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February 1999

EPA

Environmental Technology Verification Report

Ultrasonic Aqueous Cleaning Systems
Smart Sonic Corporation
SMARTSONIC®

ETV ETV ETV

EPA/600/R-99/004 VS
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Environmental Technology Verification Report

Ultrasonic Aqueous Cleaning Systems
Smart Sonic Corporation, **SMARTSONIC®**

By

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U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
CINCINNATI, OHIO 45268

Notice

The information in this document has been funded in part by the U.S. Environmental Protection Agency (EPA) under a Cooperative Agreement number CR 824433-01-0 with the California Environmental Protection Agency (Cal/EPA), Department of Toxic Substances Control (DTSC). This verification effort was supported by the Hazardous Waste Treatment and Pollution Prevention Pilot Project under the US EPA Environmental Technology Verification (ETV) Program. This verification effort has been subjected to EPA's and Cal/EPA's peer and administrative review, and has been approved for publication as an EPA document.

This verification is limited to the use of the Smart Sonic aqueous cleaning systems for cleaning RMA (rosin mildly activated), no-clean, and water washable solder pastes from printed circuit board stencils. US EPA and DTSC makes no express or implied warranties as to the performance of the Smart Sonic aqueous cleaning systems. Nor does US EPA and DTSC warrant that the Smart Sonic aqueous cleaning systems are free from any defects in workmanship or materials caused by negligence, misuse, accident or other causes. Mention of corporation names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products.

Foreword

The Environmental Technology Verification (ETV) Program has been established by the U.S. Environmental Protection Agency (EPA) to evaluate the performance characteristics of innovative environmental technologies across all media and to report this objective information to the permitters, buyers, and users of environmental technology. EPA's Office of Research and Development (ORD) has established a five year pilot program to evaluate alternative operating parameters and determine the overall feasibility of a technology verification program. ETV began in October 1995 and will be evaluated through October 2000, at which time EPA will prepare a report to Congress containing the results of the pilot program and recommendations for its future operation.

EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), has partnered with the California Department of Toxic Substances Control (DTSC) under an ETV Pilot Project to verify pollution prevention, recycling, and waste treatment technologies. This Pilot Project focuses on, but is not limited to, hazardous waste management technologies used in several EPA "Common Sense Initiative" industry sectors: printing; electronics; petroleum refining; metal finishing; auto manufacturing; and iron and steel manufacturing.

The following report reviews the performance of the Smart Sonic Aqueous Cleaning Systems. These cleaning systems are used in the electronics industry to clean various types of solder pastes from printed circuit board stencils.

Acknowledgment

Pat Bennett, DTSC's Project Manager, wishes to acknowledge the support of all those who helped plan, implement the verification activities, and prepare this report. In particular, a special thanks to Ms. Norma Lewis, Project Manager, and Mr. Sam Hayes, Quality Assurance Manager, of EPA's National Risk Management Research Laboratory in Cincinnati, Ohio.

DTSC's Project Manager acknowledges the efforts by DTSC's Project Team members and by DTSC's Technical Review Panel. DTSC's Project Team members included Mr. Bruce LaBelle, Mr. Dick Jones, and Mr. Phil Loder. DTSC's Technical Review Panel included Mr. John Wesnousky, Mr. Wolfgang Fuhs, and Mr. Tony Luan.

DTSC's Project Manager would also like to thank the printed circuit board manufacturers for participating in the verification activities. A special thanks to the printed circuit board facilities that allowed DTSC's Project Team to conduct on-site observations and inspections. These facilities and contacts included:

Mr. Thanh Vo
PNY Electronics
Santa Clara, CA

Mr. Tom Lord
Kaiser Electronics
San Jose, CA

Mr. Mike Moynihan
Technetics
El Cajon, CA

Mr. Bob Dudley
Altron
Fremont, CA

Mr. Roger Lara
Wiltron
Morgan Hill, CA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington D.C. 20460

ENVIRONMENTAL TECHNOLOGY VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**ULTRASONIC AQUEOUS CLEANING SYSTEMS**
APPLICATION:	**CLEANING PRINTED CIRCUIT BOARD STENCILS**
TECHNOLOGY NAME:	**SMART SONIC®**
COMPANY:	**SMART SONIC CORPORATION**
ADDRESS:	**2373 TELLER ROAD, #107 NEWBURY PARK, CALIFORNIA 91320**
PHONE:	**(805) 499-7440**
FAX:	**(805) 375-5781**

The U.S. Environmental Protection Agency has created a program to facilitate the deployment of innovative environmental technologies through performance verification and information dissemination. The goal of the Environmental Technology Verification (ETV) Program is to enhance environmental protection by substantially accelerating the acceptance and use of innovative, improved, and more cost-effective technologies. The ETV Program is intended to assist and inform those individuals in need of credible data for the design, distribution, permitting, and purchase of environmental technologies. This verification statement provides a summary of performance results for the Smart Sonic Aqueous Cleaning Systems, registered trademark **SMART SONIC®**.

PROGRAM OPERATION

The EPA's ETV Program, in partnership with recognized testing organizations, objectively and systematically documents the performance of commercial ready environmental technologies. Together, with the full participation of the technology developer, they develop plans, conduct tests, collect and analyze data, and report findings. Verifications are conducted according to a rigorous workplan and established protocols for quality assurance. Where existing data are used, the data must have been collected by independent sources using similar quality assurance protocols. EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), has partnered with the California Department of Toxic Substances Control (DTSC) under an ETV Pilot Project to verify pollution prevention, recycling, and waste treatment technologies.

TECHNOLOGY DESCRIPTION

Smart Sonic Corporation developed the Model 2000 and Model 4200 ultrasonic aqueous cleaning systems to replace 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113), 1,1,1-trichloroethane (1,1,1-TCA) and isopropyl alcohol (IPA) based systems used in the electronics industry to clean various types of solder pastes from printed circuit board stencils.

Smart Sonic's stencil cleaning technology consists of Smart Sonic's proprietary 440-R SMT Detergent®, ultrasonic generator and 40 kHz piezoelectric transducers, stainless steel wash tank, rinse tank (included in semi-automated system), and control devices.

The semi-automated Model 2000 system is approximately 3 feet high with a 40 x 44 inch base . This unit has a separate wash tank and a manual rinse station. The automated Model 4200 system is approximately 50 inches high with a 36 x 62 inch base. The pneumatic lift used on this model extends 36 inches for a total system height of 86 inches. This system has one tank for washing with an automated rinse over the wash tank.

The combination of Smart Sonic's 440-R SMT Detergent and ultrasonics enables the removal of solder pastes from printed circuit board stencils. Detergent surfactants act as wetting agents to saturate the solder paste layer that is left on the stencil surface (from solder paste printing operation). The ultrasonics then produce an intense scrubbing action, through cavitation and implosion of microscopic bubbles that enhances removal of the saturated solder paste layer. Ultrasonics are often more effective in cleaning hard-to-reach surfaces (i.e., small stencil apertures) than brushes and hand wipes. The cleaning bath is operated at room temperature, eliminating any potential effects to stencil from cleaning solutions requiring higher temperatures.

EVALUATION DESCRIPTION

Between May and September 1998, an evaluation of two ultrasonic aqueous cleaning systems, developed by the Smart Sonic Corporation, was conducted using field and laboratory qualitative and quantitative data. The aqueous cleaning systems include Smart Sonic's Model 2000 and Model 4200 systems. The objectives of this evaluation were to verify, through independent sources, the following performance parameters:

- the ability to remove RMA (rosin mildly activated), no-clean, and water washable solder pastes from printed circuit board stencils;
- the content of volatile organic compounds (VOC) and halogenated compounds in the cleaning systems; and
- characteristics or conditions from use of this technology which may pose a significant hazard to public health and the environment.

The evaluation consisted of:

- cleaning performance validation through on-site visits of end-users and further validation through additional end-user phone contacts;
- laboratory testing for select VOCs and halogenated compounds by California's SCAQMD using SCAQMD's Clean Air Solvent (CAS) Certification Protocol (CAS Protocol uses SCAQMD Test Method 313 - gas chromatograph/mass spectrometer);
- laboratory testing for metals and pH by DTSC's Hazardous Materials Laboratory using EPA Test Method 6010/7470 and EPA Test Method 9040 respectively;
- toxicological review of laboratory results and aqueous cleaner ingredients to determine if potential hazards to human health or the environment exist; and
- industrial hygiene review of cleaning systems information manual and on-site safety observations.

Details of the evaluation, including data summaries and discussion of results may be found in the report entitled " US EPA Environmental Technology Verification Report, Smart Sonic Aqueous Cleaning Systems, SMART SONIC® (EPA/600/R-99/004)."

VERIFICATION OF PERFORMANCE

Performance results of Smart Sonic Corporation's aqueous cleaning systems, Model 2000 and Model 4200, are as follows:

- *Cleaning Efficiency:* In five facilities visited, DTSC's Project Team found no solder paste in stencil apertures when observed at 10X magnification. The size of stencil apertures ranged from 12-50 mil (1 mil=.001 inch). All end-users removed excess solder paste from stencil prior to cleaning in the Smart Sonic aqueous cleaning systems. Cleaning times ranged from 60-90 seconds. Four of the five end-users visited were using a 10% concentration of Smart Sonic's 440-R SMT Detergent (10% concentration recommended by Smart Sonic). The fifth end-user was using a 5% detergent concentration for removing water washable solder paste.

  [Additional Information: Eight additional end-users contacted via phone were satisfied with the Smart Sonic stencil cleaning systems and stated that the systems clean consistently and as good, if not better, than the previously used cleaning systems. Previously used systems included CFC-113, 1,1,1-TCA and IPA. Alcohol and wipes were the most commonly used cleaning method.]

- *VOC Content:* The 440-R SMT Detergent does not contain VOCs or halogenated compounds at a detection limit of 0.01% (v/v) using the SCAQMD's CAS Certification Protocol.

- *Metals Content:* Metals analyses conducted by DTSC's Hazardous Materials Laboratory indicate that samples of Smart Sonic's 440-R SMT Detergent concentrate showed no hazardous metals above method detection limits.

- *pH Measurement:* pH measurements conducted by DTSC's Hazardous Materials Laboratory indicates a 440-R SMT Detergent concentrate pH of 13. pH measurements conducted by DTSC's Project Team during on-site visits (using pH indicator paper with pH range 0-14) showed cleaning bath pH of 11 when using 10% 440-R SMT Detergent concentration.

- *Worker Health and Safety:* While using Smart Sonic Aqueous Cleaning Systems, Model 2000 and 4200, end-users should follow Smart Sonic's recommended safety practices as outlined in the User's Manual and 440-R SMT Detergent Material Safety Data Sheet (MSDS). The only significant toxicity associated with the 440-R SMT Detergent concentrate is acute toxicity due to its highly alkaline nature. DTSC's Industrial Hygienist recommends end-users have an eye wash station and an MSDS available within close proximity to the cleaning systems.

Results of the verification show that the Smart Sonic ultrasonic aqueous cleaning systems, Model 2000 and 4200, are capable of removing RMA (rosin mildly activated), no-clean, and water washable solder pastes from printed circuit board stencils such that no solder paste remains in stencil apertures at 10X magnification, provided that end-users follow Smart Sonic's cleaning guidelines. The Model 2000 and 4200 cleaning systems do not contain select volatile organic compounds and halogenated compounds above detection limit of 0.01% (v/v) using SCAQMD's CAS Certification Protocol (April 1997). End-users should follow Smart Sonic's operational and safety guidelines.

End-users should contact their stencil manufacturer prior to changing their cleaning process. Changing from solvents to aqueous cleaning systems may require stencil modifications to make the cleaning system and stencil compatible. In addition, the end-user should contact his/her local, state, or federal regulatory authority regarding management of spent hazardous wastes generated from use of the Smart Sonic aqueous cleaning systems (i.e., spent cleaning baths, rinse baths, and solids containing lead).

Original Signed By
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2/19/99

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California Environmental Protection Agency

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and Cal/EPA make no expressed or implied warranties as to the performance of the technology. The end-user is solely responsible for complying with any and all applicable federal, state, and local requirements.

Availability of Verification Statement and Report

Copies of the public Verification Statement (EPA/600/R-99/004VS) and Verification Report (EPA/600/R-99/004) are available from the following:

(Note: Appendices are not included in the Verification Report. Appendices are available from DTSC upon request.)

1. **US EPA / NSCEP**
   P.O. Box 42419
   Cincinnati, Ohio 45242-2419

   Web site: http://www.epa.gov/etv/library.htm *(electronic copy)*
   http://www.epa.gov/ncepihom/ *(order hard copy)*

2. **Department of Toxic Substances Control**
   Office of Pollution Prevention and
   Technology Development
   P.O. Box 806
   Sacramento, California 95812-0806

   Web site: http://www.dtsc.ca.gov/sppt/opptd/etv/txppetvp.htm
   or http://www.epa.gov/etv *(click on partners)*

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APPENDICES (Available from DTSC Upon Request)

LIST OF ACRONYMS

1,1,1-TCA	1,1,1-trichloroethane
CAS	Clean Air Solvent
CCR	California Code of Regulations
CFC-113	1,1,2-trichloro-1,2,2-trifluoroethane
CFR	Code of Federal Regulations
DI	De-Ionized (Water)
DTSC	Department of Toxic Substances Control
ETV	Environmental Technology Verification
GC/MS	Gas Chromatography/Mass Spectrometry
g/L	grams/Liter
GWC	Global Warming Compound
HML	Hazardous Materials Laboratory
IH	Industrial Hygienist
IPA	Isopropyl Alcohol
kHz	frequency (one thousand cycles per second)
mcg/gm	microgram/gram
mg/kg	milligrams/kilograms
mil	one thousandths inch (.001")
MSDS	Material Safety Data Sheet
NRMRL	National Risk Management Research Laboratory
ODC	Ozone Depleting Compound
PCB	Printed Circuit Board
RMA	Rosin Mildly Activated
SCAQMD	South Coast Air Quality Management District
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
VOHAP	Volatile Organic Hazardous Air Pollutant
v/v	volume/volume

Executive Summary

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the nation's natural resources. EPA created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative technologies through performance verification and information dissemination. The goal of the ETV Program is to enhance environmental protection by substantially accelerating the acceptance and use of innovative, improved, and cost-effective technologies. The ETV Program is intended to assist and inform those individuals in need of credible data for the design, distribution, permitting, and purchase of commercially-ready environmental technologies.

EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), has partnered with the California Department of Toxic Substances Control (DTSC) under an ETV Pilot Project to verify pollution prevention, recycling, and waste treatment technologies. The Pilot Project focuses on, but is not limited to, several EPA "Common Sense Initiative" industry sectors: printing; electronics; petroleum refining; metal finishing; auto manufacturing; and iron and steel manufacturing.

Candidate technologies for these programs originate from both the private and public sectors and must be market-ready. Through the ETV Pollution Prevention, Recycling, and Waste Treatment Pilot Project, developers are given the opportunity to have the performance of their technology or product tested and evaluated under realistic laboratory or field conditions. By completing the verification and distributing the results, EPA establishes a baseline for acceptance and use of these technologies.

This pilot project evaluates the performance of two ultrasonic aqueous cleaning systems developed by the Smart Sonic Corporation located in Newbury Park, California. Smart Sonic Corporation developed these two ultrasonic aqueous cleaning systems to replace 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113), 1,1,1-trichloroethane (1,1,1-TCA) and isopropyl alcohol (IPA) based systems that are used in the electronics industry to clean various types of solder pastes from printed circuit board stencils. The objectives of this evaluation is to verify, through independent sources, the following performance parameters:

- the ability to remove RMA (rosin mildly activated), no-clean, and water washable solder pastes from printed circuit board stencils;
- the content of volatile organic compounds (VOC) and halogenated compounds in the cleaning systems; and
- characteristics or conditions from use of this technology which may pose a significant hazard to public health and the environment.

Technology Description

Smart Sonic stencil cleaning technology consists of Smart Sonic's proprietary 440-R SMT Detergent®, ultrasonic generator with 40 kHz piezoelectric transducers, stainless steel wash tank, rinse tank (included in semi-automated system), and control devices.

The Smart Sonic stencil cleaning systems evaluated in this project include the semi-automated Model 2000 and automated Model 4200 shown in Figure ES-1. The semi-automated Model 2000 system is approximately 3 feet high with a 40 x 44 inch base. This unit has a separate wash tank and a manual rinse station. The automated Model 4200 system is approximately 50 inches high with a 36 x 62 inch base. The pneumatic lift used on this model extends 36 inches for a total system height of 86 inches. This system has one tank for washing with an automated rinse over the wash tank.

Model 2000

Model 4200

440-R SMT Detergent

Figure ES-1. Smart Sonic cleaning systems.

Evaluation Approach

The evaluation consisted of:

- cleaning performance validation through on-site visits of end-users and further validation through additional end-user phone contacts;
- laboratory testing for select VOCs and halogenated compounds by California's SCAQMD using SCAQMD's Clean Air Solvent (CAS) Certification Protocol (CAS Protocol uses SCAQMD Test Method 313 - gas chromatograph/mass spectrometer);

- laboratory testing for metals and pH by DTSC's Hazardous Materials Laboratory (HML) using EPA Test Method 6010/7470 and EPA Test Method 9040 respectively;
- toxicological review of laboratory results and aqueous cleaner ingredients to determine if potential hazards to human health or the environment exist; and
- industrial hygiene review of cleaning systems information manual and on-site safety observations.

Verification of Performance

Performance results of Smart Sonic Corporation's aqueous cleaning systems, Model 2000 and Model 4200, are as follows:

- *Cleaning Efficiency:* In five facilities visited, DTSC's Project Team found no solder paste in stencil apertures when observed at 10X magnification. The size of stencil apertures ranged from 12-50 mil (1 mil=.001 inch). All end-users removed excess solder paste from stencil prior to cleaning in the Smart Sonic aqueous cleaning systems. Cleaning times ranged from 60-90 seconds. Four of the five end-users visited were using a 10% concentration of Smart Sonic's 440-R SMT Detergent (10% concentration recommended by Smart Sonic). The fifth end-user was using a 5% detergent concentration for removing water washable solder paste.

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- *VOC Content:* The 440-R SMT Detergent does not contain VOCs or halogenated compounds at a detection limit of 0.01% (v/v) using the SCAQMD's CAS Certification Protocol.

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- *pH Measurement:* pH measurements conducted by DTSC's Hazardous Materials Laboratory indicates a 440-R SMT Detergent concentrate pH of 13. pH measurements conducted by DTSC's Project Team during on-site visits (using pH indicator paper with pH range 0-14) showed cleaning bath pH of 11 when using 10% 440-R SMT Detergent concentration.

- *Worker Health and Safety:* While using Smart Sonic Aqueous Cleaning Systems, Model 2000 and 4200, end-users should follow Smart Sonic's recommended safety practices as outlined in the User's Manual and 440-R SMT Detergent Material Safety Data Sheet (MSDS). The only significant toxicity associated with the 440-R SMT Detergent concentrate is acute toxicity due to its highly alkaline nature. DTSC's Industrial Hygienist recommends end-users have an eye wash station and an MSDS available within close proximity to the cleaning systems.

Results of the verification show that the Smart Sonic ultrasonic aqueous cleaning systems, Model 2000 and 4200, are capable of removing RMA (rosin mildly activated), no-clean, and water washable solder pastes from printed circuit board stencils such that no solder paste remains in stencil apertures at 10X magnification, provided that end-users follow Smart Sonic's cleaning guidelines. The Model 2000 and 4200 cleaning systems do not contain select volatile organic compounds and halogenated compounds above detection limit of 0.01% (v/v) using SCAQMD's CAS Certification Protocol (April 1997). End-users should follow Smart Sonic's operational and safety guidelines.

End-users should contact their stencil manufacturer prior to changing their cleaning process. Changing from solvents to aqueous cleaning systems may require stencil modifications to make the cleaning system and stencil compatible. In addition, the end-user should contact his/her local, state, or federal regulatory authority regarding management of spent hazardous wastes generated from use of the Smart Sonic aqueous cleaning systems (i.e., spent cleaning baths, rinse baths, and solids containing lead).

Section 1.
Introduction

Stencils are used in the printed circuit board industry to apply a solder paste pattern onto surface mounted circuit boards (termed "printing"). Electronic components are then mounted to the circuit board in the solder paste areas. Following the assembly of components, the circuit board is processed in the reflow oven in which the solder melts and forms the solder joint. After printing, the stencil is cleaned to remove residual solder paste and is stored for a future print run. It is important to clean the stencil thoroughly so as to not cause misprints in future print runs. A description of printed circuit board stencils and types of solder pastes is provided in Figure 1-1[1].

Background

Solvents used to clean solder paste from printed circuit board stencils include 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113), 1,1,1-trichloroethane (1,1,1-TCA) and isopropyl alcohol (IPA). The production of chlorinated solvents CFC-113 and 1,1,1-TCA have been banned as of January 1, 1996 (Title VI of the Clean Air Act Amendments) because these solvents contribute to stratospheric ozone depletion and global warming. Stockpiled chlorinated solvents are still used. At present, they account for less than 5 percent of total use (estimate by Smart Sonic Corporation).

Following the production ban of CFC-113 and 1,1,1-TCA, businesses began switching to alternative solvents such as IPA, but IPA contributes to tropospheric smog and therefore is considered a VOC. Use of CFC-113, 1,1,1-TCA, and IPA also generates hazardous waste and poses a potential threat to worker health and safety.

Smart Sonic Technology

Smart Sonic Corporation developed ultrasonic aqueous cleaning systems to replace CFC-113, 1,1,1-TCA, and IPA-based systems for removing solder paste from printed circuit board stencils.

General Consideration

The Smart Sonic aqueous cleaning technology was originally accepted into the US EPA's verification program as a pollution prevention technology due to its potential to reduce or eliminate the use of smog and ozone depleting chemicals and for its potential to reduce hazardous waste generation. In general, the conversion to aqueous cleaners has minimized the impact to air, but it is still uncertain how this conversion affects water and land. Unlike solvents that were typically recycled off-site and returned to the business, aqueous cleaners, once spent, require treatment either on-site or off-site. The aqueous cleaners are then discharged to a wastewater treatment facility where they are further treated and discharged to a local body of water. There are no studies to date that show the impacts of aqueous cleaners on all environmental media. A more thorough analysis is needed to compare the impacts of aqueous cleaners versus organic solvents before claims of pollution prevention can be substantiated.

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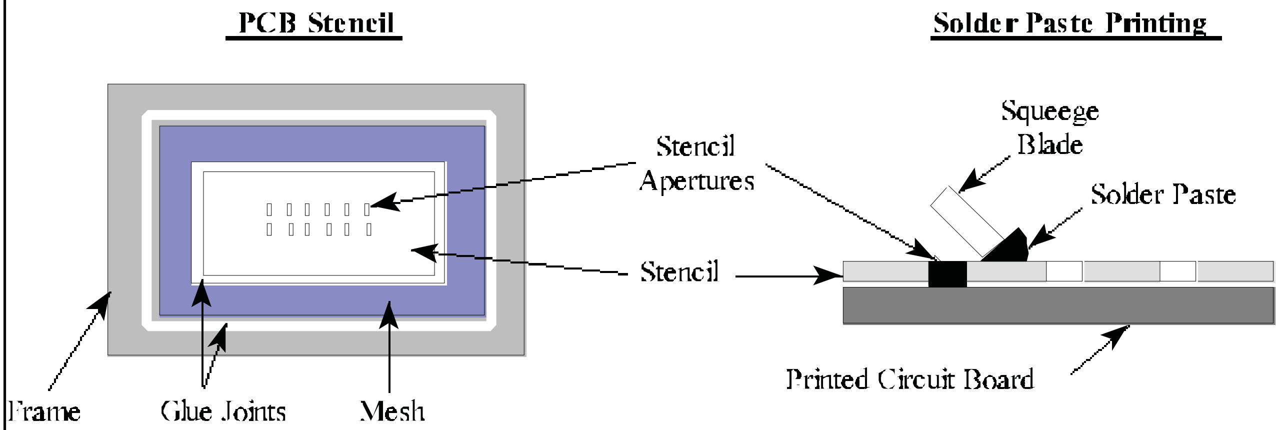
1 Howard H. Manko, Soldering Handbook for Printed Circuits and Surface Mounting, Second Edition



Stencils

Printed circuit board stencils are usually made up of different materials. The frame is aluminum, the screen is either stainless steel or polyester, and the stencil is either stainless steel, brass, or nickel. The stencil is bonded to the mesh via an adhesive. The mesh is also bonded to the frame via an adhesive.

Solder Pastes[1]

Solder paste consists of a powdered solder (typically a tin/lead powdered alloy) suspended in a flux base and a suitable vehicle. The flux base consists of rosin, resin, or a water soluble ingredient. Another component of the flux system is the active ingredients which give the flux its chemical strength. The vehicle and plasticizer are needed to give the material its consistency, suitable for screening. There are several types of solder pastes that are used in PCB printing operations. These include Rosin Moderately Activated (RMA), No-Clean, and Water Washable. The main distinction between these solder pastes are the type of fluxes used.

Rosin Mildly Activated (RMA) - made of a variety of natural and modified rosins. These fluxes contain a number of chemical additives called activators to give the flux more chemical strength for tarnish removal.

No-Clean - resin and synthetic based fluxes which are an extension to the rosin based fluxes. These fluxes are very low solid content formulations and are designed to be left on the PCB board without adding any detrimental residues.

Water Washable - nonrosin organic based fluxes. These fluxes can range in strength (i.e., tarnish removal, cleaning action) and are water soluble.

Figure 1-1. Description of PCB stencil and solder paste types.

This verification will not make reference to pollution prevention and therefore will not attempt to compare Smart Sonic's aqueous cleaning technology to that of other CFC-113, 1,1,1-TCA, and IPA-based cleaning systems.

Section 2.
Description of Technology

Smart Sonic Corporation's stencil cleaning systems consist of Smart Sonic's 440-R SMT Detergent, ultrasonic generator with 40 kHz piezoelectric transducers, stainless steel wash tank, rinse tank (included in the semi-automated system), and control devices. Smart Sonic's stencil cleaning systems evaluated in this project include the semi-automated Model 2000 and automated Model 4200 shown in Figures ES-1 and 2-1. The semi-automated Model 2000 system is approximately 3 feet high with a 40 x 44 inch base. This system has a wash tank and a separate rinse station. System operations include preparing the initial wash bath, manually lowering the stencil in the wash tank, setting the wash cycle timer (cleaning time) and pressing the start button, manually removing the stencil from the wash tank after completion of the wash cycle, rinsing the stencil in a separate rinse tank using a hand-held spray nozzle (supplied with system), and drying the stencil using dry compressed air or allowing to air dry.

The automated Model 4200 system is approximately 50 inches high with a 36 x 62 inch base. A pneumatic lift, used to raise and lower the stencil in the wash bath, extends 36 inches for a total system height of 86 inches. This system has one tank for washing with an automated rinse over the wash tank. System operations include preparing the initial wash bath, loading the stencil into the pneumatic lift, setting the wash cycle timer (ultrasonic time) and pressing two start buttons (safety feature used to keep hands clear of pneumatic lift), and drying the stencil using dry compressed air or allowing to air dry. The automated functions include raising and lowering the stencil into the wash bath, cleaning the stencil to the preset wash time, and rinsing the stencil using an automated rinse over the wash bath. The volume of rinse water used is predetermined by the speed of the pneumatic lift during its opening cycle.

A feature of both systems are indicator lights and alarms to indicate either a low and/or high level condition in the wash tank. There are also several options for each system such as a power drain to pump the spent wash bath and rinses from the tanks for further waste management, a heater for cleaning applications requiring higher solution temperatures, and for the Model 4200 system an optional auto fill button for filling the wash tank with water and detergent. A brochure on Smart Sonic's stencil cleaning systems is provided in Appendix A.

The combination of Smart Sonic's 440-R SMT Detergent and ultrasonics enables the removal of solder pastes from printed circuit board stencils. The detergent surfactants act as wetting agents to saturate the solder paste layer that is left on the stencil surface (from solder paste printing operation). The ultrasonics then produce an intense scrubbing action, through cavitation and implosion of microscopic bubbles, that enhances removal of the saturated solder paste layer. Ultrasonics are often more effective in cleaning hard-to-reach surfaces (i.e., small stencil apertures) than brushes and hand wipes. The cleaning bath is operated at room temperature, eliminating any potential effects to stencil from cleaning solutions requiring higher temperatures.

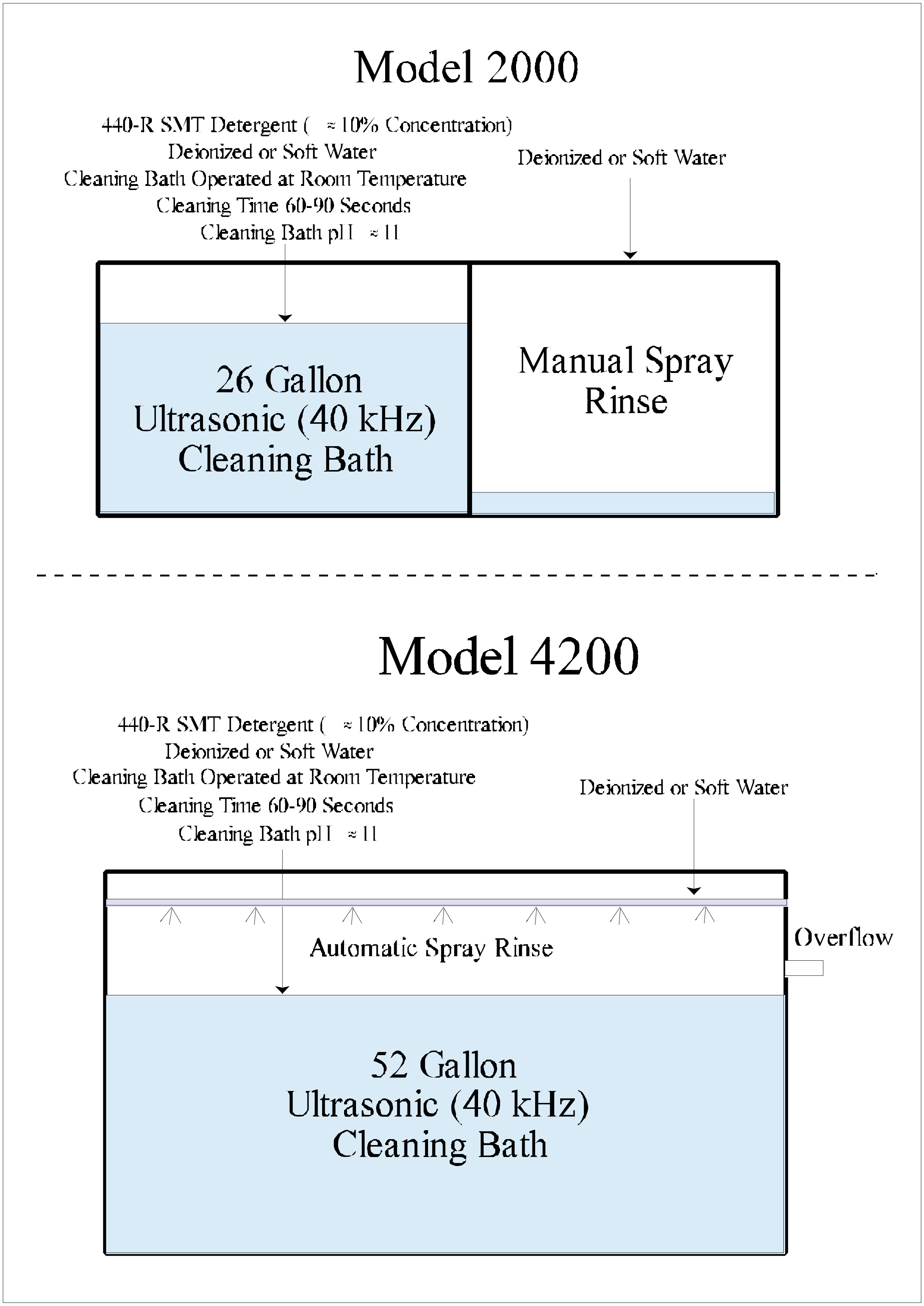


Figure 2-1. Smart Sonic cleaning system operating parameters.

Section 3.
Verification Activities and Results

3.1 Laboratory Testing Conducted by DTSC Project Team

DTSC's Project Team conducted VOC analyses, metals analyses, and pH measurements of two 440-R SMT Detergent samples. The purpose of this activity was to:

- determine if the 440-R SMT Detergent contains VOCs or halogenated compounds using the SCAQMD's CAS Protocol; and
- identify any metals which may pose a potential health and safety or environmental problem.

DTSC's Project Team obtained a third sample from an end-user which was spiked with known compounds and concentrations in order to determine the accuracy of SCAQMD's test method. DTSC and US EPA Project team selected four compounds, one from each of the four functional groups of compounds used in SCAQMD's calibration standards. The four functional groups include oxygenated organic compounds, hydrocarbon compounds, aromatic compounds, and chlorinated compounds. The selected compounds include 2-butanone, octane, toluene, and carbon tetrachloride. The sample was spiked with approximately 1% of each compound. Currently, SCAQMD's CAS Protocol does not require a spiking of samples.

3.1.1 Sampling of Smart Sonic 440-R SMT Detergent (Concentrate)

DTSC's Project Manager and two Project Team members sampled two sites on May 28, 1998. A 500 ml detergent sample from each site was transported to DTSC's HML in Southern California for metals analyses and pH measurements. A 1000 ml detergent sample from each site was transported to SCAQMD laboratory for VOC analyses. In addition, a 100 ml detergent sample was taken from one of the sites and transported to SCAQMD laboratory for spiked sample analyses. All samples were drawn from unopened 5-gallon containers. A trip report identifying the sites, contacts, team member roles, and sampling activity is provided in Appendix B.

3.1.2 Results of VOC Analyses

SCAQMD conducted VOC analyses of the two 440-R SMT Detergent concentrate samples using SCAQMD's CAS Certification Protocol (CAS Protocol requires SCAQMD to use SCAQMD's Test Method 313 *"Determination of Volatile Organic Compounds by GC/MS"*. SCAQMD evaluated the GC/MS data for the presence of Volatile Organic Hazardous Air Pollutants (VOHAPs), Ozone Depleting Compounds (ODCs), and Global Warming Compounds (GWCs). Results of VOC analyses are shown in Table 3-1. The list of VOHAPs, ODCs, and GWCs targeted in SCAQMD's CAS Protocol is provided in Tables 3-3, 3-4, and 3-5. SCAQMD's laboratory reports are provided in Appendix C.

Table 3-1. Results of SCAQMD's VOC Analyses

SCAQMD Test Method 313	VOHAPs	ODCs	GWCs
Sample 1	Non-Detect	Non-Detect	Non-Detect
Sample 2	Non-Detect	Non-Detect	Non-Detect

In both samples, the GC indicated two peaks that SCAQMD further evaluated using mass spectrometry. One of the compounds was tentatively identified as heptane, 2,4-dimethyl. The second compound was identified as "unknown." Based on semi-quantitative calculations, the concentrations of these two compounds would not exceed the SCAQMD limits to cause concern. Overall results indicate that both end-user samples of 440-R SMT Detergent showed no detection [0.01% (v/v) detection limit] of VOCs or halogenated compounds.

SCAQMD's spiked sample QA/QC results, shown in Table 3-2, indicated that recovery of spiked compounds were well within the 75% - 125% requirement.

Table 3-2. Results of SCAQMD's Spiked Sample Recovery Analyses

Spiked Compound	% Recovery
n-Octane	102.2
2-Butanone	98.49
Toluene	97.42
Carbon Tetrachloride	93.08

During review of the VOC analyses, DTSC's Project Manager found a discrepancy between the GC/MS calibration procedure used during the SCAQMD testing and the GC/MS calibration procedure outlined in the CAS Protocol. The CAS Protocol requires a multi-level calibration using .1, 1, 10, and 25 g/L standards. Prior to testing Smart Sonic's 440-R SMT Detergent samples, a single-point calibration of the GC/MS was performed. This results in a single-point calibration response factor instead of an average response factor that would be obtained from a multi-level calibration. Calibration checks using 25 g/L standards showed that target analytes were within ±25% of the single-point calibration response factor.

Table 3-3. SCAQMD Targeted Hazardous Air Pollutants

CAS NUMBER	CHEMICAL NAME	CAS NUMBER	CHEMICAL NAME
75070	Acetaldehyde	126998	Chloroprene
0355	Acetamide	1319773	Cresols/Cresylic acid (isomers and mixture)
75058	Acetonitrile		
98862	Acetophenone	95487	o-Cresol
53963	2-Acetylaminofluorene	108394	m-Cresol
107028	Acrolein	106445	p-Cresol
79061	Acrylamide	98828	Cumene
79107	Acrylic acid	94757	2,4-D, salts and esters
107131	Acrylonitrile	3547044	DDE
107051	Allyl chloride	334883	Diazomethane
92671	4-Aminobiphenyl	132649	Dibenzofurans
62533	Aniline	96128	1,2-Dibromo-3-chloropropane
90040	o-Anisidine	84742	Dibutylphtalate
1332214	Asbestos	106467	1,4-Dichlorobenzene(p)
71432	Benzene (including benzene from gasoline)	91941	3,3-Dichlorobenzidene
		111444	Dichloroethyl ether (Bis(2-chloroethyl)ether)
92875	Benzidine		
98077	Benzotrichloride	542756	1,3-Dichloropropene
100447	Benzyl chloride	62737	Dichlorvos
92524	Biphenyl	111422	Diethanolamine
117817	Bis(2-ethylhexyl)phthalate (DEHP)	121697	N,N-Diethyl aniline (N,N-Dimethylaniline)
542881	Bis(chloromethyl)ether	64675	Diethyl sulfate
75252	Bromoform	119904	3,3-Dimethoxybenzidine
106990	1,3-Butadiene	60117	Dimethyl aminoazobenzene
156627	Calcium cyanamide	119937	3,3-Dimethyl benzidine
105602	Caprolactam	79447	Dimethyl carbamoyl chloride
133062	Captan	68122	Dimethyl formamide
63252	Carbaryl	57147	1,1-Dimethyl hydrazine
75150	Carbon disulfide	131113	Dimethyl phthalate
56235	Carbon tetrachloride	77781	Dimethyl sulfate
463581	Carbonyl sulfide	534521	4,6-Dinitro-o-cresol, and salts
120809	Catechol	51285	2,4-Dinitrophenol
133904	Chloramben	121142	2,4-Dinitrotoluene
57749	Chlordane	123911	1,4-Dioxane (1,4-Diethylene oxide)
7782505	Chlorine		
79118	Chloroacetic acid	122667	1,2-Diphenylhydrazine
532274	2-Chloroacetophenone	106898	Epichlorohydrin (1-Chloro-2, 3-epoxypropane)
108907	Chlorobenzene		
510156	Chlorobenzilate	106887	1,2-Epoxybutane
67663	Chloroform	140885	Ethyl acrylate
107302	Chloromethyl methyl ether	100414	Ethyl benzene

Table 3-3. Continued

CAS NUMBER	CHEMICAL NAME	CAS NUMBER	CHEMICAL NAME
51796	Ethyl carbamate (Urethane)	108101	Methyl isobutyl ketone (Hexone)
75003	Ethyl chloride (Chloroethane)	624839	Methyl isocyanate
106934	Ethylene dibromide	80626	Methyl methacrylate
	(Dibromoethane)	1634044	Methyl tert butyl ether
107062	Ethylene dichloride	101144	4,4-Methylene bis (2-chloro-
	(1,2-Dichloroethane)		aniline)
107211	Ethylene glycol	75092	Methylene chloride
151564	Ethylene imine (Aziridine)		(Dichloromethane)
75218	Ethylene oxide	101688	Methylene diphenyl diisocyanate (MDI)
96457	Ethylene thiourea		
75343	Ethylidene dichloride	101779	4,4-Methylenedianiline
	(1, I -Dichloroethane)	91203	Naphthalene
50000	Fomaldehyde	98953	Nitrobenzene
76448	Heptachlor	92933	4-Nitrobiphenyl
118741	Hexachlorobenzene	100027	4-Nitorphenol
87683	Hexachlorobutadiene	79469	2-Nitropropane
77474	Hexachlorocyclopentadiene	684935	N-Nitroso-N-methylurea
67721	Hexachloroethane	62759	N-Nitrosodimethylamine
822060	Hexamethylene-1,6-	59892	N-Nitrosomorpholine
	diisocyanate	56382	Parathion
680319	Hexamethylphosphoramide	82688	Pentachloronitrobenzene
110543	Hexane		(Quintobenzene)
302012	Hydrazine	87865	Pentachlorophenol
7647010	Hydrochloric acid	108952	Phenol
7664393	Hydrogen fluoride	106503	p-Phenylenediamine
	(Hydrofluoric acid)	75445	Phosgene
7783064	Hydrogen sulfide	7803512	Phosphine
123319	Hydroquinone	7723140	Phosphorus
78591	Isophorone	85449	Phthalic anhydride
58899	Lindane (all isomers)	1336363	Polychlorinated biphenyls
108316	Maleic anhydride		(Aroclors)
67561	Methanol	1120714	1,3-Propane sultone
72435	Methoxychlor	57578	beta-Propiolactone
74839	Methyl bromide	123386	Propionaldehyde
	(Bromomethane)	114261	Propoxur (Baygon)
74873	Methyl chloride	78875	Propylene dichloride
	(Chloromethane)		(1,2-Dichloropropane)
71556	Methyl chloroform	75569	Propylene oxide
	(1, 1, I -Trichloroethane)	75558	1,2-Propylenimine (2-Methyl
78933	Methyl ethyl ketone (2-Butanone)		aziridine)
60344	Methyl hydrazine	91225	Quinoline
74884	Methyl iodide (Iodomethane)	106514	Quinoline

Table 3-3. Continued

CAS NUMBER	CHEMICAL NAME	CAS NUMBER	CHEMICAL NAME
100425	Styrene	75354	Vinylidene chloride
96093	Styrene oxide		(1,1-Dichloroethylene)
1746016	2,3,7,8-Tetrachlorodibenzo-	1330207	Xylenes (isomers and mixture)
	p-dioxin	95476	o-Xylenes
79345	1,1,2,2-Tetrachlorethane	108383	m-Xylenes
127184	Tetrachloroethylene	106423	p-Xylenes
	(Perchloroethylene)	0	Antimony Compounds
7550450	Titanium tetrachloride	0	Arsenic Compounds (inorganic
108883	Toluene		including arsine)
95807	2,4-Toluene diamine	0	Beryllium Compounds
584849	2,4-Toluene diisocyanate	0	Cadmium Compounds
95534	o-Toluidine	0	Chromium Compounds
8001352	Toxaphene (chlorinated	0	Cobalt Compounds
	camphene)	0	Coke Oven Emissions
120821	1,2,4-Trichlorobenzene	0	Cyanide Compounds[1]
79005	1,1,2-Trichloroethane	0	Glycol ethers[2]
79016	Trichloroethylene	0	Lead Compound
95954	2,45-Trichlorophenol	0	Manganese Compounds
88062	2,4,6-Trichlorophenol	0	Mercury Compounds
121448	Triethylamine	0	Fine mineral fibers[3]
1582098	Trifluralin	0	Nickel Compounds
540841	2,2,4-Trimethylpentane	0	Polycyclic Organic Matter[4]
108054	Vinyl acetate	0	Radionuclides (including
593602	Vinyl bromide		radon)[5]
75014	Vinyl chloride	0	Selenium Compounds

Note: For all listings above which contain the word "compounds" and for glycol ethers, the following applies: Unless therwise specified, these listings are defined as including any unique chemical substance that contains the named hemical (i.e.,antimony, arsenic, etc.) as part of that chemical's infrastructure.

[1] X'CN where X=H' or any other group where a formal dissociation may occur. For example KCN or $Ca(CN)_2$

[2] Includes mono- and di-ethers of ethylene glycol, diethylene glycol, and triethylene glycol $R(OCH2CH2)_n$-OR' where

n=1,2, or 3
R=alkyl or aryl groups
R'= R, H, or groups which, when removed, yield glycol ethers with the structure:
$R(OCH2CH)_n$-OH. Polymers are excluded from the glycol category.

[3] Includes mineral fiber emissions from facilities manufacturing or processing glass, rock or slag fibers (or other mineral derived fibers) of average diameter 1 micrometer or less.

[4] Includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100°C.

[5] A type of atom which spontaneously undergoes radioactive decay.

Table 3-4. SCAQMD Targeted Ozone Depleting Compounds

Class I		Class 11	
Group I:	***Group VI:***		
CFC-11	Carbon Tetrachloride	HCFC-21	HCFC-226
CFC-12		HCFC-22	HCFC-231
CFC-113	***Group V:***	HCFC-31	HCFC-232
CFC-114	1,1,1-Trichloroethane	HCFC-121	HCFC-233
CFC-1 15	(Methyl Chloroform)	HCFC-122	HCFC-234
	All isomers of the	HCFC-123	HCFC-235
	above chemical	HCFC-124	HCFC-241
	except 1,1,2-	HCFC-131	HCFC-242
	Trichloroethane	HCFC-132b	HCFC-243
Group II:		HCFC-133a	HCFC-244
Halon-1211	***Group VI:***	HCFC-141b	HCFC-251
Halon-1301	Methyl Bromide	HCFC-142b	HCFC-252
Halon-2402		HCFC-221	HCFC-253
All isomers of the	***Group VII:***	HCFC-222	HCFC-261
above chemicals	HBFC-22B1	HCFC-223	HCFC-262
	All isomers of the	HCFC-224	HCFC-271
Group III:	above chemical	HCFC-225ca	All isomers
CFC-13		HCFC-225cb	of the above
CFC-1 I I			chemicals
CFC-112			
CFC-211			
CFC-212			
CFC-213			
CFC-214			
CFC-215			
CFC-216			
All isomers of the			
above chemicals			

Table 3-5. SCAQMD Targeted Compounds With Global Warming Potential

CO2	CFC-11
	CFC-12
Methane	CFC-13
Nitrous Oxide	CFC-113
	CFC-114
HFC-23	CFC-115
HFC-32	Halon-1301
HFC-41	Carbon Tetrachloride
HFC-43-10mee	Methyl Chloroform
HFC-125	HCFC-22
HFC-134	HCFC-141b
HFC-134a	HCFC-142b
HFC152a	HCFC-123
HFC-143	HCFC-124
HFC-143a	HCFC-223ca
HFC-227ea	HCFC-225cb
HFC-236fa	
HFC-245ca	
Sulphur hexafluoride	
Perfluoromethane	
Perflouroethane	
Perfluoropropane	
Perfluorobutane	
Perfluorocyclobutane	
Perfluoropentane	
Perfluorohexane	

3.1.3 Results of Metals Analyses

DTSC's HML conducted metals analyses of the two 440-R SMT Detergent concentrate samples. Results of metals analyses are shown in Table 3-6. The laboratory report provided by HML is provided in Appendix D. Overall results indicate that both end-user samples of 440-R SMT Detergent concentrate showed no detection of metals.

Table 3-6. Results of DTSC's HML Metals Analyses

Analytical Procedures Used: Digestion: EPA SW 846 Method 3050B
Analysis: EPA SW 846 Method 6010B

Metal	Detection Limit (mg/kg)	Sample 1	Sample 2
Silver	1.0	<1	<1
Arsenic	1.0	<1	<1
Barium	1.0	<1	<1
Beryllium	0.10	<.1	<.1
Cadmium	0.10	<.1	<.1
Cobalt	1.0	<1	<1
Chromium	1.0	<1	<1
Copper	1.0	<1	<1
Molybdenum	1.0	<1	<1
Nickel	1.0	<1	<1
Lead	1.0	<1	<1
Antimony	1.0	<1	<1
Selenium	0.20	<.2	<.2
Thallium	1.0	<1	<1
Vanadium	1.0	<1	<1
Zinc	1.0	<1	<1

Table 3-6. Continued

Analytical Procedure Used: Hg Method 7470A (Manual Cold Vapour Technique)

Metal	Detection Limit (mcg/gm)	Sample 1	Sample 2
Mercury	0.02	<0.02	<0.02

3.1.4 Results of pH Measurement

DTSC's HML conducted pH measurements of the two 440-R SMT Detergent concentrate samples. Results of the pH measurements are shown in Table 3-7. Results indicated a concentrate pH of 13. NOTE: The 440-R SMT Detergent MSDS provided by Smart Sonic states a pH of 12.4.

Table 3-7. Results of DTSC's HML pH Measurements

Analytical Procedure Used: pH EPA Method 9045C

	Sample 1	Sample 2
pH at 23 °C	13.0	13.0

3.2 End-User Data Collection

DTSC's Project Manager contacted, by phone, Smart Sonic end-users and gathered data in the following areas:

- process parameters (bath characteristics, stencil size, solder paste type);
- performance (cleaning, maintenance);
- waste generation rates and management; and
- overall satisfaction.

The purpose of the phone questionnaires was to:

- provide supportive information to the evaluation of this technology; and
- develop a database of information from which to select end-users for on-site visits.

A list of end-users was provided by Smart Sonic in July, 1997 and then updated by Smart Sonic in June, 1998. DTSC's Project Team then contacted two end-users of each system type (Model 2000, Model 4200) followed by type of solder paste cleaned (RMA, no-clean, and water soluble). For instance, two end-users using a Model 2000 cleaning system to remove RMA solder paste from printed circuit board stencils were contacted. Another two end-users using the Model 2000 cleaning system to remove no-clean solder paste were also contacted.

DTSC's Project Manager contacted 61 facilities (37 facilities were contacted via voice mail, questionnaires were sent to 8 facilities via facsimile, and 16 facilities were sent questionnaires via e-mail). Follow-up calls and e-mails were directed at some of the facilities to increase response rate.

A total of 12 completed questionnaires were received, a response rate of approximately 20%. Two end-users have been using de-ionized (DI) water as the cleaning solution and one end-user recently changed to DI water instead of the Smart Sonic 440-R SMT Detergent solution. DI water can be used to remove water soluble solder paste from stencils. This report will not use any data provided by end-users of DI water cleaning solutions since this evaluation addresses the performance of Smart Sonic cleaning systems which includes the cleaning equipment and 440-R SMT Detergent cleaning solution. Table 3-8 provides a summary of the number and type of end-users that responded to the questionnaires.

Table 3-8. Number and Type of End-User Questionnaire Responses

	Solder Paste Type		
Cleaning System	RMA	No-Clean	Water Washable
Model 2000	2	2	4
Model 4200	1	1	0

Note: There was a total of 9 responses with one end-user cleaning both no-clean and water washable pastes.

As shown in Table 3-8, four additional end-user responses were needed to fulfill the phone questionnaire requirements i.e., two end-users of each system type and solder paste type. This requirement was established to allow some flexibility and choice in selecting end-users for on-site performance validation (Section 3.3). The lack of phone responses was not critical in that DTSC's Project Team located other facilities, from a previous phone inquiry of Smart Sonic end-users, that could fulfill the on-site performance validation activity.

Original questionnaire responses are provided in Appendix E. Facilities that provided incomplete or unclear responses were contacted a second time via phone. A summary of the questionnaires, identifying key responses, is shown in Appendix F.

3.2.1 Summary of End-User Data

The following is a brief summary of questionnaire responses:

Cleanliness: All respondents (total of 9) were satisfied with the Smart Sonic stencil cleaning systems and stated that the systems clean consistently and as good, if not better, than the previously used cleaning system (most commonly used cleaning method was alcohol and wipes). Cleaning bath concentrations ranged from 5-15 % by volume of Smart Sonic's 440-R SMT Detergent concentrate. The size of stencils cleaned were 8 mil pitch or greater. Respondents did not indicate any standards or specifications for measuring cleanliness but stated that PCB stencils are visually inspected for solder paste residue. Most facilities pre-wipe stencils (i.e., remove excess solder paste) prior to cleaning in the Smart Sonic systems.

Waste Generation: The amount of spent cleaning solution generated from the Model 2000 cleaning systems ranged from 20-25 gallons per week to 20-25 gallons per month. The amount of spent cleaning solution generated from the Model 4200 cleaning systems ranged from 50 gallons per week to 50 gallons per 2 weeks. The waste generation figures given above do not include the amount of rinse water or solids that are generated from the cleaning systems. Although the Systems Information Manual provided by Smart Sonic recommends that the cleaning bath be changed every week, respondents indicated that the bath change-out time varied from weekly to monthly.

Waste Characterization and Waste Management: Two of the nine respondents analyzed their spent cleaning solutions as having hazardous waste characteristics (results were not available). None of the other respondents analyzed their spent cleaning solutions for hazardous characteristics. Eight of nine respondents are managing their spent cleaning solutions and rinse waters through evaporation with the ninth respondent treating its aqueous waste on-site. Most end-users that evaporate the spent aqueous solutions are not characterizing the spent cleaning solution prior to evaporation. The residue from evaporation, however, is assumed hazardous and is managed as hazardous waste. Solids generated in the cleaning bath (mainly tin-lead fall-out from solder paste) are managed as hazardous waste.

Maintenance: None of the questionnaire responses indicated any maintenance problems from using the Smart Sonic cleaning system. Cleaning systems have been in place from as little as 3 months up to 3 years. Some stencils have been subjected to as many as 300 cleaning cycles.

Stencil Issues: Four of the nine respondents claimed that the Smart Sonic cleaning system removes/degrades the epoxy fiducials from some stencils. Fiducial marks are used to visually align the stencil to the printed circuit board prior to solder paste printing. DTSC's Project Manager called stencil manufacturers to discuss the issue of fiducial removal/degradation.

Two causes for fiducial removal/degradation as stated by these manufacturers include:

- fiducial bonding area, approximately 1 mm in diameter and .002 inch deep, is very small which results in a mechanical bond that is somewhat weak [2,3,4]; and
- fiducials may be dislodged during the solder paste printing process, especially if fiducials are located on the stencil surface that makes contact with the printing squeegee[5].

Once the fiducial is removed/degraded, end-users remark the area with black permanent ink after cleaning the stencil. None of the end-users stated that this problem effected production or product quality. One stencil manufacturer stated that they have overcome fiducial degradation caused from aqueous cleaners by changing the type of epoxy used and how the epoxy is bonded to the stencil[3].

Two of the nine respondents claimed that some stencils have debonded from the screen. Stencils, usually made of stainless steel, are bonded to a screen (stainless steel or polyester) via a proprietary epoxy/glue. All respondents stated that debonding occurred at the stencil/epoxy interface. In speaking with stencil manufacturers, debonding can occur under the following conditions:

- high cleaning solution temperature (temperatures exceeding 125 to 130°F softens the epoxy/glue joint)[6,7,8];
- different contraction/expansion rates of the stainless steel stencil and epoxy/glue[7];
- stress on epoxy/glue joint during printing operation (varies with image design)[6];
- physical characteristic of epoxy/glue (i.e., rigidness, flexibility)[6,9]; and
- pH of solution is greater than 12[6].

Three of the stencil manufacturers contacted stated that they had overcome the debonding problem by using alternative epoxies that remain more flexible. Epoxies that are not as hard tend to hold up better to the mechanical stresses that are incurred during printing and cleaning operations. All of the respondents that had debonding problems and switched to alternative epoxies have had no reoccurrences of debonding.

One respondent claimed that the Smart Sonic detergent coupled with the ultrasonics separates fine pitch stepped stencils. The stepped stencils started debonding after approximately 12 cleaning cycles. Stepped stencils (i.e., laminated stencils) are used to achieve different thicknesses of solder paste throughout the print. These stencils consists of two sheets of stainless steel which are bonded with an epoxy adhesive and then cured in an oven. DTSC's Project Manager contacted the end-user's stencil manufacturer but it was not known what caused the debonding. The end-user has cleaned other types of stencils (i.e., single sheet) in its Smart Sonic aqueous cleaning system without any debonding problems.

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2 Phone Conversation 7/30/98: Hybrid Integrated Services
3 Phone Conversation 7/30/98: Photo Stencil Incorporated
4 Phone Conversation 7/31/98: UTZ Engineering, Incorporated
5 Phone Conversation 7/30/98: Electro Precision Incorporated
6 Phone Conversation 7/30/98: I Source
7 Phone Conversation 7/30/98: Pela Tech
8 Phone Conversation 7/8/98: AlphaSigma Stencils
9 Phone Conversation 7/8/98 and 7/30/98; Electro Precision Incorporated

Another respondent claimed that the emulsion used on the stencil screen is degraded by the Smart Sonic cleaning system. An emulsion is used on the screen as a block-out to prevent solder paste from flowing through the screen, during the printing operation, and on to unwanted areas of the printed circuit board. One of the stencil manufacturers who conducts business with many of Smart Sonic end-users stated that their previous emulsions were being degraded by the Smart Sonic cleaning systems, however, this emulsion was replaced by a proprietary emulsion and there have been no other occurrences of emulsion degradation[9].

3.3 On-Site Performance Validation

DTSC's Project Team visited end-users of Smart Sonic's cleaning systems to:

- validate cleaning performance i.e., no solder paste in stencil apertures at 10X magnification (each end-user must have had Smart Sonic cleaning system in operation for at least 6 months); and
- gather additional process information and identify issues that merit further evaluation.

As mentioned in Section 3.2, DTSC's Project Manager received twelve phone questionnaires. Out of the twelve questionnaires, nine respondents conditionally agreed to have DTSC's Project Team conduct on-site visits. From these nine respondents, one respondent operated its bath with water only and another respondent operated its bath above room temperature (higher temperature solutions used to clean adhesives, inks, or built-up flux residues). This left seven respondents for potential on-site visits. The following list represents the type of cleaning system used and type of solder paste removed for the seven respondents.

	RMA	no-clean	water washable
Model 2000	2	0	3
Model 4200	1	1	0

As shown in the list above, two additional respondents were needed to complete the on-site performance validation i.e., one respondent using the Model 2000 with no-clean solder paste and one respondent using the Model 4200 with water washable solder paste. To locate additional end-users, DTSC's Project Manager:

- contacted Smart Sonic for an updated list of end-users; and
- reviewed a list of end-users that were contacted in a previous questionnaire conducted in August, 1997.

Given this additional information, the Project Manager identified the remaining end-users that could be visited to complete the on-site performance validation. Unfortunately, there were not enough end-users to justify a formal selection process. Therefore, DTSC's Project Manager contacted end-users that agreed to a site-visit. The Project Manager focussed on end-users located in California because many of the end-users were grouped in two major areas in California, thereby making it more feasible for on-site visits.

Five end-users were visited by DTSC's Project Team. A site visit was scheduled with the sixth and final end-user (Model 4200/RMA), but the end-user had scheduling conflicts and therefore was not available. Table 3-9 represents the type of cleaning system used and type of solder paste removed for the five end-users that were visited by DTSC's Project Team. Details of on-site visits are provided in Appendix G.

Table 3-9. Number and Type of End-Users Visited by DTSC's Project Team

	RMA	no-clean	water washable
Model 2000	1	1	1
Model 4200	0	1	1

3.3.1 Results of On-Site Performance Observations

Results of on-site observations and inspections are as follows:

- In five facilities visited, DTSC's Project Team observed no solder paste in stencil apertures at 10X magnification. The size of stencil apertures ranged from 12-50 mil. All end-users removed excess solder paste from stencil prior to cleaning in the Smart Sonic cleaning systems. Cleaning times ranged from 60-90 seconds. Four of the five end-users visited were using a 10% concentration of Smart Sonic's 440-R SMT Detergent (10% concentration recommended by Smart Sonic). The other end-user was using a 5% detergent concentration for removing water washable paste. This 5% concentration is adequate because the flux in the solder paste is water soluble.

  - At one facility (Model 4200/No-Clean), an operator pre-cleaned a stencil with alcohol wipes prior to final cleaning in the Smart Sonic system. After final cleaning, the DTSC Project Team detected a few solder balls in one corner of a 50 mil stencil aperture (DTSC Project Manager estimated a blocked area of approximately 5%). DTSC's Project Manager discussed the finding with the president of Smart Sonic and learned that the operator was not following recommended cleaning practices. Smart Sonic states in its Operations Manual that "alcohol and other chemical wipes should be discouraged since they may react with the solder paste making it more difficult to remove." Smart Sonic's representative immediately informed the facility to not use alcohol prewipes. DTSC's Project Team revisited this facility on December 4, 1998. DTSC's Project Team observed the facility cleaning a stencil using Smart Sonic's recommended cleaning practices. The Project Team also conducted a cleanliness inspection of the stencil following the cleaning operation and found no solder paste in stencil apertures when observed using 10X magnification.

- DTSC's Project Team was unable to visit a facility using a Model 4200 system to clean RMA solder paste due to an end-user scheduling conflict. DTSC's Project Team did, however, visit a facility using Smart Sonic's Model 2000 system to clean RMA solder paste and after observing a stencil cleaning operation found no solder paste in stencil apertures (20-50 mil) using 10X magnification. The performance of the Model 4200 system in cleaning RMA solder paste should be similar to the Model 2000 system in cleaning RMA solder paste given that:
  - Smart Sonic's recommended 10% 440-R SMT Detergent bath concentration is used; and
  - Smart Sonic's recommended cleaning practices are followed.

  The Model 2000 and 4200 systems are very similar in that both systems use 40 kHz piezoelectric transducers and have equivalent ultrasonic power. In addition, the stencil is located the same distance from the transducers in each system[10]. The only observed differences between the two systems is that the Model 4200 system has several automated functions which include: raising and lowering of the stencil into the wash bath, cleaning the stencil to the preset wash time, and rinsing the stencil using an automated rinse over the wash bath.

  As a final note, RMA solder paste is becoming the least used solder paste in the industry. The military and its contractors are the few remaining users of RMA solder pastes[11].

- Two end-users stated that stencil separation had occurred. One end-user claimed that stencil separation only occurred when the cleaning bath was heated to 140°F for cleaning epoxy. The second end-user claimed that separation was caused by poor bonding of the stencil to the screen at the manufacturer. DTSC's Project Manager contacted several stencil manufacturers to discuss conditions which may cause stencils to separate. See Section 3.2.1, paragraph entitled "*Stencil Issues*" for a list of these conditions.

- Stencils had been cleaned 20 to 1000 times in the Smart Sonic cleaning systems without damage.

- pH tests (using pH indicator paper with pH range 0-14) showed cleaning bath pH of 11 when using 10% 440-R SMT Detergent concentration.

- Results of health and safety observations are discussed in Section 3.4.1.

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10 E-mail on November 4, 1998: President of Smart Sonic Corporation

11 Phone Conversation 11/24/98: AIM (Solder Supplier)

3.4 IH / Toxicologist Review

A DTSC IH conducted a health and safety review of the following items to determine whether conditions exist which may pose a hazard to worker safety:

- a review of Smart Sonic's Systems Information Manual; and
- observations of end-users operating Smart Sonic's cleaning systems.

A DTSC Toxicologist also conducted a review of the following items to determine whether characteristics or conditions exist which may pose a hazard to public health and the environment.

- Smart Sonic's 440-R SMT Detergent ingredients list (proprietary) and MSDSs; and
- results of metals analyses conducted by DTSC's HML and VOC analyses conducted by SCAQMD's Laboratory.

3.4.1 Results of DTSC's IH and Toxicologist Review

A total of three different site visits were conducted by DTSC's IH; two facilities using the manual Model 2000 cleaning system and one facility using the automated Model 4200 cleaning system. DTSC's IH concluded that:

- While using Smart Sonic Aqueous Cleaning Systems, Model 2000 and 4200, end-users should follow Smart Sonic's recommended safety practices as outlined in the Systems Information Manual and 440-R SMT Detergent MSDS. DTSC's IH also recommended that the end-user have an eye wash station located and a MSDS available within close proximity to the cleaning systems.

The details of DTSC's IH review are shown in Appendix H (memorandum). Although the IH did not review maintenance activities (i.e., preparing the detergent bath and initiating start-up procedures; removing and managing spent detergent solution and tank bottoms), DTSC's Project Manager identified further safety precautions through review of the Systems Information Manual. The following is a list of activities and proposed safety practices:

- Loading 440-R SMT Detergent into cleaning bath - wear eye protection, gloves, and appropriate clothing as stated in detergent MSDS;
- "Degassing" detergent solution (to remove dissolved air from cleaning bath) can cause an extremely loud squeal for a short duration- use appropriate ear protection.
- Removing stencil from Model 2000 detergent bath - be aware that when stencils are lifted above waist height, detergent solution may drip down gloves and contact skin or clothing. Protective clothing should be worn to prevent skin contact.
- Removing lead-bearing sludge from bottom of cleaning tank/drain trap and wiping down cleaning tank - wear appropriate protection to prevent contact with lead.

DTSC's toxicologist concluded that the only significant toxicity associated with the 440-R SMT Detergent concentrate would be acute toxicity due to its highly alkaline nature. DTSC's Toxicologist review is shown in Appendix I (memorandum).

Note: Smart Sonic's 440-R SMT Detergent ingredients are proprietary and are not shown in this report or its appendices.

Section 4.
Review Existing Analytical Data Provided by SCAQMD

DTSC's Project Team reviewed existing analytical data provided by the SCAQMD.

Note: This existing data was not independent data collected by DTSC's Project Team; nonetheless, the data provides supportive information to the VOC analyses conducted by DTSC's Project Team as part of this verification (Section 3).

In September of 1997, Smart Sonic submitted a sample of 440-R SMT Detergent to SCAQMD for VOC analyses using SCAQMD's CAS Protocol (April 1997). The VOC analyses were conducted by SCAQMD on October 14, 1997. SCAQMD's laboratory report (Appendix J) was reviewed by DTSC's Project Team and compared to the product ingredient list supplied by Smart Sonic.

DTSC Project Team's review revealed that Smart Sonic's 440-R SMT Detergent (concentrate) contained 0.1% methanol which is ten times greater than the detection limit stated in the CAS Protocol. DTSC's Project Team Manager collaborated with SCAQMD about the findings and SCAQMD in turn informed Smart Sonic that the 440-R SMT Detergent did not currently meet the CAS Protocol.

Smart Sonic consulted with its "blender" (contractor who manufactures the 440-R SMT Detergent for Smart Sonic) to determine why methanol was used in the 440-R SMT Detergent formulation. Smart Sonic stated that the "blender" substituted a prior ingredient with methanol without informing Smart Sonic of the change.

SCAQMD requested Smart Sonic to change its formulation or reduce the methanol concentration to bring the 440-R SMT Detergent within the limits of the CAS Protocol. Smart Sonic reformulated its 440-R SMT Detergent with a non-methanol ingredient (440-R SMT Detergent ingredients are proprietary). On March 18, 1998, Smart Sonic submitted a sample of its reformulated 440-R SMT Detergent (concentrate) to SCAQMD for VOC analyses. The VOC analyses of the reformulated 440-R SMT Detergent were conducted by SCAQMD on March 26, 1998. SCAQMD determined that the reformulated 440-R SMT Detergent passed the CAS Protocol (Appendix K).

Manufacturing lot numbers at or above the Lot Number Q8089412 contained the reformulated 440-R SMT Detergent. DTSC's laboratory analyses in Section 3 were conducted using samples from lot numbers Q8089412 and Q8089416.

Section 5.
Hazardous Waste Management / Hazardous Waste Regulations

As with most types of cleaning systems, Smart Sonic's aqueous cleaning systems will also generate wastes that will require some form of management, depending on the characteristics of the wastes. Generators of wastes are required to determine whether the wastes meet the characteristics of a hazardous waste as identified in Part 261, Title 40 of the US Code of Federal Regulations (40 CFR 261) or in Section 66261, Chapter 11, Title 22 of the California Code of Regulations (22 CCR §66261). If wastes are identified as hazardous wastes, these wastes must be managed in accordance to federal, state, or local regulations. On-site treatment of hazardous wastes may also require a permit, and generators must contact their regulatory authority prior to treating hazardous wastes. Hazardous wastes will generally require a licensed hazardous waste hauler for transporting.

The US EPA and DTSC encourages pollution prevention, reuse, and recycling to eliminate or further reduce the quantity of generated hazardous waste. As with any direct or indirect manufacturing process there is potential for further waste reduction. Some common waste reduction options include:

- extending bath life (i.e., filtration);
- reuse of spent materials in manufacturing process (i.e., rinse water, metals);
- recycling of spent materials through ion exchange, filtration, and in some instances evaporation.

As stated above, use of several of these techniques may require a permit if the waste is characterized as being hazardous (considered treatment of a hazardous waste). If however, by using one of these management techniques a material is recycled back into the cleaning process or manufacturing process, this activity may be exempt from permitting. Again, generators must contact their regulatory authority for a permitting determination.

Section 6.
Vendor's Comments

The following information was provided by Smart Sonic. The purpose is to provide the vendor with the opportunity to share additional information on their technology. This information does not reflect agreement or approval by the US EPA and Cal/EPA.

Systems Costs - As of the printing of this Report, the baseline costs of the Model 2000 and Model 4200 systems are $20,000 and $35,000 respectively. The price of the 440-R SMT Detergent® is $19.80 per gallon in 5 gallon pails and $18.00 per gallon in 55 gallon drums.

440-R SMT Detergent – As with any cleaning process, the most important feature is the chemistry. Unlike saponifiers that are consumed during the cleaning process and require continuous replenishment, Smart Sonic's 440-R SMT Detergent is a surfactant (wetting agent) that is not consumed or "loaded" when cleaning solder paste. In addition, saponifiers operate at elevated temperatures whereas Smart Sonic's 440-R SMT Detergent operates at ambient temperature. Therefore, chemistry and energy consumption is a fraction of that of a system using a saponifier chemistry.

Waste Management – Because 440-R SMT Detergent is not consumed during the cleaning process, the wash solution need only be changed one time per week independent of the number of stencils cleaned, so wastewater generation is limited. While 440-R SMT Detergent can be filtered by conventional means and prepared for drain disposal like other aqueous waste streams, 440-R SMT Detergent also provides the flexibility of routine evaporation of associated wastewater. Because 440-R SMT Detergent contains no hazardous ingredients, no VOCs and the pH is mild alkaline, the resulting wastewater can simply and safely be evaporated to the atmosphere in standard wastewater evaporation equipment. The non-hazardous liquid is sent to the atmosphere reducing everything down to solder paste for recycling and small amounts of dry detergent residue for disposal as solid industrial waste. There is absolutely no liquid hazardous waste for disposal and no liability associated with drain disposal!

Other Cleaning Applications – While the Smart Sonic Stencil Cleaning Process is guaranteed to clean any type of solder paste from any fine-pitch stencil, the process is not limited to cleaning solder paste. By slightly raising the wash temperature from ambient to 110 degrees F. (43 degrees C.), wet SMD adhesives can be cleaned from stencils and misprinted PCBs and post solder flux residue can be cleaned from reflow and wave solder pallets, oven radiators, conveyor fingers and other tooling.
New Cleaning Systems – Smart Sonic Corporation has introduced several new cleaning systems:

- The Model 1500 Stencil & Pallet Cleaner for small and startup PCB assemblers;
- The Model 2003 Stencil & Pallet Cleaner for cleaning solder paste at ambient temperature and SMD adhesives or post solder flux residue at elevated temperatures in the same machine and at the same time; and
- The Model 5000 fully automated stencil cleaner which uses less chemistry than the Model 4200 and offers an optional drying cycle.

Smart Sonic has also introduced the Model EZ-0 Wastewater Evaporator. The EZ-0 prevents waste residue scorching for easy clean out and is ergonomically designed for ease of maintenance.

Award Winning Process – Since the introduction of the Smart Sonic Stencil Cleaning Process in 1990, the process has been evaluated and tested by recognized experts in the field of surface mount technology, field tested by over 500 installations worldwide and, most recently, by California's South Coast Air Quality Management District.

In 1995, Smart Sonic was presented the "SMT Vision Award" at the Surface Mount International Show, San Jose, CA for introducing the industry's first truly environmental and user safe stencil cleaning process.

In 1998, Smart Sonic was again awarded the "SMT Vision Award" for the introduction of the Model 5000 Stencil and Pallet Cleaner. The Model 5000 uses less than half the chemistry of it's predecessor (the Model 4200) and can wash, rinse and safely dry a stencil in less than 6 minutes which is three times faster than the nearest competitor.

The Smart Sonic Stencil Cleaning Process has also received the Canadian High Technology Award for *Best New Product* and was a finalist for the NEPCON West Milton S. Kiver Award (Excellence Award) for *Excellence in Electronics Packing* & Production.

Smart Sonic Contact -The latest information about Smart Sonic products can be obtained from Smart Sonic at:

Tel: 1(805) 499-7440 **e-mail: bill@smartsonic.com**
Fax: 1(805) 375-5781 **http://www.smartsonic.com**

Availability of Verification Statement and Report

Copies of the public Verification Statement (EPA/600/R-99/004VS) and Verification Report (EPA/600/R-99/004) are available from the following:

(Note: Appendices are not included in the Verification Report. Appendices are available from DTSC upon request.)

1. **US EPA / NSCEP**
   P.O. Box 42419
   Cincinnati, Ohio 45242-2419

   Web site: http://www.epa.gov/etv/library.htm *(electronic copy)*
   http://www.epa.gov/ncepihom/ *(order hard copy)*

2. **Department of Toxic Substances Control**
   Office of Pollution Prevention and
   Technology Development
   P.O. Box 806
   Sacramento, California 95812-0806

   Web site: http://www.dtsc.ca.gov/sppt/opptd/etv/txppetvp.htm
   or http://www.epa.gov/etv *(click on partners)*