Industrial Cleaning Source Book

University of Wisconsin - Extension
Solid and Hazardous Waste Education Center

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Acknowledgements

Much of the material in Sections I-V of this manual was derived from the United States Environmental Protection Agency, Control Technology Center, Solvent Alternative Guide (SAGE). The SAGE software program is designed to assist manufacturers in finding suitable replacements for solvents used in cleaning. For more information on the SAGE program, contact the Control Technology Center at 919/541-0800.

Bibliographic entries and vendor listings were taken from the Great Lakes Technical Resource Library and reflect a variety of sources.

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INTRODUCTION

This source book is designed to provide manufacturers with basic information about industrial cleaning technologies. This information should help provide companies that are considering replacing an existing cleaning technology with a new method with some direction for their decision making. The information in this source book is not solely adequate for making a decision to alter an existing cleaning process. Additional information from technical assistance providers, equipment vendors, and engineering consultants should be used in addition to the information provided here.

WHY CHANGE

Solvent cleaning operations are wasteful. While solvent evaporation provides advantages when dry parts are required, it also accounts for significant losses of solvent that could be used for cleaning other parts. Open top vapor degreasers commonly lose 60% of their solvent through evaporation. Dip tank, spray, and wipe-down cleaning all lose large amounts, or all, of the solvent through evaporation. Measure the cost of this wasted solvent and then ask yourself if there isn't a better way to clean.

RCRA, SARA, TRI, CAA, OSHA, CERCLA, are familiar acronyms that highlight the regulatory burden from solvent cleaning. Solvent cleaning operations produce hazardous waste and/or emissions that require extensive regulatory reporting, affect worker health and safety, and can incur long term liability to your company. Think of the fime and effort that goes into complying with hazardous waste regulations and the ask yourself if there isn't a better way to clean.

EVALUATING CLEANING REQUIREMENTS

Changing a cleaning process to a new technology requires careful planning to avoid risk to the manufacturing process and product. A stepwise approach to evaluating your existing cleaning operation and choosing a new method will help to ensure success.

1) Determine if you need to be cleaning the part in question. Can multiple cleaning steps be combined? Can the soils on the part be eliminated to reduce the need for cleaning? Can soils be carried through several manufacturing steps before cleaning?

2) Know exactly how clean the part needs to be for the next manufacturing step. Are you over-cleaning? Establish cleaning standards that can be verified by testing the part.

3) Understand cleaning fundamentals. What is the nature of the soils on your parts? What cleaning chemistries are suitable for removing those soils. Can difficult to clean soils be replaced with easy to clean soils?

4) Evaluate what cleaning options are available based on your soils and the types of cleaning chemistries available. Focus on a few technologies that are likely to succeed and study them in depth. Will the new process require more energy or generate a new waste stream?

5) Test the cleaning options by sending your parts to the manufacturer for cleaning or by having the equipment installed for testing in you facility.

6) Based on your evaluation, implement the cleaning option that provides an adequately clean part at the lowest overall cost, without affecting product quality or production efficiency, or generating a new an unmanageable waste stream. Train you employees on using and maintaining the new equipment.

USING THE SOURCE BOOK

The information in the following sections describes a wide variety of cleaning technologies, and discusses substrates and other special considerations. Using this information, along with references from the bibliography and information from equipment vendors, should give you enough background to narrow the choices of alternative cleaning technologies for your facility. Once you have identified a few likely choices, make full use of the services of your state technical assistance program, engineering consultants, and equipment vendors to assist you in choosing the best cleaning alternative. In Wisconsin you can contact the pollution prevention specialists at the University of Wisconsin-Extension, Solid and Hazardous Waste Education Center to assist with your evaluation. Their telephone number is 608/262-0385 or 414/475-2845.

SECTION I CLEANING METHODS AND EQUIPMENT

ABRASIVE CLEANING

Abrasive cleaning refers to the use of an abrasive material as a cleaning agent. This process is primarily a blasting process as opposed to a rubbing process. Abrasive cleaners may use metallic particles, sand or organic media such as crushed walnut shells. The propellant is usually air or water. New processes have been developed using CO_2 pellets, wheat starch, and bicarbonate of soda as the media. The process is very effective for removal of surface layers such as the removal of rust or scale. In some cases, abrasive blasting must be followed by a chemical cleaning in order to prevent corrosion problems. Operator protection from fine particles suspended in air may be an issue. Most processes will generate a waste consisting of the cleaning media combined with the soil or metal that has been removed. This may be a hazardous waste that requires special handling.

General Information

Abrasive cleaning refers primarily to a blasting type of operation (e.g. sand-blasting).

This type of process uses a media propelled by compressed gases or a liquid to impinge on a surface.

Blasting media can vary widely and includes the following:
- metal needles or shot
- glass particles
- walnut shells
- corn cob
- sodium bicarbonate
- wheat starch
- CO_2 pellets
- plastic pellets

Abrasive cleaning is usually preferred for removal of heavy scale and paint on large surfaces.

Metals subject to hydrogen embrittlement are frequently cleaned using a blasting process.

The corrosion resistance of stainless steels and other substrates can be affected if a corrosion prone material is used as the abrasive media.

This process is primarily a surface material removal process. As such, it is not highly suited to removal of fluid residues.

Abrasive cleaning will affect surface finish. It may also cause dimensional changes in thin parts.

Some materials may be subject to work hardening of the surface.

Wet blasting is most commonly used for more delicate or finer operations than air blasting. For example, wet blasting is most commonly used for removing:
- minute burrs on precision parts
- fine tool marks
- light mill scale
- surface oxide (electronics)
- welding scale

Wet blasting is not recommended for cleaning heat resistant alloys with a high titanium and aluminum content.

Environmental Issues

The waste being generated will consist of a mixture of abrasive media and the soil being removed.

Most abrasive blast systems are closed, in that they allow reuse of the abrasive media.

If disposal is required, the use of materials such as wheat starch and bicarbonate of soda may be easier to handle, as the abrasive media can be more easily separated from the soil.

Safety

Operators may require protection from fine particles suspended in the air.

ACETONE CLEANING

Acetone is a good drying agent and is used in precision cleaning applications as a hand wipe solvent. It is extremely flammable. Acetone is also a VOC and local regulations may affect its use. For those applications that absolutely require a high volatility substance, it may be a useful chemistry.

General Information

Acetone is an organic solvent classified as a ketone. Ketones are most generally used as solvents in the protective coating, plastics and rayon industries.

Acetone is commonly used as a wipe solvent in precision cleaning. It is also commonly used as a 50:50 mix with isopropyl alcohol (IPA).

Environmental Issues

Acetone is a VOC. Depending on your location and the amount of acetone used, the material may require special reporting or permitting.

Safety

Acetone is extremely flammable and must be handled with care.

ALCOHOL CLEANING

Alcohols are typically found as drying agents and as cleaners in precision applications. Isopropanol is fairly common in some precision cleaning operations. It is very common as a hand wipe solvent in clean rooms. Alcohols are not effective on non-polar soils such as waxes and oils. Alcohols have fairly good compatibility with most materials, for brief periods of time. Methanol is incompatible with Viton. Alcohols are flammable and must be treated accordingly. They are also VOCs. Exact emission regulations will depend on your local requirements.

General Information

Alcohols are most commonly used as drying agents for intricate assemblies.

Methanol and isopropanol have fair degreasing capabilities.

Methanol is incompatible with Viton. Isopropanol is compatible for brief exposure with most elastomers.

Isopropanol is commonly used as a wipe solvent in precision cleaning.

Alcohols are not good for removal of non-polar soils (e.g. waxes and oils).

Environmental Issues

The various alcohols are VOCs. Depending on your location and the amount of alcohol used, the material may require special reporting or permitting.

Safety

The alcohols are flammable materials and must be handled accordingly.

There may be health problems associated with the use of methanol.

AQUEOUS CLEANING SOLUTIONS - ACIDIC

Acidic aqueous cleaning solutions may contain mineral acids (nitric, sulfuric, phosphoric, hydrofluoric), chromic acids or organic acids (acetic or oxalic). They may also contain detergents, chelating agents and small amounts of water-miscible solvents. Acidic aqueous cleaning is typically used for scale, rust and oxide removal. Most materials will be attacked by acidic solutions, depending on exposure time. A large concern in some applications is the possibility of hydrogen embrittlement caused by acidic cleaning. Waste disposal will involve pH adjustment and possible removal of the soil components.

General Information

Acidic cleaners are effective for removing rust from ferrous parts.

Acidic cleaners are commonly used for the removal of:
- mill scale (hot rolled scale)
- scale developed during welding
- scale developed during heat treating
- superficial oxide which interferes with painting, porcelain enameling, tinning, galvanizing, or electroplating
- rust and corrosion products
- hard water scale
- products of reaction of hard water with soil, especially protein (milkstone, beerstone)

Acidic cleaners can also be used to clean aluminum, a metal susceptible to etching when cleaned with strong alkaline detergents.

Acidic cleaning solutions can contain mineral acids (nitric, sulfuric, phosphoric, hydrofluoric), chromic acids, or organic acids (acetic or oxalic), plus detergents, chelating agents and small amounts of water miscible solvents.

Acids commonly used in acidic aqueous cleaners include: sulfuric, nitric, or hydrochloric acids, and organic acids such as acetic, oxalic, or cresylic acid.

Nitric and hydrofluoric acids are used for brightening aluminum and stainless steel.

Some types of stainless steels will rust or dissolve under acidic conditions. Contact between stainless steel and hydrochloric or heated sulfuric acid should be minimized.

All stainless steels are pitted by prolonged contact with acidic solutions containing chlorides.

Magnesium can be affected by slightly acidic cleaners, especially those containing chlorides.

If cleaned parts are to be painted, then cleaning in a phosphoric acid based solution also provides a level of corrosion protection by forming a phosphate coating.

Certain soils, especially those that are inorganic, are either removed in acidic cleaners or are dissolved by acids, or both.

Safety

Dilution of some acids, such as sulfuric acid, produce heat.

Water should never be added to strong acid solutions. Add the acid to water with caution.

Acidic chemicals are corrosive to the skin and extremely harmful to more sensitive areas of the body, especially the eyes.

AQUEOUS CLEANING SOLUTIONS - ALKALINE

Alkaline aqueous cleaning solutions are the most common form of aqueous chemistry. These solutions may have pH values that range from a pH of 8 to a pH of 14. Alkaline chemistries commonly have various additives to improve performance characteristics. These may include such things as sequestering agents, emulsifiers, surfactants, and inhibitors. Inhibitors prevent attack of the substrate being cleaned. A common inhibitor involves the use of silicates. These materials will require very careful rinsing to prevent problems with later painting or plating operations. These solutions can be used with all types of liquid processes (e.g. sprays, ultrasonics, immersion, and power washers). These chemistries remove coolants and cutting oils, shop dirt, finger prints, cosmolene, petrolatums, and some water soluble paints. Parts cleaned include hydraulic valve bodies, fuel injector components and machined aluminum castings. These solutions are used for all cleanliness levels. Cost per gallon is generally cheaper than for semi-aqueous compounds. You should not automatically assume that you can put alkaline aqueous solutions down the drain. You need to check with your local water treatment authority before disposing of these solutions down the drain.

General Information

Alkalinity may range from pH 8 to pH 14.

Cleaner composition may consist of water, an alkali, a sequestrant, a surfactant of some type, and possibly a corrosion inhibitor.

Cleaners may be anionic, cationic or neutral. Non-ionic cleaners are lower foaming and may be more suitable for applications using agitation or sprays.

The ionic cleaners will probably require more careful rinsing than do the non-ionic types.

Emulsifiers may be added in order to keep oils and greases dispersed in the solution.

Aqueous processes may require rinse and drying stages.

Alkaline cleaners have been used to remove:
- cutting oils and coolants
- cosmolene
- grease
- finger prints
- shop dirt

Alkaline cleaners may be designed to allow good separation between the water and contaminants such as oils. This allows control of the waste streams produced during cleaning: by allowing the contaminated liquid to separate, the aqueous solution can be recycled back to the process and the contaminant can be trapped.

High pH values do not automatically mean that a cleaner will etch susceptible metals. Inhibitors may reduce etch rates while maintaining cleaning capabilities.

Silicates may be used as inhibiting agents. These materials must be thoroughly rinsed off in order to prevent problems with painting or plating operations.

Alkaline aqueous cleaners have been successfully used to clean mild and stainless steels. Flash corrosion may be a problem with other materials.

Alkaline cleaners may be used over a very broad range of temperatures. This may increase its suitability for general purpose cleaning.

Aqueous systems can be designed as closed loop systems. Various filtration technologies can be used to separate the water from the contaminant.

Environmental Issues

Closed loop cleaning systems will still generate a waste stream, although at a greatly reduced rate compared to an open loop system. The waste may be in the form of contaminated filters and reverse osmosis membranes.

Do not assume that you can automatically put your waste water directly down the drain. Contact your local POTW first and thoroughly discuss all aspects of your proposed cleaning system. Water consumption may be an issue in areas with low water supplies.

Safety

Safety issues will involve primarily the process equipment. The equipment must be designed to operate in an aqueous environment where exposure to water mists or sprays will not cause electrical hazards.

High Process liquid temperatures may be a source of concern.

AQUEOUS CLEANING SOLUTIONS - NEUTRAL

Neutral aqueous solutions have near neutral pH. The various chemistries may include the use of surfactants, builders, or other additives. These solutions work well where a high degree of chemical solvency is not required. These solutions are excellent for use in spray and ultrasonic applications. They may also be used in steam equipment. Neutral chemistries are not ideal for immersion processes. These solutions are good at removing chlorides or other salts, and organic soils. They are excellent for the removal of particles. Most existing equipment can be converted

to use neutral aqueous chemistry with a minimum of effort. The largest concern is with corrosion issues. The largest process issue with any aqueous chemistry is the need for a drying system. Incoming water quality may also have a great effect on process quality. You will need to coordinate closely with your local POTW if you are going to implement an aqueous process. You must be sure that your current water system can supply your new requirements and that you can handle the discharge rate.

General Information

Neutral aqueous cleaning refers to the use of neutral or near neutral pH aqueous chemistries.

Neutral aqueous chemistries may include the use of surfactants, builders, and other additives.

Neutral solutions work well where a high degree of chemical solvency is not needed. The use of surfactant additives will greatly increase the wetting capability of aqueous solutions.

Chemical additives are available in liquid or powder form.

Neutral solutions are excellent for use in spray or ultrasonic equipment. Neutral chemistries will not be ideal for immersion processes, which depend more on chemical action.

Neutral solutions are excellent at removing chlorides or other salts. These chemistries are also good for organic soils and particulate removal.

Many types of existing equipment can be converted to neutral water with minimal effort. The concerns will be mostly directed towards corrosion issues e.g. can the system pumps and tanks handle water without corroding.

The largest process issue with neutral chemistries will probably be the possible requirement for a drying system. Common drying systems include forced hot air, infrared heating or centrifugal spin off. It is possible that the use of hot water will raise the part temperature enough to provide adequate flash drying.

The condition of your incoming water may have a great effect on the efficiency of water cleaning. Water hardness and other chemical properties vary widely from region to region.

Neutral aqueous chemistries may be sensitive to variation in soil loading.

Environmental Issues

Environmental disposal issues will depend on the soils that are in the used water.

Do not assume that just because you are using water, that you can automatically dispose of the water directly to the sewer. Contact your local POTW to review your particular application, prior to converting to water. Make sure that your facility and the local POTW can handle the increase in water disposal and water supply.

Closed loop cleaning systems will still generate a waste stream, at a greatly reduced rate compared to open loop system. The waste may be in the form of contaminated filters and reverse osmosis membranes.

Safety

Safety issues will involve primarily the process equipment. The equipment must be designed to operate in an aqueous environment where exposure to water mists or sprays will not cause electrical hazards.

High process liquid temperatures may be a source of concern.

BRUSHING

Brushing is an effective process for removal of paint, scale, rust and other tightly adhered materials. Brushing may also remove some of the base material of your part. Brushes may be made of wire or of synthetic materials that have been impregnated with various types of abrasive grit. Brushing may also be used to remove surface particles. Brushes may be manual or may be part of a highly automated process. Brushes have been used at the highest semiconductor cleanliness levels. This would not be an effective process for fluid removal.

General Information

Brushing uses the mechanical rubbing action of a material to remove various types of soils.

Brushing is typically used in for removal of the following:
- rust or scale
- excess weld metal
- flash
- oxide films
- paint

Brushing has been used in ultra-clean applications to remove very small particles. In this case, the brush material is acting as a wipe mechanism rather then a surface removal material.

Brushes may be made of twisted wire, tampico, abrasive impregnated plastics or rubber, or polyvinyl alcohol.

Brushing may be highly automated or completely manual.

Brushing is a good alternative wherever surface material removal is required.

CO_2 PELLET CLEANING

Carbon dioxide pellet blasting is being used to replace other blasting type operations. The advantage to the CO_2 pellets is that they turn into a gas upon contact with the material to be cleaned. This leaves the operator with only the soil to dispose of. The pellets can be propelled at various speeds. They can also be generated in different sizes. CO_2 pellets have been used to strip paints and to remove grease and oil. Some parts may be subject to thermal shock from the pellets and should be tested first. Thin parts may be damaged by pellet impact. The use of CO_2 pellets does not generate a new source of CO_2, a greenhouse warming gas. The CO_2 used is reclaimed from other chemical processes.

General Information

CO_2 pellet cleaning is a form of abrasive cleaning.

CO_2 pellets are generated in a proprietary machine and are then used just like any other blast media.

The pellets can be propelled at various speeds. They can also be formed in different sizes.

Shortly after impact, the CO_2 pellets turn into a gas. This means that only the soil being removed needs to be disposed of.

This is a very effective process for removal of coatings, sealants, and adhesives. It will also remove grease, oil and paint.

It has been used on metallic and aircraft composite material substrates.

Thin composites may be effected by blast pressures.

This process has been combined with xenon flash lamp techniques to improve the paint stripping characteristics of either stand alone process.

CO_2 pellet cleaning should be considered wherever other abrasive blast processes are being used.

Environmental Issues

There are growing concerns with CO_2 as a green house warming gas. The CO_2 used in CO_2 pellet cleaning is not a new generator of CO_2. The CO_2 gas used is a by-product of other processes.

The contaminant being removed will end up at the location at which the snow flakes turn into a gas. This makes it very easy to control and collect the soil being removed.

Disposal issues will depend on the type and amounts of soil removed. The process is not designed to work with heavy soil loadings. That means that the amount of disposal material should be minimal.

CO_2 SNOW CLEANING

This process uses "snow flakes" generated from CO_2 gas. The CO_2 snow is very effective at removing certain small size ranges of particles. Some companies have had success in remove thin fluid layers also. The process is probably best suited for higher cleanliness levels on parts such as optical components, thin film mirrors, and other delicate surfaces. The exact cleaning mechanism is still under debate. Some sources describe it as a kinetic energy or momentum dependent process i.e. the CO_2 snow is knocking off particles. Other tests indicate that the kinetic energy of the snow has very little to do with cleaning; that the mechanism may involve a solid to gas phase transition action as the flakes impact a surface. The process can use welding grade CO_2 gas, if subsequent purifier units are used. The process does not generate new CO_2, a green house warming gas. Instead, it uses CO_2 that is derived from other chemical processes.

General Information

CO_2 snow cleaning uses "snow" particles formed from CO_2 gas.

The process is effective for particle removal. Some success has been reported on removing finger prints and flux residue.

Shortly after impact, the CO_2 pellets turn into a gas. This means that only the soil being removed needs to be disposed of.

CO_2 snow cleaning is more suitable for the higher cleanliness levels.

It would be a good option for particle removal, and possibly thin fluid removal, on delicate surfaces, such as: optical components and thin film mirrors.

The equipment required is fairly simple:

- a source of CO_2 gas
- a gas purifier (optional)
- a proprietary "snow" gun

The "snow" gun can be mounted in a controller for automated processes. One version of a snow gun has been designed to clean small (less than .25" diameter) blind holes.

Welding grade CO_2 can be used if it is processed through a purifier.

The process can add back a certain amount of contaminant, depending on how pure the CO_2 gas is. This is usually not a problem except for the highest semiconductor cleanliness levels.

Environmental Issues

There are growing concerns with CO_2 as a green house warming gas. The CO_2 used in CO_2 snow cleaning is not a new generator of CO_2. The CO_2 gas used is a by-product of other processes.

The contaminant being removed will end up at the location at which the snow flakes turn into a gas. This makes it very easy to control and collect the soil being removed.

Disposal issues will depend on the type and amounts of soil removed. The process is not designed to work with heavy soil loadings. That means that the amount of disposal material should be minimal.

DIBASIC ESTERS (DBE)

The dibasic esters are a mixture of methyl esters of adipic, glutaric, and succinic acid. DBE is commonly used as a paint stripper. DBE may be used at 100 percent strength or may be mixed with other chemicals. One additive is NMP (n-methylpyrollidone). DBE is also found as a solvent in the so-called semi-aqueous processes. Pure DBE has a TLV of about 1 ppm. It also has a very low vapor pressure. This means that it is possible to formulate DBE with other chemicals so that the actual air emissions are very low. DBE is considered to be biodegradable. It may be recycled using a vacuum still. DBE is a VOC and may be regulated in your area.

General Information

The dibasic esters (DBE) are a mixture of methyl esters of adipic, glutaric, and succinic acid.

DBE may be used at 100 percent strength or may be mixed with other chemicals. One additive is NMP (n-methyl pyrollidone).

DBE is commonly used as a paint stripper. It has been used to clean paint guns and lines.

DBE has a low vapor pressure, meaning air emissions are likely to be low.

DBE may be biodegradable. It can be recycled using a vacuum still.

Environmental Issues

DBE's are VOCs and may be regulated in your area.

Safety

TLV of pure DBE is estimated to be 1 ppm.

ETHYL LACTATE SOLUTIONS

Ethyl lactate is a colorless liquid with a high vapor pressure (1.6 mbar at 20 degrees C). It may be a VOC depending on your location. It has a flash point of 47 degrees C. Ethyl lactate is being tested as a possible substitute for the glycol ethers used in the semiconductor industry. It is also being tested for use in precision cleaning. Testing has shown that ethyl lactate is a very good cleaner for such soils as silicone oils and greases, lithium grease, layout inks, finger prints, tapping oils (sulfur base), and machining coolants. Ethyl lactate cleans very well even without rinsing. The material can be rinsed quite well with water. Ethyl lactate is considered to be biodegradable.

General Information

Ethyl lactate is also called a lactate ester.

Ethyl lactate is currently being tested as a possible substitute for the glycol ethers used in the semiconductor industry.

Testing has shown that ethyl lactate is an excellent solvent for:
- silicone oils and greases
- lithium grease
- finger prints
- layout inks
- tapping oils (sulfur based)
- machining coolants

Ethyl lactate will affect some polymers. Most metals are not affected by short exposure.

Ethyl lactate cleans very well without rinsing. If rinsing is desired, the material will rinse easily with water.

Environmental Issues

Ethyl lactate has a vapor pressure of 1.6 mbar, at 20 degrees C. It may be classified as a VOC, depending on your location.

The material is considered to be biodegradable.

Safety

Ethyl lactate has a flash point of 47 degrees C.

GLYCOL ETHERS

Glycol ethers are frequently found under the trade name of "Cellosolve." The various forms of glycol ethers include ethylene glycol monobutyl ether, ethylene glycol monoethyl ether, and ethylene glycol monobutyl ether acetate. Glycol ethers are commonly found in the semiconductor industry where they are used to strip photo resist. Glycol ethers tend to emulsify well for cleaning and separate easily during recovery. The various forms may be found as components of custom cleaning chemistries. The semiconductor industry has completed a study linking glycol ethers to an increase in miscarriages of assembly line workers. The two specific compounds under study are diethylene glycol dimethyl ether and ethylene glycol monoethyl ether acetate. The TLV of ethylene glycol methyl ether acetate

is 5 ppm. The glycol ethers are VOC's and may be regulated in your area. They are also flammable and must be handled accordingly.

General Information

May be known by the trade name of "Cellosolve."

Found in various forms including ethylene glycol monobutyl ether, ethylene glycol monoethyl ether and ethylene glycol monobutyl ether acetate.

Commonly used in the semi-conductor industry to strip photo resist materials.

Glycol ethers tend to emulsify well for cleaning and separate easily during recovery.

May be found as components of custom cleaner chemistries.

Environmental Issues

Glycol ethers are VOCs and may be regulated in your area.

Safety

TLV of ethylene glycol methyl ether acetate is 5 ppm.

The semi-conductor industry has completed a study linking glycol ethers to an increase in miscarriages of assembly line workers. The two compounds under study are diethylene glycol dimethyl ether and ethylene glycol monoethyl ether acetate.

Glycol ethers are flammable and must be handled accordingly.

HEAT CLEANING

Many light oils heavy, mill scales, paints and other coatings can be removed by heat cleaning. This method is applicable where there is no danger of part damage from heat deformation or corrosion at high temperatures. It is not suitable to substrates with low melting temperatures. Hot salt baths, fluidized bed reactors or ovens are used to bring parts to a high temperature (800 F) in a controlled environment to bake off soils.

General Information

Heat cleaning can remove soils, mill scale and coatings without use of solvents or other cleaners.

High temperatures may have adverse effects on some substrates.

Can be combined with annealing or other heat treating processes.

Suitable for cleaning paint hooks and other heavy coatings.

Environmental

Release of gases resulting from combustion of some soils may require permitting in some areas.

Heat cleaning can require large amounts of energy.

Safety

High operating temperatures require special handling equipment.

HIGH PRESSURE SPRAYS

High pressure sprays are very effective at particle removal. This method is used in all levels of cleaning; from precision cleaning of disk drive parts to cleaning of lapped automotive parts. This process has been used to strip paints. The term "high pressure" usually refers to pressures above 500 psi. This pressure is a pump pressure, not the actual pressure at the piece surface. The standard cleaning liquid is usually water. In some cases, a chemical additive may be used with the water. If a chemical is used, it must be low foaming. The use of flammable or combustible chemicals in spray equipment is very dangerous. A relatively safe material can become explosive in spray form. A good example would be a terpene compound. High pressure spray equipment may be manual or may be highly automated. Removal of particles less than .0001 in. diameter may require an automated system with nozzle configurations designed to impinge specific areas of a part. High pressure sprays are often part of a larger cleaning system. Process cost will vary with pump pressures and delivery volumes. In general, this is a fairly inexpensive process.

General Information

Very effective at particle removal. Excellent for cleaning blind, tapped holes.

High pressure sprays are probably not necessary for lower cleanliness levels. For example, the removal of machining chips does not require high pressure; the removal of lapping compounds might.

Nozzle design will greatly influence process efficiency. Nozzles range from fan jet to needle jet designs.

Basic system consists of:
- liquid supply
- supply pump with filter
- high pressure pump with filter
- spray wand (removable nozzles increases adaptability)
- tank or booth (very common to use a glove box)

Process optimization will involve:
- nozzle design
- nozzle configuration within spray header (spray pattern)
- impingement angle
- cleaning liquid chemistry
- pressure (flow rate)
- dwell time

Any chemical additive must have very low foaming properties.

Redeposition of contaminant from spray bounce back may be problem.

Good for all levels of cleanliness. Cleanliness level required will dictate cleaning system filter requirements.

May use manual spray wand or automated spray header.

May be used alone or as part of a system combining other process steps.

"High pressure" usually means pressures above 500 psi. These are pump pressures, not surface pressures. Very

high pressures, some above 10,000 psi., have been used to strip paint.

Usually uses water as the cleaning liquid. Since the process depends on kinetic energy, the use of chemical additives may be of little value.

May require subsequent drying process.

Environmental Issues

This type of equipment can consume water and generate waste, at rates exceeding 10 gpm. Most systems can be designed to recirculate the cleaning liquid through a storage tank. The contaminant that has been removed from the part can then settle out or be separated from the cleaning liquid.

The contaminant that is removed from the part may become a waste that has to be treated or disposed of.

You must make sure that your supply of water, if used, is adequate for your anticipated requirements. Some areas are limited on availability of new water permits.

Do not assume that if you use water, that you can spray in the open and allow the water to run to drain. Check with your local water and sewer authorities first.

Safety

Combustible and flammable chemicals may become explosive when sprayed. Appropriate safety precautions must be designed into the process and equipment if these types of materials are used.

High pressure liquid streams can be dangerous to operators. This is especially true of needle jet configurations. Appropriate operator protection must be considered.

High pressure systems must be designed with mechanical components that can withstand operating pressures.

IMMERSION CLEANING

This process is widely used in a number of applications. It is best for removal of soluble fluids and contaminants. The chemistry of the immersion bath must be matched to the type of contaminant that you are removing. The process depends on chemical solvency action. Agitation of an immersion bath will usually increase the efficiency of the process. The addition of heat may also increase the process efficiency. Agitation can be accomplished with the addition of megasonics, ultrasonics, spray under immersion, submerged spargers, etc. Heating elements may be mounted externally to the tank or may be submerged. Immersion tanks can become heavily loaded with soils in a short time. If soil loads are heavy, the use of ultrafiltration, recirculation or separation systems will probably help. If parts are heavily soiled, a pre-wash station will usually increase final bath life.

General Information

Good process for removal of soluble fluids and contaminants.

Not recommended, as a stand alone process, for the higher cleanliness levels.

This process depends primarily on chemical solvency properties. Cleaning liquid selection will be very important.

Process optimization will involve:

- chemistry match to the contaminants to be cleaned
- soak time
- bath temperature
- control of soil loading in the tank

Agitation of the part or process liquid will increase cleaning. Any of the following may be used to increase agitation:
- ultrasonics
- mechanical agitation of the part
- spray under immersion
- submerged spargers

May be used as a presoak for subsequent cleaning steps. An example process for very difficult soils might be as follows:
- immersion soak (use a solvent matched to the contaminant)
- ultrasonic cleaning in a different tank
- high pressure spray (used to remove loosened contaminant)
- low pressure spray (used as a rinse)
- dry (if required)

Immersion may use hot or cold tanks.

May be a manual process or part of a highly automated operation.

A stand alone dip tank may become heavily loaded with soils very rapidly. The use of recirculation/filtration/separation systems is recommended for heavily used tanks.

Environmental Issues

Environmental disposal issues will depend on the soils that are in the used water.

Do not assume that just because you are using water that you can dispose of the water directly to the sewer.

Make sure that your facility and the local POTW can handle the increase in water disposal and water supply.

Closed loop cleaning systems will still generate a waste stream at a greatly reduced rate compared to open loop system. The waste may be in the form of contaminated filters and reverse osmosis membranes.

Safety

Safety issues will involve primarily the process equipment. The equipment must be designed to operate in an aqueous environment where exposure to water mists or sprays will not cause electrical hazards.

High process liquid temperatures may be a source of concern.

LASER ABLATION

This process has been used to strip paint from aircraft. At the other extreme, it has been used to remove sub-micron particles and thin fluid films from semi-conductor components. In either case, the laser energy is being used to vaporize a contaminant. Some work has been done using the laser to vaporize a thin liquid layer which in turn

removes particles. This type of process may be relatively expensive in both time and equipment. Laser ablation may be a good choice for assemblies that may be damaged by other methods.

General Information

Laser ablation uses short pulses of high peak power laser radiation to rapidly heat and vaporize thin layers of contaminants.

At one extreme, laser ablation is being used to remove paint from very large aircraft surfaces. At the other extreme, laser ablation is being used to remove thin films and particles from semiconductor wafer surfaces.

The laser ablation process used on semiconductor wafers uses an adsorbing transfer medium, a liquid, to remove particles. The transfer medium is vaporized by the laser. As the transfer medium is vaporized, it carries off particle contaminants. Energy transfer media includes water, ethanol, and 2-propanol.

Laser ablation will work on partially or completely assembled parts.

Laser ablation can remove very thin layers such as a chromium oxide layer from 304L stainless steel.

Environmental Issues

Laser ablation generates very little waste. The waste is the volume of material vaporized from the substrate surface.

Safety

Eye protection may be required.

LOW PRESSURE SPRAYS

Low pressure sprays are used for rinsing or removal of loose contaminants. This process uses the kinetic energy of a spray to knock off loose particles and to flush away liquids. Low pressure sprays are used at all levels of cleanliness. Low pressure refers to pump pressures below about 200-300 psi. This can be compared to the high pressure sprays that typically operate above 500 psi. Low pressure sprays should not be depended upon to remove tightly adhered particles. The low pressure sprays will work best on contaminants that have been loosened with another process such as ultrasonics, chemical solvency, or high pressure sprays. Low pressure sprays can be used with most cleaning chemistries. If a soap or additive is used in the liquid, it should be low foaming. Process equipment may vary from manual spray wand devices to highly automated systems with custom spray headers. Low pressure sprays are very common as part of a larger cleaning system. Equipment costs are relatively inexpensive. Most of the cost will come from the system plumbing design i.e. the pump and filtration system. Flammable or combustible liquids may become explosive when sprayed. This can be safely handled with the proper equipment design.

General Information

Very effective method for gross removal of loose contaminants, solid or liquid.

Can be used for all levels of cleanliness.

Commonly used as a rinse cycle within a larger sequence of cleaning steps.

Basic system consists of:
- tank or booth
- spray wand
- liquid reservoir
- pump and filter

The process uses kinetic energy to move material.

Low pressure spray systems usually operate below 200-300 psi.

May be used with most cleaning chemistries.

Any chemical additives to cleaning liquids must be low foaming.

Nozzle design will affect cleaning efficiency.

Process optimization will involve:
- nozzle design
- nozzle configuration within spray header (spray pattern)
- liquid flow rates
- cleaning liquid selection
- dwell time

May be used in manual or automated processes.

May require a secondary drying process.

Environmental Issues

Most issues will be related to the cleaning liquid used and the contaminant being removed.

Low pressure rinse systems are not necessarily low liquid flow. Liquid wastes may be generated at a high rate. In addition, consumption of fresh liquid may be high.

Liquid wastes may be recirculated through a storage tank. This would allow separation of liquid and contaminant.

The contaminant removed from your parts may become a waste that has to be treated or disposed of.

You must make sure that your supply of water, if used, is adequate for your anticipated requirements. Some areas are limited on availability of new water permits.

Do not assume that if you use water, that you can spray in the open and allow the water to run to drain. Check with your local water and sewer authorities first.

Safety

Combustible and flammable chemicals will become explosive when sprayed. Appropriate safety precautions must be designed in to the process and equipment if these types of materials are used.

MEGASONICS

Megasonic cleaning is a higher frequency version (700-1000 kHz) of acoustic cleaning than ultrasonics (20-40 kHz). A primary difference between the two frequency ranges is the absence of significant cavitation effects in the megasonic range. This feature reduces surface damage significantly so that parts that might be damaged in an ultrasonic bath can often be cleaned without damage in a megasonic bath, using the same solutions. The technique has proven effective for removing submicron particles from silicon wafers without wafer damage. The apparatus required is similar to that of ultrasonics except for the transducers which operate in the 700-1000 kHz. range. Megasonic cleaning is more of a line of sight operation than is ultrasonics. With ultrasonics, cavitation occurs everywhere within a tank. With megasonics, only the side of the part facing the transducer will be cleaned.

General Information

Megasonics uses high frequency acoustic waves to generate pressure waves in a fluid. The process is sometimes called acoustic streaming.

The higher megasonic frequencies do not cause the cavitation effects that are found with ultrasonics. This reduces cavitation erosion significantly.

Megasonics are used primarily for particle removal. It may also be used to increase the efficiency of chemical cleaning with surfactants or detergents.

Megasonics have been used to remove particle below 0.3 microns in size.

Exposure time and megasonic power are the two most significant variables that affect megasonic cleaning. As megasonic power or exposure time increase, particle redeposition decreases.

Optimum power levels for silicon wafer cleaning have been found to be between 200 and 250 watts.

Typical exposure times are 10 to 30 minutes.

Cleaning efficiency improves with increasing temperature.

Environmental Issues

Any environmental issues will depend on the particular cleaning chemistry being used.

Safety

Process noise levels may require hearing protection for operators.

N-METHYL PYROLLIDONE (NMP)

NMP is an excellent solvent for many coatings, including epoxy resins, polyurethanes, polyamidimide based wire enamels, water based coatings, and printing inks. NMP is being used in several paint stripping operations. NMP is also used to clean engine parts i.e. parts with heavy oil and carbon deposits. Many plastics, including polystyrene, ABS, polyvinyl chloride, and polyesters are soluble in NMP. NMP is used in both immersion and ultrasonic processes. NMP is water miscible, meaning that any solvent residue can be removed with water rinsing. NMP is commonly used in its pure state, but it is available blended with various surfactants and thickeners. Many oils become miscible in NMP only when the solvent is above 63 degrees C. This means that a reduction in temperature can be used to remove oils from used solvent. The solvent can then be reused and the

oil can be disposed of. NMP is combustible, with a flash point of 91 degrees C.

General Information

NMP is an excellent solvent for many coatings including epoxy resins, polyurethanes, polyamidimide based wire enamels, water based coatings and printing inks. It also works on varnishes and lacquers.

NMP is miscible in water. It is commonly used in the pure state but can also be blended for special applications. It can also be blended with various surfactants and thickeners.

NMP is being used in several paint stripping applications.

The use of brass or bronze valves in process piping is not recommended.

Typical pH of NMP is 8.0 - 9.5.

Many plastics, including polystyrene, ABS, polyvinyl chloride, and polyesters are soluble in NMP. Assemblies containing these materials should be tested before using NMP.

NMP is used in both immersion and ultrasonic equipment. It can be used to clean engine parts (removal or oil and carbon deposits, to remove printing ink residues, to remove epoxies, and to remove temporary coatings from optical components.

Many oils become miscible in NMP only at temperatures above 63 to 68 degrees C. This means that if contaminated NMP was in a settling tank, the oils would separate from the NMP. The separated NMP could be sent back to the wash tank.

A model process would involve an immersion/ultrasonic cleaning tank with NMP, followed by a rinse with clean water and a subsequent drying step, if required.

Environmental Issues

Safety

NMP has a TLV of 100 ppm.

NMP is a combustible liquid. The flash point is 91 degrees C.

NO CLEAN OPTIONS

The term "no clean option" refers to various alternatives and strategies that may be used in place of traditional solvent cleaning.

The first option that should always be considered is the elimination of the cleaning process that you are concerned with. Examine your process with a very critical eye. Ask yourself why you're cleaning at all.

Move two processes closer together and eliminate the intervening cleaning step. One manufacturer was cleaning parts destined for a plating operation. The plating operation was cleaning the parts prior to plating. The two processes were physically separated and the reason for cleaning the parts between processes was the fear of soil deposition while

parts were in waiting to be plated. By moving the processes physically closer, the level of soil build up was reduced and the cleaning step was eliminated. A number of large companies have found that cleaning processes have been created where process flow sheets do not specify them. Make sure that you really need to clean at the location that cleaning is taking place.

Eliminate the use of a solvent. One company noticed that the machine tools being used were always clean and had no rust problems. They used the same fluid that was in the machine tools in an agitated immersion cleaner. This reduced the number of different types of chemicals being used and being disposed of.

A powder coat process used to clean all of the part hooks in a solvent. A pyroclastic oven was purchased. All the part hooks are currently cleaned in the oven. This results in no solvent emissions and no waste disposal.

One company was cleaning transmission cases prior to filling them with transmission fluid. Instead of cleaning with a solvent, they switched to the same transmission fluid that the case was to be filled with.

Controlling the soils on a part can reduce or eliminate the need for cleaning. One machine toll company was using TCA to clean heavy lapping oils. By adding a small amount of detergent to the lapping oil, the parts were easily cleaned in an aqueous system.

If you're cleaning parts for heat treatment, you may be able to switch to an oil/coolant that is easily burnt off.

Use air knives to remove excess process fluids instead of a solvent or hand wipe process.

Match your process fluids to your cleaning methods. Switch to water soluble fluids if you are thinking of aqueous cleaning. Minimize the number of different types of fluids that you use.

Put the same amount of engineering effort into designing your cleaning process that you would put into a new facility or machining cell.

PETROLEUM DISTILLATES

Petroleum distillates are aliphatic hydrocarbons and synthetic paraffinic hydrocarbons. Petroleum distillates include mineral spirits, kerosene, white spirits, naphtha, and Stoddard solvent. The paraffinic hydrocarbons have generally lower flammability, lower aromatic content, narrower boiling range and higher solvency than the aliphatic hydrocarbons. They are also more expensive than the aliphatic hydrocarbons. Mineral spirits cost around $3/gallon. Paraffinic hydrocarbons for electronic cleaning may cost up to $32/gallon. Petroleum distillates work well on heavy oil and grease, tar, and waxes. These materials usually have low surface tensions, allowing them to penetrate and clean small spaces. Due to the flammability of these products, they are usually used at near room temperatures. They are typically used in immersion processes. Ultrasonics may or may not work depending on the particular formulation that you are using. Petroleum distillates are also found as the solvent component in some of the so-called semi-aqueous solvents. Petroleum distillates are VOCs and may be regulated in your area. Toxicity levels for petroleum distillates are considered to be low, but will vary with the specific material that you are using.

General Information

Aliphatic hydrocarbons can be broken into two groups: Petroleum distillates and synthetic paraffinic hydrocarbons.

Petroleum distillates include mineral spirits, kerosene, white spirits, naphtha, and Stoddard solvent. These products may contain trace amounts of benzene and other aromatics.

When compared to petroleum distillates, the paraffinic hydrocarbons have lower flammability, lower aromatic content, narrower boiling range and higher solvency. They are also more expensive than the petroleum distillates.

The petroleum distillates (and paraffinic hydrocarbons) work well on hard to clean organic soils such as heavy oil and grease, tar, and waxes. Petroleum distillates can typically handle high soil loads.

These products typically have low liquid surface tensions (22 - 28 dynes/cm.). This allows them to penetrate and clean small spaces.

Petroleum distillates typically operate at near room temperatures. This is due to the flammability of the products.

Petroleum distillates are usually used in immersion baths. Ultrasonics may or may not work, depending on the particular product.

When the cleaning power of the bath is exhausted, you will usually have to replace the entire bath.

Petroleum distillates are compatible with most materials including most elastomers. Mineral spirits may not be compatible with EPDM, SBR and silicone.

Petroleum distillates are frequently used in manual wipe down processes.

Environmental Issues

Petroleum distillates are VOCs and may be regulated in your area.

Petroleum distillates can be recovered by distillation or disposed of through fuel blending.

The paraffinic hydrocarbons have low evaporative loss rates.

Safety

Petroleum distillates are flammable and must be handled accordingly.

Using petroleum distillates in spray equipment may create an explosive hazard.

POWER WASHING

Power washers or power washing is a generic term that is applied to large cleaning machines. These machines may combine washing, rinsing and drying cycles. The machines may use rotating baskets for part containment. Power washers may combine any number of the classic "wet" processes, such as immersion cleaning, ultrasonic cleaning and spray cleaning. The machine may be custom designed to handle a high volume of one type of part, or a number of different parts that can be fixtured in a similar manner. The system may incorporate a custom spray system to clean blind holes. Power washers may require less floor space than the same process would when laid out in a linear sequence. Costs of equipment will vary greatly but should be competitive with equivalent linear systems.

General Information

Power washers or power washing is a generic term applied to a number of processes and equipment. Usually the term refers to a large, self contained machine.

Power washers may combine washing, rinsing and drying cycles within one cabinet.

Power washers may include ultrasonics, high and/or low pressure sprays, and immersion cleaning.

Power washers may be custom designed to handle high volumes of one part type or they may be a general cleaning station designed to handle a range of part types.

Power washers may take up less floor space than a piece of equipment that is designed to implement the same processes in a linear fashion.

SEMI-AQUEOUS SOLUTIONS

Semi-aqueous solutions are basically an emulsion type cleaner consisting of a solvent and water. The solvents are typically VOCs such as terpenes, glycol ethers, dibasic esters or hydrocarbons. The semi-aqueous solutions produce a residue that can be removed with water rinsing. In some cases, it may be possible to leave the film on the part as a protective coating. Semi-aqueous solutions may be very effective for parts with heavy soil loadings. The semi-aqueous processes usually require at least a semi-closed loop process. The used semi-aqueous solution is allowed to collect and separate in a decanter. This produces a waste water stream, which may be recycled and a solvent stream, which may also be reused. Semi-aqueous systems may also be developed as completely closed loop processes.

General Information

Semi-aqueous solutions use a solvent with residues that can be removed by rinsing parts in water.

The solvent used usually has a low vapor pressure. The solvent is frequently combined with water to form an emulsion.

Common solvents include terpenes, glycol ethers, dibasic esters and hydrocarbon blends.

Semi-aqueous solutions are good for heavily soiled parts. They are effective on organic soils. Good examples are pigmented drawing compounds, lubricants, heavily oiled soils, and lubricants.

Semi-aqueous chemicals can be used in most types of process equipment, such as immersion tanks and spray processes. Some of the chemicals can also be used with ultrasonics.

In some applications, the semi-aqueous chemical is used without rinsing. This can provide a protective film on parts that are subject to rust.

Environmental Issues

Environmental disposal issues will depend on the soils that are in the used water.

Do not assume that just because you are using water, that you can automatically dispose of the water directly to the sewer. Contact your local POTW to review your particular application, prior to converting to water.

Closed loop cleaning systems will still generate a waste stream at a greatly reduced rate compared to open loop system. The waste may be in the form of contaminated filters and reverse osmosis membranes.

Safety

Safety issues will involve primarily the process equipment. The equipment must be designed to operate in an aqueous environment where exposure to water mists or sprays will not cause electrical hazards.

High process liquid temperatures may be a source of concern.

STEAM CLEANING

Steam cleaning is frequently a manual operation. The steam generation equipment can be portable. The process is very useful for infrequent cleaning of large objects. If production rates do not justify the purchase of a spray system, a steam system is probably a good substitute. Most steam cleaners require a small amount of floor space. The cleaning area may have to be vented or cleaning may have to be conducted in the open. Steam systems can use alkaline detergents to assist the cleaning. Chemical concentrations may be lower than those required in immersion type cleaners. Cleaning detergents with high silicate levels may cause a scale build up in some types of equipment, this will be evidenced by an increase in back pressure in the system.

General Information

Steam cleaning is frequently found as a manual operation.

Steam generation equipment can be portable allowing cleaning to take place at various locations, inside or outside of a plant.

Good process for infrequent cleaning of large objects. If production rates do no justify the purchase of a spray system, a steam system may be a good substitute.

Alkaline cleaners can be used in steam equipment to good effect. Chemical concentrations may be lower then are required in immersion equipment.

High silicate cleaners may cause scale build up in the cleaning equipment.

Steam cleaning is good for both fluid and particle removal. It is good for removing heavy oil and grease loads. It may be a good preliminary process in order to reduce soil loading in a wash tank.

Environmental Issues

Environmental issues will depend on the soil being removed and the specific chemistry being used.

If steam cleaners are used outside, the process may result in ground water or soil contamination.

Safety

Operator protection from the hot steam is usually required.

Heavy use of steam cleaning inside confined areas may require extra ventilation or cooling requirements.

SUPER CRITICAL FLUID CLEANING

This process uses primarily CO_2 in a super critical state to achieve cleaning. When a fluid is at or above its super critical point, it will have liquid like and gas like properties. The super critical CO_2 becomes an excellent solvent

for many soils. The process requires that parts be placed in a pressure chamber. CO_2 gas is then introduced to the sealed chamber and the temperature and pressure are raised until the super critical point is achieved. Process temperature may range from about 35 C to 65 C. Process pressures may range from about 2000 psig to 4000 psig. This process works very well for complex shapes and parts. Non-metallic materials such as gaskets and O-rings need to be tested for compatibility with the process. The process works well on fluid contaminants. Some suppliers report good results on particle removal as well. The pressure and temperature of the super critical fluid can be "tuned" to match the soil. Capital costs may be high. On-going operating costs can be very low. Cycle times will vary depending on pressure vessel design. If the vessel is closed using manual bolts, the cycle time will be fairly long. The process can be designed to be a closed-loop process. The only waste stream is the contaminant being removed.

General Information

This process uses CO_2 gas that is in a super critical state, i.e. at an elevated temperature and pressure.

Super critical fluids have both liquid and gas like properties. This allows the fluid to penetrate very small gaps and complex assemblies.

Super critical CO_2 has excellent solvent properties. One source compares it to hexane, in solvency power.

Super critical CO_2 has been used to remove:
- silicone oils
- flux residues
- petroleum oils
- machining oils
- dielectric oils
- lubricants
- adhesive residues
- plasticizers
- fats and waxes

Parts are placed into a pressure vessel into which CO_2 gas is introduced. The temperature and pressure are then raised until the super critical state is reached.

A basic system consists of:
- compressor
- heat exchanger
- extraction vessel
- pressure control valve
- heat exchanger
- separation vessel

Process temperatures may range from 35 C to 65 C. Pressures may vary from about 2000 psig to 4000 psig.

The process works very well for complex shapes and assemblies.

Non-metallic materials will have to be tested for compatibility.

The process works well on removing trace fluids. Some suppliers claim effective removal of particle contamination also.

It may be possible to tune the operating pressure and temperature to match the soil being removed.

Do not use parts that can not be subjected to elevated atmospheric pressures.

This process has been aimed towards the precision cleaning industry. With further development it should become more broadly usable.

Potential candidates for super critical CO_2 cleaning include:
- missile gyroscopes
- accelerometers
- thermal switches
- nuclear valve seals
- electromechanical assemblies
- polymeric containers
- special camera lenses
- laser optics components
- porous ceramics

Environmental Issues

The process can be designed to be closed loop: After cleaning, the CO_2 is removed from the pressure vessel and the temperature and pressure is reduced. This causes the soils to drop out in a holding tank. The CO_2 gas is then recycled back to the pressure vessel.

There are growing concerns with CO_2 as a green house warming gas. The CO_2 used in super critical cleaning is not a new generator of CO_2. The CO_2 gas used is a by-product of other processes.

Safety

The largest safety concern is the use of high pressure components in the process equipment.

TERPENES

Terpenes are derived from natural sources and are considered to be biodegradable, nontoxic and non-corrosive. They have a low viscosity and can be used in low temperature applications. Some specific terpenes are a-pinene and d-limonene. Terpenes can be used as a component of a semi-aqueous cleaning solution or by themselves. They are good solvents for heavy petroleum greases and residues. They can be used with immersion and ultrasonic systems. They can also be used in spray applications, with precautions. Terpenes may be explosive when sprayed. Terpenes do not stain or etch. Some elastomers are not suitable for continuous service when in contact with terpenes.

General Information

Terpenes are derived from natural sources, such as citrus and pine oils. They are generally considered to be biodegradable.

Terpenes typically have very strong odors, even in low concentrations.

Terpenes are generally not aggressive toward metals and most plastics or polymers. Some elastomers may not be compatible with terpenes.

Terpenes first found use as substitute solvents in printed circuit board cleaning operations.

Citrus based terpenes are capable of dissolving heavy petroleum greases and residues, such as cosmolene. Citrus and pine oil terpenes will clean cosmoline in about 30 minutes at ambient temperatures.

Terpenes typically do not stain or etch.

Terpenes work at low temperatures; it may not be necessary to heat the cleaning bath.

The most common process to use with terpenes is a straight immersion bath, usually with some type of agitation.

Spray systems should be used with care; terpenes are highly flammable when sprayed. Most spray systems use an inert atmosphere blanket.

Commercial terpene solvents may have a surfactant added to the terpene. This allows the use of water as a rinse agent. The terpene will form an emulsion with the water. This emulsion can later be separated and the terpene can possibly be reused.

Some terpenes will polymerize; they can form sticky threads on the solvent can or drum. An insoluble tar-like substance may form in long standing terpenes.

Safety

Terpenes are combustible materials. When sprayed, terpenes can become a severe fire hazard.

Many terpenes are listed as GRAS (generally recognized as safe) materials. Exposure limits to d-limonene may become an issue.

ULTRASONIC CLEANING

Ultrasonic cleaning uses the energy generated by sound waves to create cavitation bubbles. The collapse of these bubbles creates a scrubbing action. This is very effective for removing many contaminants. An ultrasonic system requires a tank, transducer(s), an ultrasonic generator and a cleaning liquid. Tanks can be sized to fit almost any size part. Transducers can be bonded to the tank bottom or sides. Several transducers may be used on one tank. The number used will depend on the energy required to remove a contaminant. Transducers also may be of the submersion type. This allows the addition of ultrasonic cleaning to an existing tank, such as a vapor degreaser tank. Each transducer will have a generator to supply power. These generators typically operate in the 20 - 40 kHz range. The cleaning liquid is typically an aqueous solution. The solution may have various cleaning agents added to improve cleaning efficiency. An ultrasonic system may cause erosion of almost any material. This erosion depends on the material you're cleaning. Cleaning efficiency will be affected by cleaning time, fixture design, piece part shape, chemical additives and temperature. This is a generally effective and wide ranging process. It can be used in many industries.

General Information

Good for all levels of cleanliness, very good for particle removal and can be used with most solvents and materials.

Basic system consists of:
- tank (various materials - stainless most common).
- transducers (bottom and/or side mounted or immersion).
- generator (usually 40 KHz. range).

- liquid supply

Uses "cavitation" to create a scrubbing action:
- sound waves form vacuum "bubbles."
- bubbles form and collapse very rapidly.
- collapse can create pressure of 50,000 lbf. and 10,000 degrees F temperatures within the bubble.

Frequently used as one step in a multi-stage cleaning system.

A multi-stage system could consist of the following steps:
- ultrasonic wash
- spray rinse
- ultrasonic overflow rinse
- high pressure spray rinse
- air knife blow-off
- vacuum dry

Can cause surface erosion of parts.

Erosion will depend on:
- bath temperature
- solvent
- material hardness
- surface finish
- cleaning time

Most generators provide for frequency adjustments to help eliminate erosion problems.

Ultrasonics may raise cleaning bath temperatures. If temperature is determined to be an important control parameter in your process, you may have to add chiller coils to the ultrasonic tank.

Fixtures can create "shadows," blocking action of sonic waves.

Sonic waves can bounce delicate parts if not held firmly.

Effectiveness with blind holes is questionable, use hole flush techniques in addition to ultrasonics.

Trapped air bubbles on or in a part will prevent cleaning.

Environmental Issues

Ultrasonic erosion may contaminate cleaning bath with metals: Cleaning parts with tin/lead solder may cause lead particles to be present in waste solvent. Test solvents after cleaning for presence of regulated contaminants. Even "pure" water needs to be tested after cleaning.

Energy consumption may be high, depending on heaters, amount of time that ultrasonics are on, amount of pumping, etc. Use timers and temperature controllers to reduce power consumption.

Safety

Audible noise levels may be high, test noise levels at full system operation to determine operator protection requirements.

Exposure of bare skin to ultrasonics is harmful, don't place your hands in a tank if the ultrasonics are on.

UV/OZONE CLEANING

This is a dry process used to remove trace contaminants. The process uses ultraviolet (UV) light, usually combined with ozone, to decompose organic materials. This process depends entirely on line of sight exposure to the UV light. The process is very dependent on the thickness of the soil; the greater the thickness, the longer it will take to clean. The ozone may be generated by the UV light or may be injected from another source. Safety is an issue with this process due to the intense UV light generated. In addition, the presence of ozone is a safety issue. The UV lights may contain mercury and will be a safety hazard if broken. The process is best for materials with thin organic films that need to be removed and for the higher cleanliness levels. Commercial equipment is fairly inexpensive. The UV light may cause corrosion on some metals, depending on length of exposure.

General Information

This is a dry process used to remove very small amounts of fluid contaminants. It is not applicable to particle removal.

UV energy, from a UV lamp, is emitted in two wavelengths; 185 nanometers (nm) and 254 nm. The 185 nm energy is absorbed by oxygen and produces ozone, which oxidizes organic materials. The 254 nm energy is absorbed by organic materials and increases their molecular activity so that they will react with ozone.

The process usually takes place in a type of "oven." This contains the ozone that is generated and isolates the UV light source.

The process depends on line of sight exposure to the UV light source. It is therefor best suited for simple, flat surfaces.

Exposure times are usually 5 to 10 minutes, depending on contamination thickness.

The process is used on various vitreous and crystalline surfaces:
- 99.5% alumina
- gallium
- arsenide
- silicon
- lithium niobate
- indium phosphide
- mercury cadmium telluride
- quartz
- glass

The process may work on various metallic substrates, depending on exposure time. Long exposure times may affect the surface of various metals.

Copper is readily oxidized when exposed to UV/ozone.

Processing temperatures are usually less than 70 degrees C.

The closer a part is to the uv source, the more efficient the process. Typical distances are 4 to 10 mm.

UV/Ozone will not remove inorganic materials such as oxides and salts.

The cleaning rate is about 5 to 10 Angstroms per minute. One source recommends that contaminant film thickness should not exceed 100 Angstroms.

Organic surfaces can be treated with UV/Ozone to improve their adhesion to other organic surfaces.

Safety

UV radiation is harmful to the eyes and the skin. Most systems are closed in order to prevent exposure to UV radiation.

Ozone is biologically harmful. Most systems are hermetically sealed or otherwise isolated from the outside atmosphere.

The mercury used in UV lamps is dangerous if the lamp should leak or break.

VAPOR DEGREASERS

Vapor degreasing equipment can be converted to be operated with aqueous cleaners. A simple conversion would involve disconnecting the refrigeration system and adding an agitation system to the tank. This can be accomplished through the addition of a submerged air pipe. The air pipe has holes drilled in it and is connected to an air supply. During cleaning air bubbles from the submerged pipe cause turbulence in the cleaning bath. Agitation may also be accomplished through the addition of immersible ultrasonic generators. This might be more effective than simple air bubble turbulence. Make sure that the system pump and plumbing materials are compatible with the new cleaning liquid to be used.

It may be possible to convert your equipment for use with semi-aqueous solvents. This will probably require the addition of decanting or separation equipment. Most semi-aqueous chemical suppliers should be able to assist you. Contact the original manufacturer of the equipment that you have. Some manufacturers have retrofit kits that can be used to convert existing equipment to other cleaning solutions.

Conversion of existing vapor degreasers for use with flammable solvents is not recommended. The design and liability issues are probably not worth the effort. Most vapor degreasers have hand spray wands attached. Some combustible cleaners will become explosive when they are sprayed.

WATER CLEANING

Water, without any additives, can be a very effective cleaning agent. It is effective at removing aqueous based machining coolants, ionic salt contaminants, and for the removal of bulk contaminates such as dirt, grit, and grease. The quality of the water supply may have a large effect on its usefulness. Some water supplies will need to be demineralized prior to use. Pure water is most frequently used in steam systems and in high and low pressure spray systems. The waste stream generated will have to be treated based on the type of soil being carried with the water.

General Information

Pure water is defined as water without any detergent or other chemical additives. Pure water may simply be tap water or may be deionized, filtered water.

Water works very well as an energy transfer fluid in spray systems. If you are removing chips or particles and

you don't require some type of chemical solvency, water is an excellent option.

Water can work well in gross or bulk decontamination such as the removal of dirt, grit or grease. High pressure spray or steam would be best for this application.

High pressure water has been use to remove mill scale from steel, barnacles from ship hulls, paint from aircraft, and to clear clogged pipelines.

Water is also an excellent fluid for use with ultrasonic systems.

Water is very good at removing potentially damaging chlorides or other salts.

Many types of existing equipment can be converted to water with minimal effort. The concerns will be mostly directed towards corrosion issues e.g. can the system pumps and tanks handle water without corroding.

The largest process issue with water will probably be the possible requirement for a drying system. Common drying systems include forced hot air, infrared heating or centrifugal spin off. It is possible that the use of hot water will raise the part temperature enough to provide adequate flash drying.

The condition of your incoming water will have a great effect on the efficiency of water cleaning. Water hardness and other chemical properties vary widely from region to region.

Environmental Issues

Environmental disposal issues will depend on the soils that are in the used water.

Do not assume that just because you are using water, that you can automatically dispose of the water directly to the sewer. Make sure that your facility and the local POTW can handle the increase in water disposal and water supply.

WIPE CLEANING

Wipe cleaning is usually a manual operation. It is best used for non-repetitive operations and large surfaces. Wiping solvents are selected for the particular application and may be acidic, alkaline or solvent based. Wiping will generate more waste than other processes. The wipe material becomes contaminated with cleaning chemical and soil. Repetitive use of wiping in a process may indicate a need for process flow change.

General Information

Wipe cleaning is usually a manual operation.

Wipe chemicals may be acidic, alkaline or solvent based. Wipe materials may be common sponge or cloth or may be a more sophisticated material such as polyvinyl alcohol.

Environmental Issues

Wiping can generate a large amount of bulky waste (the wipes) that must be disposed off.

The disposal method will depend on the type of chemical used as the wipe solvent. In addition, the type of soil on the wipe may affect disposal methods.

XENON FLASH LAMP CLEANING

Xenon flash lamp cleaning uses the photo energy from a flash tube to burn off layers of coating materials. It has been used to remove coatings from aircraft skins. It has been used on both composite and metallic materials. The process has been combined with CO_2 pellets cleaning and used for paint stripping on aircraft. Strip rates of 1 square foot/minute have been achieved. The process may allow the removal of coatings to a certain depth instead of all the way to bare substrate. The process generates a small waste stream consisting of burnt coating materials. The process is still in development and is fairly expensive.

SECTION II SUBSTRATES

ALUMINUM

Abrasive processes may damage the surface finish or appearance of aluminum. If this is not a problem, abrasive blast processes are very effective in preparing castings and other parts for coating.

If steel grit is used for blasting processes, the steel particles that are left in the aluminum substrate may corrode.

Organic solvents will not usually be adequate for most cleaning.

Alkaline cleaning is the most common chemistry used for aluminum. Alkaline solutions that contain silicates as an inhibitor may cause the formation of aluminum silicates on the part. This may lead to problems with subsequent finishing processes.

Alkaline cleaning is not effective for oxide layer removal. Use acid cleaning instead.

Aluminum is sensitive to chemistry pH and process temperature. High pH cleaners may etch the surface of the part. This will depend on the amount of inhibitor in the particular chemistry that you are using. High process temperatures may cause an oxide layer growth on your part. This can affect some parts and processes. You should verify the process temperatures that you plan to use prior to full process implementation.

BERYLLIUM ALLOYS

Alkaline cleaning has been used very successfully on a variety of aerospace parts.

BRASS PRODUCTS

Alkaline and emulsion cleaners are the most generally useful chemistries.

Alkaline cleaners should contain inhibitors.

Strong alkaline cleaners may tarnish parts.

COPPER MATERIALS

Alkaline cleaners should include inhibitors in order to reduce tarnishing.

Emulsion cleaning is very effective depending on the soil.

IRON PRODUCTS

Alkaline, emulsion and petroleum distillate cleaners are the most generally useful chemistries.

Alkaline chemistries may include corrosion inhibiting additives.

Acidic aqueous chemistries are not good general cleaning agents. They are used primarily for scale or oxide removal. Strong acid chemistries are used for pickling. Prolonged contact with neutral or acidic solutions is not recommended due to attack of the base metal.

High carbon and low alloy steels are susceptible to hydrogen embrittlement.

MAGNESIUM ALLOYS

Neutral or weakly alkaline cleaners will attack magnesium. Acids may also attack magnesium. Alkaline cleaners should be above pH 10.5.

Solvent based cleaners are effective on magnesium.

Cleaners with phosphate additives may cause attack of the base metal and should be tested.

The use of inhibitors in aqueous chemistries is recommended.

NICKEL ALLOYS

Alkaline and emulsion cleaners are good general cleaners.

There are no special precautions involved with cleaning nickel alloys.

STAINLESS STEEL

Generally easy to clean.

Alkaline cleaners are probably the most generally useful chemistry with stainless steel.

Petroleum distillates work well with soils that can not be cleaned with alkaline chemistries.

Acidic chemistries are primarily used to remove oxides and scales.

Most problems due to contamination during processing:
- using contaminated abrasives during blasting operations.
- using shop air to blow off parts.
- handling finished, cleaned product with bare hands.
- using machine tools that have been used with other (iron) materials.
- using iron shot or other iron materials during processing.

Passivation/electropolish are not substitutes for cleaning.

TITANIUM ALLOYS

Alkaline, emulsion and petroleum distillates are effective cleaners for titanium.

The largest concern when cleaning titanium is probably the avoidance of hydrogen embrittlement problems.

One source recommends acid pickling after any cleaning operation.

ZINC

Zinc is subject to attack by either alkaline or acidic solutions. Neutral solutions or low alkaline (pH 8 or pH 9) solutions are the best general aqueous cleaners for zinc. Other effective chemistries include emulsion cleaners and solvent based cleaners.

Alkaline cleaners should include an inhibitor to prevent attack on the base metal. If silicates are the inhibiting agent, the parts must be thoroughly rinsed after cleaning.

Acid cleaners are used primarily when removing oxides.

Zinc is cleaned effectively by the use of ultrasonics, sprays and immersion cleaning.

ZIRCONIUM ALLOYS

Alkaline and emulsion cleaners are good general cleaners.

Acetone and alcohol are also good general cleaners.

Most processes, especially ultrasonics, are effective with zirconium.

SECTION III AQUEOUS ADDITIVES

BUILDERS

Builders are the most common component found in alkaline cleaners.
They are used to aid in suspending soils and in preventing soil redeposition.

Typical builders are sodium salts of phosphates, carbonates, silicates, hydroxides, and zeolites.

Builders may also act as water softeners and as sequestering and buffering agents.

Common builders are EDTA (ethylenediaminetetraacetic acid) and sodium silicates.

CHELATING AGENTS

Chelating agents are used to solubilize hard water salts so that they stay in solution.

Chelating agents are used in alkaline cleaners.

Chelating agents do not decompose or lose their effectiveness at high temperatures.

A major disadvantage of chelating agents is that they impair the ability of other chemicals to remove emulsified oil and dissolved metals from the solution. This can create a waste disposal problem.

Chelating agents are produced in both powder and liquid form.

The most common chelating agents are ethylene diamine tetracetic acid (EDTA) and nitrilo triacetate (NTA).

EMULSIFYING AGENTS

Emulsifiers allow non-water soluble soils to be cleaned with aqueous chemistries. For example, an emulsion cleaner can be used to clean petroleum based soils. The emulsion cleaner would then be rinsed off using an aqueous rinse.

Most emulsion cleaners use a solvent suspended in an aqueous base. The solvents may include alcohol, methyl chloroform (TCA), methylene chloride, terpenes or petroleum products such as kerosene or petroleum oil.

Emulsion cleaners a good for removing organic contaminants. They are recommended for such things as carbonized grease and oil and for buffing or lapping compounds.

Spray application and immersion cleaning are the most common cleaning processes.

Emulsions can be broken by an acid or a salt. When this happens, the solvent will separate from the water. This can be an effective way to control waste streams i.e. contaminated solvent can be separated from water and reused or disposed of separately.

Emulsion cleaners are very similar to semi-aqueous cleaners. Aqueous chemistries may have emulsifying agents as an additive to help with cleaning non-soluble soils.

INHIBITING AGENTS

Inhibitors are commonly used to minimize the effect of alkaline cleaners on metal substrates.

Inhibitors may also be used to prevent oxidation (rusting).

Inhibitors can increase the difficulties of rinsing a cleaner from a part being cleaned.

Inhibitors may deposit a film on a part as soon as the soil has been removed or displaced. This film will interfere with future steps in processing such as plating and conversion coatings.

Rust inhibitors may be used to prevent rust on cleaned parts. They may also be used to prevent rust in cleaning equipment that is not made of stainless steel.

Inhibitors are commonly found in the high pH cleaners, since they will attack most non-ferrous materials.

The ferrous metals, magnesium, and titanium alloys are not usually attacked by the highly alkaline cleaners. The use of an inhibitor may not be required with these materials.

The low pH or neutral cleaners do not usually require inhibitors.

Inhibitors may be used in the wash stage of a single stage cleaning process. They may also be used in the rinse state of a multiple step process.

Inhibitors may be used in all types of immersion spray machines.

SEQUESTERING AGENTS

Sequestering agents combine with calcium and magnesium ions and other heavy metal ions in hard water. They form molecules in which the ions are held so securely (sequestered) that they can no longer react.

The sequestering agents prevent salts from recontaminating parts.

Common sequestering agents include orthophosphate, orthosilicate and phosphates.

The sequestering agents may also tie up the active chemicals in a detergent that may decrease the cleaning efficiency and life of a wash bath.

Phosphates are a waste water problem since they contribute to eutrophication, the enrichment of water with nutrients that increase plant growth in water ways and sewer systems.

SURFACTANTS

Surfactants are also known as wetting agents. They can be formulated as liquids or as powders.

Surfactants are used in aqueous cleaners to provide detergency, emulsification, and wetting action. Surfactants in aqueous detergents lower the surface tension of the cleaning solution. They also ensure that water drains from a part after washing.

Surfactants used in aqueous cleaners are usually biodegradable. The various soils and parts used in your process and the concentrations of your cleaner will effect the biodegradability.

The four major classifications of surfactants are: anionic, non-ionic, cationic, and amphoteric. Anionic surfactants are water soluble and have positive ions. Cationic surfactants have negative ions and are considered to be poor cleaners. Non-ionic surfactants are the most widely used for surface cleaning and have no charge. Amphoteric surfactants develop a negative or positive charge depending on whether the solution is alkaline or acidic.

Non-ionic surfactants are a class of synthetic surfactants. They are prepared by attaching ethylene oxide molecules to a water insoluble molecule. The ethylene oxide molecules, derived from petroleum, are water-soluble polymers. Depending on the number of ethylene oxides and the number of carbon atoms, the synthetic surfactants can be classified as a wetting agent, a detergent, or an emulsifier.

Ionic surfactants are good detergents; however, they are made insoluble by many hard water metal ion, such as calcium and magnesium.

SECTION IV OTHER CONSIDERATIONS

BLIND HOLES

Blind holes are most effectively cleaned by using either a manual or automated hole flushing process. Hole flushing is best accomplished with a spray system. The kinetic energy of the spray is used to loosen and remove particles. The spray system can be a manual operation using a spray with a needle jet. The system could also be a custom designed spray header with nozzles designed to match a specific part.

Ultrasonics or agitation of the process bath may work. This should be tested before any purchase of equipment that depends on the effectiveness of these processes.

If the holes are being contaminated because of an operation on a different area of the part, you may want to consider a masking or plugging operation.

DRYING METHODS

If you think that your parts must be dry after cleaning, you should verify that this is indeed necessary. If the next process step that your part will see involves another liquid or cleaning step, don't dry.

If you need to dry because the next process is physically distant or there is a time delay between processes, consider moving the processes closer together.

Drying equipment may be at least as expensive as new cleaning equipment.

There are a number of methods available for drying:
- vacuum dry
- hot air dry (with or without filtration)
- infrared heaters
- centrifugal drying
- heat lamps

Vacuum drying is good for parts with blind holes and small crevices.

Hot air drying may use HEPA filtration to produce extremely clean drying air.

Use air knives to dewater a part prior to drying. This will speed up the drying process.

If possible, use a hot rinse or hot cleaning cycle in order to raise the temperature of the part(s) being cleaned. This will accelerate the drying process.

Energy consumption of drying equipment may be high.

PAINT

Cleaning chemistry selection is also affected by the paint. Most aqueous solutions should be safe for use. Whatever cleaning solution you select, make sure to test its effects on the type of coating on your part.

Alkaline aqueous chemistries have been used to strip some water based paints.

High pressure sprays may affect the coating. This is usually not a problem if dwell time of the spray on any one spot is minimized.

PARTICLES

Never allow wet particles to dry on a part. Clean part immediately after every wet process.

Store in covered racks.

Do not store near machining or other processing operations. Machining coolants that are allowed to dry are a source.

Ultrasonics and sprays are effective processes.

PLATED SURFACE

Plated surfaces may be affected by the more abrasive processes, such as a blasting operation.

The plating material may cause problems with disposal of the cleaning fluid. For example, chromated parts that are cleaned in aqueous solutions may contaminate the water. It may require pretreatment before it can be put to drain.

PROCESS CHIPS

Metal chips are best removed using a process that utilizes kinetic energy, as opposed to chemical action. Examples would be:

- spray processes
- ultrasonics
- blasting processes (these may create metal fines instead of metal chips)
- brushing

A common way to remove chips at the process location is to use compressed air.

A cleaning operation using a liquid should only be used when there is no dry alternative available. Consider hand wiping or brushing.

PROCESS FLUIDS

You should make sure that you really need to remove the fluid before considering any cleaning options. Before you implement a cleaning process, consider some of the following:

- elimination of the source of the fluid.
- invest the same capital required for cleaning in new equipment or processes that eliminate the need for cleaning.

If you're cleaning because the next process is at a remote location, consider moving the processes closer together and eliminating the cleaning step.

If you have to clean, consider using the process fluid as the cleaning fluid. This will eliminate a new waste stream that must be handled.

If you have to clean, you should use a water soluble process fluid. This will simplify your cleaning process. This will also simplify your waste discharge issues.

Fluids are best removed by spray type processes. The cleaning liquid used will also play an important role.

In some cases, especially with non-water soluble fluids, the chemistry of the cleaning liquid will be very important. Cleaning liquids can be used to form a chemical emulsion or a solvent to put the contaminant in solution. A rinse cycle of some type will still be required in order to flush of the cleaning fluid.

THIN FILMS

Thin film coatings will preclude the use of the more abrasive processes. For example, CO_2 pellets would cause damage to a thin film, but CO_2 snow might be ideal for particle removal.

SECTION V GLOSSARY

Anion A negatively charged ion.

Aqueous cleaning Parts cleaned with water to which may be added suitable detergents, saponifiers or other additives.

Azeotrope A mixture of chemicals is azeotropic if the vapor composition is identical to that of the liquid phase. This means that the distillate of an azeotrope is theoretically identical to the solvents from which it is distilled.

Biocide An additive that is destructive to biological contaminants in a wash bath.

Biodegradable Products in waste water are classed as biodegradable if they can easily broken down or digested by, for example, sewage treatment.

BOD An abbreviation for biochemical oxygen demand; a test used to determine the amount of oxygen consumed by bacteria and other microorganisms.

Buffer A solution selected or prepared to minimize changes in hydrogen ion concentration that would otherwise occûr as a result of a chemical reaction.

Buffering agent Drives an acidic or alkaline solution to neutral.

Cation A positively charged ion.

Chelation is the solubilization of a metal salt by forming a chemical complex or sequestering.

Chronic toxicity The long-term toxicity of a product in small, repeated doses. Chronic toxicity can often take many years to determine.

COD An abbreviation for chemical oxygen demand; a test that measures the amount of potential capacity for a microorganism to react with oxygen.

Colloid A substance that remains suspended in a solution or fails to settle out of solution.

Curd To cause to become viscous or thickened into coherent mass.

Conformal coating A protective material applied in a thin, uniform layer to all surfaces of a printed wiring assembly including components.

Defluxing The removal of flux residues after a soldering operation. Defluxing is a part of most high-reliability electronics production.

Detergency Lifting soil from a surface by displacing it with surface active materials which have a greater affinity for the surface than they do for the soil.

Detergent A product designed to render, for example, oils and greases soluble in water, usually made from synthetic surfactants.

Electrolytes Compounds that conduct an electric current by the movement of ions.

Emulsifier An aqueous additive used to keep soils dispersed throughout the cleaning fluid.

Flux An essential chemical employed in the soldering process to facilitate the production of a solder joint. It is usually a liquid or solid material, frequently based on rosin.

Greenhouse effect A thermodynamic effect whereby energy absorbed at the earth's surface, which is normally able to radiate back out to space in the form of long-wave infrared radiation, is retained by gases in the atmosphere, causing a rise in temperature.

Hydrocarbon An organic chemical composed only of hydrogen and carbon. Gaseous or volatile hydrocarbons are flammable.

Hydrolysis A chemical reaction of a substance with water, leading to decomposition or other change of substance.

Hydrophilic A substance is hydrophilic if it attracts water.

Hydrophobic A substance is hydrophobic if it repels water.

Immiscible Incapable of mixing or obtaining homogeneity.

Ion An atom or group of atoms that carries a positive or negative electric charge.

Inert gas soldering A soldering process done in a relatively oxygen-free atmosphere. The process greatly reduces oxidation of the solder, so that less flux is required, thereby easing or eliminating the need for cleaning.

Low-solids flux A flux which contains little solid matter, thereby easing or eliminating the need for cleaning. (See also no-clean flux).

MEA An abbreviation for monoethanolamine.

Miscible Capable of being mixed in any ratio without separation of two phases.

No-clean flux A flux whose residues do not have to be removed from an electronics assembly, therefore, no cleaning is necessary. This type of flux is usually characterized by low quantities of residues.

ODP An abbreviation for ozone depletion potential.

Ozone A gas formed when oxygen is ionized by, for example, the action of ultraviolet light or a strong electric field. It has the property of blocking the passage of dangerous wavelengths of ultraviolet light. Whereas it is a desirable gas in the stratosphere, it is toxic to living organisms at ground level (see volatile organic compound).

Ozone depletion Accelerated chemical destruction of the stratospheric ozone layer by the presence of substances produced, for the most part, by human activities. The most depleting species for the ozone layer are the chlorine and bromine free radicals generated from relatively stable chlorinated, fluorinated, and brominated products by ultraviolet radiation.

Ozone depletion potential A relative index indicating the extent to which a chemical product may cause ozone depletion. The reference level of 1 is the potential of CFC-11 and CFC-12 to cause ozone depletion. If a product has an ozone depletion potential of 0.5, a given weight of the product in the atmosphere would, in time, deplete half the ozone that the same weight of CFC-11 would deplete. The ozone depletion potential are calculated from mathematical models which take into account factors such as the stability of the product, the rate

of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules.

Ozone layer A layer in the stratosphere, at an altitude of approximately 10-50 km, where a relatively strong concentration of ozone shields the earth from excessive ultraviolet radiation.

Photochemical reaction A chemical reaction caused by light or ultraviolet radiation.

Pickling The removal of oxides (rust) with acidic materials.

Polymers Compounds of very high molecular weights that are built up of a large number of simple molecules which have reacted with one another.

POTW Publicly Owned Treatment Works - your local water/sewage treatment facility.

PWA An abbreviation for printed wiring assembly.

Reflow soldering A method of electronics soldering commonly used with surface mount technology, whereby a paste formed of solder powder and flux suspended in an organic vehicle is melted by the application of external heat.

Rosin A solid resin obtained from pine trees which, in a pure form and usually with additives, is frequently used as a flux.

Saponifier A chemical designed to react with organic fatty acids, such as rosin, some oils and greases etc., in order to form a water-soluble soap. This is a solvent-free method of defluxing and degreasing many parts. Saponifiers are usually alkaline and may be mineral (based on sodium hydroxide or potassium hydroxide) or organic (based on water solutions of monoethanolamine).

Solvent Although not a strictly correct definition, in this context a product (aqueous or organic) designed to clean a component or assembly by dissolving the contaminants present on its surface.

Surfactant A product designed to reduce the surface tension of water. Also referred to as tensio-active agents/tensides. Detergents are made up principally from surfactants.

Terpenes Any of many homocyclic hydrocarbons with the empirical formula $C_{10}H_{16}$.

Vapor phase cleaning A cleaning process, usually with CFC-113 solvent or hydrochlorocarbon solvents, where the final rinse of the parts being cleaned is achieved by condensing solvent vapors on the parts.

Volatile organic compound (VOC) These are constituents that will evaporate at their temperature of use and which, by a photochemical reaction, will cause atmospheric oxygen to be converted into potential smog-promoting tropospheric ozone under favorable climatic conditions. Some areas may classify a substance to be a VOC based on its vapor pressure.

Water-soluble flux A flux, which itself may be free from water, but whose residues after soldering may be entirely eliminated by a water wash. Such fluxes are usually very active so adequate defluxing is an essential part of their use. They are also known as Organic Acid (OA) fluxes or inorganic acid fluxes.

Wetting agents Another name for surfactants.

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SECTION VII EQUIPMENT VENDORS

AQUEOUS WASHERS

ADF Cleaning Systems
1103 16th Avenue North
P.O. Box 278
Humboldt, Iowa 50548
Phone:515/332-5400
800/798-5100
FAX:515/332-4475

American Metal Wash, Inc.
P.O. Box 265
Canonsburg, PA 15317
Phone:412/746-4203
FAX:412/746-5738

Applied Technology
517 West 46th Street
Minneapolis, MN 55409
Phone:612/825-6111
FAX:612/885-9783

Better Engineering
7101 Bel Air Road
Baltimore, MD 21206
Phone:800/229-3380

Blackstone Ultrasonics
Nine North Main Street
P.O. Box 220
Jamestown, NY 14702-0220
Phone:716/665-2340
FAX:716/665-2480

Bowden Industries
1004 Oster Drive N.W.
Huntsville, AL 35816
Phone:800/553-3637

Cleanomat
664 Medelssohn Avenue
Golden Valley, MN 55427
Phone:612/591-9388

Continental Equipment
Corporation
6103 North 76th Street
P.O. Box 18662
Milwaukee, WI 53218
Phone:414/463-0500
FAX:414/463-3199

Durr Industries, Inc.
40600 Plymouth Road
P.O. Box 2129
Plymouth, MI 48170
Phone:313/459-6800
FAX:313/459-5837

Electronic Controls Design, Inc.
4287-A S.E. International Way
Milwaukee, Oregon 97222-
8825
Phone:503/659-6100
800/323-4548
FAX:503/659-4422

Epcon Industrial Systems, Inc.
P.O. Box 7060
The Woodlands, Texas 77387
Phone:409/273-1774

FMT, Inc.
1950 Industrial Drive
Findlay, Ohio 45840
Phone:419/422-0768
800/878-8011
FAX:419/422-0072

FPI Systems
50 Devine Street
North Haven, CT 06473
Phone:203/281-6161
FAX:203/248-3908

Graymills
Chicago, Il 60613-3594
Phone:312/248-6825
FAX:312/477-8673

Greco Bros., Inc.
Greco Lane
Providence, R.I. 02909
Phone:401/421-9306
FAX:401/274-8910

Hubbard-Hall Inc.
P.O. Box 790
Waterbury, CT 06725
Phone:203/756-5521
FAX:203/756-9017

Intercont Products
2600 North Westgate
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J.S. Mannor Machine
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Woodstock, Illinois 60098
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Man-Gill Chemical
23000 St. Claire Avenue
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Phone:216/486-5300
800/627-6422
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Napco
A subsidiary of Thermo
Electron Corporation
Plymouth Industrial Park
Terryville, CT 06786
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FAX:203/589-7304

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1615 Johnson Road N.W.
Atlanta, Georgia 30318
Phone:404/799-1292
800/366-6682
FAX:404/799-1873

Ramco
32 Montgomery Street
Hillside, New Jersey 07205
Phone:908/687-6700
FAX:908/687-0653

Roto-Jet of America Co., Inc.
2819 San Fernando Boulevard
Burbank, California 91504
Phone:818/841-1520
FAX:818/6448

Sanborn
25 Commercial Drive
Wrentham, MA 02093
Phone:508/384-3181
800/343-3381
FAX:508/384-5346

Stoelting Inc.
502 Highway 67
Kiel, WI 53042
Phone:414/894-7029

AQUEOUS CHEMICALS

BioGenesis Enterprises, Inc.
2466 South 99th Street
Milwaukee, Wisconsin 53227
Phone:414/321-8509
FAX:414/321-8609

Brulin Corporation
P.O. Box 270
Indianapolis, Indiana 46206
Phone:317/923-3211
800/776-7149
FAX:317/925-4596

C & H Chemical Company
222 Starkey Street
St. Paul, MN 55107
Phone:612/227-4343
800/328-4827

ETUS, Inc.
1511 Kastner Place
Sanford, Florida 32771
Phone:407/321-7910
FAX:407/321-3098

Fremont Industries
4400 N. Valley Industrial Blvd.
Shakopee, MN 55379
Phone:612/445-4121

Heatbath Corporation
P.O. Box 2978
Springfield, MA 01102-2978
Phone:413/543-3381
FAX:413/543-2378

Texo Corporation
2801 Highland Avenue
Cincinnati, Ohio 45212
Phone:513/731-3400

W.R. Grace & Co. - Conn.
55 Hayden Avenue
Lexington, MA 02173-7999
Phone:617/861-6600
FAX:617/861-9066

HEAT CLEANING

Armature Coil Equipment, Inc.
4725 Manufacturing Road
Cleveland, Ohio 44135-2696
Phone:216/267-6366
800/255-1241
FAX:216/267-4361

Blu-Surf
P.O. Box 190
Parma, MI 49269
Phone:517/531-3346
FAX:517/531-3589

Epcon Industrial Systems, Inc.
P.O. Box 7060
The Woodlands, Texas 77387
Phone:409/273-1774

Kolene Corporation
12890 Westwood Avenue
Detroit, Michigan 48223
Phone:313/273-9220
800/521-4182
FAX:313/273-5207

Seghers Dinamec, Inc.
351 Thorton Road, Suite 115
Lithia Springs, GA 30057
Phone:404/739-4205
FAX:404/944-2236

LOW VOC SOLVENT

Kleer-Flo Company
15151 Technology Drive
Eden Prairie, MN 55344
Phone:612/934-2555
800/328-7942
FAX:612/934-3909

Micro Care Corporation
34 Ronzo Road
Bristol, CT 06010
Phone:203/585-7912
800/638-0125
FAX:203/585-7378

Penetone Corporation
P.O. Box 22006
Los Angeles, CA 90022-0006
Phone:213/726-1579
800/433-2499
FAX:213/726-0141

Silicon Valley Chemlabs, Inc.
3446 De La Cruz Boulevard
Santa Clara, CA 95054
Phone:408/457-8418
408/970-0656
FAX:408/970-0659

MEDIA BLASTING

Alpheus Cleaning Technologies Corporation
9105 Milliken Avenue
Rancho Cucamonga, CA 91730
Phone:714/944-0055
FAX:714/980-5696

CDS Group
469 North Harrison Street
P.O. Box CN5297
Princeton, NJ 08543-5297
Phone:609/497-7284
800/221-0453
FAX:609/497-7176

Cold Jet, Inc.
455 Wards Corner Road, Suite 100
Loveland, Ohio 45140
Phone:513/831-3211
FAX:513/831-1209

Empire Abrasive Equipment Corp.
2101 W. Cabot Blvd.
Langhorne, PA 19047-1893
Phone:215/752-8800
FAX:215/752-9373

Ice Blast International Corporation
627 John Street, Victoria, B.C.
Canada V8T 1T8
Phone:604/383-2155
FAX:604/386-2512

Jet Wheelblast Equipment
A division of B&U Corporation
401 Miles Drive
Adrian, Mich. 49221
Phone:517/263-0502
FAX:517/263-0038

Long Painting Company
8025 10th Avenue South
Seattle, Washington 98108
Phone:206/763-8433
FAX:206/762-6444

Maxi-Blast Inc.
630 East Bronson Street
South Bend, IN 46601
Phone:219/233-1161
800/535-3874
FAX:219/234-0792

Pauli & Griffin Company
907 Cotting Lane
Vacaville, California 95688
Phone:707/447-7000
FAX:707/447-7036

PRESSURE WASHING

Alkota Cleaning Systems
P.O. Box 158
Alcester, South Dakota 57001
Phone:605/934-2222
800/255-6823
FAX:605/934-1808

Mi-T-M Corporation
8545 Kapp Drive, Box 50
Peosta, IA 52068
Phone:319/556-7484
800/553-9053
FAX:319/556-1235

ULTRASONIC BATH

Branson Ultrasonics
Corporation
41 Eagle Road
Danbury, CT 06813-1961
Phone:203/796-0400
FAX:203/796-0450

Crest Ultrasonics
Scotch Road
Mercer County Airport
P.O. Box 7266
Trenton, NJ 08628
Phone:609/883-4000
800/441-9675
FAX:609/883-6452

Lewis Corporation
102 Willenbrock Road
Oxford, CT 06478
Phone:203/264-3100
800/243-5092
FAX:203/264-3102

Ransohoff Company
North Fifth St. at Ford Blvd.
Hamilton, Ohio 45011
Phone:513/863-5813
800/248-9274

Sonicor Inc.
100 Wartburg Avenue
Copiague, NY 11726
Phone:516/842-3344
FAX:516/842-3389

Swen Sonic Corporation
960 Rolff Street
Davenport, Iowa 52802
Phone:319/322-0144