

## Solvent cleaning – a balanced view

*Life seems to be getting more difficult; environmental and health and safety legislation demand change, there's confusion and mis-information in the marketplace concerning the suitability of replacement solvents for cleaning and degreasing applications, and there are many options on process equipment to consider – little wonder that so many tasked with finding replacement cleaning and degreasing technologies remain reticent when considering investment for the future. In this article, Glenn Greenlees of Standard Industrial Systems reviews the current legislation governing the use of solvents for cleaning and degreasing. He hopes this information will assist those trying to identify the right choice for their particular requirement.*

### The Solvent Emissions (England & Wales) Regulations 2004

The requirements of European Directive 1999/13/EC (the 'Solvent Emissions Directive') have now been published in the above legislation, which came into force on 20 January 2004. In particular, the date of 20 May 2004 should be noted as the deadline for all users of R45, R46, R49, R60 or R61 assigned products to submit an application for a variation to their permit to operate, previously issued under Part 1 of the Environmental Protection Act 1990 and the Pollution Prevention & Control Regulations 2000, and offer an official timetable for substitution of these products.

Critically, the 2004 regulations now require that all users of the above mentioned products operated above the SED one tonne threshold must also comply with the May deadline to apply for a permit to operate and similarly, must submit a plan for their substitution. The same also applies for any operators who have installed SED regulated installations since 1st April 2001.

Unfortunately, for users of trichloroethylene in regulated cleaning applications who are required to make a substitution at the earliest opportunity, some decision makers feel forced into a making a premature choice without fully evaluating the real implications. Think of this, initial capital investment in new equipment may constitute only a very small percentage of the total cost over the working life of a cleaning installation when some of the "unknown" ongoing costs such as abatement, solvent usage and energy consumption are fully evaluated.

For many, the overriding question still remains the initial choice between water and solvent based processes. Without question many applications are well suited to cleaning with aqueous solutions, indeed many tasks such as the removal of very fine particulate matter can only be fully achieved when the polarity and high surface tension of water is used to the greatest effect. In addition, many industrial processes such as coating may benefit from surface pre-treatment including phosphating which can be included in both batch and in-line aqueous installations.

The problem arises when the facts are not fully considered and the decision to move to an aqueous format is made (often at board level) simply because of a (misguided?) desire to totally eliminate solvents from production processes. After all, what could be more environmentally friendly than water – perhaps the costs of disposal and the increasing costs of the energy required in drying processes (don't forget the Climate Change Levy) are not considered when the initial CapEx for replacement equipment is doing the rounds for approval. Some may remember the Ecobilan Report of May 1997 when it was concluded that: "For cleaning and drying metal parts, solvent technology has a lower overall environmental impact than aqueous technology".

Perhaps at this point we should review some of the reasons why we choose to utilise organic solvents for surface cleaning tasks:

- Low surface tension (typically 25-30 dynes/cm compared with 72 for water) means that liquid can enter (and exit) complex geometric component features such as fine threads and blind holes, thereby flushing out contamination.

- Solvents can generally accommodate a wide range of contaminants whereas aqueous detergents are usually "soil specific" and a variety of chemicals may be required to be effective in many manufacturing processes. In addition, when washing with water, process parameters particularly chemical concentration may require constant monitoring to ensure consistent results.

- The separate distillation within an hermetically sealed solvent system ensures that both clean liquid and pure vapour are available for each cycle therefore maintaining consistent results.

- The volatility of organic solvents ensures that thorough drying of metal component parts is both rapid and thorough. Compare the latent heat of evaporation of water at 2280kJ/kg with organic solvents at approximately 200-300kJ/kg. By applying a vacuum to the process chamber and therefore reducing the boiling point, residual component heat will ensure instant vapourisation allowing up to 10 cleaning cycles per hour.

- Hermetically sealed solvent cleaning technology ensures that all contamination is isolated in the distillation unit, no longer are we disposing of vast amounts of "dirty solvent". Furthermore, the machinery for the safe delivery and closed loop transfer of both new solvent and waste residues has been in place for many years.

### The best solvent for the future?

Apart from the reclassification of trichloroethylene from R40 ("Possible Risk of Irreversible Effects") to the more onerous R45 ("May Cause Cancer") and its corresponding move to Category 2 Carcinogen, we now have to consider the implemen-

tation of EU1999/13/EC and its implementation under the Solvent Emissions Regulations 2004.

For users operating above the one tonne threshold and preferring to remain with a solvent process an alternative must be selected:

- Perchloroethylene (tetra-chloroethylene) with an Occupational Exposure Limit (OEL) of 50 ppm remains a logical choice for use in hermetically sealed processes having been utilised throughout other European countries for many years. With a slightly lower Kauri Butanol (KB) solvency rating than trichloroethylene but a higher boiling point, perchloroethylene ensures that vigorous condensation is promoted in the vapour phase stage but care must be taken that a margin is maintained between the boiling point of the solvent and that of the contaminants to be removed. Efficient separation of solvent and soils is required in the distillation unit for an effective ongoing process.

- Methylene Chloride (dichloromethane) with a Maximum Exposure Limit (MEL) of 100 ppm displays the highest natural solvency of the chlorinated solvents and with a very low boiling point of 41 degrees C. is perfect for applications where heat sensitivity is an issue or when excess residual component heat prevents or delays onward processes such as critical measurement. Also widely used in other European countries in hermetically sealed processes this technology has now made its debut in the UK.

- Modified Alcohols such as DOWCLENEX\*, ZESTRON\* and lactate esters such as Purasolv\*\*, also possess extremely high solvency and are consistently able to give high levels of surface cleanliness of <5mg/m comparable with trichloroethylene.

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Used in hermetically sealed units in a vacuum process, modified alcohols display excellent material compatibility and can be used with plastics in very high integrity areas such as medical and electronics applications. Again, modified alcohol processes, which have been widely used throughout Europe, have now been introduced to the UK in both very large-scale industrial applications and high integrity medical and electronic environments.

- Hydrocarbons are also available for use in hermetically sealed vacuum systems and, of course, are particularly suited to removing contamination based upon hydrocarbon chemistry such as in wax removal. Sometimes utilised as the solvating agent in modified open topped co-solvent processes along with very expensive fluorinated solvent technologies (which have very poor natural solvency and are largely utilised in the process as an aid to drying), hydrocarbons are also suitable for precision cleaning where material compatibility may be a concern.

- Normal Propyl Bromide (nPB) is clearly an effective degreasing agent and is currently allocated a risk phrase of R20 ("Harmful by inhalation"). However, it is vitally important to appreciate that the reclassification of nPB has been recommended by the European Chemicals Bureau (ECB) and is likely to be allocated risk phrases including R11 ("Highly Flammable"), R60 ("May Impair Fertility") and R63 ("Possible Risk of Harm to the Unborn Child") (<http://ecb.jrc.it> Links - Classification & Labelling, Provisional list of existing substances for the 29 ATP Rev. 18, Index No. 602-019-00-5). If adopted these reproductive toxicity implications will drastically influence the product's interpretation under the regulations, requiring the operator (as with trichloroethylene) to "...in the shortest possible time work towards substituting the substance/preparation..." In addition, the Health and Safety Executive issued CHAN (Chemical Hazard Alert Notice) number 26 Revision 2 in August 2003 ([www.hse.gov.uk](http://www.hse.gov.uk) Links - In Quicksearch type "n Propyl Bromide"). Whilst nPB has not been allocated an official Occupational Exposure Limit

(OEL), manufacturers have generally recommended that limits of between 5 and 25ppm be observed. The Hazard Evaluation System & Information Service (HESIS) of the California Department of Health Services issued a Health Hazard Alert Notice in July 2003 because nPB "...is not regulated to protect workers, consumers or the environment." HESIS has recommended that "...workplace exposure be limited to about 1ppm." ([www.dhs.ca.gov/ohb](http://www.dhs.ca.gov/ohb) Links - HESIS, Publications, Hazard Alert, 1-Bromopropane).

It is interesting to note that some of the manufacturers of nPB will not permit its use as a surface cleaning agent and, consequently, restrict applications to its traditional roles including use as an alkylating agent in both pesticides and pharmaceuticals - processes that are totally sealed in production. Standard Industrial Systems is not able to comment on the suitability of nPB for the cleaning of metal parts. I would, however, emphasise that all relevant information is in the public domain.

## The best equipment for the future?

What are the prime objectives when considering capital investment in solvent cleaning and degreasing equipment? Of course the process has to work ie, give satisfactory cleaning results on a consistent basis. In addition the installation must demonstrate beyond any possible doubt its full compliance with all relevant health and safety and environmental legislation. "Future proofing" your investment would also be a distinct advantage; perhaps the ability to switch between different solvent species would be desirable to ensure long-term security? Whilst it is impossible to predict precisely how we will be cleaning metal parts in 2030, in the short to medium term it would be prudent to assume that health and environmental concerns will be subject to ever-tighter controls.

The Solvent Emissions regulations now govern how we must utilise volatile organic solvents in surface cleaning in a "hierarchical" approach, ie compliance by:

- Maintaining the annual consumption (in tonnes per location) below the quoted threshold value for the solvent concerned to be exempt from the SED.
- If the above is exceeded, by maintaining the mass flow rate (in grammes/hour per installation) below the quoted threshold value.
- If (2) above is exceeded, by continuous abatement of exhaust stack concentrations (in mg/m<sup>3</sup>) below the quoted threshold values. Additionally, fugitive emission limits must be complied with.

With regard to equipment evolution the UK approach has generally been to continuously "upgrade" the design of traditional "tank" technology to meet the changing requirements as the emphasis on economy, safety and environment has demanded. Increasing freeboard ratio, improving cooling capability, the addition of multiple lid configurations have all been reactive attempts to keep pace with the most pressing issue of the day. Could it be that the concept of dipping a basket of components into a tank, however modified, has finally run its course? With the implementation of the latest legislation perhaps it is time to adopt a "clean sheet" approach.

Sometimes it is worth looking outwards to see how problems have been solved. The German model seems most appropriate, the Green Party having introduced its own domestic environmental legislation as far back as 1990. Fourteen years later this still exceeds the requirements of the SED and has resulted in significant advancements in system and process design. Other European manufacturers did not consider it commercially prudent to address this specific market and, accordingly, may have fallen behind in both system design and solvent variety utilisation. Solvent consumption has accordingly been reduced to 2% nationally when compared to the 1990 baseline. Clearly the legislation has achieved the desired effect.

Within the UK at least it is still possible to source "enclosed" or "double-lidded" degreasing plant for use with organic solvents. Such plant was rendered obsolete in Germany by the implementation of their stricter environmental policy - the main problems being lack of residual

chamber concentration ppm control which can result in fugitive emissions to the workplace, absence of regenerable carbon (total loss of solvent) and lack of distillation residue control.

## Use of methylene chloride

As mentioned, we are now recognising the success of methylene chloride in other European countries and it is emerging as a logical replacement in the UK. Whereas trichloroethylene has moved from R40 to R45, methylene chloride will remain at R40.

The problem specifically with methylene chloride is the extremely high vapour pressure displayed by the solvent. This can present a problem when considering the use of activated base carbon in the adsorption phase of a cleaning cycle ie, reduction of the airstream solvent concentration at the end of the drying phase.

German legislation requires that cleaning chamber concentrations are reduced to below 1 gm/m<sup>3</sup> before access to the chamber by operators is permitted (this is additional to, and does not appear, in the SED).

To simply utilise the same technology as adopted for both trichloroethylene and perchloroethylene is not viable if long-term compliance is to be achieved. The ability of a given amount of carbon to adsorb methylene chloride is significantly less than that experienced with both perchloroethylene and trichloroethylene, the capacity being effectively limited by the high vapour pressure.

At zero degrees Celsius the air saturation point for methylene chloride is approximately 560mg per cubic metre at ambient pressure compared to only 40 for perchloroethylene. In a solvent cleaning system cooling of the airstream is designed to condense the solvent vapour back into liquid, even the use of "super cooling" with coils at -30 degrees Celsius will still result in residual solvent concentration of approximately 140mg per cubic metre of air at ambient pressure even if the process is 100% efficient (perchloroethylene = 6 mg/m<sup>3</sup>).

These high levels of solvent transfer to an abatement unit will quickly render the carbon saturated, the life expectancy of a typical exchange unit being measured in days rather than weeks or months as might have been expected with trichloroethylene or perchloroethylene.

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In addition, carbon at ambient temperature will not readily adsorb methylene chloride to its capacity and will tend to desorb or liberate its solvent content increasingly as the media reaches approaches the solvent boiling point of 41 degrees Celsius.

The solution is to place the treatment chamber under a vacuum during the critical drying phase of the cleaning cycle thereby utilising residual heat of the component parts to evaporate the solvent. Reducing the quantity of air at the point of cooling greatly increases solvent concentration and condensation efficiency before returning to ambient pressure conditions prior to ppm reduction to permitted levels via the carbon system.

Critically from an operational viewpoint, the vacuum drying is significantly more efficient than simply utilising recirculating air, ensuring that even very complex parts are thoroughly dried and greatly increasing throughput as previously mentioned. To maximise effectiveness the carbon units are also independently temperature controlled. Even with this proven technology regeneration of the carbon is still completed on a daily basis but means that all exhaust stacks to atmosphere are eliminated. Remember that the SED requires compliance 100% of the time.

## Conclusion

Solvent cleaning and degreasing remains an integral part of many manufacturing processes. Far from being in decline, it is recognised as a fundamental component of production requiring serious consideration to ensure that the correct process is selected in order to achieve long-term success with the guarantee of compliance. The traditional "trike tank", which seemed to be the answer to all cleaning requirements, is now a thing of the past and the UK is faced with the dilemma addressed successfully in Germany during the 1990s. Perhaps trying to reinvent the wheel is not such a good idea when proven technology is already available?

*\*DOWCLEN and ZESTRON are trademarks of The Dow Chemical Company.*

*\*\*Purasolv is a Trademark of Purac Biochem.*

### Enquiry Card No

## About the author

Glenn Greenlees, the author of this article, is marketing director of Standard Industrial Systems, an independent distributor "dedicated to offering the world's best in both aqueous and solvent cleaning technologies."

Glenn Greenlees believes that with the many changes in both environmental legislation and solvent classification it is vital that potential investors are given the facts regarding the technologies available.

He comments: "Unfortunately, whereas investment in manufacturing processes has often taken priority, cleaning of component parts either during or post production has very often been considered of secondary interest in the knowledge that the reliable results and low investment levels of the 'trike tank' could always be relied upon."

Standard Industrial Systems is the exclusive UK distributor for the German manufacturer Multimatic Oberflächentechnik, a European market leader in the design and manufacture of hermetically sealed solvent based degreasing systems.



Glenn Greenlees.



A 'Multimatic' hermetically sealed solvent cleaning machine.

Added Glenn Greenlees: "Organic solvents have been used for many years due to their ability to achieve clean and dry parts on a consistent basis. In general surface cleaning requirements are increasing in line with ever tighter machining tolerances and the flexible programming options available with Multimatic machines – including spray, immersion and vapour – ensure that the natural solvency associated with these processes is greatly enhanced. For particularly difficult applications such as the removal of polishing pastes and compounds the option of additional mechanical agitation with injection or ultrasonics is available.

"The Multimatic range includes machines for use with perchloroethylene, methylene chloride and hydrocarbons and modified alcohols. Special applications are addressed with bespoke systems. Multimatic has also applied the same advanced technology to very large scale applications, an area which Glenn Greenlees says is often avoided by many competitors offering modified traditional technologies, or addressed with significant operational conditions attached. The unconditional guarantee of long term compliance with Multimatic ensures that

purchasers of new equipment are investing in technology proven under the most stringent environmental regulations.

"In particular, UK manufacturers unwilling to gamble with long term compliance are now looking closely at the implications of correct solvent selection. The vacuum technology associated with Multimatic offers the flexibility to switch between alternative solvent species such as methylene chloride and 'DOWCLEN\*' – a level of 'future proofing' important when considering investment in cleaning technologies."

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**Footnote:** *The UK Solvent Emissions Regulations 2004 have now fully implemented the requirements of 1999/13/EC the European "Solvent Emissions Directive" into domestic law and extended the scope to include all users of trichloroethylene over the one tonne threshold limit who are now required to submit a plan for substitution by 20 May 2004 and effect that substitution at the earliest opportunity, an important change of timescale for many who were considering a target date of October 2007 for replacement.*