Amid the many advantages and disadvantages of aqueous and semi-aqueous methods, precision cleaning with solvents emerges as another practical option.

Solvent-Based Cleaning: A Viable Alternative for Precision Cleaning

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Industrial cleaning is facing a revolution. Drastic changes in the industry are being driven by two competing goals: highly cleaned parts and products, and increasingly stringent environmental regulations including limitations on chlorinated hydrocarbon production and consumption.

Ten years ago, cleaning processes were dominated by CFC-113 (Freon) degreasers and cleaned components were considered "clean enough." Today, engineers selecting appropriate cleaning processes are faced with an almost overwhelming number of choices for cleaning methods and solutions. Identifying a process to ensure that a given component is consistently cleaned to specified levels while also complying with regulations on solvent emissions, solid waste, wastewater treatment, and numerous other regulatory issues is practically a development problem in itself.

In the 1920s and 1930s hydrocarbons were the standard industrial cleaning solvents. As safety regulations tightened, hydrocarbon use dropped significantly because many organics are flammable or combustible (flammable liquids have flash points less than 140°F and vapor pressures not exceeding 40 psia at 100°F; combustible liquids have flash points at or above 140°F).

Chlorofluorocarbons (CFCs) and methyl chloroform (MCF) became the new industrial standards, exhibiting good solvency for a wide variety of organic contaminants. These solvents are inert to most materials and are not corrosive; their high vapor pressure and low heats of vaporization are beneficial in vapor cleaning processes and drying of cleaned parts. They have no flash point and low toxicity, and can be made extremely stable when formulated with adequate stabilizers, making them relatively easy to handle.[1]

Phaseouts Ushered In

In 1986, approximately 19 percent of the global fluorocarbon market (1 billion kg per year) was used for cleaning.[2] As much as 85 percent of chlorosolvent use was for cleaning applications within the electronics industry during 1991.[3] Recognition of fluorocarbons' contributions to the depletion of the ozone layer prompted a worldwide phaseout of these chemicals.

The 1987 Montreal Protocol, an international treaty involving more than 65 countries, was ratified in an effort to protect the stratospheric ozone layer by controlling the production and consumption of ozone-depleting chemicals. At a 1990 meeting in London, treaty signatories agreed to complete the phaseout of CFCs by the year 2000. In 1992, President Bush called for an accelerated deadline, yearend 1995, for complete phaseout by the United States of CFC-113, MCF, carbon tetrachloride, and three halons. Montreal Protocol signatories subsequently agreed to match this U.S. timetable.

Substitutes Proposed

A number of perfluorocarbons (PFCs) developed as replacements for CFCs have already been condemned by the Environmental Protection Agency (EPA) as potential contributors to global warming. The EPA expects to issue minimum achievable control technology requirements under the Clean Air Act by 1994.[4] PFCs are not satisfactory cleaning agents, but are excellent rinsing solvents producing spot-free, dry surfaces.[5]

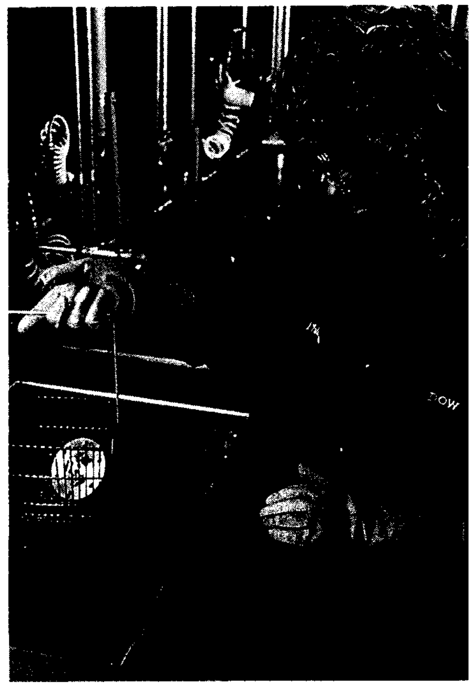
Several hydrochlorofluorocarbons (HCFCs) were similarly proposed as possible CFC substitutes. Many of these HCFCs also have been found to have low but non-zero ozone depletion potential.[4,6] The Clean Air Act freezes production of HCFCs in 2015 and phases them out entirely by 2030. Thus, perfluorocarbons and hydrochlorofluorocarbons are not suitable long-term replacements for CFCs.

Hydrofluorocarbons (HFCs) currently being developed are believed to be non-carcinogenic with zero ozone depletion potential. These compounds are not commercially available, but may be on the market as early as 1995.[7] Preliminary studies, however, indicate that HFCs will not clean as well as CFCs.[8]

Regulation Proliferation

In addition to regulations on ozone-depleting chemicals, federal, state, and local governments are enacting ordinances that dramatically reduce allowable emissions.

Volatile Organic Compounds (VOCs) are highly regulated



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in many parts of the country. These compounds evaporate at the temperature of use and, as a result of photochemical reactions, cause atmospheric oxygen to be converted into potential smog promoting tropospheric ozone under certain climatic conditions.

Many ordinances are quite limiting. The Bay Area Air Quality Management District Regulation 2, Rule 2-301, for example, severely restricts emissions from any new or modified equipment within the San Francisco Bay Area. A "modification" may be as minor as changing the solvent used with operating equipment. Such modifications are often subject to re-permitting and more stringent controls. Furthermore, some states have prohibited the use of substances due to possible toxic health effects. New Jersey, for example, has banned methylene chloride.[1]

Factors of Choice

Selection of an alternative cleaning process must be based on several factors: consideration of the soils being removed, the substrates being cleaned, the number of parts to be cleaned, existing facilities available for cleaning (i.e., equipment, floor space, etc.), the regulations that control emissions and wastes from the cleaning processes and, ultimately, any costs associated with the process.

Specified levels of cleanliness are the foremost priority. In many cases, evaluation of how clean a component is after cleaning can strain current measurement techniques. Knowledge of part size and shape is essential for the development of the appropriate cleaning process. Component material and solvent compatibility is critical. Corrosion, cracking, pitting, swelling, crazing, and many other failures can result from material incompatibility. Parts with rough surfaces, porous coatings, permanent overlapping joints, or blind holes can retain solutions that cause part defects or compromise further manufacturing operations such as coating or bonding.

Choosing an appropriate cleaning method is clearly a complicated process that must be carefully analyzed in order to meet technical requirements while remaining economically competitive. One of the first steps in selecting the appropriate cleaning process is deciding between an aqueous-based, semi-aqueous, or solvent-based approach. Following is a discussion of the pros and cons of each.

Aqueous Cleaning

Aqueous cleaning is a mature technology widely accepted for certain industrial cleaning. An estimated 85 to 90 percent of metal-cleaning applications and 90 percent of all non-surface mount electronic cleaning applications that use CFCs can be replaced by aqueous systems.[3]

Among the many approaches to precision cleaning, aqueous solutions should always be considered first, on the basis of two key advantages: the solvent (i.e., water) is inherently safe (not flammable, combustible, or toxic) and does not contribute to ozone depletion or smog. In general, aqueous cleaning solutions cost less than organic solvents. Most aqueous cleaning protocols proposed as replacements to cleaning with CFCs, however, are quite comp1ex.[9]

Aqueous cleaning solutions are usually comprised of four major components: water, builders, organic, and inorganic additives to promote better cleaning, and surfactants. In some cases, aqueous cleaning without additions has been found to provide adequate cleaning.[10]

Builders are added to the solution in the largest quantity. They are a blend of alkaline salts, generally either alkali metal orthophosphates and condensed phosphates, alkali metal hydroxides, silicates, carbonates, bicarbonates, or borates. Phosphates are the best builders, but any discharge of wastewater containing them is subjected to environmental regulations. Sometimes chelating agents (i.e., EDTA) and nitrates can be used instead of phosphates. Silicates can be difficult to remove during rinsing, while carbonates and hydroxides are effective and inexpensive builders.[1]

The organic and inorganic compounds added to promote better cleaning include glycols, glycol ethers, chelating agents, and polyvalent metal salts. Surfactants, including detergents, emulsifiers, and wetting agents, are unique because of their chemical structure. Each molecule has a hydrophobic option and a hydrophilic option. This unusual structure provides high affinity for surface adsorption.[1]