook for engineering manufacturers* (GG205)

Other sources of useful information

- For information on health and safety issues, phone the HSE InfoLine on 08701 545500 (www.hse.gov.uk).
- See HSE Engineering Information Sheet No 34 *Surface cleaning: solvent update including the reclassification of trichloroethylene*, available from HSE Books (Tel: 01787 881165, www.hsebooks.co.uk).
- Visit www.environment-agency.gov.uk/netregs/ for guidance on environmental regulations.
- For information on the SED, visit the DEFRA website (www.defra.gov.uk/ environment/airquality/solvents/index.htm).
- For suppliers of alternative substances and technologies for surface cleaning, see *The surface cleaning suppliers list*, available from the Engineering Employers' Federation (www.eef.org.uk).

Aqueous cleaning

Aqueous cleaning systems include a number of processes that use water, water-based or semi-aqueous cleaners either passively or physically. In many cases, they are a good alternative to organic solvents for surface cleaning. All parts of the component are cleaned and operating costs are lower than those for vapour degreasing.

There are five broad categories of aqueous cleaners:

- pure water;
- neutral aqueous solutions;
- acidic aqueous solutions;
- alkaline aqueous solutions;
- semi-aqueous solutions.

Aqueous cleaners do not break down soils in the same way as solvents, so the wastewaters may contain any soil and oils removed. Use of filtration or oil separation techniques can allow the cleaning solution to be re-used. Disposal options for waste cleaner or separated soils depend on the nature of these substances, but can represent a significant operating cost.

Aqueous cleaning brings cost, environmental and health benefits

In response to the ban on the use of chlorinated solvents (Genklene) following the ratification of the Montreal Protocol, SPS Technologies decided to switch from traditional vapour degreasing in one centralised tank to aqueous cleaning carried out in individual production cells. The switch resulted in net cost savings of over £27 000/year, reduced throughput time and VOC emissions, and improved working conditions.

For more details, see the industry example in the back pocket of this Guide.

Most aqueous cleaning agents consist of water and one or more of the components listed in Table 14.

Table 14 Typical components of aqueous cleaning agents

Component	Purpose
Builders	Help prevent soil being redeposited on the component. May also act as a pH buffer or sequestering agent.
Surfactants	Wetting agents used to provide detergency and encourage emulsification.
Corrosion inhibitors	Help to prevent corrosion by the cleaning agent. Promote oxidation that provides a thin protective layer on the cleaned surface.
Sequestering agents	Used to remove salts or contaminants from the wash solution by reacting with them.
Defoamers	Added to enhance the removal of cleaner from components and to enable its re-use in the cleaning system.

After aqueous cleaning, the components are wet and may require drying before further use - though this is not always necessary when a water-based surface treatment is to be applied. Drying increases the amount of energy used for cleaning and can be carried out using:

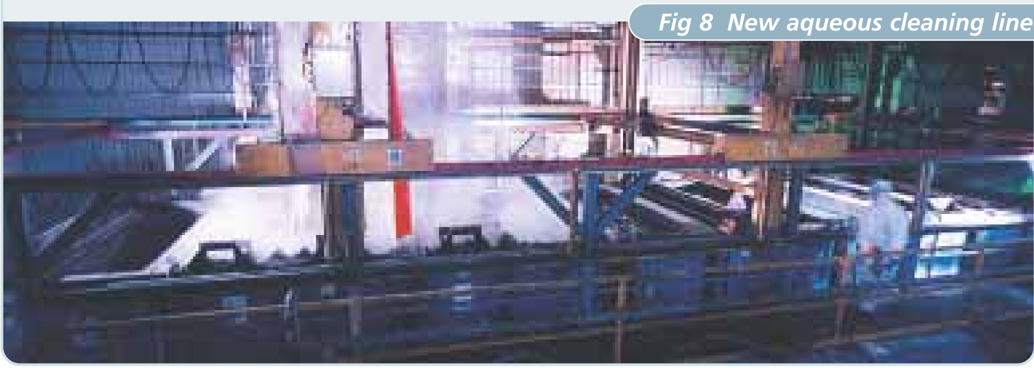
- vacuum dryers;
- centrifugal dryers;
- ovens;
- hot air dryers.

Several aqueous cleaning systems are now available that carry out washing and drying activities in the same plant or in a washing tunnel involving four stages, ie cleaning, rinsing, rinsing with de-ionised water and drying (using recirculated warm air).

Conversion coater eliminates vapour degreasing and introduces cleaner technology

Metal Treatments Birmingham explored various options to control solvent emissions from its vapour degreasing tank and thus meet the requirements of the Environmental Protection Act 1990. The solution identified by the company involved using additional aqueous cleaning processes (see Fig 8). These additional process stages were found to be effective in eliminating the most stubborn stains and the company subsequently found that it was able to cease using organic solvents altogether.

Fig 8 New aqueous cleaning line



6.1 Cleaning systems

Table 15 overleaf shows the range of cleaning systems applicable to aqueous cleaning.

Table 15 Aqueous surface cleaning systems

Cleaning agent	Contaminants removed	Applicability	Comments
Pure water	■ Water-based machining coolants. ■ Chlorides and other ionic contaminants. ■ Bulk contaminants such as dirt, grit and grease.	■ Can be a very effective cleaning agent. ■ Used mainly in steam systems and in high/low pressure systems.	■ Water used for cleaning - especially water from rinse steps - can often be recycled and re-used. ■ Depending on the contamination, the aqueous waste stream may need to be treated prior to discharge. ■ Demineralisation of some water supplies may be necessary to prevent water spots or other residues being left on the metal surface. ■ Water used in precision cleaning applications may need to be de-ionised and filtered.
Neutral aqueous solutions	■ Organic residues, eg light oils, grease. ■ Inorganic residues (particles, chlorides and other salts).	■ Cleaning delicate surfaces or to replace alkaline or acid cleaning agents. ■ Excellent for use in spray and ultrasonic applications. ■ Also used in steam equipment. ■ The key to the performance of these formulations is selecting the appropriate solution for the soil being targeted. ■ The type of mechanical agitation chosen is important.	■ Cleaning solutions from pH6 to pH8 are considered neutral. ■ Generally include surfactants, which function as wetting and emulsifying agents. Corrosion inhibitors and dispersants are also often added. ■ Effective where a high degree of chemical solvency is not required. ■ Not particularly suitable for immersion processes unless agitation is used. ■ Most vapour degreasers using organic solvents need only minor modifications to use neutral aqueous solutions. ■ Potential corrosion problems can often be overcome by changing the process or adding corrosion inhibitors. ■ A drying system may be needed. ■ The quality of the incoming water should be considered for effects on the process.
Acidic aqueous solutions	■ Scale, rust and metal oxides. ■ Not particularly good for removing oil or grease.	■ Cleaning and phosphating (without coating). ■ Acid and additive content depends on the metal to be cleaned and the contaminants to be removed.	■ May contain mineral acids (hydrochloric, sulphuric, nitric), chromic acid, hydrofluoric acid, phosphoric acid and organic acids such as acetic acid and oxalic acid. ■ Mineral acids are generally much more aggressive than organic acids and should be handled with caution. ■ Citric acid, an acidic builder, can be used to prepare a typical solution of pH4 and hydrochloric acid to generate a solution with a pH of less than 2. ■ May also contain detergents, chelating agents and small amounts of water-miscible solvents.

Table 15 Aqueous surface cleaning systems (continued)

Cleaning agent	Contaminants removed	Applicability	Comments
Alkaline aqueous solutions	■ Greases. ■ Coolants. ■ Cutting oils. ■ Shop-dirt. ■ Fingerprints. ■ Some water-soluble paints. ■ Carbonaceous soils are removed by solutions at pH13.5. ■ Oils and greases are generally removed with solution at pH8 - 13.	■ Cleaning metals machined chip-free and by chip-removing methods. ■ Pre-cleaning before treatment such as phosphating. ■ Used with all types of liquid processes to clean parts such as hydraulic valve bodies, fuel injector components and machined aluminium castings.	■ Most common form of aqueous cleaning technology. ■ Formulated by adding chemicals such as sodium/potassium hydroxide, carbonate, bicarbonate, phosphate and silicate. ■ Do not generally need the same level of attention required for acidic cleaners because they are less aggressive to the cleaning plant. Nonetheless, they must be monitored periodically and adjusted for concentration and soil loading. ■ Employ both physical and chemical means to clean the substrate surface. ■ Chemical action can occur via saponification of certain contaminants. During saponification, water-soluble soaps are produced by the neutralisation of fatty acid soils. ■ Physical cleaning occurs via wetting and emulsification provided by the addition of surfactants. These are selected according to the method employed. ■ Cleaning is performed in appropriate equipment by manual spraying, dipping and spray-dipping. ■ Can clean to high cleanliness levels when combined with good filtration and rinsing. ■ Often contain additives to improve cleaning, eg sequestering agents, emulsifiers and surfactants. Inhibitors are necessary with some metals, especially aluminium.
Strongly alkaline aqueous solutions	■ Severe soiling.	■ Electrolytic degreasing.	
Semi-aqueous solutions	■ Oils. ■ Greases. ■ Rosin fluxes. ■ Drawing compounds.	■ Effective in cleaning parts with heavy soiling.	■ Usually emulsions of water and solvents (generally flammable VOCs such as terpenes, glycol ethers, esters or hydrocarbons). Term also applied to processes where parts are first cleaned using an organic solvent and then rinsed in water. ■ The load is immersed in the solvent emulsion, which dissolves or loosens the contamination, before being transferred to a water rinse. ■ The metal surface is preferentially wetted and the oils, solvent and solid soils float off as a finely dispersed emulsion. ■ Similar disadvantages to those of aqueous cleaning, with a potential need for drying and appropriate effluent treatment. ■ May leave a residue which can be removed by a water rinse. This film is sometimes left on the part to provide a protective coating. ■ Usually employ a partially closed loop process where the used emulsion is collected and then separated in a decanter into water and solvent. The water can be recycled, while the solvent can often be filtered and re-used in the wash tank. ■ Can also be set up to re-use both the water and solvent in wash or rinse processes.

Process change allows switch to aqueous cleaning

A Swedish manufacturer of light fittings from aluminium or steel sheets, previously degreased metal sections using trike. A pollution prevention audit was carried out to analyse materials flow in the degreasing process. This audit showed that, by better housekeeping, the need for trike degreasing could be reduced by 50%. However, the selected measure actually led to the use of trike being eliminated.

The cutting fluids used to cut the aluminium sheets were difficult to remove without the use of chlorinated solvents. A change from metalworking fluids based on mineral oil to biodegradable cutting oils based on vegetable oils allowed an alkaline water-based detergent system to be used instead of trike.

VOC emissions were minimised and solvent purchase and disposal costs were significantly reduced. Cutting oil costs also fell and workplace exposure to solvents was prevented. In addition, the new system makes it easier for the company to comply with air pollution standards. Cost savings of £320 000/year were achieved following an initial capital investment of £300 000, giving a payback period of 11 months.

6.2 Aqueous cleaning good practice

The following measures will minimise waste, reduce energy consumption, minimise the load on your effluent treatment plant and minimise emissions to air.

- Schedule work to make use of appropriate cleaners with appropriate components to avoid unnecessary cleaner changes.
- Use proprietary cleaners that operate at a lower operating temperature.
- Use a minimum of two and preferably three stages of cascade rinsing (see Section 8.5.1) with air agitation.
- Generate turbulence using an eductor to:
  - provide improved cleaning;
  - maintain particulates in suspension so that they can be removed by external filtration.
- Use membrane filtration[11] to remove oil, grease, emulsions and dispersants from the cleaner.
- Use automatic dosing of proprietary concentrated cleaner to maintain optimum temperature conditions and cleaner concentration, and thus ensure consistent cleaning.
- Maintain an adequate freeboard zone above the cleaner level (minimum height of 125 mm) to minimise emissions to air. Extraction lip ducts mounted at least 50 mm above the top of the tank lip angle and minimum airflow will provide satisfactory extraction.
- Use hexagons or chroffles on the tank surface to reduce evaporative loss and energy consumption by up to 50%. The use of automated lids on larger cleaner tanks will reduce fume extraction energy costs by up to 80%, as well as reducing energy consumption for process heating.

Use of aqueous cleaners will increase your site's water consumption. The water use benchmarks given in *Minimising chemical and water waste in the metal finishing industry* (GG160)[12] allow you to compare your site's water use with the industry average. Much of GG160 is concerned with practical advice on how to reduce water consumption, particularly during rinsing. Table 16 summarises a range of best practice measures and their benefits.

[11] See *Cost-effective membrane technologies for minimising wastes and effluents* (GG54) available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

[12] Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

Table 16 Practical measures to reduce water consumption

Action	Procedure	Benefits
Measure water flow (see section 5.1 of GG160)	■ Do not just meter the water input to your site as a whole. Install meters on each process line or on each water inflow point in your cleaning process. ■ Keep regular records of water use. This will allow you to review the success of any water-saving measure. It will also help to ensure that consumption patterns are normal.	■ Provides an exact knowledge of water use throughout the plant. ■ It is a good starting point for water minimisation and helps to ensure that reduced water consumption is maintained. ■ Involves simple and low-cost technologies.
Flow controllers (see section 5.2 of GG160)	■ Install flow restrictors on water supply lines, wherever possible.	■ Significantly reduces unnecessary water use. ■ Depending on the number of restrictors required, the capital outlay is limited and units are easy to install. ■ Automatic action gives low operating and maintenance costs. ■ Installation of flow controllers on some lines can help to ensure a constant water pressure on other lines, eg those used for spray rinsing.
Countercurrent rinsing (see section 5.3 of GG160)	■ Use countercurrent rinsing with three or even four baths. In Germany, where discharge consents are much lower, it is common to incorporate up to five rinsing stages. ■ Use static drag-out tanks in conjunction with countercurrent rinse systems. Chemical drag-out accumulates in the static rinse tank and can be used to top up the plating bath. However, a static rinse bath will not provide sufficient rinsing on its own.	■ Countercurrent rinsing significantly reduces water use. Twin rinsing reduces water consumption by 98%. ■ Can be linked to the cost-effective recovery of process bath chemicals via evaporation (see Section 6.5 of GG160) or electrochemical recovery (see Section 6.4 of GG160). ■ Improved product quality. ■ Lower reject rates as a result of more effective rinsing.
Spray and fog rinsing (see section 5.4 of GG160)	■ Where possible, install spray rinsing after plating baths.	■ Up to 50% of drag-out can be recovered. ■ Drag-out is returned directly to the process baths. ■ Water consumption is only 1 - 2 litres/rack - a significant reduction compared with using a conventional rinse tank for the first rinse.
Manually operated trigger hoses (see section 5.5 of GG160)	■ Where hose use is necessary, install trigger-operated units.	■ Water flow is easily controlled and ceases when it is not required, thus reducing water use substantially. ■ Installation and maintenance costs are low. Attachments for the end of the hose cost £70 (1999 prices). For a system that reels onto a wall bracket, you can expect to pay around £200. ■ Easy to operate.

Table 16 Practical measures to reduce water consumption (continued)

Action	Procedure	Benefits
Other methods for controlling hose use (see section 5.6 of GG160)	■ Use a variety of high- and low-pressure hoses around the site. Colour-code each one so that misuse can be identified. ■ Use retractable hoses that cannot be left propped in tanks or abandoned on the floor. ■ Use a pre-programmable water delivery system where the amount required is keyed in. This ensures that only a specified volume of water is delivered at any one time.	■ Water flows are more easily controlled. ■ Colour-coded hoses are low-cost, low-maintenance items and easy to operate.
Water recycling	■ Reverse osmosis (see section 6.6 of GG160).	■ Effective method of dealing with a constant flow of wastewater. ■ Water is de-ionised and can be recycled to the treatment and rinsing processes, effectively eliminating effluent discharge and significantly reducing the site's water supply requirements. ■ Metals are removed as a concentrated solution that can often be returned to the process baths, thus reducing the amount of process chemical required. ■ Less dependent on wastewater quality than techniques such as ion exchange. Although salts and organics do affect membranes, this is not as significant as their impact on ion exchange resins.
	■ Ultrafiltration (see section 6.7 of GG160).	■ Useful for final cleaning or 'polishing' of water before it is recycled to the process. ■ Can be applied at any stage of the process. ■ Can be used to clean solutions such as hot aqueous soap cleaners, thereby extending solution life.

Envirowise has also produced an *Electroplaters plant performance optimisation tool* (IT265)[13] to help companies calculate the effect on costs and savings of making changes to their electroplating line and thus improve their productivity, efficiency and profitability. This tool uses Microsoft® Excel 97 to estimate potential cost savings and environmental benefits from adopting various features of a Best Available Technique (BAT) Model Plant in your company.

Aqueous cleaning and retrofitting of remaining trike tank reduces solvent use

EC Williams, a specialist electroplating company, has reduced trike consumption from 18 tonnes/year to around 2 tonnes/year by replacing three open-top vapour degreasing units with aqueous cleaning units and retrofitting one degreaser with a lid. Investment costs were low and operator exposure to trike has been significantly reduced.

For more details, see the industry example in the back pocket of this Guide.

Practical advice from Envirowise

Useful publications include:

- *Minimising chemical and water waste in the metal finishing industry* (GG160)
- *Electroplaters plant performance optimisation tool* (IT265)
- *Simple measures restrict water costs* (GC22) - a Case Study at a medium-sized electroplating company

Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

13 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

Biological cleaning

Biological cleaning is a well-developed technology that removes oils and greases, paints and solvents from components. Biocleaners are seen as a suitable and cost-effective alternative to conventional cleaners for the removal of oils and greases, and a number of companies now offer a wide variety of biocleaner products.

Contact the BIO-WISE Helpline on 0800 432100 to obtain free publications, information and advice about biological cleaning and other types of biotechnology. The Helpline also has details of suppliers of all types of equipment and biocleaners.

This section deals with enzyme cleaners and surfactant/bacterial remediation systems - both of which are finding a large-scale and growing use in the surface engineering industry.

Degreasing agents derived from plant materials are also available and are used in the surface engineering industry either directly or after chemical modification. These solvents include natural oils from safflower, rape, linseed and cottonseed, and turpentine obtained from pine trees. Terpenes (see Table 8) are also derived from plants. They will mix with water as well as being powerful solvents for fats and greases. Terpenes are non-toxic and degrade readily in the environment. Limonene, which is found in lemon rind but is now manufactured synthetically, is used in degreasing liquids.

7.1 Advantages of biological cleaning

The substances used in biological cleaning are generally less hazardous to human health and the environment. The systems are largely self-regenerating and thus produce less waste than other cleaning systems.

The main advantages of biological cleaning techniques are:

- generally lower running costs due to reduced energy consumption and waste disposal costs;
- improved health, safety and environmental performance;
- no requirement for legal authorisation;
- less corrosion of equipment (as may arise with alkaline or acidic treatments);
- reduced downtime;
- all parts of the component are cleaned.

In general, the disadvantages of biological treatment are:

- systems generally require specific conditions and thus pH and temperature may need to be monitored;
- certain cleaners may require replenishing;
- components may be wet following treatment;
- only used at present to treat organic contamination - they cannot deal with rust or dirt, although they may loosen this type of soil.

Biological system cuts cleaning costs by 90%

Glacier Vandervell Europe uses a number of different oils during the production of bushes for automotive applications. These oils are cleaned off the finished bushes before they are dipped in a white spirit-based wax preservative prior to packing and shipping. To reduce costs and to minimise the environmental impact of the cleaning process, the company replaced hot caustic cleaning with an in-process biological cleaning system. The biological system uses oil-degrading bacteria in a non-hazardous, water-based soak cleaner. Since the switch, annual running costs for cleaning have fallen by 90% (equivalent to £8 900/year). The system cost a total of £10 980 (for the control unit, reservoir tank and electrics), giving a simple payback period of 15 months. Other benefits include:

- elimination of the need to dispose of oil-saturated cleaning solution;
- lower heating costs;
- elimination of the need to top up the wax preservative with white spirit because the lower cleaning temperature means it no longer evaporates on contact with the cleaned bushes;
- improved working environment for operators;
- no need for production downtime and labour to change the cleaning solution.

For more details, see BIO-WISE Case Study 12 *Biotechnology cuts cleaning costs by 90%*. To obtain a free copy, contact the BIO-WISE Helpline on 0800 432100 or visit the BIO-WISE website (www.dti.gov.uk/biowise).

7.2 Cleaning technologies

Table 17 summarises the applicability, advantages and disadvantages of the two main types of biological technologies currently used for surface cleaning of metal components.

Table 17 Biological surface cleaning methods

Process	Applicability	Advantages	Disadvantages
Enzyme cleaners	■ Used instead of solvent cleaners to remove light oils before surface treatment processes.	■ Low running costs. ■ Spent enzyme cleaner solution can be safely disposed of to sewer.	■ Finite life. ■ May not be suitable to treat wide mixture of contaminants. ■ Cleaning and drip-drying of components take longer than vapour degreasing.
Surfactant/ bacterial remediation systems	■ Used for batch cleaning of components in the automotive and metal plating industries. ■ Displace and emulsify oil from component surface.	■ Effectiveness of surfactant is maintained and it does not need replacement.	■ May not be suitable for jobbing platers. ■ Cleaning and drip-drying of components take longer than vapour degreasing.

7.3 Enzyme cleaners

Enzymes are naturally produced biological catalysts that can be used to speed up the breakdown of oils.

Enzyme cleaner systems generally consist of an aerated tank maintained at a temperature of around 40°C to provide optimum conditions for the enzymes to operate. Aeration of the tank improves the cleaning efficiency by providing agitation at the surface of the components. The components are racked up and loaded into the tank; washing takes between about 20 and 30 minutes depending on the type of soil. Enzyme cleaners have a finite life (this depends on how dirty the components are), but when the solution needs replacement, it can be safely disposed of to sewer.

7.3.1 Advantages

The advantages of enzyme cleaners include:

- low operating costs compared with solvent degreasers;
- safe disposal of spent cleaner to sewer;
- no harmful emissions to air;
- improved working environment (biocleaners have a lower hazard rating under COSHH).

Switch to enzyme cleaner reduces cleaning costs by 74%

Expert Heat Treatments (EHT) has successfully switched to using an enzyme cleaner instead of organic solvents to degrease lightly oiled components prior to heat treatment. Capital costs for biological cleaning were some 59% lower than those for a conventional top-loading vapour degreaser, thus saving EHT at least £6 500. The new system is 74% cheaper to run, saving EHT over £15 300/year and giving a simple payback period of under four months.

For more details, see BIO-WISE Case Study 10 *Enzyme cleaner helps solvent costs evaporate*. A copy is provided in the back pocket of this Guide.

7.4 Surfactant/bacterial remediation systems

In these systems, traditional caustic cleaners are replaced with a surfactant cleaner capable of lifting and emulsifying a wide range of oils and other complex organics from the surface of components. This surfactant cleaning solution contains bacteria, which then degrade and eliminate the contaminants in the soak cleaner in a process called bioremediation. The surfactant cleaner is constantly rejuvenated, replenished and returned to the tank in optimum condition for steady-state operation. The effectiveness of the surfactant is maintained and does not require replacement. This avoids the need to:

- stop and remove spent cleaner;
- treat and dispose of spent cleaner.

All water-soluble detergents (preferably those that are biodegradable) can be used in this process. However, these biological systems normally use oil-degrading bacteria in a non-hazardous, water-based soak cleaner. The bacteria used in the cleaning solution are normally common species that do not cause disease in humans and are not classified as hazardous.

During cleaning, the following occur simultaneously:

- objects are washed in an aqueous solution;
- contaminants are dissolved in the washing liquid;

- the washing liquid is separated from the metal objects;
- nutrients are added to activate the micro-organisms;
- the micro-organisms degrade the hydrocarbons present in the washing liquid.

Optimum operating conditions are:

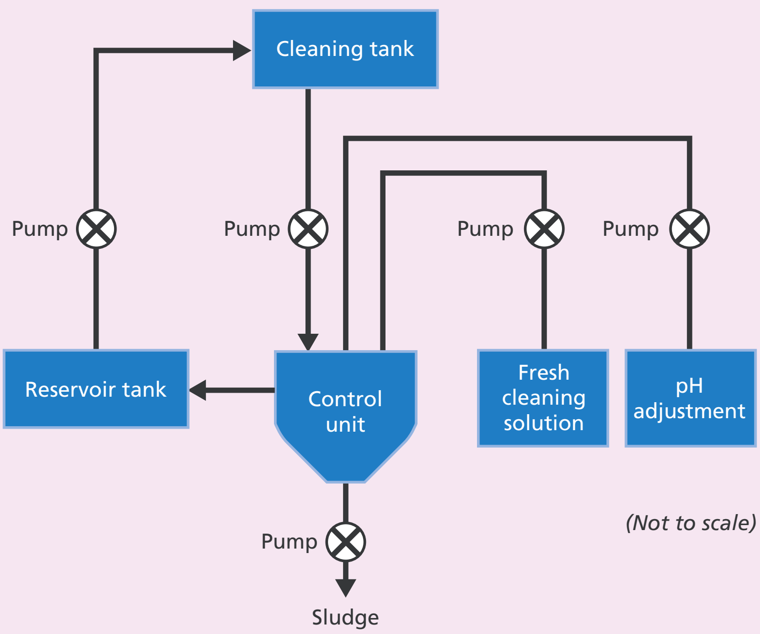
- an oil content of 50 - 500 mg/litre;
- a pH of between 6 and 8;
- a temperature of 35 - 45°C, but preferably 30 - 40°C, which is substantially lower than that required for vapour degreasing or aqueous cleaning systems (thus reducing energy costs).

The temperature, pH and surfactant levels in the cleaning tank are monitored by a control unit (see Fig 9) and adjusted automatically to maintain optimum conditions for both the cleaning and bioremediation processes.

Cleaning and bioremediation usually occur in the same tank. The cleaning solution is pumped in a closed loop system to the cleaning tank and then back to the control unit (see Fig 9). Additional tanks can be used to increase the capacity of the system. The highly effective surfactants present in the cleaning solution remove the oils from the surface of the components. These oils are then emulsified by the surfactants. The bacteria in the cleaning solution then digest the emulsified oils and degrade them to carbon dioxide and water. Small amounts of nutrients are added to the cleaning solution to activate the oil-eating bacteria. The number of bacteria present is determined largely by the level of food available, ie the oil present.

The only waste from this type of system is a small amount of sludge containing a mixture of particulates and dead bacterial cells. This sludge settles to the bottom of the control unit and is drained off periodically. A separator may be fitted to remove dead bacterial cells from the cleaning solution. The sludge is treated with sodium hypochlorite to destroy any live bacteria and sent to an effluent treatment plant for disposal.

Fig 9 Schematic diagram of a typical biological cleaning system



7.4.1 Advantages of biological degreasing and closed rinse water systems

Although capital costs may be slightly higher than for conventional cleaners, this type of biological cleaning system has a number of advantages (see Table 18).

Table 18 Advantages of surfactant/bioremediation cleaning systems

Advantage	Reason
Reduced water and electricity use	Low operating temperature
Low waste treatment costs	Closed loop system
No costly sludge disposal	Minimal sludge
Simple operation	Liquid concentrate Automatic control and adjustment
'Never dump' operation	Continuous replenishment
Compatible with all base materials	Moderate pH used
Improved operator health and safety	Classed as a low hazard cleaning solution under COSHH
Non-polluting	Bioremediation degrades contaminants to harmless substances such as carbon dioxide and water.

7.5 Biological cleaning good practice

When it is well-managed, biological cleaning is the cleanest and safest technique for removing hydrocarbon contamination from metals. It generates low levels of waste and no emissions.

Best practice is based on:

- choosing the most appropriate system for the cleaning problem;
- process optimisation (ie ensuring the process is operating correctly).

7.5.1 Choosing the most appropriate system for the cleaning problem

Selecting the most appropriate system will help to ensure that the process works optimally.

- Design the cleaning system and formulate the cleaning solution to meet the requirements of the cleaning problem. This may involve the selection of either an enzyme cleaner or a surfactant/bacterial remediation system.
- The system and formulation will depend on:
  - surface type being cleaned;
  - type of soiling;
  - degree of cleanliness required.
- Liaise with your supplier regarding system and cleaner formulation and, where possible, trial the formulation before it goes into full use.
- Contact the BIO-WISE Helpline on 0800 432100 for details of suppliers and to access free expert advice from an independent Industrial Biotechnology Specialist.

7.5.2 Process optimisation

Best practice involves monitoring and controlling the temperature, pH and hydrocarbon (soiling) levels to provide the biological process (enzymes or bacteria) with the optimum operating environment.

- Use an automated control system to monitor temperature, pH and hydrocarbon levels, or ask trained operators to monitor these variables manually and take appropriate action.
- The optimum conditions for biological systems are:
  - pH6 - 8;
  - temperature of 35 - 45°C;
  - avoidance of contamination with toxic substances such as bleaches, acids, alkalis and heavy metals;
  - a hydrocarbon (oil) content of 50 - 500 mg/litre.
- Monitor the contamination of the component being cleaned; longer contact time with the soils may be required compared with chemical cleaning systems.

Practical advice from BIO-WISE

Useful publications include:

- Case Study 10 *Enzyme cleaner helps solvent costs evaporate*
- Case Study 12 *Biotechnology cuts cleaning costs by 90%*

Available free of charge through the BIO-WISE Helpline on freephone 0800 432100 or via the BIO-WISE website (www.dti.gov.uk/biowise).

Conversion coating

Many metal surfaces require treatment with a conversion coating to increase the corrosion resistance of the surface. This category includes phosphating and chromating.

Although there are many different systems in use, they have common wastes which include:

- rinse water;
- excessive use of water;
- drag-out of treatment agents into rinse stages;
- energy losses during the heating and cooling of dip tanks.

Cost savings can be achieved in all these areas and with any type of conversion coating system.

Good practice involves examining the design, operation and management of the treatment system to:

- maximise productivity;
- reduce waste.

8.1 Plant design

This is the starting point for reducing waste and operating costs. Many simple design elements which enhance performance can be retrofitted at low cost.

- Minimise drag-out and spillage by using jigs and baskets without unnecessary hollows and flat surfaces that can carry coating out of the tank. This coating can fall onto the floor or into rinse tanks, creating waste and increasing effluent loads.
- Fit draining boards between immersion tanks to prevent losses through spillage onto the floor. Any drag-out will flow back to the tank provided that:
  - the boards are constructed of suitably resistant material;
  - the boards are angled back towards the tank.
- Ensure that the rinse tank overflow is not situated too close to the inlet valve. This allows clean water to overflow while the rinse solution becomes increasingly contaminated.
- Encourage mixing in the rinse tank by modifying the plumbing or inserting a plate between the inlet and outlet points.
- Minimise rinse water consumption by ensuring that the rinse tank receives only enough clean water to allow adequate rinsing - any more is wasted. This can be achieved in several ways, eg install conductivity probes to trigger the addition of clean water once contamination has reached a preset level instead of having water flowing into the tank continuously and regardless of whether or not parts are being rinsed.
- Improve rinse effectiveness by increasing the agitation in the rinse tanks, eg by installing air sparges at the bottom of tanks.

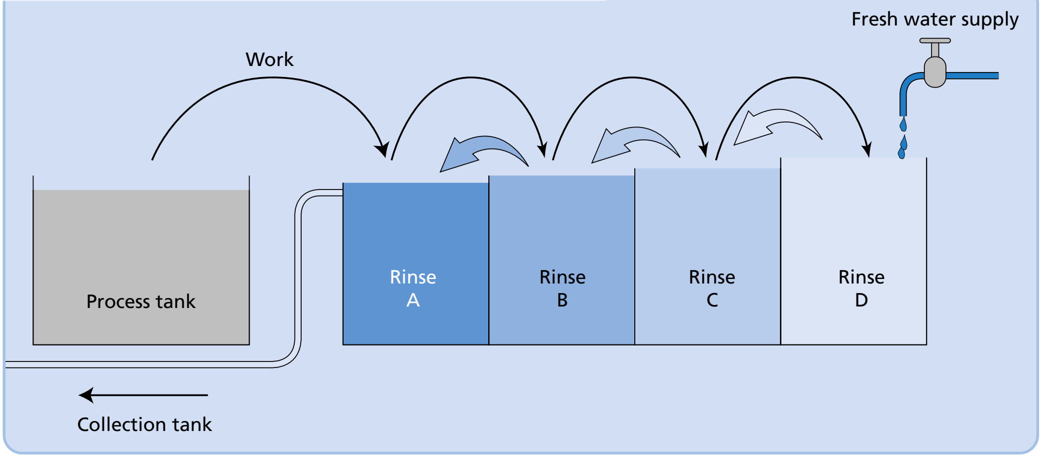
8.2 Plant operation

- Consider increasing the number of rinse stages and re-using rinse water.

The quality of the rinse water needs only to be fit-for-purpose. Therefore, water used for a final rinse, which should receive only slight contamination, could be used during earlier rinsing stages, ie countercurrent rinsing.

Such systems (see Fig 10) significantly reduce the overall amount of water used. With a two-stage rinse system, water use can be reduced by at least half. With careful thought and application of 'rinse ratios', water savings can be much higher. For more information about countercurrent rinsing, see *Minimising chemical and water waste in the metal finishing industry* (GG160)[14].

Fig 10 Schematic diagram of countercurrent rinsing



- Use spray rinses to add extra rinse stages by pumping the water from the following rinse stage to sprays above a rinse bath. This reduces drag-out from rinse baths. On the final rinse bath, the feed water pressure can be used to provide a final rinse with clean water.
- Ensure that tanks are not overfilled, thus eliminating overflow of the bath contents as items are immersed.
- Ensure that there is sufficient time for drainage back into the tank once a part is removed.
- Angle spray jets in towards the tunnel at the start and the finish of spray tunnels in large, conveyorised conversion coating systems. In such systems, parts travel on a conveyor through the degreasing area suspended on jigs or flight bars. Design the equipment so that spray does not bounce off parts as they move into or out of the tunnel.
- Reduce the amount of drag-out on conveyorised tunnel systems by designing jigs that angle the part so that its lowest point leaves the drip zone of the tunnel last, thus allowing any drag-out to run back into the tanks.
- Ensure that the parts are immersed for sufficient time to allow the conversion coating to react with the metal and achieve an adequate finish quality. If a variety of shapes and sizes are used, it may be necessary to verify timings at the start of each run and to ensure that operators are familiar with these variations.
- Implement a good housekeeping programme, eg check tanks regularly for sludge build-up and undertake cleaning when necessary.
- A preventive approach to plant cleaning is better than waiting for problems on finished parts to emerge, causing shutdowns during production time and rework.

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[14] Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

8.3 Plant management

- Ensure that solutions are maintained within the desired concentration ranges by regular measurement using probes or titration.
- Adjust refilling procedures to cope with production levels.
- Maintain solution temperatures within the design parameters. If the solution is too hot, energy is wasted; if it is too cold, quality is compromised.
- Record tank temperatures regularly to provide better control of the finish quality.
- Lag dip tanks, particularly those held at higher temperatures. Around 85% of radiative heat losses are typically avoided by lagging tanks.
- Consider using plastic balls or chroffles to form a penetrable, insulating blanket on the surface of hot liquids. Using chroffles can produce reductions of up to 60% in both surface heat and material losses.
- Instead of sending water from cooling coils (eg on a vapour degreasing plant) to drain, consider re-using the water in rinsing baths to reduce overall water use.
- When processing large numbers of parts, consider using compressed air knives to blow residual moisture from the parts as a quicker and cheaper alternative to hot air drying.

8.4 Combined cleaning and conversion

Some systems use a batch multi-stage cabinet spray unit - rather like a large dishwasher - to clean parts using a neutral or alkaline solution, followed by phosphating and rinsing. The need for VOC-based degreasers is thus eliminated. Components are lowered in baskets into the vapour zone above the boiling phosphoric acid solution for degreasing and subsequently dipped into the solution where a phosphate conversion coating is applied. After dipping, the component is once again raised into the vapour zone to remove traces of phosphoric acid. Residual condensate evaporates as the component is removed from the tank.

Immediate benefits with automated combined cleaning machine

D B Partners is a medium-sized contract finisher in Cheltenham operating a wide range of coating processes including conventional coating, screen printing and conformal coatings (a plastic protective coat applied by spraying or dipping). The company specialises in finishing components for aerospace, military and general applications. Several coating systems are used including water-based, two-pack solvent-based and powder coating.

Even though the company uses less than 5 tonnes of organic solvent a year, D B Partners decided to register with its local authority under LAPC and set itself a target for improved environmental performance as part of a bid to be 'best in class'. One of the most significant changes has been the replacement of vapour degreasing, mechanical cleaning and hand-wiping processes with an automatic, fully enclosed, aqueous degreasing and phosphating machine.

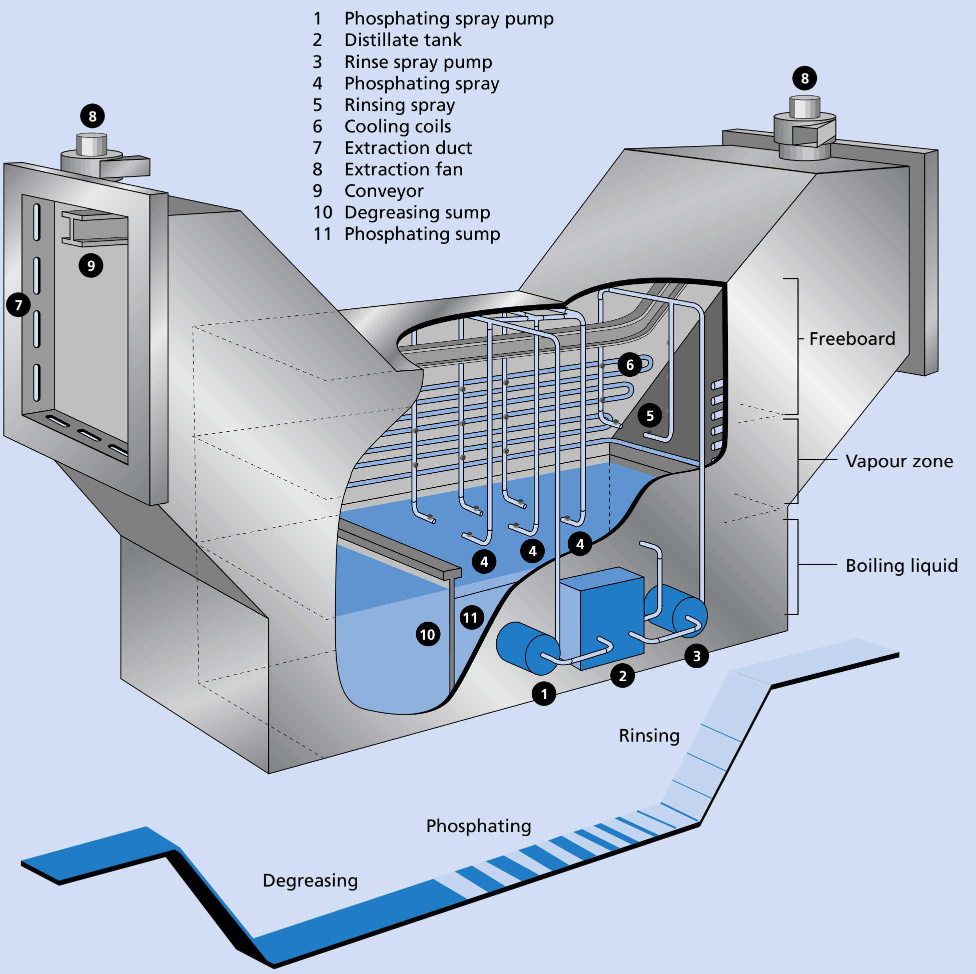
Immediate benefits include:

- elimination of increasingly expensive solvent purchases for cleaning;
- improved quality and consistency of pretreatment;
- removal of a bottle-neck in the pretreatment department.

Plant operators have also expressed their approval, welcoming the reduced possibility of exposure to cleaning solvent vapours.

Other systems, which also combine degreasing and phosphating, use methylene chloride to degrease components before they are immersed in a dip tank where they receive a phosphate layer. Such systems require less space and are especially suitable for continuous conveyor systems (see Fig 11) or for handling large batches of small to medium-sized parts.

Fig 11 Schematic diagram of a conveyorised processing plant providing degreasing, phosphating and rinsing in a single unit



Another simple approach to combined cleaning and phosphating is to use one iron phosphate tank as a cleaning solution and a second tank to finish off the phosphating. This reduces material use as the uncontaminated iron phosphate solution can be used to replenish the cleaning bath solution.

The advantages of combined degreasing and phosphating systems include reductions in:

- space requirements;
- handling time;
- chemical costs.

Another benefit of combined systems is that parts leave the process after a single stage and are protected against flash rust. Treated parts can, therefore, be stored before coating without the risk of rusting.

Combined degreasing and phosphating system improves performance

A company in Nottingham that designs and manufactures industrial, commercial and educational furniture systems, applies a thick, durable finish to product surfaces in an epoxy powder coating plant. This process requires a clean surface to obtain good adhesion.

The company's vapour degreasing plant was unable to cope with the heavy contaminant left on workpieces and hand-wiping was often used to remove residual contamination. Not only were two employees required continuously for hand-wiping, it also represented a production bottle-neck. As the company often applied colours to order, there was an additional problem with flash rusting of surfaces which needed additional rework prior to coating.

A system was sought that would degrease better and produce a conversion coating. The company had limited space available for pretreatment, so conventional multi-tank phosphating systems would not fit into the existing manufacturing space.

After trials, a combined degreasing and phosphating system was installed that uses a solution based on methylene chloride in a single tank. This solution not only cleans the workpieces, but also coats them with a phosphate layer which protects them against flash rusting and provides a good key for the powder coat.

Elimination of the need for two people to hand-wipe parts, coupled with the new ability to store parts for a week or more before coating to achieve more efficient colour runs, means that the payback period for the new combined degreasing and phosphating system was less than two years.

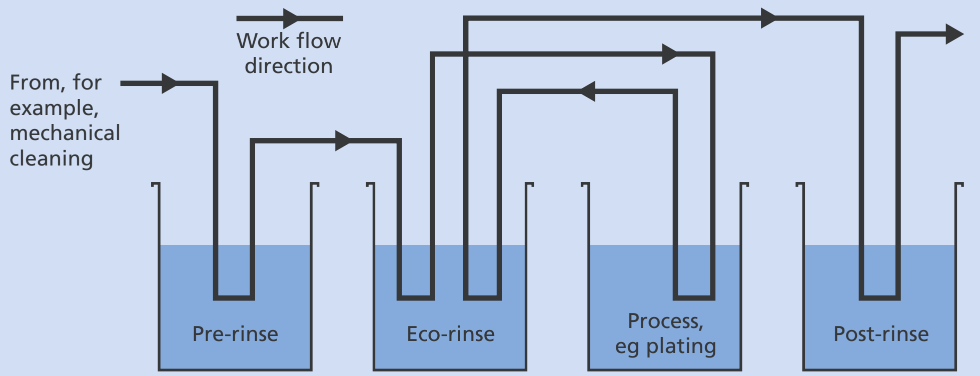
8.5 Conversion coating good practice

8.5.1 Rinse water economy

The following measures will reduce water use for rinsing:

- Reduce mass drag-out by maximising the drainage time the workpieces are held over the plating tank or in a separate drainage tank. Recommended drainage times are at least 20 seconds for rack plant and 30 seconds for barrel plant.
- Use cascade rinsing (see Fig 12), ie a series of tanks with water flowing from one to another. This can save up to 90% or more of the water needed for a single rinse and at least 70% of that needed for a twin-stage rinse. Three to five stages reduce contaminant levels such that the rinse flow can be fed forward to the preceding process tank and used as make-up water for tanks suffering natural or assisted evaporation. Drag-out recovery can be close to 100%.

Fig 12 Schematic diagram of cascade rinsing



- Use eco-rinse tanks to reduce water consumption and effluent generation. Using a single static tank, work can be dipped before and after being processed. This recovers up to 40% of drag-out.
- Consider using ion exchange technology to clean and rinse contaminated rinse water. This reduces the concentrations in discharge effluents. However, drag-out tanks prior to the running rinse system are still necessary.
- Recycle wastewater to less critical rinsing stages.

8.5.2 Other measures

- Recover drag-out and return it to process tanks.
- Recover high value materials from drag-out that cannot be returned to process tanks.
- Prevent fugitive emissions.
- Carry out regular preventive maintenance programmes in line with operational requirements on all plant and equipment used for chromium plating.
- Where possible, replace decorative chromium(VI) plating electrolytes with less harmful chromium(III) electrolytes or with chromium-free alloy electrolytes.
- Operate fume extraction backed by efficient de-misting equipment when chromium(VI) plating to minimise the release of chromic acid.

Combined system eliminates labour-intensive hand-wiping

EDL Lighting Ltd manufactures a wide range of 'task lighting' for equipment and structures requiring precision lighting. A typical fitting consists of extending arms with knuckle joints, a base, clamp, shade and diffuser. These are commonly made from several different materials, eg plastic, steel, aluminium and zinc.

The company found that its existing vapour degreaser was struggling to remove residual silicone from zinc castings and lanolin from aluminium spinnings. All items needed hand-wiping, which added considerably to the cost and the time taken to process each part. An acid etch was also used to key the surface of some components.

Several degreasing systems were assessed before the company chose a combined degreasing and phosphating system which uses a proprietary mixture of methylene chloride and phosphoric acid in a semi-automatic plant. This plant not only degreases all materials, but phosphates steel components, etches aluminium and degasses zinc - increasing coating adhesion and durability.

Hand-wiping is no longer necessary, saving on labour costs and reducing the time taken to process each component. The cost savings have been considerable and the system is estimated to have paid for itself in less than a year in labour costs alone.

Making your choice

When reviewing the way you carry out surface cleaning, start by considering the following questions:

- Can I eliminate the need for cleaning in the first place?
- Am I using the best cleaning process and solvent for my particular requirements?
- Am I using the right plant?
- Could I improve my existing plant?
- Am I following operational good practice?

Then work through the action plan below.

- ☑ Stand back and have a good look at your process. Could you reduce your costs by reducing, or even eliminating, the amount of cleaning you do? Could you change to a different method that not only maintains product quality but has a lower environmental impact?
- ☑ Talk to your suppliers and customers to see if there are changes that could prevent the need for cleaning in the first place.
- ☑ Collect data to act as a base-line against which to assess progress and to evaluate options for change.
  - Fill in daily log sheets (see appendix 2).
  - Ask the Environment and Energy Helpline on freephone 0800 585794 about free Envirowise publications and tools to help you measure and manage solvent use, or visit the Envirowise website (www.envirowise.gov.uk).
- ☑ Improve your existing processes by implementing the no-cost and low-cost good practice measures described in this Guide, eg improve your solvent management and working methods.
- ☑ Consider modifying existing plant to reduce solvent use and VOC emissions, eg fitting and using appropriate lids, installing power-operated hoists and fitting cut-out devices.
- ☑ Identify and implement opportunities for reducing water and energy use.
- ☑ Consider whether you are using the optimum cleaning method and cleaning agent for your particular application.

9.1 Generating options

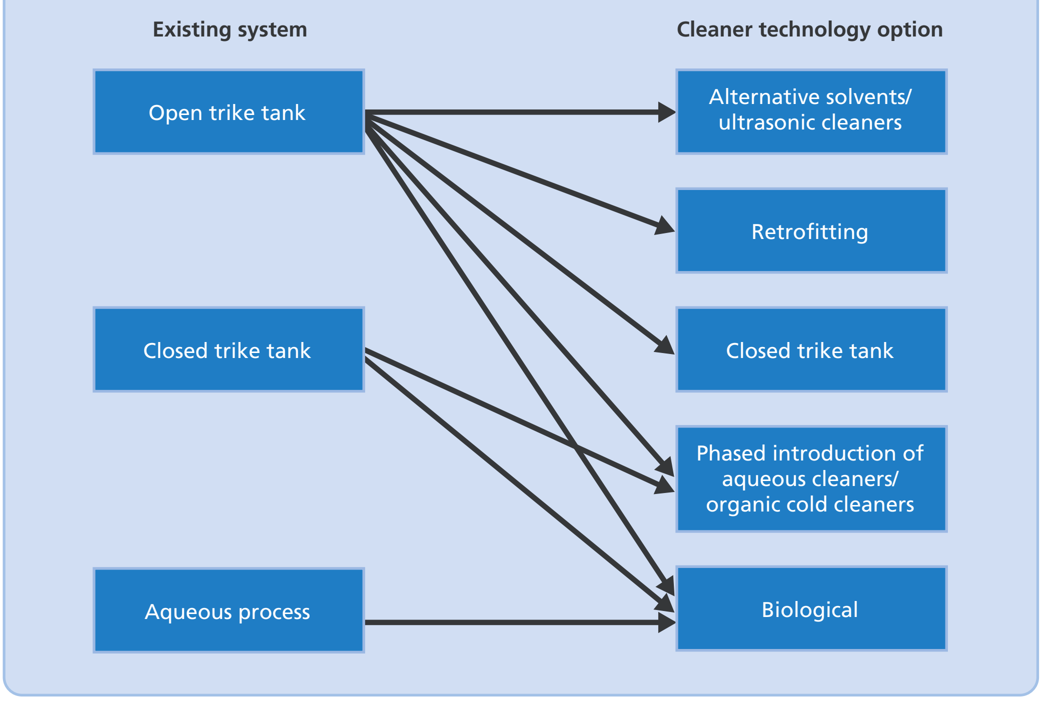
You may find that it is still necessary to move to an alternative cleaning technology to reduce costs or comply with environmental legislation.

Use the decision tree shown in Fig 13 to select several alternative options to your existing method of surface cleaning. Keep in mind the waste and resource management hierarchy shown in Fig 1 (see section 2.2)

Then use the evaluation framework described in section 9.2 to assess each option systematically in terms of costs, savings, practicality and compliance with legislation.

Remember that moving to an alternative cleaning technology or solvent will only bring cost savings and other benefits if you adopt good practice.

Fig 13 Decision tree



9.2 Evaluating options

Use the simple scoring system described overleaf as a guide to help you compare your options. The scoring system shown involves three options, but can be adapted as necessary for more alternatives.

The scoring system covers capital and operating costs, potential savings, practicality and cost of complying with legislation. It does not incorporate improvements in working practices or benefits such as improved working conditions for operators, which should also be borne in mind when making your final choice. It also does not take account of companies' individual investment procedures.

In this scoring system (see Fig 14), the **lowest** score is the best. Two example evaluations using this scoring system are shown in section 9.2.4.

Fig 14 Scoring key

Cost of legislative compliance	
High cost of present and future compliance, eg significant investment in new plant or systems, or authorisation required.	3
Moderate cost of compliance, eg medium investment in new plant.	2
Low or zero cost of compliance with current or future legislation.	1
Practicality	
New option technically complex or risky to introduce. Doubt as to whether new technique will prove effective.	3
Technically medium risk, with high success rate anticipated.	2
Low or no practical risk.	1
Capital costs	
Process requires considerable investment in new plant.	3
Process requires medium investment in new plant.	2
Simple upgrade of existing plant (low-cost or no-cost).	1
Operating costs	
New process with considerable increase in operational costs.	3
Process will result in medium increase in operational costs.	2
Low-cost or no-cost.	1
Potential savings	
Low or zero savings.	3
Moderate savings.	2
Substantial savings.	1

9.2.1 Cost of legislative compliance

Estimate the costs of complying with existing and future legislation for each option. For example, if using a solvent degreaser, you may require additional authorisation following the introduction of the Solvent Emissions Directive.

Decide whether each option is highly regulated (and thus associated with high compliance costs), moderately regulated or subject to little applicable legislation.

Score according to the key shown in Fig 14 (note that less regulated processes score lower) and fill in the evaluation matrix shown in Table 20 (see section 9.2.4).

9.2.2 Practicality

Decide how practical each option is by referring to the following questions.

- How much space is available? Will the new cleaning system fit?
- What type of soil or coating is to be removed? Will the new solvent/cleaning system be effective? Refer to the relevant section of this Guide for information.

- What is the material of the components to be cleaned/prepared? How sensitive is the component to damage from certain cleaning agents (particularly abrasives or aggressive acids)?
- Does the component have a shape that would limit the effectiveness of line-of-sight cleaning processes?
- Do the components need to be dry at the end of the cleaning process? If so, you may need to purchase drying equipment or reschedule your production process.
- How large are the components that need to be cleaned, ie less than 0.01 m^3; greater than 0.01 to 0.1 m^3; less than 0.1 to 1 m^3; or greater than 1 m^3? Certain fully enclosed degreasing equipment may not cope with components greater than a certain size.
- How many components need to be cleaned per hour (fewer than 10, 10 - 100 or more than 100)? Check with equipment manufacturers about whether this throughput can be handled.
- What existing cleaning plant is currently in use? Is retrofitting possible or more economic than equipment replacement?
- Are there quality issues around the material to be cleaned, eg client specifications?

Decide whether each option is highly impractical, moderately practical or very practical (ie low or no practical risk).

Score according to the key shown in Fig 15 (note that more practical options score lower) and fill in the evaluation matrix shown in Table 24 (see section 9.2.4).

Company's decision is based on practicality

When Pendle Polymer Engineering sought an alternative to its open-top vapour degreaser, the most critical factor was the quality of the cleaned metal surface followed by the amount of space required. For more details of the decision-making process and the practicality of the five options considered by the company, see the industry example in the back pocket of this Guide.

9.2.3 Financial appraisal

Identify the costs (capital and operational) and potential savings associated with each option. Use Table 19 to help you record these costs and savings. You will need to know your current operating costs to determine potential savings.

Direct costs include:

- capital costs;
- plant installation costs;
- raw material costs;
- labour;
- energy, eg gas and electricity;
- maintenance;
- waste management;
- other, eg authorisations.

Indirect costs include:

- product reliability;
- product manufacturing yield;
- training;
- emissions monitoring;
- management time.

Table 19 Financial appraisal

Existing method	
Option 1:	
Option 2:	
Option 3:	

Item	**Existing method**	**Option 1**	**Option 2**	**Option 3**
Capital costs		£	£	£
Annual operating costs		£	£	£
Potential annual savings		£	£	£

Decide whether each option would lead to:

- high, medium or low capital investment (less expensive options score lower);
- a considerable, moderate or no increase in operating costs (lower operating costs score lower);
- significant, moderate or zero cost savings (higher savings score lower).

Score according to the key shown in Fig 14 and fill in the evaluation matrix shown in Table 20.

Advice on how to carry out a more detailed economic evaluation of possible options is given in *Investing to increase profits and reduce wastes* (GG82)[15].

9.2.4 Using the evaluation matrix

Using the scoring system shown in Fig 14 as a guide, complete the evaluation matrix shown in Table 20. The final score is established by adding the scores for each option. **The lowest score represents the best option.**

15 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

Table 20 Evaluation matrix

Option 1:			
Option 2:			
Option 3:			

Factor	**Option 1**	**Option 2**	**Option 3**
Cost of legislative compliance			
Practicality			
Capital costs			
Operating costs			
Potential savings			
Final score			
Selected option:			

The lowest score represents the best option.

Worked examples

Figs 15 and 16 show how two engineering companies used the evaluation matrix to select the best options for their circumstances.

Fig 15 Worked example 1

Option 1:	Retrofitting open tank degreaser
Option 2:	Implement aqueous cleaning system
Option 3:	Use alternative chlorinated solvents

Factor	**Option 1**	**Option 2**	**Option 3**
Cost of legislative compliance	3	1	3
Practicality	1	2	2
Capital costs	2	1	2
Operating costs	1	1	1
Potential savings	2	1	2
Final score	9	6	10
Selected option:	Option 2 - implement aqueous cleaning system		

The lowest score represents the best option.

Fig 16 Worked example 2

Option 1:	Retrofitting open tank degreaser
Option 2:	Implement aqueous cleaning system
Option 3:	Purchase fully enclosed degreaser

Factor	**Option 1**	**Option 2**	**Option 3**
Cost of legislative compliance	3	1	2
Practicality	2	3	3
Capital costs	2	3	3
Operating costs	2	3	1
Potential savings	2	1	1
Final score	11	11	10

Selected option: Option 3 - purchase fully enclosed degreaser

The lowest score represents the best option.

Existing legislation and future developments

This appendix provides an overview of important existing legislation and future developments affecting surface engineering companies as of December 2001. It covers England and Wales only and is not exhaustive (Scottish and Northern Ireland legislation can differ, but the same essential legal requirements exist across the UK).

For information about recent legislative changes and advice on specific legislation affecting a site, companies should contact:

- the Environment and Energy Helpline on 0800 585794 (www.envirowise.gov.uk) with regard to environmental matters;
- the local HSE office or the HSE InfoLine on 08701 545500 (www.hse.gov.uk) with regard to health and safety matters.

Environmental Protection Act 1990

The Environmental Protection Act (EPA) 1990 brought together a wide range of environmental issues under a single piece of legislation. The first three parts of the EPA have the most impact on industries using solvents.

Part I of the EPA 1990

Part I of the EPA 1990 established a two-tier system of pollution control for industry. This system is gradually being replaced by a new regime designed to implement the Integrated Pollution Prevention and Control (IPPC) Directive in the UK (see overleaf).

The Environmental Protection (Prescribed Processes and Substances) Regulations 1991 (SI 1991 No 472) and subsequent amendments list the prescribed processes and prescribed substances that are controlled under Part I of the EPA 1990.

Integrated Pollution Control (IPC)
The IPC regime (Part A) covers emissions to air, land and water from the most potentially polluting processes. It is regulated by the Environment Agency.

The 1991 Regulations prescribe the manufacture and use of VOCs in certain processes - mainly undertaken by chemical producers. Descriptions of processes and abatement techniques, together with advice on the release levels that can be achieved by processes using Best Available Techniques Not Entailing Excessive Cost (BATNEEC), are published in IPC guidance notes issued by the Environment Agency. IPC authorisations generally allow operators to discharge pollutants (including VOCs) from specified ('controlled') points within mass and concentration limits. Operators are required to report total annual losses to the environment and improve their performance by implementing waste minimisation programmes.

Local Air Pollution Control (LAPC)
The LAPC regime (Part B) covers emissions to air only from less potentially polluting processes. It is regulated by local authorities, whose inspectors follow the guidance notes for particular Part B processes published by The Stationery Office on behalf of the Department for Environment, Food and Rural Affairs (DEFRA). These Process Guidance Notes set concentration limits for VOC emissions and the thresholds for annual solvent use above which companies require an authorisation to operate the process. A typical threshold is 5 tonnes/year (this excludes many small companies from regulation).

Surface degreasing requires authorisation under LAPC only if:

- it is associated with another activity that requires authorisation (usually a coating process);
- it has the capacity to consume more than 5 tonnes/year of organic solvents.

The Solvent Emissions Directive (see opposite) will require many more sites to be authorised.

Part II of the EPA 1990

Part II deals with waste on land. The Environmental Protection (Duty of Care) Regulations 1991 (SI 1991 No 2839) impose a Duty of Care on waste producers to ensure that their wastes are correctly disposed of. A company is expected to ensure that:

- any waste transported off-site is labelled adequately;
- the waste is transported by a licensed carrier;
- the waste is transferred to a suitably licensed transfer station or waste disposal site.

Part III of the EPA 1990

Part III of the EPA 1990 aims to control nuisances such as noise and odour. Many VOCs are odorous and have the potential to cause a nuisance to the public. Local authority environmental health departments, which are responsible for investigating complaints from the public, have the power to enforce prohibition of a nuisance.

Integrated Pollution Prevention and Control (IPPC)

The IPPC regime applies an integrated approach to the regulation of emissions by certain industrial activities to air, water (including discharges to sewer) and land, plus a range of other environmental effects such as noise and energy use. Regulators are required to set permit conditions based on the use of Best Available Techniques (BAT) to achieve a high level of protection for the environment as a whole. IPPC is also concerned with the restoration of sites when industrial activities cease.

Indicative standards for BAT will be defined by process guidance notes (known as BREF notes) published by the European Commission's IPPC Bureau. Until these are available, existing guidance from IPC and LAPC Process Guidance Notes will continue to be used, with supplementary guidance provided by the Environment Agency to cover new issues such as energy efficiency, site remediation and noise.

IPPC is implemented in the UK by the Pollution Prevention and Control (PPC) Act 1999, which provides for the replacement of Part I of the EPA 1990. The Pollution Prevention and Control (England and Wales) Regulations 2000 (SI 2000 No 1973) give details of a pollution control regime for implementing the IPPC Directive and for regulating other polluting activities not covered by the Directive. The Regulations and their amendments give details of the new regime's requirements and list the controlled activities and type of pollution control.

PPC establishes three tiers of regulation:

- **Integrated Pollution Prevention and Control (IPPC).** This integrated permitting regime regulates emissions to air, land and water. It is split into:
  - **Part A1** is concerned with potentially more polluting processes and is regulated by the Environment Agency. It includes all processes currently regulated under IPC.

- **Part A2** is concerned with processes with a lesser potential to pollute and is regulated by the local authority. In general, it covers those processes currently authorised under LAPC but which are also listed in Annex 1 of the IPPC Directive.

- **Local Air Pollution Prevention and Control (LAPPC).** This is known as Part B and replaces LAPC. It is similar to IPPC in procedures but will only regulate emissions to air. It covers those processes currently regulated under LAPC but not subject to the IPPC Directive. It is regulated by local authorities.

Most LAPC processes are not covered by IPPC and will transfer into the new LAPPC regime. This will result in some procedural changes but no extension of regulation to other media. The changeover is essentially an administrative one and will not involve payment of new application fees.

New or existing installations subject to substantial change have to apply for a permit immediately. The timetable for application for a permit for existing activities[16] is given in Table A1.

Table A1 Timetable for transition to PPC regime

Process	Period for application
Part A1 activities*	
Surface treatment metals and plastics (Section 2.3**)	1 May to 31 July 2004
Coating, printing and textile treatments (Section 6.4**)	1 May to 31 July 2002
Part A2 activities*	
Coating (Section 6.4**)	1 May to 31 July 2003
Part B activities	
Ferrous and non-ferrous metals, coating, manufacture of coating materials, rubber	12 months beginning 1 April 2003

* *Note that the timetable for Parts A1 and A2 is different for Scotland and Northern Ireland.*
** *See Schedule 1 of the Pollution Prevention and Control (England and Wales) Regulations 2000.*

Solvent Emissions Directive (SED)

Council Directive 1999/13/EC on the limitation of emissions of VOCs due to the use of organic solvents in certain activities and installations aims to prevent or reduce the direct and indirect effects of emissions of VOCs into the environment (mainly to air) and to reduce the potential risks to human health. This aim will be achieved by providing measures and procedures to limit emissions from certain industrial sectors, including:

- metal and plastic coating;
- surface cleaning;
- vehicle coating/manufacture;
- winding wire coating.

Because they meet LAPC requirements, many of the installations covered by the Directive will be able to comply immediately. However, some will incur additional expenditure to meet the Directive's requirements.

16 See Schedule 3 of the Pollution Prevention and Control (England and Wales) Regulations 2000.

Any sites undertaking the following surface cleaning activities fall within the SED:

- any surface cleaning activity using more than 1 tonne/year of a VOC classified as a carcinogen, mutagen or as toxic to reproduction (with Risk Phrases R45, R46, R49, R60 or R61) and any halogenated VOCs with possible irreversible effects (Risk Phrase R40);
- any surface cleaning activity using more than 2 tonnes/year of any other VOC.

New activities, new abatement equipment and substantial changes to existing activities will have to meet the requirements immediately. Existing activities need to meet the requirements for risk phrase compounds within the shortest possible time. Other activities have until 31 October 2007.

Process Guidance Notes for all solvent activities are being revised to take into account the new requirements. Specific site requirements will include:

- reduce solvent emissions below a threshold specified in the relevant Process Guidance Note; or
- reduce the solvent content of cleaning materials to less than 30%; or
- meet an emission limit value in waste gases (mg/Nm^3) and a fugitive emission limit value (percentage of solvent use).

Provided that existing installations operating existing abatement equipment meet prescribed limit values, they will not have to meet the Directive's limit values until 1 April 2013. Those installations intending to use the solvent reduction scheme route must notify the competent authority by 31 October 2005.

There are stricter requirements for activities using potentially more harmful substances such as trike. The SED sets out further control measures for users of trike and other substances classified as carcinogenic, mutagenic or toxic to reproduction. These users will also have to:

- meet strict solvent emissions;
- control emissions, as far as technically and economically feasible, to safeguard human health and the environment;
- work towards substituting the substance within the shortest possible time.

It is estimated that 40% of surface cleaning activities covered by the SED are already authorised under LAPC, but that up to 4 600 additional installations will need to be authorised or reduce emissions under the SED.

Reclassification of trike

The reclassification of trike from a category 3 carcinogen to a category 2 carcinogen will require companies to bring in tighter controls to reduce workers' exposure to the substance under COSHH. The change in the classification of trike will be implemented into UK law by the Chemical (Hazard Information and Packaging for Supply) Regulations (CHIP 3) which came into force on 24 July 2002. As part of the Approved Supply List, under CHIP 3, trike will be automatically treated as a carcinogen under COSHH and SED.

The change in the law is expected to have a major impact on degreasing operations. Workplace risk assessments are likely to require that workers' exposure to trike is reduced as far as is reasonably practicable.

For more information about the reclassification of trike and its implications for surface cleaning, see HSE Engineering Information Sheet No 34 *Surface cleaning: solvent update including the reclassification of trichloroethylene*. This is available from HSE Books (Tel: 01787 881165, www.hsebooks.co.uk).

Ozone-depleting chemicals

Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000, on substances that deplete the ozone layer, banned the use of methyl chloroform (1,1,1-trichloroethane) from 1 October 2000. This solvent had been commonly used for degreasing and the ban has resulted in many operators switching to alternatives such as trike.

Water Resources Act 1991

The Water Resources Act 1991 makes it an offence to discharge noxious or polluting matter to controlled waters, eg rivers, lakes and inland coastal waters. Discharges of effluents to controlled waters are regulated by the Environment Agency, which monitors solvent discharges closely.

Water Industry Act 1991

The Water Industry Act 1991 makes it an offence to discharge any polluting material as an effluent to a sewer without the consent of the receiving water company. Solvent discharges to sewage treatment works are monitored closely by the receiving water company.

Special Waste Regulations 1996

The Special Waste Regulations (SI 1996 No 9727) present the criteria for what constitutes a special waste and describe how the disposal of that waste is to be controlled. VOC or solvent-containing wastes are usually classified as special wastes due to their toxicity and/or flammability. Transport of special waste requires pre-notification to the Environment Agency. The Special Waste (Amendment) (England and Wales) Regulations 2001 (SI 2001 No 3148) amend and update the 1996 Regulations.

The landfill tax escalator

The landfill tax, which was introduced in October 1996, levies an additional charge for the disposal of waste to landfill on top of that demanded by the landfill operator. It aims to encourage innovation in waste management through the negative effect of increasing costs and the positive impact of developing new ways of treating waste.

The landfill tax is set to increase each year until 2004 (the standard rate will be £15/tonne from 1 April 2004), when the escalator is due to be reviewed.

Landfill Directive

Implementation of the Landfill Directive in the UK is expected to have a major impact on landfill operators. It will prevent the co-disposal of biodegradable and inert waste, thus increasing the cost of disposal to landfill. This increase will include charges for the disposal of special waste.

Example daily log sheet

Please photocopy and use the example daily log sheet opposite as required in your company.

SHOP Date ..../......./....... Degreaser No .... Operator ....

LOAD HISTORY													Minutes	Hours
Job No														
Job No														
Job No														
Job No														
Job No														
Job No														
Job No														
Job No														
Job No														
Job No														
TOTAL														
Plant on time														
TIME	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800		

Record solvent additions made and daily safety/maintenance checks on the reverse of this sheet.

Envirowise - Practical Environmental Advice for Business - is a Government programme that offers free, independent and practical advice to UK businesses to reduce waste at source and increase profits. It is managed by AEA Technology Environment and NPL Management Limited.

Envirowise offers a range of free services including:

- Free advice from Envirowise experts through the Environment and Energy Helpline.
- A variety of publications that provide up-to-date information on waste minimisation issues, methods and successes.
- Free, on-site waste reviews from Envirowise consultants, called *Fast*Track visits, that help businesses identify and realise savings.
- Guidance on Waste Minimisation Clubs across the UK that provide a chance for local companies to meet regularly and share best practices in waste minimisation.
- Best practice seminars and practical workshops that offer an ideal way to examine waste minimisation issues and discuss opportunities and methodologies.

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