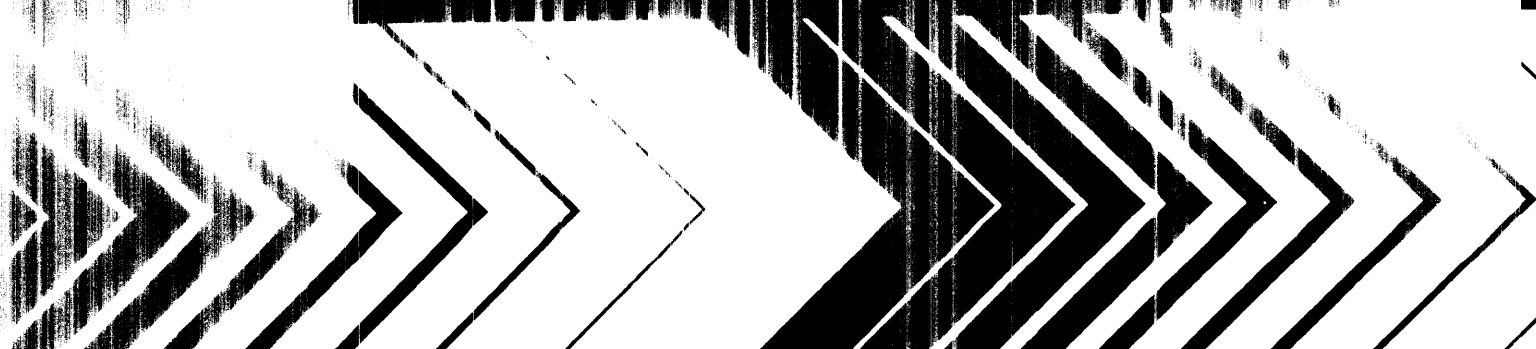


Results of the WRITE Projects



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May 1995

POLLUTION PREVENTION POSSIBILITIES
FOR SMALL AND MEDIUM-SIZED INDUSTRIES

Results of the WRITE Projects

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report is a compilation of 41 pollution prevention projects carried out under the WRITE program. It is intended for persons charged with identifying and implementing pollution prevention strategies. The reader is encouraged to contact the EPA project officers for more information.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

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DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency. It has been subjected to peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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EPA CONTRACTORS: Battelle, Columbus OH; PEI, Cincinnati OH; SAIC, San Diego, CA
(Respective project authors are appear in Section 3, under Reports)

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ABSTRACT

The Waste Reduction Innovative Technology Evaluation Program (WRITE) was a pilot program with six (6) states and one (1) local government, to identify priority needs at the respective governmental level, find promising waste minimization technologies and perform an evaluation to determine performance, pollution prevention (P2) impact and costs. The research concentrated on environmental problems and (P2) opportunities for small to medium-sized businesses, technology at pilot- or full-scale, and use of voluntary business/EPA partnerships.

A total of 41 technologies were tested and evaluated. Industries included were coating, depainting, electronics, metal plating and finishing, printing, surface cleaning, steel, and a number of miscellaneous categories. Many of the evaluations were able to list cost savings coupled with reduced or eliminated waste streams. It was found that technology benefits are largely application specific. However, favorable (or even unfavorable) findings for one application can be useful as a beginning for estimating other beneficial uses.

EXECUTIVE SUMMARY

The Risk Reduction Research Laboratory conducted a pilot program with six states and one local government to evaluate promising P2 technologies. Included were a full-scale technology demonstration, P2 impact assessment, and appraisal of relative performance and economics. A total of 41 evaluations were conducted. The results of 39 are summarized in terms of major effects on wastes (Table 1), and performance and economics (Table 2). The technology and test programs are described for two evaluations being completed.

Most of the work focuses on improvements to activities that have traditionally produced organic solvent and toxic metal waste. Selection of specific waste reduction technologies is a product of EPA and state environmental organization priorities, available technologies and the existence of sites willing to host the technology evaluations

Overall findings indicated that:

- . Technologies exist that reduce pollution, do not require large capital investment, produce equal or better performance, and feature short term payback.
- . Many processes, such as surface cleaning and solvent substitution, have potential for multi-industry applications. However, most technology performance is sensitive to the requirements of a specific application, and needs to be evaluated for that purpose prior to use.
- . Compliance issues for specific applications should be investigated with local authorities prior to making technology changes. Many states are starting to incorporate multi-media P2 in their interpretation of environmental management. The objective is to allow flexibility in order to produce less environmental hazard overall.
- . The forces regulating the adoption of new technologies, even technologies with superior performance, favorable economics and waste reduction, are governed by other equally important criteria that were not specifically identified nor evaluated by this effort. These criteria are non-technological and include categories such as requirements of future regulation, worker/customer acceptance, tradition, social custom, etc.
- . Economic figures presented here are conservative. Capital investment is estimated on the basis of choosing between the cost of new technology or keeping the status quo at no expense, rather than the difference in capital outlay between purchasing existing vs. new technology.
- . The accounting system used for calculating economics did not include longer range expenses and penalties of missing opportunities for adopting P2 technology (future disposal costs, waste management overhead and impact of new regulations, worker exposure, equipment and training; productivity; health benefits; liability; etc.). While more difficult to quantify, these expenses can be of equal significance.

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ID	STATE	SHORT TITLE	USE*	OLD	NEW
08	CT	An Automated Aqueous Rotary Washer for the Metal Finishing Industry (Compared to 1. Vapor degreaser 2. Alkaline tumbling 3. Aqueous manual washing)	S	1. Organic VOC's/wastes 2. Alkaline wastewater 3. Surfactant waste from manual washing	1. Eliminate organic wastes 2. Reduced waste volume (~90%) 3. Reduced waste volume (~80%)
09	CT	On-Site Newspaper Ink Recycling	Pr	Waste ink and solvent	Reduced ink/solvent consumption and waste generation (9,000 gal/yr ink)
10	CT	Cadmium and Chromium Recovery from Electroplating Rinsewaters	M	Cadmium/cyanide rinsewater, chromium rinsewater, treatment plant chemicals and metal hydroxide sludges, treatment plant wastewater	Cd: reduced wastewater by approx 2 million gal (w/ion exchange), generated 660 gal regenerant. Cr: potential to reduce 0.5 million gal of wastewater. Test run did not recover chrome.
11	CT	Nickel Recovery From Electroplating Rinsewater by Electrodialysis	M	Nickel bearing wastewater	Recycle 29,964 lbs/yr nickel and over 1,000,000 gal/yr water
12	CT	Chromate Recovery from Chromating Rinsewater in the Metal Finishing Industry	M	Process rinsewater, treatment plant sludge	Reduce wastewater by 450,000 gal. Generates 4 drums of still bottoms
13	IL	Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers	Pr,S	Organic solvent air emissions, solvent waste	Reduced solvent air emissions by 80% Reduced hazardous wastes. Increased aqueous waste
14	IL	Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals	M	Zinc Cyanide plating waste	Eliminate Zinc Cyanide waste. Generate alkaline noncyanide (ANC) rinsewater with zinc hydroxide recovery, water recycling
15	IL	Recycling Nickel Electroplating Waste by Low Temperature Evaporation and Reverse Osmosis	M	Nickel electroplating waste	Reduced plating waste, nickel plating bath reuse. Permeate from RO, increased electricity use, cooling water
16	IL	Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating/Degreasing Bath	S,M	Aqueous Phosphating waste water	99.8% reduction in H/W (1,500 gal/yr)
17	IL	Waste Evaluation of Soy-Based Ink at a Sheet-Fed Offset Printer	Pr,S	Air emissions from petroleum-based inks and cleaners, liquid waste from washup trays, inks and cleaners on used rags	Approx 17% reduction in ink use. Inconclusive differences for air emissions, liquid and solid wastes. Same cleaner for both.

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ID	STATE	SHORT TITLE	USE*	OLD	NEW
29	NJ	Replacement for Non-Methylene Chloride Paint Remover	D	Spent methylene chloride	Spent N-methyl-2-pyrrolidone (NMP). Eliminates 49,000 lbs of methylene chloride waste. Reuses 240,000 lbs activated carbon
30	WA	Recycling Electric Arc Furnace Dust: Jorgensen Steel Facility	St	K061 Waste (EAF Dust), Steel making residues	On-site recycling of EAF, residues into ceramic products
31	WA	Low-Volatility Solvent and Filtration System for Mechanical Parts Washing	S	Spent organic solvent, volatile releases, or mineral spirits replaced monthly	Closed loop system, low volatility solvent, solvent disposal reduced 94% by weight ^b
32	WA	Power Washer With Wastewater Recycling	S	Spent organic solvent, or steam/spray cleaning & wastewater	Eliminated solvent releases & spent solvent. Reduced wastes by 80%, waste segregation. Electrical consumption up
33	WA	Bicarbonate of Soda Blasting Technology for Aircraft Wheel Depainting	S	Spent organic solvent, dissolved paint	Eliminated solvent. Bicarbonate slurry/water, paint chips, loud noise, Rotocloner wastewater
34	WA	Onsite Solvent Recovery with an Atmospheric Still	O ₄	Spent methyl ethyl ketone (MEK)	Reduced solvent waste by 70%, generated still bottoms, still cooling water
35	WA	Onsite Solvent Recovery with Vacuum Heat- Pump Distillation	S	Spent methylene chloride (MC)	Reduced waste solvent volume 92%, generated still bottoms,
36	WA	Onsite Solvent Recovery with Low Emission Vapor Degreasing	S	Organic solvent air emissions, spent organic solvent	Air emissions reduced >99%.
37	EC	Replacement of Hazardous Material in Wide Web Flexographic Printing Process	Pr	Volatile organic constituents (VOC's) from ink and make-up solvent	72.5% reduction in VOC's (at 80% water, 20% solvent)
38	EC	Ultrasonic Cleaning as a Replacement for a Chlorofluorocarbon-Based System	S	Chlorofluorocarbon (CFC) air emissions, spent CFC's	Reduced volatile emissions by 86%
39	EC	Removal and Containment of Lead-Based Paint via Needle Scalers	D	Lead contaminated dust emissions and blasting grit	Reduced dust emissions by 99%, reduced H/W by 97.5%
40	EC	Low-VOC Wood Furniture Coatings	C	Organic solvent air emissions and wastes	Not available (NA), project being completed
41	EC	Finishing Fabricated Metal Products with Powder Coatings	C	Organic solvent air emissions and wastes	NA, project being completed 5/95

ⁿ Converting from hard to sponge rollers.

^o Converting from continuous to conductivity sensor controlled rinse.

^p Based on limited data. Findings were favorable but not conclusive.

^q Depends on work load. Payback reached after 38 units tested using air and 96 using N₂.

^r Presented economics excludes recycling of semi-aqueous solvent/rinse because supplier does not have a recycling system. Recycling plus impact of Clean Air Act Amendments, etc. could favorably impact this system.

^s Based on cleaning 150 bearings/yr.

^t Projected savings based on 1000 parts/yr.

^u Projected for formulations at Jorgensen. Actual values will depend on product type and amount sold at \$2 to \$650/ton.

^v The \$24.6 K/yr is based on the actual formulation tested at 80% water.

^w The \$117 K/yr is projected on using a 100% water-based formulation.

^x Project not completed.

ID	STATE	SHORT TITLE	PERF ^a	ECONOMICS		
				\$SAVED ^b	CAPITAL ^c	YRS ^d
01	CA	Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System	2	17.1 ^e	75	4.4 ^g
02	CA	Evaluations of Three Oil Filter Designs for Pollution Prevention Effectiveness	3 ^f	0.35 ^g 157 ^h	.36 ^g 164 ^h	~1 "
03	CA	Electroplating Rinsewater Reduction	3	496	4,100	>8
04	CA	Sulphuric Acid Anodizing	2	15	995 ⁱ	67
05	CA	Robotic Painting System: . Robotics Arm Spraying . Proportional paint mixing . Electrostatic spray guns . Automatic paint line cleaning and solvent collection Solvent Recycling Stills	2-	38.5	1,400	38
			2	4	14	3.5
06	CA	Plastic Bead Blast Paint Stripping	2	5	18	3.6
07	CA	Freon Recovery from Degreasing	2-	490	270	0.6

TABLE 1. RESULTS OF WRITE TECHNOLOGY EVALUATIONS -
MAJOR IMPACTS ON WASTES

LEGEND

^a Type of industry using technology. Industries are: C - Improved Coating Technology (low or no solvent paints and varnishes, improved application); D - Depainting (paint, varnish surface coating removal); E - Electronics; M - metal plating or finishing; P - Paper; Pr - Printing; S - Surface cleaning; St - Steel; O - Other, explained below.

O₁ Reduction of waste oil, internal combustion engines.

O₂ Metal working oils/fluids recycling.

O₃ Recycling of spilled oils/fluids, recycling of sorbent pads.

O₄ Spray painting line cleaning solvent (MEK) recycling.

^b Solvent life projected from 16 month run. Product acceptance problems, et al., cut solvent life test short. Potential for significantly longer solvent life seems likely.

ID	STATE	SHORT TITLE	USE ^a	OLD	NEW
01	CA	Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System	M	Rinse water from nickel plating, waste water treatment sludge	Recovery of nickel. Reduced water consumption and waste water by 98%. Reduced plating chemical use and treatment sludge.
02	CA	Evaluations of Three Oil Filter Designs for Pollution Prevention Effectiveness	O ₁	Used motor oil, used oil filters	Reduced waste oil by 66% (157 gal/bus/yr). Reusable filters
03	CA	Electroplating Rinsewater Reduction	M	Rinsewater, hazardous waste (H/W) sludge from treatment, waste copper anodes	Reduced rinsewater discharge by 50 gpm. Copper recovery
04	CA	Sulphuric Acid Anodizing	M	Chrome rinsewater, chrome air emissions,	Eliminate chrome waste. Reduce rinsewater volume by 60% Decrease electric consumption by 70% Generate waste H ₂ SO ₄ .
05	CA	ROBOTIC PAINTING: . Proportional paint mixing . Electrostatic spray guns . Automatic paint line cleaning and collection . Solvent recycling stills	C	Paint waste, overspray, spent solvent	Paint waste reduced approx. 50%, Recycled cleaning solvent. Still bottoms generated
06	CA	Plastic Bead Blast Paint Stripping	D	Spent Methylene Chloride	.Eliminate Methylene Chloride .Plastic bead residue
07	CA	Freon Recovery from Degreasing	S	Spent solvent	Reduced solvent consumption by 35% (229,000 lbs of freon)

ID	STATE	SHORT TITLE	PERF ^a	ECONOMICS		
				\$SAVED ^b	CAPITAL ^c	YRS ^d
23	NJ	Mobile Onsite Recycling of Metalworking Fluids	2	1.6 to 7.8	0	NA
24	NJ	A Fluid Sorbent Recycling Device for Industrial Fluid Users	2	52% to 75%	0.7	~0
25	NJ	Electronic Component Cooling Alternatives: Compressed Air and Liquid Nitrogen	2 ^p	~\$5.25 per unit tested w/air or N ₂	Air 0.2 N ₂ 0.5	~0 ^q ~0 ^q
26	NJ	Evaluation at Zerpel (Zero Liquid Discharge System) at Pioneer Metal Finishing	2-	22.5	120 (for 2000 gpd)	5.3
27	NJ	A Replacement Solvent Cleaner/Degreaser Study At Duffy Electric and Machine Company	2-	- 0.3 ^r	NA	NA
28	NJ	A Supercritical Fluid Cleaning Study: Application to Instrument Bearings	2-	1.40 ^s 9.30 ^t	75 to 100	~71 ^s ~11 ^t
29	NJ	Replacement for Non-Methylene Chloride Paint Remover	1	315	80	<1
30	WA	Recycling Electric Arc Furnace Dust: Jorgensen Steel Facility	2	10,600 ^u	10,500 ^u	1 ^u
31	WA	Low-Volatility Solvent and Filtration System for Mechanical Parts Washing	2	0.5	1.5	4
32	WA	Power Washer With Wastewater Recycling	2	22	55	3
33	WA	Bicarbonate of Soda Blasting Technology for Aircraft Wheel Depainting	2+	80	227	<4
34	WA	Onsite Solvent Recovery with an Atmospheric Still	2	10	13	<2
35	WA	Onsite Solvent Recovery with Vacuum Heat-Pump Distillation	2	18	24	<2
36	WA	Onsite Solvent Recovery with Low Emission Vapor Degreasing	2+	25	210	10
37	EC	Replacement of Hazardous Materials in Wide Web Flexographic Printing Process	2	24.6 ^v 117 ^w	63 63	2.56 ^v 0.5 ^w
38	EC	Ultrasonic Cleaning as a Replacement for a Chlorofluorocarbon-Based System	2+	27	44.4	1.6
39	EC	Removal and Containment of Lead-Based Paint via Needle Scalers	1	-7.2	NA	NA
40	EC	Low-VOC Wood Furniture Coatings	NA ^x	--	--	--

ID	STATE	SHORT TITLE	USE*	OLD	NEW
18	MN	Modifications to Reduce Drag Out at a Printed Circuit Board Manufacturer	M,E	Plating waste and wastewater	Reduced dragout by ~50%, reduced rinse water volume
19	MN	Sponge Rollers and Flow Controller for Printed Circuit Board Manufacturing	M,E	Dragout, rinse water, and treatment process wastes	Reduced drag out, reduced waste water, reduced water use
20	MN	Carbon-Black Dispersion Preplating Technology for Printed Wire Board Manufacturing	M,E	Formaldehyde 200 gal/yr, rinsewater,	Eliminated formaldehyde Reduced: rinsewater ~88%, copper ~23%
21	MN	Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium	M	Spent: chromic acid etchant, strip solution	Reduce: chrome 7,000 lb/yr, etchant 21,000 gal/yr Generate: Sodium chloride 10,000 lb/yr, sodium sulfate 5,000 lb/yr, increase water consumption 5,000 gal/yr
22	MN	Substituting Cadmium Cyanide Electroplating with Zinc Chloride	M	Cadmium cyanide wastes, grease and oil, chromium, treated water, wastewater treatment sludge	Decreases (lbs): Cd-12,100, CN-835, oil & grease-9480. Increase: Zn- 22,300, Cr-3740, sludge-101,000, treated water- 4.9 million gal,
23	NJ	Mobile Onsite Recycling of Metalworking Fluids	O ₂ ,St	Spent fluids sent to disposal	Reduced fluids waste by ~1,250 gal for small shops via on-site recycling
24	NJ	A Fluid Sorbent Recycling Device for Industrial Fluid Users	O ₃	Spent sorbent pads, spilled fluids	Spent sorbent pad waste reduced by up to 87%.
25	NJ	Electronic Component Cooling Alternatives: Compressed Air and Liquid Nitrogen	E	Freon (R12) releases	Eliminate R12 releases. Requires N ₂ or clean compressed air.
26	NJ	Evaluation at Zerpel (Zero Liquid Discharge System) at Pioneer Metal Finishing	M	Plating wastewater, sludge, hydrogen cyanide at 2.69 (compliance 1.2 ppm).	Reduced water use by 66%; ~80% process water recycled; hydrogen cyanide to .058 mg/m3; potential for metals recovery
27	NJ	A Replacement Solvent Cleaner/Degreaser Study At Duffy Electric and Machine Company	S	360 gal of spent petroleum distillate (w/toluene and ethylbenzene) Approx 50% can be recycled.	78 gal spent liquids; 39 gal semi-aqueous cleaner, 39.1 gal isopropyl alcohol
28	NJ	A Supercritical Fluid Cleaning Study: Application to Instrument Bearings	S	Freon-113 releases, toluene, hexane, isopropyl alcohol, acetone	Eliminate all releases under the old system.

SECTION 1

INTRODUCTION

This report is a summary of work done under the WRITE Pilot Program with state and local governments. Between 1989 and 1994, forty-one (41) candidate, pollution prevention technologies were evaluated. The states of California, Connecticut, Illinois, Minnesota, New Jersey, and Washington, and Erie County New York, participated in the pilot program. Specific objectives of the WRITE program were to:

- . Identify priority problem areas within each jurisdiction
- . Find new technologies that have good potential to reduce or eliminate EPA priority or problem wastes
- . Identify companies using or planning to use the technology in the near future, and willing to host a demonstration,
- . Evaluate the technology via demonstration and determination of P2 impact and economics.

The demonstrations included designing a test to quantify performance and associated environmental impact and gather data regarding previous or traditional technology (historical in most instances) that was replaced by the new.

Where complete performance or environmental impact of the new technology was not directly available from test data, such as confidentiality of certain aspects, cost of obtaining full data sets was beyond the scope of the project (such as getting full air emissions data, for example) these factors were calculated or estimated on the basis of worst case scenario. The methods of obtaining these values is explained in the final project reports.

In some instances, evaluation of the performance of a product or process was based on qualitative data. Where this was the accepted and traditional method of determining product or output quality, experts or experienced personnel in performing this determination were used in arriving at the qualitative determinations.

To the extent practical, comparisons were made between the traditional methods and the new technologies to estimate the net effects, assessing the pollution prevention (P2) impact, and estimating the economics for both old and new systems. For assessing economics, the typical assumption used for the old system was that it was already in place and no capital outlays were required. Exceptions would be if modifications were required to get or stay in compliance using the old system.

TECHNOLOGY EVALUATIONS

The evaluations consisted of performance and P2 impact data from the new technology demonstrations compared to new data, historical records or estimates of the old technology. The economic comparisons were based on historical records and estimates of the old system compared to estimates for the new. Energy consumption comparisons between the two systems was included in the evaluations where applicable.

TABLE 2. RESULTS OF WRITE TECHNOLOGY EVALUATIONS:
PERFORMANCE AND ECONOMICS

LEGEND

- ^a Performance of new technology (w/o economics or P2 considerations) : 0-unacceptable; 1-less than old system, but acceptable; 2-equivalent to old system; 3-Better than old system, 4-significantly superior.
- ^b Annual saving in \$000.
- ^c Capital costs in \$000.
- ^d Payback period in years.
- ^e Unit operated at less than 50% capacity. Projections near full capacity give a 2-year payback.
- ^f Oil change interval increased over 2X based on limited data re. oil condition. Need data on long term engine wear.
- ^g per bus.
- ^h per facility (fleet of 450 busses).
- ⁱ Required replacement of existing tanks, adding cooling equipment and modifying water treatment facility.
- ^j Compared to vapor degreasing.
- ^k Compared to alkaline tumbling.
- ^l Compared to hand-aqueous washing.
- ^m Further development/testing needed to recycle chromium rinse water. This did not get a successful demonstration during the test.

P2, Waste Minimization, Source Reduction and Recycling--

During the start of the WRITE program, and prior to the Pollution Prevention Act of 1990, the focus of the WRITE Program was equally on source reduction and recycling. After its passage, the Agency placed more priority on source reduction. The chronological progression of the WRITE technology evaluations reflect this change of emphasis, with fewer recycling projects being selected during year two and three. From a practical standpoint the full hierarchy of waste management; source reduction, recycling, treatment and disposal should be considered in arriving at the smarter way of doing business.

Federal/State EPA Partnerships--

State and local government entities were very helpful in identifying pollution problems and priorities in their jurisdictions. In many instances they were able to make valuable contacts in finding host sites for the demonstrations and in over a quarter of the technology evaluations, they were able supply people and equipment to test and evaluate the technologies and draft reports.

Additionally, there was significant benefit in working with the multiple partners in terms of promoting the P2 paradigm shift which is an important part of pollution prevention.

ID	STATE	SHORT TITLE	PERF ^a	ECONOMICS		
				\$SAVED ^b	CAPITAL ^c	YRS ^d
08	CT	An Automated Aqueous Rotary Washer for the Metal Finishing Industry (Compared to: 1. Vapor degreaser 2. Alkaline tumbling 3. Aqueous, manual washing)	2-	1.- 15' 2. 15 ^k 3. 42'	207	7
09	CT	On-Site Newspaper Ink Recycling	2-	NA	318	10
10	CT	Cadmium and Chromium Recovery from Electroplating Rinsewaters	Cd: 2 Cr: 0 ^m	Cd: 41 Cr: 5.7 ^m	Cd: 16 Cr: 16 ^m	Cd: <1 Cr: >5 ^m
11	CT	Nickel Recovery From Electroplating Rinsewater by Electrodialysis	1	188	110	1
12	CT	Chromate Recovery from Chromating Rinsewater in the Metal Finishing Industry	1	22	87	4
13	IL	Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers	3	16.5	0	0
14	IL	Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals	2-	62	88	1.5
15	IL	Recycling Nickel Electroplating Rinse Waters by Low Temperature Evaporation and Reverse Osmosis	1-	NA	115	2.8
16	IL	Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating/Degreasing Bath	2	NA	NA	0.6
17	IL	Waste Evaluation of Soy-Based Ink at a Sheet-Fed Offset Printer	2	NA	NA	NA
18	MN	Modifications to Reduce Drag Out at a Printed Circuit Board Manufacturer	2	3.4	~0	~0
19	MN	Sponge Rollers and Flow Controller for Printed Circuit Board Manufacturing	2 ⁿ 2 ^o	16.5 ⁿ 1.5 ^o	0.2 ⁿ 0.6 ^o	~0 ⁿ 0.4 ^o
20	MN	Carbon-Black Dispersion Preplating Technology for Printed Wire Board Manufacturing	3	87	221	<4
21	MN	Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium	2+	126	563	4.5
22	MN	Substituting Cadmium Cyanide Electroplating with Zinc Chloride	2	17	1973	115

verify results reported by HP.

Cost information was provided by HP and the AROS manufacturer. Where possible, the costs were checked against other sources.

Results

The AROS unit achieved good separation of contaminants from the dirty rinse water. Removals of contaminants usually ranged from 90% to 97%. Overall the HP staff regard the AROS unit as having shown good performance during the test period. Rinse water quality was maintained at a low level of nickel contamination. It was reported that no printed circuit boards were rejected because of Watts nickel plating deficiencies.

The recycling of the rinse water resulted in a 98% reduction in the use of new deionized makeup water for this plating process, equivalent to about 425,000 gallons annually per shift, per plating line.

The AROS unit also successfully produced concentrated Watts nickel solution of adequate quality to return to the plating bath solution. Fresh Watts nickel solution costs about \$5.00/gal, so recovery and recycling presented a significant direct savings. It was also calculated that a reduction of approximately three (3) tons of category F006 waste (waste water treatment sludge from electroplating operations) at the industrial waste water treatment system could be attributed to the AROS unit.

Cost information provided by HP (see Table 1) indicated that the AROS unit would produce an estimated annual cost savings of \$26,250 at the HP facility when the unit was operated at less than half its rated hydraulic capacity. This savings is reduced by an estimated annual operating and maintenance cost of \$9,419 for a net annual savings of approximately \$17,100/yr.

Capital investment is approximately \$75,000, which represents \$63,000 for the unit and \$12,000 for making the installation permanent and for training of operational personnel. Dividing \$75,000 by \$17,100 results in a payback period of 4.4 yrs and a 23% return on investment.

The AROS unit at HP was operated at less than 50% of its capacity, partly due to the reduced operation of the Watts plating line. Operating the AROS unit at a level closer to design capacity would produce significantly better economics.

In terms of the overall facility, the AROS unit treated only about 3% of the total wastewater flow. Therefore, in its cost analysis, HP made no allowance for reduced labor cost at its main wastewater pretreatment plant. If, however, the AROS unit treated a larger percentage of the total wastewater flow, a labor reduction credit could be included in the cost analysis.

The HP facility has a fully amortized wastewater treatment facility in place. At a new facility under design, sizing the unit to operate closer to design capacity, reducing the capacity for a water treatment plant, reducing the size of DI water production units and gaining some benefit in reduced operating costs could all lead to more attractive economics.

The projected payback period for the unit operating near capacity at the HP facility was estimated at 2 yrs.

ID	STATE	SHORT TITLE	PERF ^a	ECONOMICS		
				\$SAVED ^b	CAPITAL ^c	YRS ^d
41	EC	Finishing Fabricated Metal Products with Powder Coatings	NA ^e	--	--	--

#02 EVALUATIONS OF THREE OIL FILTER DESIGNS FOR POLLUTION PREVENTION EFFECTIVENESS

Participants

The state of California Department of Toxic Substances Control, Sacramento, CA assisted in implementing the evaluations and participated in test design and review of the project report. The host for this evaluation was the Orange County Transit Authority (OCTA), Garden Grove, CA. OCTA personnel operated the busses equipped with the test oil filters as well as performing required maintenance. Science Applications International Corp, on contract to EPA, helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology /Testing

Used oil and oil filters are a large source of waste in the U.S. Two approaches to minimizing this waste, as well as minimizing consumption of non-renewable energy, would be to design reusable filters and filters that extend oil life. Filters that can be cleaned instead of discarded and improved filtration function to permit more mileage between oil changes have a large potential due to the large numbers of internal combustion engines in use and vast quantities of waste generated.

Three types of oil filters were included under this project for use on diesel engine busses. The designs included a reusable wire mesh, a disposable fiber and a disposable paper filter. The test program started in January, 1991 and underwent four months of testing plus engineering and economic evaluations.

Twelve OCTA fleet busses with Detroit 6V92T diesel engines were used for the test. The twelve were selected from the same manufacturer. The busses were as similar as possible in type, age, mileage, type of service route, previous service history and oil analysis.

The busses were grouped in three sets of four. Each was fitted with a primary filter and secondary-partial flow-centrifugal filter. One group of the four served as the baseline and was equipped with regular screw-on pleated paper, primary filters. The second set was equipped with a composite, synthetic media, primary filter. The third set used primary filters made of metal screens that could be cleaned and replaced.

A fitting was installed on the test vehicles that permitted samples to be withdrawn immediately downstream of the primary filter with the engine running. During the 4-month test period, weekly oil samples were taken to analyze physical and chemical properties, additives, and contaminants. Additionally, a particle count was conducted every other week (see Table 1.).

The test parameters examined fell into 2, basic groups, those that reflected oil quality or condition and those that indicated potential engine problems. Parameters monitored were based on guidelines provided by the Detroit Engine Company.

The P2 impact evaluations focused on changes in EPA identified priority toxic substances and the primary effects due to the changes made. At the same time secondary implications were considered to the extent possible within the scope of the evaluations.

While significant efforts are being carried out in the area of comparability, risk and true costs of various options, the present requires some form of informed judgement in determining what constitutes looking far enough. Development of a common denominator is an area of priority research need and a major challenge to operating in a P2 mode.

Part of this challenge is also due to the fact that the answers for determining common denominators do not lie solely within the technical or technology sectors, but rely on the other facets of society including socio-economics and politics, and varied perceptions of what are environmental priorities among the stakeholders. To enable consensus definitions, all of these sectors need to come into play. Recognition of the need for better consensus definitions and priorities is reflected by the recent EPA adoption of the Common Sense Initiative (CSI) which includes participation of all stakeholders in the development of regulations and implementation of P2 in technology development and improvement.

OVERVIEW AND RETROSPECTIVE

The central purpose of the WRITE Program was to enhance and speed up the process by which cleaner technologies get implemented. In the pursuit of this objective a number of issues were identified that had significant bearing on the success of implementing P2 technology and on the adoption of new technology in general.

Identifying New Technology--

The states and local governments were to identify problem areas in their jurisdictions and participate in finding host companies to test, demonstrate and evaluate technologies that solve these problems. Satisfying the above criteria was a difficult part of the program. There was an overall shortage of companies willing and qualified to participate. In this sense, qualified pertains to companies using a clean technology of interest. There was also an apparent reluctance of companies entering into a joint effort with a regulatory agency such as the EPA, even within a non-adversarial or partnering arrangement.

Adoption of New Technology--

Generally, expectations regarding the rate at which new technology gets implemented, were overly optimistic. While there is a very large time gradient from simple changes of procedure to very complex and interlinked supply, process and product changes, it is even further complicated by a variety of non-technological issues. Therefore, even for win-win-win technology (i.e. technology with superior performance, reduced or eliminated waste, a small amount of capital investment and a very short payback period), significant roadblocks need to be overcome. A more rigorous examination of cause and effects of these dynamics may be desirable, but both outside the scope and mission of this program.

Based on 48,000 miles driven per bus, per year, the savings in changing from 6,000 to 18,000 miles would be approximately 170 gal of waste oil and \$350. For OCTA this would mean savings of 76,450 gal and \$157,000. More effective filtration of engine oil has good potential for pollution prevention if engine life is not adversely impacted.

Report

The full report, entitled "Evaluation of Three Oil Filter Designs for Pollution Prevention Effectiveness", by Lisa M. Brown and Robert Ludwig will be available as an EPA/600 series report.

SECTION 2

WRITE TECHNOLOGY EVALUATIONS

This section contains the summarized technology evaluations presented alphabetically by state followed by the set performed for Erie County, N.Y.

CALIFORNIA

A total of seven (7) technologies were evaluated in California, five (5) for the General Dynamics, Pomona Division, one (1) for the Orange County Transit Authority and one (1) for Hewlett-Packard in Sunnyvale.

The evaluations were done under a Memorandum of Understanding between the EPA, Risk Reduction Engineering Laboratory and the California Department of Toxic Substance Control. The project officers for the evaluations were Lisa M. Brown and Robert Ludwig, respectively.

#01 WATTS NICKEL AND RINSE WATER RECOVERY VIA AN ADVANCED REVERSE OSMOSIS SYSTEM

Participants

The host for the evaluation was the Hewlett Packard (HP) plant in Sunnyvale, California, who also ran the reverse osmosis system during the test. The state of California, Department of Toxic Substances Control, Sacramento, CA, assisted in implementing the evaluations. Science Applications International Corporation (SAIC), Santa Ana, California, on contract to EPA, helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

The metal plating industry produces large quantities of metal contaminated wastewater requiring treatment before discharge. An Advanced Reverse Osmosis System (AROS), manufactured by WTI was installed in the HP plant to treat and recover Watts nickel plating bath solution and rinse water. The technology approaches zero discharge capability. An 8 - month test program was conducted to assess the effectiveness of the AROS and estimate the incremental cost savings resulting from less use of deionized water, reduced wastewater volume being pretreated, lower effluent and sludge disposal quantities, and recovery of the plating solution.

The HP facility manufactures printed circuit (PC) boards for use in personal computers. In one step of the manufacturing process, Watts nickel plating is used to plate a thin layer of conductive material on a non-conductive surface, like epoxy/plastic or ceramic. Watts nickel is also widely used in other industries for decorative plating operations.

The test included continuous monitoring of flow volume, conductivity, and pH at various monitoring points in the system. Streams monitored include the deionized rinse water makeup line, the concentrate return line, and the permeate return line. The plating bath was sampled and analyzed weekly. Analyses were conducted for nickel, pH, Nickel PC-3 (Saccharin), boric acid, chloride, and ductility.

Independent sampling and analysis were performed by the EPA contractor over a 1-day period to

Copper spheres in anode baskets are used in the new system instead of the conventional anode bar-and-hook system that was utilized in the old plating system. This allows a 1 to 1 ratio of anode to cathode for a very even plating across the panel and through the holes.

In conjunction with the installation of the new production equipment, Chemcut Corporation was required to provide a non-sludge-producing treatment system for all waste streams generated by the process. This resulted in the installation of a new copper-recovery system in which short-bed ion-exchange columns and electrowinning technologies are used. This system now produces salable scrap copper metal, eliminating a major waste stream to the conventional sludge-producing waste treatment system.

Figure 2 shows a flow diagram of the printed circuit board copper recovery system. The copper recovered with this process represents the equivalent of approximately 365 tons of sludge that would have gone to a landfill.

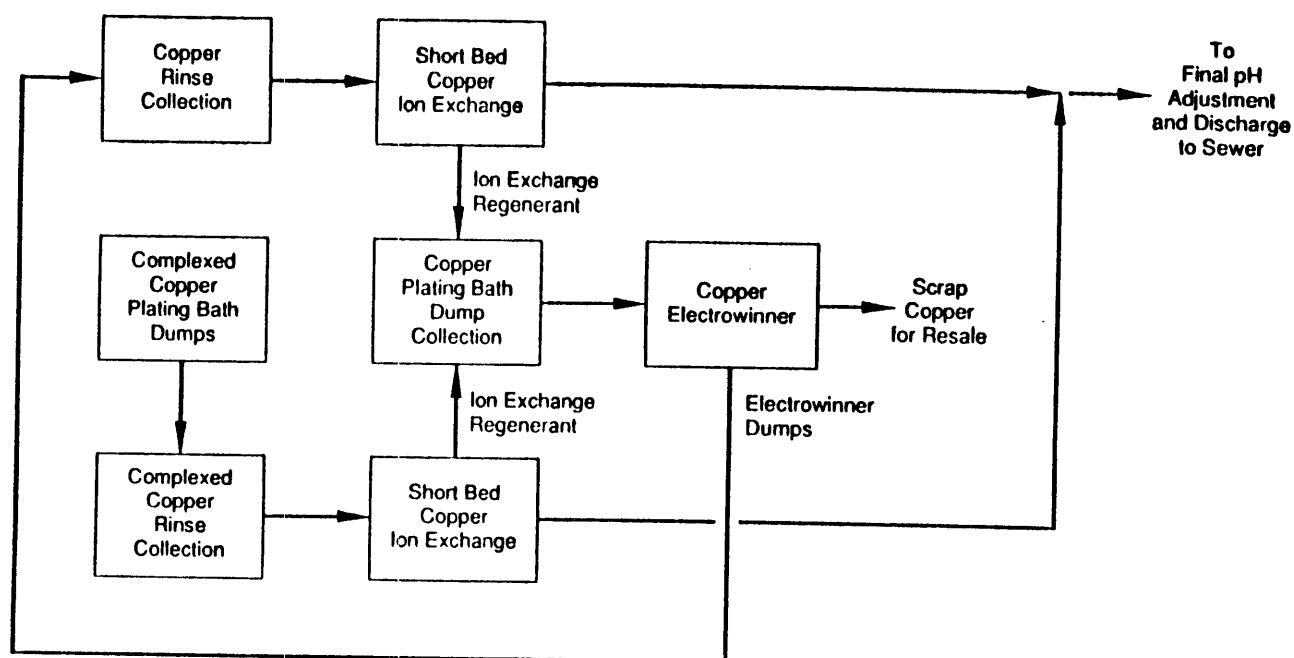


Figure 2. Flow diagram of circuit board copper recovery system

The objectives of the computerized printed circuit board plating operation evaluation included the following:

- 1) Verification of reductions in wastewater rinse flow by comparing records of present wastewater flows vs. previous wastewater flow data.
- 2) Establishment of a material balance around the printed circuit board process, if possible, using available plant data. Copper-bearing waste streams are to be identified, sampled for metal concentrations and documented for appropriate metal recovery processes.

TABLE 1. ESTIMATED ANNUAL SAVINGS FROM USE OF THE
AROS UNIT AS REPORTED BY HEWLETT-PACKARD COMPANY, 1900 COSTS

Description of Costs	Estimate Savings (\$/gal)	Quantity (gal)	Total Annual Savings (\$)
Sewer discharge fees and water costs	0.004	1,275,000	5,100
Deionized (DI) water production costs*	0.0064	1,275,000	8,160
Plating Wastewater treatment costs**	0.0062	1,275,000	7,905
Purchase of new plating chemicals at 85% reduction	5.00	1260x 0.85	5,355
Total estimated annual savings			\$26,520

* DI water production cost is for chemicals, electricity and resin replacement only. No labor, depreciation, or other costs are included on the assumption that they would remain essentially the same, whether the AROS unit was in use or not.

** Plating wastewater treatment cost includes sludge disposal, chemicals, and electricity. As in the note above, no labor, depreciation or other costs were included.

Report

The full report, entitled "Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System", by C. Schmidt, et al., is available as EPA/600/R-93/150.

Under the new system, the copper is recovered using ion-exchange and electrowinning equipment. Sludge disposal from this process has been eliminated. Anode basket plating has the following features:

- b Constant anode surface area (promotes uniform plating on parts), less product waste
- b Improved handling of anode material (anode material can be added without shutting down plating process)
- b No wasted anode material (anodes can be allowed to dissolve, completely eliminating the need to recycle unused anode material)
- b Easier to maintain proper current density (presence of the basket and the constant anode surface area aids in maintaining current density)

As presented in Table 2, cost savings in labor and waste treatment were found to be the major cost parameters, resulting in a favorable net annual operating cost savings between the original and newly installed printed circuit board plating systems. The payback period for the printed board plating system was estimated to be 8.3 years.

Due to the lack of computer automation, operation of the original system required six employees (i.e., four hourly and two engineers), versus two employees (i.e., one hourly and one engineer), for the new system. This resulted in a cost savings in labor of \$324,000 based on the plant operating two shifts per day, 8 hours per shift, and 6 days per week.

The cost savings in waste treatment of \$130,000 represents the savings resulting from the recovery of copper from rinse water and process tank solutions, which were previously treated and disposed of as hazardous sludge. Copper is now recovered as a salable by-product using ion-exchange and electrowinning equipment. The recovery process, estimated to be approximately 15 percent of the total capital installed cost of the printed circuit board system, produces solid slabs of copper which weigh approximately 30 pounds. One copper slab represents an equivalent of 0.5 tons of sludge that previously required landfill disposal at a cost of \$1200. Now, the recovered copper has a by-product value ranging from \$15 to \$20 per slab.

Cost savings in labor, waste treatment and water usage resulted in a net operating savings when compared to an estimate of the operating cost of the old plating system. These savings may increase with time as a result of startup problem resolution and reductions in chemical costs. Although a payback of 8.3 years was calculated on the capital investment of \$4.1 million, this does not consider the fact that a retrofit of the old system to the present operating capacity and waste reduction goals would have resulted in even higher capital costs. Looking at the expenditure from this standpoint, it could be reasoned that the new system is providing an instant payback because of lower capital costs and operating costs savings. Transfer of this type of computerized plating technology to smaller companies, however, would be difficult because of the high capital costs.

Results

Analyses taken during the 4-month test period revealed little differences in oil sampled from the three types of primary filters or among the 12 busses with the exception of the wear metals and particle counts below or equal to the 25 μm range.

TABLE 1. OIL ANALYSES

Parameter Group	Test Parameters
Physical/Chemical	Flash point, Fuel, Viscosity, Water content, Percent solids, Glycol, Soot, TBN
Additives	Magnesium, Calcium, Barium, Phosphorous, Zinc, Molybdenum
Contaminants	Silicon, Boron, Sodium
Wear Elements	Iron, Chromium, Lead, Copper, Tin, Aluminum, Nickel, Silver, Manganese, Antimony, Cadmium, Titanium,
Particle Counts	>5, >10, >15, >25, and >50 μm

For the wear elements, the synthetic fiber filtered oil contained slightly higher metal concentration. This difference was observed for one bus that produced consistently higher concentrations throughout the test. Busses with the synthetic fiber filter also had the lowest concentrations of particles equal or less than 25 μm . Busses with the reusable filters were in the middle, leaving the regular filters with the lowest metal concentrations and highest concentrations for particles less or equal to 25 μm .

All of the busses tested were able to go beyond the 6,000 mile oil change interval regularly practiced by OCTA. Ten of the twelve busses operated for 4 months without needing an oil or filter change. Miles traveled for the two were 14,429 and 21,571.

Little differences were revealed among the performance of the three filters for the relatively short test of 4-months. The major differences were the particle size cut below 25 μm . This particle size range was removed more effectively with the synthetic fibers. A longer test period and a larger sample size would be needed to correlate engine life with fine particle removal.

The cost of an oil change at OCTA is estimated at \$30 (Pleated paper filter), and \$40 (Synthetic fiber filter) without the cost of oil. The reusable filter is \$364, installed, with an estimated 10-year life. With labor and gaskets and 8 cleanings per year it equals \$27.50 per cleaning cycle. While the cost per filter per use is similar for the three, with the reusable being slightly less, the latter reduces the amount of waste generated by spent filters at 100 drums per year (8x450 busses).

Significant source reduction of used oil could be achieved with an extended oil change interval. For fleets with routine oil quality monitoring such as OCTA, the interval could be safely increased by a considerable amount.

#04 EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION; SULFURIC ACID ANODIZING

Participants

The state of California Department of Toxic Substances Control, Sacramento, CA assisted in implementing the evaluations. The host for the evaluation was the General Dynamics, Pomona Division Plant. Plant personnel operated the anodizing equipment during the test. PEI Inc., on contract to EPA helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

The three principal types of anodizing used by industry today are chromic acid anodizing (referred to by industry as Type I anodizing); sulfuric acid anodizing (referred to by industry as Type II anodizing); and hard anodizing, a patented process that uses a combination of sulfuric and oxalic acids as the electrolyte (referred to by industry as Type III). In addition to increasing corrosion resistance, anodizing also increases paint adhesion characteristics, making subsequent painting possible, improves the appearance, provides electrical insulation, and aids in the detection of surface flaws.

In December 1988, General Dynamics replaced its 35-year-old chromic acid aluminum anodizing system with a new computerized sulfuric acid anodizing system which utilized computerized hoists and on-demand rinsing. The new system, supplied by NAPCO, Inc., enabled General Dynamics (GD) to eliminate a major source of chromium emissions.

Besides the chemical substitution to eliminate chromium releases, the addition of automated hoist and on-demand water rinse system helped to reduce wastewater treatment requirements. The computerized automated hoists monitor the time intervals during which the parts are treated and allowed to drain. Compared with manual immersion and draining of the parts, this system reduces treatment requirements by avoiding unnecessary dragout of immersion fluids to downstream rinse tanks. Subsequently, the on-demand water rinse system reduces rinse-water usage and wastewater treatment requirements by reducing water consumption and monitoring the conductivity of the rinse water in the tank. Unlike manually operated rinse tanks, which have constant overflows, the on-demand system adds water only when the conductivity of the tank exceeds a set value.

The new automated anodizing system, which eliminated both water and air emissions of chromium was installed in 1988 and replaced a 35-year old chromic acid anodizing system. The objectives of the evaluation were to:

- 1) Analyses of the impact of computerized control on product quality. How much better quality control does it provide over conventional systems?
- 2) Establishment of a materials balance around the process.
- 3) Perform an economic analysis of the anodizing process. Determine annual operating costs and savings from eliminating chromium disposal and payback for the new system.

#03 EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION: ELECTROPLATING RINSE WATER REDUCTION

Participants

The state of California Department of Toxic Substances Control, Sacramento, CA assisted in implementing the evaluations. The host for the evaluation was the General Dynamics, Pomona Division Plant. General Dynamics personnel operated the computerized electroplating system. PEI Inc., on contract to EPA helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

Technology Description--

The Chemcut Corporation installed a new computerized printed circuit board plating system at General Dynamics at a cost of \$4,100,000. Figure 1 shows the tank configuration layout of the printed circuit board system, and Table 1 presents the standard operating sequence for the process. The new plating system eliminated rinse tanks from the process by use of a spray-rinse system contained in the transporter hoist system, allowing the circuit boards to be rinsed for only a short duration after their immersion in a process solution.

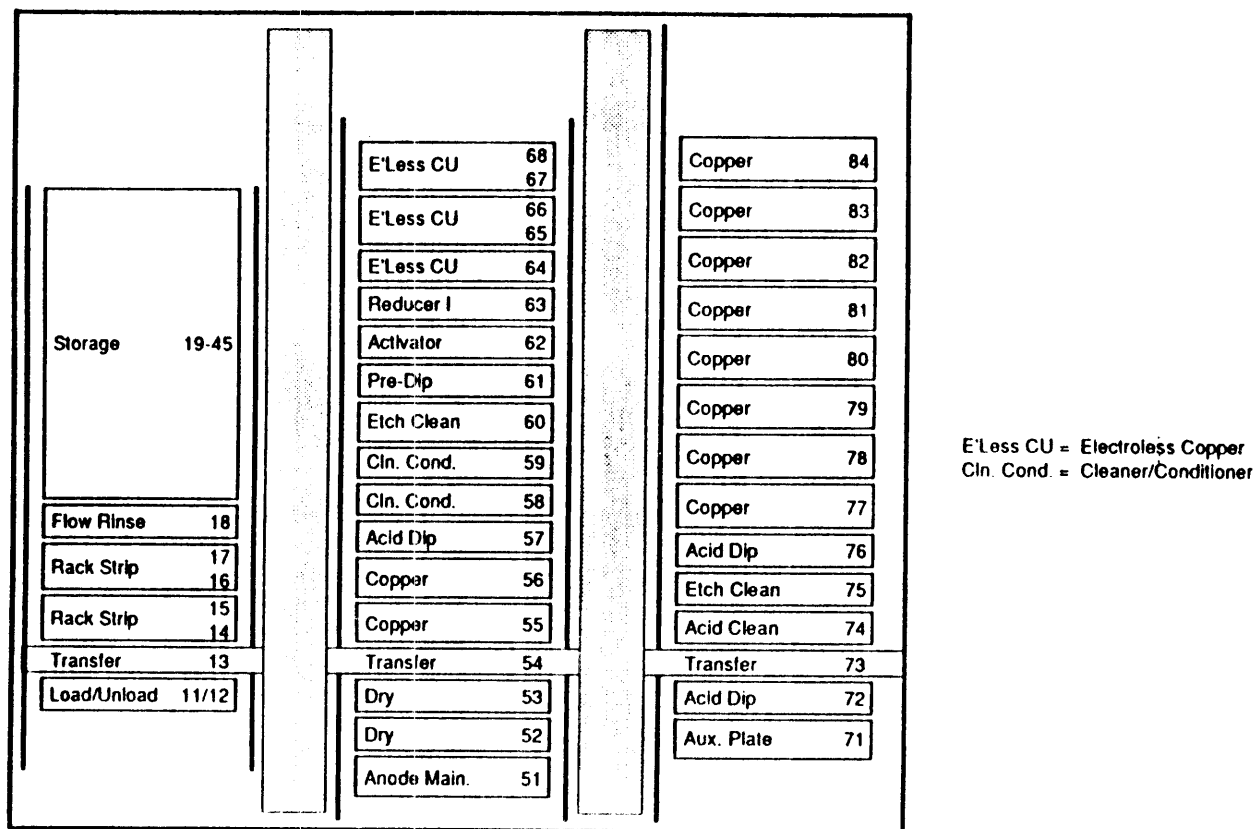


Figure 1. Tank configuration of printed circuit board system

Other capital costs, such as adding computerized hoists and on-demand rinse operations, must also be addressed if not present on the existing process. For GD, it was more cost-effective to completely replace the existing chromic acid process than to make all of the modifications.

The costs associated with testing in order to obtain military approval to modify design specifications were not addressed in the economic evaluation. This information was considered company sensitive also.

O&M costs are typically much lower for sulfuric acid anodizing than for chromic acid because it is less energy-intensive, it has a smaller plating interval, and wastewater treatment costs are less.

Because sulfuric acid is much more conductive as an electrolyte, the anodizing process usually requires less power than that required by the chromic acid process. Specific electrical energy requirements for aluminum anodizing are shown in Table 2. As shown in Table 2, a cost savings for electricity was estimated to be \$10,900. This was based on a conventional sulfuric acid usage rate of 130 Wh/m² and a chromic acid anodizing usage rate of 400 Wh/m². The amount of material anodized was based on the maximum design capacity of the new system (i.e., 625 ft²/h) and full-time operation (i.e., 4,992 hours per year). The cost for electricity (i.e., \$0.14/kWh) for a typical industrial consumer was obtained from Southern California Edison Utility Company.

TABLE 2. SPECIFIC ENERGY REQUIREMENTS FOR
ALUMINUM ANODIZING

Type of anodizing	Voltage (V)	Electrical energy, Wh/m ²
Sulfuric acid		
Conventional	12-22	70-130
Hard	25-80	150-480
Chromic acid	30-50	240-400

Wastewater treatment costs are less for sulfuric acid than for chromic acid because of a decrease in metals removal requirements. The chromic acid process requires the reduction of chrome, whereas the sulfuric acid process requires only copper removal. Chrome reduction usually requires additional tanks and chemicals for treatment and settling. The sludge from the chromic acid anodizing process is also considered hazardous and must be sent to hazardous waste landfill at a cost greater than that required for the disposal of the sludge produced by the sulfuric acid process. The annual cost savings resulting from decreased sludge disposal requirements was estimated to be \$1000, based on an annual usage of approximately 2000 pounds of chromic acid anhydride by General Dynamics. The resulting sludge produced from the use of this chemical, assuming a 25 percent solids composition, would be approximately 4 tons. GD is presently charged \$250 per ton for sludge disposal. The company has a contract with a smelter in Arizona which recycles their plant sludge for its intrinsic copper value. Because other hazardous metals from other plant processes are still contained in the resulting sludge which is sent to the copper smelter, no cost break for landfill disposal could be given for the sludge from the new sulfuric acid anodizing system.

plating operation is to be obtained for comparison with the new process. Air emissions above the baths were expected to be negligible and no air sampling was planned.

- 3) The use of copper spheres from the anode baskets for other electroplating operations is to be investigated. Savings in sampling costs due to the new system vs. the old system of sampling anode thickness to determine anode replacement is to be documented.

TABLE 1. OPERATION SEQUENCE FOR PRINTED CIRCUIT BOARD SYSTEM

Position	Step
11	Load
58	Cleaner/conditioner
59	Cleaner/conditioner
60	Etch cleaner
61	Predip
62	Activator
63	Reducer
65-66	Electroless copper
57	Acid dip
76	Acid dip
77-83	Acid copper plating
53	Dry
51	Hold
11	Unload

Results

Reductions in rinse-water discharges were verified during the plant visit by checking rinse-water flow rates via General Dynamics operating logs. Establishing a material balance around the printed circuit board process was not possible from information available from plant personnel, operating data, or system suppliers. This was due to the use of the proprietary process chemistry, developed overseas by Schering AG, West Germany, the parent company of the system supplier, Chemcut Corporation.

Under the previous plating operation, rinse-water wastes containing copper were sent to the on-site waste treatment plant for metals precipitation. The sludge was then sent off site for landfill disposal.

Although operating costs for the sulfuric acid systems were determined to be about \$15,000 lower than the old chromic acid process, payback on the capital cost of \$995,000 was calculated at 67 years.

The payback period for this process may be misleading since GDPD did not believe that they could meet the 99.8 percent removal efficiency with existing technology and were concerned about discharge of chromium in view of the 1986 California Safe Drinking Water Act. Given that compliance with both air and water regulations would not be possible with available control technology even at higher costs than that for the sulfuric acid system, the capital cost expenditure becomes less important.

Report

The full report, entitled "Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant", by Lisa M. Brown and Robert Ludwig, is available as EPA/600/S2-91-067.

TABLE 3. ECONOMIC EVOLUTION OF PRINTED CIRCUIT BOARD
PLATING OPERATION WITH ON-DEMAND RINSING^a

<u>Economic data</u>		
Annual operating costs of old process		
Anode replacement	\$65,000	
Chemical replacement	\$138,000	
Labor	\$499,000	
Water	\$12,000	
Total		\$714,000
Annual operating costs of new process		
Anode replacement	\$46,000	
Chemical replacement	\$125,000	
Labor	\$175,000	
Water	\$2,000	
Total		\$348,000
Waste treatment savings		\$130,000
Net annual operating savings		\$496,000
Capital investment		\$4,100,000
Payback period		8.3 years

^a Based on plant operation of 2 shifts per day, 8 hours per shift, 6 days per week.

Report

The full report, entitled, "Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant", by Lisa M. Brown and Robert Ludwig, is available as EPA/600/S2-91/067.

- 1) Determination of the amount of batch paint waste saved by the use of the proportional paint mixing by reviewing plant records on paint waste disposal in past years.
- 2) Verification of increased transfer efficiency of the electrostatic spray nozzles, which was estimated to have increased from 35 to 65 percent. This was to be done by reviewing plant records on paint use before and after installation of the electrostatic spray guns.
- 3) Determination of the amount of solvent reclaimed through the use of the solvent stills by reviewing plant records on solvent purchases and dirty solvent sent off site for recycling before and after installation of the solvent stills. Costs for disposal of the dried paint sludge were also to be determined based on plant records on volume of sludge incinerated.
- 4) Verification of the concentrations of VOC in the general area around the paint shop by taking air samples.
- 5) An economic analysis of the proportional paint mixing electrostatic spray and paint shop solvent still portions of the robotic paint system.

Results

The installation cost of the robotic painting system was \$1,400,000. This system included a parts conveyor, computer-controlled robotic spray arms, electrostatic spray guns, proportional paint mixing, and cleaning solvent collection equipment. The disposal of 42 tons of waste in 1987 would have cost about \$73,000 at a disposal rate of \$420/drum plus \$7,000 per truckload for transportation (80 drums). The disposal of 21 tons in 1989 would be about \$36,500, for a savings of \$36,500. The payback period from a waste-disposal standpoint alone would be almost over 40 years. This substantially overstates the payback period, however, because the savings in labor costs from painting and waste disposal and any decrease in reject parts are not included. The information is considered company sensitive and was not available.

The two solvent stills were installed at a cost of \$14,000. These units are currently being used to recycle 1,000 gallons per year of cleaning solvent (polyurethane thinner), resulting in \$1,500 in purchase savings and \$2,500 in disposal savings, for a total savings of \$4,000. The estimated payback period for this equipment, therefore, is 3.5 years. This estimate does not include increased labor costs to operate the equipment or decreased hazardous waste handling costs.

Air samples were collected in the general area around the paint shop to verify concentrations of VOCs. No previous data were available to compare the results.

Air samples were collected using charcoal tubes on a table near two paint spray booths, on the floor just outside the robotic paint booth, and on a lower shelf next to a small spray booth just inside a drive-through door leading to the outside. The sampling results are summarized in Table 1. Only 1,1,1-trichloroethane (TCA) was detected at all three sampling locations. Concentration levels ranged from 0.2 to 1.6 mg/m³, or 1.7 to 12 mg/m³ for an 8-hour time-weighted average (TWA). The OSHA TWA limits for 1,1,1-trichloroethane are 1,900 mg/m³, well above the levels detected in the paint shop. Trichlorotrifluoroethane was detected on the two charcoal tubes nearest the floor. Measured levels were 2 and 6 mg/m³, or 17 and 48 mg/m³ for the 8-hour TWA. This can be compared with the OSHA TWA limit of 7,600 mg/m³ for trichlorotrifluoroethane. It is interesting to note however, that TCA and trichlorotrifluoroethane are not used in the painting shops. Thus samples measured fugitive emissions from other work areas.

Results

The capital cost of the new sulfuric acid anodizing system installed by NAPCO, Inc., for GD in December 1988 was \$955,000. This cost included the computerized hoist and on-demand anodizing rinse systems. Actual operating and maintenance (O&M) cost data were considered company sensitive information and were not available. However, by understanding the differences between the sulfuric and chromic acid anodizing processes, O&M costs were derived by using information obtained from outside equipment vendors. Using this information an economic analysis of the sulfuric acid aluminum anodizing process was performed. The results of the economic evaluation are presented in Table 1. The payback period for the sulfuric acid anodizing system was estimated to be 67 years.

Conversion to sulfuric acid anodizing from chromic acid is not just a simple chemical substitution according to system suppliers. The conversion requires a complete change over of anodizing equipment and partial modifications to downstream waste-treatment facilities. Capital costs would be realized for such major production equipment items as the anodizing tank, rectifier, and cooling equipment.

TABLE 1. ECONOMIC EVALUATION OF SULFURIC ACID ANODIZING PROCESS

Item	\$
Annual operating costs of chromic acid process	
Electric (116,000 kWh/yr)	16,200
Water (6,000,000 gal/yr)	3,900
Total	20,100
Annual operating costs of sulfuric acid process	
Electric (38,000 kWh/yr)	5,300
Water (2,400,000 gal/yr)	1,600
Total	6,900
Operating Cost Savings	13,200
Waste reduction savings	1,000
Capital investment	955,000
Payback period	67 years

Replacement of the anodizing tank is required due to the differences in acidity between sulfuric acid and chromic acid. Because sulfuric acid is much more corrosive than chromic acid, the materials of construction of the anodizing tank must be upgraded. Because the chromic and sulfuric acid anodizing processes have different voltage and amperage requirements, the rectifier must also be replaced. The operating temperature of the electrolytic bath is also different for the two processes. The chromic process is usually maintained by steam heat at an operating temperature of 90° to 100°F, whereas the sulfuric acid process must be chilled using cooling water to an operating temperature range of 45° to 70°F.

TABLE 2 SURROGATE RECOVERIES FOR CHARCOAL TUBE BLANKS
Surrogate recovery, %

Blank No.	Surrogate recovery, %		
	1,2-Dichloroethane	Toluene	p-Bromo-flourobenzene
Laboratory blank	91	92	92
GDP-C1	79	82	83
GDP-C2	92	93	95
GDP-C3	88	94	96
GDP-CB2	88	92	94

Payback for the solvent stills is about 4 years. An even shorter payback will be realized when all the cleaning solvent can be recycled.

While some of the painting technology discussed here could be too large an investment, many smaller companies could incorporate parts of the system, such as the electrostatic sprayer and solvent stills into their operations.

Report

The full report, entitled "Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant", by Lisa M. Brown and Robert Ludwig, is available as EPA/600/S2-91/067.

Additional cost savings can be realized with the addition of computerized hoists and on-demand rinse systems. Both of these systems help to reduce water consumption. According to GD, rinse-water consumption was reduced from 20 to 8 gpm. The cost savings in reduced water consumption was estimated to be \$2300, assuming full-time operation (i.e., 4992 hours per year) and the Pomona City Water Works rate of \$0.65 per 1000 gallons. GD also expects that the computerized hoist system will lower costs associated with rejects and rework.

Effluent from the detoxification/desmut rinse-tank was chosen for sampling, since it has the greatest potential of all of the rinse tanks to contain metals. The sample taken represents a composite of the rinses performed in the deoxidation/desmut tank. The rinse water from this and other rinse tanks in the anodizing process undergoes pH adjustments and is sent to the wastewater treatment plant to remove any metals remaining in the rinse water.

The results of the deoxidation/desmut rinse tank sampling are shown in Table 3.

TABLE 3. RESULTS OF METAL SAMPLES TAKEN FROM THE
DEOXIDATION/DESMUT TANK OF THE H₂SO₄ ANODIZING PROCESS
(mg/liter)

Metal	Deoxidation/desmut	
	Rinse tank	Method detection limit
Aluminum	14.0	<0.024
Cadmium	<0.003	<0.003
Chromium	0.034	<0.004
Copper	<0.020	<0.020
Lead	0.058	<0.052
Nickel	0.045	<0.031
Silver	0.008	<0.006
Zinc	<0.006	<0.006

The only metal of any consequence in the deoxidation/desmut tank rinse water was aluminum at 14 mg/liter. Subsequent analysis of the wastewater treatment plant effluent shows reduction to 0.35 mg/liter.

Material balance calculations were not possible from the data provided by GDPD and system suppliers. The automated system has resulted in reduced rinse water, downstream waste treatment requirements, and improved product quality through reduced part rejections. Computerization of the system can be extended to the chemical and process parameters, thus further reducing labor costs, chemical usage, waste products, and further improving product quality. An analysis of the cost of computerization vs. waste reductions and cost savings would provide more insights on its transferability to other processes.

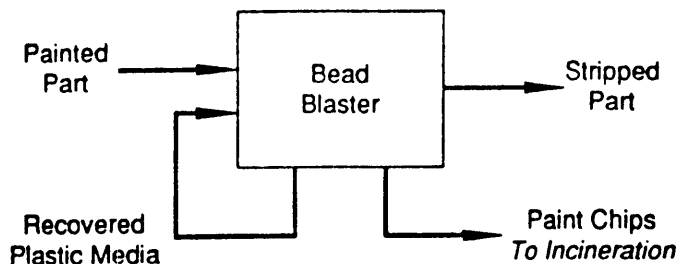


Figure 1. Schematic of production paint shop bead blast paint stripper

Results

A material balance around the bead-blasting unit was not possible from plant operating records and information made available by plant personnel. It was found that operating records were not kept with respect to when the unit was used, how many pieces were stripped or the length of time required to perform the work. The unit is used on an as needed basis and reportedly only a few hours per week.

Air sampling was not conducted because fugitive dust emissions around the unit were reported to be negligible. This assumption was considered reasonable in that the parts subjected to bead blasting are enclosed in a glove box apparatus during the paint stripping operation. In addition, the area around the bead-blast unit seemed free of debris and paint chips. Some fugitive emissions can occur, however. Failure to have the access door tightly closed during paint stripping, or during loading or unloading activity or during the cleaning of the stripping chamber and cleanout drawer all have potential of allowing some dust to escape.

The bead-blast paint stripper was installed at a cost of \$18,000. This system eliminated the disposal of about 10,000 lb/yr of spent methylene chloride and paint sludge. Although the waste from the bead-blasting unit has not been quantified, plant personnel report that there is noticeably less waste when stripping with the bead-blast unit. A recent study* indicated that waste generated from plastic bead blasting was about one-half the volume as that generated by methylene chloride stripping. Both the methylene chloride and bead-blast waste are disposed by incineration resulting in waste disposal costs of \$10,000 for methylene chloride and \$5,000 for bead-based waste.

Based on the cost savings of \$5,000 and the installed capital cost of \$18,000 of the bead-blast unit, the payback period for the cost of waste disposal alone, would be about 3.6 years. Cost calculations did not include differences in labor hours and system maintenance requirements between the two systems. Significant cost savings could be realized if the paint being removed by bead blasting did not produce hazardous waste.

* Balasco A. A., et al. Demonstration Testing of Plastic Media Blasting (PMB) at Letterkenny Army depot. Prepared by Arthur D. Little, Inc., for U.S. Army Toxic and Hazardous Materials Agency under Contract No. DAAK11-85-0008. Aberdeen Proving Ground, MD. January 1989.

#05 EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION: ROBOTIC PAINTING

Participants

The state of California Department of Toxic Substances Control, Sacramento, CA assisted in implementing the evaluations. The host for the evaluations was the General Dynamics, Pomona Division (GDPD) Plant. GDPD personnel operated the painting equipment during the test. PEI Inc., on contract to EPA helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

The GDPD paint production operations facility was completed in December 1988, to replace manual mixing and hand spraying of metal parts in naval weapon systems. It includes computer-controlled robots (a GRI OM 5000 unit), which allows quick, automated precision painting, a proportional paint mixer which feeds preselected quantities of individual paint components directly to the paint spray nozzle, to avoid batch makeup operations, electrostatic spray guns and automatic paint line, waste cleaning solvent collection systems to allow for recycle and reuse of waste paint. Spray paint booths are also available for touchups. Stills are used for recycling paint cleaning solvents. Figure 1 is a schematic of the robotic paint facility.

The painting facility uses both water-based primer and oil paints. For oil-based paints, polyurethane thinner is used for paint thinning and equipment cleaning. A thinner containing isopropyl alcohol and xylene is used with water-based primer.

The objectives of the paint facility evaluation included the following:

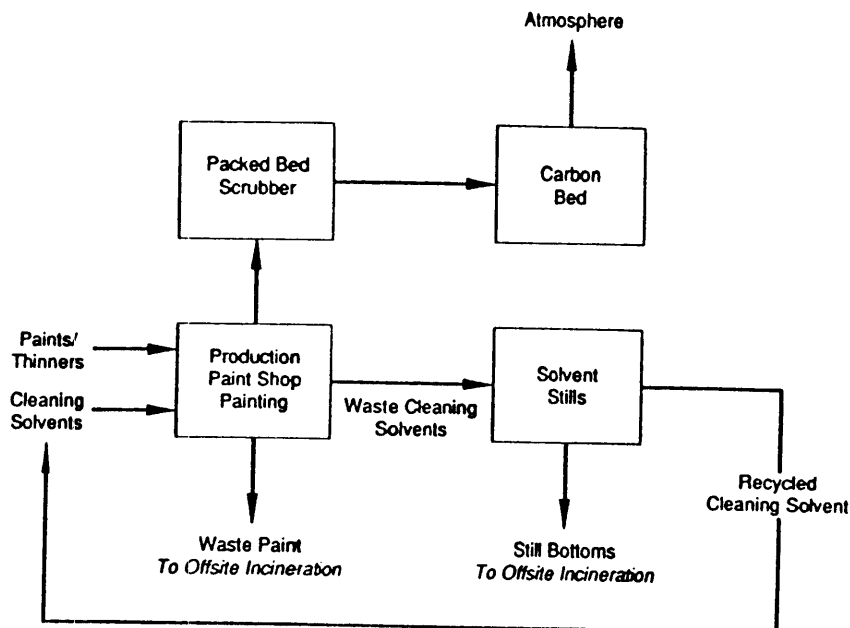


Figure 1. Schematic of production paint shop painting/recycling operations

#07 EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION: FREON RECOVERY FROM DEGREASING

Participants

The state of California Department of Toxic Substances Control, Sacramento, California assisted in implementing the evaluations. The host for the evaluation was the General Dynamics, Pomona Division (GDPD) Plant. PEI Inc., on contract to EPA helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

Three Freon recovery stills, manufactured by Recyclene, were installed in December 1988 to collect and distill waste from solvent degreasing operations throughout the GDPD facility at a cost of \$240,000 plus \$40,000 for add-on equipment to address operating problems. Recovered solvent from these stills is tested and reformulated under a quality assurance program to ensure that it meets manufacturer's original product specifications before being returned to material stores for reissue for production operations. The still bottoms are sent out for incineration.

Prior to the installation of these stills, a single, on-line Freon recovery still was installed in November 1985 to extend the life of Freon used in conveyorized cleaners. This extended the solvent changeout period to once per year and saved 35,000 lb annually in Freon purchases. This still is not included in the analysis.

Other changes in operational procedures to reduce degreaser solvent changeouts have resulted in a substantial reduction in Freon purchases. These operating changes were instituted beginning in April 1987 after GDPD completed a survey of all degreaser operations. The program objectives were to standardize all solvent cleaning operations through employee education, improved operating procedures and a solvent quality assurance program using vendor recommendations and operator input. The degreaser survey revealed that the solvent was changed every 1 to 7 days based solely on a visual analysis by the user. A quality assurance laboratory analysis program was implemented which extended the time between changeouts to 7 days, then 14 days, and finally 30 days. At the same time, the number of solvent types used was reduced from five to one over a 6-month period ending in February 1988. Manufacturing Process Specifications were changed to restrict changeout authorization to the Process Quality Assurance Laboratory to assure that proper justification for changeouts was provided. To further reduce the changeout frequency, a moisture removing desiccant was added to each degreaser which resulted in an extended use period of 30 days. A standardized operating procedure was developed to reduce evaporative losses based on manufacturer recommendations and was included in all operating instructions as well as posted on signs at each unit. Operator training was completed by all user departments, equipment operation checked, and preventive maintenance procedures updated. Standardized equipment specifications were also developed to further reduce evaporative emissions on new degreasers and ensure compliance with California South Coast Air Quality Management District regulations.

The 1988 level of 421,000 lb. of Freon purchases provides the baseline for the technical and economic evaluations that follow.

The objectives of the Freon recovery stills evaluation were to:

TABLE 1. SUMMARY OF AIR SAMPLING PERFORMED IN THE
GENERAL DYNAMICS PAINT SHOP

	Charcoal Tube 1	Charcoal Tube 2	Charcoal Tube 3
Location	On table near two paint booths and exterior door	On lower table near small booth	On floor near robotic paint booth
Distance from floor, ft	3.5	1	0
Quantity in sampled air, 1,1,1-Trichloroethane	6	10	26
Trichlorotrifluoroethane	0	100	100
Concentration, mg/m ³			
1,1,1-Trichloroethane	0.3111	0.2145	1.5647
Trichlorotrifluoroethane	0.0000	2.1447	6.0180
8-hour TWA, mg/m ³			
1,1,1-Trichloroethane	2.488	1.716	12.518
Trichlorotrifluoroethane	0.000	17.158	48.144
TWA limits, mg/m ³			
1,1,1-Trichloroethane	1900		
Trichlorotrifluoroethane	7600		

For the air samples, surrogate recoveries from compounds spiked on charcoal tubes from the field and a laboratory blank were all within the target range of 60 - 145 percent as shown in Table 2.

The paint facility with proportional paint mixing, robotic controlled, electrostatic spray guns and cleaning solvent collection equipment appears to be operating well. The main problem area at the time of testing was the waste solvent collection process. The issue to be worked out is one of separating water from solvent in the case of the water based primer cleaning solvent recycling. This problem had led to a reluctance to utilize the solvent recycled from the water based primer cleaning because of its poor quality. Only polyurethane thinner solvent from cleaning paint equipment is currently recycled.

Paint waste was reduced from about 42 tons in 1987 to 31 tons in 1988, and further, to 17 tons in 1989. About 1000 gallons of polyurethane cleaning solvent per year was being recycled through the paint shop solvent stills, during the time of the test, resulting in approximately 60 to 100 pounds of still bottoms per week, or about 5,000 pounds per year. The still bottoms and waste paint are sent off site for incineration.

Detailed costs were not available to develop a comprehensive economic evaluation of the waste minimization methods applied to the production paint shop. The payback period of almost 40 years, calculated on the overall investment of \$1.4 million is substantially overstated because labor costs savings from paint and waste disposal and decreases in reject paints or batches of leftover pre-mixed paints were not available. The very significant decrease of worker exposure to paint and solvents is also not included in the calculation.

This is a minimum payback number that is based on recycling all of the Freon that is not lost through evaporation and dragout. If less Freon is recycled, the payback period would increase but increase to a maximum of 1 year. Notwithstanding the technical problems that have been encountered in recycling the Freon, this appears to be an economical waste minimization technique.

Report

The full report, entitled "Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant," by Lisa M. Brown and Robert Ludwig, is available as EPA/600/S2-91/067.

#06 EVALUATION OF FIVE WASTE MINIMIZATION TECHNOLOGIES AT THE GENERAL DYNAMICS POMONA DIVISION: BEAD BLAST PAINT STRIPPING

Participants

The state of California Department of Toxic Substances Control, Sacramento, California assisted in implementing the evaluations. The host for the evaluation was the General Dynamics, Pomona Division (GDPD) Plant. GDPD personnel operated the bead blast equipment during the test. PEI Incorporated, on contract to EPA, helped to design the test program, supplied test personnel and equipment, and drafted the final report.

Technology/Testing

The plastic bead-blast paint stripper at GDPD was installed in June 1988 to replace methylene chloride stripping. Reusable plastic beads are used in this mechanical stripping operation, which is similar to sand blasting. Paint is stripped from the hangers used to hold parts being painted in the paint shop and from parts having paint defects.

The plastic bead-blasting booth is a Pauli and Griffin Pram Machine approximately 3 ft. by 3 ft. by 3 ft., glove box and uses size 20- to 30-mesh Poly Plus beads. The unit is used only on an as-needed basis, generally a few hours per week.

Waste generated during the operation of the plastic bead blasting unit consists primarily of paint chips and a small amount of spent plastic beads which are sent off site for incineration. Stripping by methylene chloride resulted in about 10,000 pounds per year of toxic solvent contaminated with paint sludge, which also was sent off site for incineration. Figure 1 is a schematic of the bead-blast paint stripper.

The objectives of the plastic bead blasting evaluation included the following:

- 1) Establishment of a material balance around the bead blasting operation, if possible, using plant-supplied data on input and output of plastic beads and paint. The paint chips are mixed in with the other wastes at the plant before incineration, and preliminary indications from General Dynamics were that the amount of paint chips sent out for incineration would be difficult to ascertain. If so, it was decided that an estimate of paint chips discarded annually would be made after interviewing plant personnel.
- 2) Fugitive dust emissions around the bead blasting operation were reported to be negligible during operation, as the system is completely closed. Thus, no air sampling was planned.
- 3) An economic analysis of the bead blaster was planned. Annual operating costs, which are primarily the cost of incinerating the paint chips vs. the cost of disposing of methylene chloride, were to be calculated.

Pollution Prevention Potential--

Pollution prevention was measured in terms of waste volume reduction (Table 1) and pollutant reduction (Table 2). The total waste volume generated by the automated washer is much lower than either the alkaline tumbler or hand-aqueous washer.

The processing energy requirement of the automated washer is higher than the energy requirement of any of the three older processes. The moderately higher processing energy requirement of the automated washer should, however, be weighted against the potentially higher energy requirements of the older processes in such other areas as waste treatment. Secondary pollution resulting from energy generation was not a part of this evaluation.

Although the waste volume generated by the vapor degreaser is lower than that of the automated washer, it is considered more hazardous.

Perchloroethylene is a high risk pollutant and a health problem, with inhalation and skin the main entry routes.

TABLE 1. COMPARISON OF ANNUAL WASTE VOLUME FROM THE THREE CLEANING PROCESSES

Wastestream	Volume Generated Per Year (gal)	Wastestream	Volume Generated Per Year (gal)
<u>Vapor Degreasing^a</u>		<u>Automated Washing^a</u>	
Wastewater in separator	200	Wastewater	143,000
Still bottom sludge	1,440	Oily Liquid	962
Air emissions	see Table 2		
<u>Alkaline Tumbling^b</u>		<u>Automated Washing^b</u>	
Wastewater	1,010,880	Wastewater	85,800
		Oily Liquid	577
<u>Hand-Aqueous Washing^c</u>		<u>Automated Washing^c</u>	
Wastewater	296,400	Wastewater	57,200
		Oily Liquid	385

^a Based on 5,200 bbl/yr run on automated washer instead of vapor degreaser.

^b Based on 3,120 bbl/yr run on automated washer instead of alkaline tumbler.

^c Based on 2,080 bbl/yr run on automated washer instead of hand-aqueous washer.

Spent perchloroethylene is listed under Resource Conservation and Recovery Act (RCRA) as a hazardous waste (EPA hazardous waste number F001). Other commonly used degreasing solvents are methylene chloride, 1, 1, 1-trichloroethane and trichloroethylene, all of which are considered highly hazardous and on EPA priority lists for waste reduction. The use of the automated washer overall reduces the use of these solvents.

The automated washer generates a wastewater containing surfactants, which are a lower hazard both in terms of occupational safety and the environment. Surfactants are not RCRA hazardous wastes. They can, however, cause environmental problems.

Variables due to shape and size of parts being stripped, type of paint, hazard characteristics of paint ingredients, operator skills needed, worker safety, are all factors that can have a significant impact on economics. Because of the unavailability of operating data and the infrequent use of the bead blasting unit, a comprehensive economic evaluation could not be developed. Overall, the technology is relatively inexpensive and is easily transferred to other industries and small companies.

From a pollution prevention standpoint, elimination of the generation and disposal of a toxic and volatile solvent waste and associated air releases and worker exposure appears to have a significant net benefit. While the reduced volume of waste from the bead blasting operation is incinerated as a hazardous waste for this application, other applications for which the paint being removed is not considered hazardous would benefit by totally eliminating the generation of hazardous waste.

Reports

The full report, entitled "Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant", by Lisa M. Brown and Robert Ludwig, is available as EPA/600/S2-91/067.

TABLE 4. OPERATING COSTS OF ALKALINE TUMBLING VS. AUTOMATED WASHING

Cost Element	Alkaline Tumbling Cost ^a (\$/Yr)	Automated Washing Cost ^a (\$/Yr)
Labor	18,720	10,380
Energy	2,847	6,427
Chemicals	2434	1,626
Water	4,700	399
Onsite Waste Treatment	7,299	619
Offsite Waste Disposal	0	1,574
Total	36,000	21,025

^a Based on 3,120 bbl/yr

Reducing the amount of solvent used can also reduce possible liability resulting from health claims or pollution fines, but these savings were not quantified by this study and were not in the economic calculations.

Automated washing reduces the volume of wastewater that has to be treated (either onsite or at the publicly owned treatment works) and discharged downstream. This is done without compromising the cleaned product quality, and no additional skill is required. Parts cleaned in the automated washer can be either electroplated or sent out as finished products.

One current limitation is that the automated washer cannot yet totally substitute for the three older processes. Certain delicate parts have to be cleaned by more gentle means. Some difficult-to-clean parts have to be processed through the hand-aqueous washer. Most jobs that can be run on the older processes can, however, be routed through the automated washer. Thus, the automated washer is a good technology for metal finishers who are considering an expansion in capacity.

TABLE 5. OPERATING COSTS OF HAND-AQUEOUS WASHING VS. AUTOMATIC WASHING

Cost Element	Hand-Aqueous Washing Cost ^a (\$/Yr)	Automated (\$/Yr)
Labor	16,640	6,920
Energy	3,256	4,285
Chemicals	33,134	1,084
Water	1,213	266
Onsite Waste Treatment	2,140	413
Offsite Waste Disposal	0	1,050
Total	56,383	14,018

^a Based on 2,080 bbl/yr

- 1) Determine the amount of Freon solvent reclaimed by reviewing plant records on Freon purchases and solvent sent off site before and after installation of the Freon stills. The volume of still bottoms sent out for incineration and associated costs were also to be determined, based on plant operating records.
- 2) Perform economic analysis of the Freon still recovery system capital, annual operating costs/credits, and payback.

Results

Testing of the Freon recovery stills indicated that the distillation process was working but that the Freon being recycled was contaminated with alcohol and water, which degraded the quality of the recovered product. GDPD installed separators and molecular sieves to dry and remove water and alcohol from the Freon after its distillation and recovery. These additions to each still cost \$13,000 plus installation but allowed the Freon recovery to proceed as planned and produce a quality recycled solvent.

As a result of the control measures implemented, GDPD experienced a 35 percent reduction in 1988 cleaning solvent purchases going from 650,000 pounds to 421,000 pounds.

Reduction in Freon purchases through 1988 have primarily come through improved operation procedures such as extended changeout times for Freon, and reduction in evaporative losses. A baseline of 421,000 lb of Freon for 1988 is used to calculate reductions in Freon usage attributable to the use of the three Freon stills, which are assumed to be utilized at full capacity for the first time in 1989. The following calculations were performed to calculate simple payback for the installation of the three Freon stills:

TABLE 1. ESTIMATED PAYBACK FOR FREON STILLs

Item	Lbs.	\$
Capital cost:		\$270,000
Annual operating costs:		
Estimated 1989 Freon production adjustment @ 15%:	357,850 lb	
Evaporative and dragout Freon losses @ 37.5%:	134,194 lb	
Amount of Freon processed for recycling:	223,656 lb	
Still bottoms from Freon recycling @ 5%	11,183 lb	
Avoided purchases (amount recycled) of Freon:	212,473 lb	
Cost savings from avoided Freon purchases @\$1.64/lb		\$348,456
Cost of still bottoms incineration @\$500/drum & 715 lb/drum:		\$7820
Cost savings from avoided Freon disposal:		\$148,583
Total cost savings:		\$489,219
Payback: $\$270,000/\$489,100 = 0.55$ years		

The ink in the distillation still is sent through 100- and 325-mesh filters to remove paper dust and transferred to a blending tank. At this point, a grind test and a drawdown test are performed, and the amount of virgin black ink, required for blending, is determined (typically three to four times the amount of the processed ink). The virgin ink is added to improve the color, consistency, and other functional properties of the processed ink to an acceptable range. The processed ink, blended ink, is called the final "recycled" ink.

Approximately 175 gal. of waste ink is generated each week. Previously it was sent to a vendor location where it was blended with other solvents to create a supplemental fuel. Since October of 1990, waste ink has been recycled on-site and reused for printing.

For the test, two batches of waste ink were processed through the recycling unit and samples of the waste and the recycled ink were collected for analysis. Samples of the virgin ink used at *The Courier* were also collected and analyzed. A comparison of the analytical results of the waste and recycled inks indicates the improvement achieved by the recycling process, and a comparison of the recycled and virgin inks indicates how closely the recycled product approximates the virgin product.

Results

The results of the product quality analyses are shown in Table 1. The recycled ink fared well in most of the analyses. The viscosity, as measured by ASTM D 4040-89, of the recycled ink was within ± 1 Poise and in the normal range for newspaper inks. The grind (ASTM D 1316-87) and residue (U.S. Printing Ink Method #12) analyses indicated that some very fine particulates were retained in the recycled ink, although this did not cause any problems in the printing process at *The Courier*. Tack (ASTM D 131-89) was measured at speeds specific to *The Courier* (1200 rpm at 1 min for web-fed inks). One sample was slightly above industry recommendation and the other was within this standard. Press operators at *The Courier* did not think that the sample that was slightly out of range was of significant concern.

Relative tinting strength was measured by a method similar to ASTM D 387, D 2745, and D 4838. One sample was slightly out of range. Since the recycled ink is blended with virgin ink, the ratio of virgin-to-processed ink could be increased to improve the tinting quality of the ink. Water content (ASTM D 1744-83) analyses showed that most of the water is removed in the recycling process. No industry standards are indicated for this because it depends on the individual printing process. Operators at *The Courier* observed no problems resulting from water. Water pickup (ASTM D 4942-89) analyses determines the emulsifying capability of the ink. This parameter also varies with the printing process, and the recycled ink results posed no problems.

The visual effect and behavior of the recycled ink, once it is printed on a newspaper was evaluated by (a) densitometer readings of black image areas of newspapers printed with virgin and recycled inks and (b) analysis by 11 experienced viewers of newspaper pages printed with recycled or virgin inks. The densitometer measurements show that the recycled ink was much denser than the virgin ink on the wrapper, or exterior pages, of the newspaper. The virgin ink was only slightly denser than the recycled ink on the core, or interior pages. The results of the visual judging (Table 2) showed that the newspapers printed with recycled ink were of comparable quality to those printed with virgin ink.

CONNECTICUT

The five (5) technologies evaluated for Connecticut included four dealing with metal cleaning and plating industries and one (1) with the recycling of newspaper ink. Rita Lomasney of the Connecticut Technical Assistance Program was in charge of coordinating the WRITE program for the state. Summer Kaufman of ESSAR Environmental Services was the Connecticut Hazardous Waste Management Service consultant and project officer. Lisa M. Brown was the project officer for EPA.

#08 AN AUTOMATED AQUEOUS ROTARY WASHER FOR THE METAL FINISHING INDUSTRY

Participants

The Connecticut Hazardous Waste Management Service assisted in implementing the evaluations. The host for the evaluation was the Quality Rolling and Deburring (QRD) Company of Thomaston, CT. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

One of the major steps in metal finishing is cleaning metal parts to remove oil and grease, dirt, and metal chips. Cleaning may involve washing with a detergent or degreasing with a solvent. Before installing the automated aqueous washer, QRD routed metal cleaning jobs through one of three cleaning processes: vapor degreasing, alkaline tumbling, or hand-aqueous washing.

The product quality evaluation was based on (a) an examination of the cleaned metal parts from some of QRD's normally scheduled cleaning jobs, (b) an examination of cleaned test panels from the alkaline tumbler and automated washer.

Three cleaning jobs (each containing several thousand small metal parts) were selected from the several that QRD receives every day. Job-A consisted of steel caplets that were suitable for cleaning on the vapor degreaser. Job-B consisted of aluminum rivets that were suitable for cleaning on the hand-aqueous washer. Job-C consisted of steel cylinders that were suitable for cleaning on the alkaline tumbler. Job-C involved cleaning as well as electroplating (nickel plating).

Each job was split into halves. Half was cleaned by the automated washer, and the other half by one of the older processes to provide a one-to-one comparison between the automated washer and each of the three older processes.

After each cleaning run, a predetermined number (150) of randomly selected, cleaned parts were examined for product quality.

Results

Performance--

Visual examination revealed no notable contamination on any of the parts for all three jobs nor on the cleaned test panels. The waterbreak test indicated that the parts designed for electroplating had been adequately cleaned.

The Courant generates approximately 175 gal/wk, or 9,100 gal/r of waste ink. This waste ink consists of 5,460 gal of ink, 546 gal of solvent and 3.049 gal of water. Recycling reduces 6,006 gal of ink and solvent waste. *The Courant* is also considering installing an activated carbon filter for polishing off organics in the wastewater from the separator so that the water can also be reused.

The waste ink at *The Courant* has been tested and is not considered a hazardous waste per Resource Conservation and Recovery Act (RCRA) regulations and can be disposed of according to state regulations for oily wastes. Solvent washes for other inks that contain lead or chromium in their formulation are, however, listed as hazardous wastes (EPA Waste Number K086) under RCRA. In addition, other waste inks could contain constituents that render them flammable or toxic.

The economic evaluation took into account the capital and operating costs of the recycling equipment, as well as the savings resulting from reduced amounts of raw materials (virgin ink and solvent) and disposal costs. A return on investment of about 9% is obtained in the tenth year of recycling. With a payback period of about 10 years for the \$318,000 capital requirement, the recycling equipment tested here is a large investment, even for a medium-to large-size newspaper such as *The Courant*.

The waste ink recycling evaluation demonstrated that the potential for waste reduction with ink recycling is promising. *The Hartford Courant* reduced waste volume from over 9,000 gal of waste ink to approximately 46 gal of paper dust and 3,049 gal of wastewater per year. The recycled product fared well in both product quality testing of the recycled ink and quality of the actual printed material. The slight deviation of some recycled ink test results from the industry standard did not cause any noticeable reduction in print quality. The blanket wash solvent in the waste was also recovered and reused.

Report

The full report, entitled "On-site Waste Ink Recycling" by Arun Gavaskar, et al., is available as EPA/600/R-92/251.

Different surfactants vary widely in terms of aquatic toxicity and ease of biodegradation. Surfactants accumulate within aquatic organisms and impair their functions. When compared with alkaline tumbling or hand-aqueous washing, the automated washer generates lower amounts of these surfactant wastes.

The results of the study indicate that measurable pollution prevention accrues from using the automated washer instead of any of the three older cleaning processes.

Tables 3, 4, and 5 compare the operating costs of the older cleaning processes and those of the automated washer. The results of the economic calculations showed that, based on a capital requirement of \$207,260, the payback period for QRD (where the ROI exceeds 15%) was about 7 yrs.

TABLE 2. POLLUTANTS GENERATED BY THE THREE CLEANING PROCESSES

Pollutant	Medium	Amount Generated Per Year (b)	Pollutant	Medium	Amount Generated Per Year (b)
<u>Vapor Degreasing^a</u>			<u>Automated Washing^a</u>		
Perchloroethylene	Sludge	45	Anionic surfactant	Water	2
Perchloroethylene	Water	negligible	Non-ionic surfactant	Water	22
Perchloroethylene	Air	6,145			
<u>Alkaline Tumbling^b</u>			<u>Automated Washing^b</u>		
Anionic surfactant	Water	43	Anionic surfactant	Water	1
			Non-ionic surfactant	Water	13
<u>Hand-Aqueous Washing^c</u>			<u>Automated Washing^c</u>		
Non-ionic surfactant	Water	105	Anionic surfactant	Water	1
			Non-ionic surfactant	Water	9

^a Based on 5,200 bbl/yr run on automated washer instead of vapor degreaser.

^b Based on 3,120 bbl/yr run on automated washer instead of alkaline tumbler.

^c Based on 2,080 bbl/yr run on automated washer instead of hand-aqueous washer.

TABLE 3. OPERATING COSTS OF VAPOR DEGREASING VS. AUTOMATED WASHING

Cost Element	Vapor Degreasing Cost ^a (\$/YR)	Automated Washing Cost ^a (\$/Yr)
Labor (base rate)	13,866	17,300
Energy	2,943	10,712
Chemicals	1,795	2,711
Water	0	655
Onsite Waste Treatment	Negligible	1,032
Offsite Waste Disposal	1,440	2,614
Total	20,044	35,044

^a Based on 2,080 bbl/yr

Figure 2 shows the chromium system configuration. The primary ion exchange resin is anionic to remove hexavalent chrome. In the future, a cationic resin component will be added to the primary resin to remove any trivalent chrome that may be present in the rinsewater. The anionic resin is also regenerated with a 15 to 20% NaOH solution. The resulting solution (sodium chromate) is run through a secondary (cationic) exchange unit that is designed to convert the regenerant back to chromic acid and return it to the plating tank.

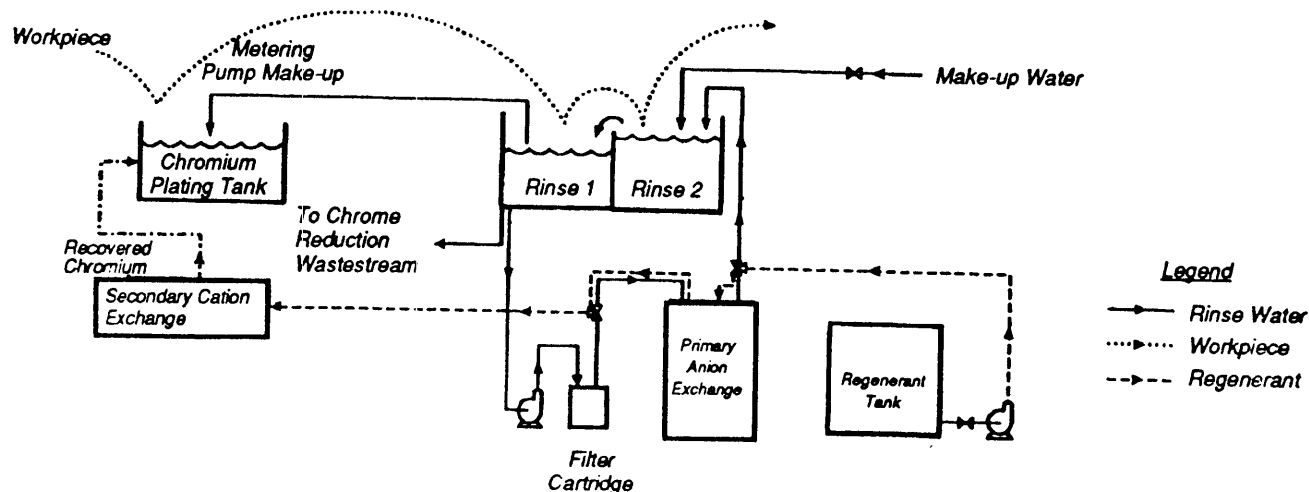


Figure 2. Ion exchange recovery of chromium from plating risnewater

The test included collecting three samples each of the rinsewater, before and after passing through the ion exchange system. These samples were analyzed in the laboratory to evaluate the removal of contaminants.

Results

The results of the laboratory analysis of the cadmium rinsewater samples showed that most of the cadmium and cyanide were removed by ion exchange - in some cases, to below detection levels. The Ph of the rinsewater remained steady at alkaline levels throughout the testing.

A statistical t-test (95% significance level) was performed based on the averages and standard deviations of the 1-min "before" and "after" (CD-X1) data. Suspended solids levels were very low in both "before" and "after" samples. After ion exchange, concentrations of cadmium, cyanide, and iron in the rinsewater decreased significantly. Overall dissolved solids levels also showed a significant decrease after ion exchange. This indicated a decline in dissolved mass levels.

Interestingly, conductivity did not show any significant change after ion exchange indicating that the current-carrying capacity of the rinsewater did not change. During ion exchange, heavier ions (cadmium, iron, etc.) transfer to the resin and lighter sodium ions are transferred to the water. Thus, dissolved mass in the water decreases but conductivity remains relatively constant. Small amounts of fresh makeup water were added to the rinsewater loop from time to time to compensate for the water lost to evaporate and dragout with the parts; this also helped maintain conductivity.

Report

The full report, entitled, "An Automated Aqueous Rotary Washer for the Metal Finishing Industry", by Arun Gavaskar, et al., is available as EPA/600/R-92/188.

#09 ON-SITE NEWSPAPER INK RECYCLING

Participants

The Connecticut Hazardous Waste Management Service assisted in implementing the evaluations. The host for the evaluation was the *Hartford Courant*. *Courant* personnel operated their equipment during the test period. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

The recycling process is shown in Figure 1. The major components of the recycling unit were purchased from Separations Technologies Inc. Other equipment was added as required. Trays containing waste ink (consisting of 75% black and 25% colored ink) from the press room are emptied on a 1/4-in. wire mesh to remove nuts, bolts, and other gross contaminants. The waste ink was then placed in a large waste ink storage tank. Once enough ink was collected, the batch was processed. Processing involved vacuum distillation, filtration, and blending.

Waste ink from the storage tank was transferred to the still and distilled at 140°C under vacuum. Solvent and water from the waste ink are vaporized, condensed (by a chiller), and collected in a separator tank where where the condensate forms water and solvent phases under gravity. The water is drained off and discharged to the municipal sewer under permit, and the solvent is reused in cleaning the presses.

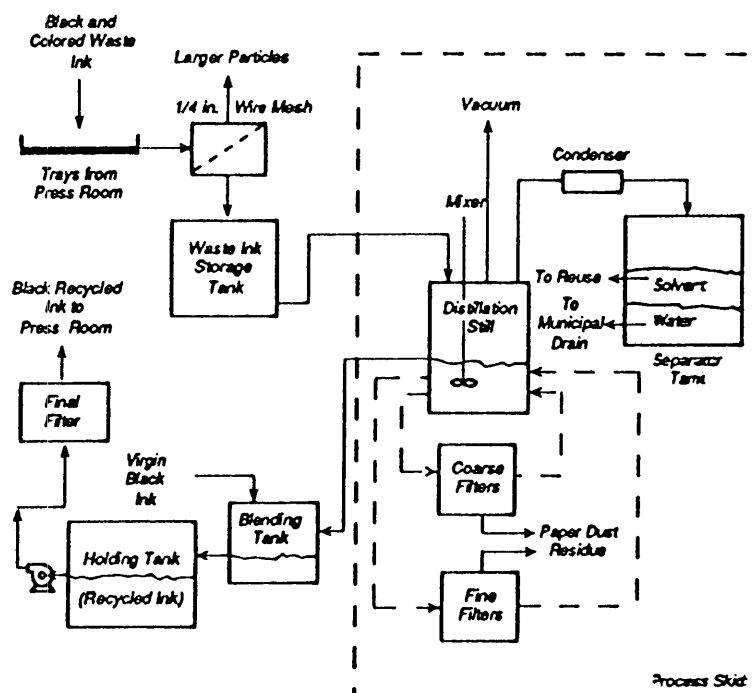


Figure 1. Waste Ink Recycling Process

Prior to ion exchange, approximately 69 lb. of cadmium and 281 lb. of the cyanide were discharged annually. Now, because most of the cadmium can be recovered and reused, this pollutant is virtually eliminated from the waste stream. Some cyanide is also destroyed in the cadmium recovery process.

On the chromium line, without ion exchange, approximately 80 lb. of chromium is discharged annually. With ion exchange, most of the chromium will be captured on the resin, which will be regenerated with NaOH. The regenerant then will pass through a cation exchange resin from conversion of sodium chromate to chromic acid. However, when this recovery was performed during the pilot unit testing, the final regenerant liquid still showed a pH of 13.08. This indicates that sodium chromate had not been converted to chromic acid. However, when this recovery was performed during the pilot unit testing, the final regenerant liquid still showed a pH of 13.08. This indicates that sodium chromate had not been converted to chromic acid; if it had been, the pH would have been much lower. This may be because (a) an excess of NaOH was used to regenerate the resin and/or (b) insufficient resin was available to exchange all the sodium in the regenerant. Further testing is needed to determine the feasibility of the chromic acid recovery process.

The economic evaluation, comparing the costs of the ion exchange operation with those of the former practice (counterflow rinse) are summarized in Tables 2 and 3. The cost of cadmium anodes is approximately \$15/lb, making the value of the 69 lb/yr of recovered cadmium approximately \$1,036/yr.

The chromium deposited on the ion exchange resin also has value if it can be successfully recovered as chromic acid. The cost of chromic acid is \$2.50/lb. Approximately 80 lb/yr of chromium metal is deposited on the ion exchange resin. This corresponds to about 154 lb. of chromic acid (CrO_3). However, further testing is needed to establish the feasibility of chromic acid recovery from the chromium in the regenerant.

The purchase price of the cadmium ion exchange system was \$8,100. The EMR equipment price was \$4,125. Installation costs at Torrington, including materials and labor, was approximately \$3,500, to which \$5,000 was added to approximate the cost of in-house pilot testing to determine specifications for the individual plant.

The purchase price of the chromium ion exchange system is estimated to be \$8,200. Installation cost at Torrington is expected to be \$3,500, including materials and labor. The approximate cost of \$5,000 for in-house testing was also added for this unit.

For the cadmium ion exchange system, the return on investment (with cost of capital equal to 15%) was less than 1 year. For the chromium process, the return on investment (with capital at 15%) was over 5 years. Because chromic acid recovery from the regenerant is yet to be established, no recycled chromium value is assumed. These calculations take into account taxes, depreciation, inflation, etc. and is based on the worksheets provided in the Facility Pollution Prevention Guide (EPA 600/R-92/088). The costs include engineering and installation as well as increased overhead.

TABLE 1. ANALYTICAL TESTS
(Results of Analytical Tests for Product Quality)

Batch No.	Sample Type	Viscosity (Poise)	Grind (mil) 4/10 ^a	Residue %	Tack (gram-meter)	Tinting Strength % ^b	Water Content %	Water Pickup %
1,2	Waste Ink	NA ^c	NA	NA	3.4	69	23.6	NA
1	Recycled Ink ^d	19	0.4/0.3	0.0817	4.4	96	0.102	86
2	Recycled Ink ^d	21	0.6/0.3	0.0735	3.9	92	0.049	80
--	Virgin Ink	20	0.3/0.0	0.0019	4.0	100	0.057	50
--	Industry	--	<0.4/<0.2	<0.01	3.7-4.3	>93	--	--

^a 4/10 refers to 4 or 10 scratches at reported endpoints.

^b Strength of recycled ink was compared to the virgin ink and given as a percentage of the virgin ink strength.

^c NA=Not analyzed. Tests could not be performed because of the large amount of water in the sample.

^d Processed ink blended with virgin ink in the ratio of 1:3.

TABLE 2. RESULTS OF VISUAL JUDGING^a FOR PRODUCT QUALITY

Parameter	Wrapper Page (outer)			Core Page (inner)		
	#Viewers Preferring Virgin Ink	#Viewers With No Preference or Preferring Recycled Ink ^b	Upper 95% Confidence Bound on the Proportion Preferring Virgin Ink	# Viewers Preferring Virgin Ink	# Viewers With No Preference or Preferring Recycled Ink ^b	Upper 95% Confidence Bound on the Proportion Preferring Virgin Ink
Glossiness	0	11	0.238	2	9	0.470
Smoothness	0	11	0.238	4	7	0.650
Opacity	0	11	0.238	4	7	0.650
Rub Resistance	3	8	0.564	1	10	0.364
Blackness	0	11	0.238	4	7	0.650
Absorption/ Bleed-Through	2	9	0.470	1	10	0.364
Sharpness	1	10	0.364	3	8	0.564

^a Eleven experienced viewers of newspapers.

^b Processed ink blended with virgin ink in the ratio 1:3.

TABLE 3. OPERATING COSTS COMPARISON FOR CHROMIUM SYSTEM

Item	Amount Used per Year	Unit Cost	Total Annual Cost
<u>Without Ion Exchange</u>			
Freshwater	480,000 gal	\$0.70/1,000 gal	\$336
Wastewater treatment	1,920,000 gal	\$15/1,000 gal	\$7,200
Total			\$7,536
<u>With Ion Exchange</u>			
Freshwater	12,500 gal	\$0.70/1,000 gal	\$9
Chemicals (50% NaOH)	240 gal	\$1.50/gal	\$360
Energy	1,492 kW hr	\$0.075/kW hr	\$112
Labor	149 hr	\$7/hr	\$1,043
Routine maintenance			
-filters	12	\$5	\$60
-labor	24	\$7/hr	\$168
Waste Disposal			
-regenerant	840 gal	\$15/1,000 gal	\$13
-filters	6	\$400/36 units	\$67
Total			\$1,832

Report

The full report, entitled "Cadmium and Chromium Recovery from Electroplating Rinsewaters" by Arun Gavaskar, et al., is available as EPA/600/R-94/050.

#10 CADMIUM AND CHROMIUM RECOVERY FROM ELECTROPLATING RINSEWATERS

Participants

The Connecticut Hazardous Waste Management Service assisted in implementing the project. The host for the evaluation was the Torrington Company of Torrington, CT who also operated the ion recovery unit. The ion exchange system was manufactured by CTEO Tek, Inc. and supplied by Plating Services Inc. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

The objectives of this study were to evaluate (1) the effectiveness of the ion exchange unit in cleaning the rinsewater for reuse in the rinse tanks, (2) the pollution prevention potential of this technology, and (3) the cost of ion exchange versus the cost of the former practice (disposal).

Figure 1 shows the cadmium ion exchange system configuration. The water from Rinse 1 tank is first passed through a filter to prevent suspended solids from contacting the resin in the ion exchange column. The anionic resin captures the cadmium-cyanide complex, and the water is returned to the Rinse 2 tank. An emergency bypass valve allows this water to be discharged to waste in case cadmium or cyanide levels are found to be too high.

The resin is periodically regenerated with a 15 to 20 % NaOH solution, and the regenerant is taken to the electrolytic metal recovery (EMR) unit, where cadmium is recovered on the cathode and returned to the plating tank. Some cyanide is destroyed by decomposition during the EMR process.

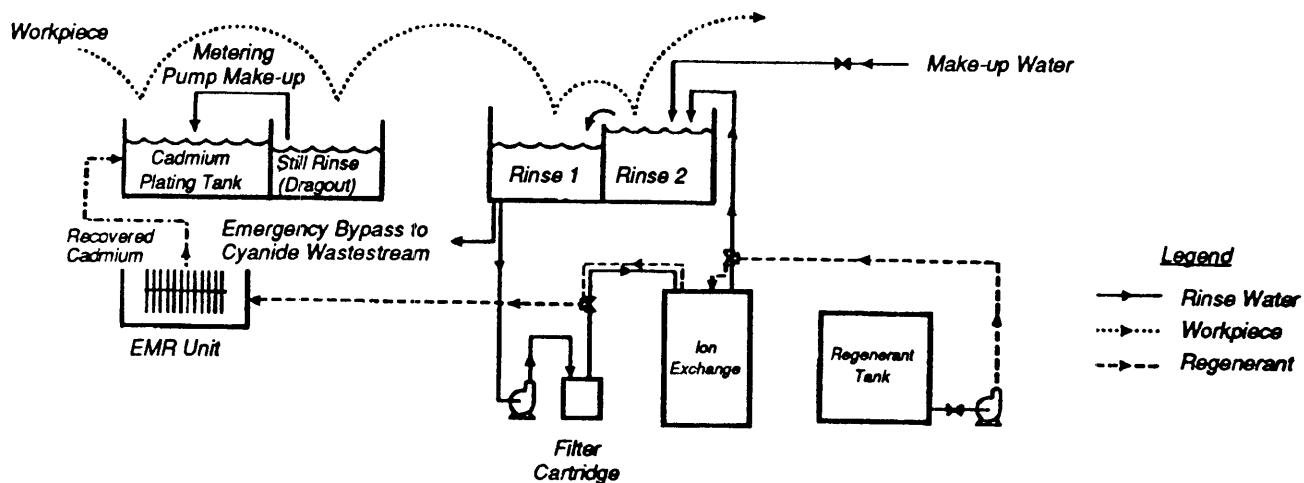


Figure 1. Ion exchange recovery of cadmium from plating risnewater

The ions present in the rinsewater are transferred across the membranes into the concentrate loop. This concentrate is periodically blended into the concentrate tank. Steam coils present in this tank raise the temperature of the concentrate, which is then sent to an atmospheric evaporator (fan). The fan drives off some of the water. The concentrated nickel stream from the atmospheric evaporator is sent to the plating baths where the nickel is reused.

There are two nickel-plating lines at APB. Each line has its own plating bath and rinse tank. The two lines and the electrodialysis unit are operated for two shifts (10 to 16hrs) per day. Some makeup water is added daily to the system to make up for evaporative and other system losses. Testing for this study was conducted over one complete shift. Samples of the water were collected from the various locations, and water meters were installed as shown in Figure 1 to estimate water usage.

To evaluate the performance of the overall recovery system, periodic water samples were collected from the two nickel rinse tanks and the rinse recycle tank. To evaluate the internal profile of the recovery unit, periodic samples were collected from the dialysis feed tank, stack outlet water, and the stack outlet concentrate. To evaluate the suitability of returning the concentrate to the plating baths periodic samples were collected from the concentrate tank and the two nickel plating baths.

Results

Nickel concentration was reduced from nearly 3,000 mg/L in the rinse tanks to less than 100 mg/L in the stack outlet and rinse recycle tank water. Other contaminants are reduced similarly. Both cation and anion levels (total dissolved solids) were reduced by electrodialysis. The nickel concentrations in the rinse tanks were contained below 3,000 mg/L by the balance between the contaminated dragout and the relatively clean recycled water entering the tanks. Additional contaminant control is brought about by the addition of approximately 60 gal/day of fresh water to make up for evaporative losses.

As much as 90% of the nickel is removed from the water loop as the water makes a pass from the dialysis feed tank to the stack outlet water stream. The rest of the nickel remains in the rinsewater returned to the rinse tank. Thus, all the nickel is recovered and reused. The nickel removed from the water loop accumulates in the concentration loop.

On the test day, the evaporator was not functioning properly, and the nickel level in the concentrate could not be brought up to that in the plating baths. Therefore, no concentrate was sent to the plating baths. After the test day, however, APB did manage to adjust the evaporator and obtain an evaporator outlet stream that was sent directly to the plating baths. When the nickel level in the concentrate was increased, there was a concomitant increase in the level of contaminants (iron chloride, etc.). On the test day, it appeared that with further concentration in the evaporator, the contaminant levels in the concentrate would be of the same order of magnitude as the levels in the plating baths. However, indicators of contamination, such as iron or total dissolved solids, needed to be continuously monitored in the evaporator outlet stream and the plating baths to ensure good bath quality. The existence of fouling substances that can be inadvertently introduced makes the system vulnerable to contaminants.

Pollution Prevention Evaluation--

Based on readings taken at water meters installed in the water lines shown in Figure 1, it was determined that 4,350 gal of water overflowed from the rinse tanks during one shift on the test day and 4,310 gal was returned by the recovery unit. Extrapolating to an annual basis, 2,154,000 gal of water flows through the recovery unit.

The results of the laboratory analysis of the chromium rinsewater samples showed that after ion exchange, the rinsewater pH levels were slightly alkaline (9.31 to 9.45) because chromate ions (and any other contaminant anions) had been substituted with hydroxide ions. The alkaline pH was neutralized in the rinse tanks by the chromic acid residue on the parts (workpiece).

Similar statistical analyses were performed on the chromium data as have been described for the cadmium. Suspended solids levels were significantly reduced by the cartridge filter ahead of the resin. Chromium (total chromium) and iron levels decreased significantly after ion change. Iron removal may be due either to removal of ferrous suspended particles on the cartridge filter or to deposition of complexed iron on the resin. As in the cadmium tests, dissolved solids mass decreased significantly, but conductivity (current-carrying strength) remained constant after ion exchange. This is because heavier chromates in the rinsewater were replaced with lighter hydroxide ions.

Table 1 summarizes the waste volume reduction. By using ion exchange, large volumes of water are saved from going to waste. This water can be reused as a rinse on the cadmium and chromium lines. Without ion exchange, Torrington must maintain high rinsewater flow rates (8 gpm for the cadmium line and 2 gpm for the chromium line). These continuous flows generate large amounts of wastewater that have to be treated on site. With the ion exchange system on the cadmium line, Torrington requires only 50 gal/day to make up for dragout losses.

TABLE 1. WASTE VOLUME REDUCTION

Without Ion Exchange		With Ion Exchange	
Waste Description	Amount Generated per Year ^a	Waste Description	Amount Generated per Year ^b
Cadmium System Wastewater	1,920,000 gal	Wastewater	0 gal
		Regenerant	660 gal
		Filter cartridges	6
Chromium System Wastewater	480,000 gal	Wastewater	0 gal
		Regenerant	840 gal
		Filter cartridges	12

^(a)Based on values of 16 hr/day, 5 days/wk, 50 wk/yr.

^(b)Based on pilot tests conducted by the Torrington Company and resin capacity.

In terms of pollutant reduction on the cadmium line, the pollutants of interest are cadmium and cyanide. Before ion exchange, cadmium in the rinsewater was lost to wastewater, which was sent to an on-site wastewater treatment plant. The wastewater was treated in a steel cyanide treatment tank using chlorine gas, sodium hypochlorite, calcium hypochlorite, and NaOH to oxidize the cyanide. The cadmium and other metals formed hydroxides that settled in the clarifier as sludge, which was then hauled off site for disposal. The treated water was discharged to the municipal sewer under a permit.

The electrodialysis recovery system maintains a continuous supply of acceptably clean recycled water. Nickel, a hazardous but valuable chemical, is recovered and reused. The maintenance and energy requirements of the system are relatively high, but the elimination of wastewater treatment result in annual savings leading to a payback period of 1 year at APB. There are other cost benefits that are not easily quantifiable (e.g., eliminating nickel from treatment plant sludge and reducing permitting costs) that may help offset the higher operating costs.

The long-term effects of closing the nickel recovery loop still are a concern, and future research into the operation of this system is needed to ensure good product quality and to reduce maintenance requirements.

Report

The full report, entitled "Nickel Recovery From Electroplating Rinsewater by Electrodialysis" by Arun R. Gavaskar, et al., will be available as an EPA/600 series report.

TABLE 2. OPERATING COSTS COMPARISON FOR CADMIUM SYSTEM

Item	Amount Used per Year	Unit Cost	Total Annual Cost
Without Ion Exchange			
Freshwater	1,920,000 gal	\$0.70/1,000 gal	\$1,344
Wastewater treatment	1,920,000 gal	\$22/1,000 gal	\$42,240
Total			\$43,584
With Ion Exchange			
Freshwater	2,500 gal	\$0.70/1,000 gal	\$9
Chemicals (50% NaOH)	96 gal	\$1.50/gal	\$144
Energy	1,564 kW hr	\$0.075/kW hr	\$117
Labor	173 hr	\$7/hr	\$1,211
Routine maintenance			
-filter cartridges	6	\$5	\$30
-EMR anode plates	1	\$30	\$30
-EMR cathode plates	12	\$30	\$360
-labor	24 hr	\$7/hr	\$168
Waste Disposal			
-regenerant	660 gal	\$22/1,000 gal	\$15
-filters	6	\$400/36 units	\$67
Total			\$2,151

The evaluation showed that rinsewater on both cadmium and chromium lines at Torrington Company can be reused after subjecting it to filtration and ion exchange to remove impurities. Large volumes of water are thus saved, and large amounts of hazardous metal sludge are kept from the environment. The sidestreams from ion exchange are negligible compared with the wastewater and sludge wastestreams that are generated under the old method.

QRD has operated the chromating line with the recovery system for about 1 year. The recovery system configuration at QRD is shown in Figure 1. QRD uses three different chromate formulations, blue, clear, and yellow. The chromating line receives a variety of parts that first are zinc-plated and then chromated.

Contamination accumulates mainly in the Rinse 1 Tank, which functions as a dragout rinse. The contaminated water is processed through the recovery unit at an average rate of 1 gal/min.

The recovery system is fully automated and integrated into the chromating line, requiring little operator attention.

The chromating line operates during 1 shift/day, but the recovery unit remains on 24 hr/day so that the rinsewater gets additional cleaning after contaminant contribution from the chromating line stops. Approximately 50 gal/day of fresh tap water is added into Rinse 2 Tank daily to make up for evaporative losses. Once every 3 or 4 weeks, the still bottoms are evacuated into the sump tank. The sump tank also stores the rinsate generated when the chromate lines are purged before a formulation switch. When the sump tank is full, QRD plans to process its contents through the recovery unit and concentrate it down to a smaller volume. Approximately 200 gal of final concentrate is generated in one year of operation at QRD. The 200 gal of concentrate, containing chromates, can be either reused or disposed of as hazardous waste. QRD has not reused the concentrate because it contains a mixture of three different chromate formulations. Other plants that use only a single formulation may be able to reuse the concentrate, provided that contaminants (such as zinc and iron) do not accumulate to the extent that chromating quality is affected.

Testing for this study was conducted over one shift (6 hours of continuous chromating line operation), and the following morning before the next day's shift. Samples were collected periodically from the locations shown by asterisks in Figure 1.

Results

Rinsewater quality was monitored throughout the shift and the results are shown in Table 1. Water quality in Rinse 1 continues to deteriorate as the contribution from the dragout increases. Contamination in the Rinse 2 Tank is maintained at very low levels by the periodic influx of clean processed water from the recovery unit.

Table 1 shows the characterization of the still bottoms and the chromate solutions. The contaminants that are removed from the rinsewater can be seen accumulating in the still bottoms. From this table, it can be seen that the still bottoms concentration of chromium is below that in the blue chromate tank. Additional chromate would have to be added to the still bottoms solution to raise the concentrate level. If only one formulation were being used, the replenished concentrate could possibly have been returned to the chromate tank. Plants that reuse the chromate concentrate would have to carefully monitor dissolved solids levels to ensure that contaminants such as zinc and iron do not cause the chromating quality to deteriorate.

#11 NICKEL RECOVERY FROM ELECTROPLATING RINSEWATER BY ELECTRODIALYSIS

Participants

The Connecticut Hazardous Waste Management Service assisted in implementing the evaluation. The host for the evaluation was Automatic Plating of Bridgeport (APB), Inc, Bridgeport, CT. APB personnel also operated the plating and recovery equipment. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology and Testing

The goal of this study was to evaluate the technical, pollution prevention, and economic issues involved in using an electro dialysis recovery system to recover rinsewater and nickel from the nickel-plating line in a metal-finishing plant. The recovery system configuration is shown in Figure 1. Rinsewater overflow from the rinse tanks is sent to the dialysis feed tank by a level controller. After electro dialysis, the recycled water is stored in the rinse recycle tank and sent back to the rise tanks. A small amount of sulfuric acid is added to the rinse tanks to remove flash rust after nickel plating. From the dialysis feed tank, water is circulated through the electro dialysis membrane stacks and back to the feed tank. Part of the cleaned water coming out of the stack outlet is channeled into the rinse recycle tank for storage. In this water loop, there is a carbon filter to remove organics and a cartridge filter to remove and carryover carbon particles.

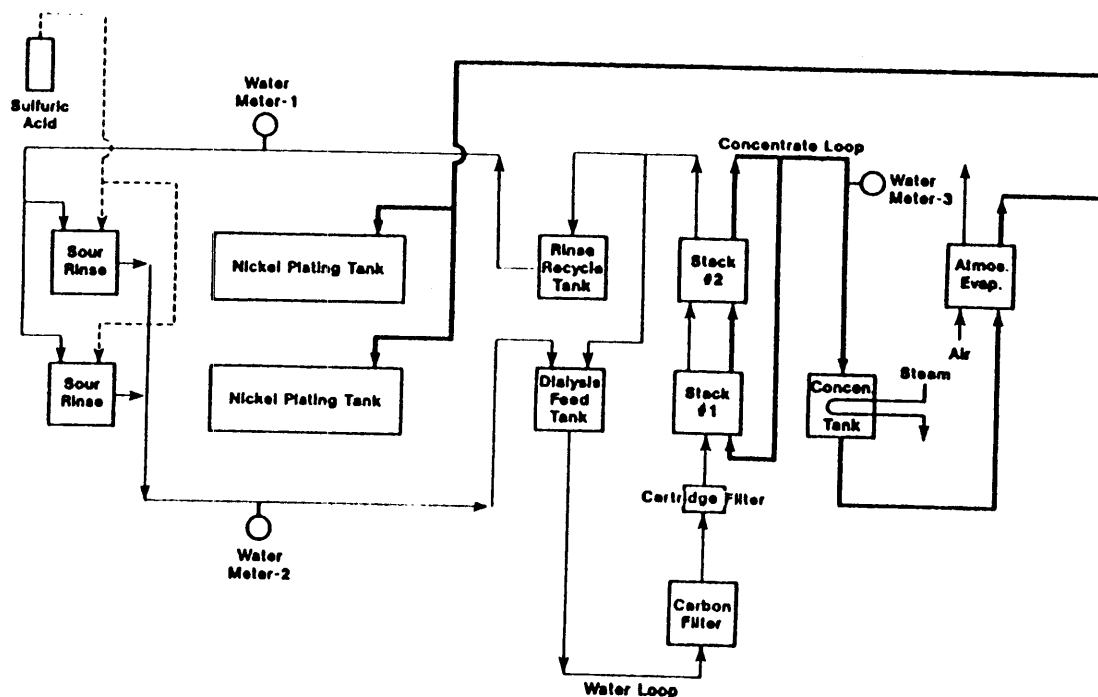


Figure 1. Nickel recovery system

The amount of savings realized is highly dependent on the wastewater treatment costs that a plant would incur without the recovery unit. Because QRD performs a multitude of finishing operations, its unit cost for wastewater treated (\$88/1000 gal) is relatively high.

The recovery system at QRD prevents the generation of large volumes of wastewater and hazardous sludge that otherwise would result from the chromating operation. Further pollution prevention would be possible at plants that use only one formulation, through potential reuse of the chromium contained in the still bottoms. Zinc and iron levels would have to be closely monitored if such reuse was practiced.

This recovery system has potential for use in many applications that generate wastewater. A negative effect is the relatively high energy consumption of the recovery unit. Future versions of this system are aiming to reduce this energy requirement.

Report

The full report, entitled "Chromate Recovery from Chromating Rinsewater in the Metal Finishing Industry" by Arun R. Gavaskar, et al., will be available as an EPA/600 series report.

In order to allow sufficient flow through the process, the rinsewater flow rate at APB when the recovery unit is in operation generally is kept twice as high as it is without the recovery unit. Therefore, if the recovery unit were absent, the flow would be half as much (or 1,077,000 gal/yr), all of which would be wastewater that would be sent to the on-site wastewater treatment plant with the nickel ending up in the sludge, and disposed of as a hazardous waste. Treatment plant effluent would also be subject to limits on the discharge of soluble nickel.

By using the electrodialysis system, the nickel and water are recovered and reused. Based on the concentrations and flows registered during testing, it is estimated that approximately 29,964 lb of nickel is recovered and reused each year when operating 2 shifts per day, 50 weeks per year.

Economic Evaluation--

Table 1 shows a cost comparison for operating with and without the recovery unit. Consumption and unit cost data were obtained from APB's plant records. The electrodialysis unit has relatively high energy and maintenance costs. The electricity required to maintain the voltage across the stacks is the main energy component. Most major maintenance is performed under a service agreement with the manufacturer. Because wastewater treatment and its associated costs are eliminated, there is a payback of 1 year at APB. This payback is based on a capital cost (purchase and installation) of \$110,000 for the electrodialysis unit.

TABLE 1. OPERATING COST COMPARISON

Items	Annual Usage	Unit Cost	Total Annual Costs
<u>Without Recovery Unit</u>			
Water	1,077,000 gal	\$4.19/1000 gal	\$4,515
Chemicals	188,418 lb NiSO ₄	\$1.97/lb NiSO ₄	\$201,607
Wastewater Treatment	1,077,500 gal	\$14/1000 gal	\$15,085
Total			\$ 221,207
<u>With Recovery Unit</u>			
Water (make-up)	15,000	\$4.19/1000 gal	\$63
Energy			
- Steam	4.9x10 ⁸ Btu	\$6/10 ⁶ Btu	\$2,940
- Electricity	78,600 Kwh	\$0.118/Kwh	\$9,275
Maintenance			
- Service Contract	4 visits	\$3,000/visits	\$12,000
- Carbon Change	6 changes	\$1,020/change	\$6,120
- Evaporator Cleaning	12 cleanings	\$120/cleaning	\$1,440
- Miscellaneous	Upkeep on electrical units		max \$1,000
Total			\$32,838

Most printing processes begin with a photographic negative. Developing the negative generates a number of chemical wastes that usually require special treatment for either recycling or disposal. The photographic chemicals used in producing the master negative account for small amounts of waste, although the silver is usually recovered. For flexography, the plate is developed after exposure to a bright light and by washing away the unexposed areas with a solution.

In nearly every step of the printing process, some volatile chemicals are released into the air. The volatiles range from water to various alcohols, plastic thickeners, homogenizers, and chemical diluents. Each ink loses volatile material as a result of storage in the open ink reservoir; during rotation on the various rollers that determine the film thickness to be applied to the plate; as lost material on the plate; and during the heated drying phase. The ink ultimately reaches a rub-off-free state after the material on which it is printed passes through the heated drying zone of the press.

In addition to volatile losses associated with the inks, adhesives and solvents evaporate from the adhesive-coated label surfaces. Cleaning agents used on the press will also evaporate into the air. These cleaning solvents can range in type from water, with small concentrations of detergents to various organic chemicals.

This project compared the volume and toxicity of air emissions and liquid wastes produced by the printing processes before and after switching to water-based inks and an aqueous cleaner and then determined the economics of such process changes.

Results

Before implementing the use of water-based ink and detergent cleaner, the solvent-based, waste ink was disposed of as a hazardous waste with the attendant administrative costs. No liquid ink wastes were sent to the sanitary sewer before the use of water-based inks. Although the total amount of liquid solvent-based waste manifested in a year was on company records, this information was considered proprietary and was not made available for the purpose of this project. It was not possible to directly measure the amount of alcohol-based ink and cleaner wastes that would have been generated from printing runs similar to those evaluated with the water-based inks.

Company officials reported that in their experience, the amount of solid and liquid wastes generated are essentially the same for both ink types. The main difference, however, was that liquid wastes from the water-based inks did not have to be disposed of as hazardous wastes for this project and that the organic solvent releases were minimized.

Evaluation of Changes in Toxicity--

Toxicity reduction evaluations for the ink and cleaner wastes were accomplished with the Degree-of-Hazard scheme developed and used by the Illinois Hazardous Waste Research and Information Center. The equivalent toxic concentration was calculated for four printing scenarios: (1) green alcohol-based ink with solvent-based cleaner; (2) purple alcohol-based ink with solvent-based cleaner; (3) green water-based ink with detergent cleaner; and (4) purple water-based ink with detergent cleaner. For estimated emissions to the air, the alcohol-based inks and cleaners had relative toxicities about 10 times higher than those for the water-based emissions. The same reduction was found in the liquid waste comparison. In actuality, no liquid wastes were discharged to the sewer when the company was using alcohol-based inks and cleaners. Therefore, the relative toxicity of these wastes increased from zero. Offsetting this is the fact that the undiluted alcohol-based wastes were previously sent to a landfill in the waste-containing drums.

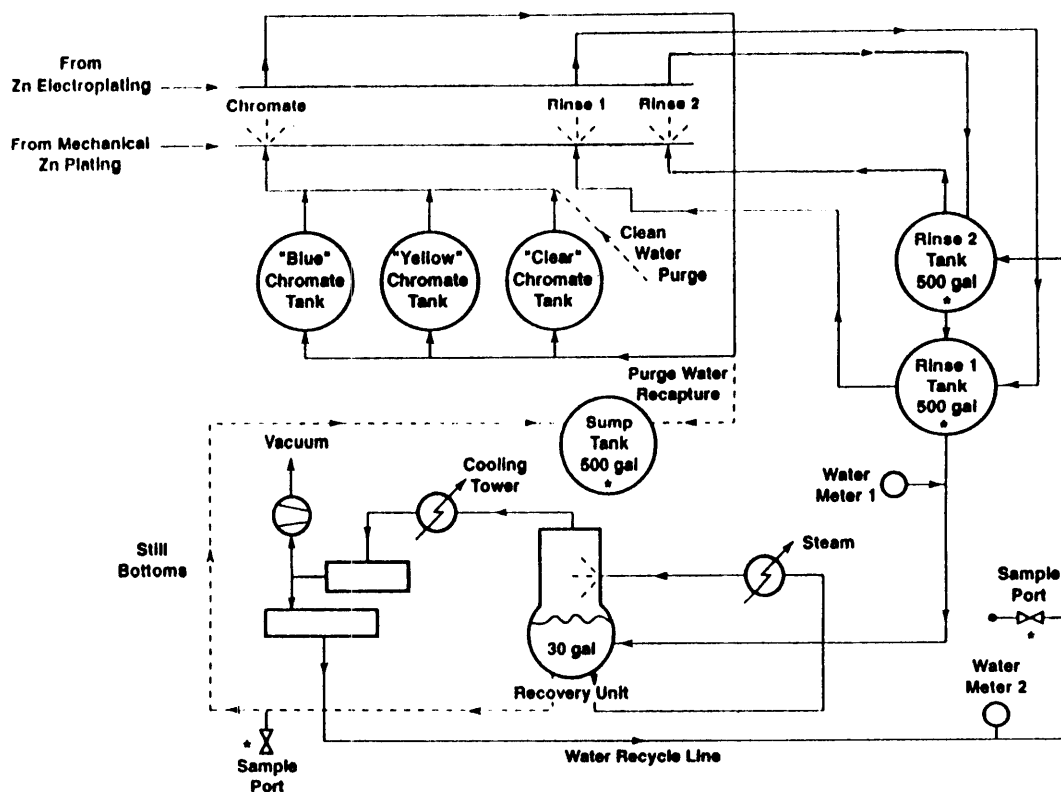
#12 CHROMATE RECOVERY FROM CHROMATING RINSEWATER IN THE METAL FINISHING INDUSTRY

Participants

The Connecticut Hazardous Waste Management Service assisted in implementing the evaluations. The host for the evaluation was the Quality Rolling and Deburring Company (QRD) of Thomastown, CT. QRD personnel operated the metal finishing and recovery processes during the test. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology and Testing

The recovery unit tested was manufactured and provided by Cellini Purification Systems, Inc.*. Similar units with varying capabilities may be available from other vendors.



* sampling locations

Figure 1. Chromating rinsewater recovery system

#14 ALKALINE NONCYANIDE ZINC PLATING AND REUSE OF RECOVERED CHEMICALS

Participants

The P&H Plating Company of Cook County, Illinois provided the test site. The Hazardous Waste Research and Information Center (HWRIC), a division of the Illinois Department of Energy and Natural Resources, Champaign, Illinois provided test personnel, designed the test and drafted the final report.

Technology/Testing

This work was undertaken to evaluate the feasibility of using an innovative, closed-loop rinsewater treatment system to precipitate plating chemicals for recovery and reuse and to produce purified water for recirculation to the rinsing tanks and sprayers. The goal of this study was to achieve zero discharge of the wastewater and total recycle of the recovered precipitate, thereby reducing the amount and toxicity of the waste from a zinc plating operation. The zinc cyanide (CN) plating line was converted to one that uses an alkaline, noncyanide zinc (ANC) plating bath. A recovery/recycle (R/R) unit was then designed, installed, and tested to determine how completely the goals of the project were being met. The effectiveness of the R/R system in reducing the process wastes was evaluated by: quantifying the effectiveness of the removal of the zinc through precipitation by pH adjustment, the basis of the recovery system; determining the quality of the precipitate and the treated water that were recovered; comparing the plating quality of the CN-based operation to that of the ANC-based processes that used both the recycled chemicals and the treated rinsewater; and analyzing the costs associated with the change in the process and the installation and use of the R/R system. The R/R unit was designed, installed, and tested by engineers from the Center for Neighborhood Technology (CNT).

The CNT Recovery/Recycle--

The relatively simple principles involved in the design of the CNT R/R system are similar to those for a standard wastewater flocculation treatment to remove metals before disposal of water and sludge wastes. Ideally, 100% of the zinc in the CNT R/R system's rinsewater would be recovered and returned to the plating bath. Additionally, all rinsewater would be recycled. The projected result would be substantial savings for the company in plating chemicals and water from this rinsewater purification that both recovers and reuses as well as treats.

In the plating process at P&H, there is the usual parts pretreatment or cleaning, followed by the plating process, a spray rinse, and finally, submersion into two counterflow rinse tanks. Although cleaning requirements for ANC plating are generally more stringent than those for CN plating, no change was required to the pretreatment portion of the line at P&H. The company had already installed a very stringent cleaning component to their plating lines to ensure good parts cleaning and, presumably, better plate quality. The CNT R/R system was plumbed from the spray rinse tank into which the counter flow tanks ultimately overflowed. The rinsewater flows into a tank where the Ph is measured and automatically adjusted to a Ph between 10 and 10.5.

This Ph monitoring and control tank is a continuous flow stirred reactor (CFSR). It is designed to stimulate precipitation by sparging with compressed air entering from the bottom of the tank. The flow rate through the CFSR is set at 10 gallons/minute. The precipitate/water slurry next flows into a flat-bottomed clarifying tank. To facilitate the settling process, the tank is baffled. A recirculating pump is used to pull water from the clarifying tank through the dual filtering system to remove suspended hydroxide. The filtered water then either flows to a storage tank for reuse or to the waste treatment area for disposal. The precipitate that has settled in the clarifying tank is removed and combined with that collected on the filters. This composite hydroxide is placed in a filter press to remove as much water as possible. The water that is removed is returned to the precipitation reactor and the dewatered hydroxide is analyzed and stored for future use or disposed if not needed. Figure 1 shows the system components

**TABLE 1. CHARACTERIZATION OF DISTILLATION STILL BOTTOMS AND
CHROMATE TANKS**

Sample No.	Time	Cr mg/L	Zn mg/L	TDS mg/L	Conductivity mhos/cm	pH
<u>Still Bottoms</u>						
C-SB-1	9:30 a.m.	162	258	2,280	2,700	3.52
C-SB-2	12:30 p.m.	168	277	2,240	2,500	3.59
C-SB-3	3:30 p.m.	216	385	3,170	3,200	3.80
C-SB-4	8:00 a.m. ^a	224	420	3,610	4,000	3.95
<u>Chromate Tanks</u>						
Blue	2:00 p.m.	1,254	1,739	16,740	12,000	2.57
Yellow	2:00 p.m.	1,471	15	3,590	15,000	1.55
Clear	2:00 p.m.	3,860	0.743	25,110	28,000	2.87

^a Next day.

Table 2 lists the major operating costs with and without the recovery system. At QRD, the recovery unit generates a savings in annual operating costs of \$22,159. The recovery unit was purchased by QRD for \$78,000, incurring an additional \$9,000 in installation and auxiliary equipment costs (such as cooling tower, piping, etc.) A payback was estimated at 4 years.

TABLE 2. MAJOR OPERATING COSTS COMPARISON AT QRD

Item	Annual Amount	Unit Cost, \$	Annual Cost, \$
<u>Without Recovery System</u>			
Water (rinse)	450,000 gal	4.65/1,000 gal	2,093
Wastewater treatment	450,000 gal	88.00/1,000 gal	<u>39,600^a</u>
		Total	41,693
<u>With Recovery System</u>			
Water (rinse, makeup)	12,500 gal	4.65/1,000 gal	58
Water (cooling, makeup)	12,500 gal	4.65/1,000 gal	58
Water disposal	200 gal	350.00/55 gal	1,273
<u>Energy</u>			
- electricity	60,950 kW/hr	0.068/kW hr	4,145
- steam	3,000,000 lb	0.004/lb	12,000
Maintenance	-	-	1,200
Labor	100 hr	8.00/hr	800
		Total	<u>19,534</u>

The CNT R/R system has been in continuous operation for over 3 years. Maintenance consists of proper care of the mechanical parts and periodic replacement and cleaning of the filters. Zinc hydroxide is removed from the rinsewater with an efficiency averaging 84%. The amount of precipitate recycled to the bath depends largely on the number of jobs requiring use of that line. The company estimates that it recycles 30% of the zinc hydroxide it recovers. Approximately 70% of the purified water is used in the rinsing operation or to replenish the plating bath.

Plating Quality Comparison--

Although the reasons for plating are sometimes purely ornamental, more frequently it is for protection of the part. Finishes may be bright or dull, and it may not always be possible to achieve the desired luster with the ANC system. Advances in the last decade have, however, provided less toxic bath alternatives that produce parts with a surface finish similar to the CN-based process. Ultimately, whether the plate is satisfactory or not is up to the customer, but two commonly used standard tests can be performed to evaluate quality -- thickness and corrosion resistance. When parts plated on both the CN and ANC lines were compared for these standards, both processes produced parts with the desired thickness and acceptable corrosion protection.

Toxicity Comparison--

The change to ANC plating resulted in the reduction in health and environmental risk due to the elimination of cyanide from the process. This is a very substantial risk reduction. CN plating requires extensive treatment before disposal and uses chemicals hazardous to human health. Chemical substitution to achieve source reduction, as was done for this project, not only reduced process costs but also the company's liability because of the reduced toxicity of the chemicals being handled and disposed.

The exposure of shop workers to toxic chemicals presents the most serious health and safety consideration for the electroplating industry. Although no occupational illness has been documented for electroplating operators, they are routinely exposed to hazardous substances known to cause serious health problems. The use of cyanide, generally considered the most potentially dangerous of the electroplating chemicals, is carefully monitored and employees are trained to use it properly. Combining employee education with substitution of less toxic chemicals may provide the least costly and most productive control of workplace hazards. Replacing cyanide plating solutions with noncyanide baths is strongly recommended.

Economic Comparison--

Although reduced risks may be sufficient to justify the change from CN to ANC, the economic benefits derived were significant. An economic comparison was calculated to include cost of making the change as well as the capital investment required. The economics involved are compiled in Table 1. An annual cost savings of \$14,000 is achieved by the switch from a CN to an ANC process with a savings of \$62,000 when the R/R system is also added to the line. These savings take into account the annual cost of operation of the R/R system which is \$10,900.

Making the switch from CN to ANC requires disposal of the exiting 1,800 gallon CN bath at a cost of \$20/gallon for a total cost of \$36,000. This was included as part of the capital investment for this project. Adding the R/R system increases the capital investment to a total of \$87,822. The analysis in Table 2 was prepared using 1992 cost data, an inflation rate of 4%, a discount rate of 7.7%, depreciation schedule of 7 years, and a project life of 10 year, and process operation 8 hours/day, 5 days/week for 50 weeks/year. The analysis shows that the recycling option provides the greater economic benefit, the shorter payback period, and the larger return on investment.

ILLINOIS

Five technologies were identified and tested with the help of the Illinois Hazardous Waste Research and Information Center (HWRIC), Dr. Gary Miller, project officer. Two technologies focused on waterbased inks and printing, three dealt with metal cleaning and plating. The EPA project officer was Paul Randall.

#13 INK AND CLEANER WASTE REDUCTION EVALUATION FOR FLEXOGRAPHIC PRINTERS

Participants

The MPI Label System Incorporated of University Park, Illinois provided the test site. The Hazardous Waste Research and Information Center (HWRIC), a division of the Illinois Department of Energy and Natural Resources, Champaign, Illinois provided test personnel, designed the test and drafted the final report.

Technology/Testing

MPI wanted to eliminate employee exposure to any liquid or gaseous hazards resulting from handling of hazardous materials and an equal desire to minimize the possibility of future litigation resulting from use of such substances. This decision forced each plant to substitute water-based inks for alcohol-based inks, and at the same time, change from alcohol solvent cleaning agents to aqueous cleaning agents.

The water-based inks were already available on the commercial market. Implementing this change, however, required extensive cooperation between the ink manufacturer and the printing plant because of different printing conditions, changing customer requirements, and changing paper stock to be compatible with the water-based inks.

Because water-based inks are easier to remove or clean with aqueous agents when wet, a terpene-type (d-limonene) cleaner was initially tried. Later, a dilute aqueous solution of detergent proved to be even easier to handle, odor free, and less expensive. MPI reported that it is their standard practice to try new cleaning agents as they are introduced to the commercial market by testing them to determine if they can improve their process and be safer to use.

Printing wastes are generated at most stages of the printing process. Ink wastes result when the reservoir, the various rollers, and the printing plate are cleaned at the end of a run. Excess ink in the reservoir can be collected for reuse, but the other ink quantities removed during cleaning generally remain as waste. MPI Label Systems keeps a 50 gallon barrel of water adjacent to each press. During cleanup when water-based inks are used, soiled parts and cleaning towels are rinsed in this water to remove ink residues. At the end of the week, barrels of rinse water are transferred to an ink splitting device that absorbs the various ink pigments on a cellulose-based porous material. The nearly clear filtrate passes through for disposal in the sanitary sewer, with permission from the local water treatment plant. The pigment-colored cellulose is accepted at the local landfill along with paper wastes from the print line. Some paper wastes are also accumulated during setup operations, although an experienced printer is usually able to minimize them. Exceptional amounts of waste labels are, however, occasionally generated during the production of multicolor labels because of color registration difficulties. The adhesive based, print-free trimmings, part of the label stock, are collected on a separate waste roll.

TABLE 2. COMPARISON OF ECONOMIC INDICES FOR THE ALKALINE NONCYANIDE PLATING PROCESS WITH AND WITHOUT THE RECOVERY/RECYCLE SYSTEM

Index	Option	
	ANC	ANC+R/R
Capital Investment	\$36,000	\$87,822
Payback Period	3 years	1.5 years
Net Present Value	\$57,500	\$281,122
Implied Rate of Return	27.0%	71.9%

The company has recently converted all of its plating lines from CN-based to ANC-based. With this change the company may consider the delisting process.

Report

The full report, entitled "Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals", by Jacqueline M. Peden, is available as EPA/600/R-94/148.

Solvent emissions to the plant air have been reduced by at least 80%. Toxicity of these emissions has gone from hazardous to non-hazardous, based on EPA regulations. Solid waste generated and destined for local landfills has been reduced in volume and is no longer classified as hazardous. This waste is mostly bulk paper for which a recycling system is being sought.

The approximate annual savings at MPI Label Systems resulting from the ink and cleaner change is estimated by the plant manager to total \$16,500 (Table 1). There is essentially no difference in raw material costs for the inks and cleaners. MPI feels that the overall productivity of the plant has increased, but the specific economic value of this increase was not determined. Annual waste disposal and handling account for at least a savings of \$15,000. The facility saves about \$500 each year because of a lowered insurance premium based on improved working conditions. Savings because of new wiping materials (nondisposable) equals about \$1,000 annually. Additionally, these changes did not require capital investment nor increased operational expenses.

TABLE 1. ECONOMIC SUMMARY OF SAVINGS
USING WATER-BASED INKS AND CLEANERS

Parameter	Savings
<u>Water-based inks</u>	
Printing speed	Approximately 10% faster
Raw Materials	None
Waste disposal and handling	Minimum annual savings = \$10,000
<u>Aqueous cleaners</u>	
Disposal	Minimum annual savings = \$5,000
Raw materials	None
<u>Overall Savings</u>	
Insurance liability	Approximately \$500/yr
Inventory	None
Wiping materials	Annually at least \$1,000
Annual total	At least \$16,500

Report

The full report, titled "Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers" by Gary D. Miller, et al., is available as report no. EPA/600/R-93/086.

Reverse osmosis is a pressure-driven membrane separation process in which a feed stream under pressure (200 to 800 psi) is separated into a purified "permeate" stream and a "concentrate" stream by selective permeation of solution through a semi-permeable membrane. The reverse osmosis unit used in this project was an Model PES/OSMO-19T-80SSXXC reverse osmosis machine for process evaluation. It was equipped with one Model Number 192T-MSO5 thin-film, composite, spiral-wound membrane cartridge. The solution was pre-filtered through a 5 µ cartridge filter for the reverse osmosis testing.

Four, 55-gallon drums of nickel electroplating rinse water were collected from the Graham Plating facility and processed through the low temperature evaporation (Drums A and B) and the reverse osmosis (Drums C and D) systems. The reverse osmosis tests were conducted at two different operating pressures: Drum C at pressures of 250 to 300 psi and Drum D at 350 to 380 psi.

This project was performed to evaluate the effectiveness of low temperature evaporation and reverse osmosis technologies for recovery and reuse of water and plating bath chemicals associated with electroplating rinse waters. These technologies were examined on a pilot scale at the HWRIC pilot laboratory facility by using rinse water samples collected from a Graham Plating nickel electroplating line. Economic assessments conducted for these technologies assumed that 7,200 gallons of nickel electroplating rinse water would have to be processed per day at this facility on a 5-day week and 80% availability basis.

Nickel analyses were done to determine how efficiently the system removed nickel from the rinse water and concentrated it for potential recycling. Analyses for total organic carbon (TOC) were done to indicate the fate of organic constituents (e.g., brighteners) in the rinse water. Immediately after samples were collected, electrical conductivity measurements were made to indicate the soluble salts present in the samples.

Results

The low temperature evaporation system exhibited consistent productivity throughout the tests regardless of the chemical concentrations of the feed solution provided to the system. The evaporation system concentrated the rinse water, which had exhibited initial nickel concentrations of 2,540 to 4,140 mg/L to nickel levels as high as 13% to 18%. These levels are well above the 8% required for use in the plating bath. The concentrate, permeate, and distillate nickel concentrations exhibited in samples collected throughout the tests have been summarized (Table 1). The evaporation system concentrated the organic constituents of the rinse water from initial TOC levels of 550 to 990 mg/L to final levels of 25,000 to 26,000 mg/L.

The concentration rate of the organic components paralleled the nickel concentration rate suggesting that little of the organic material was lost to volatilization. Distillate produced by the low temperature evaporation system was very low in nickel concentration (average of 0.37 to 0.71 mg/L). Additionally, TOC concentrations in the distillate were very low (average 3.04 to 3.50 mg/L).

Disadvantages of the low temperature evaporation system include its relatively high (\$140,000) capital cost and high energy requirements (\$20/2,000 gal processed). The implied rate of return of 10.6% and payback period of 6.9 yr, determined in the economic assessment for this system, suggest that it is a marginal investment opportunity by today's standards. These estimates, however, do not consider the reduced future liabilities brought about by large decrease of hazardous waste discharges from the facility.

and the path of the water and the solids as they flow through the system.

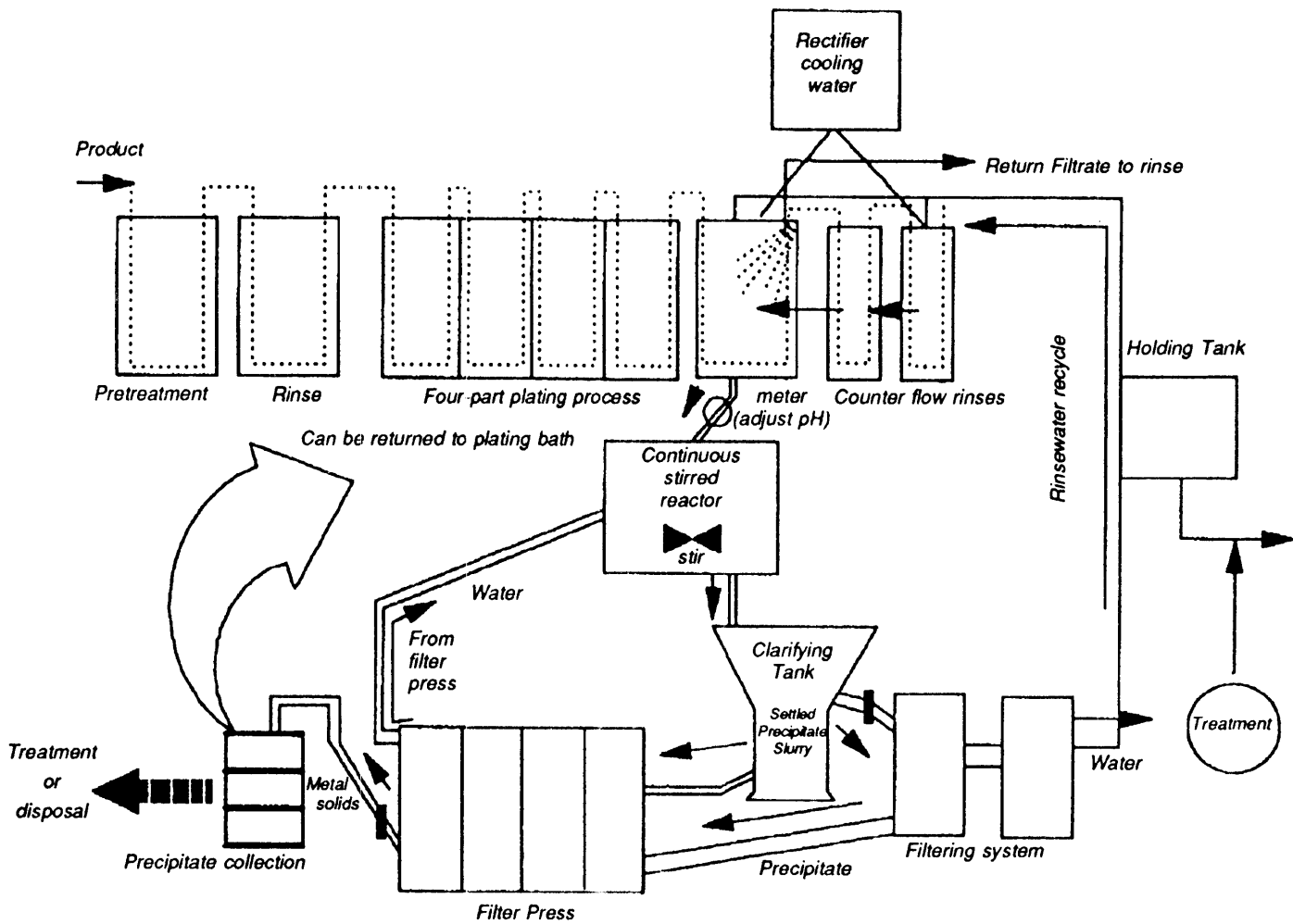


Figure 1. P & H plating alkaline noncyanide plating line with CNT designed recovery/recycle system

Results

R/R System Performance--

Although system operation generated problems, it proved to be a highly efficient and economically advantageous addition to the plating operation. The quality of the zinc hydroxide precipitate and the purified water were generally of adequate purity for recycling. Careful and regular analysis of the essential bath chemicals is recommended to ensure contaminants are not introduced through these recycling efforts.

Advantages of the reverse osmosis system include its relatively high production rates with respect to low concentration feed solutions. Additionally, it would require lower capital investment (about \$50,000) than a comparably sized low temperature evaporation system. Energy costs required to operate a reverse osmosis system would be only about \$2.50/1,000 gallons processed.

Disadvantages associated with a reverse osmosis system include its inability to concentrate the feed solution to levels beyond the 12,560 to 18,200 mg/L levels revealed in this study. This factor alone would prevent use of a stand-alone reverse osmosis system at the Graham Plating facility. Another disadvantage is the lower quality permeate produced by the system. This solution would probably have to be reused within the plant or further processed through the reverse osmosis system before discharge to the POTW.

Conclusions--

- p Both the low temperature evaporation and reverse osmosis systems appear to offer advantages under specific operating conditions.
- p The reverse osmosis system is best adapted to conditions where the feed solution has a relatively low nickel concentration. It can process the low concentration feed solution with relatively high efficiency to a level of 4,000 to 5,000 mg/L. At this point, the solution could be transferred to a low temperature evaporator for further concentration.
- p The low temperature evaporation system appears to be best adapted to processing solutions with relatively high nickel concentrations. It can process these solutions so that a concentrate solution composed of 8% or more nickel is produced along with a very high-quality distillate solution.
- p Installed at the Graham Plating facility, the units would require a capital investment of \$115,000, which would be paid back in 2.8 years through a 27.6% implied rate of return.
- p Electrical conductivity measurements could be used as good indicators for correlating nickel & TOC concentrations & membrane flux characteristics for this plant.

Report

The full report, entitled "Recycling Nickel Electroplating Rinse Waters by Low Temperature Evaporation and Reverse Osmosis", by Timothy C. Lindsey, is available as report no. EPA/600/R-93/160.

TABLE 1. COMPARISON OF ANNUAL OPERATIONAL COSTS FOR CN PROCESS, ANC PROCESS WITHOUT R/R UNIT, AND ANC PROCESS WITH R/R UNIT AT P&H PLATING CO.

Process Operation	CN Costs (\$)	ANC Costs (\$)	ANC + R/R* Costs (\$)
Bath makeup	1,771	1,860	1,860
Bath maintenance	22,325	21,225	19,425
Water usage			
1. Use @ \$7.56/7480 gallons	1,213	1,213	364
2. Sewering @ \$5.59/7480 gallons	897	897	269
Wastewater treatment			
1. Cyanide oxidation	14,000	0	0
2. Metal precipitation	69,000	69,000	20,700
3. Labor @ \$15/hour	7,500	7,500	2,250
Sludge disposal @ \$209/cubic yard	2,600	2,600	1,820
Total	119,306	104,295	46,688

* Assumes 70% water and 30% zinc hydroxide recycled.

The recovery efficiency for zinc hydroxide from the CNT system averages 84%. However, due to the variability in the numbers and types of plating jobs and the general fluctuations in business (all of which play a role in the amount of zinc hydroxide needed for the line), the company does not recycle all of the precipitate that is covered. Additionally, the recovered zinc hydroxide is not a totally suitable substitute for the zinc ingots traditionally used to add zinc to the plating bath. All of the precipitate produced is passed through the filter press, which greatly reduces its volume. Approximately 30%, depending on production needs, is returned to the plating bath. The remaining 70% is stored for later use or disposed as a hazardous waste. While it would be possible to petition to delist this waste, the amount being produced is less than 5% of the metal waste that the company produces and must routinely dispose. Since much of the other metal waste was from cyanide-based plating lines, it is sent to disposal as a hazardous waste. Currently, the company is finding it more economically advantageous to add the zinc hydroxide to the hazardous metal waste rather than separating, storing it, and applying for delisting.

generation. Aqueous cleaners are being used in many industrial surface preparation operations including airplane components, printed circuit boards, advanced composites, fasteners, and automotive parts.

The tank life of the aqueous cleaners is limited by the buildup of the dirt and oils in the bath. This buildup makes the cleaning effectiveness begin to deteriorate, while also inhibiting the performance of other chemicals in the bath. Although the aqueous degreasers do not carry all the risks and liabilities associated with the disposal of waste organic solvent cleaners, periodic replacement of the bath creates different waste disposal problem.

Current disposal options for spent aqueous cleaning solutions include tankering, incineration, or discharge. The rising costs associated with these disposal and pollution control options are the main incentives to extend the life of the aqueous cleaner baths. Rather than wasting raw materials, the aqueous cleaners have the potential to be recycled. Depending on the physical characteristics of the bath solution, the life of the bath can be extended by skimming contaminants off the top, settling heavier fractions to the bottom, or filtering out suspended species.

Conventional filtration techniques rely on depth or screen filters to remove oil and dirt from a process solution, but conventional filter media clog easily. They require frequent backflushing or disposal, which result in additional wastes. Membrane filtration is a more advanced technique that takes advantage of thin-film membranes and turbulent flow patterns to deliver a more consistent flow rate and a higher quality filtrate than conventional filtration. Ultrafiltration is one class of membrane filtration that uses membranes with pore diameters ranging from 10^{-9} to 10^{-6} m. The ultrafiltration process works by producing two separate streams: concentrate and permeate. The **permeate** stream contains only the components in the feed solution small enough to pass through the membrane pores (water, solubilized species). The **concentrate** stream contains everything else that is rejected by the membrane (such as emulsified oil and dirt).

The recent development of more durable membranes, such as PVDF, has expanded the application of ultrafiltration beyond its origins in the food industry to successfully handle industrial process solutions with extreme pH, high temperatures, and high oil concentrations. Because of its unique capabilities to concentrate oily wastewater and produce a clear filtrate, ultrafiltration has emerged as promising technology for extending the life of aqueous cleaner baths. Ultrafiltration of oil-water emulsions is a more straightforward method for removing and concentrating oil than are other physical, chemical, or thermal means. Ultrafiltration does not require a stockpile of chemicals and does not produce a chemical sludge that requires special treatment or disposal. Instead, ultrafiltration produces a water phase that requires no further treatment and a concentrated phase only a fraction of the original volume that can sustain combustion or be disposed of efficiently. Ultrafiltration requires no heat input, relatively low energy, and little operator attention.

One of the greatest limitations of ultrafiltration membranes is their tendency to foul. **Fouling** is detected as the decrease in permeate flux over time, where the **flux** is defined as the volumetric flow rate of permeate per cross sectional area per unit of time. Fouling is mainly due to the accumulation of particles on the membrane surface and/or within the pores of the membrane itself. In industrial applications, where ultrafiltration could be used to filter aqueous cleaning baths, fouling will typically be due to oils, suspended solids, free surfactant, and metal precipitates. When a membrane shows signs of fouling, the flux can largely be restored by cleaning the membrane, but a portion of the flux may be unrecoverable because of irreversible fouling.

#15 RECYCLING NICKEL ELECTROPLATING RINSE WATERS

Participants

The Graham Plating Company in Chicago, Illinois provided the test site and operated the wastewater recycling system. The Hazardous Waste Research and Information Center (HWRIC), a division of the Illinois Department of Energy and Natural Resources, Champaign, Illinois provided test personnel, designed the test and drafted the final report.

Technology/Testing

Low temperature evaporators (Licon, Inc., Pensacola, FL) heat water under a vacuum to produce steam at relatively low temperatures (150 to 160° F). The unit tested was a model C-3, single effect, pilot-scale evaporator especially designed for conducting pilot-scale tests on a variety of feed solutions. Figure 1 provides a schematic of material flow through a low temperature evaporation system.

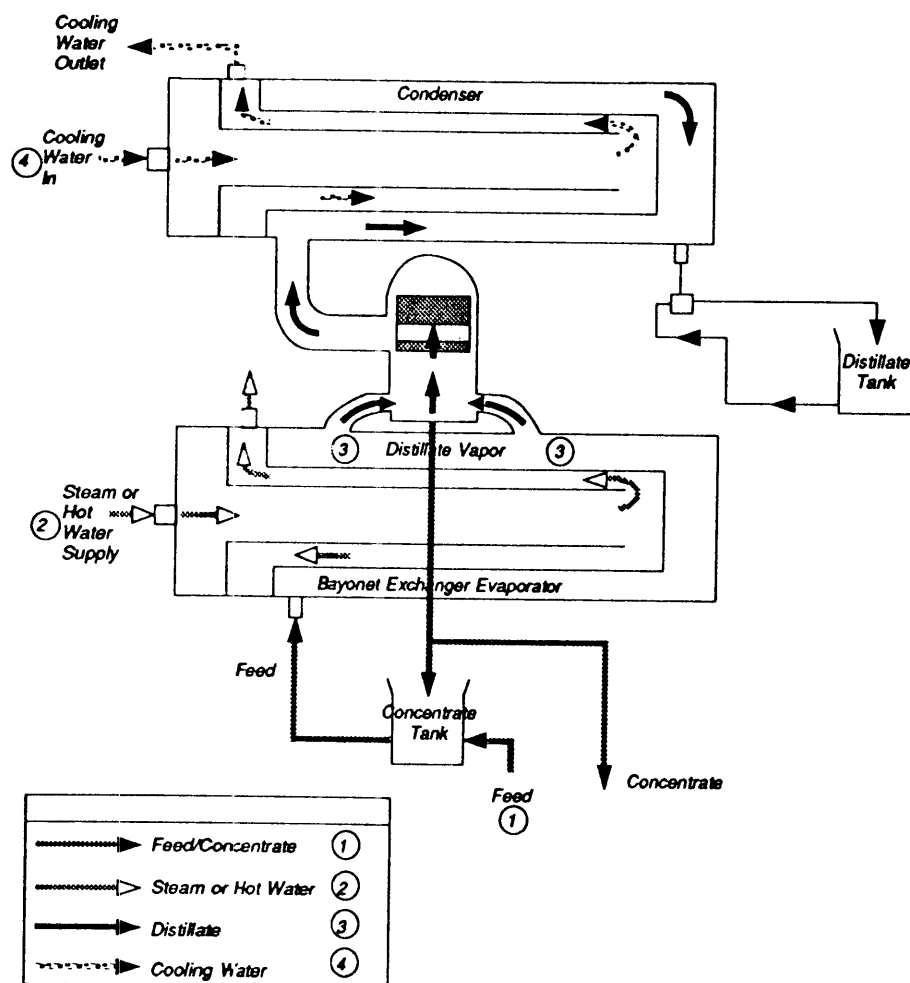


Figure 1. Basic flow diagram for single effect evaporator

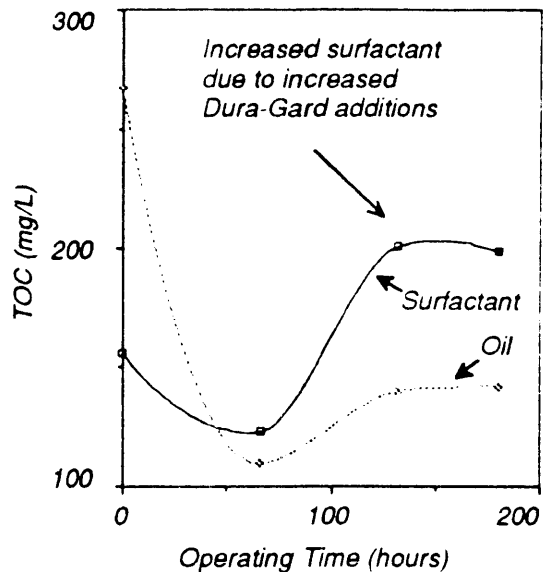


Figure 2. Oil and surfactant in bath vs. time

The costs and benefits associated with installing an ultrafiltration system were analyzed to determine the economic feasibility of this technology. Based on the estimated expenditures and savings, the payback period associated with this technology was only 6.9 mo. The net present value and interest rate of return indices were \$152,143 and 178%, respectively. Therefore, investment in an ultrafiltration system represented a very attractive economic alternative.

In summary the findings of this evaluation indicated that:

- The application of ultrafiltration produced significant reductions in hazardous waste. This is especially significant in comparison to earlier methods using separate degreasing and phosphating tanks and organic solvent.
- For metal fabricating, and potentially similar applicants, use of this technology can be economically attractive although capital investment is required.
- Other applications for recycling/reusing wastewater via ultrafiltration have good potential for P2 improvements as well as good economics. However, they should first carefully investigate the highly sensitive parameters such as fouling, at small scale and identify variability in their operation and its effect on the process.

Report

The full report, entitled "Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating/Degreasing Bath" by Gary D. Miller, et al., is available from the National Technical Information Service. The project Summary is distributed by EPA as report number EPA/600/SR-93/144.

TABLE 1. COMPARISON OF NICKEL CONCENTRATIONS IN CONCENTRATE, DISTILLATE, AND PERMEATE

Osmosis	Low Temp. Evap.			Reverse
	Product	Drum A	Drum B	Drum C
<u>Concentrations at beginning of test (mg/L):</u>				
Concentrate	4,140	2,540	2,580	1,425
Distillate	2.5	2.2	--	--
Permeate	--	--	44.5	14.5
<u>Concentrations at end of test:</u>				
Concentrate	17,000	128,000	12,560	18,200
Distillate	1	0.3		—
Permeate	--	--	210	790
<u>Ratio of distillate permeate to concentrate:</u>				
Distillate	0.02%	0.01%	--	--
Permeate	--	--	1.4%	1.54%

The feed solution processed through the reverse osmosis system contained initial nickel concentrations of 1,425 to 2,580 mg/L (Table 1). Nickel concentrations increased steadily until approximately 60% of the water volume was processed and nickel concentrations were up to 4,000 to 5,000mg/L. After this point productivity started to drop due to solids precipitating and fouling the membrane. The final concentrations achieved with the reverse osmosis process ranged from 12,560 mg/L to 18,200 mg/L, well below the 8% nickel concentration required for the plating bath. Some of this solution could be used to replace water losses in the electroplating process. The reverse osmosis system, however, would probably produce excess volumes of concentrated rinse water composed of 1.2% to 1.8% nickel. This material would have to be further processed with the use of an alternative technology such as low temperature evaporation or be shipped to a facility that could exact the nickel for use in other industrial processes.

The reverse osmosis system concentrated the organic constituents present in the rinse water feed solution from initial TOC levels of 340 to 540 mg/L to levels of 2,800 to 3,500 mg/L. These concentrations suggest that the organic bath constituents are concentrated by the reverse osmosis equipment at rates that parallel the nickel concentration rates.

The quality of the cleaned rinse water permeate produced by the reverse osmosis equipment averaged 89 to 134 mg/L nickel. These levels are about 98.5% lower than the nickel concentrations present in the concentrated solution, but would not, however, be acceptable for discharge to publicly owned treatment works (POTW). The nickel levels present in this solution could be further reduced by passing this solution through the reverse osmosis equipment again.

TABLE 1. QUANTITY OF INKS USED

Ink Color	Ink Type	Ink Used (g)	Ink Used (g)/100 Sheets	% Difference
Black	Petroleum	241.8	3.8	19
	Soy	162.7	3.2	
Blue	Petroleum	124.8	2.0	25
	Soy	79.5	1.6	
Red	Petroleum	109.7	1.7	0
	Soy	87.1	1.7	
Yellow	Petroleum	85.8	1.4	27
	Soy	53.6	1.1	

The amount of blanket cleaners used is shown in Table 2. Almost 46% more blanket cleaners were used during the petroleum ink run (3,455.4 g compared with 2,368.0 g). Some of this difference can be attributed to the larger amount of blanket cleaners used during the longer make-ready that occurred during this run.

TABLE 2. QUANTITY (g) OF BLANKET CLEANERS USED

Ink Type	Cleaner Name	Cleaner Used (g)
Petroleum	V120	1,768.7
	Clean Quick	1,686.7
Soy	V120	1,141.2
	Clean Quick	1,226.8

Results

Both types of inks appeared to require approximately the same amount of cleaners and effort to remove from the presses. On average in typical practice, the amount of cleaner used for the two inks would be expected to be about the same.

Based on laboratory results and on the amount of inks and cleaners used (Tables 1 and 2), the amounts of solids and volatiles in the inks and cleaners were calculated (Table 3). The amounts of volatiles were used to estimate the total mass of air emissions. Over 90% of the liquid wastes originated from the inks. As for the volatiles, over 99% originated from the cleaners in both cases.

#16 EVALUATION OF ULTRAFILTRATION TO RECOVER AQUEOUS IRON PHOSPHATING/DEGREASING BATH

Participants

R.B. White, Incorporated of Bloomington, Illinois, provided the test site and operated their process equipment during the test. The Hazardous Waste Research and Information Center (HWRIC), a division of the Illinois Department of Energy and Natural Resources, Champaign Illinois, provided test personnel, designed the test and drafted the final report.

Technology/Testing

R.B. White, Incorporated, of Bloomington, Illinois operates a sheet metal fabrication facility that manufactures painted steel shelving units.

Cold-rolled steel arrives at the plant from the steel mill coated with mill oils to protect the bare metal from corroding or staining during storage and fabrication operations. During fabrication, coolants and lubricants are also applied to the metal working surface. Before being painted, the metal surfaces are cleaned to remove the mill oils and metal working fluids and then preconditioned to bond well with the paint coating.

Fabricated parts are cleaned and phosphated in a 5000-gal heated, aqueous immersion tank and rinsed with a fresh water spray. The company previously operated separate degreasing and phosphating tanks using trichloroethylene for degreasing. In 1985, it switched to a single-stage, aqueous iron, phosphating/degreasing system to improve worker safety and reduce the generation of organic solvent emissions and hazardous waste.

Although the switch eliminated the risks and liabilities associated with organic solvents, it introduced a new waste disposal problem. Simultaneous degreasing and phosphating in the same bath formed an oil-water emulsion. With extended use, the buildup of oil in the bath reduced cleaning and phosphating efficiency, and product quality was compromised. Additionally, dragout of oil from the bath into the rinse water eventually pushed oil and grease levels in the discharge over the allowable limit.

In the past, oil skimmers were used to control oil slicks on the surface and prolong the life of the bath, but the skimmers were only partially effective. When oil in the bath began to sacrifice product quality and the discharge levels edged closer to the maximum allowable limit, the bath had to be replaced. Depending on production rates, the bath typically lasted 3 to 4 months. Replacing the bath required a full day of lost production time to take the process off-line, make arrangements with a waste transporter to drain and dispose of the contents, and recharge the tank with 5000 gallons of fresh water and raw materials.

The spent bath was classified as RCRA hazardous waste because it failed Toxicity Characteristic Leaching Procedure (TCLP) tests for xylene. Since land disposal of liquid wastes is prohibited, the bath, sludge, and skimmed oil were incinerated in a cement kiln. Disposal costs, including transportation and incineration, ran about \$1/gallon which came to \$5000/bath, or about \$15,000/yr. This amount was in addition to the costs associated with lost production time and replacement of water and raw materials.

Aqueous cleaners have already replaced solvent degreasers in many industrial surface preparation operations. The water-based cleaners effectively remove protective oils, cutting oils, hydraulic fluids, silicone oils, water soluble coolants, shop dirt, finger prints, and other contaminants. Special additives also make the aqueous cleaners versatile coating solutions. Some aqueous cleaners have made it possible to eliminate some separate degreasing and coating processes as well as reduce waste

Cost--

The main cost factor considered was that of raw materials. No equipment expenditures were required by OPS to switch from using petroleum to soy inks. The operating conditions of the press, such as temperature and speed, were the same for each ink so there was no difference in overall rate of production or utilities used because of the type of ink used. Insurance, monitoring requirements, reporting and record keeping, and permit requirements are the same for each type of ink. Any differences in future costs for remediation or property damage would be minimal. Employee health costs may slightly favor the use of soy-based inks because of reduced employee exposure to breathing released petroleum based chemicals.

The purchase prices of raw materials (inks, cleaners, and paper) for this print job are approximately the same for both types of ink. Generally soy inks cost about 10% more. The average purchase price for both the soy inks and petroleum inks is about \$8.00/lb (or \$0.018 g). Actual costs, depending on the color, range from about \$4.00 to \$12.00/lb. Costs do vary, however; when the amount of materials used for petroleum inks is compared with the amount of materials for soy inks.

Overall, soy inks have some environmental and other advantages for sheet-fed offset printers. The main environmental advantage is that they release less than 1/5th of the mass of volatile organic chemicals compared to petroleum inks. The soy inks also spread about 15% further which offsets the small difference in cost that currently exists. In this study all other factors including make-ready time, appearance of printed product, and clean-up effort were essentially equivalent between the two types of inks.

Report

The full report, entitled "Waste Evaluation of Soy-Based Ink at a Sheet-Fed Offset Printer" by Gary Miller, et al., is available as EPA/600/R-94/144.

Results from the bench- and pilot-scale studies were used to develop a full-scale modified-batch test conducted on site at the facility. Figure 1 shows how the full-scale test applied ultrafiltration directly to the 5000-gallon iron phosphating/degreasing bath.

The objective was to directly measure the effect of ultrafiltration on the process solution under actual plant conditions. The full-scale test took into account the constant input of oil from the production line and the daily addition of bath chemicals. The full-scale test also helped identify problems with the ultrafiltration equipment and anticipate changes that should be made on a permanent unit.

The full-scale in-plant testing featured an ultrafiltration system provided by Koch Membrane Systems (Model UF-4) equipped with four 1-in tabular PVDF membranes (1000,000 MWCO, 4.4 ft² total area). Data obtained from the full-scale modified-batch test was used to determine whether ultrafiltration would be a viable option for waste reduction at the plant. Technical, operational, and economic aspects associated with the ultrafiltration equipment were examined to evaluate the feasibility of this technology to improve the company's metal fabrication operation.

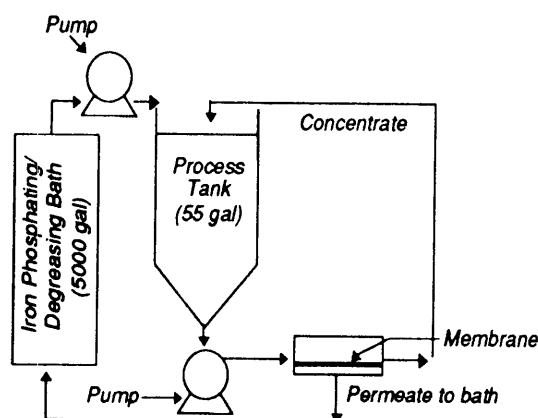


Figure 1. Modified-batch scheme ultrafiltration.

Results

When field testing began, the iron phosphating/degreasing bath had not been replaced in over 3 months. The aqueous solution was murky with dirt and oil, and large patches of free oil floated on the surface. The changes that took place over the next 11 days of ultrafiltration testing produced a dramatic effect. Surface oil slicks disappeared and were replaced by a clean, light foam. The bath solution was visibly clearer, and plant personnel testified that it looked like a freshly recharged bath. Results of total organic carbon (TOC) analyses for the full-scale testing showed the change in oil and surfactant concentrations during the test (Figure 2).

The total surface area of the boards plated for each rack was also tracked for each sampling period.

Two modifications to reduce drag out were made and independently tested after taking baseline samples. The first modification was to slow the withdrawal rate of the racks as they were pulled from the process tanks.

A second modification was tested using a withdrawal rate between the baseline and first modification rates and increasing the drain time over the process tank before transfer to the rinse tank.

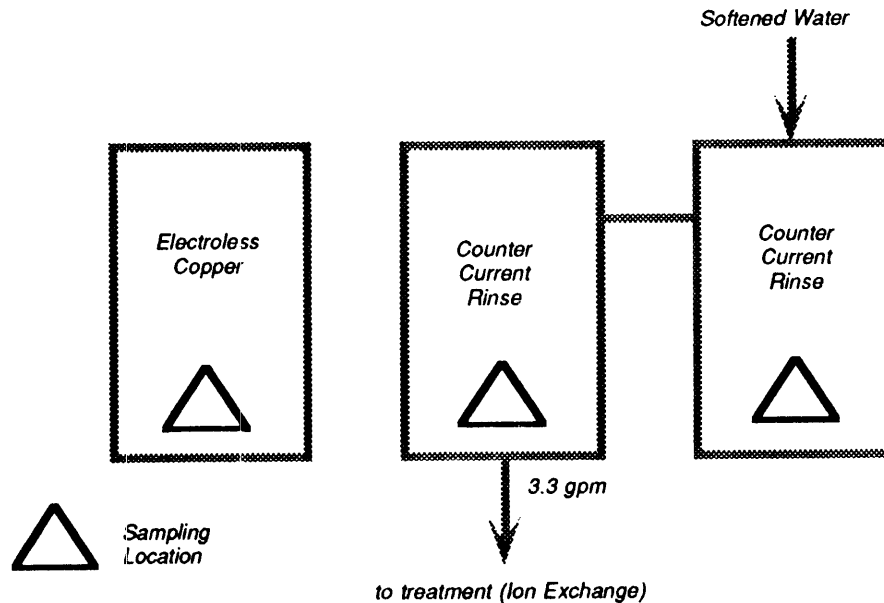


Figure 2. Electroless Copper Process Diagram

Results

Results for the micro-etch bath are summarized in Table 1, and results for the electroless copper bath are summarized in Table 2. The reduction in drag out for the micro-etch bath was 45% as a result of the first modification and 41% as a result of the second modification. For the electroless bath, drag out was reduced by 50% after the first modification and 52% after the second modification.

For modification 1, the reduction in drag out was calculated to prevent 194 g/day of copper from the micro-etch bath and 9 g/day of copper from the electroless bath from entering the rinse-water waste stream. The figures for the second modification were 180 and 9 g/day, respectively. These figures assumed a copper concentration of 30 g/L in the electroless bath and a production level of 1200 ft² of printed circuit board per day.

Economic calculations were based on the cost of existing treatment and disposal methods for the rinse-water waste streams.

#17 WASTE EVALUATION OF SOY-BASED INK AT A SHEET-FED OFFSET PRINTER

Participants

The Office of Printing Services at the University of Illinois was the host site for the project. The Hazardous Waste Research and Information Center (HWRIC), a division of the Illinois Department of Energy and Natural Resources, Champaign, Illinois, provided test personnel, designed the test and drafted the final report.

Technology/Testing

Soy inks for sheet-fed offset printing are defined as those that have a minimum of 20% soy oil by volume. The soy oil replaces petroleum oils in the ink vehicle and varnish components. Use of the soy oil affects color, drying, and other operating characteristics of the inks. Soy-based inks used in sheet-fed presses still contain at least 10% petroleum oils. Research is continuing to increase the proportions while maintaining satisfactory printing characteristics. The objectives of this study were to determine environmental impacts and associated economics.

Data for this study were collected during a full-scale print run on a Miller TP104 Plus six-color press. For this evaluation a 4400 sheet, six-color, work-and-turn print job was selected. Only four of the six colors were included in the study because the type of ink used for two of the colors was not changed between the runs. All inks included in the study were manufactured by Handschy, Incorporated of Bellwood, Illinois.

In-plant measurements consisted of weighing the containers of inks, blanket cleaners, and roller cleaners used during make-ready and printing at each press unit before and after each print run. Cleanup rags were weighed before and after each print run and wastes in the wash-up trays were weighed at each press unit at the end of each run. Samples of each type and color of ink and each cleaner used were analyzed, at the same temperature as the press, for total solids and volatile content, at the Hazardous Waste Research and Information Center's (HWRIC) Hazardous Materials Laboratory.

The operators at the university Office of Printing Operations (OPS) used the same cleaners for both petroleum and soy-based inks because no satisfactory substitutes had been identified.

Results

The study results showed that the petroleum-based ink run required larger quantities of three of the four colors of ink than the soy-based ink print run (Table 1).

#19 SPONGE ROLLERS AND FLOW CONTROLLER FOR RINSE WATER REDUCTION AT A PRINTED CIRCUIT BOARD MANUFACTURER

Participants

The host for the evaluation was Hutchinson Technology, Incorporated (HTI) plant of Hutchinson, MN. Hutchinson personnel also operated the plating equipment during the test. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, provided test equipment and personnel and drafted the test report.

The process lines used for evaluating the technologies in this study produce flexible circuits (FC's) and printed wire boards (PWB's). The lines evaluated were typical for the industry. Two studies were conducted for reducing waste water. Absorbent sponge rollers were added to reduce dragout on the horizontal FC cleaning line. A flow controller valve was added to reduce rinse water on the PWB line.

Absorbent Rollers for Drag Out Reduction--

The FC manufacturing process at HTI uses an automated horizontal wet process line that employs conveyors to transport the flexible circuits and liquid sprayers to apply the process solutions. The production line consists of the following steps:

- (1) Acid cleaner
- (2) First rinse (water from second rinse)
- (3) Second rinse (fresh reverse osmosis water)
- (4) Micro etch (sodium persulfate solution)
- (5) Third rinse (water from fourth rinse)
- (6) Acid rinse (5% sulfuric acid)
- (7) Fourth rinse (water from final rinse)
- (8) Fifth rinse (water from final rinse)
- (9) Final rinse (fresh deionized water).

At the start of the study, HTI was using pairs of hard roller squeegees (standard equipment on the horizontal process line) to remove excess solution from flexible circuits as they exited each bath. Absorbent rollers were tested as replacements for the upper squeegees between the acid cleaner and the first rinse, Steps 1 and 2 above. As each piece leaves this bath, it carries solution containing cleaner and copper salts. The acid cleaner, the squeegees, and the first rinse are shown in Figure 1. The soft, absorbent rollers that replaced hard rubber squeegees in the wet process line were made of PVA (polyvinyl alcohol), a porous material that has high absorption and retention capabilities and is pliable and elastic. PVA's resistance to abrasion and chemicals makes it appropriate for use in this type of process.

The PVA rollers were evaluated to determine the reduction of drag out from the acid bath to the subsequent rinse bath. Any reduction of drag out would mean that the rinse could maintain its dilution capability with a lower flow of fresh water into the tank, thereby reducing the volume of wastewater exiting the tank. It was expected that any reduction of drag out would necessitate more frequent replacement of the acid bath due to accelerated buildup of the impurities that previously were transferred to the rinse baths.

TABLE 3. SOLID AND VOLATILE CONTENTS OF INKS
AND CLEANERS USED (g)

Parameter	Petroleum Print Run	Soy Print Run
Ink Solids	537.17	371.36
Cleaner Solids	64.78	48.64
Total Solids	601.95	420.00
Ink Volatiles	24.93	11.54
Cleaner Volatiles	3,905.22	2,992.76
Total Volatiles	3,930.15	3,004.30

As shown in Table 3, the estimated mass of volatiles emitted from the inks is less than 1.0% of the total mass emitted from the inks and cleaners. Since most of the air emissions were from the cleaners, less than 1% overall reduction in air emissions resulted from using the soy-based inks. The longer the print run the greater the reduction in volatile emissions from using soy inks.

Liquid Components--

The two main liquid wastes from the printing press were from washup trays, and inks and cleaners on used rags.

The amount of liquids in the washup trays from this study was measured directly at the end of the print runs. Almost 10% more liquids were generated in the washup trays after the petroleum ink run. This liquid was a mixture of inks and various cleaners. The amount of each ink and each cleaner that ended up in these trays and the rags (less the amount of evaporated and on printed product) was not determined.

Differences resulted from operator induced variability, extended make-ready during the petroleum ink run, and more thorough cleaning conducted at the end of the soy ink run. From this it cannot be determined which ink generated more liquid wastes.

Solid waste that may be generated in printing includes the waste sheets in starting (make-ready) trimmings and excess number of pages printed to compensate for losses that may occur during folding, binding and any other final preparation steps. Because the soy inks generally spread further (by an average of about 17%), less used ink containers may be generated with those inks. The amount of the other solid wastes would be unaffected by the type of ink used.

Based on observations of manually operated presses at this and other facilities, automation or efficient press set-up, rather than the choice of ink, results in less solid waste being generated during printing. Once operators are familiar with the use of either the petroleum or soy inks, the amount of solid waste generated during make-ready will not be noticeably different. In both cases, more waste paper might be generated on some jobs because of difficulties in obtaining acceptable colors or other print quality factors. In this regard, neither ink appears to have a clear advantage over the other.

Results

Absorbent Rollers--

The average drag out rate decreased from 27.6 ml/ft² with hard rollers, to 9.8 ml/ft² with the sponge rollers, or a reduction of 65%. At the 1.0 gpm flow rate used with the hard rollers, about 120,000 gallons of wastewater were discharged per year, assuming 250 eight-hour work days. If drag out is reduced by 65%, the flow of water into and out of the rinse tank could also be reduced by 65%. This is a projected savings of 78,000 gallons/year, with an equal decrease in wastewater generation.

With reduced drag out, the acid bath will require less frequent replenishment with concentrate and water to maintain sufficient volume. However, it will require more frequent replacement to preserve cleaner effectiveness.

The amount of cleaner concentrate and water needed to replenish the acid bath solution will be reduced by the same amount as the drag out. At the hard roller drag out rate of 0.175 gpm for the typical circuit production rate of 24 ft²/min, about 2100 gallons of cleaner concentrate and 18,900 gallons reverse-osmosis water are required annually to maintain production. (0.175 gpm x 60 min/hr x 8 hrs/dy x 250 days/yr = 21,000 gal/yr solution; concentrate:water = 1:10). With the PVA rollers and the resulting 65% reduction in drag out, the annual requirements for concentrate are an estimated 744 gallons, while water requirements drop to 6696 gallons. Total drag out becomes 7440 gallons of cleaner per year. This produces an annual savings of 1356 gallons of cleaner concentrate and 12,204 gallons of water.

Controlled Flow--

Data were collected on the volume of rinse water used in the final counter-current cascade rinse of the tin-lead plating line during the one week period before the conductivity sensor and automatic valve were installed. At the 0.4 gpm flow rate, a total of 1810 gallons of water were used in the rinse when continuous flow was maintained for the duration of each work shift. A total of 320 PWBs, each with a 4 ft² surface area (12 in x 24 in per side), were processed during this week. The total PWB area produced was 1280 ft², and 1.41 gallons rinse water were used per square foot of PWB. The water used was constant at 1810 gallons per week, regardless of the production rate, when the line was operated without the use of the control system.

With the control system installed and set at 30 micro Siemens (mS), 430 gallons of water were used to process 167 PWBs, or 668 ft², during the week following installation. This is a rate of 0.64 gal/ft² of PWB, an apparent 55% reduction when compared with the 1.41 gal/ft² measured the week before. However, in order to compare the actual water savings, it is necessary to note that, with the previous method of preset continuous inflow, 1810 gallons of water would have been used regardless of production. The second week required only 430 gallons, a 76% reduction from the continuous flow practice of 1810 gallons per week. At an average production rate of 300 PWB per week, annual water use would be 90,500 gallons without the flow controller (based on 1810 gal/wk and 50 weeks/yr.) and 38,400 with the flow controller (based on 300 PWB, or 1200 ft²/week, 50 weeks/yr, at 0.64 gal/ft²).

Economic Evaluation for Absorbent Rollers--

Table 1 compares operating costs for the acid cleaning step and subsequent rinse with the hard roller squeegees and with the soft, absorbent rollers. The costs are based on operating one, 8-shift per day, 250 days per year.

MINNESOTA

Of the five technologies evaluated one was performed under the auspices of the Minnesota Technical Assistance Program (MnTap), Cindy McComas, project officer. Two more sites, Hutchinson and Paramax were identified with the assistance of MnTap (Paul Pagel), project officer) while the remainder (McCurdy, SL Modern Hardchrome and Aeroquip) were located and tested with the assistance of Battelle, Columbus Laboratories. All five are in the area of electroplating process improvements. The EPA project officer was Teresa Harten.

#18 MODIFICATIONS TO REDUCE DRAG OUT AT A PRINTED CIRCUIT BOARD MANUFACTURER

Participants

The host for the evaluation was Micom Incorporated of Brighton, MN. Micom personnel also operated the equipment during the test. The design of the test program was a collaboration with EPA and the Minnesota Technical Assistance Program (MNTAP) of the University of MN, on a cooperative agreement with the Minnesota Pollution Control Agency. MNTAP supplied test personnel and helped to write the draft report.

Technology/Testing

The project evaluated modifications that reduce drag out at a single plating line of a printed circuit board manufacturer. It was hoped that by demonstrating the success of the modification in a fully operational setting, the technology would be transferred to other plating/rinsing systems within the company as well as to other companies in the metal finishing industry.

Two interrelated modifications that effectively help prevent wastes from entering the rinsing processes are (1) reducing drag out, which is the carryover of concentrated solutions from plating baths and (2) reducing rinse water flows. When drag out is reduced, rinse water can be conserved because less will be needed to achieve effective rinsing.

Procedure--

The evaluation took place at the sensitize line where a number of process baths including etchant (micro-etch), activator, accelerator, electroless copper, and rinse tanks, first etch and then chemically deposit copper onto the insides of the circuit board through holes. Drag out from two of the line's process baths, the micro-etch and the electroless copper, was a significant source of copper discharged into the rinse-water waste stream leaving the line. Figure 1 shows a schematic of the micro-etch process, and Figure 2 provides the same for the electroless copper process. Rinse water from the two processes had to be treated by an onsite, ion-exchange unit for copper removal before it could be discharged to public sewer.

Treatment of spent micro-etch and electroless baths included copper recovery in both cases and regeneration of etchant in the case of the micro-etch solution.

To determine baseline drag out, samples were taken at the process tanks and at the two rinse tanks following each process tank - both before and after a rack of circuit boards was moved through the three-tank system. Over a 2-week period, 12 sample sets were taken to calculate 12 baseline drag out values. Additional measurements taken to calculate drag out included rinse-tank water volumes for each of the rinses. These volumes were measured during each of the 12 sampling periods.

TABLE 2. OPERATING COST COMPARISON OF CONTINUOUS AND CONTROLLED FLOW

	CONTINUOUS FLOW			SENSOR-CONTROLLED FLOW	
	Unit Cost	Units/yr	Cost/yr	Units/yr	Cost/yr
MATERIALS AND EQUIPMENT					
Controller Maintenance	\$25/hr	N/A‡	N/A	2 hrs	\$50
Deionized water for rinse†	\$17/1000 gal	90,500 gal	\$1,538	38,400 gal	\$653
WASTE MANAGEMENT					
Water Treatment	\$13/1000 gal	90,500 gal	\$1,176	38,400 gal	\$499
TOTAL COST			\$2,714		\$1,203
NET SAVINGS					\$1,511

* All Unit cost data were provided by HTI.

† Cost includes ion exchange regeneration and waste disposal costs.

‡ N/A = not applicable because maintenance not required.

Note: The average production rate of HTI of 300 PWB/week on the tin-lead line was used to estimate water consumption.

The cost of the rinse water control equipment was \$250, and installation required about 10 hours at \$25 per hour, for an installed cost of \$500. If the maintenance cost is included, the total capital cost for the first year's use of the rinse water controller is \$550. With a total savings of \$1511, the payback is less than 5 months (payback=\$550/\$1511 per year = 0.36 yrs).

Using absorbent rollers reduced the quantity of acid cleaner concentrate and water required to maintain the bath. It allowed the amount of water flowing into the rinse to be decreased in proportion to the reduction in drag out and reduced the total copper loss from the acid bath and the subsequent rinse by more than 50%. This reduces the heavy metal content of the sludge resulting from wastewater treatment.

The acid cleaner was found to degrade the soft rollers over time, requiring that they be replaced every five to six months. The materials compatibility of the rollers and the solution must be considered for all applications. The replacement cost and labor to replace the rollers were low enough that they had little impact on the annual savings. The payback period for the equipment change was less than one week.

Overall, the use of soft, absorbent rollers proved very effective in minimizing drag out even though they were used only on the top surface of the flexible circuits due to the processing equipment and items tested at HTI. It is expected that the rollers would be even more effective if used both above and below the flexible circuits, as recommended by the manufacturer. The rollers can be applied to other types of processing lines in which the items can be passed between a set of the rollers.

Report

The full report, entitled "Sponge Rollers for Drag Out Reduction and Flow Controller for Rinse Water Reduction At a Printed Circuit Board Manufacturer" will be published as an EPA series 600 report.

TABLE 1. SUMMARY OF MICRO-ETCH RESULTS

Sampling	Withdrawal Rate (ft/min)	Time of Withdrawal (seconds)	Drain Time (seconds)	Total Time (seconds)	Drag Out (ml/ft ²)
Baseline	100	1.7	3.4	5.1	12.1
Mod 1	11	14.9	2.5	17.4	6.7
Mod 2	40	4.3	12.1	16.4	7.1

TABLE 2. SUMMARY OF MICRO-ETCH RESULTS

Sampling	Withdrawal Rate (ft/min)	Time of Withdrawal (seconds)	Drain Time (seconds)	Total Time (seconds)	Drag Out (ml/ft ²)
Baseline	94	1.8	5.2	7.0	6.0
Mod 1	12	13.9	3.2	17.1	3.0
Mod 2	40	4.3	11.9	16.3	2.9

The economic evaluation showed that the company could save \$2640 per year in rinse water treatment and disposal costs by implementing modification 1 or \$2460 per year by implementing modification 2. An additional savings of \$710 per year for modification 1, or \$660 for modification 2, could be realized in avoided water and sewer charges if the company reduced rinse-water flow rates in proportion to the reduced copper contamination resulting from the modifications.

The company decided to adopt the second modification as its normal operating procedure. The increase in drain time did not slow production at the company.

Report

The full report, titled "Modifications to Reduce Drag Out at a Printed Circuit Board Manufacturer", by Teresa M. Harten et al., is available as report no. EPA/600/SR-92/114.

The BH™ bath (Step 5) is an aqueous, carbon-black dispersion which eliminates the need for EC metalization before electrolytic plating. The steps before and following Step 5 are similar to those used in the EC process.

Unlike the EC process, with BH™ technology the rinse after the microetch process step is the only rinse water stream that goes to the ion-exchange system. The rest goes to the discharge line. The carbon-black dispersion process uses only two rinse water flows, and the process solutions contain nonhazardous material.

Waste Reduction Evaluation--

The amount of waste resulting from the EC operation, run at full production, was evaluated to represent baseline data. The amount of waste from the carbon-black dispersion process using BH™ technology, run at 1/2 capacity, was then compared with this baseline. The rinse water characterization included analyses for copper, pH, and total solids content.

Results

The production rate on the carbon-black dispersion process line using BH™ technology (i.e., 3.3 ft²/min) was found to be 2.1 times as fast as the production rate on the electroless copper (EC) process line (i.e., 1.6 ft²/min). Production rates were timed during field testing and compared with production schedules maintained by McCurdy Circuits. McCurdy Circuits operates the electroless copper process at approximately the full capacity of 1.6 ft²/min. which yields 200,000 ft²/yr.

Tables 1, 2, and 3 show annual projections of the chemicals used, costs incurred, and wastes generated, with the process operating at capacity.

Conclusions--

Because the carbon-black dispersion process reduces wastes, avoids many hazardous chemicals and metals, is cost effective, and yields an acceptable product, it should be considered a viable alternative to the EC process. If the shop involved is a job shop, client input and requirements would be important in determining the feasibility of incorporating the carbon-black dispersion process. Although this study provides generalizations for companies considering carbon-black dispersion, it is recommended that each company examine its specific requirements to determine the suitability of this alternative technology for specific applications.

Formaldehyde (a suspect human carcinogen that poses a significant health hazard when inhaled or ingested or through direct physical contact) is completely eliminated in the BH process, whereas approximately 200 gal/yr are used in the EC bath. Palladium and trace amounts of cyanide, also used in the EC process, are not present in the carbon-black dispersion process.

Economic Evaluation--

The economic evaluation was based on data obtained from McCurdy Circuits, including the unit costs and amounts used of chemicals and water, and from suppliers. The current capital cost of carbon-black dispersion equipment was obtained from an equipment vendor. The calculations are based on the production rate of 200,000 ft² of PWB per year, approximately the rate of the current EC system. The BH process cost basis is half a year, running at capacity, i.e., the time it would take to process approximately 200,000 ft² of PWB.

Conductivity-Sensor-Controlled Flow Valve--

The tin-lead plating line for printed wire boards uses plating baths and racks to hold and move items through the line. It consists of the following process steps:

- (1) Acid cleaner (weak)
- (2) Rinse (water from Step 3)
- (3) Rinse (water from Step 5)
- (4) Preposi-etch
- (5) Rinse (water from Step 6)
- (6) Rinse (fresh tapwater)
- (7) Sulfuric acid dip (10%)
- (8) Acid copper plate
- (9) Rinse (water from Step 10)
- (10) Rinse (fresh tapwater)
- (11) Tin-lead plate
- (12) Rinse (water from Step 13)
- (13) Rinse (water from Step 14)
- (14) Rinse (fresh deionized water)

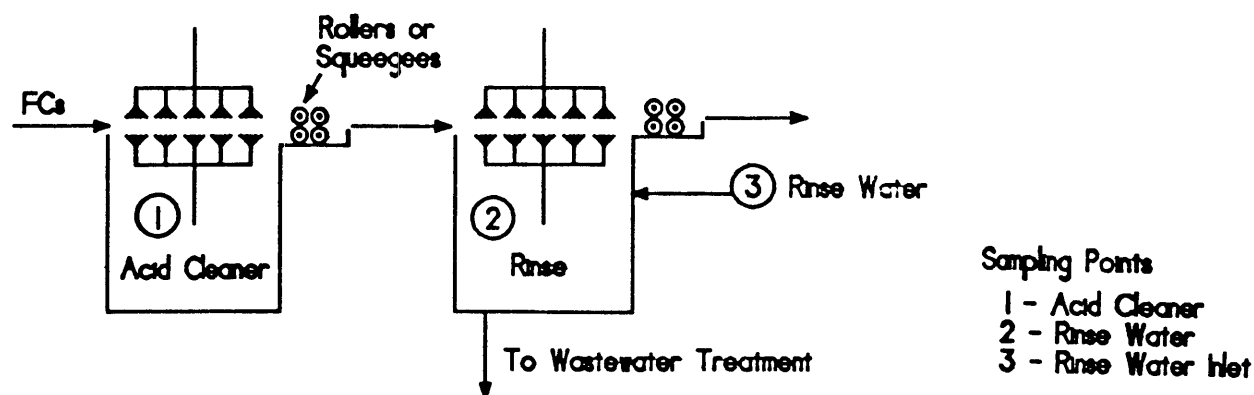


Figure 1. Drag out reduction

A conductivity controller was installed in the final rinse tank (Step 14). When the study began, HTI was maintaining a continuous 0.4 gpm fresh water flow into this tank when the line was running. This rate had been established by HTI to provide adequate rinsing. The shortcoming of this approach was that the inflow is not reduced during periods of light production. This resulted in a steady stream of wastewater that must be treated, even though it may be only slightly contaminated.

HTI engineers adapted a flow valve so that it was controlled by a conductivity sensor. This was a simple adaption of standard equipment, at a cost of \$250. Such systems can also be purchased from equipment suppliers, at about the same cost.

When rinse water conductivity, as a measure of metal content exceeds a specified point, the valve opens, adding fresh deionized water to the rinse. Once conductivity drops below the set point, the inflow of water is stopped. As compared with the practice of maintaining a uniform flow, this approach should conserve water, particularly during periods of reduced plating line throughput. Decreased water use would reduce the wastewater volume and treatment costs.

In tests conducted by McCurdy Circuits, product quality of the carbon dispersion processed boards was equivalent to that of the electroless copper processed boards. In addition, PWBs using the BH carbon dispersion technology have passed MIL-P-55110D qualification and performance standards for plated through-holes.

TABLE 2. COMPARISON OF ANNUALLY ADJUSTED MAJOR OPERATING COSTS*

Description	Electroless Copper	Blackhole™	Blackhole™ Savings, %
Chemicals	\$89,600	\$37,500	58
Tap water	3,200	403	87
D.I. water	503	38.3	92
Energy ^(b)	N/A	N/A	0
Labor	50,000	25,000	50
Waste disposal	N/A	N/A	0
Waste treatment labor	10,000	3,330	67
Totals	\$153,000	\$66,300	57

* Because the BLACKHOLE™ production rate is approximately twice as fast as that of the electroless copper process, the costs are adjusted to take this into account. The BLACKHOLE™ costs reflect a half year of processing, where as the electroless copper costs represent a full year.

TABLE 3. SUMMARY OF WASTE REDUCTION

Waste Types	Electroless Copper Process	Blackhole™ Process	Net Change in Waste
Rinse water	13.8 gal/ft ²	1.7 gal/ft ²	12.2 gal/ft ²
Chemical use	11,755 gal + 38 lb	90 gal + 611 lb	not calculable
Copper waste (in rinse water)	324 mg/ft ²	248 mg/ft ²	76 mg/ft ²
Total solids	23,800 mg/ft ²	4,510 mg/ft ²	19,300 mg/ft ²

Report

The full report, titled "Carbon Black Dispersion Preplating Technology for Printed Wire Board Manufacturing" by Dale Folsom, et al., is available as report no. EPA/600/R-93/201.

There is an overall savings of over 50% in annual operating costs. Although costs for roller replacement and bath treatment increase when the PVA rollers are used, these increases are more than offset by net savings in water and acid cleaner concentrate and in waste rinse water treatment. The cost of using the hard rollers is an estimated \$29,865 per year. The estimated cost of using the soft rollers is \$13,322 per year, a reduction of \$16,543.

Payback is defined as the minimum time to recover the capital cost of the equipment (payback in years = capital cost/savings per year). The capital cost of are \$200 for two sets of rollers, yielding a payback of less than a week (\$200/\$16,537).

TABLE 1. OPERATING COST COMPARISON OF HARD AND SOFT ROLLERS

	Unit Cost*	Hard Rollers		Soft Rollers	
		Units/yr	Cost/yr	Units/yr	Cost/yr
Materials & Equipment					
Replacement rollers	\$50/ea	—†	—	4	\$220
Reverse-osmosis water for rinse	\$10/100 gal	120,000 gal	\$1,200	42,000 gal	\$420
Reverse-osmosis water for bath replenishment	\$10/1,000 gal	18,900 gal	\$189	6,696 gal	\$67
Acid cleaner concentrate for bath replenishment	\$11.75/gal	2,100 gal	\$24,675	744 gal	\$8,742
Bath replacement (cleaner+water+labor)	\$396/bath	4 baths	\$1,584	6 baths	\$2,376
Waste Management					
Rinse water treatment	\$13/1,000	120,000 gal	\$1,560	42,000 gal	\$546
Bath batch treatment	\$0.50/gal	1,240 gal	\$620	1,860 gal	\$930
Sludge disposal	\$245/ton	306 lb	\$37	336 lb	\$41
Total cost			\$29,865		\$13,322
Net Savings					\$16,543

* All unit cost data were provided by HTI.

† Hard rollers last indefinitely.

Economic Evaluation for the Sensor-Controlled Valve--

Table 2 summarizes the estimated annual operating costs for the tin-lead line, final rinse before and after the rinse water controller was installed. Significant savings are realized from the reduced use of water. These are slightly offset by maintenance costs for the controller. The effect on sludge disposal costs is negligible.

With the flow controller, a savings of 52,100 gallons per year could be realized, assuming the line operates for 50 weeks. At a cost of \$17 per 1000 gallons deionized water and \$13 per 1000 gallons for wastewater treatment this amounts to a savings of \$1563 per year for water purchase and waste treatment.

Materials and Methods--

One test site uses a chromium plating solution and one a chromic acid for etching copper. At each site, metal analyses were performed on the chromium solution and the catholyte solution to determine contaminant levels in the process solution and the rate of metals buildup in the catholyte solution. From the analyses, the rate of metals buildup in the catholyte solution was determined. This corresponded with metals removal from the process solution, which in turn was used to determine the bath life-extending capabilities of the lonsep™ process and the waste reduction potential.

Operating costs with and without the lonsep™ process were used along with installation costs to determine the economics of the process.

Results

The results from the two sites are discussed separately for each site because the bath process and the lonsep™ process used at the two sites were different. For each site, the discussion is divided into the three project objectives: waste reduction potential, economic evaluation, and product quality evaluation.

Chromium Plating at SL Modern Hard Chrome--

At SL Modern Hard Chrome's 1,400-gal hard chromium plating solution was recovered continuously by placing the lonsep™ unit (cell) directly into the bath. The catholyte solution is contained in a plastic 55-gal drum outside the bath and is circulated through the lonsep™ cell.

The waste generated by the process is sludge from the lonsep™ catholyte solution. This catholyte sludge contains levels of chromium at 2000 to 3200 mg/L total chromium and 760 to 1050 mg/L hexavalent chromium and therefore must be handled as a hazardous waste. With the catholyte solution replaced monthly, the annual discharge of total chromium is 6.5 kg (14.2 lb).

The bath life is projected to be over 40 years, which results in approximately 35 gal of solution saved/yr (that would otherwise be disposed of), based on an operation schedule of 250 days/yr (1,400-gal bath/40 yr).

Waste hexavalent chromium is significantly reduced with the use of the lonsep™ unit - from 165 lb to 14.2 lb. The 14.2 lb of chromium is the small amount lost to the catholyte solution. The reduction is the result of not having to replace the bath periodically and of having all rinse water returned to the plating bath to make up evaporative water losses.

Chromium is saved not only through reduced replacement of plating solution, but also through the reduced number of rejects. For every reject, the company must strip and replate the part. The reject data are based on estimates of plant personnel, because no records were maintained. This decrease in rejects is estimated at 5% and corresponds to approximately 237 lb chromium/yr that is not disposed of with the stripper and that need not be purchased for addition to the plating solution. The 237 lb of chromium oxide is calculated from the company's plating rate from this bath of 42,900 ft²/yr, at a plating amount of 1.77 oz CrO₃ per ft², and a 5% savings (0.05x 42,900 ft²/yr x 1.77 oz/ft² x 1/16 oz/lb.)

#20 CARBON-BLACK DISPERSION PREPLATING TECHNOLOGY FOR PRINTED WIRE BOARD MANUFACTURING

Participants

The host company for the evaluation was McCurdy Circuits of Orange County, CA. McCurdy personnel also operated the plating process during the test. Battelle, Columbus Laboratories helped design the test program, supplied test personnel and equipment, and wrote the draft report.

McCurdy operates two process lines for the through-hole plating of Printed Wire Boards (PWBs): one uses electroless copper (EC) and the other uses the carbon-black dispersion process. The EC process at McCurdy Circuits consists of the following 18 operational steps:

1. Acid cleaner
2. Rinse (to discharge line)
3. Microetch (sodium persulfate solution)
4. Rinse (to ion exchange line)
5. Activator-pre-dip
6. Catalyst
7. Rinse (to discharge line)
8. Rinse (to discharge line)
9. Accelerator
10. Rinse (to discharge line)
11. EC
12. Rinse (to separate ion exchange system)
13. Sulfuric acid 10%
14. Rinse (to ion exchange system)
15. Anti-ox
16. Rinse (to discharge line)
17. Deionized (D.I.) water rinse (to discharge line)
18. Forced air dry

In the first 17 steps, racks of PWBs are moved from tank to tank with an automated hoist. All the rinses are single flow through, which generates more wastewater than does cascading or multiple-use rinses. Because of drag out, the rinse following the EC bath (Step 11) contains complexed copper, which is hard to treat by typical metal hydroxide precipitation. Rinse water from the EC process is collected in one of three drain lines: one to a discharge line, another to the first ion-exchange collection system, and the third to an ion-exchange system for the EC rinse.

Whereas the EC process is essentially a batch process, the carbon-black process is a continuous system in which parts are placed on a roller conveyor. This carbon-black dispersion technology, termed BLACKHOLE™ (BH) technology by the vendor/inventor, consists of fewer baths and a simplified process. It has only the following 11 process steps:

1. BH™ cleaner
2. Rinse (water from step 4, to discharge line)
3. BH™ conditioner
4. Rinse (fresh tap water, to rinse #2)
5. BH™ bath
6. Dryer
7. Microetch
8. Rinse (water from step 10, to ion exchange system)
9. Anti-tarnish
10. Rinse (fresh tap water)
11. Dry

TABLE 2. ECONOMICS OF THE CHROMIUM PLATING LINE*

Description	Annual Use	Rate (\$)	Annual Cost (\$)
<u>Without lonsep™</u>			
Cr bath	35 gal	\$11.30/gal	\$ 396
Bath disposal	35 gal	2/gal	70
CrO ₃ due to rejects	237 lb	1.13/lb	268
Labor due to rejects	140 hr	20/hr	2,800
Strip solution replacement and disposal	100 gal	1.50/gal	150
Total without lonsep™			\$3,684
<u>With lonsep™</u>			
Catholyte solution			
Sodium sulfate	120 lb	18/100 lb	22
Sodium carbonate	288 lb	18/100 lb	52
Water	660 gal	2.66/1000 gal	2
Barium carbonate	36 lb	1.22/lb	44
Sludge disposal	4 drums	205/drum	820
Labor	41 hr	20/hr	827
Maintenance	-----	-----	1,080
Power	8,100 Kwh	.0902/Kwh	731
Total with lonsep™			\$3,578
Annual Savings			\$ 106

* Wastewater discharge costs are not applicable. Analytical costs are assumed to be the same for both cases.

Chemical analyses of the chromium plating solution were conducted to verify that the solution met operational specifications for hard chromium plating solutions. Analysis of the bath showed it was within specifications. The contaminant level was below the maximum of 52 g/L and the chromium level was above the minimum of 140 g/L.

The chromium-plated parts, are inspected for pits, blisters, other deformities, and chromium thickness. Since installation of the lonsep™ unit, the number of rejects has decreased by about 5%. The improved chromium plating quality has produced more uniform chromium deposit and fewer pits.

Paramax--

At Paramax, chromium-based etchant was tested as a batch process. Eight of the six cells in the process line were used, and over a 2-day period, 200-gal etchant baths were removed from the process line to a treatment tank and pumped through the lonsep™ unit. The unit ran continuously for 3 days.

Annual chemical usage and cost for both processes are shown in Table 2. As seen in Table 3, BH has lower operating costs than does EC in all cost categories that could be obtained from company data. The major savings accrued through lower chemical and labor (time) costs, and the total savings added up to more than 50%.

TABLE 1 ANNUAL CHEMICAL USE AND COSTS

Description	Chemical Usage (gal/yr)	Unit Cost (\$/gal)	Cost (\$/yr)	Adjusted Cost (\$/yr)
EC Acid cleaner	145	21.70	3,150	3,150
Microetch:				
Sulfuric acid	195	0.08	15.26	15.6
Sodium persulfate	1,800 lb	1.00 lb	1,880	1,880
Activator	2,500	3.35	8,380	8,380
Catalyst:				
Predip	15.9	3.35	53.3	53.3
Catalyst	21.8	280	6,100	6,100
Accelerator	393	18.65	7,300	7,300
Electroless Copper:				
Copper	3,950	10.35	40,900	40,900
Sodium hydroxide	2,250	2.50	5,630	5,630
Formaldehyde	199	6.20	1,230	1,230
Sulfuric Acid	308	0.08	24.6	24.6
Anti-Ox	1,250	11.95	14,900	14,900
Blackhole™			Total:	89,600
Cleaner	41.2	400	16,500	8,250
Conditioner	41.4	400	16,600	8,280
Blackhole™	68.0	595	40,500	20,250
Microetch				
Sodium persulfate	1,130 lb	1.00	1,130	565
Sulfuric acid	13.2	0.08	1.06	0.53
Copper sulfate	50.0 lb	6.62	331	166
Anti-Tarnish				
CTCS 501	6.60	12.00	79.2	39.6
Sulfuric acid	3.30	0.08	0.26	0.13
			Total	37,500

* Because the BLACKHOLE™ process has a production rate of approximately twice that of the electroless copper process, costs were adjusted to compare a half year of processing for BLACKHOLE™ to a full year for electroless copper.

BH equipment having the capacity of the system tested at McCurdy Circuits cost \$212,000 (in 1992 dollars), with an estimated installation cost of \$9,000. The payback period is less than 4 yr, with an assumed cost of capital of 15%.

Economic Evaluation--

Because the lonsep™ unit at Paramax is still undergoing testing, most of the cost analysis was based on Paramax estimated derived from economic information in plant records and experience of Paramax personnel. These estimates indicated that the unit can prevent disposal of approximately seven etchant baths/wk and, thus, save disposal and replacement chemical costs.

Operating cost factors involved in the economic analysis for Paramax include labor, maintenance, chemicals, utilities (water and electricity), and waste treatment/disposal. Table 4 compares costs with and without the lonsep™ unit.

TABLE 4. ECONOMICS OF THE ETCHING LINE

Description	Annual Use	Rate (\$)	Annual Cost (\$)
<u>Without lonsep™</u>			
Etchant (concentrate)	20,625 gal	4.85/gal	\$100,031
Etchant disposal	41,250 gal	2.31/gal	95,288
Labor for disposal	150 gal	20.00/hr	3,000
Water*	20,625 gal	2.66/1000/gal	55
Total			\$198,374
<u>With lonsep™</u>			
Catholyte solution:			
Sodium chloride	10,000 lb	3.50/50 lb	700
Sodium sulfate	5,000 lb	17.50/100 lb	875
Soda ash	1,000 lb	0.23/lb	230
Water*	25,000 gal	2.66/1000 gal	66
Labor	2,000 hr	20.00/hr	40,000
Maintenance	—	—	30,000
Power	1,430 Kwh	0.045/Kwh	65
Total			\$ 71,936

* Water costs include sewage fee.

The capital cost of the unit (specific to Paramax), including installation and modifications, was \$563,000. Dividing this by the estimated annual savings results in a payback period of 4.5 yr.

#21 EVALUATION OF AN ELECTRODIALYTIC PROCESS FOR PURIFICATION OF HEXAVALENT CHROMIUM

Participants

The host companies for this evaluation were Paramax Incorporated of St. Paul, MN and SL Modern Hard Chrome in Camden, NJ. Both companies operated their electrodialytic equipment during the test. Battelle, Columbus Laboratories helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology and Testing

SL Modern Hard Chrome has specialized in industrial hard chrome plating for over 35 years and plates a full spectrum of materials, ranging from aluminum through the copper, ferrous, and nickel base alloys to zinc.

Paramax uses a chromic acid solution to etch copper from printed wire boards (PWB). As copper builds up in the etching solution, the etching rate becomes unacceptably slow. Prior to installing Ionsep™, the chromic acid solution was replaced with fresh solution at the operator's discretion. Replacement frequency ranged from once a day to once a week.

Ionsep™ Electrodialytic Process--

The Ionsep™ process extends the life of process solutions by removing metals other than chromium from the process solution. This improves plating and etching product quality and extends process solution life. For this application, the process removed copper and converted some of the trivalent chromium to hexavalent.

Figure 1 shows a two-compartment cell used for the purification of a chromium plating solution. The Ionsep™ electrodialytic process uses a voltage gradient to separate salt in a solution into cations and anions.

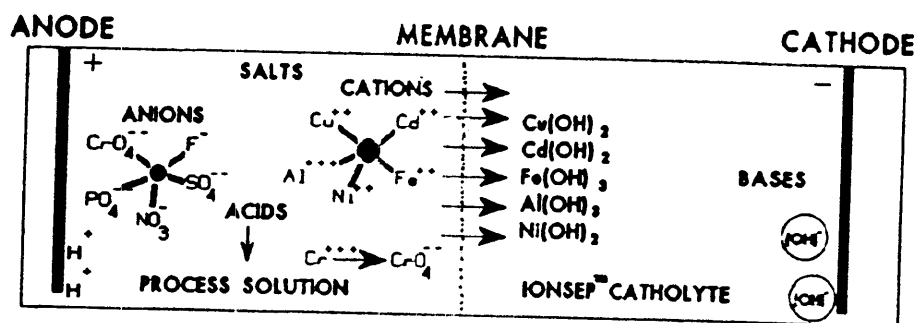


Figure 1. Ionsep™ electrodialytic process
(Source: Ionsep™ Corporation, 1989)

Chromium is present in the anionic chromate form in the plating and etching solutions. Metal contaminants (cations) migrate across a semipermeable membrane, under the influence of the electric field. Conversion of the electroplatable metal cations to insoluble hydroxides occurs when the cations migrate through the membrane; this migration eliminates the buildup of metals on the cathode. Membranes in the electrodialytic cells serve to physically separate the acidic, basic, and other process solutions.

#22 SUBSTITUTING CADMIUM CYANIDE ELECTROPLATING WITH ZINC CHLORIDE

Participants

The host for the evaluation was Aeroquip, Incorporated, Industrial Connectors Division, Van Wert, Ohio. Industrial Connectors personnel also operated the electroplating system during the test. Battelle, Columbus Laboratories helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

The cadmium cyanide and the zinc chloride plating processes for the rack plating line at Aeroquip are compared in Table 1. Hydrochloric acid is used to condition parts (shown as step 12 in Table 1) before plating in the zinc chloride process whereas sodium cyanide is used in the cadmium cyanide process.

The cadmium cyanide plating line had separate tanks to apply either clear chromate or yellow chromate coatings (steps 18 and 20). Previously, Aeroquip used clear chromate coating on most (90% to 95%) of the cadmium-plated parts.

Currently, Aeroquip uses yellow chromate coating on all zinc-plated parts because (1) Aeroquip has adopted a worldwide standardization and (2) yellow chromate coating vastly improves the corrosion protection of the zinc-plated fittings.

The yellow chromate solution used by Aeroquip contained approximately a five times greater chromium concentration than did the clear chromate solution. In the water-soluble oil application step (step 22) the concentration of the oil was reduced by a factor of approximately ten in the zinc chloride plating process from the level used in the cadmium cyanide plating process. The change was necessary to obtain improved adhesion of chromate coating during the subsequent heat-curing step.

All wastes from the plating operations end up in three waste streams -- treated wastewater, dewatered sludge, and waste oil -- that are discharged or sent for disposal from the wastewater treatment plant. The treated wastewater is discharged to a waste sewer. The dewatered sludge is collected in a 20-yd³ hopper and sent to an off-site hazardous landfill once a month. The waste oil is collected in drums and sent to an off-site hazardous waste incinerator every 3 months.

Product Quality Evaluation--

Product quality was measured by the corrosion resistance of plated parts determined by salt-spray tests carried out in accordance with the ASTM Method B117-90 (Standard Test Method of Salt Spray [Fog] Testing). As part of their quality acceptance criteria for zinc-plated parts, Aeroquip's engineering process specification has adopted the ASTM Method B633-85 (Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel) requirement of 96 hr of freedom from white corrosion products in salt-spray testing. An additional internal acceptance test by Aeroquip was performed. The acceptance criterion is freedom from red rust after 360 hr exposure to salt spray.

Table 1 summarizes the waste reduction potential of the new technology. The top part of Table 1 lists the wastes from infrequent bath replacement and the estimated amount of chromium stripped from rejected parts. The bottom part of Table 1 lists the chemicals used to make the lonsep™ catholytic solution and the additional barium carbonate used to adjust the sulfate levels of the chromium plating bath.

TABLE 1. WASTE REDUCTION OF THE CHROMIUM PLATING LINE

Waste	Annual Generation
<u>Without lonsep™</u>	
CrO ₃ in bath solution	80 lb (41.6lb Cr)
CrO ₃ due to rejects	237 lb (123lb Cr)
Total CrO ₃	317 lb (165 lb Cr)
<u>With lonsep™</u>	
Catholyte solution	
Sodium sulfate	120 lb
Sodium carbonate	288 lb
Additional barium sulfate from sulfate reduction w/BaCO ₃	43 lb
<u>Total†</u>	<u>451 lb (14.2 lb Cr⁶⁺)</u>

* Sludge from lonsep™ not included because it should equal the amount of metal contaminants disposed of with the chromium plating solution without lonsep™

† The sludge for 1 yr would contain 14.2lb Cr⁶⁺.

The annual operating costs with and without the lonsep™ units are itemized in Table 2. The capital cost of a 250-amp lonsep™ unit in the fall of 1991 was \$20,000. Because there is a savings of \$106 in annual costs using the lonsep™ unit, there is a payback on the unit of 189 yr.

Although economic considerations are important, they are not the only justification for installing waste reduction equipment. SL Modern Hard Chrome has zero discharge from its plating operations to the city water treatment system because all rinsewater is returned to the plating baths.

A second comparison test was conducted by Aeroquip to directly compare performance of cadmium and zinc plated parts. Seven groups of parts of each zinc and cadmium plating, and representing rack and barrel plating products were subjected to the 96hr white corrosion and 360 red rust salt spray tests.

Results

The initial test zinc plated parts from the rack plating line passed the 96 hr test but a small number of parts (3 of 48) in each laboratory did not pass the 360 hr. red rust test. The barrel plating line, zinc plated parts passed both the 96 and 360 hr tests. White corrosion started to appear after 168 hrs. Red rust was first noticed at 432 hrs.

The comparison test series resulted in all the zinc coated parts passing the 96 hr, white corrosion and 360 hr, red rust tests. Red rust first appeared in some types of parts after 504 hrs.

All cadmium plated parts passed the 96 hr test for white corrosion. The appearance of white corrosion was delayed to 336 hrs and beyond. No red rust was observed on any of the cadmium-plated specimens after 504 hr of exposure, at which point the tests were ended.

These results demonstrated that while both types of plating passed the comparison tests, the cadmium-plated parts exhibit a superior corrosion resistance to zinc-plated parts with regard to the appearance of white corrosion products and red rust in salt-spray tests.

Waste Reduction Potential--

Waste reduction potential of the process substitution was determined on the basis of waste volume reduction and reduction of toxic pollutants. Waste volume reduction was estimated for the treated wastewater and the dewatered sludge. Toxic pollutants were cadmium, cyanide, chromium, and chlorine. Tables 2 and 3 show the changes in the total waste and toxic pollutant reduction, respectively.

TABLE 2. ANNUAL GENERATION OF RELATED WASTEWATER AND SLUDGE FROM CADMIUM- AND ZINC-PLATING PROCESSES (AEROQUIP DATA)

Year	Plating Process	Treated Wastewater, gal	Sludge lb
1989	Cd	40,000,000	282,000
1991 ^(a)	Zn	44,900,000	383,000

(a) Adjusted to the 1989 production rate of the electroplating process.

The increases in wastewater and sludge were due to an increase in plating bath concentration from approximately 3 oz/gal of cadmium in the cadmium-plating baths to approximately 3.5 oz/gal zinc in the zinc-plating baths. The decrease in oil and grease was due to an approximately ten-fold decrease in the concentration of oil used in the water-soluble oil dip tank. The increase in chromium was due to an approximately fivefold increase in the chromate bath concentration. The chromium, which also is a priority pollutant, was effectively converted from the toxic hexavalent form to a much less toxic trivalent form in the wastewater treatment plant, resulting in a reduced health risk relative to cadmium.

Paramax has since established that the recovered etchant meets its requirements for etching solutions. The company is currently using 12 cells to keep up with the buildup of copper and has successfully recycled the etchant during production.

Calculation of the waste reduction potential was based on the difference between the amount of chromic acid etch solution disposed without lonsep™ treatment and the amount of chromic acid etch that can be reused after treatment with the lonsep™ unit.

Use of the lonsep™ unit prevented disposal of approximately 7.5 baths/wk. Paramax currently disposes of 8.5 baths/wk and estimates that, with the lonsep™ unit, disposal will be reduced to one bath/wk. Each bath contains 110 gallons (the lonsep™ unit, can treat up to 500 gallons or about four baths in 4 days), which means that 41,250 gallons of etchant bath solution is saved per year (7.5 bath/wk x 110 gal/bath x 50 wk/yr). The etchant concentrate is diluted 50% to make up the bath. Therefore, the lonsep™ unit could reduce 20,625 gallons of etchant concentrate per year needing disposal. This amount of etchant contains approximately 7,154 lb of chromium that would otherwise have gone to waste (80 g/L CrO_3 in etchant x 52 g Cr/100 g CrO_3 x 20,625 gal x 3.785 L/gal). Table 3 summarizes the items evaluated in the waste reduction analysis.

TABLE 3. WASTE REDUCTION OF THE ETCHING LINE

Description	Amount Discarded Per Year
<u>Without lonsep™</u>	
Etchant	20,625 gal
Water	20,625 gal
Chromium	7,100 lb
<u>With lonsep™</u>	
Catholyte solution:	
Sodium chloride	10,000 lb
Sodium sulfate	5,000 lb
Soda Ash	1,000 lb
Water	25,000 gal
Chromium	42 lb*

*Estimated

TABLE 4. CAPITAL COST TO CONVERT (1992)

Parameter	Barrel Plating Lines	Rack Plating Line	Subtotal
Expense (cleanup of old equipment and waste disposal)	\$428,000	\$ 999,000	\$ 1,427,000
New equipment	\$424,000	\$ 122,000	546,000
Subtotal	\$852,000	\$1,121,000	
Total			\$ 1,973,000

Report

The full report, titled "Substituting Cadmium Cyanide Electroplating with Zinc Chloride Electroplating" by B.C. Kim, et al., is available as report no. EPA/600/R-94/074.

The etchant was sampled and analyzed for both chromium and contaminants at the end of the 3-day treatment/recovery process. These analyses were used to determine whether the renovated bath was within specifications and whether bath quality was an indication of product quality. Although total chromium in the etchant remained constant, hexavalent chromium increased. The hexavalent chromium started at approximately 74% of the total and increased to about 99%. It is believed that oxidation of the trivalent chromium back to the hexavalent form caused the increase in hexavalent chromium concentration. The resulting hexavalent chromium concentration of 30.3 g/L in the etchant over the 3-day sampling period approached the minimum specification level of 31 g/L. This could be increased further by longer treatment or by adding etchant concentrate. At the time this study was conducted, the etchant had not been reused and the effect of recovered solution on in-house printed wire board product quality had not been evaluated.

The cationic contaminants were within specification. The 10.8 g/L (mostly copper) was below the maximum level of 25 g/L. Because the chromium and the contaminant levels are both near specification levels, the etchant should be acceptable.

Report

The full report, titled "Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium Solutions" by Dale Folsom, et al., is available as report no. EPA/600/R-94/071.

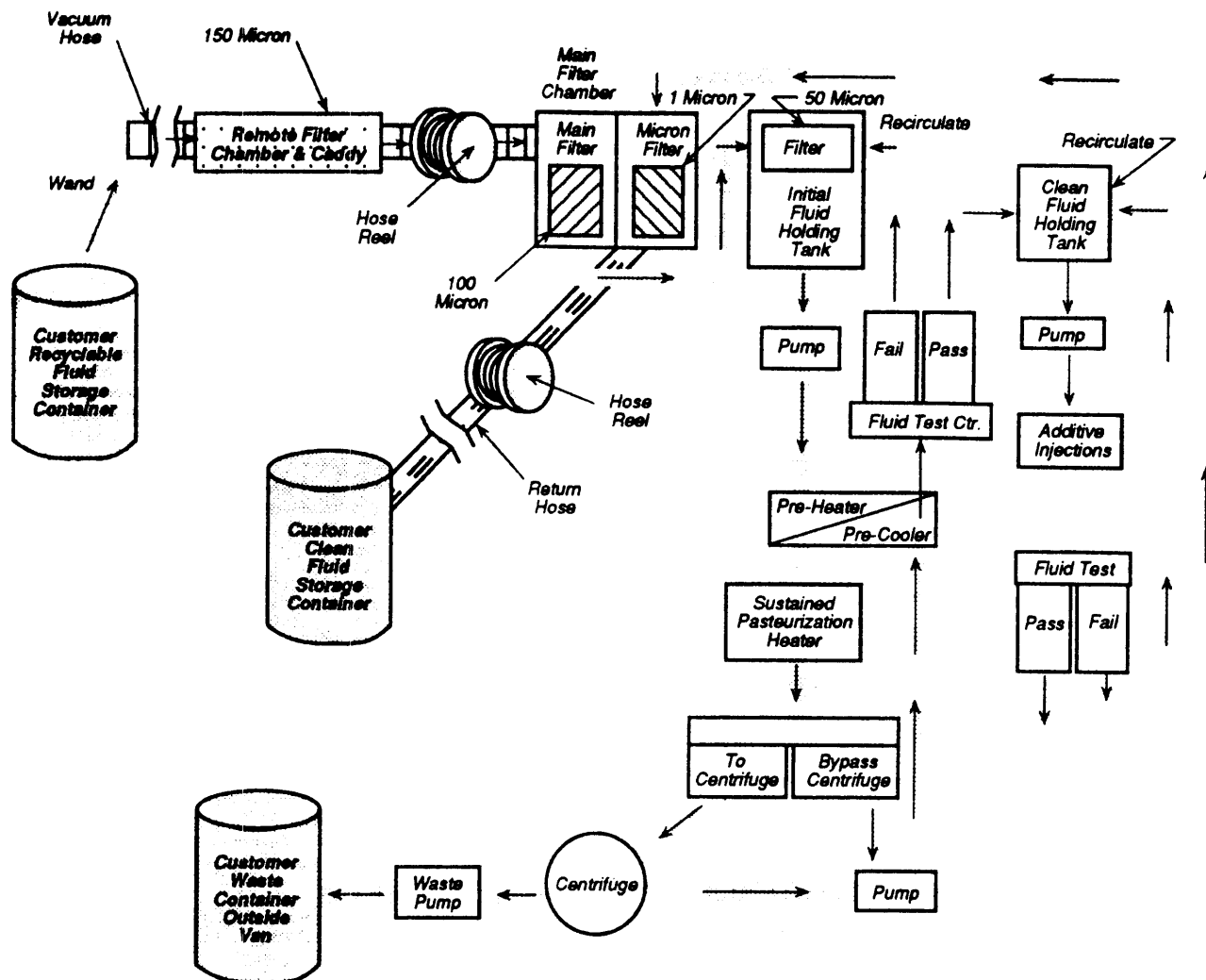


Figure 1. Metalworking fluids recycling system flowchart

The main purpose of metalworking fluids in machining operations is to provide lubricity and cooling without causing corrosion or other problems.

Results:

Degree of removal of non-dissolved and dissolved particulates during recycling is shown in Table 1. High concentrations of these particulates affect tool life, surface finish, and chemical breakdown. Particulates also provide substrates for microbial growth. At all three sites, the results showed considerably lower concentrations of nondissolved particulates in the recycled fluids (E1-R, E2-R, and S1-R) as compared with concentrations in the spent fluids (E1-S, E2-S, S1-S0).

Dissolved solids levels remained approximately the same after recycling, which indicated the effect of contaminant precipitation and fresh additive introduction. At the three sites tested, the pH of the recycled fluids was returned to a range between 8.5 and 9.5.

TABLE 1. COMPARISON OF ZINC CHLORIDE AND CADMIUM CYANIDE RACK PLATING PROCESSES

Process Step	Tank No.	Operation	
		Zinc Chloride Plating Line	Cadmium Cyanide Plating Line
1	1	Soak clean	Soak clean
2	2	Rinse	Rinse
3	3	Electroclean	Electroclean
4	4	Rinse	Rinse
5	5	Rinse	Rinse
6	6	Hydrochloric acid pickle	Hydrochloric acid pickle
7	7	Rinse	Rinse
8	8	Rinse	Rinse
9	9	Electroclean	Electroclean
10	10	Rinse	Rinse
11	11	Rinse	Rinse
12	12	Hydrochloric acid pre-dip	Sodium cyanide pre-dip
13	13	Zinc plating	Cadmium plating
14	14	Rinse	Rinse
15	15	Rinse	Rinse
16	16	Nitric acid dip	Rinse
17	17	Yellow chromate dip	Nitric acid dip
18	18	Rinse	Rinse
19	19	Chromate seal	Rinse
20	20	Rinse	Yellow chromate dip
21	21	Drip tank dip	Rinse
22	22	Water-soluble oil dip	Water-soluble oil dip

An initial series of tests were performed by both Aeroquip and an independent laboratory (Detroit Testing Laboratory (DTL), Inc.). Tests included four types of zinc plated parts from the rack plating line. Additionally, Aeroquip tested four types of zinc plated parts from the barrel plating line.

Lubricity and wear preventive characteristics of a metalworking fluid affect workpiece quality and tool life. Lubricity and wear characteristic were measured by the standard "four-ball test" (ASTM D 445). For Site E1, the recycled sample caused a much lower average scar diameter than did the spent sample, but not as low as the virgin sample. This indicated that the recycled and virgin samples performed about the same. The presence of some emulsified tramp oil could have improved the lubricity results of the spent sample E2-S.

A major factor in metalworking fluid spoilage (rancidity) is microbial growth. In the recycling process, existing microbes are killed during the pasteurization step, the dead biomass is removed during the centrifugation step, and a measured quantity of biocide is added to control future microbial growth. ASTM E 686-85 evaluates the effectiveness of biocides at use concentrations. No microbial growth was observed in the samples up to 6 weeks after recycling.

Currently, there are no published standards for recycled fluids. Each user establishes requirements based on the same factors used in selecting a virgin fluid. At the three test sites evaluated in this study, recycled fluids appeared to satisfy the functional requirements of the users.

On an average, Safety-Kleen visits each user once every 10 weeks and recycles 250 gallons of spent fluid per visit, thereby yielding a potential annual reduction of 1250 gallons for a typical small user. Approximately 4 gallons of tramp oil per visit are generated during recycling. The tramp oil is hauled away at a competitive fee by Safety-Kleen for use as supplemental fuel. Residue generated on the filters (mostly metal chips) is transferred to the user's waste metal bin and later reclaimed for its metal value.

According to a 1991 study by the Independent Lubricant Manufacturer's Association, the volume of metalworking fluids (concentrate) manufactured in the United States, has increased from 67 million gallons in 1985 to 92 million gallons in 1990. By extending the life of metalworking fluids through onsite recovery, considerable amounts of fluid can be prevented from going to waste. The total volume of fluids going to waste, may be significantly higher than the manufacturer volumes (as much as 20 times higher, in some cases) since many types of fluids are diluted into 3% to 5% solutions with water.

The economic evaluation compared costs for recycling versus costs for disposal. Recycling costs included the onsite service charge for the customer and tramp oil disposal cost. Disposal costs included spent fluid disposal cost and hazard analysis costs. The annual savings for a typical small user, who recycles 1,250 gallons/yr of metalworking fluid was approximately \$1,600 if the spent fluid was nonhazardous, and \$7,800, if the spent fluid was hazardous (by the Toxicity Characteristic Leaching Procedure).

This evaluation found that recycling of metalworking fluids is a good option for small-to medium-sized plants with machining operations. In the absence of published standards for recycled fluids quality and performance, the user has to evaluate the recycled product by the same criteria used to select a virgin brand. Direct, extended time testing of tool life and work piece quality vs. recycled fluid characteristics may be desirable to establish recycled fluid standards.

Report

The full report, titled "Mobile Onsite Recycling of Metal Working Fluids" by Arun Gavaskar, et al., is available as report no. EPA/600/SR-93/114.

TABLE 3. TOXIC POLLUTANTS FROM CADMIUM- AND ZINC- PLATING PROCESSES

(lb/yr based on production rate of 3.29 million ft²)

Pollutant	Cadmium Plating	Zinc Plating
Cd	12,100	0
Total CN	835	0
Total Cr	677	4,420
Zn	0	22,300
Oil & grease	14,600	5,120

As a result, the overall hazard level of the waste was substantially reduced by eliminating cadmium and cyanide. Consequently, the process substitution has reduced the company's potential liability due to accidental worker exposure and environmental release of these hazardous materials. An added benefit is the elimination of chlorine for destruction of cyanide in the wastewater treatment plant.

Economic Evaluation--

Economic evaluation of the process substitution was based on a simple payback period analysis with the use of the cost data provided by Aeroquip. The evaluation included estimation of capital costs for the process conversion and operating costs of both processes. Table 4 shows the capital cost (in 1992 dollars) for converting to the zinc plating process.

Approximately 72% (\$1,427,000) of the total cost was for expenses related to cleaning up the cadmium process equipment and for disposal of the waste generated from the cleanup operation. The remaining 28% (\$546,000) was for installing new equipment. The operating costs for the zinc-plating process was slightly lower than that for the cadmium-plating process, resulting in an annual savings estimated at \$17,200.

Based on these costs, the estimated payback period is 115 yr. The process change, therefore, cannot be justified on economic grounds alone. Justification would be based on the improved worker safety and reduced environmental pollution plus the market's requirements for zinc-plated rather than cadmium-plated parts in many applications. In comparing the two processes for a new installation, the zinc chloride plating process offers obvious advantages over the cadmium cyanide plating process.

Results

The average adsorbency ratio and extraction efficiency for low viscosity fluids is plotted against the number of extraction cycles in Figures 1 and 2. The average adsorbency ratio 13.99 g to 14.79 g of fluid per g of dry weight of pad.

The results of the rate-of-release tests are given in Table 1. The MPP and MEP of the fresh pads for the low-viscosity fluid were 6.19 and 5.21 g/g, respectively. The decrease in MPP was 23.6% and 28.9% for pads reused for four and eight times, respectively, and the decrease in MEP was 24.8% and 31.1%, respectively.

Although the pad performance was degraded by approximately 25% after four uses, the degradation in performance was relatively insignificant for 4 additional uses. For the medium and high-viscosity fluids, the MPP and MEP were measured only for the fresh sorbent pads.

The results of the fluid pickup tests are presented in Table 2. Regardless of fluid types, the sorbent pads effectively removed fluids from the floor. Only 2.4% to 5.2% of the spilled fluids were left on the floor. Moreover, the sorbent pads effectively removed low and medium-viscosity fluids even after they were reused four or eight times.

The objective of comparing costs of pad disposal versus reuse was met by using fluid capacities and process time measured during the study and supplemented by literature and company historical data. For low-viscosity fluid, substantial savings occurred as a result of pad recycling. Savings of up to 51.4% and 75.3% were possible with as few as two and as many as eight reuse cycles, respectively. Additional savings were also possible, but much less significant, as reuse cycles increased to more than eight times. Similarly, the cost per use was greatly reduced, from \$4.80 for single use to \$1.19 for eight uses (see Figure 3). For medium viscosity fluid, the annual pad recycling savings were 50.5% and the per use cost was \$2.38 for two uses. Additional uses and savings are very unlikely because the sorbent pads became severely separated and deformed as a result of the extraction process.

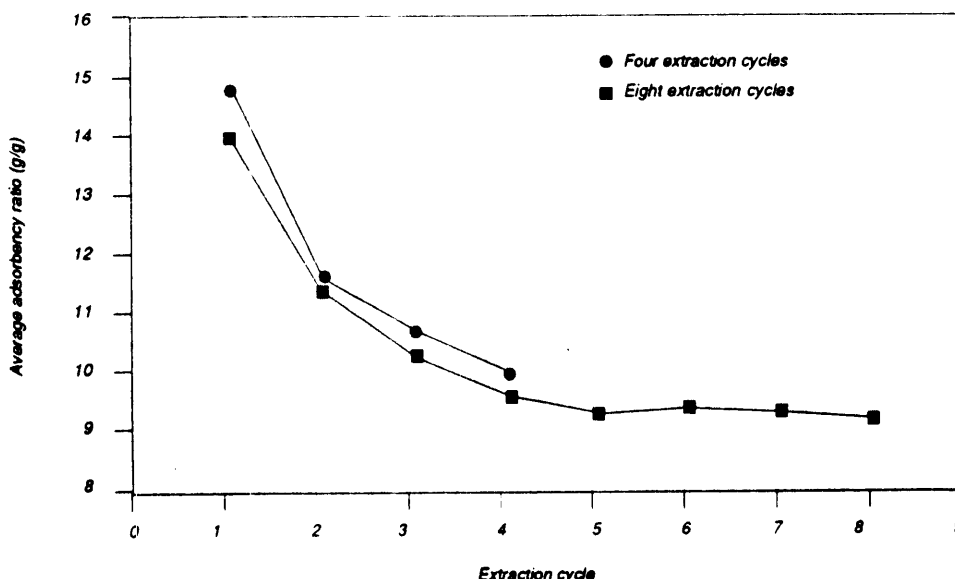


Figure 1. Adsorbency ratio for low-viscosity fluid

NEW JERSEY

Seven technologies were evaluated under the New Jersey contingent of the WRITE program. The projects were performed with the help of the New Jersey Department of Environmental Protection and Energy (NJDEPE, Project Officer, Norine Binder) and the New Jersey Institute of Technology (NJIT, Project Officer, Daniel Watts). The EPA Project Officer was Johnny Springer Jr.

#23 MOBILE ONSITE RECYCLING OF METALWORKING FLUIDS

Participants

The hosts for the evaluation were three, small-to-medium sized machine shops in the Philadelphia, PA, area (known to EPA only as E1, E2, and S1). The Safety-Kleen Corporation of Elgin, Illinois was the vendor, providing the metalworking fluids and operating the mobile, on-site recycling units. Battelle, Columbus Laboratories helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

Safety-Kleen provides metalworking fluid recovery services to a variety of businesses, primarily those that generate relatively small quantities of fluid waste. The mobile service performs the recycling on the generator's property, thus eliminating the need to transport potentially hazardous waste. Each mobile truck-mounted unit, operating on its own power, is capable of processing fluid at a maximum rate of 300 gal/hr.

The recycling process (Figure 1) consists of filtering, pasteurizing, and centrifuging the spent fluid. The fluid is first sent through a 100- μ filter to remove any large particulates. It is then pumped through a preheater and then a heat exchanger to kill bacteria and fungi, as well as to reduce fluid viscosity. Centrifuging to separate tramp oil and other debris from the usable fluid, is next. Additives are then incorporated into the fluid to restore performance. In the final step, the fluid flows through a 1- μ filter to remove any remaining particulates.

The technology was evaluated at three small-to-medium sized machine shops (sites) in the Philadelphia, PA, vicinity. The three sites were chosen from among Safety-Kleen's customer base. Two of the sites (called E1 and E2) used emulsion-type metalworking fluids. The third site (called S1) used a synthetic fluid.

At each site, one sample each of the spent, recycled, and virgin fluids (at their normal use concentrations) was collected and subjected to a series of tests. The comparison were then made between the virgin, spent and recycled fluids.

The accumulation of very small particulates over time and use could limit the number of times a given batch of fluid could be recycled. Conductivity of the samples was measured as an indicator of the dissolved solids levels in the fluids.

Users of metalworking fluid often monitor the pH as an easily measured indicator of fluid quality. A change in pH may indicate chemical degradation or degradation due to microbial growth. The recycling process seeks to restore pH to a range of 8.5 to 9.5. This alkaline pH improves emulsion stability and corrosion resistance characteristics of the fluid.

TABLE 2. FLUID PICKUP BY SORBENT PADS

Fluid viscosity	Pad Condition	Fluid pickup (%)			
		Replicate No. /pad No.			Average
		1/28	2/29	3/30	
Low	Fresh	96.4	98.2	98.2	97.6
	4X ^a	93.2	97.2	96.2	95.5
	8X ^b	94.2	95.8	95.8	95.3
		1/31	3/32	3/33	
Medium ^c	Fresh	97.1	96.2	97.5	96.9
	4X	97.5	94.1	94.2	95.3
	8X	95.8	93.8	99.5	94.8 ^d
		1/34	2/35	3/36	
High	Fresh	100	94.2	100	98.1
	4X	N/A	N/A	N/A	N/A
	8X	N/A	N/A	N/A	N/A

^a Pad extracted four times.

^b Pad extracted eight times.

^c For all medium-viscosity fluid tests, pads were soaked at 50% pad sorbing capacity before extractions.

^d Based on the performance of Pads No. 31 and 32 only.

N/A = Data not available because pad could not pass through ExtractorTM.

Because the capital cost for the ExtractorTM was relatively insignificant (\$699) and the annual savings would be substantial, the payback period of the investment would be only 2.8 to 5 weeks.

The sorbent pad recycling evaluation demonstrated that roller compression technology can be effectively used to extract low and medium-viscosity fluids from meltblown polypropylene sorbent pads. The ExtractorTM is particularly useful for low-viscosity fluid applications; the sorbent pads can be reused at least eight times. For medium-viscosity fluids, no more than two to three reuse cycles are possible. The potential to reduce waste by recycling sorbent pads can be substantial. For example, for a 1,858-m² (20,000-ft²) plant, annual sorbent pad consumption can be reduced from 3,600 pads to 1,800 or 450 if the pads can be reused for two or eight times, respectively. Correspondingly, the number of drums for disposal of pads would be reduced from 24 drums (assuming 150 oil-saturated pads per drum) to 6.5 or 1.6 drums (assuming 275 desaturated pads per drum). The 14 to 16 drums of waste fluids extracted from the sorbent pads would be processed for reuse or hauled away for disposal at a waste-to-energy facility.

The economic benefits of the roller compression technology were substantial. The use of the ExtractorTM by shops and plants that handle and/or use various oils and fluids would result in annual savings of 51% to 75%. The savings come primarily from the lower disposal costs for spent pads. Further savings may be possible if extracted fluids can be recycled. The per use cost of sorbent pads can be significantly reduced from \$4.80 for a single use to \$1.19 or less for eight or more reuse cycles.

Report

The full report, titled "A Fluid Sorbent Recycling Device for Industrial Fluid Users" by Abraham S.C. Chen, et al., is available as EPA/600/SR-93/154.

Corrosion characteristics are important parameters for water-based metalworking fluids because of their effect on workpiece quality and tool life. The results of the iron chip corrosion test (ASTM D4627) on the virgin samples (E1-V, E2-V, and S1-V) showed that E1-V and S1-V generated no rust at the use concentration (approximately 5% solution of the concentrate in tap water).

Tramp oil is the nonemulsified floating oil that builds up in metalworking fluid sumps from sources such as leaking equipment seals (hydraulic oils, gear oils) or from the workpiece itself. No phase separation was noticed in any of the recycled samples, indicating the tramp oil had been removed.

TABLE 1. ANALYSIS OF NON-DISSOLVED SOLIDS

Sample No.	Non-Dissolved Solids Concentration (mg/100 mL) ^a		Dissolved Solids (Conductivity) μmhos/cm ²
	Total	Inorganic	
E1-S ^b	79.10	27.25	2,400
E1-R	22.55	1.45	1,810
E1-V	3.55	2.50	700
E2-S ^b	12.55	0.50 ^c	1,820
E2-R	5.60	3.00	1,750
S1-S	33.80	14.50	1,450
S1-R	17.00	1.95	1,460
S1-V	5.18	0.78	1,930

^a By ASTM D 2276. Particulates smaller than 8 microns.

^b Analyzed skimming off and discarding the floating tramp oil. E1-S=spent emulsion, site 1; E1-R=recycled emulsion, site 1; E1-V=virgin emulsion, site 1; etc.

^c Possible inhomogeneity giving a low value.

The results of emulsion stability testing at elevated temperature showed small amounts of phase separation in spent samples E1-S and E2-S. The recycled samples remained as a single phase even after 96 hrs, indicating that emulsion stability had been restored during recycling.

Foaming can reduce effective film strength, reduce heat transfer, and interfere with the settling of metal fines. Tendency of the fluids to foam was tested by ASTM D 892-89. Foam volume in the recycled samples (E1-R, E2-R, and S1-R) was significantly higher than that in the spent or virgin samples. This can be attributed to introducing fresh emulsifier (surfactant) during recycling. A correction can be made for this effect by adding an antifoam agent during recycling. Safety-Kleen, however, does not add an antifoam agent unless the user specifically reports a foaming problem.

At all three sites, the recycled and virgin fluid viscosities were very close. This indicated that the recycling process had restored this parameter. The viscosity measurements also indicated that the recycling process succeeded in returning the fluids to the required use concentration (oil/water ratio).

A higher level of accuracy or component identification confidence (CIC) is needed to avoid the cost of erroneously replacing non-defective components, potential damage created during component replacement, and multiple iterations of testing and repair. An experiment was performed to compare the capability of each cooling method to identify components with thermally intermittent failure modes. Thirteen test articles were evaluated with the use of each of the three cooling methods, r-12, air and nitrogen.

Three technicians, working independently, evaluated the test articles following a randomized sequence of cooling methods. For each evaluation, the technicians assigned a CIC level which reflected their confidence that they had been able to isolate the cause of the circuit failure using the assigned cooling method.

Electrostatic Discharge--

The amount of electrostatic charge buildup generated by the cooling material as it is dispensed is a concern because of the vulnerability of electronic components. Two experiments were designed to compare the electrostatic charge generated by the various cooling method/nozzle combination for R-12, compressed air and liquid nitrogen.

The first experiment measured the electrostatic charge generated on the nozzle during release of cooling material. During a 10-to 12-sec material release, the nozzle was held parallel to and approximately 1 inch from the platen of an Ion Systems, Incorporated, Model 200 Charged Platen Monitor*, which measured charge buildup. Two measurements were taken for each cooling method/nozzle combination. The second experiment measured electrostatic charge buildup when cooling material was dispensed toward circuit boards placed on the platen of an Ion Systems Model 200 Charged Platen Monitor. Six circuit boards were evaluated, with two measurements taken for each cooling method/nozzle combination. The six circuit boards were selected to provide component and density variety.

Cooling Rate and Absolute Temperature Drop--

The cooling rate and absolute temperature drop were measured for each method. An experiment was designed to estimate the rate of change of component temperature. Two test boards were fabricated, one having integrated circuits and the other having wound-film capacitors. Each test board contained three components with thermocouple buried inside and one exposed thermocouple. During tests, all four thermocouples on a test board were connected to a four-channel data logger, which simultaneously recorded temperatures of all four thermocouple as cooling material was directed at the target component. Two measurements were taken for each combination of test board, cooling method, direction, and distances. Before each measurement, the cooling material was dispensed directly at the exposed thermocouple to determine the absolute lowest temperature that could be achieved given the test distance, direction, and cooling method.

Operator Safety--

Exposure to sound created by the operation of the compressed-air tool was a safety concern. To assess the potential safety hazard, personnel from the Newark AFB Bioenvironmental Engineering Office took sound-level measurements during operation of the compressed-air tool.

#24 A FLUID SORBENT RECYCLING DEVICE FOR INDUSTRIAL FLUID USERS

Participants

The host for the evaluation was Cook's Industrial Lubricants Incorporated of Linden, NJ who is a custom blender of industrial lubricants. Battelle, Columbus, Laboratories supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

In the process of mixing, handling, and packaging of fluids, spills occasionally occur. At the end-users's sites, the fluids may be spilled or cutting oils splattered during their use in the machining process. Currently, the spilled or splattered fluid is removed by hand with sorbent pads made of melt-blown polypropylene. Workers simply lay the pads over the spilled fluid and mop the spilled areas. Once the pads are saturated with fluid, they are drummed for disposal.

During the evaluation the Extractor™, manufactured by Environmental Management Products, was used to recover the spilled fluid from the saturated sorbent pads. The Extractor™, recovers the fluid by compressing the pads between two gear-driven counter-rotating rollers. The desaturated sorbent pads are then reused several times until the quality of the pads degrades.

The two types of waste considered in this study were the spent sorbent pads themselves and the waste fluid adsorbed. The current practice of once through use was compared to desorption and recycling. The roller compression method extracts the sorbed fluid and permits reuse of the pads. Although the extracted fluid is contaminated with the dirt and debris picked up during the spill, it may be processed for reuse. Therefore, this technology reduces the number of sorbent pads used and the volume of sorbent pads and fluids sent to disposal. Additionally, there is potential for reprocessing and recycling the desorbed fluid.

The extraction efficiency test (ASTM Standard Method F726-81) was used to determine the number of extraction cycles a sorbent pad could endure before becoming unusable due to tearing, deforming, and other general deterioration. The test was also used to examine the rate of decrease in the pads' sorbing capacity (or adsorbency ratio) and the percentage of fluid to be removed by roller compression. Because fluid removal is dependent on the fluid viscosity, tests were conducted with three different fluids covering a range of viscosities.

The correlation of performance of the sorbent pads vs. the number of cycles through the extraction process was investigated. To determine product performance, both quantitative and qualitative aspects of pad degradation were examined. Pad degradation was quantified using the rate-of-release test (ASTM Standard Method F716-82).

The Maximum Practical Pickup (MPP) and Maximum Effective Pickup (MEP) of new pads were compared with those of pads that had passed through the Extractor™ four and eight times, respectively. If the used pads had a different rate of release, the test indicated degraded pad performance.

The ability of sorbent pads to leave a clean floor after use was measured by the fluid pickup test. The percentage of pickup by a new pad was compared with that of recycled pads.

Distance from the target component affects the component cooling capabilities of both compressed air and liquid nitrogen. As the distance from the component to the nozzle increased from 0.25 in. to 1 in., the minimum component temperature decreased for both alternative methods. A comparison of component minimum temperature data for two different directions of application indicated that R-12 is not sensitive to application direction. In contrast, compressed air provided lower component temperatures for integrated circuits, but liquid nitrogen yielded lower component temperatures for wound-film capacitors. The most likely explanation of this difference is the variability resulting from manual positioning of the nozzles.

Results

Accuracy--

The accuracy testing identified that the compressed air system was correct 11 out of 13 times, liquid nitrogen 9 out of 13 times, and R12, 11 out of 13 times. Due to the number of criteria that impact on variability and the limited scope of the project, the results of comparing accuracy among the three techniques was considered inconclusive. Additional testing in this area could provide better information.

ESD Risk--

Averages of each pair of measurements indicate that both the compressed air and the liquid nitrogen alternatives generated lower electrostatic charge buildup is not increased by using either of the alternative component cooling technologies. If aerosol cans of R-12 have been used successfully, either compressed air or liquid nitrogen should be acceptable alternatives.

Technician Safety--

A sound level of 81 DBA was recorded at the operator work position. Because the sound levels did not exceed 84 DBA, additional measurements were not required by the Air Force and, in accordance with Air Force Regulation 161-35, hearing conservation precautions were deemed unnecessary.

Pollution Prevention Potential--

The average R-12 release per article was 232.65 g (0.51 lb). With the adoption of either alternative technology, release of R-12 would be eliminated along with the wastestream of empty aerosol cans. Neither usage nor production information for the United States was available when this report was written; quantities consumed vary by user, ranging from a few cans per month in repair shops to over a thousand cans per year in production operations. In light of the Montreal Protocol of 1987, substitutes for R-12 will be required & subsequently R-12 is not an option for the future.

Economic Evaluation--

Data presented in the project report indicate that a material cost savings of \$5.28 per circuit board can be projected if testing is done with liquid nitrogen instead of R-12. This would result in payback of \$500 dispenser investment after 95 circuit boards have been tested. For a shop that has an existing adequate air supply, the average operating cost savings for compressed air is \$5.26 per board. This would pay back a \$200 air-tool investment after 38 circuit boards have been tested. The payback period would be extended if additional investment were required to compress and deliver air to the work stations. Table 2 summarizes investment and payback figures for each alternative technology.

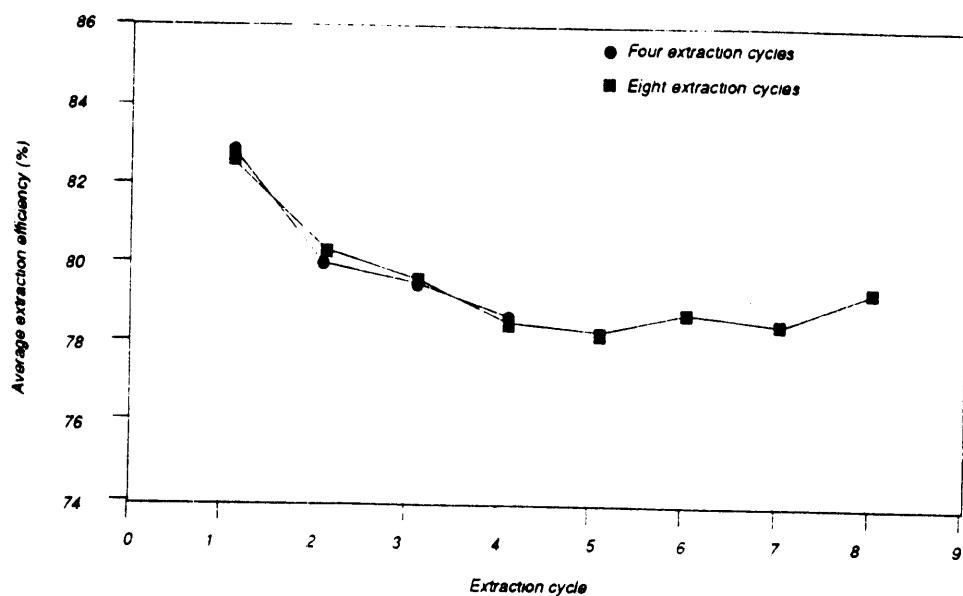


Figure 2. Extraction efficiency for low-viscosity fluid

TABLE 1. MAXIMUM PRACTICAL PICKUP AND MAXIMUM EFFECTIVE PICKUP

Pad condition	Fluid viscosity	Pad texture	Pad no.	Fluid sorbed at saturation (g)	Time to "stop" dripping ^a (min)	Maximum effective pickup ^b (g/g)	Time to "stop" dripping ^c with fan on (min)	Maximum effective pickup ^c (g/g)
Fresh	Low	Unpleated	1	346.54	120	5.55	61.0	4.69
			2	360.28	120	6.57	61.5	5.57
			3	350.83	120	6.45	62.0	5.37
			Average	325.55	120	6.19	61.5	5.21
Extracted four times	Low	Unpleated	4	255.95	120	4.51	60.0	3.90
			5	203.96	120	4.62	60.0	3.75
			6	195.71	120	5.07	60.0	4.13
			Average	218.54	120	4.73	60.0	3.92
Extracted eight times	Low	Unpleated	7	194.06	> 120	4.42	60.0	3.58
			8	195.57	> 120	4.34	60.0	3.47
			9	197.65	> 120	4.45	60.0	3.58
			Average	195.76	> 120	4.40	60.0	3.54
Fresh	Medium	Unpleated	10	445.65	> 120	11.82	60.0	9.19
			11	447.36	> 120	11.18	60.0	8.58
			12	452.59	> 120	11.75	60.0	9.36
			Average	448.53	> 120	11.58	60.0	9.04
Fresh	Medium	Pleated	10B	306.25	> 120	7.78	60.0	6.86
			11B	292.09	> 120	7.80	60.0	6.96
			12B	303.41	> 120	7.81	60.0	6.95
			Average	300.58	> 120	7.80	60.0	6.92
Fresh	High	Unpleated	19	444.54	120	13.67	60.9	12.14
			20	417.91	120	13.54	60.9	12.19
			21	392.16	120	13.68	60.9	12.38
			Average	418.20	120	13.63	60.9	12.24

^a At the end of the time recorded, dripping continued at a rate of more than 5 to 15 drops/min.

^b Maximum Practical Pickup = Fluid sorbed at the end of 2 hr/sorbent pad dry weight.

^c Maximum Effective Pickup = Fluid sorbed at the end of 1 hr with fan on/sorbent pad dry weight.

#26 EVALUATION OF ZERPOL (ZERO LIQUID DISCHARGE SYSTEM) AT PIONEER METAL FINISHING

Participants

The host for the evaluation was the Pioneer Metal Finishing Company of Franklinville, New Jersey. The test was performed in cooperation with the New Jersey Department of Environmental Protection and Energy and the New Jersey Institute of Technology (NJIT). NJIT prepared the draft report.

Technology/Testing

The Zerpol system has been in place at the Pioneer Metal Finishing facility since 1981. In this system, aqueous effluent is accumulated in processing tanks to allow conditioning in a batch mode. In the metal finishing application, conditioning is a stepwise process. Initially, an active oxygen compound is added, as needed, to oxidize cyanide ions. This step is followed by the addition of sodium hydrosulfite to reduce chromium, if present. Sodium hydroxide is added for pH adjustment to induce precipitation of metals.

After a two to three day settling period, the clarified water is transferred to a storage tank and used in the shop process as needed. Approximately two-thirds of the recovered water is used in the process for noncritical rinsing and about one-third of the total flow is directed to the boiler. The net effect of the operation is the near total reuse of the effluent stream, thus attaining a zero discharge condition at the location. The residual solids streams generated from the precipitation process and from the boiler blowdown are sent off-site for reuse or disposal. The metal contents are reclaimed by smelting. Figure 1 provides a diagram of the process.

Test Description--

A previous EPA supported study by researchers at the University of Central Florida evaluated the effectiveness of the Zerpol process as a waste management technique for the metal finishing industry. The study concluded that there were potential applications for the process in certain segments of the metal finishing industry. However, the report raised some questions that could not be answered based on the limits of the evaluation that was carried out. These questions included uncertainties regarding rinse water quality, boiler economics and operation, product quality, and safety.

The purpose of this project was to confirm and extend the previous study of the Zerpol process to provide information about its waste reduction potential, operation implications, safety issues, and economics. As a result, this study focused on 3 main objectives. The first objective was to evaluate the quality of the recovered and recirculated water to determine its ability to produce good quality plated product effectively and efficiently. The second objective was to evaluate the quality and quantity of the condensate produced by the boiler to determine its suitability for process critical rinsing requirements. The third objective was to evaluate the capacity of the water storage tanks in relation to system operational requirements and flow rate.

Three types of data were gathered during six days of testing, conducted over a 32 day period. Composite stream samples were obtained for chemical analysis. Samples were taken from ten sampling points and analyzed for cyanide ions, calcium, magnesium, copper, nickel, chromium, iron, zinc, cadmium, phosphorus, total solids, total suspended solids, total dissolved solids (TDS), and pH. Actual flow rate measurements of the generated effluent, recirculated water, steam condensate and boiler fuel gas were also taken.

#25 ELECTRONIC COMPONENT COOLING ALTERNATIVES: COMPRESSED AIR AND LIQUID NITROGEN

Participants

The host for the evaluation was Newark Air Force Base (NAFB), Ohio. Battelle, Columbus Laboratories supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

The electronic circuit boards that are tested and repaired daily at NAFB come from a variety of Air Force Systems, such as inertial guidance systems used in KC-135, C-5, and C-141 aircraft and a fuel-saver advisory system used in the KC-135.

Aerosol cans of refrigerant, such as R-12 and R-22, are commonly used in the electronics manufacturing and repair industries for trouble-shooting circuit boards that have known or suspected thermally intermittent failure modes. Thermally intermittent failures occur when temperature changes and material expansion or contraction aggravate the mechanical failure to create an electrical discontinuity condition. Due to the elimination of CFC's, users are seeking technologies that will replace them.

Two alternative technologies were evaluated, one process utilizing compressed air and the other using liquid nitrogen. In the air system (Figure 1), compressed air enters a tangentially drilled stationary generator which forces the air to spin down the long tube's inner walls toward the hot-air control valve at sonic velocity. A percentage of the air, now at atmospheric pressure, exits through the needle valve at the hot-air exhaust. The remaining air is forced back through the center of the sonic-velocity airstream, still spinning. Because it moves at a slower speed, a heat exchange to take place, with the slower-moving inner air stream giving up heat to the outer, faster-moving air column. The slower inner air column exits through the center of the stationary generator and out the cold exhaust. To obtain the required temperatures in the range of -35°C to -40°C , the tool requires clean, dry, room-temperature air flowing at 15 scfm at 100 psi pressure.

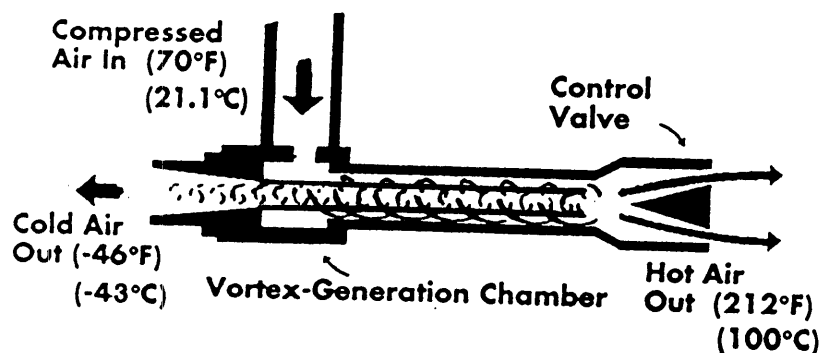


Figure 1. Compressed air spray gun

The second alternative technology evaluated uses liquid nitrogen. A 1/2-L Dewar flask was used with a release valve that allowed a stream of nitrogen gas and liquid droplets to be directed through a small-diameter stainless-steel nozzle.

recirculation rate is about 1,700 gallons per day.

Pollution Prevention Impact--

It should be noted that Pioneer Metal Finishing reported discharge violations frequently while the former continuous discharge treatment system was in operation from 1975 to 1981. These violations were a primary reason the previous treatment system was replaced. There have been no reported violations since the Zerpul system became operational. While the previous system discouraged efforts to reduce or minimize water use, the installation of the Zerpul system reduced water use and, reportedly, stimulated additional pollution prevention efforts.

Table 1 provides data on the contents of the water sludge from the plating process. This material is suitable for metal recovery by smelter. Measured levels of hydrogen cyanide at the effluent mixing tank and at the boiler blowdown sump were low (0.058mg/m³ and 0.101mg/m³, respectively) and within the OSHA standards.

TABLE 1 WASTE SLUDGE CONSTITUENTS

Material Analyzed	lbs/1000 sq. ft.
CN	-
TDS	-
Ca	0.058
Mg	0.0047
Cd	0.000099
Cr	0.23
Cu	0.19
Fe	0.30
Ni	1.53
Zn	0.60
P	-

The operation of the Zerpul system and the boiler were fine tuned to match the requirements of the plating process. The 25,000 gallon effluent processing tank used to hold the effluent for 5 work days (old system) now holds effluent for about 18-20 work days. This results in a reduction in the amount of chemicals used to precipitate the metal hydroxides in the effluent processing tanks. The Zerpul system enables 80-83% of the process water to be recirculated. About 7-8% goes into the boiler blowdown and is transported for treatment. The remaining 1-2% is lost to evaporation.

Economics--

The cost for a 2000 gal/day Zerpul system is \$120,000. Table 2 provides information on the annual cost savings achieved. The payback period (\$120,000/\$22,500) is 5.3 years.

Pollution Prevention Potential--

The purpose of replacing aerosol cans of refrigerant is to reduce the amount of pollutants released into the atmosphere. During the accuracy experiments, the weight of R-12 released during evaluation of each circuit board with thermally intermittent failure modes was determined. These data provided a measure of the average amount of R-12 substituted by either of the alternative cooling methods.

Economics Evaluation--

The approach to estimating operating costs was to measure the volume of each cooling material used during test article accuracy evaluations and calculate a per-board material cost.

Cooling Rate and Absolute Temperature Drop--

The three cooling techniques differed in how they cooled components. The fastest initial cooling rates were obtained with R-12, although the cooling rate decreased as component temperature dropped. Liquid nitrogen provided the coldest temperatures of the three cooling materials and at an accelerating cooling rate in the same temperature range as R-12. Compressed air achieved the least cold temperatures and the slowest cooling rate. As with R-12, the cooling rate decreased as component temperature dropped. Table 1 shows the temperatures achieved under one set of conditions.

The three cooling methods differed in their sensitivity to such parameters as component type application distance, and application direction. Liquid nitrogen and compressed air provided lower temperatures with integrated circuits than with the wound-film capacitors. R-12 was not significantly sensitive to the type of component and provided minimum temperatures for capacitors and integrated circuits that were not significantly different under each application distance/direction combination.

TABLE 1. MINIMUM TEMPERATURE ACHIEVED (AT 1/4-IN DISTANCE) AND ELAPSED TIME FOR THREE COOLING POINTS

Component Type/Test	Aerosol R-12		Compressed Air		Liquid Nitrogen	
	Temperature (bC)	Elapsed Time (sec)	Temperature (bC)	Elapsed Time (sec)	Temperature (bC)	Elapsed Time (sec)
<u>Integrated Circuit</u>						
Target Component	-45.0	18.0	-27.5	29.0	-175.0	31.0
Exposed Thermocouple	-54.5	--	-35.5	--	-175.0	31.0
<u>Wound-Film Capacitor</u>						
Target Component	-53.5	77.5	-11.5	121.0	-134.0	51.0
Exposed Thermocouple	-59.5	--	-35.0	--	-175.0*	--

* Minimum thermocouple temperature assumed to be -175 °C based on wound-film capacitor tests.

#27 A REPLACEMENT SOLVENT CLEANER/DEGREASER STUDY AT DUFFY ELECTRIC AND MACHINE COMPANY

Participants

The host for this test was the Duffy Electric and Machine Company of Chillicothe, Ohio. Duffy Electric also operated the cleaning unit during the test. Battelle, Columbus Laboratories on contract to EPA, provided test personnel and equipment and drafted the final report.

Technology and Testing

Duffy Electric & Machine Company repairs and rebuilds electric motors. The company overhauls large electric motors (AC and DC with greater than 15 hp output). The company also overhauls small electric motors. The process involves gross cleaning of electromechanical devices to achieve a level of cleanliness that facilitates inspection, repair, and testing.

The cleaning system used in this study is comprised of a cleaning unit and a rinse unit. The cleaning unit is the IBR Series 400 parts washer, made by Inter Basic Resources, Inc., of Grass Lake, Michigan.

The unit features an 11-inch-diameter impeller blade, mounted at the inside bottom of an immersion tank, that rotates at 100 rpm. Cleaning fluid is circulated through a 50- μ m filter at 5 gallons per minute, at 1 foot of head pressure (Figure 1) to create turbulence in the cleaning fluid. A 100-VAC electric motor powers the unit which is 16 in x 19 in x 11.5 in and it holds approximately 14.5 gallons. An insertion heater is used to bring the ester bath to approximately 130° F.

The IBR alcohol rinser consists of a chamber that encloses a manifold sprayer, fitted with an array of nozzles to spray isopropyl alcohol (IPA) onto the parts from a variety of angles. The unit uses pneumatic pumps driven by air at 110 to 120 psig. Alcohol is drawn from a 5-gallon drum by an internal pump. The manifold moves up and down at about 4 cycles per minute while rinsing the parts for a typical 5 minute cycle. The runoff, caught by a pan and drain at the bottom of the unit, is pumped by a smaller air motor back into the 5-gallon drum.

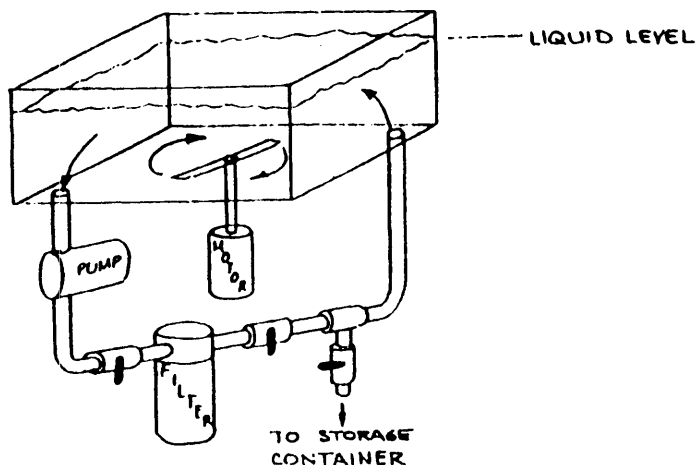


Figure 1. Illustration of IBR parts washer and circulation system

TABLE 2. INVESTMENT COST AND PAYBACK		
Cooling Method	Investment	Payback/ circuit boards tested
Compressed Air	\$200	38
Liquid Nitrogen	\$500	95

The cost of equipment to deliver compressed air that is clean, dry, and near room temperature in the volume and pressure required to achieve maximum cooling capability will depend on existing equipment and the number of tools to be used.

Report

The full report, entitled "Electronic Component Cooling Alternatives: Compressed Air and Liquid Nitrogen" by Stephen C. Schmidt, et al. is available as EPA/600/SR-94/170.

The check of appearance and color was used to assess how soiled the cleaner and alcohol had become. By the 7th week of the study, or after washing 30 parts, the cleaner and rinse were very darkly colored. After 100 parts were cleaned, they appeared highly contaminated.

Specific gravity is useful to track how much soil loading the cleaner and alcohol experience. Both solutions showed a small, monotonic increase in specific gravity over time. The main contaminants expected to be present in the cleaner are oils and suspended solids; in the alcohol, the main contaminant is dragout cleaner.

The pH of the cleaning solution was measured for solution acidity or alkalinity changes over time. This test was done to determine whether exposure to moisture over time caused any acid increase in the ester cleaner. Acidity was determined by extracting samples of the cleaner with water (ASTM D 2110). The pH dropped rapidly, reaching a steady state of about 5.04 in the seventh week. In all cases, the materials in the compatibility tests experienced a net decrease in weight and thickness, which is probably caused by removal of process oils, colorants, stabilizers, and other additives. The loss of these constituents could have a negative effect on the performance of the elastomers.

TABLE 1. TOTAL SOLIDS RESIDUE ON PARTS

Sample ID	Motor Part	Sample Date	Days of Study	Weight of Primary	Solids Duplicate	(g/parts set) Average
H2	A	6/17/93	8	3.22	3.27	3.25
H3	B	6/17/93	8	3.05	3.29	3.17
H4	A	7/16/93	37	1.99	1.76	1.87
H5	B	7/16/93	37	1.44	1.24	1.34
H6	A	7/27/93	48	1.83	2.06	1.94
H7	B	7/27/93	48	1.33	1.55	1.44
H8	A	8/6/93	58	1.24	1.01	1.13
H9	B	8/6/93	58	1.62	1.66	1.64
H10	A	8/19/93	71	2.60	1.98	2.29
H11	B	8/19/93	71	1.50	1.30	1.40
H12	A	8/27/93	79	2.79	3.42	3.11
H13	B	8/27/93	79	2.73	2.81	2.77

P2 Impact--

Contaminants in the ester cleaner primarily are oil, grease, and shop dirt. Therefore, the cleaner itself is assumed to present little environmental or health hazard during use. Annual solvent usages were calculated to be 51.4 gal of cleaner and 55.2 gal of IPA. These values represent a worst-case estimate for the cleaner because it was not fully spent at the time the study was concluded. The annual volumes of waste liquids were calculated to be 39.0 gal of cleaner and 39.1 gal of IPA.

The petroleum solvent formerly used by Duffy Electric Company had been supplied at a rate of 360 gal per year. Industry estimates indicate that about half of the amount of petroleum solvent supplied is recovered. The remainder is lost due to dragout, evaporation, and spillage during transfers. Therefore,

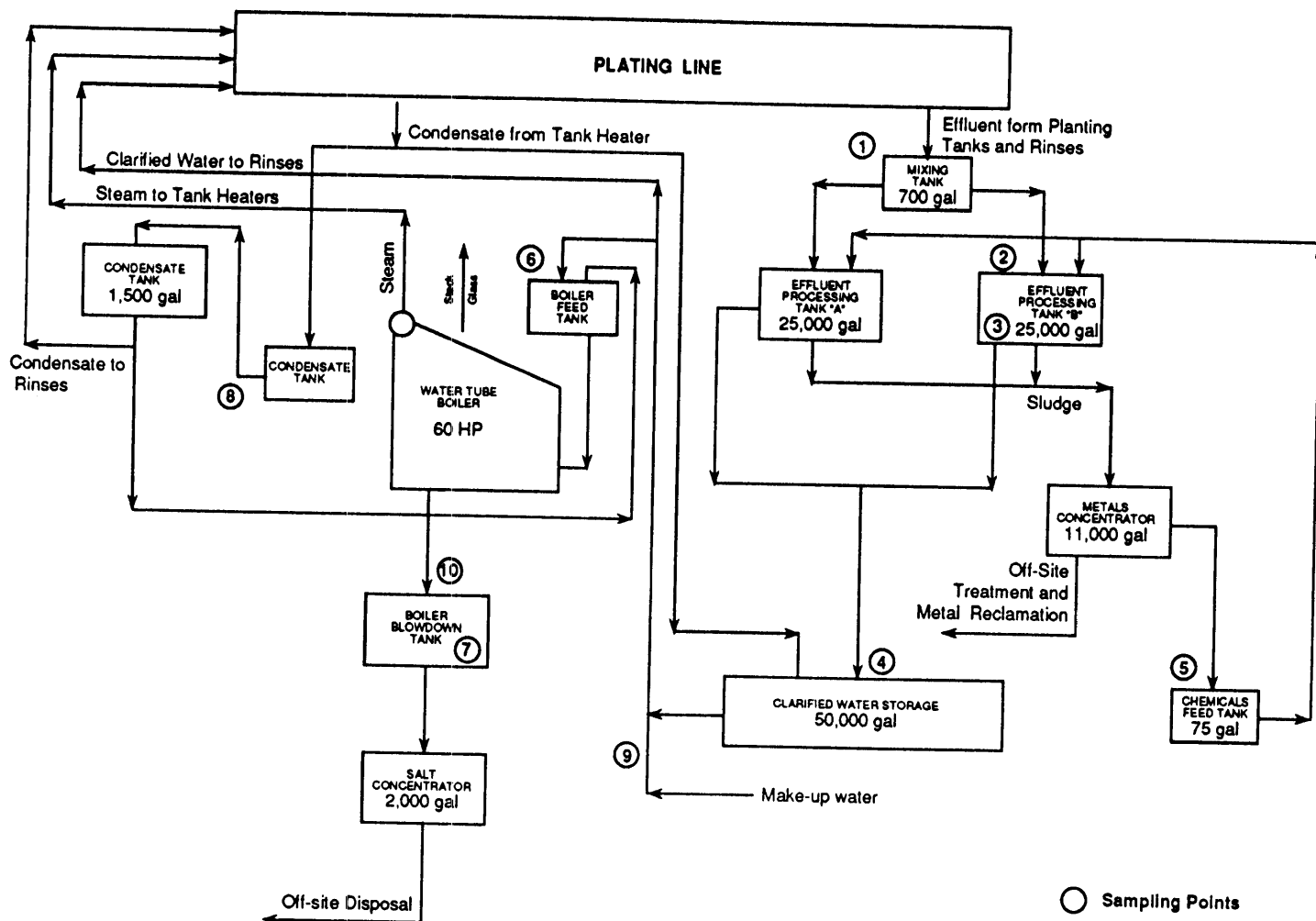


Figure 1. Pioneer Metal Finishing Inc. ZERPOL SYSTEM - basic process flow diagram

In addition, historical operating and maintenance data on the present Zerpul System and the system that preceded it, a system that involved precipitation of metal sludges and continuous discharge of the treated aqueous effluent, were also included in the data used for this study.

Results

Performance--

Evaluation of the Zerpul technology based on the 3 main objectives led to the following findings:

The average TDS of the clarified recirculated process water is about 10,000 ppm. The metals concentration of the recirculated water is higher than what is allowed for discharge into a typical POTW. The measured values in PPM were: Ni - 10.1 (vs. limit of 3.98); Cyanide - 2.9 ppm (vs. 1.20). These observed levels are routinely maintained by Pioneer because they are economically achievable and do not interfere with the plating process. The average TDS of the steam condensate is about 500 ppm and 100,000 ppm for the steam condensate and boiler blowdown, respectively. The clarified water

#28 A SUPERCRITICAL FLUID CLEANING STUDY: APPLICATION TO INSTRUMENT BEARINGS

Participants

The host for the test was the Honeywell Space Systems Group of Clearwater, Florida, with materials and testing support from the Naval Air Station of Jacksonville, Florida. Battelle, Columbus, under contract to EPA, provided project test personnel, gathered data and prepared the draft project report.

Technology/Testing

The goal of this study was to evaluate a supercritical fluid (SCF) cleaning system that could be used to clean precision parts that traditionally have been cleaned by organic solvents.

Typical bearing cleaning methods include solvent cleaning, aqueous cleaning, and vapor degreasing. Many commonly used chlorinated solvents such as 1,1,1-trichloroethane and CFC-113, will not be manufactured after 1995 because of legislation stemming from evidence that these solvents deplete stratospheric ozone. Still other chlorinated solvents such as trichloroethylene, perchloroethylene, and methylene chloride present health hazards to persons using them, as well as constituting hazardous air emissions targeted for reduction by EPA.

This study focused on SCF cleaning of instrument bearings for the following reasons: (1) users of instrument bearings have relied heavily in the past on CFCs and other organic solvents and have been aggressive in looking for alternatives to meet current and scheduled environmental regulations; (2) assembly and testing of instrument bearings requires cleaning at various stages, for which the efficacy of the cleaning must be very high and the potential for contamination must be very low; and (3) the high value of instrument bearings merits an investment in finding and developing improved cleaning methods

In this study, a single-component fluid consisting of supercritical carbon dioxide (CO₂) was used as the cleaning medium. The system operating range is shown in Figure 1. By varying pressure of the cleaning chamber and thereby density of fluid, the solvent power can be tailored to dissolving specific types of contaminants.

The essential elements of the system consist of:

- . CO₂ source (compressed gas cylinder)
- . Chiller to liquify CO₂ gas
- . Pressure pump to elevate line pressure
- . Hot water bath to elevate line temperature to that of the extraction vessel
- . Cylindrical extraction vessel (2.5-L capacity)
- . UV detector to observe removed contaminants
- . Pressure reduction valve
- . Separator vessel
- . CO₂ flow indicator.

Samples to be cleaned are placed on a cylindrical parts rack that fits inside the extraction vessel. The process is started by drawing CO₂ from the gas cylinder, purging it of water and other higher melting point compounds in a cold trap, then pressurizing and heating the CO₂ to the same P-T conditions as in the extraction vessel. Heat tape is wound around all critical fluid transfer lines and temperatures are monitored at various points by thermocouples. SC CO₂ flows through the cylindrical cleaning chamber from the bottom, where it dissolves and carries away soluble substances out through the top. After extraction, the CO₂ and dissolved contaminants pass through a pressure reduction valve, where pressure is dropped below P_c, and then enter the separator vessel. As CO₂ returns to the gaseous state, its

TABLE 2. ECONOMIC EVALUATION

Expenses	Annual Cost Savings
chemical usage	\$10,000
labor/maintenance	\$33,000
waste disposal	\$15,000
energy usage (increase)	- \$13,000
net savings	\$45,000
taxes	- \$22,500
net savings after taxes	\$22,500

Conclusions--

The Zerpel zero discharge system can be used successfully at metal finishing shops where the treated effluent and the generated condensate can be recirculated and reused for rinsing without impairing product quality.

There are some potential drawbacks to the Zerpel system. The quality of the recirculated process water (10,000 ppm TDS) may not be acceptable for all types of metal finishing. Deionized (DI) water may still be required in some critical rinsing operations. The increased workload on the boiler will increase energy costs and may also erode boiler life expectancy due to scaling. Softeners are required ahead of the system make-up if the calcium and magnesium in the system water supply exceed 5ppm.

The results of this investigation demonstrated that at this facility, the Zerpel zero discharge system, eliminates the discharge of an aqueous wastestream by allowing recycling of most of the process water. The system facilitates the recovery of metals. Salts from the boiler blowdown are treated as wastes in a standard water treatment facility.

The positive factors represent a reduction in the volume of waste generated at the facility through a series of process modifications that have stimulated additional source reduction initiatives at the facility.

Report

The full report, entitled "Evaluation of Zerpel (Zero Liquid Discharge System) by Hanna J. Saqa, will be available as EPA/600 series report.

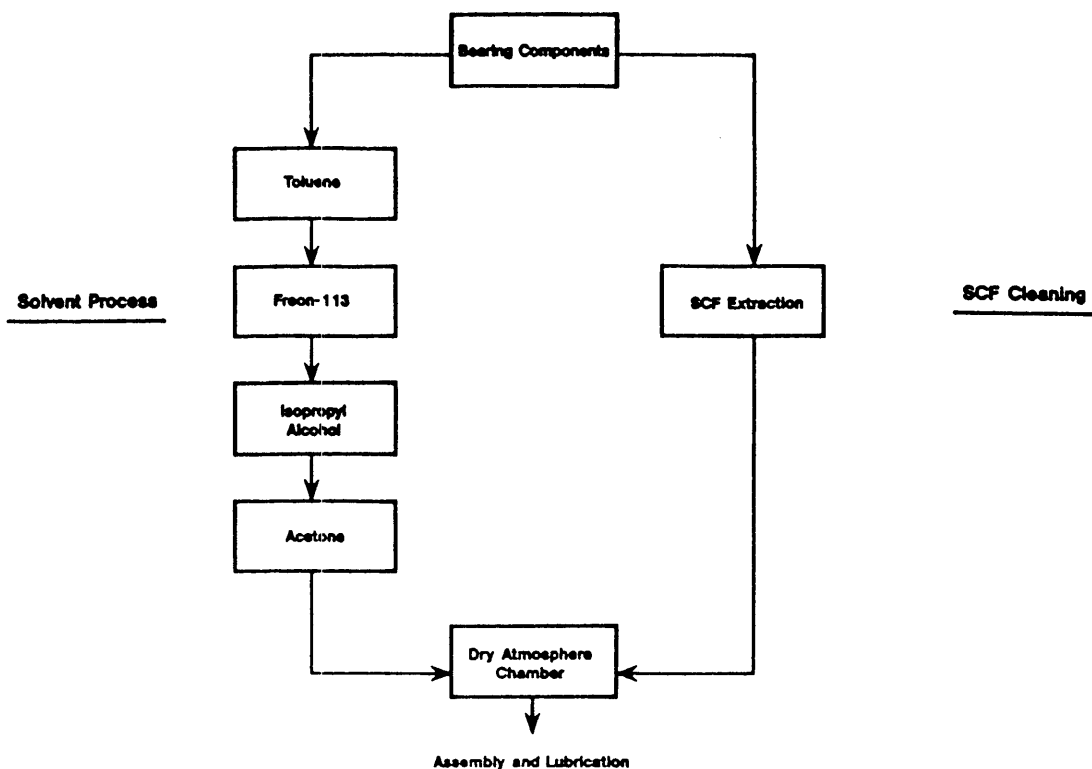


Figure 2. Comparison of solvent and SC CO₂ cleaning process steps used by Honeywell Space Systems Groups for instrument bearing cleaning

TABLE 1. OPERATING CONDITIONS FOR SC CO₂ CLEANING

Parameter	Scientific Units	Engineering Units
Pressure (gauge)	240 bars	3500 psi
Temperature	85° C	185° F
SC CO ₂ Density	0.6 g/cm ³	40 lb/ft ³
SC CO ₂ Flow Rate: (mass)	3.4 kg/hr	7.4 lbs/hr
(linear)	1 cm/min	0.4 in/min
(volume)	80 cm ³ /min	5 in ³ /min
Time	1-3 hours	1-3 hours

Product Quality Evaluation: The product quality evaluation consists of two parts: cleaning effectiveness and material compatibility. Determination of product quality involved testing both steel test coupons and actual bearings. The sample sets were artificially lubricated with several typical lubricants and then cleaned by both the solvent system and the SC CO₂ system for comparison. Both sets of parts were examined visually to determine gross cleaning. The test coupons were further analyzed by Fourier transform infrared (FTIR) spectroscopy and X-ray photoelectron spectroscopy (XPS). Torque tests were performed on the bearings to determine if they had been adequately cleaned.

The cleaner used in this study, Petroferm BIOACT™ 285, was selected because it is representative of this class of material. BIOACT is a mixture of high molecular-weight aliphatic esters and can be categorized as a semiaqueous fluid. The cleaner is meant to be used without dilution and must be rinsed with alcohol, such as IPA, rather than with water. The alcohol used is a technical grade that is at least 98% IPA, with the remainder being water. The IPA evaporates rapidly due to its high vapor pressure (3 mm Hg @ 68°F).

Testing: The product quality evaluation involved analytical testing to ensure that the new technology provided an acceptably cleaned product. Cleaning effectiveness was evaluated on the basis of visual inspection by an experienced technician at Duffy. Additionally, for the purposes of this test, a more quantitative approach was also tried to monitor cleaning effectiveness.

Two similar motors were selected from the shop's inventory, each was disassembled, and a rotor housing with stator and end cover were selected for testing. The two sets of motor parts were contaminated with an oil/carbon mixture, representative of the soils found on actual motor parts. The soiled parts were heated in a 105°C oven for 16 to 24 hours (MIL-C-85570B) and then cleaned at regular intervals. Cleaning performance was determined by measuring residual soluble surface material on the parts. The parts were cleaned using the IBR cleaning system, then visually inspected by a Battelle technician and by Duffy staff.

Thereafter, the parts were cleaned by agitation in a 1-L bath of hexane. The hexane was evaporated onto platinum weigh dishes to determine nonvolatile matter according to ASTM D 1353, i.e., the amount of residue remaining after cleaning.

Certain parameters for monitoring the condition of the cleaner and alcohol also were checked, including appearance, color, nonvolatile matter (alcohol only), specific gravity, and pH of a water extract of the ester cleaner.

One of the product quality parameters was designed to show possible adverse effects of the cleaner and IPA on wire insulation materials. Tests were conducted to evaluate whether the elastomers are compatible with BIOACT™ 285. Swell ratio (by weight and thickness change, ASTM method D 2765) was measured in small (approximately 2-inch-square) coupons of the elastomers Buna-N, Hypalon M, silicone, and neoprene. These materials are used for electrical insulation on the wire leads of older electric motors.

Waste volume was determined by measuring the volumes of spent cleaner and IPA after completion of testing. The test was completed after cleaning about 108 parts over a twelve week period.

Results

Performance--

The data in Table 1 show that the residual soil levels on both sets of motor parts varied consistently over the course of the study. Except for the first measurement (day 8), residue measurements from day 37 to day 86 are within 1 to 2 g per set of motor parts. The higher values on day 8 are believed to be due to removal of debris from the motors or to incomplete cleaning, because these results are not consistent with the remainder of the cleaning runs. Higher residue measurements at 71 and 79 days are believed to be caused by soil-loading of the ester cleaner.

TABLE 2. POLYMERIC MATERIALS TESTED IN THIS STUDY

Common or Trade Name	Chemical Name	Nominal Sample Thickness (in)
Teflon™	Polytetrafluoroethylene (PTFE)	0.064
Delrin™	Polyoxymethylene, Acetal Resin (POM)	0.12
Meldin™	Porous Polyimide (PI)	0.21 (0.6 dia. rod)
Phenolic	Phenol-Formaldehyde Resin (PF)	0.265

SC CO₂ cleaning did not result in a length change in the phenolic material but did in the Teflon™ and Delrin™ materials. In general, the polymer coupons increased in length. The magnitude of the increase was greater due to SC CO₂ cleaning than from the alcohol and Freon™ cleanings. The length changes were all less than 0.6%, therefore dependent upon the situation this change may not be significant.

Pollution Prevention Potential--

At the site of this study, approximately 150 bearings are cleaned per year. Approximately 300 mL of each of 5 solvents (Freon™, toluene, hexane, isopropyl alcohol and acetone) are used for cleaning each bearing. This means that approximately 12 gallons of each solvent is generated as waste (some in the form of air emissions) per year. Freon™-113 will no longer be manufactured after 1995. Toluene is on EPA's list of 17 priority chemicals that was targeted for 33% voluntary reduction by 1992 and 50% reduction by 1995. These emissions and wastes are substituted with CO₂. CO₂ is not generally considered as a hazardous material or waste. It is, however, correlated with global warming. Additionally, wastes can be produced as part of its manufacture and processing. Use of waste CO₂ as distinct from that manufactured from virgin material and for the express purpose for making CO₂ also impacts the net effect of P2. Sources such as lime kilns, for example, would not produce a net increase of CO₂ while utilizing a waste product from that operation.

Economics--

The economics of the SC CO₂ cleaning process include capital and operating costs. Capital costs include investment in equipment and installation. Operating costs include purchasing CO₂, energy, labor, and maintenance. These costs were determined by records of purchases and experiences in using the system, provided by Honeywell. Table 3 compares the major operating costs of the two.

The SC CO₂ system can process a maximum of 20 bearings per load, while the solvent system is a small bench top unit that cleans one bearing at a time. The cost estimate for the SC CO₂ system is based on running a full load each time. This may not actually be feasible with a facility that cleans only 150 bearings a year. The annual operating cost per bearing would be higher for smaller production rates. Honeywell recycles their Freon™ which would result in a lower purchase cost, but this would be offset by the cost of recycling. In this scenario the purchase cost was used because the recycling costs were not readily available. The disposal cost does not include the price of Freon™ disposal.

about 180 gal of spent solvent can be collected for distillation and later reuse, and another 180 gal is unrecoverable. In contrast, the new cleaning system generates 106.6 gal of spent solvent per year, of which 16.1 gal of IPA is unrecoverable due to evaporation, and 78.1 gal of liquid waste is produced.

Air emissions need further study when evaluating the benefits of an ester- and alcohol based cleaning system and making comparisons with other petroleum distillates or chlorinated organics. The petroleum distillate solvent contains an unknown amount of toluene, ethylbenzene, and other hazardous air pollutants. The chlorinated solvents are both volatile and toxic. The ester-based cleaner itself does not result in any significant evaporation. Although the alcohol rinse has a high evaporation rate, its constituents are not generally considered as hazardous as those found in petroleum solvents or chlorinated solvents.

Economics--

Table 2 gives the annual operating costs of both the existing petroleum solvent cleaner and the alternative ester-based cleaning system. The major operating cost of the new cleaning system is due to the cost of the ester cleaner and IPA rinse. If a heating element is used, energy usage also needs to be considered. Disposal costs may vary depending on the system currently in use. At this shop a contractor retrieves the used petroleum solvent for recycling and supplies the shop with a clean recycled product for use.

Under the ester/alcohol system, the same contractor supplies the cleaning and rinsing fluids. While these solvents could be recycled, the contractor does not have a recycling system in place. Recycling of these fluids could favorably impact the price of the ester/alcohol system. Changes in disposal costs and compliance requirements could also significantly change this equation.

TABLE 2. ANNUAL OPERATING COSTS

New Cleaning System	
Ester: 51.4 gal @ \$20.00 per gal	\$1,028
Isopropyl Alcohol: 55.2 gal @ \$3.00 per gal	\$166
Disposal: 78.1 gal @ \$2.50 per gal	\$195
Total ^a	\$1,389
Existing Petroleum Solvent System	
Solvent purchase and disposal	\$1,070
Total ^b	\$1,070

^a Total does not include labor, energy, and small maintenance costs.

^b Total does not include cost of drying the parts, should faster drying be necessary.

The ester/alcohol system may be less expensive in comparison with chlorinated solvents. Actual applications need to be considered for determining economics.

Report

The full report, "Replacement Solvent Cleaner/Degreaser Study at Duffy Electric and Machine Company, by Bruce M. Sass, et al., will be available as an EPA series 600 report.

#29 REPLACEMENT NON-METHYLENE CHLORIDE PAINT REMOVER

Participants

The host for the evaluation was the Tooele Army Depot, Consolidated Maintenance Facility, Tooele, Utah, who also operated the Parts Chemical Cleaning System (PCCS). Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

The focus of this study is on the Parts Chemical Cleaning System (PCCS), which is designed for depainting, cleaning and applying conversion coatings to ferrous and nonferrous engine parts and powertrain subassemblies. Application of conversion coatings is a surface preparation method to provide corrosion protection and increase adhesion of the paint.

The PCCS is designed such that an automated overhead monorail transports baskets of parts through tanks of paint remover and various rinses prior to application of conversion coatings. A pre-programmed system controls the process by controlling the material handling equipment that immerses the baskets into the tanks for predetermined dwell times, drains the baskets, and moves the baskets to succeeding tanks.

The rinsewater from the process contains paint remover, dissolved paint resins, pigments, and other paint additives. This rinsewater is piped into a holding tank and then is later treated by a fixed-film biological reactor prior to merging it with a stream that goes to the Industrial Waste Treatment Facility. The system employs automatic controls to regulate tank solution levels, temperatures, agitation tank ventilation, tank heating and solution filtration.

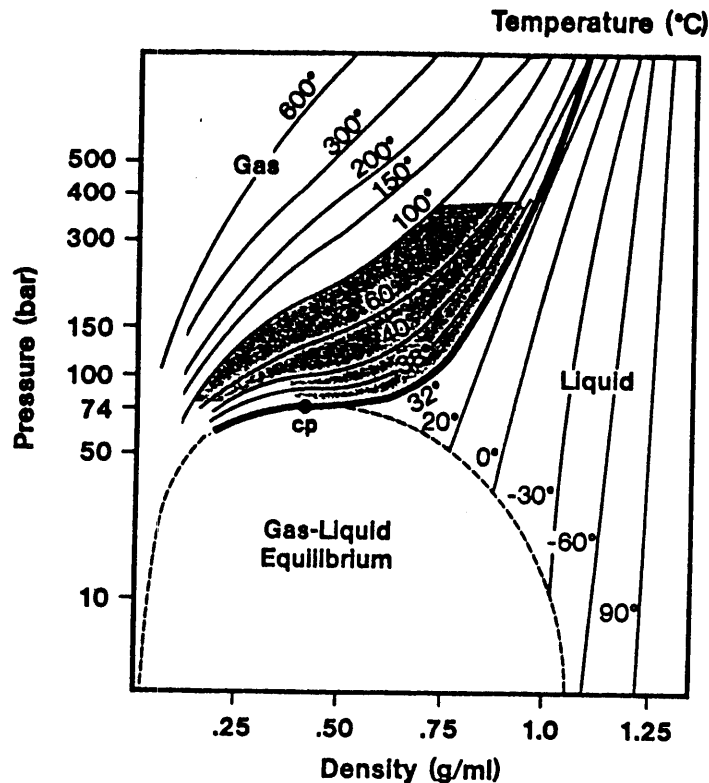
This study provides an investigation of an 86% N-methyl-2-pyrrolidone (NMP) and 14% monoethanolamine (MEA) mixture as a substitute for methylene chloride solvent in an immersion paint removal operation.

To evaluate product quality, test coupons were made and processed through the paint remover system along with actual parts. An equal number of coupons were coated with heat resistant coatings and chemical agent resistant coatings (CARC) respectively. The degree of paint removal from the coupons was qualitatively evaluated. The baskets of actual parts were evaluated on a pass/fail basis. To evaluate the pollution prevention potential of the new paint remover solvent system, three process streams were evaluated. First, the paint removal solvent was evaluated for dissolved metals (Cd, Cr, Cu, Pb, Mn, Ni, and Zn) and concentrations of NMP and MEA. The rinsewater entering the biological reactor was analyzed for concentrations of metals, NMP, MEA, pH, total suspended solids, total organic carbon, and chemical oxygen demand. After treatment by the biological reactor, the rinsewater was also analyzed for the same analytes.

Results

The NMP/MEA solvent mixture removed the heat resistant coating from ten out of thirteen test coupons. The mixture also performed well at removing the polyurethane topcoat of the CARC. The topcoat was removed on all test coupons. The mixture demonstrated difficulty in removing the primer coat of the CARC system. Percent removal ranged from 32% to 95%. Based on visual observations of the test coupons, the NMP/MEA mixture removed the primer coat more readily on smooth surfaces than rough surfaces.

solvent power decreases substantially and contaminants drop out of solution and remain in the separator vessel. The CO₂ continues to flow out of the separator vessel through a flow indicator and to the atmosphere. The operating conditions for the SC CO₂ cleaning unit are listed in Table 1.



Source: Schneider (1978).

Figure 1. Pressure-density diagram for pure CO₂. Isotherms are solid lines; Cp is critical point; shaded area is useful cleaning region

The Space Systems Group purchased supercritical fluid processing equipment from Liquid Carbonic in 1990, and modified it extensively to perform cleaning operations. Supercritical fluid cleaning is one technology that the Space Systems Group is evaluating as a substitute for organic solvents. A comparison between solvent and SC CO₂ cleaning processes is shown in Figure 7. The SC CO₂ cleaning unit (shown in Figure 1) is operated full time at the facility and now routinely handles a portion of the cleaning workload. The cleaning system is still being evaluated by Honeywell, and improvements are continually being considered and implemented.

WASHINGTON STATE

Seven technologies were evaluated for the state of Washington. Robert Burmark of the Washington Department of Environmental Quality (DEQ) was the Project Officer for the state, participating in identification of state pollution issues, locating host companies, preparation of Quality Assurance Plans and, assisting with the demonstrations.

#30 RECYCLING ELECTRIC ARC FURNACE DUST: JORGENSEN STEEL FACILITY

Participants

The testing was performed at the Earle M. Jorgensen (EMJ) Steel Company in Seattle. The developer of the technology, Roger B. Ek and Associates, provided a pilot scale unit that used K061 electric arc furnace dust generated by the plant. The developer provided test personnel to operate the unit. The SAIC Inc., on contract to EPA, provided test personnel to design EPA's part of the test, obtain the data and drafted a final report.

Technology/Testing

The steel-making industry produces a large amount of Electric Arc Furnace (EAF) dust as part of normal production. A glass technology called Ek Glassification™ (hereafter called "the Process") has been developed by Roger B. Ek and Associates, Inc. (hereafter called "the Developer") to recycle this listed waste (K061) and convert it, along with other byproducts of the steel-making industry (i.e., spent steel slags, spent refractories, mill scale, and grinding swarf), into marketable commodities that are defined as nonleachable by TCLP protocols. These products may include colored glass and glass-ceramics; ceramic glazes, colorants, and fillers; roofing granules and sand-blasting grit; and materials for Portland cement production.

The goal of this project was to evaluate the effectiveness of the Process in generating a nonleachable product from K061-listed waste. Three glass recipes were designed for use at EMJ, identified as Glass I, II and III. The EPA test program focused on recipe II.

Due to the scope of the effort, the EPA work was restricted to the collection of two duplicate samples from each of the solid products for the Glass II recipe (granular and castable).

The test furnace was located in the steel-melting area of the EMJ plant so that fugitive emissions could be collected with the steel plant's dust collection system and routed back to the baghouse.

Gas burners were used to bring the furnace up to operating temperature (2,400 to 2,500°F). This operation required approximately 12 hr. Once the operating temperature was reached, the glass batch was added. The electric heating system utilized two, commercial-sized, 1-1/4-in. diameter, molybdenum electrodes.

The testing used natural gas as the primary melt energy. The purpose of the electric melting tests was to establish melt conductivity, measure the amperage flow at constant voltage and select glass temperature isothermal conditions. These data were used to determine the specifications for transformer equipment (especially the operating voltage range) to be used in full-scale operations. The electrodes also provided heat to maintain the furnace temperature between 2,400 and 2,500°F. Each batch produced about 250 to 300 lb. of molten product.

The impact on the polymer materials used in bearings as ball retainers and oil seals was analyzed. Polymer coupons were subjected to either SC CO₂ cleaning or to one of two solvents (IPA or Freon™) for 4.5 hours. Measurements of weight change (swell ratio) and length change were made for instrument bearing cleaning.

Results

Results of the cleaning tests after SC CO₂ cleaning, showed no contamination in any of the coupons tested with the exception of the Mil-L-6085 contaminated coupons. An aliphatic ester was detected at the 0p polarization angle. Unfortunately, the Mil-L-6085 contaminated coupon that was cleaned by the solvent system was not analyzed at the 0p polarization angle. Therefore, it is not certain whether aliphatic ester would have been detected by FTIR on the solvent-cleaned coupon. It can only be concluded that SC CO₂ cleaning did not remove all of the ester lubricant. However, it is not known from FTIR if SC CO₂ cleaning of Mil-L-6085 lubricant is comparable to solvent cleaning or inferior to solvent cleaning. FTIR does show that SC CO₂ cleaning removed PAO and PFPE lubricants from 440C bearing surfaces as effectively as solvent cleaning, within the sensitivity of the method.

Bearing Tests --

A performance test of the cleaned product may be the most important test of the SC CO₂ cleaning method. In this case, instrument miniature bearings were cleaned using the SC CO₂ method to determine cleaning effectiveness. Removal of lubricating fluids from bearings is expected to be less efficient compared with cleaning flat coupons.

Spin-axis bearings with Teflon retainers were supplied by the Naval Air Station, Jacksonville, Florida. Torque tests had been performed on these bearings after they were received from the manufacturer and again after they were cleaned and relubricated at Jacksonville Naval Air Station. All of the bearings were new, and had not been used other than for testing purposes. The startup and running (or dynamic) torque tests are appropriate for spin-axis bearings, which are defined by MIL-STD-206B.

The procedure for testing torque involved running baseline torque tests on solvent cleaned bearings and comparing these results with SC CO₂ cleaned and relubricated bearings. These tests show whether SC CO₂ cleaning affects the measured torque, possibly due to incomplete cleaning, swelling of ball retainers, or other effects.

Polymer Compatibility Tests --

This portion of the product quality evaluation determined whether the SC CO₂ cleaning method has adverse effects on the polymer components of a product. These may include changes in appearance, swelling of the material, or changes in length. Certain polymers that are commonly used in bearings as ball retainers or as oil seals were tested to determine if they are adversely affected by SC CO₂ and CFC solvent cleaning. The polymeric materials tested are listed in Table 2. The coupons were subjected to SC CO₂, Freon™-113, or isopropyl alcohol (IPA) for approximately 4.5 hours per each procedure. Three types of measurements were conducted on the polymer coupons: appearance, length change and swell ratio. Sample coupons were cut from sheet stock in approximately 1 in x 1 in dimensions for appearance and swell ratio tests. Sample coupons were cut from sheet stock in approximately 1 in x 6 in pieces for the length change tests.

After removing the coupons from the CFC bath or SC CO₂ chamber the coupons were inspected visually under white light for color change, curling, thinning, and other obvious signs of damage. No changes were noted by visual inspection.

Results

Samples analyzed by NET Pacific for EPA indicated low leachability characteristics for metals in the final products as shown in Table 1. The leachable metal content in both the castable and the granular samples was within the TCLP limits for all compounds for which they were analyzed. Barium, chromium, lead, and zinc were the only compounds detected in either of the EPA samples. Comparison of these data to those obtained by Sound Analytical Services, Inc. (see Table 1) produced similar results (for the granular product only) even though the Developer's laboratory could not achieve the same detection limits as the EPA laboratory.

TCLP analyses were performed on Glasses I and III by the Developer's laboratory. The results of these analyses indicated that the products were within the TCLP leaching maximums.

Stack gas sampling data were previously gathered during earlier tests at the Oregon Steel Mill (OSM). Although these data suggest acceptable air emissions, the data are of questionable quality because they do not satisfy EPA stack testing protocols and standards.

TABLE 1. TCLP RESULTS AND COMPARISON TO
REGULATORY LIMITS FOR SAMPLES FROM EMJ

EPA HW No. ¹	Contaminant	EPA Castable Sample ² (mg/L)	EPA Granular Sample ² (mg/L)	Developer Granular Sample (mg/L)	Regulatory Level ³ (mg/L)
D004	Arsenic	<0.0025	<0.0025	<0.2	5.0
D005	Barium	0.043	0.025	<0.1	100.0
D006	Cadmium	<0.0035	<0.0035	<0.1	1.0
D007	Chromium	0.050	0.13	0.1	5.0
D008	Lead	0.067	0.120	<0.1	5.0
D009	Mercury	<0.000086	<0.000086	<0.002	0.2
D010	Selenium	<0.001	<0.001	<0.3	1.0
D011	Silver	<0.0092	<0.0092	<0.1	5.0
----	Zinc	0.95	0.60	0.6	NR

Cost estimates were performed for the OSM plant by the developer. A full-scale system producing 60 tons of glass/day, and operating 350 days/yr would require an initial cost of \$10,500,000 for design, construction and start up.

For a ten yr. period, the Process could produce a gross profit of \$63,195, 000 while avoiding \$43,040,000 in disposal costs, for a total savings of \$106 million, not including reduced liability benefits, and avoidance of administrative costs for permits and managing of hazardous waste under the old system.

The actual savings realized will depend on the types and amounts of the products sold. Estimates of market conditions during the OSM test period indicated that the lowest value products were cement

Pollution Prevention Impact--

The NMP/MEA paint removal system eliminates the use of methylene chloride for this depainting operation. As a result, this system prevents the disposal of 48,843 lbs of used methylene chloride annually. Since methylene chloride is no longer a part of the system, Tooele can now regenerate the activated carbon used in its building ventilation system. Prior to this innovation, the spent carbon material was considered a hazardous waste. This change resulted in the saving of 240,000 lbs of activated carbon from disposal as hazardous. The fixed-film biological reactor removed 89% to 98% of the NMP.

TABLE 1. ECONOMIC EVALUATION DATA

Activities	Annual Cost Savings
Process Operation	\$140,000
Activated Carbon Disposal	\$174,000
Payback Period	Less than 1 year

NMP/MEA is a viable replacement for methylene chloride in the removal of heat resistant and chemical agent resistant coatings. However, health effects considerations require that the choice between NMP and methylene chloride be a more deliberate one. EPA's Office of Pollution Prevention and Toxics has issued a report entitled Lifecycle Analysis and Pollution Prevention Assessment for NMP in Paint Stripping. This report states that NMP may cause reproductive and developmental effects in humans. The report further states that the primary risk of exposure to NMP is through dermal contact and that this exposure can be effectively controlled through use of impervious protective gloves. U.S. EPA considers methylene chloride to be a hazardous air pollutant because of its low exposure limit and high volatility. Methylene chloride is also a suspected human carcinogen by the National Institute of Occupational Safety and Health (NIOSH) and by the American Conference of Governmental Industrial Hygienist (ACGIH).

Report

The full report, entitled "A Replacement Non-Methylene Chloride Paint Remover Study at Tooele Army Depot, Tooele, Utah" by Bruce Sass, et al., will be available as an EPA series 600 project report.

#31 LOW-VOLATILITY SOLVENT AND FILTRATION SYSTEM FOR MECHANICAL PARTS WASHING

Participants

The host for the mechanical parts washing project was the Titus-Will Ford dealership garage in Tacoma WA. Mechanics at Titus-Will operated the equipment. Battelle, Columbus Laboratories, on contract to EPA, provided test personnel, designed the test and drafted the final report.

Technology/Testing

The Breakthrough/Edge-Tek Filter System technology, which is produced by Inland Technology, was evaluated in this study. It has two components: Breakthrough, a low-volatility solvent, composed mostly of C11-C13 hydrocarbons with cleaning potential similar to that of mineral spirits, and a two-stage filtration system built into the parts washing station (Figure 1).

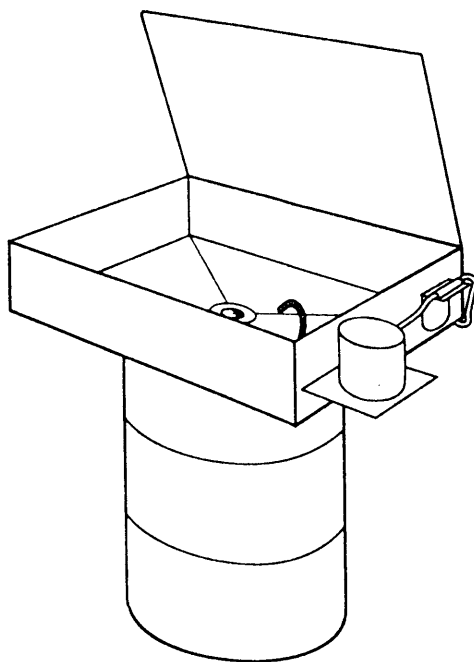


Figure 1. Typical Breakthrough/Edge-Tek Filter System

The first stage is a coarse ($80\text{-}\mu\text{m}$ nominal pore size) reusable stainless steel filter, and the second is a fine ($0.1\text{-}\mu\text{m}$ nominal pore size) single-use filter. The filters are designed to remove suspended matter in the solvent, thus lengthening the solvent's useful lifetime. There is some indication that the fine filter, made of cellulosic material is also capable of removing grease and oil from the system. Heavier hydrocarbons may separate as colloids and then be filtered out. Periodically – typically monthly – the coarse filter can be removed and washed with the solvent and the particulate can be collected for disposal as solid waste; the fine filter can be discarded and a new filter installed. Approximately yearly the material that accumulates in the bottom of the parts washing station must be removed and disposed of properly.

additives at \$2 to \$6/ton. The highest value products, such as glass ceramics and architectural tiles sold from \$175 to \$650/ton.

Conclusions were:

- The glass types tested, resulted in relatively non-leachable products
- For the metals of interest for K061 waste (cadmium, chromium, and lead), leachability values were lower than those allowed under RCRA regulations for TCLP.
- The Process can utilize other (non-listed) foundry wastes to replace constituents that would be purchased as virgin additives for glass-making. Ideally this could result in both a conservation of resources and recycling of both hazardous and non-hazardous wastes at the foundry.
- This project did not focus on investigating compliance issues in terms of air emissions and waste water generated during batch charging, melting, quenching and drying of the three glass products. It is believed that significant variation in emission species and concentrations are possible, due to the specific application and associated operational procedures.
- Compliance issues should be evaluated on a case-by-case basis at least until full-scale data are accumulated to better identify the variability associated with applying this technology.

Report

The full report, titled "Recycling of Electric Arc Furnace Dust: Jorgensen Steel Facility," by Trevor W. Jackson and Jamie Sue Chapman is available as report number EPA/600/R-95/007.

Results

The initial batch of Breakthrough solvent required disposal 16 months after Titus-Will switched to the Breakthrough/Edge-Tek Filter System. Due to faulty communications and the improper use of the system, as described below, the contents — solvent and sludge — of a 30-gal parts washing station weighing approximately 120 lb., had to be disposed of prematurely. On an annual basis at this rate of use, this is the equivalent to 90 lb of waste per parts washing station.

A small number of used fine filter elements, each weighing approximately 1 lb, also required disposal. Therefore, the total amount of waste with Breakthrough as used at Titus-Will during the study was approximately 100 lb per parts washing station per year. Replacing the mineral spirits-based system with Breakthrough thus reduced the volume of waste requiring disposal by 1500 lb per year per station. The total waste reduction cannot be estimated because no information is available for losses with the previous system due to drag out and evaporation. However, the data on Breakthrough is favorable; through the end of the study less than two gallons (approximately 16 lbs.) of solvent had been added to the station due to account for drag out and evaporation.

At the time of this test, a few of the mechanics wanted to replace the used Breakthrough solvent with fresh because they were no longer convinced that the solvent was working as efficiently as it should. Consequently, it was discovered that the mechanics were not adhering to vendor-recommended procedures regarding the fine filter replacement. It was found later in the study that most of the mechanics had removed the fine filters from the washing units, either replacing them with a coarser substitute (e.g., rags or paper towels) or operating the unit with only the coarse filter installed. The latter was the case for the unit used for sampling. While this prevented the determination of the maximum Breakthrough solvent life, the 16 month period did provide a conservative data point for comparing waste amounts and economics with the previous system using mineral spirits.

The results of flashpoint analyses on the sludge and on both fresh and used Breakthrough solvent are presented in Table 1.

TABLE 1. SUMMARY OF RESULTS OF FLASHPOINT ANALYSES

Sample Location	Flashpoint (°F)
Solvent in Reservoir	104
Sludge	122
Fresh Solvent	158
Regulatory Level	140

Tables 2 and 3 present the results of the total and the Toxicity Characteristic Leaching Procedure (TCLP) extractable metals analyses. As seen in Table 2, the total metals concentrations were elevated only in the sludge taken from the tank. This would be expected, because the particulate matter should be accumulating in the sludge. The TCLP-extractable metals analyses showed cadmium, chromium, and lead concentrations below RCRA-regulated levels. The used solvent, however, does contain a concentration of TCLP-extractable cadmium equal to the regulatory level and TCLP-extractable lead in excess of the regulatory level; thus it would require treatment and disposal as a hazardous waste.

This system replaces higher volatility, organic solvent such as CFC's and chlorinated organics previously used for parts cleaning.

Site Description--

At Titus-Will, the systems are used to clean parts during maintenance and repair of Ford cars and trucks. The facility has more than 20 parts washing stations with which they have over one year of experience. Each system is assigned to a specific mechanic who is responsible for filter cleaning and replacement. For this evaluation, only one of the systems was tested due to resource and economic constraints. After consulting with the mechanics and service manager to find how the systems were being used and maintained, the test system was picked as representative of the systems installed, based on a qualitative analysis of the number of service jobs and types of parts cleaned.

Product Quality Evaluation--

Product quality refers to the sufficient cleanliness of parts to be examined for wear, cracks and defects and reassembly as required. This is a subjective judgement made by each mechanic. Based on the observations and interviews, it was concluded that the solvent will provide adequate cleaning under circumstances similar to the procedure described here.

During each of three site visits, mechanics were observed while performing cleaning operations. A number of mechanics were interviewed during and after cleaning observations to gain insight into how they determine whether a part is acceptably clean and what additional measures they might take to remove dirt or soil if the solvent did not produce acceptable results.

Based on their experience, the mechanics observed that, compared to the previous solvent used, Breakthrough required more scrubbing in order to remove grease and oil. Consequently, they felt that more time was spent on cleaning parts. The service manager, however, did not see any significant increase in the overall time required to perform these service jobs. Because of the large portion of time spent on disassembly/assembly, small differences in the cleaning operation appeared insignificant.

There were some limitations to the technology. Certain materials that had not been a problem with the mineral spirits-based solvent were found to be incompatible with the Breakthrough/Edge-Tek Filter System. For example, transmission fluid in the system clogged filters very quickly because it formed an emulsion with colloids large enough to be captured on the fine filter. Brake fluid also did not mix well with the solvent. Finally, parts exposed to high heat often had "baked-on" deposits that were difficult or impossible to remove using Breakthrough alone, leading to some use of spray-on cleaners. Parts that required painting after cleaning also needed an additional cleaning because Breakthrough leaves a thin, waxy film to which paint will not adhere.

Because the Breakthrough/Edge-Tek Filter System replaces volatile solvent cleaning, waste reduction is achieved through the elimination of solvent discharge which is part of the monthly replacement. Before the Edge-Tek Filter System was installed and Breakthrough introduced, the solvent and sludges in Titus-Will Ford's mineral spirits-based parts washing stations were removed every month and replaced with a mixture of fresh and recycled solvent as part of a maintenance contract. A typical parts washing station contained 20 gal, or about 140 lb, of solvent. Over a year, each station typically generated more than 1600 lb of used solvent for disposal, plus an undetermined amount lost to volatilization and drag out.

The equipment cost was supplied by the manufacturer and is shown for a 30-gal parts washing station complete with the Edge-Tek Filter System, not including the solvent. Startup costs consist primarily of the initial solvent supply, along with a short period of operator training. Working capital was estimated as a 1-month supply of consumables, i.e., one fine filter. The contingency was estimated as a fixed percentage of the equipment, materials, installation, and engineering costs combined. Note, however, that most of these costs are zero, because the shop requires no modification for the new technology. The only utility connection required is an electrical outlet supplying 110V and 15 amps. The Standard Depreciation, Income Tax, Inflation, and Cost of Capital Rates were estimated.

The primary economic benefit of using the Breakthrough/Edge-Tek Filter System is the reduction in waste disposal costs. There is a net reduction of 0.75 ton per year per station in wastes disposed of or sent off site for recycling. This is a savings of \$60 per month to dispose of this material. A payback period of fewer than 4 years was found. At 4 years the return on investment (ROI) was 9.67%, and after 10 years the ROI was greater than 29%.

Economically, the Breakthrough/Edge-Tek Filter System appears to be a viable waste reduction technology. The system has a moderate payback period and moderate ROI over its life, given the inputs used.

Discussion--

The evaluation of the Breakthrough/Edge-Tek Filter System marginally demonstrated that the combination has the potential to reduce the amount of waste generated during parts cleaning. For this application the process provided parts having an acceptable degree of cleanliness for the operations at the host site. However, due to problems with system maintenance and sampling, the results did not support the claims made by the vendor.

Report

The full report, entitled "Low Volatility Solvent and Filtration System for Mechanical Part Washing" by David P. Evers, et al. will be available as EPA 600 report series in the near future.

TABLE 2. SUMMARY OF RESULTS OF TOTAL METALS ANALYSES

Sample Location	Cadmium mg/L	Chromium mg/L	Lead mg/L	Nickel mg/L	Aluminum mg/L	Iron mg/L
Solvent in Tank	1.0	1.2	36	1.5	12.6	166
Water in Tank	0.75	0.65	8.4	<0.75	12.5	281
Sludge	23.7	65.9	1,065	41.7	4050	25,050
Fresh Solvent	<0.12	<0.27	<1.5	<0.58	<1.7	1.8

TABLE 3. SUMMARY OF RESULTS OF TCLP METALS ANALYSES

Sample Location	Cadmium mg/L	Chromium mg/L	Lead mg/L	Nickel mg/L	Aluminum mg/L	Iron mg/L
Solvent in Tank*	1.0	1.1	36	1.7	<1.7	168
Water in Tank	0.318	<0.007	0.16	0.157	0.13	41.4
Sludge	0.183	<0.011	0.90	0.14	0.41	16.4
Fresh Solvent	<0.12	<0.27	<1.5	<0.58	<1.7	0.92
Reg. Level	1.0	5.0	5.0	NA**	NA**	NA**

* High metals content may be due to removed fine filter

** NA = Not Applicable

Total Organic Carbon (TOC) analyses were conducted on the sample of water and sludge taken from the tank. The TOC of the water sample was 26,000 mg/L, whereas the sludge TOC was 25,000 ppm. Both values indicate that a considerable amount of organic matter accumulated in the respective samples. The TOC of the water sample is high enough to require pretreatment before disposal to a POTW.

Economic Assessment--

Process economics of interest included capital costs, operating and maintenance costs, and waste disposal costs. Capital costs included the cost of the equipment, the cost of installation, and any other one-time costs associated with making the equipment operational. Operating and maintenance costs included all those associated with day-to-day operation of equipment, such as detergent costs, water cost, energy costs, maintenance materials (including spare parts) and labor to operate and maintain the equipment. Waste disposal costs included on-site and off-site treatment costs or income.

An economic analysis was performed comparing the costs to install, operate, and maintain the Breakthrough/Edge-Tek Filter System with the previous system. Economic indicators such as payback period and return on investment were calculated and used to estimate the economic benefits. The evaluation included a combination of the available site-specific costs that were not business-sensitive to the host company. Other costs were based on engineering judgments made by Battelle, based on typical costs associated with the activity. A discussion of these follows.

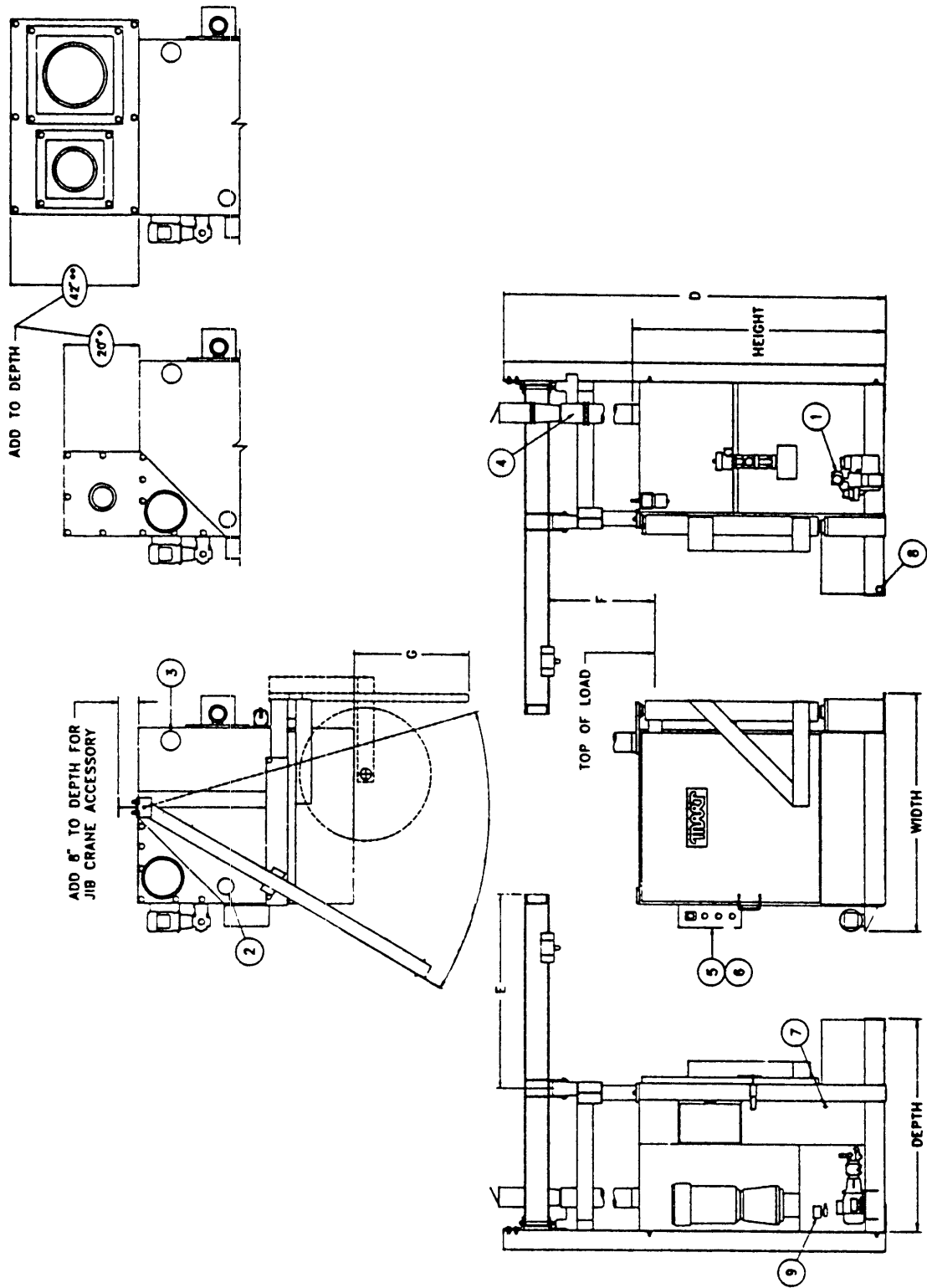


Figure 1. Typical MART power washing layout (Source: MART Corporation)

#32 POWER WASHER WITH WASTEWATER RECYCLING

Participants

The host for the project was the Municipality of Metropolitan Seattle, Atlantic Base Garage, where bus parts are cleaned for routine bus inspection and maintenance. The Metro garage operated their equipment during the test. Personnel from the Washington State Department of Environmental Quality assisted in the test. Battelle, Columbus Laboratories, on contract to EPA, provided test personnel, helped to design the test and drafted the final report.

Technology/Testing

Seattle Metro uses the Power Washer to clean parts in the course of daily maintenance of the busses used in the metropolitan area mass transportation system. The primary measure of product quality is whether the part is clean enough to allow visual inspection for damage, which is a qualitative measure performed by experienced operators.

The objectives for this test were to measure waste volume and identify the relative hazards by quantifying types and levels of contaminants and compare these to existing or previous cleaning systems. The system used at Metro produces four wastestreams; wastewater, settled particulate matter/sludge, skimmer/flotation waste, and a small amount of steam.

Identification of metals, oil and grease, TOC, pH and flash point was performed. The steam from washer was not measured due to the small amounts generated, complexity of measuring problem, the expected significance/impact of this waste and the budget limitations of the project. For a rigorous treatment of this area, the air emissions measurements could be included.

The technology, as evaluated, consisted of two separate components: the Mart Power Washer*, which is the high-pressure, high-temperature cleaning unit; and the Mart Clean Machine, which is the wastewater recycling system (Figures 1 & 2). The Mart Power Washer is representative of a general class of high-pressure, high-temperature aqueous cleaning systems. The washer has potential to replace other techniques for cleaning automotive parts such as organic solvents used for dipping, wiping and spraying, as well as vapor degreasing. It also replaces manual cleaning with high pressure water and detergent.

The Clean Machine cleans and recycles wash water. Three processes are used in the Clean Machine to separate oil, grease, and particulate matter from the wastewater. (1) A hydrocyclone is used to remove large particles and entrain air into the wastewater. Large particles are allowed to settle out in a sludge collection bin, from which the sludge can be removed periodically. (2) An air flotation chamber, where entrained air is used to bring oil and grease to the surface. (3) A powered, rotating, oil/grease skimmer and skimmer cleaning scraper, to remove the oil and grease that collects on the wastewater surface. The skimmer deposits the material in a holding device for further treatment, processing, or disposal.

In a typical parts cleaning operation, parts to be cleaned are fastened to the Power Washer turntable. The washer is operated for a brief period, usually 5 minutes. After the parts have cooled enough to be handled, they are inspected.

If parts do not meet inspection requirements, several adjustments can be made to improve system operation. These include repeating or extending cycle time, reorienting parts on wash table,

increasing detergent concentration or, lastly, replacing washwater and detergent. For the duration of the use of the Power Washer, the wash water had not as yet been replaced.

Results

With the previous, manual spray-cleaning operation, approximately 170 gallons per month of water, oil and grease, and particulate matter was disposed of as wastewater. Currently, the amount of material requiring disposal monthly is 25 gallons of particulate waste. The oil and grease removed from the water with the Clean Machine, on the order of 5 gallons per month, is recycled off-site. The volume of makeup water has been reduced to approximately 75 gallons per month, the majority of which is lost as condensed steam during Power Washer loading and unloading.

Since installing the Power Washer/Clean Machine equipment, Seattle Metro has also eliminated seven solvent cleaning stations. Solvent waste production has been reduced by approximately 210 gallons per month. The total reduction in waste volume (including water vapor air releases) approaches 275 gallons per month, or about 2000 pounds.

Waste Reduction Assessment--

There has been an overall reduction in hazardous waste volume with use of the Power Washer in conjunction with the Clean Machine. This reduction is approximately 80%, when all wastestreams -- aqueous, solvent, and sludge -- are considered. In addition, the wastestreams generated are segregated so that the waste oil and grease can be collected easily and recycled off site, the particulate matter disposed of properly, and the wastewater treated efficiently.

Economics of the system were based on data from Seattle Metro on the purchase price for the Power Washer/Clean Machine equipment and estimates for installation and start-up costs as percentages of capital cost.

Use of the Power Washer has decreased labor hours for cleaning parts by approximately three-quarters of a man-year. This was reflected as a productivity credit in the analyses because the operator is now free to perform other duties. Detergent use has been reduced by over 80%.

Savings in purchases of solvent, water and natural gas are also realized. However, there is a net increase in electricity consumption, largely due to the fact that the unit is electrically heated.

The Mart Power Washer and Clean Machine combination can reduce the amount of waste generated when compared to manual, high-pressure spraying or solvent cleaning. The system is capable of providing parts with an acceptable degree of cleanliness for the application tested.

For this and similar applications, the process economics are reasonably attractive. The return on investment over a 10 year period was calculated at greater than 28%. Using natural gas for heating water (vs. electricity) could further improve the economics.

If no oil film can be tolerated on the cleaned parts, such as painting operations, this system may not be an acceptable cleaning method without additional cleaning.

Report

The full report, entitled "Power Washer With Wastewater Recycling Unit," by David P. Evers, et al., will be available as an EPA report.

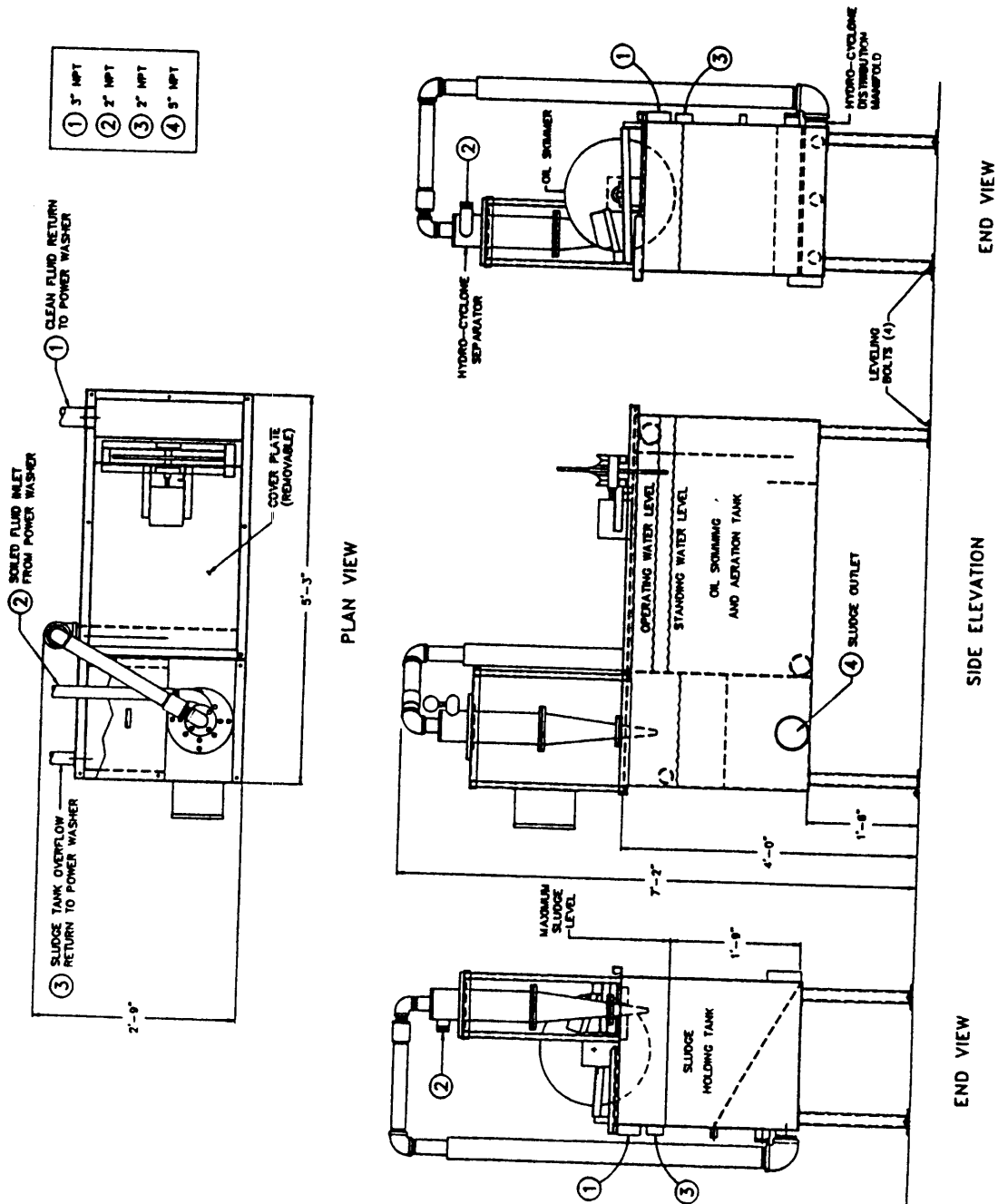


Figure 2. Typical MART clean machine layout (Source: MART Corporation)

The effectiveness of bicarbonate of soda blasting depends on optimizing a number of operating parameters including nozzle pressure, standoff distance, angle of impingement, media flow rates water pressure, and traverse speed.

The present study evaluated the bicarbonate of soda blasting technology, ARMEX®/ACCUSTRIP™ (see Figure 1), marketed by the CDS Group (Houston, Texas). The evaluation was conducted at NASA/JCS's Ellington Field, which maintains and repairs a fleet of 37 aircraft.

Product Quality Evaluation--

Although the quality of the work for this bicarbonate blasting system was based on paint removal without damage to the wheel surface that either modified metal performance or masked any cracks during inspection, an additional concern was the anodized layer below the paint. This thin (around one ten-thousand of an inch), electrochemical oxide layer is used to improve the corrosion resistance of the metal. Because of the relative vulnerability of this layer between the paint and metal the condition of this layer was used to determine the performance of the depainting process.

This study did not evaluate the effects of blasting on metal substrate damage and crack closure, because of previous work published on that topic.

Results

About 30 gallons of wastewater were generated and collected in a vat during each of the two blasting sessions. The mean values for the measured pollutants are presented in Table 1. The Cr concentration did not meet the local discharge limits, so the wastewater could not be disposed of to the Publicly Owned Treatment Works (POTW). Approximately 8 gallons of solid waste settled to the bottom of the vat after bicarbonate blasting of 4 wheels. Metal concentrations measured are presented in Table 2. Only a very small fraction of the metals was leachable under the Toxicity Characteristic Leaching Procedure (TCLP) conditions (see Table 2). TCLP requires the waste to meet limits of 1.0 mg/L Cd, 5.0 mg/L Cr, and 5.0 mg/L Pb. No regulations had been set for Cu, Mn, Ni, and Zn. The wastewater in the rotoclone separator contained less than detection limit of TSS and a very small amount of heavy metals, ranging from 0.005 mg/L of Cd to 0.39 mg/L of Zn. For the particular case tested, the wastewater could be sewered without treatment.

Other considerations were hazards that the stripping technology might pose to workers. These included toxic airborne particulate and unsafe noise exposures. Air quality in the vicinity of the blasting operator was measured in terms of airborne metal concentrations. Noise levels were measured on a sound-level meter and a dosimeter.

Air emissions were measured in the breathing zone of the operator and analyzed for Cd, Cr, Cu, Pb, and Zn. The cloud of mist created around the blasting activity was maintained within the work area and removed by a ventilation system consisting of an exhaust hood and a rotoclone dust separator.

The results of the airborne metal exposure study indicated that 8 hrs. time-weighted average (TWA) exposure to the airborne metals were below specified OSHA and American Conference of Governmental Industrial Hygienists (ACGIH) limits. Sound levels measured periodically in the operator's hearing zone during the two blasting sessions, on the "A" - weighted scale, ranged from 76.8 decibels (dBA) to 120.0 DBA. Dosimetry samples integrated cumulative noise. If the actual work period were increased to a full 8 hours, the projected 8-hour TWAs would be 121.3 dba for the first test and 115.9 DBA for the second test. A peak level of 146 DBA, the maximum level the dosimeter is capable of measuring, was recorded during both periods sampled.

#33 BICARBONATE OF SODA BLASTING TECHNOLOGY FOR AIRCRAFT WHEEL DEPAINTING

Participants

The Paint Stripping Shop at Ellington Field, National Aeronautics and Space Administration/Lyndon B. Johnson Space (NASA/JCS) Center in Houston, Texas, hosted the test and assisted in implementing the evaluations. Battelle, Columbus Laboratories, on contract to EPA, helped design the test program, supplied test personnel and equipment, and wrote the draft report.

Technology/Testing

Bicarbonate of soda blasting is a relatively new process that is commercially available. Compressed air delivers sodium bicarbonate media from a pressure pot to a nozzle where the media mix with a stream of water. The media/water mixture impacts the coated surface and removes old coatings from the substrate. The water dissipates the heat generated by the abrasive process, aids the paint removal by hydraulic action, and reduces the amount of dust in the air. As another convenience, the workers, do not need to prewash or mask the surface. The dust, unlike that of plastic media, is not an explosive hazard, nor is sodium bicarbonate toxic in this form. The airborne particulates generated from the stripping operation, however, can contain toxic elements from the paint being removed.

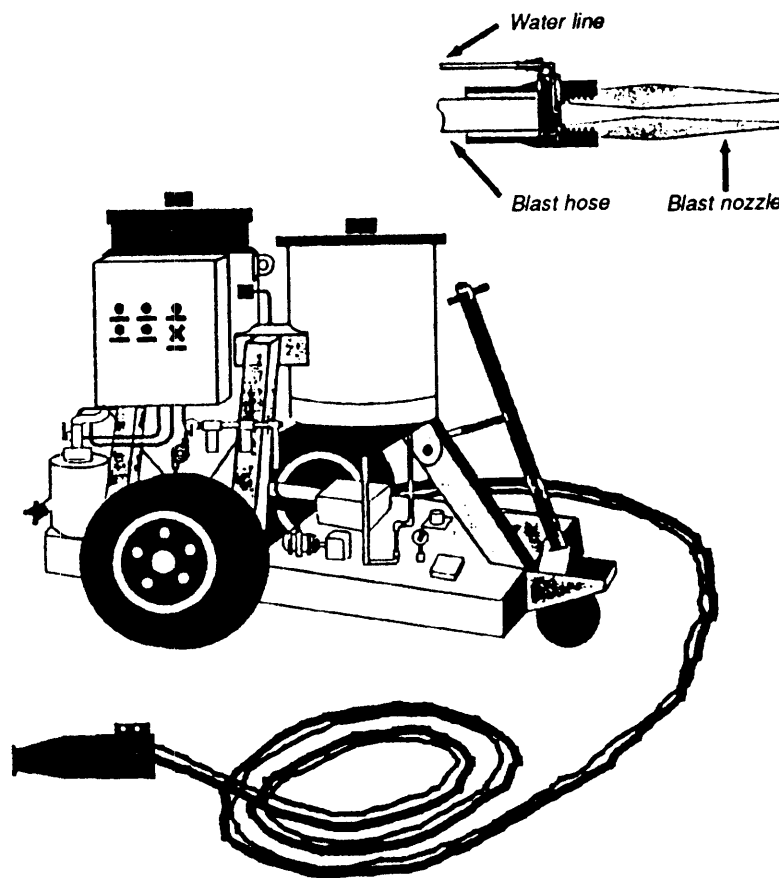


Figure 1. ACCUSTRIP SYSTEM™ with Wet Blast Head

Economic Evaluation--

Cost comparisons were made for bicarbonate blasting vs. chemical stripping. Blasting times to strip each wheel were measured during the test. NASA/JSC historical data were used to determine chemical stripping times. The capital investment, operating costs, and payback period were calculated according to the worksheets provided in the U.S. EPA Waste Minimization Opportunity Assessment Manual. The results of the economic analysis indicated that a return on investment (ROI) greater than 15% (which is the cost of capital) could be obtained in 4 years, or that the payback for NASA/JSC would be 4 years.

Conclusions/Recommendations--

The bicarbonate of soda blasting evaluation demonstrated that the blasting technology can effectively strip paint from aircraft wheels. The blasting technology substantially reduced the number of man-hours required for paint stripping in comparison to chemical stripping. The time saved was more than 95%.

The liquid waste accumulated in the vat exceeded the discharge limit for Cr and could not be sewered into the POTW. The quantity to be shipped away as hazardous waste was about 7.5 gal/T-38 aircraft wheel. The solid waste in the vat contained paint chips and debris, most of which was insoluble under the TCLP conditions. The wastewater in the rotocloner separator could be sewered without treatment.

Although convenient for this application and within existing local limits, the source reduction of this waste as well as reuse/recycling should be investigated in greater depth.

Although the exhaust ventilation system kept the heavy metal concentrations in the workspace below OSHA and NASA limits, the opportunities for source reduction to minimize rotocloner wastewater should be explored as well as possibilities for recycling and reuse of this water.

The operator of the blasting equipment was required to wear a full-face air-purifying respirator and protective clothing. Although the present test results did not make this an OSHA requirement, previous testing of this system produced chrome particulate concentrations that did. The added precautions are recommended until a better understanding of the system is developed. Improved lighting for better visibility at the work surface also is recommended.

The noise measurements indicated that, under the conditions encountered during this study, hazardous noise exposures can result. Therefore, engineering control of noise exposure should be investigated.

Report

The full report, entitled "Bicarbonate of Soda Blasting Technology for Aircraft Wheel Depainting" by Abraham S.C. Chen et al., is available as EPA/600/R-94/127.

**TABLE 1. OIL AND GREASE, TSS, Ph, AND METAL
CONTAMINANTS IN WASTEWATER COLLECTED FROM THE VAT**

Parameter	Mean Concentration	Local ^a Discharge Limit
Oil and grease (mg/L)	49.1	200
TSS (mg/L)	253	365
pH	8.367	6-10
Cd ^b (mg/L)	0.033	0.2
Cr ^b (mg/L)	8.0890	5.0
Cu ^b (mg/L)	1.240	2.0
Pb ^b (mg/L)	1.430	1.5
Mn ^b (mg/L)	0.022	3.0
Ni ^b (mg/L)	0.006	3.0
Zn ^b (mg/L)	5.990	6.0

^a Maximum allowable limits for grab samples, Industrial Waste Permit No. 1030, City of Houston, Texas, March 10, 1989.

^b Total metal.

**TABLE 2. TOTAL AND LEACHABLE METALS IN SOLID WASTE
THAT SETTLED TO THE VAT BOTTOM**

Metal	Field Blank	Total Metal Mean Concentration (mg/kg)	Field Blank	Leachable Metal Mean Concentration (mg/L)
Cd	0.50	2.73	0.0050	0.0303
Cr	0.69	146.07	0.0127	2.2006
Cu	1.30	32.97	0.0036	0.3927
Pb	1.70	70.87	0.0190	0.5397
Mn	0.19	2.77	0.0056	0.0023
Ni	0.50	0.72	0.0050	0.0017
Zn	1.90	281.33	0.0560	4.2840

Data have been corrected with field blank.

Table 1 shows the characterization results. In appearance and color, the spent samples varied vastly from the clear recycled and virgin samples. All the measured parameters showed a significant improvement from spent to recycled samples but were not quite up to virgin grade. The water content increase in the recycled samples was traced to a slight leakage from the water-cooled condenser. Site personnel were able to correct the problem after the completion of testing.

Results

Of 55 gallons processed, 39 were recycled, 16 were residue, and 4 were lost to air emissions. This was characterized as a typical run.

Table 2 shows the waste reduction achieved by distillation. Through recycling, large volumes of spent solvent waste were reduced to small volumes of distillation residue, which was disposed of as RCRA hazardous waste. MEK is a hazardous chemical listed on the Toxic Releases Inventory (TRI). The solvent is on EPA's list of 17 chemicals targeted for 33% reduction by 1992 and 50% reduction by 1995.

TABLE 1. CHARACTERIZATION OF SOLVENT SAMPLES

Sample	Appearance	Color ^a	Specific Gravity	Nonvolatile Matter mg/100 ml	Conductivity μ mhos/cm	Water Content % by wt	Acid Acceptance ^b	Purity % ^c
<u>Atmospheric Unit (MEK)</u>								
Spent	Dark Grey w/sediment	- ^e	0.845	6,951	7.05	1.89	NA ⁱ	78.41
Recycled	Clear	5	0.827	2.6	3.30	5.42	NA	85.02
Recycled Dup ^d	Clear	5	0.821	2.0	3.40	5.56	NA	85.54
Virgin	Clear	5	0.800	2.2	1.15	0.09	NA	99.09

^a On a scale of 5 to 500, with 500 being the darkest color. ASTM D1209 and D2108.

^b Measured as equivalent NaOH wt% ASTM D2942.

^c Gas chromatography analysis based on ASTM D2804.

^d Duplicate analysis of the same sample.

^e Not comparable with standards. Sample was too dirty.

ⁱ NA = not analyzed

The economic evaluation compares the costs of recycling to conventional practice. Table 3 shows the major operating costs associated with disposal and the atmospheric batch unit. For the unit, recycling saved $\$10,000/\text{yr}$. The purchase price of the atmospheric batch unit is $\$12,995$. A detailed calculation based on worksheets provided in the Facility Pollution Prevention Guide (EPA, 1992) indicated a payback period of less than 2 years.

#34 ONSITE SOLVENT RECOVERY WITH AN ATMOSPHERIC STILL

Participants

The host for the atmospheric still evaluation was Navistar International Transportation Corporation, Plastics Division, Columbus, Ohio. Company personnel also operated the distillation equipment. Battelle, Columbus Laboratories, on contract to EPA provided test personnel, designed the test and drafted the final report.

Technology/Testing

Atmospheric distillation is the simplest technology available to recover liquid spent solvents. Units that can distill as little as 5 gallons or as much as 55 gallons/batch are available. Some units can be modified to operate under vacuum for higher-boiling solvents ($>135^{\circ}\text{C}$). Contaminant components with lower boiling points than the solvent or that form an azeotrope with the solvent cannot be separated (without fractionation) and may end up in the distillate. The unit used in this study (Figure 1) was Model LS-55D, manufactured by Finish Thompson, Inc. It was used by Navistar to recycle spent methyl ethyl ketone (MEK) to clean spray painting lines between colors.

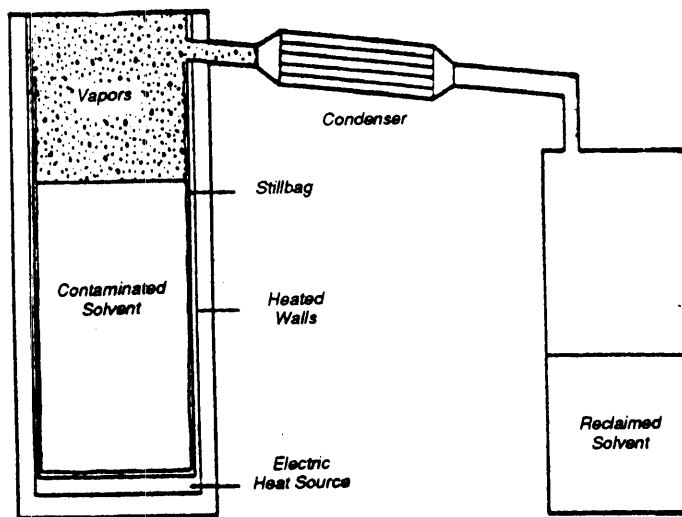


Figure 1. Atmospheric distillation unit

The product quality objective for the distillation unit was to show that the recycled solvent was of sufficient quality to reuse. One 55 gallon drum of spent solvent was processed in ~12 hrs. The distillation residue, often a relatively small fraction of the spent solvent, is disposed of as hazardous waste.

The amount of residue left behind is a function of the application and not the distillation units. Samples of the spent and recycled solvents were analyzed by standard ASTM methods to determine the improvement in quality. Virgin solvent samples also were collected at each site and subjected to the same tests for comparison.

#35 ONSITE SOLVENT RECOVERY WITH VACUUM HEAT-PUMP DISTILLATION

Participants

The vacuum heat-pump still was tested at Cooper Industries, Belden Division, in Richmond, Virginia. The Plant personnel operated the distillation equipment. Battelle, Columbus Laboratories, on contract to EPA provided test personnel, designed the test and drafted the final report.

Technology and Testing

The vacuum heat pump unit was tested on spent methylene chloride (MC) at a site that manufactures wires and cables. The MC is used for cold (immersion) cleaning of wires and cables to remove markings (Ink).

The vacuum unit tested, Model 040 is manufactured by Mentec AG in Switzerland and supplied in the United States by Vaco-Solv Chicago, Inc. Its configuration is similar to a conventional vacuum distillation system except that the pump, in addition to drawing a vacuum, functions as a heat pump (Figure 1). No external heating or cooling is applied. The heat pump generates a vacuum for distillation and compresses vapors for condensation. Because of this feature, the unit used 50% to 75% less energy than conventional systems. Model 040 is suitable for solvents with boiling points up to 80°C.

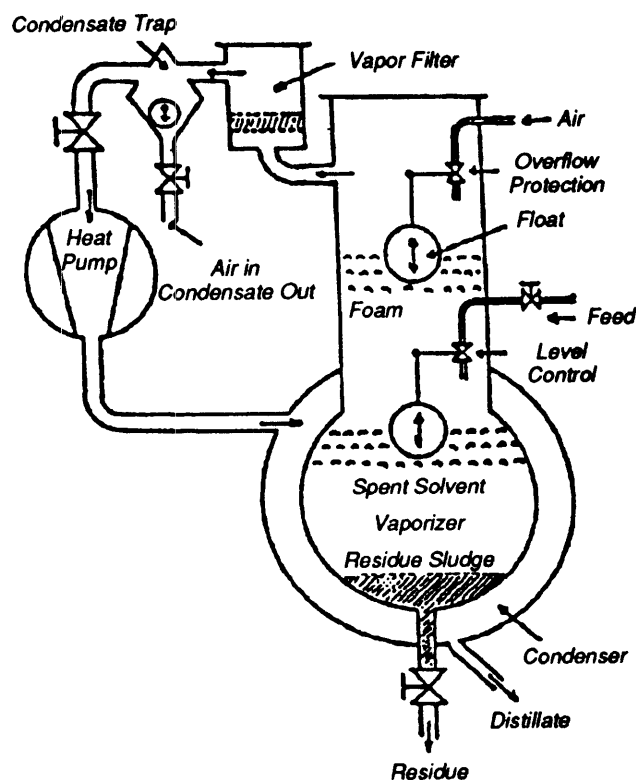


Figure 1. Vacuum heat-pump distillation unit (Source: Vaco-Solv Chicago, Inc.)

TABLE 2 WASTE REDUCTION WITH ATMOSPHERIC STILL

-Disposal Option-		-Recycling Option-	
Wastestream	Annual Volume	Wastestream	Annual Volume
<u>Atmospheric Unit Test Site:</u>			
Spent MEK	880 gallons	Distillation residue	262 gallons
Drums	17 drums	Still bags	17 bags
		Cooling Water	18,360 gallons
		Drums	5 drums

TABLE 3 MAJOR OPERATING COSTS FOR ATMOSPHERIC STILL

Item	Annual Usage	Unit Cost (\$)	Annual Cost (\$)
<u>Disposal Option</u>			
Virgin solvent	880 gal	10.50/gal	9,240
Disposal			
-labor	8 hr	8/hr	64
-drums	17	40/drum	680
-disposal fee	900 gal	400/55 gal	6,545
Total			16,529
<u>Atmospheric Unit</u>			
Virgin Solvent	245 gallons	10.5/gallons	2,573
Operating labor	17 hours	8/hours	136
Routine Maintenance			
-spare parts	1'	86/ea	86
-labor	12 hrs	8/hr	96
Energy	1,265 kWh	0.4/Kwh	51
Cooling water	18,360 gal	1/1000 gallon	18
Disposal			
-labor	3	8/hr	24
-drums	5	40/drum	200
-residue disposal	262 gal	675/55 gallons	3,215
-still bags	17	84/12 bags	119
Total			6,518

Report

The full report entitled "Onsite Solvent Recovery", by Arun R. Gavaskar is Available as EPA/600/SR-94/026.

Table 1 shows the characterization results for samples from the vacuum unit. In appearance and color, the spent samples varied greatly from the clear recycled and virgin samples. All the measured parameters showed a significant improvement from spent to recycled solvent but they did not quite measure up to virgin grade.

Some performance characteristics of MC were also evaluated. The Ph of the water extract of the recycled solvent was fairly close to the "virgin" value of 7. The spent sample Ph of 5 indicates the presence of potentially corrosive components. The corrosion test on steel and aluminum (ASTM D2251) yielded noticeable corrosion only in the case of the steel strip placed in the spent solvent sample. No such corrosion was evident due to the recycled solvent, indicating that recycling improved the quality.

Table 2 shows the waste reduction achieved. Through recycling, large volumes of spent solvent waste were reduced to small volumes of distillation residue, which is disposed of as a RCRA hazardous waste.

TABLE 2. WASTE REDUCTION BY ATMOSPHERIC AND VACUUM UNITS

-Disposal Option-		-Recycling Option-	
Wastestream	Annual Volume	Wastestream	Annual Volume
<u>Vacuum Unit Test Site:</u>			
Spent MC	3,000 gallons	Distillation residue	136 gallons
Drums	55 drums	Air emissions	218 gallons
		Drums	3 drums
		Used oil	1 gallon

For the vacuum unit (Table 3) savings from recycling are \$18,300/yr. An explosion-proof vacuum unit costs \$23,500. The payback period for this unit also was less than 2 yrs.

Report

The full report entitled "Onsite Solvent Recovery", by Arun R. Gavaskar, et al., is available as EPA/600/SR-94/026.

Spent solvent is continuously sucked into the evaporator at the inlet valve. The vacuum drawn generates vapors, which are sucked into the heat pump, compressed, and sent to the condenser. The temperature stabilizes automatically according to the specific solvent and the ambient air temperature. The condenser surrounds the evaporator to allow heat exchange between the cool spent solvent and the warm condensing vapors.

The product quality objective for the distillation unit was to show that the recycled solvent was of sufficient quality for reuse.

The amount of residue left behind is a primarily a function of the application and impurities contained in the solvent and not the distillation unit. Samples of the spent and recycled solvents were analyzed by standard ASTM methods to determine the improvement in quality. Virgin solvent samples also were collected to each site and subjected to the same tests for comparison.

Results

A 55 gallon drum of spent MC was processed in approximately 12 hours. For each 55 gallons processed, there were 3 gallons of residue and 4 gallons lost to air emissions. The vacuum unit was being operated at a faster rate than recommended by the manufacturer. Because the unit's built-in condenser-evaporator heat exchange was not sufficient for this rate, site personnel had attached an air-cooled condenser at the outlet to restrict vapor loss to 4 gallons/55 gallons of spent solvent. To prevent the release of this vapor into the work area the vapor was led through a pipe to the roof of the facility and discharged per state regulations.

The manufacturer claimed that slowing the still would reduce the 4 gallons lost to the air during the process. While a possibility, this was not verified.

During the vacuum unit test, the "virgin" sample was found to be a sample of MC obtained by the site from a solvent recycling company. The "virgin" solvent specifications met the requirements for the company's application, and it had been used satisfactorily at the site in the past.

TABLE 1. CHARACTERIZATION OF SOLVENT SAMPLES

Sample	Appearance	Color ^a	Specific Gravity	Nonvolatile Matter mg/100 mL	Conductivity μ mhos/cm	Water Content % by wt	Acid Acceptance	Purity % ^c
<u>Vacuum Unit (MC)</u>								
Spent	Dirty grey-brown	-e	1.220	34,101	1,063			
Recycled	Clear	5	1.286	20.37	137	0.25	0.004	86.4
Recycled Dup ^d	Clear	5	1.288	17.88	136	0.24	0.005	NA
Virgin	Clear, tinge of yellow	10	1.298	57.16	36	0.14	0.003	90.1

a On a scale of 5 to 500, with 500 being the darkest color. ASTM D1209 and D2108.

b Measured as equivalent NaOH wt% ASTM D2942.

c Gas chromatography analysis based on ASTM D2804.

d Duplicate analysis of the same sample.

e Not comparable with standards. Sample was too dirty.

f NA-not analyzed.

The testing consisted of loading machined steel parts into the unit and running the cleaning cycle, which is largely automatic, as previously described. Cycle times, load weights and PCE concentrations were measured around the outside of the LEVD, inside upon first opening of the lid and shortly thereafter, and ambient concentrations in the work area. A pair of flame ionization detectors were used for these measurements.

TABLE 1. LEVD CLEANING CYCLE

Stage	Vendor-Recommended Time Settings	Times Set for This Testing
Solvent heat-up (once a day)	Variable ^a	Variable ^a
Solvent spray (optional)	10-180 sec	not used
Vapor fill	Variable ^b	Variable ^b
Degreasing	20-180 sec	60 sec
Condensation	120 sec	120 sec
Air recirculation	120 sec	120 sec
Carbon heat-up	Variable ^c	Variable ^c
Desorption	60 sec	60 sec
Adsorption	60-240 sec ^d	240 sec

^a Requires 1 hr on days following overnight shutdown when sump solvent temperature drops to 70°F. After weekend shutdowns, when sump solvent temperature drops to 20°F, it may take 1.5 hr for solvent to reach vapor temperature. Timer on unit allows automatic heat-up.

^b Depending on the workload mass and type of metal. Varied from 8.5 min for 165 lb to 36.5 min for 915 lb of steel parts.

^c Carbon heat-up took approximately 22.5 min during testing.

^d At 60 sec, if monitor shows that chamber concentration is above 1 g/m³, then the adsorption stage proceeds to the full 240-sec stage. This sequence repeats if necessary.

Testing was conducted on the LEVD using perchloroethylene (PCE) solvent. Test runs were conducted on machined steel parts with and without cutting oil on the parts. The pollution prevention aspect of the LEVD was the main focus of this technology. The completely enclosed design of the working chamber allows the potential for air emissions only when the cleaning cycle is complete and the lid is opened. Any solvent vapor not evacuated from the chamber during condensation or adsorption releases to the atmosphere.

Table 2 shows the total cycle times and emissions recorded from the LEVD by a flame ionization detector (FID) probe inserted (for this test) into the working chamber below the designated vapor level. FID measurements began during the adsorption stage and continued until after the lid was opened. A second FID probe (ambient), positioned outside the unit near the lid seal, took continuous measurements all around the unit during operation, with special emphasis around the lid to detect any leaks. Ambient levels (3 to 4 ppm) in the indoor facility on the test days were observed.

#36 ONSITE SOLVENT RECOVERY WITH LOW EMISSION VAPOR DEGREASING

Participants

The Low Emission Vapor Degreaser (LEVD) was tested at Davidsburg, Michigan, which is a manufacturing site for Durr Automation Inc. where the LEVD's are made. Durr personnel operated the equipment. Battelle, Columbus Laboratories, on contract to EPA provided test personnel, designed the test and drafted the final report.

Technology/Testing

The LEVD is used in Europe, where vapor degreasers are regulated as a point source. Previous studies (Battelle, 1992) on conventional open-top vapor degreasers have shown that a large part of the solvent (more than 90% in some cases) is lost through air emissions, which are considerable even though vapor degreasers are required to have primary cooling coils (tapwater cooled) and a certain freeboard height. Air emissions are mainly workload-related, caused either by dragout of solvent on the workload itself (and subsequent vaporization) or by disturbance in the air-vapor interface during entry and exit of the workload. Other sources are convection and diffusion during startup, operation, idling, shutdown, and, to a small extent, equipment leaks.

Air emissions are a concern for metal finishers because many solvents used in vapor degreasing have been targeted by EPA in the 33/50 Program, in Clean Air Act Amendments and Environmental and Occupational Safety and Health Administration (OSHA) regulations, which have become more stringent. Pollution control devices available for conventional vapor degreasers include increased freeboard height, refrigerated coils, and covers to eliminate drafts and reduce diffusion.

In contrast, LEVD units are completely enclosed, airtight units. This evaluation used Model 83S (Size 1), manufactured in the United States by Durr Automation, Inc. Figure 3 shows its operation. Loads can range from 330 to 1100 lb (of steel parts) in this model. When the lid is shut and the unit is switched on, compressed air hermetically seals the lid shut for the duration of the cycle.

Table 1 shows typical cleaning cycle stages. During "vapor fill," solvent vapors enter the chamber from the outer jacket and degreasing begins. During "condensation," solvent vapors are condensed out by a refrigerated cooling coil at the bottom of the chamber. During "air recirculation," the air-solvent mixture is recirculated through a chiller to condense out more solvent. During "carbon heat-up," solvent adsorbed in the previous cycle is released (desorbed) to the circulating air and condenses out in the chiller. During "adsorption," the chamber air is recirculated in the reverse direction – first through the chiller and then through the carbon. Most residual solvent vapor in the cold air is adsorbed on the carbon. A photoionization detector (PID) probe verifies that the chamber air has less than 1 g/m³ of solvent and signals the air compressor to release the seal on the lid to end the cycle. If the chamber air has more than 1 g/m³ of solvent, the cycle loops back to the desorption stage. The entire cycle is programmed and requires no operator attention except to load and unload the workload. The LEVD also works as a distillation unit to clean the liquid solvent in the sump. During distillation, the unit is switched on without any workload in the chamber.

The shape of the parts may affect cycle time. Parts with recesses that can trap solvent should be arranged in the basket so that the solvent liquid drains out. Other features offered by the vendor (oscillating or rotating baskets) may need to be used. Otherwise, either the air recirculation stage time must be increased, or the unit will loop into several adsorption cycles until the chamber concentration falls below 1 g/m³.

Results

Figure 2 shows how a typical LEVD cleaning cycle ends. The same pattern was evident in the other runs. Time zero corresponds to the start of measurements when the FID probe in the working chamber was activated. Just before the adsorption cycle ended, the chamber FID read 52 ppm, which was below the targeted 1 g/m^3 (150 ppm of PCE). When the lid was retracted, the chamber concentration dropped sharply as the residual solvent vapor in the chamber dispersed. The ambient FID probe showed a corresponding increase (to 6 ppm). Both FID readings soon stabilized to facility ambient levels (3 to 4 ppm). The solvent concentration at the edge of the chamber opening dropped from 6 ppm to ambient level in approximately 2.5 minutes (Figure 2), resulting in operator exposure well below the OSHA limit.

In all the test runs, the solvent concentration was below the targeted 1 g/m^3 (150 ppm PCE). The volume of the working chamber is 0.6 m^3 . Assuming that all the residual solvent vapor (1 g/m^3 maximum) in the chamber is discharged to the ambient area, the typical air emission through the opened top is 0.6 g (0.00132 lb)/cycle or less. It takes 1 hour to clean 560 lb of oiled steel parts. Therefore, the air emission from this LEVD mode is 0.00132 lb of solvent/hr.

In comparison, a typical conventional open-top vapor degreaser, cleaning at a similar rate ($\sim 560 \text{ lb}$ of steel parts/hr) would emit approximately 0.147 lb of solvent/ ft^2 /hr (EPA, 1989), or 0.662 lb of solvent/hr from its 4.5-ft^2 opening during continuous operation.

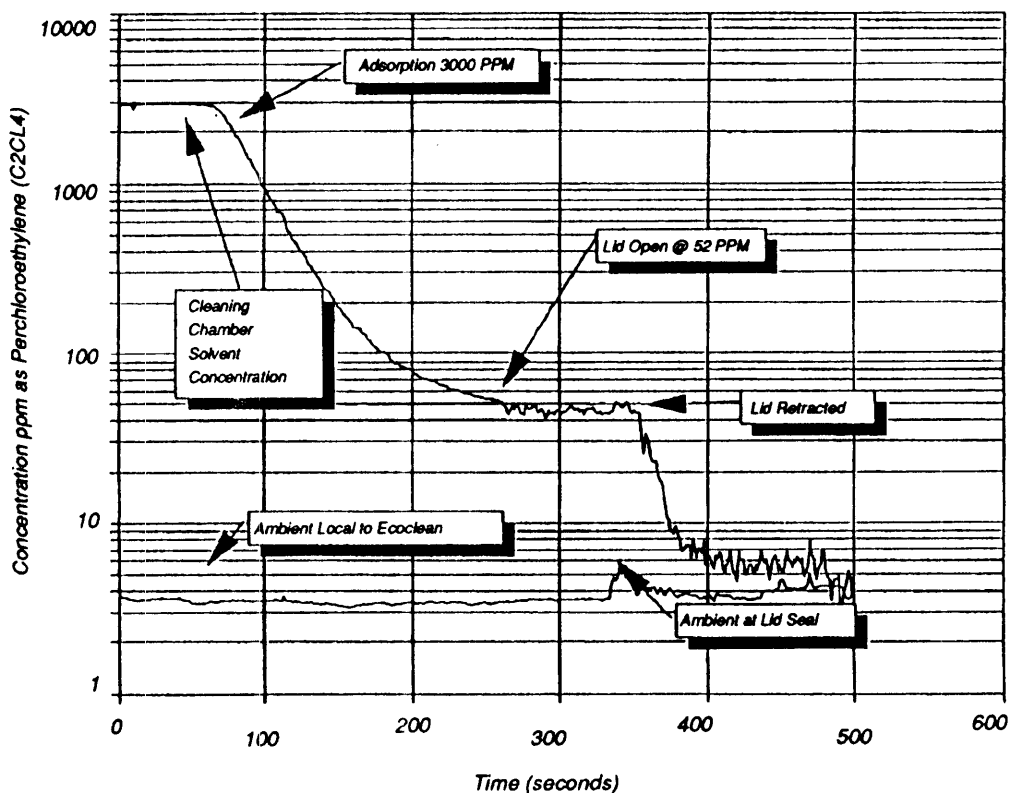


Figure 2. Concentrations at the end of the cleaning cycle for Run 1

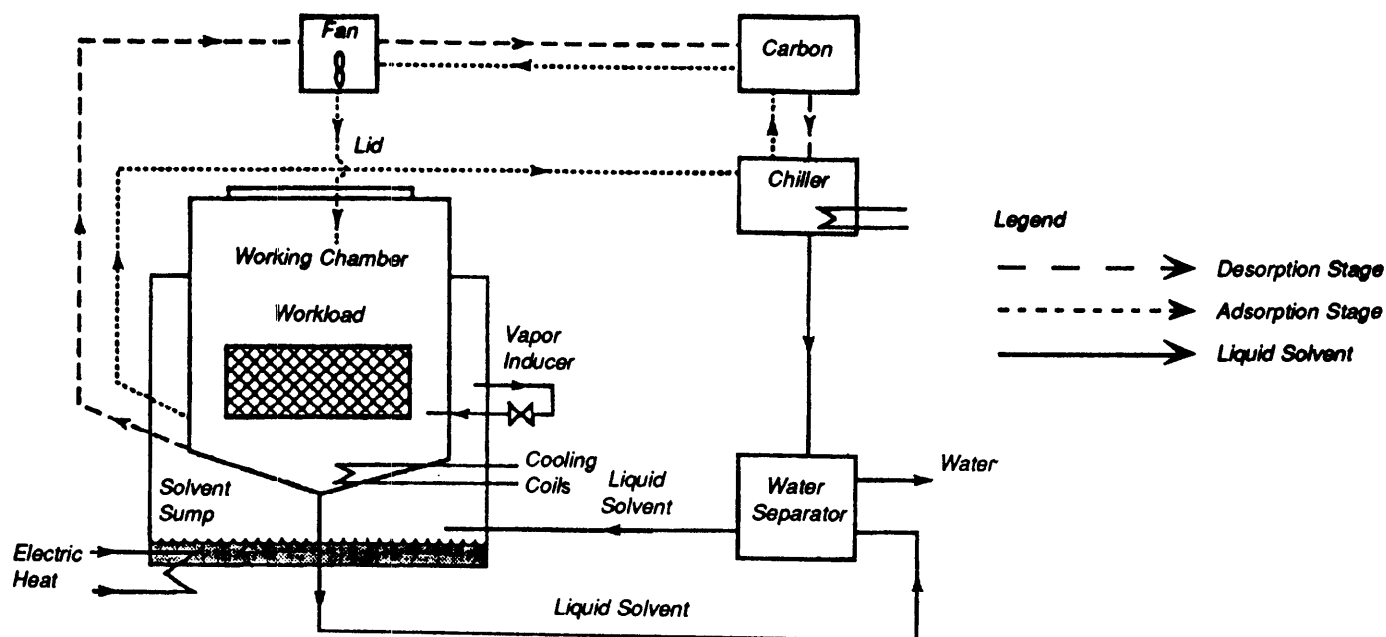


Figure 1. Low-emission vapor degreaser
(Source: Durr Automation, Inc)

TABLE 2. EMISSIONS FROM LEVD

Run No. ^a	Mass of Steel Parts (lb)	Final Chamber Concentration ^b (ppm)	Total PCE Emission ^c (lb/cycle)	Total Cycle Time (min)	Emission Rate (lb/hr)
1	165	52	0.0005	—	—
2	165	75	0.0007	39 ^d	0.0011
3	900	92	0.0008	67.5	0.0007
5	165 ^e	43	0.0004	50.5	0.0005
6	165 ^e	47	0.0004	40 ^d	0.0006
8	915 ^e	78	0.0007	69	0.0006
Target ^f	560	150	0.0013	60 ^g	0.0013

^a Runs 4, 7, and 9 were interrupted to allow other measurements.

^b At the moment when the seal on the lid is released.

^c Based on 150 ppm = 1 g/m³ of PCE and a chamber volume of 0.6 m³.

^d Normally the machine is programmed to release the lid when solvent concentration in the chamber falls below 1 g/m³ (150 ppm of PCE). This target was easily met in all the test runs.

^e Workload parts were dipped in cutting oil before the run.

^f The test parts were already hot from being used in previous runs when inserted into working chamber. Hence, total cycle times for these runs are lower than normally expected.

^g Expected cycle time for 560 lb of steel parts (workload).

Other cost/benefit factors should be taken into account when making economic decisions. The LEVD does not require capital and operating expenditures for auxiliary equipment that may be required for a standard conventional vapor degreaser (increased freeboard ratio, refrigerated coils, lip exhausts, room ventilation) in order to meet or anticipate increasingly stringent environmental and worker safety regulations. The LEVD is a self-contained unit that requires no additional facility modifications to achieve significant emission reductions.

Conclusions--

- The LEVD evaluated in this study demonstrated good potential for pollution prevention/waste reduction.
- The LEVD reduced air emissions significantly compared to emissions from a conventional vapor degreaser.
- Longer payback period may not be attractive. However, this number may be significantly impacted by such less quantifiable factors such as the Clean Air Act amendments, the avoidance of auxiliary equipment that is needed with conventional degreasers as add-on hardware, and by potential, downward trends in prices of the units with time.

Report

The full report titled "On Site Solvent Recovery" by Arun R. Gavaskar, et al., is available as report number EPA/600/R-94/026.

Therefore, the LEVD reduces air emissions by more than 99% compared to air emissions from the typical conventional open-top vapor degreaser (i.e., with a 0.75 freeboard ratio, primary cooling coil, electric hoist, and no lip exhausts) used in this calculation.

The pollution prevention potential of this unit is further enhanced by its ability to perform as a liquid solvent distillation system for cleaning the sump solvent; this capability was not a part of this evaluation. When pollution prevention is an objective, the LEVD also affords greater production flexibility because it has none of the idling losses between loads or downtime losses during shutdown of the conventional degreaser.

Table 3 lists the LEVD's major operating costs and the operating costs for a conventional open-top vapor degreaser with similar production capacity. With a vendor-quoted purchase price for the LEVD of \$210,000, and savings in annual total operating costs of \$25,000, mainly from reduced labor costs (due to larger batch size) and less solvent required (due to solvent recovery). The LEVD pays for itself in 10 years.

TABLE 3. OPERATING COSTS FOR LOW-EMISSION VAPOR DEGREASING

Item	Annual Volume	Unit Cost	Total Cost
<u>Conventional Degreaser</u>			
Operating Labor	4,000 hr	\$8/hr	\$32,000
Electricity	25,500 kWh	\$0.04/kWh	\$ 1,020
Cooling water	480,000 gal	\$1/1000 gal	\$ 480
Maintenance:			
-Labor	22 hr	\$8/hr	\$ 176
-Materials	-	-	\$ 88
Net Solvent Loss	2,642 lb	\$0.71/lb	<u>\$ 1,876</u>
		Total	\$35,640
<u>LEVD</u>			
Operating Labor	333 hr	\$8/hr	\$ 2,664
Electricity	93,725 kWh	\$0.04/kWh	\$ 3,749
Maintenance			
-Labor	262.5 hr	\$8/hr	\$ 2,100
-Materials	-	-	\$ 2,100
		Total	<u>\$10,613</u>

The most significant retrofit was installation of an Enercon corona discharge treater.

Modifications to the Hudson/Sharp 48 inch, central impression, six-color, flexographic printing press included upgrading drying capacities and using enlarged exhaust and supply fans.

Because of prohibitive costs, the Heinrich (W&H) press was not modified or retrofitted and was not used in the water-based ink tests. Future plans would include replacing this press with one that could accommodate the ancillary equipment required for water-based ink use.

Ink metering rolls were replaced to facilitate drying. Pumps were also replaced to accommodate the new printing inks. Additional ductwork and noise abatement equipment were needed.

Table 1 shows the VOC emissions as a function of ink use, based on historical data.

TABLE 1. VOC EMISSIONS BASED ON INK USE, 1990

Month	Ink used (lb/wk)	VOCs calculated (lb/wk)
April	3,038	2,111
May	1,681	1,700*
June	2,686	2,289
July	2,109	1,731
August	2,945	2,345

* This value is derived from the historical operational data and attributed to high makeup solvent use during the event.

Table 2 provides information on the total pounds and percent of ink used, calculated VOC emissions, and VOC emissions as a percentage of ink used for each of the four 1-week-long evaluation periods.

A review of the quality assurance sheets indicates that the use of water-based inks typically did not change product quality although some problems arose after customer use, depending upon the ultimate use of the packaging, what the package contained, and the means by which the packages were sealed. Heat and stress of the printed package material caused by the package folding and sealing process at times resulted in a loss of ink adhesion.

Some combinations of water ink and solvent ink were incompatible. Water inks did not provide a consistent opaque white for lamination to cover metallized films and resulted in "blocking" (or transfer of print) when printing on Saran-coated materials, especially cellophane. In most cases, however, depending on the surface printed, no difference was noted with the use of water-based inks.

Normal propyl alcohol added in small amounts (less than 1%) to prevent water ink foaming at the ink pan and to assist in ink wetting was beneficial. Variations of the pressure sensitive "stickyback" material used to attach the printing plates to the plate cylinder (solid versus cushioned stickyback) also enhanced printed solid plate backgrounds without pin-holding. The plate material may also have an effect. Photo polymer plates work well with water but are more expensive than rubber. Nylon plates are a possible compromise with a longer life than rubber plates.

ERIE COUNTY, NY

Five technologies were identified for Erie County. The Project Officer for Erie County was Paul Kranz of the Erie County Department of Environmental Planning, Division of Environmental Compliance. Because Erie County was the last to join the WRITE Program, three evaluations are completed while two are still in the final report writing stage. For these, only the test program is described.

#37 REPLACEMENT OF HAZARDOUS MATERIAL IN WIDE WEB FLEXOGRAPHIC PRINTING PROCESS

Participants

The Lustreprint Company hosted the test and operated the equipment. Test design and management was by Erie County Environmental Compliance Services, (ECEECS), Buffalo, New York. The test personnel were supplied by Recra Environmental, Incorporated on contract to ECECS.

Technology/Testing

A wide web flexographic printing firm substituted water-based inks for solvent-based inks when manufacturing flexible packaging, using plastic sheet substrates (e.g., plastic bags for bread). The project objectives were to evaluate the technical feasibility (particularly as related to process implementation and performance), the economic effect, and the resulting change in VOC emissions achieved by the substitution. The technical evaluation was to quantify the reduction in both volatile and liquid-phase solid hazardous wastes.

This is a study of the effectiveness and applicability of ink substitutions to reduce waste in a wide web (greater than 16 in. wide) flexographic printing process. The Lustreprint Company prints flexible packaging whose products are used in the food and snack industry and in medical, industrial and consumer applications. Printing is completed on a number of different web materials, (commonly polypropylene (acrylic coated, Saran coated, and uncoated corona pretreated), cellophane (Saran coated), polyester (both metallized and unmetallized), polyethylene, and nylon (both Saran coated and uncoated)). At the time of this study, Lustreprint used one Hudson/Sharp 48 in., central impression, six-color, flexo-press and one Heinrich (W&H) five-color, flexo, stack press.

New York's regulations require that a facility reduce overall plant emissions to within the compliance level of 100 tons/yr. As an option, Lustreprint chose to reduce the use of solvent-based inks and adhesives. The first step eliminated solvent-based adhesive used in laminating. This was followed by a phase-in of water-based inks in the printing operation. The company goals are to reduce all volatile organic air emissions to an extent that would eliminate the need for costly air abatement and permitting and to eliminate all liquid-phase solid waste, at the facility.

To achieve these goals, ink use was monitored over four, one week long, study periods: 3 weeks when both water-based and solvent-based inks were used and 1 week when only solvent-based inks were used. Historical data for emissions and waste generation were extrapolated for comparison with the weekly experimental data. From the 4-week ink use and waste analysis data, the VOCs, released as emissions from the printing process, could be calculated. A material accounting approach was used for these calculations. All liquid wastes generated during the test periods were segregated and analyzed for percent volatile constituents. Substituting water-based inks required press modifications.

TABLE 3. VOC REDUCTION

Week	Total ink (lb)	Factored* VOC (lb)	Water ink (%)	Reduced VOC (lb)	Reduction (%)
1	2,363	1,772	52.9	827.5	53.3
2	2,254	1,634	22.5	1,252.7	23.4
3	2,252	1,633	0.0	1,571.5	0
4	1,237	897	55.6	509.09	43.3

* Calculated by taking 72.5% of the total ink quantity.

Waste Reduction--

Historically, 315 gal of solid waste was generated each month. This translates to approximately one-and-one-half, 55 gal drum or 424 lb/wk. The printing operations during Week 1 were an 87% decrease from normal in solid waste generation (from 424 lb to 55.5 lbs); and 100% elimination of solid waste generation in Weeks 3 and 4.

Note that much of this waste decrease can be attributed to factors other than the type of ink used. The WRITE Program evaluation and the use of the waste generation from increased awareness of press operators and deterred waste generation. This induced press operators to reuse solvent for additional cleaning or reuse in the solvent inks.

Economic Analysis--

An economic analysis of the changeover from solvent to water-based ink is included as part of this project.

Fixed, variable, and overhead costs are affected by this substitution and are considered. Fixed costs include the purchase and installation of new equipment (primarily the Enercon corona discharge treater) and costs for replacing equipment ancillary to the central impression cylinder press, such as pumps, dryer upgrade, ink pans, etc.

Variable cost adjustments include the premium paid, or reduced cost, for water-based inks. Disposal costs were calculated by using the amount of waste solvent ink generated in gals and the most recent disposal cost figures provided by Lustreprint. Other variable costs included variations in labor hours and utilities.

Overhead costs also play a role in determining the cost savings. Items such as the time previously expended for regulatory compliance, insurance costs, employee equipment and safety training, and OSHA compliance were expected to be reduced as a result of removing hazardous waste from the shop floor. These potential cost savings were estimated from existing figures where available.

Based on these costs, payback period was calculated (Table 4).

The payback period could be further reduced by eliminating the solid waste disposal. With the complete changeover to water inks and the planned purchase of an ink splitter, at approximately \$8,000, an additional savings for solid waste disposal would be possible. The payback period would then be reduced 0.53 year.

TABLE 2. INK AND VOC EMISSION DATA FOR 4-WEEK STUDY PERIOD

Measured Parameter	Week 1	Week 2	Week 3	Week 4
No. of inks	23	32	33	22
Solvent ink (lb)	1,112	1,746	2,252	549
Water ink (lb)	1,251	508	0	688
Total ink (lb)	2,363	2,254	2,252	1,237
Solvent ink (%)	47.1	77.5	100	44.4
Water ink (%)	52.9	22.5	0	55.6
VOC emissions (lb) (calculated)	827.5	1,251.7	1,571.5	509.0
VOC emissions (%) (% of ink total)	35.0	55.5	69.8	41.1
Waste (lb)	55.6	20.0	0.0	0.0
Waste VOC content (lb)	54.3	4.7	0.0	0.0

VOC Reduction--

Substituting with water based ink reduced the emissions generated from the printing process. For each percent increase in waterbased ink use, the calculated reduction in VOC emissions was 14 lb (Table 3).

As can be seen from Table 3, for Weeks 1 and 2, the VOC generation decreased in proportion to the percentage of water-based ink used. A 52.9% water-based ink use resulted in a 53.3% reduction in VOC emissions. Similarly, in Week 2, a water-ink use rate of 22.5% resulted in a VOC emission reduction of 23.4%.

For Week 4, the corresponding reduction in VOC emissions was less significant: a 55.6% water-ink use rate reduced VOC emissions only 43.3%. Total ink use for Week 4 was 1,237 lb of combined water ink and solvent ink. This amount is approximately half that was used during the other 3 weeks of the study. The number of different inks used in Week 4 is, however, comparable with that used in Week 1. With the same number of ink changes at the printing stations and with each change requiring a cleaning before adding new ink, the amount of cleaning make-up solvent relative to total ink use is expected to increase. The contribution of VOC emissions from clean-up solvents reduced the overall effectiveness of VOC reduction by water inks.

#38 ULTRASONIC CLEANING AS A REPLACEMENT FOR A CHLOROFLUOROCARBON-BASED SYSTEM

Participants

The host for the test, who also ran the vapor degreaser was Conax Buffalo Incorporated, Cheektowaga, New York. Recra Environmental Incorporated, of Amherst, New York, on contract to Erie County Environmental Services, provided test personnel, gathered the data and wrote the draft report.

Technology/Testing

Conax has been engaged in the design and manufacture of highly engineered, precision product for industrial, aerospace, nuclear, fiber optic, and military applications. At Conax, stainless steel, aluminum and copper parts coated with standard screw oils, water-based coolants, in-house shop dirt, and metal shavings are in-house shop dirt, and metal shavings are cleaned in a series of cleaning and rinsing tanks of modular design using a heated alkaline solution. Previously, cleaning activities involved the use of two types of freon-based solvents that generated more than 10,000 lb of fugitive emissions annually from two vapor degreasers and two work bench stations.

Since 1990, chlorinated solvents and chlorofluorocarbons (CFC-113) including trichloroethylene, 1, 1, 1-trichloroethane, trichlorotrifluoroethane (freon), and a freon/acetone mixture have been used at Conax. The CFCs are used for both degreasing parts after machining, and cleaning parts prior to assembly, shipment, or stock. Until recently, four operations within Conax utilized chlorinated solvents and CFCs. These include machining centers parts cleaning, machine shop vapor degreasing, assembly vapor degreasing, and final assembly cleaning.

The ultrasonic parts cleaning system was installed to avoid and eliminate the problems associated with further CFC use.

The Miraclean* system used by Conax is designed and manufactured by Chautauqua Metal Finishing Supply of Jamestown, New York. It is a modular design of cleaning and rinsing tanks, employing an aqueous cleaning agent within the ultrasonic tank to accelerate and facilitate the cleaning action (i.e., cavitation). Miraclean systems have a variety of available options such as additional rinse tanks and dryer station to meet individual customer needs.

The ultrasonic cleaning system purchased by Conax entails six cleaning stations (see Figure 1).

The ultrasonic cleaning system was evaluated for 131 batches of parts ranging from large tubes to pins and from 1 to several thousand parts/batch. Because this was considered typical production, the results would be extrapolated to an annual basis. Average cleaning times and chemical addition requirements were documented, and subjective quality control inspections were done on each batch. Project forms developed for the project tracked the time in minutes for each batch at each station in the cleaning process. Clean and rinse tank Ph was monitored along with the clean and heated rinse tank temperatures. The number and description of parts in each batch were also listed on another project form. Averages for processing times, Ph, and temperatures were calculated along with totals for a breakout of batch part quantities from 1 to 15, 15 to 100, 100 to 1,000 and 1,000 + parts/batch.

TABLE 4. PAYBACK PERIOD

Variable	Initial Investment	Projected Savings	Payback Period, year
Current process revisions	\$62,901	\$ 24,587	2.56
Adding an \$8000 ink splatter	\$70,901	\$ 34,887	2.03
Full water-based ink conversion	\$62,901	\$117,078	0.54

Conclusions--

By installing an in-line corona treater, higher surface tension water-based inks could be used. This, in turn, reduced VOC emissions approximately 72.5%, when compared with those for solvent-based inks. The water-based ink formulas contain about 20% solvent. For a process using a quantity of approximately 2250 lb of solvent-based ink (weekly), VOC emission levels were about 1570 lb. For every 1% increase in water-based ink use, VOC emissions were reduced 14 lb.

The substitution of water based inks did not adversely affect product quality or nonhazardous scrap waste generation. Some changes in operating procedures were, however, necessary because of the nature of water-based inks. The average reduction of 95% of liquid F003 waste from waste ink and cleaning solvents recorded during the study period resulted from operational practice changes.

The payback period for the corona treater and equipment modifications is 2.56 years. Additionally, through segregation of wastes once full implementation of water-based inks is achieved, the payback period could be reduced to 0.54 years.

This successful implementation of water-based inks in flexographic wide web printing should be considered as a VOC source reduction method for similar printing operations.

Report

The full report, entitled "Replacement of Hazardous Material in Wide Web Flexographic Printing Process" by P.B. Kranz, et al., is available as EPA/600/SR-93/149.

TABLE 1. HISTORICAL AND PROJECTED

Year	Fugative Emission (lb)	Hazardous Waste (lb)
1987	25,215	2,670
1988	32,990	1,290
1989	12,819	4,400
1990	10,876	1,595
1991*	6,900	1,890
1992†	3,450	1,380

* Estimated for remainder of 1991.

† Projected for 1992.

Emissions generated at Conax originated from cleaning operation at the machining centers, the assembly tables, and the Blakslee vapor degreaser. The elimination of CFC use at the machining centers by substituting aqueous cleaners into the bench top ultrasonic cleaning units reduced emissions by 14,500 lb/yr over a period from 1987 to 1990.

The elimination of the Blakslee vapor degreaser further reduced emissions to a projected total of 3,450 lb/yr for 1992, a reduction of 68% from 1990. Total volatile emission reduction projections, from 1987 to 1992, are 86% from 25,215 to 3,450 lb/yr resulting from the two operational changes.

An economic analysis of the changeover from CFC vapor degreasing using the Blakslee unit to the Miraclean ultrasonic system utilizing an aqueous-based cleaning solution is included as part of the project.

Fixed and variable costs have been considered as part of the evaluation. Fixed costs include the cost for equipment and installation of the Miraclean system. These costs include the ultrasonic equipment, NEMA enclosure, three tank system, pumps, filter, sparger pump, tank covers, overhead crane, supplies, and labor.

Variable costs included in the economic assessment were raw materials, power costs, sewer fees, off-site disposal, water costs, and labor. Raw material cost was determined using 1990 cost data and material use supplied by Conax. Labor cost was estimated using \$15/hr as a basis. Sewer fees and water cost information was supplied by Conax. Total operating costs were determined as a summation of variable costs.

A total operating cost/batch of parts cleaned was also determined for comparison.

Based on these costs, annual savings and payback period for the new Miraclean system were calculated for the project.

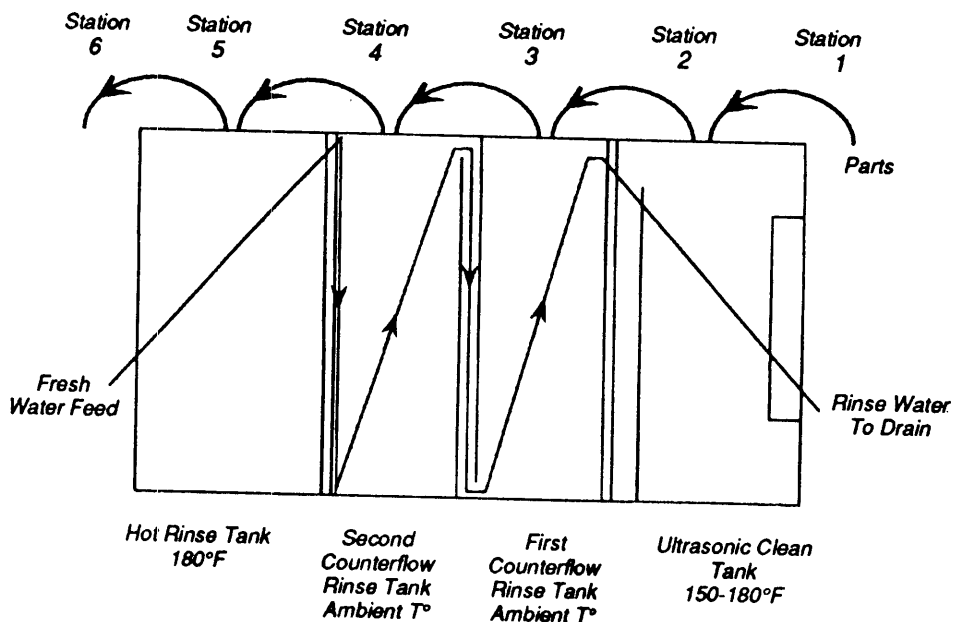


Figure 1. Conax's Miraclean System Schematic

Results

For comparison purposes, historical information on fugitive emissions reporting and hazardous waste generation was acquired from Conax. Fugitive emissions data was collected from Form "R" reports. Totals for each are shown in Table 1.

A significant reduction in fugitive emissions is noted from 1987 to 1990 resulting from the elimination of bench top freon cleaning units at the machining areas. Fugitive volatile emission reductions from the 1990 efforts also resulted in the elimination of the Blakslee freon vapor degreasing unit. The Miraclean system was installed in August 1991.

A log of cleaning activity was kept for 2 weeks during January 1992 (1/13-24/92). Engineers at Conax described this 2 week period as typical of production for the facility. Information was gathered on 131 batches of parts cleaned during the 2 week period. Average time/batch spent in the Miraclean unit is approximately 8 minutes. This compared well with the 7 min/cycle for the vapor degreasers.

Wastes associated with the vapor degreasing units included emissions and stillbottoms estimated at 26 drums/yr and 1,134,000 million gal/yr of non-contact cooling water. The water-based cleaning medium used in the Miraclean system generated an estimated 1050 lb/yr of waste that, subsequent to neutralization, could be sewered along with the 567,000 gal/yr of rinsewater. Approximately 55 gal/yr (450lb) of oil collected by the ultrasonic cleaning process was sent for fuel blending.

#39 REMOVAL AND CONTAINMENT OF LEAD-BASED PAINT VIA NEEDLE SCALERS

Participants

The New York State Thruway Authority (NYSTA) provided two bridges for paint removal while Pentek Incorporated, the developer of the technology provided the test hardware and operated it during the test. Recra Environmental Incorporated, of Amherst, New York, on contract to Erie County Environmental Services, provided test personnel, gathered the data and wrote the draft report.

Technology/Testing

The use of abrasive blasting with expendable grit media for removing lead-based paints from steel structures has been the standard for many years, mainly because of its efficiency both in removing the lead-based paint and in achieving the surface cleanliness and profiles required for subsequent coating operations.

The process's generation of difficult-to-contain, airborne, lead-contaminated particulates presents a high potential of lead exposure to workers and the local environment. Although sophisticated systems to control or contain airborne particles would minimize the potential for environmental contamination, they may result in more hazardous localized environments for workers and result in substantially higher overall costs for lead-based paint removal operations. Additionally, using expendable abrasive grit to remove lead paint generates excessive amounts of waste material that requires disposal as hazardous waste.

The industrial participants for this program were the New York State Thruway Authority (NYSTA) and Pentek, Incorporated. The NYSTA is responsible for the operation and maintenance of the New York State highway system. Pentek has been manufacturing dustless surface preparation equipment for use by nuclear facilities and hazardous waste remediation/cleanup contractors since 1985.

The Pentek system is a form of power tool cleaning that combines material removal and containment. The Pentek CORNER-CUTTER® (Figure 1), a hand-held needlegun for surface preparation in tight spots and/or vertical and inverted horizontal steel or concrete surfaces, is one of three models of surface preparation tools that Pentek manufactures.

Material is removed through the actions of pneumatically operated reciprocating steel cutting bits made into needles that scarify and pulverize the paint or coating. The removed material is contained first by using an adjustable shroud located at the tool's point of operation to localize containment, and second, by transporting the contained materials via vacuum to an attached VAC-PAC containment vessel. The vacuum head of the containment drum is equipped with high-efficiency particulate air (HEPA) filters that prevent the escape of airborne dust.

Conventional abrasive blasting employs compressed air to propel expendable abrasive particles against the surface to be cleaned, to produce a surface profile required by Standards and Specifications of the Steel Structures Painting Council No. 6. The spent abrasive and paint debris are manually collected for disposal, usually as hazardous waste.

The total fixed costs for the Miraclean system according to information provided by Conax was \$44,411. Variable costs calculated for the two systems are listed in Table 2.

Annual savings projected using the aqueous ultrasonic system was calculated to be \$27,178. This resulted in a per bath savings of \$7.94 (\$7.26/batch vs. \$15.20/batch for vapor degreasing). A payback period for the system using the savings calculated and reported total costs was determined to be 1.6 yr.

TABLE 2. VARIABLE COSTS

	Freon Vapor Dgreaser (\$)	Aqueous Ultrasonic Cleaning System (\$)
Utility Costs	1,559	8,087
Labor Costs	8,205	8,295
Raw Material Costs	33,939	1,203
Water costs	1,780	890
Sewer Costs	6,200	6,200
Off-Site Disposal	370	200
Total Operating Costs	52,053	24,875

With the installation of an ultrasonic parts cleaning unit, utilizing water-based cleaners, the elimination of vapor degreasing with solvent-based cleaners is possible without impacting cleaning quality.

The quality of the cleaning realized by Conax as a result of the changeover is as good, or in some cases, better than with vapor degreasing.

Annual waste reduction realized was over 12,000 lb when fugitive emissions are included.

An annual cost savings of \$27,178 was calculated and results primarily from a reduction in raw material costs, a savings that is anticipated to become more significant over time. This savings provides a 1.6 yr payback period for the project.

Report

The full report, titled "Ultrasonic Cleaning as a Replacement for a Chlorofluorocarbon-Based System" by P.B. Kranz, et al., is available as report no. EPA/600/R-93/223.

The abrasive blast media consisted of Ebony Grit 20, a non-silica, lead-free abrasive.

To minimize the potential for cross-contamination and to satisfy bridge painting schedules and other logistical concerns, these comparative evaluations were conducted on two separate bridges. The bridges had similar structures and closely matching coats of paint.

On Day 1 of the conventional abrasive blasting test on Bridge #10, background information regarding the process was obtained and both cleanup activities from the prior day's work and setup activities for work to be performed were observed and recorded. Background lead-in-air concentrations, used as a baseline for both technology evaluations, were also monitored. On Day 2, work procedures were observed. Monitoring of personal and area air was performed as well as taking data for measurements to assess productivity and waste generation.

Information relative to time and labor requirements for daily cleanup and job site mobilization and demobilization activities was also gathered. This information was integrated with job site observations to estimate the man hours required and their associated costs.

The Pentek system was evaluated at NYSTA Bridge #1. Evaluation consisted of observing and documenting mobilization, paint removal, and cleanup and demobilization activities.

Results

Equipment, equipment maintenance, vehicles, utilities and fuel, containment structures, and personal protective equipment costs were not separately included in the evaluation. For simplicity and uniformity, a standard labor rate of \$15/hr was assumed for all labor classifications. Based on demonstrated production rates, approximately eight Pentek systems, each using three CORNER-CUTTERS®, would be needed to equal the production rate of the two-operator abrasive blasting system..

Labor requirements for support, mobilization, and demobilization were also higher for the Pentek system, primarily because of the number of workers required. Cleanup labor costs were substantially higher for the abrasive blasting process. These comparative labor costs are shown in Table 1.

TABLE 1. TOTAL ESTIMATED LABOR COSTS

Labor Category	Abrasive Blasting (\$)	Pentek (\$)
Paint Removal	1,500	18,450
Support	1,125	6,090
Mobilization	945	1,440
Demobilization	210	720
Cleanup	5460	240
Labor Total	9,240	26,940

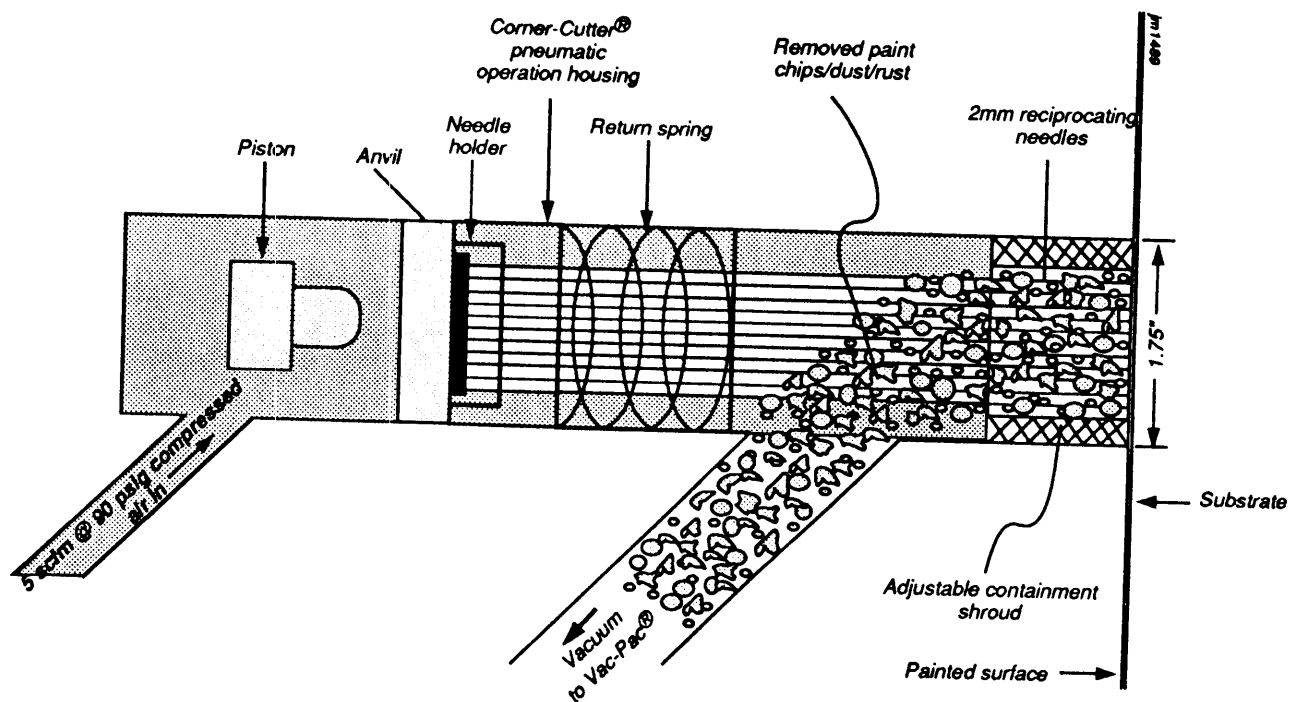


Figure 1. Pentek CORNER-CUTTER[®] schematic

Both paint removal technologies were evaluated on NYSTA bridges located on Interstate 90 in western New York. The abrasive blasting evaluation was done on Bridge #10 and the Pentek evaluation was done at Bridge #1. The evaluations consisted of observations of work practices, equipment and labor requirements and time required to complete various tasks as well as to physically measure background and work-in-progress airborne dust and lead concentrations during the paint removal operations. Waste materials from both processes were collected and analyzed for lead concentrations. Interviews were conducted with NYSTA, Pentek, Inc., and paint removal contractor personnel to obtain background information and historical data relative to the evaluations.

NYSTA Bridge #10 is of rolled beam design and composed of approximately 151 tons of steel and 14,946 ft² of surface area. The paint thickness ranged from 10 mils to 13 mils.

Historically, surface preparation of similar NYSTA bridges, using conventional abrasive blasting methods to SSPC-SP 6 specifications, has generated 0.15 to 0.20 tons of waste (spent abrasive, paint and miscellaneous dirt, rust, and mill scale) per ton of steel. This would equate to 22.7 to 30.2 tons of hazardous waste for bridge #10. This waste has been characteristically hazardous because of its leachable lead content.

Bridge #1, also of rolled beam design, is comprised of approximately 315 tons of steel and approximately 25,000 ft² of surface area. The paint thickness on this bridge was estimated by NYSTA to also range from 10 to 13 mils. As with Bridge #10, previous testing by NYSTA had determined the presence of lead-based paints.

containment structures and engineered systems necessary when using abrasive blasting technology to ensure worker health and safety and protection while under stricter air emission standards.

Report

The full report, entitled "Removal and Containment of Lead-Based Paint via Needle Scalers" by P.B. Kranz, is available as EPA 600/R-94/114.

Table 2 shows the amount of waste generated during the evaluation periods and extrapolates these numbers to a complete bridge. As can be seen, abrasive blasting generates approximately 40 times more waste than the Pentek system. Note that only 31 tons of waste were disposed from this job, and that, based upon use estimates, approximately 50.8 tons of abrasive grit would be used.

Table 3 summarizes total costs for labor, materials, and hazardous waste disposal. Material costs were based on the assumption that the abrasive blast media was the only expendable material used. This cost was based on each operator using 0.5 ton of grit/hr.

TABLE 2. HAZARDOUS WASTE GENERATION AND DISPOSAL COSTS

Removal System	Removal Area (ft ²)	Waste Generated (lb)		Lb Waste / (ft ²)	Est. Total Waste (lb)	Total Waste (tons)	Disposal Costs (\$/ton)*	Total Disposal Costs (\$)
		Theoretical	Actual					
Abrasive	1,180	4,170**	4,807	4.1	61,500	30.8	300	9,240
Pentek	119	7.4†	11.5	0.1	1,500	.75	300	225

*Industry average for bulk waste including transportation.

†Theoretical waste generated based upon .175 ton waste/ton of steel cleaned.

‡Theoretical waste generated based upon 11.5-mil. paint thickness and paint solids density of 66.3 lb/ft.³

TABLE 3. TOTAL COSTS

Category	Abrasive Blasting (\$)	Pentek (\$)
Labor	9,240	26,940
Materials	1,957	0
Hazardous waste disposal	9,240	255
Total	20,437	27,165

For the 8-hr time-weighted averages (TWA), the abrasive blasting data indicated OSHA Permissible Exposure Limits (PELs) were exceeded for total dust, respirable dust, and total airborne lead on three samples and for respirable lead on two of four samples.

The Pentek air sampling results exhibited no detectable airborne lead or respirable dust and only negligible amounts of total dust.

The Pentek system was significantly less efficient in removing paint (i.e. ft.²/hr), especially the orange primer coat. It was also less effective while performing around irregular surfaces such as nuts and bolts heads and in inaccessible corners. The NYSTA bridge inspectors indicated that a post-blast would be needed for the Pentek-cleaned sections to meet SSPC-SP 6 specifications.

The Pentek dustless needlegun system labor costs were approximately 300% higher than those of the conventional abrasive blasting process; however, the overall costs were mitigated by the 97.5% reduction in generation of hazardous waste. Additionally, fugitive emissions of airborne dusts were reduced up to 99%, which serves to enhance the level of environmental protection and worker health and safety.

The dustless needlegun system may be competitive when factoring in costs of sophisticated

#41 FINISHING FABRICATED METAL PRODUCTS WITH POWDER COATINGS

Participants

The host for this evaluation was the Diversified Control, Inc. (DCI) of Orchard Park, NY. The study, evaluation and preparation of the draft report was a joint effort by Erie County Department of Environment and Planning, Division of Environmental Compliance Services (ECS) and Recra Environmental, Inc. (RECRA).

Technology/Testing

The DCI facility manufactures junction boxes for the telecommunications and cable television industries. The company has utilized wet, solvent-based epoxies, water-based coatings and most recently, powder coating as a finishing process. Powder coatings used are primarily the polyester thermosetting types.

The coatings are electrostatically applied to cold-formed, galvanized, steel coil stock that has been cleaned, sealed, and then cured using an electric-resistance, infra-red process.

The evaluation compared product performance, environmental impact and economics of the three technologies, wet organic solvent, water-based solvent and powder coating.

Measurements taken included discharge wastewater analysis for metals, oil sand grease, total dissolved solids and Ph. The volume and characteristics of process solid waste were also be determined. Solid waste characteristics includes ignitability, corrosivity, reactivity, and toxicity and TCLP determinations for toxic metals and volatiles. Other data sources were company historical records and vendor data.

Results

The evaluation has been completed and the final draft is being prepared. The detailed results will be published in the final report.

Report

The final report, entitled "Finishing Fabricated Metal Products with Powder Coating" will be published as an EPA/600 series report.

#40 LOW-VOC WOOD FURNITURE COATINGS

Participants

The host for the evaluation was the Dinaire Corporation of Buffalo, NY. Dinaire, Gruner Road facility personnel participated in the evaluation by manufacturing furniture using low VOC wood stains as well as providing data and information regarding traditional wood finishing process parameters for comparison purposes. The study, evaluation and preparation of the draft report was a joint effort by Erie County Department of Environment and Planning, Division of Environmental Compliance Services (ECS) and Recra Environmental, Inc. (RECRA).

Technology/Testing

The main objective for this evaluation were to determine the performance of reduced volatile organics content stains and water-based stains on wood furniture. The overall performance will be determined by evaluating the product/process acceptability/performance, the wastes and releases generated and other pollution impacts, the economics of using these coatings and comparing these results with the same determinations calculated for the traditional wood staining process using solvent based stains.

The Dinaire, Gruner Road facility manufactures wood casual dining room furniture using a variety of materials for table tops, chairs and case goods. Materials used include solid oak, high pressure laminates and ceramic tile.

The facility uses stain in a range of shades with low-VOC and water-based formulations. Stains are applied to table tops on a flat line Venjakob automatic carousel spray unit, which is microprocessor controlled. The coatings are air dried and cured via a UV curing oven.

The waste and emissions from the process will be characterized to determine volumes, concentrations and toxicities for selected parameters of interest.

Dinaire historical records will be used to provide information regarding waste, product performance and the economics of the high VOC staining process used previously.

Results

The evaluation has been completed and the draft report is in the final stages of preparation. The detailed findings will be published in a final report.

Report

The full report, entitled "Utilizing Low Volatility Organic Content Exterior Coatings For Wood Furniture" will be available as an EPA/600 series report.

SECTION 4

INDUSTRY INDEX

This section is a cross reference among industry/technology types, project titles, page numbers, and project numbers used for the organizing the 41 projects. Table 1, presented below, is arranged on the basis of an alphabetic listing by industry/technology types. The industry/technology types represented are coating technology, depainting, electronics, metal plating and finishing, "other" (miscellaneous industries), printing, surface cleaning and steel.

TABLE 1. INDUSTRY INDEX

Technology	Project Title	Page	Project. #
C - Improved coating technology (low- or no-solvent paints, varnishes, improved application)	Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Robotics Painting	30	05
	Low-VOC Wood Furniture Coatings	178	40
	Finishing Fabricated Metal Products with Powder Coatings	179	41
D - Depainting (paint, varnish, surface coat removal)	Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Plastic Bead Blast Paint Stripping	34	06
	Replacement Non-Methylene Chloride Paint Remover	133	29
	Removal and Containment of Lead-Based Paint via Needle Scalers	173	39
E - Electronics	Modifications to Reduce Drag Out at a Printed Circuit Board Manufacturer	82	18
	Sponge Rollers and Flow Controller for Printed Circuit Board Manufacturing.	85	19
	Carbon-Black Dispersion Preplating Technology for Printed Wire Board Manufacturing	90	20
	Electronic Component Cooling Alternatives: Compressed Air and Liquid Nitrogen	140	25

SECTION 3

REFERENCES

References used for this report are the project plans, Quality assurance plans, final Project Report and Project Summaries used to summarize the 41 technical evaluations under the WRITE program presented in Section 2. Specific references for each of the 41 projects may be found in the respective full Project Reports available through the EPA Center for Environmental Research Information (CERI) or the National Technical Information Service (NTIS).

Conclusions and recommendations presented in Section 1, Introduction are based on the author's interpretations of the results as well as understandings reached during the 5-year period of managing the WRITE program and participating in conducting the projects for the state of Washington.

	Evaluation of ZERPOL (Zero Liquid Discharge System) at Pioneer Metal Finishing	119	26
O - Other			
O ₁ Reduction of waste oil for internal combustion engines	Evaluation of Three Oil Filter Designs for Pollution Prevention Effectiveness	17	02
O ₂ Metal working oils/fluids recycling	Mobile Onsite Recycling of Metalworking Fluids	106	23
O ₃ Recycling of spilled oils/fluids, recycling of sorbents	A Fluid Sorbent Recycling Device for Industrial Fluid Users	110	24
O ₄ Spray painting line cleaning solvent (MEK) recycling	Onsite Solvent Recovery with an Atmospheric Still	152	34
Pr - Printing	On-Site Newspaper Ink Recycling	44	09
	Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers	62	13
	WASTE EVALUATION OF SOY-BASED INK AT A SHEET-FED OFFSET PRINTER	78	17
	Replacement of Hazardous Material in Wide Web Flexographic Printing Process	164	37
S- Surface cleaning	Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Freon Recovery	37	07
	An Automated Aqueous Washer for the Metal Finishing Industry	40	08
	Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers	62	13
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Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Electroplating Rinse Water Reduction	20	03
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SECTION 5

WRITE PROGRAM REPORT LIST

The specific project reports and project report summaries may be obtained by ordering through the Center for Environmental Research Information (CERI), or the National Technical Information Service (NTIS) at the addresses indicated below.

CERI Publications Unit, US EPA
26 W. Martin Luther King Drive
Cincinnati, OH 45268
(513)569-7582

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703)487-4650

CALIFORNIA:

Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System, C. Schmidt, et al., EPA/600/R-93/150.

Evaluation of Three Oil Filter Designs for Pollution Prevention Effectiveness, Lisa M. Brown and Robert Ludwig, to be available as an EPA/600 series report.

Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Electroplating Rinse Water Reduction, Lisa M. Brown and Robert Ludwig, EPA/600/S2-91/067,

Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Sulfuric Acid Anodizing, Lisa M. Brown and Robert Ludwig, EPA/600/S2-91/067.

Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Robotics Painting, Lisa M. Brown and Robert Ludwig, EPA/600/S2-91/067

Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Bead Blast Paint Stripping, Lisa M. Brown and Robert Ludwig, EPA/600/S2-91/067.

Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division; Freon Recovery, Lisa M. Brown and Robert Ludwig, EPA/600/S2-91/067.

	A Supercritical Fluid Cleaning Study: Application to Instrument Bearings	127	28
	Low-Volatility Solvent and Filtration System for Mechanical Parts Washing	139	31
	Power Washer with Wastewater Recycling	144	32
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NEW JERSEY:

Mobile Onsite Recycling of Metalworking Fluids, Arun Gavaskar, et al., EPA/600/SR-93/114.

A Fluid Sorbent Recycling Device for Industrial Fluid Users, Abraham S.C. Chen, et al., EPA/600/SR-93/154.

Electronic Component Cooling Alternatives: Compressed Air and Liquid Nitrogen, Stephen C. Schmidt, et al., EPA/600/SR-94/170.

Evaluation of ZERPOL (Zero Liquid Discharge System) at Pioneer Metal Finishing, Hanna J. Saqa, will be available as an EPA/600 series report.

A Replacement Solvent Cleaner/Degreaser Study at Duffy Electric and Machine Company, Bruce M. Sass, et al., will be available as an EPA/600 series report.

A Supercritical Fluid Cleaning Study: Application to Instrument Bearings, Bruce M. Sass, et al., will be available as an EPA/600 report.

Replacement Non-Methylene Chloride Paint Remover, Bruce M. Sass, et al., will be available as an EPA/600 report.

WASHINGTON:

Recycling Electric Arc Furnace Dust: Jorgensen Steel Facility, Trevor W. Jackson et al., EPA/600/R-95/007.

Low-Volatility Solvent and Filtration System for Mechanical Parts Washing, David P. Evers, et al., will be available as an EPA/600 series report.

Power Washer with Wastewater Recycling, David P. Evers, will be available as an EPA/600 series report.

Bicarbonate of Soda Blasting Technology for Aircraft Wheel Depainting, Abraham S.C. Chen, et al., EPA/600/R-94/127.

Onsite Solvent Recovery with: an Atmospheric Still Vacuum Heat Pump Distillation Low Emission Vapor Degreaser, Arun R. Gavaskar, et al., EPA/600/R-94/026.

ERIE COUNTY, NY:

Replacement of Hazardous Material in Wide Web Flexographic Printing Process, P.B. Kranz, et al., EPA/600/SR-93/149.

Ultrasonic Cleaning as a Replacement for Chlorofluorocarbon-Based System, P.B. Kranz, et al., EPA/600/R-93/223.

Removal and Containment of Lead-Based Paint via Needle Scalers, P.B. Kranz, et al., EPA/600/R-94/114

CONNECTICUT:

An Automated Aqueous Washer for the Metal Finishing Industry, Arun Gavaskar, et al., EPA/600/R-92/188.

On-Site Newspaper Ink Recycling, Arun Gavaskar, et al., EPA/600/R-92/251

Cadmium and Chromium Recovery from Electroplating Rinsewaters, Arun Gavaskar, et al., EPA/600/R-94/050.

Nickel Recovery from Electroplating Rinsewater by Electrodialysis, Arun Gavaskar, et al., to be available as an EPA/600 series report.

Chromate Recovery from Chromating Rinsewater in the Metal Finishing Industry, Arun Gavaskar, et al., to be available as an EPA/600/ series report.

ILLINOIS:

Ink and Cleaner Waste Reduction Evaluation for Flexographic Printers, Gary D. Miller, et al., EPA/600/R-93/086.

Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals, Jacqueline M. Peden, EPA/600/R-94/148.

Recycling Nickel Electroplating Rinse Waters by Low Temperature Evaporation and Reverse Osmosis, Timothy C. Lindsey, EPA/600/R-93/160.

Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating/Degreasing Bath, Gary D. Miller, et al., EPA/600/SR-93/144.

Waste Evaluation of Soy-Based Ink at a Sheet-Fed Offset Printer, Gary Miller, et al., EPA/600/R-94/144.

MINNESOTA:

Modifications to Reduce Drag Out at a Printed Circuit Board Manufacturer, Teresa M. Harten et al., EPA/600/SR-92/114

Sponge Rollers and Flow Controller for Printed Circuit Board Manufacturing, will be available as an EPA/600 series report.

Carbon-Black Dispersion Preplating Technology for Printed Wire Board Manufacturing, Dale Folsom, et al., EPA/600/R-93/201.

Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium, Dale Folsom, et al., EPA/600/R-94/071.

Substituting Cadmium Cyanide Electroplating with Zinc Chloride Electroplating, B.C. Kim, et al., EPA/600/R-94/074.

SECTION 6

WRITE PROGRAM PERSONNEL

CALIFORNIA: U.S. EPA project officer - Lisa M. Brown (301) 975-5044

Robert Ludwig California Department of Toxic Substances, principal investigator -

Hosts for technology evaluations - General Dynamics, Pomona Division, Pomona, CA; Hewlett Packard, Sunnyvale, CA; Orange County Transit Authority, Orange County, CA.

CONNECTICUT: U.S. EPA project officer - Lisa M. Brown (301) 975-5044

Connecticut Hazardous Waste Management Service, Connecticut Technical Assistance Program, principal investigator - Rita Lomasney. ESSAR Environmental Services The Connecticut Hazardous Waste Management Service consultant - Sumner Kaufman.

Hosts for technology evaluations - Quality Rolling and Deburring, Thomaston; The Hartford Courant; the Torrington Company, Torrington, CT; Automatic Plating of Bridgeport, Bridgeport, CT.

ILLINOIS: U.S. EPA project officer - Paul M. Randall 513 569-7673

Illinois Hazardous Waste Research and Information Center, principal investigator - Gary Miller. Hosts for technology evaluations - MPI Label System Inc., University Park, IL; P&H Plating Company, Cook County, IL; Graham Plating Company, Chicago, IL; R.B. White, Bloomington IL; Office of Printing Services, University of Illinois, IL.

MINNESOTA: U.S. EPA project officer - Teresa Harten 513 569-7565

Minnesota Environmental Control Agency and Minnesota Technical Assistance Program Agency, and Minnesota Technical Assistance Program, University of Minnesota - principal investigators, Cindy McComas and Paul Pagel.

Hosts for technology evaluations - Micom Inc, Brighton MN; Hutchinson Technology Inc., Hutchinson, MN; McCurdy Circuits, Orange County, CA; Paramax Inc. St. Paul, MN; SL Modern Hard Chrome, Camden, NJ; Aeroquip Inc., Industrial Connectors Div., Van Wert, OH.

NEW JERSEY:

U.S. EPA project officer - Johnny Springer 513 569-7542

New Jersey Department of Environmental Protection - principal investigators, Mohamed Elsaady, Anthony Tomljanovic, New Jersey Department of Environmental Protection and Energy - Norine Binder; New Jersey Institute of Technology - Daniel Watts Hosts for technology evaluations - Cook's Industrial Lubricants Inc., Linden, NJ; Newark Air Force Base, OH; Pioneer Metal Finishing Company, Franklinville, NJ; Duffy Electric and Machine Company, Chillicothe, OH; Safety-Kleen Corporation, Elgin, IL; Honeywell Space Systems Group, Clearwater, Tooele Army Depot, Consolidated Maintenance Facility, Tooele, UT.

WASHINGTON:

U.S. EPA project officer - Ivars Lics 513 569-7718

Robert Burmark.

State of Washington Department of Ecology - principal investigator

Hosts for technology evaluations - Earle M. Jorgensen Steel Company, Seattle, A; Titus-Will Ford, Tacoma, WA; Municipality of Metropolitan Seattle, Atlantic Base Garage; Ellington Field, National Aeronautics and Space Administration/Lyndon B. Johnson Space Center, Houston, TX; Navistar International Transportation Corporation, Plastics Division, Columbus, OH; Cooper Industries, Belden Division, Richmond, VA; Durr Automation Inc., Davidsburgh, MI.

ERIE COUNTY, NY:

U.S. EPA project officer - Paul Randall 513 569-7673

Erie County Department of Environmental Planning - principal investigator Paul Kranz.

Hosts for technology Evaluations - Lustreprint Company, Erie County; Conax Buffalo Inc., Cheektowaga, NY; New York State Thruway Authority; Dinaire Corporation, Buffalo, NY; Diversified Control Inc., Orchard Park, NY.

**EPA CONTRACTORS:
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