

Citation: Schwartz S, Lorber M. 2000. EPA's metal finishing facility risk screening tool (MFFRST) Part 2: Updates to Source Emission Characterization. Pages 30-58 in, Proceedings: The AESF/EPA Conference for Environmental Excellence. Held Jan 17-29, 2000, in Orlando, Florida. Published by, AESF, 12644 Research Parkway, Orlando, FL. 32826-3298.

EPA'S Metal Finishing Facility Risk Screening Tool (MFFRST): Part 2. Updates to Source Emission Characterization

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Introduction

MFFRST is a "user-friendly" tool that enables anyone to perform a screening characterization of health risks to workers and neighbors of metal finishing facilities. It was developed by the U.S. Environmental Protection Agency (EPA) under the Common Sense Initiative (CSI) Metal Finishing Sector. This tool focuses on human health impacts from inhaling chemicals emitted from metal finishing facilities. The tool has three major modules that are combined to calculate health risks. The first module characterizes atmospheric emissions from process tanks in metal finishing shops. *It is this module only that will be discussed in this report.* The second module models the movement (i.e., fate and transport) of the process tank emissions to human receptors both in the metal finishing shop as well as to local neighbors external to the shop. The second module then calculates the level of exposure from those emissions. The third module calculates the carcinogenic and non-carcinogenic risks from that level of exposure.

MFFRST was first introduced in January, 1999 at the AESF/EPA Conference

for Environmental Excellence (Lorber, et al., 1999; Schwartz and Lorber, 1999). At that time, the proposed methodology and input data for MFFRST had been developed, but not installed into the software tool. Only the "shell" of MFFRST was available; i.e., essentially just the different computer screen graphics that would be available. The fully installed tool was completed and available in time for display at the June, 1999 SURF/FIN® Conference. After both appearances, comments were solicited on all aspects of MFFRST. Expert opinions were sought from individuals in the metal finishing industry, federal government (EPA, OSHA), state agencies, non-government organizations, consultants, and others. As of this writing, 62 individuals were sent the June, 1999 version of MFFRST and documentation. Of those, 14 provided comments back to EPA.

Only the comments that address the first module (i.e., the calculation of emissions from metal finishing process tanks) will be discussed in this report.

This paper will also conduct a simple "reality" test for the procedures which estimate atmospheric emissions in

MFFRST. Emissions of constituents associated with specific plating lines are compared against stack emissions of those same constituents as reported in the TRI data base which accompanies MFFRST.

Comment Summary

There were two types of comments received that would impact the quantitative emissions calculations; (1) comments on the methodology used (e.g., algorithms used to calculate process tank emissions), and (2) comments on the process tank operating parameters, on which emissions calculations were dependent (e.g., concentration of chemicals in process tanks, electrolytic tank current density). Most comments were of the second type, and were all addressed as described in the Update section of this report. The most significant comments follow.

1. In MFFRST, the user is given defaults for all input data, including the number and type of individual process tanks in each process line, the concentration of chemicals in each tank, current density, cathode efficiency, etc. As one of the defaults, the first two processes in each process line were an organic solvent degreaser followed by an aqueous-based alkaline cleaner. A significant number of the comments received indicate that solvent degreasing is no longer a commonly used process in metal finishing lines. Further, commenters suggested that most lines currently begin with an alkaline cleaning bath followed by an electrocleaning process. (Electrocleaning is essentially an alkaline cleaner in a tank that has an electrical current running through it, much like an electroplating tank).
2. For solvent degreasers, MFFRST gave the user the option of several organic solvents, including toluene. Commenters suggested that where solvent degreasing is still used, toluene is rarely used as a solvent. In addition, commenters suggested that we add trichloroethylene (also called TCE or trichloroethene) and methylene chloride to the list of solvents available to the user.
3. One commenter suggested that the default surface area size of most process tanks, 40 ft², was much too large, and that 10 ft² was more realistic. This is a significant comment, since emissions are essentially proportional to tank surface area.
4. There were a variety of comments suggesting that the default chemical concentrations used for various process tanks were not realistic (e.g., the concentration of gold in the gold plating tank was listed as 30 grams per liter [g/l], whereas it should have been about 5 g/l). Similarly, some commenters indicated that other operating parameters were not realistic (e.g., some current densities, cathode efficiencies).
5. Commenters noted that MFFRST included process tanks in several generic lines that do not always appear (or are optional) in real-world process lines (e.g., an acid etch tank between copper strike and copper plating tanks), and in some cases MFFRST omitted tanks that might frequently be placed in a process line (e.g., a nickel plating tank should be inserted prior to the gold strike tank in a gold plating line).

6. One commenter points out that the source of atmospheric emissions in some electroplating tanks is from air agitation in addition to emissions caused by the electrical activity. MFFRST assumes that the source of emissions from electro-chemical tanks (to include anodizing, and electrocleaning in addition to electroplating) is entirely a result of the electrical activity.

Other relevant comments were:

- Some of the comments take issue with the fact that MFFRST uses efficiency estimates for air pollution control devices that represent only one manufacturer's design, and will not be representative of all such devices (e.g., one manufacturer's wet scrubber will perform different than another's, or the wet scrubber used in the referenced studies may have been over- or under-designed).
- One commenter noted that emissions from all process tanks are based on algorithms relating to emissions from hard chromium electroplating tanks. The commenter suggests that MFFRST fails to take into account the fact that hard chromium tank contents are of a different viscosity than most other tanks, therefore creating a different quantity/quality of mist/emissions.
- One commenter implies that we should report inorganic bath constituents either as the entire chemical (e.g., copper cyanide), or as ions (e.g., cyanide), but to consistently use one or the other.
- There were several comments

suggesting that acid etch/desmutt/deoxidize baths should have different default acid constituents and concentrations than those used in MFFRST.

- Commenters suggested that in some real-world baths there are chemicals typically used that MFFRST neglected to note (e.g., sodium hydrogen sulfate instead of, or in addition to, sulfuric acid in acid etch tanks).
- One commenter thought that the use of aeration air bubble diameter and tank surface tension as parameters to define emissions associated with aerated tanks was unrealistic. The commenter believes that most facilities do not have the capacity to determine these two parameters.

Comment Response and Screening Tool Updates

MFFRST has been updated from its June, 1999 status based on response to the comments discussed above. Changes were also made based on new information that has become available to us (e.g., a silver plating line has been added).

Process operating parameters (i.e., tank constituents, tank concentrations, current density, cathode efficiency, tank type and sequence) that affect emission rates have been verified and adjusted as necessary using data available from two currently recognized metal finishing texts:

- The Electroplating Engineering Handbook, 4th Edition, 1984, Published by Chapman & Hall,

reprinted 1998

- Metal Finishing 99 Guidebook and Directory Issue, Published as the 13th issue of Metal Finishing magazine by Elsevier Science, Inc., Volume 97, Number 1; January, 1999

These texts each provide numerous ranges and process options for each electroplating line presented in MFFRST. For example, there are several electroplating tank formulations for electroplating copper from cyanide solutions. There are numerous formulations for acid etching/ desmutting/ deoxidizing. There are numerous electroplating line configurations that will satisfactorily plate a specific metal. Different lines use different degreasing/cleaning methodologies (e.g., some use solvents, others use aqueous alkaline cleaners with or without electrification, some use combinations of these methods). Many of the available electroplating options depend on the substrate to be covered (e.g., steel, cast iron, stainless steel, aluminum, other electroplated surfaces).

In developing and subsequently updating the default parameters for metal finishing lines for MFFRST, the operating parameters used are considered to be *typical* representations, based upon engineering judgement and interpretation of the available texts and other information. It is unlikely that any *individual* metal finishing line is exactly like the lines presented in MFFRST. Figures 1 - 16 present these typical default lines. It is envisioned that these default lines will be chosen by the relatively novice user (e.g., a neighborhood resident). However, the more sophisticated user (e.g., electroplating shop management, regulators) may choose to modify the: default metal

finishing line configurations, operating parameters, exhaust gas flow rates, type of air pollution control device(s), efficiency of air pollution control device(s), etc., in ways that will better characterize the facility of interest.

The default parameters used in the revised version of MFFRST as well as controlled and uncontrolled emissions values (both in milligrams per cubic meter [mg/m^3] and milligrams per day [mg/day]) are contained in Tables 1 - 4. Table 1 presents default bath chemical concentrations, current densities for electrolytically activated tanks, cathode efficiencies for electrolytically activated tanks, and uncontrolled emission concentrations from electrolytically activated tanks relative to hard chromium plating tanks. (Hard chromium plating is given the value of 1.0). Table 2 presents the calculated concentrations of controlled and uncontrolled emissions from all metal finishing tanks (in mg/m^3). Table 3 presents the OSHA ventilation rating used to calculate ventilation requirements for each metal finishing tank, as well as the default tank surface areas and calculated volumetric ventilation rates. Table 4 is essentially the same as Table 2, but presents calculated controlled and uncontrolled emissions in terms of mass loading (mg/day). Tanks for which OSHA does not appear to require ventilation have been assigned a default mass loading of zero. However, the MFFRST user can elect to insert a ventilation rate, which will in turn cause a loading to be calculated.

For all metal finishing lines, the updated version of MFFRST provides an alkaline cleaning step followed by an alkaline electrocleaning step as a degreasing/cleaning default. Each process line illustration in

MFFRST also depicts a solvent degreaser, but unless the user chooses to select it, this step is *not* included in emissions calculations. (The user may select solvent cleaning instead of the alkaline cleaning processes, or in addition to them.)

In response to comments, toluene has been eliminated as a solvent available to the user in the solvent degreasing step of every metal finishing line (assuming the user selects solvent degreasing). However, TCE and methylene chloride have been added as degreasing solvent options. The default solvent degreasing option is now TCE (it had been methyl ethyl ketone). It is worth noting that electroplaters still report significant amounts of toluene emission to the atmosphere under the Toxic Release Inventory (TRI) data base.

The default tank surface area has been changed from 40 ft² to 20 ft² in response to comments, and after discussion with industry experts. In essence, this change cuts the default emission rates in half from the June, 1999 MFFRST version.

Uncontrolled emissions from tanks that are electrically activated (i.e., electroplating, anodizing, electrocleaning) have been, and continue to be, calculated based on algorithms incorporating the use of:

1. concentration of tank contents
2. toxicity of tank contents
3. temperature of tank contents
4. tank surface area
5. current density
6. cathode efficiency.

Uncontrolled emissions from tanks that are not electrically activated (i.e., alkaline cleaning, acid etching/ desmutting/ deoxidizing, chromate conversion,

phosphate coating, electroless nickel plating, sealing, passivation) have been, and continue to be, calculated based on algorithms incorporating items 1 - 4 above, as well as parameters reflecting the effects of aeration, specifically:

7. rate of tank aeration (cubic feet of aeration air per square foot of tank surface)
8. aeration air bubble diameter
9. surface tension of tank contents.

One commenter noted that some electrically activated tanks are also mixed using aeration. Consequently, the emissions rate from such tanks should be some value that is greater than either the value for electrically activated tanks or the value for non-electrically activated tanks. We agree with this commenter. However, we have not identified any information that would suggest how the combination of electrical activation and aeration would quantitatively affect emissions. In addition, given the diverse nature of real-world metal finishing operations, and the level-of-accuracy of the default parameters and the algorithms used to calculate emissions, we believe that neglecting this issue will not cause MFFRST emissions estimates to be significantly understated. It is further noted that, if a user of MFFRST is dissatisfied with the level of emissions predicted, he or she may adjust any input parameter, including the quantitative rates of emission.

On a similar issue, we agree with the commenter who states that aeration air bubble diameter is a parameter that most facilities will not be able to measure or know accurately. MFFRST uses a default diameter of 0.1 inches. Lowering the diameter an order of magnitude, from 0.1 inches to 0.01 inches, causes emission rates

to decrease less than 4%. Raising the diameter an order of magnitude, from 0.1 inches to 1 inch, causes emission rates to increase about 60%. These variations in emissions rate relative to bubble diameter are not meaningful enough that accepting the default diameter will cause significant error in overall emissions estimates. The same commenter believes that most facilities will not be able to measure or know their surface tension accurately. We disagree, believing that there are readily available, easy to use, surface tension monitoring devices for those MFFRST users who do not want to accept the default values.

With respect to the choice of efficiency estimates for air pollution control devices (or combinations of devices), it is true that the air pollution control devices used as the basis for MFFRST controlled emission estimates represent only the specific devices (or products, as in the case of fume suppressants and polymer balls) used in the study that forms the basis for emissions estimates (the Hard Chrome Pollution Prevention Demonstration Project, Interim Report, EPA Common Sense Initiative (CSI), Metal Finishing Subcommittee, November, 1996). However, because of the infinite number of design permutations and combinations available for the application of such devices to metal finishing operations, accommodating any possible air pollution control device is deemed to be well beyond the scope of this project.

It is true that MFFRST bases its emissions estimates for electrically activated tanks on testing done specifically at hard chromium electroplating tanks. Further, EPA agrees with the commenter who states that viscosity and surface tension characteristics of other electrically activated tanks used in metal finishing shops are

different than for hard chromium tanks. Also, because of this difference, it is agreed that MFFRST's extrapolation of hard chromium plating tank emissions data to the emissions from other electroplating tanks may not be entirely accurate. Nevertheless, we have no knowledge of a better method of estimating emissions from other electrically activated tanks. Furthermore, such extrapolation is the EPA method of choice stated in the electroplating emission factors estimates published in EPA's Compilation of Air Pollutant Emission Factors, AP-42, 5th Edition, 1995.

It is true that some inorganic chemical compound emissions in MFFRST are stated as the full compound (e.g., as sulfuric acid rather than sulfate, or sodium hydroxide rather than sodium), and some only as the relevant toxic portion of a compound (e.g., chromium emissions rather than chromic acid emissions, or copper and cyanide [separately] rather than copper cyanide). The rationale used for this apparent inconsistency is that the body of toxicological data from which to determine health risks is sometimes aimed at whole compounds, and sometimes (especially for metals) at just the toxic portion of the compound.

With respect to the choice of acids used in acid etch/desmutt/deoxidize tanks, there are at least five mineral acids commonly used in various combinations depending upon the metal being plated, the substrate metal being plated upon, the plater's proprietary choices, and the acid suppliers' proprietary choices. Those five acids are sulfuric, hydrochloric, nitric, hydrofluoric, and phosphoric. In most cases, following alkaline cleaning/electrocleaning, MFFRST defaults to a 25% (250 gram/liter) solution of sulfuric acid. However, MFFRST is

configured so that the user may choose any combination of mineral acids he or she prefers.

It is true that MFFRST has omitted a variety of chemical components from many of the process tanks. Typically this is because those components are either present in very low quantities or because they are not particularly toxic by themselves or in comparison with other bath components, or both. Examples are detergents and surfactants in alkaline cleaners, acid salts in etching and plating baths, or weak acids/alkalis such as boric acid and sodium bicarbonate. The MFFRST revisions provide the user with the ability to add these chemicals, and also any toxicological data, as they see fit.

As noted above, a typical silver plating line has been added to MFFRST. For the earlier MFFRST version, we did not have an adequate reference for estimating the silver plating tank parameters that affect atmospheric emissions.

Comparing MFFRST to TRI Data

A user of MFFRST can evaluate the impact of TRI-reported emissions to nearby residents. Facility codes SIC Code 3471, Plating and Polishing, of the 1996 TRI data base, were collected into a separate data base and input to MFFRST. By selecting one of these records, a user can evaluate, in a screening mode, the impact of those emissions to nearby residents (with other appropriate inputs such as stack height, distance to the residence, etc.).

If an individual would like to assess the impacts of a specific metal finishing facility, but that facility did not enter emissions data into the 1996 TRI data base, than alternately

the user could select a generic plating line, or lines, to describe emissions from the specific facility in question. Obviously, the user would need to know what type of plating operations, and what type of tanks, are in the facility. Given a reasonable representation of the plating operation within the facility, one obvious question is, then, how well would MFFRST predict emissions out of the stack of that facility. Do the generic lines in MFFRST reflect the metal finishing industry as portrayed in the TRI data? More specifically, how well do the emissions predicted to occur in MFFRST compare with emissions as reported in the TRI data base?

As a crude way of attempting an answer to this question, we compared average Toxic Release Inventory (TRI)-reported emissions with the emissions predicted by MFFRST for the pre-defined generic plating lines. The TRI data used were for 18 chemicals reported by SIC Code 3471 facilities in TRI. The 18 chemicals are those that are available for use in the process tanks in the 16 MFFRST metal finishing lines (see Figures 1 - 16). The comparative data are shown on Table 5.

The comparison accuracy is tenuous at best because TRI lists total annual emissions of each chemical for a facility, whereas MFFRST shows the amount of controlled emissions from each process tank that has the potential to emit that chemical. For instance, 6 facilities reported on TRI that they emitted to the atmosphere an *average* of 89.2 pounds per year each of cadmium. The only location where cadmium is an available emission source in MFFRST is from the cadmium plating tank on the cadmium plating line (Figure 8). The MFFRST controlled emissions of cadmium are 0.0245 pounds per year; more than 1,000

times less than the 89.2 pounds reported by TRI. This 1,000 fold difference appears to be typical for metal emissions.

Another example that illustrates this difference is copper. The TRI value for average emissions of copper to the atmosphere per facility is 239 pounds per year. MFFRST predicts that all tanks that might be a source of copper produce a total of 0.0755 pounds per year; again, more than a 1,000 fold difference. (Tanks that might emit copper are the copper cyanide strike and copper cyanide plating tanks on the decorative chromium plating line [Figure 2], the copper cyanide strike and the copper cyanide plating tanks on the copper plating line [Figure 6], and the copper cyanide strike and the acid copper plating tank on the acid copper plating line [Figure 7].)

These differences are important and will be investigated further. At the time of this writing, we considered these as probable reasons for these differences:

- MFFRST predicts controlled emissions that use air pollution control devices that are typically more than 99.9% effective. If TRI submittals are for tanks that are uncontrolled, or for air pollution control devices that are significantly less than 99.9% effective, this would clearly help explain why MFFRST predicted emission rates are lower.
- Not all process tank emissions may be captured by tank exhaust systems, in which case tank emissions that are not captured will not be treated by the tank air pollution control device (APCD), with a small portion released to the atmosphere from the stack. For TRI records, MFFRST

assumes that the entire reported emission is an emission from the stack. For the generic plating line emission that are compared to TRI emissions in Table 5, MFFRST assumes that 99 percent of tank emissions are captured by APCDs, with 1% escaping into the work place (to which metal plating workers are exposed).

TRI respondents have recognized that some of their emissions are not captured by their exhaust systems, and have estimated that a significant proportion of tank emissions by-pass APCDs. We reviewed TRI data for both fugitive and stack emissions in the electroplating industry, and observed that for metals, metal compounds, and acid emissions (e.g., sulfuric acid), respondents have reported that approximately one third to two thirds of these total emissions are, in fact, fugitive rather than stack. As noted, we have assumed that all TRI reported emissions are stack emissions which can impact nearby residences.

Assuming a meaningful portion of emissions from the tank are not captured in the exhaust system can make a significant difference in the estimation of total emissions (total emissions equal emissions into the workplace + out of the stack). This is illustrated in the following example. Say 100 pounds of a metal plating constituent are emitted from the tank in the direction of the exhaust ventilation before the APCD. Currently, MFFRST would assume 1 pound gets into the workplace environment and 99 lbs is routed into the ventilation system and through the APCD before being

emitted into the atmosphere. If the APCD was 99.9% efficient, the amount of total emissions from the APCD to the atmosphere is 0.099 lb, and adding the 1 lb which gets into the workplace, the “total” emissions predicted by MFFRST from the tank are 1.099 lb. If instead 10% were assumed to be “fugitive” and escape into the workplace, the calculation would be 10.09 lb. As seen, an assumption of 10% fugitive emissions leads to total emissions that are an order of magnitude higher than a 1% fugitive emission assumption. An assumption of 66% fugitive emissions leads to total emissions that are >60 times more than a 1% fugitive emission assumption.

Therefore, the treatment of fugitive emissions by TRI respondents, compared to MFFRST’s treatment of fugitive emissions, is one reason why TRI-reported emissions are significantly higher than MFFRST emissions.

- TRI-reporting facilities might emit the chemicals in question from processes that are not in the MFFRST tool. For instance, MFFRST does not account for emissions from mechanical operations such as grinding, buffing, and welding.
- Many facilities have more than one metal finishing line. For instance, in the example above, with copper, if there were 30 lines that conducted copper plating, instead of the three lines cited in MFFRST, then MFFRST emissions would be 10 times as high.

- Besides the important assumption that the APCDs reduce tank emissions by 99.9% (or so) before stack emissions, there may be further refinements to MFFRST assumptions in the process models that would lead to higher estimated emissions:

- 1) There may be more turbulence in process tanks than that estimated by MFFRST, creating greater emissions. (In electroplating tanks, MFFRST estimates turbulence in proportion to current density, and inversely proportional to cathode efficiency. In non-electroplating tanks turbulence is a function of aeration rate, bubble size, and surface tension.
- 2) Metal finishing tanks may be larger in surface area than the 20 square feet assumed as a default in the MFFRST model. Doubling tank surface area would double emissions.
- 3) Actual concentrations of chemicals in metal finishing baths may be higher than those used as defaults in MFFRST.
- 4) Actual ventilation rates at TRI-reporting facilities may be higher than those predicted by MFFRST. In some cases, MFFRST predicts no ventilation (e.g., gold plating, acid etching).

- Those reporting emissions under TRI may be overestimating emissions. This would not be hard to imagine. If emissions estimates are based on stack testing, stack testing is usually a one-time event, which may not be representative. Also, there is significant room for error if emissions are estimated by subtracting the sum of: (1) the

amount of metal plating/coatings shipped to customers on the facility's product, plus (2) the amount discharged in wastewater, plus (3) the amount of metals disposed of as solid waste, *from* the amount of metals/metal-containing chemicals purchased.

For the five organic solvents that the MFFRST user has available, MFFRST predicted concentrations are very similar to the TRI reports. For instance, for trichloroethylene (TCE), TRI shows that the average emission per facility is 2.21×10^4 pounds per year. MFFRST predicts that a single TCE solvent degreasing tank will emit 1.04×10^4 pounds per year.

It is probable that the reason the TRI versus MFFRST comparison is good for solvent emissions, but poor for metal emissions, is that MFFRST assumes that there are essentially no controls on exhausts from solvent degreasing operations. This implies that MFFRST may significantly overpredict the effectiveness of air pollution control devices on metal-bearing tanks.

In order to properly test MFFRST, emissions from various tanks in an actual metal finishing shop should be tested, both controlled and uncontrolled. At the same time, all operating parameters should be measured (e.g., tank surface area, rates of aeration, ventilation rate, tank concentrations).

While we attempt to locate such data, we will also be further investigating the procedures whereby TRI emissions are developed. This should shed additional light on the differences between MFFRST emissions as compared to TRI emissions.

References

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Table 1. Relative concentrations of uncontrolled atmospheric emissions from various surface coating operations in the electroplating industry.

Type of Plating-Related Process Operation	Contaminant of Concern	Concentration of Contaminant in Bath** (gm/lit.)	Typical Current Density** (amp/sq.in.)	Cathode Efficiency** (%)	Concentration of Emissions Relative to Chromium Emiss. from Hard Chromium Plating Tanks* (no units)
I. ELECTROLYTIC PROCESSES					
Hard Chromium Plating Bath	Chromium (+6)	160	1.5	20	1.0E+000
	Sulfuric Acid	2.5	1.5	20	1.6E-002
Decorative Chromium Plat. Bath	Chromium (+6)	164	1	20	6.8E-001
	Sulfuric Acid	1.6	1	20	6.7E-003
Trivalent Chromium Plating Bath	Chromium (+3)	10	0.5	95	4.4E-003
Nickel Plating Bath	Nickel	75	0.4	95	2.6E-002
Anodizing, Sulfuric Acid	Sulfuric Acid	150	0.1	95	1.3E-002
Anodizing, Chromic Acid	Chromic Acid	100	3	95	2.6E-001
Gold Plating Bath	Gold	5	0.06	95	2.6E-004
	Cyanide (CN)	10	0.06	95	5.3E-004
Copper Strike Bath	Copper	18	0.15	40	5.6E-003
	Cyanide (CN)	26	0.15	40	8.1E-003
Copper (Cyanide) Plating Bath	Copper	60	0.3	100	1.5E-002
	Cyanide (CN)	80	0.3	100	2.0E-002
Copper (Acid) Plating Bath	Copper	55	0.35	95	1.7E-002
	Sulfuric Acid	55	0.35	95	1.7E-002
Cadmium Plating Bath	Cadmium	45	0.3	90	1.2E-002
	Cyanide (CN)	60	0.3	90	1.7E-002
Zinc (Cyanide) Plating Bath	Zinc	35	0.35	70	1.5E-002
	Cyanide (CN)	100	0.35	70	4.2E-002
Zinc (Chloride) Plating Bath	Zinc	40	0.28	95	9.8E-003
Silver Strike Bath	Silver	6	0.2	90	1.1E-003
	Cyanide (CN)	70	0.2	90	1.3E-002
Silver Plating Bath	Silver	50	1	100	4.2E-002
	Cyanide (CN)	50	1	100	4.2E-002
Electrocleaning	Sodium Hydroxide	80	0.8	100	5.3E-002
	Sodium Phosphate	15	0.8	100	1.0E-002
	Sodium Metasilicate	25	0.8	100	1.7E-002
II. NON-ELECTROLYTIC PROCESSES					
Alkaline Cleaning Bath (typical)	Sod. Hydroxide	80	n/a	n/a	n/a
	Sod. Phosphate	15	n/a	n/a	n/a
	Sod. Metasilicate	25	n/a	n/a	n/a
Acid Etch/Desmut Bath (typical)	Sulfuric Acid	250	n/a	n/a	n/a
Acid Desmutt/Deoxidize	Nitric Acid	500	n/a	n/a	n/a
	Sulfuric Acid	150	n/a	n/a	n/a
Phosphate Coating Bath	Phosphoric Acid	50	n/a	n/a	n/a
Nickel Plating Bath (Electroless)	Nickel	10	n/a	n/a	n/a
	Sod. Hypophosph.	20	n/a	n/a	n/a
Anodizing Sealer	Nickel	2	n/a	n/a	n/a
	Chromium (+6)	20	n/a	n/a	n/a
Chromate Conversion Bath	Chromium (+6)	45	n/a	n/a	n/a
Hexavalent Chromium Passiv.	Chromium (+6)	3	n/a	n/a	n/a
Acid Etch (for Zinc Plating)	Hydrochloric Acid	100	n/a	n/a	n/a
Bright Dip (for Zinc Plating)	Nitric Acid	5	n/a	n/a	n/a
III. SOLVENT DEGREASING					
	1,1,1-Trichloroethane	1,340	n/a	n/a	n/a
	Perchloroethylene	1,620	n/a	n/a	n/a
	Methanol	790	n/a	n/a	n/a
	Methyl Ethyl Ketone	810	n/a	n/a	n/a
	Trichloroethylene	1460	n/a	n/a	n/a
	Methylene Chloride	1330	n/a	n/a	n/a

Table 2. Concentration levels of atmospheric emissions with various control devices for various surface coating operations in the metal finishing industry.

Type of Plating Operation	Contaminant of Concern	Uncontrolled Emissions	Polymer Balls	Fume Suppressants (@<28 dyne/cm)	Fume Suppressants + Polymer Balls	Packed Bed Scrubber	Packed Bed Scrubber + Fume Suppress.+ Polymer Balls
Hard Chromium Plating Bath (from AP-42 Data*)	Chromium	2.8E+000	9.6E-001	3.7E-001	6.9E-002	4.8E-002	6.0E-003
I. ELECTROLYTIC PROCESSES							
Hard Chromium Plating Bath (from Common Sense Initiative Data*)	Chromium (+6)	5.4E+000	2.3E-001	1.9E-002	6.2E-003	3.8E-002	2.2E-003
	Sulfuric Acid	8.4E-002	3.6E-003	3.0E-004	9.7E-005	5.9E-004	3.4E-005
Decorative Chromium Plat. Bath	Chromium (+6)	3.7E+000	1.6E-001	1.3E-002	4.2E-003	2.6E-002	1.5E-003
	Sulfuric Acid	3.6E-002	1.5E-003	1.3E-004	4.1E-005	2.5E-004	1.5E-005
Trivalent Chromium Plating Bath	Chromium (+3)	2.4E-002	1.0E-003	8.3E-005	2.7E-005	1.7E-004	9.6E-006
Nickel Plating Bath	Nickel	1.4E-001	6.1E-003	5.0E-004	1.6E-004	1.0E-003	5.8E-005
Anodizing, Sulfuric Acid	Sulfuric Acid	7.1E-002	3.0E-003	2.5E-004	8.2E-005	5.0E-004	2.9E-005
Anodizing, Chromic Acid	Chromic Acid	1.4E+000	6.1E-002	5.0E-003	1.6E-003	1.0E-002	5.8E-004
Gold Plating Bath	Gold	1.4E-003	6.1E-005	5.0E-006	1.6E-006	1.0E-005	5.8E-007
	Cyanide (CN)	2.8E-003	1.2E-004	1.0E-005	3.3E-006	2.0E-005	1.2E-006
Copper Strike Bath	Copper	3.0E-002	1.3E-003	1.1E-004	3.5E-005	2.1E-004	1.2E-005
	Cyanide (CN)	4.4E-002	1.9E-003	1.5E-004	5.0E-005	3.1E-004	1.8E-005
Copper (Cyanide) Plating Bath	Copper	8.1E-002	3.4E-003	2.8E-004	9.3E-005	5.7E-004	3.3E-005
	Cyanide (CN)	1.1E-001	4.6E-003	3.8E-004	1.2E-004	7.6E-004	4.4E-005
Copper (Acid) Plating Bath	Copper	9.1E-002	3.9E-003	3.2E-004	1.0E-004	6.4E-004	3.7E-005
	Sulfuric Acid	9.1E-002	3.9E-003	3.2E-004	1.0E-004	6.4E-004	3.7E-005
Cadmium Plating Bath	Cadmium	6.7E-002	2.9E-003	2.4E-004	7.7E-005	4.7E-004	2.7E-005
	Cyanide (CN)	9.0E-002	3.8E-003	3.2E-004	1.0E-004	6.3E-004	3.7E-005
Zinc (Cyanide) Plating Bath	Zinc	7.9E-002	3.4E-003	2.8E-004	9.0E-005	5.5E-004	3.2E-005
	Cyanide (CN)	2.2E-001	9.6E-003	7.9E-004	2.6E-004	1.6E-003	9.2E-005
Zinc (Chloride) Plating Bath	Zinc	5.3E-002	2.3E-003	1.9E-004	6.1E-005	3.7E-004	2.2E-005
Silver Strike Bath	Silver	6.0E-003	2.6E-004	2.1E-005	6.9E-006	4.2E-005	2.4E-006
	Cyanide (CN)	7.0E-002	3.0E-003	2.5E-004	8.0E-005	4.9E-004	2.9E-005
Silver Plating Bath	Silver	2.2E-001	9.6E-003	7.9E-004	2.6E-004	1.6E-003	9.2E-005
	Cyanide (CN)	2.2E-001	9.6E-003	7.9E-004	2.6E-004	1.6E-003	9.2E-005
Electrocleaning	Sodium Hydroxide	2.9E-001	1.2E-002	1.0E-003	3.3E-004	2.0E-003	1.2E-004
	Sodium Phosphate	5.4E-002	2.3E-003	1.9E-004	6.2E-005	3.8E-004	2.2E-005
	Sodium Metasilicate	9.0E-002	3.8E-003	3.2E-004	1.0E-004	6.3E-004	3.7E-005
II. NON-ELECTROLYTIC PROCESSES							
Alkaline Cleaning Bath (typical)***	Sod. Hydroxide	3.1E-001	1.3E-002	1.1E-003	3.5E-004	2.2E-003	1.3E-004
	Sod. Phosphate	5.8E-002	2.5E-003	2.0E-004	6.6E-005	4.1E-004	2.3E-005

	Sod. Metasilicate	9.6E-002	4.1E-003	3.4E-004	1.1E-004	6.8E-004	3.9E-005
Acid Etch/Desmut Bath (typical)****	Sulfuric Acid	2.1E+001	8.9E-001	7.4E-002	2.4E-002		Note 1
Acid Desmutt/Deoxidize****	Nitric Acid	4.2E+001	1.8E+000	1.5E-001	4.8E-002		Note 1
	Sulfuric Acid	1.3E+001	5.4E-001	4.4E-002	1.4E-002		
Phosphate Coating Bath***	Phosphoric Acid	1.9E-001	8.0E-003	6.6E-004	2.1E-004	1.3E-003	7.6E-005
Nickel Plating Bath (Electroless)***	Nickel	3.7E-002	1.6E-003	1.3E-004	4.3E-005	2.6E-004	1.5E-005
	Sod. Hypophosphite	7.5E-002	3.2E-003	2.6E-004	8.6E-005	5.3E-004	3.0E-005
Anodizing Sealer***	Nickel	4.9E-003	2.1E-004	1.7E-005	5.7E-006	3.5E-005	2.0E-006
	Chromium (+6)	4.9E-002	2.1E-003	1.7E-004	5.7E-005	3.5E-004	2.0E-005
Chromate Conversion Bath***	Chromium (+6)	3.4E-001	1.5E-002	1.2E-003	3.9E-004	2.4E-003	1.4E-004
Hexavalent Chromium Passiv.***	Chromium (+6)	1.5E-002	6.3E-004	5.2E-005	1.7E-005	1.0E-004	6.0E-006
Acid Etch (for Zinc Plating)****	Hydrochloric Acid	8.4E+000	3.6E-001	3.0E-002	9.6E-003		Note 1
Bright Dip (for Zinc Plating)****	Nitric Acid	4.2E-001	1.8E-002	1.5E-003	4.8E-004		Note 1
III. SOLVENT DEGREASING**							
	1,1,1-Trichloroethane	1.8E+002	n/a	n/a	n/a	n/a	n/a
	Perchloroethylene	5.2E+001	n/a	n/a	n/a	n/a	n/a
	Methanol	1.4E+002	n/a	n/a	n/a	n/a	n/a
	Methyl Ethyl Ketone	2.6E+002	n/a	n/a	n/a	n/a	n/a
	Trichloroethylene	1.0E+002	n/a	n/a	n/a	n/a	n/a
	Methylene Chloride	3.8E+002	n/a	n/a	n/a	n/a	n/a

* Data for hard chromium plating represent average of relevant data from "Hard Chrome Pollution Prevention Demonstration Project", Interim Report, Nov 27, 1996, USEPA Common Sense Initiative, Metal Finishing Subcommittee (except for column with packed bed scrubber and mist eliminator, which is from USEPA's Compilation of Air Pollutant Emission Factors, AP-42, 5th Ed., Jan, 1995). Data for other electrolytic tanks is product of hard chromium plating tank data times factors in last column of Table 1.

** Emissions for solvent degreasing (in mg/cu.meter) are based on the AP-42 emissions factor for 1,1,1-trichloroethane of 0.15 lb/hr/sq.ft, for the surface area (20 sq.ft) and volumetric flow rate (4,500 CFM) given in Table 3.

*** Concentrations for Hexavalent Chromium Passivation, Electroless Nickel Plating, the Anodizing Sealer, Alkaline Cleaning, Phosphate Coating, and Chromate Conversion are back-calculated from Table 4 mass emission levels, combined with the volumetric flow rates in Table 3.

**** Concentrations of emissions for Acid Etching/Desmutting/Bright Dip processes are back-calculated from Table 4 mass emission levels, combined with aeration air volumetric flow rates (10 CFM per sq.ft. of tank surface, times the tank surface area from Table 3).

OSHA does not appear to require that these tanks be ventilated external to the plant. Consequently, the only applicable air pollution controls are polymer balls and/or fume suppressants.

Note 1: Bath not vented, hence no applicable air pollution control equipment

Table 3. Ventilation rates, tank surface areas, and volumetric flow rates for various surface coating operations in the electroplating industry.

Type of Plating Operation	Contaminant of Concern	Estimated OSHA Ventilation Category (40CFR1910.94 (d)(2)(v)&(vii))	Minimum Ventilation Rate (cu.ft./min-sq.ft) (40CFR1910.94(d)(4) (i),(ii), & (iii)(a)(2))	Estimated Tank Surface Area (sq.ft.)	Calculated Volumetric Flow Rates (cu.ft./min.)
I. ELECTROLYTIC PROCESSES					
Hard Chromium Plating Bath	Chromium (+6)	A-1	340	20	6,800
	Sulfuric Acid	B-1	225	20	4,500
Decorative Chromium Plat. Bath	Chromium (+6)	A-1	340	20	6,800
	Sulfuric Acid	B-1	225	20	4,500
Trivalent Chromium Plating Bath	Chromium (+3)	B-3	170	20	3,400
Nickel Plating Bath	Nickel	B-2	225	20	4,500
Anodizing, Sulfuric Acid	Sulfuric Acid	B-3	170	20	3,400
Anodizing, Chromic Acid	Chromic Acid	A-3	170	20	3,400
Gold Plating Bath	Gold	D-4	0	8	0
	Cyanide (CN)	C-4	0	8	0
Copper Strike Bath	Copper	D-3	0	20	0
	Cyanide (CN)	C-3	110	20	2,200
Copper (Cyanide) Plating Bath	Copper	D-2	110	20	2,200
	Cyanide (CN)	C-2	170	20	3,400
Copper (Acid) Plating Bath	Copper	D-4	0	20	0
	Sulfuric Acid	B-4	0	20	0
Cadmium Plating Bath	Cadmium	D-3	0	20	0
	Cyanide (CN)	C-3	110	20	2,200
Zinc (Cyanide) Plating Bath	Zinc	B-3	170	20	3,400
	Cyanide (CN)	C-3	110	20	2,200
Zinc (Chloride) Plating Bath	Zinc	B-4	0	20	0
Silver Strike Bath	Silver	A-4	110	8	880
	Cyanide (CN)	C-4	0	8	0
Silver Plating Bath	Silver	A-3	170	8	1,360
	Cyanide (CN)	C-3	110	8	880
Electrocleaning	Sod. Hydroxide	C-2	170	20	3,400
	Sod. Phosphate	D-2	110	20	2,200
	Sod. Metasilicate	D-2	110	20	2,200
II. NON-ELECTROLYTIC PROCESSES					
Alkaline Cleaning Bath (typical)	Sod. Hydroxide	C-2	170	20	3,400
	Sod. Phosphate	D-2	110	20	2,200
	Sod. Metasilicate	D-2	110	20	2,200
Acid Etch/Desmut Bath (typical)	Sulfuric Acid	C-4	0	20	0
Acid Desmutt/Deoxidize	Nitric Acid	B-4	0	20	0
	Sulfuric Acid	C-4	0	20	0
Phosphate Coating Bath	Phosphoric Acid	B-2	225	20	4,500
Nickel Plating Bath (Electroless)	Nickel	B-2	225	20	4,500
	Sod. Hypophosphite	D-2	110	20	2,200
Anodizing Sealer	Nickel	B-1	225	20	4,500
	Chromium (+6)	A-1	340	20	6,800
Chromate Conversion Bath	Chromium (+6)	A-4	110	20	2,200
Hexavalent Chromium Passivation	Chromium (+6)	A-3	170	20	3,400
Acid Etch (for Zinc Plating)	Hydrochloric Acid	C-4	0	20	0
Bright Dip (for Zinc Plating)	Nitric Acid	C-4	0	20	0
III. SOLVENT DEGREASING					
	1,1,1-Trichloroethane	C-1	225	20	4,500
	Perchloroethylene	B-2	225	20	4,500
	Methanol	C-3	110	20	2,200
	Mehyl Ethyl Ketone	C-3	110	20	2,200
	Trichloroethylene	C-1	225	20	4,500
	Methylene Chloride	C-1	225	20	4,500

Table 4. Daily mass emission levels external to the plant with various control devices for various surface coating operations in the electroplating industry.

Type of Plating Operation	Contaminant of Concern	Uncontrolled Emissions	Polymer Balls	Fume Suppressants (@<28 dyne/cm)	Fume Suppressants + Polymer Balls	Packed Bed Scrubber	Packed Bed Scrubber + Fume Suppress.+ Polymer Balls
I. ELECTROLYTIC PROCESSES							
Hard Chromium Plating Bath	Chromium (+6)	1.5E+006	6.4E+004	5.3E+003	1.7E+003	1.1E+004	6.1E+002
	Sulfuric Acid	2.3E+004	1.0E+003	8.2E+001	2.7E+001	1.6E+002	9.5E+000
Decorative Chromium Plat. Bath	Chromium (+6)	1.0E+006	4.4E+004	3.6E+003	1.2E+003	7.2E+003	4.2E+002
	Sulfuric Acid	1.0E+004	4.3E+002	3.5E+001	1.1E+001	7.0E+001	4.1E+000
Trivalent Chromium Plating Bath	Chromium (+3)	3.3E+003	1.4E+002	1.2E+001	3.8E+000	2.3E+001	1.3E+000
Nickel Plating Bath	Nickel	2.6E+004	1.1E+003	9.2E+001	3.0E+001	1.8E+002	1.1E+001
Anodizing, Sulfuric Acid	Sulfuric Acid	9.8E+003	4.2E+002	3.5E+001	1.1E+001	6.9E+001	4.0E+000
Anodizing, Chromic Acid	Chromic Acid	2.0E+005	8.4E+003	6.9E+002	2.3E+002	1.4E+003	8.0E+001
Gold Plating Bath	Gold	No significant emissions from Gold Plating, unless aerated and externally ventilated.					
Copper Strike Bath	Cyanide (CN)						
	Copper	2.7E+003	1.2E+002	9.6E+000	3.1E+000	1.9E+001	1.1E+000
Copper (Cyanide) Plating Bath	Cyanide (CN)	3.9E+003	1.7E+002	1.4E+001	4.5E+000	2.8E+001	1.6E+000
	Copper	1.1E+004	4.8E+002	4.0E+001	1.3E+001	7.9E+001	4.6E+000
Copper (Acid) Plating Bath	Cyanide (CN)	1.5E+004	6.4E+002	5.3E+001	1.7E+001	1.1E+002	6.1E+000
	Copper	No significant emissions from Acid Copper Plating unless aerated and externally ventilated.					
Cadmium Plating Bath	Sulfuric Acid						
	Cadmium	6.1E+003	2.6E+002	2.1E+001	7.0E+000	4.3E+001	2.5E+000
Zinc (Cyanide) Plating Bath	Cyanide (CN)	8.1E+003	3.4E+002	2.8E+001	9.3E+000	5.7E+001	3.3E+000
	Zinc	1.1E+004	4.6E+002	3.8E+001	1.3E+001	7.7E+001	4.4E+000
Zinc (Chloride) Plating Bath	Cyanide (CN)	3.1E+004	1.3E+003	1.1E+002	3.6E+001	2.2E+002	1.3E+001
	Zinc	No significant emissions from Zinc Chloride Plating unless aerated and externally ventilated.					
Silver Strike Bath	Silver	2.2E+002	9.2E+000	7.6E-001	2.5E-001	1.5E+000	8.8E-002
	Cyanide (CN)	2.5E+003	1.1E+002	8.8E+000	2.9E+000	1.8E+001	1.0E+000
Silver Plating Bath	Silver	1.2E+004	5.3E+002	4.4E+001	1.4E+001	8.8E+001	5.1E+000
	Cyanide (CN)	1.2E+004	5.3E+002	4.4E+001	1.4E+001	8.8E+001	5.1E+000
Electrocleaning	Sod. Hydroxide	4.0E+004	1.7E+003	1.4E+002	4.6E+001	2.8E+002	1.6E+001
	Sod. Phosphate	7.5E+003	3.2E+002	2.6E+001	8.6E+000	5.3E+001	3.0E+000
	Sod. Metasilicate	1.2E+004	5.3E+002	4.4E+001	1.4E+001	8.8E+001	5.1E+000
II. NON-ELECTROLYTIC PROCESSES							
Alkaline Cleaning Bath (typical)	Sod. Hydroxide	4.3E+004	1.8E+003	1.5E+002	4.9E+001	3.0E+002	1.7E+001
	Sod. Phosphate	8.0E+003	3.4E+002	2.8E+001	9.2E+000	5.6E+001	3.3E+000
	Sod. Metasilicate	1.3E+004	5.7E+002	4.7E+001	1.5E+001	9.4E+001	5.4E+000
Acid Etch/Desmut Bath (typical)***	Sulfuric Acid	1.7E+005	7.3E+003	6.0E+002	2.0E+002	Bath not vented, hence no applicable air pollution control equipment	
Acid Desmutt/Deoxidize***	Nitric Acid	3.4E+005	1.5E+004	1.2E+003	3.9E+002	Bath not vented, hence no applicable air pollution control equipment	

	Sulfuric Acid	1.0E+005	4.4E+003	3.6E+002	1.2E+002	Bath not vented, hence no applicable air pollution control equipment	
Phosphate Coating Bath	Phosphoric Acid	3.4E+004	1.5E+003	1.2E+002	3.9E+001	2.4E+002	1.4E+001
Nickel Plating Bath (Electroless)	Nickel	6.9E+003	2.9E+002	2.4E+001	7.9E+000	4.8E+001	2.8E+000
	Sod. Hypophosphite	1.4E+004	5.8E+002	4.8E+001	1.6E+001	9.6E+001	5.6E+000
Anodizing Sealer	Nickel	1.4E+003	5.8E+001	4.8E+000	1.6E+000	9.6E+000	5.6E-001
	Chromium (+6)	1.4E+004	5.8E+002	4.8E+001	1.6E+001	9.6E+001	5.6E+000
Chromate Conversion Bath	Chromium (+6)	3.1E+004	1.3E+003	1.1E+002	3.5E+001	2.2E+002	1.3E+001
Hexavalent Chromium Passivation	Chromium (+6)	2.1E+003	8.8E+001	7.2E+000	2.4E+000	1.4E+001	8.4E-001
Acid Etch (for Zinc Plating)***	Hydrochloric Acid	6.9E+004	2.9E+003	2.4E+002	7.9E+001	Bath not vented, hence no applicable air pollution control equipment	
Bright Dip (for Zinc Plating)***	Nitric Acid	3.4E+003	1.5E+002	1.2E+001	3.9E+000	Bath not vented, hence no applicable air pollution control equipment	
III. SOLVENT DEGREASING**							
	1,1,1-Trichloroethane	3.3E+007	n/a	n/a	n/a	n/a	n/a
	Perchloroethylene	9.5E+006	n/a	n/a	n/a	n/a	n/a
	Methanol	1.3E+007	n/a	n/a	n/a	n/a	n/a
	Methyl Ethyl Ketone	2.3E+007	n/a	n/a	n/a	n/a	n/a
	Trichloroethylene	1.9E+007	n/a	n/a	n/a	n/a	n/a
	Methylene Chloride	6.9E+007	n/a	n/a	n/a	n/a	n/a

Table 4. (cont'd)

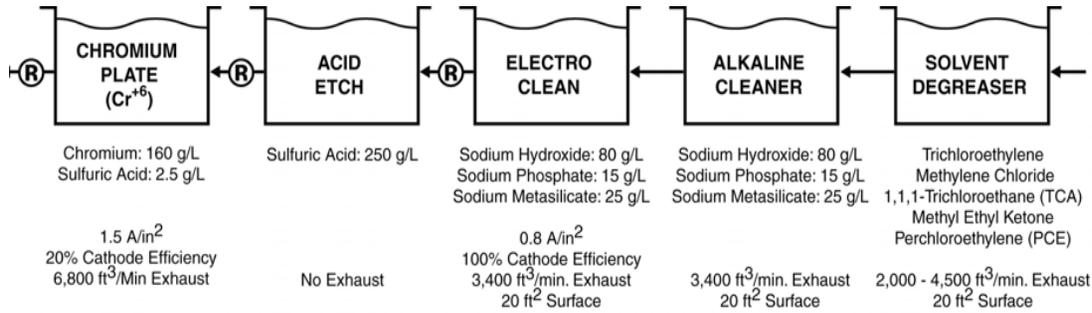
Type of Plating Operation	Contaminant of Concern	Uncontrolled Emissions	Chevron Mist Eliminator	Series Dual Chevron Mist Eliminator	Mesh Pad Mist Eliminator	Packed Bed Scrubber + Mist Eliminator	Composite Mesh Pad Mist Eliminator	Composite Mesh Pad + Fume Suppressant	Chevron Mist Eliminat. + Fume Suppressant
I. ELECTROLYTIC PROCESSES									
Hard Chromium Plating Bath	Chromium (+6)	1.5E+006	3.1E+004	1.4E+003	6.7E+003	2.0E+001	2.7E+003	1.7E+002	9.2E+002
	Sulfuric Acid	2.3E+004	4.8E+002	2.1E+001	1.0E+002	3.2E-001	4.2E+001	2.6E+000	1.4E+001
Decorative Chromium Plat. Bath	Chromium (+6)	1.0E+006	2.1E+004	9.3E+002	4.5E+003	1.4E+001	1.8E+003	1.1E+002	6.3E+002
	Sulfuric Acid	1.0E+004	2.0E+002	9.1E+000	4.4E+001	1.3E-001	1.8E+001	1.1E+000	6.1E+000
Trivalent Chromium Plating Bath	Chromium (+3)	3.3E+003	6.7E+001	3.0E+000	1.5E+001	4.4E-002	5.8E+000	3.6E-001	2.0E+000
Nickel Plating Bath	Nickel	2.6E+004	5.3E+002	2.4E+001	1.2E+002	3.5E-001	4.6E+001	2.9E+000	1.6E+001
Anodizing, Sulfuric Acid	Sulfuric Acid	9.8E+003	2.0E+002	8.9E+000	4.4E+001	1.3E-001	1.8E+001	1.1E+000	6.0E+000
Anodizing, Chromic Acid	Chromic Acid	2.0E+005	4.0E+003	1.8E+002	8.8E+002	2.7E+000	3.5E+002	2.2E+001	1.2E+002
Gold Plating Bath	Gold	No significant emissions from Gold Plating, unless aerated and externally ventilated.							
	Cyanide (CN)								
Copper Strike Bath	Copper	2.7E+003	5.5E+001	2.5E+000	1.2E+001	3.7E-002	4.8E+000	3.0E-001	1.7E+000
	Cyanide (CN)	3.9E+003	8.0E+001	3.6E+000	1.7E+001	5.3E-002	7.0E+000	4.4E-001	2.4E+000
Copper (Cyanide) Plating Bath	Copper	1.1E+004	2.3E+002	1.0E+001	5.0E+001	1.5E-001	2.0E+001	1.2E+000	6.9E+000
	Cyanide (CN)	1.5E+004	3.0E+002	1.4E+001	6.7E+001	2.0E-001	2.7E+001	1.7E+000	9.1E+000
Copper (Acid) Plating Bath	Copper	No significant emissions from Acid Copper Plating unless aerated and externally ventilated.							
	Sulfuric Acid								
Cadmium Plating Bath	Cadmium	6.1E+003	1.2E+002	5.5E+000	2.7E+001	8.2E-002	1.1E+001	6.7E-001	3.7E+000
	Cyanide (CN)	8.1E+003	1.6E+002	7.3E+000	3.6E+001	1.1E-001	1.4E+001	9.0E-001	4.9E+000
Zinc (Cyanide) Plating Bath	Zinc	1.1E+004	2.2E+002	9.9E+000	4.9E+001	1.5E-001	1.9E+001	1.2E+000	6.7E+000
	Cyanide (CN)	3.1E+004	6.4E+002	2.8E+001	1.4E+002	4.2E-001	5.5E+001	3.5E+000	1.9E+001
Zinc (Chloride) Plating Bath	Zinc	No significant emissions from Zinc Chloride Plating unless aerated and externally ventilated.							
Silver Strike Bath	Silver	2.2E+002	4.4E+000	2.0E-001	9.6E-001	2.9E-003	3.8E-001	2.4E-002	1.3E-001
	Cyanide (CN)	2.5E+003	5.1E+001	2.3E+000	1.1E+001	3.4E-002	4.5E+000	2.8E-001	1.5E+000
Silver Plating Bath	Silver	1.2E+004	2.5E+002	1.1E+001	5.5E+001	1.7E-001	2.2E+001	1.4E+000	7.6E+000
	Cyanide (CN)	1.2E+004	2.5E+002	1.1E+001	5.5E+001	1.7E-001	2.2E+001	1.4E+000	7.6E+000
Electrocleaning	Sod. Hydroxide	4.0E+004	8.1E+002	3.6E+001	1.8E+002	5.4E-001	7.1E+001	4.4E+000	2.4E+001
	Sod. Phosphate	7.5E+003	1.5E+002	6.8E+000	3.3E+001	1.0E-001	1.3E+001	8.3E-001	4.6E+000
	Sod. Metasilicate	1.2E+004	2.5E+002	1.1E+001	5.5E+001	1.7E-001	2.2E+001	1.4E+000	7.6E+000
II. NON-ELECTROLYTIC PROCESSES									
Alkaline Cleaning Bath (typical)	Sod. Hydroxide	4.3E+004	8.7E+002	3.9E+001	1.9E+002	5.8E-001	7.6E+001	4.7E+000	2.6E+001
	Sod. Phosphate	8.0E+003	1.6E+002	7.3E+000	3.6E+001	1.1E-001	1.4E+001	8.9E-001	4.9E+000
	Sod. Metasilicate	1.3E+004	2.7E+002	1.2E+001	5.9E+001	1.8E-001	2.4E+001	1.5E+000	8.1E+000
Acid Etch/Desmut Bath (typical)***	Sulfuric Acid	1.7E+005	Bath not vented, hence no applicable air pollution control equipment						
Acid Desmutt/Deoxidize***	Nitric Acid	3.4E+005	Bath not vented, hence no applicable air pollution control equipment						
	Sulfuric Acid	1.0E+005							
Phosphate Coating Bath	Phosphoric Acid	3.4E+004	7.0E+002	3.1E+001	1.5E+002	4.6E-001	6.1E+001	3.8E+000	2.1E+001

Table 5. Comparison of TRI data with MFFRST Predictions.

Chemical Name	TRI Data				MFFRST Runs Using Default Values (lbs/yr)							
	Number of Facilities	Percentage	Average	Maximum	Hard Chromium Plating	Decorative Chromium Plating	Trivalent Chromium Plating	Anodizing (Chromic Acid)	Cadmium Plating	Copper Plating (Cyanide)	Copper Plating (Acid)	Gold Plating
1,1,1-Trichloroethane	12	2.9%	1.31E+004	4.12E+004								
Cadmium	6	1.4%	8.92E+001	5.00E+002					2.45E-002			
Chromium	19	4.6%	2.54E+002	1.00E+003	1.07E-002	1.07E-002		4.85E-001				
Chromium compounds	57	13.7%	1.76E+002	1.35E+003			1.33E-002					
Copper	46	11.1%	2.39E+002	2.55E+003		3.44E-002				3.44E-002	6.73E-003	
Cyanide	40	9.6%	3.76E+002	2.13E+003		4.66E-002			3.26E-002	4.66E-002	9.70E-003	
Dichloromethane	5	1.2%	2.42E+004	6.94E+004								
Hydrochloric acid	38	9.2%	3.00E+003	3.71E+004			1.61E+000	1.61E+000	1.61E+000			
Methanol	4	1.0%	9.05E+003	1.50E+004								
Methyl ethyl ketone	21	5.1%	2.95E+004	2.50E+005								
Nickel	94	22.7%	2.66E+002	6.67E+003		6.39E-002	6.39E-002					6.39E-002
Nitric acid	181	43.6%	8.68E+002	1.21E+004				8.05E+000				
Phosphoric acid	56	13.5%	6.88E+002	1.10E+004								
Silver	3	0.7%	1.75E+002	5.00E+002								
Sulfuric acid	36	8.7%	7.72E+002	1.19E+004	4.02E+000	8.05E+000		2.41E+000		4.02E+000	8.05E+000	4.02E+000
Tetrachloroethylene	18	4.3%	2.07E+004	6.60E+004								
Trichloroethylene	52	12.5%	2.21E+004	1.55E+005								
Zinc	48	11.6%	6.35E+002	5.15E+003								

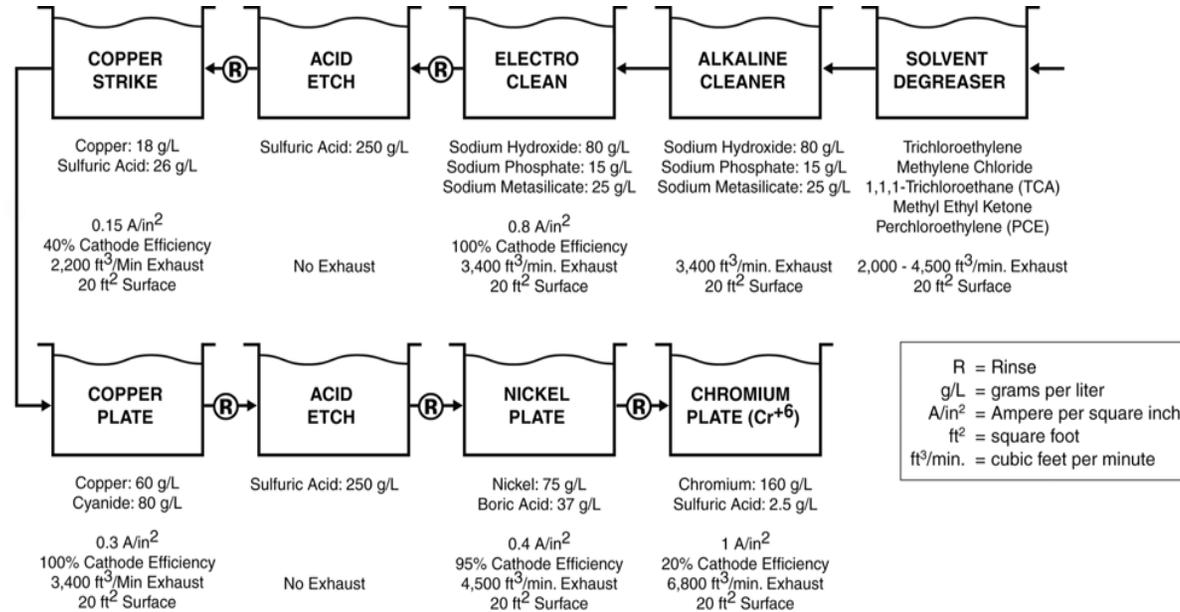
Table 5. (cont'd).

Chemical Name	TRI Data				MFFRST Runs Using Default Values (lbs/year)								
	Number of Facilities	Percentage	Average	Maximum	Nickel Plating	Electroless Nickel Plating	Anodizing (Sulfuric Acid)	Chromate Conversion Coating	Phosphate Coating	Zinc Plating (Cyanide)	Zinc Plating (Chloride)	Silver Plating	Vapor Degreasing
1,1,1-Trichloroethane	12	2.9%	1.31E+004	4.12E+004									1.80E+004
Cadmium	6	1.4%	8.92E+001	5.00E+002									
Chromium	19	4.6%	2.54E+002	1.00E+003			3.37E-002						
Chromium compounds	57	13.7%	1.76E+002	1.35E+003				7.61E-002					
Copper	46	11.1%	2.39E+002	2.55E+003									
Cyanide	40	9.6%	3.76E+002	2.13E+003						7.66E-002	1.71E-001		
Dichloromethane	5	1.2%	2.42E+004	6.94E+004									3.84E+004
Hydrochloric acid	38	9.2%	3.00E+003	3.71E+004						1.61E+000			
Methanol	4	1.0%	9.05E+003	1.50E+004									6.95E+003
Methyl ethyl ketone	21	5.1%	2.95E+004	2.50E+005									1.27E+004
Nickel	94	22.7%	2.66E+002	6.67E+003	6.39E-002	1.69E-002	3.37E-003						
Nitric acid	181	43.6%	8.68E+002	1.21E+004			8.05E+000	8.05E-002		8.05E-002			
Phosphoric acid	56	13.5%	6.88E+002	1.10E+004					3.90E-001				
Silver	3	0.7%	1.75E+002	5.00E+002								1.45E-001	
Sulfuric acid	36	8.7%	7.72E+002	1.19E+004	4.02E+000	4.02E+000	6.46E+000				4.02E+000	4.02E+000	
Tetrachloroethylene	18	4.3%	2.07E+004	6.60E+004									5.25E+003
Trichloroethylene	52	12.5%	2.21E+004	1.55E+005									1.04E+004
Zinc	48	11.6%	6.35E+002	5.15E+003						2.69E-002			



R = Rinse
g/L = grams per liter
A/in² = Ampere per square inch
ft² = square foot
ft³/min. = cubic feet per minute

Figure 1. Hard Chromium Plating



R = Rinse
g/L = grams per liter
A/in² = Ampere per square inch
ft² = square foot
ft³/min. = cubic feet per minute

Figure 2. Decorative Chromium Plating

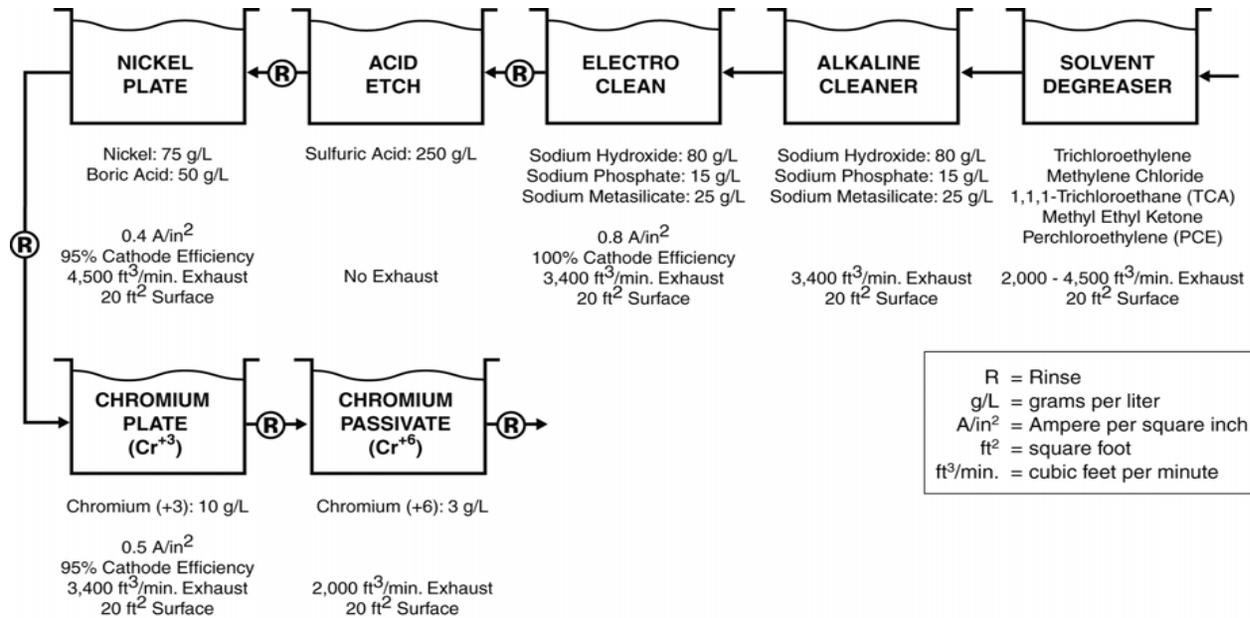


Figure 3. Trivalent Chromium Plating

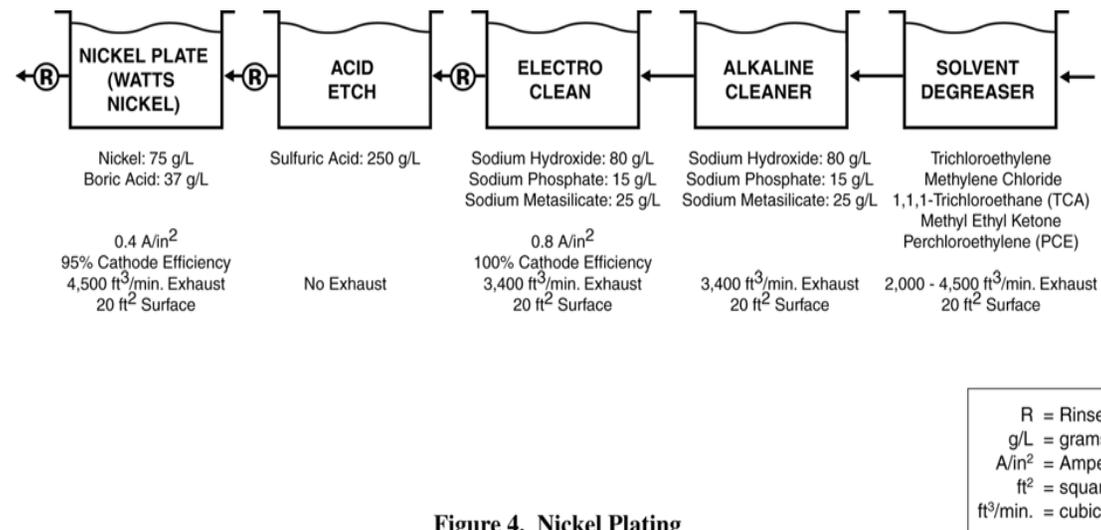


Figure 4. Nickel Plating

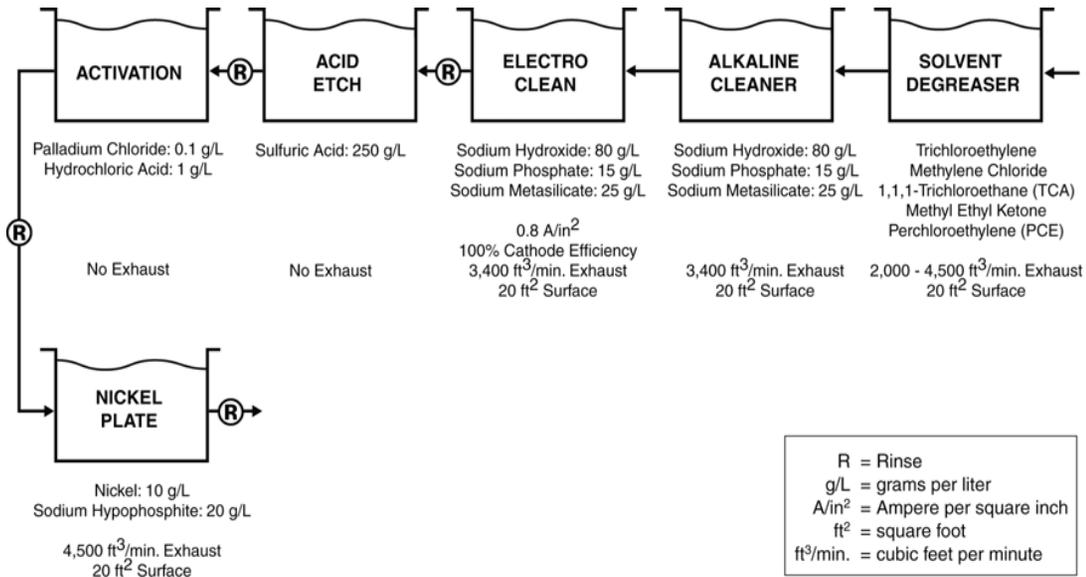


Figure 5. Electroless Nickel Plating

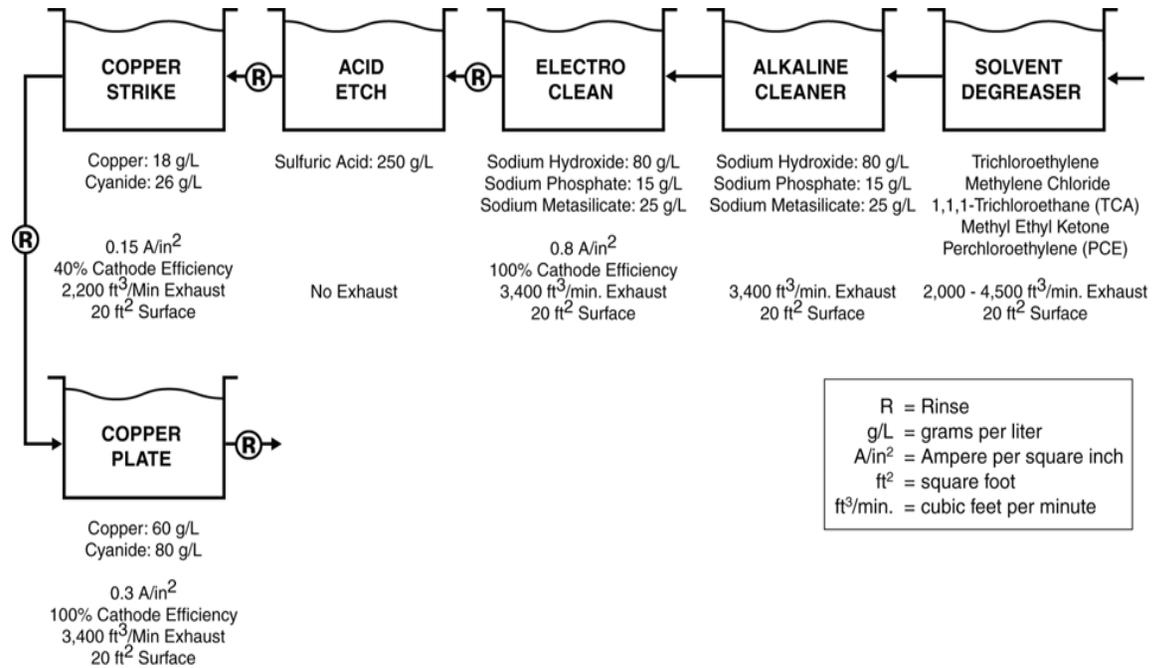


Figure 6. Copper Plating (Cyanide)

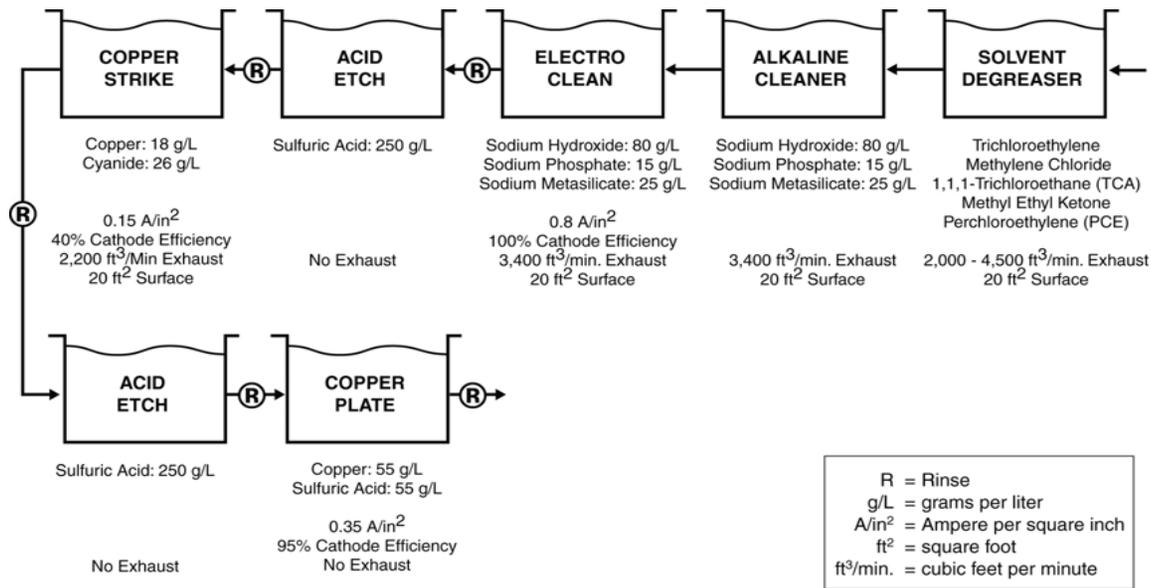


Figure 7. Copper Plating (Acid)

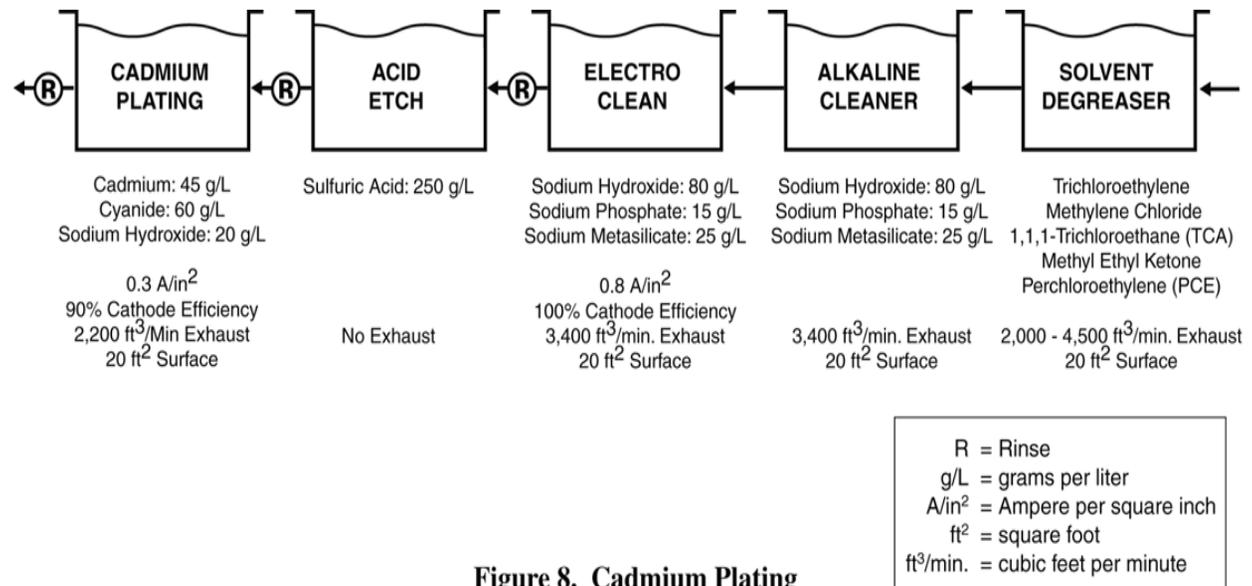


Figure 8. Cadmium Plating

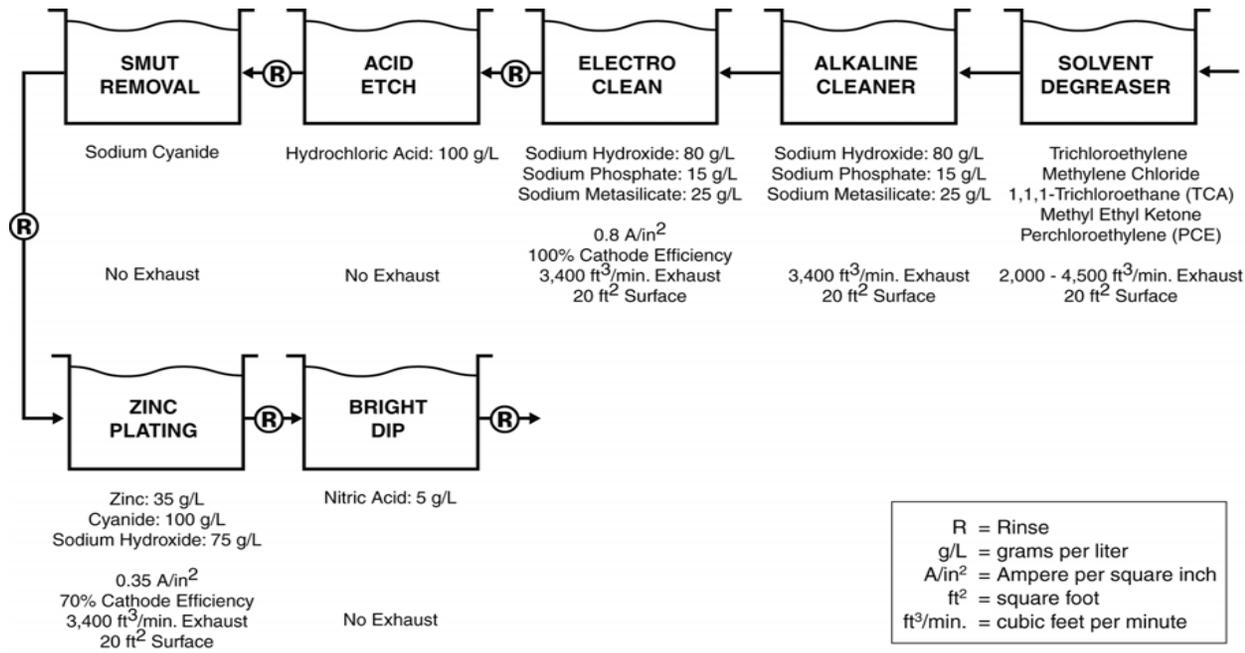


Figure 9. Zinc Plating (Cyanide)

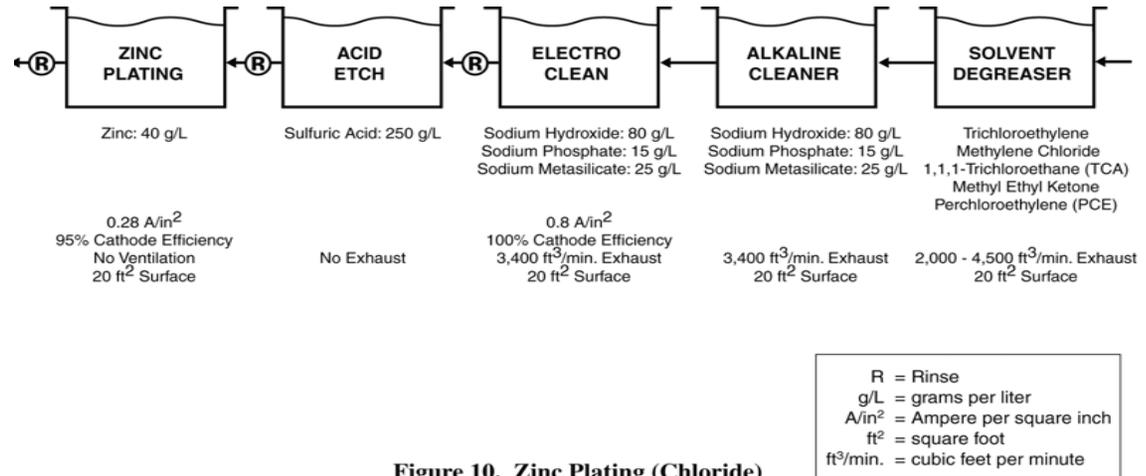


Figure 10. Zinc Plating (Chloride)

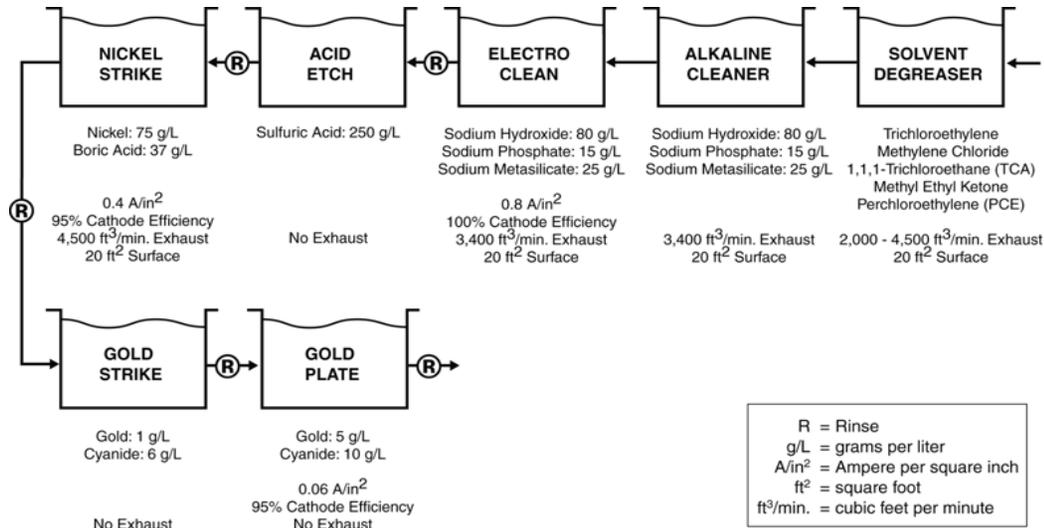


Figure 11. Gold Plating

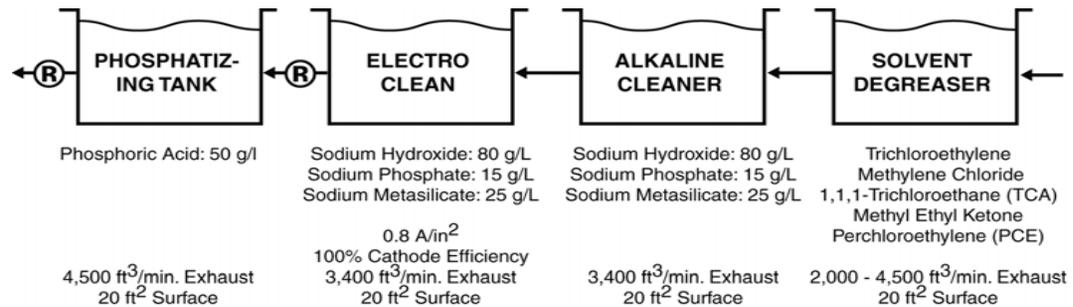


Figure 12. Phosphate Coating

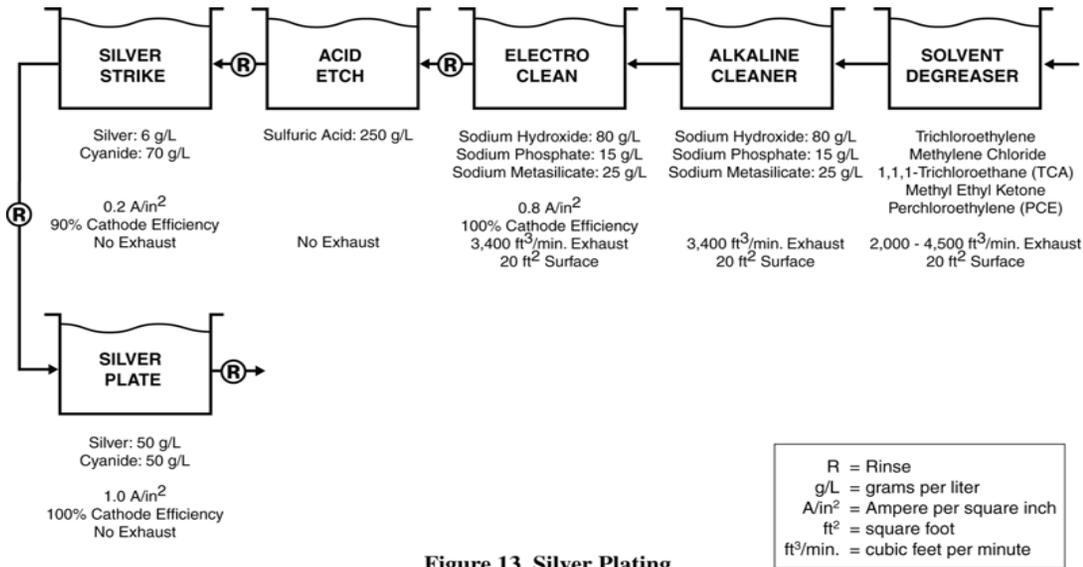


Figure 13. Silver Plating

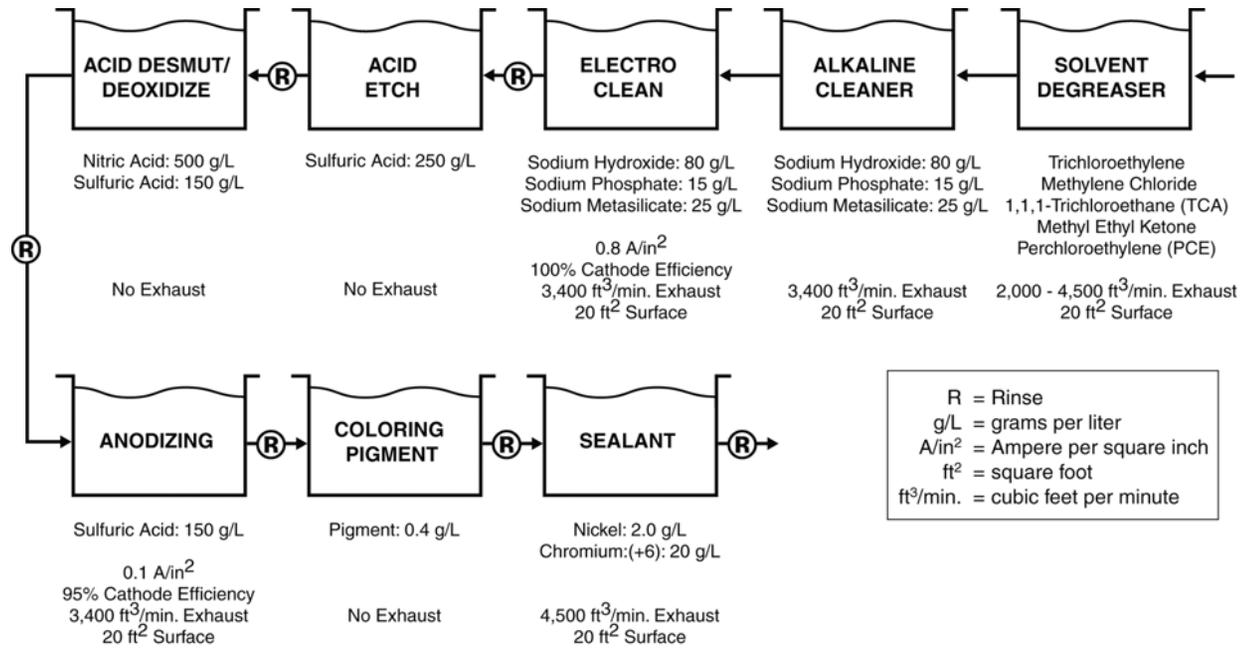


Figure 14. Anodizing - Sulfuric Acid

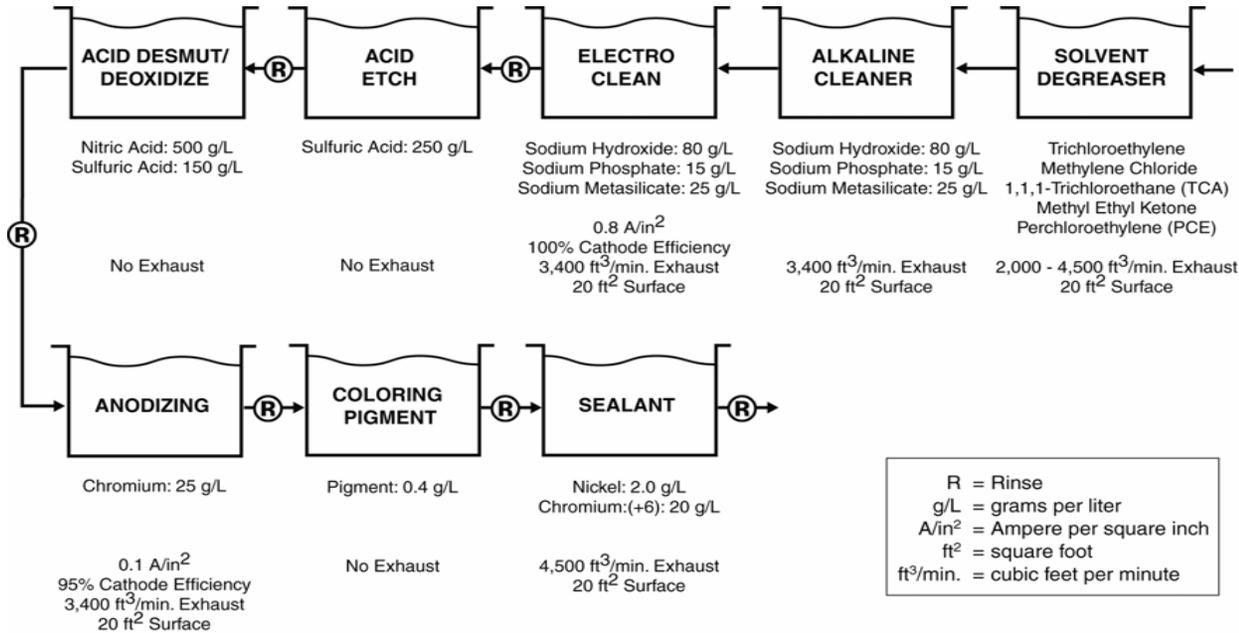


Figure 15. Anodizing - Chromic Acid

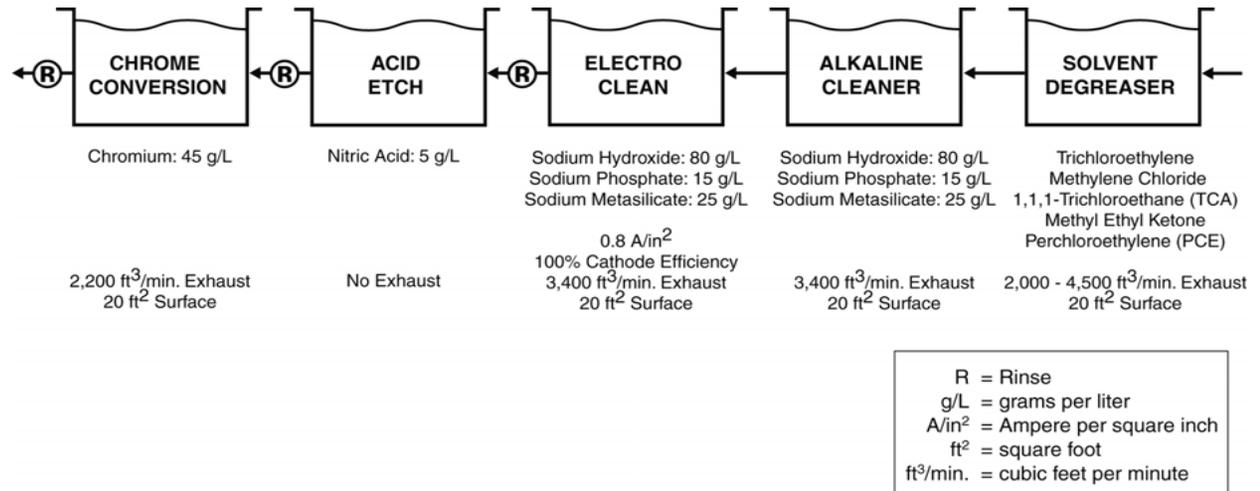


Figure 16. Chromate Conversion Coating