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13 Key Criterion for HCFC-141b Aerosol Replacements

How to Test Alternative Solvents to Ensure Long-Term Effectiveness

by Steve Cook

The most widely used aerosol solvent in the electronics industry is going away. The EPA has phased out HCFC-141b, which was introduced as a replacement cleaner to CFC chemistry in the early 1990's. An estimated nine million pounds of HCFC-141b were used for cleaning last year alone. New replacements are now available — which unlike the conversion from CFCs — perform better, are more eco-friendly, and are more efficient in terms of total usage cost.

December 31, 2002 was the last date to manufacture HCFC-141b. Title VI of the Clean Air Act directs the Environmental Protection Agency (EPA) to protect the ozone layer through several regulatory and voluntary programs. Acting under this directive, and to meet the requirements of the Montreal Protocol, the EPA stopped all production for domestic consumption of HCFC-141b due to its ozone depletion factor. As a result, many companies have begun the search for a new solvent to replace this popular cleaner.

HCFC-141b was popular because it is nonflammable, evaporates rapidly, cleans efficiently, and is moderately compatible with plastics. Therefore, a proper evaluation of alternatives must consider these factors.

Beyond flammability, evaporation, cleaning capability, and plastics compatibility, the following decisive factors must also be investigated before a solvent can truly be considered a viable replacement. The first four items are the very critical; so an HCFC-141b aerosol replacement must pass all four to be considered an adequate alternative. They are:

1. SNAP approval
2. Nonflammable in aerosol form
3. California Proposition 65 compliance
4. Exposure limit appropriate for aerosol application

   Once the alternative passes these criteria it must be evaluated for suitability in the user's specific applications. The following are basic criteria used to distinguish various solvents and their uses:

5. Cleaning efficiency as good or better than HCFC-141b
6. Kauri Butanol Value (Kb)
7. No ozone depletion potential
8. No noxious fumes
9. Evaporation
10. Low surface tension
11. Plastic compatibility similar to or better than HCFC-141b
12. Low VOC content
13. Low global warming potential

Criteria 1: SNAP Approval

A viable 141b alternative must be SNAP listed. The EPA created the Significant New Alternatives Program (SNAP) under section 612 of the Clean Air Act. SNAP evaluates the overall risk to human health and the environment posed by alternatives to Class I and Class II ozone depleting substances. Substitutes are reviewed on the basis of ozone depletion potential, global warming potential, toxicity, flammability, and the use-specific exposure potential as described in the March 18, 1994 final SNAP rule (59 FR 13044).

Lists of acceptable and unacceptable substitutes are updated periodically in the Federal Register. Compounds listed as pending or those that have been submitted for approval may be used after a 90-day waiting period. However, the user must be aware that the EPA may not ultimately approve the process or compound.

Criteria 2: Flammability

In the electronics and industrial industries, many aerosol-cleaning products are used on live circuits or the substrate is powered down, cleaned, and immediately powered back up — often still wet. In those cases, the product must be nonflammable when used in an aerosol. Furthermore, it is always safer to use nonflammable products when they are available. An aerosol product is nonflammable if it propagates a flame of less than 18 inches when sprayed through a standing flame. A flammable aerosol should not be considered as a viable HCFC-141b replacement. Testing for aerosol flammability should be performed in compliance with ASTM D 3065.

Criteria 3: Prop 65

The third pass/fail criterion is based on the that have

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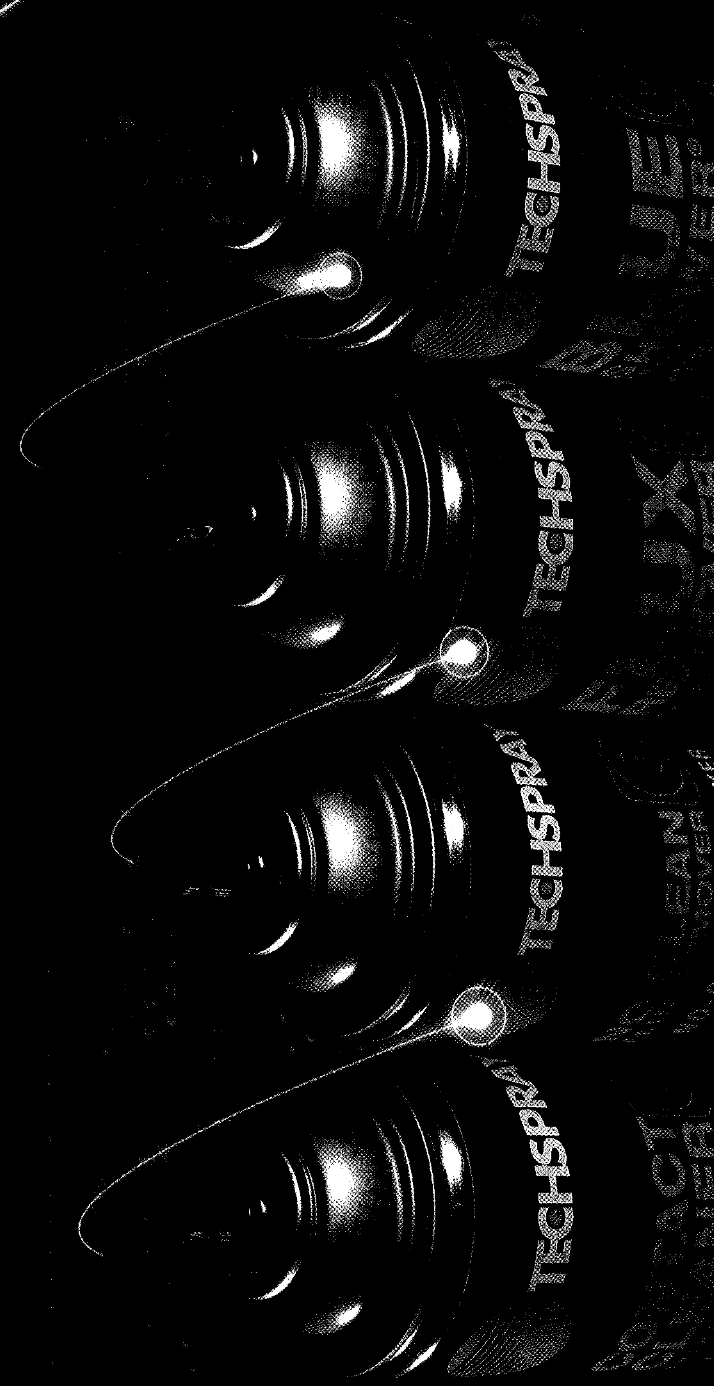

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The use of this product for cleaning is subject to U.S. Patent No. 5,904,412

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been determined by the state of California to be known carcinogens or producers of reproductive toxicity. The proposed product must not be on this list. If any of the ingredients in a blend are Prop 65 listed, then the product is not a good 141b replacement.

Criteria 4: Exposure Limit

In contrast to sealed cleaning systems, aerosols, by the nature of the delivery method, have greater exposure potential. Because of this, it is inadvisable to use an aerosol solvent that falls below a 50 ppm (parts per million) exposure level.

Criteria 5: Cleaning Efficiency

In order to be considered a good 141b alternative, a solvent must clean in compliance with Mil-PRF-29608. In this standard, four different contaminants are used to contaminate four different coupons.

a. Mil-C-81309 (corrosion preventative)
b. Mil-H-83282 (hydraulic fluid)
c. VV-D-1078 (silicone damping fluid)
d. J-STD-004, Type R (rosin soldering flux)

Five drops of a test soil are applied to each of the three panels with a pipette or eyedropper and spread with a brush. This procedure is repeated for each of the test soils. The MIL-C-81309 coupons are then baked at 105 C +/- 1 C (221 F +/- 2 F) for one hour. Panels coated with flux in accordance with the J-STD-004 are dried at room temperature for one hour. Panels coated with fluids in accordance with MIL-H-83282 and VV-D-1078 should be tested wet.

The soiled panels are then placed approximately 45° from horizontal. The compound under test should be sprayed for five seconds across each panel and allowed to evaporate for 10 minutes. The bottom edge and the reverse side of the panel should be wiped to remove displaced soil.

The cleaning efficiency calculation is expressed as cleaning efficiency. The coupons must be cleaned, dried, and weighed prior to contamination. Record this weight as W1. After the panels are soiled as explained above, the result should be recorded as W2. After the panels are sprayed and wiped, they should be reweighed and recorded as W3.

$$\% \text{ Cleaning efficiency} = W2-W3/W2-W1 \times 100$$

Criteria 6: Kauri Butanol Value

A Kauri Butanol (Kb) value is a measure of solvent power of hydrocarbon solvents — another test for cleaning effectiveness. Kauri gum is readily soluble in butanol and insoluble in hydrocarbons. Therefore the Kb value is the measure of the volume of solvent required to produce turbidity in a standard solution of Kauri gum dissolved in butanol.

High Kauri Butanol values indicate relatively strong solvency. Naphtha's usually have a Kb value of about 30, while toluene is around 105. All Kb values should be tested and calculated in compliance with ASTM D 1133.

Criteria 7: Ozone Depletion Potential

The Ozone Depletion Potential (ODP) should be reviewed when considering HCFC-141b replacement chemistry. This is particularly important because HCFC-141b is being phased out because it has an ODP value of 0.11. The ideal replacement should have a minimal potential to avoid future government intervention and negative ecological impact. When there is a blend of two or more chemicals and each has an ODP value, record the highest individual ODP value for the blend.

Criteria 8: Noxious Fumes

In an aerosol cleaning application, the surrounding air may become saturated with atomized aerosol vapor. Many times cleaning is performed at an isolated workstation with minimal airflow. In these instances, air quality is critical. Therefore, another criterion that is used to determine a replacement is odor. A subjective test can be used where the products are ranked from 1-10 with a score of 10 being the most offensive.

To perform this test, take blind aerosol samples of the finished products and allow each test subject to spray a substrate for two seconds. You then ask each person to rank the odor from 1-10. Add the results and divide by the number of participants to get the mean average. A minimum of five participants is recommended.

Criteria 9: Evaporation Rate

Whether cleaning a part or reworking a bad component on a printed circuit board, down time and production time are critical. In a cleaning operation, the ideal product will clean the part and then dry immediately. A relative evaporation rate is indicative of the compound's ability to dry.

The evaporation should be done relative to Trichloroethylene. In this test the dry time of the test material is divided by the dry time of the reference solvent and this gives the relative evaporation rate. If the product evaporated in the same time the result would be one. A number of less than one means that a same amount of a comparative solvent will dry faster. The relative evaporation should be tested and recorded in accordance with ASTM D 1901.

Criteria 10: Surface Tension

Surface tension is the phenomenon that creates an inward pull or internal pressure on a liquid, which tends to restrain the liquid from flowing. This is what makes water bead up instead of spreading out indefinitely. Water has a surface tension of 73 dynes/cm. A surface tension of less than 25 dynes/cm is considered ideal for precision cleaning. A low surface tension gives the solvent the ability to flow in, around, and under various parts for more efficient cleaning. This becomes especially important on highly populated boards or boards with minimal clearance. A Surface Tensiometer should be used to conduct this test.

Criteria 11: Plastic Compatibility

Plastic parts and components are commonplace on many printed circuit boards and many more electronics are encased in plastic. Plastic will react very differently when in contact with a solvent depending upon whether the plastic is stressed or nonstressed. Therefore, the plastic should be tested both stressed and nonstressed. The two scores should then be averaged for each plastic tested.

For example, we tested 14 different plastics with 42 possible points (14x3). We then took the total score each solvent received and divided that number by 42 with the perfect score being zero. Therefore the lower the number the more compatible with a variety of plastics the solvent will be.

Nonstressed test plastic is placed approximately 45 degrees from horizontal. The specific plastic under test is sprayed for five seconds and allowed to dry. Immediately after the solvent evaporates, check the coupon for texture changes and pliability. To do this, physically grab the coupon, checking for softness, stickiness, and fragility. The plastic should then be given a score from 0-3.

0 = No impact
1 = Slightly impacted
2 = Moderately impacted and compatibility for this plastic type in question
3 = Highly impacted and probably not suitable for this type of plastic

To test the plastic in stressed condition, use a jig in compliance with ASTM-D 543. The plastic is bent at an approximate 30-degree angle, sprayed for five seconds, and scored by the same criteria as explained above.

Criteria 12: Low VOC

A Volatile Organic Compound (VOC) is any volatile compound of carbon, excluding carbon monoxide, methane, carbon dioxide, carbonic acid, ammonium carbonate, metallic carbides or carbonates, and exempt compounds. VOCs and the secondary photochemical oxidant products have a potential to cause damage to the environment and human health. As a result, a low VOC is favorable with an exempt compound being optimal. Since many solvents are volatile organics, any value of less than 1,200 grams per liter for the blend is considered desirable.

Criteria 13: Global Warming Potential

The final criterion is the Global Warming Potential (GWP). The ideal replacement should not be a global warmer. GWP represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide. All GWP values shown are calculated over a 100-year time horizon. As CO_2 is the standard it is assigned a value of one, and water is assigned a value of zero. Most hydrofluorocarbons (HFC) and hydrochlorofluorocarbons (HCFC) have GWP' ranging from 93 to 12,100. ■

About the Author

Steve Cook is Laboratory Manager and Head Chemist at Tech Spray, L.P. He is a member of SATA since 2001, being active on the regulatory and technical committee. This year, he was elected to the National Aerosol Association's board of directors. He can be reached at scook@techspray.com.