CASE STUDIES

IN

SOURCE REDUCTION

AND

SOLVENT SUBSTITUTION

INLAND TECHNOLOGY INCORPORATED
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Inland Technology Incorporated, is a privately owned corporation that is dedicated to the development and production of advanced solvents that are critical to all industries having to respond to the environmental challenges of the 1990s. Inland, operating from their facilities in Tacoma, Washington, is committed to customer satisfaction through quality - Total Quality Management (TQM) is an essential component of Inland's corporate commitments. During the past eight years, Inland has become a preeminent company in the advancement of environmentally responsive solvents:

- Inland is a member of the Joint Association for the Advancement of Supercritical Technology (JAAST). Inland was invited to participate as a full member amongst other technology giants such as Los Alamos National Laboratories, Battelle Northwest Laboratories, IBM, Boeing, Hughes and Autoclave Engineering.

- Inland is an invited member of International Air Transport Association and participated in their subcommittee for non-chlorinated paint stripping alternatives.

- Inland is active in the ASTM G-4 subcommittee searching for new technologies for cleaning LOX lines.

- Inland is active in the SAE G-9 subcommittee on advanced methods for sealant applications.

- Inland is an invited participant on U.S. Environmental Protection Agency's "Use Cluster" committees for development of printing and aerospace industry regulations.

TO DATE, THE SCIENTISTS AND ENGINEERS AT INLAND TECHNOLOGY INC. HAVE DEVELOPED SUCCESSFUL SUBSTITUTES FOR THE FOLLOWING PROBLEM SOLVENTS:

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<tr>
<th>TOXIC SOLVENT</th>
<th>USAGE</th>
<th>SUBSTITUTES</th>
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<tr>
<td>Methylene Chloride</td>
<td>Paint stripping; cold tank soak; resin removal</td>
<td>CITREX X-CALIBER</td>
<td>Both products are biodegradable; CITREX is not regulated by RCRA or SARA, Title III. Both are low VOC.</td>
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<tr>
<td>1,1,1-trichloroethane</td>
<td>Electronic &amp; electrical cleaning. Also, metal preparation</td>
<td>CITRA SAFE® TEKSOL EP</td>
<td>CITRA SAFE is biodegradable; TEKSOL EP is not regulated by SARA, Title III. Both are low VOC and non chlorinated</td>
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<tr>
<td>Methyl Ethyl Ketone (MEK)</td>
<td>Surface preparation for painting or welding</td>
<td>SAFETY PREP CITRA SAFE TEKSOL EP</td>
<td>SAFETY PREP, CITRA SAFE and TEKSOL EP are biodegradable; all are low VOC's</td>
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<tr>
<td>Toluene / Xylene</td>
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<td>SAFETY PREP CITRA SAFE TEKSOL EP</td>
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<td>Todarol Solvent / Mineral Spirits</td>
<td>Parts washing &amp; paint clean up</td>
<td>CITRA SAFE TEKSOL EP BREAKTHROUGH</td>
<td>Low VOC's; CITRA SAFE is biodegradable; BREAKTHROUGH is free from most regulations TEKSOL EP is low toxicity</td>
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<tr>
<td>Trichloroethylene</td>
<td>Degreasing &amp; resin removal</td>
<td>CITREX TEKSOL EP CITRA SAFE</td>
<td>CITREX and CITRA SAFE are biodegradable, low VOC. TEKSOL EP is non chlorinated with low toxicity</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>Degreasing</td>
<td>CITRA SAFE ISO-PREP BREAKTHROUGH</td>
<td>Non-halogenated Low VOC's, easier disposal; Low Toxicity</td>
</tr>
<tr>
<td>Methyl Ethyl Ketone (MEK)</td>
<td>Paint Gun Cleanup</td>
<td>EP 921</td>
<td>Biodegradable, High Flash Point, Low VOC, not regulated by RCRA or SARA Title III</td>
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<tr>
<td>Freon 113</td>
<td>Vapor Degreasing; Precision Cleaning</td>
<td>CITRA SAFE OR SKYSOL WITH ULTRA FILTRATION</td>
<td>CITRA SAFE biodegradable; SKYSOL is not regulated by RCRA or SARA Title III, Section 313, both are low VOC's</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
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</tr>
</tbody>
</table>

It should be noted that performance needs vary from application to application and that none of these substitutes will be expected to be 100% cross over for all applications.

The chemical behaviors of these substitutes (vapor pressures, dry time, etc.) may differ from solvents being used which may require changes in work practices in order for substitutes to be successful.

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SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:

The Boeing Company

PROJECT:

Develop a workable substitute for the Methyl Ethyl Ketone and M.E.K./Toluene blends used for surface preparation processes throughout the client’s manufacturing facilities. The principal thrust of the project involved replacing the manual wipe usages of M.E.K. and its blends in preparation for painting, bonding, and sealant application.

CONCERNS:

V.O.C. regulations at the time demanded low vapor pressures which often implies limited cleaning power and problems with residue.

a. The candidate must be non-reactive to all types of aerospace substrates and pass rigorous metallurgical tests.

b. The candidate must be effective on nearly as wide a spectrum of contaminants as the solvents it is replacing.
c. The candidate must be less hazardous to workers than the target solvent.
d. The candidate must carry less of a regulatory burden than the target solvent.
e. The candidate must be reasonably competitive when all costs are considered.
f. The candidate had to produce the same end result as the target solvent.

SUBSTITUTION PROCESS:

a. Develop several aqueous, semi-aqueous and non-aqueous candidates for testing.
b. Keep vapor pressure of candidates below 5 MMHG.
c. Conduct limited lab and field testing. Develop and test possible product and process changes to compensate for limitations observed in the testing.
d. Submit final candidates to Boeing Toxicology and Boeing Material Technology for final testing and possible approval.

METHODOLOGY:

The Final candidate was a very specialized distillation of a mono terpene eventually, identified as CITRA SAFE ®. While many of the other terpene and d-Limonene candidates failed primarily due to residue formation or adverse effects on substrates, or adverse toxicology, the product CITRA
SAFE® was able to pass the client's rigorous requirements.

RESULT:

The client is in a continuing process of substituting the use of CITRA SAFE® for M.E.K. and M.E.K./Toluene blends wherever practicable. CITRA SAFE® prepares a multitude of surfaces for paint or sealant application as well or better than M.E.K.

CITRA SAFE® has been awarded the following Boeing Commercial Aircraft Specifications:

BAC 5000
BAC 5504
BAC 5750

And has received the following specification from Boeing Military Airplanes:

EAA1734P026 for use on the B2 Bomber project.

In substituting for the M.E.K. and M.E.K./Toluene blends we found that CITRA SAFE® substituted well in surface preparation applications as well as applications requiring adhesive and heavy grease of boe-lube removal.

CITRA SAFE® did not substitute well in paint gun cleanup, or in the removal of the blue dyechem layout dye.

ECONOMIC RESULTS:

The client reports using 60-70% less by volume of the substitute per unit of production than was used of M.E.K. This is primarily a result of lower vapor pressure <2mmHg for CITRA SAFE® vs 75mmHg for M.E.K.
The use of CITRA SAFE® instead of M.E.K. has raised the possibility of considerable savings in hazardous waste disposal since M.E.K. contaminated material (rags, absorbants, etc.) are considerably more expensive to designate and dispose of properly.
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:

The Boeing Company

PROJECT:

Eliminate or severely reduce the use of the Methyl Ethyl Ketone used for cleaning paint guns & painting equipment used in aerospace coating applications. A successful substitute must be less hazardous than M.E.K. and must fit within the V.O.C. regulations promulgated by P.S.A.P.C.A. and S.C.A.Q.M.D.

CONCERNS:

The project raised three major areas of concern:

1. V.O.C. regulations demand near non-volatility in paint gun cleaning materials. This lack of volatility raised possible contamination issues with regards to painting subsequent to cleaning with substitute.

2. Most paint equipment is designed to be resistant to M.E.K. there will be very little data available regarding component resistance to any substitutes.

3. There are a great variety of coating systems in use today. The goal of the project
was to create a substitute with the near universal applicability of M.E.K.

SUBSTITUTION PROCESS:

1. Try to create on a macro scale a material that mimics some of the electrochemical characteristics of M.E.K.
2. Keep the vapor pressure below .5 mmHg & the volatile content below 200 grams per liter.
3. Test candidates on as many paint & coating systems as possible.
4. Devise & test purging techniques to eliminate paint contamination questions.

METHODOLOGY:

The final candidate was a cleaning formulation identified as EP921. This material was constructed from mutually antagonistic materials that as a whole mimic, on a macro scale, the solubility parameters & the solubility vector enjoyed by Methyl Ethyl Ketone.

Its near non-volatility would allow it to compete effectively, in terms of emissions, with M.E.K. coupled with a vapor capture system of 99.7% efficiency.

Cleaning effectiveness equal to M.E.K. on 1011 Epoxy Primer, 1060 Series Topcoat, iron, alkyd enamels, varnish, polyurethanes, & silicone coatings.
Contamination concerns have been eliminated by the successful use of a warm water final rinse to remove residue of EP921 followed by air blast to dry prior to use again.

Testing on paint gun components to date has not resulted in identifying any material adverse effects.

RESULTS:

The client is continuing testing & initiating B.M.T. materials testing prior to developing specifications for use. Northrop Aviation has also conducted tests & has received preliminary approval from S.C.A.Q.M.D., P.S.A.P.C.A. Evaluation regarding Aerospace V.O.C. regulations is in process. The original client is experimenting with other applications for this mimic of M.E.K.

To date, good preliminary results have been obtained in the following Traditional M.E.K. applications:

- Felt marker remover
- Removal of glues & adhesives
- Mild paint remover
- Grease & oil remover
- Machinists blue dye removal
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:


PROJECT:

Replace the client’s vapor degreaser using Freon 113 with an alternate chemistry and process to accommodate the Montreal Protocol phase out and to eliminate T.R.I. reporting requirements.

REQUIREMENTS:

Client’s parts needed near 100% removal of ionic contaminants and extremely low N.V.R.

CONCERN:

One of the major concerns was component sensitivity to alternate solvents. Since the solvent alternatives could not be used in a vapor phase, contaminant build-up
was also a major concern. Aqueous cleaning was ruled out by the client because of evaporation concerns in complicated geometries.

SUBSTITUTION PROCESS:

A. Off Line process testing was initiated to identify effective substitutes.
B. Rigorous component testing was initiated to determine sensitivity.
C. Assorted application methodologies were developed and tested for feasibility.

METHODOLOGY:

Original vapor degreaser was used as a cleaning containment station modified to accept a small low pressure pump coupled to a small hand-held wand. A separate pumping system was retro-fitted to provide constant flow through Inland Technology's Edge Tek Filter System. The substitute solvent that performed most satisfactorily was CITRA SAFE by Inland Technology.

The final process methodology is to spray CITRA SAFE onto the part as it is held in the old vapor degreaser tank. Let part sit for approximately four minutes. The part is then sprayed again - concentrating on the solder joints. The excess chemical is then blown off the part with air, and the part is then placed in a well-ventilated area for ten minutes to dry.

Continuous micro-filtration through the Edge Tek Filter System maintains process purity requirements during a 30 day change out cycle for the CITRA SAFE solvent.
RESULTS:

The client has been using this new process in production for one year. Cleanliness tests (Omegameter 600 SMD) indicate 100% ionic contaminant removal.

The new process has eliminated the emission of nearly 6,000 Lbs. of CFC per year and has consumed approximately 315 Lbs. of CITRA SAFE per year. The slight increase in labor cost has been more than made up by vastly lower chemical acquisition and disposal costs and by the elimination of the need for T.R.I. reporting.
Citra-Safe Cleaning Experiment

The sample used for this experiment was a surface mounted daughter board, which was comprised of two .030" pitch devices, various SOIC package sizes, and 1206 package size capacitors and resistors. The type of flux used in the solder paste was Rosin based, Mildly Activated. The reflow profile used was standard, with the belt speed adjusted to accommodate the thermal mass of this product.

The cleaning procedure using Citra-safe as the only cleaning solvent was as follows:

- The chemical was sprayed onto the sample.
- The sample was allowed to sit for 4 minutes.
- The sample was then sprayed again, with the spray concentrating on the solder joints.
- The excess chemical was then blown off the sample with an air gun, and the sample was placed in a well ventilated area for 10 minutes to dry completely.

The sample board was tested for cleanliness at Pacific Circuits in their Omegameter 600 SMD. The results (see attached printout) indicate that the Citra-safe removed 100% of the ionic contaminants on the circuit board tested. It should be noted that the Citra-safe in the tank at the time of testing was fresh. There will be a follow up experiment run by myself after a volume of printed circuit board assemblies have been run through this same batch of solvent, to determine the useful life of Citra-safe in this application.
OMEGA
METER
600-SMD

14:54 hrs. - 10/21/91

TEST RESULTS
RUN STATUS: PASS
RES.: 60.35 kQ-cm.
TIME: 10 min.
VOL.: 230.25 ml.
AREA: 618.5 sq. in.
BD. #: 0000000000
ALC.: 76 %
P/F.: 10.0 µs/sq. in.

TOTAL CONTAMINATION:

⇒ 80.0 µs. NaCl/sq. in. ←

(*) = over-range
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:
Hewlett Packard - Corvallis, Oregon.

PROJECT:
The client was preparing ink jet nozzles for plasma coating under high vacuum.
The existing cleaning process required an initial cleaning in a vapor degreaser using Trichloroethylene (T.C.E.) followed by an acetone rinse. The client wanted to eliminate the use of both solvents if possible.

REQUIREMENTS:
This process required near 100% removal of organic contaminants to prevent out-gassing of organics in the vacuum process.

CONCERN:
The major concerns centered around contaminant buildup in the cleaning media,
and the potential for the substitute cleaning materials to leave sufficient organic residue to cause out-gassing problems.

SUBSTITUTION PROCESS:

A. Off-line testing was initiated with candidate substitutes.

B. Process changes were tested, modified to optimize cleaning effectiveness.

C. Various combinations or hybrid techniques of solvent/aqueous cleaning methods were tested.

METHODOLOGY:

The original two-step cleaning process was ultimately replaced with a three step process:

STEP ONE:

Clean the parts in a low velocity spray of CITRA SAFE using the EDGE TEK FILTRATION SYSTEM in continuous recirculation mode as a means of controlling contamination build up.
STEP TWO:

Dip the parts pre-cleaned in Step One in an agitated bath containing deionized water and a small percentage of a specialized surfactant.

STEP THREE:

The parts are then rinsed in deionized water and air dried prior to entering the coating process.

RESULT:

The client has been using this substitution technique for about nine months. The process has eliminated the use and emission of a significant quantity of T.C.E. and acetone.

The new process is achieving organic residue levels equal to or lower than the original process using T.C.E. and acetone.
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:

Hewlett Packard-Corvallis, Oregon

PROJECT:

The client was cleaning vacuum pumps which were used to evacuate process gases. The residue from these gases contaminated and deteriorated the lubricants used in the pumps. The existing cleaning process required the use of Acetone and Isopropyl Alcohol with manual scrubbing in small sinks (tanks). The client wanted to eliminate the use of both solvents, if possible.

REQUIREMENTS:

This process required an aggressive solvent that would effectively remove heavy oil contamination and dry completely leaving no residue.
CONCERN:

The major concerns focused on the strength of the substitute solvent and the contaminant buildup in the solvent over an extended period of time.

SUBSTITUTION PROCESS:

A. Small scale tests were conducted with candidate substitutes.

B. Equipment used in the cleaning process was modified to control contaminant buildup and maximize cleaning effectiveness.

METHODOLOGY:

The original two step cleaning process was ultimately replaced with a one step process.

ONE:

Parts are cleaned in a low velocity spray of CITRA SAFE ® using the EDGE TEK FILTER SYSTEM in a continuous recirculation mode as a means of controlling contamination build up. The parts are air dried before re-assembly.

RESULT:

The client has been using this substitute process for 20 months. The
process has reduced the usage of Acetone and Isopropyl Alcohol by over 75%.
The filtration system has successfully controlled contaminant buildup and
allowed the solvent to be used for extended periods of time before
removal. These periods of use are becoming longer as the client becomes
more familiar with the system.
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:

Hewlett Packard - Boise, Idaho

PROJECT:

The client was cleaning Surface Grinding Tools to remove machining oils. The existing cleaning process required the use of stoddard solvent, contaminated with chlorinated solvents, in a partswasher serviced by a solvent rental company. The client wanted to eliminate the use of rented stoddard solvent.

REQUIREMENTS:

This process required an effective solvent that would remove machine oils and provide a safer material for the employees to work with.
CONCERN:

The major concerns focused on the strength of the solvent, personal safety and contaminant build up in the solvent over an extended period of time.

SUBSTITUTION PROCESS:

A. Small scale tests were conducted with candidate substitutes.

B. New equipment was installed in the cleaning process to control contaminant build up and maximize cleaning effectiveness.

METHODOLOGY:

The original one step cleaning process using stoddard solvent was replaced with a one step process using BREAKTHROUGH which is safer to use.

STEP ONE:

Parts are cleaned in a low velocity spray of BREAKTHROUGH using the EDGE TEK FILTRATION SYSTEM in a continuous recirculation mode as a means of controlling contamination build up. The parts are then air dried.
RESULT:

The client has been using this substitute process for 5 months. The process is effectively cleaning parts and has totally eliminated the use of stoddard solvent in this area.

The filtration system has successfully controlled contaminant build up and eliminated the need to have stoddard solvent waste removed from the plant each month.
Goal:
Removal of large vapor degreasers from plant 1 & 2.

Reason:


* Employee safety: No longer necessary to work around trichloroethane.

* Equipment failure: Vapor degreaser at plant 1 has a limited lifespan.

Current Situation:
The only cleaning methods presently available at both facilities are the vapor degreasing tanks, pressure washer, alkaline clean, and hand wipe operations.

There are three empty tanks with controls and a 3 basin ultrasonic clean line. These can all be used in testing and bringing in a new process.

The customers of the cleaning processes are:

* NPH: Required by MIL-STD-767
* FPI: Water Break Surface Required
* Shop: Requirements for a clean/dry part

Any operation which returns the parts clean and dry will be sufficient for the shop needs. NPH and FPI will require testing to prove the new cleaning process meets the needs of each customer.
SOLVENT SUBSTITUTION

CASE STUDY

CLIENT:

The Weyerhaeuser Corporation - Federal Way, Washington

PROJECT:

Reduce or eliminate one of the corporation's largest hazardous waste streams. This waste stream was the near monthly change out of dirty stoddard solvent - for fresh solvent that was used for metal parts cleaning in mill maintenance and automotive maintenance at 358 sites. Each typical 30 gallon parts washer generated nearly 2,000 lbs. of D 001 Hazardous Waste per year.

REQUIREMENTS:

Develop a Non-R.C.R.A. cleaning compound, and find a way to keep it clean enough for parts cleaning for long periods of time.

CONCERNS:

1. Would the substitute clean as well as stoddard solvent?
2. Could cross contamination be successfully controlled?

3. Would the filters or solvent accumulate sufficient heavy metals to fail T.C.L.P.?

4. Could the whole process be made cost competitive with the original process?

5. Could particulate and tramp oil be preferentially removed from the cleaner?

SUBSTITUTION PROCESS:

A. Test available filtration technology and media.

B. Develop candidate substitutes for stoddard solvent.

C. Run extensive field tests in a variety of applications.

D. Make design changes as needs are identified.

METHODOLOGY:

ONE:

Developed the EDGE TEK FILTER SYSTEM to mount on the Parts Washer and supply continuous recirculations and cleaning of the solution.

This axial flow, torturous path developed from specialized media provides particulate filtration down to .1 micron nominal, exhibits high contaminate loading capabilities, and has a strong attraction for the longer chain molecules of tramp oil and grease.
TWO:

Develop an effective, low hazard cleaning solution to substitute for stoddard solvent.

The third generation substitute developed for use with this system is a high flash point, Non-R.C.R.A., non-photo-chemical reactive, low toxicity, odorless material called BREAKTHROUGH.

THREE:

Developed a training protocol to aid the successful use of the system and to control cross contamination.

RESULTS:

The original client continues to phase in the parts washing system. Other clients have also initiated adoption of the system, either in whole or in part. These include:

The U.S. Navy
Mc Donald Douglas
International Paper
Kodak Corporation
Flow International

and many others from Auto Dealerships to Aerospace.

The use of BREAKTHROUGH has allowed the disposal of properly managed systems to waste oil for energy recovery. This has the potential for eliminating a tremendous amount of hazardous waste.
A one year study by Weyerhaeuser at their Cosmopolis, Washington Paper Mill showed that in 1990 prior to conversion to Inland’s Edge Tek Filter System, the mill generated and manifested 30,000 pounds of hazardous waste that was generated solely by the 22 parts washers onsite.

In 1991, after conversion, the mill only generated 500 lbs. of hazardous waste from the same number of parts washers. This 98% reduction of hazardous waste was solely the result of the conversion to the Inland Edge Tek Filter System.

Subsequent economic analysis by Weyerhaeuser showed a significant economic savings attributable to the Inland Edge Tek System.

Total cost of monthly operation and disposal analyzed over one year averaged only $18.32 per month, per parts washer.
AVTECH Corporation designs and manufactures sophisticated electronic ballasts used to power fluorescent lights on various commercial aircraft around the world. We also design and build various magnetic components (transformers, inductors, etc.) which are used in large numbers in our ballasts. These parts are traditionally cleaned in a batch mode using a vapor degreaser with CFC-113 (Freon). This process works very well for removing mildly activated rosin (RMA) flux and other contaminants from these parts before they get sealed using a vacuum varnishing process. The parts exit the vapor tank clean and dry in just a couple minutes.

A substitute cleaning process was needed for these components with the pending phase-out of vapor degreasers by the Puget Sound Air Pollution Control Agency on July 1, 1993. Aqueous (water) cleaning with saponifier cleaned the parts fairly well, but there were unacceptable side effects. The mild steel laminations used in the transformers and chokes rusted, and the wire windings trapped water which complicated the drying process. We wanted to avoid hand cleaning the parts with isopropyl alcohol, as this would be a messy, labor intensive process given the volume of parts we build.

After several unsatisfactory attempts to find an alternative solvent that did not cause worker discomfort from the solvent odor, I received some brochures from Inland Technology. Their client and project list was noteworthy. I contacted them after I read some of their success stories of reduced hazardous waste disposal, reduced regulation, and reduced worker health hazard using their extensive line of substitute solvents.

Later that week a Sales Engineer from Inland met me at AVTECH to see our vapor cleaning process. In the weeks that followed, I sent their chemist samples of soldered parts, MSDS information on the RMA flux, and a list of plastics which are used in the bobbins of our magnetic parts. He decided to develop a new cleaning agent for the electronics industry, named Dry-Sol, that would dissolve the RMA flux very quickly. He selected Teksol EP solvent to be used as a rinsing agent after cleaning the parts in the Dry-Sol. Teksol EP removes the residual Dry-Sol along with the dissolved contaminants. Cycle time is short. Cleaning is accomplished in about five minutes. An oven had to be added to speed up the drying process.

Two alternative solvents from firms other than Inland Technology proved to be effective flux removers, but the odor from them was overpowering. One competitor's solvent had a very strong turpentine odor. The other one (a terpene) had a very strong citrus odor. I made it clear early in my development work with Inland Technology that operator comfort and safety would carry equal weight with cleaning effectiveness in our selection of alternative solvents, and they delivered. Both the Dry-Sol and Teksol EP from Inland Technology have a mild odor, and the cleaning effectiveness and economics look very good when compared with vapor degreasing electronic parts using CFC-113.