



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org



21327

Distr.
LIMITED

ID/WG.541/10(SPEC.)
24 November 1995

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

First Global Consultation on Environmental
Management/Cleaner Technologies in the
Metallurgical Industry

Vienna, Austria, 16-18 October 1995

***WASTE MINIMIZATION AND
CLEANER PRODUCTION IN THE
METALWORKING INDUSTRY****

*Prepared by
the UNIDO Secretariat*

* This document has not been edited.

V.95-59786

SUMMARY AND OVERVIEW

This set of abstracts of technical reports was prepared by the Industrial Cooperation and Consultations Service of UNIDO in cooperation with the Industrial Information Section to serve as a follow-up paper of the Global Consultation on Environmental Management in the Metallurgical Industry held in Vienna, Austria on the 16-17 October 1995.

The material was reviewed from the perspective of energy conservation, pollution control and waste minimization opportunities in the metallurgical industry with emphasis on cleaner production as a practical approach for achieving ecologically sustainable industrial development.

UNIDO hopes that this document will assist companies and institutions at national, regional and international level in this important industrial sector, to make decisions that are both economically and environmentally sound and which contribute to the further development of a sustainable iron and steel industry.

Acknowledgement

We are grateful to the Office of Research and Development and the Risk Reduction Engineering Laboratory of the United States Environmental Protection Agency for providing Environmental Case Studies, Project Summaries and Research Briefs on Pollution Prevention and Waste Minimization to UNIDO.

CONTENTS

1	Waste Minimization Assessment for a Manufacturer of Microelectronic Components	8
2	Waste Minimization Assessment for a Manufacturer of Outdoor Illuminated Signs	8
3	Waste Minimization Assessment for a Manufacturer of Printed Plastic Bags	8
4	Waste Reduction Activities and Options for a Manufacturer of Plastic Containers by Injection Molding	9
5	Waste Reduction Activities and Options for a Manufacture Electroplating Chemical Products	9
6	Waste Reduction Activities and Options for a Manufacturer of Fire Retardant Plastic Pellets and Hot Melt Adhesives	9
7	Waste Reduction Activities and Options for a Manufacturer of Automobile Radiators	10
8	An Automated Aqueous Rotary Washer for the Metal Finishing Industry	10
9	Waste Minimization Assessment for a Manufacturer of Penny Blanks and Zinc Products	10
10	Waste Reduction Activities and Options for an Autobody Repair Facility	11
11	Waste Minimization Assessment for a Manufacturer of Rotogravure Printing Cylinders	11
12	Waste Reduction Activities and Options for a Manufacturer of Hardened Steel Gears	11
13	Waste Minimization Assessment for a Manufacturer of Screwdrivers	12

14	Waste Minimization Assessment for a Manufacturer of Pliers and Wrenches	12
15	Waste Minimization Assessment for Manufacturer of Gravure-Coated Metalized Paper and Metalized Film	13
16	Waste Minimization Assessment for a Manufacturer of Aerial Lifts	13
17	Waste Minimization Assessment for a Manufacturer of Mountings for Electronic Circuit Components	14
18	Waste Minimization Assessment for a Manufacturer of Parts for Truck Engines	14
19	Waste Minimization Assessment for a Manufacturer of Electrical Rotating Devices	14
20	Recycling Nickel Electroplating Rinse Waters by Low Temperature Evaporation and Reverse Osmosis	15
21	Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating/Degreasing Bath	15
22	Minimization Assessment for Multilayered Printed Circuit Board Manufacturing	16
23	Waste Minimization Assessment for a Manufacturer of Printed Circuit Boards	16
24	Waste Minimization Assessment for a Manufacturer of Speed Reduction Equipment	17
25	Waste Minimization Assessment for a Manufacturer of Metal Bands, Clamps, Retainers, and Tooling	17
26	Waste Minimization Assessment for a Manufacturer of Injection-Molded Car and Truck Mirrors	18
27	Waste Minimization Assessment for a Manufacturer of Custom Molded Plastic Products	18
28	Waste Minimization Assessment for a Manufacturer of Permanent-Magnet DC Electric Motors	18
29	Waste Minimization Assessment for a Manufacturer of Metal-Plated Display Racks	19

30	Waste Minimization Assessment for a Manufacturer of Prototype Printed Circuit Boards	19
31	Waste Minimization Assessment for a Manufacturer of Automotive Air Conditioning Condensers and Evaporators	20
32	Waste Minimization Assessment for a Manufacturer of Military Furniture	20
33	Metal Recovery/Removal Using Non-Electrolytic Metal Recovery	20
34	Composites from Recycled Wood and Plastics	21
35	Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals	22
36	Waste Minimization Assessment for a Manufacturer of Rebuilt Railway Cars and Components	22
37	Waste Minimization Assessment for a Manufacturer of Sheet Metal Components	23
38	Waste Reduction Activities and Options for a Manufacturer of Wire Stock Used for Production of Metal Items	23
39	Waste Reduction Activities and Options for a Manufacturer of Finished Leather	23
40	Waste Reduction Activities and Options for a Manufacturer of Room Air Conditioning Units and Humidifiers	24
41	Waste Reduction Activities and Options for a Manufacturer of Systems to Produce Semiconductors	24
42	Waste Reduction Activities and Options for a Manufacturer of Electroplated Wire	24
43	Waste Reduction Activities and Options for a Transporter of Bulk Plastic Pellets	25
44	Waste Minimization Assessment for a Manufacturer of Cutting and Welding Equipment	25
45	Waste Minimization Assessment for an Aluminum Extrusions Manufacturer	26
46	Waste Minimization Assessment for a Manufacturer of Can-Manufacturing Equipment	26

47	Waste Minimization Assessment for a Manufacturer of Refurbished Railcar Bearing Assemblies	26
48	Waste Reduction Activities and Options for a Manufacturer of Paints Primarily for Metal Finishing	27
49	Waste Minimization Assessment for a Manufacturer Producing Galvanized Steel Parts	27
50	Waste Minimization Assessment for a Paint Manufacturing Plant	27
51	Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System	28
52	Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant	28
53	Cadmium and chromium Recovery from Electroplating Rinsewaters	29
54	Removal and Containment of Lead-Based Paint Via Needle Scalers	29
55	Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium Solutions	30
56	Waste Minimization Assessment for a Manufacturer of Chemicals	30
57	Waste Minimization Assessment for a Manufacturer Sheet Metal Cabinets and Precision Metal Parts	31
58	Waste Minimization Assessment for a Manufacturer of Aluminum Extrusions	31
59	Waste Reduction Activities and Options for a Scrap Metal Recovery Facility	31
60	Waste Minimization Assessment for a Metal Parts Coating	32
61	Waste Minimization Assessment for a Manufacturer of Aluminum and Steel Parts	32
62	Waste Reduction Activities and Options for a Fabricator and Finisher of Steel Computer Cabinets	32
63	Recovery of Metals Using Aluminum Displacement	33
64	Waste Minimization Assessment for a Manufacturer of Brazed Aluminum Oil Coolers	33

65	Waste Reduction Activities and Options for a Manufacturer of Commercial Refrigeration Units	34
66	Waste Minimization Assessment for a Manufacturer of Finished Metal Components	34
67	Waste Minimization Assessment for a Manufacturer of Metal-Cutting Wheels and Components	34
68	Waste Minimization Assessment for a Manufacturer of Finished Metal and Plastic Parts	35
69	Waste Minimization Assessment for a Manufacturer Producing Printed Circuit Boards	35
70	Waste Minimization Assessment for a Manufacturer Motor Vehicle Exterior Mirrors	36
71	Waste Minimization Assessment for a Manufacture Aluminum Cans	36
72	Waste Minimization Assessment for a Manufacturer of Machined Parts	37
73	Waste Minimization Assessment for a Manufacturer of Components for Automobile Air Conditioners	37
74	Waste Minimization Assessment for a Printed Circuit Board Manufacturer	38
75	Pollution Prevention Case Studies Compendium	38
76	Contaminants and Remedial Options at Selected Metal - Contaminated Sites	38
77	Superfund Innovative Technology Evaluation Program - Technology Profiles	39
78	Guides to Pollution Prevention - The Paint Manufacturing Industry	39
79	Guides to Pollution Prevention - The Metal Finishing Industry	40
80	Guides to Pollution Prevention - The Fiberglass-Reinforced and Composite Plastics Industry	41
81	Guides to Pollution Prevention - The Automotive Repair Industry	42
82	Guides to Pollution Prevention - The Printed Circuit Board Manufacturing Industry	43
83	Guides to Pollution Prevention - The Fabricated Metal Products Industry	44

84	Guides to Cleaner Technologies - Alternative Metal Finishes	45
85	Guides to Pollution Prevention - The Automotive Refinishing Industry	46
86	Guides to Pollution Prevention - Metal Casting and Heat Treatment Industry	47
87	Guides to Pollution Prevention - The Mechanical Equipment Repair Industry	48

1 Waste Minimization Assessment for a Manufacturer of Microelectronic Components

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA's Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures microelectronic components. Thin-film circuitry is generated on sheet-alumina substrates using photolithography for pattern generation and vacuum-chamber vapor deposition to form circuit components. Integrated circuits and other components are attached to the ceramic substrates. The team's report, detailing findings and recommendations, indicated that the waste streams generated in the greatest quantities are rinse water and waste developer and that significant cost savings could be realized by installing flow meters and flow reducers in certain production areas.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

2 Waste Minimization Assessment for a Manufacturer of Outdoor Illuminated Signs

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium- size manufacturers who want to minimize their generation of hazardous waste but lack the

expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee inspected a plant making large and small outdoor signs with the use of steel channels and sheeting, plastic sheeting, paint, adhesives, electrical wiring, and hardware. The team's report, detailing their findings and recommendations, identified the greatest opportunities to minimize waste in the painting, cleaning, and letter gluing operations. The greatest savings would result from the reactivation of an unused electrostatic paint spray system.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

3 Waste Minimization Assessment for a Manufacturer of Printed Plastic Bags

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing printed plastic bags for snack foods-approximately 1.8 million lb/yr. Plastic stock is ink printed and oven cured. To make single-layer bags, a heat seal process is used, and the bags are then packaged and shipped. For certain products, a plastic or metalized film is laminated to the printed plastic film, the rolls are slit to obtain individual bags, and the bags are packaged and shipped.

The team's report, detailing findings and recommendations, indicated the most waste was generated in the lamination process and that the greatest savings could be obtained by installing an automatic adhesive/solvent mixing system to reduce

(75%) the waste from the unused metalized film adhesive/solvent mixture.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project. For additional information please contact the authors.

4 Waste Reduction Activities and Options for a Manufacturer of Plastic Containers by Injection Molding

By Hanna Saqa and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures plastic containers by injection molding. The manufacturing process involves melting of a plastic resin and injection of the melt into molds in the shape of the container to be manufactured. The cooled and solidified container is removed from the mold, the mold is cleaned with solvent when required and the injection process is repeated. A portion of the containers are also made by blow molding which involves use of compressed gas to move the resin melt onto the walls of the mold. The rest of the operation is similar.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified for pollution prevention include change in equipment to eliminate use of hydraulic oil, change in mold cleaning procedures, and modifications to metal machining operations. It should be pointed out that this facility had already initiated an aggressive pollution prevention program. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed

assessment.

5 Waste Reduction Activities and Options for a Manufacturer of Electroplating Chemical Products

By Alan Ulbrecht and Daniel Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that produces chemicals for use in electroplating baths. The process formulates and blends concentrates of metal salts and additives which are used in electroplating and other metal finishing operations. The resulting solutions are clarified and tested for quality and consistency.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified include a spill prevention plan, expanded use of ion exchange, and electrowinning to recover metal from concentrated waste streams. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

6 Waste Reduction Activities and Options for a Manufacturer of Fire Retardant Plastic Pellets and Hot Melt Adhesives

By Hanna Saqa and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures fire retardant plastic pellets and hot melt adhesives. The manufacturing process for the plastic pellets uses a batch procedure in mixers where resins are combined with flame retardants and other additives. The mix is allowed to solidify and formed into pellets. The hot melt adhesive is produced by extruding a polymer with the necessary additives followed by washing and pelletizing.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included changes in sequencing of production, modifications of wastewater treatment practices, changes in hydraulic oil use and reuse practices. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

7 Waste Reduction Activities and Options for a Manufacturer of Automobile Radiators

By Kevin Gashlin and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that remanufactures automobile radiators. The process involves cleaning the radiator, locating and repairing any leaks, painting, and reinstallation.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified include changes in the cleaning procedure, more efficient rinsing operations, and change of paint from solvent-based to water-based. Implementation of the identified waste minimization opportunities was not part of

the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

8 An Automated Aqueous Rotary Washer for the Metal Finishing Industry

By Arun R. Gavaskar, Robert F. Olfenbuttel, Jody A. Jones and Tad C. Fox

Product quality, waste reduction, and economic issues involved in the use of an automated aqueous rotary washer in the metal finishing industry were evaluated in this study. The automated washer can be used for most metal parts that would ordinarily be cleaned by vapor degreasing, hand-aqueous washing, or alkaline tumbling. The automated washer had good potential to reduce waste, was economically viable, produced good product quality, and also avoided the vapor degreaser's use of perchloroethylene. When compared with hand-aqueous washing and alkaline tumbling, the automated washer used less chemicals. The payback period was about 7 years.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

9 Waste Minimization Assessment for a Manufacturer of Penny Blanks and Zinc Products

By Richard J. Jendrucko and J. Clifford Maginn Jr.

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing penny blanks, dry cell battery cans, and other zinc products approximately 120 million lb/yr. Zinc ingots and scrap zinc are melted in an electric furnace. The molten zinc is formed into coils of strip for further processing or sale to industrial customers. The circular penny blanks are formed in a press, upset to form a rim on the edge, copper plated, and visually inspected. Battery can blanks are pressed from the strip, drawn into can shape, cleaned, and dried.

The team's report, detailing findings and recommendations, indicated that the most waste was generated as dross in melting the zinc and that the greatest savings could be obtained by reducing drag-out from the plating tanks to reduced downstream sludge formation and installing driers to dewater the sludge before shipment for disposal.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

10 Waste Reduction Activities and Options for an Autobody Repair Facility

By Kevin Gashlin and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was an autobody repair facility. A site visit was made in 1990 during which several opportunities for waste minimization were identified. These opportunities include alternative spraying systems to improve transfer efficiency, increased use of waterbased paints, and onsite distillation to permit recycling of solvents.

Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

11 Waste Minimization Assessment for a Manufacturer of Rotogravure Printing Cylinders

By Marvin Fleischman, F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Louisville performed an assessment at a plant manufacturing cylinders for rotogravure printing. A considerable amount of waste is generated by the various plating operations in the plant. The plant operates its own wastewater treatment system. The team's report, detailing findings and recommendations, indicated that the most significant cost savings could be realized by installing a batch still onsite to recover xylene.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory (RREL), Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

12 Waste Reduction Activities and Options for a Manufacturer of Hardened Steel Gears

By Alan Ulbrecht and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized

businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures hardened steel gears of various sizes and application. The manufacturing steps include grinding, cutting, degreasing, and surface finishing.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options for pollution prevention include changes in use of metal working coolants, degreasing operations, and the rinsing procedures used in the plating operations. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

13 Waste Minimization Assessment for a Manufacturer of Screwdrivers

By Harry W. Edwards*, Michael F. Kostrzewa, and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures screwdrivers-over 30 million/yr. Plastic handles are fabricated from virgin and recycled plastic beads. Five plastic extruders are used to form plastic rods that are cut to length and machined into handles. The finished handles are painted and then assembled into screwdrivers with metal blades forged in another plant.

The team's report, detailing findings and

recommendations, indicated that the waste stream generated in the greatest quantity is waste plastic and that significant cost savings could be realized by pelletizing the plastic scrap before its sale to a recycler.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Centre, PA Philadelphia

14 Waste Minimization Assessment for a Manufacturer of Pliers and Wrenches

By Harry W. Edwards, Michael F. Kostrzewa, and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures pliers and wrenches. The products are manufactured from metal blanks that have been forged in another plant. In the case of the pliers, the blanks are machined, etched, primed, and assembled. The handles are then plastic coated and the finished pliers are inspected, packaged, and shipped. For wrench manufacture, the metal blanks are nickel and chromium-plated, inspected, and packaged.

The team's report, detailing findings and recommendations, indicated that the greatest quantity of waste in this plant came from the machining and plating operations. The greatest cost-saving opportunity recommended to the plant involved the replacement of 1,1,1-trichloroethane vapor degreasing with nonhazardous aqueous cleaning.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

15 Waste Minimization Assessment for Manufacturer of Gravure-Coated Metalized Paper and Metalized Film

By Richard J. Jendrucko, Thomas N. Coleman and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at the University of Tennessee performed an assessment at a plant that manufactures gravure-coated metalized paper and film. White coated paper purchased as a raw material is coated with a water-based or solvent-based mixture, and a thin layer of aluminum is deposited on the coating. Another coating is applied on top of the metalized surface. Rolls of film bought by the plant also receive a thin layer of aluminum.

The team's report, detailing findings and recommendations, indicated that a large quantity of solvent evaporates from the plant's processes and that a large quantity of unused coating mixture is wasted. The greatest cost savings can be achieved by the plant through the installation of an automated system for mixing and diluting coating mixtures.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report

of the same title available from University City Science Center.

16 Waste Minimization Assessment for a Manufacturer of Aerial Lifts

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures aerial manlifts, ventilating driers, and air driers. The production of aerial manlifts requires sawing, cutting, and machining of metal, zinc plating or painting, and assembly. For the most part, only assembly operations are required for production of the ventilating and air driers.

The team's report, detailing findings and recommendations, indicated that the waste streams generated in the greatest quantity are spent rinse waters from plating and paint preparation, and the greatest cost savings could be achieved by replacing the currently used parts washer with a system that uses a less hazardous solvent.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

17 Waste Minimization Assessment for a Manufacturer of Mountings for Electronic Circuit Components

By Richard J. Jendrucko, Kelly L. Binkley and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at the University of Tennessee performed an assessment at a plant that manufactures ceramic mountings for electronic circuit components. Several types of mountings, varying in size and number of ceramic layers and connectors, are manufactured by the plant. Ceramic sheets are manufactured onsite and coated with tungsten paste. The sheets are scored or cut, cured, inspected, and nickel-plated, gold-plated, and brazed as required.

The team's report, detailing findings and recommendations, indicated that the waste stream generated in the greatest quantity is wastewater from the plating lines and that significant cost savings could be achieved by purifying and reusing the effluent from the onsite wastewater treatment plant.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in separate report of the same title available from University City Science Center.

18 Waste Minimization Assessment for a Manufacturer of Parts for Truck Engines

By Richard J. Jendrucko, Kelly Binkley, Todd Thomas, Stephanie Wilson, Eric W. Daley and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at the University of Tennessee performed an assessment at a plant that manufactures turbochargers, fan drives, and vibration dampers for truck engines. Metal castings are machined and cleaned; degreased, coated and/or painted, if required; and assembled, inspected, packaged, and shipped.

The team's report, detailing findings and recommendations, indicated that the plant could achieve significant cost savings by replacing its solvent-based painting system with an electrostatic powder coating system, thereby reducing paint overspray.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

19 Waste Minimization Assessment for a Manufacturer of Electrical Rotating Devices

By Richard J. Jendrucko, Thomas N. Coleman and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and

medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992).

The WMAC team at the University of Tennessee performed an assessment at a plant that manufactures several varieties of electrical rotating devices. Metal stock is machined, cleaned, and surface-treated if required. Laminations, which are used in rotor, stator, and stepper assemblies, are manufactured in-house from strip stock. Rotors, stators, and steppers are manufactured through a series of operations and are then assembled into the finished devices.

The team's report, detailing findings and recommendations, indicated that spent solutions from the four-stage aqueous cleaner are the waste streams generated in the greatest quantity and that significant cost savings could be achieved by discontinuing the use of Freon™ vapor degreasing for precision parts cleaning.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

20 Recycling Nickel Electroplating Rinse Waters by Low Temperature Evaporation and Reverse Osmosis

By Timothy C. Lindsey

Low temperature evaporation and reverse osmosis systems were each evaluated (on a pilot scale) on their respective ability to process rinse water collected from a nickel electroplating operation. Each system offered advantages under specific operating conditions. The low temperature evaporation system was best suited to processing solutions with relatively high (greater than 4,000 to 5,000 mg/L) nickel concentrations.

The reverse osmosis system was best adapted to conditions where the feed solution had a relatively low (less than 4,000 to 5,000 mg/L) nickel concentration. In electroplating operations where relatively dilute rinse water solutions must be concentrated to levels acceptable for replacement in the plating bath, a combination of the two technologies might provide the best process alternative.

Initially, the reverse osmosis system could be used to concentrate the feed solution. This could be followed by low temperature evaporation processing to concentrate the solution to levels acceptable for replacement in the plating bath.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

21 Evaluation of Ultrafiltration to Recover Aqueous Iron Phosphating-Degreasing Bath

By Gary D. Miller, Timothy C. Lindsey, Alisa G. Ocker, and Michelle C. Miller

Pollution prevention efforts studied in the report summarized here targeted the hazardous waste generated from a 5,000 gal iron phosphating/degreasing bath used by a metal fabricator to clean and precondition steel parts for painting. When oil buildup in the bath began to sacrifice product quality and the discharge levels of oil and grease in the rinse water edged closer to the maximum allowable limit, all 5,000 gal were dumped and replaced.

Periodic dumping, about three times each year, resulted in at least 15,000 gal/yr of hazardous waste. Several waste minimization alternatives were considered, and ultrafiltration was selected as the most promising technology to recover and reuse the bath and to reduce the total amount of hazardous waste generated.

This project was carried out in four stages: (1) initial assessment of the problem and evaluation of alternatives, (2) bench-scale screening of ultrafiltration membrane candidates, (3) pilot-scale study at the Illinois Hazardous Waste Research and

Information Center (HWRIC) and (4) full-scale implementation and testing onsite at the company's facility.

Full-scale testing integrated the new waste reduction scheme into the facility's production process by applying ultrafiltration directly to the 5,000gal iron phosphating/ degreasing bath. Ultrafiltration successfully removed oil contamination from the bath and returned clean process solution back to the original 5,000gal tank. Ultrafiltration concentrated the hazardous component down to 10gal of oily waste and reduced hazardous waste generation 99.8%. Permeate flux rates were high enough to compete with the constant input of oil from the production line, and concentrations of oil in the bath were maintained at acceptable operating levels.

The estimated payback period associated with implementing ultrafiltration was only 6.9 month.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

22 Minimization Assessment for Multilayered Printed Circuit Board Manufacturing

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium- size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University inspected a plant manufacturing multilayered circuit boards. This complex operation has seven key elements: preparing individual layers of boards; transferring circuit patterns to these layers and forming copper oxide castings; bonding to form multiple layers; applying copper (electroless plating) to ensure electrical contact; applying photoresist to define the area on which copper circuits are to be plated; applying copper

electrolytically to establish circuit patterns on outer board surfaces followed by tin or tin/lead plating to protect the circuits; and applying solder and final cleanup after selectively removing protective tin layers.

All these elements of the manufacturing process generate hazardous waste, e.g., electrolytic application of copper generates sulfuric acid; propylene glycol methyl ether; copper-laden deionized water; and rinse water; ethoxylated octylphenol; copper-free drag-out-laden water; and copper sulfate.

The plant had already instituted waste minimization techniques: the team's report, detailing findings and recommendations, indicated that additional reductions and savings, although not as great, were still possible. The greatest reduction would come from separating liquid wastes into four streams containing differing amounts of waste.

Copper-containing streams could be further treated and reused in process rinses and baths. Spent process solutions could be stored for recycling and reclaiming.

23 Waste Minimization Assessment for a Manufacturer of Printed Circuit Boards

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so.

Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University inspected a plant producing printed circuit boards - a plant that already had taken steps to control its hazardous wastes. Producing a circuit board involves many major processes and subprocesses: preparing the board; depositing copper on the board by electroless plating; applying dry film; electrolytically plating copper; electrolytically plating tin; etching and stripping; applying solder;

and, perhaps, plating gold on connectors.

Each of these steps produces hazardous wastes, e.g., electrolytic copper plating results in acid soap dumps, copper and tin drag-out, and sulfuric acid. The main sources of metallic contamination (copper [both dissolved and metallic], tin, lead, gold) are the rinses after scrubbing, plating, and etching.

Although the greatest amount of waste can be reduced by reusing effluent from the MEMTEK™ (with some further treatment), the greatest dollar savings can be found by changing the dry film developer. The present brand adheres strongly to the unexposed film and requires an aggressive acid soap; a less aggressive, nonhazardous soap could be used with a less-adhering dry film developer.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separated report of the same title available from the authors.

24 Waste Minimization Assessment for a Manufacturer of Speed Reduction Equipment

By F. William Kirsch and J. Clifford Maginn

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant manufacturing speed reduction equipment - approximately 110,000 speed reduction units/yr. Plant operations include machining and assembling parts for worm gear shafts and other shafts, worm gear bodies, hubs and housings, bearings and seals. Keyed and threaded shafts are case-hardened, ground with a thread grinder, and deburred. Component parts are washed with an aqueous cleaner before assembly, and finished assemblies are spray painted with solvent-based paints and lacquer thinner.

Spent cutting fluid and sludge, including turnings, and spent wash water are shipped offsite for disposal. Spent hydraulic oil and nonaqueous cutting fluid are shipped to a recycler. Waste paint and spent lacquer thinner are shipped offsite for incineration.

The team's report, detailing findings and recommendations, indicated that most waste consists of spent aqueous cutting fluid, and that the greatest savings could be obtained by ultrafiltration and recycle of spent wash water.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

25 Waste Minimization Assessment for a Manufacturer of Metal Bands, Clamps, Retainers, and Tooling

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003 July 1988).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures metal bands, clamps, retainers, and tooling - approximately 2 million lb/yr of product. Metal undergoes cutting, machining, cleaning, and electroplating as required. The specific processes are determined by the particular product being produced.

The team's report, detailing findings and recommendations, indicated the most waste was generated by metal cleaning and that the greatest cost savings would result from using deionized water instead of tap water to make up and maintain the reagent baths in the metal cleaning and electroplating lines.

This Research Brief was developed by the principal

investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same site available from the authors.

26 Waste Minimization Assessment for a Manufacturer of Injection-Molded Car and Truck Mirrors

By Marvin Fleischman, Clay Hensen, Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Louisville performed an assessment at a plant that manufactures injection-molded car and truck mirrors-over 2.5 million/yr. Purchased parts and injection-molded plastic parts manufactured onsite are painted as needed and assembled.

The team's report, detailing findings and recommendations, indicated that a large quantity of waste is generated by the painting process and that waste plastic also is generated in significant amounts. The greatest cost savings can be achieved in this plant by using an alternate method of disposing of the waste paint sludge generated in the paint booths.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

27 Waste Minimization Assessment for a Manufacturer of Custom Molded Plastic Products

By Richard J. Jendrucko and Phylissa S. Miller

The U.S. Environmental Protection Agency (EPA)

has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing custom-molded structural foam plastic products-approximately 840,000 parts per year. Resin pellets are blended with cobrant pellets and regrind, then processed through a mold and press machine. Unfinished products are degated to remove seams, have attachments inserted, and are drilled, if necessary. Next, parts are patched and sanded. Finally, the part undergoes finishing operations including nickel coating, spray fill application, and top coat application.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the mold and press machines but that the greatest savings could be obtained by utilizing electrostatic spray equipment in the finishing department to reduced (by 28%) the amount of paint solids waste generated.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

28 Waste Minimization Assessment for a Manufacturer of Permanent-Magnet DC Electric Motors

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing permanent-magnet DC electric motors-approximately 12 million motors and repair parts per yr. The armatures and stators are manufactured separately and then assembled into complete motor units. After assembly, the motors are appropriately masked and painted according to customer specifications.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the armature assembly line but that the greatest savings could be obtained by installing an electrostatic powder coating system to reduce the generation of waste paint solids (93%) and to eliminate the generation of waste paint liquids.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title, which is available from the authors.

29 Waste Minimization Assessment for a Manufacturer of Metal-Plated Display Racks

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing metal-plated display racks. Steel wire, tubing, and sheets undergo machining operations, and the resulting parts are then nickel and brass-plated, nickelplated, zinc-plated, nickel and chrome-plated, or painted. The various finished parts are assembled into display racks.

The team's report, detailing findings and recommendations, indicated that the majority of

waste was generated by the plating lines and that the greatest waste reduction would result from utilizing a Zero Discharge Recovery system in the nickel-plating baths.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

30 Waste Minimization Assessment for a Manufacturer of Prototype Printed Circuit Boards

By F. William Kirsch and Gwen P. Loobys

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant manufacturing prototype printed circuit boards. Various processes are involved including photographic operations, drilling, scrubbing, laminating, etching, and plating. The majority of the waste generated by this plant comes from the plating process.

The team's report, detailing findings and recommendations, indicated that the greatest waste reduction and cost savings would result from recovering copper, tin, and lead from the plating wastewater.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

31 Waste Minimization Assessment for a Manufacturer of Automotive Air Conditioning Condensers and Evaporators

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/62517-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing automotive air conditioning condensers and evaporators - approximately 400,000 units per year. To make condensers, extrusions and steel coil are machined degreased, welded, and painted. Header assemblies are brazed and degreased. Fins are produced and placed inside header assemblies before final brazing, leak testing, packaging and shipping. To make evaporators, aluminum side sheet stock and coil and box extrusions are machined and degreased along with aluminum tube stock. All parts are assembled with the fins before brazing, cleaning, and chromate surface treatment. After leak testing, evaporators are packaged and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the non-chromate waste water treatment facility but that the greatest savings could be obtained by converting to a powder coating technique in the condenser line to eliminate both contaminated paint solids and paint liquids.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

32 Waste Minimization Assessment for a Manufacturer of Military Furniture

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/62517-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing military furniture approximately 12,000 units/yr. Wood and formica are laminated together via glue curing and then undergo woodworking operations including cutting, drilling, and routing. Finished boards are either packaged and shipped or transported to assembly. Metal stock is cleaned with solvent and then undergoes various metalworking operations. Metal pieces are partially assembled, painted, then either packaged and shipped or transferred to assembly before being packaged and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated during the painting operations and that the greatest savings could be obtained by installing an electrostatic powder coating system to completely eliminate paint solvent evaporation, paint solids waste, and paint-laden air filters.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate document of the same title available from the authors.

33 Metal Recovery/Removal Using Non-Electrolytic Metal Recovery

By Vance G. Leak

Radiator repair shops most commonly use hot caustic solutions to clean radiator sections before resoldering. These "boil-out" solutions become

contaminated with dirt, rust, paint, and metals such as lead, copper, zinc, and tin. Metal levels as high as 18,000 ppm lead, 500 ppm copper, 1,000 ppm zinc, and 2,500 ppm tin have been reported.

The project summarized here investigated onsite recovery of these metal values as an alternative to current disposal practices.

Cooling the used solutions allowed dissolved metals to settle along with other solids and allowed reuse of up to 80% of the solution. This settled material was effectively stripped of metal hydroxides by using sodium sulfide. The hydroxide precipitate was then treated with two leachants to remove copper and leave a lead-rich sludge suitable for recovery by smelting. Ammonium carbonate was an effective copper leachant; ammonium persulfate was ten times less effective than ammonium carbonate.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH to announce key findings of the research project that is fully documented in a separate report of the same title.

34 Composites from Recycled Wood and Plastics

By John A. Youngquist, George E. Myers, James H. Muehl, Andrzej M. Krzysik and Craig M. Clemons

The ultimate goal of our research was to develop technology to convert recycled wood fiber and plastics into durable products that are recyclable and otherwise environmentally friendly. Two processing technologies were used to prepare wood-plastic composites: airlaying and melt-blending.

Research was conducted in (1) developing laboratory methods for converting waste wood, wastepaper, and waste plastics into forms suitable for processing into composites; (2) optimizing laboratory methods for making composite panels from the waste materials; (3) establishing a database on the effects of formulation and bonding agent on physical and mechanical properties of composites; (4) establishing the extent to which the composites can be recycled without unacceptable loss in properties; and (5) reaching out to industry to provide education, to develop applications, and

to extend the database.

Overall, the program demonstrated that both air-laid and melt-blended composites can be made from a variety of waste wood, wastepaper, and waste plastics. The composites exhibit a broad range of properties that should make them useful in a wide variety of commercial applications.

For air-laid composites, the waste materials were demolition wood waste and waste plastics from milk bottles (polyethylene) and beverage bottles (polyethylene terephthalate). Results showed that air-laid composites made from these waste ingredients possessed properties very similar to those of composites made from the virgin ingredients.

In addition, air-laid composites containing 20% reground panels possessed some properties that were superior to those of the original composites. For melt-blended composites, waste materials were wastepaper, polyethylene from milk bottles, and polypropylene from automobile battery cases or ketchup bottles. Waste magazines were slightly inferior to waste newspapers as a reinforcing filler; the properties of composites made from waste newspaper were better than those of composites made from wood flour, which is currently used in some commercial composites. Properties of wood-plastic composites were generally parallel to those of the plastics; thus, different balances in composite properties are possible from using waste plastic.

Outreach activities included the organization and presentation of two international conferences on wood fiber-plastic composites, presentations at many conferences, publication of several papers, and several spin-off cooperative studies with industry. One major study with industry demonstrated the commercial feasibility of making melt-blended composites from old newspapers and polypropylene.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

35 Alkaline Noncyanide Zinc Plating and Reuse of Recovered Chemicals

By Jacqueline M. Peden

A metal finishing process can create environmental problems because it uses chemicals that are not only toxic but also resistant to degradation or decomposition. A study was undertaken at a zinc electroplating operation to achieve zero discharge of wastewater and total recycle of recovered precipitates.

The first step in this project was to change an existing zinc cyanide (CN) plating line to one that used an alkaline noncyanide (ANC) zinc bath. The project then investigated a closed-loop system to treat plating rinsewater from the ANC zinc plating line so the plating chemicals were recovered and the water purified. The goal was to return both the recovered zinc hydroxide and the clean water to the plating line for continued use. The system that was designed and installed, at P&H Plating Co., a Chicago area operation used precipitation by pH adjustment to remove the zinc from the rinsewater.

The precipitated zinc hydroxide was collected on filters, dewatered using a filter press, and stored for reuse in the plating line as needed. Once filtered, the water was recirculated to the rinsing portion of the plating line. The recovery/recycle system successfully purified the rinsewater and facilitated the recycling of the cleaned water and the precipitated zinc hydroxide. Eliminating cyanide from the plating process meant the line workers were dealing with a less toxic plating bath, made compliance with regulations easier and reduced treatment and disposal costs for the company.

The recycling of the recovered water and the zinc hydroxide further reduced the costs for treatment and disposal. The replacement of this single CN line with an ANC line resulted in an annual savings to P&H Plating of \$14,000 from the elimination of the need to pretreat the plating line rinsewater to oxidize cyanide. The addition of the recovery/recycle system increased the company's savings to \$62,000/yr. The reuse of 30% of the recovered zinc hydroxide and 70% of the treated rinsewater reduced annual water usage and wastewater discharge by 841,911 gal and reduced the amount of sludge disposed annually by 14 yd³.

The payback period for the recovery/recycle system

is slightly less than 18 mo. Installation and use of this system for other ANC plating operations would result in reductions in wastes and increased economic benefits similar to those experienced by P&H Plating Co.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the WRITE program demonstration that is fully documented in a separate report of the same title.

36 Waste Minimization Assessment for a Manufacturer of Rebuilt Railway Cars and Components

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium- size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee inspected a plant that rebuilds approximately 2,000 railway cars (open, flat, and freight) each year and that refurbishes wheel assemblies and air brake systems.

The team's report, detailing their findings and recommendations, indicated that the greatest opportunities to minimize waste came from the railcar painting operation where paint and primer solids and sludge are generated.

The team recommended installing an electrostatic spray paint system for priming and painting to reduce the overspray losses.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

37 Waste Minimization Assessment for a Manufacturer of Sheet Metal Components

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant that manufactures precision sheet-metal components, primarily for electronics and medical equipment. Sheet metal is machined into desired components that are anodized or chromated if aluminum; degreased and painted if required; and assembled, inspected, packaged, and shipped.

The team's report, detailing findings and recommendations, indicated that the plant could achieve significant cost savings and waste reduction by replacing its standard paint spray guns with high-volume low-pressure paint guns, thereby reducing paint overspray.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

38 Waste Reduction Activities and Options for a Manufacturer of Wire Stock Used for Production of Metal Items

By Alan Ulbrecht and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization

assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures wire stock used for production of metal items. The facility processes carbon steel and stainless steel coiled rods by cold drawing them into smaller diameter wire which is sold as stock for production of metal items such as ball bearings and springs. The process involves several surface cleaning and preparation steps in addition to simple cold drawing.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included improvement of quality of acid wastes leading to beneficial secondary use, and modification of rinsing procedures to reduce flow of wastewater. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

39 Waste Reduction Activities and Options for a Manufacturer of Finished Leather

By Patrick Eyraud and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a manufacturer of finished leather.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Recommendations included 1) changeover to water-based coatings; 2) installation of a solvent recovery reuse capability; 3) use of a hand pump to reduce spillage during transfer and physical layout considerations to reduce the distances materials must be moved; 4) reducing the

volume of the container for test mixes; 5) improvements to the computercontrolled spray-coating operation to reduce overspray; and 6) the use of covers over formulated coating mixtures to reduce air emissions.

Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

40 Waste Reduction Activities and Options for a Manufacturer of Room Air Conditioning Units and Humidifiers

By Hana Saqa and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a facility that manufactures room air conditioners and humidifiers.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. These opportunities include more efficient recovery of degreasing solvents, movement to aqueous degreasing procedures, and segregation and reuse of hydraulic and lubricating fluids.

Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

41 Waste Reduction Activities and Options for a Manufacturer of Systems to Produce Semiconductors

By Alan Ulbrecht and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a facility that manufactures systems for vapor deposition of organometallic compounds or metals used in the production of semiconductors.

As part of the manufacturing process it is necessary to test the systems using the materials actually used in semiconductor production. Test deposition of materials containing arsenic, indium, or gallium, among others, result in much of the waste stream.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included changes in degreasing procedures and modifications to filtering systems.

Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

42 Waste Reduction Activities and Options for a Manufacturer of Electroplated Wire

By Alan Ulbrecht and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures electroplated wire for use in the automotive, computer, aerospace, and related industries. The wire is plated with copper, silver, nickel, tin, or tin-lead according to customer specifications. The process involves cleaning of the base wire followed by electroplating using a reel-to-reel technique. A site visit was made in 1990 during which several opportunities for waste minimization were identified.

Options identified included reduction of discharge volume, improved rinsing operations, changes in the wire drawing operation and consideration of a zero-discharge system. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

43 Waste Reduction Activities and Options for a Transporter of Bulk Plastic Pellets

By Hanna Saqa and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a trucking company which specializes in the transportation of dry bulk plastic pellets from the manufacturer to the user. The assessment focused on the large volumes of hot water which are used to clean the tank trucks between shipments.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included recirculation of the water and use of compressed gasses as a partial replacement for the water stream used to clean the trucks.

Implementation of the identified waste

minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

44 Waste Minimization Assessment for a Manufacturer of Cutting and Welding Equipment

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant that produces custom-built cutting and welding equipment. Components are fabricated from steel and other raw materials that are cleaned, machined, welded, and painted. Machines are then assembled, tested, and calibrated. The hazardous wastes generated by the plant include tramp oil, spent cutting fluid, spent lacquer thinner, and chromium-contaminated paint dust and filters.

The team's report, detailing findings and recommendations, indicated that the plant could achieve the greatest dollar savings by replacing chromium containing solvent-based paints with chromium-free water-based paints.

This Research Brief was developed by the principal investigator and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title that is available from the University Centre Science Centre.

45 Waste Minimization Assessment for an Aluminum Extrusions Manufacturer

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing aluminum extrusions over 36 million lb/yr. Primary and scrap aluminum is melted down, cast into logs, then heat treated. Next, the logs are extruded into desired shapes. Extrusions are sheared, heat treated, then either buffed, anodized (colorized), painted, or shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the anodizing line but that the greatest savings could be obtained by installing an electrostatic powder coating system to eliminate spent toluene, air filters, plastic sheets, paint ash, and evaporated solvents.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

46 Waste Minimization Assessment for a Manufacturer of Can-Manufacturing Equipment

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity*

Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment for a plant that produces equipment for manufacturing and decorating aluminum beverage cans. Each component manufactured undergoes a unique series of operations including cutting, machining, welding, and painting.

The team's report, detailing findings and recommendations, indicated that spent cutting fluid and contaminated hydraulic fluid are the largest wastes generated by the plant and that significant savings could result from instituting a recycling program for the waste cutting fluid.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

47 Waste Minimization Assessment for a Manufacturer of Refurbished Railcar Bearing Assemblies

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant that rebuilds railcar bearing assemblies—approximately 163,200 bearing components per year. Bearings are disassembled, washed, then inspected. "Premium" bearings, those still within specifications, are reassembled with new grease and bearing seals, packaged, and shipped. Nonpremium bearings are buffed, rinsed in hot water, and then chrome plated to build up the bearing surfaces. After chroming, the parts are rinsed, baked, and allowed to air cool. Cooled bearings are reassembled with new grease and seals, then packaged and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated during the railcar bearing cleaning operation and that the greatest savings could be obtained by instigating onsite wastewater treatment and recirculating recovered water to reduce (90%) water consumption in the railcar bearing cleaning operation.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

48 Waste Reduction Activities and Options for a Manufacturer of Paints Primarily for Metal Finishing

By Patrick Eyraud and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that produces paints primarily intended for metal finishing.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. These opportunities include improved solvent handling techniques, reuse of some solvent washing wastes, and changes in equipment washing techniques. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

49 Waste Minimization Assessment for a Manufacturer Producing Galvanized Steel Parts

By F. William Kirsch and J. Clifford Maginn

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant producing galvanized steel parts—approximately 10,000 tons/yr. The major process operations are degreasing and rinsing, acid pickling and rinsing, prefluxing, and galvanizing. All these operations, except galvanizing, result in the formation of waste streams requiring off-site disposal. Bottom dross from the galvanizing kettle and zinc oxide skimmed from the surface of the molten zinc are sold as usable products.

The team's report, detailing findings and recommendations, indicated that most waste was generated in acid pickling and rinsing and that the greatest savings could be obtained by continuous air agitation to extend the life of the pickling acid and rinse by enabling more complete removal of dissolved iron when those solutions are treated.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

50 Waste Minimization Assessment for a Paint Manufacturing Plant

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the

expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/788/003, July 1988).

The WMAC team at Colorado State University inspected a plant blending and mixing raw materials into paints, coatings, stains, and surface-treating products. For water-based paints, water, latex, resins, extenders, and pigments are mixed and blended. For oil-based paints, solvents replace water and latex, and plasticizers, tints, and thinners are also added. These batches are then transferred to let-down tanks where additional ingredients are incorporated.

After testing, the paints meeting specifications are filtered, canned, labeled, and packaged for shipping. Hazardous wastes result when the mixing vessels, tanks, and lines are cleaned. For example, cleaning a let-down tank after a water-based paint has been blended requires about 35 gal water; after a 400-gal tank for a solvent-based paint, about 5 gal mineral spirits. Because the spirits are sent off-site for recovery, most of the waste results from cleaning up after mixing water-based paint. This waste is hazardous because it contains mercury used as the bactericide.

Although the plant reuses rinse water, recovers solvent, and has adopted other measures to reduce waste, the team report, detailing findings and recommend actions, suggested that additional savings could result from installing a pipe cleaning system, using a solvent-recovery system based on distillation, and substituting an organic material for the mercury bactericide.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

51 Watts Nickel and Rinse Water Recovery via an Advanced Reverse Osmosis System

By C. Schmidt, I. Erbas-White, and R. Ludwig

The full report summarizes the results of an 8-mo test program conducted at the Hewlett-Packard

Printed Circuit Production Plant, Sunnyvale, CA (HP) to assess the effectiveness of an advanced reverse osmosis system (AROS).

The AROS unit, manufactured by Water Technologies, Inc. (WTI) of Minneapolis, MN, incorporates membrane materials and system components designed to treat metal plating rinse water and produce two product streams: (1) a concentrated metal solution suitable for the plating bath, and (2) rinse water suitable for reuse as final rinse. Wastewater discharge can be virtually eliminated and significant reductions realized in the need for new plating bath solution and rinse water.

The AROS unit performed very reliably during the test program. During a 5,000-hr trial, approximately 190,000 gal of rinse water were treated to produce 1,100 gal of concentrated plating bath for recycle. The second output stream from the AROS unit was recycled as clean rinse water, reducing the demand for deionized water production.

In addition, wastewater treatment and disposal costs were reduced by approximately \$13,000. If operated at full capacity, the unit capital cost was estimated to have a payback period of approximately 2 yrs. The AROS was evaluated under the California/EPA Waste Reduction Innovative Technology Evaluation (WRITE) Program, in which the cooperative efforts of the U.S. Environmental Protection Agency (EPA) and the California Environmental Protection Agency were used to evaluate innovative pollution prevention techniques.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

52 Evaluation of Five Waste Minimization Technologies at the General Dynamics Pomona Division Plant

By Lisa M. Brown and Robert Ludwig

Eight waste reduction technologies encompassing five Industrial process areas at the General Dynamics Pomona Division (GDPD) were technically and economically evaluated under the

California/U.S. Environmental Protection Agency (EPA) Waste Reduction Innovative Technology Evaluation (WRITE) Program. Evaluations were made through site visits and followup discussions with GDPD staff and equipment suppliers.

The technologies included (1) computerized printed circuit board plating; (2) sulfuric acid anodizing; (3) robotic paint facility operations with (a) proportional paint mixing, (b) water-based solvent replacement, (c) electrostatic paint spraying, and (d) solvent distillation; (4) bead-blast paint stripping; and (5) Freon recovery.

Overall, there was a decrease in hazardous waste generation and an increase in productivity or reuse of recycled materials. In most cases, the technologies could be easily transferred to other industries except for the prohibitive costs of the computerized circuit board and some processes within the robotic paint operation.

The payback period estimates ranged from less than a year for the Freon recovery still to 67 yr for the sulfuric acid anodizing system. Difficulties in estimating payback periods resulted mainly from the unavailability of company-sensitive information.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory Cincinnati, OH, and California's Department of Toxic Substances Control, Sacramento, CA, to announce key findings of the research project that is fully documented in a separate report of the same title.

53 Cadmium and chromium Recovery from Electroplating Rinsewaters

By Arun R. Gavaskar, Robert F. Olfenbuttel and Jody A. Jones

This evaluation addresses the product quality, pollution prevention potential, and economic factors involved in the use of ion exchange to recover cadmium and chromium from electroplating rinsewaters and to remove contaminants for reuse of rinsewater. Cadmium, chromium, and cyanide (which is part of the cadmium bath) are on EPA's 33/50 list of target chemicals.

Test results showed that the water returned to the rinse after ion exchange was of acceptable quality for both the cadmium and chromium processes. The ion exchange resins are regenerated with sodium

hydroxide (NaOH). On the cadmium line, the regenerant was subjected to electrolytic metal recovery (EMR) to recover cadmium for reuse in the plating bath. On the chromium line, the regenerant was passed through a cation exchange resin in an effort to recover chromic acid. Although the recovery results were good on the cadmium line, chromic acid could not be recovered in this test.

The pollution prevention potential of ion exchange on the cadmium and chromium rinsewater is good; however, further testing is needed to establish good recovery of chromium as chromic acid from the regenerant. The ionexchange processes also proved economically viable.

This Project Summary was developed by the U.S. EPA's Risk Reduction Engineering Laboratory (RREL), Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

54 Removal and Containment of Lead-Based Paint Via Needle Scalers

By Paul B. Kranz, James E. Stadelmaier, and Paul M. Randall

This report describes a comparative technical and economic evaluation of using a dustless needlegun system versus a conventional abrasive grit blasting system to remove lead-based paint from steel structures. The study objectives were to comparatively analyze the operational and logistical aspects of using dustless needleguns for leadbased paint removal as they relate to hazardous waste generation, worker health and safety, and associated economic factors.

The dustless needlegun system demonstrated its ability to produce a substantial reduction (97.5%) in the generation of hazardous waste when compared with that of conventional abrasive blasting. The needlegun also substantially reduced (up to 99%) the airborne concentrations of respirable dusts and lead-containing particulates generated during paint removal operations.

Labor costs were decidedly higher (approximately 300%) for the dustless needlegun system primarily because of slower production rates that necessitate more operating personnel. These costs are substantially mitigated by reduction of costs

associated with expendable abrasive blast material and hazardous waste disposal. Conventional abrasive blasting proved decidedly superior in the quality of surface preparation based on prescribed contract specifications.

The dustless needlegun system is shown to be economically competitive with conventional abrasive blasting when considering the reduced requirements for containment, hazardous waste disposal, and worker protection.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

55 Evaluation of an Electrodialytic Process for Purification of Hexavalent Chromium Solutions

By Dale W. Folsom, Jody A. Jones and Robert F. Olfenbittel

The evaluation summarized here addresses the waste reduction and economics of an electrodialytic process that can be used to selectively remove impurities that build up in chromic acid solutions with use. The removal of impurities extends the useful life of the chromic acid solution and reduces periodic replacement of the solution. The electrodialytic units tested in this evaluation were manufactured by Lonsep™.

The units were tested at SI. Modern Hard Chrome in Camden, NJ, (a hard chromium plating solution) and at Paramax in St. Paul, MN, (a chromic acid solution etching copper from printed wire boards). The electrodialytic process was found to effectively remove the impurities that build up in chromic acid solutions.

The rate of return on investment was not cost effective for the hard chromium plating bath but was cost effective for the chromic acid etch bath, which had a payback of less than 5 yr.

In these two examples, the payback was related to the rate of contaminant buildup in the solution—the more frequently a solution was replaced when contaminants were not removed, the shorter the payback after an electrodialytic process had been

installed. The chromium plating operation annually reduced chromium needing disposal by 73 kg (161 lb), and the copper etching operation projected an annual reduction of 4,410 kg (9,700 lb).

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate Technology Evaluation Report of the same title.

56 Waste Minimization Assessment for a Manufacturer of Chemicals

By Gwen P. Looby and Phylissa S. Miller

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing acrylic emulsions, low molecular weight resins, herbicides, and specialty chemicals—approximately 300 million lb/yr. In general, monomers, additives, activators, and catalysts are metered and mixed in tanks then pumped sequentially into reactor vessels.

Once the product is formed, the solution is pumped into a blend tank where more chemicals, such as binders, emulsifiers, and thickeners, are added. From the blend tank the product is passed through filters for clump removal then pumped into either storage tanks or drums for shipping.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the wastewater treatment system and that the greatest savings could be obtained by installing a natural gas-fired dry-off oven in the wastewater treatment system to reduce (by 81%) the amount of sludge removed to the landfill.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to

announce key findings of an ongoing research project. This brief provides only summary information and is not intended for use as a thorough analysis. A fully documented report of the same title is available from the authors.

57 Waste Minimization Assessment for a Manufacturer Sheet Metal Cabinets and Precision Metal Parts

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment for a plant that manufactures sheet metal cabinets and precision metal parts. To make the cabinets, sheet metal is cut to size, bent, welded, and polished. The metal parts are then surface treated and painted. The machined parts are produced from bar stock which is cut, drilled, milled, and ground as needed.

The team's report, detailing findings and recommendations, indicated that the most waste was generated by the chromate conversion and iron phosphate coating processes that prepare the parts for painting. The plant could achieve the greatest cost savings by replacing solvent-based painting with powder-based painting.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title, which is available from the authors.

58 Waste Minimization Assessment for a Manufacturer of Aluminum Extrusions

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA)

has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Louisville performed an assessment at a plant manufacturing aluminum extrusions-over 10 million lb/yr. Aluminum parts are extruded and tempered followed by electrostatic painting, anodizing or shipping

The team's report, detailing findings and recommendations, indicated that the most waste was generated by the painting process and that the greatest savings could be obtained by replacing the currently used paints with electrostatic powder coatings

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

59 Waste Reduction Activities and Options for a Scrap Metal Recovery Facility

By Hanna Saqa and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a facility that processes scrap metal to recover refined metals for reuse.

The facility concentrates on recovery of tungsten, molybdenum, and tantalum. The processes used by the facility involve washing, degreasing, mechanical cleaning, and acid treatment.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified include improved process pH control, changes in solid precipitation

technology, and add reuse. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

60 Waste Minimization Assessment for a Metal Parts Coating

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant where automotive parts are coated with epoxy, vinyl, or polyester powders; with liquid plastisol; or with paint. After the WMAC team analyzed five process lines (for applying coatings) and the reworking operation (where unacceptably finished parts are stripped), a report was prepared detailing their findings and recommendations.

They found three ways to reduce the evaporation of methylethyl ketone (MEK), the largest source of waste on the process lines: reduce the open surface area of the MEK container, cool the MEK, or meter the MEK. They also found ways to reduce wastes from the rework process by installing controls, repairing defective drive components, or using alternative methods to remove defective coatings.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

61 Waste Minimization Assessment for a Manufacturer of Aluminum and Steel Parts

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

That document has been superseded by the Facility Pollution Prevention Guide (EPA/600/R-92/088, May 1992). The WMAC team at Colorado State University performed an assessment at a plant that manufactures a variety of steel and aluminum parts. Raw material is machined and the resulting parts are welded, ground, and chromated. Parts are then painted and logos and other lettering are screened onto the parts. The parts are shipped following inspection, assembly, and packaging.

The team's report, detailing findings and recommendations, indicated that the waste streams generated in greatest quantity are rinse water and paint wastes, and that the greatest cost savings could be achieved by replacing the conventional paint guns currently used with more efficient substitutes.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

62 Waste Reduction Activities and Options for a Fabricator and Finisher of Steel Computer Cabinets

By Kevin Gashlin and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department

of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a fabricator and finisher of steel computer cabinets.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. These opportunities include improved painting technology, rationalization of metal-working oils and coolants, and changes in degreasing solvent management. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

63 Recovery of Metals Using Aluminum Displacement

By Steven C. Meyers

Metal finishing operations generate waste streams containing heavy metals such as copper, lead, tin, and nickel. Standard pretreatment practice has involved removing these metals from the effluent before discharge using a variety of techniques, primarily precipitation as a sludge that must be disposed of as a hazardous waste.

This project investigated aluminum displacement as a pretreatment process for selected waste streams. The process has the potential of producing not only effluent suitable for discharge but also nonhazardous pure metal suitable for recovery. Testing of copper sulfate solutions at various flow rates showed copper removal in a range of 85% to 97%. The pH was determined to have an insignificant effect on copper removal when held in a range of pH 2 to 3.5.

Recirculation testing of copper sulfate solutions reduced copper concentrations from 200 to 1.5 ppm. Recirculation testing of tin/lead fluoborate solutions reduced lead concentrations from 104 to 0.65 ppm. Eight other waste streams were evaluated to determine metal removal efficiency.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title.

64 Waste Minimization Assessment for a Manufacturer of Brazed Aluminum Oil Coolers

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee inspected a plant manufacturing brazed aluminum oil coolers that are used in heavy equipment. After the cooler components are fabricated, they are degreased (with Chlorothenet, which is recycled); assembled; brazed to join internal and external coil fin surfaces (involving a molten salt bath and a quench tank whose sludge is disposed of on-site in a sand filter bed); cleaned (with solutions and rinse waters needing treatment and disposal); and painted.

The team's report, detailing findings and recommendations, indicated that a significant minimization opportunity could be effected by replacing molten salt bath brazing with vacuum brazing. The implementation cost would be high and the payback years relatively long, but the percent waste reduction (80%) and annual savings would be pronounced.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

65 Waste Reduction Activities and Options for a Manufacturer of Commercial Refrigeration Units

By Kevin Gashlin and Daniel J. Watts

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey.

One of the sites selected was a facility that manufactures commercial refrigeration units. The manufacturing operations include design, metal working, metal finishing, and blowing of polyurethane foam into panel jacketing for insulation purposes.

A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included new techniques to reduce CFC emissions from foam manufacture, new foam production cleaning techniques to reduce methylene usage, improved painting techniques to reduce VOC emissions, and reduction of solvent wastes from general cleaning procedures.

Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

66 Waste Minimization Assessment for a Manufacturer of Finished Metal Components

By Harry W. Edwards and Michael F. Kostrzewa, F. William Kirsch and J. Clifford Maginn

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise

to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/62517-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant manufacturing finished metal components -approximately 260,000 sq ft/yr. Customer-specified coatings and surface treatments are applied to prefabricated aluminum and stainless steel parts. Aluminum parts may be finished by hard-coat or soft-coat anodizing, and chromate conversion coating. Stainless steel parts are finished by surface passivation. Parts are also processed for surface inspection using a fluorescent dye and ultraviolet light.

The team's report, detailing findings and recommendations, indicated that most waste was generated in the aluminum anodizing process, and that the greatest savings could be obtained by using hot deionized water instead of nickel acetate solution to seal pores in the aluminum oxide coating applied by anodizing.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

67 Waste Minimization Assessment for a Manufacturer of Metal-Cutting Wheels and Components

By F. William Kirsch and J. Clifford Maginn

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of hazardous waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/62517-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing metalcutting wheels and components-approximately

6,000,000 units/yr. Tungsten carbide inserts for metal cutting are pressed, sintered, shaped by grinding, and ultrasonically cleaned. About half are coated with titanium nitride by chemical vapor deposition.

Premolded ceramic inserts are ground to specifications and ultrasonically cleaned. Steel disks for diamond-plated cutting wheels are machined, cleaned, treated with sulfuric acid, coated with a diamond abrasive compound in a nickel lattice (plated from a nickel sulfamate solution) and given a final electroless plating of nickel. Aluminum and aluminum resin disks for diamond cutting wheels are machined to working specifications, a diamond abrasive compound is applied, and the wheels are machined to final specifications.

The team's report, detailing findings and recommendations, indicated that most waste, other than treated wastewater, consists of sludge filtered from machine coolant, and that the greatest savings could be obtained by recycling treated water from the plant's wastewater treatment facility to the gas/water separators of the chemical vapor deposition units.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

68 Waste Minimization Assessment for a Manufacturer of Finished Metal and Plastic Parts

By Harry W. Edwards, Michael F. Kostrzewa and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

That document has been superseded by the Facility

Pollution Prevention Guides (EPA/600/R-92/088, May 1992). The WMAC team at Colorado State University performed an assessment at a plant that applies coatings to metal and plastic components supplied by its customers. Several different coating operations are performed, but the ones that generate consistent and significant quantities of waste are anodizing of aluminum parts, chromating of aluminum parts, and painting of plastic and metal parts.

The team's report, detailing findings and recommendations, indicated that large quantities of spent rinse water and process solutions, and spent solvent and still bottoms are generated by the plant and that the life of the black dye bath could be extended to yield significant cost savings.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

69 Waste Minimization Assessment for a Manufacturer Producing Printed Circuit Boards

By Harry W. Edwards and Michael Kostrzewa, Phylissa S. Miller

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant which manufactures single-sided, double-sided, and multilayer printed circuit boards - approximately 259,000 sq /Yr. In general, circuit art work is received and digitized. The circuit design film template is laser generated from the digitized art work. In addition copper/epoxy laminates and copper foil (the inner layers material for multilayer

boards) are cut into blank cards and layers with hydraulic shears.

Component holes are cut by drilling machines. Drilled cards are mechanically scrubbed to prepare for plating. Circuit patterns are created on the boards and foil layers with a dry-film photoresist process and the multilayer boards are built up. The actual copper circuit pattern is generated by a series of photo-lithographic and plating processes. Final processing includes legend application, routing, rinsing, electrical testing, inspections, packing, and shipping.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the plating lines and the greatest savings could be obtained by installing a spray rinse and electrowinning system on the first rinse tank of the electrolytic copper plating line to reduce both copper plating rinse water (88%) and plating sludge (80%) due to drag-out in the first rinse tank.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

70 Waste Minimization Assessment for a Manufacturer Motor Vehicle Exterior Mirrors

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing exterior motor vehicle mirrors-approximately 3 million mirrors per year. Galvanized steel and stainless steel stock undergo stamping, pressing, and cutting operations followed by degreasing.

Stainless steel mirror housings are buffed, assembled, packaged, and shipped. Galvanized steel, zinc die-cast, and plastic mirror parts are washed then electrostatically primed and painted. Parts are assembled, packaged, and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of the waste was generated in the cleaning and washing areas but that the greatest savings could be obtained by installing an electrostatic powder coating system to reduce primer/paint overspray (100%), solvent evaporation (55%), cleaning solvent evaporation (80%) and still bottoms (80%).

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

71 Waste Minimization Assessment for a Manufacturer Aluminum Cans

By F. William Kirsch and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium- size manufacturers who want to minimize their generation of hazardous waste but lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7881003, July 1988).

The WMAC team at Colorado State University inspected a plant producing more than one billion aluminum cans each year for a local beverage producer. After the cans have been formed, they are cleaned and painted. These two operations generate the waste: most can cleaning wastes are treated and sewerred, and the hazardous painting and inking operations' wastes are shipped to a hazardous waste disposal facility.

The on-site treatment facility treats the can washing effluent so that the oil can be hauled to an oil recycler, the sludge disposed of off-site, and the clarified liquid discharged to the sewer. Because the plant had already initiated many steps to minimize and manage its wastes, the WMAC's team report, detailing their findings and recommendations, was

only able to suggest that a nonhazardous reagent be substituted for the presently used reagent that contains from 2% to 4% ammonium fluozirconate. The can washing sludge would then be nonhazardous, and all of the hazardous waste disposal costs could be saved.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors.

72 Waste Minimization Assessment for a Manufacturer of Machined Parts

By Harry W. Edwards, Michael F. Kostrzewa, Phylissa S. Miller and Gwen P. Looby

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at Colorado State University performed an assessment at a plant manufacturing machined parts—approximately 500,000 units/yr. This facility performs precision machine-shop work on a job shop basis. The process begins with cutting the stock to size, machining, and hand deburring the parts. Next, the parts are machine deburred in a large tumbler, washed, degreased, shipped offsite for chromating, and returned, assembled, inspected, packaged, and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated by the deburrer rinse but that the greatest savings could be obtained by replacing the cutting fluid concentrate, thereby eliminating the need for degreasing with 1,1,1-trichloroethane.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City

Science Center.

73 Waste Minimization Assessment for a Manufacturer of Components for Automobile Air Conditioners

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing charged air coolers, round tube plate fin (RTPF) condensers, and air conditioner tubes for automotive air conditioning systems—approximately two million lb/yr. Even though this plant has three distinct product manufacturing lines, the processes can be generalized to the following: initially fins are produced and partially assembled with various components. These partial assemblies are vapor degreased and then either packaged and shipped or brazed either manually or in a vacuum brazing oven. Units are assembled into final products, painted black, inspected, packaged, and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the rinse tanks and the hot water flush testing stations but that the greatest savings could be obtained by replacing solvent-based vapor degreasing systems with a detergent-based immersion system to eliminate and evaporated solvent losses.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from the authors

74 Waste Minimization Assessment for a Printed Circuit Board Manufacturer

By Gwen P. Looby and F. William Kirsch

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small- and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA Waste Minimization Opportunity Assessment Manual (EPA/625/7-88/003, July 1988).

The WMAC team at the University of Tennessee performed an assessment at a plant manufacturing printed circuit boards for television sets approximately 4.3 million sq ft of finished boards per yr. To make printed circuit boards, the plant begins with making screens as all printing is accomplished using silkscreening techniques. The circuit boards undergo several operations including punching, scrubbing, printing, etching, and soldering. Finished boards are inspected, deslugged, electrically tested, packed, and shipped.

The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the circuit board production lines but that the greatest savings could be obtained by installing a closed-loop cooling water system to reduce (60%) excess water usage in the UV-light curing ovens after screen printing and the cooling of the cupric chloride etch tanks.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title, which is available from the authors.

75 Pollution Prevention Case Studies Compendium

The Pollution Prevention Research Program encourages the development and adoption of processing technologies and products in the United States that will lead to reducing the aggregate generation rates for pollutants entering the various environmental media. It includes projects to

improve the understanding of environmental problems that might be amenable to pollution prevention approaches, and projects that demonstrate innovative pollution prevention approaches and technologies.

Pollution Prevention Research supports studies and research and demonstration projects that are designed to further the utilization of source reduction and to a lesser degree recycling as preferable environmental improvement strategies. Projects within the program are supported through in-house activities, contracts with outside organizations, and cooperative agreements with universities and other government agencies.

The Risk Reduction Engineering Laboratory (RREL) serves as the lead organization within the EPA's Office of Research and Development for research related to pollution prevention. Spearheading pollution prevention research within RREL is the Pollution Prevention Research Branch (PPRB) of the Waste Minimization, Destruction and Disposal Research Division. Efforts cover all sectors identified in EPA's Pollution Prevention Strategy (January, 1991), i.e., manufacturing, agriculture, energy and transportation, municipal water and wastewater, federal facilities and municipal solid waste. The program also contains a technology transfer element for incorporating results from other's research and for disseminating the results of the program's efforts.

As a major part of the effort to disseminate the results of its research, PPRB has produced a second compilation of case studies. These studies are the culmination of some of the major current research efforts being conducted in the area of pollution prevention. It is a compilation of summaries of pollution prevention demonstrations, assessments and research projects conducted within the Branch. We hope that this compendium will facilitate the development and adoption of pollution prevention techniques throughout the United States and other countries. This report covers a period of May 1992 to May 1994 and work was completed as of February 1995.

76 Contaminants and Remedial Options at Selected Metal - Contaminated Sites

This document provides information that facilitates characterization of the site and selection of

treatment technologies at metal-contaminated sites that are capable of meeting site-specific cleanup levels. The document does not facilitate the determination of cleanup levels. This document will assist Federal, State, or private site removal and remedial managers operating under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), or state regulations.

This document focuses mainly on the metalloid arsenic and the metals cadmium, chromium, lead, and mercury. Other metals are discussed, particularly those that have a strongly favorable or unfavorable influence on the performance of a treatment technology.

The remedial manager faces the challenge of selecting remedial options that meet established cleanup levels. A wide range of physical, chemical, and thermal process options are available for remediation of metal-contaminated sites. These options can reduce mobility, reduce toxicity, or allow separation and concentration of metal contaminants. No single process option can remediate an entire metal-contaminated site. The remedial manager must combine pretreatment and posttreatment components to achieve the best performance by the principal process option.

This document is designed for use with other remedial guidance documents issued for RCRA, CERCLA, and/or State-mandated cleanups to accelerate the remediation of metal-contaminated sites.

Sections describing contaminants at metal-contaminated sites and the behavior, fate, and transport of metals in the environment are provided to assist the remedial manager in identifying the matrix and chemical species likely to be present. The section on remedial options outlines the arrangement of treatment trains to achieve performance levels. Technology performance data provided can help the remedial manager narrow options to those most likely to achieve site-specific cleanup goals. The descriptions of remedial options cover innovative and emerging technologies, as well as proven treatments.

Some standard information sources on containment and water treatment technologies are indicated. These technology areas are not covered in this document because they are thoroughly discussed in

other documents

77 Superfund Innovative Technology Evaluation Program - Technology Profiles

The Superfund Innovative Technology Evaluation (SITE) Program evaluates new and promising treatment and monitoring and measurement technologies for cleanup of hazardous waste sites. The program was created to encourage the development and routine use of innovative treatment technologies. As a result, the SITE Program provides environmental decision-makers with data on new, viable treatment technologies that may have performance or cost advantages compared to traditional treatment technologies.

This document, prepared between June 1993 and October 1993, is intended as a reference guide for those interested in technologies under the SITE Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs. The two-page profiles are organized into two sections for each program, completed and ongoing projects, and are presented in alphabetical order by developer name. Reference tables for SITE Program participants precede the sections and contain EPA and developer contacts. Inquiries about a specific SITE technology or the SITE Program should be directed to the EPA project manager; inquiries on the technology process should be directed to the technology developer contacts.

Each technology profile contains (1) a technology developer and process name, (2) a technology description, including a schematic diagram or photograph of the process, (3) a discussion of waste applicability, (4) a project status report, and (5) EPA project manager and technology developer contacts. The profiles also include summaries of demonstration results if available. The technology description and waste applicability sections are written by the developer. EPA prepares the status and demonstration results sections.

78 Guides to Pollution Prevention - The Paint Manufacturing Industry

This guide is designed to provide paint manufacturers with waste minimization options appropriate for this industry. It also provides

worksheets designed to be used for a waste minimization assessment of a paint manufacturing facility, to develop an understanding of the facility's waste generating processes and to suggest ways that the waste may be reduced. Besides paint manufacturing plant operators and environmental engineers, this document may be useful to our regulatory agency representatives and consultants.

The worksheets and the list of waste minimization options were developed through assessments of two Los Angeles area paint manufacturing firms commissioned by the California Department of Health Services (Calif. DHS 1987). The two firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options.

Reducing waste is a high priority for the paint manufacturing industry. In 1981, U.S. paint, coating, and ink manufacturers represented 44 percent of the market for solvents (Pace 1983). Solvents are used in the industry as carriers for resins and pigments and to clean the various process equipment used for production. Although cleaning solvents are often distilled and reused, a residual paint sludge remains, which contains solvents and in some cases, toxic metals such as mercury, lead and chromium. Depending on the constituents, the wastes could be considered RCRA wastes F002 (halogenated solvents), F003 (non-halogenated solvents such as acetone and xylene), F004 (non-halogenated solvents such as cresols, cresylic acid, nitrobenzene, and solvent blends), or F005 (nonhalogenated solvents such as toluene, methyl ethyl ketone, and benzene). These wastes are currently banned from land disposal.

The amount of wastes disposed of by paint manufacturers is high. For example, in 1984 the paint manufacturing industry in California disposed of 21,000 tons of solvent bearing waste off-site, making this industry the highest-volume generator of manifested solvent wastes in that year (ICF 1986).

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental

Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization.

The options and procedures outlined can also be used in efforts to minimize other wastes generated in a facility. EPA has also developed a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization opportunity assessment and develop options for reducing hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are also explained.

In the following sections of this manual you will find:

- An overview of the paint manufacturing industry and the processes used by the industry;
- Waste minimization options for paint manufacturers;
- Waste Minimization Assessment Guidelines and Worksheets;
- An Appendix, containing case studies of waste generation and waste minimization practices of two paint manufacturers and Where to get help: additional sources of information.

79 Guides to Pollution Prevention - The Metal Finishing Industry

The purpose of this guide is to help the metal finishing industry identify, assess, and implement waste minimization options. It is envisioned that the guide will be used by metal finishing companies, particularly plant operators and environmental engineers, as well as regulatory agency representatives, industry suppliers, and

consultants. To provide the industry with the information and guidance necessary to implement an effective waste minimization program, this manual contains:

- A profile of the metal finishing industry and the processes used in it;
- Well-established and practical waste minimization options for the industry;
- Waste minimization assessment guidelines and worksheets;
- Appendices containing case studies of waste generation/waste minimization practices in the industry and sources of information and help.

The worksheets and the list of waste minimization options were developed from assessments of San Francisco Bay Area firms in California commissioned by the California Department of Health Services (DHS 1988). Operations, manufacturing processes, and waste generation and management practices were surveyed, and existing and potential waste minimization options were characterized.

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste, and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered to be the preferable method from an environmental perspective. A few states consider waste treatment to be a third approach to waste minimization, but EPA does not, and therefore waste treatment is not addressed in this

guide.

Waste Minimization Opportunity Assessment

A Waste Minimization Opportunity Assessment (WMOA), sometimes called a waste minimization audit, is a systematic procedure for identifying ways to reduce or eliminate waste. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

In 1992, EPA published the *Facility Pollution Prevention Guide* (USEPA 1992) as a successor to the *Waste Minimization Opportunity Assessment Manual*. While the *Waste Minimization Opportunity Assessment Manual* concentrated primarily on the waste types covered in the Resource Conservation and Recovery Act (RCRA), the *Facility Pollution Prevention Guide* deals with "multimedia" pollution prevention. It is intended to help small- to medium-sized production facilities develop broad-based, multimedia pollution prevention programs. Methods of evaluating, adjusting, and maintaining the program are described. Later chapters deal with cost analysis for pollution prevention projects and with the roles of product design and energy conservation in pollution prevention.

80 Guides to Pollution Prevention - The Fiberglass-Reinforced and Composite Plastics Industry

This guide is designed to provide fiberglass-reinforced and composites (FRPC) plastics fabricators with waste minimization options appropriate for this industry. It also provides worksheets designed to be used for a waste minimization assessment of an FRP/C fabricating plant, to be used in developing an understanding of the plant's waste generating processes and ... suggest ways to reduce the waste. The guide should be used by FRP/C fabricating companies, particularly their plant operators and environmental engineers. Others who may find this document useful are regulatory agency representatives,

industry suppliers and consultants.

In the following chapters of this manual you will find:

- A profile of the fiberglass-reinforced and composite plastics industry and the processes used by the industry;
- Waste minimization options for FRP/C fabricating firms;
- Waste minimization assessment guidelines and worksheets;
- Appendices containing: Case studies of waste generation and waste minimization practices of FRP/C fabricating firms and Where to get help: additional sources of information.

The worksheets and the list of waste minimization options for FRP/C fabricating were developed through assessments of FRP/C fabricating firms by Woodward-Clyde consultants, commissioned by the California Department of Health Services (Calif. DHS 1989). The firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Finally, economic analyses were performed on selected options.

Overview of Waste Minimization Assessment

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about waste minimization. The options and procedures outlined also can be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is considered environmentally preferable to

recycling. While a few states consider treatment of hazardous waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessment

EPA has also developed a general manual for waste minimization in industry. The Waste Minimization Opportunity Assessment Manual (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are explained in the next section.

A Waste Minimization Opportunity Assessment (WMOA) is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are: planning and organization, assessment, feasibility analysis and implementation. The steps involved in conducting a waste minimization assessment are presented in more detail below. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess.

After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

81 Guides to Pollution Prevention - The Automotive Repair Industry

This guide is designed to provide automotive repair facilities with waste minimization options appropriate for the industry. It also provides worksheets designed to be used for a waste minimization assessment of an automotive repair facility, to develop an understanding of the facility's waste generating processes and to suggest ways that the waste may be reduced.

The guide is designed primarily for use by operators of automotive repair shops. Others who

may find this document useful are operators of vehicle fleets, regulatory agency representatives, and consultants. In the following sections of this report you will find:

- An overview of the automotive repair industry;
- Waste minimization options for automotive repairers;
- Waste minimization assessment worksheets;
- Appendices containing case studies of two automotive repair shops and one parts washer lease and service company. Also included are completed waste minimization assessment worksheets for a hypothetical shop and Where to get help: Regional EPA offices and other sources.

The worksheets and the list of waste minimization options were developed through assessments of two Northern California-area automotive repair facilities and one Northern California parts washer lease and service company as commissioned by the California Department of Health Services (CDHS 1987). The firms' operations, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options. Additional information was developed from the assessment of three Southern California automotive repair facilities commissioned by the City of Santa Monica Department of General Services (CSM 1989).

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be

used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is considered environmentally preferable to recycling. While a few states consider treatment of waste an approach to waste minimization, EPA does not and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessments

EPA has developed a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one.

A Waste Minimization Opportunity Assessment (WMOA) is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are: planning and organization, assessment, feasibility analysis, and implementation. The steps involved in conducting a waste minimization assessment are presented in more detail below. Briefly the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

82 Guides to Pollution Prevention - The Printed Circuit Board Manufacturing Industry

This guide is designed to provide printed circuit board manufacturers with waste minimization options appropriate for this industry. It also provides worksheets designed to be used for a

waste minimization assessment of a manufacturing facility, to develop an understanding of the facility's waste generating processes and to suggest ways that the waste may be reduced.

The worksheets and the list of waste minimization options were developed through assessments of three Santa Clara area prototype circuit board manufacturing shops. The assessments were commissioned by the California Department of Health Services (CDHS 1987). The firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options.

Today's industry is faced with the major technological challenge of identifying ways to effectively manage hazardous waste. Technologies designed to treat and dispose of wastes are no longer the optimal strategy for handling these wastes for two major reasons. Firstly, the potential liabilities associated with handling and disposing of hazardous wastes have increased significantly. Secondly, restrictions placed on land disposal of hazardous wastes have caused considerable increases in waste disposal costs. The economic impact of these changes is causing industry to explore alternatives to treatment and disposal technologies.

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a facility.

EPA has also developed a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing

hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are also explained.

In the following sections of this manual you will find:

- An overview of the printed circuit board (PC board) manufacturing industry and the processes used by the industry;
- Waste minimization options for printed circuit board manufacturers;
- Waste Minimization Assessment Guidelines and Worksheets;
- An Appendix, containing: Case studies of waste generation and waste minimization practices of three printed circuit board manufacturers and Where to get help: additional sources of information.

Overview of Waste Minimization Assessment

In the working definition used by EPA, waste minimization consists of source reduction (preventing the generation of waste at its point of origin) and recycling. Of the two approaches, source reduction is usually considered preferable to recycling from an environmental perspective. Treatment of hazardous waste is considered an approach to waste minimization by some states but not by others, and is not addressed in this guide.

83 Guides to Pollution Prevention - The Fabricated Metal Products Industry

This guide was prepared to provide plant operators or environmental engineers of commercial fabricated metal facilities with guidelines and options to minimize both hazardous and non-hazardous wastes. Others who may find this document useful are regulatory agency representatives and consultants.

The worksheets and the list of waste minimization options were developed through assessments of Los Angeles area firms commissioned by the California

Department of Health Services (DHS 1989). The firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options.

Four types of processes used in metal fabrication are examined in this guide: machining operations, parts cleaning and stripping, metal surface treatment and plating, and paint application. These processes use a variety of hazardous materials, including metal-working fluids, solvents, alkaline and acid cleaning solutions, treatment and plating solutions that contain hazardous metals such as chromium and cadmium, as well as cyanide and other chemicals, and paints containing solvents and heavy metals. Many of those hazardous substances are being phased out in some applications, in favor of more benign compounds.

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization.

EPA has also developed a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual* (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are also explained.

In the following sections of this manual you will find:

- An overview of the fabricated metal industry and the processes used in it;

- Waste minimization options for the industry;
- Waste Minimization Assessment Guidelines and Worksheets;
- An Appendix, containing: Case studies of waste generation and waste minimization practices of three facilities: Where to get help: Sources of useful technical and regulatory information.

Overview of Waste Minimization Assessment

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered preferable to recycling from an environmental perspective. Treatment of hazardous waste is considered an approach to waste minimization by some states but not by others, and thus is not addressed in this guide.

A Waste Minimization Opportunity Assessment (WMOA), sometimes called a waste minimization audit, is a systematic procedure for identifying ways to reduce or eliminate waste. The steps involved in conducting a waste minimization assessment are presented in detail.

84 Guides to Cleaner Technologies - Alternative Metal Finishes

A cleaner technology is a source reduction or recycle method applied to eliminate or significantly reduce the amount of any hazardous substance, pollutant, or contaminant released to the environment. The emphasis of cleaner technologies is on process changes that can prevent pollution. Pollution prevention occurs through source reduction, i.e., reductions in the volume of wastes generated, and source control (input material changes, technology changes, or improved operating practices).

Cleaner technologies include process changes that reduce the toxicity or environmental impact of wastes or emissions. Processes that reduce waste toxicity by transferring pollutants from one environmental media to another (e.g., from wastewater to sludge or from air emissions to scrubber wastes) are not inherently cleaner and are not considered to be source reduction.

Cleaner technologies also include recycle methods,

but recycling should be considered only after source reduction alternatives have been evaluated and implemented where technically feasible. Where they are used, recycling techniques should take occur in an environmentally safe manner

Without metal finishing, products made from metals would last only a fraction of their present life-span. Metal finishing alters the surface of metal products to enhance properties such as corrosion resistance, wear resistance, electrical conductivity, electrical resistance, reflectivity, appearance, torque tolerance, solderability, tarnish resistance, chemical resistance, ability to bond to rubber (vulcanizing), and a number of other special properties (electropolishing sterilizes stainless steel, for example).

Industries that use metal finishing in their manufacturing processes include:

- Automotive;
- Electronics;
- Aerospace;
- Telecommunications;
- Hardware;
- Jewelry;
- Heavy Equipment;
- Appliances;
- Tires.

A wide variety of materials, processes, and products are used to clean, etch, and plate metallic and non-metallic surfaces. Typically, metal parts or workpieces undergo one or more physical, chemical, and electrochemical processes. Physical processes include buffing, grinding, polishing, and blasting. Chemical processes include degreasing, cleaning, pickling, etching, polishing, and electroless plating. Electrochemical processes include plating, electropolishing, and anodizing

85 Guides to Pollution Prevention - The Automotive Refinishing Industry

This guide is designed to provide automotive

refinishers with waste minimization options appropriate for their industry. It also provides worksheets designed to be used for a waste minimization assessment of an automotive refinishing shop to develop an understanding of the waste generation processes and to suggest ways that the waste may be reduced.

The guide is designed primarily for use by automotive refinishers. Others who may find this document useful are operators of vehicle fleets, regulatory agency representatives and consultants.

In the following sections of this report you will find:

- An overview of the automotive refinishing industry;
- Waste minimization options for automotive refinishers;
- Waste minimization assessment worksheets;
- Appendices containing: Case studies of six automotive refinishing shops. Also included are completed waste minimization assessment worksheets for a hypothetical shop;
- Where to get help: Regional EPA offices and other sources.

The worksheets and the list of waste minimization options were developed through assessments of six Southern California area automotive shops as commissioned by the California Department of Health Services (Calif. DHS 1987). The firms operations and waste generation and management practices were surveyed and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options. Additional information was developed from the assessment of a Southern California automotive refinishing shop commissioned by the City of Santa Monica Department of General Services (CSM 1989).

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing

regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered environmentally preferable to recycling. While a few states consider treatment of waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessments

EPA has developed a general manual for waste minimization in industry. The Waste Minimization Opportunity Assessment

Manual (USEPPK 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one.

A Waste Minimization Opportunity Assessment (WMOA) is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are: planning and organization, assessment, feasibility analysis, and implementation. The steps involved in conducting a waste minimization assessment are outlined in detail. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

86 Guides to Pollution Prevention - Metal Casting and Heat Treatment Industry

This guide is designed to provide the metal casting and heat treating industry with waste minimization options. It also provides worksheets for carrying out waste minimization assessments for metal casting and heat treating plants. It is envisioned that this guide will be used by metal casting and heat treating companies, particularly their plant operators and environmental engineers. Others who may find this document useful are regulatory agency representatives, industry suppliers and consultants.

In the following sections of this manual you will find:

- A profile of the metal casting and heat treating industry and the processes used in it;
- Waste minimization options for the industry;
- Waste minimization assessment guidelines and worksheets;
- Appendices, containing case studies of waste generation and waste minimization practices in the industry and Where to get help: additional sources of information.

The worksheets and the list of waste minimization options were developed from assessments of firms in Southern California commissioned by the California Department of Health Services (DHS 1990). Operations, manufacturing processes, and waste generation and management practices were surveyed, and existing and potential waste minimization options were characterized.

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific

information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business, including air emissions, wastewater discharges, and solid waste.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is preferable to recycling. While a few states consider treatment of waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessment

EPA has developed a general manual for waste minimization in industry. The Waste Minimization Opportunity Assessment Manual (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an ongoing one.

In 1992, EPA published the Facility Pollution Prevention Guide (USEPA 1992) as a successor to the Waste Minimization Opportunity Assessment Manual. While the Waste Minimization Opportunity Assessment Manual concentrated primarily on the water types covered in the Resource Conservation and Recovery Act (RCRA), the Facility Pollution Prevention Guide deals with "multimedia" pollution prevention.

87 Guides to Pollution Prevention - The Mechanical Equipment Repair Industry

This guide is designed to provide the mechanical equipment repair industry with waste minimization options. It also provides worksheets for carrying out waste minimization assessments for mechanical equipment repair shops. It is envisioned that this guide will be used by mechanical equipment repair shops and regulatory agency representatives, industry suppliers, and consultants.

In the following sections of this manual you will find:

- A profile of the mechanical equipment repair industry and the processes used in it.
- Waste minimization options for the industry.
- Waste minimization assessment guidelines and worksheets.
- Appendices, containing case studies of waste generation and waste minimization practices in the industry and Where to get help: additional sources of information.

The worksheets and the list of waste minimization options were developed through assessments of several repair shops in California commissioned by the California Department of Health Services (DHS 1990). Waste generation and management practices were surveyed, and existing and potential waste minimization options were characterized.

Overview of Waste Minimization

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization. The options and procedures outlined can also be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and recycling. Of the two approaches, source reduction is usually considered preferable to recycling. While a few states consider treatment of waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessment

EPA has developed a general manual for waste minimization in industry. The Waste Minimization Opportunity Assessment Manual (USEPA 1988) tells how to conduct a waste minimization

assessment and develop options for reducing hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an ongoing one.

In 1992, EPA published the *Facility Pollution Prevention Guide* (USEPA 1992) as a successor to the *Waste Minimization Opportunity Assessment Manual*. While the *Waste Minimization Opportunity Assessment Manual* concentrated primarily on the waste types covered in the Resource Conservation and Recovery Act (RCRA), the *Facility Pollution Prevention Guide* deals with "multimedia" pollution prevention. It is intended to help small-to medium-sized production facilities develop broad-based, multimedia pollution prevention programs.