Cleaning Urethane, Ink and Paint Manufacturing Vessels: A Toxics Use Reduction Case Study

Raffi and Swanson Inc.
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The Toxics Use Reduction Institute FY 97 Matching Grants Program

The Toxics Use Reduction Institute
University of Massachusetts Lowell

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The Toxics Use Reduction Institute is a multi-disciplinary research, education, and policy center established by the Massachusetts Toxics Use Reduction Act of 1989. The Institute sponsors and conducts research, organizes education and training programs, and provides technical support to promote the reduction in the use of toxic chemicals or the generation of toxic chemical byproducts in industry and commerce. Further information can be obtained by writing the Toxics Use Reduction Institute, University of Massachusetts Lowell, One University Avenue, Lowell, Massachusetts 01854.

Toxics Use Reduction Institute
Matching Grants Program

The Institute annually provides direct funding to Massachusetts industries on a matching basis for toxics use reduction (TUR) feasibility and technology studies. The Matching Grants Program was initiated in FY 93 to facilitate the development and use of innovative techniques that reduce the use of toxic chemicals or the generation of toxic by-products in Massachusetts businesses. Grants are awarded on a competitive basis for companies to conduct TUR studies at their facilities. Recipients prepare project reports which assist in transferring toxics use reduction technologies and methods to other companies.

Notice

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1. Summary

In 1995, Raffi and Swanson, Inc. received a $20,000 grant from the Massachusetts Toxics Use Reduction Institute (TURI) to examine alternatives to toxic solvents in the company's cleaning operations. Raffi and Swanson set a project goal of reducing chemical use and byproducts from these cleaning operations by 50%. Raffi and Swanson met this goal, reducing chemical use and emissions by roughly 50% (roughly 46,000 lb.) and chemical byproducts 50% (roughly 200,000 lb.). These reductions were achieved through the implementation of over thirty worker-identified changes to cleaning practices. These changes included redesigning equipment and procedures to eliminate the need for solvent cleaning, methods to increase solvent reuse, and more careful management of solvent distribution and application throughout the site. These changes have saved Raffi and Swanson approximately $18,000/yr.

During the course of the project, Raffi and Swanson worked closely with the TURI Surface Cleaning Lab to evaluate alternatives to N-methyl pyrrolidone in the company's urethane reactor vessel cleaning operation. The Surface Cleaning Lab evaluated seven aqueous cleaners and four semi-aqueous cleaners as replacements for N-methyl pyrrolidone. Two semi-aqueous cleaners were the most promising substitutes but the inability to recycle the cleaners makes them cost-prohibitive.

Despite having exceeded the 50% reduction goal for solvents used in cleaning operations, Raffi and Swanson is looking to go further. The company has received several bids that would eliminate nearly all solvent-cleaning of portable containers. Other semi-aqueous chemistries that hold promise for eliminating N-methyl pyrrolidone are also being examined. Lastly, the highly successful worker-management team continues to meet and work towards fulfilling its goal of reducing wash solvent use to the extent economically and technically feasible.

2. Raffi and Swanson, Inc.

Located in Wilmington, Massachusetts, Raffi & Swanson, Inc. (R&S) manufactures specialty coatings, inks, and adhesives for use on textiles, plastics, and metals. The company sells its products to manufacturers for use in final products or as intermediate materials. Raffi and Swanson operates under Standard Industrial Classification (SIC) code 2851 (paint and allied products) and reports on 23 chemicals in three production units under the Massachusetts Toxics Use Reduction Act (TURA). Raffi and Swanson's chief production processes include loading, mixing, reacting, filtering, transferring and packaging. The company's cleaning operations are conducted in on-line and off-line systems using a combination of pressure spraying and mechanical brushing.

3. Project Management

At the start of the project, Raffi and Swanson recognized the need for both management and worker participation in the project. Two project teams were created as forums for involvement: the TURA Team and the Solvent Wash Elimination and Alternative Techniques Team (SWEATT). The TURA Team was comprised of management, supervisory, research and development personnel and a general practice TUR planner (consultant). The team acted both as a steering committee for the project and as a forum to discuss project activities and assign work tasks. SWEATT was comprised of workers from each solvent-using department. Workers volunteered for SWEATT and were responsible for developing and implementing TUR options on the plant floor. Both the TURA Team and SWEATT met every other week and posted minutes for the meetings.

In addition to setting up teams, Raffi and Swanson saw the need for a tracking system that could measure solvents used in cleaning operations on a regular basis. Raffi and Swanson wanted to establish a baseline of solvent use and emissions from which to measure TUR progress. The TURA and SWEATT teams developed a tracking system that monitored all solvents used for the purpose of cleaning by each manufacturing department. The tracking system also measured all cleaning solvent waste. Results were summarized weekly, graphed, and posted on the Raffi and Swanson employee bulletin board. To ensure that all solvents used in cleaning would be tracked by the system, the company made important changes to its solvent handling and distribution system. Raffi and Swanson eliminated distribution lines of plant cleaner (a solvent mixture). Prior to this change, any operator could go to solvent manifolds located in several places in the plan, and pump their own solvent. Now employees are required to sign-out solvent from a centralized distribution area. Rather than workers getting their own solvents, all solvent requests must go through a single employee that signs out solvent for each department.

The TURA Team and SWEATT split the project into two sub-projects. One focused on evaluating aqueous and semi-aqueous chemistries to clean urethane vessels. The second focused on making procedural, equipment, and formulation changes to reduce the need to clean and the use of cleaning solvents in the company's centralized container cleaning operation. Each of these sub-projects is reviewed in detail in the following sections of this report.

4. Evaluating Alternative Urethane Cleaning Chemistry

One of Raffi and Swanson's main product lines involves the manufacture of urethane products for the textile coating industry. Making urethane products involves mixing and reacting isocyanate-terminated species with hydroxyl-terminated species. This operation results in long urethane polymer chains. Compounding additives are then added to the urethane polymer in the same mixing vessel to adjust the batch physical properties to the customer's desired specification. Following the compounding operation, the batch is packaged into 55-gallon product drums and shipped to customers.

Before making another batch, residues left on the interior reaction vessel walls must be cleaned. Residues which are not completely removed from the reaction vessel will interfere with future polymerization reactions by pre-maturely "capping" the molecular chain being formed. This premature ending of the chain formation results in a low molecular weight polymers and corresponding poor physical properties. Therefore, the cleaning operations of the tanks are critical to the end-product's quality.

In 1993, Raffi and Swanson changed its urethane vessel cleaning process. The company shifted from using a solvent mixture known as "plant cleaner" (composed of methyl ethyl ketone (MEK), methyl isobutyl ketone, toluene, ethyl acetate, and xylene) to N-methyl-pyrrolidone (NMP). The switch to NMP was an improvement over the plant cleaner process since NMP cleans better, has a lower flash point, poses a lower occupational hazard, and contains fewer Volatile Organic Compounds (VOCs) per gallon. In the cleaning process, 15 gallons of NMP are sprayed onto the 1,500 gal tank walls at 400 psi, drained at the bottom of the vessel, filtered, and recirculated. An MEK rinse follows the NMP wash and is also sprayed, drained, filtered, and recirculated. Process wastes and emissions include dirty cleaning solvents, fugitive emissions, and sludge that accumulated in 400 micron filter bags.

In 1995 Raffi and Swanson began considering alternatives to NMP when the chemical became a listed TURA substance because of its developmental and reproductive hazards. Cost considerations were also an issue since N-methyl-pyrrolidone wash solvent must be distilled in a costly process involving a contractor that brings mobile vacuum distillation equipment to the plant site. Raffi and Swanson was also interested in getting away from using an MEK rinse. The rinse results in a VOC emission and has a low flash point.

The intent of this task was to test aqueous and semi-aqueous chemistries to further improve the urethane vessel cleaning process. Aqueous and semi-aqueous chemistries typically have lower flammability, lower VOCs, and fewer worker health concerns

4.1 Lab Testing

To evaluate the efficacy of aqueous and semi-aqueous solutions in cleaning urethane residues, the Toxics Use Reduction Institute Surface Cleaning Lab performed a series of bench scale tests. Candidate aqueous and semi-aqueous cleaning solutions were identified via a literature search, an Internet search, a review of TURI vendor files, and recommendations from colleagues. Once the candidate aqueous and semi-aqueous chemistries were identified, the Surface Cleaning Lab performed a series of tests examining their cleaning efficacy. These tests were performed on two Raffi and Swanson coatings, a hydrophobic product (base-coat #51144) and a hydrophilic product (top coat #51072). The following sections review each of the six lab tests. Complete results for each test are presented in Appendix A[1].

4.1.1 Lab Test 1: Screening Chemistries *February 5, 1996*

The Surface Cleaning Lab conducted tests on eight chemistries -- four water-based cleaners and four semi-aqueous cleaners (terpenes). The tests were conducted on metal samples covered with hydrophilic and hydrophobic coatings. Samples were placed into beakers with the solution and agitated with a stir rod for 30 minutes at 160°F.

Test results showed that two aqueous cleaners (69MC and PolySpray 790P) and two semi-aqueous cleaners (HTF 85B and EP 921) had the highest performance (see Table 1). All chemistries had a more difficult time removing the base-coat #51144 verses the #51072. Since base-coat #51144 was more difficult to remove, all subsequent tests were conducted only on this urethane product

[1] Material safety data sheets for all chemistries are on file at the TURI Surface Cleaning Lab.

Table 1: Screening Results

	Chemistry	Percent Removal	Standard Deviation	Qualitative Results (#51072)*	Qualitative Results (#51144)*	Recommendation
Aqueous-based chemistry	PolySpray Jet 790	44.82	2.45	4	6	optimize further
	PolySpray Jet 790	37.04	31.71	6	7	do not test more
	PolySpray Jet 790	41.51	30.19	6	8	do not test more
	PolySpray 69 MC	50.79	6.29	1	4	optimize further
Semi-aqueous based chemistry	Cleppo 288-D	48.54	36.42	8	3	do not test more
	Safe Strip	94.81	3.43	4	4	do not test more
	HTF 85B	98.61	2.09	2	2	optimize further
	EP 921	99.84	.08	3	1	optimize further

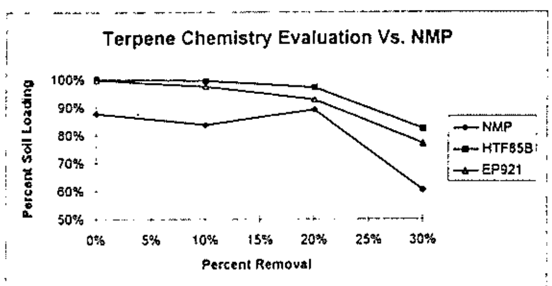
*based on a comparative rating of 1 to 8 with 1 being the best.

4.1.2 Lab Test 2: Semi-aqueous and NMP @ Different Soil Loadings *February 20, 1996*

The next test examined the two leading semi-aqueous chemistries (based on Lab Test 1 results) and N-methyl pyrrolidone (the current Raffi & Swanson urethane cleaning chemical). In this test, the cleaners were loaded with the urethane at different levels. Loading the cleaners was done to determine at what soil levels cleaning efficacy begins to decline. Lab Test 2 was conducted on metal samples covered with #51144 coatings. Samples were placed into beakers with solution and agitated with stir rod for 30 minutes at 160°F.

Test results showed that both semi-aqueous chemistries out-performed NMP at all percent soil loadings (see Figure 1). The HTF-85B performed better than EP921 and N-methyl pyrrolidone at all loading levels.

Figure 1: Soil Loading Results



Loading	NMP	HTF85B	EP921
0%	88%	100%	100%
10%	84%	99%	98%
20%	89%	97%	93%
30%	60%	82%	77%

4.1.3 Lab Test 3: Aqueous Cleaner Evaluation *March 4, 1996*

Lab Test 3 took a closer look at the performance of six aqueous cleaners. Since aqueous cleaners use a surfactant process -- as opposed to NMP and semi-aqueous that dissolve the urethane coating -- the cleaners were evaluated by how easily the urethane coating peeled off following immersion. The tests were conducted on metal samples covered with #51144 coating. Samples were placed into beakers with solution at different concentrations and agitated with stir rod for 30 minutes.

One aqueous cleaner (PolySpray 69MC) did an excellent job lifting off the urethane coating when compared with the other cleaners. Urethanes were peeled off easily at concentrations as low as 20%. (see Table 2 - test results indicated by POE (Peeled Off Easily) and DNP (Did Not Peel)).

Table 2: Aqueous Cleaner Test Results

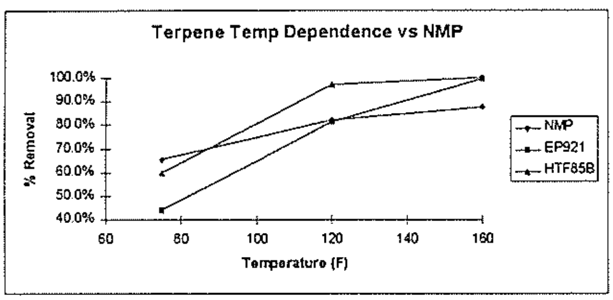
Conc.	Aluminex 5781	Aluminex 4874	PolySpray P	69MC	PolySpray XS	PolySpray C	Aluminex 5834
50%	POE		POE	POE	POE	POE	DNP
40%	DNP		DNP	POE	DNP	DNP	
30%				POE			
20%				POE			
10%				DNP			

4.1.4 Lab Test 4: Semi-aqueous and NMP Temperature Dependence *March 8, 1996*

This test examined the cleaning efficacy of two semi-aqueous chemistries and NMP at different temperatures. Raffi and Swanson preferred a process that would clean at lower temperatures since lower temperature processes present fewer hazards and use less energy. As in prior tests, Lab Test 4 was conducted on metal samples covered with #51144 coating. Samples were placed into beakers with solution at different temperatures and agitated with stir rod for 30 minutes.

Tests were conducted at 75°F, 120°F, and 160°F. Cleaning performance improved at elevated temperatures for all materials although performance began to plateau for two materials (HT-85B and NMP) at 120°F (see Figure 2).

Figure 2: Temperature Test Results



Temperature	NMP	EP921	HTF85B
75	65.6%	44.0%	59.7%
120	82.3%	81.2%	97.4%
160	87.6%	99.6%	99.9%

4.1.5 Lab Test 5: 69MC Rinsability Study *April 4, 1996*

This test was performed to determine what percentage of drag-out of 69MC could be tolerated in deionized (DI) rinse water. Investigators then extrapolated the number of times rinse water could be reused before leaving visible residue on metal coupons to the number of times the rinse could be reused in a urethane reactor. To perform the test, different concentrations of 69MC in DI water (0% to 5%) were rinsed on 304 stainless steel coupons. The coupons were inspected with a microscope and pictures were taken of rinsing spots.

DI rinse water with 1% 69MC showed no spotting. The 2% 69MC rinse showed good results with exception of a single streak. Rinse water with 3% 69 MC, 4% 69 MC and 5% 69 MC all exhibited heavy streaking. Using 2% as the maximum permissible amount of 69 MC in rinse water, a fifteen gallon DI rinse could contain no more than 0.3 gallons of concentrated 69 MC. Therefore the number of rinses that could be reused (assuming a 15 gallon charge) equals:

$$No.Rinses = \frac{0.3}{D \bullet x}$$

where: D = amount of 69MC residue left in tank after cleaning
x = volume fraction of 69 MC in cleaning solution

Lab Test 6: 69MC Temperature and Foam Study *April 8, 1996*

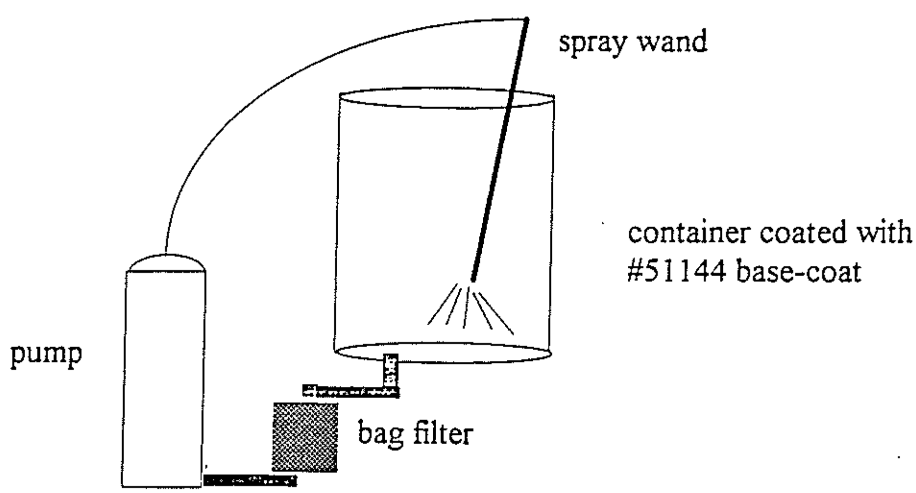
This test was performed to determine the effect of temperature on 69 MC cleaning and to determine the amount of foam generated at various temperatures. Coupons were coated using the same methods used in previous experiments. Cleaning was performed in the laboratory's Miele pressure washer at temperatures 60°F, 120°F, and 160°F with a 15% solution of 69 MC.

Although the process did not remove all of the base-coat #51144, some of the urethane was removed and the rest of the coating could be easily peeled of the coupon. The 69 MC posed no foaming problems at all temperatures.

Bench Scale Testing

The Surface Cleaning Lab tests indicated that one aqueous chemistry (PolySpray 69 MC) and one semi-aqueous chemistry (HTF 85B) had the greatest potential as a substitute for N-methyl pyrrolidone. Therefore, following the TURI Surface Cleaning Lab tests, Raffi and Swanson conducted in-plant bench scale tests on both chemistries. To perform these tests, the sidewalls of a ~50 gal. stainless steel container was coated with base-coat #51444. The drum was then allowed to dry for a specified time period at ambient temperatures -- rendering the urethane semi-cured. Raffi and Swanson's pilot reactor was used to heat the cleaning solutions to ~180°F. A recirculating pump delivered cleaning solution to a nozzle inserted in the top of the container. Cleaning solution was sprayed out of the nozzle at ~400 psi and piped from the bottom of the container through a filter bag back into the pump. Figure 3 depicts the bench scale set-up.

Figure 3: Bench Testing Set-up



4.2.1 Bench Test 1: 69MC *May 31, 1996*

This test was performed to examine the cleaning efficacy of 69 MC at a bench scale level. A stainless container was coated with #51144 urethane, allowed to sit 4 hours, and cleaned for 17 minutes using 10 gal of 100% 69 MC heated to 200 F.

The 69 MC removed the urethane coating wherever the spray directly impinged the container walls and bottom. Where there was no impingement, the coating swelled but was not removed. The cloth filter bags filled up with material that had the consistency of melted marshmallows. The filter bag filled during the test requiring the test to be aborted. Results of this test were poor in two respects. First, where there was only indirect impingement, the 69 MC did no remove coating. Second, the filter bag collected a significant amount of undissolved coating -- making filtering of 69 MC a difficult task.

4.2.2 Bench Test 2: HTF 85B versus NMP *May 31, 1996*

This test was performed to compare the cleaning efficacy of HTF 85B and NMP at a bench scale level. Stainless containers was coated with #51144 urethane, allowed to sit 4 hours, and cleaned for roughly 15 minutes using 15 gal of 100% HTF 85 B and NMP heated to 200 F.

Both the HTF 85B and the NMP dissolved the coating in areas were there was direct impingement and in areas were the was no direct impingement. Both chemistries dissolved the urethane base-coat #51144. HTF 85B appeared to remove the urethane somewhat better than NMP. HTF 85B's odor was not as strong as that of NMP's.

4.3 Summary of Lab and Bench Test Results

Lab tests at the TURI Surface Cleaning Lab found that PolySpray 69 MC was the best aqueous cleaner of the seven chemistries test. However, when tests were performed at the bench scale, 69 MC results were not acceptable. The 69MC cleaner did not remove the urethane unless it directly impinged the container walls. Since there are numerous recessed areas inside the urethane reactors, cleaning with 69MC would leave water-entrapped residues. Since hydroxyl molecules terminate the polymer reaction, these residues would ruin subsequent batches of urethane product. It is possible that expensive upgrades to Raffi and Swanson's high-pressure washing system could remove all of the urethane coating but its equally likely that no mater how thorough a power wash, some residue would be left on difficult to clean areas such as the underside of the mixing blades or in recessed areas around the shaft collar. The 69 MC results were also problematic from the standpoint of filtering and separation. Cleaning with 69 MC would require a new settling and separation system to remove the urethane marshmallow-like residue cleaned off the reactor walls.

Lab tests found that HTF 85B cleaned Raffi and Swanson's base-coat urethane better all of the aqueous cleaners, better than the other semi-aqueous, and better than NMP. HTF 85B contains terpene organic solvents and dibasic ester. HTF 85B has a high vapor pressure (<0.3654 mmHg), has low VOC potential, and is less toxic than NMP.

4.4 Economic Evaluation

An cost comparison of NMP versus HTF 85B was performed to examine how switching to HTF 85B would affect operating costs. Annual purchase, disposal and recycling costs and amounts were used. The comparison shows that NMP has significantly lower operation costs than HTF 85B. NMP can be recycled twice before being too contaminated for further recycling at which time it is disposed of as hazardous waste. HTF 85B is not recyclable.

Table 3: Economic Comparison

	NMP			HTF 85B		
	Cost/lb.	Pounds	Cost	Cost/lb.	No. lb.	Cost
Purchase	2.1	16,500	$34,650	2.12	30,493[a]	$64,645
Recycle	0.419	13,993	$5,858		0	$0.
Disposal	0.114	21,450[b]	$2,438	0.114	39,641[b]	$4,505
Total			**$43,946**			**$69,150**

a. The estimated amount of HTF 85B purchased per year is equal to the amount of NMP purchased plus the amount of NMP recycled.

b. The estimated amount of NMP-containing and HTF 85B-containing material disposed of is equal to 1.3 times the amount purchased -- this assumes that both cleaning chemistries become loaded with 30% solids over the course of their use.

Qualitatively, HTF 85B is a better cleaning material than NMP, is less hazardous to workers, and smells better. However these qualitative factors do not outweigh the increased operation costs that would occur with a switch from NMP to HTF 85B.

Raffi and Swanson has not discontinued its efforts to find suitable substitutes for NMP. At the time this report was written the company had contacted vendors selling a recyclable semi-aqueous chemistry. Raffi and Swanson hopes that through continued testing and evaluation, the company will identify a less-hazardous material for use in its urethane reactor vessel cleaning operations.

4.5 Other Improvements to Urethane Cleaning System

In addition to the chemistry work described in the preceding sections, Raffi and Swanson made two equipment-related changes to improve the reactor cleaning process. First, Raffi and Swanson performed tests to evaluate whether surface polishing of the urethane reactor inside surfaces would make cleaning easier. The inside surface of the reactors was extremely rough and covered with baked-on coatings from years of urethane processing. The rougher the surface, the higher the coefficient of friction and the more difficult it is to clean the reactor sidewalls. The tests were performed on three different surface finishes (unpolished coupons, mirror #4 finish, and mirror #8 finish) in the same bench set-up depicted in Figure 3. This set-up was used to simulate conditions in the company's 1,500 gallon reactors. The tests showed that polishing the reactor to a mirror #8 finish considerably improved the rate at which uncured urethanes were removed from the reactor sidewalls. Based on these results, Raffi and Swanson hired a contractor to mechanically polish one of the company's reactor vessels. The polished reactor is easier to clean. Raffi and Swanson has seen improvements in product quality from the reactor as well.

The second equipment change was the installation of a pressure gauge on the high-pressure pump used to deliver wash solvent (~ 400 psi) to the urethane vessels. By installing a pressure gauge, Raffi and Swanson can monitor the pump's performance and determine when pump performance begins to degrade. By properly maintaining the pump, Raffi and Swanson can make sure the process delivers sufficient pressure to blast residue off the reactor side-walls.

5. Reducing Plant Cleaner Use

The second grant-related effort was work by the TURA and SWEATT teams to reduce the amount of plant cleaner used to clean production containers. Plant cleaner is solvent mixture composed of toluene, methyl ethyl ketone, ethyl acetate, methyl isobutyl ketone, and xylene. Plant cleaner is used in centralized container cleaning operation. The insides of the containers, which range in size from 5 gal to 200 gal, become covered with coatings during mixing and blending operations. The containers are brought by workers to the container cleaning operation where they are cleaned manually or with the use of an automated unit.

The TURA and SWEATT teams' first efforts were to track the use of cleaning solvent throughout the plant (described in detail in section 3). Tracking solvent use and discharge *by department* gave the TURA and SWEATT teams the ability to measure improvement from an objective baseline.

The SWEATT team was instrumental in identifying opportunities to reduce wash solvent use. Since the team was staffed by representatives from Raffi and Swanson's five main production departments, the team was able to review each area for opportunities. Highlights of changes made as a result of SWEATT efforts follow in sections 5.1, 5.2 and 5.3.

5.1 Changes in Procedures

Reuse Plant Cleaner	Workers switched from using clean plant cleaner to keep the bottom of mixing containers moist to using dirty plant cleaner. The small amount of dirty plant cleaner (~1 gal) keeps the coating from hardening. Hardened coatings are more difficult to clean than uncured ones. Plant cleaner is also reused in this operation as many times as possible to reduce the amount of dirty plant cleaner generated. Production departments such as the grind room are saving solvent washes in drums for reincorporation into subsequent production runs.
Revise Grind Formulas	SWEATT carried out a study comparing waste generation and production rates of ball mills with horizontal mills. The study showed that horizontal mills generated far less waste per batch, processed material nearly an order of magnitude faster, and improved product quality. Recommendations were developed to begin reformulating high-volume products from the ball mills to the premier mills.
Restrict Plant	In the past, workers could get their own plant cleaner. Delivery of drums

Cleaner Delivery	of plant cleaner now requires sign-off by department personnel. As a result, plant cleaner is used with greater discrimination.

5.2 Data Collection Changes

Survey Plant Cleaner Usage and Discharge	SWEATT instituted a survey to monitor all wash solvent use and discharge. Monitoring made it possible to track reduction trends and provided the team with information on the major operations in the plant using plant cleaner.
Container Survey	SWEATT instituted a survey to determine the size and number of container being cleaned. The survey highlighted the production department generating the greatest number of containers needing cleaning -- prompting SWEATT to concentrate its TUR efforts in those areas.

5.3 Equipment Modifications

Modify Containers and Procedures to Eliminate the Need for Solvent Cleaning	A SWEATT team member developed a packing method that reduced the number of containers needing cleaning by roughly 50%. Under the old process, after a 100 or 200 gal job was packaged, the dirty container was sent to the solvent washing area where it was cleaned using plant cleaner. Under the new process, the water-phase part of the coating was poured first into the batch by running down the sidewalls of the container. Coating the container sidewalls with the water-phase, made cleaning the vessel with water possible. To increase the effectiveness of water-cleaning, a small nozzle on flexible hose spraying ~0.25 gal per minute was installed and used to spray-down the sidewalls of containers during the packaging operation. Raffi and Swanson also designated that specific containers be used in the operation. These containers were polished to make them easier to clean. The valves on these containers were relocated and switched from gate valves to molasses valves. The change made it much easier and quicker to clean the valves.
Add Site Glass to Automatic Unit	A SWEATT team member recommended installing a site glass to give greater control over the use and discharge of solvent from the automatic solvent washing system used to clean 100 gal and 200 gal containers. The site glass makes it possible to see when new solvent needs to be added to the system and when dirty plant cleaner should be replaced with clean plant cleaner.
Eliminate Direct Plant Cleaner Pumping	Raffi and Swanson made plumbing changes so that plant cleaner can no longer be pumped directly from a solvent manifold into a drum or cleaning operation on the plant floor. Workers now sign-out drums. The sign-out procedure helps track usage and reinforces SWEATT's goal of reducing plant cleaner use wherever possible.

5.4 Summary of Plant Cleaner Reductions

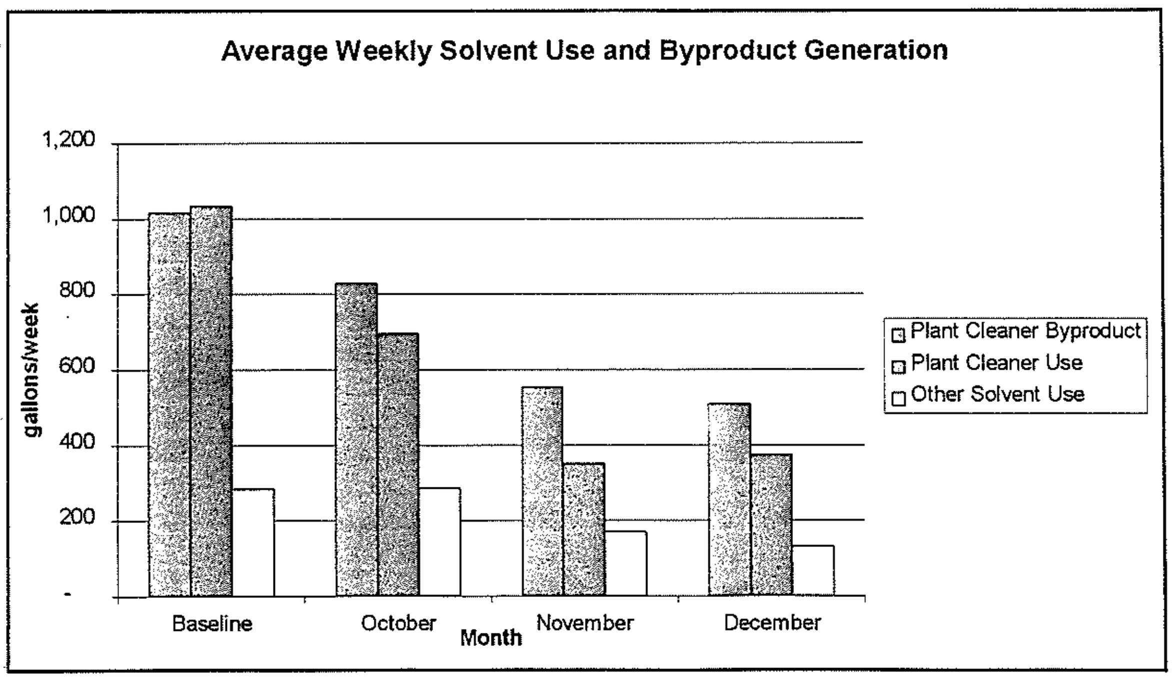
Table 4 presents plant chemical reduction data. Before the start of the project, Raffi and Swanson decided to track all solvents used in cleaning. This gave the company a good baseline to track progress. As Table 4 indicates, the changes outlined previously have yielded considerable annual reductions in both use and byproduct.

Table 4: Annual Plant Cleaner

Chemical	Baseline Use/Emissions (lb.)	Use/Emissions Reduction (lb.)	Baseline Byproduct (lb.)	Byproduct Reduction (lb.)
Toluene	47,736	23,868	205,889	102,945
Methyl Ethyl Ketone	27,769	13,885	116,270	58,135
Ethyl Acetate	11,108	5,554	51,697	25,848
Xylene	3,333	1,666	14,342	7,171
Methyl Isobutyl Ketone	3,333	1,666	13,852	6,926
Total	93,279	***46,639***	402,050	***201,025***

Figure 4 shows this progress has occurred steadily since SWEATT and the TURA Team began working on reduction projects in September 1995.

Figure 4: Average Weekly Solvent Use and Byproduct Generation



5.5 Financial Evaluation

Table 5 presents a rough financial analysis of the changes implemented under the TURI grant to date. Only costs that have a measurable effect on cash flow have been included in the analysis.

Table 5: Finanical Analysis

RCRA Waste Savings	*Change/ Wk (gal)*	*Annual Change (gal)*	*% Reject*	*cost/gal*	*RCRA Savings*
	481	24,050	17%	0.75	$ 3,066
Still Elec. Savings	*Still hr./mo.*	*Still kW/hr*	*Reduced Use of Still*	*Electricity Rate ($/kW-hr)*	*Elec. Savings*
	107	78.5	50%	0.04811	$ 2,424
Still Labor Savings			*labor cost/yr.*	*% still red*	*Labor savings*
			25,000	50%	$ 12,500
TOTAL					**$ 17,991**

5.6 Future Efforts

With more than 50% of solvent use reduced in the container cleaning operation, Raffi and Swanson has turned its sights on further reductions. Raffi and Swanson prepared and mailed requests for proposal to over 10 vendors of alternative cleaning systems. These vendor systems include carbon dioxide blasting, automated terpene and water-based cleaning, plastic media cleaning, and high-pressure water blasting. Raffi and Swanson received bids from several firms and is in the process of evaluating the technologies.

APPENDIX

TURI
Surface Cleaning Laboratory
Experimental Log

DATE OF TEST: February 2, 1996
PURPOSE OF TEST: Phase I preliminary 'lift' study of solvent action on two Durane coatings

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANTS: Durane base coatings #51144 and #51072
CONTAMINATING PROCESS: Coatings applied by swab
ANALYTICAL METHOD: Visual inspection of coating lift after cleaning

LABORATORY PROCEDURES: Five cleaning chemistries were tested at concentrated (i.e, full-strength) levels. Ten 2" x 4" ss coupons were contaminated, five with Basecoat #51072 and five with Basecoat #51144. Contaminated coupons were allowed to set for 15 minutes followed by application of the cleaners for a contact/reaction time of 30 minutes.

RESULTS: Visual observations were made and recorded on the chemistries' effectiveness. Cleaners were rated on a scale of 1 to 5 for each coating, with a rank of 1 being the best performer.

Chemistry	#51072 Coating	#51144 Coating	Notes and Observations
Terpene Tech 85B	2	4	Dissolving mechanism
U.S. Polychem 69 MC	3	1	Lift & Dissolve mechanisms
Frederick Gumm 228-D	1	3	Lift & Dissolve mechanisms
Sentry Chem. Safe Strip	4	2	Dissolving mechanism
Inland Tech EP-921	4	5	Dissolving mechanism

CONCLUSIONS: In this brief test, the U.S. Polychem and the Frederick Gumm chemicals performed best. More testing with these and other chemistries will be required.

DATE OF TEST: February 5, 1996
PURPOSE OF TEST: Completion of Phase I 'lift' study in preparation for in-depth testing

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANTS: Durane base coatings #51072 and #51144
CONTAMINATING PROCESS: Coatings applied by swab and allowed to cure overnight
ANALYTICAL METHODS: Gravimetric and scrape tests after cleaning

LABORATORY PROCEDURES: Twenty-four 2" x 4" ss coupons were precleaned in a 20% solution of ND-Supreme in a Crest 40 KHz ultrasonic console for 20 minutes at 140^{o}F followed by rinsing in DI (deionized) water for 2 minutes at 120^{o}F. The coupons were then placed under ambient air knives for 2 minutes, dried for 30 minutes in a convection oven and allowed to cool for 30 minutes. After cooling, the coupons were measured for a clean weight on an analytical balance.

Half of each coupon was contaminated with Basecoat #51144 and the other half with Basecoat #51072. After overnight curing, the coupons were weighed for a contaminated weight.

Eight cleaning chemistries were tested at appropriate operating conditions for time, same-source agitation, concentration and temperature. All cleaning trials were performed for 30 minutes at 160°F (+/-5°F) in 600 mL beakers with stirbar agitation. The stirbar setting was maintained constant for each cleaner tested. Water-based chemistries were diluted to 50% while the rest of the chemistries were used at full-strength. After cleaning, the coupons were immersed in tap water for 2 minutes at 100°F (municipal water rinsing is not recommended for some cleaning chemistries; rinsing will be more carefully evaluated in Phases II and III). After rinsing, the coupons were dried at 140°F in a convection oven for 60 minutes, allowed to cool overnight and weighed.

Four of the chemistries, the U.S. Polychemical formulations, showed a lifting action on the coatings. To evaluate this mechanism for coating removal, a scrape test was performed on the coupons' remaining basecoat after cleaning. The other four cleaners use a dissolving mechanism on the coatings. Gravimetric analysis was successfully employed instead to determine the cleaning efficiencies of these chemistries.

RESULTS:

U.S. Polychem Polyspray Jet 790P (50% solution) - #51072 Coating totally removed on all 3 coupons. Remaining #51144 Coating scraped and pulled off with little effort.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
4	60.4205	61.4891	60.9933	0.4958	46.40%
5	59.7666	60.8911	60.4188	0.4723	42.00%
6	60.484	61.4893	61.0261	0.4632	46.08%
				Average	44.82%
				StDev.	2.45%

U.S. Polychem Polyspray Jet 790 XS (50% solution) - Effective on the #51072 Coating (except coupon #7). Scrape test showed that the #51144 Coating could be pulled off with quite a bit of effort.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
7	59.9058	61.0715	61.042	0.0295	2.53%
8	60.11	61.2037	60.7258	0.4779	43.70%
9	60.6564	61.5477	60.9692	0.5785	64.91%
				Average	37.04%
				StDev.	31.71%

U.S. Polychem Polyspray Jet 790C (50% solution) - Not effective on the #51144 Coating.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
10	60.0143	61.09	60.4747	0.6153	57.20%
11	60.7083	61.8142	61.1438	0.6704	60.62%
12	60.278	61.3615	61.2888	0.0727	6.71%
				Average	41.51%
				StDev.	30.19%

Frederick Gumm Cleppo 288-D (50% solution) - Effective on the #51144 Coating but a longer cleaning time will be necessary to remove the #51072 Coating.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
13	60.3352	61.8657	61.2669	0.5988	39.12%
14	60.5393	61.6671	60.6663	1.0008	88.74%
15	60.7022	62.1118	61.8616	0.2502	17.75%
				Average	48.54%
				StDev.	36.42%

Ecolink Safe Strip (non-diluted) - Excellent removal of the #51072 Coating but a longer cleaning time will be necessary to remove the #51144 Coating.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
16	60.5761	61.6049	60.656	0.9489	92.23%
17	60.3589	61.4997	60.3737	1.126	98.70%
18	59.9049	61.1859	59.9882	1.1977	93.50%
				Average	94.81%
				StDev.	3.43%

U.S. Polychem 69MC(non-diluted) - Lifts off the #51072 Coating in 10 minutes. Scrape test showed that the remaining #51144 Coating could be removed easily after cleaning.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
19	60.2195	61.3182	60.8249	0.4933	44.90%
20	60.4775	61.4268	60.9516	0.4752	50.06%
21	60.2207	61.2342	60.6523	0.5819	57.41%
				Average	50.79%
				StDev.	6.29%

Terpene Technologies HTF-85B (non-diluted) -Almost as effective as EP-921(below); lower %-Coating removal on coupon #22 due to high contaminant loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
22	60.0098	62.058	60.0875	1.9705	96.21%
23	60.106	61.169	60.1068	1.0622	99.92%
24	60.2287	61.1451	60.2314	0.9137	99.71%
				Average	98.61%
				StDev.	2.09%

Inland Technologies EP-921(non-diluted) - Most effective chemistry tested. Total Coating removal in approx. 20 minutes.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
25	60.5203	61.7187	60.5213	1.1974	99.92%
26	59.3011	60.1552	59.3024	0.8528	99.85%
27	60.242	61.0863	60.244	0.8423	99.76%
				Average	99.84%
				StDev.	0.08%

CONCLUSIONS: The Safestrip, Cleppo-228C, PolySpray Jet 790C & 790XS were ineffective in this coating removal application and will not be considered for further testing. The 69MC and the Polyspray Jet 790P will need longer cleaning cycles to remove all of the urethane.

The EP-921 and HTF-85B were excellent performers. Two concerns remain: the low flash point of EP-921 (146°F) and rinsing configurations.

DATE OF TEST: February 20, 1996
PURPOSE OF TEST: Phase II determination the soil loading characteristics of cleaners EP-921 and HTF-85B, as compared to NMP (n-methyl-2-pyrrolidone) currently in use.

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANT: Durane base coating #51144
CONTAMINATING PROCESS: Coating applied by swab and allowed to cure overnight
ANALYTICAL METHOD: Gravimetric analysis after cleaning

LABORATORY PROCEDURES: Five coupons in each chemistry at each percentage of soil loading, described below, were cleaned. By observing how efficient the chemicals are at various levels of dissolved urethanes, the best performing terpene (i.e., semi-aqueous) cleaner can be ascertained. The soil loading will be done as a weight percentage of Basecoat #51144 to the total weight of contaminated cleaning solution. Soil loadings were increased in increments of 10% from 0% to 50% for a total of 30 coupons to be cleaned for each chemical.

Previous testing had determined that Basecoat #51144 was more difficult to remove so soil loading tests were performed with this coating. All coupons were contaminated in an identical fashion to the Phase I testing.

Three 400 mL beakers were filled with 350 mL of each chemical. Cleaning was conducted at 160°F for 30 minutes with stirbar agitation. Rinsing commenced with a 60-second tap water rinse at 130°F followed by a brief acetone rinse (to eliminate residual water/cleaner prior to gravimetric analysis). The coupons were dried under a UV light for 10 minutes and then allowed to cool overnight.

To determine the amount of Basecoat #51144 needed to achieve a particular percentage, the specific gravities of the cleaning solutions were obtained from Material Safety Data Sheets (MSDSs): NMP = 1.025, EP-921 = 0.9800, HTF-85B = 0.9932. The chart below shows the grams of Basecoat #51144 needed to be added to each chemistry to achieve a specified loading:

Cleaner	10%	20%	30%	Concentrations
NMP	40.00g	89.69g	153.75g	
EP-921	38.11g	85.75g	147.00g	
HTF-85B	38.86g	86.91g	148.98g	

The amount of urethane removed during cleaning was taken into consideration when increasing the soil loading. All urethane added to increase soil loading was uncured to reduce the time taken to dissolve.

It was assumed that there were no evaporative or dragout losses with respect to chemical volume. Therefore, a solvent volume of 350 mL was used for all soil loading calculations.

RESULTS:

NMP - No soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
1	60.42	61.2718	60.4887	0.7831	91.93%
2	59.7665	60.4789	59.8633	0.6156	86.41%
3	60.4839	61.3083	60.6515	0.6568	79.67%
4	59.9056	60.663	59.9399	0.7231	95.47%
5	60.0143	60.9037	60.1513	0.7524	84.60%
				3.531	87.62%
					6.21%

Inland Tech EP-921 - No soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
1	60.6562	61.3097	60.6566	0.6531	99.94%
2	60.7081	61.3835	60.7082	0.6753	99.99%
3	60.3344	61.3955	60.335	1.0605	99.94%
4	60.7016	61.6404	60.717	0.9234	98.36%
5	60.359	61.2314	60.3592	0.8722	99.98%
				4.1845	99.64%
					0.72%

Terpene Tech HTF-85B - No soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
1	59.9047	60.8014	59.9049	0.8965	99.98%
2	60.2195	60.822	60.2197	0.6023	99.97%
3	60.477	61.1145	60.4773	0.6372	99.95%
4	60.2211	60.8589	60.2211	0.6378	100.00%
5	60.0083	60.729	60.009	0.72	99.90%
				3.4938	99.96%
					0.04%

NMP - 10% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
6	60.4197	61.2909	60.5188	0.7721	88.62%
7	59.7668	60.5674	59.8698	0.6976	87.13%
8	60.4838	61.4613	60.6831	0.7782	79.61%
9	59.9053	60.9938	60.0204	0.9734	89.43%
10	60.1101	60.9607	60.3303	0.6304	74.11%
				3.8517	83.78%
					6.66%

Inland Tech EP-921 - 10% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
6	60.6562	61.3019	60.6708	0.6311	97.74%
7	60.0137	60.6603	60.0164	0.6439	99.58%
8	60.7082	61.6846	60.7346	0.95	97.30%
9	60.278	61.0849	60.2823	0.8026	99.47%
10	60.3344	61.4548	60.4056	1.0492	93.65%
				4.0768	97.55%
					2.41%

Terpene Tech HTF-85B - 10% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
6	60.539	61.409	60.5428	0.8662	99.56%
7	60.7019	61.8941	60.7044	1.1897	99.79%
8	60.5755	61.2914	60.5788	0.7126	99.54%
9	60.3591	61.2216	60.3643	0.8573	99.40%
10	59.3007	60.1078	59.3208	0.787	97.51%
				4.4128	99.16%
					0.93%

NMP - 20% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
11	60.6562	61.4064	60.6783	0.7281	97.05%
12	60.0137	60.7303	60.0804	0.6499	90.69%
13	60.7082	61.2288	60.7426	0.4862	93.39%
14	60.278	60.9753	60.4015	0.5738	82.29%
15	60.3344	61.1885	60.4885	0.7	81.96%
				3.138	89.08%
					6.74%

Inland Tech EP-921 - 20% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
11	60.1058	60.6858	60.1275	0.5583	96.26%
12	60.2287	61.0412	60.2767	0.7645	94.09%
13	60.5201	61.2172	60.5646	0.6526	93.62%
14	60.2423	60.969	60.3341	0.6349	87.37%
15	59.9511	60.6721	60.011	0.6611	91.69%
				3.2714	92.61%
					3.35%

Terpene Tech HTF85B - 20% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
11	59.9047	60.7873	59.9083	0.879	99.59%
12	60.2195	60.921	60.2228	0.6982	99.53%
13	60.477	61.0192	60.499	0.5202	95.94%
14	60.2211	61.0052	60.2619	0.7433	94.80%
15	60.0083	60.7387	60.0424	0.6963	95.33%
				3.537	97.04%
					2.34%

NMP - 30% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
16	60.5386	61.7741	60.7543	1.0198	82.54%
17	60.7016	61.9505	61.2649	0.6856	54.90%
18	60.5752	61.7028	60.9753	0.7275	64.52%
19	60.359	61.2255	60.7621	0.4634	53.48%
20	59.9047	60.993	60.4955	0.4975	45.71%
				3.3938	60.23%
					14.15%

Inland Tech EP-921 - 30% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
16	60.6562	61.6654	60.8742	0.7912	78.40%
17	60.0137	61.105	60.2685	0.8365	76.65%
18	60.7082	61.8099	60.9082	0.9017	81.85%
19	60.278	61.4399	60.5666	0.8733	75.16%
20	60.3344	61.2438	60.5804	0.6634	72.95%
				4.0661	77.00%
					3.37%

Terpene Tech HTF-85B - 30% soil loading.

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
16	60.4197	61.4393	60.5603	0.879	86.21%
17	59.7668	60.663	59.9172	0.7458	83.22%
18	60.4839	61.5339	60.5702	0.9637	91.78%
19	60.1101	61.3927	60.4882	0.9045	70.52%
20					
				3.493	82.93%
					9.00%

Estimated dragout and evaporative losses were calculated by adding the original solvent volume to the volume of Basecoat #51144 added (density of 8.2 lb/gal) and subtracting the final volume of contaminated solvent. Losses were:

EP-921 - 42 mL (7.8%)
HTF-85B - 15 mL (2.63%)
NMP - 3 mL (0.55%)

CONCLUSIONS: Data obtained reveals that HTF-85B is the best semi-aqueous solvent tested and should be trialed on a pilot scale level. Phase III testing will focus on determining the most effective cleaner from U.S. Polychem & General Chemical products.

DATE OF TEST: March 4, 1996
PURPOSE OF TEST: Phase III determination of the most effective aqueous cleaner for removing Durane coating

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANT: Durane base coating #51144
CONTAMINATING PROCESS: Coating applied by swab and allowed to cure overnight

ANALYTICAL METHOD: Peel test after cleaning

LABORATORY PROCEDURES: Seven chemistries were tested under identical conditions at 160°F for 30 minutes with stirbar agitation. Cleaner concentrations started at 50% with incremental decreases of 10 %.

Cleanliness levels achieved were determined by a peel test after cleaning. If an aqueous chemistry is effective, the remaining urethane should peel easily from the surface of the coupon. Chemistries tested include:

Company	Tradename	Ph	Ingredients
U.S. Polychem	Polyspray C	12.5	20-30% Potassium Hydroxide
U.S. Polychem	Polyspray P	11.5	5-15% Tetra Potassium Hydroxide
U.S. Polychem	Polyspray XS	11.5	2-8% Sodium Silicate
			2-10% Tetra Potassium Pyrophosphate
U.S. Polychem	69 MC		20-30% Amino Ethyl Alcohol
General Chemical	Aluminex 5761	13	1-2% Potassium Hydroxide
			5-6% Sodium Metasilicate
			2-4% Borax
			5% Nonyl Phenyl Ethoxylate
General Chemical	Aluminex 5834	14	<10% Gluconic Acid, Potassium Salt
			<5% Ethoxylated Alcohol
			<5% Octylphenoxypolyethoxyethanol
			<12% Silicates
General Chemical	Aquaclean 4784	12	<2% Potassium Hydroxide
			<15% Ethylene Glycol Monophenyl Ether
			<15% Diethylene Glycol Monobutyl Ether
			<15% Diethylene Glycol
			<5% Triethanolamine

RESULTS:

X - Indicates Basecoat #51144 peeled off coupon after cleaning.

Conc.	Aluminex 5761	Aluminex 5834	Aquaclean 4874	Polyspray P	69MC	Polyspray XS	Polyspray C
50%	X	X	*	X	X	X	
40%			*	X	X		
30%					X		
20%					X		
10%							

*The Aquaclean worked on a dissolving mechanism (due to high glycol ether content) performed a 100% removal.

CONCLUSIONS: U.S. Polychem's 69MC outperformed all other aqueous cleaners tested to date.

DATE OF TEST: March 8, 1996

PURPOSE OF TEST: Determine the temperature dependence of two terpene cleaners, as compared to NMP

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANT: Durane base coating #51144
CONTAMINATING PROCESS: Coating applied by swab and allowed to cure overnight
ANALYTICAL METHOD: Gravimetric analysis after cleaning trials

LABORATORY PROCEDURES: Three coupons were cleaned in 500 mL of each solution at temperature levels of 75°F, 120°F and 160°F. Cleaning cycle duration was 30 minutes followed by an acetone rinse as previously described (all coupons were prepared and contaminated using the same methods in prior experiments).

Data for cleaning efficiency at 160°F was imported from Phase II.

RESULTS:

NMP - Ambient °F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
19	60.2196	61.7264	60.8123	0.9141	60.67%
20	60.4776	62.0680	61.0376	1.0304	64.79%
27	60.2424	61.4824	60.5981	0.8843	71.31%
				2.8288	65.59%
					5.37%

Inland Tech EP-921- Ambient °F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
11	60.7079	62.2201	61.5401	0.68	44.97%
12	60.2775	61.6108	60.8862	0.7246	54.35%
14	60.5386	62.3071	61.7279	0.5792	32.75%
				1.9838	44.02%
					10.83%

Terpene Tech HTF-85B - Ambient °F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
6	60.4836	62.0351	61.0971	0.938	60.46%
7	59.9048	61.4770	60.4385	1.0385	66.05%
10	60.0137	61.6361	60.7846	0.8515	52.48%
				2.828	59.67%
					6.82%

NMP - 120°F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
21	60.2213	61.9631	60.8190	1.1441	65.68%
22	60.0081	61.6345	60.2803	1.3542	83.26%
23	60.1057	61.5124	60.1346	1.3778	97.95%
				3.8761	82.30%
					16.15%

Terpene Tech. HTF-85B - 120°F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
16	60.5752	62.4356	60.6127	1.8229	97.98%
25	60.5201	62.1252	60.6090	1.5162	94.46%
28	59.9508	61.3642	59.9562	1.408	99.62%
				4.7471	97.35%
					2.64%

Inland Tech EP-921 - 120°F

sample #	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
8	60.1098	61.4076	60.3152	1.0924	84.17%
24	60.2288	61.8040	60.6116	1.1924	75.70%
26	59.3009	60.6873	59.5260	1.1613	83.76%
				3.4461	81.21%
					4.78%

DATE OF TEST: April 4, 1996
PURPOSE OF TEST: Ascertain the limits of cleaner drag-out tolerated in DI rinsing

SUBSTRATE MATERIAL: 304 stainless steel coupons
CONTAMINANTS: Durane base coating #51144
CONTAMINATING PROCESS: Coating applied by swab and allowed to cure overnight
ANALYTICAL METHODS: Microscopic and visual observation after cleaning

LABORATORY PROCEDURES: In the first part of this experiment, the rinsing effects of seven different solutions were evaluated:

1) 0% 69MC / 100% 16.4 M-ohm-cm DI water
2) 1% 69MC / 99% 16.4 M-ohm-cm DI water

3) 2% 69MC / 98% 16.4 M-ohm-cm DI water
4) 3% 69MC / 97% 16.4 M-ohm-cm DI water
5) 4% 69MC / 96% 16.4 M-ohm-cm DI water
6) 5% 69MC / 95% 16.4 M-ohm-cm DI water
7) 100% 69MC / 0% 16.4 M-ohm-cm DI water

Seven ss coupons were precleaned in the same manner as previous trials. One coupon was immersed in each rinsing solution for 10 minutes at ambient temperature. After immersion, the coupons were dried under a UV light for 10 minutes and allowed to cool for 10 minutes.

Since the non-volatile residues on the test coupons contained no organic material, FT-IR measurements were not taken. Instead, the coupons were inspected under a microscope and photomicrographs taken with a Polaroid Microcam at low magnification ranges.

In the second part of this experiment, a parts washer was used to establish cleaning efficiencies and cleaner foaming at different temperatures. Cleaning was performed in a Miele low-pressure, cabinet-style spray washer. The Miele recirculates 4.5 gallons of solution with a discharge pressure of 13 psi. The ss pieces were arranged in the washer so that the face of the sheets were directly facing the spray jets.

Cleaning was performed at 90°F, 120°F and 160°F. The parts were cleaned for 30 minutes at the desired temperatures and rinsed with tap water from a hand-held spray system at room temperature. In addition to cleanliness determinations by visual observation, foam levels in the Miele were also noted for each temperature.

RESULTS: In part one of this experiment, rinse spots appear as dark streaks on the coupons' surfaces. The 1% contamination of 69MC showed no streaks (the dark spots were polished spots on the coupons). The 2% rinse was acceptable except for the one streak on the coupon. All specimens >3% cleaner showed heavy streaking.

In part two of this experment, the 69MC was low-foaming at all temperatures tested. The percent-coating removal at the different temperatures was as follows:

1) 90°F - The edges of the plates had some hardened urethane - 0% Removal
2) 120°F - All of the urethane had hardened and was starting to lift off - 5% Removal
3) 160°F - A few contaminated spots remained, but the majority of urethane was removed - 80% Removal

CONCLUSIONS: This data would seem to suggest that the maximum amount of 69MC tolerated would be 2%. For a 15 gal. DI rinse this would be 0.3 gal. concentrated 69MC. Number of rinses that could be accomplished with the same charge should be:

$$Rinses = \frac{.3}{D*x}$$

D = amount of Dragout cleaning solution from tank
x = volume fraction of 69MC in cleaning solution

DATE OF TEST: April 8, 1996
PURPOSE OF TEST: Phase III to determine (1) the effect of temperature on the cleaning effectiveness of Cleaner 69 MC and (2) the amount of foam generated at various temperatures under pressure spray agitation

SUBSTRATE MATERIAL: 304 stainless steel samples
CONTAMINANT: Durane base coating #51144
CONTAMINATING PROCESS: Coating applied by swab and allowed to cure overnight
ANALYTICAL METHOD: Gravimetric analysis after cleaning

LABORATORY PROCEDURES: Three 10" x 16" 304 stainless steel pieces were contaminated with Basecoat #51144. Cleaning was performed in a Miele low-pressure, cabinet-style spray washer. The Miele recirculates 4.5 gallons of solution with a discharge pressure of 13 psi. The ss pieces were arranged in the washer so that the face of the sheets were directly facing the spray jets.

Trials were conducted at 90°F, 120°F and 160°F with solutions of 15% 69MC. This concentration was used due to operating problems with the Miele washer, otherwise a concentration of 30% would have been tested. The parts were cleaned for 30 minutes at the desired temperatures and rinsed with tap water from a hand-held spray system at room temperature. In addition to cleanliness determinations by gravimetric analysis, foam levels in the Miele were also noted for each temperature.

RESULTS:

Temperature °F	clean mass (g)	mass with contamination (g)	mass after cleaning (g)	contaminant removed (g)	Percent Removal
90	1121.2	1206.0	1200.6	5.4	6.37%
120	1124.9	1190.7	1186.9	3.8	5.78%
160	1452.2	1504.4	1483.9	20.5	39.27%

Although the Miele did not remove all of Basecoat #51144, this could be attributed to the low cleaner concentration. The plates exhibited several clean spots and the urethane could be peeled off the surface.

U.S. Polychem's 69MC posed no foaming problems at all temperatures tested.

Summary of Phase I testing for Raffi & Swanson-

Phase I evaluation of eight chemistries was completed on 2-8-96. The following results were obtained.

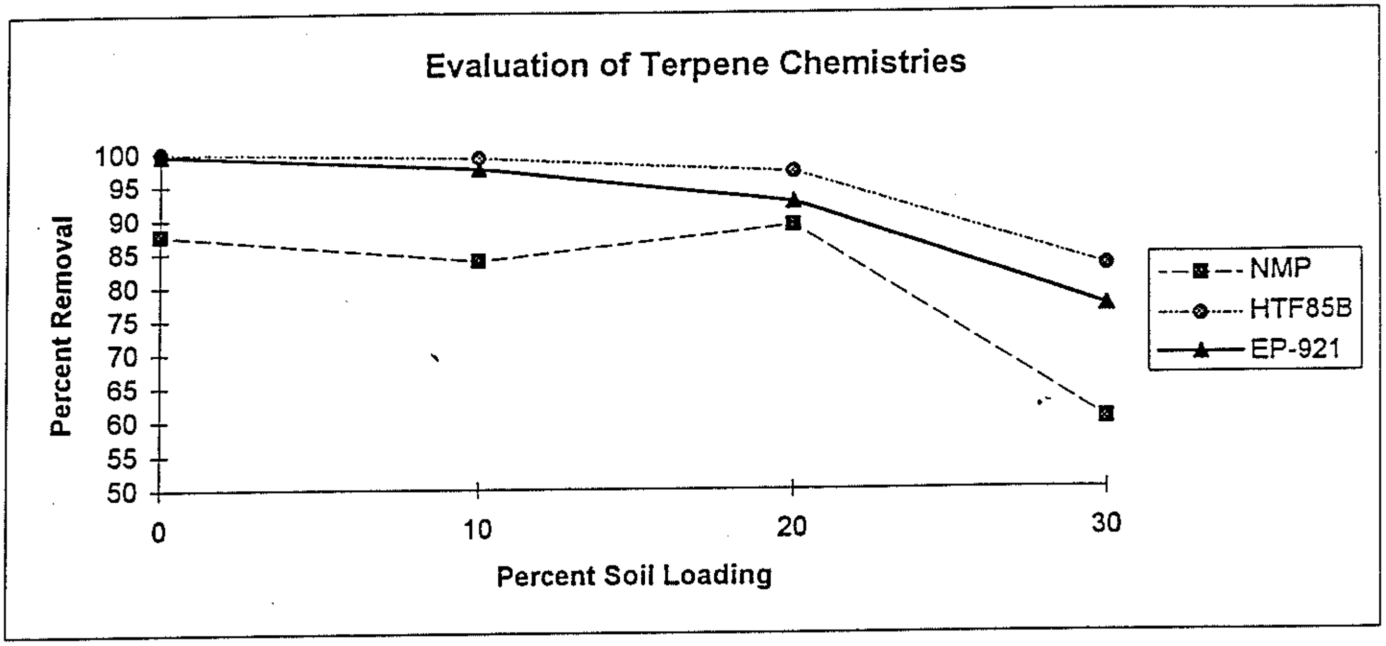
Chemistry	% Removal	StdDev	Effectiveness on Coatings* #51072	#51144	Reccomendations for future testing
PolySpray Jet 790 P[W]	44.82	2.45	4	6	Optimize cleaning time and concentration
PolySpray Jet 790 XS[W]	37.04	31.71	6	7	Should not be tested further
PolySpray Jet 790 C[W]	41.51	30.19	6	8	Should not be tested further
69 MC	50.79	6.29	1	4	Optimize cleaning time and evaluate soil loading
Cleppo 288-D[W]	48.54	36.42	8	3	Should not be tested further
Safe Strip	94.81	3.43	4	4	Should not be tested further
HTF 85B	98.61	2.09	2	2	Optimize Rinse and evaluate soil loading
EP 921	99.84	.08	3	1	Optimize Rinse and evaluate soil loading

*based on a comparative rating of 1 to 8 with 1 being the best

[W]Indicates a chemistry that was diluted with water to 50%

All chemistries had a tougher time removing the basecoat #51144 as compared to the #51072 (except for the Cleppo 288-D). Due to this we might want to think of just testing with the #51144 to expedite testing results.

Phase II Testing Results for Raffi & Swanson



	NMP Efficiency		HTF85B Efficiency		Inland Tech EP-921	
Loading	Ave. removal	STD	Ave. Removal	STD	Ave. Removal	STD
0.00%	87.62%	6.21%	99.96%	0.04%	99.64%	0.72%
10.00%	83.78%	6.66%	99.16%	0.93%	97.47%	2.56%
20.00%	89.08%	6.74%	97.04%	2.34%	92.61%	3.25%
30.00%	60.23%	14.15%	82.93%	9.00%	77.00%	3.37%

Breakdown of Chemistries tested for Raffi & Swanson as of March 8, 1996:

Company name	Tradename	Positive	Negative
Ecolink	Safe-Strip		High VOC content (995 g/l). Not as effective as terpenes and 69MC
U.S. Polychem	Polyspray C		Least effective of the Polyspray series.
U.S. Polychem	Polyspray P	Low environmental impact, could be effective with spray system	Will require a longer cleaning time than other chemistries and quite a bit of agitation
U.S. Polychem	Polyspray XS		Not as effective as Polyspray P.
U.S. Polychem	69MC	Performed excellent in lab testing. Filtration should be easy. Low envirn-mental impact	Experimental chemical.
Frederick Gumm	Cleppo 228-D		Highly caustic, had better results in lab with other chemistries
Terpene Tech.	HTF 85B	Outperformed NMP in lab tests, highest Solvency of all chemicals tested	Will have to be used at elevated temperature, still some questions about filtration Can also be made into a water based chemical.
Inland Tech.	EP-921	Good solvency in lab tests.	Low flash point and needs to be solvent rinsed
ISP Tech	NMP		Health, safety and regulatory concerns.
General Chem.	Aquaclean 4784	Good Removal of Basecoat #51144	Contains <45% Glycol Ethers (e-series), Would have problems in filtration

Chemical Properties of Chemistries tested for Raffi & Swanson:

Company Name	Tradename	Classification	pH	Flashpoint	Listed Chemicals
Ecolink	Safe-Strip	NMP Based Solvent	N/A	197 F	Gamma-Butyrollactone (96-48-0)
					N-Methylpyrrolidone (872-50-4)
U.S. Polychem	Polyspray C	Alkaline Aqueous	12.5	None	20-30% Sodium Hydroxide(1310-58-3)
U.S. Polychem	Polyspray P	Alkaline Aqueous	11.5	None	5-15% Tetra Potassium Diphosphate(7320-34-5)
U.S. Polychem	Polyspray XS	Alkaline Aqueous	11.5	None	2-8% Sodium Silicate(10213-76-3)
					2-10% Tetra Potassium Pyrophosphate(7320-34-5)
U.S. Polychem	69MC	Alkaline Aqueous	12	None	20-30% Amino Ethyl Alcohol (141-43-5)
Frederick Gumm	Cleppo 228-D	Caustic Aqueous	14	None	13.5% Potassium Hydroxide (1310-58-3)
					9% Ethylene Glycol Phenyl Ether(122-99-6)
					1% Diethylene Glycol Phenyl Ether(104-68-7)
					10% Diethylene Glycol Monomethyl Ether (111-77-3)
					5.94% Tetrahydrofurfural Alcohol (97-99-4)
Terpene Tech.	HTF 85B	Tarksol 97 Solvent	N/A	>200 F	Tarksol 97 Solvent
Inland Tech	EP-921	D-limonene Terpene	N/A	147 F	Propylene Carbonate (108-32-7)
					d-Limonene (5989-27-5)
ISP Tech	NMP	Cyclic Amine	N/A	199 F	1-Methyl-2-Pyrrolidinone (872-50-4)
General Chem.	Aquaclean 4784	Alkaline Aqueous	>12	>212 F	<2% Potassium Hydroxide (1310-58-3)
					<15% Ethylene Glycol Monophenyl Ether (122-99-6)
					<15% Diethylene Glycol Monobutyl Ether (112-34-5)
					<15% Diethylene Glycol (111-46-4)
					<5% Triethanolamine (102-71-6)