

Merit Partnership Pollution Prevention Project for Metal Finishers



FINDING AN ALTERNATIVE TO SOLVENT DEGREASING Ultrasonic Aqueous Cleaning



The Merit Partnership is a joint venture between U.S. Environmental Protection Agency (EPA) Region 9, state and local regulatory agencies, private sector industries, and community representatives. The partnership was created to promote pollution prevention (P2), identify P2 technology needs, and accelerate P2 technology transfer within various industries in southern California. One of these industries is metal finishing, which is represented in the Merit Partnership by the Metal Finishing Association of Southern California (MFASC). Together, MFASC, EPA Region 9, and the California Manufacturing Technology Center (CMTC) established the Merit Partnership P2 Project for Metal Finishers. This project involves implementing P2 techniques and technologies at metal finishing facilities in southern California and documenting and sharing results. Technical support for this project is provided by the Institute for Research and Technical Assistance (IRTA) and Tetra Tech EM Inc. (formerly PRC Environmental Management, Inc.). The project is funded by the Environmental Technology Initiative and EPA Region 9 and is implemented, in part, by CMTC through the National Institute of Standards and Technology.

INTRODUCTION

Chlorinated solvents have traditionally been used for degreasing because (1) they quickly dissolve organic soils such as oil, grease, and dirt from parts and (2) residual solvent on parts evaporates rapidly, leaving them clean, dry, and ready to be finished. Today, however, use of most chlorinated solvents is being phased out by increasingly stringent state and federal air regulations.

Reasons for Replacing Solvent Degreasing with Aqueous Cleaning

- ◆ Comply with federal and state regulations
- ◆ Eliminate solvent storage and handling
- ◆ Eliminate potential for accidental releases
- ◆ Create safer working conditions
- ◆ Eliminate air regulation compliance costs
- ◆ Eliminate solvent purchase and disposal costs
- ◆ Eliminate emissions of ozone-depleting, global warming, and hazardous compounds

Some solvents used in metal finishing, such as 1,1,1-trichloroethane (TCA), are ozone-depleting and global warming compounds. Other solvents, such as perchloroethylene (PERC) and trichloroethylene (TCE), are subject to increasingly stringent regulations because of the risks they pose to human health.

Solvent Substitution Strategy

1. Identify and contact aqueous cleaning chemical vendors and arrange for bench top testing to determine:
 - cleaning potential for shop-specific soils
 - substrate compatibility with cleaning chemicals
2. Contact aqueous cleaning unit vendors and perform testing at vendor facilities to identify the chemical and unit combination that best meets cleaning requirements
3. Arrange for an on-site demonstration of aqueous cleaning unit and chemicals; systematically test cleaning chemical candidates and vary operating parameters to identify best cleaning performance

Numerous aqueous, or water-based, cleaning chemicals are now available that are significantly less toxic than chlorinated solvents. Because organic soils are less soluble in water than in chlorinated solvents, chemical and physical mechanisms such as surfactants, emulsifiers, agitation, sprays, and ultrasonics are often used to enhance cleaning effectiveness. This fact sheet focuses on ultrasonic aqueous cleaning as an alternative to solvent degreasing.

AQUEOUS CLEANING CHEMICALS

Many aqueous cleaning chemicals are available for use with ultrasonic and other types of cleaning units. Chemicals with surfactants, compounds that penetrate and loosen soil by lowering surface and interfacial tension, are typically the most effective. Inhibitors, compounds that reduce corrosion of metal parts, and emulsifiers, compounds that keep oil and grease in suspension to prevent their re-adsorption onto parts, may be included in the cleaning chemical and may enhance cleaning performance.



The cleaning chemical should be compatible with the metal being cleaned and capable of removing the specific type of soil present. Part rinsing may be required after aqueous cleaning to prevent contamination of subsequent process operations.

Unlike solvents, which eventually become saturated with dissolved soils and become spent, aqueous cleaning solutions are typically immiscible with most organic soils and therefore have longer useful lives. Oils float to the surface of a nonemulsifying aqueous cleaning solution and can be skimmed off, and heavy soils settle and can be filtered or manually removed. Aqueous cleaning solutions may also be amenable to biodegrading filters that remove organic contaminants. If an aqueous cleaning solution's quality and concentration are maintained, the solution can be used for longer periods than solvents before requiring disposal.

Although fresh aqueous cleaning solutions are usually classified as nonhazardous, they may accumulate enough contaminants such as metals or oil and grease during the cleaning process to be classified as hazardous waste when disposed. Chemical analysis should be performed to determine the waste classification of a spent aqueous cleaning solution. Spent solutions are typically treated in an on-site wastewater treatment system or shipped off site for disposal.

ULTRASONIC CLEANING TECHNOLOGY

Ultrasonic cleaning involves application of high frequency sound waves, typically in the 20-to 50-kilohertz range, in a tank of cleaning solution to produce an intense microscopic scrubbing action. The ultrasonic waves create an oscillating high and low pressure front in the solution that produces millions of microscopic bubbles at the surface of the part. These bubbles implode, radiating a shock wave that heightens chemical activity and strips away contaminants from the parts. Ultrasonic cleaning action can penetrate very fine pores and crevices of part surfaces, making it ideal for precision and general cleaning.

Types of Aqueous Cleaning Units

Spray - Parts are sprayed with cleaning solution at high pressure in an enclosed cabinet.

Immersion - Parts are immersed in cleaning solution agitated by mechanical oscillation, submerged spray nozzles, or ultrasonics.

Wet Blast - Parts are blasted with a water and abrasive medium slurry at extremely high pressure.

Sink-Top - Parts are manually scrubbed in a sink, and cleaning solution is applied via a nozzle or flow-through brush.

Ultrasonic waves are transmitted into the cleaning solution by transducers. Transducers are rated according to their frequency and maximum wattage; generally, the higher the wattage, the greater the cleaning action. Using excessive ultrasonic power may cause erosion or "burning" on soft metal parts. Transducers can be positioned to target specific areas of the parts, and the greater the number of transducers used, the greater the ultrasonic coverage.

HELPFUL HINT: OIL SKIMMING AND FILTRATION

Cleaning performance and cleaning solution life can be improved by using an oil skimmer and filter. Most aqueous cleaning units can be equipped with these features. The skimmer removes oil floating on top of the solution that may otherwise leave a film on parts removed from the unit. The filter removes solids and dirt that may degrade cleaning solution.

CASE STUDY: ARTISTIC PLATING AND METAL FINISHING, INC.

Under the Merit Partnership, an ultrasonic cleaning unit was demonstrated at the Artistic Plating and Metal Finishing, Inc. (Artistic), facility in Anaheim, California. The purpose of the project was to compare the cleaning effectiveness and operational performance of an aqueous cleaning unit to those of a solvent degreasing unit. Artistic processes zinc die-cast and forged-steel parts for commercial customers. Plating operations include copper, nickel, and chrome electroplating on a hand-operated rack line and copper electroplating on a manually operated barrel hoist line.

Artistic degreases parts before electroplating to remove contaminants such as oil, particulates, and buffing compounds. The buffing compounds are particularly difficult to remove and thus they represent a rigorous test for cleaning systems.

SOLVENT DEGREASING OPERATIONS

Artistic operates a 150-gallon vapor-spray degreasing unit manufactured by Baron Blakeslee Inc. Artistic staff spend about 5 labor hours per day degreasing parts. Parts are loaded into baskets that are lowered into the unit by a manually operated hoist. Artistic staff load between 6 and 60 parts in a basket, depending on the size of the parts, and typically degrease two baskets per batch. Artistic degreases about 120 baskets of parts per day. Most of the parts degreased are zinc die-cast parts; however, forged-steel parts are also degreased occasionally. The degreasing unit requires about 1 hour per week for operation and maintenance (O&M).

Artistic uses PERC in the vapor-spray degreasing unit. In 1996, the facility used 6,138 pounds of PERC. Artistic contracts with a PERC vendor to collect and distill spent PERC

for reuse. The PERC vendor gives the facility account credit for the spent PERC, but Artistic pays for disposal of solids that accumulate at the bottom of the degreasing unit (still bottoms). In 1996, Artistic generated 783 pounds of spent PERC and about 15 gallons of still bottoms, which resulted in a net collection and disposal cost of \$306.

Annual PERC Regulatory Costs	
Emission Fee:	\$1,130
SCAQMD Permit:	\$250
Other Permits:	\$400
Total:	\$1,780

The difference between the volumes of clean PERC purchased and spent PERC disposed of equals the amount of solvent emissions, which for Artistic to-

totalled 5,355 pounds in 1996. South Coast Air Quality Management District (SCAQMD) PERC emission fees and other permit fees associated with operating the degreasing unit totalled \$1,780 in 1996.

ULTRASONIC CLEANING UNIT AND AQUEOUS CLEANING CHEMICAL

Because of increasingly stringent regulatory requirements, Artistic wanted to replace PERC degreasing with an aqueous cleaning alternative that would still meet the facility's cleaning requirements. Artistic, in cooperation with the Merit Partnership, evaluated different types of aqueous cleaning units, including spray cabinets, mechanically agitated immersion units, and ultrasonic immersion units, and numerous types of cleaning chemicals. Testing was performed at both the Artistic facility and vendor facilities using parts from Artistic to compare the performance of different types of cleaning units and chemicals. Part cleanliness was assessed based on visual observation, wipe tests, and subsequent plating performance. Based on the results and a cost analysis, ultrasonic cleaning was selected as the type of cleaning process and Daraclean 236 as the cleaning chemical with the greatest potential to meet Artistic's high cleanliness standard. Daraclean 236, which is manufactured by W.R. Grace and Company of Lexington, Massachusetts, is an aqueous, mild alkaline cleaner that contains organic surfactants, water conditioners, and inhibitors.

The ultrasonic cleaning unit was tested under actual production conditions at the Artistic facility for an 8-week period. During the demonstration, the existing PERC degreasing unit was shut down, and all parts that required degreasing were cleaned in the ultrasonic unit. The ultrasonic unit, which was rented from SAS Equipment, Inc., of Claremont, California, contains three 1,200-watt, 40-kilohertz ultrasonic transducers; holds 100 gallons of cleaning solution; and is electrically heated. Parts are immersed in the cleaning solution on racks that are hung from a bar positioned across the top of the unit.

An oil skimmer and particulate filter are optional features that were not available for the ultrasonic unit demonstrated at the Artistic facility. Instead, Artistic staff used hydrophobic absorbent pads to remove oil that floated to the top of the



Ultrasonic Cleaning Unit

cleaning solution, and solids were cleaned from the bottom of the unit at the end of the demonstration period.

OPERATING PARAMETERS

Artistic staff spent the first week of the demonstration period performing shakedown testing of the ultrasonic cleaning unit to determine the operating parameters that would provide optimal cleaning performance. The critical parameters for Artistic's application were (1) cleaning time, (2) cleaning solution temperature, (3) cleaning solution concentration, and (4) number of racks cleaned per batch. Cleaning parts for about 15 minutes was found to be optimal; shorter cleaning time did not adequately clean parts, while longer cleaning time often left a layer of smut or oil on part surfaces. Although cleaning performance improved at higher temperatures, heating the solution above 170 °F caused streaking and spotting on parts. The most effective concentration of the cleaning solution was found to be 10 percent by volume during initial testing. Finally, cleaning performance was found to be proportional to the number of racks loaded into the unit; the more racks loaded, the better the cleaning.

Ultrasonic Cleaning Unit Operating Parameters		
<u>Parameter</u>	<u>Shakedown Testing Range</u>	<u>Optimal Setting</u>
Cleaning Time	5 to 45 min.	15 min.
Temperature	160 to 180 F	170 F
Concentration	5 to 20%	10%
Number of Racks	2 to 8 racks	8 racks

RESULTS

The ultrasonic cleaning unit met Artistic's cleaning requirements at a level equivalent to that achieved by the solvent degreasing unit. Artistic staff cleaned an average of 100 racks of parts per day (13 batches of 8 racks), which was a throughput equivalent to the 120 baskets of parts per day processed in

Zinc Die-Cast Part Cleaning Process and Duration

<u>Solvent Degreasing</u>		<u>Ultrasonic Cleaning</u>	
1) Loading into basket	(10 min)	1) Racking	
2) Degreasing	(20 min)	2) Ultrasonic cleaning	(15 min)
3) Unloading from basket	(10 min)	3) Rinsing	(5 min)
4) Racking		Total time	= 20 min
Total time	= 40 min		

the PERC degreasing unit. During the 8-week demonstration, facility production generally involved forged-steel parts; consequently, only a small quantity of zinc die-cast parts were cleaned in the ultrasonic unit. However, the forged-steel parts are the more difficult parts to clean because they have more buffing compound on their surface. Therefore, Artistic staff expect the unit to clean zinc die-cast parts equally well or better.

Artistic staff reacted positively to the ultrasonic unit because it decreased the labor required to clean parts and did not emit unpleasant and harmful fumes. Before implementing ultrasonic cleaning, forged-steel parts were cleaned first by solvent degreasing, if required, then by soaking in a hot alkaline tank followed by manual brushing to remove residual buffing compound. With the ultrasonic unit, the forged-steel parts are dipped into the alkaline soak tank and then brushed for much shorter periods because the ultrasonic unit softens and removes most of the buffing compound. This process change reduced the labor hours required for cleaning forged-steel parts by 50 percent as compared to solvent degreasing.

The labor hours required for cleaning zinc die-cast parts also decreased by about 50 percent. When the solvent degreasing unit was used, zinc die-cast parts were loaded into and un-

"Based on the demonstration results, ultrasonic aqueous cleaning can completely replace our solvent degreasing operations."

Ruben Angel
Artistic Environmental Coordinator

loaded from a basket before and after degreasing, respectively, before being racked for plating operations. With the ultrasonic unit, racked parts can be placed directly into the unit for cleaning, eliminating basket loading and unloading time.

During the testing period, the aqueous cleaning solution was used for about 4 weeks before being replaced. About 0.6 gallon of cleaning chemical was added to the solution every week in order to maintain the solution concentration. Spent solution was treated in Artistic's on-site wastewater treatment plant.

An average of two absorbent pads were used each week to remove oil from the cleaning solution. The spent pads were disposed of off site as hazardous waste.

The ultrasonic cleaning unit demonstrated at the Artistic facility was leased for \$495 per week; the purchase price of the unit is \$14,000. O&M of the ultrasonic unit, including removing oil, adding water to make up for evaporative losses, and measuring the solution concentration, required less than 0.5 hour per week, which is about 50 percent less than O&M labor for the solvent degreasing unit.

ULTRASONIC AQUEOUS CLEANING RESULTS

	<u>Per Year</u>		<u>Annual</u>
	<u>PERC</u>	<u>Aqueous</u>	<u>Savings</u>
Chemical Purchase Cost	\$2,890	\$2,400	\$490
Haz Waste Disposal Cost	\$306	\$60 (oil pads)	\$250
Cleaning Labor	1,320 hours	660 hours	\$4,620
O&M Labor	52 hours	26 hours	\$1,300
Air Permitting Cost	\$1,780	\$0	\$1,780

Total Annual Savings = \$8,440

Capital Cost = \$14,000 (assuming unit purchase)

Payback Period = 1.7 years

Assuming permanent implementation of ultrasonic cleaning at the facility, Artistic would realize a cost savings of \$8,440 per year by decreasing or eliminating hazardous waste disposal, process labor requirements, and air permitting costs. If Artistic purchased the demonstration unit, the payback period would be about 1.7 years.

Motivated by the positive demonstration results, Artistic management decided to permanently implement aqueous ultrasonic cleaning and remove the solvent degreasing unit. However, Artistic plans to purchase a tank, transducers, an oil skimmer, and a filtration system and build its own ultrasonic cleaning unit. Artistic estimates that it can build an ultrasonic unit with significantly greater capacity at a cost lower than the purchase cost of a comparable commercially available unit.

For more information on the Merit Partnership or this case study, contact the following individuals:

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