CLEANING LABORATORY EVALUATION SUMMARY

SCL #:	2020
DateRun:	09/15/2020
Experimenters:	Alicia McCarthy
ClientType:	Manufacturer of Ceramic Capacitors
ProjectNumber:	Project #3
Substrates:	Ceramics
PartType:	Part
Contaminants:	Waxes
Cleaning Methods:	Immersion/Soak
Analytical Methods:	Gravimetric
Purpose:	To evaluate the performance of cleaning solutions used to remove wax from parts in a new degreaser.

Experimental Procedure:

Morgan Advanced Materials is a global manufacturer specializing in advanced materials. The New Bedford facility manufactures ceramic feedthroughs for medical and aerospace markets. Morgan used trichloroethylene (also known as TCE, and designated as a Higher Hazard Substance under the Toxics Use Reduction Act program) for several tasks, including wax removal after ceramic grinding. The facility used a vapor degreaser equipped with an ultrasonic tank for cleaning. Morgan wanted to eliminate or significantly reduce its use of TCE. Drivers included:

- Employee health and safety
- Environmental impact reduction
- Tighter restrictions on exposure limits
- TURA fee reduction or elimination

The company used water-soluble pink and brown waxes for their grinding/lapping operation. In conjunction with Morgan's sister company in California, they identified an aqueous mixture of Borax and Arm & Hammer™ baking soda at 180°F designed to clean both types of wax from the ceramic parts, but in order to make it effective for the New Bedford facility, Morgan needed to invest in a new piece of equipment. Importantly, the new equipment needed a filtration system to remove the thin layer of wax left after the cleaning operation.

Results:

New Equipment

Morgan received a grant from TURI to offset some of the cost of the new equipment purchase. The facility worked with a number of suppliers to identify a piece of equipment that would suit their production volume requirements and mesh well with their existing workflow. They chose a Crest Ultrasonics vapor degreaser unit, used as a series of immersion tanks.

EHS Evaluation of Alternative Cleaning Solutions

Along with the new equipment, Morgan sought a cleaner that would effectively remove both the pink and brown wax. They determined through in-house testing that the mixture of 1% borax (sodium tetraborate) and 1% baking soda (sodium bicarbonate) in water at 180°F was effective. Morgan asked the TURI Cleaning Laboratory to test additional alternatives. The alternatives tested by the lab are commonly used detergents. Although Morgan preferred a powdered cleaner, the TURI Lab tested both powdered and liquid detergents to develop a larger set of options and understand their relative environmental, health and worker safety benefits. Before testing for performance, the TURI Lab screened the potential alternatives—Gain, Method, Surf, Tide, and Seventh Generation—for health and safety factors using the Pollution Prevention Options Analysis System (P2OASys) tool. The evaluation results are in the table below, and are compared with the original TCE solvent, and borax, the substance of concern in the borax-sodium bicarbonate mixture. It should be noted that for the water-based cleaning solutions, it is the concentrated ingredients of most concern that are evaluated. In the table above, all of the alternatives tested pose significantly improved impacts over TCE for environmental and worker health and safety. Acute exposure to TCE can result in serious skin and eye irritation and central nervous system effects including drowsiness, headache, lightheadedness that may lead to unconsciousness, or death. TCE is a known human carcinogen and poses chronic human health hazards to the central nervous system, kidney, liver, immune system, male reproductive system, and the developing fetus. TCE is toxic to aquatic organisms, a hazardous air pollutant, and a common groundwater contaminant. TCE is a highly volatile solvent, and when broken down in the air, phosgene, a significant lung irritant can be formed. It should be noted that borax poses some concern for respiratory and skin irritation and high concern for developmental and reproductive toxicity, and therefore should be handled carefully with limited exposure. Borax also has a high concern for ecological hazards, as similar reproductive and irritating effects have been observed in aquatic life.

P2OASys Evaluation

	Original Solvent	Alternative Selected by Morgan	Detergent Concentrates Evaluated by TURI

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Category	TCE	Borax (substance of concern in mixture)	Gain Powder	Method 4x Laundry Liquid	Surf Laundry Powder	Tide Powder	Seventh Generation Liquid
Acute Human Effects	VH	H	H	H	H	H	M
Chronic Human Effects	VH	VH	M	M	M	M	M
Ecological Hazards	VH	H	M	M	L	M	M
Environmental Fate & Transport	VH	M	H	M	H	H	M
Atmospheric Hazard	H	L	L	M	H	H	M
Physical Properties	VH	M	H	M	H	H	M
Life Cycle Factors	VH	H	L	L	L	L	L

L - low; M - medium; H - high; VH - very high

All of the alternative products pose some concern for skin and eye irritation. Many household laundry detergents contain small amounts (0.1–1.0%) of chemicals that may be of high concern. The main difference between the alternatives tested is the physical form of the concentrates, which creates different hazards for the worker. Powdered detergents can be hazardous to the worker as exposure to dusts and concentrated powders can be irritating to the respiratory system. Liquid detergents have preservatives, and either liquids or powders may have fragrances added. Some common preservatives and fragrances are skin sensitizers, and some have been suspected of causing endocrine disruption. The higher concern ratings for the powdered detergents under environmental fate and transport are due to the high persistence in air, and moderate persistence in soil and sediment of some of their ingredients. The higher concern ratings for physical properties is due to the powdered detergents having a higher pH than the liquids. While this screening evaluated the ingredients of the concentrate, not the process, one process factor of note is the similar high temperature (160°F–180°F) and burn hazard that exists for TCE in a vapor degreaser as well as all aqueous alternatives.

Testing of Alternative Cleaning Solutions The TURI Lab tested the performance of each detergent using guidelines emulating the process in Morgan’s facility. At this point, Morgan had already changed out their TCE with the borax mixture, so that cleaning process was replicated in the lab. Morgan uses immersion in hot deionized (DI) water, followed by immersion in the borax mixture, then immersion in water followed by hot-air drying. The process uses automated transfer between tanks; each step in the process is performed for ten minutes. At their facility, Morgan uses 180°F water; however, they were interested in seeing if cleaning could be performed effectively within 30 minutes at a lower temperature (160°F). The company was also interested in alternatives that were both powder and liquid detergents; a powder option was preferred for storage and ease of measurements. Morgan evaluates performance based on visual observation; therefore, TURI also completed visual observations to determine if parts were achieving the designated threshold of cleanliness. Because the parts using the pink wax were more geometrically complex, it was expected that the pink wax would be harder to remove than the brown wax. Therefore, the TURI lab tested all the viable alternatives on the pink wax before testing the effective detergents on the brown wax. Five grams of ceramic parts coated with pink wax were immersed into each cleaner at a constant temperature of 160 °F for 30 minutes. Observations were recorded every 10 minutes, and the cleanliness of ceramic parts was determined based on visual observations. The experiment was repeated at a temperature of 180 °F with similar effectiveness, although the lower temperature required slightly more cleaning time to achieve the same results. Seventh Generation was the least effective of the detergents tested on the pink wax, leaving cleaner residue and residual wax inside the parts. Surf was the most effective of the powder detergents at removing the pink wax; the parts were clean after 20 minutes at 180°F. Tide and Gain performed similarly to each other at both temperatures. Method left residual wax inside the parts at both temperatures. At this point in lab testing, Morgan received customer approval for their Borax mixture use. It performed well, and the EHS evaluation still showed significant improvement over TCE. The company decided to move forward with the Borax mixture as their alternative. A final test was completed by the TURI lab comparing a powder detergent and a liquid detergent on Morgan’s brown wax-contaminated parts adhered to a metal plate (see image on p. 1). Due to limited parts available at the lab, only two cleaners were tested at the two different temperatures. Method liquid detergent did not leave a residue on the small parts and metal plate like the powder detergent. Both were unable to completely remove the wax from the plates within 30 minutes, but the parts were cleaned and became unstuck from the metal plate. Adding agitation and a heated rinse step would likely help with reducing the cleaning time and remove residual residue from the metal plates.

Pink Wax: Visual Observations from Testing

Cleaner	Type	Temp (F)	Time (min)	Observation
Surf	Powder	160	10	Pink wax starting to come off parts and floating to top.

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			20	Pink wax sank to bottom, and majority of parts seem completely clean.
			30	All ceramic parts visibly clean.
		180	10	Pink wax dissolved and turned solution pink. Majority of parts clean.
			20	All ceramic parts are visibly clean.
			30	Tested to full time, but parts already visibly clean
Tide	Powder	160	10	Pink wax starting to come off parts and floating to top.
			20	Pink wax sank to bottom. Parts not visible due to cloudiness of solution.
			30	All ceramic parts are visibly clean.
		180	10	Solution was too cloudy to determine how clean ceramic parts are.
			20	Ceramic parts were not visible due to cloudy solution.
			30	All ceramic parts are visibly clean.
Gain	Powder	160	10	Pink wax coming off parts and floating to top.
			20	Pink wax sank to bottom. Majority of the ceramic parts look visibly clean.
			30	All ceramic parts are visibly clean.
		180	10	Solution turned green color. Majority of ceramic parts were visibly clean.
			20	Majority of ceramic parts look clean.
			30	All ceramic parts are visibly clean.
Method	Liquid	160	10	Pink wax floating to the top. Majority of parts look clean.
			20	Minimal pink wax is on ceramic part.
			30	Majority of parts look clean. Some residual wax inside parts.
		180	10	Almost all pink wax was cleaned off ceramic parts.
			20	Majority of parts look clean on outside. Some residual wax inside parts.
			30	All parts look clean outside. Some residual wax inside parts. Wax turned white.
Seventh Gen	Liquid	160	10	Pink wax floating to the top. Majority of parts look clean.
			20	Minimal pink wax on ceramic parts.
			30	Holes contain some pink wax. Cleaner residue on parts. Rinse step needed.
		180	10	Solution cloudy and no parts were visible to see cleanliness.
			20	Solution cloudy and no parts were visible to see cleanliness.
			30	Pink wax found inside parts. Cleaner residue on parts. Rinse step needed.

Brown Wax: Visual Observations from Testing

Cleaner	Type	Temp (F)	Time (min)	Observation

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Gain	Powder	160	10	Solution turning green/brown. Can't see part in solution.
			20	Can't see part in solution or how much was removed.
			30	Almost all wax removed. White residue on parts. Needs rinse step.
		180	10	Solution turning green/brown. Can't see part in solution.
			20	Solution maintaining the same cloudiness and color. Can't see part.
			30	Almost all wax removed. White residue on parts and plate.
Method	Liquid	160	10	Wax looks like it is peeling off plate. Good portion of wax removed.
			20	80% of the brown wax has been cleaned off the metal plate.
			30	All smaller parts attached by wax on plate have come off. No residue.
		180	10	Brown wax and tiny parts are falling off metal plate.
			20	2/3 of metal plate is clean. Some wax and parts attached to metal plate.
			30	Metal plate 95% clean and parts removed. No residue.

Cost Analysis

Using the new Borax mixture and investing in a new ultrasonic cleaner to handle their throughput, Morgan will realize savings in chemistry costs, disposal and compliance fees, and labor, as noted in the table below. Ongoing annual savings from the Borax system are expected to be approximately $30,000. Using the full cost of the new ultrasonic cleaner, Morgan will see a return on investment in a little over three and a half years, or a little over two and a half years factoring in the TURI grant.

Cost Comparison: Old vs. New Cleaning Systems

Category	Annual Costs ($)		Capital Costs ($)
	TCE	Borax Mixture	New Ultrasonic cleaner
Capital investment			109,642
TURI Grant			-30,000
Chemistry	6,105	500	
Waste disposal	1,300		
TURA fees	6,825		
Labor - cleaning time	20,800	2,080	
Labor - initial training			2,000
Totals	35,030	2,580	81,642

Summary:

Conclusion:

This qualitative evaluation demonstrated the feasibility of using heated commercially available detergents to remove waxes such as those used by Morgan. For example, Method liquid detergent performed well and is a safer alternative to TCE. However, Morgan chose to continue with the borax mixture, because it also performed well and using it became a familiar process. Despite the irritation and toxicity associated with borax, its use still results in a safer work environment and a significant improvement over TCE. The facility had also received approval from its customers to use the borax mixture and obtaining approval for a new mixture would be time-consuming for the company and its customers. By eliminating TCE, Morgan has significantly enhanced the health and safety of its workers, eliminated the reporting under TURA and is saving money. The TURI Lab testing on alternative cleaners, while not directly used by Morgan, provides a starting point for other facilities and applications looking for aqueous options for wax removal.