



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

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Post Solder Solvent Cleaning Handbook

IPC-SC-60A

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2215 Sanders Road, Northbrook, IL 60062-6135

Tel. 847.509.9700 Fax 847.509.0700
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Post Solder Solvent Cleaning Handbook

Developed by the Solvent Cleaning Task Group (5-31a) of the
Cleaning and Coating Committee of IPC

Users of this standard are encouraged to participate in the
development of future revisions.

Contact:

IPC
2215 Sanders Road
Northbrook, Illinois
60062-6135
Tel 847 509.9700
Fax 847 509.9798



Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Solvent Cleaning Task Group (5-31a) of the Cleaning and Coating Committee are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

Cleaning and Coating Committee	Solvent Cleaning Task Group	Technical Liaisons of the IPC Board of Directors	
Chairman Frank Cala Church & Dwight	Chairman William Kenyon Global Centre for Process Change	Stan Plzak Pensar Corp.	Peter J. Murphy Parlex Corp.
Solvent Cleaning Task Group			
David C. Adams, Rockwell Collins	Dr. William G. Kenyon, Global Centre for Process Change	Charles M. Pitarys, Kyzen Corporation	
Sami B. Awad, Crest Ultrasonics Corp.	Gregg Klawson, GTE CSD	Rick Reynolds, Precision Cleaning for Advanced Technologies Magazine	
Beth A. Bivins, Petroferm Inc.	Thomas W. Lecky, Van Waters & Rogers Inc.	John H. Robison, Cauldron Company/Radiance Service	
Francis R. Cala, Ph.D., Church & Dwight Co. Inc.	Kuan-Shaur Lei, Compaq Computer Corporation	Jerald G. Rosser	
Thomas A. Carroll, Hughes Space & Communications Co	Dr. Andy C. Mackie, Ph.D., Praxair Inc.	David F. Scheiner, Kester Solder Division	
Peter Marc Carter, Rockwell Collins	James F. Maguire, Boeing Defense & Space Group	Steve Scherrer, Great Lakes Chemical Corp.	
Suae-chen Chang, Albemarle Corporation	Peter Maltby, Branson Ultrasonics Corp.	Stanley S. Seelig, Seelig & Associates	
Robert Cooley, Stryker Instruments	John Mastorides, Group Technologies Corp.	Mahendra K. Sharma, Eastman Chemical Company	
Frances B. Crocram, Great Lakes Chemical Corp.	Mary Muller, Eldec Corporation	Xianyu Shea, Stryker Instruments	
Charles H. Darwin, U.S. EPA	James R. Mulligan, E. I. du Pont de Nemours and Co.	Ronald L. Shubkin, Albemarle Corporation	
Donald A. Elliott, Elliott Technologies Inc.	Terry L. Munson, CSL Inc.	Tim Skidmore, Multicore Solders, Inc.	
Roger Etherington, Vulcan Chemicals	Michele Nelson, 3M Company	Ronald A. Smith, Eastman Chemical Company	
Howard S. Feldmesser, Johns Hopkins University	Beverly Newton, Dionex Corporation	Dr. John E. Sohn, Lucent Technologies Inc.	
Joe R. Felty, Raytheon Systems Company	David Nicol, Lucent Technologies Inc.	Pin Su, Telcordia Technologies	
Alan Gickler, Johnson Manufacturing Co.	Robin L. O'Connor, Delphi Delco Electronics Systems	Dr. Laura J. Turbini, Georgia Institute of Technology	
Dr. Michael E. Hayes, Petroferm Inc.	R. Bruce Officer, Sanders, A Lockheed Martin Co.	Lee R. Wilmot, Hadco Corporation	
Kenneth S. Hill, Raytheon Systems Company	Nitin B. Parekh, Unisys Corporation	Philip W. Wittmer, Delphi Delco Electronics Systems	
Joseph E. Kane, Lockheed Martin Corporation	Rod F. Patterson, Raytheon Systems Company		
Donald Karp, Trace Laboratories - Central	Douglas O. Pauls, CSL Inc.		

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Post Solder Solvent Cleaning Handbook

1 SCOPE

This handbook addresses solvent cleaning of electrical/electronic assemblies, parts and application tools after soldering.

1.1 Purpose The content of this text is intended to provide a basic understanding of the subject and to serve as a guide to users or prospective users of solvent cleaning technology, allowing selection or improvement of solvent cleaning processes.

Notes:

1. Content of this revision is limited to those solvents that have a wide use in electronic assembly cleaning operations as of date of publication.
2. New solvents or formulations that are developed and then proven effective for this use will be included in a future revision.
3. Since *normal propyl bromide (nPB)* and its formulations are legal for sale and use for electronics cleaning, pending the issuance of a final rule by the U.S. Environmental Protection Agency (EPA) Significant New Alternatives Program (SNAP) office, all references to *nPB* or *brominated* cleaning agents in this document are in italics (see Annex C).
4. Transportation and storage related temperatures and weights are also provided in English units for safety related reasons. It is recognized that certain paragraphs are U.S. specific and other countries will need to substitute equivalent requirements/information.

1.2 Terms and Definitions All terms and definitions used throughout this handbook are in compliance with IPC-T-50. Other basic terms and definitions, essential for the discussion of the subject, are provided below or are defined in appropriate sections of this handbook.

Solvent Cleaning – A cleaning process that uses a solvent medium, instead of water, for washing and rinsing the electronic parts and assemblies. In solvent cleaning, drying is application and equipment dependent. In vapor defluxing, drying is accomplished by evaporating residual liquid solvent on the part being cleaned into the vapor zone generated by the boiling solvent. In all other applications, drying occurs by evaporation of residual solvent into the air, taking care to keep the vapor in air levels within recommended limits.

Wash or Washing – The primary cleaning operation that removes undesirable impurities (contaminants) from surfaces by chemical and physical effects, mainly dissolution of the contaminants.

Rinse or Rinsing – A cleaning operation (usually following the wash step) where fresh solvent replaces - via a dilution mode - any residual contamination, leaving surfaces wet with pure solvent.

Drying – The process of removing any residual liquid solvent on the surface of the washed and rinsed parts. In a vapor defluxing process, drying is accomplished in the vapor zone created by the boiling solvent in the wash zone of the cleaning machine. Drying can be augmented by passing superheated solvent vapor across the surface of the parts, to ensure complete removal of residual liquid solvent. This technique is especially effective with complex geometries that can entrap liquid solvent.

Defluxing (Flux Removal or Post Solder Cleaning) – The cleaning process designed to remove solder flux and by-products. Other objectives are removal of process residues and materials used as production aids, such as solvent soluble maskants. Impurities left by board or component fabrication processes or other operations may be removed during the process, thus the defluxing process widens the process window for assemblers.

1.2.1 Chemical Material Acronym Definitions

HCFC Hydrochlorofluorocarbon
 HFC Hydrofluorocarbon
 HFE Hydrofluoroether
nPB *normal Propyl Bromide*
 CFC Chlorofluorocarbon
 TCE Trichloroethylene
 PCE Perchloroethylene

2 APPLICABLE DOCUMENTS

This section contains references to industry standards, federal regulations, test methods and vehicles which are applicable to post solder solvent cleaning. Not all of these are cross-referenced in the text. They are listed below for the convenience of the readers.

2.1 Industry Standards

2.1.1 IPC Standards¹

IPC-B-24 Surface Insulation Resistance Test Board

IPC-B-25 Multipurpose Test Board

1. IPC, 2215 Sanders Road, Northbrook, IL 60062

IPC-B-36 Cleaning Alternatives Test Board**IPC-T-50** Terms and Definitions for Interconnecting and Packaging Electronic Circuits**IPC-SA-61** Post Solder Semi-Aqueous Cleaning Handbook**IPC-AC-62** Post Solder Aqueous Cleaning Handbook**IPC-CH-65** Guidelines for Cleaning of Printed Boards and Assemblies**IPC-CS-70** Guidelines for Chemical Handling Safety in Printed Board Manufacturing**IPC-TP-383** Organic Surface Contamination: Identification, Characterization, Removal Effects on Insulation Resistance and Coating Adhesion**IPC-PE-740** Troubleshooting Guide for Printed Board Manufacture and Assembly**IPC-TM-650** Test Methods Manual

2.3.25 Detection and Measurement of Ionizable Surface Contaminants

2.3.27 Cleanliness Test - Residual Rosin

2.3.27.1 Rosin Flux Residue Analysis - HPLC Method

2.3.28 Ionic Analysis of Circuit Boards, Ion Chromatography Method

2.3.30 Solvent pH Determination in Anhydrous Fluorocarbon Solvents

2.3.38 Surface Organic Contaminant Detection Test

2.3.39 Surface Organic Contaminant Identification Test (Infrared Analytical Method)

2.6.3.1 Moisture and Insulation Resistance - Polymeric Solder Masks and Conformal Coatings

2.6.3.3 Surface Insulation Resistance, Fluxes

2.6.9.1 Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy

2.6.9.2 Test to Determine Sensitivity of Electronic Components to Ultrasonic Energy

2.6.13 Assessment of Susceptibility to Metallic Dendritic Growth : Uncoated Printed Wiring

2.6.14 Resistance to Electrochemical Migration, Polymer Solder Mask

2.1.2 Joint Industry Standards¹**J-STD-001** Requirements for Soldered Electrical and Electronic Assemblies**J-STD-004** Requirements for Soldering Fluxes**J-STD-005** Requirements for Soldering Pastes**J-STD-006** Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications**NOTE:** For additional documents and references related to general cleaning issues (IPC, DOD, EIA, UL, ASTM and ANSI) the reader is referred to the IPC Cleaning Handbook; IPC-CH-65).**2.2 U.S. Federal Regulations²****2.2.1 Federal Laws****CAA** Clean Air Act**CWA** Clean Water Act**RCRA** Resource Conservation and Recovery Act**CERCLA** Comprehensive Environmental Response, Compensation and Liability Act**SARA** Superfund Amendment and Reauthorization Act**2.2.2 Federal Standards****O-A-51** Acetone, Technical**O-E-760** Special Industrial Solvents**O-M-232** Methanol (Methyl Alcohol)**O-T-236** Tetrachloroethylene (Perchloroethylene); Technical**O-T-620** 1,1,1-Trichloroethane, Technical, Inhibited (Methyl Chloroform)**O-T-634** Trichloroethylene, Technical, Inhibited**TT-B-848** Butyl Alcohol, Secondary, For Use in Organic Coatings**TT-I-735** Isopropyl Alcohol**TT-M-261** Methyl Ethyl Ketone**TT-N-95** Naphtha, Aliphatic**TT-N-97** Naphtha, Aromatic**TT-T-548** Toluene Ethyl Alcohol, (Ethanol) Denatured Alcohol, Proprietary Solvents**2.2.3 Department of Defense³****MIL-C-81302** Cleaning Compound, Solvent, Trichlorotrifluoroethane

2. General Services Administration, Federal Supply Service, Bureau Specifications Section (3FBP-W), Suite 8100 470 L'Enfant Plaza SW, Washington, DC 20407

3. Standardization Documents Order Desk, 700 Robbins Avenue, Bldg. 4D, Philadelphia, PA 19111-5094

MIL-C-85447 Cleaning Compounds, Electrical & Electronic Components

MIL-N-15178 Naphtha, Solvent

MIL-T-81533 Trichloroethane 1,1,1 (Methyl Chloroform) Inhibited, Vapor Degreasing

2.2.4 Occupational Safety and Health Administration⁴

OSHA 29 CFR 1910.1000 Air Contaminants

OSHA 29 CFR 1910.134 Respiratory Protection

OSHA 29 CFR 1910.106 Flammable and Combustible Liquids

2.2.5 Environmental Protection Agency⁵

EPA 40 CFR 63 National Emission Standards for Hazardous Air Pollutants for Source Categories

EPA 40 CFR 82 Protection of Stratospheric Ozone

EPA 40 CFR 117.3 Determination of Reportable Quantities for Hazardous Substances

EPA 40 CFR 131.36 Toxic Criteria for those States not Complying with Clean Water Act Section 303(c)(2)(B)

EPA 40 CFR 261 Identification and Listing of Hazardous Waste

EPA 40 CFR 302.4 Designation of Hazardous Substances

EPA 40 CFR 355.30 (b) Emergency Release Notification

EPA 40 CFR 370 Hazardous Chemical Reporting: Community Right To Know

EPA 40 CFR 372 Toxic Chemical Release Reporting: Community Right-to-Know

2.2.6 Department of Transportation⁶

DOT 33 CFR 153.203 Procedure for the Notice of Discharge

2.2.7 American Conference of Governmental Industrial Hygienists (ACGIH)⁷ and National Institute of Occupational Safety and Health (NIOSH)⁸

Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents, and Biological Exposure Indices Published by ACGIH Worldwide.

Permissible Exposure Limit (PEL) (eight hour exposures)
Short Term Exposure Limit (STEL) (typically 15 minutes)

2.3 Other

2.3.1 American Standards for Testing Materials⁹

2.3.1.1 Test Methods

ASTM Method D-56 Flash Point, TAG Closed Cup

ASTM Method D-92 Flash Point, Cleveland Open Cup

ASTM Method D-93 Flash Point, Pensky-Martens Closed Cup

ASTM Method D-1078 Distillation Range of Volatile Organic Liquids.

ASTM Method D-1133 Kauri-Butanol Value for Hydrocarbon solvents

ASTM Method D-1320 Tensile Strength of Paraffin Wax (withdrawn without replacement)

ASTM Method D-2106 Amine Acid Acceptance of Halogenated Organic Solvents

ASTM Method D-2109 Non-Volatile Matter in Halogenated Organic Solvents and Their Admixtures.

ASTM Method D-2111 Specific Gravity of Halogenated Organic Solvents and Their Admixtures

ASTM Method D-2942 Total Acid Acceptance Of Halogenated Organic Solvents

ASTM Method D-2989 Acidity/Alkalinity of Halogenated Organic Solvents and Their Admixtures.

ASTM Method D-3401 Water in Halogenated Organic Solvents and Their Admixtures

ASTM Method D-3443 Chloride in Trichlorotrifluoroethane

2.3.1.2 Standard Specification of Materials

ASTM D 329 Acetone

ASTM D 362 Toluene (Discontinued without replacement)

ASTM D 740 Methyl Ethyl Ketone

ASTM D 1153 Methyl Isobutyl Ketone

4. OSHA, Public Affairs Office - Room: 3647, 200 Constitution Avenue, Washington, DC 20210

5. EPA, 401 Main Street SW, Washington, DC 20460-0003, Telephone: 800-424-8802

6. DOT, 400 Seventh Street SW, Washington, DC 20590

7. ACGIH, 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240

8. NIOSH, 200 Independence Avenue SW, Room 715H, Washington, DC 20201

9. ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

- ASTM D 1836** Commercial Hexanes
- ASTM D 3622** N-Propyl Alcohol
- ASTM D 4079** Methylene Chloride (Vapor Degreasing Grade)
- ASTM D 4080** Trichloroethylene
- ASTM D 4081** Perchloroethylene (Drycleaning Grade)
- ASTM D 4126** 1,1,1 Trichloroethane
- ASTM D 4376** Perchloroethylene (Vapor Degreasing Grade)
- ASTM D 4701** Methylene Chloride (Technical Grade)
- ASTM D 5309** Cyclohexane 999
- ASTM D 6368** Vapor-Degreasing Grade and General Solvent Grade for *Normal Propyl Bromide*

2.3.2 National Fire Protection Association (NFPA)¹⁰

NFPA 35 Definitions of Flammable & Combustible Substances

2.3.3 Environmental Protection Agency

EPA-453/R-94-081 Guidance Document for the Halogenated Solvent Cleaner NESHAP

3 CLEANING SOLVENTS/SOLUTIONS

A general rule of cleaning is “like dissolves like,” which means that usually nonpolar contaminants are best removed by nonpolar solvents, while polar or ionic contaminants are best removed by polar solvents. Thus a mixed or complex soil will often require a multicomponent solvent cleaning agent formulation to achieve the desired cleaning result in a single cleaning operation. There are several key areas of concern when selecting such cleaning solvents/solutions.

- Effectiveness (See 3.1)
- Stability (See 3.2)
- Safety (See 3.3)
- Environmental (See 3.4)
- Cost (See 3.5)
- Summary (See 3.6)

3.1 Effectiveness To be effective, a cleaner should have the characteristics as defined below:

3.1.1 Wetting Characteristics The cleaning agent should possess good wetting characteristics which ideally should change minimally during the cleaning operation to assure flow and wetting in all areas to dissolve and remove

contaminants. Wetting is generally dependent upon the viscosity and surface tension of the solvent. Solvent formulations possessing low viscosities and low surface tensions will typically have the best wetting characteristics. (Refer to Section 3.1.2)

3.1.2 Solvency Power The cleaner should possess good solvency power (affinity for the contaminant). The cleaner must be capable of dissolving the contaminants present or wetting is of little value other than to mechanically wash away the contaminant. It is difficult to state the solvency power of a cleaner in absolute terms and therefore relative measures are often used. Examples of such relative measures, which are of limited utility, are solubility of contaminant in g/cm³, solution viscosity changes with specific percent loading, Kauri-Butanol value and aniline point number. A much better method is solubility parameter data, which gives the best indication of the ability of a solvent or solvent formulation to remove a soil. Also, it should be noted that solvency can be enhanced by proper choice of cleaning equipment, agitation methods or cleaning cycle.

3.1.3 Multiple Components A cleaner should contain both polar and nonpolar components. The nonpolar portion is needed to efficiently remove nonionic contaminants such as rosin, oils, fingerprint oils, etc., and the polar components for dissolving (solvating) ionic contaminants such as flux activators, plating salt residues, or salts from handling (see Section 5.1). To achieve the polar/nonpolar characteristics, solvent blends and azeotropes are becoming more prominent. The nonpolar component is often a halogenated solvent, either chlorinated, *brominated*, chlorofluorinated or hydrofluorinated. The polar component solvent is typically an alcohol such as methanol, ethanol, 2-propanol or 1-propanol. Other components such as chlorocarbons or hydrocarbons, are often used to adjust the balance of solvent power and compatibility for specific uses. Stabilizers are often added as well to prevent degradation of the solvent formulation during use.

3.1.4 Degradation The cleaner should not, when properly used, degrade hardware or components comprising the electronic assembly. Marking/symbolization should not be removed by the cleaning solvent/solution. (Refer to Section 4.)

3.1.5 Residues The cleaner should not leave detrimental solvent residues after final rinse. Adequate purity of solvents is a very important factor in being able to achieve an acceptable degree of surface cleanliness. Solvent residues/impurities encountered in the cleaning process can be generally attributed to the items in paragraph 3.1.5.1 through 3.1.5.3.

10. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101

3.1.5.1 Suspended Matter (Particulate matter insoluble in the solvent but suspended due to particle size and/or specific gravity.) The probability of this type of impurity being present increases if adequate controls are not implemented on production cleaning equipment or if solvents are initially packaged or repackaged utilizing insufficient controls or inadequate storage containers.

3.1.5.2 Contaminants in Solvents as a Consequence of Manufacture Small fractions of organic compounds distilled over with the solvent during the solvent manufacturing operation are commonly encountered impurities which do not, for practical purposes, interfere with the intended cleaning function or behavior of the solvent. In certain high reliability aerospace applications, where the presence of trace impurities such as sulfur or silicones are considered detrimental, the user will need to have the composition of the solvent certified to ensure end user requirements are met.

3.1.5.3 Dissolved Contaminants (From cleaning operations and codistilled by reclaiming processes.) The use of reclaimed solvent has distinct economical advantages and is the principle behind all vapor phase cleaning equipment. No problem is encountered as long as codistilled contaminants, such as mineral and silicone oils, are not present in the reclaimed solvent (i.e., a controlled/known source is providing the solvent material to be reclaimed). However, reclaimed solvents available at low cost in bulk quantity from commercial reclaimers who coiled solvent scrap from a variety of possibly uncontrolled sources can pose problems if not properly analyzed prior to use. The risk assumed by the user when applying reclaimed solvent can be high if adequate controls (i.e., incoming inspection) are not implemented. Subsequent operations after cleaning, such as conformal coating, can be adversely affected. Often such reclaimed solvent is used upstream for cleaning parts prior to assembly or for maintenance cleaning, reserving the pure material for final assembly cleaning.

Another potential source of contamination in incoming material is repackaging by distributors and/or users. Care must be taken to ensure the plastic coating inside drums or pails (drum liner) is compatible with the solvent formulation. Individual companies must determine their own incoming requirement to minimize product liability.

3.2 Stability The stability (long use life) of the cleaning agent is important from a reliability/cost standpoint. The cleaner should exhibit resistance to both chemical and thermal decomposition.

3.2.1 Resistance to Chemical Decomposition Some halogenated solvents (1,1,1-trichloroethane (no longer produced), trichloroethylene, perchloroethylene, *n*-propyl bro-

mide) are susceptible to chemical decomposition (previously called "going acid," but more precisely degradation to unwanted or harmful decomposition products) in the presence of heat, moisture, and contact with certain metals. Such decomposition products are acidic and corrosive. Most commercially available cleaning solvents are formulated with stabilizer systems included. Inhibitors and anti-oxidants are present to prevent solvent degradation and acid acceptors are present to neutralize any acidity that might develop. During operation, the stabilizers may become depleted and, therefore periodic testing of the solvent is required. (Refer to Paragraph 8.6 - Solvent Monitoring.)

3.2.2 Resistance to Thermal Decomposition Most halogenated solvents (1,1,1-trichloroethane, trichloroethylene, perchloroethylene, *n*-propyl bromide, HCFCs, HFCs and HFEs) are susceptible to thermal decomposition (previously called "going acid," but more precisely degradation to unwanted or harmful decomposition products) in the presence of elevated sources of heat; such as hot spots on immersion heaters, contact with the heating elements of radiant space heaters (either electrical or gas) or contact with the heat generated by a welding torch. Once the thermal limits of a solvent molecule are exceeded, no stabilizer package can prevent decomposition. The user must take care to ensure that such contact cannot take place.

3.3 Safety Users of solvent cleaners must also evaluate other safety factors such as fire safety considerations, and both the acute and chronic health effects of the specific cleaning solvent chemicals. Users should always make themselves completely knowledgeable on all aspects of all the Material Safety Data Sheets or MSDS (as supplied by the chemical manufacturer) applicable to the materials in use.

Health effects, in addition to potential inhalation hazards, include irritation to, or corrosion of eye and skin tissues. An evaluation of eye and/or face protection requirement should be done. Skin irritation or corrosion may be a potential hazard and it can be prevented by wearing appropriate protective gloves.

For complete safety information, see IPC-CS-70. It should also be noted that, when using any chemical, a current Material Safety Data Sheet must always be reviewed prior to putting the cleaning agent into service.

3.3.1 Fire Safety The halogenated solvents, along with their low percent alcohol blends, are generally nonflammable. Users should be aware that multi-component azeotropes only possess that particular composition at the boiling point. Thus, if the formulation contains a flammable component, the composition could become rich in that component at room temperature, and the mixture could

Other commonly used solvents such as 2-propanol, terpenes, and other hydrocarbons are flammable or combustible and should be handled and stored according to local safety regulations. These materials can all be used safely as long as the precautions recommended by the supplier are rigorously followed.

The flash point test of a liquid or combination of liquids is normally run to determine how the cleaning agent should be packaged and shipped. It was not intended to predict behavior in a vapor defluxer. It is not uncommon for a cleaning agent to have a flammable range, usually expressed as the concentration in the air that can be ignited, but yet not have a flash point.

Factory Mutual (FM) and the National Fire Protection Association (NFPA) regard liquids with a flash point below 140°F to be “flammable,” and liquids whose flash point is above 140°F but below 200°F to be “combustible.” Flammable liquids pose explosion hazards if their vapors are not properly removed by either local or general ventilation. Users of flammable solvent cleaners must also recognize that installations where these liquids are to be used must conform to certain construction standards such as explosion proof wiring, switches, lights, motors, etc., (see NFPA 35 and OSHA 29 CFR 1910.106 for additional information.) Users of flammable liquids should also verify with their local fire department the need for notification and permission of the use of these liquids. Notification may also be required under EPA’s Community Right to Know regulations 40 CFR 355.30(b), 370.20, 370.21 and 370.25 to report storage and usage of certain chemicals to both the local fire department and emergency planning commission.

3.3.2 Workplace Exposure It is important for worker safety that vapors of a chemical used in the manufacturing area be maintained below the maximum threshold limit value (TLV). TLVs are established by the American Conference of Government & Industrial Hygienists (ACGIH). TLVs are generally used by OSHA for determination of compliance with workplace safety standards. Modern closed or sealed equipment can permit the use of materials with low exposure limits (low TLVs), as well as equipment that has been properly retrofitted to comply with modern requirements.

3.3.2.1 PEL/STEL It is a legal requirement to maintain worker exposure to solvent vapors at or below the Permissible Exposure Limit (PEL) for eight-hour exposures, and at or below the Short Term Exposure Limit (STEL) for shorter time periods (typically 15 minutes) as published by OSHA in the air contaminants section of 29 CFR 1910.1000.

It is equally important to maintain worker exposures to solvent chemicals, on which OSHA has not established a PEL or STEL, at or below the Threshold Limit Value

(TLV) for eight-hour exposures as published by the American Conference of Governmental Industrial Hygienists (ACGIH) and/or the National Institute of Occupational Safety and Health (NIOSH) through proper local ventilation or work practices, or both. OSHA requires that engineering controls (i.e., local ventilation) to be the primary method of controlling employee exposure, and requirement to wear personnel protective equipment (PPE) in the form of respirators to be used as a last resort if engineering controls fail to control exposures. Should wearing of respirators be required to adequately protect workers from vapors of cleaning solvents, the user is required to have a written respiratory protection plan (see 29 CFR 1910.134).

3.3.2.2 Workplace Exposure Monitoring Three common methods used for monitoring of solvent concentration in air are the use of air sampling pumps, organic vapor monitor (OVM) badges, and the organic vapor analyzer (OVA). Both the air sampling pump technique and the OVM badges provide a TWA (time weighted average) of a solvent concentration in the air. The organic vapor analyzer (OVA) provides an instantaneous reading of a solvent concentration in air.

Air Sampling Monitor – The method utilizes a sampling pump and a charcoal tube to collect a given volume of air. It is suggested that the air sampling be conducted over an eight hour period. The charcoal tube is sent to a laboratory and then analyzed for the selected solvent concentration.

Organic Vapor Monitor – The organic vapor monitor (OVM) is similar to a sampling pump although without the mechanical pump. One can wear the OVM as a badge by clipping it onto a shirt pocket for a specified time. The main disadvantage of the method is limited selectivity of the solvent being monitored. The OVM will need to be shipped to an analytical lab for analysis.

Organic Vapor Analyzer – The organic vapor analyzer is essentially a portable gas chromatograph using a flame ionization detector. The method provides measurement of trace quantities of hydrocarbons and organics. It is also used to detect leaks from solvent cleaning equipment as well as measure the instantaneous solvent concentrations in air. Laboratory calibration of the equipment is required to select the solvent to be monitored. Additionally, a technically trained operator will be required to conduct the monitoring and interpret the data for determination of solvent concentrations in air.

3.4 Environmental The selection of a solvent cleaning process, including materials and equipment, must incorporate the inherent impact that a given solvent will have on air emissions, water discharges and waste generation from the facility. Each of these three environmental mediums may require a permit depending on the usage rate and existence of other air emissions, water discharges and waste generation at that facility.

Air Emissions – All cleaning solvents have a vapor pressure, and because of this, either local or general ventilation is required to keep employee exposures below acceptable levels. Accordingly, the use of a solvent cleaning process will result in air emissions of the solvent cleaning agent chemical(s) to the atmosphere. Such emissions may be regulated by the state (or other local permitting authority), the Montreal Protocol, or the Clean Air Act (CAA), depending on the type and amount of chemical(s) emitted, and the total chemical emissions at that facility. An air emissions permit may be needed if the emissions threshold for a given chemical is met by the solvent cleaning process, or if the total air emissions of either a given chemical at that facility from all process sources is exceeded, or if the total air emissions of a group of chemicals at a facility is exceeded (such as volatile organic compounds, VOCs at that facility). (Reference Section 9.2 for more detailed considerations.)

ODP – The Ozone Depletion Potential (ODP) of solvents containing chlorine or bromine ranges from near-zero to significant. The ODP is determined by a Scientific Assessment Panel (SAP) which reports to the UN Technology and Economic Assessment Panel (TEAP). Ozone depletion models used by SAP are currently being updated to permit accurate assessment of halogenated solvents with short atmospheric lifetimes.

GWP – The Global Warming Potential (GWP) of a molecule is a function of its atmospheric lifetime. Many halogenated solvents as well as non-halogenated cleaning materials such as carbon dioxide (used in the supercritical CO₂ cleaning process) have atmospheric lifetimes that could contribute to global warming. Various time horizons are used to express GWPs, without universal agreement on one standard scale. While not currently a basis for regulation, GWPs are taken into account during the cleaning agent qualification process.

HAP – Many substances, including some solvents, are regulated as Hazardous Air Pollutants (HAPs) although they may not be regulated on the basis of ODPs or GWPs. HAPs include such common chlorinated solvents as trichloroethylene (TCE) and perchloroethylene (PCE). In some areas, HAP listing can preclude the use of a particular material, or more importantly, provide guidance on the design of proper equipment and proper workplace practices to allow its use.

Handling – All solvents should be handled with care, using the protective equipment and precautions outlined on the MSDS supplied by the manufacturer. In particular with the solvents characterized by high cost per kg or having a low allowable workplace vapor in air level, it is critical to transfer solvent into the cleaning machine below the vapor-air interface using a proper drum transfer pump. In the case of flammable solvents, air driven instead of electrical pumps should be used. Many of the larger cleaning

machines are fitted with transfer pumps as an option, which ensures that solvent is added to and removed from the cleaner properly. Such transfer pumps are often included if the cleaner is fitted with an attached still for recycling the solvent.

Recycling – Nonflammable solvents are readily recycled by use of a relatively simple still. The still can either be piped directly to the cleaner, to multiple cleaners (assuming the same soil is being removed in each cleaner) or a stand-alone unit. If similar soil chemistry is used for manual cleaning operations, including rework and repair, spent solvent from these cleaning operations can be combined with the solvent from the batch or conveyorized cleaning units, thus maximizing the solvent that is recycled and reused (see Section 8.5 for details of recycling still design, options, features, operation and maintenance).

Waste Generation – The generation of spent or waste cleaning solvents may be heavily regulated as a hazardous waste. It is imperative that all spent cleaning solvents be analyzed and characterized by someone knowledgeable in the hazardous waste generation, storage and shipment regulations. These regulations may subject a facility to extensive rules on personnel training, recordkeeping, storage and handling requirements. Even if hazardous waste rules are not applicable, local or state rules on solid waste, not regulated as hazardous, may apply (see Section 9.4 for further information).

Water Discharges – The following information is pertinent for users dealing with waste water streams from water separators and water cooling coils. Generally, the discharge of any new wastewater stream, both by total flow and by chemical makeup, will require a permit from the local publicly owned treatment works (POTW) under the Clean Water Act (CWA). In addition, such a permit may also require co-current state approval (and in rare cases, regional EPA approval). Hence, it is imperative that any new or additional wastewater flow from a solvent cleaning process step be reviewed with local POTW officials BEFORE commencing the discharge of wastewater. Such a review may result in the POTW waiving the need for a permit, or in reducing the monitoring requirements of a required permit. If wastewater discharge to an on-site septic disposal system is contemplated, any such groundwater discharges must be reviewed with the facility's state groundwater protection bureau on the need for a groundwater discharge permit. Extreme caution must be exercised in discharging wastewater containing cleaning solvents, as contaminated groundwater and possible soils may result, which can be extremely costly to remediate. Reference 9.3 for additional details.

Community Right-to-Know – In addition to the above considerations regarding air emissions, water discharges, and waste generation, the annual usage or storage amount of certain chemicals will subject a facility to community reporting

requirements to federal EPA, the state and local emergency planning commissions or fire departments. In addition, spills or leaks of certain chemicals above established thresholds will require self-reporting to federal, state and local agencies (see Section 9.5 for further detailed information).

3.5 Cost The costs (including initial acquisition and reclamation efficiency) must be reasonable. Solvents with low exposure limits, highly volatile, and flammable materials may require sophisticated equipment and controls to prevent excessive material loss and higher than permissible exposure levels. Previously mentioned factors of stability, effectiveness, disposal, work practices and safety, coupled with initial cost of the solvent are all important in determining total process cost based on overall cost per part cleaned.

3.6 Summary The cleaning agent should:

- not be harmful to employees
- possess excellent wetting ability to enable rapid exchange of the working volume of the cleaning agent under components and within blind holes or other entrapment areas
- be able to remove both soluble and particulate contaminants
- be compatible with the product, equipment and work area
- be stable during repeated reuse
- be cost efficient (lowest cost per part cleaned)

4 Properties of Cleaning Solvents

4.1 Introduction Several types of organic solvents are used in the cleaning of printed wiring boards (PWBs) and printed wiring assemblies (PWAs). Solvents are also contained in conformal coatings, which contact the laminate surface. The most common of the solvents are halogenated solvents, aliphatic hydrocarbons, alcohols, ketones, and aromatic solvents (see Tables 1 and 2). Blends of the various solvents are also commonly used. This section contains the following:

- Physical Properties
- Solvency
- Solvent monitoring / stability
- Safety and Environmental properties
- Cleaning processes

Discussion in each section is limited to the most commonly used solvents for cleaning PWAs (see Tables A-2 & A-3, Annex A).

4.2 Physical Properties The physical properties of several families of solvents are listed in the following tables.

Table 1 Physical Properties of Hydrocarbons and Oxygenated Solvents

Table 2 Physical Properties of Allowed and Discontinued Halogenated Solvents

Table A-2 Hydrogenated and Oxygenated Solvent Formulations (Annex A)

Table A-3 Halogenated Solvent Blends and Azeotropes (Annex A)

Note that blends of each of the solvents are available. The various blends and azeotropes do exhibit slightly different physical properties. Properties for a number of such blends are listed in Table A-2 and Table A-3 (Annex A). Individual manufacturers should be contacted for specific information by trade names.

4.3 Solvency Solvency of one material in another can be determined by comparing solubility parameters of the two materials involved. The closer the solubility parameters are, the better the solvency of the two compounds in each other. Obviously solvents or solvent formulations which have a similar solubility parameter as rosin would be best suited for the removal of rosin residues. The solubility parameter for epoxy resin (typical of laminate) is very close to that of methylene chloride, thus, methylene chloride was found to be the cause of resin softening and white spotting when military multilayer PWAs were defluxed with a cleaning solvent containing methylene chloride.

Both the older Hildebrand and modern Hansen solubility parameters which relate the actual soil and the cleaning solvent give a more accurate guide to cleaning efficacy and are therefore preferred for today's complex soils. An older guide used for predicting solvency was the Kauri-Butanol (KB) number per ASTM Method D-1133, which was an indirect measure related to the power of a solvent for dissolving Kauri gum.

It is critical to note here that neither of these solvency tests give a measurement for effectiveness of ionic contamination removal. This must be determined on an individual basis, taking into account the particular soldering materials, components and soldering parameters in the assembly operation. In general, multi-component formulations containing a base solvent and an alcohol are strongly recommended for ionic removal. Contact individual cleaning solvent suppliers for specific product performance capabilities, as they often have comparative laboratory data available for reference.

4.4 Polymer and Marking Compatibility At any temperature, the interactions between polymers (plastics, elastomers, solder resist, and inks used in marking) and solvents depend on a number of factors. Examples are: the chemical properties of the polymer in question, the polymer formulation parameters, the degree of crosslinking (curing or vulcanizing conditions), annealing or thermal

Table 1 Physical Properties of Common Hydrocarbons and Oxygenated Solvents

Property	Cyclopentane	Cyclohexane	Toluene	Xylene	Methanol	Ethanol	2-Propanol	1-Propanol	OS-10	OS-20
General Solvent Type	Hydrocarbon	Hydrocarbon	Hydrocarbon	Hydrocarbon	Alcohol	Alcohol	Alcohol	Alcohol	Methyl Siloxane	Methyl Siloxane
Boiling Point °C (°F)	49 (120)	81 (177)	110 (230)	127-159 (261 - 318)	64 (147)	78 (172)	82 (180)	97 (207)	100 (212)	152 (306)
Flash Point, TCC °C (°F)	-37 (-35)	-18 (-1)	4 (40)	27 (80)	11 (52)	14 (57)	12 (54)	22 (72)	-3 (27)	34 (93)
Flammable Limits - LEL (vol % in air)	1.5									
Flammable Limits - UEL (vol % in air)	8.7									
Vapor Pressure at 20°C, torr	400	78			95	45	33			
Relative Evaporation Rate (butyl acetate = 1)		5.6								
Vapor Density (air = 1.00)										
Liquid Density at 25°C, g/cm ³ (lb/gal)	0.750 (6.30)	0.775 (6.47)	0.867 (7.23)	0.868 (7.24)	0.792 (6.61)	0.765 (6.63)	0.787 (6.57)	0.815 (6.80)		
Surface Tension at 20°C, dyne/cm	22.6	24.6 ¹	28.4	28.9	22.6	22.8	22.6	23.9	15.2	16.5
Viscosity at 20°C, cp	0.50	0.91 ¹	0.59	0.69	0.62	1.22	2.40	2.26	0.65	1.00
Solubility of water in solvent (weight % at 20°C)	Negligible	Negligible	0.04	0.02	∞	∞	∞	∞		
Solubility of solvent in water (weight % at 20°C)	Negligible	Negligible	0.05		∞	∞	∞	∞		
Solubility Parameter (Hansen) (Cal/cm ³) ^{1/2}										
- Nonpolar	8.1	8.2	8.8	8.1	7.4	7.7	7.7			
- Polar	0	0	0.7	3.4	6.0	4.3	3.0			
- Hydrogen bond	0.1	0.1	1.0	1.0	10.9	9.5	8.0			
Solubility Parameter (Hildebrand), (Cal/cm ³) ^{1/2}	8.1	8.2	8.9	8.8	14.5	13.0	11.5	11.9		
Kauri Butanol Value	53	56	94-105	94					17	15
VOC Content, grams/liter	738	775								
Exposure limit, ppm	600									
Atmospheric Lifetime, years									15 days	15 days
Global Warming Potential (CO ₂ = 1) =>100 yr ITH										
Ozone Depletion Potential	0	0	0	0	0	0	0	0	0	0

Notes: ¹Values @ 25°C

1. Blank space indicates data not available.