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Vapor-Phase Cleaning: An Old Technology Is Riding High On the Comeback Trail

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For many production engineers, cleaning is a thorn in their side. In the past, the decisions were simple: a spray can of CFCs for spot cleaning and a vapor degreaser for cleaning the whole board. But the ozone issue forced most suitable chemistries off the market, and now many conflicting obligations must be balanced when selecting a solvent. But times are changing, and this report will review some of the new cleaning chemistries arriving onto the market and evaluate their effectiveness in vapor phase cleaning systems.

A Thumbnail History of Vapor Degreasing

The commercialization of the first "safety solvents" in the mid-1950s introduced vapor phase cleaning technology to industry. These chemistries replaced flammable alcohol-, benzene- and ketone-based cleaners and all the handling problems they posed. Since then, vapor degreasing has been widely adopted in the electronics industry because it works so inexpensively and reliably. Despite the ozone issue, the use of nonflammable solvents has saved many lives over the past forty years.

The biggest dilemma for process engineers has been the diminished range of **nonflammable** solvent choices. "The efforts by the EPA to protect the environment have put stringent controls on the

selection and use of fast-drying solvents," notes Frank Salamone, Sales Manager at Ultra-Kool, Inc., a Pennsylvania-based manufacturer of vapor degreasers. Since the mid-1980s, engineers have been able to gradually eliminate CFCs, 1,1,1-TCA and other Class I ozone depleters. The 1997 phase-out of HCFCs eliminated that option from vapor tanks. Among the remaining choices, TCE is viable but it brings a whole host of health risks and regulatory problems. Methylene chloride, perc and other old-style solvents are equally burdensome.

But there has been progress on the equipment side as well as on the solvents. "Today's tighter, more efficient equipment helps protect the ozone layer while keeping operating costs at reasonable levels," Salamone notes. Today there are five viable solvent choices for traditional vapor phase electronics cleaning: HFC solvents from DuPont, the fully-fluorinated PFC solvents from 3M Corp., the HFE solvents also from 3M, brominated solvents from a number of vendors, and a single HCFC blend from Asahi. From the gloomy perspective of only five years ago, the introduction of five new choices is a remarkable accomplishment.

Hydrofluorocarbons Are An Optimal Choice

DuPont pioneered the commercialization of CFCs, but in many respects it took a back seat in the commercialization of ozone-safe alternatives. With their recent introduction of the Vertrel® family of hydrofluorocarbon solvents ("HFCs"), DuPont has shown that they understand precision cleaning better than anyone.

HFCs are relatively mild solvents. When mixed with additives, they azeotrope easily to strengthen their cleaning power so they are highly effective at normal temperatures. They are easily contained in modern "low emission" vapor systems. These solvents are fast-drying and have almost no aroma. Their materials compatibility is very good even with the additives which boost their cleaning power. Shipping, handling and storage characteristics are excellent.

The DuPont solvents have a superior environmental pedigree. Completely ozone-safe, they also have a low global warming impact and by themselves do not contribute to low-altitude smog (although some of the additives do). The toxicity ratings for HFC solvents are very good, with a threshold limit of 200 part per million (ppm) and a maximum exposure level of 400 ppm. These are very acceptable limits because with today's modern degreasers anything over ten parts per million is a rare event.

HFCs are easy to find. They are available in bulk and aerosol packaging through a well-established base of DuPont distributors. There also is a fairly broad range of blends at different price points, and DuPont and MicroCare

have jointly developed an inexpensive blend for use in aerosol cans.

Perfluorocarbons (PFC) Solvents Contribute to Global Warming

Produced by 3M Corp., perfluorocarbons ("PFCs") are termed "fully fluorinated" solvents and have several extraordinary attributes. First and foremost, they have the best toxicity ratings of any solvent on the market today. They are compatible with most materials and their handling is straightforward. Since some blends are dense enough to float a golf ball, PFCs can easily displace oils, fluxes and grime. PFCs also are widely used as carriers in deposition processes, such as the placement of lubricants on CD drives. Most interestingly, PFCs are being considered as the feed stock for synthetic blood.

PFCs achieve this remarkable degree of compatibility in exchange for being pretty weak cleaners. In fact, PFCs won't clean anything at all unless they are mixed with other additives. But PFCs are loners -- like oil and water, PFCs and additives refuse to stay blended -- so in most instances PFCs are used in very high concentrations.

Other drawbacks include cost and environmental concerns. While PFCs are amazingly expensive they can be the right choice for some applications. In terms of the environment, they are completely ozone-safe. But PFCs are so stable that they never decompose, giving PFCs a major global warming factor. Therefore, while the E.P.A. allows its use and they are available in aerosol packaging for specialty requirements, it is unlikely that PFCs will ever see widespread deployment in vapor degreasers.

Hydrofluoroethers(HFE) Solvents Are an Excellent But Expensive Choice

3M Corp. also is aggressively marketing a family of hydrofluoroether solvents ("HFEs") to the electronics industry. This answer, while technically excellent may not be the choice for everyone.

These solvents are easily contained in modern "low emission" vapor systems. They are fast-drying and have almost no aroma. Their materials compatibility is very good. Shipping, handling and storage characteristics are excellent. HFEs are completely ozone-safe, with a very low global warming impact and they do not contribute to low-altitude smog. The toxicity ratings are very good at 600 ppm, they are generally plastic-safe and offer easy storage and handling.

Like HFCs and PFCs, HFEs are pretty weak cleaners. With azeotropic additives, their cleaning power can be boosted to very acceptable levels and they work well in modern vapor systems.

HFEs are most often found in "co-solvent" vapor degreasing systems, a process refined by the talented scientists at Petroferm, Inc. in Fernandina Beach, Fla. Co-solvent cleaning uses non-volatile polar organic solvents in conjunction with HFEs. The organic solvent is mixed with the HFEs in the boiling sump of the machine. The HFEs boil but the vapors are recaptured in the cold trap. Meanwhile, the organic solvent never gets hot enough to volatilize so it stays in the boiling sump of the machine. The result is spectacular cleaning and relatively quick cycle times. Co-solvent cleaning requires submersion, which is not suitable for all types of parts. "For contamination that is extremely difficult to clean, or for very high temperature applications, co-solvent cleaning is the process of choice," reports Rich Stewart, Director of International Sales and Marketing at Petroferm.

One drawback, of course, is the cost. The capital expense of a co-solvent system is not trivial, and the HFEs can be costly. But the drag-out losses are minimal and the quality of the results are exceptional.

3M is actively marketing the material through a number of repackagers, and the competition is fierce. Available in aerosol and in bulk packaging, HFEs are a great but perhaps slightly expensive choice.

Hydrochlorofluorocarbons (HCFCs) Are Ozone-Depleting Solvents

Of all the HCFC choices, only HCFC-225 remains as a legal and safe option for use in vapor cleaning systems.* Produced in Japan by Asahi, it has been available in the U.S. for four or five years. Initially hailed as a replacement of CFC-113, its rate of acceptance has been limited by environmental and safety issues.

As a cleaner, HCFC-225 is a good choice. It is a fairly active cleaner and works well in vapor phase systems. It works on a broad variety of contamination. It dries quickly, is easily recycled, and has almost no aroma. It is a low-VOC material and, depending upon the particular blend selected, can be 100% free of VOCs. While there are some problems with materials compatibility, they are manageable. All other things being equal, this chemistry should be a very viable candidate.

Unfortunately, HCFC-225 contains chlorine and is an ozone-depleting material. It has an Ozone Depletion Potential of 0.02 and is listed in the Montreal Protocol (although with a delayed phase-out date). Most customers, having endured the problems of migrating from ozone-depleting solvents, would prefer to not to be faced with that trauma again. They would rather

make the switch once to a completely ozone-safe alternative if possible.

Three smaller issues linger. First, the material is fairly expensive, although not at the level of the HFEs and PFCs. Secondly, HCFC-225 cannot be sold in the European Union, Australia nor New Zealand. This forces multinational manufacturers to specify different manufacturing processes in different parts of the world, which is a complexity most firms would avoid if they could. Lastly, HCFC-225 normally is not available in aerosol packaging, which limits the usefulness of the solvent in many electronics facilities.

Brominated Solvents Are Powerful Cleaners

The last of the five choices is a new and unusual chemistry, a bromine compound called n-propyl bromide or "NPB." Bromine is in the halogen family of chemicals, just like chlorine and fluorine, so NPB offers similar cleaning horsepower. The handling and toxicity issues are well understood because NPB has been used for years in a wide variety of industrial applications. It has been approved by the E.P.A. as a replacement for ozone-depleting solvents, although aerosol approval may be withheld.

Uniquely, NPB is more comparable to 1,1,1,-TCA than CFCs. It has very high Kari-Butanol ratings and is easily the most aggressive of these five solvents. It boils at higher temperatures which means it is a good choice for removing waxes and some coatings. Like 1,1,1-TCA, materials compatibility can be an issue. NPB solvents have been assigned a toxicity rating of 100 ppm, which is on the lower side of the scale but manageable. Perhaps most importantly, NPB is much less expensive than any of the other new choices on the market today.

Two issues cloud the horizon for NPB. First, like 1,1,1-TCA and unlike the HFCs, moisture can accumulate in the solvent and cause it to go "acid." End-users will have to be conscientious about monitoring the stabilizer in the solvent. There are significant differences in NPB blends and their stabilizer packages which affect their cost, their purity, and even their aromas. Customers will have to be cautious when selecting a vendor of NPB.

The second problem is ozone-depletion issue. NPB has an ozone depletion potential in the range of 0.02, roughly the same as HCFC-225. But there the solvent is not listed on the Montreal Protocol and therefore is exempt from many of the ozone regulations. Brominated solvents are prohibited in the E.U.

Overall, NPB has very familiar handling and storage requirements, offers better cleaning at higher temperatures than the other new alternatives, and is about one-third the price of the HFEs and HCFC-225. This combination of

factors will make NPB the cleaner of choice in many applications.

More Challenges, More Choices

While there always has been a segment of the cleaning industry forecasting the end of vapor degreasing, "solvent cleaning is here to stay," says Salamone of Ultra-Kool. Computer models show the ozone layer should start to rebuild early in the next century. Looking to the future of precision cleaning, the environmental issues looming on the horizon include smog caused by volatile organic solvents, climatic change from the use of global warmers, the recycling and disposal of waste solvents, and the availability and disposal of water used in aqueous cleaning systems. Solving these problems will make the ozone issue seem like a walk in the park. Engineers looking for long-term solutions should keep an eye on these issues.

In our opinion, NPB offers superior cleaning, simplified handling and is an excellent value. For companies demanding lower temperatures, greater safety, or with materials compatibility issues, DuPont's HFCs are probably the best choice. But any one of these five cleaners potentially is highly suitable for vapor degreasing with today's newer, tighter machines.

The best way to compare the solvents? Try them all in benchtop applications. Develop a standardized testing routine using small circuit boards or other sample parts. Obtain solvent samples from selected vendors and try them at room temperature. If they work when they are cold, they will work even better warmed in a vapor degreaser.

Whichever alternative solvent is selected, good chemical management will be a mandatory requirement. Spills, aroma problems and drag-out losses are signs of sloppy housekeeping. Engineers should search for the cleaning and dispensing technologies which will minimize costs, improve personnel safety and maximize production efficiencies. Good chemical management will minimize those risks and increase cleaning effectiveness and keep cleaning costs to a minimum.

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EDITORS NOTE: Since MicroCare packages the electronics industry's broadest line of solvent alternatives, it is one of the few sources of unbiased, hands-on experience with all of cleaning chemistries ranging from old-style CFCs through to the newest formulations included in this report. It's

important to realize, however, that technology and information have evolved from the situation reported in this article. Contact MicroCare for more details and questions.

Related Information:

- For additional information about the ozone-safe DuPont HFC solvents, check out the Vertrel® solvents web site.
- For other information about the Bromothane™ brand of nPB solvents, check out the Bromothane™ web site.
- For additional help, use the *Solvent Selection Guide* in this Site to help determine the optimal recommendation.
- A simplified PDF version of the same Selection Guide also is available.

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