Assessment of Pollution Prevention & Control Technology For Plating Operations

By George C. Cushnie, Jr, Paul D. Chalmer, and William A. Sonntag.

Did your company participate in the NCMS survey of plating shops? Here are some important highlights concerning the industry.

Market and regulatory forces are putting pressure on platers to make the right decisions on pollution prevention control technology, and increasing the consequences of poor choices. Timely, accurate information is critical.

Platers need to know more than what does, and does not, work. They need to know under what circumstances a particular technique or piece of equipment will be right for their shop, and what they must do to maximize the likelihood of success. They may not get a second chance.

The next few years will bring continuing pressure to meet effluent guidelines, and increased cost for waste disposal. At the same time, pressure to minimize manufacturing costs will be relentless.

To address these issues, a continuing project to assess pollution prevention and control technology available to the plating industry, and to provide this information to those who can benefit from it, is being sponsored by the National Center for Manufacturing Sciences (NCMS), in cooperation with the National Association of Metal Finishers (NAMF), with assistance from AESF. A survey was prepared to gather information and literature for compiling a meaningful report. The results show which treatment, recovery and bath maintenance

been most success—ful for different plating processes, and the costs for purchasing and operating these technologies. The results also cover trends in chemical substitution, the identification of compliance-problem pollutants, sludge generation rates, off-site sludge recovery, disposal options, and other topics.

Table 1
The 25 Most Frequently Operated Metal Finishing Processes

Process Name	Percent of Shops Using Process	Average Volume of per Shop*
Passivation	42	244
Nickel (Watts) plating	41	4,336
Chromate on aluminum	39	634
Copper (CN) plating	38	874
Chromate on zinc plate	37	1,798
Cadmium (CN) plating	30	1,390
Electroless nickel plating	30	832
Decorative Cr(+6) plating	28	1,615
Tin (acid) plating	28	579
Zinc (non-CN) plating	28	5,012
Sulfuric acid anodizing	27	1,636
Hard chromium plating	26	4,033
Nickel (sulfamate) plating	25	677
Silver (CN) plating	25	471
Chromate on cadmium	24	404
Zinc phosphate	24	1,083
Gold (CN) plating	21	155
Bright dip of Cu/Cu alloys	20	81
Copper (sulfate) plating	19	1,703
Black oxide	17	325
Brass plating	17	730
Hard coat anodizing	15	1,719
Zinc (CN) plating	15	4,287
Tin-lead plating	15	356
Chromic acid anodizing	14	872

Characterization of Respondents

The plating shops that responded to the survey were diverse in geographical location, size, the processes they use and other factors. In general, they represented the jobshop sector of the plating industry. Of the 300[a] initial respondents, 253 are electroplating jobshops and 47 are captive shops.

Geographical distribution was relatively diverse, but concentrated in major electroplating regions. The majority of respondents (86 percent) are located in the Far West, Midwest and Northeast. The average and median year that respondents began metal finishing operations was 1985. The range of starting dates is 1887 to 1992. About 18 percent started operations after August 31, 1982, the cut-off date where new facilities are required to meet pretreatment standards for new sources (PSNS). The data show that the vast majority of the companies responding to the survey have 100 or fewer employees (88.8 percent). The average and median number of employees are 67 and 35, respectively. The range of employees is from 1 to 3,000.

Metal Finishing Process Characterization

Collectively, the respondents operate 154 different types of metal finishing processes. The 25 most-frequently-used processes are identified in Table 1 (excludes pre-plating, post-plating and stripping processes).

Wastewater and Discharge Characterization

The majority of respondents are indirect dischargers, meaning they discharge to a publicly owned treatment works (POTW), rather than directly to a stream, river or other water body. The survey results indicate that captive shops are more likely to be direct dischargers that are jobshops. Estimates of the U.S. Environmental Protection Agency (EPA) in 1984 indicated a similar trend.[2]

[a] Data presented in this article are based on the initial 300 responses. Additional data are contained in the final report.

The electroplating discharge rates (average daily flows) of the survey respondents vary from 0–420,000 gal/day. Some higher discharge rates were reported for combined plating and non-plating industrial discharges (See Fig. below). Many shops indicated that they have made dramatic progress in reducing wastewater flow rates, the most significant of which are shown in Table 2.

Respondents are required to meet either CFR 413 (Electroplating Categorical Standards), CFR 433 (Metal Finishing Categorical Standards), or non-standard effluent limitations. Non-standard limitations are more stringent than the categorical standards, for one or more pollutant parameters. Some of the non-standard limitations are written in terms of pollutant mass and flow rates—for example, 0.37 lbs/day chromium with a maximum flow of 40,000 gal/day—rather than concentration limitations. The percentage of respondents that are required to meet each type of effluent limitation are:

- 40 CFR 413: 28 percent
- 40 CFR 433: 8 percent
- Non-Standard: 64 percent

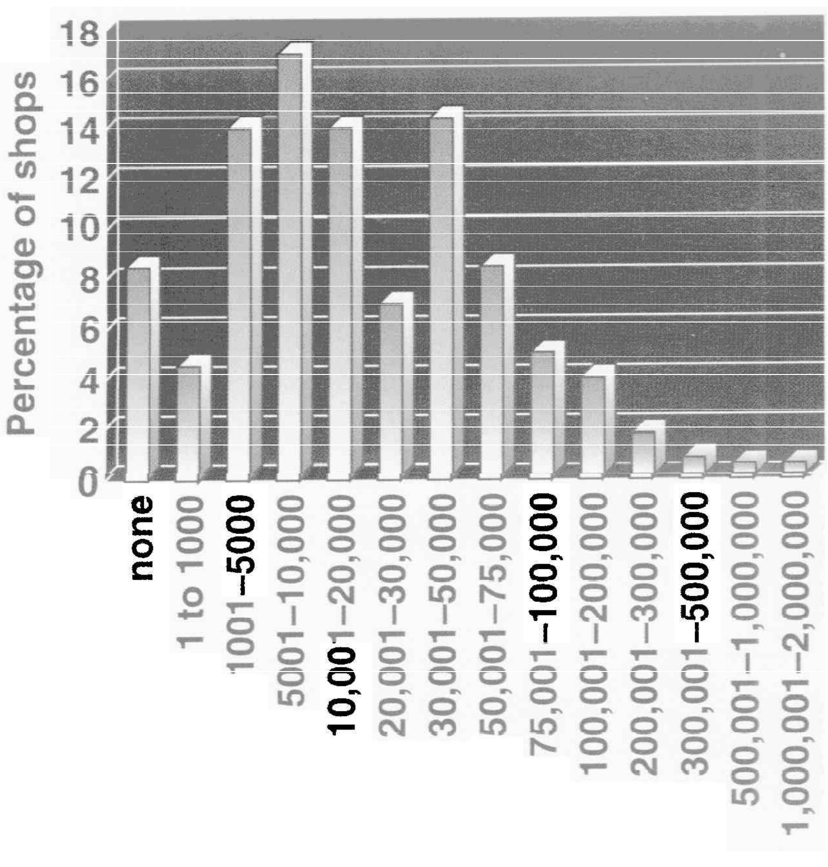
Table 2

Shop ID	Gal/Day From—To	Percent Reduction	Since (Base Year)
PS 022*	140,000–70,000	50	1980
PS 036	52,700–2,700	95	1978
PS 059	90,000–10,000	89	1977
PS 118	232,630–42,630	82	1983
PS 139	127,000–52,000	59	1986
PS 150	400,000–100,000	75	1986
PS 172	150,000–70,000	53	1975
PS 184	121,000-11,000	91	1982
PS 207	68,000–18,000	74	1986
PS 213	130,000–50,000	62	1985
PS 250	91,000–11,000	88	n/a
PS 268	87,000–17,000	80	1987
PS 292	160,000–60,000	63	1985
PS 296	1,900,000–1,700,000	11	n/a
PS 298	160,000–90,000	70	1990

*The names of respondents are maintained in confidence by using a code system. PS stands for plating shop.

In addition to concentration, or pollut ant mass discharge standards, 16 per cent of respondents indicated they ar also subject to aquatic-based effluer standards. These limits require that a industrial wastewater be sufficientl treated so that certain percentages c organisms (typically fish and water fleas are able to survive in the effluent for a given period of time.

Average Discharge Rate **(gal/day)**



Drag-out and Rinsewater Reduction

For the typical electroplating jobshop, the drag-out of process solutions and the subsequent contamination of rinsewaters are the major pollution control problems. The survey asked respondents to indicate the methods they use to reduce the formation or loss of drag-out and the usage rate of rinsewater. The most frequently used drag-out reduction methods are: Allowing parts/racks to drip over process tanks; using drag-out rinses; reducing the speed of rack/part withdrawal; using drip shields; and positioning the part to minimize solution holdup.

On the average, all drag-out reduction methods used have been successfully applied. Some shops had specific problems with one or more methods, such as a build-up of bath contaminants. These problems are discussed in the full report.

The most frequently used methods of reducing water use involve the application of: Flow restrictors; counterflow rinses; manually turning off water; and air agitation. As with drag-out methods, rinsewater reduction methods have been generally successful, with the highest success ratings given to the use of flow restrictors and counterflow rinsing.

Chemical Recovery Technologies

According to respondents, chemical recovery technologies are most frequently purchased to (in order of frequency): help meet effluent regulations, reduce wastewater treatment coats, reduce plating chemical purchases, and reduce the quantity of waste shipped off-site.

The survey of platers requested detailed technical, performance and operating cost data for chemical recovery technologies. The survey of suppliers requested technical descriptions, operating data and capital cost data. As a result of obtaining data from both sources, plus information from an extensive literature review, the NCMS report contains a substantial amount of information for the lowi chemical recovery technologies Electrodialysis, electrowinning, atmospheric evaporators, vacuum evaporators, ion exchange, reverse osmosis and mesh pad mist eliminators.

A separate subsection of the report is devoted to each of these technologies.

Solution Maintenance Methods and Technologies

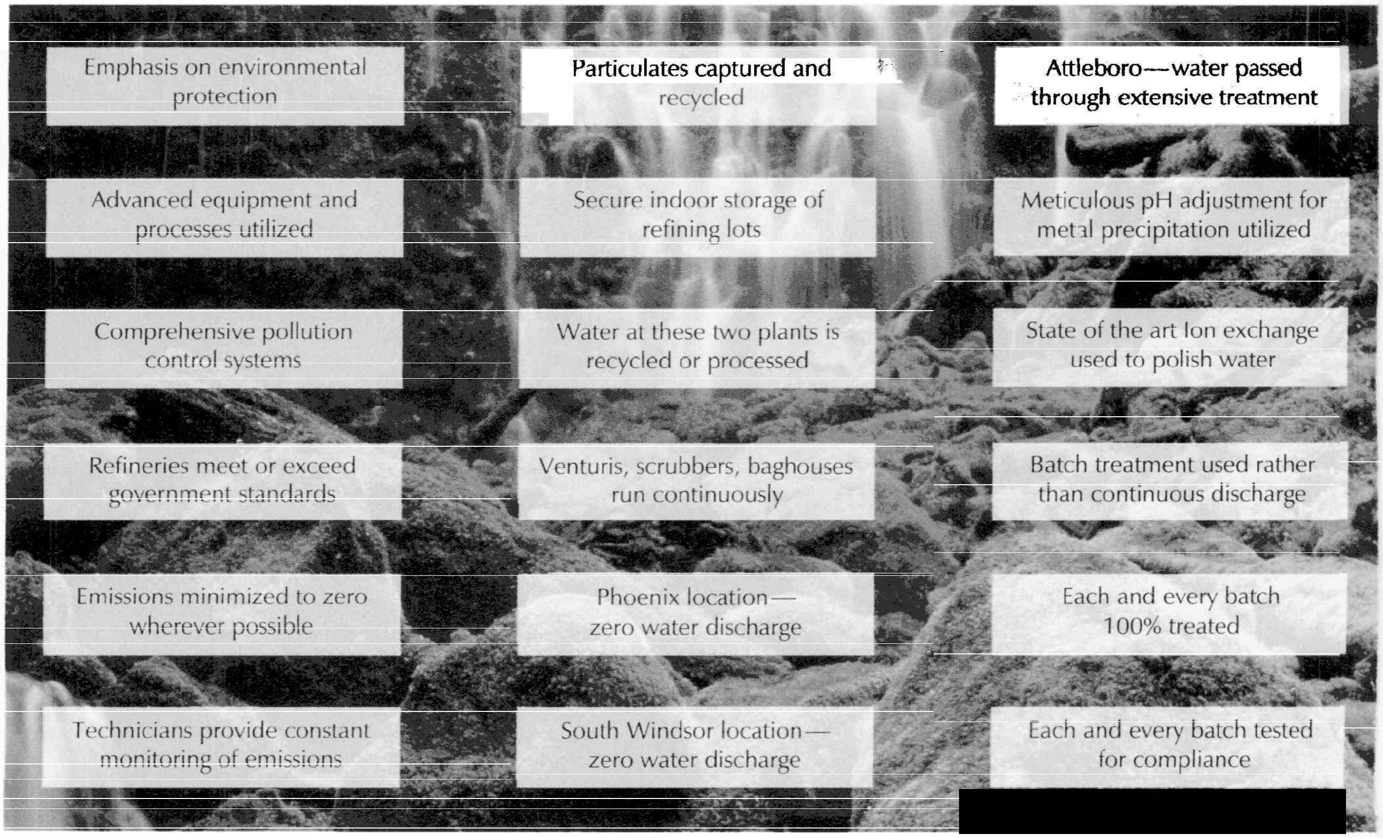
Metal finishing solutions are subjected to a variety of forces that cause them to become unusable. The key contributing factors are

1. Depletion of bath chemicals
2. Chemical breakdown of process chemicals or chemical side reactions
3. Contamination from impurities in make-up water, chemicals or anodes
4. Anodic/cathodic etching of parts and inert electrodes
5. Corrosion of parts, racks, bussing, tanks, heating coils, etc.
6. Drag-in of non-compatible chemicals
7. Build-up of by-products, such as carbonates
8. Breakdown of maskant, fume suppressant and wetting agents
9. Errors in bath additions
10. Airborne particles entering the tank

Solution maintenance replaces the practices of (1) using a fresh chemical solution until it is degraded, and replacing it with fresh solution; or (2) decanting a portion of a degraded solution and replacing it with fresh solution. In both cases, the spent sotution usually is treated either on-site or transported to a treatment/disposal site. On-site treatment is not always possible because concentrated wastes may upset treatment facilities desiged primarily for treating dilutes rinse waters.

Two major categories of solution maintenance were identified--preventive and corrective. Within the NCMS report, preventative solution maintenance refers to the practices that avoid bath contamination, or involve monitoring and adjusting of solution chemistry. Corrective solution maintenance refers to the practice of removing contaminants from the bath, whether they are dissolved or particulate, organic or inorganic. Both preventive and corrective solution maintenance involve the use of methods, techniques and technologies. Methods and techniques are typically procedural in nature, or low capital items that can be implemented quickly and have an almost immediate payback. Technologies are generally equipment packages that have a moderate-to high-capital-cost, and payback periods of one year or greater. Most preventive measures are either methods or techniques. Some technologies, however, would fall into this category, such as an electroless nickel bath automatic replenishment system. Corrective measures include both methods/techniques, such as dummy plating, and technologies, such as microfiltration.[1]

Within the NCMS report, the corrective technologies, which are generally less familiar to platers, are covered in detail. The methods of preventive and corrective solution maintenance that are commonly applied by plating shops-filtra-



tion, for example--are more familiar to platers, and, therefore, receive less coverage.

Substitute Technologies

The survey shows that respondents have made significant strides in reducing or eliminating the use of chlorinated solvents, cadmium, cyanide and chromium. These materials, sometimes referred to as the four Cs, have been identified by EPA as key targets for control within the metal finishing industry. About 60 percent of respondents attempted material input changes that potentially reduce or eliminate the use of one or more of the four Cs, or another pollutant problem. Comments indicated these changes were made in an effort to reduce potential effects on the environment and worker health, to help meet environmental regulations, and to reduce operating costs.

Although most of the material input changes were successful, some failures were reported. Even some successful changes produced adverse effects on production. The NCMS report summarizes the status of change in these areas and conveys the attitudes and concerns of the respondents.

Among respondents, the number of solvent users has changed since 1980. The shops are divided into three groups: (1) Those in existence in 1980, (2) those established from 1981 to 1985 (inclusive), and (3) those established from 1986 to 1993 (inclusive). The number of solvent users remained approximately the same from 1980 to 1985 in the older shops. It then declined substantially from 1986 to 1993. In 1980, 53 percent of the shops used solvents. That figure dropped to 39 percent by 1993. Twenty-six percent of the solvent users in 1980 had eliminated its use by 1993. For shops established from 1981 to 1985, the frequency of solvent use was below that of the older shops in 1985. From 1986 to 1993, the percentage declined similarly to the use rate of the older shops. Thirty-one percent of the shops established from 1981 to 1985, that originally used solvents, have eliminated its use. The most recently established shops (1986–93), currently have about the same number using solvents as the shops established in 1981–85.

End-of-pipe Treatment; Sludge Disposal/Recovery

Various technologies are used by platers for end-of-pipe treatment. These technologies have been grouped in the report into conventional and alternative methods. Conventional treatment is a series of unit processes used extensively by industry, that have provided reliable treatment for many electroplating operations (such as, metals precipitation using sodium hydroxide and polymer). Alternative treatment methods are sometimes used by platers to reduce capital and/or operating costs, or to improve pollutant removal efficiency.

EPA developed electroplating and metal finishing pretreatment standards by identifying commonly used treatment practices, and determining their effectiveness, by collecting effluent data from well-operated systems. Conventional treatment was selected by EPA as the standard system. The use of conventional treatment, therefore, will provide sufficient pollutant removal to meet discharge standards for most plating shops. There are two major exceptions to this rule:

1. Many plating shops are regulated by local discharge standards that are more stringent than Federal standards, and conventional treatment may be insufficient to meet these limitations.

2. The treatment systems selected by EPA for establishing the Federal stan-

ards were those systems that EPA determined to be "property operating facilities." For example, EPA omitted facilities that (a) Did not have well-operated treatment processes; (b) had complexing agents, such as non-segregated wastes from electroless plating and (c) had dilution from non-plating wastewaters. As a result, some plating facilities may not meet the properly operated facilities criteria used by EPA, and may have difficulty meeting Federal standards using conventional treatment.

In cases where conventional treatment is insufficient to meet discharge limitations for a given facility, there are four basic choices for attaining compliance:

1. Correctør upgrade the existing processes.

2. Make internal changes, such as, improve rinsing; add recovery segregate waste streams, to "normalize" the wastewater.

3. Use conventional treatment, plus additional treatment, such as polishing.

4. Use altemative treatment processes.

information on each of these methods is covered in the report.

One frequent concern of platers is the availability and cost of disposal for treatment process residuals (mainly, FOO6 sludge). Respondents generate an average of 180,000 lbs/yr of sludge, and spend an average of $40,000/yr for sludge disposal. The report provides data from each respondent covering sludge generation rates, the location of their disposal site, the distance that sludges are hauled, the solids concentration of the sludge, and disposal charges. Thirty-three percent of the respondents are using off-site metals recyclers as an alternative to land disposal of treatment residuals and spent process solutions. The report identifies the recycling companies used by the respondents, gives an overview of their recovery processes, presents criteria for determining the applicability of off-site recycling, and compares the costs of recycling to land disposal.

Changes from 1975-93 In Pollution Control Technology

Pretreatment standards for the electroplating industry were first established in 1974, but it was not until promulgation of 40 CFR 413 (on September 7, 1979) that Electroplating Categorical Pretreatment Standards became a reality. Several years later, EPA promulgated the Metal Finishing Categorical Standards (40 CFR 433). Prior to the existence of Federal standards, plating shops were regulated focally (if at all), presumably, with wide variation in efffuent limitations and levels of enforcement. Most plating shops did not have treatment systems for cyanide destruction and metal removal.

. About 12 percent of the respondents that were in business in 1975 (excludes zero-discharge shops) indicated that their initial treatment system was installed by that year.

- By 1985, after the compliance dates for Federal regulations, 70 percent of the surveyed shops (excluding zero-discharge shops) had installed their initial treatment systems.
- Most initial treatment systems were installed between 1980-85, although by 1985 there were still a substantial number of shops that had not installed an initial system.
- Most plating shops installed conventional treatment to meet Federal regulations.
- Although difficult to asses accurately, it appears that an early trend occurred during the late 1970s and early 1980s, when a significant percentage of shops attempted to utilize advanced technology instead of conventional treatment. These early efforts generally resulted in failure, and the shops later resorted to conventional systems. One prominent example of this trend is the implementation of high-surface-area electrowinning as an end-of-pipe technology. Between 1979 and 1983, approximately four percent of the shops (excluding zero-discharge shops) installed this technology at an average cost of $88,380. Only one of these systems is currently operating, and it was modified extensively by the user. Early failures such as this appear to have had a negative impact on advance technology. No single technology has since emerged as a significant replacement for conventional treatment. in fact, changes in end-of-pipe methods have moved toward simpler technologies.
- The most significant technology change with respect to end-of-pipe treatment since 1975 is the use of sludge dehydration equipment (such as sludge dryers), to reduce the volume of sludge shipped off-site (29 percent of the respondents have installed this technology, with about 80 percent purchased between 1988 and 1993). The most popular non-conventional end-of-pipe treatment methods (ion exchange, evaporation, and membrane technology) are covered in the report.

it should be noted that the majority of respondents were jobshops. More frequent use of advanced end-of-pipe technology may exist in other industry seg ments, such as captive aerospace facilities.

Approximately eight percent of the shops have attained zero-discharge. These shops are generally smaller and less diverse than the shops with discharges. The average and median number of employees at the zero discharge shops are 32 and 18, respectively. For all shops, the employee figures are average - 67, and median-35. Of the zero-discharge shops, 42 percent are primarily hard-chromium platers. The hard-chromium process is one of the easiest to operate as a closed-loop, because of the high ratio of evaporation to drag-out (for example, it permits the use of spray rinsing over the bath, drag-out recovery rinsing, etc.). The remaining zero-discharge shops operate various metal finishing processes, including: cadmium, nickel and zinc plating; conversion coating; and aluminum finishing. Details of these metal finishing processes and pollution prevention and control technologies are contained in the database and summarized in the report.

Status of Pollution Prevention

Pollution prevention has emerged as an important method of attaining compliance and reducing operating costs. Widespread success has been achieved using simple methods and techniques that reduce drag-out losses and rinsewater use. More than 90 percent of the shops indicated that they utilize these tools, and have benefited from them. Although some Shops have had great success with chemical recovery technologies, these generalliy have been much less frequently applied than drag-out and rinsewater reduction efforts. The most successful of the chemical recovery technologies is atmospheric evaporation, which is generally regarded as the most simple to use. Bath maintenance technologies are less frequently used than are chemical recovery, and generally have been less successful.

Causes of Failure for Some Advanced Technology

Many installations of chemical recovery technologies and advanced bath maintenance have not been successful (approximately 30 to 40 percent). The survey respondents indicate that failure is most frequently caused by maintenance problems; misapplication of the technology (often the result of ignorance on the part of manufacturer's representatives and/or the plating shop personnel); poor design; inability to purchase replacement parts (usually manufacturer went out of business); poor technical support by manufacturers; improper operation of technology by shop personnel; technically too complex for employees; chemical recovery caused a build-up of contaminants in plating bath; recovery process destroyed plating chemicals; recycled water was of insufficient quality; chemical product was insufficiently concentrated for return to plating bath; inadequate capacity; and high residuals generation.

Maintenance problems were the most frequent cause of system failure. The maintenance problems most often reported with advanced technologies are: low quality system components; mechanical problems with pumps and valves; damage to, or fouling of, components by plating chemicals; and excessive labor requirements for system cleaning.

Most Pressing Problems And Technological Needs

The respondents indicated that their most pressing environmental problems were:

- Increasing costs of compliance (73 percent)
- Frequently changing regulations (55 percent)
- Meeting effluent discharge standards (38 percent)
- Eliminating the use of solvents (25 percent)
- Meeting air emissions standards (24 percent)
- Lack of disposal sites (19 percent)

The environmental technology needs identified by the respondents were:

- Alternatives to solvent cleaning/degreasing (12 percent)
- Better cyanide plating alternatives or controls (11 percent)
- Improved methods for water reduction, closed-loop processing, source reduction, recycling or zero discharge (9 percent)
- Better cadmium plating alternatives or controls (8 percent)
- Improved methods or more affordable end-of-pipe treatment (7 percent)
- Alternative to chromium metal finishing, including all uses such as anodizing, plating and conversion coating (6 percent)

Future Efforts

The initial NCMS project has established a benchmark assessment of pollution prevention and control technology for plating operations. Data collected during the project were entered into a relational database. These data and other information were then used to prepare an extensive report that has been published in a hard-bound format. Both project products are publically available. These project results will assist platers in various ways, including: sharing ideas for drag-out and water use reduction; providing useful technology descriptions; providing an explanation of EPA's pollution prevention concept; summarizing cost and performance data from actual technology installations involving chemical recovery; bath maintenance and waste treatment; summarizing plater's experiences with alternative process chemicals that may reduce the hazards of plating processes, and the wastes that result; and providing detailed data for off-site metals recycling options.

This assessment has been made possible by the efforts of numerous platers, technology suppliers and other parties. Hopefully, this industry will continue these efforts by participating in updates of the assessment. Each repetition of the assessment process will refine our technical knowledge, and lead to more cost-effective means of complying with environmental regulations.

The NCMS report and database contain such a wealth of information that a complete analysis of the results would take years to perform. One of the reasons for including a disk copy of the database with the report is to allow platers, suppliers, researchers and other interested individuals the opportunity to perform their own analyses and develop their own conclusions. ❑

References:

1. G. Cushnie, *Assessment of Pollution Prevention and Control Technology for Plating Operations*, National Center for Manufacturing Sciences (1994).
2. USEPA, *Guidance Manual for Electroplating and Metal Finishing Pretreatment Standards*, Effluent Guidelines Division (1984).

Order the Report

Pollution Prevention and Control Technology for Plating Operations (book and database package) is available from AESF Publications Sales. Cost is $48.50. Database is not sold separately. Make checks payable to AESF. To order by credit card, call toll-free 1-800/334-2052.

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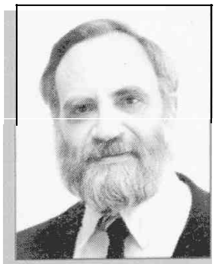

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