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GUIDE

ENVIRONMENTAL
TECHNOLOGY
BEST PRACTICE
PROGRAMME

VAPOUR DEGREASING

Be Solvent Wise

GOOD PRACTICE: Proven technology and techniques for profitable environmental improvement

VAPOUR DEGREASING

This Good Practice Guide was prepared for the Environmental Technology Best Practice Programme by the Metal Finishing Association.

RECYCLED

ENVIRONMENTAL
TECHNOLOGY
BEST PRACTICE
PROGRAMME

The Environmental Technology Best Practice Programme is a joint Department of Trade and Industry and Department of the Environment initiative managed by AEA Technology through ETSU and the National Environmental Technology Centre.

The Environmental Technology Best Practice Programme promotes the use of better environmental practices that reduce business costs for UK industry and commerce.

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While these themes are applicable to every industrial sector, the Programme supplements them by focusing on 'areas of special attention' which can either be an industrial sector or a particular pollutant.

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SUMMARY

UK industry uses large quantities of organic solvents for component cleaning during the manufacture of metal products. This consumption, with its associated release of volatile organic compounds (VOCs), raises important environmental issues.

Traditional open-topped vapour degreasers still predominate in the UK. The four chlorinated organic solvents - trichloroethylene, 1,1,1-trichloroethane, methylene chloride and perchloroethylene - used in vapour degreasing are all hazardous. 1,1,1-Trichloroethane has a significant ozone-depleting potential and is being phased out under the Montreal Protocol. Trichloroethylene, methylene chloride and perchloroethylene are classified as Category 3 carcinogens. Further restrictions on VOC emissions are expected to become the major factor controlling both solvent cleaning processes and equipment requirements. UK environmental legislation already imposes stringent limits on VOC emissions from many industrial processes, including solvent cleaning as part of a coating process.

A recent Health and Safety Executive (HSE) survey of vapour degreasing operations in the UK revealed widespread poor practice. However, efficient use of the appropriate cleaning practice produces:

- cost savings through reduced solvent consumption;
- improved employee health and safety;
- environmental benefits through reduced VOC emissions.

This Good Practice Guide is intended to help companies that use vapour degreasing for component cleaning to become more profitable while reducing environmental impact. The Guide describes:

- the principles involved in vapour degreasing;
- alternative cleaning processes;
- modern vapour degreasing equipment;
- common problems associated with the design and operation of vapour degreasing plants;
- cost-effective improvements to existing plant;
- good operational practice for vapour degreasing;
- health and safety measures designed to reduce operator exposure to solvents and VOCs;
- relevant environmental legislation.

An Action Plan that focuses on measures to reduce solvent consumption and thus reduce costs is presented. Measures to protect the health and safety of employees are also emphasised.

1 THE PROBLEM

Important environmental issues are raised by industry's use of large quantities of organic solvents for cleaning metal components both during manufacture and for maintenance purposes. Some solvents have been shown to contribute to ozone depletion in the upper atmosphere and some contribute substantially to volatile organic compound (VOC) emissions to the atmosphere. In 1988, an estimated 43 000 tonnes (t) of VOCs were emitted from surface cleaning processes.

A more recent industry estimate suggests that between 20 000 t and 30 000 t of solvents were used in 1994 for all metal cleaning and that about 45% of this was used for vapour degreasing ie 9 000 - 14 000 t.

VOCs are a large family of carbon-containing compounds that are emitted or evaporate into the atmosphere. They can take part in photochemical reactions with other substances in the air, eg nitrogen oxides, to produce harmful ground level ozone. Some VOCs are also toxic or carcinogenic. While VOCs occur naturally, current concerns centre on those emitted from commonly-used substances - including industrial cleaning solvents.

Vapour degreasing is an effective and widely used technique for component cleaning. However, a recent Health and Safety Executive (HSE) investigation[1] revealed widespread poor practice in UK industry. Poor practice can result in high solvent consumption leading to extra costs, an unsafe working environment and an adverse environmental impact.

UK environmental legislation now imposes stringent VOC emission limits on many industrial processes. For many users of vapour degreasing plant, these may necessitate:

- making major improvements to control systems;
- changing to an enclosed plant;
- installing 'bolt-on' abatement devices;
- changing to an alternative degreasing process.

A new generation of vapour degreasing equipment is being designed for those operators for whom this process is still the preferred method of cleaning components.

VOC emissions can be hazardous to health. All employers have a duty under UK health and safety regulations to minimise the risk to employees and need to be aware of the best method of tackling this problem.

Efficient use of appropriate cleaning processes can, however, result in:

- cost savings for the user;
- improved employee health and safety;
- environmental benefits through reduced VOC emissions.

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[1] *A Survey of Degreasing Operations.* Report on a survey of vapour degreasing processes carried out by inspectors from HSE's Field Operations Division between April and September 1994. B J Robinson (Mar 1995). Available from the Engineering National Interest Group, HSE Birmingham Area Office (0121 609 5200).

1.1 WHY PRODUCE THIS GUIDE?

Information about efficient vapour degreasing is available from many sources, including suppliers of solvent and degreasing equipment. However, this information is not always readily to hand, and consequently many operators are not taking advantage of measures which can:

- cut cleaning costs;
- improve product quality;
- reduce the effects on the working and wider environment.

This Guide is intended to provide a single, accessible source of information on good practice in vapour degreasing operations and to raise awareness of the benefits. For the purposes of this Guide, 'vapour degreasing' refers to operations using halogenated hydrocarbon solvents.

The Guide describes:

- modern vapour degreasing equipment;
- modifications you may be able to make to your existing plant;
- good practice for operators of all vapour degreasing plant.

The main alternatives to vapour degreasing are also outlined, since they may offer preferable ways of complying with environmental legislation.

Vapour degreasing may also be carried out using flammable solvents. This process is highly specialised and not in common use. It is not, therefore, covered by this Guide.

This Guide can help if you are in the process of purchasing new degreasing plant, upgrading existing equipment or simply improving operating practices to make efficient use of your cleaning process.

An Action Plan at the end of this Guide summarises the various ways in which operators of vapour degreasing equipment can reduce both their solvent consumption and the environmental impact of their process.

Less solvent consumed means lower costs, and a better environment, both inside and outside your plant.

2 COMPONENT CLEANING - THE OPTIONS

2.1 FIRST PRINCIPLES

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 often be true, it is always worth examining.

2.1.1 Why clean?

Components are cleaned to remove substances on the surfaces of parts which are detrimental or harmful to:

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

2.1.2 What is being removed?

A variety of substances or soils are removed by vapour degreasing, including:

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

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

2.2 MINIMISING THE NEED FOR CLEANING

There are energy, material, waste disposal and labour costs associated with all cleaning methods. Any opportunities to reduce the amount of cleaning or eliminate it - without compromising product quality - will reduce costs.

Prevention should therefore be the **first** priority. Operators could consider:

- changing working methods to eliminate inter-process cleaning;
- improving handling procedures to prevent inter-operation soiling;
- applying a temporary protective coating (with the aim of avoiding subsequent cleaning);
- using sealed containers which control the air inside;
- removing moisture by using absorbents such as silica gel (thus preventing corrosion occurring);
- providing good inter-operational protection by wrapping components in VPI paper (a material impregnated with chemicals such as amines);
- prevention of unauthorised cleaning.

Reduction should be the **second** 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 results in a heavy cleaning operation and greater cost. Better communication between the manufacturer and the metal finisher could help save money and time.

2.3 CLEANING METHODS

Having avoided or minimised cleaning where possible, residual contamination can be removed by a variety of methods. The choice for 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.

The following sections give an overview of the most widely available cleaning alternatives.

2.3.1 Vapour degreasing

Vapour degreasing in properly designed units can be used for virtually any cleaning/degreasing application, from the removal of heavy oils and greases to light contamination. The main advantages of vapour degreasing are:

- the load is dry on leaving the plant;
- the load is free from residual surface condensation;
- the solvents usually used are non-flammable.

However, there are disadvantages. The most important is the need to control vapour emission levels to avoid health risks and environmental pollution. The use of modern equipment, combined with the good housekeeping measures described in this Guide, will minimise these risks and reduce solvent consumption, and hence operating costs.

2.3.2 Aqueous cleaning

A wide range of industrial cleaning units using dunking (immersion) or spray cleaning treatment are available for inter-process cleaning.

The effectiveness of these units has been greatly increased by recent improvements in the cleaning efficiency of the chemicals employed and in filter and oil separator design. In many cases it is possible to combine cleaning and surface pre-treatment - such as phosphating - in one unit.

Multi-stage equipment that incorporates the cleaning and rinsing stages together with hot air or vacuum drying is now available. Alternatively, work can be dried in a centrifugal dryer, oven or - on a small scale - even in heated sawdust.

The advantages of water-based processes include:

- no solvent emissions;
- lower material costs.

The disadvantages include:

- possibly higher energy requirements because work may have to be dried after cleaning;
- rinse waters may need treatment prior to discharge or re-use.

2.3.3 Semi-aqueous cleaning

Semi-aqueous or solvent emulsion type cleaners can be used to remove heavy oils and greases. 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. The disadvantages are similar to those of aqueous cleaning, with a potential need for drying and appropriate effluent treatment.

2.3.4 Organic solvent cold cleaning

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

A wide range of solvent cleaners is being marketed as replacements for the chlorinated solvents that are now being phased out (see Appendix 1). 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, and then 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 should not normally be used. Most formulations on the market have a flash point above 45°C to allow a significant margin of safety above ambient temperatures.

Specially formulated solvent cleaners, which allow the solvent plus contaminants to be washed off in a subsequent water rinse, are also available. Components are normally dried using hot air.

2.3.5 Non-solvent processes

A dry process may be the most effective option for some products and soils. A growing range of processes are available including:

- shot and vapour blasting;
- dry-ice blasting;
- plasma cleaning;
- steam cleaning;
- ultraviolet or vacuum-thermal treatment.

section 2

BENEFITING FROM A CHANGE IN CLEANING TECHNOLOGY

A metal finishing company in the south of England set itself the task of eliminating solvents from all its processes where this was technically feasible. A solvent audit was carried out to establish which solvent-using processes were the most expensive. One particular cleaning process was targeted and replaced with an aqueous wash system. This and other measures have resulted in a reduction in solvent consumption from 20 tonnes to just over 8 tonnes in only one year!

The new wash system paid for itself, in terms of reduced solvent purchases and disposal costs, within six months. The company is now saving around £7 000/year in reduced operating costs.

Solvent reduction has not stopped there. A new vapour degreasing plant, with improved enclosure and a better vapour condensation system, is being installed and the purchase of distillation equipment to recover spent solvents is planned. The company expects its annual solvent consumption to be less than three tonnes. This may allow the company to de-register its processes with the local authority.

3 SPECIFYING THE RIGHT PLANT

Once vapour degreasing has been confirmed as the preferred cleaning method, it is worth examining the benefits of using modern plant. Efficient solvent use and safe waste disposal are important features of such degreasing units. This Section discusses those features of a modern vapour degreasing plant that are intended to reduce both running costs and environmental impact.

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

3.1 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 or boiling liquid may be needed to clean thin metal parts.

3.1.1 Vapour control

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

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

3.1.2 Which solvents are used?

The solvents most commonly used are all chlorine-containing compounds and are essentially non-flammable, though some can be ignited by high energy ignition sources (such as a welding torch) in certain limited concentrations in air. Only four solvents are generally used in vapour degreasing plants, although they are known by a variety of trade names. Table 1 is intended to help you identify which solvent you are using in your plant.

The list of trade names in Table 1 is not exhaustive and has been compiled from information currently available to the Environmental Technology Best Practice Programme. The listing of a product does not constitute an endorsement by the Programme of either the product or its effectiveness, and neither does the omission of a product discriminate against its effectiveness.

Common name	IUPAC* name	Chemical formula	Trade names
Trichloroethylene	trichloroethene	$CHCl{:}CCl_2$	Altene, Hi-tri, Neu-tri, Tavoxene, Trielena, Triklone, Tristabil, Vorclin
Methyl chloroform	1,1,1-trichloroethane[2]	$CH_3.CCl_3$	Baltane, Chlorothene, Genklene, Solvethane
Methylene chloride	dichloromethane	CH_2Cl_2	Aerothene, Methoklone, Propulsol, Solvaclene, Striptron, Ukalene, Ukatronic
Perchloroethylene	tetrachloroethene	C_2Cl_4	Dowper, Perklone, Perstabil, Pertene, Soltene, Vors

* *International Union of Pure and Applied Chemistry*

Table 1 Solvents and their trade names

Trichloroethylene

This is the most widely used vapour degreasing solvent. It is used for the removal of soils, oils, greases and buffing compounds. Trichloroethylene's properties include:

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

However, trichloroethylene is harmful to health and has a relatively low occupational exposure limit ie the Maximum Exposure Limit is 100 ppm. Trichloroethylene is also unstable in a welding arc, breaking down to products which may be harmful to health if welding continues. Because of its occupational exposure limit, trichloroethylene is not normally considered suitable for cold or wipe cleaning.

1,1,1-Trichloroethane

This is no longer a viable option for vapour degreasing as it has a significant ozone-depleting potential and is difficult and expensive to obtain[2]. Historically, many vapour degreasing units were converted from trichloroethylene to 1,1,1-trichloroethane to take advantage of the latter's lower toxicity. Such plant will now have to be replaced or converted back to using trichloroethylene. In many cases this will mean upgrading the plant to meet current emission limits.

Methylene Chloride

This solvent, which has a low boiling point (40°C) and the best cleaning power of the four main solvents, is often preferred for:

- cleaning temperature-sensitive components;
- cleaning components that must leave the degreaser cool enough to handle;
- use where an aggressive solvent is required.

However, methylene chloride has a lower latent heat of evaporation than the other three main solvents. This means that less solvent condenses on to the component and the washing action is therefore reduced.

[2] Under EC Regulation 3093/94, the production within, and import into, the European Union of 1,1,1-trichloroethane is banned from 1 January 1996.

Perchloroethylene

This well-known dry-cleaning solvent has a higher boiling point than the others (121°C). It is therefore:

- excellent for removing high melting-point waxes;
- more efficient for cleaning components with a low heat capacity (eg thin sections);
- has a greater washing action.

However, it is a less powerful cleaning solvent than trichloroethylene. As with trichloroethylene, this solvent may produce harmful breakdown products if welding activities are carried out in the vicinity of the degreasing equipment.

3.1.3 Changing solvents

The different solvents are not necessarily immediately interchangeable. If changing from trichloroethylene to either perchloroethylene or methylene chloride, existing plant will require modifications. For example, thermostats will need re-setting if changing between trichloroethylene and perchloroethylene while changing to methylene chloride requires a reduction in heat input.

Furthermore, a change from 1,1,1-trichloroethane to trichloroethylene (or any other solvent) constitutes a relevant change under Section 11(11) of the Environmental Protection Act 1990. This places a requirement on operators of such plant to apply to the local authority for a variation of conditions[3] and to pay the relevant fee.

3.2 KEY DESIGN FEATURES OF MODERN PLANT

Modern vapour degreasers can typically be subdivided 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 for use where compliance with environmental regulations is more difficult to achieve. These types of plant will also result in lower occupational exposure than many conventional open-topped degreasers.

3.2.1 Conventional top loading unit

A basic vapour degreasing unit is shown in Fig 1.

Sump

This contains solvent which is heated by either electricity, steam or thermal fluid transfer media. The use of gas is no longer recommended for new plant. Adequate controls are vital for the safe and efficient operation of the plant. Sump heating controls consist of:

- A **bottom safety cut-out.** This is a safety device, which is set to limit the temperature of the solvent to prevent overheating and 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** to prevent operation with insufficient liquid solvent in the sump. This device is intended to prevent fire or damage to the plant. It is worth noting that the bottom safety cut-out will not protect against low solvent levels; both controls are recommended for safe operation of degreasing plant.

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[3] See *Solvent Substitution in Vapour Degreasing,* DoE/Welsh Office Circular AQ 2/94.

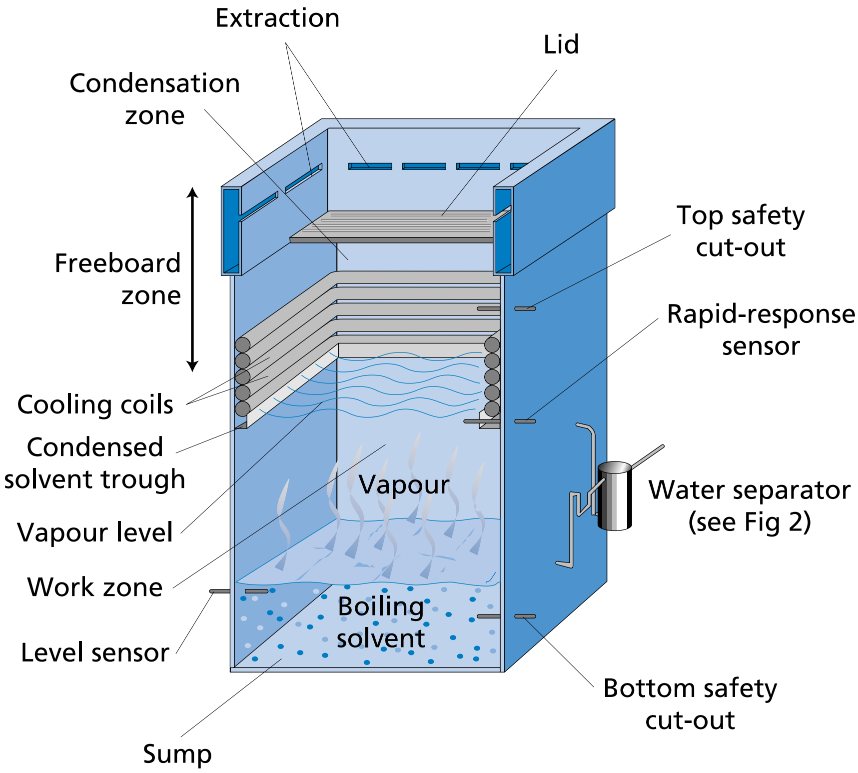

Fig 1 A conventional top loading vapour degreaser

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 only reaches the condensation zone when the component and solvent vapour temperatures have equalised.

A **rapid-response sensor** may be installed as an energy-saving device just below the condensation zone. 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. Appendix 2 gives the boiling points for the different solvents used in vapour degreasing.

Vapour condensing on the coils is collected and allowed to flow through a pipe to the **water separator** (see Fig 2). 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 (see Section 5.3).

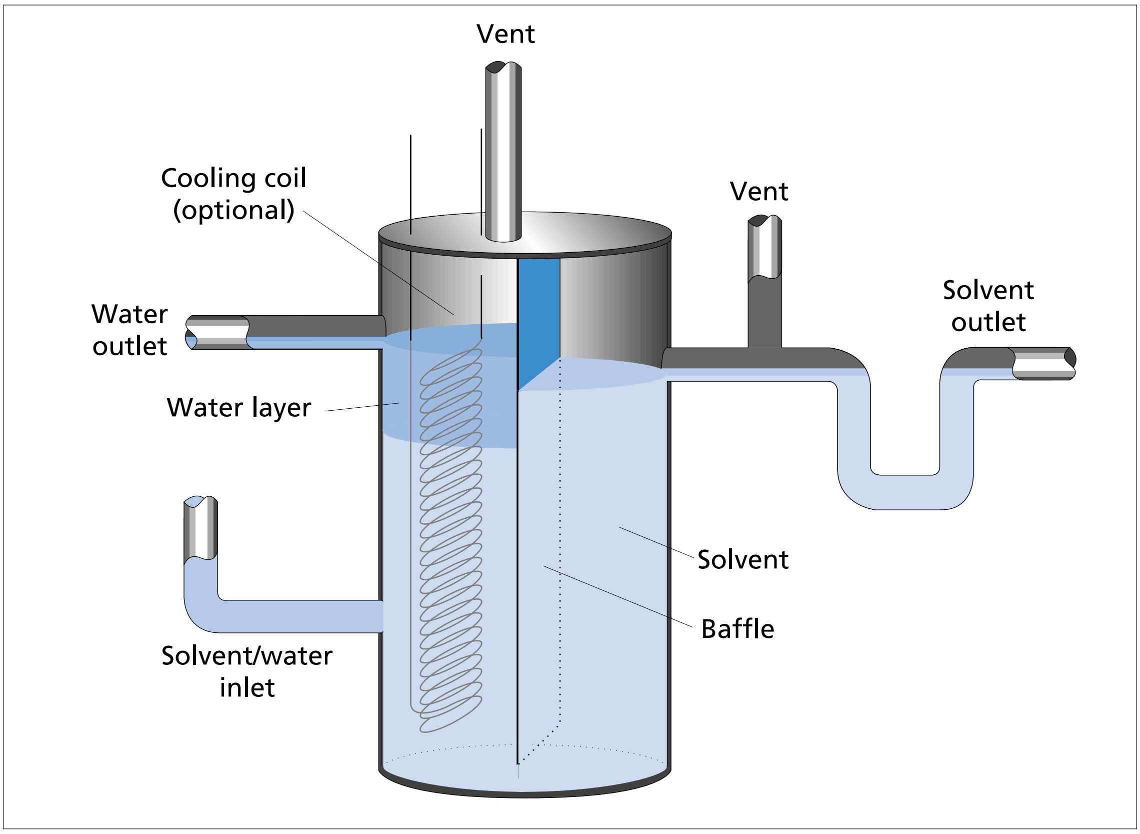

Fig 2 Schematic diagram of a typical water separator

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 degreaser should be designed to allow work to pass **slowly** through this zone during loading and unloading. Speeds over 3 m/min (11 ft/min) 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 the solvent loss via the rim extraction vents (see below).

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 be switched off, thus preventing solvent loss to the environment. The device should be designed and positioned for easy, weekly inspection and testing.

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, are essential to prevent excessive vapour loss. They should be fitted between the top of the freeboard zone and below the rim extraction vents. Good design practice avoids lids, or any other covers, being 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 should therefore always be positioned **below** the vents.

Lids are intended to minimise solvent losses while the plant is:

- heating up;
- idling;
- cooling;
- switched off.

Every effort should be made to use the lid when components are inside the unit. Lids should only be removed temporarily during loading and unloading. A segmented lid design should be fitted on long equipment as it allows partial opening when processing work of shorter dimensions. Lift-out lids increase the chance of 'dragging out' solvent vapour if they are removed quickly. Roller shutters or sliding panels which move horizontally do not have this disadvantage and are generally recommended.

Automatic or motorised lids with horizontal movement can maintain the most effective control. They 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.

Rim extraction vents

Vents (to one, two or four sides) ducted to a suitable point outside the building are intended to help prevent the workforce from being exposed 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. This may be necessary if the degreasing operation is covered by the environmental regulations described in Appendix 1.

The concentration of solvent in the air reaching the vents is significantly minimised by operational good practice (see Section 5).

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. Too high an entry speed causes vapour to be displaced by the 'piston effect'. This problem can be aggravated by the area of the load base, which in general should not exceed 50% of the surface area of the degreasing tank.

When degreasing is complete (ie condensation on the work has ceased), the parts should be removed slowly, as excessive lifting speed will draw vapour from the tank into the extraction zone.

The unloading/loading equipment, which operators should be trained to use, should be used for **all** loads, and not just those too heavy or awkward for easy lifting. This will ensure that the correct loading and unloading speed is used every time.

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 3). 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.

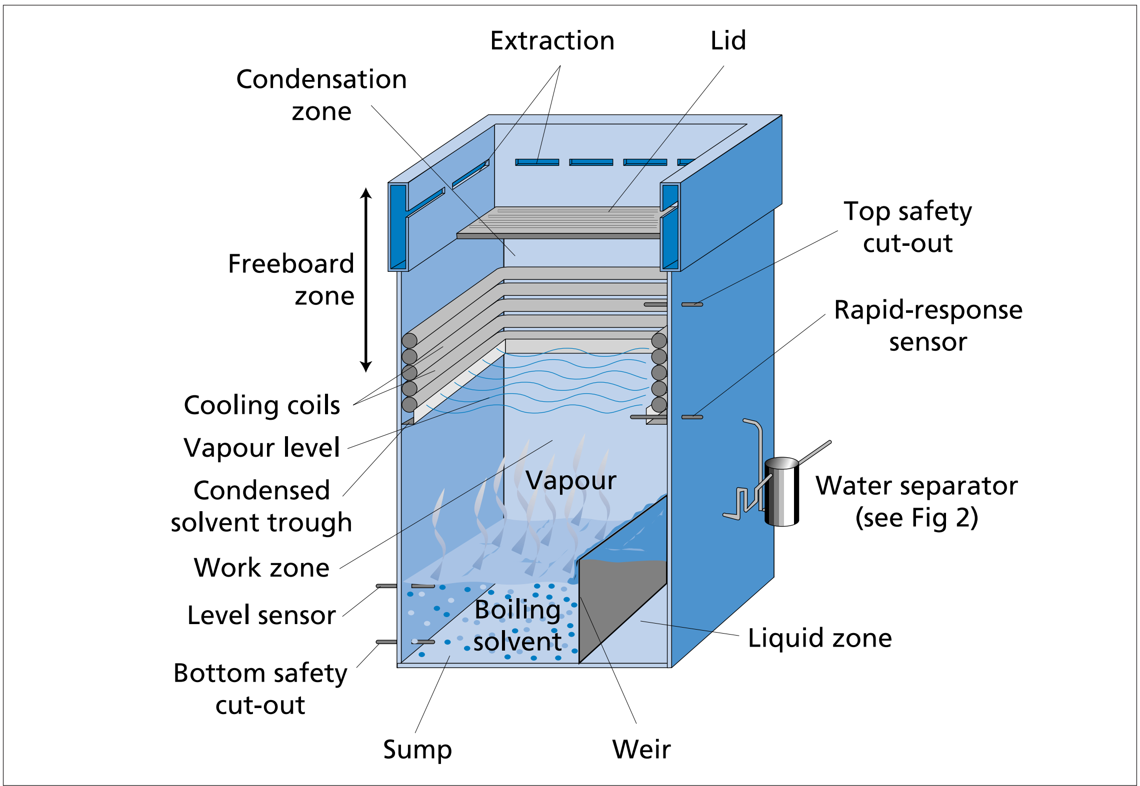

Fig 3 Modified vapour degreaser incorporating boiling liquid/vapour

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. These can be used to help remove stubborn particulate matter, but to avoid excessive solvent loss and unnecessary operator exposure, spraying should take place low down in the degreaser, below the cooling coils.

3.2.2 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 4) 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 complete. The cleaning cycle is either controlled manually, according to timers fitted to the unit, or controlled by internal sensors which detect when each cleaning stage is complete. 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. Better control can be achieved by using rapid-response temperature measurement and switching devices installed immediately below the cooling coils. When the

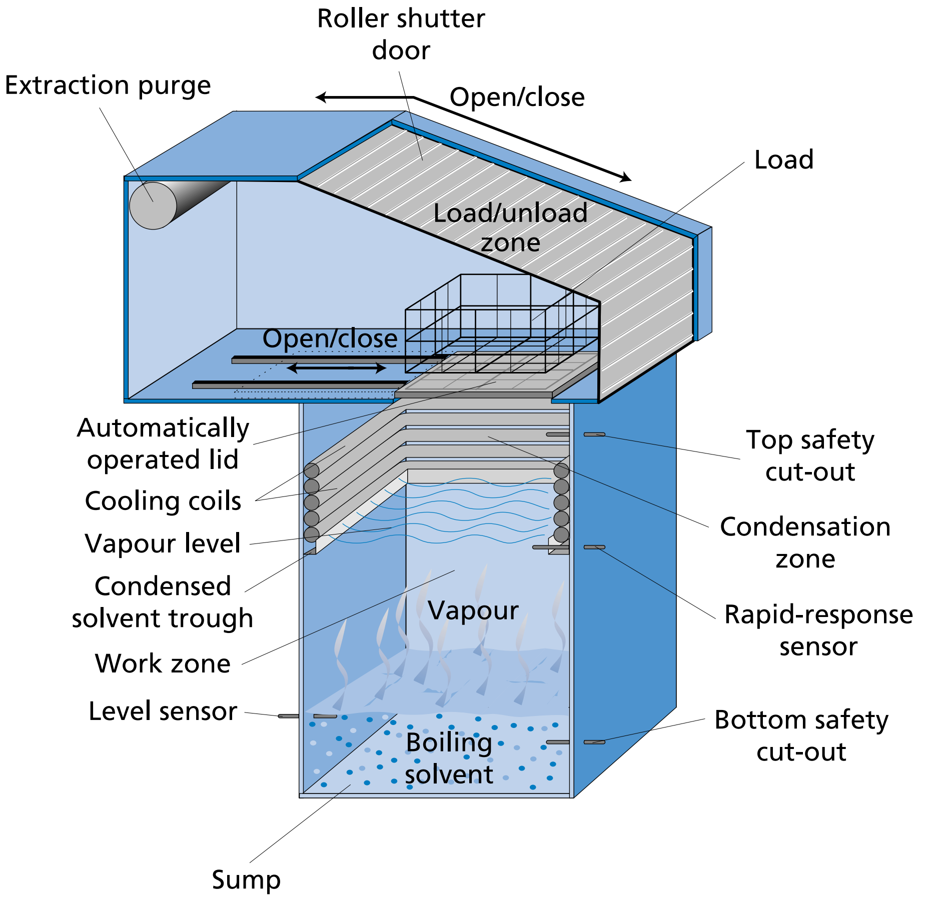

Fig 4 Multiple door vapour degreaser

vapour level rises above the sensing point, this signals that the solvent is no longer condensing on the load, and the unload cycle can commence.

Extraction purge

This system, which removes the air/solvent mixture from the load/unload zone, operates immediately prior to the unload cycle. It only operates 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 either be supplied 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 be achieving 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.

For many operators of conventional degreasing plant, top loaders with multiple doors may represent the simplest way of complying with controls on solvent vapour emissions without substantially altering existing cleaning practices. Companies just above the threshold levels for registration with their local authority (see Appendix 1) may, for example, be able to reduce their solvent consumption to below threshold levels. Companies that are well above the threshold for registration, may have to consider fitting adsorption equipment to the extraction system to comply with emissions limits.

3.2.3 Totally sealed end loading plant

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 5. 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, then distilled and returned to the clean solvent tank.

During the load/unload operation, extractors within the cleaning chamber create a positive air flow 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 the atmosphere. The advantage of this type of unit is that solvent consumption is dramatically reduced, potentially requiring no more than 100 litres of make-up solvent in a year, for a typically-sized plant. Solvent vapour around the plant is reduced to low or negligible levels, and emissions are well within the limits set by regulation.

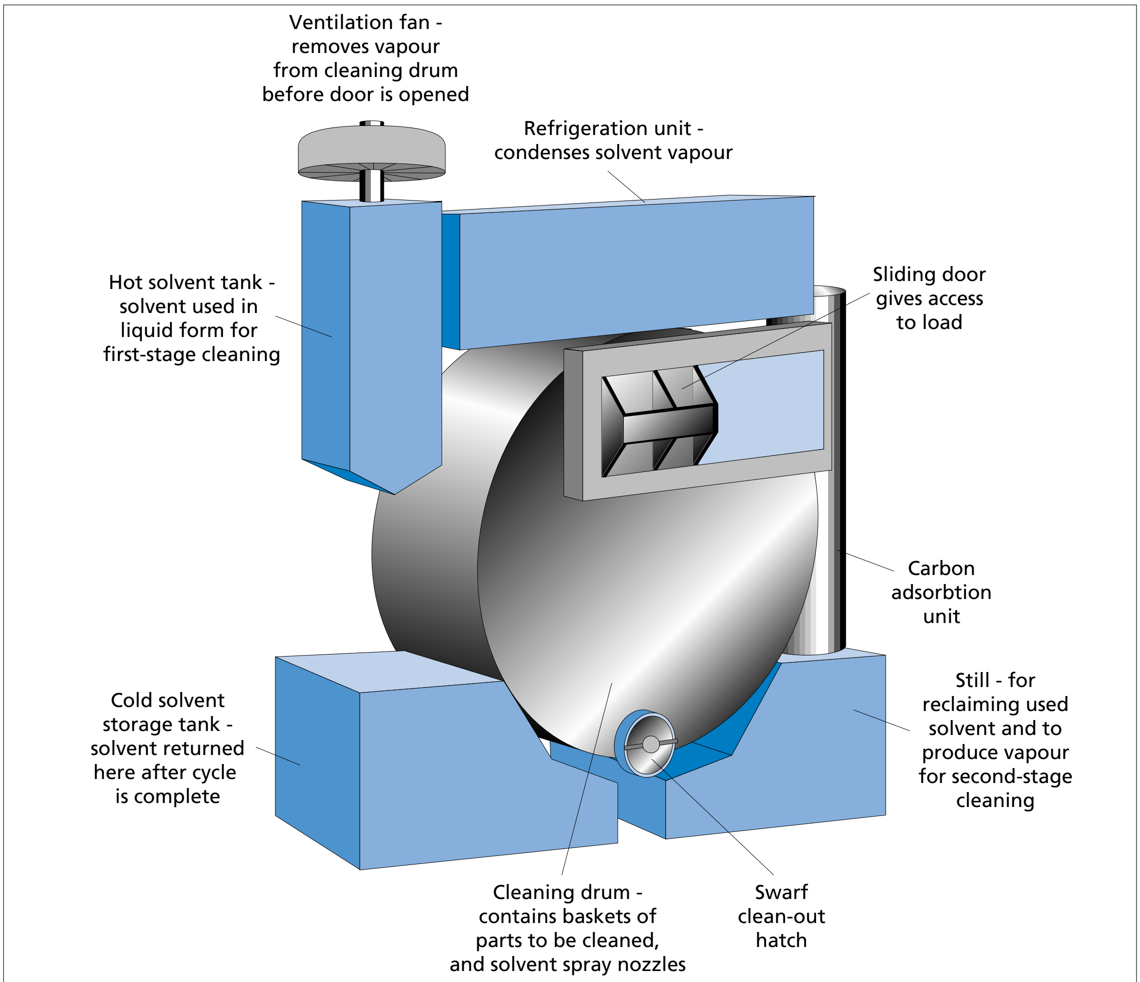

Fig 5 Totally sealed end loading plant

4 IMPROVEMENTS TO EXISTING PLANT

4.1 WHY IMPROVE?

Most of the degreasing plants currently operating in the UK are conventional in design and contain only basic features. While it is not cost-effective for most companies to invest in a new state-of-the-art degreaser, there are many inexpensive ways to improve existing plant performance and reduce running costs by making changes to both plant design and operating procedures.

4.2 COMMON PROBLEMS

section 4

In 1994, HSE inspectors carried out a survey of vapour degreasing operations in UK factories (see note on page 1 for details). This survey produced useful information about the types of degreasers in use and their operation. The inspectors visited 170 sites, where a total of 273 degreasers were being operated. A detailed examination of one degreaser was undertaken at each of the 120 sites that were using trichloroethylene. Over 93% of the degreasers were traditional open-topped types, some were provided with lids, covers and hoists. The age distribution of the plants examined during the survey is shown in Fig 6.

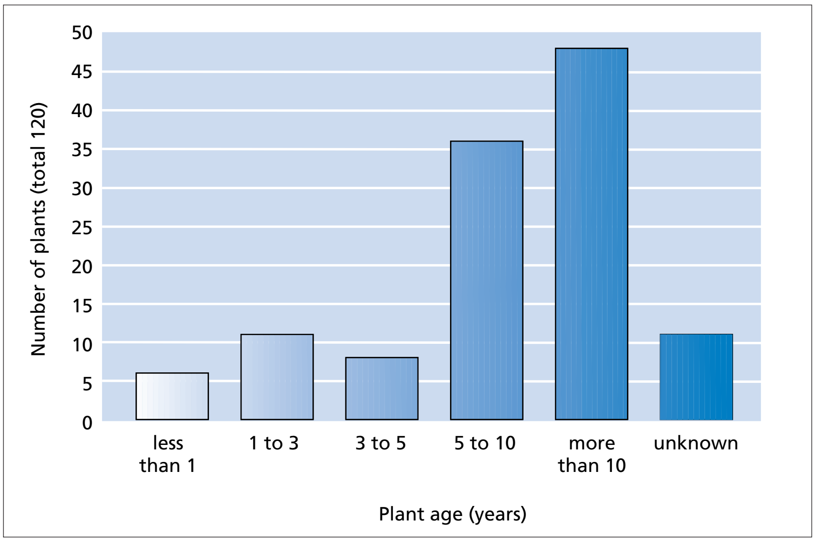

Fig 6 Age of degreasing plant in the UK (HSE Survey)

Degreasing equipment generally has a long useful life; the oldest plant in the survey was over 30 years old. The practical, on-site improvements described below are suitable for equipment of all ages.

The HSE survey also highlighted a number of common problems with the design of degreasing plant. All these problems result in more solvent than necessary being used, leading to increased costs, and environmental and safety problems. Table 2 summarises the extent to which major features could be improved at sites surveyed by the HSE.

Design feature	Degreasers needing improvement
Inadequate rim ventilation	67%
Hoist speed too fast	63%
Sited in potential draughts	60%
Inadequate topping-up method	60%
Inadequate freeboard ratio	51%
Unsuitable lid or no lid at all	36%

Table 2 Design features needing improvement (HSE survey)

4.3 POSSIBLE ANSWERS

The following solutions to the common problems highlighted in the HSE survey can all be applied to existing plant. In some cases they can be designed and constructed in-house. In other cases help from outside suppliers will be required.

4.3.1 Improve rim ventilation

Adequate rim ventilation (lip extraction) is essential for trichloroethylene degreasing to prevent the operator from being exposed to unacceptable levels of solvent vapour. It is important to remember that the ventilation will control, rather than eliminate, vapour emissions.

Ventilation should normally be installed on at least two sides of the tank rim unless the plant is less than 350 mm wide, in which case single-side ventilation should be adequate. Four-sided rim ventilation is often installed on modern degreasers. While it is important that extraction rates are high enough to protect operators, excessive extraction results in unnecessary solvent consumption. An extraction rate of 640 - 915 m^3/hr per m^2 (35 - 50 cu ft/min per sq ft) of bath surface is recommended.

For any degreaser with a specific rim vent slot design, extract fan specification and ductwork configuration there will be a specific rim vent slot velocity. Some users may find it easier to check this measurement rather than the total volume of air extracted. The degreaser supplier should be consulted for the appropriate figure.

4.3.2 Fit and use power-operated hoist and lifts correctly

A power-operated hoist is recommended for all vapour degreasing plants to control the speed of entry/exit of work. This speed should be set so that it cannot exceed 3 metres/min (11 ft/min). Higher entry speeds will result in vapour spilling over into the workplace or excessive extraction to the atmosphere via the rim vents. This problem can be aggravated by loads with a large base area. As a guideline, the load base-size should not exceed 50% of the surface area of the degreasing tank.

4.3.3 Improve siting

Air turbulence in the plant area should be avoided as this can cause serious solvent losses. In the HSE survey, only 39% of the degreasers were judged to be located in positions free from draughts. Some units were subject to draughts from more than one source.

Features that create air currents, and thus disturb the vapour in degreasing units, include:

- doors;
- windows;
- heating and ventilation systems;
- busy passages.

Degreasers should be:

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

4.3.4 Install fixed pipework for topping up

The HSE survey found that the most common practice when topping up the degreaser was for solvent to be poured in from a drum or bucket, sometimes even when the plant was hot! This practice increases operator exposure levels and the chance of spillage.

Spillage should be avoided 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 for the site operator. Spillage also increases the risk of water courses being contaminated by solvent; this could lead to the site operator being prosecuted.

Fixed pipework, connected to the sump, allows new solvent to be pumped directly from the container.

4.3.5 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 the chance 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.

A freeboard ratio of at least 0.75:1 and preferably 1:1 is recommended. Older degreasing plant typically have a ratio of 0.6:1 or less. Of the plants measured during the HSE survey, 51% had a freeboard ratio of less than the minimum recommended 0.75:1. Employee exposure is more likely to be unnecessarily high if the freeboard ratio is less than 0.75:1.

4.3.6 Fit and use appropriate lids

HSE found that 85% of the conventional open-topped degreasers it inspected were provided with covers. However, 25% of these covers were considered **unsuitable** because they:

- caused vapour drag-out when lifted;
- were made of unsuitable material;
- were incorrectly fitted above the rim ventilation slot.

The last of these is of particular concern. 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 presents a fire hazard as residual oil and grease in the plant is exposed to direct heat in the sump.

Lids should be designed to fit between the top of the freeboard zone and below the extraction vents. Lids, which can be retrofitted to conventional plant, should preferably be of a roller or slide design, rather than lift-out panels. Horizontal movement on roller and sliding shutters is less likely to disturb the vapour in the plant than lift-out panels. Segmented lids are useful on long degreasing units, since they allow partial opening when degreasing smaller items.

A complete new double-door system (see Section 3.2.2) 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, plant equipped with double doors is unlikely to achieve the solvent emission limits permitted under existing environmental legislation (see Appendix 1); carbon adsorption of the exhaust gases may be required.

4.3.7 Install support frames within the condensation zone

Frames fitted within the condensation zone allow work that is 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 wastage and operator exposure. Carefully designed frames can also prevent damage to parts of the plant, such as the cooling coils and fins, and thus reduce maintenance costs.

4.3.8 Fit time controller/alarm and idling cut-out

Excessive cleaning wastes time, energy and solvent. Once load conditions and effective cleaning times have been established, timers and alarms provide an effective mechanism for controlling the duration of the cleaning process. Using appropriate lid designs and interlock devices prevents poor operation and minimises solvent loss.

A rapid-response sensor installed immediately below the condensation zone acts as an energy-saving device (see Section 3.2.1). 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.

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

This safety feature helps minimise operator exposure to solvent fume during plant clean out. Extraction at the clean-out hatch is particularly important if the degreasing unit is set in a pit. It does not, however, make entry to the degreaser safe.

4.4 PRIORITISING PLANT MODIFICATIONS

Most of the suggested modifications could be applied to the majority of existing vapour degreasing plants in the UK. The ease with which the modifications can be made, and the level of benefit that may be expected from them, will vary according to the type of modification and the plant. Table 3 indicates the 'typical' level of costs and benefits associated with the various modifications. Table 4 summarises the specification of a conventional open-topped degreasing plant incorporating the suggested modifications.

Modification	Cost	Cash saving	Environmental benefits	Health & 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
Double doors	High	Medium/High	High	High	Consider
Extraction to clean-out hatch	Low	None	Low	High	Consider

Table 3 Relative benefits of plant modifications

Zone or quantity		Dimensions
Sump:	minimum size	5 - 10% of tank height.
	heat input	80 mm (3 in) below minimum solvent level. Interlocked to cooling water and sump level.
	supply	Element output 2 - 4 watts/cm^2.
Work zone		As required by work type/size. Deeper rather than longer/wider.
Condensation zone:		Vapour at mid point of coils.
	refrigerated	Methylene chloride.
	water cooled	Trichloroethylene and perchloroethylene.
	temperature	Inlet at 10 - 20°C, outlet at 30 - 40°C.
Freeboard zone		0.75 - 1.00 times the tank width.
Lid		Sliding or roller type.
Extraction - four sides		640 - 915 m^3/hr per m^2 (35 - 50 cu ft/min per sq ft) of working surface.
Load horizontal face area		Not more than 50% the area of the entry dimensions.
Raise/lower speed		3 m/min (11 ft/min) maximum.
Solvent additions		Pumped via fixed pipe to sump.
Dump drain hatch		Local extraction at 3 660 m^3/hr per m^2 (200 cu ft/min per sq ft) of opening.

Table 4 Sample specification for a conventional open-topped degreasing plant

5 OPERATIONAL GOOD PRACTICE

5.1 INTRODUCTION

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.

The 1994 HSE survey (see note on page 1 for details) found that a significant proportion of sites with degreasing equipment needed to improve operational aspects of their cleaning process. Fig 7 shows some of these aspects; most of the improvements are aimed at providing adequate staff protection. Poor operational control invariably leads to:

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

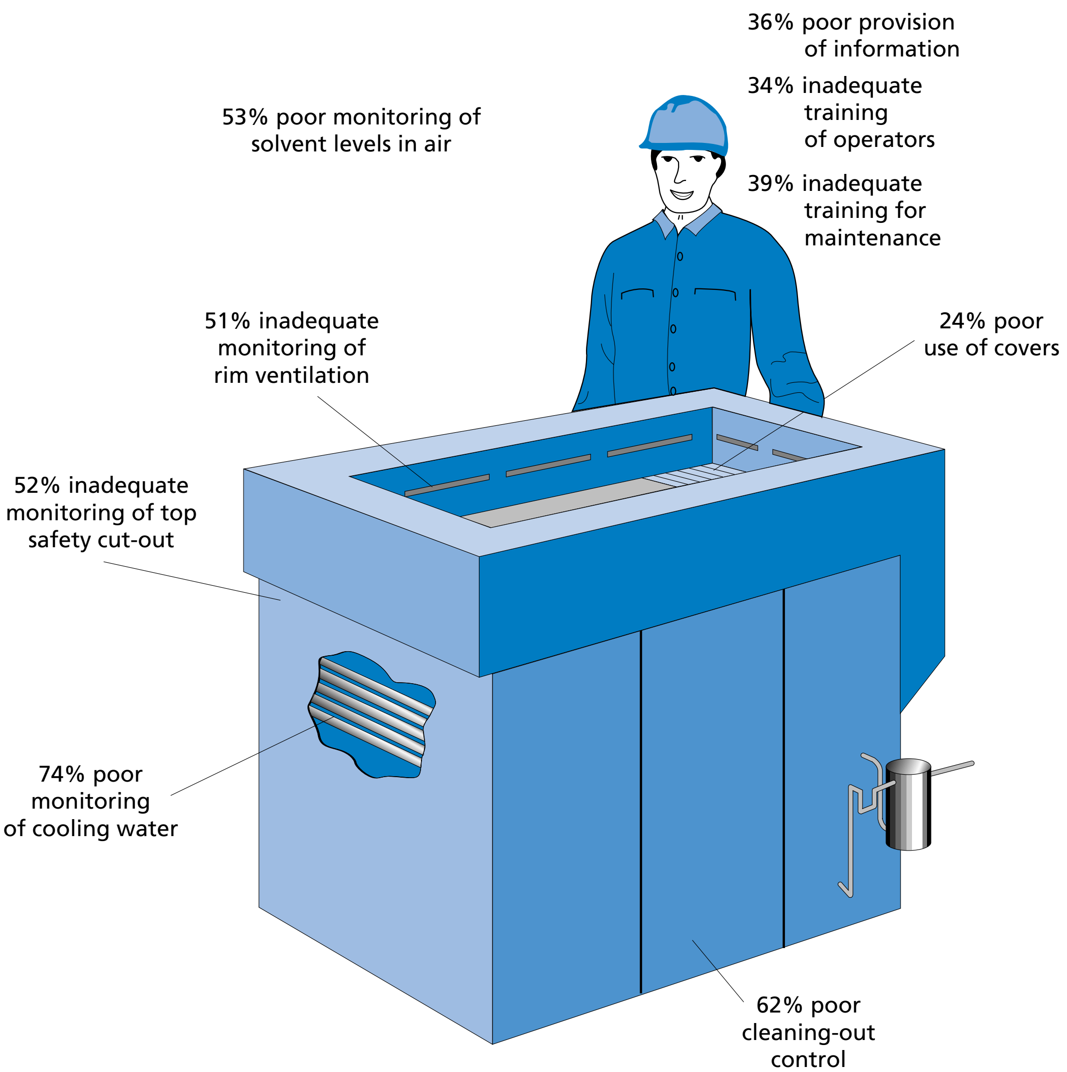

Fig 7 Operational features needing improvement (HSE Survey)

section 5

5.2 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 8). All the losses shown can be minimised by attention to good housekeeping during operation, plant maintenance and waste disposal.

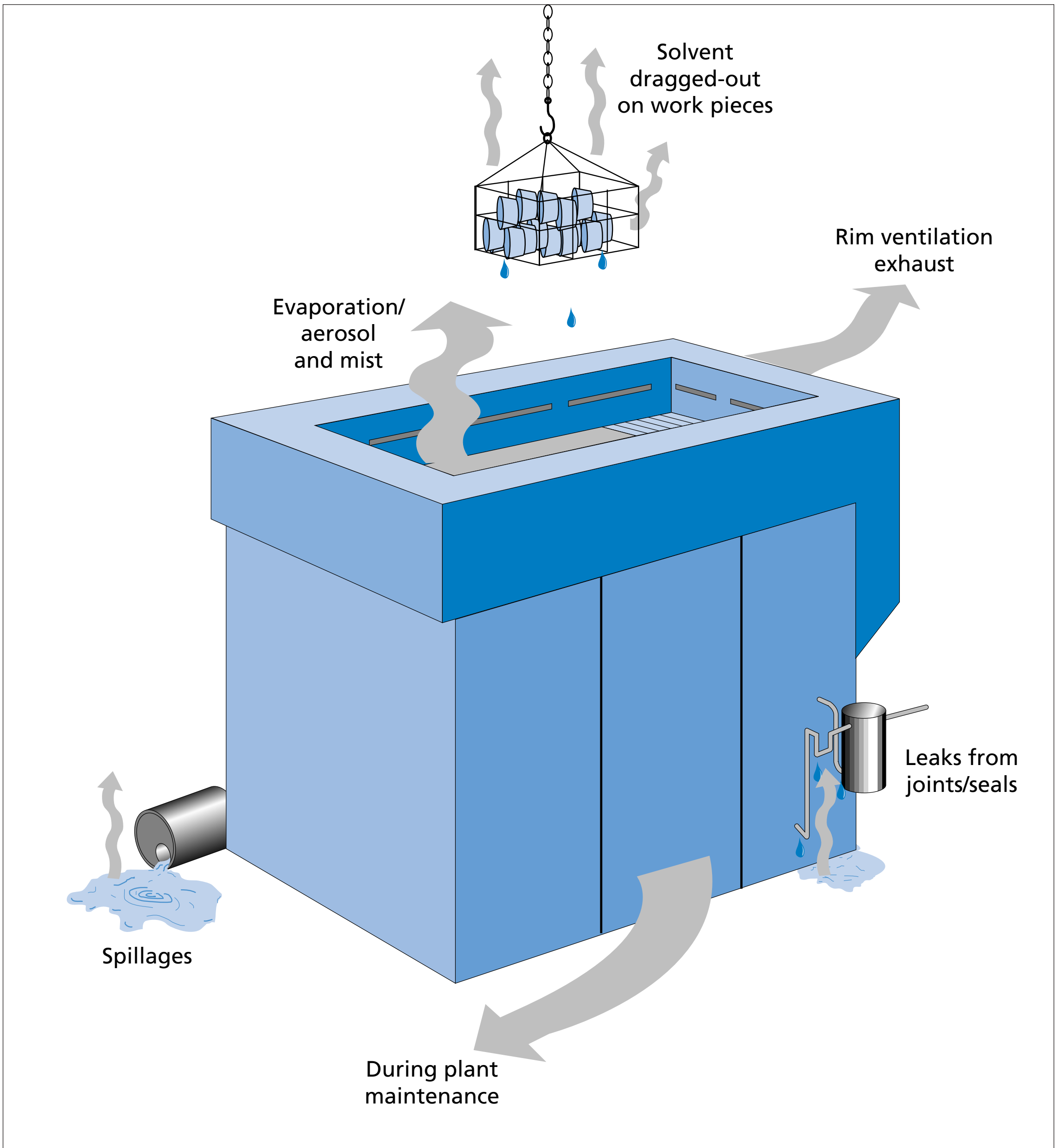

Fig 8 Potential routes for solvent loss from a degreasing unit

section 5

5.2.1 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.

These losses can be minimised by the following actions.

Use the lids provided

Using lids is important, particularly when the plant is starting up, closing down or idling. Sectional lids or roller shutters (where fitted) should only be opened as far as is needed for loading or unloading.

Load/unload the plant at the correct speed

Parts should pass slowly through the condensation zone and then wait in the freeboard zone for the load to 'dry'. The time needed for this 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.

The need to wait for the load to dry is another reason for using mechanical handling for even the smallest of loads. Without such equipment, there is a danger that the plant operator, perhaps to avoid fatigue, will not allow sufficient time and rush the procedure. Conversely, an operator may remain standing over the plant for longer than necessary, thereby increasing his exposure to the solvent significantly. Manual loading also encourages operators to lean on the extraction box or even hang work from it. These practices may damage the plant and, by closing the slot in the extraction vent, make extraction ineffective. If mechanical handling is not reasonably practicable, it is possible to provide suitable hooks so that baskets of components may be hung up to drain and dry properly in the freeboard zone.

Turn the work in the freeboard zone

This action minimises solvent 'drag out' on loads with cupped areas or blind holes. Plants with a deep freeboard (see Section 4.3.5) facilitate turning.

Jig the work appropriately

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

> 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 almost a three-fold increase in the load of components, eliminate the lance and significantly reduce the piston effect when loading the degreaser.

5.3 PLANT MAINTENANCE

Degreasing plants require routine maintenance and cleaning if they are to continue to perform effectively.

5.3.1 Regular maintenance

Scheduled maintenance is designed to ensure systems and controls are functioning correctly and the plant is safe. Safe operation depends on the correct operation of the sensors controlling:

- sump level;
- sump temperature;
- vapour temperature;
- freeboard temperature.

These controls should be checked 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. The method does, however, rely on the person carrying out the inspection knowing what should happen.

Plant should never be left unattended during such tests and two people should always be present. Correct reconnection of the control devices is essential. It is therefore advisable that this procedure is only carried out by properly qualified and experienced staff.

The top safety cut-out, situated in the freeboard zone, is particularly important in that 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. The cut-out should be set to turn-off the heat input to the sump when the temperatures given in Table 5 are reached.

Solvent	Cut-out temperature
Methylene chloride	30°C
Trichloroethylene	55°C
Perchloroethylene	80°C

Table 5 Top safety cut-out temperatures

Control tests/measurements should be carried out and recorded on simple charts posted either on, or in the immediate vicinity of, the plant. Table 6 lists the plant characteristics that operators are advised to measure and the suggested frequency of testing. Operators should be encouraged 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.

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 rise in vapour level cuts out heater. Turn coolant back on.
Acid acceptance value:		
enclosed/automatic plant	Daily	Titration kit from solvent supplier.
open-topped 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	Three monthly*	Measure air flow-rate using anemometer.

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

Table 6 Plant control monitoring

In addition to providing useful data, this approach can generate a feeling of 'ownership' in operators.

5.3.2 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 given in Table 7;
- inadequate component cleaning or corrosion;
- bad odour;
- failure of plant controls.

Solvent	Maximum sump temperature
Methylene chloride	50°C
Trichloroethylene	110°C
Perchloroethylene	140°C

Table 7 Manufacturers' recommended maximum sump boiling temperatures

Irrespective of the above, major cleaning should be carried out at least once a year. In many cases more frequent cleaning may be appropriate.

5.3.3 Precautions during major cleaning

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

It is likely that the plant will need to be cleaned internally after removal of solvents by distillation or discharge and this should normally only be attempted on plant which has cooled to room temperature. Waste sludge in the sump should be removed by draining and scraping it through the clean-out door. A safe system of work which involves entry into degreasers should involve at least the following points:

- Entry must be specifically authorised by a responsible person, preferably in writing using a formal permit-to-work procedure.
- The degreaser will have been cooled, drained of as much solvent and sludge as is reasonably practicable and must be thoroughly ventilated at high and low level before entry takes place.
- A person entering the degreaser must have full protective clothing including boots, overalls and gloves resistant to the solvent in use.
- Compressed air (self contained or air hose) full face, positive pressure breathing apparatus must be worn by the person in the tank and similar equipment must be ready for immediate use by at least one other person outside the degreaser (see Fig 9).
- A person entering a degreaser must wear harness and lifeline (see Fig 9).
- A rescue plan needs to be established to enable a person to be rescued quickly from the degreaser in an emergency. This is likely to involve additional people being present or very readily available on call. It may also involve the use of a powered hoist to which the lifeline can be attached.
- Oxygen resuscitation equipment must be available and persons must be trained to use it.
- The extraction system should be left in operation.

Trichloroethylene and perchloroethylene are denser than air and therefore tend to form a layer at the bottom of the plant.

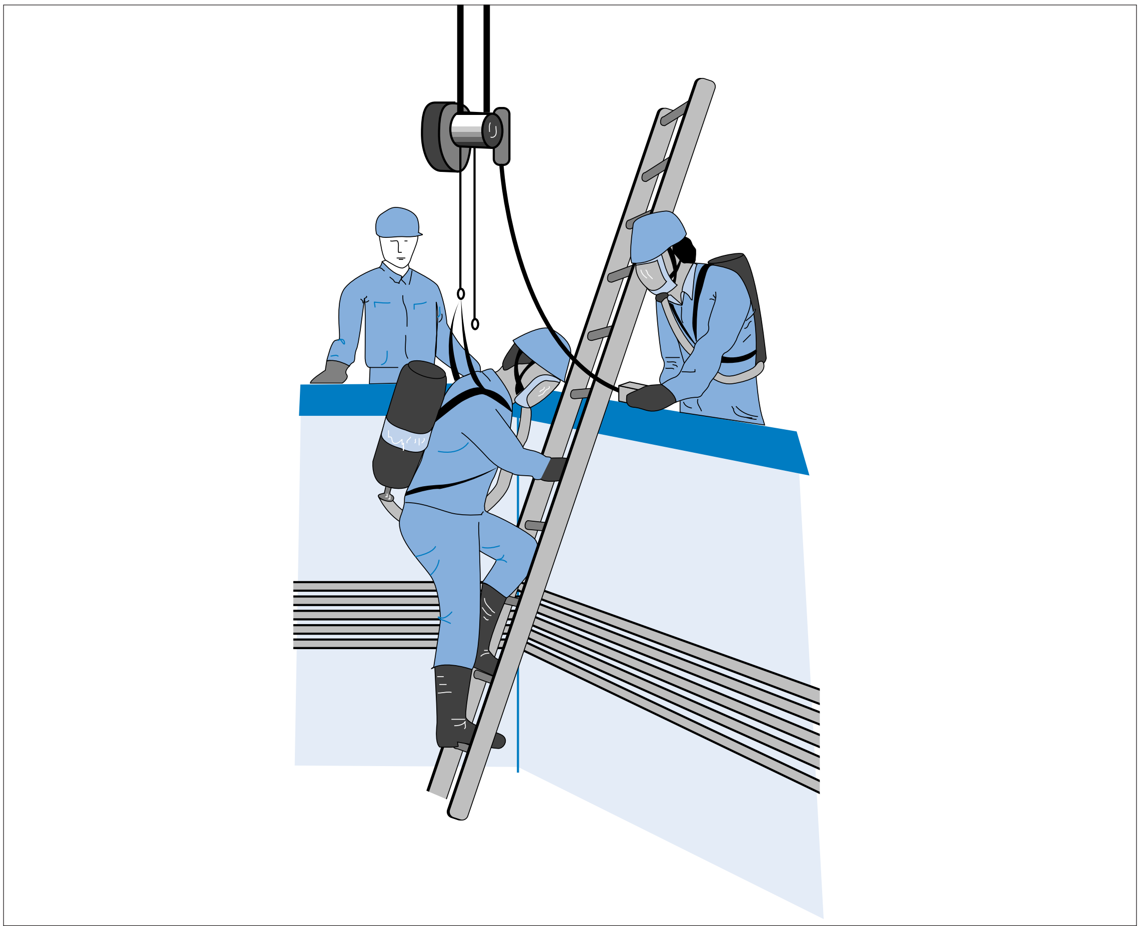

Fig 9 Working inside a degreaser

Other useful precautions include:

- taking care during scraping operations to avoid damage to heaters and sensors;
- isolating the plant heating system by switching off and removing control fuses or handles;
- placing a notice on the switches stating that personnel are in the plant and the control unit must not be touched.

When acid residues are present, neutralisation or **'sweetening'** can be carried out by filling the degreaser with a 1% weight to volume solution of sodium carbonate in water and heating the unit to approximately 50°C. This temperature should be maintained for three hours and the plant then allowed to cool to room temperature. The resulting solution should be removed and discarded in an approved manner.

5.4 WASTE MANAGEMENT

Good waste management practice is essential because degreasing plant wastes are hazardous to health. There are duties placed on plant operators to ensure that the wastes are properly handled; failure to do so may lead to prosecution (see Appendix 1). There are also commercial advantages to efficient handling, since solvent recovery may be possible.

Different waste solvents should not be mixed. Separate storage and clear identification are critical.

5.4.1 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. Table 7 in Section 5.3.2 lists the maximum boiling points for the three main solvents beyond which sump liquors (ie the combined residual solvent and the accumulated contaminants) should no longer be used. The **sump safety cut-out** should therefore be set at this temperature.

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

5.4.2 On-site solvent recovery

Solvent in the waste can be recovered and recycled on-site by distilling the sump contents while in the degreaser. Condensate from solvent waste distilled in the degreasing unit is collected by diverting the flow from the water separator into another container. If the bottom safety cut-out operates, there is no more scope for recovery in the plant. Clean-out is normally needed at a solvent level of 50% by volume, which 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.

Recovered solvent should be checked for acidity and, if necessary, stabiliser added to correct this. Data sheets and other information provided by the supplier should be followed at all times.

5.4.3 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.

Such residues should be transported by a licensed waste carrier to a specialist recycling company, where the remaining solvent can be removed. Once the solvent content has been extracted by the recycler, 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 usage for the purposes of Local Authority Air Pollution Control (LAAPC) (see Appendix 1).

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

5.4.4 Waste disposal

If further solvent recovery is not practicable, the correct procedure for disposing of final waste should be followed:

- all spent solvents should be properly segregated, packaged and labelled;
- only trained personnel should be involved in the handling and storage of spent solvent;
- correct handling procedures should be adopted;
- movements of both spent solvent for reclaim and final waste should be adequately documented and recorded.

Final waste **must** only be disposed of via an authorised licensed waste disposal contractor. The Duty of Care Regulations 1991 (see Appendix 1) require careful management and documentation at all stages.

Internal and/or external recovery processing of solvent wastes means that the final waste should contain minimal levels of chlorinated solvents. Where the level of chlorinated solvent remaining is less than 1 - 2% of the final waste, it can often be incinerated in a conventional incinerator. A specially-designed thermal oxidation plant, operating at around 1 200°C and fitted with air pollution control equipment, is necessary for wastes containing higher levels of chlorinated solvents.

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

5.5 TRAINING

Plant operators are crucial to the efficient operation of degreasing plant. Effective operators do not just happen, they have to be trained. This Guide - read in conjunction with the operator's handbook for the specific degreasing plant - provides useful information for operators.

A broad, well-structured training programme, consisting of a minimum of 4 - 6 hours instruction, is beneficial for operators of simple open-top degreasers. This should also be sufficient to cover the basic operation of automatic machines. Areas to be covered include:

- theory of operation;
- health, safety and regulations;
- 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 8.

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

Table 8 Training check list

5.6 ASSESSING PROGRESS

All the suggestions made in the preceding sections of this Guide have the potential to save your company money.

However, as with any waste minimisation exercise, it is important to understand what effects your actions have had. This enables decisions on further action to be taken and makes it easier to target the most cost-effective improvements. The following are important in achieving this understanding.

5.6.1 Managing solvent use

Various tools to help companies with this approach are available, including formal environmental management systems, solvent management plans and monitoring & targeting procedures. These can be used as stand-alone activities or as parts of a broader waste minimisation programme. This Guide outlines some of the basic requirements for measuring solvent consumption; the Environmental Technology Best Practice Programme has published a Good Practice Guide on implementing cost-effective solvent management. These Guides can be obtained free of charge from the Environmental Helpline on 0800 585794

5.6.2 Measuring solvent consumption

The Environmental Protection Act 1990 requires companies operating prescribed coating processes using more than a certain amount of solvent each year to be authorised by their local authority (see Appendix 1). This requirement applies to coating companies operating vapour degreasing plants. 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, perhaps as part of a solvent management plan. Plant operators are advised to record, as a minimum, the data noted in Table 9.

Management action	Volume per year	Weight per year	Unit price	Cost per year
(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'*

Table 9 Recommended solvent management record

Plant operators are also recommended to record:

- the number of hours the plant is turned on;
- the number of hours spent degreasing.

The number of hours that the plant is turned on but not degreasing, effectively represents wasted solvent, energy and cooling water. It should be noted that where a rapid-response sensor (see Section 3.2.1) is fitted, energy consumption is reduced significantly when the plant is not degreasing. This information can be built up from a daily log sheet as shown in Appendix 3.

This information provides useful plant management data and, not least, an appreciation of degreaser operating costs.

5.6.3 Measuring the cost of cleaning

Cleaning costs are either **direct** or **indirect** (see Table 10). 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.

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

Table 10 Possible costs of degreasing plant cleaning

Typical annual costs for operating a conventional vapour degreasing plant using trichloroethylene are given in Table 11.

Item	Annual cost (£)
Labour	13 000
Trichloroethylene	5 000
Cooling water[4]	1 500
Heating	1 000
Spent solvent disposal	650
Depreciation	1 500
Total	**22 650**

*Assumptions:

- plant open top area of 1 m x 0.6 m.
- single shift operation, one full-time operator.
- repetitive, jigged components.
- standard plant without automatic handling.

Table 11 Annual operating costs: trichloroethylene degreasing plant*

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%.

5.7 HEALTH AND SAFETY MONITORING

Monitoring is also necessary to demonstrate that a healthy and safe working environment is being maintained. Even though the solvents used have strong and characteristic odours, **the threshold of smell should not be used as a 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 should be taken.

Solvent in air monitoring is concerned with the level of exposure of the operator during the entire shift. There are two considerations:

- The occupational exposure limits normally quoted are eight-hour time-weighted averages. Where the occupational exposure limit is a **Maximum Exposure Limit (MEL),** the limit should not normally be exceeded and exposure levels should be as far below the MEL as is reasonably practicable. Trichloroethylene and methylene chloride have been assigned MELs under the COSHH regulations.
- Many substances are assigned a short-term exposure limit, which is again a time-weighted figure, but over a 15-minute reference period. Where substances with a MEL also have a short-term MEL, this figure should **never** be exceeded. Both trichloroethylene and methylene chloride have short-term MELs.

For a properly designed, installed, operated and maintained traditional, open-topped degreaser, experience has shown that eight-hour time-weighted operator exposure levels will be 20 parts per million or less for trichloroethylene degreasers. For enclosed and automated plants, lower exposures can be achieved.

[4] In electroplating shops, cooling water is often diverted to rinse tanks.

Operator exposure can be measured and compared against both long-term and short-term exposure limits, using methods described below.

5.7.1 Measuring exposure

Full shift personal exposure can be conveniently measured using **direct reading diffusion** tubes. These are attached to the operator's collar, as close to the breathing zone as possible. The level of exposure is indicated by a coloured band created by reaction with the solvent. Properly used, such tubes can give a good indication of operator exposure, but more accurate sampling methods are available if necessary. These methods are described in the HSE publication MDHS70 *General Methods for Sampling Airborne Gases and Vapours;* solvent suppliers can advise on their use.

Short-term indicator tubes contain a reagent which changes colour as a measured quantity of solvent-containing air is drawn through it by a small vacuum device. The length of the colour stain indicates the solvent concentration. The device may be mechanically operated or manually pumped. This test takes only a few minutes to complete and is, therefore, able to register intermittent high levels of solvent in the air. Such tests, carefully done, can be used to give a reasonable comparison with the short-term exposure limit though the sampling period is less than 15 minutes. Short-term tests of this nature performed by a competent person can also be very useful for indicating particular problems with poorly maintained plant or poor operating procedures. They can also demonstrate that improvements made to either plant or operating procedures have been effective.

Care should be taken when using this form of test, since the person carrying out the measurements may be exposed to unacceptable levels of the solvent. If there is a reason why the test is being carried out, other than as a routine operation, suitable protective clothing and appropriate respiratory equipment should be worn.

5.7.2 Health surveillance

Although not normally required for workers associated with degreasing operations, biological monitoring is a useful way of checking exposure to solvent. Of the 170 sites surveyed by HSE Inspectors in 1994, 20 carried out some form of health surveillance. The survey found that:

- four sites carried out general screening;
- six sites carried out urine testing, but only three specifically screened for trichloroacetic acid (TCA), the metabolic by-product of trichloroethylene;
- seven sites tested lung function;
- one site specifically surveyed staff for dermatitis;
- one site used a health questionnaire.

Enquiries about health problems revealed the symptoms listed in Table 12.

Symptom	Frequency encountered
Facial flushing (degreasers' flush)	4
Central nervous system (CNS) symptoms, eg dizziness, headache, light-headedness	3
Respiratory irritation, eg coughing	2
Tiredness	2
Nausea	2
Gastro-intestinal symptoms, eg flatulence, hunger	1
Dry skin	1
Unidentified health effects	1

Table 12 Symptoms recorded by HSE inspectors

5.7.3 Health, safety and first aid

Solvents are harmful; trichloroethylene, perchloroethylene and methylene chloride are all Category 3 carcinogens. Exposure routes and the likelihood of risk are summarised in Table 13.

Exposure route	Likelihood of risk
Inhalation	Most common
Eye contact	Possible
Skin contact	Possible
Oral contact	Highly unlikely under normal operation

Table 13 Exposure to degreasing solvents

Table 14 presents information on over-exposure to solvents, including exposure routes, possible effects and precautions to prevent exposure. First aid measures are also indicated. For specific information on a particular solvent, always refer to the manufacturer's data sheet.

Route of exposure	Possible effects	Safety precautions	First aid
Inhalation	Inhalation presents the greatest potential hazard. All four chlorinated solvents may produce an anaesthetic effect. Exposure times needed to cause light-headedness or dizziness vary from solvent to solvent. Repeated and prolonged exposure to chlorinated solvents at or above levels producing mild anaesthetic effects should be avoided. Exposure to very high concentrations of vapour could be fatal.	Full face, positive pressure breathing apparatus may be necessary depending upon the operation. Such protection is essential when work requires personnel to enter tanks and confined spaces which may contain concentrated solvent vapours. Safe systems of work should always be followed.	Remove the worker to fresh air. Call a physician or take the worker to an emergency medical facility. Start resuscitation if breathing stops. **Note to Physician:** May cause myocardial sensitisation. Avoid use of epinephrine or other sympathomimetic drugs.
Eye contact	Solvent spattered into the eyes may cause irritation which disappears rapidly. Solvent splashes can cause appreciable discomfort.	**Avoid contact with eyes.** Under normal conditions, use safety glasses or their equivalent. Wearing contact lenses is not recommended. Wear chemical goggles where liquid splash contact is likely.	Flush eye with flowing water immediately and continuously for at least 15 minutes. Consult medical personnel.
Skin contact	Chlorinated solvents are not likely to be absorbed through the skin in significant quantities. However, frequent daily contact with chlorinated solvents can de-fat the skin and produce dermatitis. Occasional brief contact is not likely to produce adverse effects. Severe irritation may result if solvent is in persistent contact with the skin and cannot evaporate.	**Avoid contact with skin.** For frequent contact, gloves of viton fluoroelastomer give the best protection. Polyvinyl alcohol gloves are satisfactory, but may be vulnerable to water. PVC gloves only give short-term protection. Gloves should be replaced at the supplier's recommended intervals but in any case they should be discarded as soon as they begin to deteriorate.	Flush the skin immediately and thoroughly with water while removing contaminated clothing. Discard contaminated leather articles such as shoes and belts.
Oral ingestion	Minimal hazard from accidental ingestion. Intentional ingestion of larger amounts could result in serious effects or even death (due to the anaesthetic effects of the solvents).	Do not store solvents in unlabelled or improperly labelled containers.	Do not induce vomiting. Call physician or take the worker to an emergency medical facility.

Table 14 Over-exposure to common degreasing solvents (methylene chloride, methyl chloroform, trichloroethylene, perchloroethylene)

6 ACTION PLAN

This action plan summarises the various ways in which operators of vapour degreasing plants can reduce both their solvent consumption and the environmental impact of their process. There are four main questions to be considered when seeking to minimise waste and thus reduce costs:

- 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?

6.1 CONSIDERING YOUR PROCESS

Now is the time to 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? Prevention is the first priority, followed by reduction.

Section 2 discusses the options available for component cleaning and highlights the advantages and disadvantages of the different methods. Some companies have found that a combination of cleaning technologies is best .

Consider:

- Changing working methods and/or handling procedures to avoid or reduce the need for cleaning.
- The factors that affect the choice of cleaning method for a particular application.
- Changing to a different cleaning process or a combination of processes eg:
  - vapour degreasing;
  - aqueous cleaning;
  - semi-aqueous cleaning;
  - organic solvent cold cleaning;
  - non-solvent processes.

6.2 SPECIFYING NEW PLANT

Even if you are sure that vapour degreasing is still the best method for your application, it may be worthwhile examining your plant specification. Modern vapour degreasing plants are designed with an emphasis on efficient solvent use and operator safety.

When drawing up the specification for a vapour degreasing plant with an emphasis on waste minimisation, it helps to be familiar with the principles of both the process and the chemicals to be used. Section 3 explains these principles and describes the main features of the three categories of modern vapour degreasers.

Ask yourself:

- How well is the vapour controlled?
- Am I using the optimum solvent for the application? Remember that an altered specification may be required 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 bulk treating small parts? A totally sealed end loading unit may be the answer.
- Do I need to fit air pollution control equipment?

6.3 IMPROVEMENTS TO EXISTING PLANT

While it may not be cost-effective for most companies to invest in a new state-of-the-art degreasing unit, existing plant can be easily and cheaply modified to improve performance. The practical, on-site improvements described in Section 4 are suitable for all ages and types of degreasing equipment.

- Improve rim ventilation to reduce the risk of operator exposure to unacceptable vapour levels.
- Fit power-operated hoists and lifts.
- Avoid loads with a base area greater than half the surface area of the degreasing tank.
- Locate the degreaser away from any draughts.
- Position degreasers in a no-smoking area, away from sources of heat and flames.
- Install fixed pipework connected to the sump for topping up with fresh solvent. This avoids operator exposure and possible spillages.
- Increase the depth of the freeboard zone such that the freeboard ratio is at least 0.75:1 and preferably 1:1.
- Fit and use appropriate lids, preferably of a roller or slide design. The lid should fit between the top of the freeboard zone and below the extraction vents. Lids can be retrofitted to most conventional degreasing units. Segmented lids are useful on long equipment.
- Install support frames within the condensation zone to support work mounted on jigs. Frames also prevent damage to vulnerable parts of the plant.
- Fit time controllers/alarms and idling cut-outs to eliminate excessive cleaning and save energy.
- Add extraction to the clean-out hatch in the sump to prevent operator exposure during plant maintenance.
- Prioritise plant modifications according to their relative benefits (see Table 3 in Section 4.4).
- Follow the sample plant specification given in Table 4 in Section 4.4.

6.4 OPERATIONAL GOOD PRACTICE

The efficiency of any plant depends on how well it is operated and maintained. Section 5 suggests ways in which you can get the best out of your plant through operational good practice. Many are simple low-cost or no-cost good housekeeping measures, others are associated with keeping a check on how the plant is running.

- Use the lids provided, particularly when the plant is starting up, closing down or idling.
- Load/unload the plant at the correct speed, allowing adequate time for the work to dry. A maximum speed of 3 m/min is recommended.
- Use mechanical handling (hoists and lifts) for **all** loads.
- Turn the work in the freeboard zone to minimise solvent drag-out.
- Implement a routine maintenance and cleaning programme:
  - Perform regular checks on the sensors controlling sump level, sump temperature, vapour temperature and freeboard temperature (see Table 6 in Section 5.3.1).
  - Record test results on charts posted on or near the plant.
  - Investigate unusual trends immediately.
  - Only clean plant that has been allowed to cool to room temperature.
  - Clean plant regularly to reduce the need for personnel to enter the plant.
  - Ensure that full protective clothing is worn by personnel entering the tank during cleaning.
  - Enforce working procedures and precautions designed to ensure operator safety. These should be written down and publicised within the company.
  - Don't forget that some solvents are denser than air and will tend to form a layer at the bottom of the plant.
- Involve plant operators in improving plant operation.
- Follow good waste management practice and keep different wastes separate.
- Consider solvent recovery from waste either on-site or via specialist solvent recyclers. Check recovered solvent for quality (particularly acidity) prior to re-use.
- Follow the correct procedures for disposal of final waste, having regard to the Duty of Care.
- Implement a training programme for operators and maintenance personnel as suggested in Table 8 in Section 5.5.
- Manage solvent use as part of a solvent management plan or a waste minimisation programme.
- Measure and record your solvent consumption. Calculate mass balance (see Table 9 in Section 5.6.2) in preparation for sending information on solvent consumption and solvent losses to your local authority (if registered).
- Measure all the costs associated with vapour degreasing.
- Implement an exposure monitoring regime that considers both short-term and long-term operator exposure to solvents.
- Consider implementing a health surveillance programme.
- Be aware of the exposure routes, possible effects, safety precautions and first aid measures. Consult the manufacturer's data sheet for specific information on the solvent you are using.
- Keep up-to-date with relevant environmental and safety legislation and any forthcoming changes that might affect your future operations. Contact the Environmental Helpline on 0800 585794 for free advice.

Appendix 1

RELEVANT LEGISLATION

Solvent-cleaning processes are being increasingly affected by national and international measures to:

- phase-out substances that contribute to the depletion of the stratospheric ozone layer;
- limit the emission of volatile organic compounds (VOCs) that could contribute to the formation of ground level ozone.

MONTREAL PROTOCOL

The Montreal Protocol on Substances That Deplete the Ozone Layer (as amended at the London and Copenhagen meetings of the Parties to the Protocol) places stringent controls on the use of chlorinated organic solvents. The Protocol requires the production of chlorofluorocarbons (CFCs), halons, carbon tetrachloride and 1,1,1-trichloroethane to be phased out by certain dates. The European Union has subsequently brought forward these phase-out dates. Table A1 shows the phase-out dates stated by the Protocol and those enforced within the European Union. Although these dates apply to the production - rather than the use - of these substances, supplies of 1,1,1-trichloroethane are becoming increasingly difficult and expensive to obtain.

Substance	EC Regulation 3093/94	Montreal Protocol
CFCs	1 January 1995	1 January 1996
Halons	1 January 1994	1 January 1994
Carbon tetrachloride	1 January 1995	1 January 1996
1,1,1-trichloroethane	1 January 1996	1 January 1996

Table A1 Phase-out dates for ozone depleting substances

CONTROLS ON VOC EMISSIONS

Restrictions on the emission to atmosphere of VOCs are expected to become the major factor controlling both solvent cleaning processes and their equipment requirements. These controls do not only apply to chlorinated solvents such as trichloroethylene, but to any alternative volatile solvent.

Under the United Nations Economic Commission for Europe (UNECE) VOC Protocol, the UK has agreed to reduce, by 1999, the UK's annual emissions of VOCs by at least 30% compared with 1988 levels. In November 1993, the Department of the Environment (DoE) published details of the Government's proposed strategy[5] to meet the UK's international obligations. The DoE predicts that, for surface cleaning, emissions will fall by 56% from 43 000 tonnes (t) in 1988 to 19 000 t in 1999.

ENVIRONMENTAL PROTECTION ACT 1990

Local Authority Air Pollution Control

In the UK, local authority control of air pollution under Part I of the Environmental Protection Act 1990 (EPA 1990) applies rigorous controls to solvent cleaning where it forms part of a **coating process.** These controls are not applied to the use of solvent cleaning in other industrial sectors.

[5] *Reducing emissions of Volatile Organic Compounds (VOCs) and levels of Ground Level Ozone: A UK Strategy,* Department of the Environment October 1993.

The prescribed processes and prescribed substances controlled under Part I of the EPA 1990 are listed in the Environmental Protection (Prescribed Processes and Substances) Regulations 1991 (SI 1991/472 and subsequent amendments). Under Schedule 1 of the 1991 Regulations, coating processes which are likely to use more than five tonnes of organic solvent in any 12-month period are designated Part B processes subject to Local Authority Air Pollution Control (LAAPC).

Users of degreasing equipment as part of a coating process are exempt from registration with their local authority if:

- less than five tonnes/year of degreasing solvent is used;
- no other solvents are used in the process.

Where total solvent use is more than five tonnes/year and if degreasing as part of a coating process uses more than two tonnes/year, an emission limit of 20 mg/m^3 (as total carbon excluding particulate matter) applies[6].

Operators of degreasing equipment that falls under LAAPC may need to consider major design alterations such as plant enclosure and the installation of air pollution abatement equipment, eg activated carbon adsorption or incineration.

Demonstrating compliance

An inventory of all potential emission sources will determine whether or not VOC mass emission compliance **is** required. All emissions should be tested annually for VOCs, with mass emission testing being carried out under typical conditions. Further tests are required whenever processes are subjected to change.

Details of the amounts and types of solvent used must be sent to the local authority every six months. Section 5.6.2 and Table 9 explain how to calculate **mass balance.**

Duty of Care

The Environmental Protection (Duty of Care) Regulations 1991 (SI 1991/2839) 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 adequately labelled;
- the waste is transported by a licensed carrier;
- the waste is transferred to a suitably licensed transfer station or waste disposal site.

DRAFT PROPOSED 'SOLVENTS' DIRECTIVE

The European Commission has proposed a directive to limit the emissions of VOCs from certain industrial processes - the so-called 'solvents' Directive. The proposed Directive's proper title is *A Council Directive on the Limitation of the Emissions of Volatile Organic Compounds due to the Use of Organic Solvents in Certain Processes and Industrial Installations.* Published drafts indicate that the proposed 'solvents' Directive would extend control to **all applications** of solvent cleaning.

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[6] *Secretary of State's Guidance - Coating of Metal and Plastic* PG6/23 (92) ISBN 0 11 752604 5. HMSO.

HEALTH AND SAFETY REGULATIONS

The Health and Safety at Work etc Act 1974 imposes general duties on employers, the self-employed and employees to ensure health, safety and welfare in the workplace. Detailed requirements are set out in a series of regulations made under the Act. Those of particular relevance to vapour degreasing include:

- Management of Health and Safety at Work Regulations 1992;
- Workplace (Health, Safety and Welfare) Regulations 1992;
- Provision and Use of Work Equipment Regulations 1992;
- Manual Handling Operations Regulations 1992;
- Control of Substances Hazardous to Health Regulations 1994 (COSHH);
- Chemicals (Hazard Information and Packaging for Supply) Regulations 1994 (CHIP2).

Each of these regulations has its Approved Codes of Practice (ACOP) and Guidance.

The discharge of solvents to the air and their subsequent inhalation has the potential to harm those exposed. In addition, many substances can be harmful by ingestion, absorption through the skin or other sensitive areas (see Section 5.7.3).

Basic health and safety principles include:

- preventing exposure by selecting materials with no, or minimal, hazard;
- minimising exposure through good plant and engineering practice;
- proper training of operators and other personnel;
- providing appropriate personal protective equipment (PPE).

All the solvents referred to in this Guide are classified as **substances hazardous to health** under COSHH. A risk assessment must therefore be carried out before any work is undertaken which is liable to expose any employees to such substances. Arrangements must be made to ensure that any such exposure is either prevented, or where this is not reasonably practicable, adequately controlled. The COSHH Regulations require that, as far as is reasonably practicable, the prevention or control must be secured by measures **other** than the provision of PPE.

The COSHH Approved Code of Practice (ACOP) states that 'reasonably practicable' should be considered in the light of:

- the degree of exposure;
- the circumstances of the use of the substance;
- informed knowledge about its hazards;
- current developments.

Appendix 2

SOLVENT PROPERTIES

Property	1,1,1 - trichloroethane	Methylene Chloride	Trichloroethylene	Perchloroethylene
Toxicity: Maximum Exposure Limit (MEL)	350 ppm	100 ppm	100 ppm	–
Occupational Exposure Standard (OES)	–	–	–	50 ppm
Solvency - Kauri Butanol (KB) value	124	136	130	90
Vapour density (Air = 1)	4.5	2.93	4.54	5.83
Boiling point	72°C	40°C	87°C	121°C
Vapour pressure (mm of mercury)	105	380	59	15
Flashpoint none	none	none	none	
Flammable limits at room temperature:				
minimum	7.7%	14%	8%	none
maximum	15.1%	22%	10.5%	none
Atmospheric life	2 200 days	175 days	7.7 days	156 days
Ozone depletion potential	0.12	0	0	0
Greenhouse warming potential	0.23	0	0	0
Photochemical ozone creation potential	0.001	0.009	0.066	0.005
Dizziness threshold (20 minutes)	1 500 ppm	1 000 ppm	400 ppm	500 ppm
Azeotrope - water + solvent (v/v)	N/R	N/R	1 + 5	1 + 13
Azeotrope - water boiling point	N/R	N/R	73°C	88°C
Stack discharge (solvent)	20 mg/m^3	20 mg/m^3	20 mg/m^3	20 mg/m^3

Appendix 3

EXAMPLE DAILY LOG SHEET

ENVIRONMENTAL
TECHNOLOGY
BEST PRACTICE
PROGRAMME

Be Solvent Wise

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

		Mins	Hours
LOAD HISTORY			
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

appx A3