

MIL-HDBK-1015/2
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MILITARY HANDBOOK

CHEMICAL ENGINEERING

ELECTROPLATING TECHNICAL SYNOPSIS



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ABSTRACT

The purpose of this handbook is to assist managers responsible for Navy electroplating shop designs to select alternative process technologies. It reviews several aspects of electroplating and assesses the application of certain technology alternatives to specific plating processes commonly used at Navy facilities. The primary emphasis of this handbook is environmental factors including: in-process controls to minimize hazardous waste generation and water use, end-of-pipe treatment alternatives, space and logistic considerations (tank layouts, shop configurations), and selected process mechanisms (tank materials, bath purification, ventilation).

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FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from these criteria in the planning, engineering, design, and construction of Naval shore facilities cannot be made without prior approval of NAVFACENGCOM HQ Code 04.

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CHEMICAL ENGINEERING CRITERIA MANUALS

<u>Criteria Manual</u>	<u>Title</u>	<u>PA</u>
MIL-HDBK-1015/1	Electroplating Facilities	HDQTRS
MIL-HDBK-1015/2	Chemical Engineering, Electroplating Technical Synopsis	HDQTRS

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CHEMICAL ENGINEERING, ELECTROPLATING TECHNICAL SYNOPSIS

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Section 1: INTRODUCTION

1.1 Scope. This handbook provides design criteria for preparing an inventory of plating processes used by the Navy (refer to Table 1); tabulating information on space and logistics, selecting process mechanics, in-process waste controls and waste treatment technology alternatives; and, preparing specific technology recommendations for most common processes used by the Navy.

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Table 1
Plating Processes at Naval Facilities

	LOUISVILLE, KY NOC	NORFOLK, VA NAF	NORFOLK, VA NSY	CHERRY PT., NC NAF	YOKOSUKA NFEC	PEARL HARBOR, HI NSY	GUAM, NSRF	CHARLESTON, SC NSY	LONG BEACH, CA NSY	PENSACOLA, FL NAF
COMMON METAL PLATING										
Brass		•	•						•	
Cadmium	•	•	•	•				•	•	•
Chromium/Hard	•	•	•	•	•	•	•	•	•	•
Copper, Non-distinguished					•					
Copper, Acid					•	•	•	•		•
Copper, Cyanide	•	•	•	•	•	•				•
Decorative Chromium			•	•		•		•	•	
Lead				•				•		
Nickel, Non-distinguished				•		•				
Nickel, Chloride		•	•	•			•			
Nickel, Sulfamate		•	•	•			•	•		•
Nickel, Watts		•	•					•		
Nickel, Woods								•		
Tin				•						•
Tin/lead				•			•			
Zinc, Acid								•		
Zinc/ Cyanide		•	•		•					
PRECIOUS METALS PLATING										
Gold								•	•	
Silver, Cyanide	•	•	•	•		•			•	•
Silver, Non-cyanide								•		
ANODIZING										
Alodine				•				•	•	•
Anodizing				•						
Anodizing, Chromic			•			•		•		•
Anodizing, Sulfuric								•		•
Hardcoat, low temp.								•		
Magnesium				•						
CONVERSION AND POST TREATMENT										
Black Oxide		•	•	•				•		•
Chromating	•	•	•					•	•	•
Chromate Seal	•							•	•	

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Table 1
Plating Processes at Naval Facilities (cont)

	LOUISVILLE, KY NOC	NORFOLK, VA NARF	NORFOLK, VA NSY	CHERRY PT., NC NARF	YOKOSUKA NFEC	PEARL HARBOR, HI NSY	GUAM, NSRF	CHARLESTON, SC NSY	LONG BEACH, CA NSY	PENSACOLA, FL NARF
Copper		•						•		
Phosphating, Non-distinguished				•						
Phosphating, Hard	•									
Phosphating, Manganese	•	•	•			•		•	•	•
Phosphating, Zinc	•		•							•
Seal, Ni Acetate		•	•					•		•
Seal, Sodium Dichromate		•	•			•		•	•	
Zincate		•	•					•	•	•
ELECTROLESS PLATING										
Nickel		•		•					•	•
SURFACE PREPARATION										
Cleaning	•	•	•	•		•		•	•	•
Vapor Degreasing		•	•					•	•	•
Activation		•	•					•		•
De-Rusting		•	•					•		•
Bright Dip		•	•			•		•	•	•
Coloring			•					•	•	
Etching		•				•		•	•	
Magnesium Anodize				•						
Metal Strips										
Aluminide		•		•						
Anodize		•						•		•
Chrome		•	•					•	•	
Cadmium		•	•							•
Nickel		•	•					•	•	•
Brazed		•						•		
Non-Brazed		•								
Plasma Sprayed		•								
Paint Strip	•		•					•	•	
Passivate-Stainless		•	•	•				•		
Phosphate, Acid Pickle	•						•	•		
Polishing	•							•		

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Table 1
Plating Processes at Naval Facilities (cont)

	LOUISVILLE, KY NOC	NORFOLK, VA NARF	NORFOLK, VA NSY	CHERRY PT., NC NARF	YOKOSUKA NFEK	PEARL HARBOR, HI NSY	GUAM, NSRF	CHARLESTON, SC NSY	LONG BEACH, CA NSY	PENSACOLA, FL NARF
OTHER										
Brush Plating		•	•					•		
Diffusion, Nickel/Cadmium		•								
Metallizing		•			•	•		•		

1 Non-cyanide cadmium

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Section 2: TABULATION OF TECHNOLOGY ALTERNATIVES

2.1 General

- a) Space and logistics.
- b) Selected process mechanics.
- c) In-process waste control.
- d) End-of-pipe treatment.

2.2 Space and Logistics. The location of a plating shop in a Navy facility and its layout depends upon available space, number and type of processes, size and volume of work, and relationship to other manufacturing operations in the facility. There are no standard shop designs that fit all situations because the requirements and functions of a plating shop are varied. In general, the plating shop should be located convenient to the manufacturing operations in which the parts to be plated are worked. If the location of the plating shop does not affect work flow, the shop should be located convenient to utilities, ventilation, sewer collections, Industrial Wastewater Treatment Plant (IWTP), or other peripherals.

2.2.1 Shop Configurations. The major design elements to be considered in configuring a shop are as follows:

- a) Areas receiving material to be plated.
- b) Systems to transport materials to and within plating departments.
- c) Plating shop layout including racking/unracking, plating and rectifier areas.
- d) Ancillary plating areas for filtration, stripping, solution maintenance, and rack, anode, and chemical storage.
- e) Support areas for laboratory, offices, inspection, lockers, lunchroom, and restrooms.
- f) Utilities including power, water, and waste treatment.

Small errors in the design and location of support and staging areas have subtle impacts on production efficiency, but they can be as dramatic as more obvious errors such as missizing equipment or misapplying a process. For example, moving materials is time consuming, may require special handling equipment and, as a result, is costly. Therefore, plants should be configured so that all materials; process chemicals, racks, anodes, and parts to be plated can be handled as infrequently and as quickly as possible.

2.2.2 Tank Layouts. Military plating shops often differ from private industry shops in the greater variety of processes that they provide including many which are highly specialized and used infrequently. Military shops are mostly manual operations with some use of motor driven trolley hoists and

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overhead crane systems. Commercial industry shops are either captive (for example, automobile manufacturers that plate their own parts) or job shops that sell metal finishing services. The captive shops generally have only a few heavily used processes and most are fully automated. The job shops usually offer a greater number of processes than captive shops. Some job shops have automated process lines; however, most are manual or semi-manual operations. The number and type of processes, tank sizes, and production volumes all impact on how a plating shop should be configured.

Navy plating shops should be designed to facilitate moving work and other materials to and from the plating area. Likewise, the tanks in the plating areas should be arranged to streamline work flow. Although the alternatives for tank configuration are limited only by imagination, there are four basic designs. The advantages and disadvantages of each are briefly reviewed in paras. 2.2.2.1 through 2.2.2.4. Examples of several existing Navy plating shop configurations are contained in Appendix A.

2.2.2.1 Common Well Configuration. In this layout, cleaning and post treatment for all plating is done in common tanks as shown in Figure 1.

a) Advantages:

- (1) Efficient for small work volumes to each of several plating processes.
- (2) Applies to processes with long plating, as opposed to cleaning times, such as hard chrome, anodizing, copper, zinc, cadmium, and jewelry plating.
- (3) Minimizes walking.
- (4) Bath maintenance can be consolidated.
- (5) Easy to supervise production.

b) Disadvantages:

- (1) Inefficient at high production levels (not easy to use hoists and monorails).
- (2) Floor drippings can be a significant pollution source.

2.2.2.2 Common Well Configuration Plus Transfer. At higher production levels the common well configuration loses its efficiency. However, the advantages of the layout can be retained and others added by using a transfer station to route parts to and from the plating tanks as shown in Figure 2.

a) Advantages:

- (1) Higher volumes of work can be processed.
- (2) Floor drippings are less likely.
- (3) Can be automated.

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- (4) Minimizes walking.
- (5) Bath maintenance can be consolidated.

b) Disadvantages:

- (1) Since the cleaning steps control work flow, use of the plating tanks can be suboptimal.
- (2) Requires close production supervision to keep up work flow.

2.2.2.3 Straight Line Configuration. For intermediate and high production levels, each plating process usually has its own cleaning and post treatment tanks. The simplest configuration is a straight line. However, many Navy shops have too many different processes to allow for dedicated cleaning and post treatment. In such cases, an arrangement similar to the San Diego NARF can be used (refer to Appendix A).

a) Advantages:

- (1) Increased productivity.
- (2) Can be adapted to a hoist.

b) Disadvantages:

- (1) Staging/support areas cannot always be located conveniently.
- (2) Tanks can be designed to minimize walking (e.g., built long, narrow), but they often lead to quality problems such as variation in plating thickness as well as difficulties with temperature, filtration, and agitation control.

2.2.2.4 Circle Configuration. For high volume finishing processes, a loop or circle configuration is the most efficient. Figure 3 illustrates circle configuration tank layout. Support and staging areas are located convenient to the plating line configuration.

a) Advantages:

- (1) Appropriate for high production plating.
- (2) First and last process tanks are closer than in straight line layout which reduces walking.
- (3) Can be automated.
- (4) Can be dedicated to more than one metal finish by putting process tanks on runners.
- (5) Staging areas can be located conveniently.

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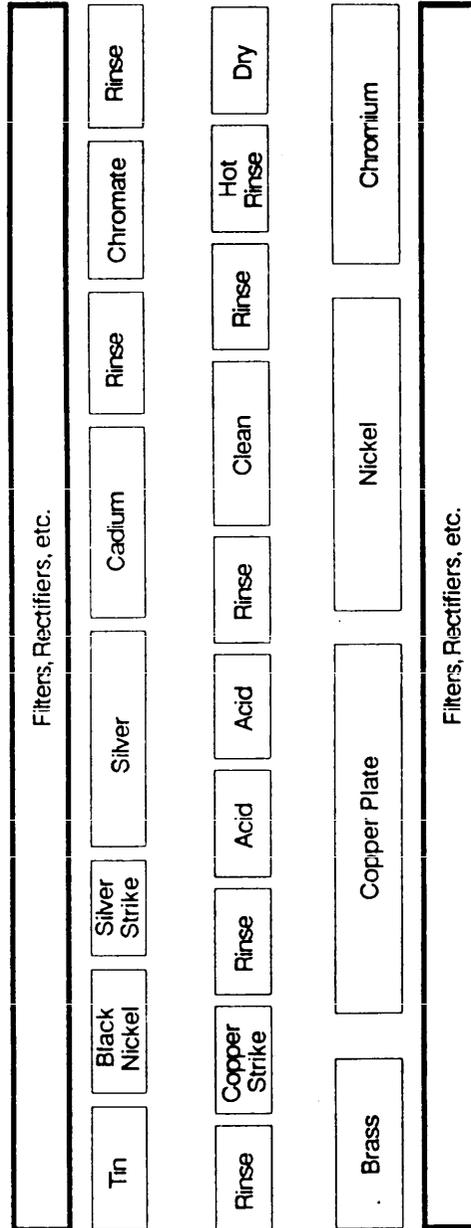


Figure 1.
Common Well Tank Layout

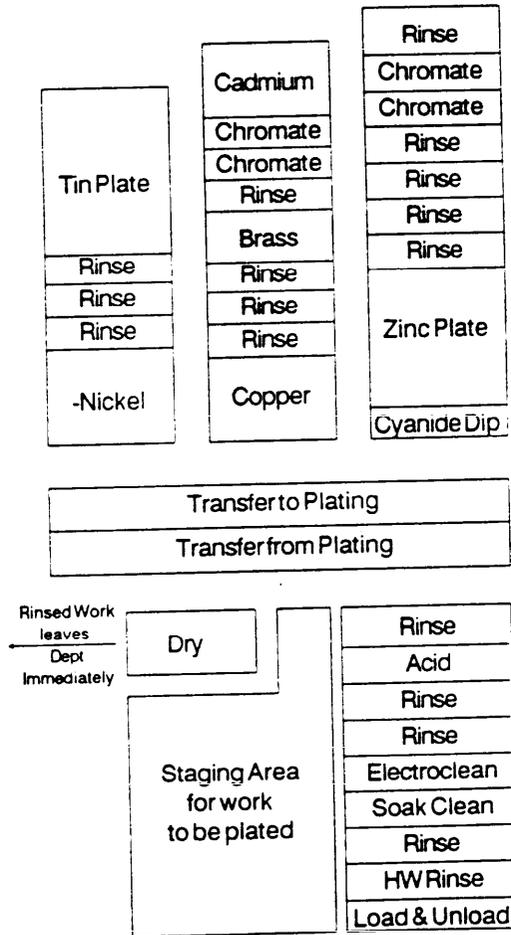


Figure 2
Common Well Plus Transfer Tank Layout

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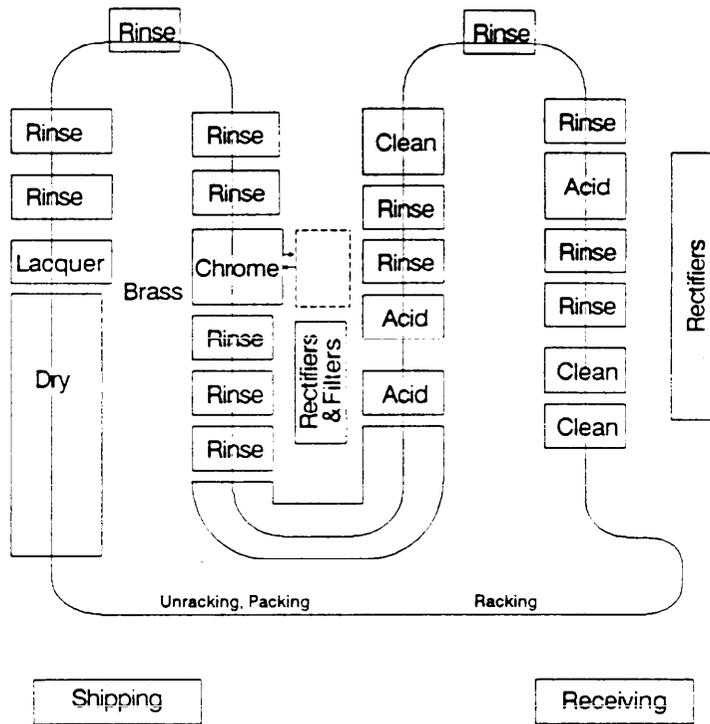


Figure 3
Big Circle Tank Layout

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b) Disadvantages:

(1) Only one metal finishing process can be operated at a time.

(2) Difficult to change tank locations or orientations.

2.3 Selected Process Mechanics. Paras. 2.3.1 through 2.3.4 specify process mechanics alternatives for tank construction materials, tank linings, bath purification and ventilation.

2.3.1 Tank Construction Materials. The basic requirement of a plating tank is to hold its contents without leakage or contamination. Accordingly, the material of construction must be resistant to the process solution, unless a lining is used, in which case the lining must be resistant.

In the past, plating tanks were made of wood. Currently, the common materials of construction are fiberglass, plastic, steel, and stainless steel. The decision to use one material versus another hinges on the application. Plastic tanks are chemically resistant and light weight but are limited in application by temperature. Large plastic tanks must be reinforced for added strength. Steel tanks are stronger than plastic but they can carry stray currents, and iron and other metals leach out from the steel in acid solutions which contaminate the process. As a result, lined steel tanks are very common in the industry.

2.3.2 Tank Linings. Linings come in several forms including sheet linings, tank liners, liquid applied linings, and tank sheathings. Materials used for linings include rubber, thermoplastics, thermosetting resins, and metallics (stainless steel and lead). Table 2 compares the applications and limitations of the commonly used construction materials.

2.3.3 Bath Purification. Table 3 reviews the bath purification alternatives available to plating facilities. The alternatives range from physical removal to chemical treatment and each has specific advantages, disadvantages and applications.

2.3.4 Ventilation. Among the most critical safety needs of a plating shop is proper ventilation to protect workers from potentially toxic or dangerous concentrations created in the workroom. Table 4 assesses ventilation alternatives covering air supply, exhaust air, ducting, fans, and air pollution control.

2.4 In-Process Waste Control. The capital cost of standard end-of-pipe equipment to treat electroplating wastewater depends upon the volume of water being treated. To reduce this cost, platers have used techniques to lower rinsing rates without affecting plating quality. The operating costs of standard end-of-pipe treatment equipment depends upon the amount of contamination in the wastewater; therefore, platers have turned to methods to reduce the drag-out from process baths to the rinse tanks. Rinse rate reduction and drag-out techniques can minimize the cost of wastewater treatment. If fully applied across plating processes, they enable some facilities to avoid end-of-pipe waste treatment altogether. The in-process

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technologies to control waste generation discussed in paras. 2.4.1 through 2.4.2.3 are state-of-the-art for plating shops. General in-process pollution controls such as process substitution and bath purification are important waste reduction methods. These applications are reviewed in Table 5.

2.4.1 Water Reduction Methods. Refer to Table 6. Water reduction methods are divided into four parts as follows:

- a) Proper rinse tank design and operation.
- b) Water- and waste-reduction methods.
- c) Drag-out controls.
- d) High technology applications.

2.4.1.1 Proper Rinse Tank Design and Operation. The measures described in this paragraph apply to all waste control programs for electroplaters. All rinse tanks should be properly designed and should contain the equipment described below. Figure 4 illustrates a properly designed rinse tank.

a) Rinse Tank Features. A properly designed rinse tank should be supplied with water from a distribution pipe or sparger at the bottom of the tank. Fresh water enters the tank through holes drilled in the pipe at 3 in. (76.2 mm) intervals. The incoming water creates a rolling action to help scour the work clean, and the entire tank volume dilutes the drag-out. A dam-type discharge also improves rinsing. The tank shown in Figure 4 has both of these features.

b) Flow Control Devices. At many plating shops the personnel use more water than is necessary to adequately rinse parts. Mechanical flow control valves aid in solving this problem by restricting the amount of water that can be introduced to a rinse tank. Mechanical flow controls maintain a specified flow rate independent of the valve setting. The controls, which can be used with single or countercurrent rinses, remove the control of rinse rates from the operator, and water is not wasted. Flow controls are rated in 1/2 gallons per minute (gpm) (1.892 L/min) intervals. Most plating applications require valves in the 0.5 to 5 gpm (1.892 to 18.925 L/min) range. Mechanical flow control valves are cheap and apply best to rinse tanks in frequent use.

Alternatively, electronic controllers that regulate rinse rates based on the conductivity of the rinse water are also marketed. However, they are expensive, sensitive to operate, require maintenance, and, for most applications, are not much more effective than mechanical valves in reducing water use. They are not recommended for most Navy applications.

An alternative device to conductivity controls is the timer rinse control. This device consists of a flow control, solenoid valve, timer relay, and pushbutton or foot switch. When a part is lowered into a rinse tank the plater pushes a start button which activates the timer relay and opens the solenoid valve. The valve automatically closes when the timer cycle is complete. This device delivers an exact volume of water to the rinse tank. This volume can be accurately selected by the size of the flow control and the timer setting.

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Table 2
Plating Tank Construction Materials

Process	Temperature of	Materials for self-standing tanks					Linings for self-standing tanks (steel)				
		Steel	Stainless steel	Fiberglass	Poly-ethylene	Poly-propylene	Polyvinyl chloride	Rubber semi-hard	Synthetic rubber	Lead	Plastisol
Pre-treat											
Alkaline cleaning • •	Ambient	S	S ₁	S	S	S	S ₁	S	S	U	S
	Up to 150	S	S ₁	S	S	S	S ₁	S	S	U	S ₁
	Over 150	S	S ₁	S	S	S	U	U	S	U	U ₁
Mariatic acid - 50% • •	Ambient	U	U	S	S	S	S	S	U	U	U
	Up to 150	U	U	S	S	S	S	S	U	U	U
	Over 150	U	U	S	S	S	U	U	U	U	U
Sulfuric acid - 20% • •	Ambient	U	U	S	S	S	S	S	S	S	S
	Up to 150	U	U	S	S	S	S	S	S	S	S
	Over 150	U	U	S	S	S	U	U	S	*	
Nitric acid - 50% • •	Ambient	U	S	S ₂	U	S	S	U	U	U	U
	Up to 150	U	S	S ₂	U	S	S	U	U	U	U
	Over 150	U	S	S ₂	U	U	U	U	U	U	U
Chemical treat											
Chromate dips	Ambient	U	S	S	S	S	S	U	U	S	S
Phosphating •	Up to 160	U	S	S ₂	S	S ₂	U	*	*	U	*
	Over 160	U	S	S ₂	S	S ₂	U	*	*	U	*
Black oxide	Over 250	S	S ₁	U	S	U	U	U	U	U	U
Electro-process											
Cyanide plating Acid Chloride Nickel Chromium	Up to 150	S	S ₁	S	S	S	S	S ₂	*	U	S
	•	U	U	S	S	S	S	S ₂	*	S	S
	•	U	U	S	S	S	S	S	*	U	S
	•	U	U	S	S	S	S	S	*	U	S
	•	U	U	S	S	U	S	U	U	S	S
Chromic anodizing Sulfuric	Ambient	S	S ₁	S ₂	S ₁	S ₂	S ₁	U	*	U	S
	32-75	U	U	S	S	S	S	S	S	S	S ₁

S = satisfactory
S₁ = satisfactory but not necessary
S₂ = check with supplier
* = no data
U = unsatisfactory

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Table 3
Process Mechanics: Bath Purification

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(1) FILTRATION (BATCH AND CONTINUOUS)	<p>Continuous filtration recommended for Cu, Ni ZnCN, Zn Acid</p> <p>Batch filtration recommended for Cd, Zn Cn</p>	<p>Prevents deposit roughness</p> <p>Provides high covering power with less chance of burning</p>	<p>High initial cost</p> <p>Batch filtering requires process shut down</p>	<p>Flow rates 25-50 gal./sq. ft./hr. for Cr, Ni, Cu</p> <p>Flow rates 15 gal./sq. ft., hr. for Cd, Zn</p> <p>Filter media: polypropylene for Cr, Cu, Ni, Cd, Zn</p> <p>Micro porosity: 15 for Cr, Cu, Ni, Zn, 30 for Cd</p> <p>Use carbon treatment with Cu, Ni, Zn</p> <p>Safe operating ranges for carbonate:</p> <p>Cd: 3-5 oz./gal. Zn: 4-10 oz./gal. Cu: 3-5 oz./gal. Ag: 4-10 oz./gal.</p> <p>Temperatures for freezing are specific to each type of solution</p>
(2) CHEMICAL TREATMENT FOR CARBONATE REMOVAL	CN plating solutions	<p>Prevents dumping of contaminated solutions</p> <p>Improves plating quality</p> <p>Does not require special equipment</p> <p>Reduces viscosity and therefore drag-out</p>	<p>Labor intensive</p> <p>Requires frequent chemical analysis</p> <p>Must filter out carbonate and dispose</p> <p>Requires process shutdown</p>	
(3) FREEZING TO REMOVE CARBONATES	CN plating solutions	<p>Prevents dumping of contaminated solutions</p> <p>Improves plating quality</p> <p>In color climates, freezing can be accomplished without cooling equipment</p>	<p>Requires cooling equipment in warmer climates</p> <p>Labor intensive</p> <p>Requires frequent chemical analysis</p> <p>Must dispose of residual</p> <p>Requires extended process shut down</p>	

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Table 3 (Cont.)
ProcessMechanics: Bath Purification

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(4) DUMMYING (BATCH)	Use with hard Cr, Ni, Cu to remove trace metal Use with hard Cr to reoxidize Cr (+3)	Low cost Can be performed in plating tank	Causes process interruption Requires knowledgeable operator	High rate of agitation is desirable Close anode to cathode spacing
(5) ELECTROLYTIC UNITS (CONTINUOUS)	Use with hard Cr to remove trace metals and Cr (+3) Especially useful with closed loop rinsing	Highly effective Maintain low concentration of cationic impurities Does not require process shut down	High initial cost Difficult to clean Requires maintenance Requires additional floor space	One unit can generally serve two hard Cr tanks

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Table 4
Process Mechanics: Ventilation

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(1) SUPPLY AIR	Replaces contaminated air removed by exhaust Required on all ventilation systems	Does not require any ducting	Generally inadequate supply of infiltration air Creates large negative pressure in building May cause hazardous cross drafts	Defeated by energy conservation measures such as weatherstripping and limited access
(a) Infiltration Air				
(b) Replacement Air (RA)		Maintains only slight negative (0.05-0.10 in water gauge) pressure in building Ensures adequate air flow	Can reduce efficiency of local exhaust hoods Requires additional duct-work and hood	FIA should supply 90% of total air flow with remaining 10% supplied by infiltration
(2) EXHAUST AIR	Removes toxic fumes from work station Must have adequate flow for given conditions of vapor concentration			Minimum velocity of 125-225 FPM required

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Table 4 (Cont.)
Process Mechanics: Ventilation

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(a) Push-pull/ Lateral Hood	Tanks without surface obstructions	Does not obstruct work area over tank	Lateral hoods do not enclose or confine contaminants	Quantity of air pushed should be 10% of that pulled
(b) Pull-Pull/ Lateral Hood	All tanks with ventilation systems	Low exhaust volume Does not obstruct work area over tank	Easily upset by cross drafts Large fume removal volumes	Pushed air supply should be approximately 1000-2000 FPM
(c) Enclosing Hood or Canopy Hood	Only tanks not requiring open space over working area	Not easily upset by cross drafts Minimizes fume removal volume Encloses or confines contaminants	Does not enclose or confine contaminants Blocks work areas over tank	Should be of rigid construction
(3) DUCT WORK	Connects supply air and exhaust air hoods with respective blowers and air supply/exhaust areas			Should be of non-metal construction for corrosion resistance Should have blast gates to permit balancing of air flow Should be sloped for drainage Should have adequate access parts for inspection/cleaning

Table 4 (Cont.)
Process Mechanics: Ventilation

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(5) POLLUTION CONTROL				
(a) Mist Eliminator	Hard chromium plating exhaust	Eliminates mist from exhaust air Returns condensed mist to plating bath Requires no additional equipment	May cause need to increase exhaust blower capacity by causing pressure drop	Should be located in vertical duct above plating tank Should be designed for corrosion resistance
(b) Fume Scrubber	Chromium and cyanide plating exhaust	Eliminates mist or vapor from exhaust air	Generates wastewater which must be treated Requires support equipment such as pump, water supply tank, etc.	Should be designed to provide adequate air to water contact Should be designed to eliminate mist from exhaust air

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Table 4 (Cont.)
Process Mechanics: Ventilation

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES	DESIGN CONSIDERATIONS
(4) FAN				
(a) Centrifugal with backcurved blade	Relatively clean air with no condensible fumes or vapors	High tip speed High efficiency Non-overloading	Blade shape conducive to buildup of contaminants	Should have protective coating in corrosive applications Should be belt driven
(b) Centrifugal with forward curved blade (squirrel cage)	Applications with low to moderate static pressures	Low space requirements Quiet operation	Not recommended for dust or fumes where a high static pressure scrubber is used	Should be belt driven
(c) Axial propeller fan	General ventilation	Capable of moving large volumes of air	Limited to low pressure	Should be belt driven in plating shops Materials of construction should provide corrosion resistance Should be belt driven
(d) Axial vane or tube fan	General ventilation	Capable of moving large volumes of air Capable of generating high pressures		

Table 5
General Waste Reduction Technologies Advantages

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(1) GENERAL	Some waste reduction technologies can only be applied to certain processes, others are applicable to all processes	<p>Most have low initial and operating costs</p> <p>Provide a high rate of return on investment</p> <p>Reduce the mass of pollutants treated at the IWTP*</p> <p>Reduce hazardous sludge generation at the IWTP</p> <p>Reduce process chemical usage by returning chemicals to baths</p> <p>Technologies are widely applied and well proven</p>	<p>May require changes to shop layout and reduce available floor space</p> <p>May require additional labor to operate and maintain</p> <p>May concentrate bath impurities and require more frequent purification</p>
(2) BATH PURIFICATION	<p>Utilized to minimize dumping of spent plating baths</p> <p>Includes: filtration, chemical treatment, carbon treatment, phy./chem. treatment & electrolytic treatment**</p> <p>Applicable to most plating solutions</p> <p>Not applicable to cleaning solutions</p>	<p>Reduces generation of hazardous waste</p> <p>Improves plating quality and speed</p> <p>Reduces amount of rejected work</p>	<p>Required capital investment</p> <p>Often labor intensive</p> <p>Often generates hazardous sludge at plating shop</p>
(3) CONTROLLING CHEMICAL COMPOSITION OF PLATING SOLUTIONS	<p>Minimizing plating chemical concentration of all baths</p> <p>Minimizing carbonate conc. of CN baths</p>	<p>Reduces viscosity of bath and therefore drag-out volume</p> <p>Lowers metals and CN conc. of drag-out</p> <p>Increases consistency of plating quality</p>	<p>Requires frequent analysis of solutions</p> <p>Requires frequent bath additions</p>

*IWTP is industrial waste treatment plant

**For specific information on each method is refer to para 2.3

Table 5 (Cont.)
General Waste Reduction Technologies Advantages

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(4) USE OF SPENT PROCESS SOLUTIONS AS TREATMENT CHEMICALS AT IWTP	Only applicable to spent acid dips and alkaline cleaners	Reduces waste hauling charges Reduces usage of treatment chemicals	Increases chemical handling Reduces control of treatment process at IWTP
(5) PROCESS SUBSTITUTING			
(a) Acid Copper Plating Solution	Replaces CuCN solution, except direct deposit on zinc and steel	Simple waste treatment Low chemical cost Bath composition is not critical High anode to cathode efficiencies Tolerates higher current densities than CN bath	Yields only 1/2 as much copper per unit electricity as CN bath
(b) Acid Zinc Plating Solution	Replaces ZnCN	Simple waste treatment Produces good deposits Plates on cast iron and malleable iron parts Operates at high current densities High conductivity Minimal hydrogen embrittlement	Bleedout of entrapped solution may occur Poor ductility on thicker deposits Filtration and cooling coils required
(c) Two Bus Bar Hard CR Plating	Replaces conventional hard CR process	Improves plating quality & speed High operating temp. increases evaporation and recovery Improved racking and masking methods reduce labor requirements	Requires retraining of employees

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Table 6
Water Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(1) RINSE TANK OPERATIONS (a) Tank Aeration	Applicable to all rinses except rinses w/high conc. of volatile acid	Increases rinsing efficiency and hence reduces water needs Does not require operator attention No maintenance	Requires air supply Cannot provide major water savings unless it is used in conjunction w/other water reduction methods
(b) Rinsing Over Bath	For use w/large parts suspended by a hoist (e.g., hard Cr) Limited to baths w/high evaporation rates (e.g., Reversible rack, hard Cr)	Provides direct recovery Can provide zero discharge from hard Cr and Ni plating	High pressure spray could cause housekeeping problem Could reduce effectiveness of rinsing and result in surface corrosion of plated part
(c) Drain Boards and Drip Guards	Catches drips from parts after plating, during transfer to rinse tank Only applicable when rins tanks are located next to process solutions	Keeps drag-out from dripping on floor and entering sewer Easy installation No maintenance or operator attention	No specific disadvantages
(2) FLOW CONTROLS (a) Conductivity Cells	Applicable to single rinse tanks Suited to intermittent production	Major water savings in high intermittent operations Assures consistent rinse quality Saves floor space, since only single rinse tank is needed	High initial cost Often misused by operators Little savings over flow regulations at high production
(b) Flow Regulators	Applicable to all rinses	Inexpensive (\$10 per tank) Easy installation Low maintenance Available in wide range of flow rates (0.25 GPM minimum)	Provides major water savings only when used in conjunction w/other water reduction methods (e.g., countercurrent rinsing)

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Table 6 (Cont.)
Water Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(c) Timer Rinse Control	Applicable to any single rinse tank	Major water savings Saves floor space since only single rinse tank is needed Low maintenance Simple operation	Requires operator cooperation High initial cost
(3) RINSING ALTERNATIVES			
(a) Spray Rinse	Most applicable for parts w/out hidden surfaces Recovery possible for process solutions above 140° F	Major water savings Can be automated for zero discharge Demonstrated at several navy shops w/hard Cr plating	Drag-out cannot be completely removed from hidden surfaces Requires education of operator to work effectively Requires maintenance of pumps and valves
(b) Countercurrent Rinsing	Applicable to all rinses	Major water reduction No maintenance necessary Can be utilized in conjunction w/other water reduction measures (e.g., flow regulators, reactive rinsing)	Requires two or more rinse tanks Requires extra rinsing step Operators may skip rinse steps
(c) Drag-In/out Rinsing	Intended for use w/low temperature baths	Recovery of plating solution Reduces use of rinsewater	Requires two or more rinse tanks Can slow production

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Table 6 (Cont.)
Water Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(d) Reactive Rinsing	Reuse rinsewater/e.g. acid dip rinsewater fed to alkaline cleaner rinse or to last rinse in the process Applicable to single or multiple rinse	Major water savings at very low cost Can improve rinsing efficiency Rinse water can be used several times across production lines Normal head pressure can be used to route some rinsewaters Inexpensive pumps can be used to route remaining rinsewaters	Potential for cross contamination of solutions Requires additional plumbing

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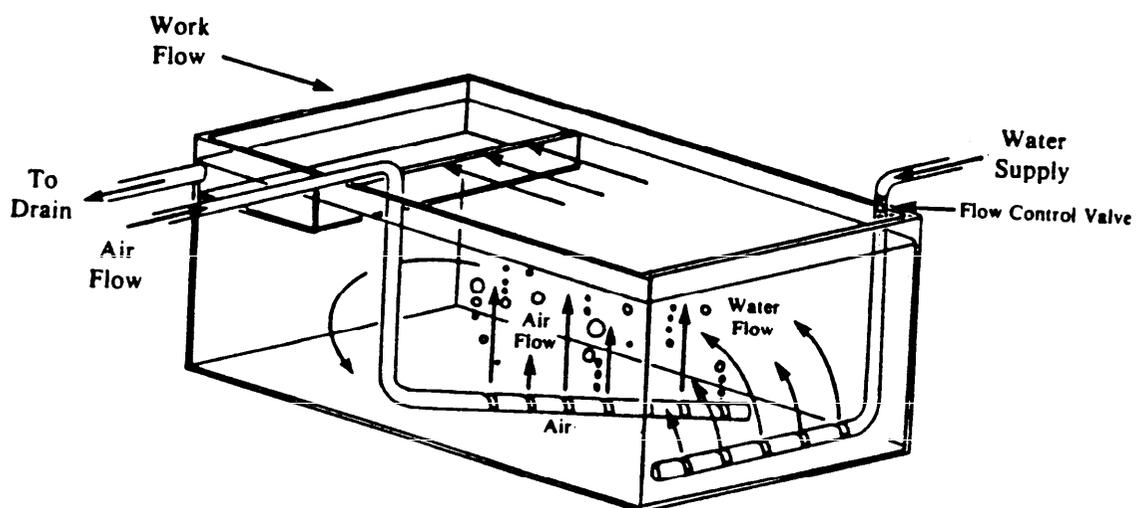


Figure 4
Proper Rinse Tank Design

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A major advantage of the timer control is that water is used only when needed; idle rinse tanks have zero flow. Timer control is best suited to shops with intermittent and uneven work flow as found in most Navy shops.

c) Air Agitation. The effectiveness of rinsing can be improved by agitating the water in the tank. Too often this is accomplished by high rinsing rates, which is wasteful. Air agitation is an alternative to that practice. Air bubbles introduced into the rinse tank help to dislodge the plating solution from the work piece. The amount of air required depends upon the surface area of the tank. The bubbles materially improve the rinsing efficiency of each unit of water by increasing agitation. Air is generally supplied from a low pressure blower and introduced through a pipe distributor which is located diagonally across the bottom of the tank (see Figure 4). A low pressure blower can serve several rinse tanks at low cost.

d) Longer Drainage Periods. Allowing work pieces to drain into the plating solution for longer periods of time will reduce drag-out losses. As more plating solution drains from the work piece while it is suspended over the plating tank, less contamination gets into the rinse water. A drip bar can be stationed over the plating tank so that the platers can hang the work pieces and racks on the bar and increase draining time. The bars can be fabricated easily in the plating shop by welding support legs onto the sides of the rinse tanks. A drip bar should not be used where it presents an obstruction to work flow.

2.4.1.2 Water Conservation Through Countercurrent Rinsing. Electroplaters have long reduced water use by employing several rinse tanks connected in series. Fresh water flows into the rinse tank located farthest from the process tank and overflows, in turn, to the rinse tanks closer to the process tank. This technique is called countercurrent rinsing because the work piece and the rinse water move in opposite directions. In time, the first rinse becomes contaminated with drag-out and reaches a stable concentration which is lower than the process solution. The second rinse stabilizes at an even lower concentration which enables less rinse water to be used than if only one rinse tank were in place. The more countercurrent rinse tanks (three-stage, four-stage, etc.), the lower the rinse rate needed for adequate removal of the process solution.

a) Benefits. The rinse rate needed for adequate cleaning is governed by an exponential equation that depends on the concentration of contaminants in the drag-out, the amount of contamination that can be tolerated in the final rinse tank before poor plating results, and the number of countercurrent rinse tanks. As a rule of thumb, each added rinsing stage enables the rinsing rate to be reduced by 50 percent. Typically, a single rinse runs at 4 gpm (15.14 L/min), a double countercurrent rinse at 2 gpm (7.57 L/min), and a triple countercurrent rinse at 1 gpm (3.785 L/min).

b) Drawbacks - Countercurrent rinsing systems are not without drawbacks. They are expensive. The cost of a counterflow rinse tank depends on the number of rinse tanks and their size. Another problem with counterflow rinsing is space limits. The application of counterflow rinsing requires extra room to install additional tanks; this creates additional problems since many platers are already working in cramped quarters. The added rinsing can slow production; this is not usually a significant problem because rinsing is not the slowest production step.

water containing nickel salts and other process additives. Accordingly, the drag-in from the acid rinse tank will partially replenish process chemicals in the nickel tank. This is an example of reactive rinsing. Nickel rinse water does not harm the rinsing step after the acid bath, and it helps to conserve chemicals in the nickel plating tank and the fresh water feed line to the acid rinse tank can be turned off to save several gallons of water per minute.

2.4.1.5 Improving Rinsing Efficiency Through Reactive Rinsing. A good example of how the technique can be used to improve rinsing efficiency is also illustrated in Figure 5. Cleaner solutions are alkaline -- soapy and, therefore, difficult to rinse. Therefore, platers use large volumes of water to rinse cleaning solutions; they depend on the subsequent acid solutions to neutralize any cleaners still clinging to the work. This reduces the useful life of the acid baths, increasing chemical use and waste handling of spent acid baths.

With reactive rinsing the acid rinse tank discharge is fed to the cleaner rinse tank. The primary neutralization of the drag-out from the cleaning process will then occur in the cleaner rinse tank and not in the acid process tank. The parts get very well rinsed, and the life of the acid solution is prolonged. In addition, several more gallons of water are saved each minute because the fresh feed to the cleaner rinse tank can be turned off.

2.4.1.6 Cost of Reactive Rinsing Applications. Reactive rinsing is not expensive. In this example two thirds of the original flow rate was saved without purchasing any additional tanks. Some plumbing is required but it is not extensive because the feed rinse tanks can be elevated slightly in order to gravity flow rinse water to the receiving rinse tank.

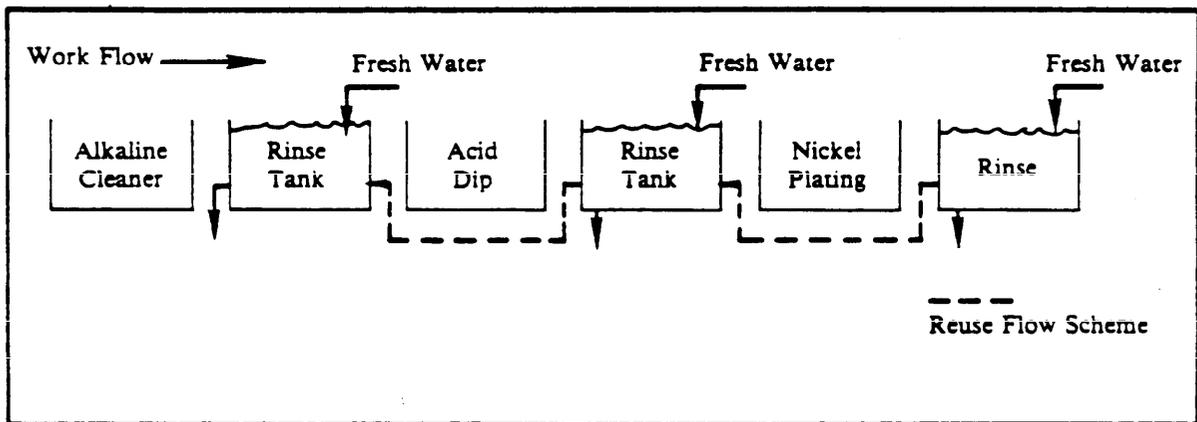


Figure 5
Intraprocess Reactive Rinsing

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In this example, the nickel rinse would be raised an inch or two above the acid rinse, which in turn would be raised above the cleaner rinse. If it is not practical to elevate the tanks, then inexpensive submersible pumps can be used to move the rinse water.

In some plating shops rinse water is reused several times across processes. Figure 6 illustrates the reuse scheme used in one facility. Sensible reactive rinsing schemes dramatically reduce water use and water costs at plating shops. One shop reduced rinse rates from 140,000 to 40,000 gallons per day (gpd) (529,900 to 151,400 L/d) using reactive rinsing across processes without adding to plating bath contamination. The reuse of rinse water must be approached carefully. While cleaning lines and the final rinse tank of a process are always candidates for reactive rinsing, plating rinse waters cannot be reused at random because of the danger of cross contamination.

2.4.2 Waste Reduction Methods. Table 7 examines the technologies discussed in paras. 2.4.2.1 through 2.4.2.3. They are designed to capture plating metals in the drag-out before being flushed in the rinse tank. The drag-out solution can be either recycled, recovered, or chemically treated separately. In some shops, end-of-pipe can be avoided entirely using these methods. The high cost of treating rinse water is eliminated, there is no waste treatment sludge to manage (another high cost), compliance violations caused by malfunction of the end-of-pipe equipment is avoided, and process chemicals are saved. In shops where end-of-pipe controls are still needed, these methods still save money from process chemical conservation and reduced pollution control operating costs.

2.4.2.1 Single Drag-out Tanks. Platers can use a stagnant rinse tank to capture drag-out before the plated parts are cleaned in running rinses. The stagnant or drag-out rinse tank is initially filled with fresh water. Work pieces are rinsed in this tank immediately after processing, and much of the process solution is captured before the piece is cleaned in the running rinse. As a result, the amount of pollution in the firm's discharge is reduced considerably.

In time, the contaminant concentration in the drag-out tank will increase until it no longer effectively captures process solution. When this occurs or before it occurs, the drag-out solution must be replaced with fresh water and the cycle begun again. The discarded drag-out solution is potentially a hazardous waste problem.

For some processes, the drag-out solution can be recycled back to the plating process where it will no longer be a waste treatment problem. This is practical for heated processes such as nickel, chromium, and certain copper plating processes because evaporation in the process tank is sufficient to make room for the drag-out. Some platers use an evaporation system on the drag-out or process tank to reduce the volume enough to return drag-out to cold plating processes (such as zinc and cadmium). However, evaporative recovery is not cost effective for most Navy plating shops because plating production volumes are low. Alternatively, the metal can be recovered from the drag-out solution. For recovery methods, refer to para. 2.4.2.3.

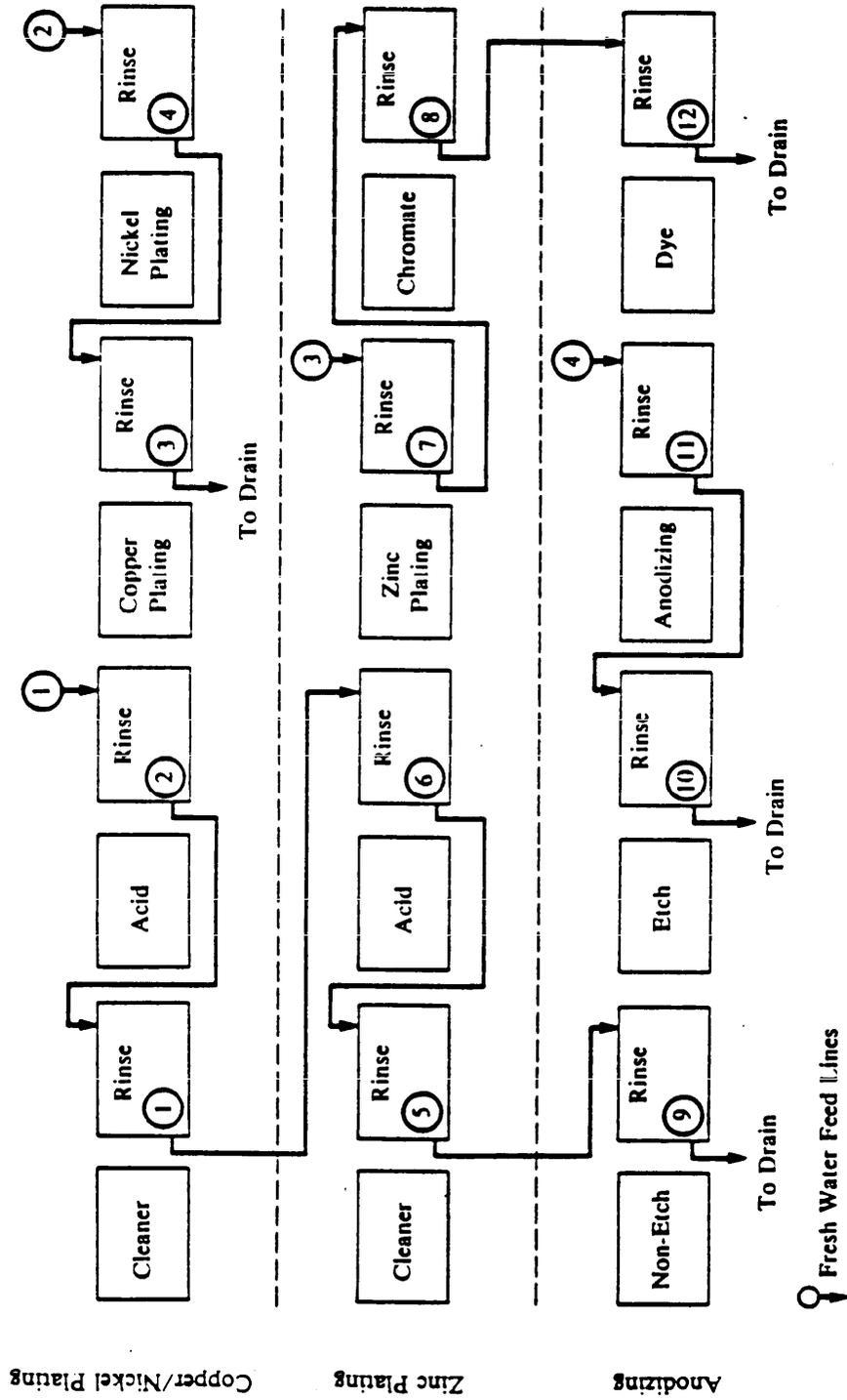


Figure 6
Example of Interprocess Reactive Rinsing System

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Table 7
Waste Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(1) GENERAL	<p>Must have significant drag-out to justify purchase</p> <p>Systems available for most types of plating baths</p>	<p>Most will recover plating chemicals and reuse water</p> <p>Moderate capital and low maintenance costs for some units</p> <p>Can reduce or eliminate generation of hazardous waste</p>	<p>High capital and operating costs for some units</p> <p>Often requires large floor space</p> <p>May concentrate bath impurities</p> <p>Requires segregated wastestreams</p>
(2) DRAG-OUT TANKS (a) Still Rinse	<p>Applicable to all process solutions above 104°F</p> <p>Need concentration technology (e.g., evap.) for cold solutions unless solution is batch treated</p> <p>Not applicable to cleaning lines</p>	<p>Can recover 75% or more of drag-out</p> <p>Reduces use of rinsewater</p>	<p>Requires two or more rinse</p> <p>Concentrates bath impurities</p> <p>Concentration technologies, if needed, add to costs</p>
(b) Multiple Still Rinses	<p>Same as above</p>	<p>Increased recovery uses no more than counter flow rinsing</p>	<p>May need space for additional tanks</p>
(3) HIGH TECHNOLOGY CONTROLS (a) Electrodialysis	<p>Applicable to Cd, Zn, and Ni plating</p> <p>Not applicable to Cr</p>	<p>Units are compact</p> <p>Only utility required is DC power supply</p> <p>Low operating cost</p>	<p>Feed stream must be free of particulates</p> <p>Requires concentrated feed stream</p> <p>Requires periodic membrane cleaning, replacement</p> <p>Not widely applied in the field</p>

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Table 7 (Cont.)
Waste Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(b) Electrolytic	Applicable to Ag, Cd, Zn, Sn, and Cu plating	Some units recover metal and avoid hazardous waste generation	Requires concentrated feed stream
	Limited success with Ni	Some units destroy cyanide	Some units generate sludge requiring disposal
(c) Evaporation	Not applicable to Cr	Metal recovered is usually in elemental form	
	Can be used with some plating strip processes	Process is well understood by platers	
	Applicable to all common plating solutions	Wide variety of design configurations to suit site specific needs	Most units require a source of energy
(d) ION Exchange	Applicable to all plating processes including Cr and Ni	Application of low pressure blowers have advanced field	Requires concentrated feed stream
		Low capital cost	Some units require source of cooling water
		Applicable to dilute feed streams	Requires periodic regeneration and replacement of resin
			Requires storage/handling of hazardous chemicals
			Feed stream must be free of particulates
			Feed stream must be free of organic contaminants
			Some units require subsequent treatment/disposal of spent regenerant solutions
			Requires extensive maintenance

Table 7 (Cont.)
Waste Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(e) ION Transfer Membranes	Applicable only to hard Cr plating	May be used as a bath purification technology	Evaporator sometimes required to complete recovery process Generates a small quantity of hazardous sludge requiring disposal
(f) Reverse Osmosis	Applicable only to Ni, Zn, and Cu plating	Most systems are mechanically simple	High capital and operating costs Requires concentrated feed stream Feed stream must be free of particulates Most systems are open-loop and do not eliminate end-of-pipe treatment Requires frequent maintenance

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If the drag-out solution cannot be recycled, or recovered through high technology controls then a small batch treatment system may be an economical alternative if it will enable the facility to avoid end-of-pipe treatment of the rinse waters. If end-of-pipe treatment is still necessary, there is no advantage to drag-out controls on nonrecoverable or recyclable drag-out solutions.

2.4.2.2 Multiple Drag-out Tanks. Controlling the amount of plating solution that is dragged from work pieces upon their removal from the process tank reduces the amount of contamination in the rinse tanks. A single drag-out tank, installed immediately following the plating process will capture some of the contamination. Two or more drag-out tanks will capture most of it.

The multiple drag-out technique is similar to counterflow rinsing, because it uses several rinse tanks. The difference is that instead of a single drag-out tank and two or more running rinses, the multiple drag-out method uses several drag-out tanks and a single running rinse. Most of the drag-out is captured in the first tank, leaving the second tank less contaminated than the first. As a result, the concentration of pollution in the discharge from the running rinse tank is lower than it would be if only one drag-out tank were used. More drag-out tanks lower the discharge concentration even further. As a rule of thumb, each drag-out tank reduces the discharge concentration by 50 percent. Accordingly, two drag-out tanks are twice as effective as one, and three drag-outs are four times as effective as one.

The concentration of pollutants in the running rinse tank does not remain constant. As pollution builds up in the drag-out tanks, it also increases in the running rinse tank. However, the more drag-out tanks used, the slower the buildup of contaminants in the running rinse. This is the principle behind multiple drag-out tanks. Using two or more drag-out tanks, the concentration of pollutants in the discharge from the running rinse tank can be controlled below effluent limits for extended periods of time. The length of time depends on five factors:

- (1) Concentration of the process solution.
- (2) Rate of drag-out.
- (3) Number and size of the drag-out tanks.
- (4) Rinse rate.
- (5) The number of rinse tanks in the plating shop.

The concentration in the drag-out tanks must be reduced eventually, or the concentration of contaminants in the rinse tank will exceed pollution control standards. Recycling the drag-out solution to the process bath is the most efficient way to control drag-out tank concentrations. An alternative is to periodically replace the solution with fresh water and chemically batch treat the drag-out. Another alternative is to turn to high technologies such as electrolytic, ion exchange, electrodialysis or evaporation (refer to para. 2.4.2.3).

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2.4.2.3 High Technology Controls. High technology waste treatment methods have some application for end-of-pipe treatment of wastewater, but are better used for reducing contamination at the plating processes. In some applications these technologies are very effective in minimizing the generation of electroplating wastes. However, some water treatment methods are expensive although prices are dropping. Some are difficult to operate because they are extremely sensitive to variations in temperature and pH, and some require frequent maintenance to run efficiently. Their application as an in-process control technique is generally limited to high production processes and to specialty plating, like gold and rhodium, and to situations in which targeted in-process controls will eliminate the need for end-of-pipe treatment. Table 7 includes a review of their application.

a) Ion Exchange. Ion exchangers create a chemical reaction between a solid resin and a fluid to interchange ions from one substance to another. Ion exchange resins are usually made from organic compounds. In electroplating processes, ion exchange units can be used to extract polluting chemicals from the drag-out tanks as the solution is cycled through the unit.

Ion exchange has several drawbacks. The primary problem is that the exchange resin must be regenerated frequently by backwashing with chemicals to remove the metals, and the backwash solution is generally a hazardous waste. Also, resins eventually lose their effectiveness and must be replaced periodically. As a result, ion exchange can be a very expensive way to eliminate a single metal from electroplating discharges.

A cationic (positively charged ion) section in the deionizer removes metals, hydrogen, and ammonium, and an anionic (negatively charged ion) section removes nonmetals such as sulfates, carbonates, and chlorides. Water discharged from the ion exchange unit is deionized and can be recycled back to the drag-out tank.

b) Reverse Osmosis. In reverse osmosis, pressure is applied to the surface of a solution (wastewater) to force pure water through a semipermeable membrane too dense to permit the passage of the contaminant. Reverse osmosis can be used on drag-out tanks in order to recirculate purified water to the drag-out tank, and, at the same time, concentrate the process solution and return it to the process tank. The use of reverse osmosis has several drawbacks:

(1) The permeable membrane may let a particular ion go through the water, while another ion may be inhibited upon the application of pressure. Thus, the desired purity would not be obtained.

(2) The membrane is extremely sensitive both to temperatures greater than 100 degrees Fahrenheit (F) (37.7 Celsius (C)) and to strong acid or alkaline solutions.

(3) The membrane requires attentive maintenance to avoid clogging by dirt and oil.

(4) At pressures over 600 psi (4137 kPa), the interior structure of the membrane deteriorates, and less permeate is allowed to pass.

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As in the case of ion exchange, reverse osmosis is an expensive pollution control method.

c) **Electrodialysis.** Electrodialysis uses electricity and semipermeable, chemically treated, plastic membranes to separate soluble minerals from water. By applying an electrical current, cations are drawn to a cathode, and anions are drawn to an anode, leaving purified water in a center cell. Electrodialysis units are difficult to maintain, having tens to hundreds of compartments located between a single set of electrodes. Membranes are a significant maintenance problem, subject to deterioration and clogging. Costs for this method are high.

d) **Evaporation.** Using evaporation systems platers can return drag-out wastes of higher concentrations than the original bath. As a result they are useful in returning drag-out solutions in cold processes. The most common basic types of evaporators include:

(1) The thin-film or rising-film evaporators which provide a very fast rate of heat input to a thin film of solution.

(2) Flash evaporators which are similar to thin-film evaporators but have design elements which reduce the overall energy requirements for evaporation.

(3) Submerged tube evaporators which are similar to rising-film evaporators but include an integrated evaporation/condensation unit that reduces equipment cost.

(4) Atmospheric evaporators which are normally operated below the boiling temperatures using a vent fan to pass large volumes of air through a packed column where the warm solution is sprayed.

The savings and economics for evaporation depend on the concentration of rinse water being evaporated and volume of drag-out. Plating solutions contain contaminants which, when evaporated and returned to the bath, can result in bath failure. A cation exchanger is often needed to eliminate the contamination. Another drawback with many evaporators is the need for large volumes of cooling water although after use the cooling water can be chilled and reused or used directly in rinse tanks. Most evaporation systems cost tens of thousands of dollars and apply economically only to high production shops.

Recently, inexpensive atmospheric evaporators have appeared on the market which boost the evaporation rate in heated processes by 3 to 5 times to provide added room for returning drag-out solutions. Among others, these energy efficient units apply to nickel, decorative chromium, tin, and some copper processes.

e) **Electrolytic Recovery.** Recent advances in techniques to plate out metals in drag-out solutions have made electrolytic recovery an effective method of in-process pollution control. Commercially available units have become affordable and more widely used in private industry. This technology can be applied to all metal processes except for chromium.

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Electrolytic units exist for chromium (e.g., Innova Chrome Napper used at several Navy shops), but these are termed ion transfer membrane technologies. Rather than plating out, the chromate anions are captured by the membrane as a result of a selective electrical driving force.

It is also effective on drag-out tanks following plating strip tanks which is a major pollution source in any facilities (refer to para. 3.4.2).

2.5 End-of-Pipe Treatment. Table 8 reviews the conventional technologies for end-of-pipe treatment. Clearly, plating shops should employ the source control methods addressed in paras. 2.4.1 and 2.4.2 before turning to end-of-pipe equipment. The methods are capital intensive, require maintenance, and are subject to upsets that shut down the entire system and generate hazardous sludge which adds to costs and pollution control problems of a facility. Nonetheless, these technologies have been proven and are accepted by Federal and State pollution control authorities.

Table 8
End of Pipe Treatment Technologies

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(1) CONVENTIONAL TECHNOLOGIES* (a) General	Waste streams containing heavy metals and cyanide	Widely applied and proven reliable Easily automated	High initial and operating costs May not meet stringent local limitations Generates large volumes of hazardous waste Large space requirements
(b) Chromium Reduction Sulfur Compound	Reduces Cr (+6) to Cr (+3) prior to precipitation	Provides nearly complete reduction Low maintenance	Requires additional treatment step for Cr removal Economical treatment requires segregation of Cr (+6) wastestream Need to reduce pH to 2.5 prior to reduction and neutralize after reduction Often releases gases having a noxious odor
(c) Cyanide Oxidation Alkaline Chlorination	Wastestreams containing cyanide (non-complexed)	Provides nearly complete oxidation of non-complexed CN Low maintenance	Requires two step process for efficient treatment High treatment chemical cost Not effective w/complexed CN Requires wastestream segregation Requires use of hazardous treatment chemical Can produce toxic chlorinated organic compounds

*These technologies are so widely applied that they are referred to as conventional

Table 8 (Cont.)
End of Pipe Treatment Technologies

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(d) Sulfide Precipitation	Wastestreams containing Cr (+6) and other heavy metals	Can achieve lower metal concentrations than hydroxide precipitation Previously applied to military plating wastewaters Direct treatment of Cr (+6)	Produces large sludge volumes which may be reactive Process control is more difficult than hydroxide precipitation
(e) Sodium Borohydride Precipitation	Wastestreams containing Cr (+6) and other heavy metals	Generates less sludge than hydroxide precipitation	High treatment chemical cost
(f) ION Exchange	Wastestreams containing Cr and heavy metals, two major applications: (1) Treatment step prior to conv. treatment to reduce the volume of wastewater (2) Polishing step after conv. treatment to further reduce concentration of pollutants	Direct treatment of Cr (+6) Allows for recycle of treated water Direct treatment of Cr (+6) and CN Can achieve lower metal concentrations than hydroxide precipitation	Process evolves hydrogen gas Additional treatment of regenerant required

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Table 8 (Cont.)
End of Pipe Treatment Technologies

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
(d) Metal Hydroxide Precipitation	Wastestreams containing heavy metals	Uses common treatment chemicals	Cannot precipitate metals to low levels of solubility in presence of chelating compound Resulting sludge is hazardous
(2) SUBSTITUTE TREATMENT TECHNOLOGIES			
(a) General	Metal finishing wastewaters	May offer cost savings May provide better or more efficient treatment	Requires close control of chemical addition Generally unproven
(b) Ferrous Sulfate Reduction	Reduction of (+6) to Cr (+3)	Reduction can be accomplished at neutral pH (reduced chemical use) Requires less process equipment than conventional reduction	Results in larger sludge volumes Neutral pH reduction only proven on pilot scale Difficult process to control High initial cost
(c) Ozone Oxidation of CN	Wastestreams containing CN	Can be used w/UV radiation to destroy complexed CN Can simultaneously destroy TTO Reduces handling of toxic treatment chemicals Low operating cost Highly effective treatment	Maintenance of O ₃ generator is expensive

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Section 3. PROCESS RECOMMENDATIONS

3.1 General. This section recommends space and logistics, process mechanics, and pollution control practices for eleven Navy electroplating processes and two cleaning processes, as examples of how to use the tables presented in Section 2. Processes were selected on the basis of the frequency of their occurrence (refer to Table 1). Table 9 lists these processes and includes basic information about each process. Plating sequences for the processes are summarized in Appendix B and C. Users of this handbook can apply the assessment charts to other plating processes.

3.2 Space and Logistics. The efficiency of process configurations to minimize material handling and maximize the use of time for each operator depends on several factors. Tank layouts vary according to the type of plating (rack, hoist, barrel, etc.), the production volume, the type and number of processes, and the amount of available space in the facility (refer to para. 2.2.2).

3.2.1 Low Production Shops. The common well tank layout should be used for low production shops. The tanks should be organized to minimize the walking distance between process steps. The common well should include surface preparation and post treatment processes.

3.2.2 Moderate to High Production Shops. A straight line tank configuration should be used for moderate to high production shops. The tanks should be arranged lengthwise in each row to allow maximum accessibility. Loops or circles are recommended for high production applications, depending on the size and shape of the plating area.

With either arrangement, the hard chrome plating should be given a separate area. The hard chrome plating requires additional space for masking, racking, and anode storage (refer to Appendix A, Long Beach NSY arrangement).

3.3 Process Mechanics. Table 10 recommends tank shell materials, tank linings, and tank ventilation rates for each of the eleven common Navy processes referred to in paras. 3.4.2 through 3.4.12.

Tank ventilation rates are for lateral exhaust hoods. Use either push-pull or pull-pull systems when tank surface obstructions (racks, parts, rigging) will not impede air flow. The push-pull type can significantly reduce the required exhaust rate. Use only pull-pull when obstructions are expected, such as with 2 bus bar hard chrome plating.

3.4 Pollution Control. Pollution control recommendations for each process are presented in Tables 11 through 20 and are based on the tables presented in Section 2. In addition, Navy shops should institute the basic controls listed in Table 6 which include:

- a) Controlling chemical composition of plating solutions.
- b) Rinse tank operations.
- c) Use of drain boards and drip guards.
- d) Properly sized flow regulators.

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Key observations about each process are specified in paras. 3.4.1 through 3.4.12.

3.4.1 Alkaline Cleaning. Most alkaline cleaning solutions are viscous and hard to rinse, making them prime candidates for reactive rinsing. Use a single rinse, fed with the overflow from the acid rinse tank. The acidic rinse water will aid in removing the alkaline film on the parts. Use a double counter flow rinse tank in the rare case where reactive rinsing is not possible.

Metals build up in electro cleaners (chromium is often stripped in electro cleaners) and they can be a measurable source of water pollution. For this reason, cleaner solutions should be replaced frequently at facilities that use source controls as their pollution control program.

3.4.2 Acid Cleaning. Use a single overflow rinse following acid dip and gravity flow the overflow to the alkaline cleaner rinse for reactive rinsing. Metals build up in acid baths during the cleaning processes or from stripping; these baths are often a major source of water pollution (refer to paras. 3.4.5 and 3.4.11). As a result, acid baths used for stripping should be replaced frequently unless a drag-out tank is used to capture the metal contaminants for removal (refer to para. 3.4.5).

In most processes, a single rinse tank with the overflow fed by gravity to the cleaner rinse for reactive rinsing is recommended. For added protection of contaminant-sensitive plating baths such as cadmium and precious metals, two rinses after the acid bath can be used.

3.4.3 Anodizing. Most anodizing baths are operated at room temperature or lower and therefore have little evaporation. The chromic acid (Type I) baths are the most common in Navy shops. This solution has a lower concentration of chrome than hard chrome plating baths. This fact combined with the lower bath evaporation rate make recovery uneconomical.

Good rinsing is required after the cleaning step (prior to anodize) to assure elimination of the drag-out of alkaline solutions which will neutralize the anodizing solution. Spray rinsing of parts before anodizing is a good technique.

3.4.4 Black Oxide. A two-stage rinse is necessary after the black oxide coating with the first stage heated (175 degrees F) (79.4 degrees C) to prevent damage to parts (note temperature of black oxide baths). The second rinse should be at room temperature. Drag-out can be returned to the process bath to make-up for evaporation but care should be taken to coordinate the return with temperature control of the bath. The first rinse can be returned to the process tank to make-up for evaporation. The second rinse should be a single overflow with a timer control.

The spent black oxide solutions (except Class 3) can be used as treatment reagents at the IWTP.

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Table 9
Common Navy Electroplating Processes and Solution Characteristics

PROCESS	SOLUTION CONSTITUENTS	BATH OPERATING TEMPERATURE	SPECIAL RINSING CONSIDERATIONS
1. Alkaline Cleaning	Alkaline salts, sequestering agents, dispersants, wetting agents	125-200°F	Viscous solution, requires double rinse or reactive rinsing with acid rinse
2. Acid Cleaning	Hydrochloric, sulfuric acid, nitric-sulfuric mixtures	60-80°F	None
3. Anodizing	Type I - chromium trioxide Type II - sulfuric acid Type III - sulfuric acid, oxalic acid	Type I - 90-95°F Type II - 68-85°F Type III - 32-50°F	Some Navy facilities use deionized water but not usually required
4. Black Oxide	Class 1 - Sodium hydroxide/sodium nitrate Class 3 - Sodium and potassium dichromate Class 4 - alkaline oxidizing proprietary bath	Class 1 - 285-305°F Class 3 - 750-850°F Class 4 - 250-265°F	First rinse after coating should be 175°F, second rinse at room temperature
5. Cadmium Plating (a) Cyanide (b) Non-cyanide	Cadmium oxide, sodium cyanide, sodium hydroxide, sodium carbonate Fluoboric acid, cadmium anoxide, sulfuric acid, proprietary additions Chromium trioxide, sulfuric acid	80-85°F 60-80°F	Baths are susceptible to contamination, rinse prior to bath must be clean Same as above
6. Chromium Plating (Hard)	Chromium trioxide, sulfuric acid	Conventional 130°F Two Bus Bar 140°F	Viscous solution, requires extensive rinsing Two bus bar plating increases drag-out
7. Chromate	Type II - Chromic acid, sodium hydroxide, sulfuric acid	68-85°F	None
8. Copper Plating (a) Rochelle Cyanide (b) Acid Copper (c) Pyrophosphate	Copper cyanide, sodium cyanide, sodium carbonate, Rochelle salt Copper sulfate, sulfuric acid Copper pyrophosphate, potassium pyrophosphate, potassium nitrate, ammonia	140 to 150°F 75 to 95°F 122 to 150°F	None None Strike does not need a rinse
9. Nickel Plating (a) Sulfamate	Nickel sulfamate, nickel chloride, boric acid additives	Strike: 70 - 75°F Plate: 100 - 140°F	Rinsing not rinsed between nickel strike and nickel plate

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Table 9 (Cont.)
Common Navy Electroplating Processes and Solution Characteristics

PROCESS	SOLUTION CONSTITUENTS	OPERATING TEMPERATURE	BATH TEMPERATURE	SPECIAL FINISHING CONSIDERATIONS
(b) Watts	Nickel sulfate, nickel chloride, boric acid proprietary brighteners	140°F	140°F	None
10. Phosphate Coating (a) Manganese	Manganese dihydrogen phosphate, accelerators	210°F	210°F	Requires rapid rinsing following phosphate coat to prevent drying Use hot rinse preceeding phosphate coat
(b) Zinc	Zinc dihydrogen phosphate, nitrate accelerator	210°F	210°F	Requires rapid rinsing following phosphate coat to prevent drying Use hot rinse preceeding phosphate coat
11. Cadmium Plating Cyanide	Silver cyanide, potassium cyanide, potassium carbonate, potassium hydroxide, brightener	100-120°F	100-120°F	None
Non-cyanide	Silver salts, potassium hydroxide, proprietary additives	70-80°F	70-80°F	Baths are susceptible to contaminants, rinse prior to bath must be clean
12. Zinc Plating (a) Cyanide	Sodium cyanide, sodium hydroxide, Sodium carbonate, zinc cyanide	68-122°F	68-122°F	None
(b) Acid	Zinc sulfate, ammonium chloride, aluminum sulfate	75-85°F	75-85°F	None
13. Zincate	Zinc oxide, sodium hydroxide, ferric chloride, Rochelle salt	60-80°F	60-80°F	Highly viscous, double rinse or dip and spray rinse recommended

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Table 10
Recommendations for Process Mechanisms

PROCESS	TANK SHELL MATERIAL ¹	TANK LINING TYPE ²	VENTILATION CONTROL VELOCITY FPM ³	BATH PURIFICATION
Anodizing				
Type 1	CS	PVC/PP	100	Dummying
Type 2	CS	PVC/PP	General ⁴	Decanting
Type 3	CS	PVC/PP	General	Decanting
Black Oxide				
Class 1	CS	--	100	Not required
Class 2	CS	--	150	Not required
Class 3	CS	--	100	Not required
Cadmium Plating	CS/PP	PVC/PP	General ⁴	Carbonate removal
Chromium Plating (hard)	CS	Lead	150	Electrolytic removal of iron and copper
Chromate	CS/PP	Lead/PP	General ⁴	Not required
Copper Plating				
(a) Cyanide	CS/PP	PVC/PP	50	Carbonate removal
(b) Acid	CS/PP	PVC/PP	50	Continuous filtration 1-2 turnovers/hr
Nickel Plating	CS/PP	PVC/PP	50	Continuous filtration 1-2 turnovers/hr
Phosphate Coating	CS/PP	PP	50	Not required
Silver Plating	CS/PP	PVC/PP	50	Carbonate removal
Zincate	CS/PP	PVC/PP	General ⁴	Not required
Zinc (and Cyanide)	CS/PP	PVC/PP	General	Carbonate removal for cyanide baths
Alkaline Cleaning	CS	PVC/PP	75	Not required
Acid Cleaning	CS/PP	PP	General ⁴	Not required

¹ CS - Carbon steel; PP - Polypropylene; PVC - Polyvinyl chloride

² With carbon steel tank shell

³ Assumes lateral exhaust hood

⁴ General room ventilation required

Reference: Based on information and formulas in Pensacola NARF Local Process Specification LPS/PN 376.

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Table 11
Pollution Control Recommendations: Anodizing (Chromium or Sulfuric)

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Non-Etch	Double counter flow rinse Can reuse anodize rinse water Mechanical flow control (1 to 3 gpm)*	Periodically dispose of bath	pH control Precipitation
Etch	Double counter flow rinse Mechanical flow control (1 to 3 gpm)*	Same as above	Same as above
Anodize	Same plus can reuse at etch rinse	Same	Same plus chromium reduction
Hotwater Seal	Hot rinse (200 °F) Mechanical flow control (0.25 gpm)*	Same	Same
Nickel Acetate Seal	Same	One drag-out tank Return entire drag-out solution daily	Same

* Timer if production is intermittent

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Table 12
Pollution Control Recommendations: Black Oxide

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	Same	Same
Black Oxide	Double counterflow Mechanical flow control (1 to 3 gpm)*	Heated drag-out bath Return solution to process	Use spent bath as IWTP chemical

* Timer if production is intermittent

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Table 13
Pollution Control Recommendations: Cadmium Cyanide

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single Rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	None if end-of-pipe treatment is in-place For source control use drag-out rinse and electrolytic removal of metals	Same
Cadmium	Double counterflow Mechanical flow (1 to 3 gpm)*	Same	Same plus cyanide control reduction
Post Treatment (Chromate)	A single double counterflow for all post treatments Hot final bath Mechanical flow control (1 to 3 gpm on cold and 0.5 gpm on hot rinse)*	None	Same plus chrome reduction

* Timer if production is intermittent

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Table 14
Pollution Control Recommendations: Chrome (hard)

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Double counterflow rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	Same	Same
Chrome	Rinse over bath Spray rinse with automatic recovery Double countercurrent rinse with automatic recovery Mechanical flow controller (0.5 to 1 gpm)*	Automatic recovery	None if complete recycle, otherwise chrome reduction

* Timer if production is intermittent

Table 15
Pollution Control Recommendations: Chromate

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Refer to Table 14 (Chromium Plating), and Table 19 (Zinc Plating)			

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Table 16
Pollution Control Recommendations: Nickel

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Nickel	Single rinse Reuse nickel rinse water Gravity flow to cleaner rinse	Same	Same
Nickel	Single or double (counterflow) rinse Gravity flow to acid rinse Mechanical flow control (1 to 3 gpm)*	Double drag-out tank Evaporator on process tank** Return entire drag-out solution daily	Same

* Timer if production is intermittent

** Delete if production is intermittent

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Table 17
Pollution Control Recommendations: Phosphate

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	Same	Same
Phosphate	Single or double (counterflow) rinse Mechanical flow control (1 to 3 gpm)*	Single drag-out tank Return portion of drag-out daily	Same

* Timer if production is intermittent

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Table 18
Pollution Control Recommendations: Silver Cyanide

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	Same	Same
Silver	Double counterflow rinse Mechanical flow control (1 to 3 gpm)*	Single drag-out tank Ion exchange or electrolytic recovery of metal	Same

* Timer if production is intermittent

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Table 19
Pollution Control Recommendations: Zinc

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single Rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	None if end-of-pipe treatment is in-place For source control use drag-out rinse and electrolytic removal of metals	Same
Zinc	Double counterflow rinse Mechanical flow control (1 to 3 gpm)*	Same	Same plus cyanide reduction
Post Treatment (Chromate)	One double counterflow for all post treatments Hot final bath Mechanical flow control (1 to 3 gpm on cold and 0.5 gpm on hot rinse)*	None	Same plus chrome reduction

* Timer if production is intermittent

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Table 20
Pollution Control Recommendations: Zincate

PROCESS STEP	RINSING TECHNOLOGY	WASTE REDUCTION TECHNOLOGY	END-OF-PIPE TREATMENT
Alkaline Electro Cleaner	Single rinse Reuse acid rinse water Flow controls on acid rinse	Periodically dispose of bath	pH control Precipitation
Acid	Mechanical flow control (1 to 3 gpm)* Gravity flow to cleaner rinse Single or double (counterflow) rinse	Same	Same
Zincate	Spray rinse Double counterflow rinse Mechanical flow control (1 to 3 gpm)*	Same	Same

* Timer if production is intermittent

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3.4.5 Cadmium Plating. All cyanide plating baths are susceptible to contamination including the buildup of carbonates. Chemical treatment or freezing out of the carbonates is the standard bath purification practice. Facilities in the northern United States can pump solutions to outdoor holding tanks on cold winter days to inexpensively remove carbonates.

The acid rinse precedes the cyanide plating tank. It needs to be clean for several reasons: first, the acid drag-out can reduce the pH of the cadmium bath (typically operated at a pH of 12). Second, the acid rinse is often used to strip cadmium from rejected parts. In the stripping process, other metals including copper and nickel also leach into the acid baths.

These metals will be dragged into the cadmium bath from a dirty acid rinse. Accordingly, counterflow rinsing is recommended for the rinse tank preceding the cadmium bath. Some platers add a drag-out after the acid rinse and chemically treat the solution periodically or electrolytically remove metals from the drag-out in order to protect the cadmium bath and to reduce the contribution to the wastewater stream of dissolved metal from the acid bath. Strips are a major source of water pollution. Almost as much cadmium can be found in the acid bath, if it is used as a strip, as in the plating process.

Alkaline solutions are more difficult to rinse than acid or neutral solutions. Double or triple counterflow rinses are, therefore, recommended after cadmium processes. Drag-out tanks with electrolytic systems are extremely effective for recovering cadmium. They should be used if the facility is using source controls rather than end-of-pipe treatment. The recovered metal can be used as anodes for the cadmium plating tank. An added advantage is that much of the cyanide is destroyed by the electrolytic unit.

3.4.6 Chromium Plating (Hard). Chromium plating is the most widely applied Navy plating process. It is recommended that all shops convert to the two bus bar plating system which provides better plating quality and reduced pollution.

Drag-out from chrome plating should be recovered in the rinse operation and returned to the bath. The initial rinse should be over the tank using a hand spray, providing direct recovery. Subsequent rinsing can be accomplished in several ways. For shops with low chromium production, use one drag-out rinse followed by an overflow rinse with a timer control. The drag-out can be returned using a bucket or a small transfer pump. For shops with high production rates, use either a spray or countercurrent rinse with automatic recovery.

The recovery of drag-out may cause a build-up of cationic impurities (e.g., iron, copper, Cr(+3)). Therefore, continuous electrolytic bath purification is recommended.

3.4.7 Copper Plating. Both cyanide and acid copper solutions are commonly used by the Navy. The volume of copper plating at Navy shops is usually low, therefore recovery equipment is not recommended. However, since the cyanide bath is heated a drag-out rinse can be used to capture and return the drag-out to the process. For acid copper plating a countercurrent rinse or single rinse with a timer control are recommended.

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A high carbonate level in the cyanide bath will increase bath viscosity and therefore increase drag-out. The carbonate level should be closely monitored and the bath should be treated when the level increases beyond 6 oz/gal (44.9 g/L).

3.4.8 Nickel Plating. Nickel plating baths are prime candidates for evaporative recovery because the process operates at 120 to 150 degrees F (48.8 to 65.5 degrees C). One to five gallons per hour (3.785 to 18.925 L/h) evaporate from nickel baths. This can be increased by a factor of 3 (or more) using inexpensive evaporators on the plating solution. Using 2 drag-out tanks, nearly all of the process solution can be captured and recycled to the plating process. If 2 drag-out tanks are used, then a single rinse should be sufficient to thoroughly clean the work, except at very high production rates.

3.4.9 Phosphate Coating. The rinse after cleaning should be hot so as to increase cleaning efficiency. That rinse should not be allowed to build up to more than 1.0 percent of the preceding tank content. A hot-stagnant rinse followed by an overflow rinse at room temperature is acceptable.

Following phosphate coating use either a countercurrent rinse or a single rinse with a timer control. Since metal concentrations in phosphate baths are low, drag-out tanks are recommended even for low production rates because returning the drag-out can entirely eliminate this process as a major waste-water pollution problem.

3.4.10 Silver Plating. Recommendations for rinsing following silver plating vary depending on the production rate. One or two drag-out tanks with either electrolytic recovery or ion exchange is recommended. Electrolytic methods have the added advantage of destroying cyanide.

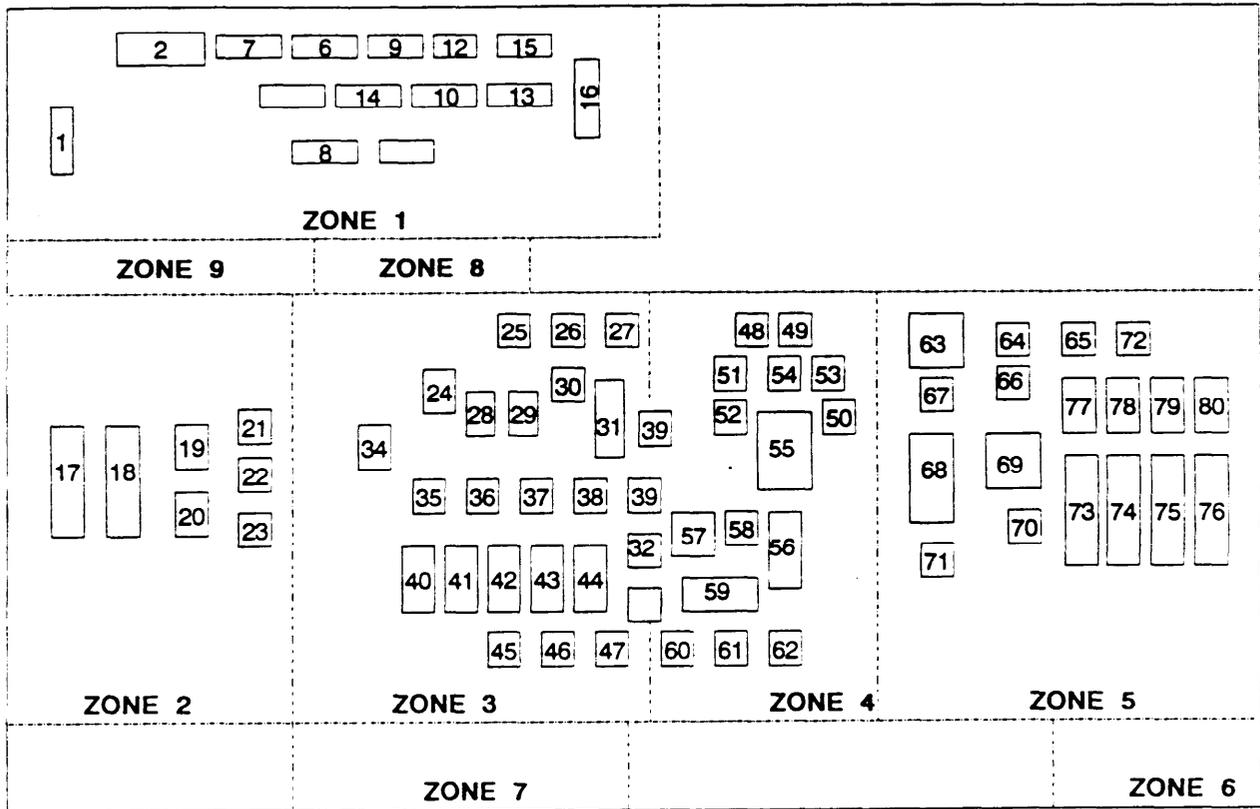
3.4.11 Zinc plating. The volume of zinc plating varies among Navy activities but is generally low (refer to para. 3.4.5).

3.4.12 Zincate. The volume of zincate production is generally low at Navy shops. Combined with the low cost of the solution, low operating temperature and the low metal content, recovery is not feasible.

The zincate solution is viscous and requires a double rinse. A countercurrent rinse is recommended. A timer control can be used in conjunction with the countercurrent rinse to further reduce water use.

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APPENDIX A
EXAMPLES OF EXISTING NAVY PLATING SHOP CONFIGURATIONS



Tank No.	Description						
1	Degrease	21	Rinse	41	Snplate	61	Nielectroless
2	Caustic	22	Crplate	42	Niplate	62	Nielectroless
3	Rinse	23	Hotrinse	43	Cuplate	63	Al etch
4	Paint strip	24	Caustic	44	Cuplate	64	Rinse
5	Epoxy strip	25	Pickle	45	Black Ni	65	Rinse
6	Pickle	26	Rinse	46	Niplate	66	Andoize
7	Rinse	27	Br. dip	47	Auplate	67	Andoize
8	Pickle	28	Cdplate	48	Nistrip	68	Andoize
9	Br. dip	29	Agplate	49	Rinse	69	Di. chromate
10	Rinse	30	Ag strike	50	Port. bbl.	70	Hotrinse
11	Hotrinse	31	Snplate	51	Rinse	71	Dye
12	Rinse	32	Niplate	52	Rinse	72	Imdite
13	Cr dip	33	Pbplate	53	Cd plate	73	Imdite
14	Neutralizer	34	Degrease	54	Cd plate	74	Rinse
15	Caustic	35	CN dip	55	Phosphate	75	Soda ash
16	Rinse	36	Rinse	56	Rinse	76	Imdite
17	Cr plate	37	Hotrinse	57	Zn plate	77	Alum
18	Cr plate	38	rinse	58	Houto blk	78	Imdite
19	Cr plate	39	Hotrinse	59	Rinse	79	Imdite
20	Cr plate	40	Cleaner	60	Rinse	80	Imdite

Figure A-1
Puget Sound NSY Plating Shop Layout

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APPENDIX A (cont)

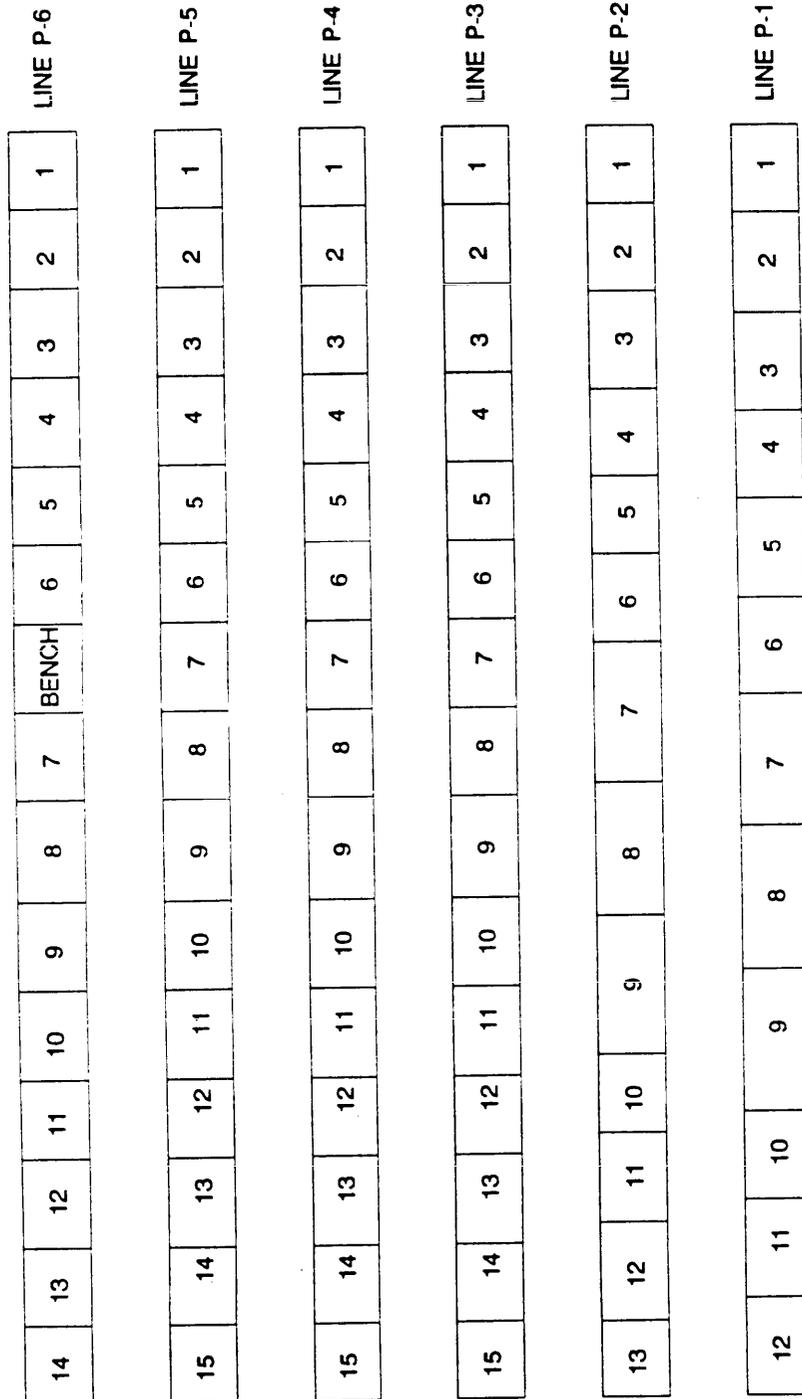


Figure A-2
Tank Layout at San Diego NARF Plating Shop

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APPENDIX A (cont)
PLATING LINE TANK SEQUENCEPlating Line P-1

- P-1-1 - Unichrome 80, Tetrapotassium Pyrophosphate (Cleaner)
- P-1-2 - Deruster, Sodium Hydroxide
- P-1-3 - Running Rinse (no control)
- P-1-4 - Inactive
- P-1-5 - Inactive
- P-1-6 - Cadmium Strip, Ammonium Nitrate
- P-1-7 - No tank
- P-1-8 - Cadmium Oxide Plate, CdCN
- P-1-9 - Cadmium Oxide Plate, CdCN
- P-1-10 - Stagnant Water Rinse*
- P-1-11 - Hot Water Rinse**
- P-1-12 - Air Dryer

Plating Line P-2

- P-2-1 - Unichrome 80, Tetrapotassium Pyrophosphate
- P-2-2 - Inactive
- P-2-3 - Running Rinse
- P-2-4 - Hydrochloric Acid
- P-2-5 - Running Rinse
- P-2-6 - Nickel Strike
- P-2-7 - Nickel Sulfamate Plating
- P-2-8 - Nickel Sulfamate Plating
- P-2-9 - Stagnant Water Rinse
- P-2-10 - Inactive
- P-2-11 - Stagnant Rinse
- P-2-12 - Hot Water Rinse**
- P-2-13 - Air Dryer

Plating Line P-3

- P-3-1 - Anode Cleaner, Sodium Hydroxide
- P-3-2 - Running Rinse
- P-3-3 - Nitric Acid
- P-3-4 - Stagnant Water Rinse
- P-3-5 - Hydrofluoric Acid
- P-3-6 - Running Rinse
- P-3-7 - Sulfuric Acid
- P-3-8 - Hydrochloric Acid
- P-3-9 - Nickel Sulfamate Plating
- P-3-10 - Running Rinse
- P-3-11 - Tin Plating
- P-3-12 - Stagnant Water Rinse
- P-3-13 - Cadmium Oxide Plating, CdCN
- P-3-14 - Stagnant Rinse
- P-3-15 - Hot Water Rinse**
- P-3-16 - Air Dryer

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APPENDIX A (cont)
PLATING LINE TANK SEQUENCEPlating Line P-4

- P-4-1 - Alkaline Cleaner
- P-4-2 - Running Water Rinse
- P-4-3 - Hydrofluoric Acid
- P-4-4 - Running Rinse
- P-4-5 - Zincate, Sodium Hydroxide
- P-4-6 - Stagnant Water Rinse
- P-4-7 - Copper Cyanide Plating
- P-4-8 - Running Rinse
- P-4-9 - Nickel Sulfamate Plating
- P-4-10 - Running Rinse
- P-4-11 - Silver Cyanide Plating
- P-4-12 - Silver Cyanide Plating
- P-4-13 - Running Rinse
- P-4-14 - Hot Water Rinse**
- P-4-15 - Air Dryer

Plating Line P-5

- P-5-1 - Anode Cleaner, Sodium Hydroxide
- P-5-2 - Stagnant Rinse
- P-5-3 - (a) Nitric + (b) Hydrolic Acid
- P-5-4 - Running Rinse
- P-5-5 - Sodium Meta Nitrobenzene
- P-5-6 - Copper Cyanide Plating
- P-5-7 - Stagnant Water Rinse*
- P-5-8 - Hydrochloric Acid
- P-5-9 - Inactive
- P-5-10 - Copper Cyanide Plate
- P-5-11 - Running Rinse
- P-5-12 - Sodium Dichromate (Surface Treatment)
- P-5-13 - Running Rinse
- P-5-14 - Hot Water Rinse
- P-5-15 - Air Dryer

Plating Line P-6

- P-6-1 - Inactive
- P-6-2 - Stagnant Rinse
- P-6-3 - Parco Lubrite
- P-6-4 - Deruster, Sodium Hydroxide
- P-6-5 - Black Oxide, Sodium Hydroxide
- P-6-6 - Hot Water Rinse
- P-6-7 - No Tank
- P-6-8 - No Tank
- P-6-9 - No Tank
- P-6-10 - Nickel Sulfamate
- P-6-11 - Stagnant Water Rinse
- P-6-12 - Silver Cyanide Plating
- P-6-13 - Silver Strip
- P-6-14 - Running Water Rinse

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APPENDIX B
SURFACE PREPARATION PROCEDURES FOR COMMON MATERIALS

Chromium

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Abrasive clean
3	Mask
4	Electrolytic alkaline clean
5	Rinse
6	Rinse (hot)

Copper and Copper Base Alloys

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Rinse (hot)
3	Mask
4	Alkaline electroclean
5	Rinse
6	Rinse (hot)
7	Bright dip
8	Rinse
9	Rinse
10	Acid dip for alkaline plating
10A	Cyanide dip
11A	Rinse (stagnant)
12A	Rinse

Low Carbon Steel

<u>Step</u>	<u>Operation</u>
1	Stress relief
2	Vapor degrease
3	Alkaline Clean
4	Rinse
5	Rinse
6	Acid dip (pickling)
7	Alkaline descaling
8	Rinse
9	Rinse

High Carbon Steel

<u>Step</u>	<u>Operation</u>
1	Stress relief
2	Vapor degrease
3	Mechanical clean
4	Mask
5	Alkaline electroclean
6	Rinse
7	Rinse
8	Acid dip
9	Rinse
10	Smut removal
11	Rinse
12	Rinse
13	Acid etch
14	Rinse

Notes: Rinse water is cold unless otherwise indicated. Drag-out rinse used after cyanide solutions is part of integrated treatment system.

Source: Pensacola NARF Local Process Specification LPS/PN 376.

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APPENDIX C
PLATING AND COATING PROCEDURESCHROMIUM

<u>Step</u>	<u>Operation</u>
1	Surface preparation ¹
2	Anodic etch/activate
3	Chromium plate
4	Rinse
5	Dry
6	Remove Mask
7	Bake
8	Corrosion prevention

CHROMIC ACID ANODIZING (A1)

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Mask
3	Solvent wipe
4	Clean
5	Rinse
6	Etch
7	Rinse
8	Desmut
9	Rinse
10	Anodize
11	Rinse
12	Dye (if required)
13	Seal
14	Dry

CADMIUM

<u>Step</u>	<u>Operation</u>
1	Surface preparation
2	Cadmium plate
3	Rinse (drag-out)
4	Rinse
5	Dry
6	Remove masking
7	Bake
8	Chromate
9	Rinse
10	Dry
11	Corrosion prevention

¹ Refer to Appendix B, Surface Preparation Procedures for Common Materials.

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APPENDIX C (cont)

COPPER ON ALUMINUM

<u>Step</u>	<u>Operation</u>
1	Zincate (see procedure)
2	Cyanide copper strike
3	Cyanide drag-out
4	Rinse
5	Acid copper plate
6	Rinse
7	Remove masking
8	Rinse
9	Dry
10	Bake
11	Corrosion prevention
12	Proceed to further plating operations

COPPER ON STEEL

<u>Step</u>	<u>Operation</u>
1	Surface preparation ¹
2	Cyanide copper strike
3	Rinse (drag-out)
4	Rinse
5	Acid copper plate
6	Rinse
7	Dry
	If further plating required proceed to process
8	Remove masking
9	Bake
10	Corrosion prevention

NICKEL

<u>Step</u>	<u>Operation</u>
1	Surface preparation ¹
2	Nickel strike
3	Nickel plate
4	Rinse
5	Dry
6	Remove masking
7	Bake
8	Corrosion prevention

SILVER ON STEEL

<u>Step</u>	<u>Operation</u>
1	Surface preparation ¹
2	Cyanide copper strike
3	Rinse (drag-out)
4	Rinse
5	Nickel strike
6	Rinse
7	Silver strike
8	Silver plate
9	Rinse (drag-out)
10	Rinse
11	Remove masking
12	Rinse
13	Dry
14	Bake (if required)
15	Corrosion prevention

¹ Refer to Appendix B, Surface Preparation Procedures for Common Materials.

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APPENDIX C (cont)

ZINCATE AND STRIPPING ALUMINUM

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Abrasive blast
3	Mask
4	Solvent wipe
5	Alkaline clean
6	Rinse
7	First acid dip
8	Rinse
9	Second acid dip
10	Rinse
11	Zincate
12	Rinse
13	Rinse
14	Strip (immersion)
15	Rinse
16	Zincate
17	Rinse
18	Rinse

ZINCATING MAGNESIUM

<u>Step</u>	<u>Operation</u>
1	Cathodic electroclean
2	Rinse
3	Chromic acid pickle
4	Rinse
5	Acid activation
5A	Alkaline activation
6	Rinse
7	Zincate
8	Rinse
9	Copper strike (see procedure for CN)
10	Proceed to further plating operations

BLACK OXIDE

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Alkaline electroclean
3	Rinse
4	Acid dip
5	Rinse
6	Coat
7	Rinse (stagnant)
8	Rinse
9	Chemical acid rinse
10	Dry

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APPENDIX C (cont)

ZINC ON STEEL

<u>Step</u>	<u>Operation</u>
1	Surface preparation
2	Acid dip
3	Rinse
4	Sodium Cyanide Soak
5	Rinse
6	Plating
7	Rinse
8	Bake (if necessary)
9	Chromate treatment
10	Rinse

PHOSPHATE ON STEEL

<u>Step</u>	<u>Operation</u>
1	Vapor degrease
2	Alkaline electroclean
3	Rinse (hot)
4	Abrasive blast
5	Phosphate
6	Rinse
7	Chromic-phosphoric acid
8	Dry
9	Bake (if necessary)

Sources: Zinc on Steel from Puget Sound NSY Process Instruction No. 0630-149G CH-1; all other procedures from Pensacola NARF Local Process Specification LPS/PN 376.

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