

MIL-HDBK-1015/1  
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# MILITARY HANDBOOK

## ELECTROPLATING FACILITIES



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## ABSTRACT

This handbook provides guidance for the design of electroplating facilities constructed for the Navy. It includes descriptions of industrial plants by metal finishing systems for the production of inorganic finishes on metallic substrates, in contrast to metallic substrates finished with organic coatings or organic substrates finished with metallic coatings. Emphasis has been placed on processes, systems, and equipment which have wide application within industry and the Navy.

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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.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commander, Naval Facilities Engineering Command (Code 04), 200 Stovall Street, Alexandria, VA 22332-2300; telephone (202)325-0450.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

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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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## Section 1: INTRODUCTION

1.1 Scope. This handbook contains design criteria for the design of electroplating facilities constructed for Navy use. The criteria include descriptions of industrial plants by metal finishing systems for the production of inorganic finishes on metallic substrates, in contrast to metallic substrates finished with organic coatings or organic substrates finished with metallic coatings. This military handbook describes electrodeposition and other metal finishing processes equipment, instrumentation, exhaust systems, utility distribution, and special architectural features pertinent to electroplating facilities. This handbook does not cover pollution control systems and recovery processes after the effluents leave the facilities. Emphasis has been placed on processes, systems and equipment which have wide application within industry and the Navy and for which there is significant design experience.

1.2 Cancellation. There are no cancellation or supersession data.

1.3 Definitions

1.3.1 Electroplating Facilities. For this document, electroplating facilities means facilities necessary to electroplate (electrodeposit), anodize, or conversion-coat parts, components, and equipment used by the Navy. Electroplating is the deposition of an adherent metallic coating upon an electrode (workpiece) for the purpose of securing a surface with properties or dimensions different from the basis metal. Anodizing is an electrolytic oxidation process in which the surface of a metal, when anodic, is converted to a coating having desirable protection, decorative or functional properties. Conversion-coating is produced by chemical or electrochemical treatment of a metallic surface that gives a superficial layer containing a compound of the metal (for example, chromate coatings on zinc or cadmium, or oxide coating on steel).

1.3.2 Facilities (General Definition). Facilities means the aircraft, vessels, buildings, installations, structures, equipment, vehicles, and other property owned by, or constructed or manufactured for lease to, the Department of the Navy.

1.4 Policy. The basic policy of the Navy in regard to electroplating is to increase the useful life of items through the application of electrodeposits. The purpose is to reduce the rate of corrosion and modify the surface characteristics relating to hardness, dimensions, and aesthetic appearance. The facility used to house the electroplating equipment and systems should be compatible with the local environs and meet the local environmental regulations. The design should provide the optimum economic consideration, including the function to be performed, the life of the function, habitability, first costs, maintenance costs, energy conservation, and operating costs. The design must produce a facility satisfactory to the operational and functional requirements of the management command, field division or office, and a degree of flexibility to permit future changes in use. The engineering solution must provide a usable facility and reasonably assure the award of a construction contract within the funds available.

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1.4.1 Guidelines. This document forms the guidelines for the design of electroplating facilities.

1.4.2 Standards. Consult the regional offices of the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and appropriate state and local regulatory agencies for information on applicable regional or local regulations.

1.4.3 Cooperation With Review Agencies. Submit project plans to EPA, and local and state regulatory agencies for information and comment or approval.

1.4.4 Safety and Health Considerations. The basic policy of the Navy is to design, construct, and operate facilities that are safe and protect the health of the operators. The design of electroplating facilities shall incorporate safety and health guidelines and requirements given in either the Department of Commerce PB-2737803, or the Department of Labor OSHA 2206 (29 CFR 1910, OSHA Safety and Health Standards for General Industry), and should incorporate the features of the National Institute of Safety and Health (NIOSH), Good Work Practices for Electroplaters. A safety system analysis should be conducted in accordance with Military Standard, MIL-STD-882, System Safety Program Requirements, OPNAV Instruction (OPNAVINST) 5100.24, Navy Systems Safety Programs, and NAVFACINST 5100.11F, Command Safety and Health Programs.

1.4.5 Environmental Considerations. The basic policy of the Navy in regards to pollution control relative to electroplating facilities is that the Navy will cooperate with other concerned agencies at the local, state, and Federal levels. This policy is detailed in OPNAVINST 5090.1, Environmental and Natural Resource Protection Manual. Also refer to Environmental Quality, including Pollution Abatement, in Military Handbook MIL-HDBK-1190, Facility Planning and Design Guide. Also refer to applicable United States Environmental Protection Agency (EPA) and state guidelines.

1.4.6 Environmental Impact Statements. These statements are normally not required for improvement projects for pollution abatement. Guidelines on when to submit statements are given in OPNAVINST 5090.1.

1.4.7 Energy Conservation. Recent definition of national tasks emphasizes the urgency of intensifying efforts to incorporate energy conservation features in all facilities design. The following documents contain direction and guidance for standard and accepted design practice relating to basic energy conserving features. These features are to receive fullest consideration during the design process.

a) Executive Order No. 12003, Energy Policy and Conservation,  
20 July 1977.

b) NAVFACINST 410.5, Techniques of Energy Conservation,  
5 March 1974.

c) MIL-HDBK-1190.

d) NAVFACINST 4100.7, Project Engineering Documentation,  
7 March 1975.



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e) Guidelines for Energy Conservation in New Building, Interim Design Criteria, January 1975.

In addition to full utilization of the preceding references, innovative design approaches are necessary to meet energy conservation goals.

1.4.8 Water Conservation. It is the policy of the Navy to employ water conservation measures to the extent feasible and economical. Such methods as reuse of the wastewater within the facilities, after toxic materials have been removed, must receive full consideration in facilities planning and design.

1.4.9 Project Management. Electroplating facilities are considered to be industrial facilities which involve complex processes and hazardous/toxic materials subject to regulation by local, state and federal authorities. They must also comply with pertinent Department of Defense (DoD) requirements including those given in the documents: DoD 4145.19-R-1, Storage and Handling of Hazardous Materials, and MIL-HDBK-1005/13, Hazardous Waste Storage Facilities. Therefore, the acquisition of these facilities, beginning with planning, through design, construction, testing and acceptance procedures and certification (if required) will be according to NAVFACINST 4862.5, Navy Hazardous Material Control Program, (latest revision).

1.5 Operating and Maintenance Manual. The preparation and furnishing of an operating and maintenance (O&M) manual will be included in the scope of work of all Architect-Engineering (A-E) contracts for the design of electroplating facilities.

1.6 Special Provisions in Seismic Areas. Refer to NAVFAC P-355, Seismic Design for Buildings, Section 10, Mechanical and Electrical Elements; Section 11, Structures Other than Buildings; and Section 12, Utility Systems, for recommended provisions in seismic areas.

1.7 Purpose. This handbook is a general guide for designing electroplating facilities. It covers "at source" pollution control systems particular to electroplating facilities. Design criteria for any wastewater collection and treatment, if required, in addition to pollution control systems provided in the plating shops, are contained in MIL-HDBK-1005/9, Industrial and Oily Wastewater Control. The design criteria presented and referenced herein will assist the engineer in the design of Navy facilities.

1.8 Design Procedures. Figure 1 shows the basic steps normally followed for completing electroplating facility designs.

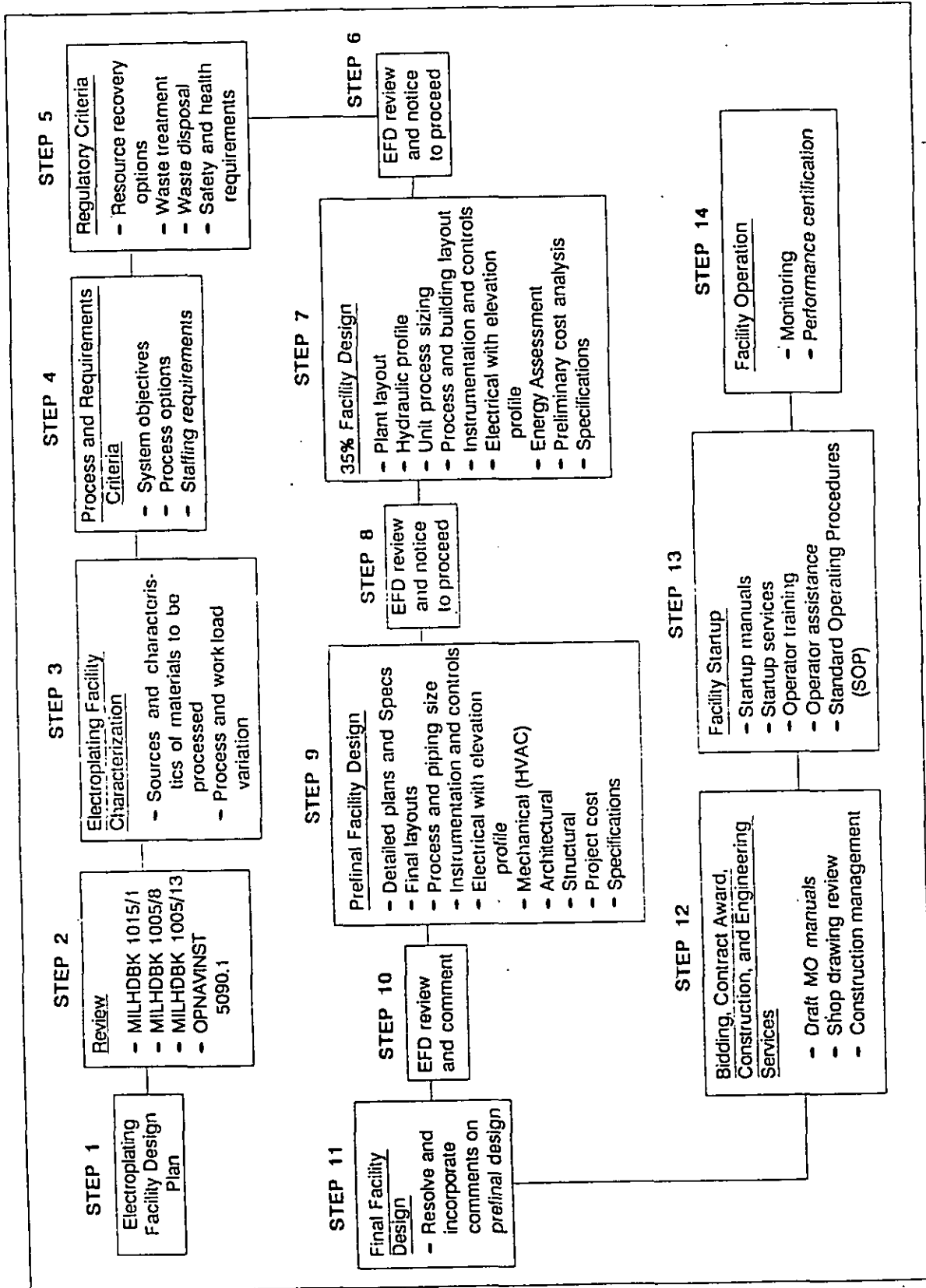


Figure 1  
Work Task Diagram for Electroplating Facility

## Section 2: ELECTROPLATING SYSTEMS

### 2.1 Processing Steps

2.1.1 Design Steps. The processing sequence shown in Figure 2 defines the steps to be performed to finish an item from its receipt to shipment.

2.1.2 Design Relations. Figure 3 shows typical processing steps in electroplating and anodizing metals. It should be noted that rinsing techniques have not been included in Figure 3 because these techniques depend on the items being processed and depend on the item size, racking, and volume of items being handled. Additional considerations in rinsing techniques are local, state, and federal regulations and the design of the water recovery systems covered in the plant layout. Rinsing and techniques for rinsing are discussed in para 6.1.3.1 through para 6.1.3.7. Figure 4 shows the processing steps for anodizing aluminum. Figure 5 shows the processing steps for anodizing and painting of magnesium.

### 2.2 Electroplating System Design

2.2.1 System Design. The system design depends on the following:

- a) Decisions to design are generally made as shown in Figure 6,
- b) Size of the item being processed,
- c) Number of items being handled during a work shift,
- d) Physical shape (entrapment of electrolytes, for example, or an assembly of parts to form the item),
- e) Amount of handling for the process steps (racking or barrel plating),
- f) Material (electrodeposit) being plated, and
- g) Type of handling required (manual, semiautomatic, or automatic).
- h) Time to Plate. The time to deposit the specified coating thickness determines the size of the electroplating system, after the racking sizes are known and the number of items have been stated. When the thickness has been specified, the time to achieve the deposit is calculated using Equation (1) and the plating factor (F) given in Table 1. The timing of a typical complex processing series is given in Table 2 for copper/nickel/chromium and nickel/chromium and in Table 3 for hard chromium deposits.

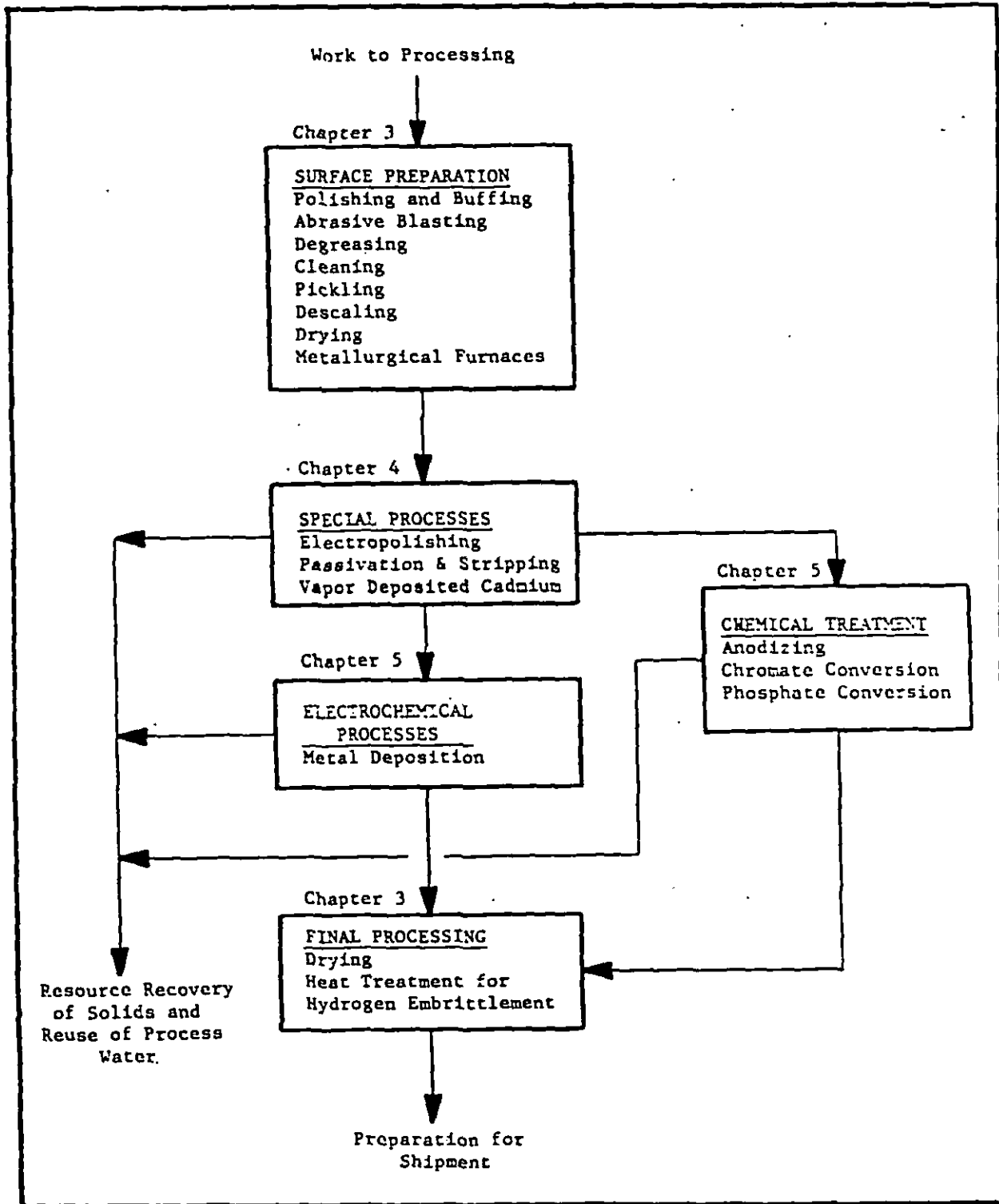


Figure 2  
Flow of Work for a Typical Electroplating System

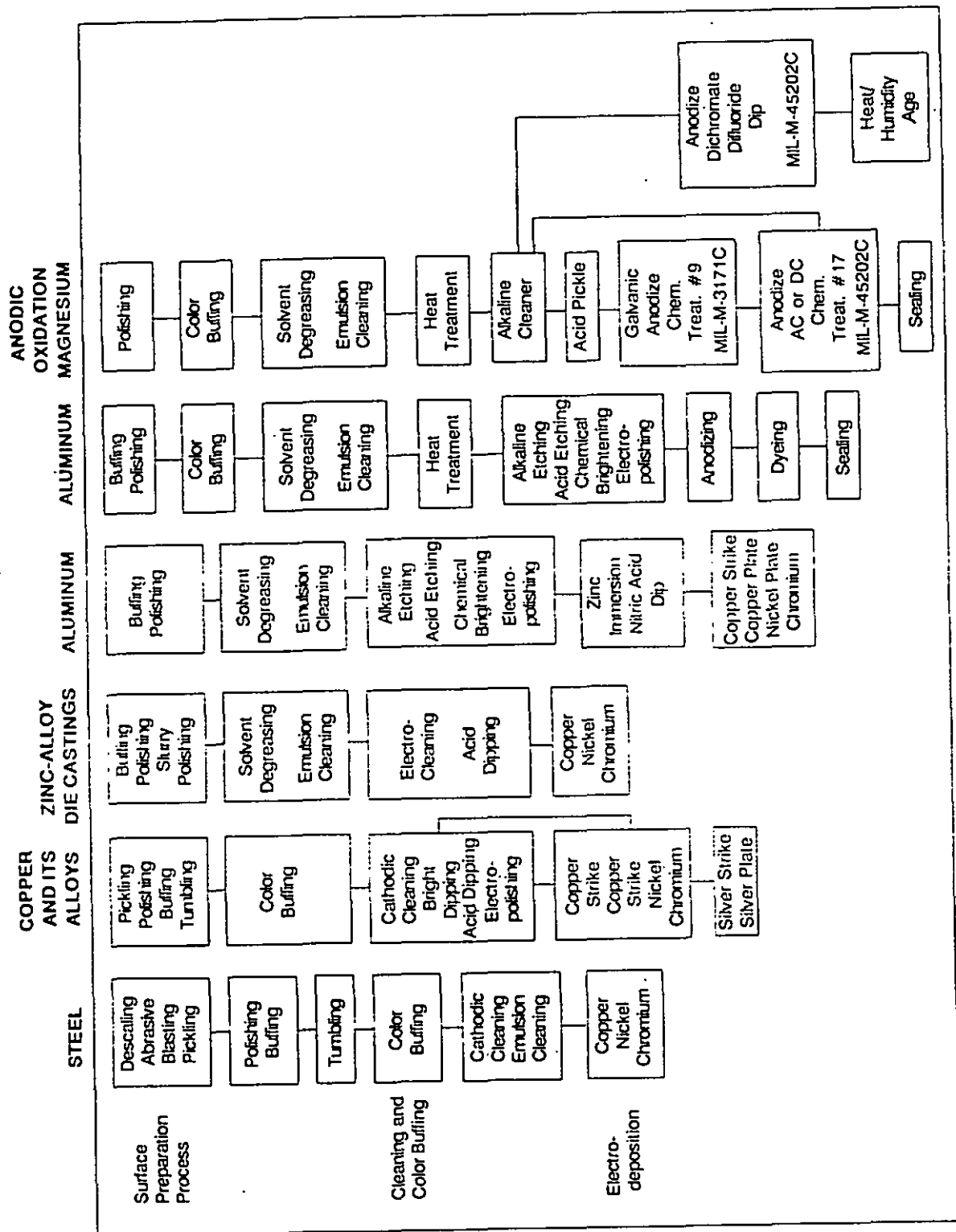


Figure 3  
Typical Electroplating Process Steps

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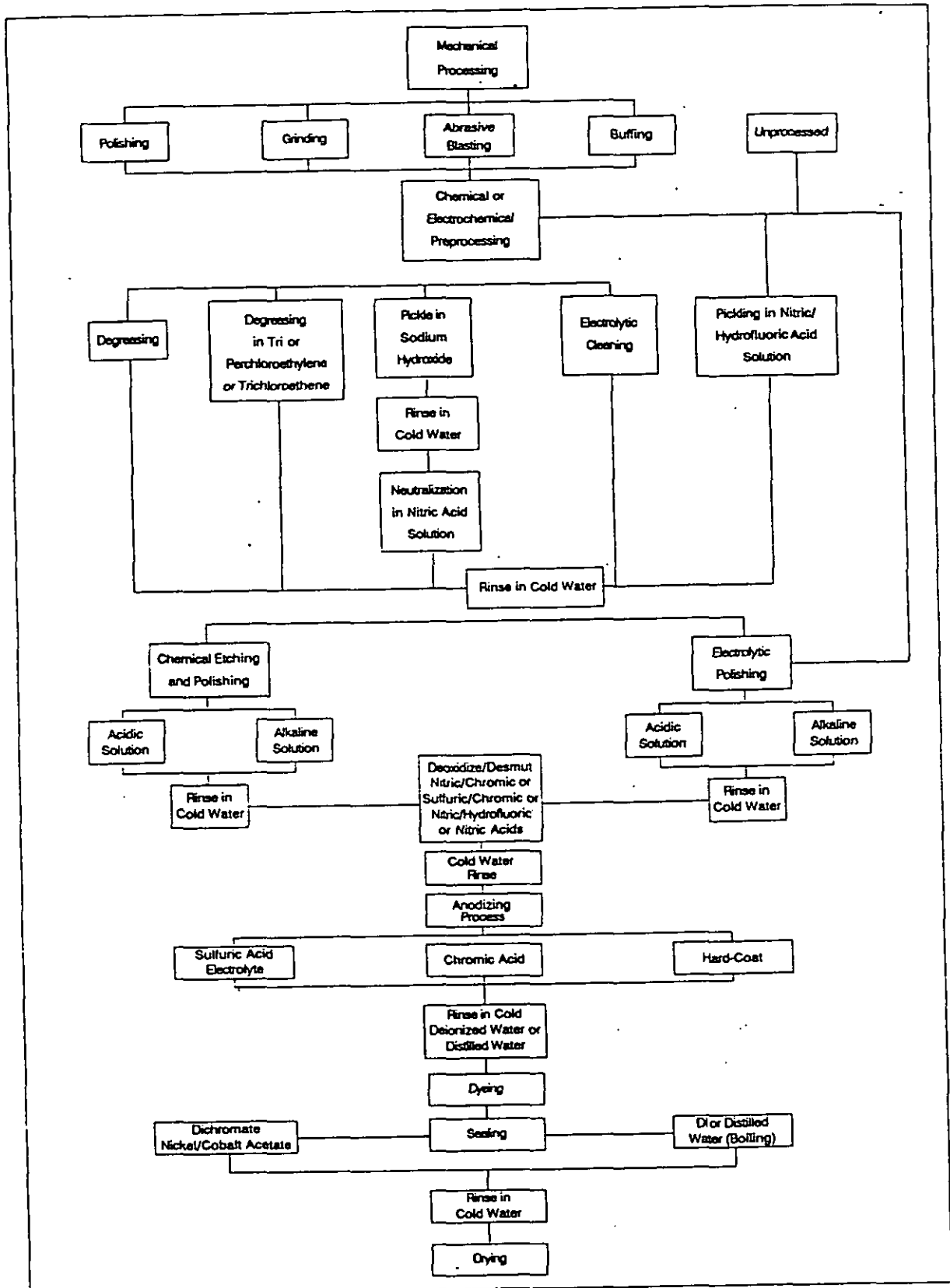


Figure 4  
Typical Anodizing Aluminum Process

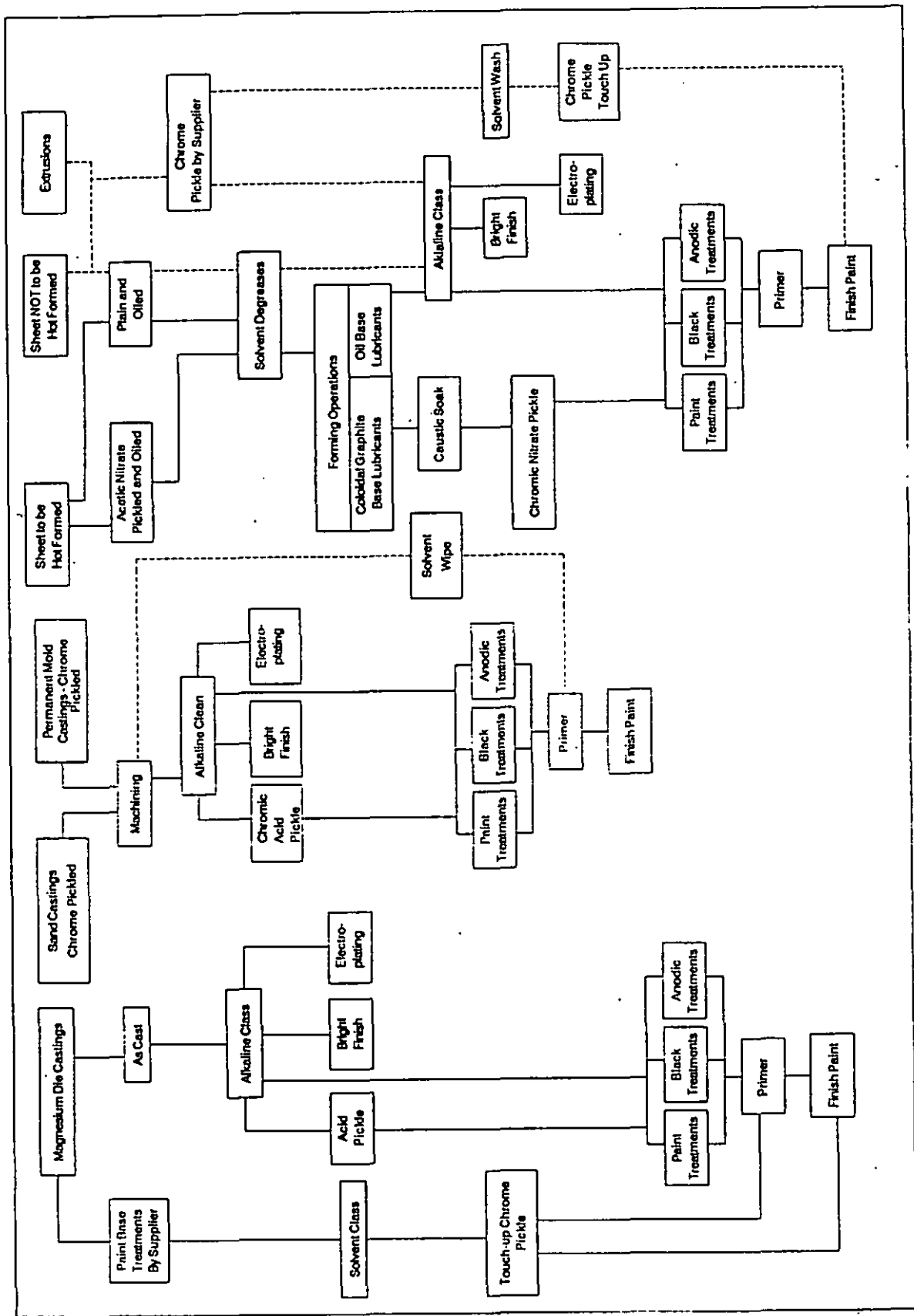


Figure 5  
Typical Processing Steps for Treating and Painting Magnesium





EQUATION:  $H_m = 1000TF/C$  (1)

Where:  $H_m$  - Time, hours  
 T - Thickness, in mils (0.001 in.) or 0.00254 micrometers, ( $\mu\text{m}$ )  
 F - Plating Factor  
 C - Current Density, Amperes per square foot ( $\text{A}/\text{ft}^2$ ) or Amperes per square meter ( $\text{A}/\text{m}^2$ )

Table 1  
 Electrodeposition Data for Typical Processes

	USUAL CATHODE EFFICIENCY (%)	Amp Hrs PER $\text{ft}^2$ TO DEPOSIT 1 mil AT 100% EFFICIENCY	(F) *FACTOR	(C) USUAL CURRENT DENSITY IN $\text{Amps}/\text{in.}^2$
Brass	50	1.95	0.027	0.035
Cadmium	96	9.73	0.07	0.18
Chromium	14	51.8	2.57	2.5
Copper (Acid)	98	17.8	0.126	0.21
Copper (Cyanide)	70	8.89	0.088	0.21
Gold (Cyanide)	95	6.2	0.045	0.04
Indium	65	12.0	0.128	0.14
Lead	98	6.9	0.049	0.10
Nickel	95	19.0	0.139	0.25
Rhodium	80	22.9	0.199	0.10
Silver	99	6.2	0.043	0.18
Silver (Noncyanide)	45	3.0	0.018	0.18
Tin (Alkaline)	70	7.8	0.077	0.14
Zinc (Cyanide)	98	14.3	0.101	0.21

\*Factor is equal to  $\text{A-hr}/\text{in.}^2$  to apply a mil (0.001 in.) deposit at the usual cathode efficiency.

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Table 2  
 Typical Systems for Electrodeposition of  
 Copper/Nickel/Chromium and Nickel/Chromium

ELECTRODEPOSITS	SYSTEMS	TOTAL THICKNESS mils ( $\mu\text{m}$ )	TOTAL TIME MINUTES
Copper/Nickel/Chromium	A, B, D, F	2.0 (50)	50
Copper/Chromium	A, B, F	0.8 (20)	15
Nickel/Chromium	D, F	1.2 (30)	35
Nickel/Microcracked Chromium	D, G	1.3 (33)	45
Duplex Nickel/Chromium	C, E, F	1.2 (30)	35
Duplex Nickel/Micro- cracked Chromium	C, E, G	1.3 (33)	45

## A - Copper Strike

Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	30 (2.8)
Plating time (100% efficiency), minutes	2
Heating, degrees F (degrees C) (a)	120-150° (49-66°)
Filtration	Yes
Agitation	Optional

B - Bright, high-speed copper (0.8 mils, 20  $\mu\text{m}$ )

Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	40 (3.7)
Plating time (100% efficiency), minutes	10
Heating, degrees F (degrees C) (a)	70-80° (21-27°)
Filtration	Yes
Agitation	Yes

C - Semibright Nickel (0.9 mils, 23  $\mu\text{m}$ )

Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	40 (3.7)
Plating time (100% efficiency), minutes	26
Heating, degrees F (degrees C) (a)	130-150° (54-66°)
Filtration	Yes
Agitation	Yes

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Table 2 (Continued)  
 Typical Systems for Electrodeposition of  
 Copper/Nickel/Chromium and Nickel/Chromium

D - Bright Nickel (1.2 mils, 30 $\mu\text{m}$ )	
Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	40 (3.7)
Plating time (100% efficiency), minutes	35
Heating, degrees F (degrees C) (a)	130-150° (54-66°)
Filtration	Yes
Agitation	Yes
E - Bright Nickel (0.3 mils, 8 $\mu\text{m}$ )	
Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	40 (3.7)
Plating time (100% efficiency), minutes	8
Heating, degrees F (degrees C) (a)	130-150° (54-66°)
Filtration	Yes
Agitation	Yes
F - Chromium (0.01 mils, 0.3 $\mu\text{m}$ )	
Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	144 (13.4)
Plating time	
Conventional (10% efficiency), minutes	2
High-speed (25% efficiency), seconds	55
Heating, degrees F (degrees C) (a) (b)	115-150° (46-66°)
Filtration	No
Agitation	No
Ventilation (c)	Yes
G - Microcracked Chromium (0.025 mils, 0.64 $\mu\text{m}$ )	
Current density, A/ft <sup>2</sup> (A/m <sup>2</sup> )	216 (20)
Plating time (25% efficiency), minutes	2.5
Heating, degrees F (degrees C) (a) (b)	115-150° (46-66°)
Filtration	No
Agitation	No
Ventilation (c)	Yes

(a) Operating temperature

(b) Cooling as well as heating may be required

(c) Chemical suppressants (mist, foam, or spray) may be used in addition to ventilation

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Table 3  
Hard-Chromium Plating of Typical Parts

PART	SUBSTRATE	COATING THICKNESS Mils ( $\mu\text{m}$ )	PLATING TIME MINUTES
Face seals	Steel or Copper	3-7 (75-180)	600
Aircraft engine parts	Nickel-based alloys, or high strength Steel	3-7 (75-180)	600
Piston rings	Steel, Cast Iron	6-10 (150-255)	480
Balls for valves	Brass, Steel	0.3-0.5 (7.5-13)	20
Lock bodies	Brass	0.2-0.3 (5-8)	20
Engine cylinders	Cast Iron	10 (255)	300
Bushings	1018 carburized Steel, 56HRC	1 (25)	45
Cutting tools	Tool Steel	0.05 (1.3)	5
Rifle barrels (30-calibre)	Steel	1 (25)	40
Hydraulic cylinders	1045 Steel	0.5 (13)	40
Hydraulic shafts	Steel	0.08-0.12 (2-3)	8-12
Pins	Steel	0.5 (13)	30
Ring gauges	Steel	8 (205)	240
Plug gauges	1045 Steel	5 (125)	150
Crankshafts (worn)	Steel	5-50 (125-1,250)	150- 1,200

## Section 3: SURFACE PREPARATION

3.1. Mechanical Polishing, Buffing, and Coloring

3.1.1 Polishing and Buffing. The equipment for polishing and buffing are similiar and may be classified as manual, semiautomatic, and automatic. The process of buffing is performed to provide a shiny or reflective surface and, contrary to polishing, is not done to size an item. Buffing is performed:

- a) to obtain satin, brushed, or butler finishes,
- b) to cut down for preliminary smoothness,
- c) to cut and color for intermediate luster, and to color for the production of high luster or mirror finish.

Polishing is a precision process, and as the process modifies the shape of items and machines these items to a specific size, rigid production standards are followed.

3.1.1.1 Automatic and Semiautomatic Machines. Automatic and semiautomatic machines consist of one or more polishing heads, a conveyor to feed items across the heads, and fixturing to locate the items in correct position on the conveyor. For large items, the heads, whether they are wheels or belts, may traverse the items to be polished. In establishing a mechanical polishing process, the wheel diameter or belt size, horsepower of the drive, abrasive material and its feed system, and finishing are to be specified.

3.1.1.2 Polishing Materials. Materials used for polishing are buffs and buffing compounds. Buffs are composed of muslin, canvas, felt or leather, as specified. These buffs may be hard or soft depending on the binders and whether or not they are stitched, as specified. The buffing compounds may be liquid or bars, as specified. The compounds may be aluminum oxide of various sizes or silicon dioxide also of various sizes, as specified. The liquid or bars, in addition to compounds, consist of bonding and lubricating agents. The buffing compounds may be automatically fed or manually applied, as required.

3.1.1.3 Polishing Speeds. Polishing speeds are between 6,000 and 8,000 feet per minute (fpm) for glued wheels because the adhesive breaks down at 9,000 fpm.

3.1.1.4 Exhaust Systems for Polishing Machines. Adjustable baffles and an exhaust system are desirable to reduce hazards and to increase cleanliness and quality. For dry polishing and grinding on metals and alloys containing highly toxic metals such as beryllium, cadmium, hexavalent chromium, cobalt and lead, local exhaust should be installed in accordance with OSHA, 29 CFR 1910.94.

3.2 Abrasive Blasting

3.2.1 Glass Bead Blasting. Impact blasting with glass beads is used for cleaning, decorative purposes, deburring and peening. Peening action acts to impart a layer of compressive stresses on the surface of the item being

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blasted. This action improves the mechanical resistance to shock, vibration, and fatigue. This is an alternative to shot blasting. Glass bead blasting is preferred to shot peening for surface preparation prior to engineering chromium plating (refer to American Society for Testing and Materials (ASTM) B630, Preparation of Chromium for Electroplating With Chromium). The items are processed using glass beads conforming to Military Specification (Mil Spec.) MIL-G-9954, Glass Beads, for Cleaning and Peening; size 13 at an air pressure of 100 pounds per square inch gauge (psig) for dry processing and 40 psig for wet processing, after they are masked to prevent blasting areas that are to be protected. These items are degreased and dried for further processing.

3.2.2 Abrasive Silica. Table 4 shows the air consumption for abrasive blasting. Table 5 provides information on cleaning rates and comments on the reuseability of the abrasive media. Table 6 provides information on physical data of the nonmetallic abrasive media.

Table 4  
Air Consumption

NOZZLE ORIFICE (in.) (mm)		CUBIC FEET PER MINUTE REQUIRED @ 100 psig	ABRASIVE CONSUMPTION PER HOUR (lb)
3/16	4.8	60	260
1/4	6.4	105	490
5/16	7.9	160	812
3/8	9.5	232	1,152
7/16	11.1	315	1,584
1/2	12.4	412	2,024
5/8	15.9	580	2,518
3/4	19.1	840	3,174

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Table 5  
Examples of Cleaning Rates With Some Abrasives

ABRASIVE	ABRASIVE CONSUMPTION (lb/ft)	PRODUCTION RATE (ft <sup>2</sup> /min)	ETCH (mils)	COMMENTS
Silica Sand 16/40 Mesh	2.6	4.75	1-1/2	Dusty
*Garnet 36 Grit	*3.6	3.55	1-1/2	Very little dust-reusable
*Aluminum Oxide	*3.1	4.58	1-1/2	Very little dust-reusable
*G-40 Steel Grit	*5.5	3.06	2-1/2	No Dust Grey Metal-reusable
Crushed Flint 12/30 Mesh	3.6	2.69	3	Reusable
Staurolite 50/100 Mesh	3.1	4.85	1/2	Smooth Surface
Coal Slag 16/40 Mesh	3.2	3.83	2-1/2	Reusable-Imbedding
Copper Slag 16/40 Mesh	3.1	4.36	2	Reusable-Imbedding

\*These abrasives are normally reused.

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Table 6  
Physical Data on Non-Metallic Abrasives

	HARDNESS (MOHR SCALE)	SHAPE	SPECIFIC GRAVITY	BULK DENSITY (lb/ft <sup>3</sup> )	COLOR	FREE SILICA wt %	DEGREE OF DUSTING	REUSE
<u>NATURALLY OCCURRING ABRASIVES</u>								
Sands								
Silica	5	rounded	2-3	100	white	90+	high	NR
Heavy Mineral	5-7	rounded	3-4	128	variable	<5	med	S
Flint	6.5-7	angular	2-3	80	grey-white	90+	med	S
Garnet	7-8	angular	4	145	pink	nil	med	S
Zircon	7.5	cubic	4.5	184	white	nil	low	S
Novaculite	4	angular	2.5	100	white	90+	low	S
<u>BY-PRODUCT ABRASIVES</u>								
Slags								
Boiler	7	angular	2.8	80-90	black	nil	high	NR
Copper	8	angular	3.3	100-120	black	nil	low	S
Nickel	8	angular	2.7	84	green	nil	high	NR
Walnut shells	3	cubic	1.3	44	brown	nil	low	NR
Peach pits	3	cubic	1.3	44	brown	nil	ow	NR
<u>MANUFACTURED ABRASIVES</u>								
Silicon carbide	9	angular	3.2	105	black	nil	low	S*
Aluminum oxide	8	blocky	4.0	120	brown	nil	low	S

S - Suitable    NR - Not Recommended



3.2.3 Metallic Shot (Peening). The shot and grit size is given in the Society of Automotive Engineers (SAE) J444, Cast Shot and Grit Size Specifications for Peening and Cleaning, Recommended Practice. When water is added to the abrasive shot, the process is called the vapor blast or wet blast system. Peening intensity is measured in accordance with Mil Spec. MIL-S-13165, Shot Peening of Metal Parts. (Refer to ASTM B630.)

### 3.3 Degreasing

3.3.1 Degreasing Process Selection. The selection of the degreasing process is dependent on the soil encountered, item being processed (substrate involved), and number of items being handled per unit time (surface area and volume of items). Table 7 shows typical products and processes used in degreasing work prior to electroplating or anodizing. Table 8 provides typical solvent properties for vapor and ultrasonic degreasing.

#### 3.3.2 Vapor Degreasing

3.3.2.1 Vapor Degreasers. A cross-section of the essential components of a vapor degreaser and the fluid phases, including description of an appropriate hood, are shown in Figure 7. Heat is supplied to vaporize and maintain the vapor phase by steam, gas, or electric sources. Moisture is controlled to prevent staining of work and deterioration of equipment. Since moisture and solvent vapors mix freely, the solvent and water are separated in the liquid phase in the condensate trough. This condensate is lead away from the degreaser to a precooler and a water separator, and the solvent is returned to the degreaser. The temperature of the condensate is substantially below the boiling point of the solvent-water mixture. The water separator is designed to have a capacity of not less than three minutes retention time when the condensate is generated at maximum workload and ambient humidity conditions and minimum ambient temperature condition. The vapor degreaser is required to have access doors and safety controls. A cold trap may be used to reduce solvent loss and reduce operator exposure to solvent fumes.

3.3.2.2 Safety Controls for Vapor Degreasers. The following information is obtained directly from American Conference of Governmental Industrial Hygienists (ACGIH) Publication ACGIH 4710, Occupational Health Hazard of Solvents.

a) Vapor degreasing tanks should be equipped with a condenser or vapor level thermostat to keep the vapor level below the top edge of the tank by a distance equal to one-half the tank width, or 36 in. (0.91 m), whichever is shorter.

b) Where water type condensers are used, inlet water temperatures should not be less than 80 degrees Fahrenheit (F) (27 degrees Celsius (C)) and the outlet temperature should not exceed 110 degrees F (43 degrees C).

c) Degreasers should be equipped with a boiling liquid thermostat to regulate the rate of vapor generation, and with a safety control at an appropriate height above the vapor line to prevent the escape of solvent in case of a malfunction.

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Table 7  
Degreasing Process Selection for Typical Products and Parts

INDUSTRY	PRODUCT OR PART	SOIL	CLEANING METHOD	SOLVENT OR DETERGENT	EQUIPMENT
Electronic Components	Thyristors	Flux	Ultrasonic immersion; cascade tap water rinse; dry	Strong alkaline cleaner; tap water	Aqueous cleaners
	Capacitors	Rosin Flux	Vapor rinse; ultrasonic or non-ultrasonic immersion; distillate spray; vapor rinse	Azeotrope of trichlorotrifluoroethane & methyl alcohol	Vapor plus Ultrasonic Degreaser
	Ceramic substrates	Handling and particulate dirt	Ultrasonic immersion; boiling immersion; ultrasonic immersion; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water	Ultrasonic Degreaser
Electrical Machinery	Quartz crystals	Grease, oils, particulates	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Trichlorotrifluoroethane or azeotrope of trichlorotrifluoroethane and methanol	Ultrasonic Degreaser
	Resistors	Grease, oils, particulates	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Azeotrope of trichlorotrifluoroethane and methylene chloride	Ultrasonic Degreaser
	Electric motors	Combination soils	(a) Ultrasonic immersion; tap water spray rinse; immersion rinse; dry (b) Ultrasonic immersion; boiling immersion; ultrasonic immersion; distillate spray rinse; vapor rinse	(a) Strong alkaline detergent; tap water (b) Blend of trichlorotrifluoroethane and surfactant/water emulsion; and trichlorotrifluoroethane	Aqueous cleaners Ultrasonic Degreaser
Electrical	relays	Grease, oils, particulates	Vapor rinse; ultrasonic immersion; spray rinse; vapor rinse	Azeotrope of trichlorotrifluoroethane and methanol or methylene chloride	Ultrasonic Degreaser
	Electrical switches	Rosin flux	Vapor rinse; ultrasonic immersion; spray rinse; vapor rinse	Blend of trichlorotrifluoroethane and methanol or ethanol	Ultrasonic Degreaser

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Rectifiers (except selenium)	Flux, oxides	Ultrasonic immersion; tap water rinse; dry	Acidic cleaner; tap water	Aqueous Cleaners
Rectifiers (selenium)	Flux, oxides	Ultrasonic immersion; tap water rinse; dry	Mild alkaline detergent; tap water	Aqueous Cleaners
Telephone relays and switching gear	Combination soils	Ultrasonic immersion; boiling immersion; ultrasonic immersion; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion; and trichlo- rotrifluoroethane or trichlorotrifluoro- ethane and methanol	Ultrasonic Degreaser
Teletype printers	Combination soils	Ultrasonic immersion; boiling immersion; ultrasonic immersion; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion; and tri- chlorotrifluoroethane	Ultrasonic Degreaser
Instrumentation	Gyroscopes	(a) Vapor rinse; ultrasonic immersion; distillate spray rinse; vapor rinse	(e) Trichlorotrifluoroethane	Ultrasonic Degreaser
		(b) Ultrasonic immersion; DI water rinse; dry	(b) Neutral detergent; deionized water	Aqueous Cleaner
Small parts	Oils, particulates	Ultrasonic immersions; spray rinse; vapor rinse	Azeotrope of trichlorotrifluoroethane and methylene chloride or methanol	Ultrasonic Degreaser
Watt-hour meters	Combination soils	Ultrasonic immersion; boiling immersion; ultrasonic immersion; distillate spray rinse; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion; and trichlorotrifluoroethane	Ultrasonic Degreaser
Bearings	Oil, dust, lint	Ultrasonic immersion; boiling immersion; ultrasonic immersion; spray rinse; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion and trichlorotrifluoroethane	Ultrasonic Degreaser
Mechanical Machinery Parts	Diesel engine parts	Ultrasonic immersion; tap water immersion rinse; dry	Strong alkaline detergent tap water	Aqueous Cleaner
	Gas turbine fuel nozzles	Ultrasonic immersion; tap water immersion rinse; dry	Strong alkaline detergent; tap water	Aqueous Cleaner
	Office Machines	Ultrasonic immersion; boiling immersion; ultrasonic immersion; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion; and trichlorotrifluoroethane	Ultrasonic Degreaser

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Table 7 (Continued)  
Degreasing Process Selection for Typical Products and Parts

INDUSTRY	PRODUCT OR PART	SOIL	CLEANING METHOD	SOLVENT OR DETERGENT	EQUIPMENT
Metal Finishing Industry	Aluminum Parts	Grease, oils, particulate	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Azeotrope of trichlorotrifluoroethane and methanol	Ultrasonic Degreaser
	Brass Parts	Atomospheric soils	(a) Ultrasonic immersion; immersion rinse; dry (b) Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	(a) Mild acidic detergent; tap water (b) Methylene chloride	Aqueous Cleaner Ultrasonic Degreaser
	Nickel Parts	Forming and cutting lubricants, particulates	(a) Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse (b) Ultrasonic immersion; immersion rinse; dry	(a) Perchloroethylene; methylene chloride; 1,1,1-trichloroethane (b) Strong, chelated alkaline detergent; tap water	Ultrasonic Degreaser and Vapor Degreaser Aqueous Cleaner
	Steel, mild	Grease, oils, particulates	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Methylene chloride; azeotrope of trichlorotrifluoroethane and methylene chloride; 1,1,1-trichloroethane	Ultrasonic Cleaner Plus Vapor Degreaser
	Steel, corrosion resisting	Buffing and polishing compounds	(a) Ultrasonic immersion; immersion rinse; dry (b) Ultrasonic immersion; distillate spray rinse; vapor rinse	(a) Soap-free alkaline cleaner; tap water (b) 1,1,1-trichloroethane; blend of trichlorotrifluoroethane and methanol	Aqueous Cleaner Ultrasonic Degreaser
	Titanium	Machining oils, particulates	Vapor rinse, ultrasonic immersion; distillate spray rinse; vapor rinse	Azeotrope of trichlorotrifluoroethane and methylene chloride	Ultrasonic Degreaser
	Precious Metal Parts	Buffing compounds	(a) Ultrasonic immersion; tap water rinse; dry	(a) Soap-free alkaline cleaner; tap water	Aqueous Cleaner

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Transportation Industry	Plated Precious Metal Parts	Polishing compounds	(b) Ultrasonic immersion; spray rinse; vapor rinse	(b) Methylene chloride or 1,1,1-trichloroethane	Ultrasonic Degreaser
	Ceramic and steel automotive exhaust gas sensors	Shop soils, particulates, oils	Ultrasonic immersion; tap water rinse; dry	Soap-free alkaline cleaner; tap water	Aqueous Cleaner
	Carbon steel, stainless steel and plastic fuel injector parts	Atmospheric soils, particulates, oils	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Blend of trichlorotrifluoroethane and methanol	Ultrasonic Degreaser
	Corrosion resisting steel turbine blades	Electrical discharge debris	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Blend of trichlorotrifluoroethane and methanol	Ultrasonic Degreaser
	Power steering valve spools	Metal chips, broaching oil, tool coolants	Vapor rinse; ultrasonic immersion; distillate spray; vapor rinse	Azeotrope of trichlorotrifluoroethane and methylene chloride	Ultrasonic Degreaser
			Ultrasonic immersion; immersion rinse; water displacing oil immersion	Chelated caustic detergent; tap water; water displacing oil	Aqueous Cleaner

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Table 8  
Properties of Typical Solvents Used in Vapor and Ultrasonic Degreasing

PROPERTY	1, 1, 1 - TRI- CHLOROETHANE (METHYL CHLOROFORM)	TRICHLORO- ETHYLENE	PERCHLORO- ETHYLENE
Lbs/gal at 68 °F	11.03	12.22	13.55
Boiling point, °F	166.4	188.4	250.5
Evap. Rate (CCl <sub>4</sub> =100)	100	84	39
Surface Tension at 68 °F, dynes/cm	25.9 (77 °F)	29.2	32.3
Solubility, % by wgt at 68 °F			
In water	<0.10 (77 °F)	0.11	0.02
Of water	---	0.02	0.01
Flash Point, °F	None	None	None
Vapor Pressure at 68 °F, Torr	105	---	14
Flammable Limits, % vol in air			
Lower	---	12	Nonflammable
Upper	---	86	Nonflammable
Permissible Exposure Limit (PE), (8-hr TWA), ppm*	50	50	50
Spec. Heat Liquid at 68 °F, Btu/lb °F	---	0.23	0.21
Latent Heat at B.P., Btu/lb	---	103	90
Kauri-Butanol Value, cc	---	130	90
Energy to heat ft <sup>2</sup> of tank surface to operating temperature, Btu	35	44	68
Energy to bring to boiling point each gal of solvent, Btu	253	313	485
Energy to heat one lb of steel parts to solvent temperature, Btu	10	12	19
Energy for each ft <sup>2</sup> of tank surface to keep solvent at boil, Btu	155	208	368
Energy to evaporate each gal of solvent in bath, Btu	1127	1262	1218

\*TWA: work-shift time-weighted average.

d) Tanks or machines of more than 4 ft<sup>2</sup> (0.37 m<sup>2</sup>) of vapor area should be equipped with suitable gasketed cleanout or sludge doors, located near the bottom, to facilitate cleaning.

e) Work items should be placed in and removed slowly from the degreaser at a rate no greater than 11 ft/min (0.055 m/s) to prevent sudden disturbances of the vapor level.

f) Care must be taken to prevent direct solvent carryout due to the shape of the part. Maximum rated workloads as determined by the rate of heat transfer (surface area and specific heat) shall not be exceeded.

g) Special precautions shall be taken where natural gas or other open flames are used to heat the solvent to prevent vapors from entering the combustion air supply.

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h) Heating elements should be designed and maintained so that their surface temperature will not cause the solvent or mixture to break down or produce excessive vapors.

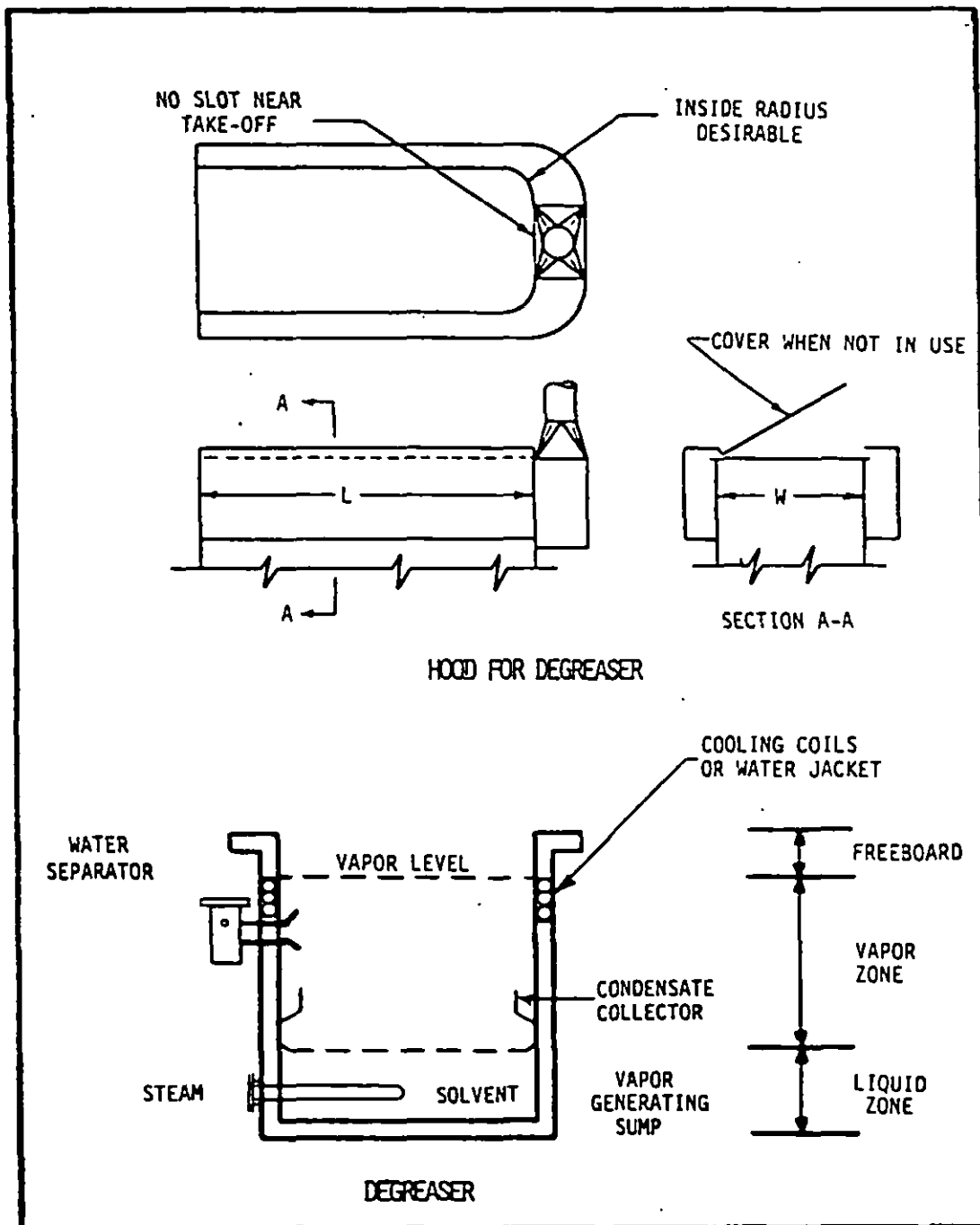


Figure 7  
Essentials of a Vapor Degreaser

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i) Degreasers should be located in such a manner that vapors will not reach or be drawn into atmospheres used for gas or electric arc welding, high temperature heat treating, combustion air, open electric motors, or for operating-personnel breathing.

j) Whenever spray or other mechanical means are used to disperse solvent liquids, sufficient enclosure or baffling should be provided to prevent direct release of airborne vapor above the top of the tank.

k) An emergency quick-drenching facility (refer to American National Standards Institute (ANSI) Z358.1, Eyewash Shower Equipment, Emergency) should be located near the degreaser for use in the event of accidental eye contact with the degreasing liquid.

NOTE: Electric arcs, open flames and hot surfaces will thermally decompose halogenated hydrocarbons to toxic and corrosive substances (such as HCl acid and/or HF acid). Under some circumstances, the toxic agent phosgene ( $\text{COCl}_2$ ) may be formed.

3.3.2.3 Space Requirements for Vapor Degreasers. Vapor degreasing is accomplished in 1 to 3 min; therefore, compact equipment is used, and a minimum of building space is required. The tank size is double the horizontal cross section of the largest item to be handled. The depth of the tank below the vapor line is required to be great enough to allow the transfer of the item from one compartment to another below the vapor line. The freeboard (vertical distance between the vapor line and the top of the tank) is required to be 60 percent of the tank width. Freeboard on long, narrow degreasers, such as are used for shafts, tubing, and pipe, are deeper than the 60 percent of the tank width to prevent drafts running the length of the tank and carrying out the solvent vapors. Diffusion losses from the vapor zone are on the order of 0.5 to 1 lb/ft<sup>2</sup> per 8-hr day. Diffusion losses are reduced by designing entrance and exit tunnels, which are silhouetted and baffled to minimize airflow through the degreaser. Manual degreasers are covered when not in operation.

3.3.2.4 Heating Requirements for Vapor Degreasers. Heat loads include losses by solvent escape internal distillation of solvent, heating the workload (items processed including racks, baskets and barrels), radiation, and normal losses by solvent clinging to the work. The design heat input required is 50 percent greater than the calculated losses. The coil heat transfer surface area needed to heat the solvent is determined by the heat input requirement and a solvent used under the most adverse conditions. The most adverse conditions to operate the vapor degreaser is a full load of work and a solvent contamination of 30 percent soil.

3.3.3 Ultrasonic Degreasing. Ultrasonic degreasing, mainly used on electronic assemblies, is carried out as follows: a presoak in a heated solvent cleaning tank to remove soils, solderflux residues, and gross surface contaminants, an ultracleaning step to remove the remaining contaminants, and a spray rinse to remove staining materials. The ultrasonic cleaning step is shown in Figure 8. Figure 9 shows the effects of amounts of soils on the cleaning rates.



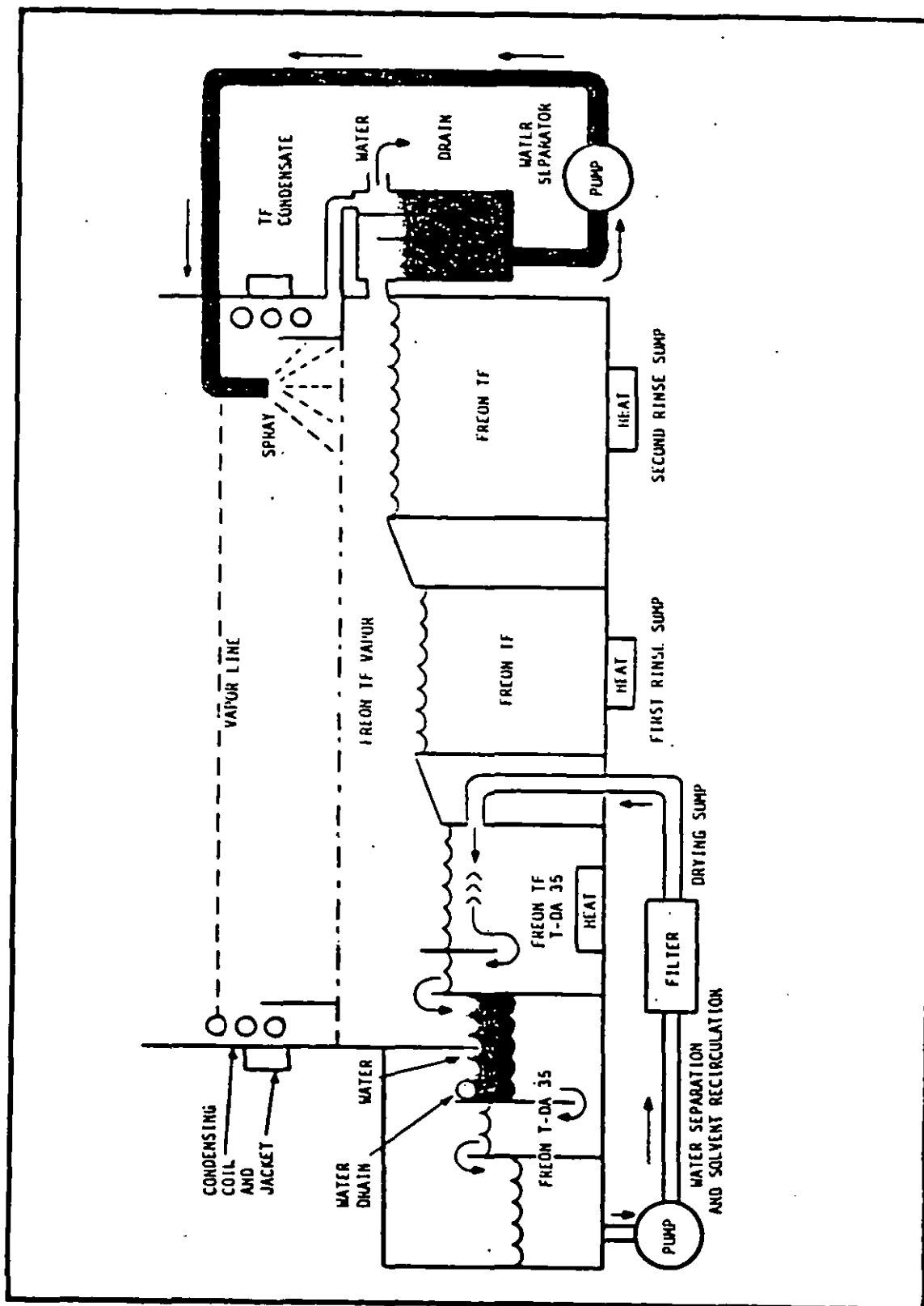


Figure 8  
Typical Large Ultrasonic Degreaser Using Fluorinated  
Hydrocarbon Solvents and Methyl Alcohol

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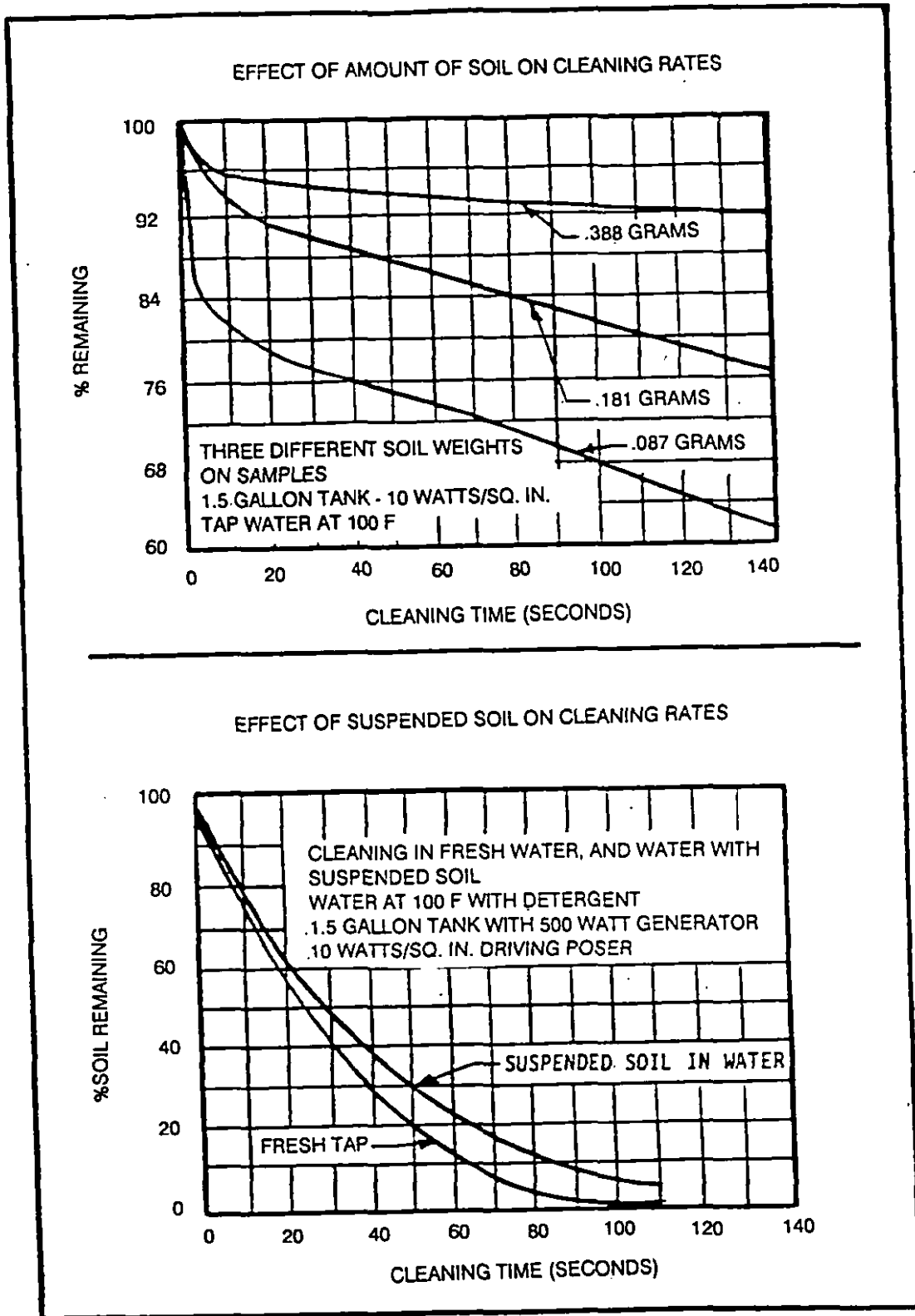


Figure 9  
Effects of Varying Amounts of Soils on Cleaning Rates of Ultrasonic Degreasers

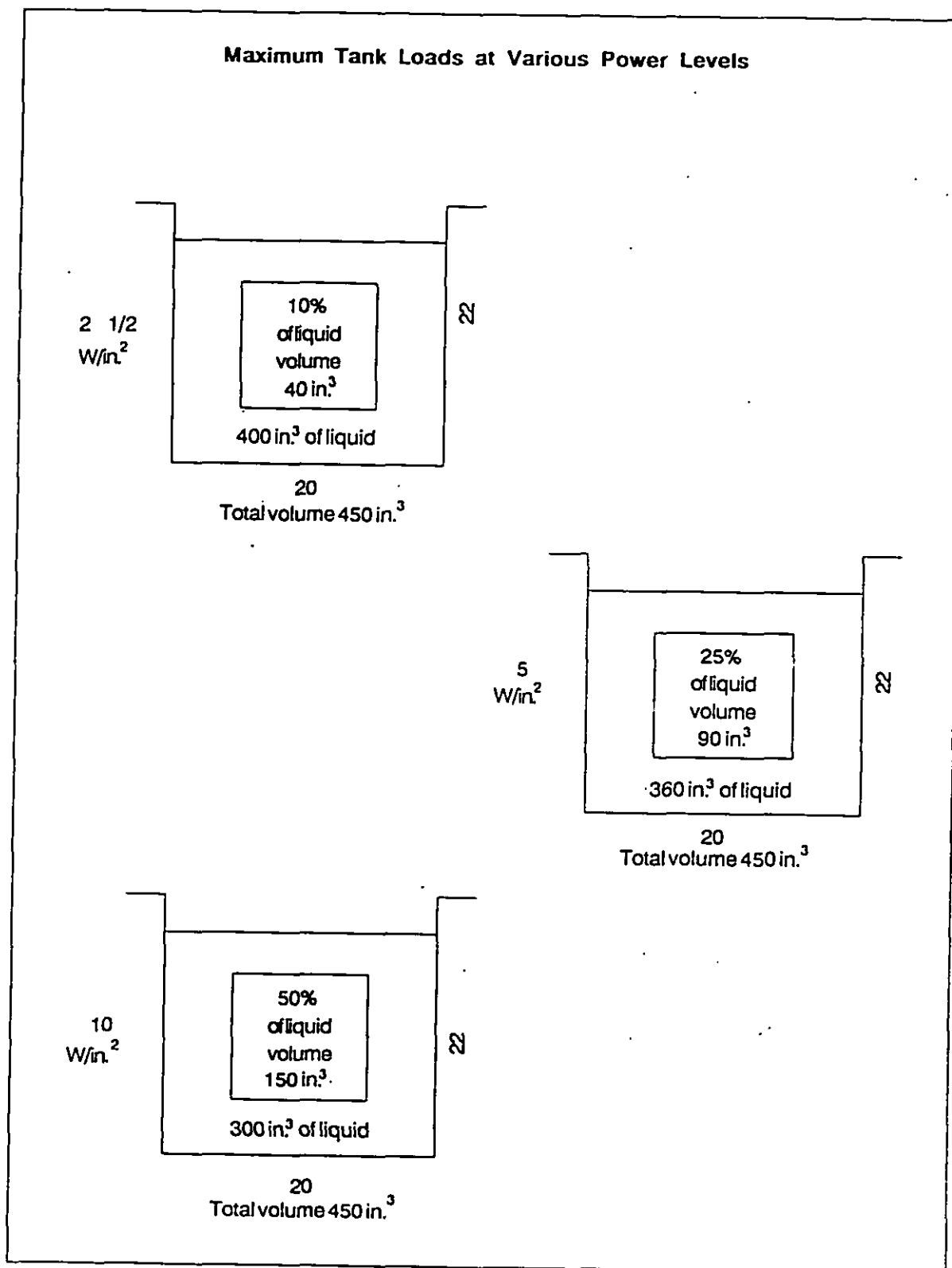


Figure 10  
Tank Size as Related to Power Input to the Liquid

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3.3.3.1 Ultrasonic Solvent/Vapor Cleaning System Size. The transducer power requirements are determined by the workload which affects the tank size. A typical transducer is rated at 1 kilowatt (kW) output, and these transducers are combined to form an ultrasonic generator of required power. Power input varies from two kW for small production units with an output of 1 kW to an electrical input of 208 V and 10 kVA with an average output of 6 kW. Tank size, as related to power input to the liquid, is illustrated in Figure 10.

3.3.3.2 Ultrasonic Cleaning Compounds. Ultrasonic cleaning compounds fall into two categories--solvents and detergents. Factors to be considered in the use of these compounds are solvent activity, wetting activity, emulsification, saponification, deflocculation, colloidal activity and suspension, pH, buffer activity, water conditioning and the effect of ultrasonic energy on the compound. When fluorinated hydrocarbons are specified for the solvent they are to conform to Mil Spec. MIL-C-81302, Cleaning Compound Solvent Trichlorotrifluoroethane, Type II.

3.3.3.3 Distillation Equipment. An essential part of a vapor degreasing system is a distillation accessory to recover spent solvents. This auxiliary still returns purified solvent to the vapor degreaser and the wastes are disposed of properly. If the wastes are steam stripped, they may contain a measurable percentage of oil by weight which is recoverable. This waste is sold to firms who are able to recover the oil for recycling. The wastes shall be stored in closed containers. The distillation equipment is normally a pot type operating at atmospheric pressure. Heat is supplied either by steam in a jacket around the still or by a steam coil in the still. Maximum efficiency is achieved by a constant level device and a solvent pump to maintain proper level of waste solvent in the still. A water separator shall be provided to remove water, and a thermometer shall be conveniently located in the still pot as a guide to measure contaminants present. In order to save energy, live steam is reduced in the boil-down period. Proper safety devices should be installed to minimize the hazards from drying out of the still pot and accumulation of waste in the still. **CAUTION:** Degreasing solvents in use tend to hydrolyze in the presence of moisture to form hydrochloric acid (HCl). Metal chips, particularly aluminum, speed the formation of corrosive acid by catalytic action. Frequent testing of degreasing solvents to detect acidity is required. Solvent that has been found acidic should be returned to the supplier and exchanged for properly inhibited new material. Where chlorinated solvents are pumped under pressure in contact with aluminum, explosions can occur. Avoid having chlorinated compounds in confined spaces when in contact with aluminum or aluminum alloys.

3.3.3.4 Optional Equipment. Optional equipment include insulation, recirculation, and solvent recovery system filtration units. These features reduce fuel and power requirements by reducing heat losses, and by recirculation of solvent, thereby reducing the number of tank dumps and new solvent additions.

### 3.4 Cleaning

3.4.1 Preliminary Cleaning. Preliminary cleaning by soaking is required to remove grease, oil, drawing and buffing compounds, corrosion-preventive oils, greases and compounds, and loosely adherent oxide residues.

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3.4.1.1 Alkaline Immersion Cleaning. These cleaning materials are composed of alkaline salts such as potassium or sodium hydroxide, silicates, phosphates or carbonates, plus additives such as sequestering agents, dispersants, corrosion-inhibitors, and various wetting agents. The additives vary depending on the type of soil encountered (e.g., buffing compounds require emulsion type agents). This step is required where soils would put a heavy burden on subsequent cleaning operations. The baths operate at or near the boiling temperature. The items are soak-cleaned for 3 to 5 min, and after soaking, the adherent cleaners are removed by spray rinsing with clean water under a pressure of not less than 15 psig, or the items are agitated in running rinse water. The pH of the alkaline cleaners range between 12.0 and 13.5 for heavy duty cleaners used on ferrous metals, and between 10.5 and 12.0 for light duty cleaners used on nonferrous metals. Nonferrous metals may require the addition of corrosion inhibitors to the cleaning salt formulations.

3.4.1.2 Emulsifiable Solvent Cleaning. Emulsifiable solvent cleaning uses petroleum-derived solvents which are mainly chlorinated hydrocarbons and surfactants that render the solvents emulsifiable. This is a soak cleaning step, and the soils are removed in the water rinse. This step reduces the soil load on subsequent cleaning steps.

3.4.1.3 Solvent Cleaning. This soak cleaning step is used to soften soluble portions of the soil and thus make the soil easily removable in an alkaline cleaning process. The agents used to soften the soils are petroleum or inhibited chlorinated solvents. The solvents are high boiling compounds used at elevated temperatures. These solvents are selected so that they do not completely dry on the surface and pigmented materials may be easily removed. The solvent cleaning tanks require recovery systems to save evaporated solvent and return this cleaner to the soak tank.

3.4.2 Alkaline Cathodic Cleaning. In alkaline cathodic cleaning, the items are made the cathode, and the tank is the anode, or anodes are placed in the tank. Operating temperature is 160 plus or minus 56 degrees F (71 plus or minus 31 degrees C); the voltage is 3 to 6 V; and the current density and time are shown in Table 9.

Table 9  
Operating Conditions for Alkaline Cathodic Cleaners

SUBSTRATE*	CURRENT DENSITY Amp/ft <sup>2</sup>	TIME MINUTES
Steel	50-100	0.5-3
Corrosion-Resisting Steel	50-150	0.5-3
Zinc	10-30	0.3-1
Copper	30-100	0.5-2
Copper Alloys	20-50	0.5-1
Nickel	20-80	0.5-1

\*Alloys affected by hydrogen embrittlement are later required to be relieved by heat.

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3.4.2.1 Anodic Cleaning. Anodic cleaning in alkaline cleaners is accomplished at 3 to 6 V with the current density varying depending on the area of the items and the number of items being cleaned. Anodic cleaning is not performed on aluminum and its alloys, chromium, lead and its alloys, nor other metals and their alloys that are soluble in alkaline cleaners.

3.4.2.2 Periodic Reverse Cleaning. Periodic reverse cleaning is accomplished by making the items alternately cathodic and anodic at approximately 6 V. This type of cleaning has the advantage of avoiding the deposit of positively charged materials on the items, thereby reducing the amount of dissolution of the basis metal.

3.4.2.3 Bipolar Electrode (Cathodic) Cleaning. Bipolar electrode cleaning (cathodic) is accomplished when the object to be cleaned is not connected to the power supply, but is placed in the cleaning solution between an anode and a cathode. That portion of the part closest to the anode becomes cathodic, and the portion nearest the cathode becomes anodic. The anodic portion is scrubbed by the evolution of oxygen, and the cathodic portion, by hydrogen. This system is efficient when treating rotating objects or for a continuous strip.

3.4.2.4 Sequential Electrolytic Cleaning. Cathodic cleaning yields more vigorous scrubbing action, since the volume of hydrogen gas given off at a cathode is twice the volume of oxygen gas formed on an anode in the same cleaner bath. Cathodic cleaning, however, suffers the disadvantage of depositing tramp metal impurities on the object being cleaned, often resulting in nonadherent deposits of the desired coating. Thus it is often advisable to clean cathodically and follow this with anodic action in the same bath (as in a periodic reverse cleaning bath) or in another bath. **CAUTION:** Some alkaline electrolytic cleaners contain surfactants which lower the surface tension, or develop soaps in cleaning, which likewise lower surface tension. Low surface tension tends to promote the formation of foams with the gases generated by electrolytic action. Foams formed by hydrogen and oxygen will erupt and endanger the operator.

3.4.3 Emulsion. Emulsion cleaning uses a two-phase medium composed of an organic solvent, and detergent in water. The emulsion cleaner is slightly alkaline, used at 140 to 180 degrees F (60 to 82 degrees C), and sprayed on the items to be cleaned by a power sprayer. The emulsion cleaning is followed by rinsing in hot water or hot spray to remove traces of organic solvent or other cleaning by-products. The emulsion is agitated by pumps, stirrers or compressed air. The tanks require exhaust ventilation. Tanks are periodically drained and flushed to remove sludge and oils. Emulsion cleaners are often used in combination with brushes.

3.4.4 Acid. Acid cleaning is usually performed after alkaline cleaning to neutralize residual films. The acid cleaning is performed on the metal alloys as shown in Table 10. Wipe on/wipe off, spray, immersion and rotating barrel methods are all used extensively for acid cleaning. Although heating greatly increases efficiency, cleaning can be done at room temperature for superior process control and economy of operation. When heat is used the usual temperature range is 140 to 180 degrees F with an occasional use as high

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as 200 degrees F (93 degrees C). Selection of method depends on the nature of soil being removed, the size and shape of the workpiece, quantity of similar workpieces, and type of acid cleaner used.

Table 10  
General Compositions of Acid Cleaners

ALLOY	AQUEOUS ACID CLEANER AND ETCHANT	
	PERCENT BY VOLUME	ACID
Aluminum Alloys	25 - 50 25 (Note 1)	Nitric Sulfuric
Copper	4 - 10 10 - 20 10 - 20	Sulfuric Hydrochloric Fluoboric
High-Carbon Steel	10 (Note 2) 10	Hydrochloric Dry Acid salts Sulfuric
Lead Alloys	10 - 25 2 - 10 20	Fluoboric Hydrofluoric Hydrochloric
Low Alloy Steel	10 - 50 4 - 10 (Note 2)	Hydrochloric Sulfuric Dry Acid Salts
Nickel Alloys	5 - 15 10 - 50	Sulfuric Hydrochloric
Corrosion-resisting Steel (Note 3)	20 - 50 5 - 50 (Note 4)  (Note 2)	Hydrochloric Sulfuric Sulfuric plus Hydrofluoric Dry Acid Salts
Zinc Alloys	1/4 - 1 1/4 - 1 1/4 - 1	Hydrochloric Sulfuric Hydrofluoric

- NOTES: 1 - Required to be zincated prior to subsequent plating.  
 2 - Indicated as 120 grams of dry salt per liter of solution.  
 3 - Required to have a nickel strike except for chromium plating, where no strike is necessary.  
 4 - 25 percent Sulfuric acid and 5 percent Hydrofluoric acid.

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3.4.5 Cleaning Equipment. General equipment requirements for the above mentioned cleaning processes are given in American Society for Metals (ASM), Metals Handbook, Volume 5, Surface Cleaning, Finishing, and Coating, pages 22 through 67. All of these processes require adequate ventilation at the process tank locations. Equipment selection for specific facilities will vary with the sizes of parts to be treated and their specific process requirements.

3.5 Pickling

3.5.1 Phosphoric Acid. Phosphoric acid pickling and metal conditioning for painting is done in accordance with Mil Spec. MIL-C-10578, Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base), for aqueous based systems, as shown in Table 11, and Federal Specification (Fed Spec.) TT-C-490, Cleaning Methods for Ferrous Surfaces and Pretreatments for Organic Coatings, Grade II, Type 4, for all alcoholic phosphoric acid systems. Immersion pickling, using Mil Spec. MIL-C-10578, Type V is commonly performed on sheet products to remove deeply embedded mill scale and on as-cast products to remove alloy segregations. The products are normally pickled for 1/2 to 1 min at 70 to 100 degrees F (21 to 38 degrees C) with a metal loss of 0.5 mil per min immersion. Pickling in phosphoric acid has the advantage of having low corrosivity imparted to the atmosphere, ability to remove oxide, and to convert the surface being treated to ferric phosphate. The ferric phosphate which forms on the surface of the steel is rather insoluble in the pickling solution and provides a surface that does not have to be immediately finished as in the case of the HCl pickling process. Currently, the steel industry is processing sheet in a 10 to 25 percent aqueous phosphoric acid solution at 180 degrees F (82 degrees C) and a hot water rinse at 140 to 150 degrees F (60 to 66 degrees C). The Footner process used in England is a pickling method where steel is pickled in an aqueous solution containing one to 1.5 percent free phosphoric acid and 0.3 to 0.5 percent iron for one to three min at 180 degrees F.

3.5.2 Hydrochloric Acid. HCl is used for batch or continuous pickling of hot-rolled or heat treated high carbon steel. The pickling bath is operated as shown in Table 12.

The process of HCl pickling is

- a) degrease,
- b) immersion pickle, and
- c) cold water running rinse.

To minimize rusting during drying, the items are rinsed in a slightly aqueous alkaline solution containing two ounces per gallon trisodium phosphate followed by a cold water running rinse.

3.5.3 Inhibitors. Inhibitors are used to save steel, allow uniform pickling, save acid and water, provide a brighter surface, reduce acid fumes, reduce load on effluent treatment, and present a better surface for



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Table 11  
Phosphoric Acid Pickling Formulations  
(as Given in Military Specification MIL-C-10578D)

MATERIAL	TYPE I <sup>1</sup>	TYPE II <sup>1</sup>	TYPE III <sup>1</sup>	TYPE V <sup>1&amp;2</sup>	TYPE V
Phosphoric acid (85%)	118 mL	35 mL	85 mL	118 mL	118 mL
Detergent <sup>3</sup>	5 mL	5 mL	---	---	5 mL
Diethyl thiourea	---	---	0.50 g	---	---
Butyl cellosolve	40 mL	62.5 mL	---	40 mL	---
Nacconol NRSF	---	---	2.0 g	---	---
Pluronic L62 (see 6.4)	---	---	---	5 mL	---
Pluronic L64 (see 6.4)	---	---	---	5 mL	---

<sup>1</sup>Water, sufficient to bring total volume to 250 milliliters (mL), shall be added.

<sup>2</sup>This formula should be aged 3 weeks before using, or diluted, when first prepared, to 1,000 mL for use without further dilution.

<sup>3</sup>Triton, X-100, ethoxylated primary or secondary alcohols, or straight-chain alkyl phenols.

Table 12  
Operating Conditions for Pickling Baths

OPERATING CONDITIONS	BATCH	CONTINUOUS IMMERSION	SPRAY
Hydrochloric Acid, wt %	8-12	6-14	10-25
Immersion time, minutes	5-15	1/60-1/3	30
Temperature, °F	100-105	170-200	65-85
Iron Concentration, wt %, maximum	13	13	---

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electroplating or conversion coating. Common inhibitors are pyridines, quinidines, aldehydes, mercaptans, thioaldehydes like thiourea and diorthotolyl thiourea. Other additives are defoaming agents, surfactants and sequestrants (like chelating agents). Inhibitors are added to maintain a concentration of 0.25 to 0.50 percent the concentration of the pickling acid. For hydrochloric acid, inhibitors conform to Mil Spec. MIL-I-17433, Inhibitor, Hydrochloric Acid Descaling and Pickling Solutions, and are intended for pickling formulations that remove mill scale.

3.5.4 Equipment Used for Pickling. Lined, welded-steel tanks are used in processing steel items for phosphoric acid pickling. The tanks are lined with lead, ceramic, rubber or vinyl materials. Where heating is required, silica immersion heaters, hotwater jackets or polytetrafluoroethylene (PTFE), "Teflon," heating coils are used. Items may be suspended by monel or acid resisting phosphor bronze baskets or hooks. For cold acid, brass baskets may be used. Inhibitors are added as required using constant or variable volume feed pumps. Acid is added by replenisher feed pumps.

### 3.6 Descaling

3.6.1 Corrosion Resisting Steel. Mill finishes for corrosion resisting steel are as shown in Table 13. These finishes are defined as shown in Appendix A. When descaling is required, descaling is performed by acid pickling or salt bath descaling.

3.6.1.1 Acid Pickling of Corrosion Resisting Steel. Aqueous nitric acid solutions containing 15 to 20 percent  $\text{HNO}_3$  are used at 100 to 120 degrees F (38 to 49 degrees C) to remove iron particle. To remove residual oxide scale, an aqueous nitric acid containing 10 percent by volume nitric acid and 1 to 2 percent by volume hydrofluoric acid is used followed by abrasive blasting. Immersion time is not more than three minutes, and the solution is at not more than 140 degrees F (60 degrees C). When martensitic alloys in the fully hardened conditions are being treated, care must be taken to avoid hydrogen embrittlement cracking. After immersion, the surfaces are thoroughly scrubbed, cold water rinsed, hot water rinsed, and dried. If the sheets are too large and the final pickling operation is done by swabbing, then an aqueous 20 percent nitric acid-2 percent hydrochloric acid solution is used, and the used solution is disposed of because the ferric chloride in this acid solution would cause pitting.

3.6.1.2 Salt Bath Descaling. The corrosion resisting steel is immersed in an oxidizing salt from three to twenty seconds and sheet or strip exits the bath through wiper rollers or high pressure air blast directed at top and bottom surfaces. This is followed by a mild sulfuric acid dip to neutralize the caustic salt and by a nitric acid-hydrofluoric acid bright dip. Typical systems are shown in Figures 11 and 12. The salt bath is operated at 400 to 900 degrees F (204 to 482 degrees C). A typical installation requires floor space 12 ft wide by 32 ft long (3.7 m wide by 9.8 m long) and an overhead clearance of 16 ft (5.8 m). Exhaust ducting is required for the salt bath section, and a burner exhaust duct is required. Electrical service is also needed. The removal of oxide scale is done by using baths of molten

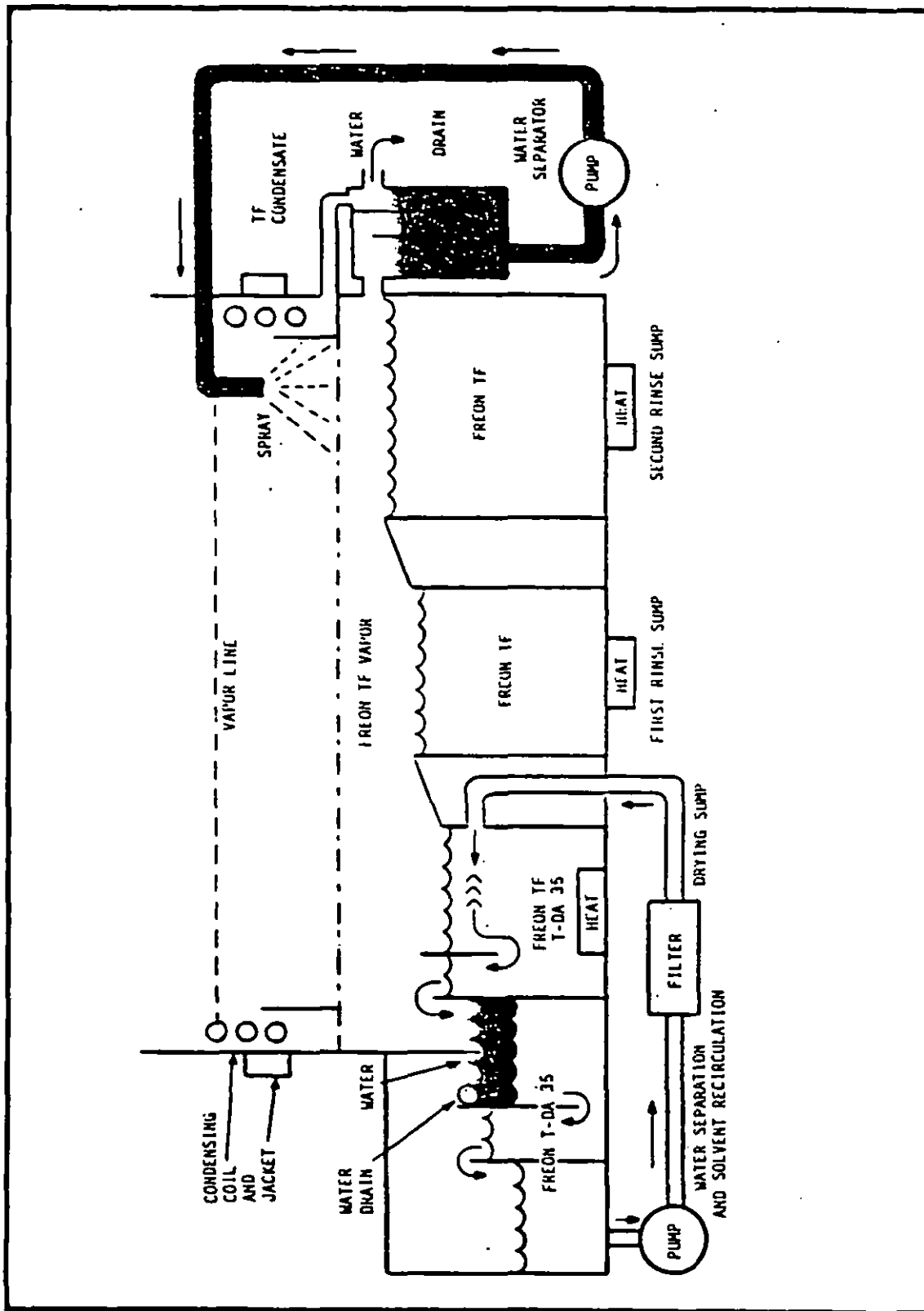


Figure 8  
Typical Large Ultrasonic Degreaser Using Fluorinated  
Hydrocarbon Solvents and Methyl Alcohol

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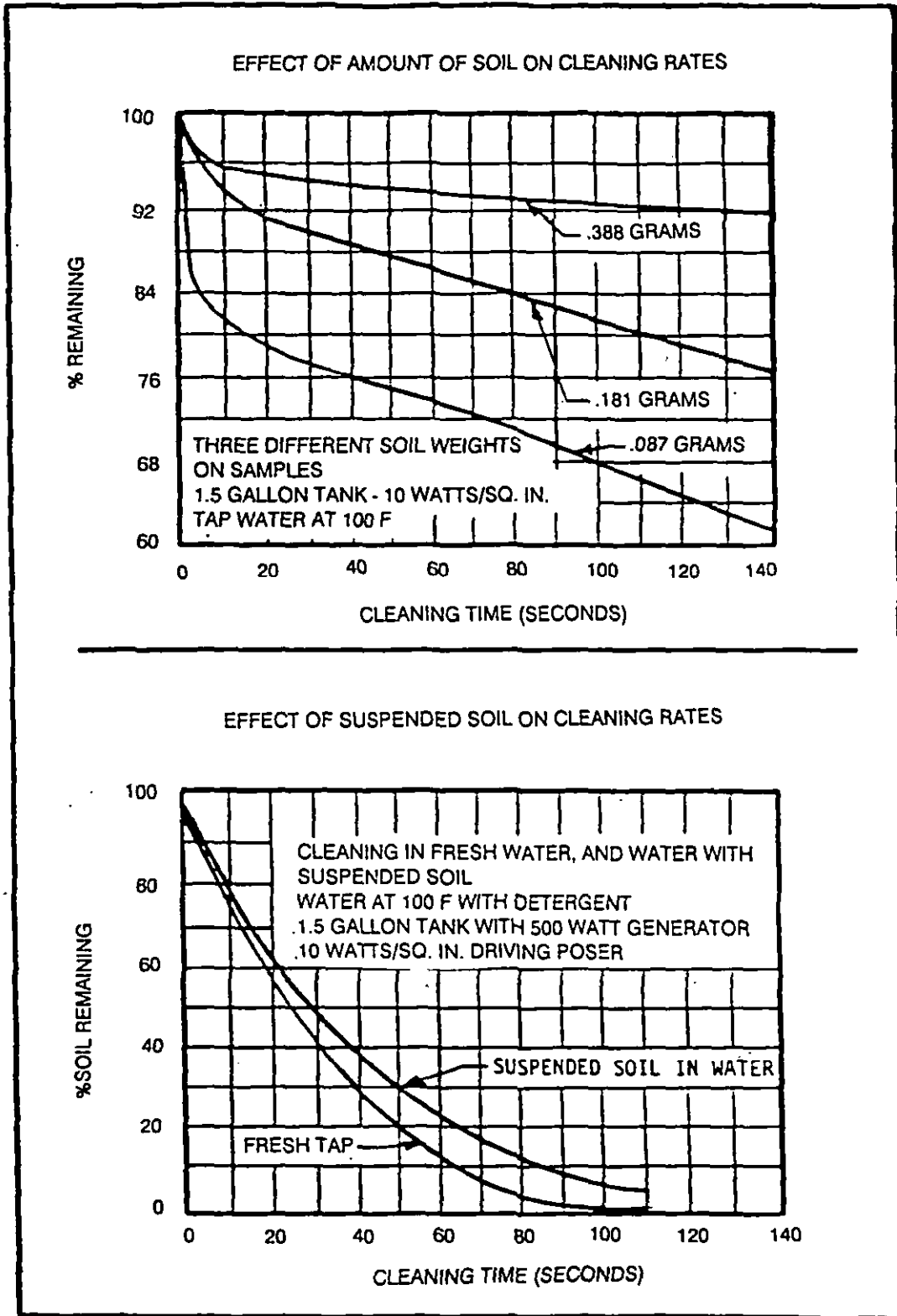


Figure 9  
Effects of Varying Amounts of Soils on Cleaning Rates of Ultrasonic Degreasers

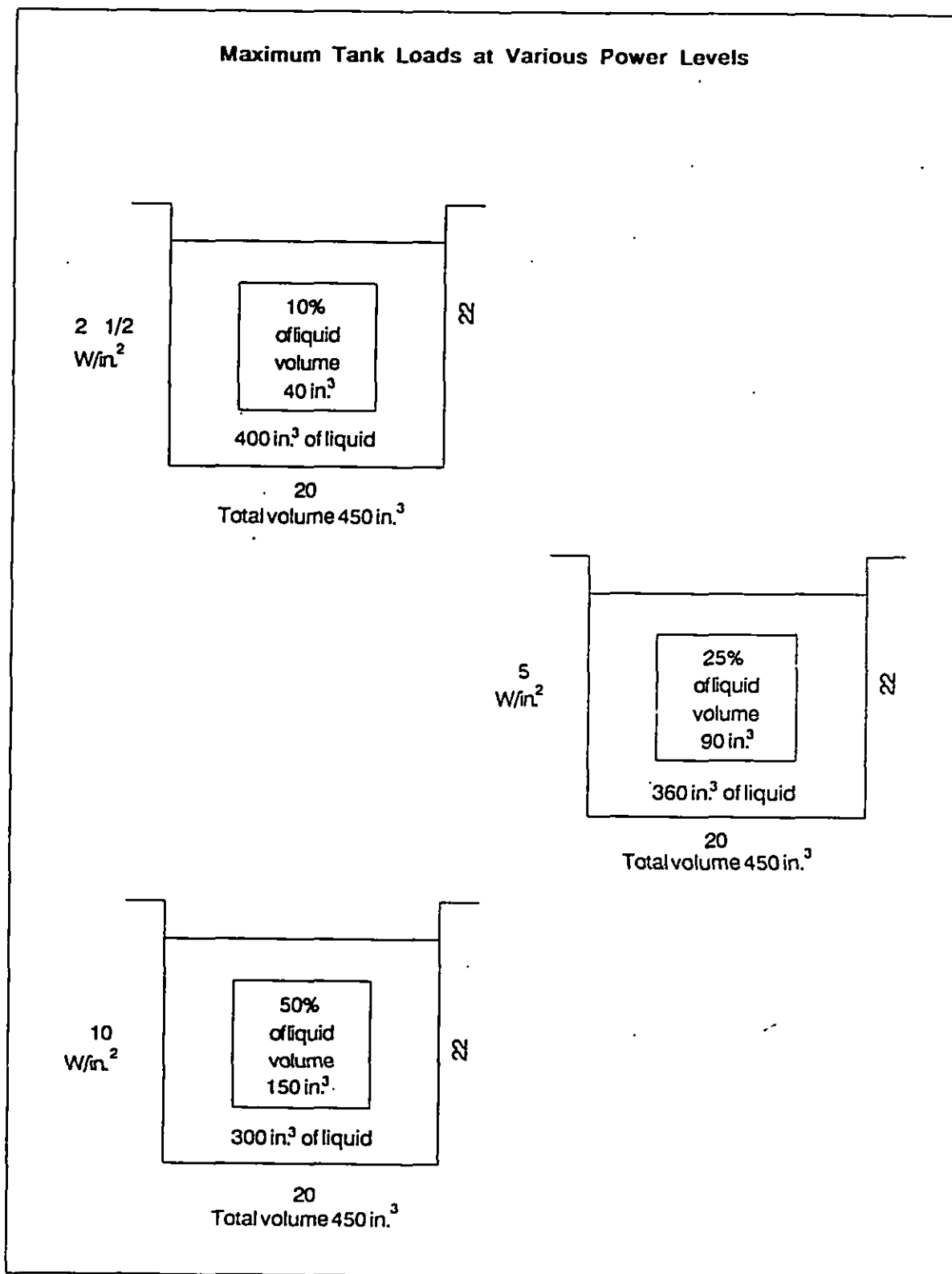


Figure 10  
Tank Size as Related to Power Input to the Liquid

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3.3.3.1 Ultrasonic Solvent/Vapor Cleaning System Size. The transducer power requirements are determined by the workload which affects the tank size. A typical transducer is rated at 1 kilowatt (kW) output, and these transducers are combined to form an ultrasonic generator of required power. Power input varies from two kW for small production units with an output of 1 kW to an electrical input of 208 V and 10 kVA with an average output of 6 kW. Tank size, as related to power input to the liquid, is illustrated in Figure 10.

3.3.3.2 Ultrasonic Cleaning Compounds. Ultrasonic cleaning compounds fall into two categories--solvents and detergents. Factors to be considered in the use of these compounds are solvent activity, wetting activity, emulsification, saponification, deflocculation, colloidal activity and suspension, pH, buffer activity, water conditioning and the effect of ultrasonic energy on the compound. When fluorinated hydrocarbons are specified for the solvent they are to conform to Mil Spec. MIL-C-81302, Cleaning Compound Solvent Trichlorotrifluoroethane, Type II.

3.3.3.3 Distillation Equipment. An essential part of a vapor degreasing system is a distillation accessory to recover spent solvents. This auxiliary still returns purified solvent to the vapor degreaser and the wastes are disposed of properly. If the wastes are steam stripped, they may contain a measurable percentage of oil by weight which is recoverable. This waste is sold to firms who are able to recover the oil for recycling. The wastes shall be stored in closed containers. The distillation equipment is normally a pot type operating at atmospheric pressure. Heat is supplied either by steam in a jacket around the still or by a steam coil in the still. Maximum efficiency is achieved by a constant level device and a solvent pump to maintain proper level of waste solvent in the still. A water separator shall be provided to remove water, and a thermometer shall be conveniently located in the still pot as a guide to measure contaminants present. In order to save energy, live steam is reduced in the boil-down period. Proper safety devices should be installed to minimize the hazards from drying out of the still pot and accumulation of waste in the still. **CAUTION:** Degreasing solvents in use tend to hydrolyze in the presence of moisture to form hydrochloric acid (HCl). Metal chips, particularly aluminum, speed the formation of corrosive acid by catalytic action. Frequent testing of degreasing solvents to detect acidity is required. Solvent that has been found acidic should be returned to the supplier and exchanged for properly inhibited new material. Where chlorinated solvents are pumped under pressure in contact with aluminum, explosions can occur. Avoid having chlorinated compounds in confined spaces when in contact with aluminum or aluminum alloys.

3.3.3.4 Optional Equipment. Optional equipment include insulation, recirculation, and solvent recovery system filtration units. These features reduce fuel and power requirements by reducing heat losses, and by recirculation of solvent, thereby reducing the number of tank dumps and new solvent additions.

### 3.4 Cleaning

3.4.1 Preliminary Cleaning. Preliminary cleaning by soaking is required to remove grease, oil, drawing and buffing compounds, corrosion-preventive oils, greases and compounds, and loosely adherent oxide residues.

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3.4.1.1 Alkaline Immersion Cleaning. These cleaning materials are composed of alkaline salts such as potassium or sodium hydroxide, silicates, phosphates or carbonates, plus additives such as sequestering agents, dispersants, corrosion-inhibitors, and various wetting agents. The additives vary depending on the type of soil encountered (e.g., buffing compounds require emulsion type agents). This step is required where soils would put a heavy burden on subsequent cleaning operations. The baths operate at or near the boiling temperature. The items are soak-cleaned for 3 to 5 min, and after soaking, the adherent cleaners are removed by spray rinsing with clean water under a pressure of not less than 15 psig, or the items are agitated in running rinse water. The pH of the alkaline cleaners range between 12.0 and 13.5 for heavy duty cleaners used on ferrous metals, and between 10.5 and 12.0 for light duty cleaners used on nonferrous metals. Nonferrous metals may require the addition of corrosion inhibitors to the cleaning salt formulations.

3.4.1.2 Emulsifiable Solvent Cleaning. Emulsifiable solvent cleaning uses petroleum-derived solvents which are mainly chlorinated hydrocarbons and surfactants that render the solvents emulsifiable. This is a soak cleaning step, and the soils are removed in the water rinse. This step reduces the soil load on subsequent cleaning steps.

3.4.1.3 Solvent Cleaning. This soak cleaning step is used to soften soluble portions of the soil and thus make the soil easily removable in an alkaline cleaning process. The agents used to soften the soils are petroleum or inhibited chlorinated solvents. The solvents are high boiling compounds used at elevated temperatures. These solvents are selected so that they do not completely dry on the surface and pigmented materials may be easily removed. The solvent cleaning tanks require recovery systems to save evaporated solvent and return this cleaner to the soak tank.

3.4.2 Alkaline Cathodic Cleaning. In alkaline cathodic cleaning, the items are made the cathode, and the tank is the anode, or anodes are placed in the tank. Operating temperature is 160 plus or minus 56 degrees F (71 plus or minus 31 degrees C); the voltage is 3 to 6 V; and the current density and time are shown in Table 9.

Table 9  
Operating Conditions for Alkaline Cathodic Cleaners

SUBSTRATE*	CURRENT DENSITY Amp/ft <sup>2</sup>	TIME MINUTES
Steel	50-100	0.5-3
Corrosion-Resisting Steel	50-150	0.5-3
Zinc	10-30	0.3-1
Copper	30-100	0.5-2
Copper Alloys	20-50	0.5-1
Nickel	20-80	0.5-1

\*Alloys affected by hydrogen embrittlement are later required to be relieved by heat.

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3.4.2.1 Anodic Cleaning. Anodic cleaning in alkaline cleaners is accomplished at 3 to 6 V with the current density varying depending on the area of the items and the number of items being cleaned. Anodic cleaning is not performed on aluminum and its alloys, chromium, lead and its alloys, nor other metals and their alloys that are soluble in alkaline cleaners.

3.4.2.2 Periodic Reverse Cleaning. Periodic reverse cleaning is accomplished by making the items alternately cathodic and anodic at approximately 6 V. This type of cleaning has the advantage of avoiding the deposit of positively charged materials on the items, thereby reducing the amount of dissolution of the basis metal.

3.4.2.3 Bipolar Electrode (Cathodic) Cleaning. Bipolar electrode cleaning (cathodic) is accomplished when the object to be cleaned is not connected to the power supply, but is placed in the cleaning solution between an anode and a cathode. That portion of the part closest to the anode becomes cathodic, and the portion nearest the cathode becomes anodic. The anodic portion is scrubbed by the evolution of oxygen, and the cathodic portion, by hydrogen. This system is efficient when treating rotating objects or for a continuous strip.

3.4.2.4 Sequential Electrolytic Cleaning. Cathodic cleaning yields more vigorous scrubbing action, since the volume of hydrogen gas given off at a cathode is twice the volume of oxygen gas formed on an anode in the same cleaner bath. Cathodic cleaning, however, suffers the disadvantage of depositing tramp metal impurities on the object being cleaned, often resulting in nonadherent deposits of the desired coating. Thus it is often advisable to clean cathodically and follow this with anodic action in the same bath (as in a periodic reverse cleaning bath) or in another bath. **CAUTION:** Some alkaline electrolytic cleaners contain surfactants which lower the surface tension, or develop soaps in cleaning, which likewise lower surface tension. Low surface tension tends to promote the formation of foams with the gases generated by electrolytic action. Foams formed by hydrogen and oxygen will erupt and endanger the operator.

3.4.3 Emulsion. Emulsion cleaning uses a two-phase medium composed of an organic solvent, and detergent in water. The emulsion cleaner is slightly alkaline, used at 140 to 180 degrees F (60 to 82 degrees C), and sprayed on the items to be cleaned by a power sprayer. The emulsion cleaning is followed by rinsing in hot water or hot spray to remove traces of organic solvent or other cleaning by-products. The emulsion is agitated by pumps, stirrers or compressed air. The tanks require exhaust ventilation. Tanks are periodically drained and flushed to remove sludge and oils. Emulsion cleaners are often used in combination with brushes.

3.4.4 Acid. Acid cleaning is usually performed after alkaline cleaning to neutralize residual films. The acid cleaning is performed on the metal alloys as shown in Table 10. Wipe on/wipe off, spray, immersion and rotating barrel methods are all used extensively for acid cleaning. Although heating greatly increases efficiency, cleaning can be done at room temperature for superior process control and economy of operation. When heat is used the usual temperature range is 140 to 180 degrees F with an occasional use as high



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as 200 degrees F (93 degrees C). Selection of method depends on the nature of soil being removed, the size and shape of the workpiece, quantity of similar workpieces, and type of acid cleaner used.

Table 10  
General Compositions of Acid Cleaners

ALLOY	AQUEOUS ACID CLEANER AND ETCHANT	
	PERCENT BY VOLUME	ACID
Aluminum Alloys	25 - 50	Nitric
	25	Sulfuric
	(Note 1)	
Copper	4 - 10	Sulfuric
	10 - 20	Hydrochloric
	10 - 20	Fluoboric
High-Carbon Steel	10	Hydrochloric
	(Note 2)	Dry Acid salts
	10	Sulfuric
Lead Alloys	10 - 25	Fluoboric
	2 - 10	Hydrofluoric
	20	Hydrochloric
Low Alloy Steel	10 - 50	Hydrochloric
	4 - 10	Sulfuric
	(Note 2)	Dry Acid Salts
Nickel Alloys	5 - 15	Sulfuric
	10 - 50	Hydrochloric
Corrosion-resisting Steel (Note 3)	20 - 50	Hydrochloric
	5 - 50	Sulfuric
	(Note 4)	Sulfuric plus Hydrofluoric
	(Note 2)	Dry Acid Salts
Zinc Alloys	1/4 - 1	Hydrochloric
	1/4 - 1	Sulfuric
	1/4 - 1	Hydrofluoric

- NOTES:
- 1 - Required to be zincated prior to subsequent plating.
  - 2 - Indicated as 120 grams of dry salt per liter of solution.
  - 3 - Required to have a nickel strike except for chromium plating, where no strike is necessary.
  - 4 - 25 percent Sulfuric acid and 5 percent Hydrofluoric acid.

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3.4.5 Cleaning Equipment. General equipment requirements for the above mentioned cleaning processes are given in American Society for Metals (ASM), Metals Handbook, Volume 5, Surface Cleaning, Finishing, and Coating, pages 22 through 67. All of these processes require adequate ventilation at the process tank locations. Equipment selection for specific facilities will vary with the sizes of parts to be treated and their specific process requirements.

### 3.5 Pickling

3.5.1 Phosphoric Acid. Phosphoric acid pickling and metal conditioning for painting is done in accordance with Mil Spec. MIL-C-10578, Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base), for aqueous based systems, as shown in Table 11, and Federal Specification (Fed Spec.) TT-C-490, Cleaning Methods for Ferrous Surfaces and Pretreatments for Organic Coatings, Grade II, Type 4, for all alcoholic phosphoric acid systems. Immersion pickling, using Mil Spec. MIL-C-10578, Type V is commonly performed on sheet products to remove deeply embedded mill scale and on as-cast products to remove alloy segregations. The products are normally pickled for 1/2 to 1 min at 70 to 100 degrees F (21 to 38 degrees C) with a metal loss of 0.5 mil per min immersion. Pickling in phosphoric acid has the advantage of having low corrosivity imparted to the atmosphere, ability to remove oxide, and to convert the surface being treated to ferric phosphate. The ferric phosphate which forms on the surface of the steel is rather insoluble in the pickling solution and provides a surface that does not have to be immediately finished as in the case of the HCl pickling process. Currently, the steel industry is processing sheet in a 10 to 25 percent aqueous phosphoric acid solution at 180 degrees F (82 degrees C) and a hot water rinse at 140 to 150 degrees F (60 to 66 degrees C). The Footner process used in England is a pickling method where steel is pickled in an aqueous solution containing one to 1.5 percent free phosphoric acid and 0.3 to 0.5 percent iron for one to three min at 180 degrees F.

3.5.2 Hydrochloric Acid. HCl is used for batch or continuous pickling of hot-rolled or heat treated high carbon steel. The pickling bath is operated as shown in Table 12.

The process of HCl pickling is

- a) degrease,
- b) immersion pickle, and
- c) cold water running rinse.

To minimize rusting during drying, the items are rinsed in a slightly aqueous alkaline solution containing two ounces per gallon trisodium phosphate followed by a cold water running rinse.

3.5.3 Inhibitors. Inhibitors are used to save steel, allow uniform pickling, save acid and water, provide a brighter surface, reduce acid fumes, reduce load on effluent treatment, and present a better surface for

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Table 11  
Phosphoric Acid Pickling Formulations  
(as Given in Military Specification MIL-C-10578D)

MATERIAL	TYPE I <sup>1</sup>	TYPE II <sup>1</sup>	TYPE III <sup>1</sup>	TYPE V <sup>1&amp;2</sup>	TYPE V
Phosphoric acid (85%)	118 mL	35 mL	85 mL	118 mL	118 mL
Detergent <sup>3</sup>	5 mL	5 mL	---	---	5 mL
Diethyl thiourea	---	---	0.50 g	---	---
Butyl cellosolve	40 mL	62.5 mL	---	40 mL	---
Nacconol NRSF	---	---	2.0 g	---	---
Pluronic L62 (see 6.4)	---	---	---	5 mL	---
Pluronic L64 (see 6.4)	---	---	---	5 mL	---

<sup>1</sup>Water, sufficient to bring total volume to 250 milliliters (mL), shall be added.

<sup>2</sup>This formula should be aged 3 weeks before using, or diluted, when first prepared, to 1,000 mL for use without further dilution.

<sup>3</sup>Triton, X-100, ethoxylated primary or secondary alcohols, or straight-chain alkyl phenols.

Table 12  
Operating Conditions for Pickling Baths

OPERATING CONDITIONS	BATCH	CONTINUOUS IMMERSION	SPRAY
Hydrochloric Acid, wt %	8-12	6-14	10-25
Immersion time, minutes	5-15	1/60-1/3	30
Temperature, °F	100-105	170-200	65-85
Iron Concentration, wt %, maximum	.13	13	---

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electroplating or conversion coating. Common inhibitors are pyridines, quinidines, aldehydes, mercaptans, thioaldehydes like thiourea and diorthotolyl thiourea. Other additives are defoaming agents, surfactants and sequestrants (like chelating agents). Inhibitors are added to maintain a concentration of 0.25 to 0.50 percent the concentration of the pickling acid. For hydrochloric acid, inhibitors conform to Mil Spec. MIL-I-17433, Inhibitor, Hydrochloric Acid Descaling and Pickling Solutions, and are intended for pickling formulations that remove mill scale.

3.5.4 Equipment Used for Pickling. Lined, welded-steel tanks are used in processing steel items for phosphoric acid pickling. The tanks are lined with lead, ceramic, rubber or vinyl materials. Where heating is required, silica immersion heaters, hotwater jackets or polytetrafluoroethylene (PTFE), "Teflon," heating coils are used. Items may be suspended by monel or acid resisting phosphor bronze baskets or hooks. For cold acid, brass baskets may be used. Inhibitors are added as required using constant or variable volume feed pumps. Acid is added by replenisher feed pumps.

### 3.6 Descaling

3.6.1 Corrosion Resisting Steel. Mill finishes for corrosion resisting steel are as shown in Table 13. These finishes are defined as shown in Appendix A. When descaling is required, descaling is performed by acid pickling or salt bath descaling.

3.6.1.1 Acid Pickling of Corrosion Resisting Steel. Aqueous nitric acid solutions containing 15 to 20 percent  $\text{HNO}_3$  are used at 100 to 120 degrees F (38 to 49 degrees C) to remove iron particle. To remove residual oxide scale, an aqueous nitric acid containing 10 percent by volume nitric acid and 1 to 2 percent by volume hydrofluoric acid is used followed by abrasive blasting. Immersion time is not more than three minutes, and the solution is at not more than 140 degrees F (60 degrees C). When martensitic alloys in the fully hardened conditions are being treated, care must be taken to avoid hydrogen embrittlement cracking. After immersion, the surfaces are thoroughly scrubbed, cold water rinsed, hot water rinsed, and dried. If the sheets are too large and the final pickling operation is done by swabbing, then an aqueous 20 percent nitric acid-2 percent hydrochloric acid solution is used, and the used solution is disposed of because the ferric chloride in this acid solution would cause pitting.

3.6.1.2 Salt Bath Descaling. The corrosion resisting steel is immersed in an oxidizing salt from three to twenty seconds and sheet or strip exits the bath through wiper rollers or high pressure air blast directed at top and bottom surfaces. This is followed by a mild sulfuric acid dip to neutralize the caustic salt and by a nitric acid-hydrofluoric acid bright dip. Typical systems are shown in Figures 11 and 12. The salt bath is operated at 400 to 900 degrees F (204 to 482 degrees C). A typical installation requires floor space 12 ft wide by 32 ft long (3.7 m wide by 9.8 m long) and an overhead clearance of 16 ft (5.8 m). Exhaust ducting is required for the salt bath section, and a burner exhaust duct is required. Electrical service is also needed. The removal of oxide scale is done by using baths of molten

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Table 13  
Mill Finishes Available on Corrosion Resisting Steel Sheet and Strip

TYPE	SHEET		STRIP
	UNPOLISHED	POLISHED	
Austenitic steels (a)			
201	2D, 2B	(b)	1, 2
202	2D, 2B	3, 4	1, 2
301	2D, 2B	(b)	1, 2
302	2D, 2B	3, 4, 6, 7	1, 2
302B	2D	(b)	---
304	2D, 2B	3, 4, 6, 7	1, 2
304L	2D, 2B	4	1, 2
305	2D, 2B	(b)	1, 2
309, 309S	2D	(b)	1, 2
310	2D	(b)	1, 2
316	2D, 2B	4	1, 2
316L	2D, 2B	(b)	1, 2
321	2D, 2B	(b)	1, 2
347	2D, 2B	(b)	1, 2
348	2D, 2B	(b)	1, 2
Martensitic steels			
403	2D, 2B	(b)	1, 2
410	2D, 2B	(b)	1, 2
420	(c)	(c)	1, 2
440A, B, and C	(c)	(c)	(d)
Ferritic steels (a)			
430	2D, 2B	3, 4	1, 2
446	2D, 2B	(b)	1, 2

- (a) All grades listed, in both sheet and strip form, are regularly available in the smooth rolled and bright annealed condition.
- (b) Usually not polished.
- (c) Not available in sheet form.
- (d) Material available in strip form on special order only; finish negotiated with supplier.

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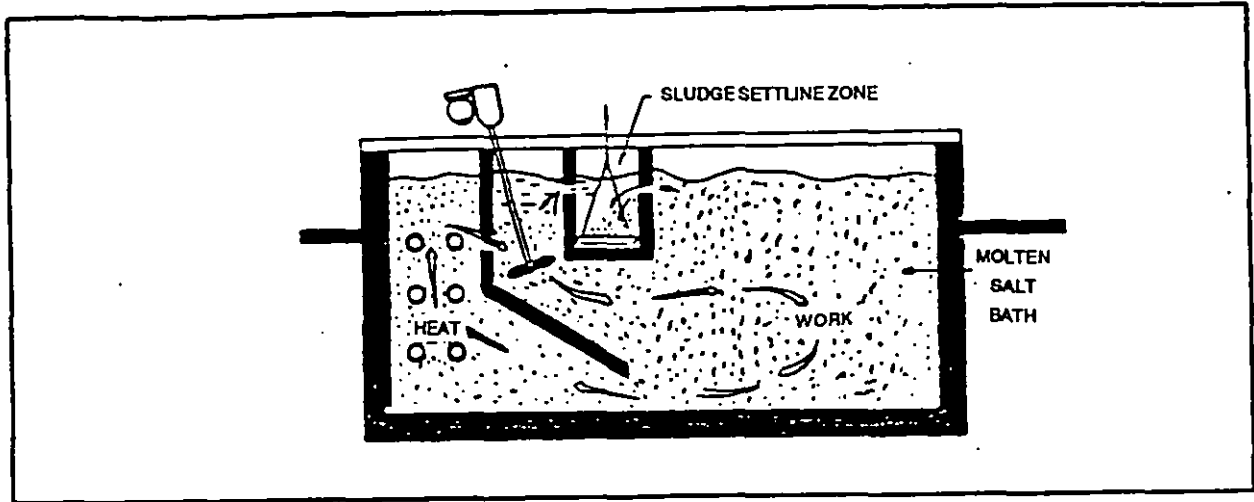


Figure 11  
Sludge Collection System Without Shutdown

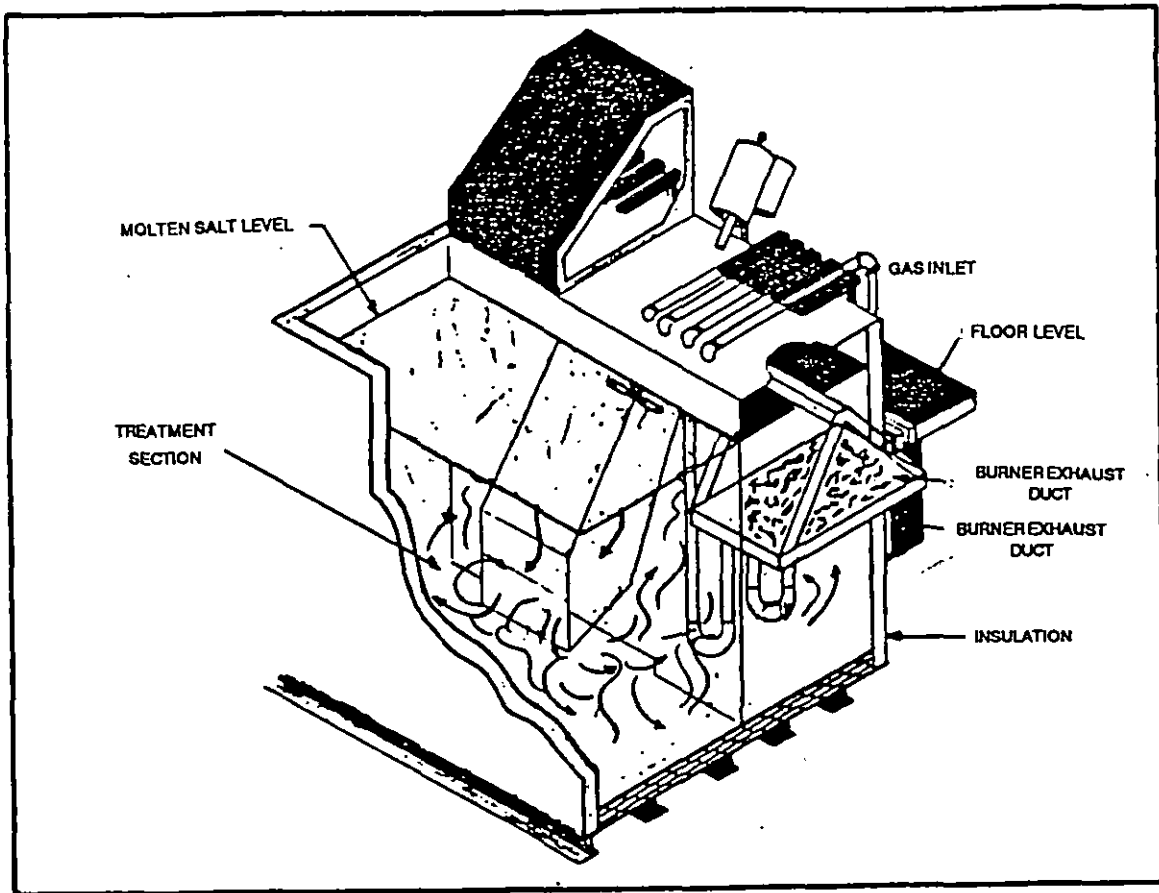


Figure 12  
Schematic of Salt Bath Furnace

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sodium hydroxide to which certain reagents are added. These baths can be used with virtually all grades of corrosion-resisting steel. Salt bath descaling has the following advantages:

- a) salts act only on the scale and do not result in metal loss or etching,
- b) does not preferentially attack areas in which intergranular carbides are present, and
- c) is useful in descaling the straight chromium grades without the preliminary abrasive blasting that is frequently required prior to acid descaling.

Use of molten salts is not recommended for those corrosion resisting steels that are precipitation hardened at the operating temperature of the bath.

3.6.2. Titanium. Titanium descaling requires special care. The common gases react down to a depth of 2 to 3 mil in the heat treated condition and 6 to 8 mils in the hot-rolled condition. Time-temperature reactions are critical. Titanium is solution treated and aged in temperatures between 700 and 1,000 degrees F (371 and 538 degrees C). Treatment temperatures are not to exceed 500 degrees F (260 degrees C). Protective coatings are used in the manufacture of titanium. These coatings lubricate and aid metal flow, act as barriers to gas contamination, and reduce surface flaws caused by nicking and scratching during manufacture. Heavy scale is removed by grinding and abrasive blasting followed by chemical cleaning. Chemical cleaning is accomplished as follows:

Ti Formula I.	Concentrated nitric acid	1-1/2 pints/gal
	Concentrated hydrofluoric acid	3 fl oz/gal
	Temperature: Room or warm	

The above solution is used for light scale. The nitric acid content must not be allowed to drop, in order to avoid hydrogen embrittlement.

Ti Formula II. Fused caustic soda at 800 degrees F (427 degrees C).

This is used for heavy scale and is followed by a water quench, then a dip in Ti Formula I.

Ti Formula III. Scale is loosened by permanganate immersion, as for pickling nickel and its alloys, then removed by the above pickle.

### 3.7 Drying

3.7.1 Blowoff. In blowoff drying, an air jet is used to blow off excess water for removing heavy draining beads from long vertical parts or from cupshaped parts. A fast moving air stream will increase the evaporation rate of solvents and reduce or eliminate staining of the items being processed. The air jet must be forceful enough to physically remove the solvent, when atmospheric drying is not rapid enough or spotting may be expected.

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3.7.2 Hot Air. Hot air drying is more effective than blowoff drying when spotting is not expected. Usually a drying oven is used after the item receives the final hot rinse. In this method, the speed of evaporation may be increased if the hot air is blown against the work. Commercial dryers use two to four pounds of steam to remove each pound of water from the work. In order to approximate the energy required if the hot rinse occurs at 190 degrees F (88 degrees C) and the work is at this temperature, then Equation (2) may be used.

$$\text{EQUATION:} \quad h = z(w - 6cr/120) \quad (2)$$

Where:  $h$  = steam per ft<sup>2</sup> of surface of the total area, lb/ft<sup>2</sup>  
 $z$  = the efficiency of the dryer usually 2 to 4  
 $c$  = specific heat of the metal  
 $r$  = ratio of the weight of the item to the total surface, lb/ft<sup>2</sup>  
 $w$  = surface water in gal/1000 ft<sup>2</sup> of total surface

When the wet metal is at room temperature and is hot-air dried, Equation (3) may be used.

$$\text{EQUATION:} \quad R = a(1 + v/4)(t_d - t_w) \quad (3)$$

Where:  $R$  = Evaporation rate, gal/1000 ft<sup>2</sup>/min  
 $a$  = airflow factor, 0.002 for parallel surfaces and 0.004 for horizontal surfaces  
 $v$  = velocity of air stream, feet per second (fps)  
 $t_d$  = dry bulb temperature, °F  
 $t_w$  = wet bulb temperature, °F

3.7.3 Absorption. Absorption drying in a tumbler is very effective in removing moisture and eliminating spotting. In addition, the items are burnished in the drying process. Inferior grades of sawdust will contain acid, gum or pitch and, therefore, the other media may be preferred. The size of absorption media is greater than 60 mesh for general use. Other sizes are 20 to 40 mesh and 40 to 60 mesh. The following media are used for the absorption of moisture and the relative efficiencies are shown.

<u>MEDIUM</u>	<u>ABSORPTION WATER TIMES MEDIA WEIGHT</u>	<u>REMARKS</u>
Maple, beech, or boxwood sawdust	1.8	Inferior grades contain acid and gum or pitch
Bagasse	3 to 3.5	No acid, gum, or pitch
Corn cob meal	2	Harder than sawdust; no acid, pitch, or gum
Argentine flint corn	2	No acid, pitch, or gum

3.7.3.1 Manual Absorption Drying. A metal box is first loaded with 4- to 6-in. (101- to 152-mm) layers of sawdust or meal, and after the work is hot rinsed and unracked, the work is loaded on top of the absorption media. In



order to speed drying, the box is heated by steam or hot water and the drying medium is rubbed over the items, and the items are moved about to contact the fresh drying medium. The dried items are shaken to remove the sawdust. If required, the remaining drying medium is removed by air jet. Although this method is easy to control, the manual drying is tedious, and loose drying media are released to the atmosphere necessitating the isolation of the process. The advantage of isolation of the manual drying process is that the sawdust or meal does not get contaminated with splashes of concentrated solutions.

3.7.3.2 Mechanical Drying. Mechanical drying is accomplished by centrifuges, drying machines, and absorption drying equipment.

a) Centrifuging. After uncracking or removal from barrels, small parts of appropriate shapes and mass may be centrifuged at moderate speeds. The centrifuge basket is perforated to allow for passage of water and air through the parts to be dried. The centrifuge is loaded with a wire basket containing the items to be centrifuged, and items are spun for one to two minutes in each direction to reduce the possibility of some parts retaining moisture. Light items (i.e., those of insufficient mass) that are not successfully dried by hot-air in an oven or by a centrifuge are better dried in sawdust tumblers. Flat parts such as washers are difficult to dry and must be spun using several reversals. Normally, up to 80 lb (36.3 kg) of work may be loaded into a manually loaded centrifuge.

b) Drying Machines. Continuous drying machines are available that may wash, rinse and dry; or rinse and dry; or just dry. For small items, the usual operation is to move the items through the machine in a perforated horizontal revolving cylinder with a helical rod for advancing the items, and hot air is introduced at the exit end. For larger items, the work is carried by an open-mesh metal conveyor belt, which is usually used for the wash-rinse-dry cycle for items to be painted. Specially designed dryers are necessary because some items must be held on racks in specific positions, or just for handling items, or racks directly from processing machines. These specially designed dryers are usually an integral part of a plating-processing machine.

c) Mechanical-Absorption Drying. Steam-heated sawdust tumbling barrels for mechanical-absorption drying are oblique tilting barrels which rotate in one direction for operation, and are reversed for unloading. When rotating in the tumbling direction, sawdust and items are held in the tumbling compartment. A screen permits a portion of the sawdust to escape, and this portion is carried over a steam or gas-heated conveyor and returned to the barrel. When the barrel is reversed for discharge, the sawdust is automatically separated by screens at the discharge end, and returned over the heated conveyor to the tumbling compartment through a chute. The dried items are discharged through the opposite end. Another type of drier is a continuous sawdust drier. This piece of equipment is similar to the continuous drying machine for small parts except the horizontal revolving cylinder is perforated only at the end where the sawdust and parts are separated. The separated sawdust is conveyed over a heater to be recharged into a hot and dried condition and is returned to the working end of the drum. The barrels are commonly steam heated, and water vapor is drawn up a stack by an exhaust fan.

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3.7.4 Dewatering Agents. Dewatering agents are organic liquid solutions which have the ability to displace water, and when the solvent evaporates, the surface of the item is left clean and dry. Furthermore, the nonvolatile portion of the dewatering agent can incorporate special surface condition agents which prevent corrosion or will allow the application of a light paint film to the item. These dewatering agents are proprietary. They are used in steel tanks at room temperature. The tanks are fitted with sumps to draw off the accumulated water, and there is a method of agitating the work to speed the dewatering process. There should be a screen above the sump to catch the fallen parts. Dewatering agents have the following advantages:

- a) all surface film is removed including substances dissolved in water;
- b) heat requirements for drying are reduced since no final hot rinse is needed, and less heat, if any, is required to remove the solvent;
- c) water is removed from deep crevices if they exist;
- d) difficult staining problems can be overcome if caused by a), b) or c); and
- e) special films may be deposited to meet unusual requirements.

The following are disadvantages of dewatering agents:

- (1) the solutions are expensive, and drag-out and evaporation losses may be high;
- (2) flash points range from 100 to 150 degrees F (38 to 66 degrees C) and therefore may be a fire hazard; and
- (3) a special tank with a cover is required, together with a means for agitating and/or slowly tumbling the work.

3.7.5 Ovens. Ovens vary widely in their design, even if a specific type is under consideration; therefore, the manufacturer of the various ovens should be consulted when the selection is being made. Considerations should be given to the following:

- a) Properties of the material being handled.
  - (1) Physical characteristics when wet and dry
  - (2) Corrosivity
  - (3) Toxicity
  - (4) Flammability
  - (5) Size, configuration, and weight
  - (6) Abrasiveness
- b) The drying characteristics of the material

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- (1) Type of moisture (bound or unbound, or both)
- (2) Initial moisture content
- (3) Final moisture content
- (4) Permissible drying temperature
- (5) Probable drying time
- c) Flow of material
  - (1) Quantity to be handled
  - (2) Continuous or batch operation
  - (3) Process prior to drying
  - (4) Exposure after processing
- d) Recovery problems
  - (1) Dust recovery
  - (2) Solvent recovery
- e) Facilities available at the site
  - (1) Space
  - (2) Temperature, humidity and cleanliness of air
  - (3) Available fuels
  - (4) Available electric power
  - (5) Permissible noise, vibration, dust or heat losses
  - (6) Source of wet feed
  - (7) Exhaust gas outlets

3.7.5.1 Cabinet. Cabinet ovens are used for small batches of work, are available in a number of sizes, and are used in manual operations. The ovens are operated at 220 degrees F (104 degrees C) or higher. These ovens are most frequently used for baking plated items to relieve stresses resulting from hydrogen embrittlement. This operation is done at 300 to 375 degrees F (149 to 191 degrees C) for one to 23 hours and depends on the configuration of the item and the thickness of the deposit.

3.7.5.2 Tunnel. Tunnel (truck-in) drying ovens are operated at 220 degrees F or higher for removing moisture on the items being processed. High pressure steam is generally used as the heat source. A mild draft of room temperature

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air is induced by a forced-draft exhaust duct usually at the oven entrance end. In large ovens auxiliary fans may be used to speed drying, and blowoff jets may be used as well. These fans and jets are placed in the first section of the tunnel or preferably, if conditions permit, over one hot rinse, or in the transfer zone between the hot rinse and dryer. Another type of tunnel dryer uses a preheated blast obtained by blowing air across electric heaters or a bank of steam pipes. A portion of the air is recirculated and a provision to withdraw moisture laden air is made. The choice between the two designs depends on the nature of the work and design of the conveyor or trucks. Since the designs are proprietary the manufacturer shall be consulted. Tunnels are not provided with automatic controls; therefore, a study of the hygroscopic conditions in the oven and exhaust stack will indicate the necessary changes in air distribution and heat supply. The allowable drying time is between 3 and 5 min.

### 3.8 Metallurgical Furnaces

3.8.1 Furnace Selection. Furnace selection depends upon the process to be performed and the temperatures required as shown in Table 14. Furnaces are designed for carbonitriding, gas-carburizing, gaseous-nitrocarburizing, liquid-carburizing, pack-carburizing, salt-bath treatment, sintering, annealing operations, heat treatment, and hydrogen-stress relieving.

3.8.2 Furnace Atmospheres. Furnace atmospheres have been classified into six groups by The American Gas Association, as follows: class 100-exothermic base, class 200-prepared nitrogen base, class 300-endothermic base, class 400-charcoal base, class 500-exothermic-endothermic base, and class 600-ammonia base. The applications of the principal furnace atmospheres are shown in Table 15.

3.8.3 Furnace Design. In furnace design which includes size and method of treatment of the items being considered, the characteristics given in ASM Metals Handbook, Volume 4, Heat Treating, are to be used after process selection. Ventilation of the fuel products is required. Ventilation of local exhaust may also be required to remove toxic fumes.

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Table 14  
Temperatures in Various Furnaces

OPERATION	°F	°C
Annealing:		
Aluminum	750	399
Brass and copper	930	499
Cold-rolled strip sheets (Steel)	1250-1400	677-760
High-carbon steel	1500	816
Malleable iron, long-cycle	1600	871
Malleable iron, short-cycle	1800	982
Manganese steel castings	1900	1038
Pack-rolled sheet steel	1600	871
Steel, castings and forgings	1650	899
Bluing steel	500	260
Carburizing	1750	954
Cyaniding	1800	982
Hardening high-speed steel	2200	1204
Heat treating medium carbon steel	1550	843
Nitriding steel	950	510
Ion-Nitriding (case hardening)	670-1070	354-577
Normalizing:		
Steel piping	1650	899
Steel sheets	1750	954
Corrosion resisting steel	1700-2000	927-1093
Strain relieving	>500	>260
Stress relieving (Nickel Electroforms)	700	371
Tempering in oil	500	260
Tempering high-speed steels	630	332

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Table 15  
Application of Principal Furnace Atmospheres

CLASS	DESCRIPTION	COMMON APPLICATION	NOMINAL COMPOSITION, VOL%				
			N <sub>2</sub>	CO	CO <sub>2</sub>	H <sub>2</sub>	CH <sub>4</sub>
1	Lean exothermic steel	Oxide coating of	86.8	1.5	10.5	1.2	---
102	Rich exothermic	Bright annealing; copper brazing; sintering	71.5	10.5	5.0	12.5	0.5
201	Lean prepared nitrogen	Neutral heating	97.1	1.7	---	1.2	---
202	Rich prepared nitrogen	Annealing, brazing stainless steel	75.3	11.0	---	13.2	0.5
301	Lean endothermic	Clean hardening	45.1	19.6	0.4	34.6	0.3
302	Rich endothermic	Gas carburizing	39.8	20.7	---	38.7	0.8
402	Charcoal	Carburizing	64.1	34.7	---	1.2	---
501	Lean exothermic- endothermic	Clean hardening	63.0	17.0	---	20.0	---
502	Rich exothermic- endothermic	Gas carburizing	60.0	19.0	---	21.0	---
601	Dissociated ammonia	Brazing, sintering	25.0	---	---	75.0	---
621	Lean combusted ammonia	Neutral heating	99.0	---	---	1.0	---
622	Rich combusted ammonia	Sintering corrosion resisting steel powders	80.0	---	---	20.0	---

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## Section 4: SPECIAL PROCESSES

4.1 Electropolishing

4.1.1 Electropolishing Processes. Electropolishing is an electrochemical process whereby the metal is removed rather than deposited, using the conditions shown in Table 16. Electropolishing is performed after all the pretreatment processes such as, buffing, polishing, machining, brazing, welding, forming and perforating, and prior to electroplating or other final processing. The electropolishing of metals is performed to:

- a) Improve appearance.
- b) Smooth and prepare for electroplating, anodizing or conversion coating.
- c) Remove excess material, as required (electromachining).
- d) Improve reflectivity by removing high points and levelling the surface. The process will not remove deep scratches.
- e) Increase corrosion resistance by removing imbedded material from mechanical operations (machining, forming, buffing and polishing).
- f) Remove burrs (deburring).
- g) Relieve stresses resulting from forming, machining, buffing, polishing, stamping and punching (see Appendix B).
- h) Remove scale resulting from heat treatment, forming, welding and brazing.

Surface irregularities, namely projections and impressions, are removed or eliminated during the electropolishing operations by leveling (dissolving the projections) which enhances the brightness and reduces roughness. In certain instances, brightness or smoothness may not be effected at the same time.

4.1.2 Metallurgical Requirements. The alloys involved in electropolishing are to be uniform in chemical composition. For best results, the grain size should be nine or better as determined by ASTM E112-80, Estimating the Average Grain Size of Metals, but size eight to nine produces very good results. When silicon, phosphorus, and tin are present, techniques other than electropolishing are required. In addition to the aforementioned, nonuniform grain structure, direction at void marks, and scale inclusions are detrimental to obtaining the required finish.

4.1.3 Electropolishing Equipment. Equipment and its layout resemble electroplating processes. The work bar is the anode and supports the parts to be electropolished. Each anode bar is placed between two rows of cathodes. Meters and controls are of conventional design similar to those used in electroplating systems. Tanks are made of corrosion resisting steel, low carbon steel, plastic or fiberglass reinforced plastic/epoxy (FRP). Tanks may

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Table 16  
Conditions and Etchants for Electropolishing

SUBSTRATE	ELECTROLYTE	TEMP °F	CATHODE	CURRENT DENSITY A/ft <sup>2</sup>	
Aluminum and Its Alloys	a) Sodium carbonate Trisodium phosphate Water	15% 5% remainder	165-190	Aluminum	50-60
	b) Sulfuric acid Hydrofluoric acid Water	1-60% 0.2-1.5% remainder	140	Aluminum	100
	c) Orthophosphoric acid Sulfuric acid Nitric acid Water	10% 60% 1% remainder	205	Aluminum	200
Carbon Steel	a) Hydrochloric acid Glycerine	25% 75%	Room	Steel or Aluminum	15
	b) Orthophosphoric acid Sulfuric acid Chromic acid Water	63% 15% 10% remainder	125	50-1000	
Copper and Its Alloys	a) Chromic acid Sodiumdichromate Acetic acid Sulfuric acid Water	7.2% 21.7% 7.2% 5.8% remainder	86	Copper	250-1000
	b) Arsenic acid Orthophosphoric acid Chromic acid Water	15% 55% 3% remainder	130	Copper	500
Nickel and Its Alloys	a) Sulfuric acid Water	70% remainder	Room	Lead or Copper	15
	b) Orthophosphoric acid Sulfuric acid Water	15-70% 15-60% remainder	Room	Lead or Copper	15
Corrosion Resisting Steel	a) Orthophosphoric acid Sulfuric acid Water	63% 15% remainder	80-175	Lead or Copper	50
	b) Orthophosphoric acid Water	75-100% remainder	150	Lead or Copper	300



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require linings of lead, rubber, or plastic materials like polyvinylchloride (PVC). The tank should not be the cathode. Cathodes are made into a pattern from rods, flat strips, etc., and suspended from cathode bars to ensure uniform current distribution. Chemical lead is the preferred cathode material, but carbon, corrosion-resisting steel, or copper may be used. The cathode to anode area should not be less than two to one unless specified otherwise herein. Heating and cooling can be through steam/water coils that are thermostatically controlled or through immersion heaters that are so placed to avoid stray currents, sludge buildup, or becoming bipolar. Inert plastic materials are preferred for coils, but if metallic coils are used, the metallic coils should be protected by making them cathodic ( $5 \text{ A/ft}^2$ ) even though they are coated by an inert plastic. Agitation is performed by back and forth movement of the work bar and is a general practice for uniform electropolishing. Air agitation has been used, but this is not the preferred practice.

A positive ventilation system capable of meeting or exceeding the requirements of Naval Occupational Safety and Health (NAVOSH) standards is required. Filtration of the electrolyte is required. Each electropolishing tank should have its own power source with a means for adjusting the current, and its own ammeter and volt meter.

#### 4.1.4 Electropolishing Bath Operation

4.1.4.1 Configuration for Electropolishing. The item to be electropolished is racked with firm positive contact and placed in the center of the tank parallel to the cathode rows on either side. Distance between the anode and cathode range between several inches and several feet, depending on the size and geometry of the item. The item to be electropolished is positioned equidistant or as nearly as possible from the cathodes, as electropolishing action is greater in high current density areas. Large variances in distance results in uneven and undesirable surface finishes.

4.1.4.2 Electrical Control. The electropolishing process is amperage controlled, with direct current at current densities of  $50$  to  $500 \text{ A/ft}^2$ . When deburring is required, the amperage may be between  $500$  and  $2,000 \text{ A/ft}^2$  where stock removal is principally burr. If electromachining is required, current densities may be up to  $250,000 \text{ A/ft}^2$ ; and the electrolyte is moved against the work piece by pumping. For most common metals,  $5$  to  $12 \text{ V}$  are required, but voltage ranges of between  $1\text{-}1/2$  and  $24 \text{ V}$  should be provided. The baths must be heated and cooled to operate within the required temperature ranges.

4.1.4.3 Electropolishing Rinse. A neutralizing (dilute acid or alkaline) rinse is required after electropolishing to prevent a milky or cloudy appearance of the surface of the dried item.

4.1.4.4 Electropolished Finishes. Finishes from satin to mirror bright are controlled by time in bath, current densities, and bath temperatures. The higher the bath temperature or current density, the brighter the finish; the longer the time in bath, the brighter the finish.

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4.1.4.5 Aluminum and its Alloys. The parameters for electropolishing are:

Time, minutes	5 to 10
Agitation	Anode Movement 2 to 3 inches plus Air
Ventilation	Required

Racks are made of titanium. Electropolishing tanks are chemical lead lined tanks. Cathode plates are used in front of the cathodes to prevent hydrogen from producing local agitation of the electrolyte in the vicinity of the items being electropolished.

The desmutting is performed in a corrosion resisting tank for five minutes at a temperature of 180 plus or minus 5 degrees F (82 plus or minus 3 degrees C). The work is then anodized as specified herein. The work rod is to be insulated from the desmutting tank so that the items are suspended away from the sides of the tank, otherwise etching of the aluminum surface will occur in the desmutting process.

4.1.5 Carbon Steel. The parameters for electropolishing carbon steel are:

Time, minutes	4 to 5
Agitation	Moderate
Ventilation	Required

If aluminum is present in the electrolyte to increase viscosity, then the agitation may be more vigorous.

4.1.6 Copper and its Alloys. The parameters for electropolishing copper and its alloys are:

Time, minutes	5 to 15
Agitation	Anode movement
Ventilation	Not required

The items are carried on copper wires, or are racked using corrosion resisting steel or titanium contacts. Tanks for electropolishing and drag-out rinsing are to be provided with covers to reduce evaporation of the solvent. Since the electropolishing is performed at room temperature and must be maintained below 85 degrees F (29 degrees C), the electrolyte is to be cooled. Rubber-lined tanks are used for electropolishing and drag-out rinse.

4.1.7 Nickel and its Alloys. Nickel and its alloys are electropolished using the following parameters:

Cathode Area Ratio (Cathode: Anode)	2:1 to 3:1
Time, minutes	8 to 15
Agitation	Air with Anode Movement
Ventilation	Required

Anode movement may be required to eliminate streaking. The movement is normally 15 to 25 cycles per min with a 4- to 6-in. stroke.

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4.1.8 Corrosion-Resisting Steel. When American Iron and Steel Institute (AISI) Type 300, corrosion resisting steel is to be mirror bright, after processing, the electropolishing parameters are:

Cathode Area Ratio (Cathode:Anode)	2:1 or 3:1
Time, minutes	8 to 15
Agitation	Air
Ventilation	Required

The process sequence is as follows:

- a) degrease in an alkaline cleaner followed by a hot alkaline cathodic cleaner,
- b) a cold water rinse and a hot water rinse,
- c) electropolish for the specified time,
- d) double running rinse, and
- e) passivate in a 5 percent by volume sulfuric acid - 1 percent sodium dichromate solution at room temperature or in a 20 percent by volume nitric acid solution at 120 degrees F (49 degrees C) for two to three min.

The iron content is not to exceed 10 ounces per gallon (oz/gal) (75 grams per liter (g/L)). Generally 4 Amp-hr/L will increase the iron content about 6 oz/gal (45 g/L). Most nickel and some iron dissolved in the process will precipitate as sludge, and the tank will have to be emptied. Racks used for the electropolishing of corrosion resisting steel are made of titanium but copper or brass racks with bronze contacts have been used, although the latter have a limited life. The tanks for the process are normally chemical lead lined. In addition to air agitation, cathode movement is required and the work is held at 20 to 45 degrees from the direction of the rod.

#### 4.2 Passivation and Stripping

4.2.1 Passivation (Corrosion-Resisting Steel). Corrosion-resisting steel is passivated after descaling and mechanically finishing the item to be processed. The item is degreased to remove machining, forming and grinding, and the flux and slag is removed by chipping or wire brushing.

Handling equipment is to be corrosion resisting steel or plastic. Monel baskets or containers must not be used. The effectiveness of the passivation treatment may be determined by ASTM A380, Recommended Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems.

4.2.2 Stripping. Stripping methods depend on the activity of the stripping solution on the deposited coating, and the inactivity of the substrate or basis metal. After use, many stripping solutions will attack the substrate causing pitting; therefore, the stripping process is tested to determine the affect of the stripping solution on the the basis metal. If the recommended process results in an adverse affect on the item because of alloy composition or a new combination of metals, then experimentation is required to determine the appropriate process. The stripping of the anodic film from

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aluminum is accomplished by vapor degreasing, immersion in an alkaline cleaning solution followed by a cold water rinse, a phosphoric acid-chromic acid stripping solution followed by a double cold-water running rinse, and is finally shop air dried.

#### 4.3 Vapor Deposited Cadmium

4.3.1 Vapor Deposited Cadmium Process. Vapor deposition of cadmium takes place at  $10^{-3}$  to  $10^{-10}$  torr, where the evaporation temperature is as high as 430 degrees F (221 degrees C) and as low as 100 degrees F (38 degrees C). The cadmium is heated to a vapor, and this vapor is deposited on the substrate which is at a lower temperature, normally room temperature. This process is used to eliminate hydrogen embrittlement of high strength steels.

4.3.2 Vapor Deposited Cadmium Equipment. The equipment for vapor deposition consists of a vacuum chamber with a rack or racks to hold the work, a roughing pump, and a diffusion pump aided by a cryogenically cooled coil and appropriate piping and gauges. The chamber is designed to accommodate the largest piece of work and provide the required distance from the work to the source of the vapor. The required distance from the source to the work is determined by the deposit thickness, the coverage on the work or area of the work, and the operating pressure of the vacuum chamber. The chamber is required to have a full-opening, hinged door at one end to remove the work and racks from the chamber.

4.3.3 General Considerations for Vapor Deposition. Cadmium used shall meet the composition of Fed Spec. QQ-A-671, Cadmium Anodes. Stripping and cleaning operations must take into account the damaging effects caused by these operations, i.e., pitting, intergranular attack, etching and hydrogen embrittlement of the work.

4.3.4 Vapor Deposited Cadmium Rack Design. Racks are designed to hold the work. The following design considerations are used:

- a) The maximum number of pieces per charge (dependent on size of chamber, capabilities of vacuum equipment and geometry of the pieces).
- b) Ease of mounting and removing the pieces on the rack (production speed).
- c) Minimizing shadowing or rack marks on finished pieces.
- d) Ease of cleaning.
- e) Ruggedness (reduction of damage during handling and cleaning).
- f) Simplicity of construction (for weight, volume, and cost reduction).

## Section 5: ELECTROCHEMICAL PROCESSES AND CHEMICAL TREATMENT

5.1 Metal Deposition

5.1.1 Operating Conditions. Typical operating conditions for metal deposition are shown in Table 17. Data presented in Table 17 provides information useful for material selection, instrumentation requirements, heating and cooling loads, power requirements, selection of the method of electrolyte agitation, material and chemical storage, and water make-up.

In general, thickness of deposits may be calculated by expanding Equation (1) and determining the efficiency of the electrodeposition process to yield Equation (4).

$$\text{EQUATION:} \quad T = 4.23 \times 10^{-3} CWhF_p/G \text{ or } 2.9 \times 10^{-6} IWKF_p/G \quad (4)$$

Where:

- T - Thickness, mils
- C - Current Density, A/ft<sup>2</sup>
- W - Weight of deposit, grams
- h - Hours
- F<sub>p</sub> - Process Factor of Efficiency, percent
- G - Specific Gravity of metal being deposited
- I - Average amperage, A
- K - A-hr

5.1.2 Bath Compositions. The bath compositions are nominal for the operating conditions given herein. Bath compositions vary with specific processes, operating parameters, and metallurgical characteristics of the same electrodeposit. As a guide to operating conditions and material selection, typical bath compositions are given in Appendix C.

5.1.3 Reversible Rack - Two Bus Bar (RR-2BB) System of Hard Chromium Plating. In the reversible rack-two bus bar system (see Figure 13), a single, low-ripple rectifier supplies the dc voltage to an anode bar and cathode bar, instead of two anode bars with a central cathode bar, as in the conventional system (see Figure 14). In this nonproprietary method, favored by many ship and aircraft maintenance facilities, racking is simplified, and there is more space for variously-shaped work to be plated in a single tank. Anodes (usually made of lead/tin (97/3)) are built into the racks, and are suitably insulated from the cathode connector. Racks straddle the two bus bars (see Figures 15 and 16) and can be reversed to permit anodic etching or plating, as the duty cycle requires. To accelerate plating rates and provide uniformity of deposit, conforming anodes are used as shown in Figure 17. This process is operated with a solution of 32 oz/gal (240 kg/m<sup>3</sup>) chromic acid and 0.32 oz/gal (2.4 kg/m<sup>3</sup>) sulfuric acid (100:1 ratio of CrO<sub>3</sub> to H<sub>2</sub>SO<sub>4</sub>); at a temperature of 140 degrees F (60 degrees C) and a voltage of 4.2-4.5 V. Control of this process is by voltage, as contrasted with conventional chromium plating, which is by current density.

5.1.4 Innovative Hard Chromium Plating (IHCP). The IHCP system uses the reversible rack-two bus bar method combined with the control of water

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Table 17  
Operating Conditions for Plating Baths

	pH	°F	°C	DENSITY A/ft <sup>2</sup>	VOLTAGE	ANODES	AGITATION	MAXIMUM TIME ALLOWANCE MINUTES
Copper								
Pyrophosphate Strike	.9 - 9.2	100 ± 10	38 ± 6	20 - 30	3 - 6	OFHC Copper	.....	2
Operation	8.2 - 8.8	130 ± 10	54 ± 6	10 - 75	1.5 - 4.0	OFHC Copper	Air	See Table 3
Rochelle-Strike	11.5 - 12.5	.....	.....	15 - 75	.....	.....	.....	.....
Cyanide-Strike	11.0 - 12.2	95 ± 25	35 ± 14	5 - 10	.....	.....	.....	.....
Acid (General)		97 ± 3	36 ± 1.7	20 - 45	1 - 4	.....	.....	.....
Acid (Printed Circuits)				1 - 6	.....	.....	.....	.....
Silver								
Cyanide-Strike	.....	75 ± 2	24 ± 1.1	16 - 27	.....	Bagged Silver	.....	.....
Cyanide	.....	73 ± 4	23 ± 2.2	5 - 6	.....	Bagged Silver	.....	.....
High Speed	.....	73 ± 4	23 ± 2.2	54 - 108	.....	.....	.....	.....
Non-Cyanide Strike	1.0 - 1.5	room		<25	1.5 - 2.0	.....	.....	.....
Plating	1.7 - 2.0	109 ± 5	43 ± 2.8	5 - 15	1 - 4	.....	.....	.....
Nickel								
Warr's Strike	3.0 - 4.0	140	60	100 - 150	12	Depolarized Ovals	Reciprocating Rod Plus Air	.....
Wood's Strike	.....	80 ± 5	27 ± 2.8	50 - 150	.....	.....	.....	.....
Low pH	1.5	115	46	25 - 100	.....	.....	.....	.....
All Sulfate	3.0 - 4.0	115	46	.....	.....	.....	.....	.....
Sulfamate								
Chloride-Free	3.0 - 5.0	125 ± 15	52 ± 8.3	15 - 40	.....	.....	.....	.....
Chloride- Containing	3.5 - 4.2	110 ± 40	43 ± 2.2	20 - 140	12	.....	.....	.....



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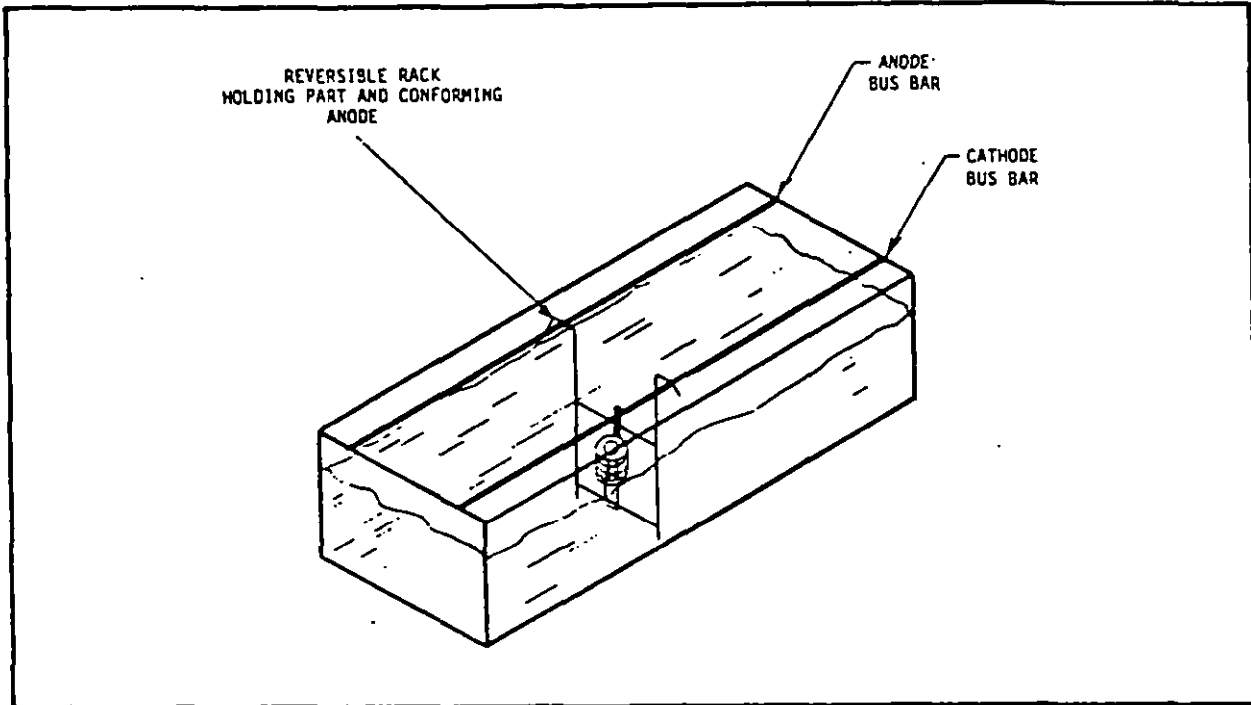


Figure 13  
Reversible Rack - Two Bus Bar Hard Chromium Plating System

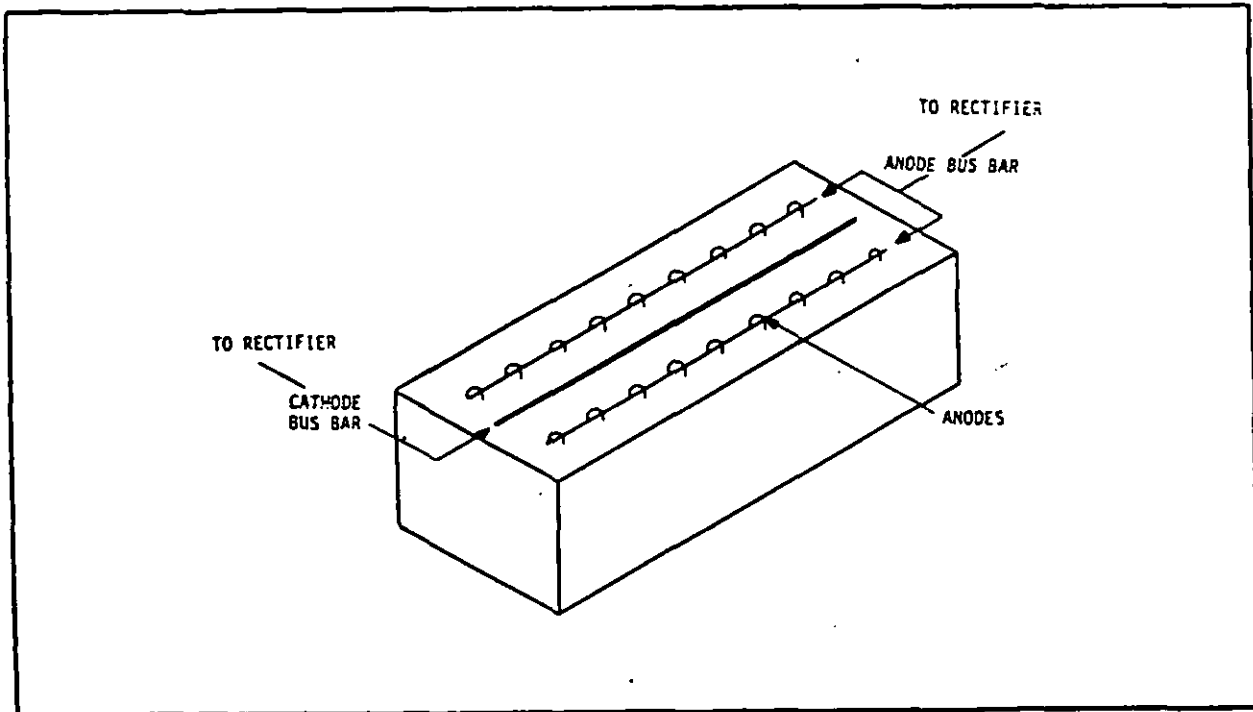


Figure 14  
Conventional Hard Chromium Plating System



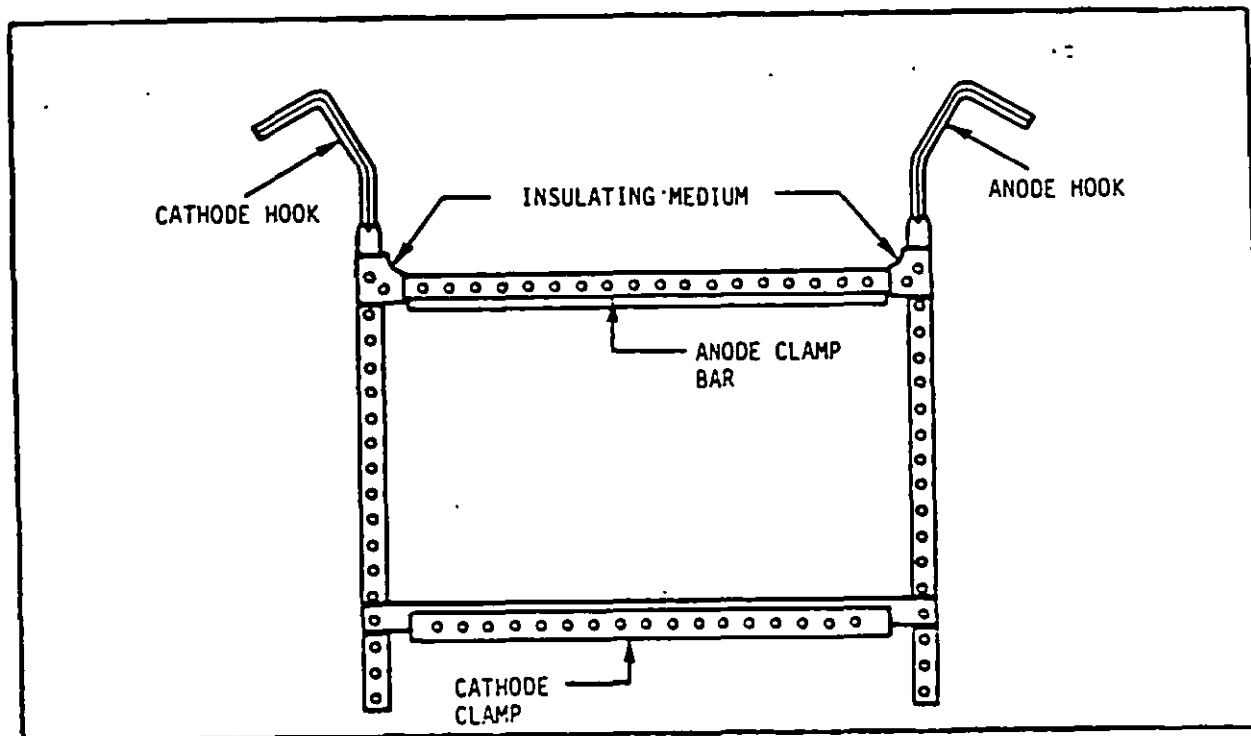


Figure 15  
Reversible Rack (Assembled)

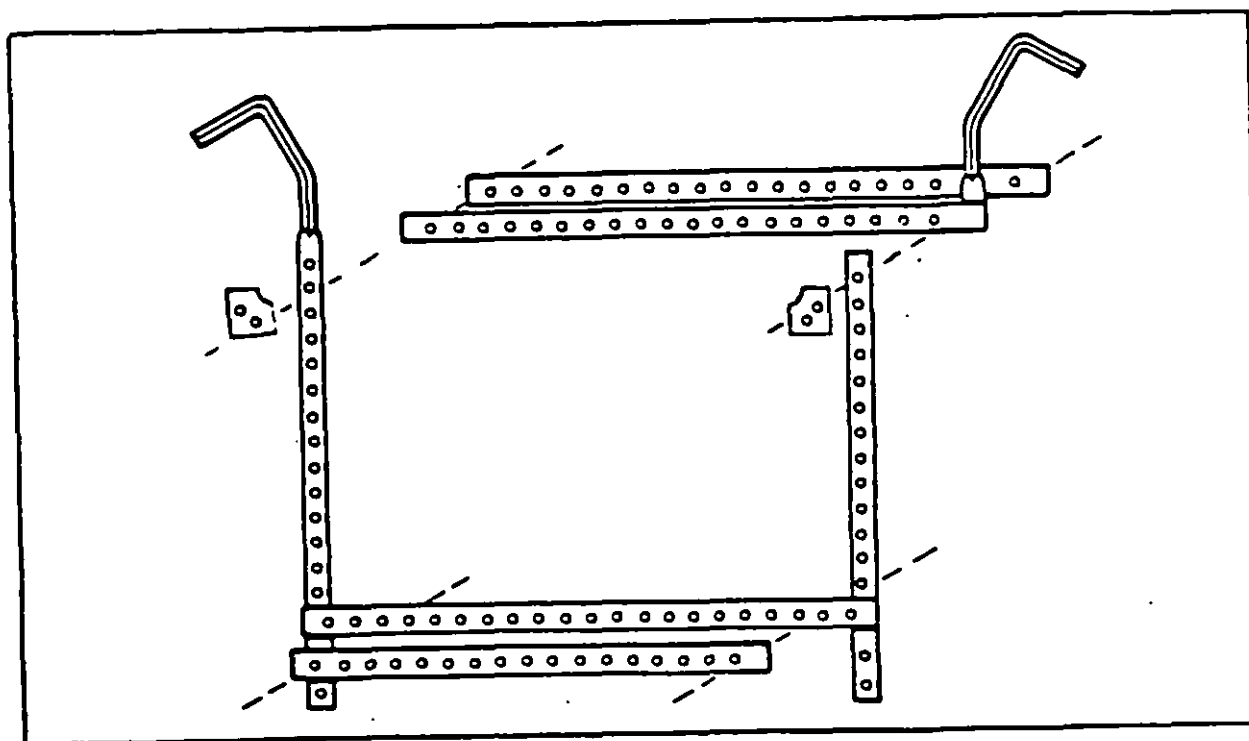


Figure 16  
Reversible Rack (Expanded)

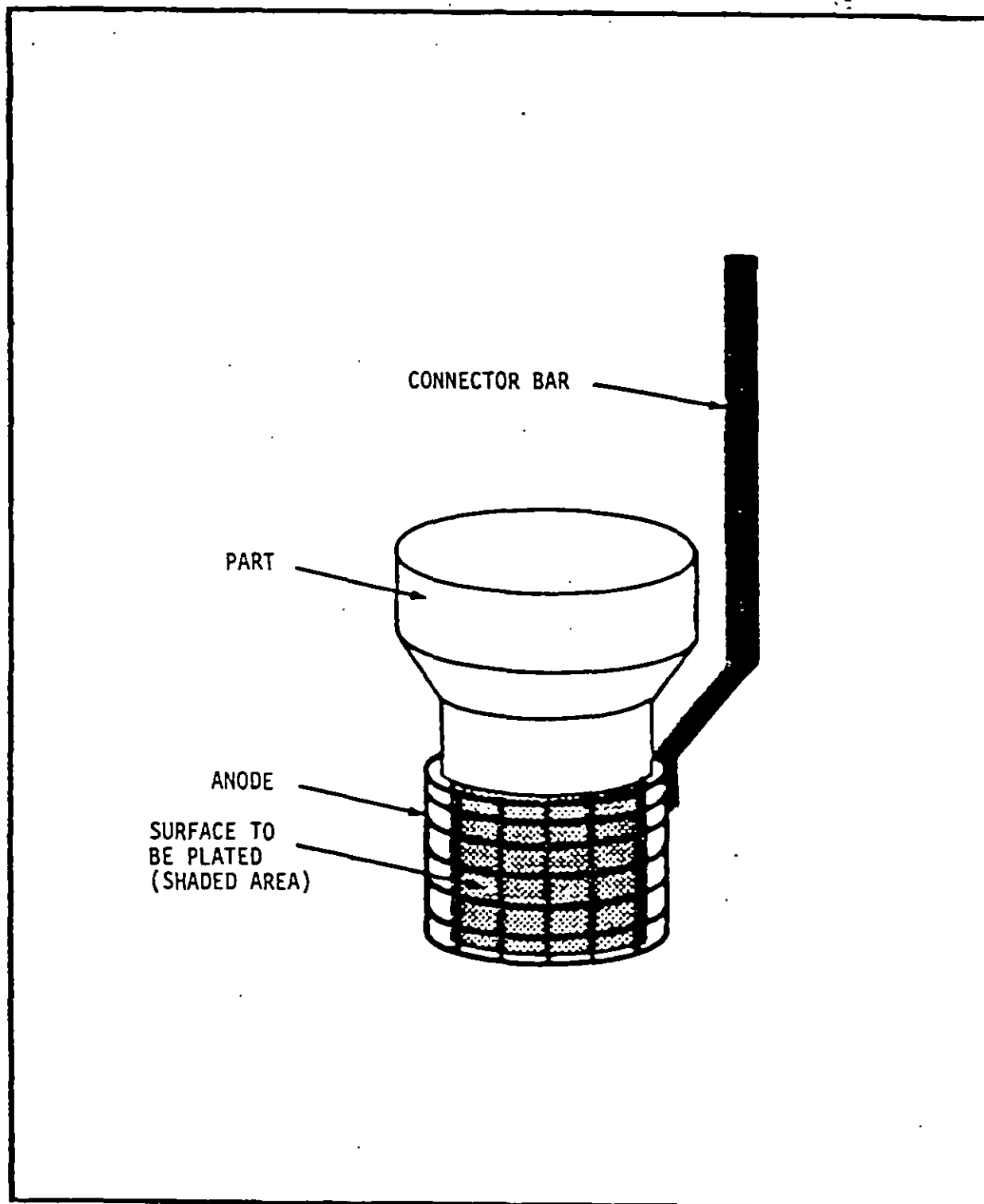


Figure 17  
Cut View of Conforming Anode With Part

evaporation and additions, as well as bath purification to provide increased productivity and zero discharge rinsing. The IHCP system is illustrated in Figures 18 and 19.

5.1.4.1 HCP Water Control. Water control is maintained by water additions from the spray rinse collections and temperature control of the plating bath. Air agitation is required at one end of the plating tank, as in the two bus bar method, by the use of a 1/2-in. (13 mm) PVC pipe to increase electrolyte circulation. No plastic chips, balls, or foam are used since surface evaporation, rinse water, and mist from the separator are used to maintain the water level.

5.1.4.2 IHCP Bath Purifier. In order to operate continuously, the IHCP bath requires a bath purifier to minimize sludge buildup. The sludge consists mainly of iron, copper, nickel, and lead with the presence of trivalent chromium in the electrolyte. The trivalent chromium is converted to hexavalent form for reuse, and the other metals are removed from the bath.

5.1.5 Selective (Brush) Plating Processes. Controlled localized electroplating is accomplished by selective (brush) plating. The equipment and solutions are specifically designed for the process.

5.1.5.1 Selective Plating Equipment. The equipment used for selective (brush/pad) plating consists of a DC rectifier with an output of not less than 30 V and 4 A. The rectifier is to have a reversing switch and an ampere-hour meter with a zero reset feature. This rectifier is to conform to Mil Spec. MIL-P-80249, Plating Unit Selective (Brush), Portable. The anodes are to conform to Mil Spec. MIL-P-80249, Type I, for air-cooled styli and Type II for solution cooled styli. A suitable electrolyte pump is to be provided as part of the equipment, as well as a clamp and a motor-driven turning-head (3 or 4 jaw chuck) for holding the work to be plated. For portability, a cart, made of a suitable corrosion-resisting metal, is provided to hold and transport the rectifier and solutions.

5.1.5.2 Solutions. Solutions for selective plating are as shown in MIL-STD-865, Selective (Brush Plating), Electrodeposition. Many of these selective plating solutions are allergic sensitizers, in addition to being strong irritants. Therefore, good work practices require strict adherence and use of protective equipment. There are proprietary plating solutions that may be used cost effectively. Suppliers of these solutions may provide technical assistance on startup upon request.

5.1.5.3 Thickness Control. The time to achieve the required thickness of electroplating is calculated by Equation (5).

$$\text{EQUATION:} \quad H_m = 12 \text{ FTA/I} \quad (5)$$

Where:

- $H_m$  - time, minutes
- F - plating factor (see Table 18)
- T - thickness, mils (0.001 in. or 0.00254 micrometers)
- A - total area plated, in<sup>2</sup>.
- I - average amperage

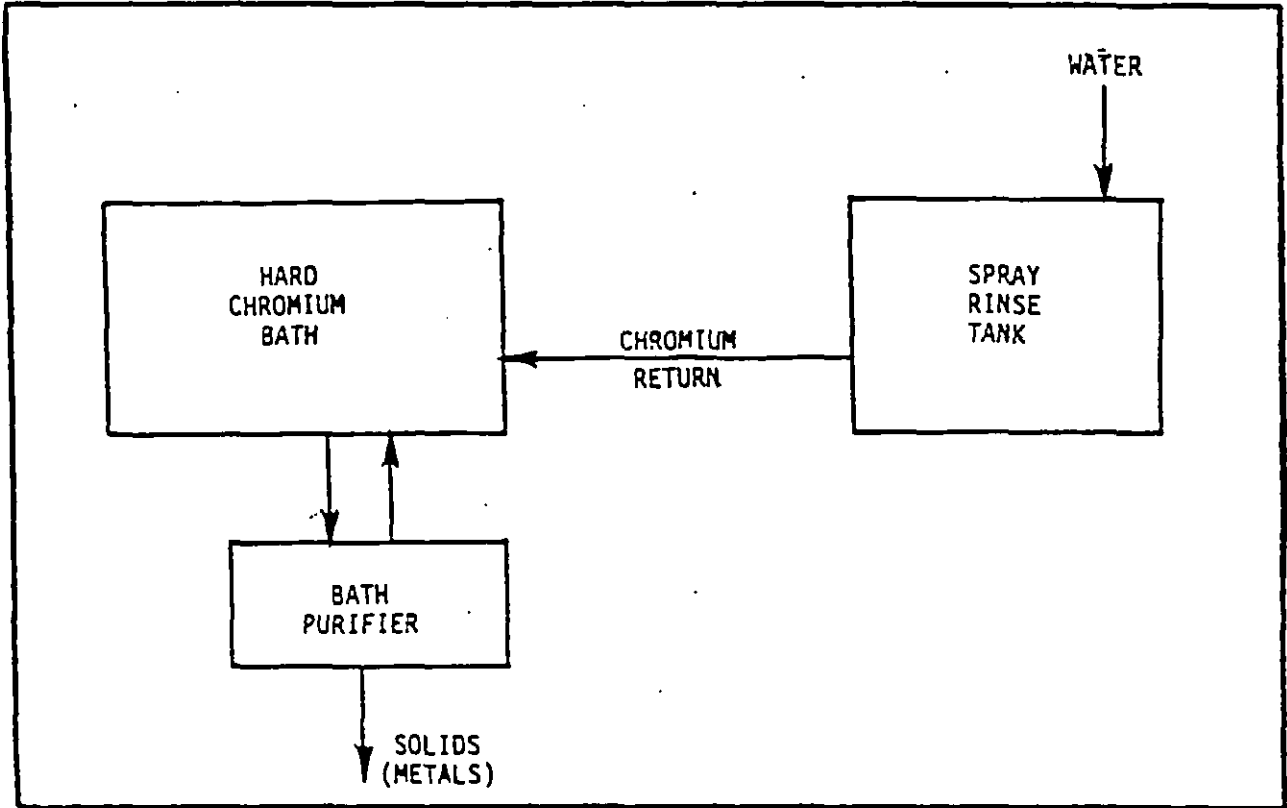


Figure 18  
IHCP Schematic

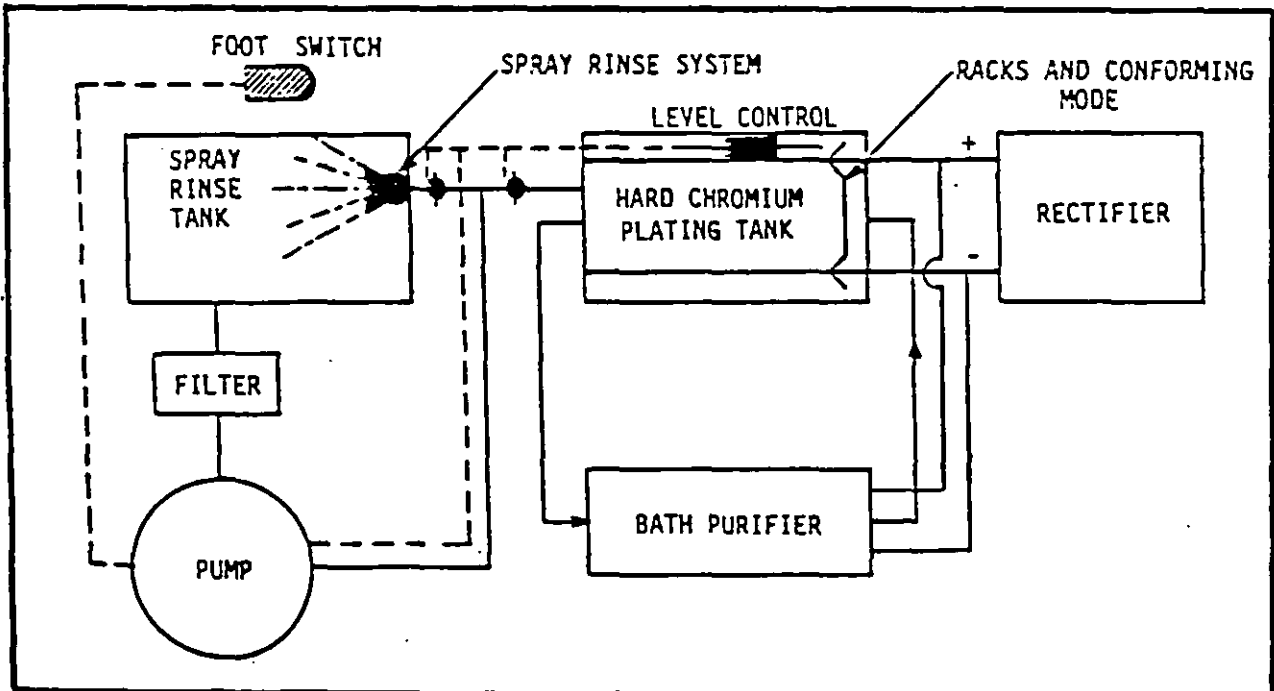


Figure 19  
IHCP Using the Reversible Rack (RR-2BB) Method

5.1.6 Precious Metal Deposits. Bath formulations for precious metal deposits are given in Appendix C. Estimating the cost of the precious metal deposit may be done using Equation (6).

$$\text{EQUATION:} \quad d = Ab/31.1G_s \quad (6)$$

Where:  $d$  - cost of plating a part or discrete area of a part  
 $A$  - area to be coated,  $\text{in}^2$ .  
 $b$  - weight of the deposit,  $\text{g}/\text{in}^2$ .  
 $G_s$  - cost of metal per troy ounce

Table 18  
 Plating Factor for Selective (Brush/Pad) Plating  
 (See Equation (4))

SOLUTION (ELECTROLYTE)	PLATING FACTOR, F
Cadmium Cyanide	1.25
Cadmium Fluoborate (LHE)*	0.63
Zinc Cyanide	1.25
Zinc Fluoborate	0.63
Tin Fluoborate	0.63
Copper Cyanide	0.40
Copper Pyrophosphate	0.90
Nickel Strike	not calculated
Nickel Sulfamate	2.10
Nickel Fluoborate	0.75
Gold Cyanide	0.40
Gold (Commercial)	1.00
Silver Cyanide	0.33

\*Low hydrogen embrittlement.

5.1.6.1 Silver. Silver may be applied over nickel or copper electroplates. The substrates may be copperplated steel, copper, nickel, or aluminum which is zincated. The zincated aluminum substrate is given a copper strike and an electroplate from an acid copper bath. On steel, the substrate is cleaned and given a copper strike followed by a copper electroplate from an acid copper bath and, finally a silver strike and a silver deposit. The silver deposit may be made from a cyanide bath or a noncyanide bath. The cyanide baths are more easily maintained and operated when compared to the noncyanide baths. Racking is a problem with noncyanide baths, since silver iodide-potassium iodide electrolyte attacks copper. Zirconium or titanium metal is used for racking and wiring, and since the resistance of these metals is greater than copper the area of the contacts and wire are 5 times that of copper.

5.1.6.2 Gold. Gold may be deposited from alkaline, neutral or acid baths. These gold deposits meet Mil Spec. MIL-G-45204, Gold Plating, Electrodeposited, and ASTM B488, Electrodeposited Coatings of Gold for Engineering Uses. Alkaline baths are very tolerant of impurities and changes

of composition. These alkaline baths have excellent throwing power, however, ceramic and plastic substrates are affected by the alkalinity. Neutral baths permit alloy deposition and little attack is observed on plastic and ceramic substrates. Acid baths are mainly used on non-metallic substrates.

5.1.6.3 Platinum. A variety of proprietary baths are available for the deposition of platinum.

5.1.6.4 Rhodium. A variety of proprietary baths are available for the deposition of rhodium. These rhodium deposits meet Mil Spec. MIL-R-46085, Rhodium Plating, Electrodeposited, when using the rhodium sulfate bath. Phosphate baths are used for very white and reflective deposits and the mixed phosphate-sulfate baths are for general decorative deposits.

## 5.2 Chemical Treatment Processes (Including Anodizing)

5.2.1 Anodizing Aluminum (Al). Table 19 shows the range of operating characteristics for typical aluminum processes. Anodizing of aluminum (Al) is generally carried out as shown in Figure 20. Specific anodizing sequences and treatments will vary due to alloying constituents, heat-treatment history of the item, and its dimensional tolerances.

5.2.1.1 Chromic Acid Anodizing. Low carbon steel tanks are generally satisfactory for chromic acid baths. The tanks to be installed are to be free of vibration. Acid proof bricks laid loosely without mortar on the bottom of the tank are desirable to avoid inadvertent short circuits. Anodizing baths need heating and cooling. Coil heat exchangers may be used for both purposes; however, electric heaters are preferred for ease of operation and lower probability of contamination. Agitation can be provided by mechanical agitator or compressed air. Thermostatic control of plus or minus 5 degrees F (plus or minus 3 degrees C) is a common practice. Exhaust ventilation through slotted ducts along the top edge of the tank walls is necessary to control chromic acid mist above the tanks.

5.2.1.2 Sulfuric Acid (Conventional) Anodizing. Tanks are generally made of low carbon steel with plasticized PVC inner lining and chlorinated rubber based paint on the outside. Lead, rubber, and acid proof brick are other options for inner lining. Acid proof stainless steel or organic materials have been used to fabricate the tanks. Temperature control equipment should control within plus or minus 2 degrees F (plus or minus 1 degree C). Requirements for agitation and ventilation are the same as for the chromic acid solutions. A separate heat exchanger and acid makeup tank are required. The tank should be lead lined steel. PVC pipes are preferred for air agitation and for the acid return lines. Cooling coils should be made of chemical lead or antimony-lead pipe.

a) Dyeing. After anodizing and rinsing, the aluminum oxide coating produced thereby may be dyed using commercial dyes which if chosen properly will be lightfast, and weather-resistant. The dyeing is carried out in a corrosion-resisting steel tank which is heated to the temperature recommended by the supplier of the dye.

Table 19  
Operating Conditions for Anodizing Aluminum (Al)

	STANDARD	CHROMIC ACID	HARD-COAT
Temperature			
°F (°C) (Note 1)	60-80 (16-27)	92-98 (33-37)	32-38 (0-3)
Current Density			
A/ft <sup>2</sup>			
(A/m <sup>2</sup> )	10-15 (1.0-1.4)	3-5 (0.3-0.5)	20-38 (2.0-3.5)
Voltage	10-25	0-50 (Note 2)	20-60
Time, minutes	20-40	5-20	60-200
Cathodes	Lead Alloy	Lead Alloy	Lead Alloy
Refrigeration	None	None (Note 3)	Required
Agitation	Air	Air	Moving Anode, CO <sub>2</sub> injection

- NOTES:
1. For consistent results, temperature is maintained within plus or minus 3 degrees F (plus or minus 1 degree C) of the operating temperature selected.
  2. Voltage is on an increasing ramp rising from 0 to 40 V in 10 min, remaining at 40 V for 20 min then rising from 40 to 50 V in 5 min and remaining at 50 V for 5 min.
  3. Consideration of heat of evolution is required for as much as 425 Btu/ft<sup>2</sup> is evolved and refrigeration may be needed if continuous anodizing is a requirement. Cold water circulation in a tube-type heat exchanger may be sufficient.

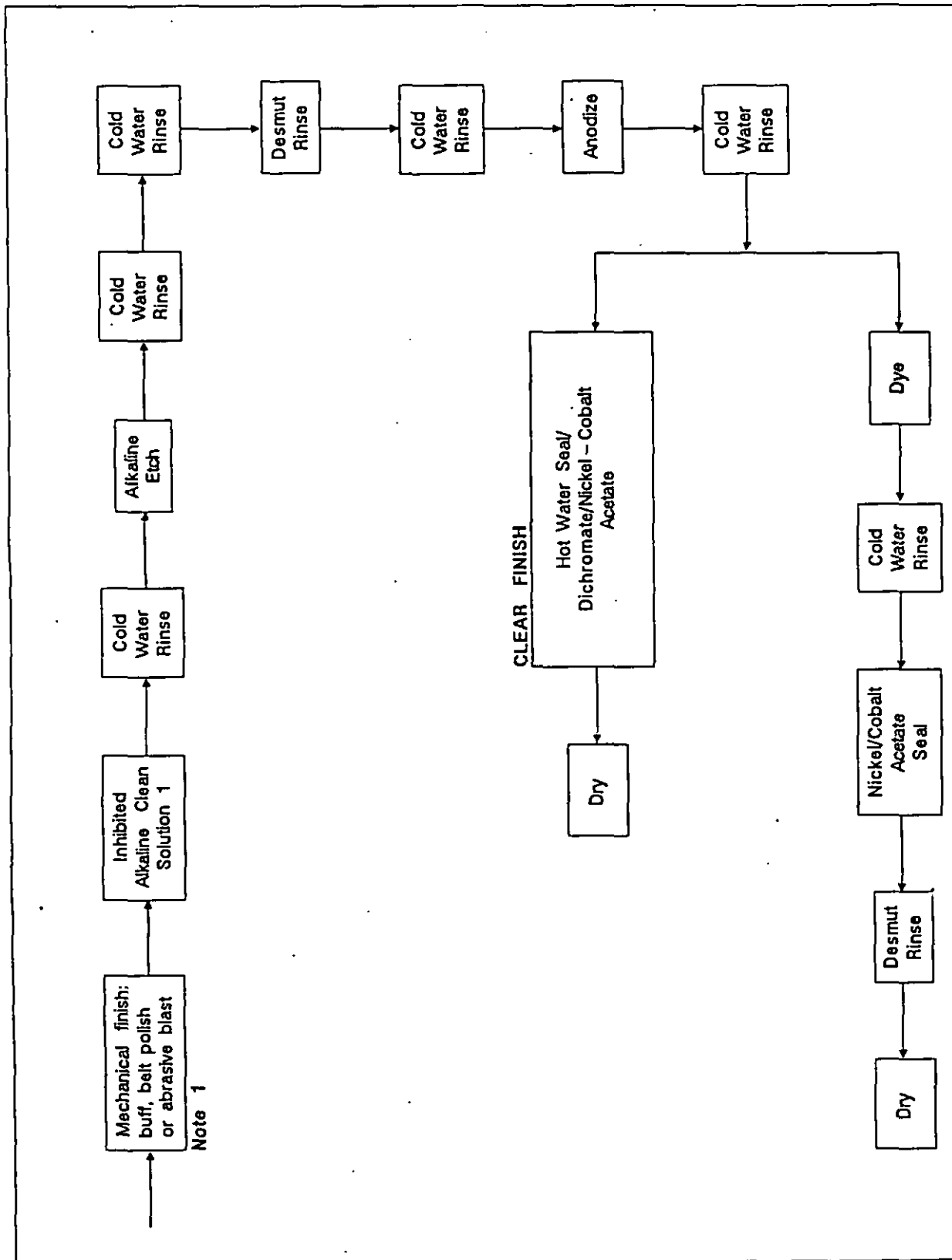


Figure 20  
General Aluminum Anodizing Process



b) Sealing. Sealing clear-finished or dyed sulfuric acid anodized coatings improves the corrosion resistance of the finished item. Sealing of clear-coated aluminum is accomplished by immersing the anodized item in boiling water. A further increase in corrosion resistance may be obtained by using dichromate or nickel/cobalt acetate in the sealing solution.

Water sealing is accomplished using the following solution:

Distilled or deionized water containing less than 100 ppm silica	
Temperature	200° - 212° F (93° - 100° C)
Time	30 min

Dichromate seal is accomplished using the following solution:

K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	13.4 oz/gal (100 g/L)
Na <sub>2</sub> CO <sub>3</sub>	2.4 oz/gal (18 g/L)
or NaOH	1.7 oz/gal (13 g/L)
Temperature	194° - 203° F (90° - 95° C)
Time	3 to 4 min

Nickel/Cobalt Acetate seal is accomplished using the following:

Nickel acetate	0.67 - 0.78 oz/gal (5 - 5.8 g/L)
Cobalt acetate	0.13 oz/gal (1 g/L)
Boric acid	1.1 oz/gal (8 - 8.4 g/L)
pH	5 - 6
Temperature	158° - 194° F (70° - 90° C)
Time	15 to 20 min

5.2.1.3 Hard-Coat Anodizing. Hard-coat anodizing parameters are shown in Table 19. This process operates at high current density and low temperature. The bath temperature is controlled by refrigeration, carbon dioxide gas injection, and by supplemental dry ice additions when necessary. The electrolyte concentration is generally an aqueous solution of 15 percent by weight sulfuric acid. Rectifiers or direct current generators used should be capable of providing continuous voltages of not less than 100 V for 24 hr. Refrigeration equipment should have a capacity sufficient to maintain the electrolyte at a temperature of 25 degrees F (minus 4 degrees C) when the bath is being operated at full capacity (See Equation (7)). The process does not require sealing; therefore, no sealing tanks are needed.

EQUATION: 
$$B_r = 0.2845EF_pD_f \quad (7)$$

Where:

- B<sub>r</sub> - Refrigeration, Tons
- E - Power, kilowatts
- F<sub>p</sub> - Process Factor (normally 0.95)
- D<sub>f</sub> - Design Factor (normally 1.20)

## 5.2.2 Chromate Conversion Coatings

5.2.2.1 Zinc and Cadmium (Chromate Conversion Coatings). Chromate conversion coatings for zinc and cadmium are divided into two main groups of full passivation and light or blue passivation. The full passivation is used for maximum protection and may be a pretreatment for painting. Light or blue

passivation is used for protection against mild corrosive atmospheres and finger marking of the product (refer to Table 20). The full passivation is obtained by dipping in a proprietary chromate conversion coating solution until the appropriate color is obtained which may be from 20 seconds to 2 minutes, then allowing the items to drain, rinsing in running cold water, rinsing in hot water, and air drying. Depending on the conversion coating, up to 48 hr may be required to cure the coating prior to further processing, i.e., packaging, or painting followed by packaging. The light or blue passivation is obtained in the same manner as the full passivation although some modification of conversion coating formulations may be required by the supplier. Normally, the coating is bleached in an aqueous sodium hydroxide solution at 60 to 140 degrees F (16 to 60 degrees C) for 10 to 30 seconds depending on the specified color. Care is taken to obtain the correct coating thickness, since poor life of the item may result when too thick a coating is obtained.

5.2.2.2 Aluminum and Its Alloys (Chromate Conversion Coatings). Conversion coatings for aluminum and its alloys are given in Mil Spec. MIL-C-81706, Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys, and a list of suppliers are to be found in Military Qualified Products List QPL-81706. The items are first vapor degreased, then soak cleaned, rinse in a cold water rinse, deoxidized in an acid deoxidizer, cold water rinsed, followed by the application of a chromate conversion coating applied by immersion, spray, or brush, swab or roll-coat, allowed to drain for 25 seconds to 3 min, rinsed in a countercurrent double rinse, and finally immersion treated in an aqueous 4 oz/gal (30 g/L) chromic acid solution at 180 to 200 degrees F (82 to 93 degrees C) for 1/2 to 1 min.

5.2.2.3 Copper and Its Alloys (Chromate Conversion Coatings). Chromate conversion coatings for copper and its alloys passivate these materials and in addition, they act as a chemical polish. The bath is non-fuming. If fire scale is present, then the items are prepickled to reduce surface roughness. The conversion coating may be used as a final finish to reduce or eliminate sulfide tarnishing or may be used as a whole or partial substitute for buffing or coloring prior to nickel or nickel/chromium plating. During the processing, 0.5 mil loss of metal is usually expected. The salts used in this process are proprietary. If large amounts are present in the copper alloy, the chromate coating will be found to be powdery.

5.2.2.4 Magnesium and Its Alloys (Chromate Conversion Coatings). Two chemical treatments are available for chromating magnesium--Dow Chemical Treatment No. 1 and Dow Chemical Treatment No. 7. Chemical Treatment No. 1 is used to prevent corrosion during shipment and storage of magnesium products. The steps in the process are shown in Figure 5 in Section 2. The chemical treatment No. 1 is applied by dipping or brushing and removes about 0.6 mils by etching; therefore, machined parts allow for this treatment process. Steel or brass inserts are not affected but are to be protected if a bright finish is to be maintained. Dow Chemical Treatment No. 7 is applied by immersion in a dichromate solution. The process involves alkaline cleaning for three to ten min at 190 to 212 degrees F (88 to 100 degrees C), double countercurrent rinsing in cold water, a dip in aqueous 20 percent hydrofluoric acid solution for one-half to five minutes at 70 to 90 degrees F (21 to 32 degrees C), double countercurrent rinsing in cold water, dipping in a boiling aqueous 18 percent dichromate solution at not less than 190 degrees F (88 degrees C) for

Table 20  
Typical Chromate Treatments

METAL	TREATMENT	SOLUTION OR BATH	TYPE OF DEPOSIT	COLOR	SPECIFICATIONS	REMARKS
Zinc and Cadmium	Acid dip which may be bleached in aqueous NaOH	(1) Acid Chromate/Sulfate (2) NaOH	Thin film of Chromium Chromate	Varies yellow to olive drab-bleached Light blue to clear	QQ-P-416, QQ-Z-325, MIL-C-17711 MIL-C-17871	
Aluminum and its Alloys	a) Alkaline	Alkaline Chromate	Oxide or Hydroxide with some Chromate	Light to dark gray	AMS 2474	MIL-C-87936A Alkaline, Soak
	b) Acid dip, 1	Acid Chromate or Fluoride w/Phosphate	Phosphate with some Chromate	Golden brown	ASTM D1730, MIL-C-5541	
	Acid dip, 2	Acid Chromate w/Fluoride or Nitrate	Chromate	Golden brown	MIL-C-81706, MIL-W-6858	
	c) Acid Pickle	Acid Chromate w/Sulfate or Phosphate	Very thin Chromate	Yellow or pale yellow	ASTM D2092	
Copper and its Alloys	Acid dip	Acid Chromate	Very thin Chromate	Copper color		
Magnesium	Dow No. 1	Acid Dichromate w/nitric acid for wrought products and w/alkali metal fluorides and nitric acid for cast items	Thin Chromate	Matte gray to iridescent yellow red	MIL-M-3171, MIL-W-6858	
	Dow No. 7	Acetic acid and sodium nitrate or hydrofluoric acid followed by dichromate immersion	Chromate	Light to dark brown		

30 min, a double countercurrent rinsing in cold water and finally a hot water rinse at 160 to 180 degrees F (71 to 82 degrees C) followed by air drying.

5.2.2.5 Equipment Used in Chromate Conversion Coatings. Items to be protected by chromate conversions may be handled by racking, wiring, or barrel coating. Items are first vapor degreased and then acid dipped, rinsed and finally conversion coated. The formulations frequently contain fluorides and, therefore, equipment is required to resist attack by this ion. Moulded polyethylene or polypropylene may be suitable, or where fluoride ions are not present, polypropylene/FGR or PVC/FGR may be used. PVC steel-lined tanks are also suitable. Chromate conversion coating solutions are operated up to 160 degrees F (71 degrees C) but most operate at room temperatures; therefore, Teflon coated heaters or Teflon tubing for refrigeration may be required to obtain temperature uniformity. In addition, agitation is required for bright passivation which is accomplished by mild air movement using a lance. The pH of solutions are between 0.1 and 4.6 except where aqueous sodium hydroxide is used for bleaching the coatings. The aluminum chromate conversion coating solution for immersion coating is fabricated from corrosion resisting steel alloy AISI 316.

5.2.3 Anodizing Magnesium (Mg). The chemical and anodizing treatments for magnesium (Mg) are given in Table 21. The significant differences between various coatings are also indicated in the table. The operating procedures are provided in Table 22. Suggested materials for construction of racks or baskets are shown in Table 23. The materials for tank construction used for anodizing Mg unless they appear in Table 24, are as follows:

<u>Solution</u>	<u>Material</u>
Alkaline cleaner	Low carbon steel
Caustic anodize	Low carbon steel
Dichromate	Corrosion resisting steel AISI Number 316 or lead-lined or vinyl-lined steel (Koroseal, Saran, or Tygon vinyl materials)
Galvanic anodize	Low carbon steel

5.2.4 Phosphate Conversion Coatings. Figure 21 shows the process of phosphatizing of ferrous metal parts. A detailed description of the baths, equipment, and handling of items is presented in MIL-HDBK-205, Phosphatizing and Black Oxide Coating of Ferrous Metals.

Table 21  
Chemical and Anodic Treatments for Magnesium

COMMERCIAL DESIGNATIONS	TEMPERATURE LIMITS FOR USE	TREATMENT	SPECIFICATIONS		REMARKS
			°F	°C	
1 Macromag 101	>450	Chrome Pickle	MIL-M-3171, type I	>232	Removes up to 0.6 mil used for temporary storage, domestic shipment, electric bonding, touch-up and brush applications.
7 Macromag D-7	>550	Dichromate	MIL-M-3171	>288	Used after machining and prior to painting, not suitable for alloys EK 30A, EK 41A, HM 21A, HM 31A, La 141a, and M1a.
9 Macromag D-9	>550	Galvanized Anodizing	MIL-M-3171, type IV	>288	Used after machining, final color dark brown to black, suitable for prolonged protection.
10 ...	>450	Sealed Chrome Pickle	MIL-M-3171, type II	>232	Combination of Dow No. 1 followed by Dow No. 7. Removes up to 0.6 mil, used for prolonged protection, final color matte gray to iridescent yellow.
12 HAE	...	Caustic Anodizing	MIL-C-13335, MIL-M-45202, & AMS-2476	...	Anodic coating thickness varies from 0.2 mil at low voltage to 1.2 mils for high voltage. Coating is hard, brittle, abrasion resistant, and excellent paint base.
17 ...	...	Anodize	MIL-M-45202 & ASTM D1732	...	Coating is hard, brittle, abrasion-resistant and excellent paint base.
.. Magnesium Elektron	>450	Fluoride Anodizing	...	>232	No detectable dimensional changes, requires corrosion prevention treatment for maximum protection. Used for substitute for shot or grit blasting, and as a paint base for baking enamel MIL-C-4607.
.. Iridite No. 15	>550	Chromate Conversion	See Table 20 (Chromate Treatment)	>288	Used after machining as a paint base.
.. CR-22	...	Acidic Anodizing	MIL-M-45202, type II, Class B and MIL-M-45202, type II, Class C	...	Used after machining as a paint base or may be sealed in an aqueous sodium silicate solution and is suitable for prolonged protection.

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Table 22  
Operating Conditions for Anodizing Magnesium

COMMERCIAL DESIGNATIONS DOW OTHER NO.	POWER SUPPLY VOLTAGE	AMPERAGE ASF	TEMPERATURE		COATING THICKNESS Mils	REMARKS
			°F	°C		
9	Macromag D-9 70 - 95 dc or 60 - 90 ac	Limits above 2 and below 10	130 ± 10	54 ± 5.5	...	70 A-min/ft <sup>2</sup> . Dow Alloys AZ31B, AZ63A, EK30A, and HK31A are ac anodized; Dow Alloys AZ80A & HK31A are ac or dc anodized. Others are dc anodized.
12	...	15	170 ± 5	77 ± 5.5	0.2-1.2	Anodized time 15 to 25 min.
.. 90	HAE 70 First Phase & Second Phase				0.2+1.2	Coating produced under Dow No. 12 are similar to HAE Treatment. First phase for 7 min and second for 60 min.
17a	...	50	73 ± 13	23 ± 7.2	<0.2	Light green - 80-100 A-min/ft <sup>2</sup> for ac and 50-60 A-min for dc (2 1/2 to 5 min).
77b 17b	...	50	73 ± 13	23 ± 7.2	>1.2	Dark green - 460 for ac and 300 A-min/ft <sup>2</sup> (15 to 23 min).
..	Magnesium Elektron	5	73 ± 13	23 ± 7.2	...	Increasing ramp voltage to 120 V over a period for 10 to 15 min.
..	CR-22	15	190 ± 5	88 ± 2.8	...	Maximum voltage for black finish 320 V for normal treatment. Anodizing time 12 to 15 min.

Table 23  
Rack or Basket Materials Used in Anodizing Magnesium (Mg)

<u>COMMERCIAL DESIGNATION</u>		
DOW. NO.	OTHER	RACK MATERIALS
1	---	CRS or Monel
7	---	CRS #316 or Monel
9	---	CRS, Monel or Phosphor bronze
10	---	CRS or Monel
12	---	High Al content Mg or Al Alloys containing more than 8% Mg
17	---	Mg alloys, Al alloys 5052, 5056 or 220 (Al alloys must be immersed in the solution on open circuit)
19	---	---
	HAE	Mg alloy protected with suitable vinyl tape
	Magnesium	Mg alloys - AZ31B, AZ63A, AZ91C or steel coated Elektron with rubber, synthetic rubber or PVC
	Iridite #15	Steel coated with PVC or CRS
	CR-22	Mg alloys

CRS - Corrosion Resisting Steel

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Table 24  
Materials for Tank Construction

SOLUTIONS	CORROSION RESISTANT STEEL			PLASTIC LINED STEEL	LEAD LINED	RUBBER LINED	CERAMIC	ACID BRICK LINED	GLASS
	STEEL	PLASTIC	STEEL						
Alkaline	R	NR	S*	NR	NR	NR	NR	NR	NR
Cleaning	R	S	R	R	NR	S	NR	NR	S
Brass	R	S	R	R	NR	S	NR	NR	S
Bronze	R	NR	R	R	NR	NR	NR	NR	NR
Cadmium	R	NR	R	R	NR	NR	NR	NR	NR
(Alkaline)	NR	NR	R	R	R	NR	NR	S	NR
Chromium	NR	NR	R	R	R	NR	NR	NR	NR
Copper	NR	NR	R	R	S	R	S	S	S
(Acid)	NR	NR	R	R	S	R	S	S	S
Copper	R	NR	S	S	NR	NR	NR	NR	NR
(Alkaline)	NR	S	R	R	NR	NR	NR	NR	S
Gold	NR	S	R	R	NR	NR	NR	NR	NR
(Alkaline)	NR	R	S	S	NR	NR	NR	NR	S
Indium	NR	R	S	S	NR	NR	NR	NR	S
Lead	NR	NR	R	R	NR	R	NR	NR	NR
Nickel	NR	NR	R	R	NR	R	NR	NR	S
Rhodium	NR	NR	R	R	NR	R	NR	NR	S
Silver	NR	NR	R	R	NR	R	NR	NR	S
Tin	R	NR	NR	NR	NR	NR	NR	NR	NR
(Alkaline)	R	NR	R	R	NR	S	NR	NR	NR
Zinc	R	NR	R	R	NR	S	NR	NR	NR
(Alkaline)	NR	NR	R	R	NR	S	S	S	S
Hydrochloric Acid	NR	NR	R	R	NR	NR	NR	NR	NR
Hydrofluoric Acid	NR	NR	R	R	NR	NR	NR	NR	NR
Nitric Acid	NR	R	R	R	NR	NR	NR	S	S
Sulfuric Acid	NR	S	R	R	R	R	R	S	S

R - Recommended S - Suitable NR - Not Recommended  
\* Do not use epoxy-fiberglass, polyester, standard polyethylene and vinylidene chloride



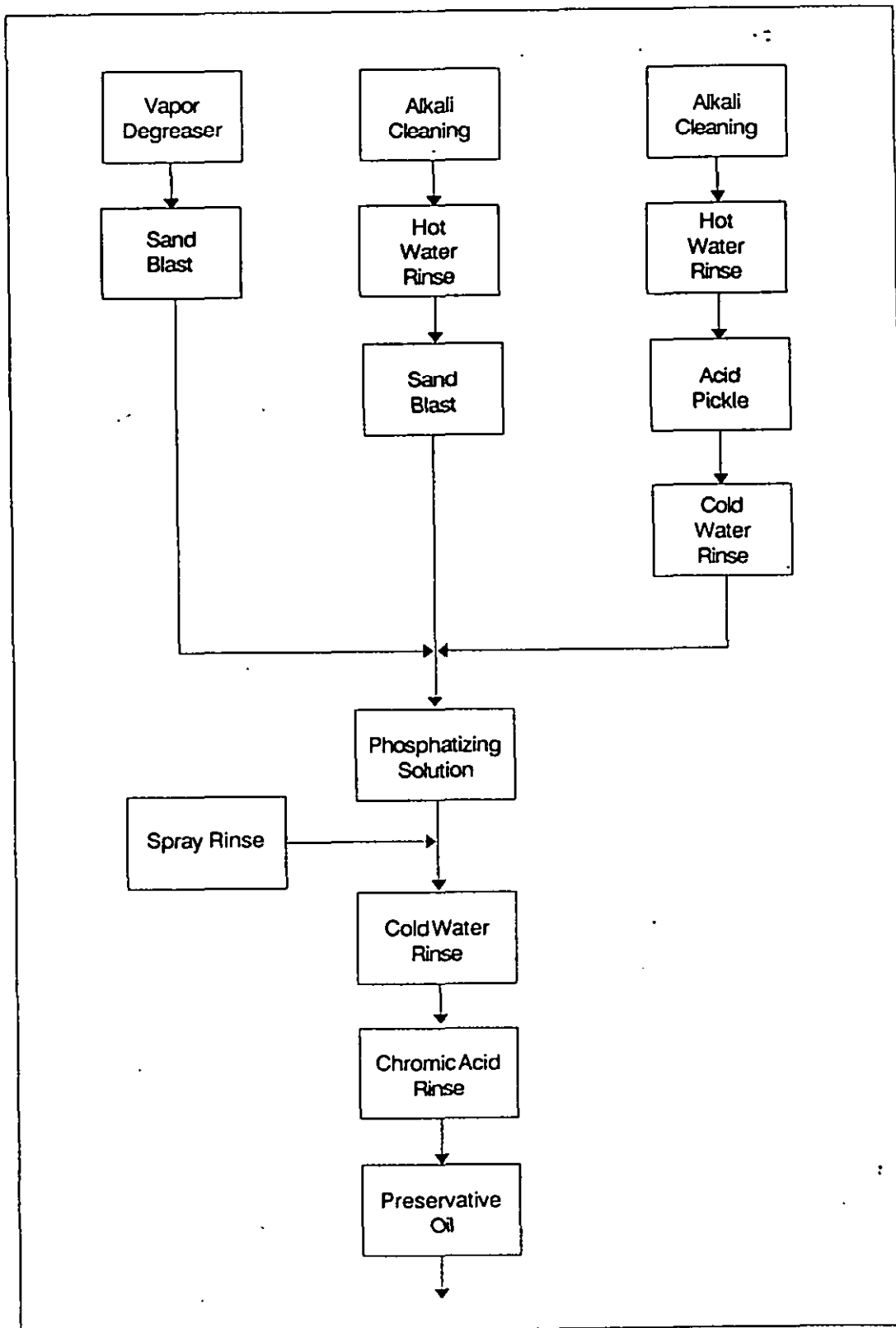


Figure 21  
Phosphatizing Process

## Section 6: PROCESS CONTROL

6.1 Electrolyte Concentration

6.1.1 Solution Makeup. A plating bath is required to be kept within the prescribed chemical limits to produce a metallic deposit that possesses consistent properties such as brightness, ductility, hardness, and smoothness as specified in the applicable specifications. These chemical limits may be maintained by automatic electrolyte additions and solute (solids) additions. They are made to electrolytes so that the baths are maintained at maximum efficiency with a minimum of additions. Proper electrolyte balance is maintained, in part, by having the anode efficiency slightly higher than the cathode efficiency. Perfect balance is kept by the addition of chemicals lost in drag-out. Since additions are required to all baths, they are best made in small amounts so that chemical limits are easily held. In order to maintain proper operating conditions, the frequency of analyses must be determined, which depends on the drag-out rate, rate of decomposition, relative anode and cathode efficiencies, the operating periods of the bath, and the amount of work processed through the bath. Under average conditions, baths are designed to have the metal content of the bath analyzed once a week. Other constituents may require more or less frequent analyses. More specific analytical requirements are gained from the supplier of the bath constituents and experience with the bath.

6.1.1.1 Water Additions. Deionized (DI water), or "distilled" water, is used for solution makeup, losses of water in baths, and in the laboratory for chemical analyses. DI water or "distilled" water is defined as water meeting ASTM D 1193-74, Reagent Water, Type IV when analyzed in accordance with FED-STD-791B, Lubricants, Liquid Fuels, and Related Products; Methods of Testing, Test Method 3290, or ASTM D1888, Particulate and Dissolved Matter in Water.

a) Contaminating Ions. Tap water contains cations and anions, which upon combining with plating solutions, can lower plating solution efficiency. The most objectionable cations are calcium and magnesium, which combine with cadmium cyanide, copper cyanide, silver cyanide, and other compounds to form highly insoluble precipitates. These cations are normally present in water as bicarbonates, carbonates, sulfates, chlorides, and nitrates. Sodium and potassium ions are not harmful, except for the reduction of the throwing power in nickel plating baths and increase in brittleness of the nickel deposits.

b) Heavy Metals. Traces of heavy metals such as iron and manganese materially affect the plating results. Contamination of the water can directly contribute to roughness, porosity, streakiness or staining, iridescent or crystalline, modular, and pitting of deposits. Water evaporates rapidly from heated baths, and where gases are evolved or bubbled through the baths. Relatively large amounts of makeup water are required where ventilation is used. Water evaporation is the major reason that the purity of the water must be controlled.

6.1.1.2 Solids Additions. Solid additions that are normally made by the operator require appropriate sampling and analyses before and after the additions are made. In order to obtain a representative sample, the bath is

required to be uniformly mixed with all solid additions in solution, sludge removed prior to making these additions, and the solution at the specified operating conditions, i.e., temperature, composition, and pH.

6.1.1.3 Electrolyte Additions. Electrolyte additions are made through drag-out recovery and the addition of electrolyte concentrates. These additions may be made automatically by feed pumps which are controlled volume pumps as described in para. 7.1.1.

6.1.2 Agitation. Agitation of electroplating solutions and rinses are accomplished in the following manner: by air, cavitation, solution circulation, convection, and mechanical means.

6.1.2.1 Air. When air is used for agitation, it must be free of contaminants, specifically hydrocarbons. This air is supplied by air compressors, aspiration in water feed, and low-pressure blowers, which force the air through perforated pipes located at or near the bottom of the tanks. The air pressure is controlled to 3 psig by an in-line pressure regulator. As a means of conserving electrical power, regenerative blowers may be used to advantage for agitation, circulation, and mixing. Syphon breakers are required in the water replenishing piping for sanitary reasons.

6.1.2.2 Cavitation. Except for ultrasonic cleaning, cavitation agitation is rarely used, because of expense and the small size of the processing equipment. In ultrasonic cleaning, the implosion of bubbles cause agitation and scrubbing action by cavitation.

6.1.2.3 Solution Circulation. Solution circulation is accomplished by use of pump and suitable piping to circulate the solution from the tank and back again, during the circulation process filtration of the solution is accomplished and cathode movement is used to increase the effect of the circulation.

6.1.2.4 Convection Agitation. Convection agitation is accomplished by placing a baffle or plate in front of a heat exchanger. When the solution is heated by the heat exchanger, the solution rises and flows over the baffle into the main body of the tank. This type of agitation produces a gentle change in the solution.

6.1.2.5 Mechanical Agitation. Mechanical agitation is accomplished by cathode movement, propellers, and paddles or barrels.

a) Cathode Movement. A reciprocating device is used to move the cathode rod or cradle back and forth slowly. Connection to the items to be plated is made by means of a flexible cable or braided connector. The movement causes hydrogen bubbles to be removed mechanically from the item. The reciprocating device is specified by amplitude of movement of the rod, number of cycles per minute of the movement (a cycle is defined as one forward and one backward movement), and the support weight for the rod.

b) Propellers and Paddles. A propeller or paddle is used to agitate the solution. This type of agitation may not be satisfactory since maintenance cost may be higher than other types of agitation. In addition,

the movement of the solution may not replenish the cathode film or remove the hydrogen bubbles.

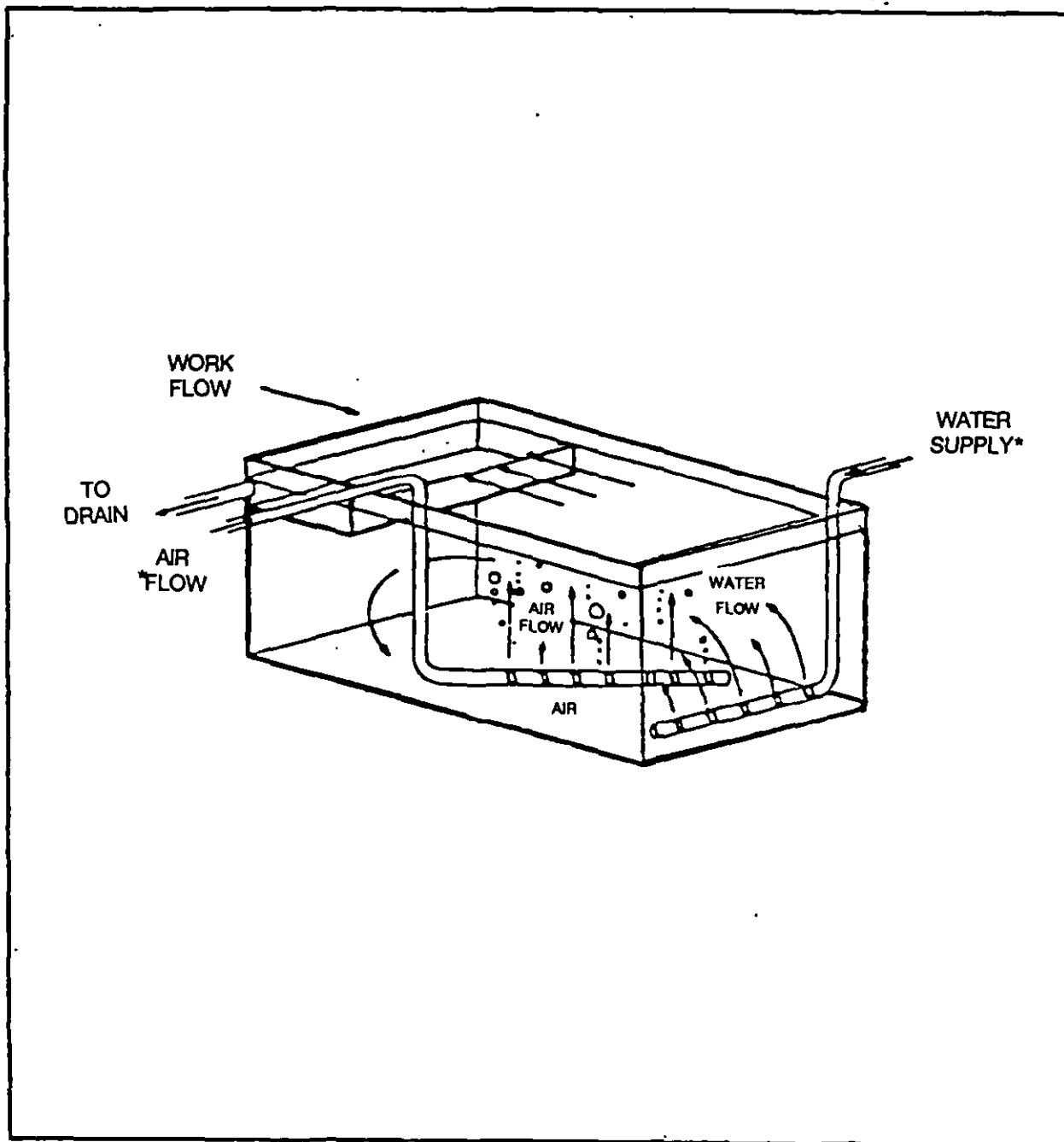
c) Barrels. Barrels agitate the solution by the movement of the item in the electrolyte and contact to the cathode is maintained through a flexible electrode. This method of plating is used to plate small parts and the agitation is usually supplemented by impellers or solution circulation. The type of agitation is chosen by the number and size of the part being plated, placement of the parts on the rack, tank size, and the shape of the tank. When selecting the method of agitation, moving the cathode through the solution is more effective in disturbing the cathode film than moving the solution past the cathode, and solution agitation requires the solution to be free from suspended solids.

6.1.3 Rinsing Techniques. Rinsing is performed for the following reasons: to prevent drag-in of solutes (processing chemicals) to subsequent processing tanks; to maintain product quality; to maintain activity of surface for further processing; to prevent precipitation of solutes; and to eliminate staining, etching and water marking of the work. Designs for rinsing work generally include: vigorous agitation of solvent (water) in rinsing tanks; introduction of solvent at the bottom of the tanks; the placement of the overflow weir opposite the entrance of the solvent; the addition of not less than one percent of the tank's volume of solvent per min; and agitation of the solvent. These features are shown in Figure 22. The amount of water necessary for rinsing is shown in the specific technique by assigning a solute level established by EPA or local regulations in force if more stringent. In the calculations it assumed that the mixing of the drag-in is complete and instantaneous. Tap or city water may be used for rinsing operations, cleaning and etching, and cooling operations. However, when rinsing aluminum, city water may be used only after the aluminum has been anodized in the standard sulfuric acid process and prior to dyeing and sealing. When water is used for anodizing and rinsing prior to dyeing and sealing, this water is required to be soft and to meet the standards as in Table 25. Tank size is normally that of the width of the production line depth and length to accommodate the largest item to be processed.

Table 25  
Allowable Maxima of Ions in Water for Anodizing Aluminum

<u>IONS</u>	<u>ppm</u>
Bicarbonate	75
Chloride	40
Copper	--*
Fluoride	3
Iron	--*
Phosphate	10
Sulfate	75
Sulfide	10
Silicate	3

\*The allowable copper and ferrous ions must be determined in order to eliminate staining of anodic coating.



\*NOTE: In-line pressure regulations must be used to prevent accidental burst of fluid flows. A backflow preventor shall be incorporated into the line to prevent syphoning of liquid from the rinse tank. A flow control valve is normally included in the water supply line.

Figure 22  
Rinse Tank Design

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6.1.3.1 Still Rinse. Still rinses do not have any water additions to the rinse tanks. These rinses are used when there are a few items being processed, and when the drag-in to subsequent tanks will not adversely affect the items being processed. The still rinse may be used for makeup of the plating bath, or disposed, or saved if valuable. The concentration of the solute in the tank is calculated in accordance with Equations (8) and (9).

EQUATION: 
$$C_e = C_o \quad (8)$$

$$C_t = C_o(1 - [V_d/(V_t + D)]^N) \quad (9)$$

Where:

- $C_e$  - Equilibrium concentration of solute in rinse tank, oz/gal
- $C_o$  - Concentration of solute being dragged into the rinse tank, oz/gal
- $C_t$  - Concentration of solute in rinse tank after  $H_m$  min, oz/gal
- $H_m$  - Number of min in the rinse operation
- $V_t$  - Volume of rinse water tank, gal
- $D$  - Volume of drag-in, gal
- $N$  - Number of rinses in  $H_m$  min

6.1.3.2 Running Rinse. Running rinses have intermittent or continuous water additions. The running rinses usually use large amounts of water and the rinse water is easily disposed. In order to reduce the load on pollution abatement facilities, ion exchange should be considered to reduce salt content of effluents. The theoretical equilibrium is shown in Figure 23. The equilibrium concentration of the solute in the rinse tank is calculated as shown in Equation (10) and the concentration of solute in the tank may be calculated as shown in Equation (11).

EQUATION: 
$$C_e = C_o[D/(MQ + D)] \quad (10)$$

Where:

- $M$  - Interval between rinses, min
- $Q$  - rate of fresh solvent, gpm

EQUATION: 
$$C_t = C_e(1 - [(V_t - D)/(V_t + D)]^N(e^k)) \quad (11)$$

Where:

- $e$  - 2.718
- $k$  -  $-QH_m/V_t$

6.1.3.3 Series Rinses. Series rinses have two or more tanks in series, and the flow of the rinse water may be fed from one tank to the next in the same direction with the items being processed. The water may be fed continuously to each tank, or may flow from one tank to the next. The equilibrium concentration of the solute in the rinse water may be calculated as shown in Equation (12).

EQUATION: 
$$C_p = C_o[D/(QM + D)]^P \quad (12)$$

Where:

- $C_p$  - Equilibrium concentration in the last rinse, oz/gal
- $Q$  - Rate of fresh solvent assuming the same rate of fresh solvent per tank, gpm
- $P$  - Number of rinses in series

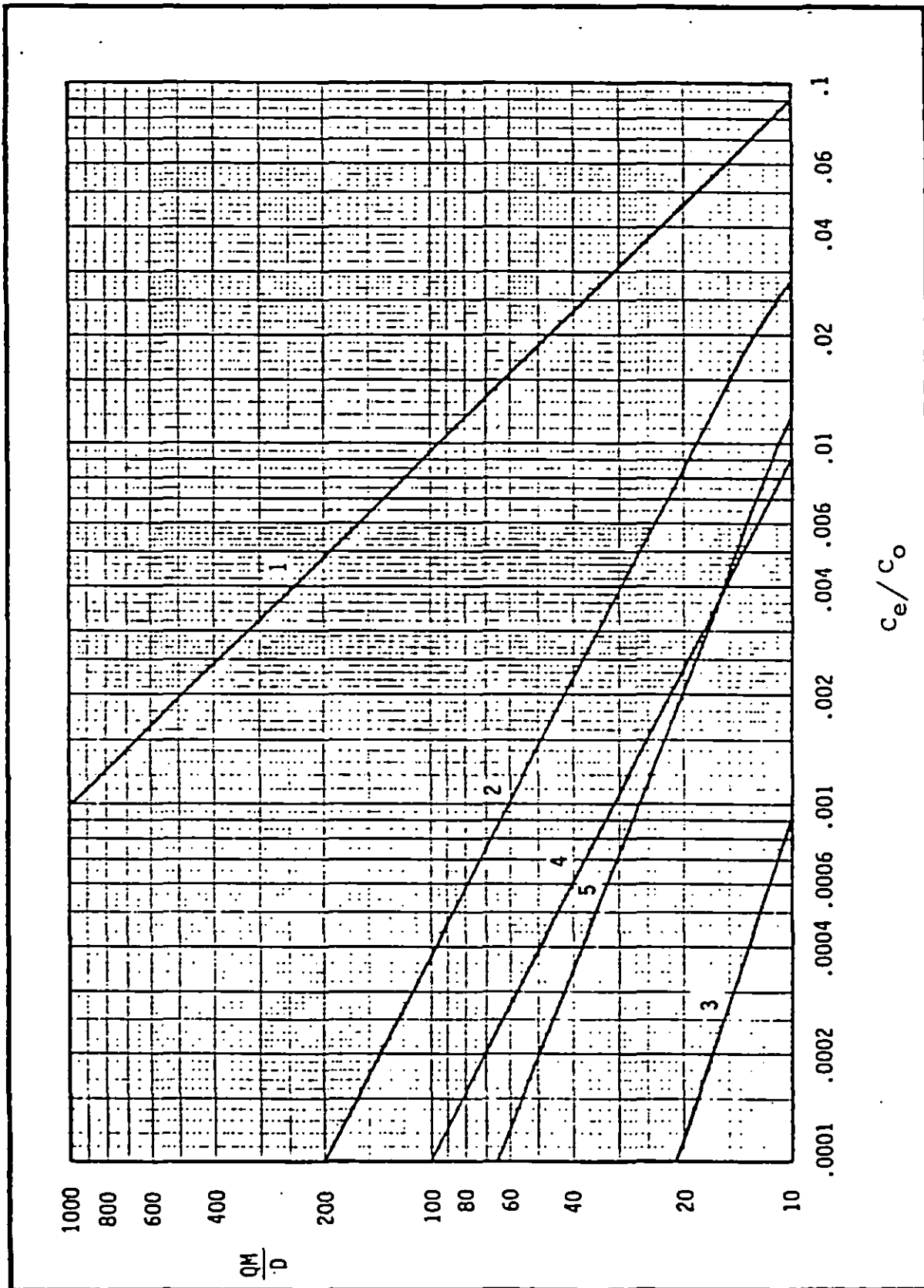


Figure 23  
Theoretical Equilibrium in Running Rinses

6.1.3.4 Cascade or Counterflow (Countercurrent) Rinse. Cascade rinses are performed in more than one tank, and the items being processed move in the opposite direction to the flow of the rinse water. The cascade rinse is the most conserving of rinse water. The equilibrium concentration of the solute in the last rinse tank may be calculated as shown in Equation (13).

$$\text{EQUATION:} \quad C_p = C_o[(Y - 1)/(Y^{(P + 1)} - 1)] \quad (13)$$

Where:  $Y = QM/D$  and  $Y > 1$

Three compartment counterflow (cascade) rinses following a still recovery rinse produce the most efficient use of water and least loss to waste treatment.

6.1.3.5 Spray Rinse. Spray rinsing techniques are generally used where any one or more of the following conditions exist: items are withdrawn from a warm bath; the bath has a high concentration of solute; a dispersed solid is present; in case of a solution containing an agent to reduce surface tension; or where the solvent evaporation rate is rapid leaving residual solute. Spray rinsing, when combined with a still or running rinse, may equal the water conservation of the cascade rinse. The equilibrium concentration of the solute in the rinse water may be calculated as shown in Equation (14). Spray rinse harnesses at the top of immersion rinse tanks, which spray the items as they emerge from the rinse, are the most efficient. The clean water spray is used for replenishment of the rinse bath.

$$\text{EQUATION:} \quad C_e = C_o(D/[M(Q + S) + D]) \quad (14)$$

Where:  $S =$  Average rate of water in spray, gpm

6.1.3.6 Recovery Rinse(s). Recovery rinses are static water rinses inserted in process lines, after processing baths. These static water rinses remove most of the concentrated runoff from the items coming out of the plating or processing tanks. The concentration of solute builds up to a point that the rinse water is fed back to replenish the processing solution. If the processing solution is operated above room temperature, solution is air-agitated, or the tank has a fume hood; then the recovery rinse water may be fed directly back to the process to replace the evaporated water. An evaporative system is needed to process the recovery rinse when losses are due to drag-out only. The evaporative system removes the solvent (water) so that the solution may be added to the process tank saving the solute (plating salts). The system consists of the solution drag-out tank a cylinder which is wetted by the solution in the drag-out tank, and an evaporative fan or blower. Typical rates are shown in Table 26. Rinse water requirements for drag-out replacement are determined as shown in Table 27. Drag-out recovery is complete for the return of all solute to the operation tank; 40 to 90 percent when a spray rinse and a still rinse are used; and is as shown when systems in Figures 24 and 25 are used. Where some loss of solute is encountered, it is advisable to consider electrolytic recovery of metals which may be used as anode materials and which reduces loads on the pollution abatement facilities.



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6.1.3.7 Reactive Rinsing. Reactive rinsing is a technique to reuse or recycle rinse water one or more times before it is discharged. This technique takes advantage of the chemical reactivity of used rinse water. Not only can water consumption be greatly reduced by recycling, but rinsing efficiency can actually be increased by this method, thus improving plating quality.

Table 26  
Typical Evaporation Rates

SOLUTION TEMPERATURE °F      °C		Model 1		Model 2	
		50% HUMIDITY gph	Dry* AIR gph	50% HUMIDITY gph	Dry* AIR (at 70° F) gph
60	16	3	10	4.5	15
70	21	6.5	13	10	19.5
80	27	10	16	15	24
90	32	14	20	21	30
100	38	19	24	28.5	36
110	43	25	29	37.5	43.5
120	49	30	35	45	52.5
130	54	37	42	55.5	63
140	60	43	48	64.5	72
150	66	50	54	75	81
160	71	57	61	85.5	91.5

\* The DRY AIR (theoretical maximum) evaporation figures are shown for comparison. Any amount of relative humidity has a direct affect on the evaporation rate of solutions at ambient temperature. Evaporation rates for solutions above ambient temperature are affected in decreasing proportion.

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Table 27  
Rinse Water Requirements Based Upon One gph

BATH CONCENTRATION	RINSE RATIO	FINAL RINSE CONCENTRATION OF 0.005 oz/gal				
		NUMBER OF COUNTER-FLOW RINSES				
oz/gal	REQUIRED	SINGLE	TWO	THREE	FOUR	FIVE
		gph	gph	gph	gph	gph
5	1,000: 1	1,000	32	10	6	4
10	2,000: 1	2,000	45	13	7	5
15	3,000: 1	3,000	55	14	7	5
20	4,000: 1	4,000	63	16	8	5
25	5,000: 1	5,000	71	17	8	6
35	7,000: 1	7,000	84	19	9	6
50	10,000: 1	10,000	100	22	10	6

BATH CONCENTRATION	RINSE RATIO	FINAL RINSE CONCENTRATION OF 0.002 oz/gal				
		NUMBER OF COUNTER-FLOW RINSES				
oz/gal	REQUIRED	SINGLE	TWO	THREE	FOUR	FIVE
		gph	gph	gph	gph	gph
5	2,500: 1	2,500	50	14	7	5
10	5,000: 1	5,000	71	17	8	6
15	7,500: 1	7,500	87	20	9	6
20	10,000: 1	10,000	100	22	10	6
25	12,500: 1	12,500	112	23	11	7
35	17,500: 1	17,500	132	26	12	7
50	25,000: 1	25,000	158	29	13	8

Notes: For 2 gph drag-out, multiply rinse flow by 2, for 1/2 gph drag-out, multiply by 0.5, etc. (All flow rates are rounded to nearest gal). Final rinse for metals other than chromium and cyanides is 0.005 oz/gal and for chromium is 0.002.

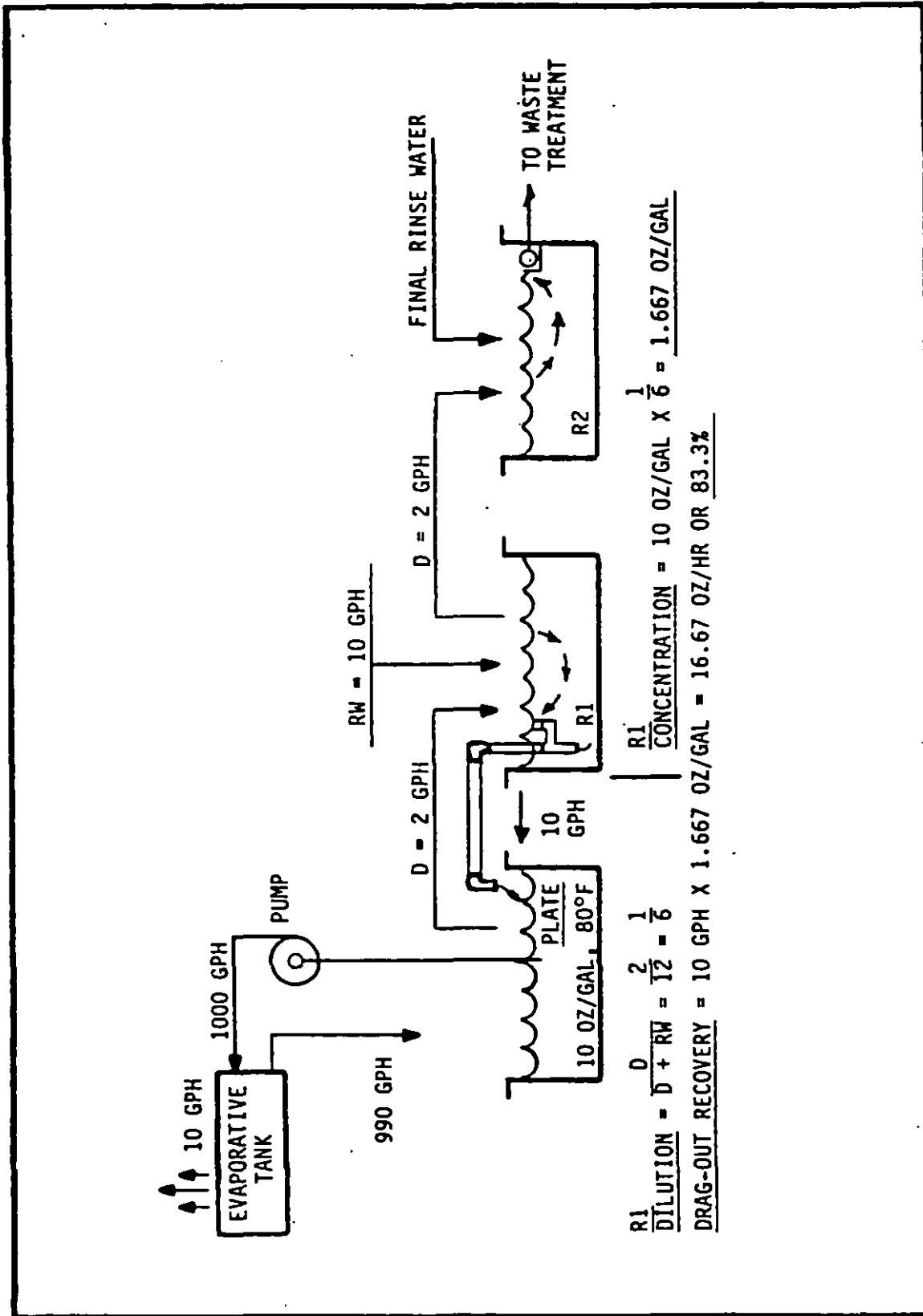


Figure 24  
Recovery Rinse with Evaporative Tank and Waste to Treatment

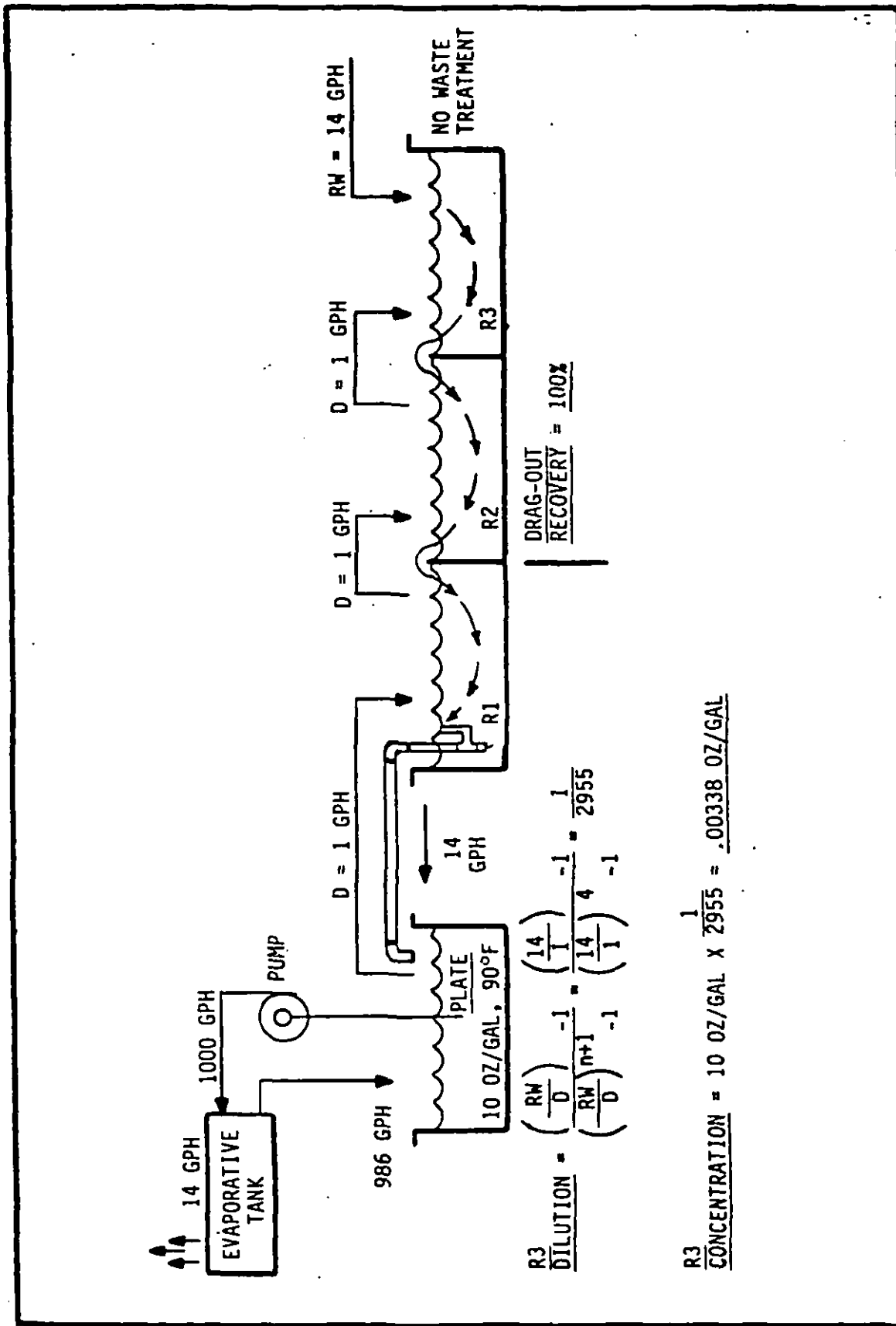


Figure 25  
Recovery Rinse With Evaporative Tank and No Waste Treatment

Counterflow rinsing, which was discussed in para. 6.1.3.4, is the standard technique platers use to reduce flow rates. However, rinse tanks are expensive and require space for installation. Reactive rinsing is a very effective alternative to counterflow rinsing without the cost or logistical constraints. Reactive rinsing does not require additional rinse tanks, so it is less expensive than counterflow rinsing. It also does not use any additional space, so it has wider application than counterflow rinsing. The following example illustrates how reactive rinsing works.

a) Intraprocess Reactive Rinsing. A typical nickel plating line is diagrammed in Figure 26. It is usually composed of three process steps:

- (1) An alkaline cleaning tank,
- (2) An acid dip tank, and
- (3) A nickel plating tank.

Each process step is followed by a running rinse tank, and each rinse tank has a separate freshwater feed line. The rinse tanks run at about 4 gpm, the nickel plating line in Figure 26 uses a total of 12 gpm. In a single 8 hr production day, this line alone accounts for 5,760 gal of water. Other types of plating lines have more than three rinse tanks so they could use even more water than a nickel process. Therefore, each plating shop employing standard rinsing methods uses tens of thousands of gallons of water each day.

b) Using Reactive Rinsing to Save Water. The parts to be plated carry over ("drag-in") to the nickel tank whatever is in the previous rinse tank. If that rinse tank is fed with fresh water, the drag-in will be comprised primarily of a dilute acid solution. This will reduce both the

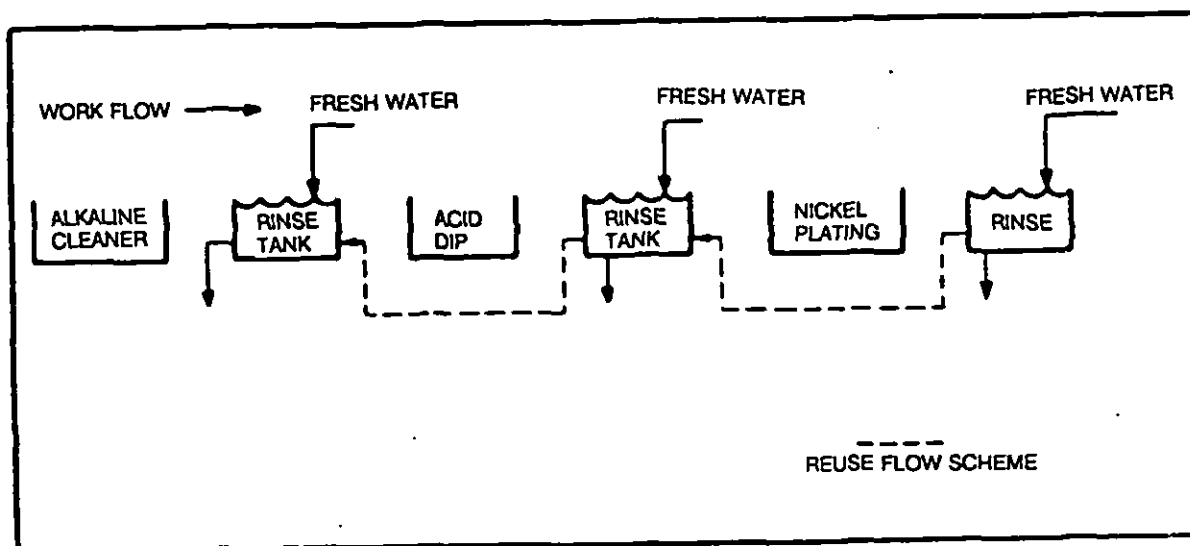


Figure 26  
Intraprocess Reactive Rinsing

nickel concentration in the process bath and, to a certain extent, the acidity of the bath. (Nickel solutions are slightly acidic.) Instead of using fresh water, the acid rinse tank could be fed with the discharge from the nickel rinse tank. Since the nickel rinse tank contains dilute process solution, it will feed the acid rinse tank with slightly acidic 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 freshwater feed line to the acid rinse tank can be turned off to save 4 gpm. This reactive rinsing application reduces water use and saves process chemicals without harming the rinse step. Some reactive rinsing applications actually aid rinsing and, therefore, improve plating quality.

c) 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 26. Cleaner solutions are alkaline (soapy) and, therefore, difficult to rinse. Therefore, platers rinse cleaning solutions in cold water tanks and depend on the subsequent acid solutions to neutralize any cleaners still clinging to work. However, cleaner solutions are neutralizing agents and they reduce the useful life of the acid baths. Clearly, this is not a very efficient rinsing system.

Acids are expensive, and their useful life should be prolonged, not reduced. Moreover, spent acid solutions are a costly waste management problem, which is a second compelling reason to lengthen the time of service of acid baths. The answer to this problem is almost obvious - use the acid rinse tank discharge to feed the cleaner rinse tank. If this is done, then neutralization of the drag-out from the cleaning process will 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 this case, another 4 gpm of water is saved because the fresh feed to the cleaner rinse tank can be turned off.

d) Interprocess Reactive Rinsing. In intraprocess, described above, reactive rinsing reuses rinse water within a process and is a powerful technique for reducing water consumption. An even more powerful technique is interprocess reactive rinsing in which rinse water is used across plating lines. Figure 27 diagrams this reactive rinsing concept. The figure includes three plating lines:

- (1) Copper/nickel
- (2) Zinc
- (3) Anodizing

The plating shop in Figure 27 would require 12 freshwater feed lines (indicated by the numbers inside the rinse tanks). Using reactive rinsing, eight of these feed lines could be shut off. Some of the savings is from intraprocess reuse. For instance, used acid rinse water is fed to the alkaline cleaning rinse tanks in both metal plating lines. Also, the anodizing rinse water, which is very acidic, is used to feed the caustic etch

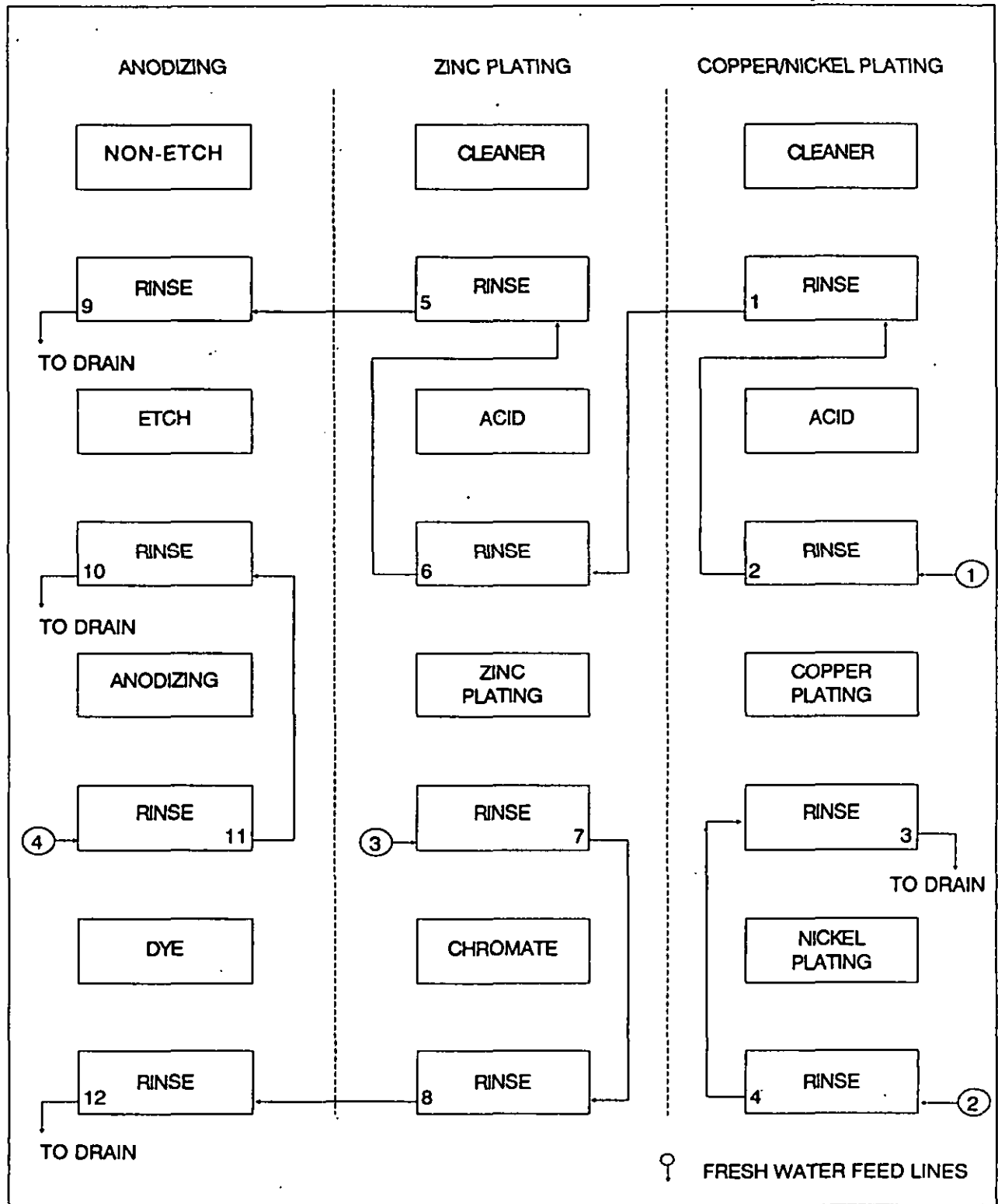


Figure 27  
Example of Interprocess Reactive Rinsing System

rinse tank. The rest of the savings is due to interprocess reuse. The copper/nickel cleaning rinse water is reused in the zinc cleaning steps and then again to feed the anodizing rinse tank for the nonetch cleaner. Rinse water from the zinc process also is used in the rinse tank after the anodizing dye.

Rinse water cannot be reused indiscriminately because it could contaminate plating baths and affect plating quality. Accordingly, reactive rinsing should be done with the guidance of a chemist or chemical engineer experienced with the facility's specific plating process. However, there are many applications for interprocess reactive rinsing similar to the one shown in Figure 27 that are safe.

6.1.3.8 Drag-Out Tank and Other Advanced Technologies. This section presents the fact that judicious use of drag-out tanks and advanced technologies can decrease the rinse water requirements and discharges.

a) Single Drag-Out Tanks. Platers often 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.

Over time, the contaminant concentration in the drag-out tank will increase until it no longer effectively captures process solution. Before the contaminant concentration becomes excessive, the drag-out solution must be replaced with freshwater and the cycle begun again. Now, the discharged 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 is sufficient to make room for the drag-out.

Some platers use an evaporative 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 many plating shops. If the drag-out cannot be recycled then it can become a waste treatment problem. Therefore, platers generally use drag-out tanks after heated solutions when the drag-out could be returned to the process tanks.

b) Multiple Drag-Out Tanks. Controlling the amount of plating solution 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



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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-outs 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

Eventually, the concentration in the drag-out tanks must be reduced. Otherwise, the concentration of contaminants in the rinse tank will exceed pollution control standards. As previously mentioned, recycling the drag-out solution to the process bath is the most efficient way to control drag-out tank concentrations. Another alternative is to periodically replace the solution with fresh water and chemically treat the spent bath. A third is to turn to high technologies such as electrolytic, ion exchange, electrodialysis or evaporation as discussed below.

c) Advanced Technologies. Advanced technologies waste treatment methods can be used for end-of-pipe treatment of wastewater and for reducing contamination during plating processes. This subsection reviews the advanced technology controls commonly proposed for application in plating shops. These technologies are very effective in minimizing the generation of electroplating wastes. However, they can be capital intensive. Some are difficult to operate because they are extremely sensitive to variations in temperature and pH, and they may require frequent maintenance to run efficiently. Their application as an inprocess control technique is generally limited to high production shops (usually captive shops) and to specialty plating, like gold and rhodium. In low volume shops drag-out controls and low cost flow reduction methods are generally enough to achieve compliance with pollution control regulations. However, when added removals are needed, advanced technology controls are very effective. Table 28 includes a review of their application.

Table 28  
Waste Reduction Methods

TECHNOLOGY	APPLICATIONS	ADVANTAGES	DISADVANTAGES
General	Must have significant drag-out to justify purchase Systems available for most types of plating baths	Most will recover plating chemicals and reuse water Moderate capital and low maintenance costs for some units Can reduce or eliminate generation of hazardous waste	High capital and operating costs for some units Often requires large floor space May concentrate bath impurities Requires segregated wastestreams
Drag-Out Tanks			
Still Rinse	Applicable to all process solutions above 104 °F Need Concentration technology (e.g., <i>evap.</i> ) for cold solutions unless solution is batch treated Not applicable to cleaning lines	Can recover 75% or more of drag-out Reduces use of rinsewater	Requires two or more rinses Concentrates bath impurities Concentration technologies, if needed, add to costs
Multiple Still Rinses	Same as above	Increased recovery uses no more than counterflow rinsing	May need space for additional tanks
High Technology Controls			
Electrodialysis	Applicable to Cd, Zn, and Ni plating Not applicable to Cr	Units are compact Only utility required is DC power supply Low operating cost Not widely applied in the field	Feed stream must be free of particulates Requires concentrated feed stream Requires periodic membrane cleaning, replacement
Electrolytic	Applicable to Ag, Cd, Zn, Sn, and Cu plating Limited success with Ni Not applicable to Cr	Some units recover metal and avoid hazardous waste generation Some units destroy cyanide Metal recovered is usually in elemental form	Requires concentrated feed stream Some units generate sludge requiring disposal

	Can be used with some plating strip processes	Process is well understood by platers	
		Wide variety of design configurations to suit site specific needs	
Evaporation	Applicable to all common plating solutions	Application of low pressure blowers have advanced field Low capital cost Applicable to dilute feed streams	Most units require a source of energy Requires concentrated feed stream Some units require source of cooling water 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
Ion Exchange	Applicable to all plating processes including Cr and Ni		Evaporator sometimes required to complete recovery process Generates a small quantity of hazardous sludge requiring disposal
Ion Transfer Membranes	Applicable only to hard Cr plating	May be used as a bath purification technology	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
Reverse Osmosis	Applicable only to Ni, Zn, and Cu plating	Most systems are mechanically simple	

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

A cationic section in the deionizer removes metals, hydrogen, and ammonium, and an anionic 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.

Ion exchange has several drawbacks. First, deionized water is purer than is needed in most plating shops. Second, the exchange resin must be regenerated frequently by backwashing with chemicals to remove the metals, and the backwash solutions must still be disposed of. Third, resins eventually lose their effectiveness, must be replaced periodically and can be a very expensive way to eliminate a single metal from electroplating discharges.

e) 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. However, 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 to temperatures greater than 100 degrees F (38 degrees 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 psig (4137 kPa), the interior structure of the membrane deteriorates, and less permeate is allowed to pass.

f) 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 because they are subject to deterioration and clogging.

g) Evaporation. Using evaporation-system platers can return drag-out wastes of higher concentrations than the original bath. There are

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basically three types of evaporators: vacuum evaporators; thin-film evaporators; and atmospheric evaporators.

(1) Vacuum evaporators lower the boiling point of the solution to reduce its volume.

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

(3) Atmospheric evaporators 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 are dependent on the concentration of rinse water being evaporated and volume of drag-out. Plating solutions do contain contaminants which, when evaporated and returned to the bath, can result in bath failure. The use of a cation exchanger before the wastes are concentrated in an evaporator is therefore recommended. Evaporation systems costs vary widely. Some atmospheric units are proven effective especially on nickel, chromium, and copper process lines.

h) Electrolytic Recovery. Recent advances in techniques to plate out metals in drag-out solutions have made electrolytic recovery an effective method of inprocess pollution control. Commercially available units are becoming widely used in the industry. This technology can be applied to all metal processes except for nickel and chromium.

6.1.4 Electrolyte Temperature Control. Electrolyte temperature control is required by certain plating solutions to keep crystal size uniform, allow for higher current densities, increase solubilities of dissolved salts in the electrolyte, increase dissociation of molten salts, decrease viscosities, increase mobility of metal ion, reduce tendencies to treeing, and increase the current densities. In addition, there may be less hydrogen absorption, less internal stress, and reduced cracking of the deposit.

6.1.4.1 Heating Solutions. The heating unit requires three to four hours to heat the solutions to operating temperatures. The energy is supplied from either steam boiler, hot water boiler, electric heater or gas heater. Direct fire boilers may affect the processing solution. Also, solids that accumulate on the bottom of the tanks cause superheating which results in solution eruptions. Estimates for the energy required to heat the solutions to operating temperature are calculated based upon Equation (15) and the results are divided by the number of hours allowed to heat the solution, i.e., three or four hours.

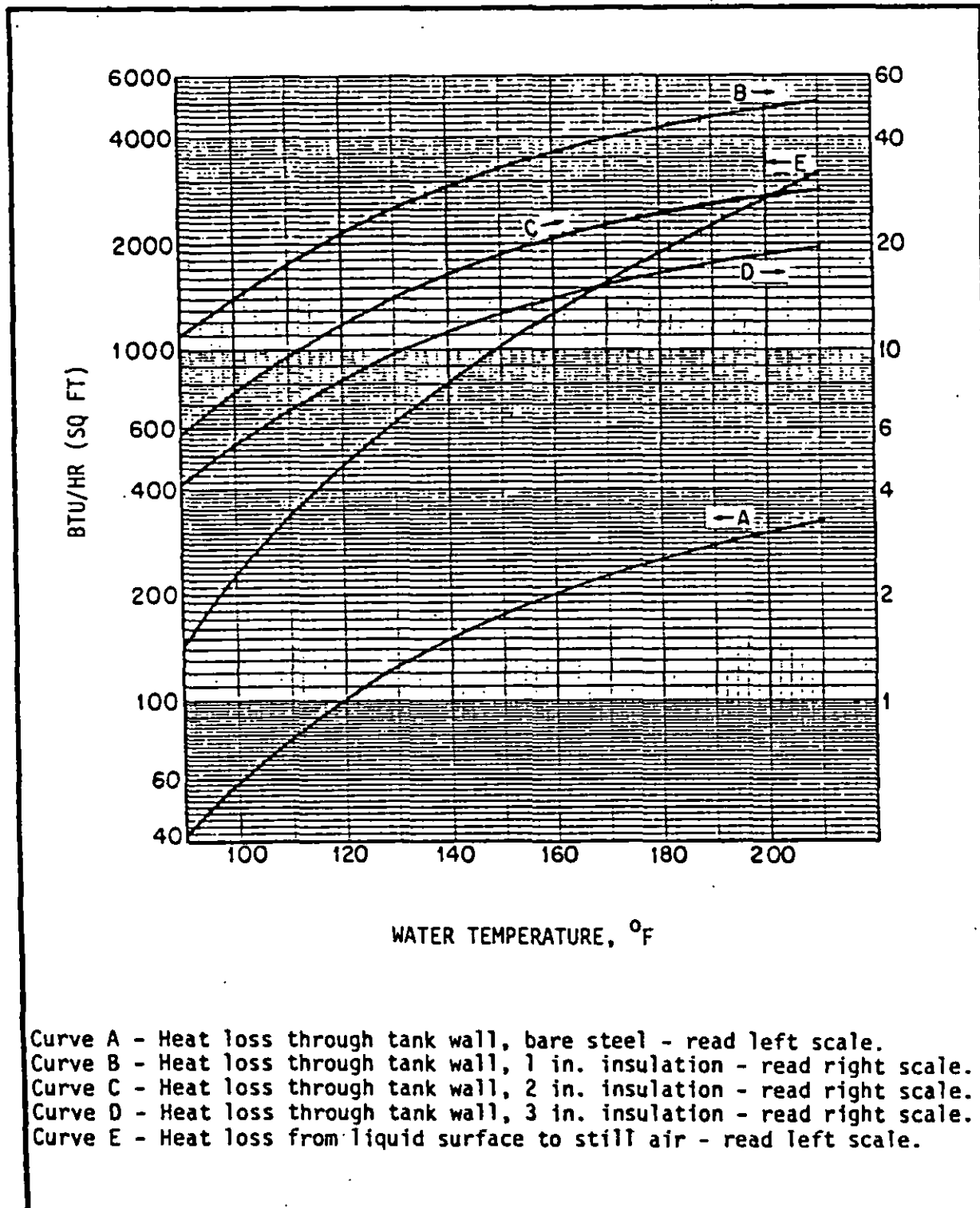


Figure 29  
 Heat Loss to Still Air at 60° F for Uncovered Water Tanks  
 (That Are Not Ventilated)

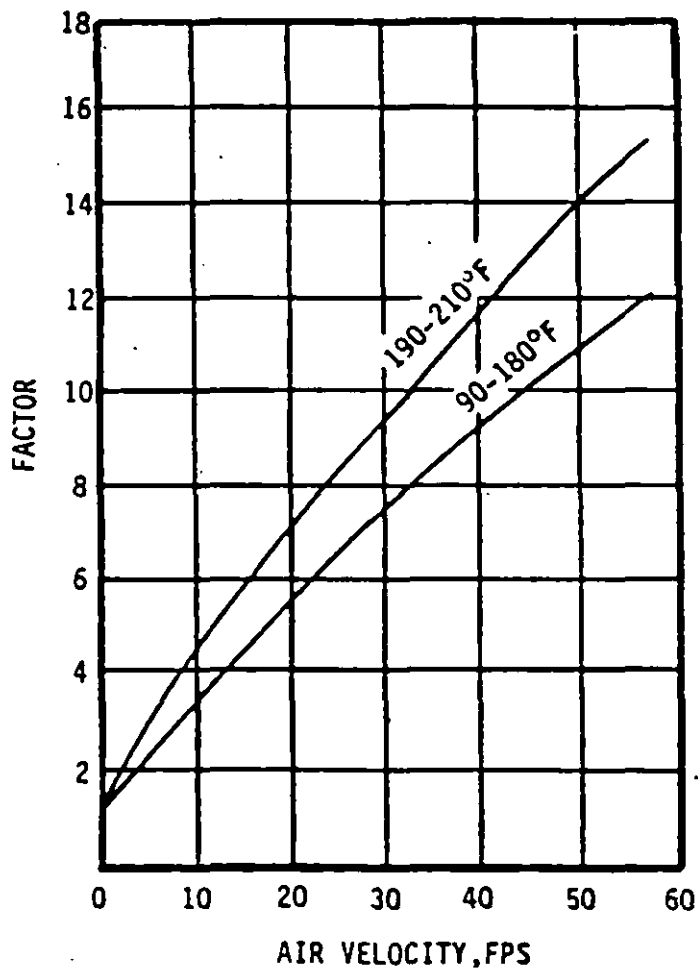


Figure 30  
Heat Loss From Water Surfaces in Ventilating Tanks  
(Air at 60° F)

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(a) Cooling Equipment. The cooling is accomplished by use of internal heat exchangers, usually plate coils or serpentine coils through which cold water or refrigerant is circulated. Mechanical refrigeration may be used to chill the water which is circulated through external heat exchangers. These external heat exchangers are made of corrosion resisting materials and are used to chill exothermic processes such as anodizing, bright dips, pickling polishes and the aforementioned plating processes. Cooling method is as follows:

<u>Cooling Method</u>	<u>Operating Temperature Range °F</u>
Refrigeration chiller	25 - 65
Chillers or well water	70 - 85
Town or City Water	90 - 100
Cooling Tower	>100

When the basic method of cooling is determined, then the selection of internal coils or external heat exchangers is required. Coils take up space in the tank, are subject to electrolytic attack from strong current, and do not provide uniform temperatures through the tank unless electrolyte circulation reduces the temperature gradient. External heat exchangers require circulating pumps, but these heat exchangers require only one quarter as much space as is needed for in-tank coils.

b) Cooling Calculations: The energy input to a plating bath is obtained using Equation (16).

$$\text{EQUATION:} \quad B_r = 3.412F_p E \quad (16)$$

Where:  $B_r$  - Refrigeration, Btu/hr  
 $F_p$  - Process Factor - (100 - Bath Efficiency)  
 $E$  - Power, Kilowatts

Figure 31 is an example of the cooling surface required for a bath when the incoming cooling water is at 45 degrees F (7 degrees C) and the effluent water is 55 degrees F (13 degrees C). The cooling water is based on a flow rate in gph equal to 0.685 times the energy input obtained from Figure 32, which is an example of cooling surface required for a bath, when the cooling water enters at 80 degrees F (27 degrees C) and exits at 95 degrees F (35 degrees C).

6.1.5 Filtration. Filtration is accomplished by either batch filtration or individual tank filters. In batch filtration, the solution is pumped into an auxiliary tank, the plating tank is cleaned, and the solution is pumped through a filter and back to the cleaned tank. This method is time consuming and requires additional floor space for the filter tank. In individual tank filtration, the filter is mounted on or in the tank. There is no auxiliary tank, and little attention is paid to the filter except for periodic maintenance to change the filter cartridge. Filter selection is based upon:

- a) the type and amount of contaminant to be removed;
- b) rate of solution turnover to remove the contaminant; and



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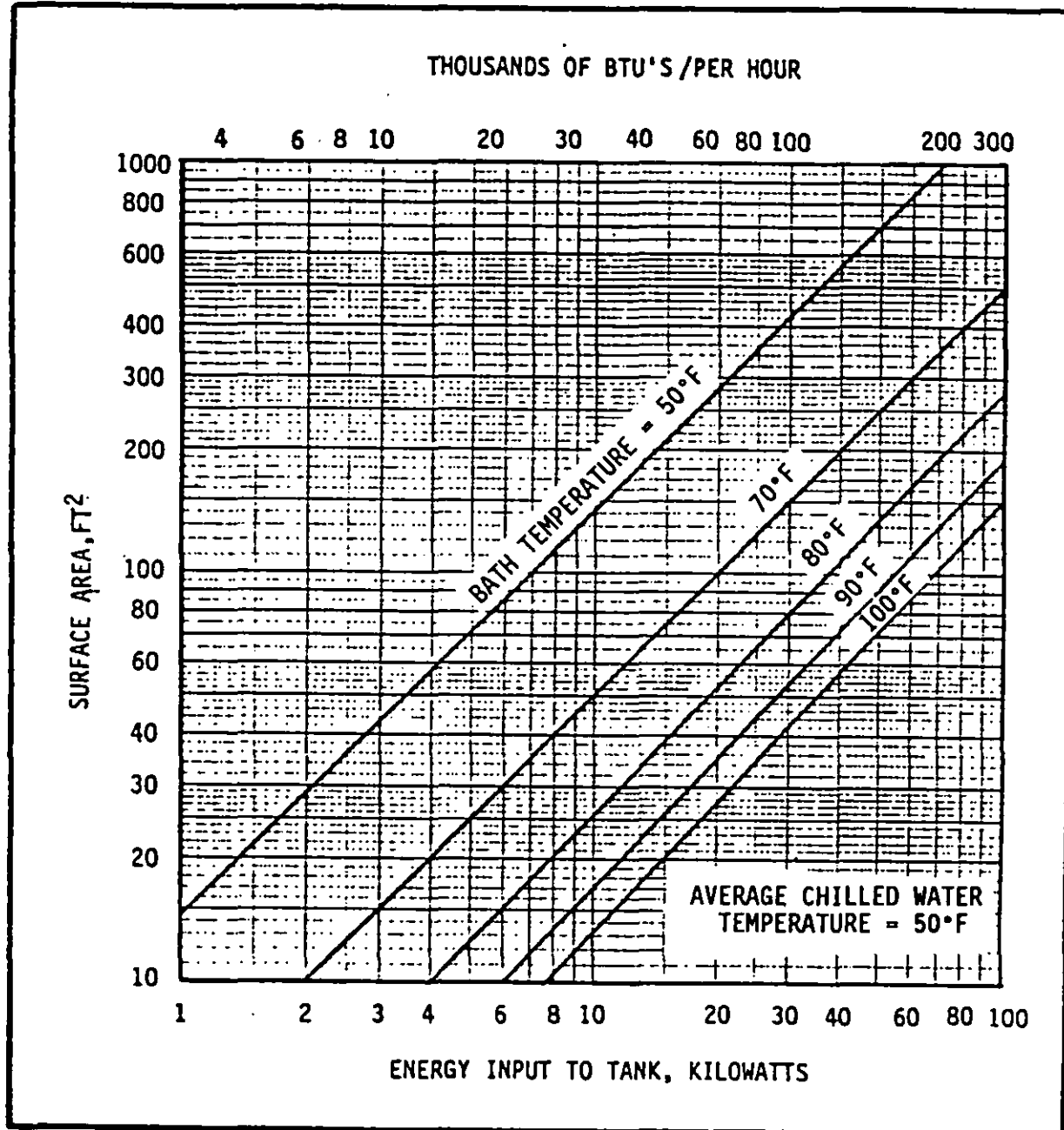


Figure 31  
Steady-State Cooling of Air Agitated Baths Using Chilled Water at 50° F

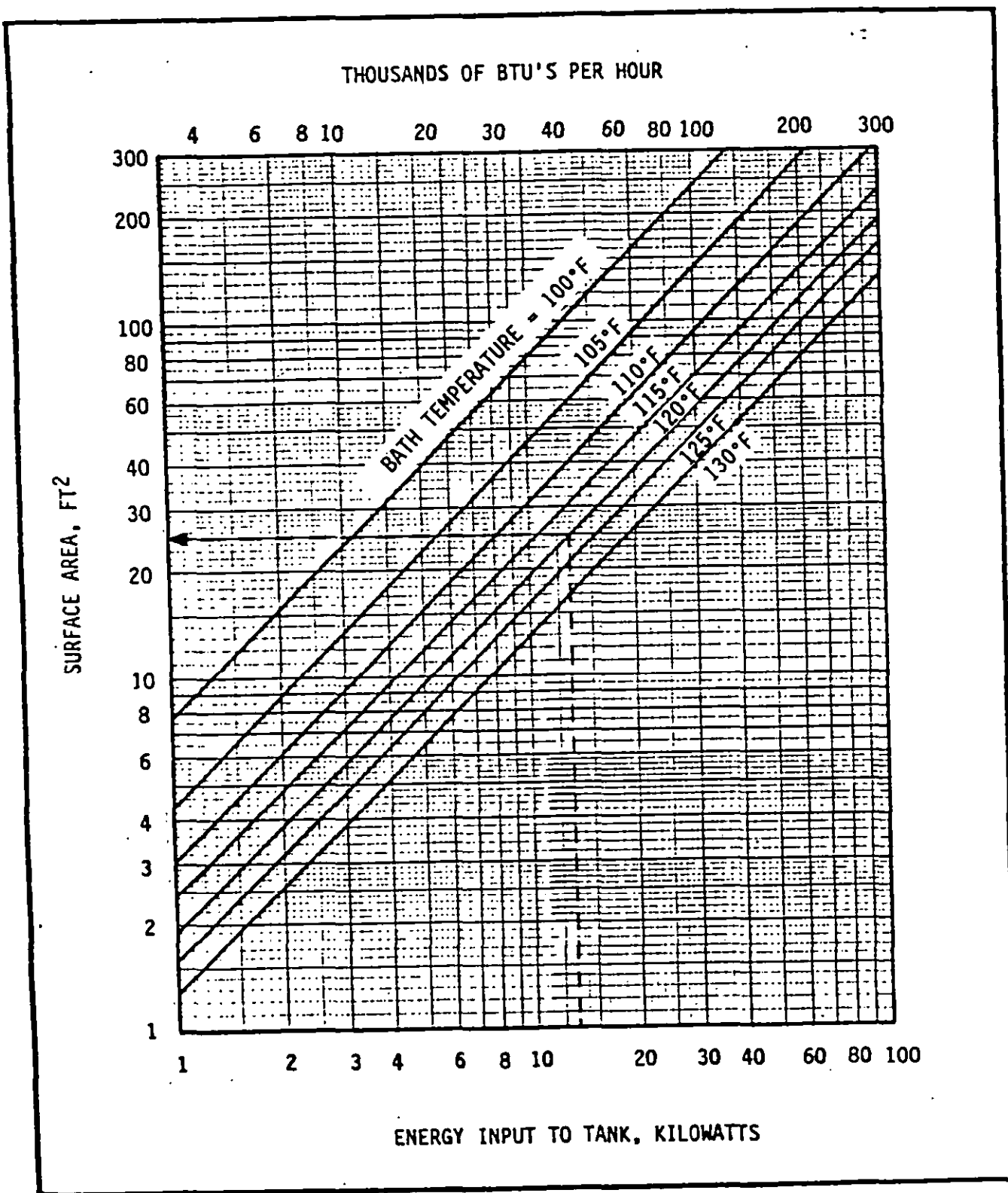


Figure 32  
Steady-State Cooling of Air Agitated Baths Using Chilled Water at 80° F

c) frequency of filtration required to maintain solution conditions for plating.

6.1.5.1 Flow Rate. The flow rate is based upon the amount of contamination to which the plating solution is subjected, and the rate at which this contamination is removed to maintain plating quality. Normally, the flow rate of electrolyte is two bath changes per hour, and the higher the flow rate, the greater the reduction in the rejection rate.

6.1.5.2 Contamination Level. The contamination level is greatest upon introduction of an item into the bath; therefore, a high flow rate is necessary to divert particles from the item being plated to the filter. The higher the flow rate through the filter, the lower the rejection rate. As a rule, the flow rate is maintained at two bath changes of electrolyte per hour.

6.1.5.3 Filtration Frequency. The frequency of filtration is based upon the rate and type of contaminant, difficulty in removing these contaminants, the general workload, and the purity of electrolyte required. Since contamination is not introduced at a steady rate, it is desirable to have the solution as free of particles as possible when introducing additional contamination into the electrolyte through the processing of items. This reduction is accomplished through continuous filtration, even during non-plating periods.

6.1.5.4 Filter Size. The size of the filtration system is based upon the amount of contaminant present and the requirement for plating clarity and uniformity of deposit. As an example, 1,000 gal (3785 L) of plating solution requires 10 ft<sup>2</sup> (0.929 m<sup>2</sup>) of precoat filter surface. If the filtration systems are smaller than required, they tend to clog rapidly, resulting in frequent cleaning and excessive wear of the pumps and filters.

6.1.5.5 Filter Material. Generally, filter systems use filter tubes for the support of the filter media. Filter porosity is selected by balancing the rate of flow with the coarsest possible filter media to achieve the optimal particle removal. The fabrics used to construct these tubes, and the use to which these tubes are put, are as follows:

Cotton	Mild alkaline and acid solutions
Polyester ("Dacron")	Mild alkaline and acid solutions, except concentrated nitric and sulfuric acid solutions
Acrylonitrile/vinyl chloride ("Dynel")	Strong alkaline and acid solutions
Glass	Strong acid solutions, except fluorides
Polyamide (Nylon)	Alkaline and mild acid solutions
Polyacrylonitrile ("Orlon")	Mild alkaline and strong acid solutions except concentrated sulfuric acid
Polypropylene	Strong alkaline and acid solutions
PVC	Strong alkaline and acid solutions
PTFE ("Teflon")	All applications

6.1.5.6 Materials for Construction of Filters. The materials for filter construction depends on the filter size, solution corrosivity, and temperature of operation. For large filter chambers, steel is used in contact with

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alkaline solutions and rubber or plastic lined steel in contact with acid solutions. In addition, steel lined with PVC, epoxy and phenolic coatings are capable of withstanding the temperatures encountered with the processing of plating solutions and should be considered. Small chambers are available in acrylic, PVC, polypropylene, and borosilicate glass. Corrosion resisting steel may offer good and economic protection against the corrosive fluids being processed.

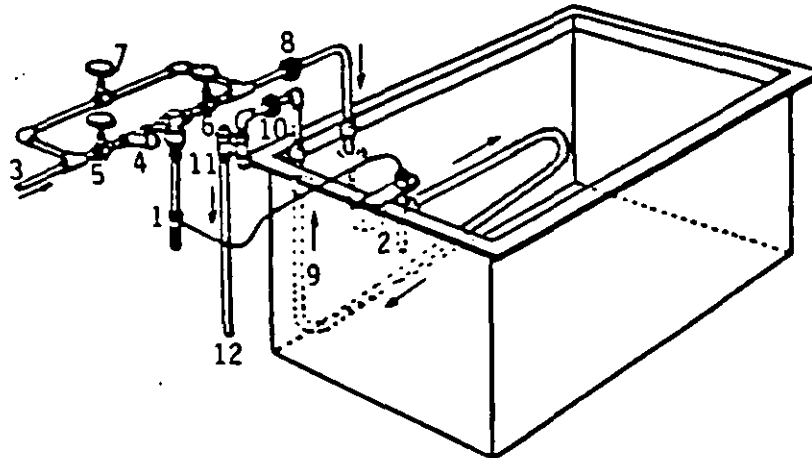
6.1.5.7 Life Expectancy. The useful life of a filter is determined by its exposure to the corrosive media, and the amount of contamination the filter is required to remove. Normally, a filter is repacked when the flow rate is reduced to one-half of the initial flow rate.

## 6.2 Plating Control Instrumentation

6.2.1 Location and Design of Instruments. Plating controls and instrumentation for individual baths or automatic systems shall be visible to the operator so that he can control and regulate the baths or systems. The controls shall not interfere with the operation of the baths or associated equipment. Automatic control instrumentation shall be provided with manual override. In general, equipment is required to meet appropriate industrial and technical society standards such as American National Standard Institute (ANSI), Instrument Society of America (ISA) and Underwriters Laboratory (UL).

6.2.2 Temperature. Temperature indicators shall be dial-type instruments of either the mercury-in-steel or vapor type. Temperature indicators with mercury fitted probes shall not be used, since the wells and probes have a history of corrosion, and releasing mercury into the plating solutions. The operating bulb is enclosed in a suitable protective casing, immersed in the solution, and connected by a capillary tube to an indicator or controller. Recording/indicating instruments are available to provide a continuous record. The indicators may be single or multipoint, up to three points, so that more than one solution or process may be monitored by a single instrument. Typical thermostatic control equipment shown in Figure 33 controls steam-heated equipment. Other thermostatic devices operate motorized valves, gas heated units or electrically heated tanks.

6.2.3 Electrolyte Level. Electrolyte level shall be monitored during plating for consistent results, and to assure that the items are completely immersed. Normally the top of the item is required to be 1-1/2 in. or more below the top of the solution level in order to provide uniform plating of all items, provided the current distribution is equal, and electrolyte is uniformly concentrated. The level may be manually controlled, but in processes where solvent evaporation losses are accelerated, automatic level controllers shall be used. Moreover, ventilation makes manual control a constant duty. Automatic level controllers are available which function by monitoring the difference in the head pressure. A typical differential head automatic level controller is shown in Figure 34. An alternative automatic level controller is the float type, which is sometimes affected by movement of the electrolyte top level because of the automatic movement of the work through the bath. This type is shown in Figure 35. The head pressure relationship is shown in Equation (17).



- 1-Direct Acting Thermostat.
- 2-Temperature sensing element.
- 3-Steam inlet.
- 4-Strainer.
- 5 & 6-Isolating valves.
- 7-Bypass valve to permit rapid heating up of solution.

- 8-Insulated coupling.
- 9-Steam coil.
- 10-Insulated coupling.
- 11-Steam trap and strainer.
- 12-Discharge to condensate return.

Figure 33  
Typical Arrangements for Thermostatic  
Control of a Steam Coil

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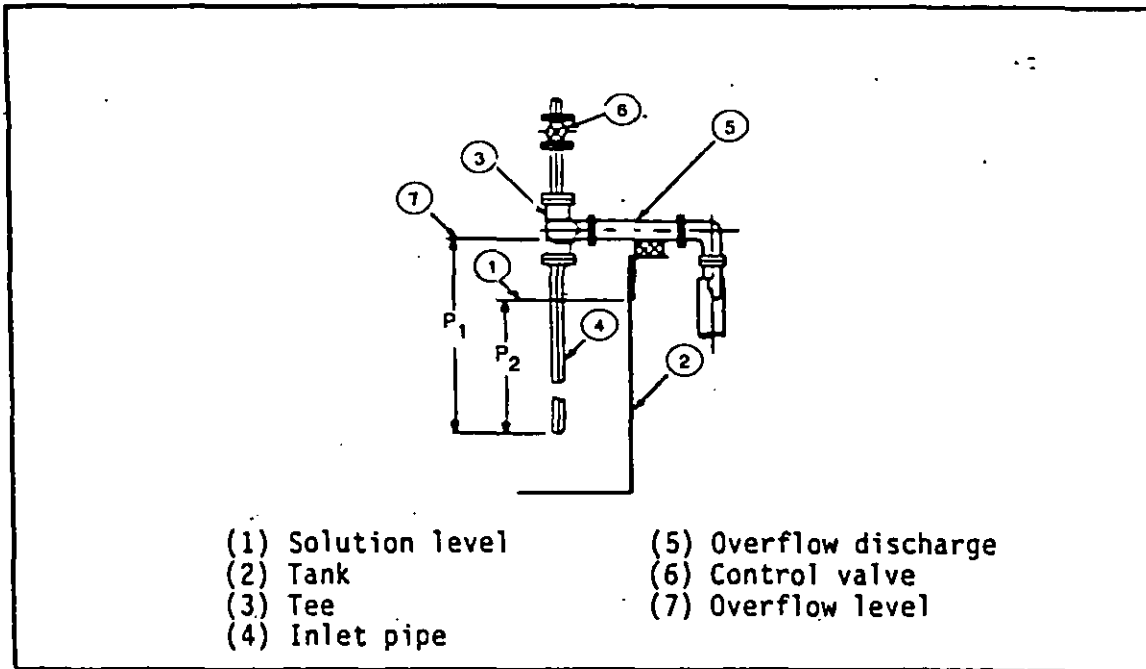


Figure 34  
 Differential Head Type Automatic Level Controller

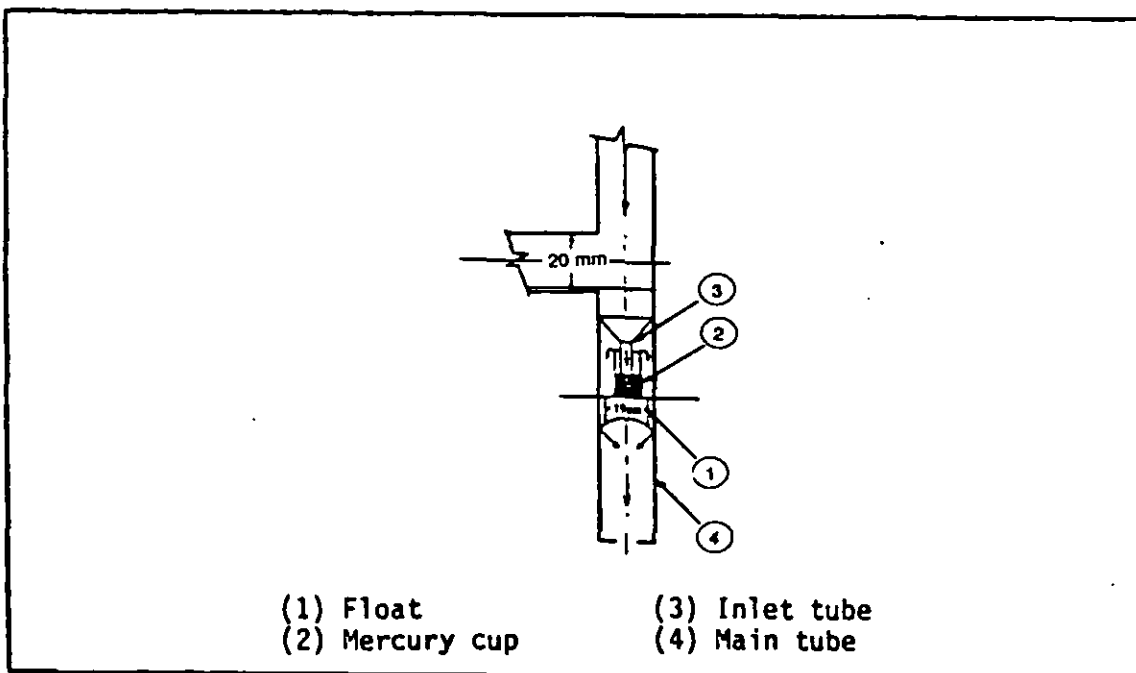


Figure 35  
 Float Type Automatic Level Controller

EQUATION: 
$$h_1 p_1 = h_2 p_2 \quad (17)$$

Where:  $h_1$  - the head of the water, in.  
 $p_1$  - the density of water (62.4 lb/ft<sup>3</sup>)  
 $h_2$  - the head of the electrolyte, in.  
 $p_2$  - the density of the electrolyte, (see Appendix D for specific gravity)

Liquid level controllers using the conductivity principle may be used, when designed for that specific purpose. The electrode should be properly insulated and made of proper material. Stilling wells may be required where operations change the level of the bath/air interface.

6.2.4 Electrical Power Instrumentation. Instrumentation is required to monitor voltage supplied to each bath using electrolytes to process the items. Also, many other baths require amperage monitoring. This includes chromium, nickel, copper, and aluminum anodizing, as well as the precious metal plating baths. The precious metal plating baths should be monitored by watt-hour meters to determine metal consumption per bath. Voltage ranges vary depending on the metal being deposited (refer to Table 17). Voltage range for electropolishing will vary but the operation range is up to 15 V for metals other than aluminum. Aluminum electropolishing may be as high as 25 V.

6.2.5 Conductivity Meters. Conductivity metering of electrolyte baths can be a sensitive method to determine the concentration of solute in the solvent. This may reflect the electrolyte level, agitation of the electrolyte and solution losses through drag-out, tank leakage, overflowing of the electrolyte, and solution decomposition and change in the efficiencies of the electrodes. Conductivity metering is generally performed continuously and, in order to be effective, the meter probes must be cleaned regularly as the probes have a tendency to clog. Conductivity meters should not be used as electrolyte level controllers.

#### 6.2.6 Automatic Replenishment of Baths

6.2.6.1 Sensors in Baths. Sensors are placed in baths to monitor conductivity, oxidation reduction potential, single ions, and pH.

6.2.6.2 Constant- and Variable-Volume Feed Pumps. Constant- and variable-volume feed pumps are used to provide chemical makeup and water to the various process baths. Chemical metering pumps are used for supplying such aqueous chemical solutions as sulfuric acid, sodium hydroxide, and sodium bisulfite. These pumps are piston-type, cast-iron epoxy coated casing with all wetted parts constructed of Hastelloy "C". The pumps are electrical-stroke control for the full range of capacity. Solenoid valves are installed downstream of the pumps to provide automatic positive shutoff when the pump is not on-line. The pumps are controlled by flowmeter through a microprocessor/controller and a sensing device such as a pH meter, oxidation reduction potential meter, and conductivity meter.

6.2.6.3 Replenisher Storage Containers. Replenisher storage containers are used to store aqueous solutions of electrolytes, autocatalytic chemicals, and cleaning solutions. These containers are provided with heaters or chillers where required, and appropriate lines for drains and filling connections.

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Care must be observed to mount containers in order not to interfere with the instruction sensors and automatic controls. Containers shall be corrosion resistant for conditions of service required for the containment of the liquid specified.

6.2.6.4 Piping (Tubing). Air lines are normally fabricated from seamless copper tubing conforming to ASTM B68, Seamless Copper Tube, Bright Annealed, or ASTM B251, Wrought Seamless Copper and Copper-Alloy Tube, and coated with PVC, and the fittings wrapped with a plastic tape. Tubing size of 1/4-, 1/2-, or 3/4-in. OD is a suitable diameter for the purpose. Process instrument tubing normally conforms to ASTM A269, Seamless and Welded Austenitic Seamless Stainless Steel Tubing for General Service, in the fully annealed condition of the same sizes as copper tubing. The fittings are tubing compression fittings; brass for copper and corrosion-resisting steel alloys A151 316 or 304 for corrosion-resisting steel. Threads are to be protected using a wrapping of PTFE tape.

6.2.6.5 Electronic Control Console. For automatic systems, one electronic control console is used which is a programmable controller system. This controller system interfaces to conventional process input/output (I/O) signals to provide data acquisition and control of the process, and Man Machine Interface (MMI). This consists of CRT display, operator keyboard and other ancillary devices for use in monitoring, controlling, and reporting on process operations. The controller system normally performs all control and operator/process interface tasks, viz., relay ladder logic functions, manual override which allows the operator to assume manual program control of any input or output, reports, i.e., custom report generation, alarms that advise the operator of abnormal or dangerous process conditions and such other functions required for complete and proper operations of the electroplating facility. The console may show structured analyses (Yourdon method) of the system, the flow of liquids, wiring controls, hydraulic controls, and electrical controls in a block diagram of the process controller. The programmable controller software uses ANSI X3.4 7-Bit American National Standard Code for Information Interchange (ASCII) language supplied through an Electronics Industries Association (EIA) interface conforming to publication EIA RS-232C, Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange (August 1969). The programmable controller is to conform to National Electrical Manufacturers' Association (NEMA) Publication ICS 3-304, Programmable Controllers.

6.2.6.6 Microprocessor Controls. Microprocess controls may be provided for sensing levels of liquid and monitoring these levels optically or by immersion. These level sensors may be programmed to determine volume to a 0.1 percent accuracy and may be programmed to correct for temperature variations. Block diagram of a typical system is shown in Figure 36. The microprocessors emit signals in the range of 4 to 20 mA, 0 to 1 mA and 0 to -10 V dc. Other microprocessors provide signals of 4 to 20 mA or 0 to 5 V. Other microprocessors monitor mass flow, correcting for temperature, pressure and viscosity changes; while still others may be provided to measure heat energy or electrical energy used in a process. In general, the microprocessor controls provide a startup for the ventilation system including scrubbers, makeup units, and exhaust fans, provide cold chilled water to enable



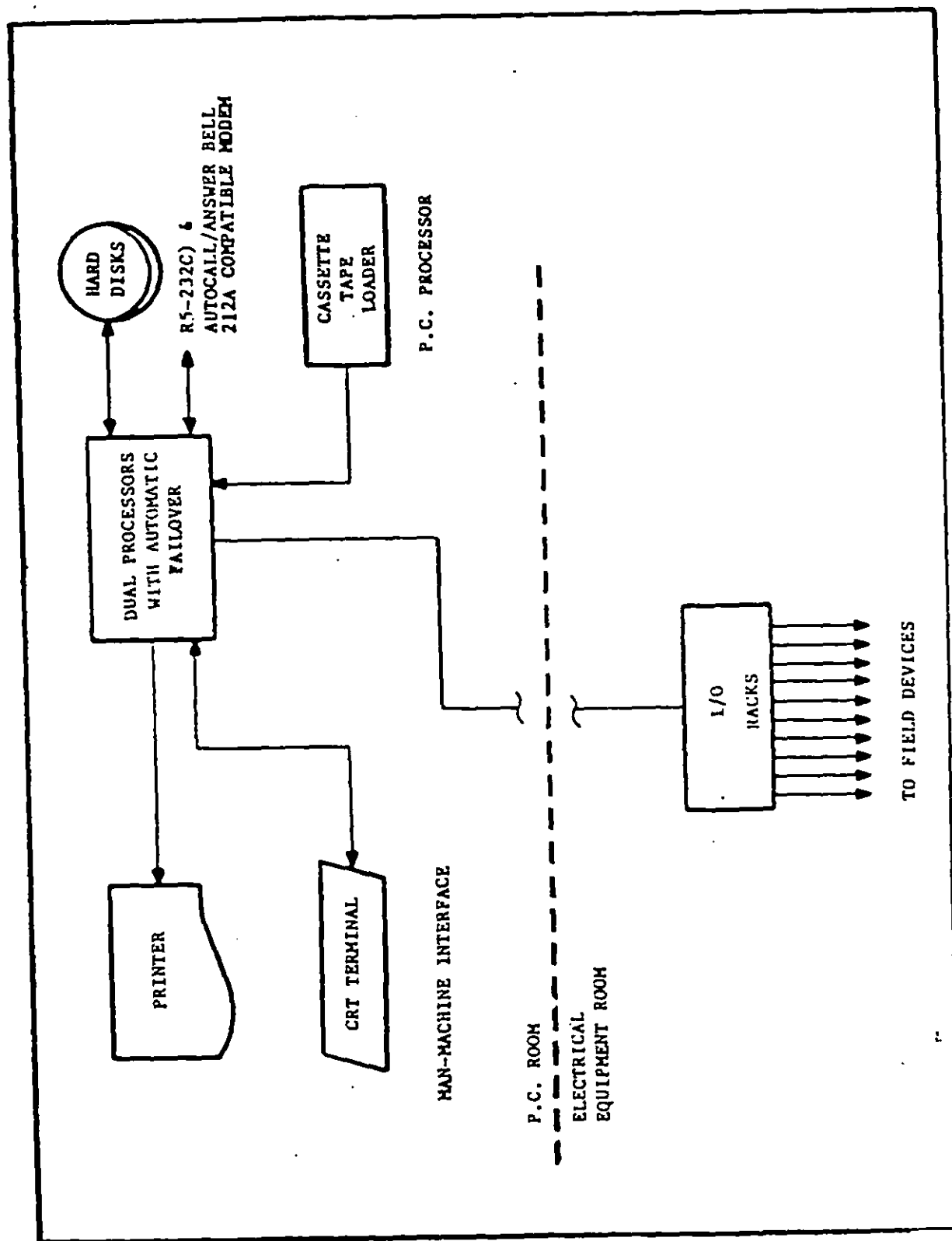


Figure 36  
Typical Microprocessor Control of Processes

temperature controllers to function, and start deionizers for water makeup; provide a continuous operation for hot water, ventilation, cold chilled water, cooling water, low pressure air and deionizers; waste treatment processing system; power failure/restore alarms; and any other hardware for proper plant operations. There are several Computer Integrated Manufacturing (CIM) protocols, such as General Motors Manufacturing Automated Protocol (MAP), that should be considered for use when designing the microprocessor controls for the plant.

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## Section 7: GENERAL EQUIPMENT

7.1 Pumps

7.1.1 Controlled Volume. Controlled volume pumps operate by adjustment of the stroke of a plunger or by pinching of flexible tubing by a rotating finger. The other method of controlling the volume of fluid is by pulse feeding.

7.1.2 Diaphragm. Diaphragm pumps are used to move high solids fluids and the only exposed parts to the fluid being pumped are the diaphragm and the body.

7.1.3 Centrifugal. Centrifugal pumps are generally employed for the movement of liquids in the electroplating plant. These centrifugal pumps are either magnetically coupled through the housing of the pump or directly coupled to the drive through a mechanical seal to prevent leakage. The advantage of the magnetically coupled pump is the absence of a rotating shaft seal although the maximum pressure is less than the directly driven pumps. Centrifugal pumps require priming; therefore, in permanent installations the takeoff is toward the bottom of the tank and a slight fall is allowed in the suction pipe of the pump or a nonreturn valve is fitted to the suction side to facilitate pump priming.

7.2 Valves

7.2.1 Plumbing. Plumbing conforms to Guide Specification NFGS-15400, Plumbing. Plug valves should be put in straight piping sections fitted with a "tee" to facilitate cleaning of clogged valves without removal of the valve. Open discharge bottom tank outlets should be fitted with a flat plate bolted to the outlet plate that has a flange valve. This enables the valve seat to be freed when crystallized salts are encountered. Electrically operated solenoid valves are used for automatically controlling the flow of liquids. Small amounts of liquids may be delivered through solenoid valves or flexible tubing that is constricted.

7.3 Air Compressors

7.3.1 Air Agitators. Air agitators are used at 1 to 3 psig (6.9 to 21 kPa) to provide uniform mixing of liquids. The air is required to be oil-free and may be supplied by a turbo-blower. An example of air agitation requirements is acid copper baths which use 2 ft<sup>3</sup> per min per ft<sup>2</sup> of solution surface delivered at one psig (6.9 kPa) per 21 in. (533 mm) of depth of solution. The air is delivered through a finger or wand directed to the bottom of the tank in this installation; other installations such as copper cyanide direct the air upward and supply air at a pressure of one psig per 18 in. (457 mm) of depth of electrolyte. In determining air pressure for agitation the specific gravity is the factor that is used. Backflow preventors are used to prevent liquid from entering the delivery finger or wand.

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7.3.2 Compressed Air Systems. Compressed air systems conform to NAVFAC Guide Specification NFGS-15411, Compressed Air Systems, (Non-Breathing Air Type). In general, materials used in compressed air systems shall be rated for not less than 100 psig (689 kPa). Appropriate regulators (airflow restrictors) shall be installed in the air lines.

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## Section 8: PLATING EQUIPMENT AND DESIGN

8.1 Racks

8.1.1 Design of Racks. Design considerations for racks in plating equipment are given to the electrodeposit, the required corrosion resistance of the rack material, the method of stripping the electrodeposit, the portion of the item to be plated, the method of holding the item in the rack, the design of the rack tip, current thieves, and the benches and storage areas where the items may be racked and unracked. An appropriately designed rack shall:

- a) conduct the current to the item so that the current density is uniform over the surface of the item,
- b) orient the item for good drainage of the electrolyte,
- c) have maximum conductivity compatible with the corrosivity of the electrolyte,
- d) minimize surface contact in an area that will not affect the service life of the item, and
- e) allow complete agitation around the item as well as throughout the processing tank.

8.1.2 Size of Racks. The rack with the items attached should:

- a) fit into the smallest tank in the process line,
- b) allow for convenient removal from the processing solution without contact with the tank sides and working electrodes,
- c) not exceed 40 lb (18 kg) in weight with the items in place, and
- d) hold the items and the rack no closer than 6 in. (152 mm) from the tank bottom, 5 in. (127 mm) from the tank sides, and 3 in. (76 mm) below the electrolyte surface.

The dimensions A through E refer to Figure 37 and provide the dimensions required for rack size.

Dimension A - Overall length required to keep pieces not less than 2 in. (51 mm) below the electrolyte and away from heaters, coolers, tank sides and bottom, air-agitation pipes, filters, overflow dams, and mechanical devices.

Dimension B - Distance from the cathode hook to the first part.

Dimension C - Rack width, which is dependent on the size of the item being plated and spacing between racks for return-type, automated systems of plating and the number of racks used on an anode in the manual systems.

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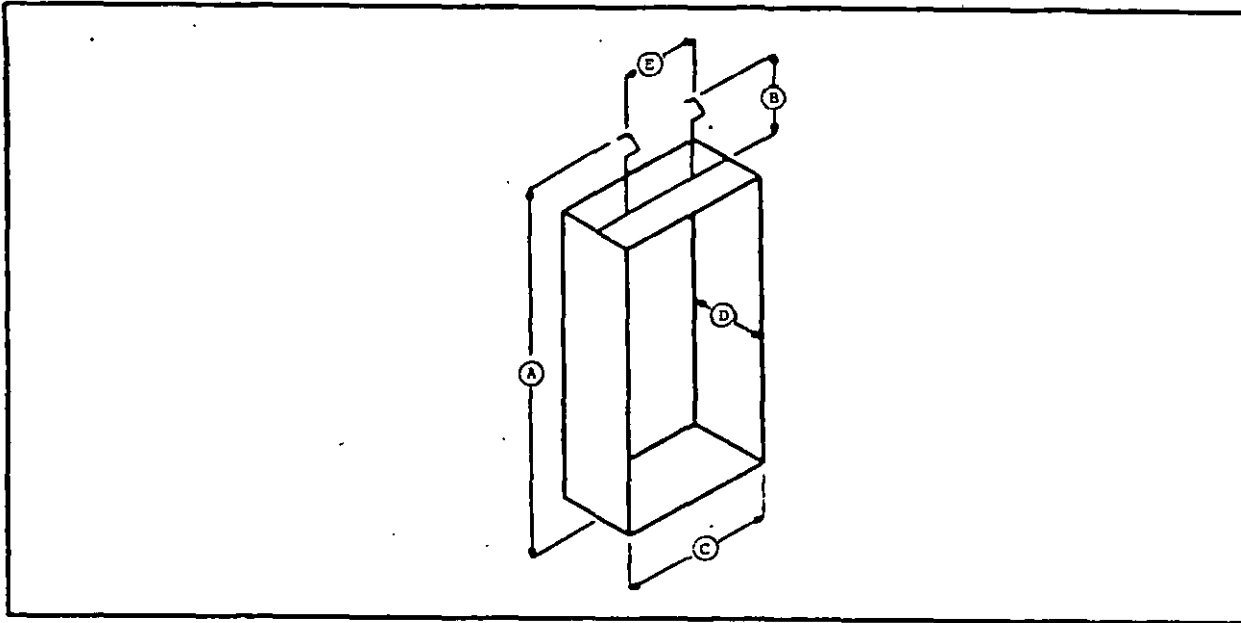


Figure 37  
Rack Dimensions

Dimension D - Thickness dimension which is in the direction of travel in automated-hoist-line systems. The rack fits between anodes allowing spaces of one to three in. between racks holding parts. On manual systems, it is the smallest anode distance that accommodates the rack in the processing bath and will permit the placement and removal of the rack and items in the bath by the plater.

Dimension E - The distance between the anode hoods used for return-type automatics.

## 8.2 Handling of Items to be Plated

8.2.1 Item Movement. Decisions of item movement are described in Table 29. The movement of the items through processes are manual, semiautomatic or automatic. The degree of automation affects instrumentation, control by electronic means and hoist or parts movement. Monorails with manual travel electric hoists are to conform to NEMA Class 12 for plating shop service where loads and utilization are randomly distributed with capacity loads. The environment is for indoor service with exposure to corrosive vapors from the various chemical cleaning and plating solutions in tanks. Hoists shall comply to ANSI B30.16, Safety Standards for Overhead Hoists, and monorail systems shall comply to ANSI B30.11, Safety Standards for Monorail Systems and Underhung Cranes, and ANSI MH27.1, Specifications for Underhung Cranes and Monorail Systems. The hoists are to comply to Hoist Manufacturer's Association (HMI) 100-74, Electric Wire Rope Hoists. The speed shall be rapid enough such that parts being plated do not become passive between plating operations. If a hoist is being used, either hook and travel speeds may have to be adjusted to meet process requirements or bath placement must be modified.

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Table 29  
Handling of Items To Be Plated

DESCRIPTION	LIMITATION AS TO PARTS		CONTROL OF TREATMENT AND TRANSFER TIMES
	WEIGHT AND SIZE	HANDLING	
Wholly manual operation	Limited to what one operator can handle	Racks, wire, trays or baskets	Dependent on operator
Chain hoist and monorail, manually operated	Greater weight and size or large number in bulk	Racks, baskets, cylinders or barrels	Dependent on operator
Motor-driven hoist and monorail (or bridge crane) operated manually or automatically	Still greater weight, size or bulk work	Racks, baskets cylinders or barrels	Dependent wholly or partially on operator
Semiautomatic return-type machines, manual loading and unloading	Limited weight and size, little bulk work	Racks, hooks, wire, trays or baskets	Single treatment automatic, other dependent on operator
Fully automatic return-type machine, manual or automatic loading and unloading	Wide range of weight and size, also bulk work	Racks, hooks, cylinders or barrels	All automatic
Fully automatic, straight-line machine, manual or automatic loading and unloading	Great variety in weight and size, but no bulk work	Racks or special fixtures	All automatic
Fully automatic machine, automatic loading and unloading of steel mill products	Relatively wide range in weight and dimensions	Continuous for sheet, strip, wire or rigid conduit	All automatic

8.2.2 Manual. Manual movement requires the most manpower and the least automation. Items are racked or wired by hand. The items are unique to each other and are handled as individuals. This handling allows the most care by personnel performing the plating. This is because they are low volume items.

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When using manually operated installations, the tank rims are to be at a convenient level to remove the work from the process tanks; therefore, a duck board platform may be used. A straight-line configuration is used to move heavy items, using a hoist or crane where items are loaded at one end and processed throughout the system and unloaded at the final stage. Another arrangement similar to the straight-line configuration is the "U" type arrangement. The "U" type arrangement folds the straight-line process arrangement, and the operator moves the items around the line of processing tanks as shown in Figure 38.

8.2.3 Semiautomatic. Semiautomatic operation allows the vertical movement of the work automatically over a single tank. This mechanism consists of a chain with hooks or carriers and with sprockets at both ends of a rectangular tank. Any point on the chain may be selected for loading/unloading. This mechanism is used only with precleaning, fully automatic machines. Usually the semiautomatic replaces "still plating tanks" manually operated, where all work is manually handled through all plating and after-plating treatments.

8.2.4 Automatic. Automatic operations for a typical installation are shown in Figure 39. Provided that the volume of items to be plated is sufficient, automatic operations have the following advantages: less floor space is used; larger and deeper tanks may be used; larger and heavier racks may be used; more efficient drag-out control is possible; there is less danger of solution contamination; the rack life is better; the ventilation is more efficient; the items are handled more cost effectively; better process control is possible; the uniformity of deposit is better at higher production rates; the use of solutions, materials and personnel is more cost effective; and the work environment is better.

8.2.4.1 Application of Automatic Operation. Items are handled in bulk by automatic barrel-type machines, electrified processing of individual items other than barrel-type machines, and nonelectrified processing equipment which may be hydraulically operated. Bulk-handling, barrel-type machines handle parts that will tumble properly, will not nest, and are smaller than 25 in.<sup>3</sup> ( $4.1 \times 10^5 \text{ mm}^3$ ) in volume.

a) Electrified processing may include the following:

(1) Complete processing through the preplating or cleaning treatments, plating one or more metals, and final rinsing and drying operations.

(2) Similar to the above except that an anodizing or electropolishing operation replaces the plating operations.

(3) Segregation of parts with a bypassing mechanism for selective plating combinations on one machine for either chromium, copper-nickel or nickel-chromium deposits.

(4) Complete cycle treatments including dual controls for deposits on outside and inside surfaces, or for deep recesses in which case an auxiliary anode may be used.





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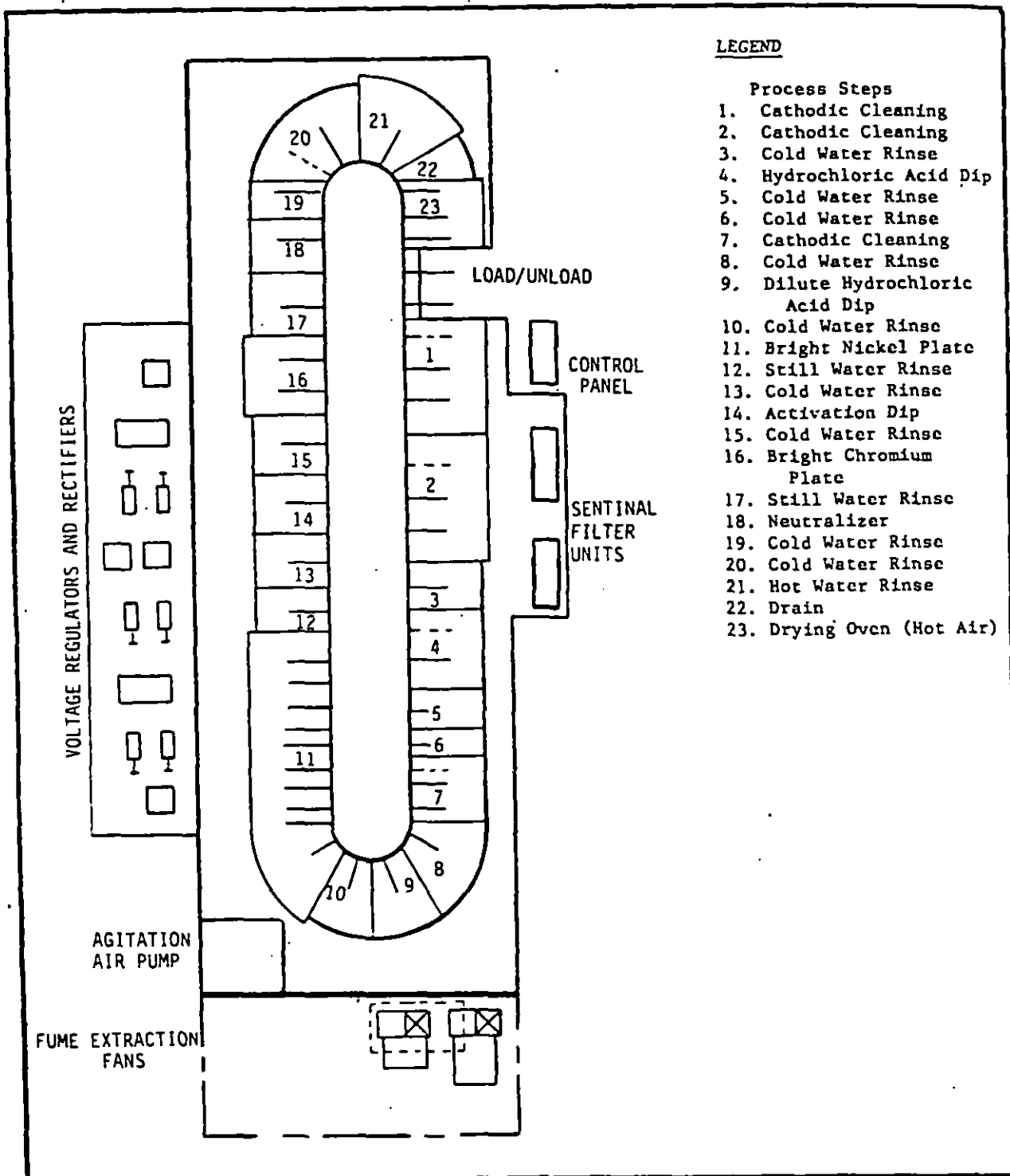


Figure 39  
Typical Automatic Production Line for  
Electroplating Nickel/Chromium

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(5) Electrolytic alkali and acid treatments, with or without prior mechanical washing in combination, for purposes other than plating.

(6) Combinations of fully automatic and semiautomatic machines for specific treatment cycles.

a) Nonelectrified processing may include the following:

(1) Cleaning, pickling, and drying prior to painting.

(2) Cleaning, pickling, and applying a prime coat prior to vitreous enameling.

(3) Cleaning, pickling, phosphate coating, and drying.

(4) Cleaning, pickling, and blackening by any one of a number of processes, followed by rinsing and drying.

(5) Bright dipping of copper and copper alloys with sulfuric-nitric acid dip, followed by rinsing, and drying.

(6) Heating to stress-relieve, anneal or harden in fused salt baths in combination with pickling, rinsing, and drying.

8.2.4.2 Automatic Machines. Automatic machines are of the following types: straightline, classified as heavy duty but can be used for light rack loads; rotary machines; and return "U" type machines. Return "U" type and straightline machines are compared in Table 30. Return "U" type machines may be continuous moving or intermittent type.

#### 8.2.4.3 Selection of Automatic Machines

a) Production requirements based upon the following information:

(1) The size, shape, weight, and area of each part and the number to be processed per day, week, or month.

(2) Whether each part can be racked so that it will drain freely without difficulty due to air or gas pockets.

(3) The maximum dimension limitations as determined by the size and shape of the largest part to be processed.

(4) The relation between weight and area of individual parts, if a wide variation exists, as an aid to proper racking.

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Table 30  
Comparison of Return "U" Type and Straight-Line Machines

CHARACTERISTICS	STRAIGHT LINE	RETURN TYPE		
		LIGHT	MEDIUM	HEAVY
Production capacity	Large	Small	Large	Large
Rack size	Very large	Small	Large	Very large
Row of racks per carrier	1-2-3-4	1	1-21-2-3	
Average weight of carrier load, lb	100-2500	10-30	30-200	200-1500
Carrier spacing, in.	30-96	18-24	18-48	30-96
Height of lift, in.	36-96	30-40	30-72	36-144
Tank width	Very large	Small	Med. to large	Med. to large
Anode accessibility	Fair	Good	Good	Good
Machine accessibility	Fair	Good	Good	Good
Cycle revamp flexibility	Poor	Fair	Good	Good
Load and unload points	Separate	Same	Same	Same
Ventilation	Poor	Good	Good	Good
Headroom	High	Low	Low to high	Low to high

(5) The ideal spacing between parts for correct processing, recognizing the essential differences for processing deeply recessed parts as compared with shallow recessed parts in relation to fixed design factors such as anode spacing and carrier spacing.

b) Specifications for item to be processed are to be established as follows:

- (1) The basis metal for each part.
- (2) The significant surfaces for each, i.e., those surfaces which must meet the specification.
- (3) The nature of the treatment, i.e., nickel-chromium plating or copper-nickel-chromium plating.
- (4) The minimum thickness of each plated coating or the time of treatment on a specific anodizing cycle.

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(5) The salt-spray hours which each type of part must pass or similar requirements.

c) Workload and rack size best suited for the job requirements determine the type of automatic machine, and are based upon the following:

- (1) A single part of unusual shape or size.
- (2) A single rack containing a specified number of parts.
- (3) Two or more racks not exceeding the overall space dimensions defining the workload.
- (4) A cluster of parts strung on wires.
- (5) A single tray or a stack of two or more trays.
- (6) A basket, cylinder, or other type container.

d) Carrier spacing depends on the total work width. There are not set standards, but for a vertical lift-type transfer with a machine using a 6-in. pitch chain, item lengths about 48 in. (1.2 m), or longer, the following may be used:

<u>WORK WIDTH</u> (in.)	<u>CARRIER CENTERS</u> (in.)
12	18
18	24
24	30
48	54

e) The number of lines is determined by the number of items required to be processed per work shift.

f) The treatment cycle is determined by the basis metal, the processing that the item went through, i.e., stamped, drawn, deburred, heat treated, cast, etc. and the desired finish.

g) The total lift at the transfer point is calculated on the item length and the hook length.

h) Transfer time may be estimated by the time required to process the item in each operation and allow the liquid in the processing to drain as required. The transfer time cannot be so quick as to cause the item to swing rapidly or excessively.

i) Anode rod spacing is determined by the electrolyte conductivity, spacing of the item and anode to provide the specified treatment.

j) Current requirements per carrier load is based on the maximum current density for designing of the current-carrying members and contacts.

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The amperes per carrier load is the product of the total plating area and the average current density per unit area. The amperes per gallon in a processing bath can influence the tank size and indirectly the design requirements of an automatic machine.

### 8.3 Electroplating and Anodizing Tanks

8.3.1 Tank Design. Suitable materials to construct plating and anodizing tanks are shown in Table 24 in Section 5. Where specific recommendations for materials of construction for tanks are given, these recommendations are to be observed. Tanks that are heated or cooled require insulation to conserve energy. Tanks constructed of metals or lined with conductive materials shall be isolated electrically; that includes ventilation ducts, piping, drains, and any conducting material that may be connected to the tanks. When the tank is designed to act as one of the operating electrodes, the tank is required to be likewise isolated electrically. Tank walls shall be smooth and all edges shall have radii that will allow easy cleaning and draining. All tank supports and reinforcements shall be attached to the tank by continuous welds to preclude the intrusion of corrosive liquids. Tank covers shall be made of corrosion resisting material suitable for the purpose intended. The tanks shall be suitable to contain the liquid specified for that tank, including the design of supports and pedestals. Tank should have drain boards to prevent drippage on floor areas. In order to assist in the design of the tanks, specific gravity of a number of solutions is given in Appendix D. Tanks fabricated from steel which may be lined or unlined are made from sheet of the following thicknesses:

<u>CAPACITY</u> <u>GALLONS</u>	<u>THICKNESS</u> <u>GAUGE</u>
100	12
500	10
>500	6

Tanks over 300 gallons capacity require solid footing.

8.3.2 Tank Size. Tanks have an aspect ratio (width/length) less than one. The tank width shall be no greater than 48 in. (1.2 m). A width of less than 20 in. (508 mm) is desirable, when possible. When tanks are wider than 20 in. they shall be provided with slots on both sides. The height of the tank, i.e., above the standing surface, should be 38 in. (0.97 m) plus or minus 2 in. (plus or minus 51 mm).

8.3.3 Carbon Steel. Carbon steel tanks are continuously double welded (back welded) and the weldments are ground smooth to facilitate cleaning, draining, and shedding of dirt.

8.3.4 Corrosion-Resisting Steel. Corrosion resisting steel tanks are designed and fabricated in the same manner as carbon steel.

8.3.5 Lined Steel. Lined steel tanks are fabricated as specified for carbon steel tanks and in addition, are to have sufficient lining to go over the top, reinforcing flange. When 3/4 full of electrolyte and the electrolyte is agitated, as required, the lining is not to be strained, torn, or damaged.

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8.3.5.1 PVC. PVC may be used for all electrolytes, at temperatures below 160 degrees F (71 degrees C), except alkaline tin plating solutions.

8.3.5.2 Rubber. Rubber lining is provided in a soft and a hard grade. Soft grade rubber is used for water rinses and aqueous hydrochloric acid solutions. Hard grade rubber liners are used for all electrolytes including the aforementioned liquids, but constituents such as fillers or accelerators may have a detrimental effect on the service of the liner.

8.3.5.3 Lead. Chemical lead lined tanks are used for sulfuric acid, flat nickel and acid copper plating service. Lead is not to be used for containment of fluoboric acid, or any alkaline cleaning or alkaline plating solution. Those materials to be used are specified in Table 24 in Section 5.

8.3.6 Plastic. Plastic tanks are resistant to corrosion and chemical attack, are light in weight, and are good electrical insulators. The plastic materials are welded-polypropylene, molded, rigid, high-density polyethylene, FRP, and rigid (unplasticized) PVC. Both PVC and FRP are described in paras. 10.6.4.1 and 10.6.4.2. Polypropylene welded tanks may be operated to a temperature of 160 degrees F and have capacities up to 275 gal (1041 L). Rigid PVC or polypropylene that are covered on the outside with FRP to provide the required mechanical strength are available as standard with capacities from 22 to 410 gal (83 to 1552 L). PVC-FRP tanks may be operated to 160 degrees F, and polypropylene-FRP tanks may be operated up to 212 degrees F (100 degrees C). Reinforcement bands are used to keep the tank walls from sagging.

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## Section 9: UNIQUE ARCHITECTURAL CONSIDERATIONS

9.1 Floor Construction

9.1.1 Floor Materials. Floors in a plating facility shall be chemical resistant mortars. Construction materials suitable for floors are given in Tables 31 and 32.

9.1.2 Housekeeping Features. The design of these floors shall be sloped to withstand spillage and splashing from electrolyte and cleaning solutions and to be self-cleaning or easily cleanable. Abrasion caused by loaded fork trucks, dollies, hand trucks and foot traffic require long wearing floors. An additional requirement is strength and resilience needed for support of rotating equipment such as pumps and electrical generators, and weight of rectifiers and tanks full of cleaning and electrolyte solutions. Slopes of floors, drains, dikes, and sumps shall be great enough to prevent standing liquids resulting from spills, leaks, and drag-out.

9.1.3 Drains and Pipes. Drains and pipe through floors are configured as shown in Figures 40 and 41. Incompatible materials shall have separate drains. The drains shall be large enough to handle spills and flushes. The drains shall be accessible for maintenance and shall be provided with covers.

9.1.4 Equipment Supports and Column Pedestals. Equipment supports and column pedestals are configured as shown in Figures 42 and 43.

9.1.5 Stairwells. Design of stairwells are as shown in Figure 44.

9.1.6 Brick Floor With Liner. Brick floor with liner is as recommended in Figure 45.

9.1.7 Trench With Cover. A covered trench is as shown in Figure 46.

9.1.8 Floor Design. Floor design is shown in Figure 47 for saucer slopes, Figure 48 for transverse slopes, and Figure 49 for longitudinal slopes where floor may get wet, appropriate dry standing places shall be provided by means of mats, false floors (duck boards) or platforms.

9.1.9 Discharge Rates. Discharge rates from trenches and clay pipe may be calculated from Figures 50 and 51.

9.1.10 Tiedowns. Tiedown rods for foundations and piers are as shown in Figure 52.

9.2 Distribution of Utilities

9.2.1 Water. Separate distribution piping is required for deionized water and municipal water. Deionized water is used for solution makeup and for rinsing anodized aluminum and magnesium prior to dyeing. Municipal water is used for feed water to the deionizers, chilled water, heating other than steam or boiler feed, and cleaning of tanks.



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Table 31  
Materials of Construction for Floors

TYPE	pH RANGE	WATER	SULFURIC ACID	HYDRO-CHLORIC ACID	NITRIC ACID	ORGANIC ACIDS	SOLVENTS	MINERAL OILS	ANIMAL OILS	CHLORIDE SALTS	SULFATE SALTS	ALKALIES
Good Concrete	7-12	R	NR	NR	NR	NR	VS	VS	NR	S	NR	VS
Good calcium aluminate cement concretes	4.5-0	R	NR	NR	NR	S	VS	VS	S	VS	VS	S
Light Duty Methods												
Quarry tile (portland cement joints)	7-12	R	NR	NR	NR	NR	VS	VS	NR	S	NR	VS
Coatings 10 to 125 mils	6-14	R	R	S	S	S	R	R	S	VS	S	VS
Latex surfacing (1/4 in. and up)	2-12	VS	S	S	S	S	NR	S	S	VS	VS	VS
Asphalt surfacing (1/4 in. and up)	1-11	R	S	VS	S	S	NR	NR	NR	R	R	S
Moderate Duty Methods												
Epoxy surfacing (polyamide-1/8 in. and up)	5-14	R	S	S	NR	S	S	VS	S	S	S	R
Quarry tile (epoxy-polyamide side joints)	5-14	R	S	S	NR	S	VS	VS	VS	VS	VS	R
Severe Duty Methods												
Paver tile (furan side and epoxy or polyester)	1-13	R	VS	VS	S	VS	R	R	R	R	R	R
Polyester surfacing (1/4 in. and up)	1-12	R	VS	R	R	VS	NR	NR	VS	R	R	S
Epoxy surfacing (polyamide (1/4 in. and up)	1-14	R	VS	R	S	VS	R	R	R	R	R	R
Brick with furan, phenolic epoxy and polyester, side and bed joints over 1/4 in. asphalt membrane	0-14	R	R	R	VS	R	VS	R	R	R	R	R

R - Recommended VS - Very Suitable S - Suitable NR - Not Recommended

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Table 32  
Chemical Resistance of Mortar Materials

	FURFURYL ALCOHOL TYPES	MODIFIED PHENOLIC TYPES	PHENOLIC TYPES	SILICATE TYPES	SULFUR TYPES	AMINE EPOXY TYPES	POLY- ESTER TYPES
Perchloric acid	NR	NR	NR	R	NR	NR	NR
Nitric acid	NR	NR	NR	R	VS	NR	R
Chromic acid	NR	NR	NR	R	R	NR	NR
Nitric acid plus hydrofluoric acid	NR	NR	NR	NR	VS	NR	VS
Sulfuric acid- strong	NR	VS	S	R	VS	NR	NR
Sulfuric acid- medium strength	S	R	VS	R	R	S	S
Hydrochloric acid	R	R	R	R	R	R	R
Hydrofluoric acid	R*	R*	R*	NR	R*	R*	R*
Phosphoric acid	R	R	R	R	R	R	R
Steam	R	R	R	NR	NR	VS	VS
Salts-unsaturated acid side	R	R	R	R	R	R	R
Salts-unsaturated alkaline side	R	VS	NR	NR	NR	R	S
Alkalies-strong	VS	S	NR	NR	NR	R	S
Alkalies-medium strength	R	VS	NR	NR	NR	R	VS
Temperature-top limit, °F	350	375	375	750- 2500	190	225	225

R - Recommended      VS - Very Suitable      S - Suitable      NR - Not Recommended

\*For hydrofluoric acid service, use carbon fillers.

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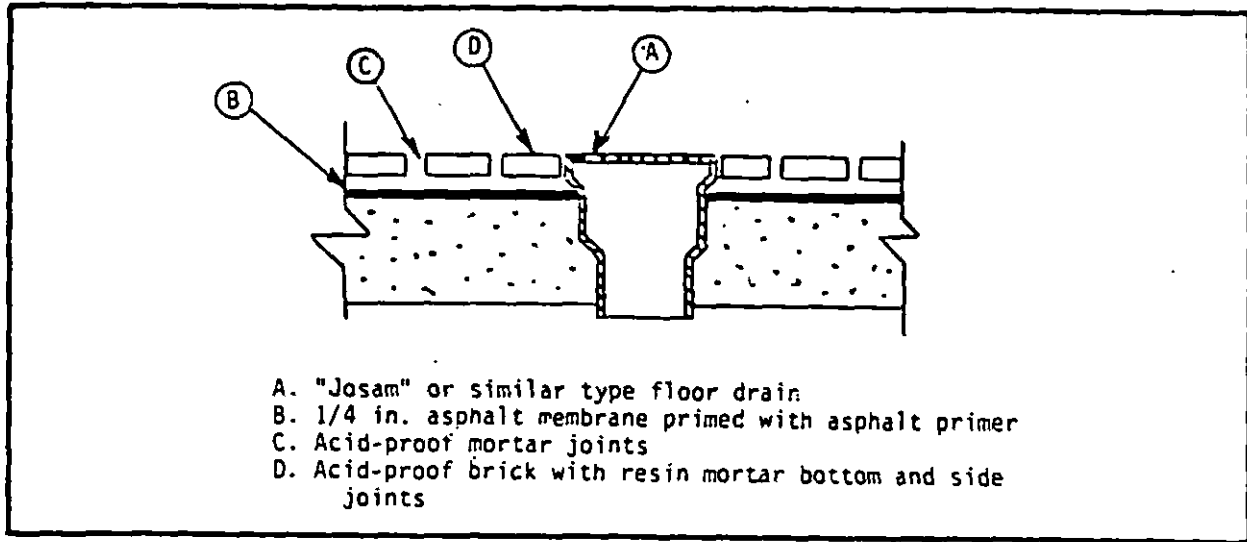


Figure 40  
An Example of Floor Drain Construction

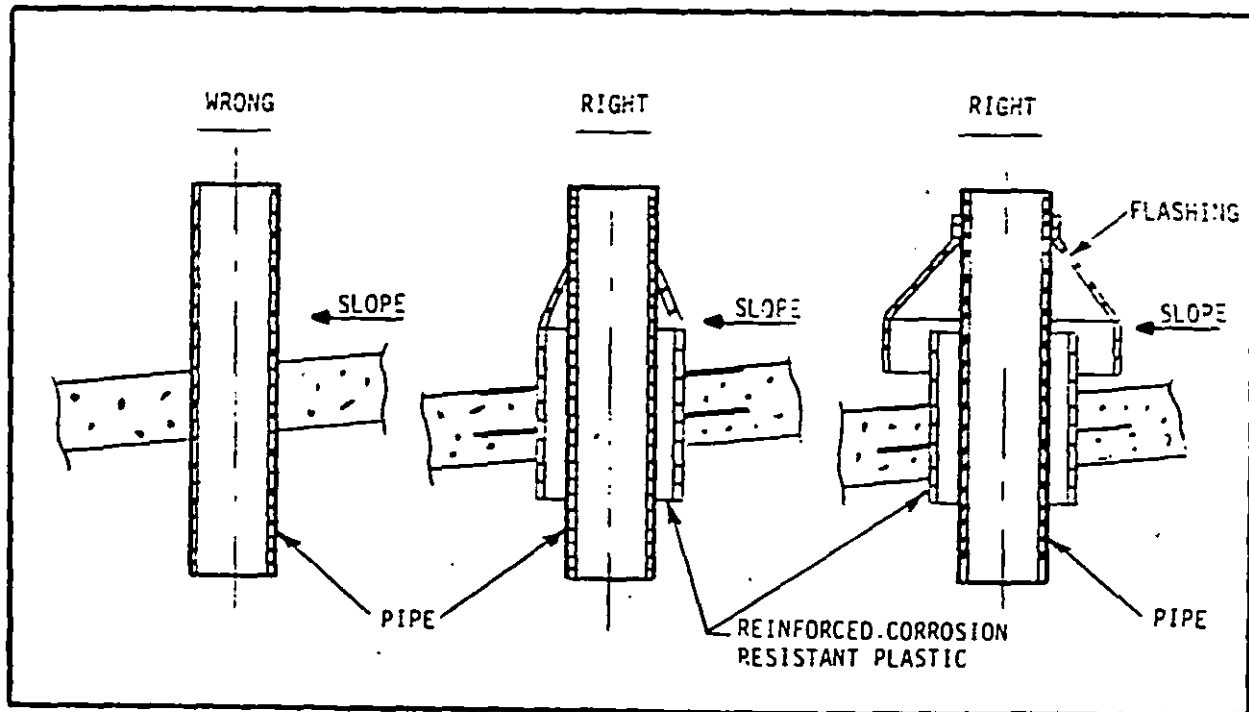


Figure 41  
Architectural Features of Pipes Through Plating Floors

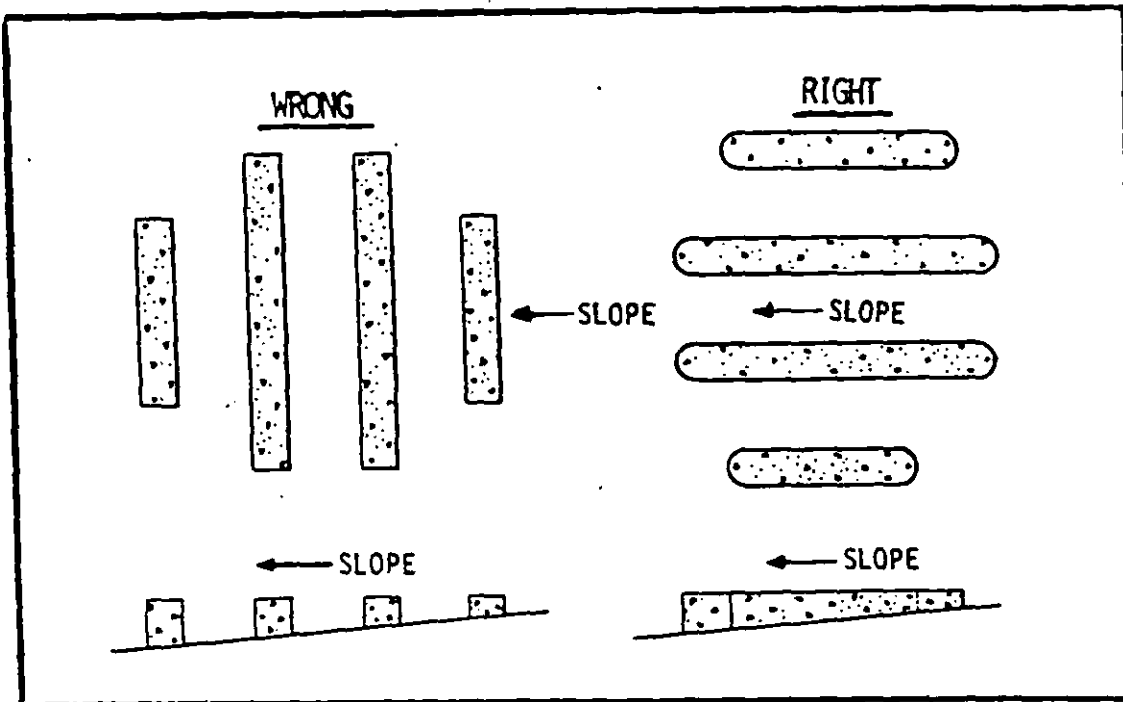


Figure 42  
Equipment Supports in Corrosive Areas

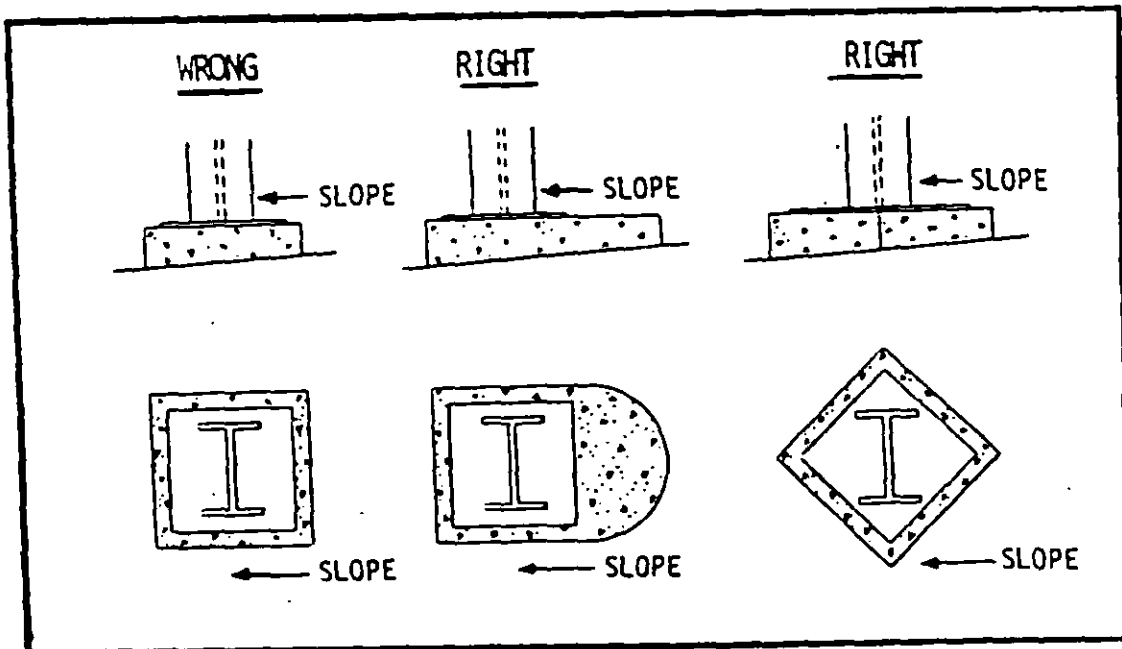


Figure 43  
Pedestal Construction on Plating Floors

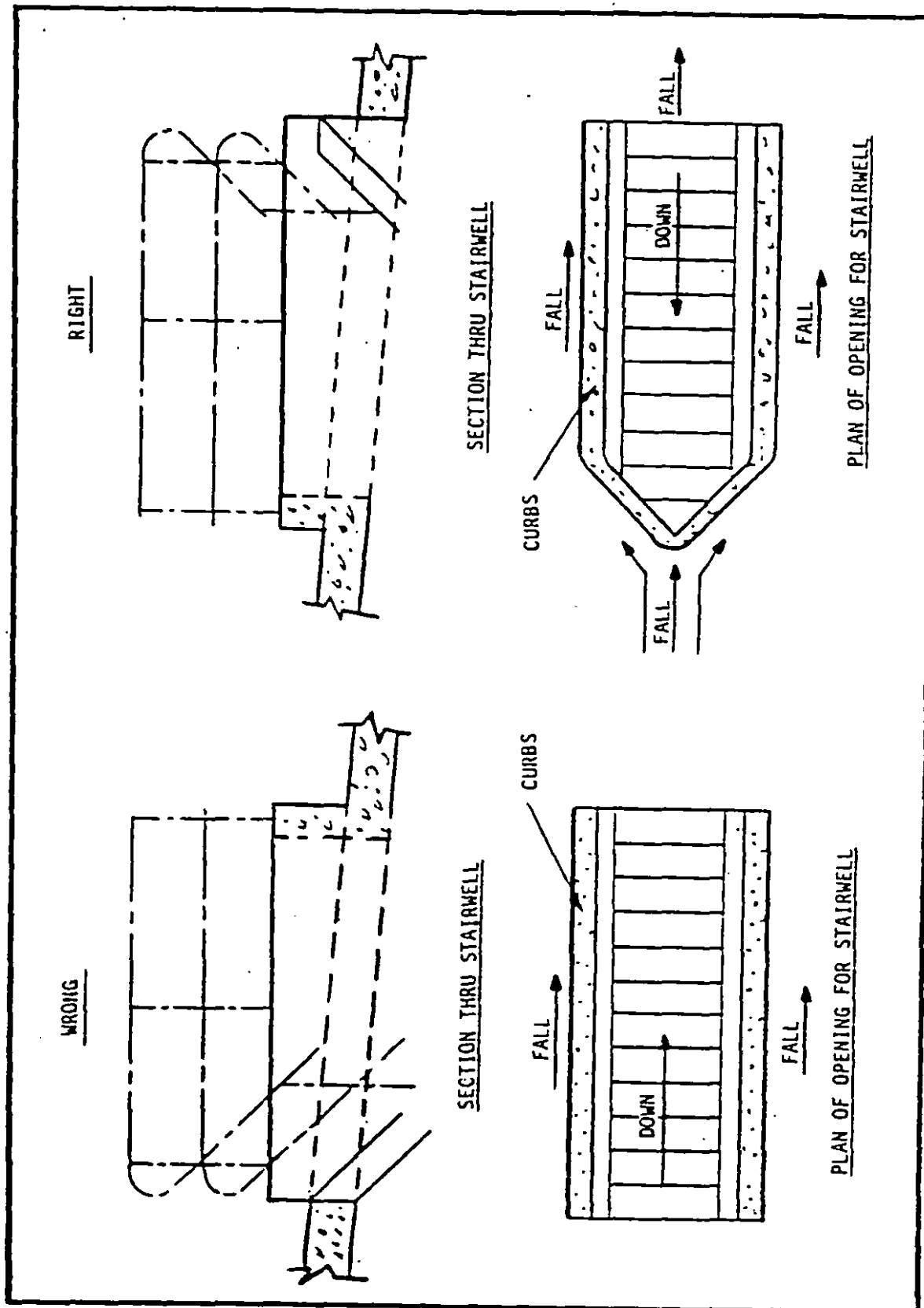


Figure 44  
Stairwell Design

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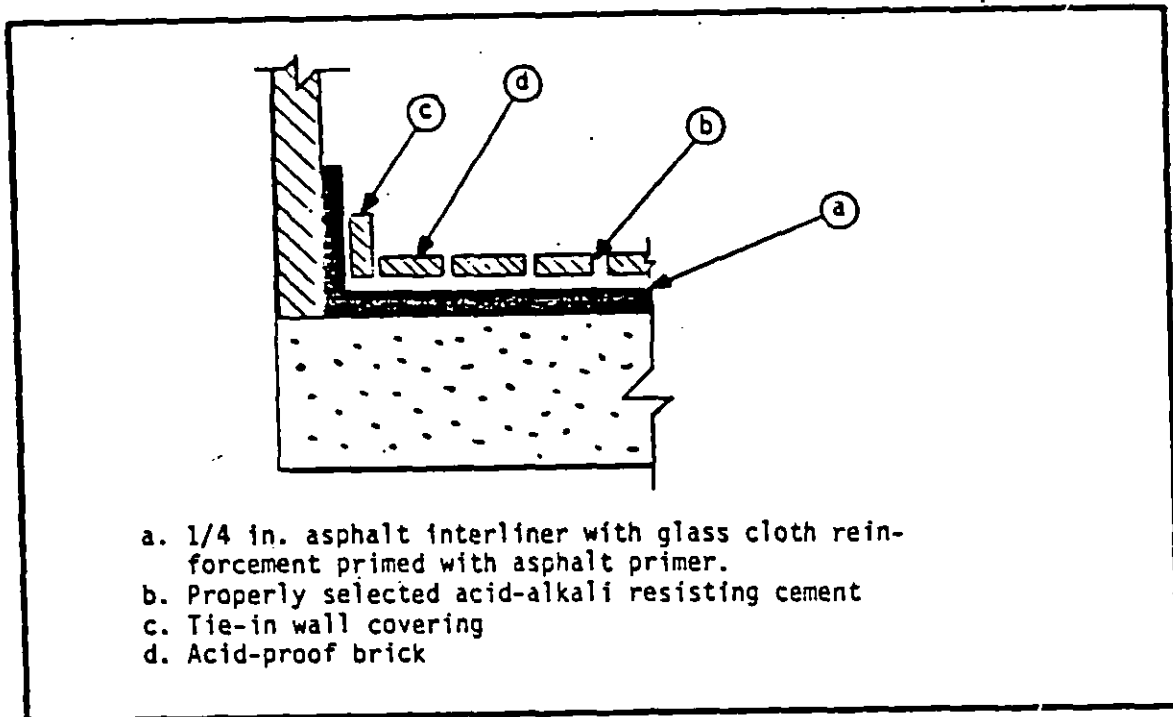


Figure 45  
 Detail of Acid-Proof Brick Floor Construction

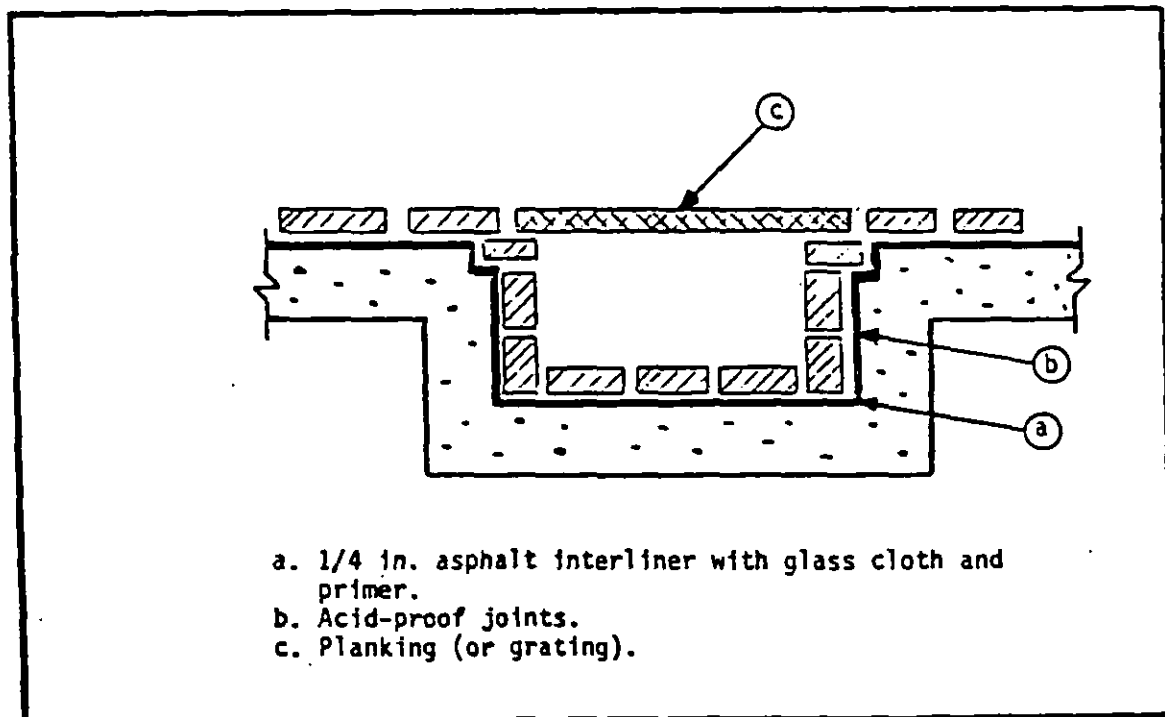


Figure 46  
 Acid-Proof Brick Drainage Trench With Cover

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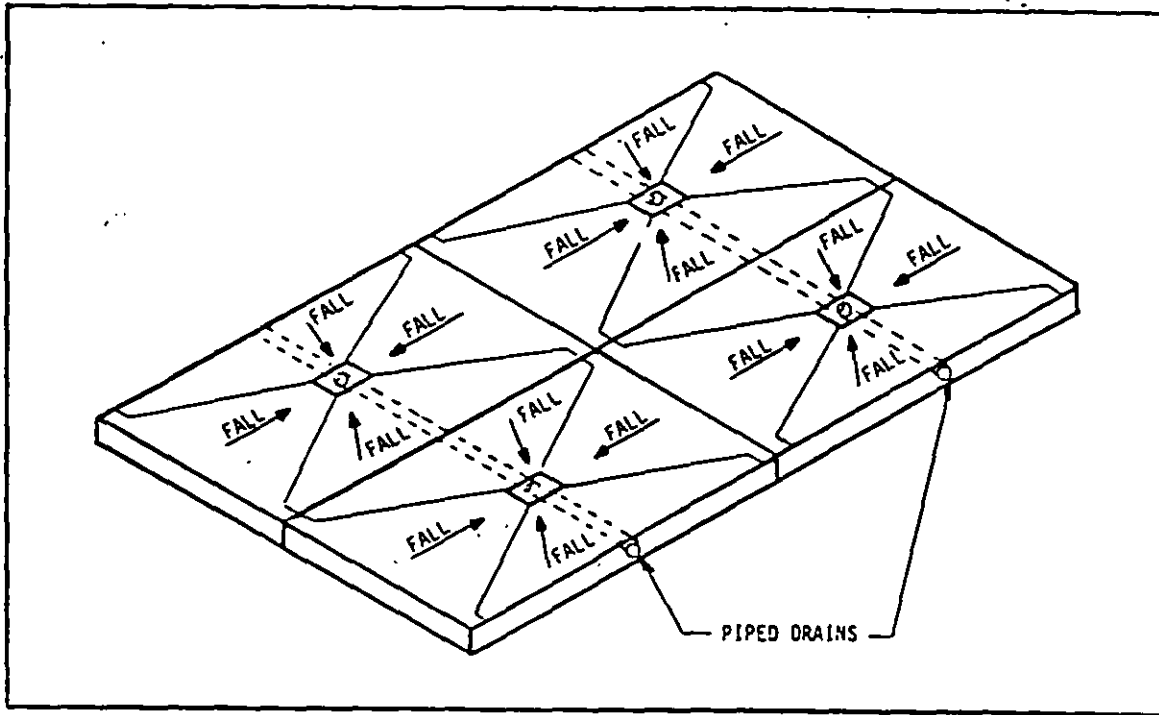


Figure 47  
Saucer Slope Floor Construction

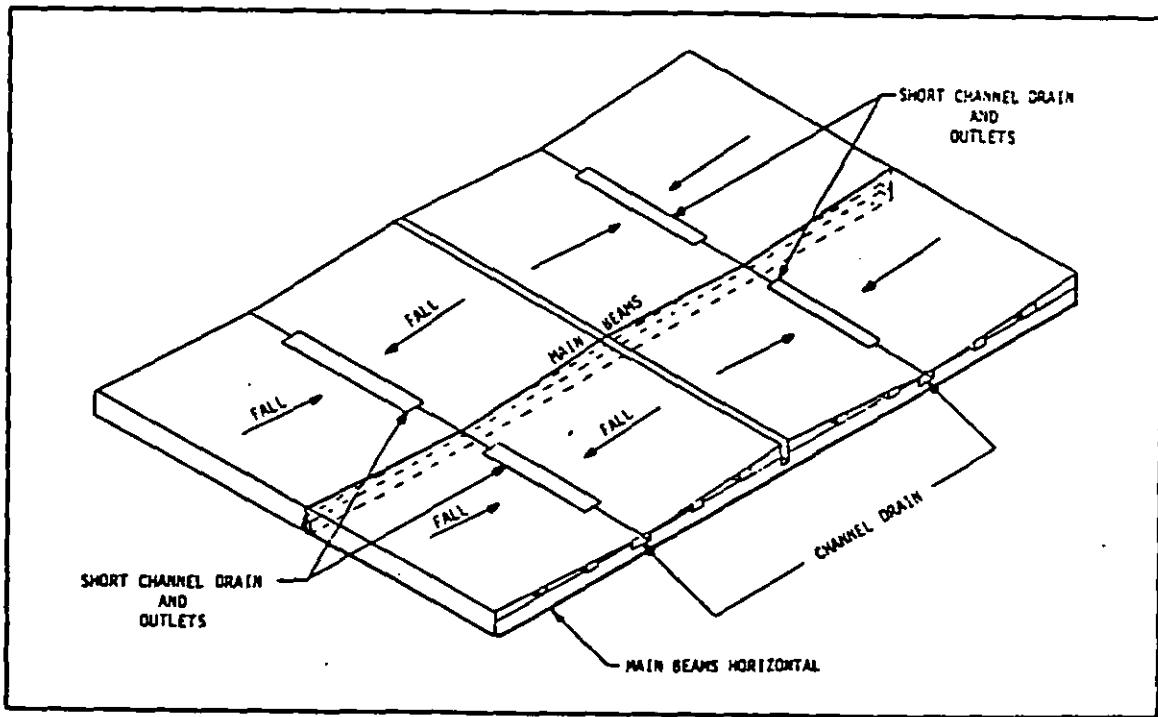


Figure 48  
Transverse Slope Floor Construction

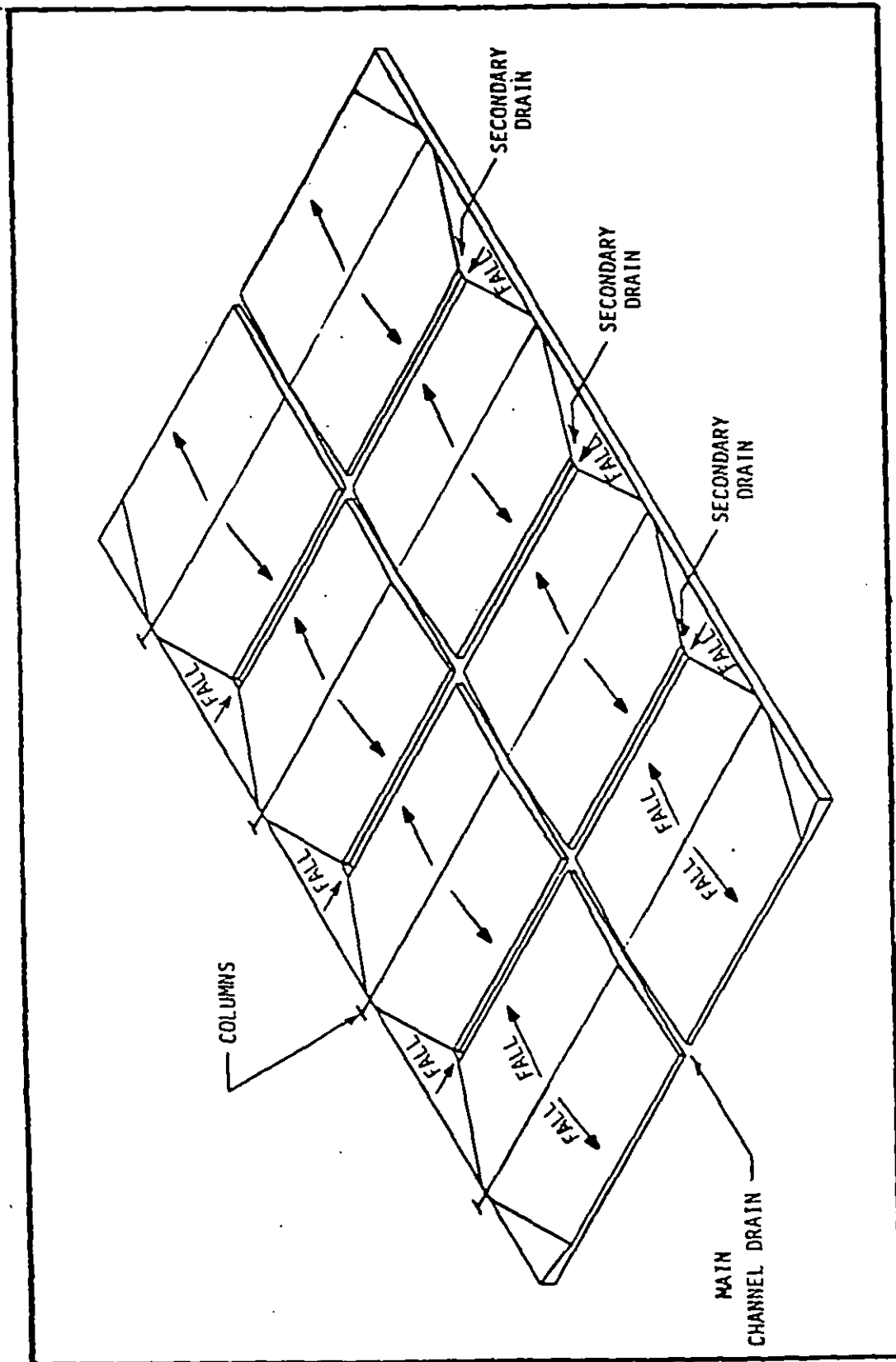


Figure 49  
Longitudinal Slope Floor. Construction



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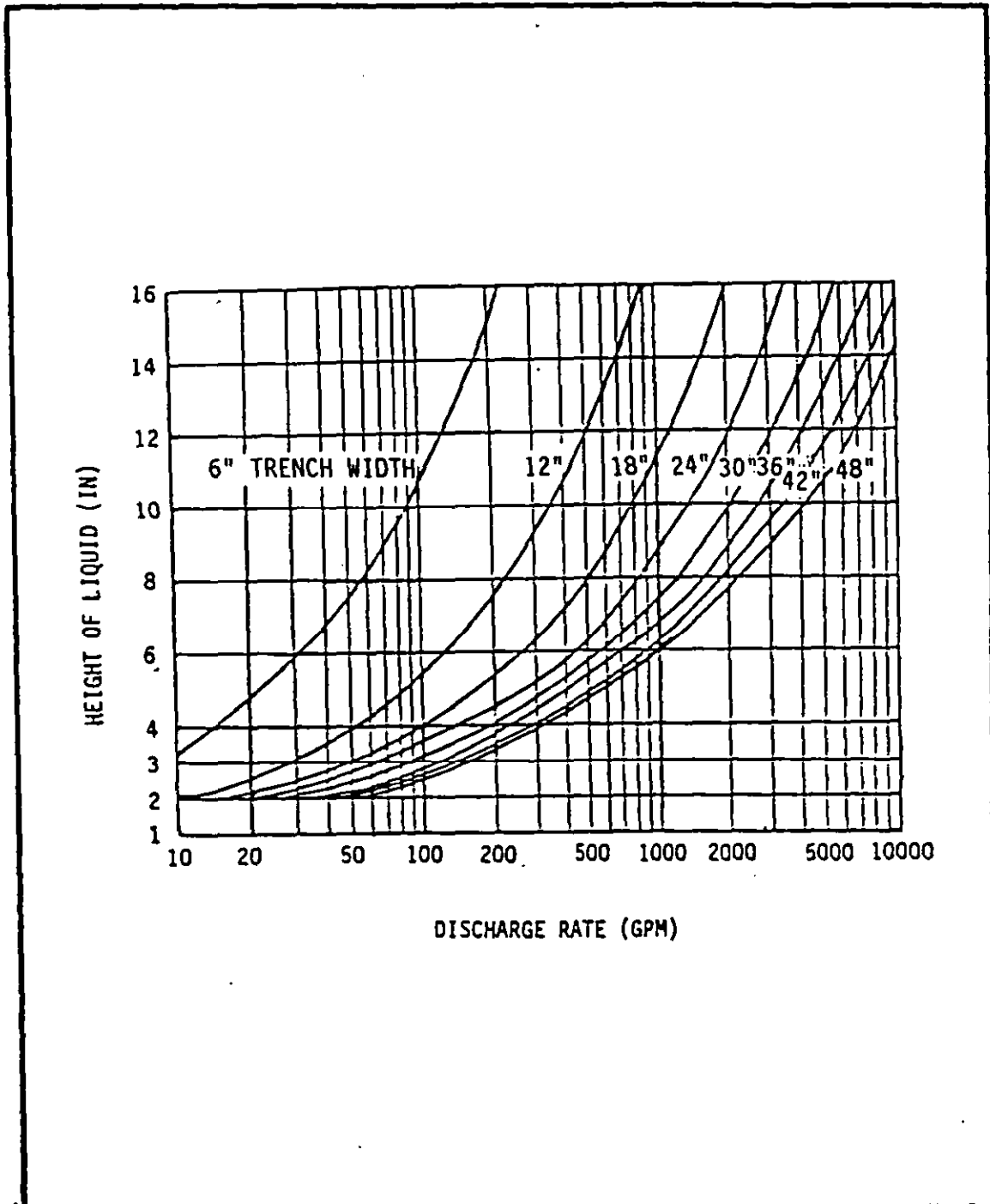


Figure 50  
The Effect of Liquid Height on Discharge Rate of Liquid  
(Acid Proof Brick Trenches Having 1/4 Inch Slope Per Foot)

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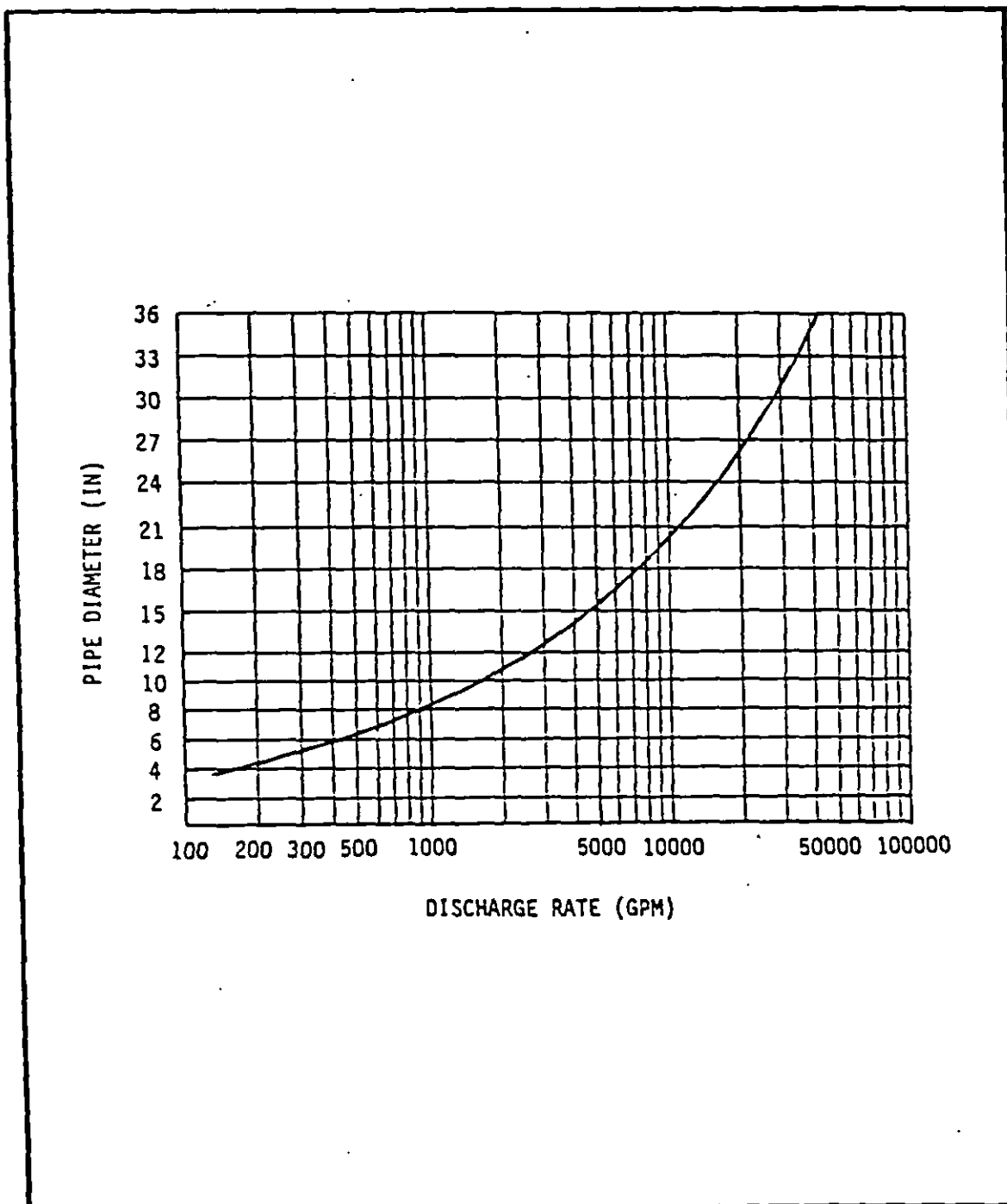


Figure 51  
The Effect of Pipe Diameter on Discharge Rate of Liquid  
(Vitrified Clay Pipe Having a Slope of 1/4 Inch Per Foot)

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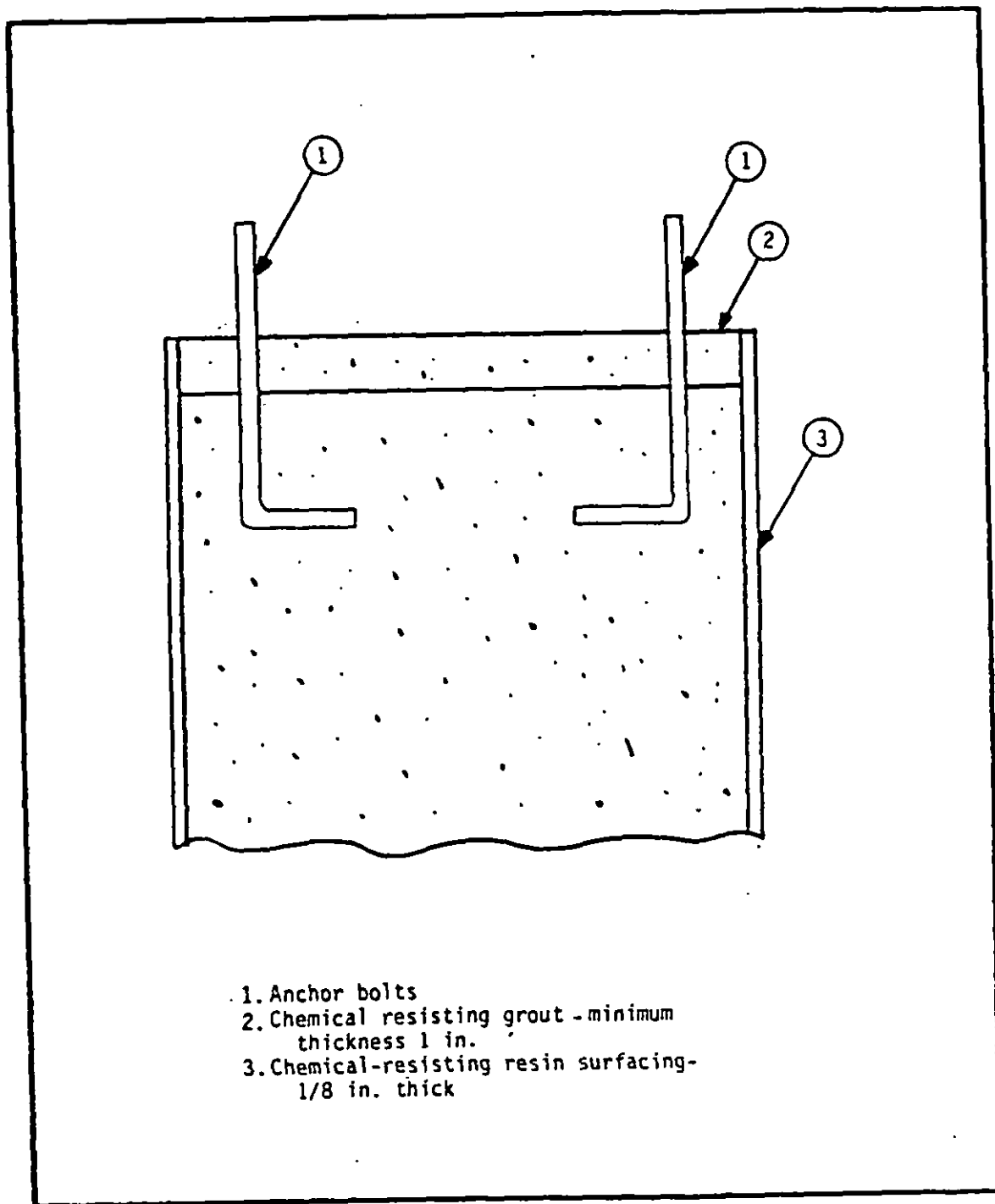


Figure 52  
Detail of Foundations and Piers

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A reduced-pressure, back-flow preventer conforming to the American Water Works Association (AWWA) Specification C506, Backflow Prevention Devices--Reduced-Pressure Principle and Doublecheck Valve Types, shall be installed in all municipal waterlines supplying tanks to prevent contamination of the water supply. Piping layouts for deionized water distribution system, and for municipal water system, and for municipal water distribution system are required. The distribution systems are to be electrically isolated from the tanks these systems are servicing. Each distribution system is to be identified as to the water it carries, i.e., deionized water or municipal water, and the identification used is required to conform to MIL-STD-101, Color Code for Pipelines and for Compressed Gas Cylinders. The distribution systems are to be convenient to the place of use, i.e., water makeup, rinsing, flushing of solids from tanks, cleaning walls and floors, and similar requirements.

9.2.2 Electrical Power. Rectifiers should be housed in a separate room isolated from the plating floor, but with access from this floor. The location of this electrical power supply room should be central to the baths which it serves, near the loading dock for access and servicing from the exterior of the plating facility, and isolated from the fumes from the baths. Since the power supplies must operate within their designed temperature range, provision must be made for adequate air circulation, and possibly air conditioning, when all the equipment is in operation. Equipment supplying electrical power shall be approved for wet and damp locations.

Ventilation required for motor-generator sets is calculated as shown in Equation (18).

$$\text{EQUATION:} \quad V = 100(E_1 - E_2) \quad (18)$$

Where:  $V$  - Ventilation, (cfm)

$E_1$  - Power input, kW

$E_2$  - Power output, kW

Ventilation of rectifiers is in accordance with NEMA, Metallic Rectifier Section for "Unusual Service Conditions", and is as follows:

a) Ambient air temperature at the equipment above 41 degrees F (5 degrees C) and not exceeding 104 degrees F (40 degrees C).

b) Average incoming cooling air temperatures not exceeding 86 degrees F (30 degrees C) during any 24 hr period.

c) Amounts of cooling air as specified by the rectifier manufacturer.

d) If the air is restricted by air ducts, then the rectifier manufacturer is required to be consulted for information on the cfm rating of the unit.

This room should have not less than three ft of space around each power supply for maintenance and repair, and if a part of any one of these

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power supplies requires more space for removal without unbolting the equipment from the floor, then this space should be provided.

9.2.2.1 DC Power. The method of wiring the electrodes of the electroplating systems is shown in Figure 53.

9.2.2.2 Pulse Plating. Pulse plating is controlled interrupted electroplating. Electrodeposition proceeds on the "ON" cycle, and is interrupted during the "OFF" cycle. Metal ions are depleted from the cathode layer during "ON" and replenished during "OFF". Pulse rectifiers are designed to control the duty cycles to generate four types of wave forms plotted as current/voltage vs. time, i.e., square, asymmetric sine, split sine, or periodic reverse square wave. Some of the advantages claimed for pulse plating are shown in Table 33. Pulse rectifiers are available in the range of 0.1 to 5000 A. At 1000 A and above, a pulse plating converter is placed between the direct current rectifier and the plating bath. This arrangement of a converter has the advantage of using available rectifiers and a fast rise time for the pulse (Short cables are necessary between the dc rectifier and the converter.). The converters provide pulses in the 1 to 1000 millisecond and 1 to 10,000 microsecond ranges, and are rated at 30 A peak current. There are square-wave pulse power supplies that provide 5 to 2000 A at the peak with average amperages of 3 to 1000 A and frequency ranges of 20 to 50,000 Hz.

### 9.2.3 Air (Heating, Cooling, and Ventilation)

9.2.3.1 Design of Air Distribution System. The distribution system for air shall not interfere with the plating operations. Sufficient clearances are required for hoists and cranes. Moveable covers are required for various finishing operations as vibratory finishers, centrifuges, and electropolishing tanks. The system shall be isolated from equipment that would cause the cover to vibrate. The heating, ventilation and air conditioning (HVAC) shall not interfere with local exhaust systems used to exhaust toxic contaminants.

9.2.3.2 Materials for Air Distribution. The materials selected shall be corrosion-resistant as recommended in para. 10.6.4, and are either nonconducting or electrically isolated from current-carrying equipment.

9.2.3.3 Energy Loads. In computing the energy requirements for the system, the energy generated or consumed by the plating processes and associated equipment must be taken into account for selection of heating, ventilating, and air-conditioning (HVAC) equipment. The interaction of HVAC loads with process operating energy loads shall be considered when designing the HVAC, and the bath auxiliary cooling and heating systems.

### 9.3 Containment of Fluids

9.3.1 Dikes and Sumps. Bulk chemical storage facilities, drum storage areas, and tanks should be provided with dikes or sumps to confine spills and leaked chemicals in a manner that facilitates detoxification and neutralization. Access of spilled and leaked chemicals to waste treatment systems shall also be designed into the system. If a tank should overflow while being filled, the overflow shall not drain on floors or personnel. The overflow should be piped and disposed of properly.

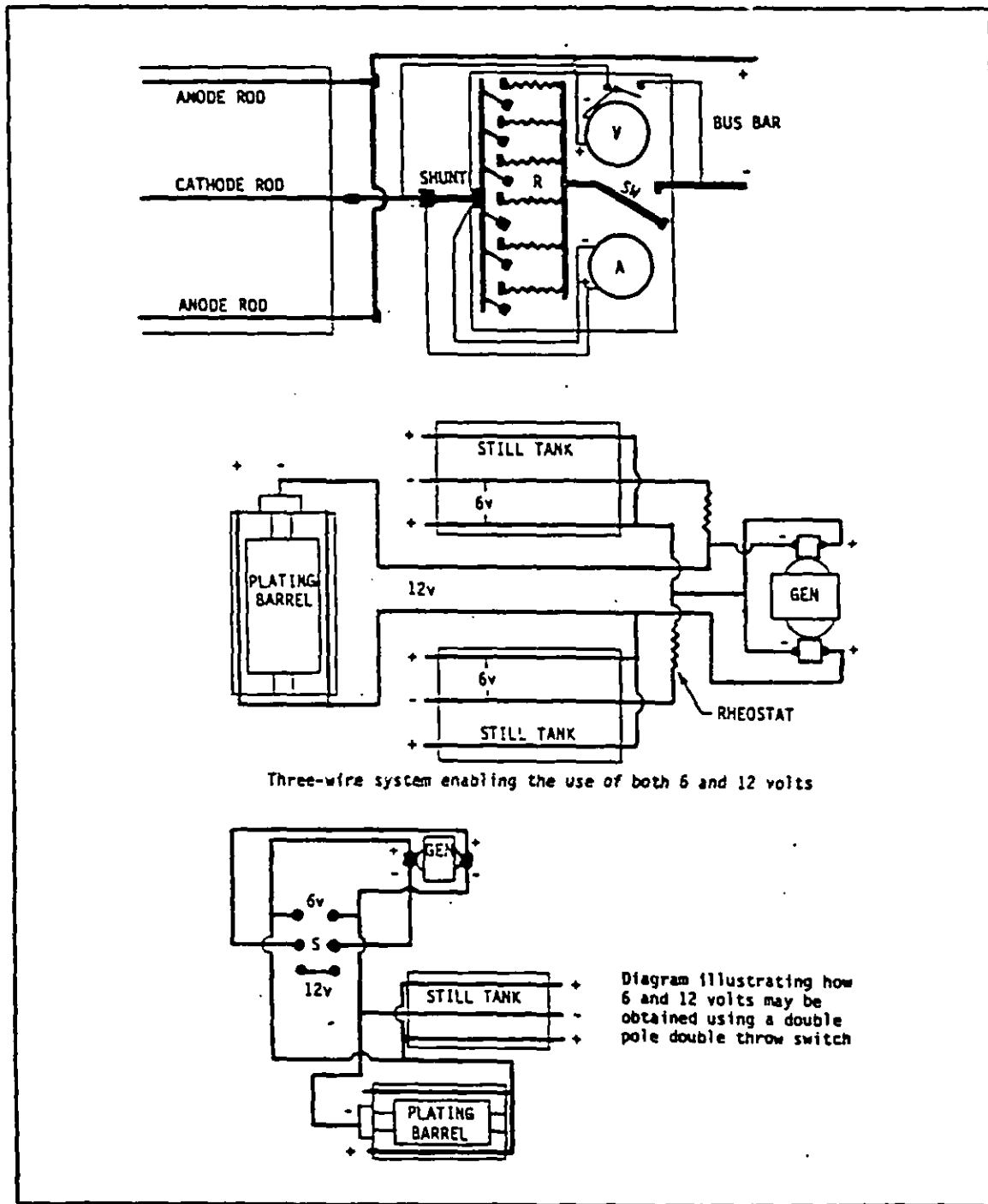


Figure 53  
Methods of Electrical Distribution to the  
Electroplating and Anodizing Tanks

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Table 33  
Applications of Pulse Plating

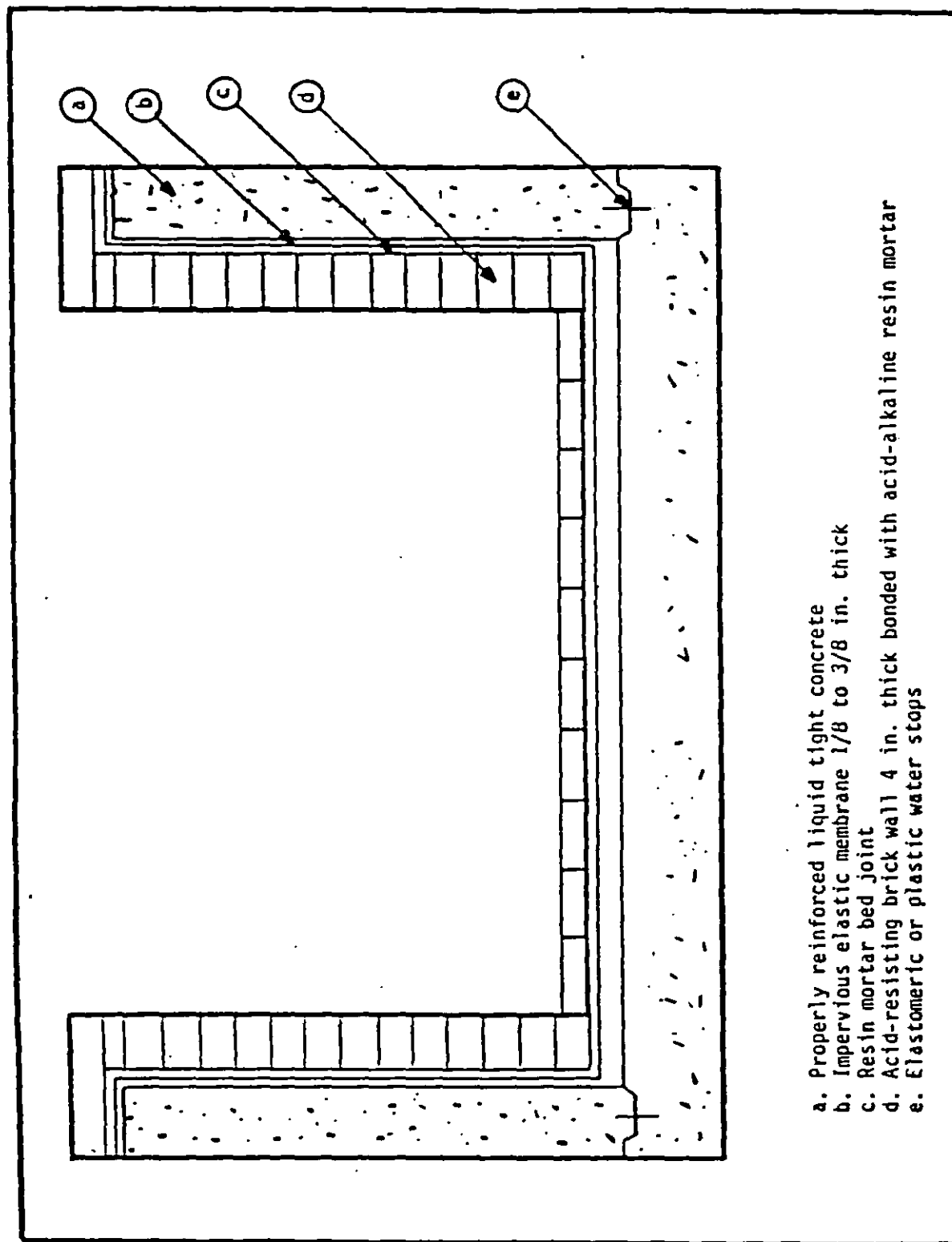
METAL	APPLICATION	REMARKS
Copper	Circuit Boards; electroforming; barrier layers; current-carrying parts for electronics	Finer grain; better throwing power, lower electrical resistance; improved ductility; reduced thermal embrittlement; better adhesion; improved distribution.
Nickel	Electroforming; barrier layers; circuit boards; electrical contacts	Finer grain; hardness can be controlled by pulse duty cycle; less hydrogen codeposition; better thermal shock stability; stress can be controlled with pulse parameters.
Gold	Circuit boards; electrical contacts; decorative parts; electronic components	Better distribution; finer grain; reduced porosity, aesthetic improvements.
Chromium	Hard chromium for technical applications	By varying pulse duty cycle, deposit can be made stress-free, crack-free, or normal, highly stressed/micro-cracked.
Silver	Electronics and decorative work	Finer grain; superior reflectivity; lower electrical resistance; reduced porosity.

9.3.2 Sump Design. Fluids which are discharged or are spilled on the floor are to be segregated as follows: chromium containing solutions, cyanide containing solutions, precious metal solutions, cadmium containing solutions, acidic solutions, and alkaline solutions. A typical sump tank design is shown in Figure 54. The floor design is to provide for the segregation of the aforementioned solutions so that they are not mixed.

9.3.3 Processing of Solutions. Solutions in the sumps are to be processed using general guidance given in Section 10.

#### 9.4 Dry Storage of Chemicals, Anodes, and Racks

9.4.1 Dry Storage. Factors enumerated in para. 9.8.2 shall be considered in the storage of all material. The shelves or storage areas shall be appropriately labeled and have convenient access and removal from the storage areas. The areas are to be near the point of use to reduce traffic



- a. Properly reinforced liquid tight concrete
- b. Impervious elastic membrane 1/8 to 3/8 in. thick
- c. Resin mortar bed joint
- d. Acid-resisting brick wall 4 in. thick bonded with acid-alkaline resin mortar
- e. Elastomeric or plastic water stops

Figure 54  
Design of Sump Tanks for Chemical Wastes or Neutralizing Chemicals



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over the plating floor. The area's traffic, by movement of stored items, shall be suitable for the loads moved over these floors and are to be smooth. Where required fire safety as well as appropriate precautions regarding the mixing of toxic materials shall be observed.

9.4.2 Dry Chemical Storage. Dry chemical storage requires the separation of dry acids, such as chromic acid, boric acid, citric acid, and oxalic acid, from alkaline materials such as potassium cyanide, sodium cyanide, calcium hydroxide, sodium hydroxide, and potassium hydroxide. Oxidizing solids and liquids like chromic acid and sodium peroxide are to be segregated from organic materials and reducing agents such as sodium nitrite or activated carbon. Hygroscopic materials are to be protected with specific efforts to separate alkali hydroxides and cyanides from the dry acids. The separation is required to take into account auto-combustion and the possible flooding of areas containing toxic materials. Hazardous material storage should be in accordance with NAVSUPINST 5100.27 C15, Navy Hazardous Material Control Program (Aug 85). Air conditioning, dehumidifiers, and heating are to be considered in the storage areas. Heavy containers should be placed on lower shelves. Cyanides and acids are not to be stored over one another.

9.4.3 Anode Storage. Anodes are stored in bins. The anodes may be stored in hot or cold areas. If large numbers are consumed at one time or replacement occurs at one time, anodes are stored to facilitate movement by fork-lift truck or hand carts. Anodes may be stored together with dry acids and dry alkaline chemicals, provided no leakage of containers occur which may damage or contaminate the anodes.

9.4.4 Rack Storage. Racks are stored under racking tables. If the undertable storage is insufficient, additional space may be obtained near the machine shop which is a convenient area for repair storage, or in overhead storage bins.

## 9.5 Wet Storage of Chemicals

9.5.1 Wet Chemical Storage. Wet chemical storage is to be convenient for the user. If continuous feed of chemicals is required, then storage of the wet chemicals is over the appropriate tank or led to the tank through appropriate piping. This piping shall be color coded and labelled in accordance with MIL-STD-101, NAVSUPINST 5100.27 C15, and ANSI A13.1, Scheme for the Identification of Piping. Separation of acids, alkalis, and cyanides from each other and the other stored chemicals is required so that there can be no accidental mixing of these chemicals. In addition, oxidizing and reducing agents shall be segregated in order to prevent fires. Examples of fires caused by auto-ignition when chemicals are mixed are potassium permanganate with sodium nitrite, hydrogen peroxide with rust-preventive compound and nitric acid with wood chips. Wet chemicals shall be prevented from freezing or overheating. The access shall be convenient for operators and for delivery to point of use.

## 9.6 Provisions for Racking Items to be Plated

9.6.1. Racking of Items. Areas for racking the items shall be convenient to the plating floor. The height of the racking tables shall be sufficient so that the operators need not bend or stoop to do the work. The area is to be

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lighted so that minimal shadows are cast over the work area. A suitable layout for racking tables is shown in Figure 55.

### 9.7 Corrosion Resisting Materials and Use of Organic Coatings for the Structure and Processing Equipment

9.7.1 Corrosion Resisting Structural Material. Material in the plating floor area shall be resistant to spills and fumes encountered in plating operations. FRP grating for deck covering and walks is suitable in most areas.

9.7.2 Organic Coatings. Organic coatings used for wall coatings shall conform to NFGS-09815, High-Build Glaze Coatings. These formulations shall be resistant to acid and alkaline spills and splatter. Ceramic tile conforming to NFGS-09310, Ceramic Tile, Quarry Tile, and Paver Tile, may be used instead of high-build glaze coatings. Metal doors, frames, supports, tank exteriors, and other metal sections not in direct contact with electrolytes and other solutions are to be protected as indicated in NFGS-09910, Painting of Buildings (Field Painting), using the guidance found in Maintenance Operating Manual MO-110, Paints and Protective Coatings. These organic coatings are to be impact resistant, or plastic sheeting is to be used to protect metal products from impact. Vinyl coatings, epoxy-polyester coatings, and polyester coatings are recommended finishes, but other acid and alkaline resistant finishes may be acceptable.

### 9.8 Plant Layout for Safety and Efficiency

9.8.1 Safe Plant Layout. Provisions for separation of alkali liquids, dry acids, wet acids, and cyanides shall be provided for safety. Solvents shall be segregated from high temperature areas. Noise and dust generating equipment, such as buffing machinery and abrasive blasters, are to be isolated from (the plating floor) personnel except for those requiring access to this equipment. The plating floor shall be open for renovation and easy exiting, with two doors opening outward, which includes one to the exterior of the building in case of explosion. The laboratory and selective plating areas shall have two exits, one each to the exterior and one each to the plating floor. The exit for flow and analyses of work, and in addition exit to the exterior are for egress in case of accident. Lavatories should be near the lunch room so that personnel may wash prior to eating. Lavatories, or equivalent areas, should be equipped with shower facilities and personal locker areas. Access to equipment and facilities shall be provided so that personnel may conveniently perform their operations and maintenance, and inspection of equipment.

9.8.2 Plant Layout for Efficiency. An important consideration in the efficient operation of the plant is the workflow into the plating shop, from the receiving of work to its exit. The offices should be located near the main entrance to monitor personnel entering and leaving the facility. The laboratory should be directly connected to the plating floor in order to provide assistance to the plating personnel. Plating personnel should have easy access to the storage facilities, chemicals, and ovens, as well as receiving area. The plating area should be sufficiently large to allow space between processing tanks for inspection and maintenance, as well as retrieval of material falling between them.

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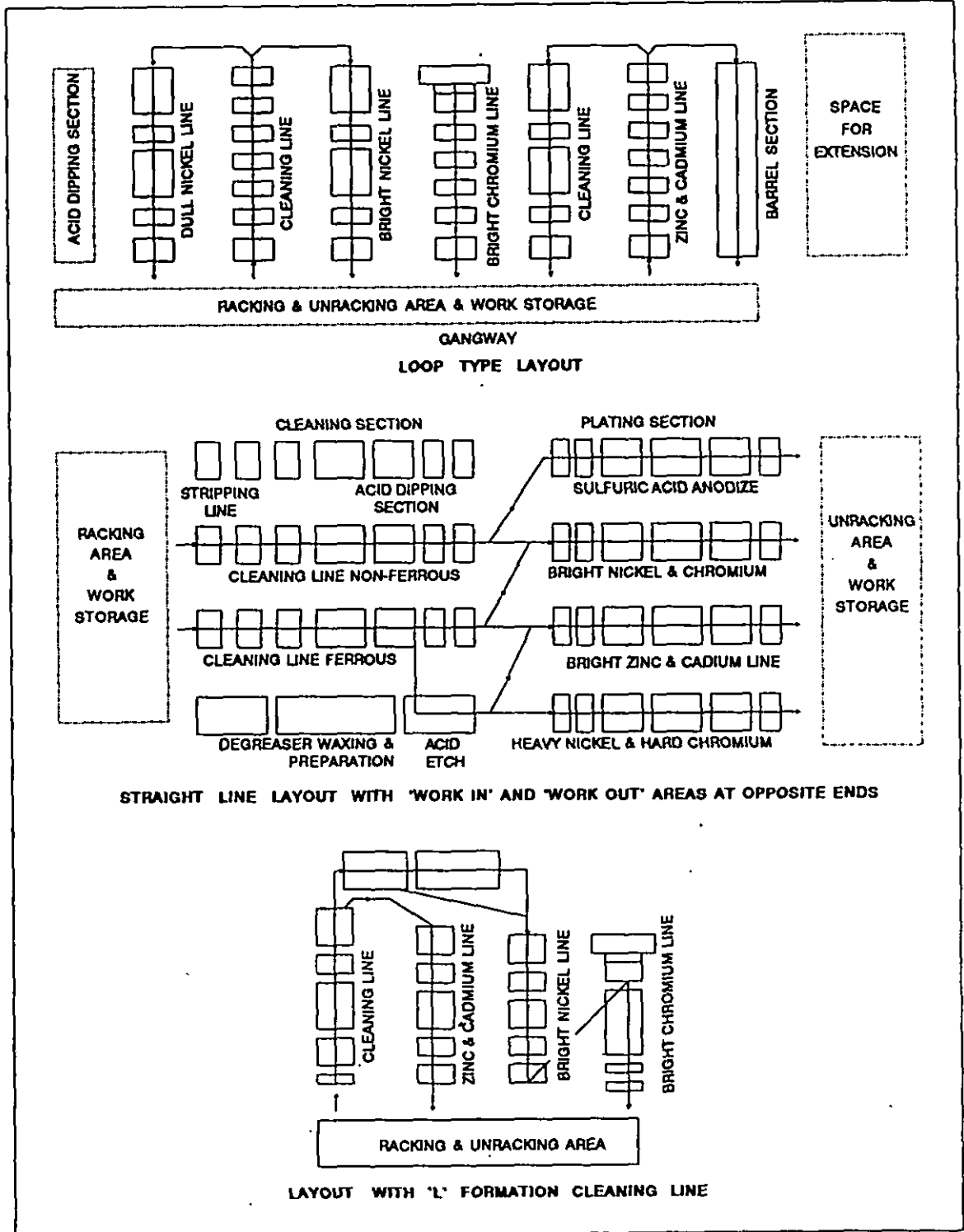


Figure 55  
Typical Floor Layouts Showing Racking Areas

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9.8.3 General Features. The general features of typical plant layout is provided as an example in Figure 56.

9.9 Safety Equipment

9.9.1 Charts and Bulletin Boards. Spill control and antidote charts are to be placed in prominent locations for use by personnel on the plating floor and in the laboratory.

9.9.2 Emergency Eyewash and Shower. Eyewashes and deluge showers are to be placed for easy access by all personnel and in compliance with ANSI Z358.1. If there is danger of loss of municipal water pressure, then a separate water supply is to be provided in addition to the municipal water supply.

9.9.3 Liquid Handling and Storage. Corrosive liquids and hazardous fluids including combustible and toxic fluids are to be provided with storage, handling and transfer equipment as described in para. 9.4 and 9.5, and must comply with the local, state, and federal regulations. The storage of chemicals and hazardous plant streams must comply with the requirements of DoD 4145.19-R-1 and NAVSUPINST 5100.27.

9.9.4 Warning Equipment. Fire protection shall be provided as required; refer to MIL-HDBK-1190. Where specified, carbon dioxide fire extinguishing systems are to be provided and shall conform to NFGS-15361 for high pressure and NFGS-15362 for low pressure.

9.9.5 Personnel Equipment. Protective clothing, including gloves, eyeshields or goggles, and shoes are to be used and provided with appropriate storage space such as lockers.

9.9.6 Signage. Signage shall meet NAVSUPINST 5100.27, and OSHA 29 CFR 1910.1200, in addition to MIL-STD-101. The signage shall be placed in accordance with ANSI A13.1.

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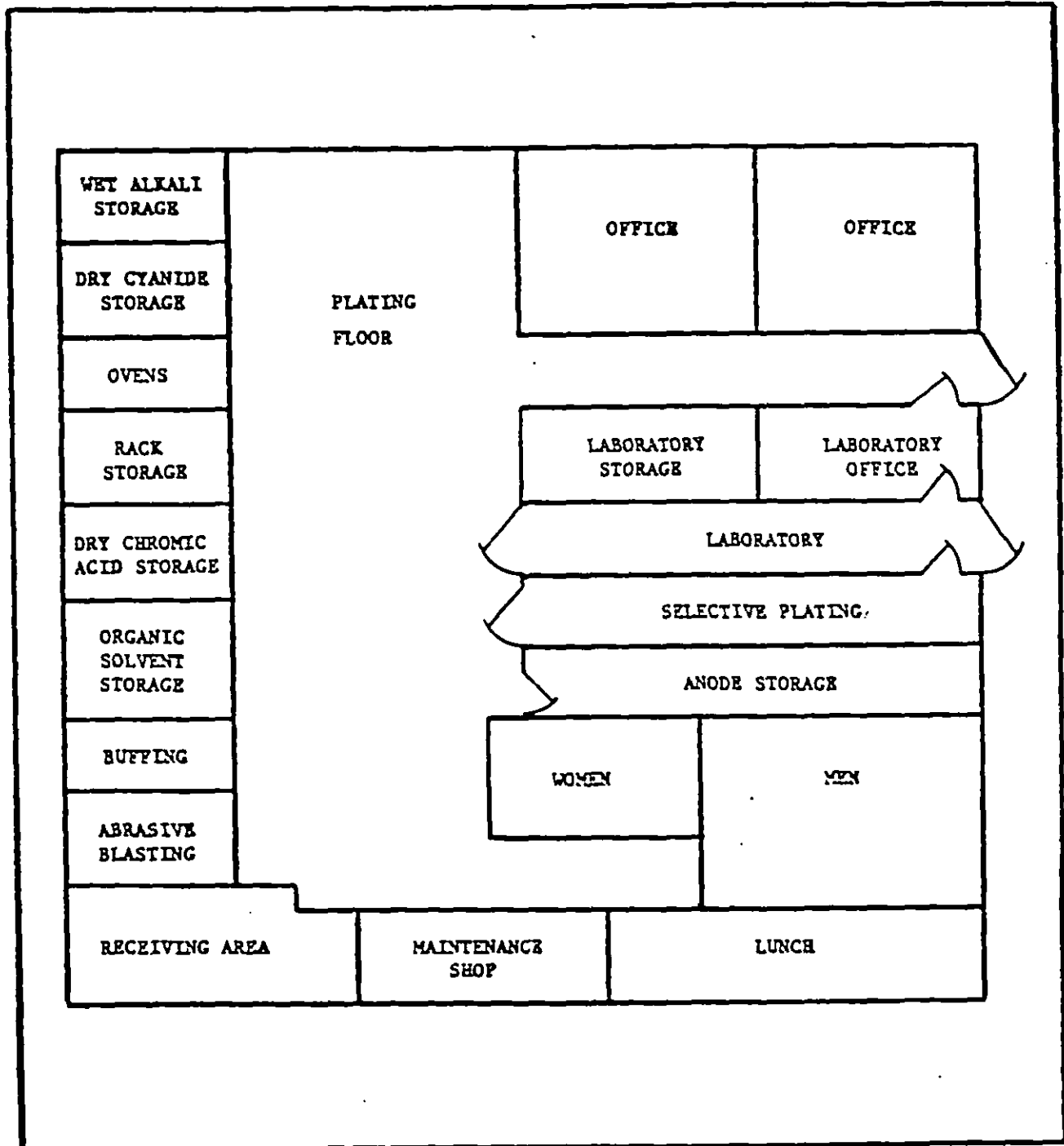


Figure 56  
Plant Layout

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## Section 10: POLLUTION ABATEMENT

10.1 Potential Pollution Sources

10.1.1 Liquid Sources. An electroplating process includes a succession of operations starting with the cleaning of the parts in various solutions, followed by electroplating in electrolyte baths (operating solutions), and final rinsing and drying of the parts to yield an electroplated product. In general, like in any other processing facility, there are liquid, gaseous, and solid discharges from an electroplating facility. Liquid streams that have to be treated and discharged arise from (water) rinsing operations; from spills; from ventilation air scrubbing; from tank dumps; from auxiliary operations like rack stripping; and from washing equipment like filters, pumps, and tanks. Cooling water is generally reused for rinsing purposes; if not reused, then its discharge must be monitored for leaks in cooling units. A typical water flow in an electroplating facility that does not use resource recovery is shown in Figure 57.

10.1.2 Gaseous Sources. Air, used to ventilate toxic vapors and mists at various processing sites like chromic acid baths and vapor degreasers, needs to be scrubbed before discharging to the atmosphere. Air used to ventilate processing areas and buildings may also need to be scrubbed as dictated by operating conditions and building layouts. Scrubbing of the gaseous streams is generally sufficient to meet requirements of the air pollution regulations.

10.1.3 Solid Sources. Solid/sludge discharges result from tank dumps, resource recovery equipment, and waste treatment equipment. They may have to be contained and then sent to acceptable hazardous waste sites or treated for disposal.

10.2 Pollution (Environmental) Control Technology

10.2.1 Liquid Discharges. Liquid stream discharges from the electroplating facilities are treated separately as appropriate to meet pollution control regulations and then generally in a common waste treatment process prior to discharge into natural aquifers/streams. Another approach that is being adopted is the use of resource recovery processes to recover chemicals from rinsewater streams for reuse in the electroplating processes and close control of electroplating baths by filtration and bath replenishment. MIL-HDBK-1005/8, Domestic Wastewater Control, is to be used for the design of a waste treatment facility with or without a resource recovery system. This handbook will cover the resource recovery process and bath control systems.

10.2.2 Gaseous Discharges. Gaseous discharge streams are from the exhaust systems used to ventilate plating rooms, plating baths where certain mists and gases are generated, areas where abrasive or impact blasting is performed, and areas where chemicals including organic solvents are used and stored. Among the gases or fumes that are removed by ventilation of plating facilities (including waste water systems) are oxides of nitrogen, hydrogen chloride, hydrogen cyanide, cyanogen chloride, sulfur dioxide, chlorine, chlorinated hydrocarbons, and hexavalent chromium aerosols.

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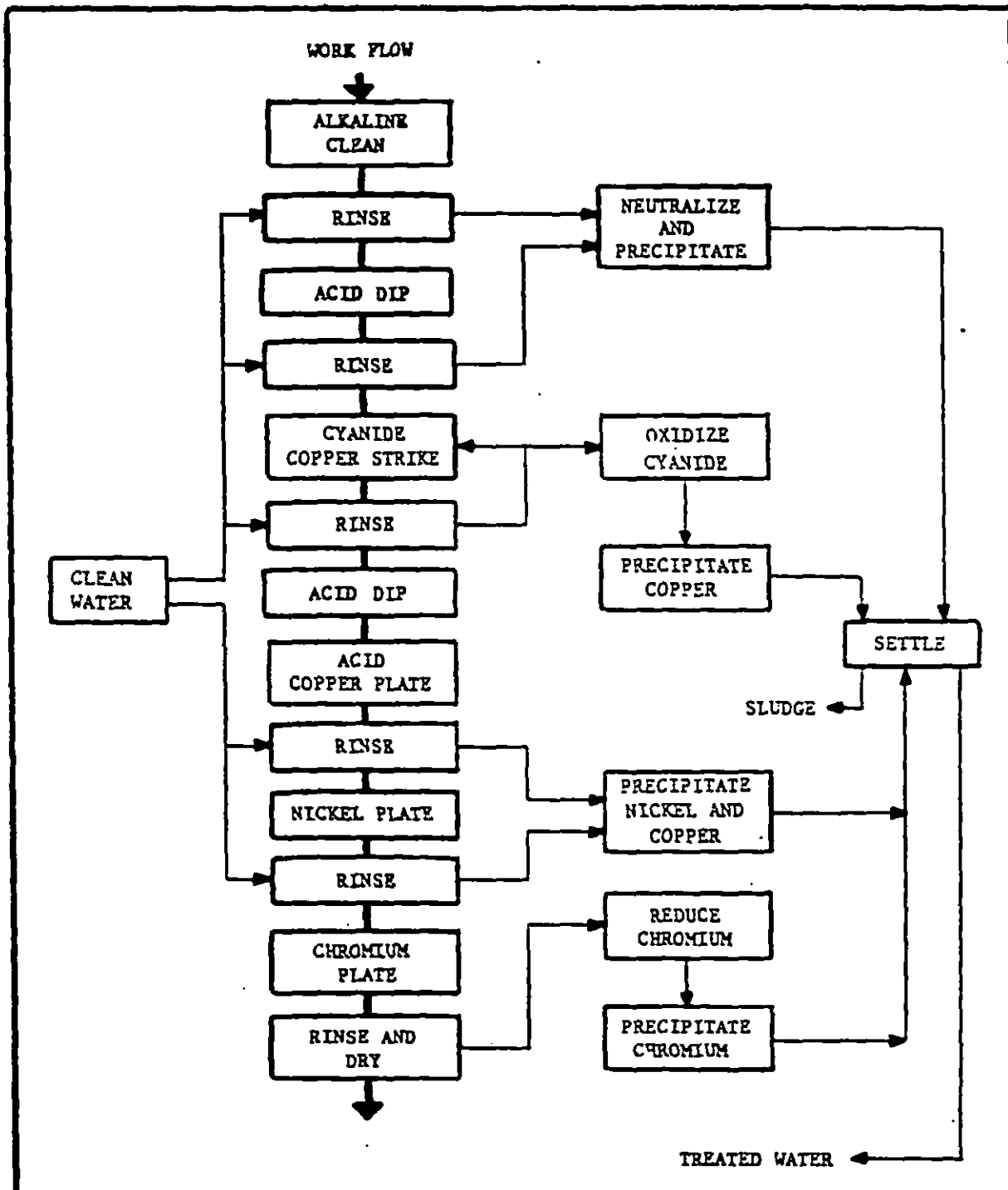


Figure 57  
Schematic Flow Chart for Water Flow in Decorative Chromium Plating  
for Zinc Die Casting (Without Resource Recovery)

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Exhaust system emissions are controlled by the use of filtration, adsorption, and scrubbing equipment to meet the Environmental Protection Agency (EPA) air pollution regulations. Ventilation/exhaust systems are installed to protect personnel from exposure to toxic substances and to meet OSHA 29 CFR Part 1910.

10.2.3 Solid Discharges. Solid/sludge discharges from electroplating facilities include both toxic wastes and nontoxic wastes. They are safely disposed to protect the public from exposure and to meet the EPA regulations. Procedures and considerations for the design of disposal systems and sites are given in MIL-HDBK-1005/8.

### 10.3 New Methods of Plating Waste Control for Electroplaters

10.3.1 Pollution Sources. There are other sources of pollution in plating shops, such as leaks from process tanks and floor drippings, but the major sources of pollution are drag-out in rinse waters and spent process solutions. Therefore, the practical approach to controlling plating waste is to concentrate on these two sources. However, the pollution load characteristics of rinse water and spent baths differ. Rinse waters are generally dilute but are large in volume, while spent solutions are usually small in volume but concentrated. These two pollution sources should be handled differently. It is the different characteristics of the two pollution sources that is the basis for the new methods of waste control for electroplating shops. These characteristics are described below.

10.3.2 Pollution Load Characteristics of Rinse Waters. The concentrations of individual metals in the untreated discharge from electroplating range from 10 to 20 mg/L. EPA regulations for individual metals are about one mg/L. If most of the drag-out is captured before the work piece is rinsed, then the rinse water could meet EPA standards without treatment. Platers have long used a single drag-out tank to minimize the contamination of rinse water and to conserve process chemicals. A single drag-out tank can rarely achieve enough drag-out control to meet discharge limits. The new methods carry the older drag-out control techniques a step or two further in order to achieve extra control for drag-out. Instead of one drag-out tank and a counterflow rinse tank, the new methods use two or more drag-out tanks and one rinse tank. In addition, the new methods make extensive use of recycled rinse water. The basic premise of the new methods for controlling wastewater is if the solution is dilute to start with, take steps to make it less concentrated so that it can be discharged without final treatment.

10.3.3 Pollution Load Characteristics of Spent Solutions. Spent process solutions are small in volume, but they are concentrated. Therefore, they should not be handled like rinse waters. In a conventional treatment system, spent baths are trickled into the facility's rinse water discharge for treatment with the rinses. In doing so, the concentrated solutions are first diluted in the rinse water and then their contaminants are removed and reconcentrated. It is more straightforward to treat the concentrated solution separately through chemical/physical means. The premise for the new method of controlling spent baths is if a discharge is already concentrated, try to concentrate it further for reuse, batch treatment, or disposal.



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10.3.4 Typical Electroplating Facility Discharges. Electroplating firms typically discharge large amounts of rinse water. In Cleveland, Ohio, for example, the average water consumption at 22 electroplating firms is 18,500 gpd. The discharge volumes at these firms range from 10,000 gpd at small shops to 150,000 gpd for very large electroplating operations. Conversely, electroplaters do not discharge large volumes of spent process solutions. The Cleveland firms each generate about 60 gpd of spent baths. However, the concentration of certain contaminants is much higher in spent baths than it is in plating rinse waters. Table 34 lists the concentration of seven pollutants in the rinse water from the Cleveland platers. The average concentration for each pollutant ranges up to 20 mg/L. Table 35 shows that spent process solutions are more concentrated than rinse water. A typical spent acid solution, for example, may contain three times the amount of zinc and nickel as a typical rinse water discharge.

Table 34  
Effluent Characteristics of 22 Cleveland Electroplating Shops

POLLUTANT	EFFLUENT CONCENTRATION	
	mg/L AVERAGE	
Cyanide, Total	14.4	
Copper	4.7	
Nickel	5.7	
Chromium, Total	20.2	
Zinc	19.3	
Lead	0.4	
Cadmium	4.3	

Table 35  
Analysis of Typical Spent Process Solutions from Cleveland Platers

POLLUTANT OR PARAMETER	SAMPLE SOLUTION	
	ALKALINE CLEANER	ACID DIP
Volume (gal)	325.0	65.0
Cyanide, Total (mg/L)	2.5	(a)
Cadmium (mg/L)	0.2	6.4
Chromium, Total (mg/L)	40.0	39.2
Copper (mg/L)	58.1	12.1
Nickel (mg/L)	6.9	128.0
Lead (mg/L)	4.4	11.6
Zinc (mg/L)	1.2	365.0

(a) Solution was not analyzed for particular pollutant.

The goals of the new methods of plating waste control are to avoid wastewater treatment and to minimize hazardous waste problems while meeting environmental regulations. Some of the material presented below may be similar to the one presented in para. 6.1.3. The text guidance presented in this section is considered essential for the pollution control of the plating shops.

10.3.5 New Methods of Plating Waste Control for Electroplaters. There are new methods of waste controls that are in widespread use in the plating industry. In several ways, these methods are similar to the traditional techniques. For one, they retain the basic features of traditional waste control such as properly designed rinse tanks, longer draining, and, in some instances, counterflow rinses. The new methods also depend on reducing drag-out and rinse rates, but the techniques are a little different, more effective, and less costly. The principal techniques used in the new methods are:

- a) Multiple drag-outs - a variation of single drag-out tanks
- b) Reactive rinsing - a technique for reusing rinse waters.

Rather than reduce the size of the final treatment equipment, the new methods of plating waste controls use multiple drag-out tanks and apply reactive rinsing techniques in order to avoid altogether the need for final treatment equipment. In instances where some final waste treatment is still necessary, the cost of the treatment is far less than it would be using standard techniques.

In para. 10.3.6 of this Section, the multiple drag-out technique is described and contrasted with traditional drag-out control measures. This section focuses on applying this technique. Using multiple drag-out tanks, the concentration of pollutants in a facility's discharge often can be reduced below acceptable effluent limits without further waste treatment.

In para. 10.3.7 of this Section, reactive rinsing is explained and compared with counterflow rinsing, which is the standard flow reduction technique.

In para. 10.4, the two techniques are integrated in a strategy for controlling wastes at plating shops. The strategy is essentially a framework for applying the new methods in order to control plating rinse waters and spent process solutions.

10.3.6 Drag-Out Controls Using 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, as Figure 58 illustrates, the multiple drag-out method uses several drag-out tanks and a single running

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rinse. Most of the drag-out is captured in the first tank, leaving the second tank less contaminated than the first. The resulting 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. Additional drag-out tanks can lower the discharge concentration by 50 percent. Two drag-outs are twice as effective as one, and three drag-outs are four times as effective as one.

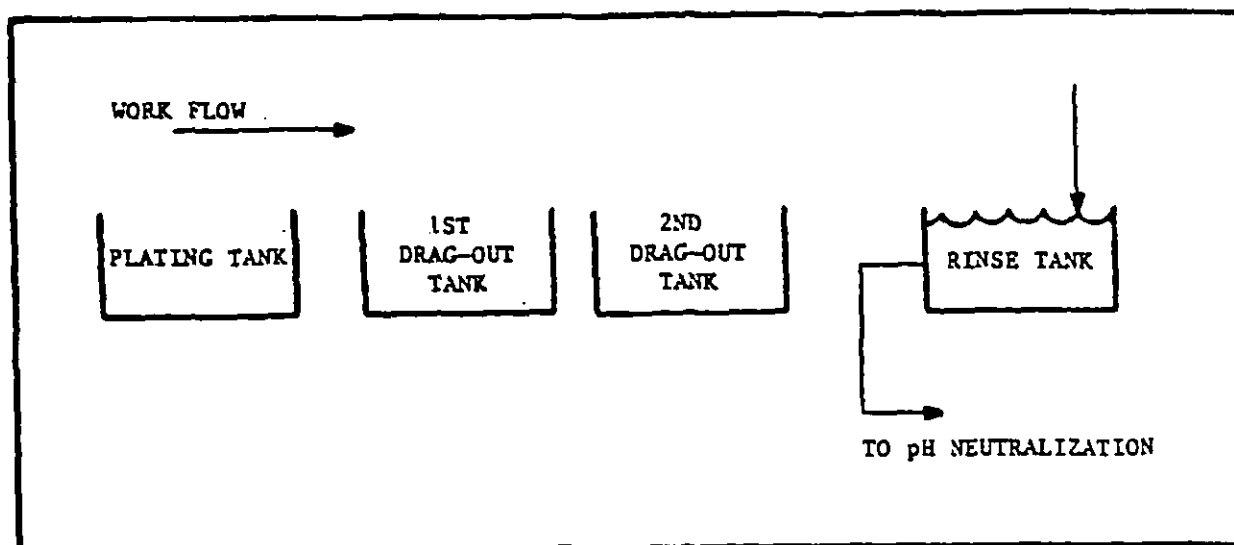


Figure 58  
Multiple Drag-Out

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 principal behind multiple drag-out tanks and a key feature of the new methods of plating waste control. 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:

- a) Concentration of the process solution
- b) Rate of drag-out
- c) Number and size of the drag-out tanks
- d) Rinse rate
- e) The number of rinse tanks in the plating shop.

#### 10.3.6.1 The Factors Controlling Pollution Concentrations in Rinse Water.

Figure 59 is a graph illustrating the effect of the factors identified above on the concentration of pollutants in a running rinse tank. The upper solid curve plots the discharge concentration over time from a rinse station without

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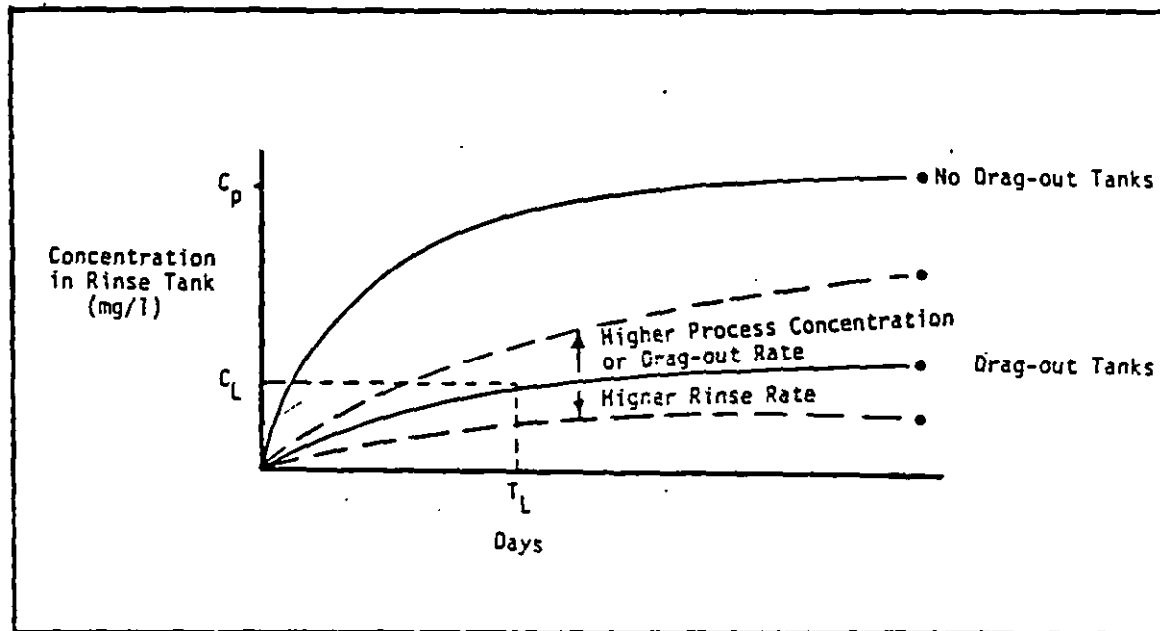


Figure 59

## Effects of Control Parameters on Rinse Tank Discharge Concentration

any drag-out tanks, and the lower solid curve plots the concentration for one with two drag-out tanks. The curve for one drag-out tank would fall between the two curves shown in the figure.

a) It takes longer for a two tank drag-out system to reach a certain concentration limit ( $C_L$ ) than a system without a drag-out tank or with only one drag-out. The curve for three or more drag-out tanks would fall below the curve for two drag-outs and take longer to reach a concentration limit in the discharge from the rinse tank.

The strength of the process solution also affects the concentration of pollutants in the rinse discharge. A high strength solution will pollute more quickly than a low strength solution and, consequently, the rinsewater will reach  $C_L$  sooner. The higher the drag-out rate, the quicker the rinse waters become contaminated. Figure 59 illustrates these effects for the two drag-out tank case. The solid curve is shifted upward for higher drag-out rates or highly concentrated process solutions and is illustrated by the upper dashed curve. The time to reach a specific discharge concentration is reduced. Lower values for these factors would shift the curve downward and increase the time to reach  $C_L$ .

b) Rinse rates have just the opposite effect. At higher rates, the curve shifts downward because dilution in the rinse tank is increased and the time to reach  $C_L$  is increased. The lower dashed curve illustrates this effect.

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c) If  $C_L$  is the effluent limit for the metal being plated then  $T_L$ , shown in Figure 59, indicates the time it takes a double drag-out rinse tank discharge system to reach this limit. This is the time at which the drag-out solutions must be replaced or purified if  $C_L$  is to be maintained in the discharge from the running rinse. Using two drag-outs,  $T_L$  usually ranges from 2 to 16 hr, depending on the process concentration and the rinse rate.

d) Actually, drag-out solutions need replacement far less frequently because government limitations apply to the facility's combined rinsewaters from all processes and not to individual rinse tank discharges. Most processes have four rinse tanks, so there is a four to one dilution within each process. Electroplating shops with five or more processes are common, and process dilution can increase  $T_L$  by a factor of "5 times 4" or at least 20. The time for a particular drag-out solution ( $T_L$ ) to be replaced in order to keep a facility's combined discharge below a government limitation ( $C_L$ ) will range from 5 to 40 working days (based on 8 hours of production per day). Figure 60 illustrates this effect. The drag-out is discharged without further treatment when it will meet government limits.

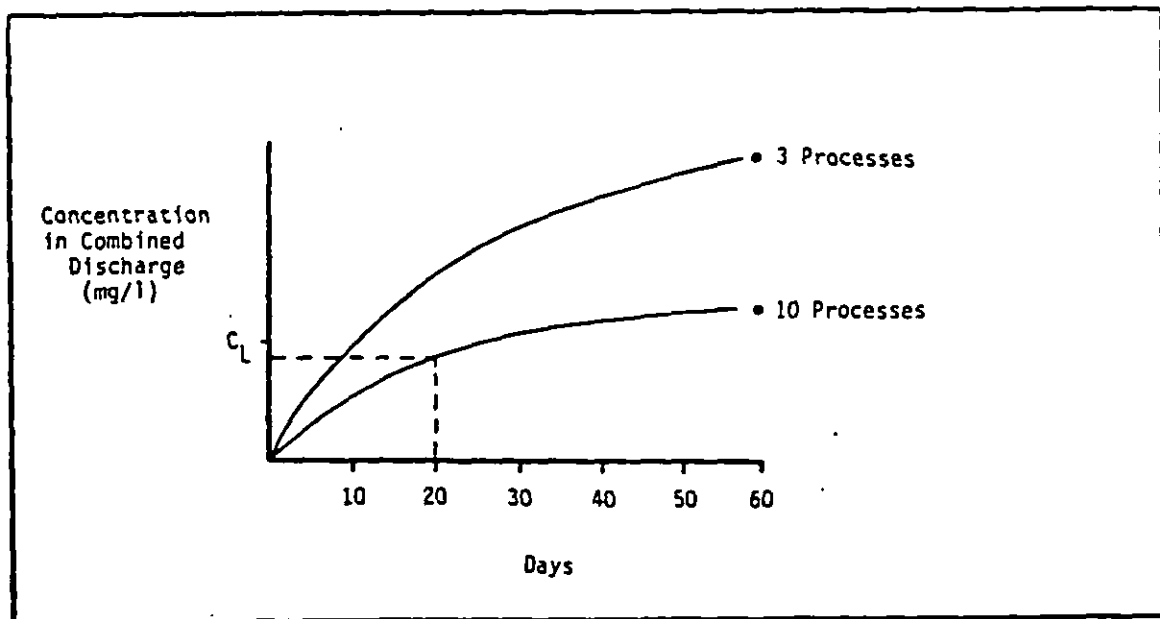


Figure 60  
Concentration in Combined Discharge

10.3.6.2 Managing Drag-Out Solutions. There are two techniques for discarding drag-out solutions. In the first, the entire volume of the first drag-out tank is drained when time " $T_L$ " is reached. It is replaced with the entire volume of the second drag-out tank, and the second drag-out tank is filled with freshwater in a two stage system. If there are more than two drag-out tanks, then the last one is filled with freshwater and the upstream tanks are replenished with solutions from the next downstream tank.

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Alternatively, drag-out solution can be trickled from the appropriate drag-out tank as in a slow counterflow rinse tank system. The advantage of this method is that a steady concentration is maintained in the running rinse instead of cycling from zero to the value that assures that  $C_L$  is not exceeded in the facility's combined discharge. The technique requires electronic controls to maintain the proper trickling rate.

There are three ways to handle discarded drag-out solutions:

- a) Recycle drag-out solution to the plating bath
- b) Treatment in place
- c) Batch treat onsite.

The application of these methods depends on the chemistry and operating conditions of the processes, and the size and location of the facility.

10.3.6.3 Recycle Drag Out Solution to the Plating Bath. The best alternative for managing drag-out solution is to return it to the process tank from which it came. Total recycle eliminates the drag-out from being a hazardous waste problem and conserves process chemicals. Returning drag-out directly to the process is possible if the process bath is hot and there is sufficient evaporation for the amount of solution dragged out each day.

Returning drag-out solution to the plating tank is a technique that should not be used indiscriminately, because it can affect plating quality. For example, copper pyrophosphate plating is a heated process, but contaminants build up in the bath due to chemical reactions that occur in the process solution. The drag-out will reduce this contamination. Since recycling drag-out returns the contaminants to the plating tank along with the process solution, drag-out recovery usually is not used for this plating process. There are many plating processes in use, and the generalized application of drag-out recovery is not appropriate for all processes. However, the technique can be used after most heated plating baths.

Many plating baths are operated at room temperature, and as there is little evaporation from them the drag-out cannot be returned directly to these processes. Table 36 lists common plating processes and their operating temperatures, and identifies those that are candidates for returning drag-out to the process. In instances in which drag-out cannot be recycled directly, advanced technology recovery techniques (refer to para. 6.1.3.8) such as reverse osmosis and evaporation can be used in plating shops to concentrate the drag-out into volumes small enough to be returned to cold process baths. There are two primary drawbacks to these techniques:

- a) They are expensive.
- b) They not only concentrate the excess solution in the drag-out tank, but they also concentrate the impurities in the drag-out.

When the concentrate is returned to the process, the concentrated impurities can contaminate the plating solution and impair the quality of the plating. The concentrate can be purified using ion exchange to remove impurities

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selectively, but this increases cost of recovery. In general, the following methods of handling drag-out solutions which cannot be returned to the plating bath are more cost effective than high technology controls.

10.3.6.4 Treatment in Place. When the drag-out solution cannot be returned to the plating tank, the next best alternative is treatment in place. A process called integrated treatment was developed several years ago by Lancy Laboratories, Zelienpole, Pennsylvania. It was primarily designed to complete in-process the first step in the two-step treatment of chromium and cyanide. The second step would be carried out in the final treatment system. Figure 61 illustrates the elements of the Lancy integrated treatment technique. A solution of treatment chemicals is circulated between the drag-out tank and a waste treatment reservoir. The advantage of the technique is that it eliminates the need to separate chromium and cyanide rinsewaters from the other plating rinsewater for conventional final treatment. As a result, waste treatment costs are lowered. However, integrated waste treatment still requires final treatment equipment for rinsewaters, which the new methods of plating waste control try to avoid.

Table 36  
Direct Drag-Out Recovery Potential of  
Electroplating Processes

PROCESS	OPERATING TEMPERATURE, °F	DIRECT RECYCLE OF DRAG-OUT
Alloy	60 - 100	S
Antimony	130	Yes
Arsenic	110	No
Brass	90	No
Bronze	70 - 160	S
Cadmium	70	No
Chromium	120	Yes
Copper	60 - 120	S
Gold	70 - 150	Yes
Indium	70	No
Iron	70 - 190	S
Nickel	70 - 160	S
Palladium	80 - 130	S
Platinum	200	Yes
Rhodium	110	Yes
Silver	70 - 120	Yes
Tin	70 - 120	S
Zinc	80 - 150	S

S - Some Processes

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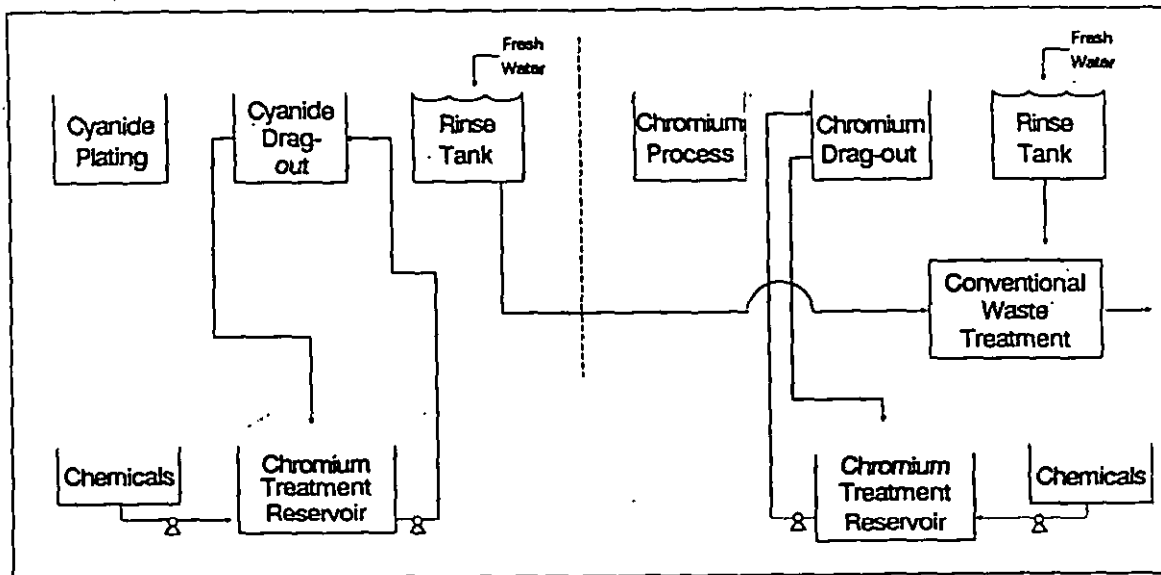


Figure 61  
Integrated Treatment for Chromium and Cyanide Plating Rinse Water

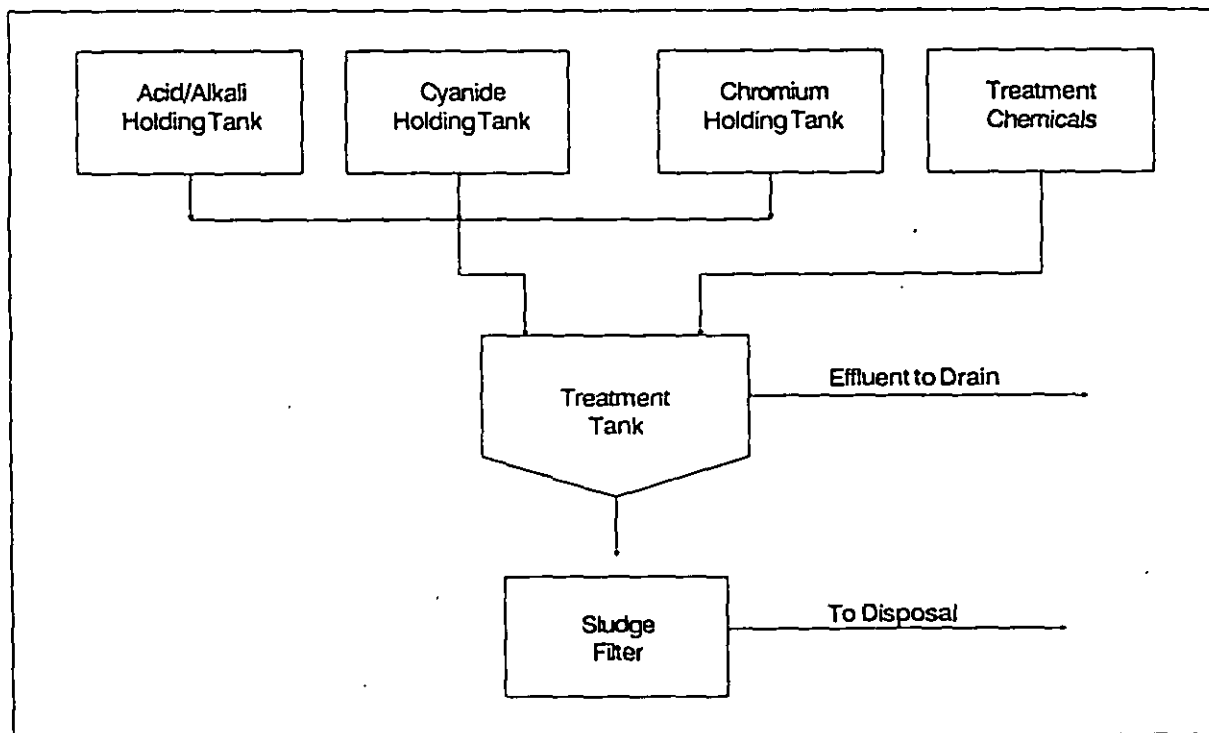


Figure 62  
Batch Treatment System



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10.3.6.5 Batch Treatment Onsite. If the drag-out solution cannot be returned to the process tank or treated entirely in place, it has to be chemically treated, usually in a batch treatment system. In these instances, the drag-out solution can be handled like other spent electroplating process baths.

In addition to drag-out solutions and spent baths, the plating shops' waste include cleaners, acids, and posttreatment solutions. Spent baths can be treated onsite in the batch treatment system or shipped offsite to a private waste treater. Central processing facilities that recover metals may be able to refine drag-out solutions and certain other spent plating baths.

A diagram of a batch treatment system for spent plating baths (including drag-out solutions) is shown in Figure 62. The solutions to be treated are discarded on a schedule, and the size of the treatment system is designed for the schedule specific to each plating shop.

10.3.7 Water Conservation Through Reactive Rinsing. Reactive rinsing technique description and discussion is given in para. 6.1.3.7.

The advantage of the reactive rinsing is that it is not expensive. In the example discussed in para. 6.1.3.7, two thirds of the original flow rate was saved without purchasing any additional tanks. The nickel rinse tank could be elevated slightly in order to gravity flow rinsewater to the receiving rinse tank. In the example, the nickel rinse would be raised above the acid rinse, which in turn would be raised above the cleaner rinse. Little head pressure will be needed to run rinse water through the three tanks. The system will work if the nickel tank is raised or even tilted on standard building bricks, and the acid rinse tank is elevated half that distance. If it is not practical to elevate the tanks, then inexpensive submersible pumps can be used to move the rinsewater. In contrast, counterflow rinsing, the conventional flow reduction technique, is many times more expensive than reactive rinsing, and its application is constrained by space limitations.

#### 10.4 Resource Recovery Systems

10.4.1 Chemical Recovery and Reuse. A number of techniques are available for recovering or reusing process solutions. Examples of chemical recovery and reuse are: reprocessing of oil, reclamation of oil, recycling of oil, reuse of spent etchants, recovery of metals from spent process baths, regeneration of etchants, drag-out recovery and recovery from mists. The costs and reduced availability of certain process solutions encourage recognition of process solutions as a valuable resource rather than a disposal problem.

Precious metal wastes produced include: gold, silver, rhodium, palladium, platinum, osmium, ruthenium, iridium, and indium. Due to the intrinsic value of precious metals, every effort should be made to recover them as an integral part of the electroplating operations. Recovery techniques for precious metal wastes include: evaporation, ion exchange, and electrolytic methods.

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10.4.2 Water Reuse. Reductions in the amount of water used can be realized through installation and use of efficient rinse techniques. Cost savings associated with water use reduction result from lower cost for rinse water and reduced chemical costs for wastewater treatment. An added benefit is that the waste treatment efficiency is also improved. Rinse steps may consume over 90 percent of the water used by a typical facility. Consequently, the greatest water use reductions can be anticipated to come from modifications of rinse techniques.

Rinsing is essentially a dilution step which reduces the concentration of contaminants on the workpiece. The design of rinse systems for minimum water use depends on the maximum level of contamination allowed to remain on the workpiece as well as on the efficiency or effectiveness of each rinse stage. Since the purpose of rinsing is to remove process solution drag-out from the surface of the workpiece, the best way to reduce the amount of rinsing required is to reduce the drag-out. A reduction in drag-out results in a reduction of waste that has to be treated. Drag-out is a function of several factors including: workpiece geometry, viscosity, surface tension of the process solution, withdrawal and drainage times and racking.

Commonly used rinse types include single running rinse, countercurrent rinse, series rinse, spray rinse, and dead, still, or reclaim rinses. The use of different rinse types will result in wide variations in water use. Table 37 shows the theoretical flow arrangements for several different rinse types to maintain a 1,000 to 1 reduction in concentration. Table 38 shows the mean flows (L/m<sup>2</sup>) found at a few plants for three rinse water-intensive operations.

By combining different rinse types, a plant can greatly reduce water consumption and in some cases form a closed loop rinsing arrangement. Some examples of primary rinse types and specialized rinsing arrangements include: closing the loop with a countercurrent rinse, closing the loop with spray followed by countercurrent rinse, closing the loop with countercurrent rinsing followed by spray rinsing, closing the loop with dead rinse followed by countercurrent rinsing, and closing the loop with recirculatory spray.

Another method of conserving water through efficient rinsing is by controlling the flow of feedwater entering the rinse tanks. Some flow control methods are: conductivity controllers, liquid level controllers, manually operated valves, and orifices or flow restrictors.

Table 37  
Theoretical Rinsewater Flows Required to Maintain a  
1,000 to 1 Concentration Reduction

TYPE OF RINSE	SINGLE			COUNTERCURRENT	
	SINGLE	SERIES		2	3
NUMBER OF RINSES	1	2	3	2	3
REQUIRED FLOW (gpm)	10	0.61	0.27	0.31	0.1

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Table 38  
Comparison of Rinse Type Flow Rates for Sampled Plants

OPERATION	RINSE TYPE AND MEAN FLOW (L/m <sup>2</sup> )			
	SINGLE STAGE	2 STAGE SERIES	2 STAGE COUNTER-CURRENT	3 STAGE COUNTER-CURRENT
Alkaline Cleaning	1504.	235.6	67.36	28.76
Nickel Electroplating	322.9	88.96	26.54	7.44
Zinc Electroplating	236.8	33.78	21.79	7.84

## 10.5 Bath Purification Systems

10.5.1 Purification Methods. Virtually all plating solutions eventually require purification for removal of impurities. Solutions containing wetting agents often require the most use of adsorption by activated carbon. When wetting agents are present and oil is introduced into the bath, the oil is dispersed throughout the solution and clings to the parts, causing peeling of electroplate or spotting of work. Solutions not containing wetting agents have a tendency to float oil to one corner depending on the recirculation pattern set up by the pump. Other purification systems include: combination of filtration and activated carbon, carbonate removal system for both  $K_2CO_3$  and  $Na_2CO_3$  by chemical precipitation or by refrigeration, dummy plating, and selective cation exchange.

10.5.2 Purification Selection. The choice of purification method depends on tank size, desired purification and availability of auxiliary equipment. Batch purification in a separate treatment tank is only necessary if continuous purification methods are inadequate. Table 39 shows recommendations for filtration and purification of plating solutions.

## 10.6 Ventilation/Exhaust Systems

10.6.1 Ventilation Rates. The rates for ventilating open surface tanks on a cfm/ft<sup>2</sup> basis are determined by formulas presented in the ACGIH 2080, Industrial Ventilation, Manual of Recommended Practice, latest edition, and MIL-HDBK-1003/17, Industrial Ventilation Systems. This method of determining the rates is accepted by OSHA. This handbook is to be used in the design of the ventilation systems including hoods, ducts, and fans. Push-pull systems are effective at approximately one-half the calculated rate. A safety factor is added to the calculated value for the area subjected to cross drafts or other conditions that affect the uniform distribution of airflow across the tank. Makeup air shall be provided to prevent cross drafts.

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Table 39  
Recommendations for Filtration and  
Purification of Plating Solutions

PROCESS	pH	TEMPERATURE °F	FILTRATION	TURN- OVERS* /hr	FILTER TUBES /100 gal	FIBER/ CORE	MICRON POROSITY	CARBON TREATMENT
Anodizing	1	60-90	Optional	1	1	U/U	15	No
* Ni seal	5.5	200	Desirable	2	2	U/S	15	Batch
Brass, Bronze	10	100-200	As Required	2	2	U/U	15	No
Cadmium	12	100	As Required	2	2	U/U	30	No
Chromium Hexavalent	1	110-130	Optional	1-2	1-2	U/U	15	No
Chromium Trivalent	2-3.5	75	Continuous	2	3	U/U	1-5	No
Copper Acid	1	75-120	Continuous	2-3	3	U/U	15	Periodic
* Cyanide	11-13	70-150	Continuous	2-3	3	U/U	15	As Needed
* Electroless	14	100-140	Continuous	1-2	2	U/U	3	No
* Fluoborate	1	70-120	As Required	1	1	U/U	15	As Needed
* Pyrophosphate	8-9	110-130	Continuous	2-3	2	U/U	10-20	As Needed
Gold Acid	3-6	80-125	Continuous	2	2	C/U	1-5	Periodic
* Cyanide	7-12	75	Continuous	2	2	C/U	5	Periodic
* Lead Fluoborate	1	100	Continuous	1	1	U/U	15	No
Nickel Bright	3-5	125-150	Continuous	2-3	2-3	C/U	15-30	Yes
* Semibright	2-5	130	Continuous	2-3	2	C/U	15	Yes
* Chloride	2	120-150	Continuous	2-3	2	C/U	15	Yes
* Electroless	4-11	100-200	Continuous	2-3	2	U/U	15	As Needed
* Sulfamate	3-5	100-140	Continuous	2-3	2	C/U	15	Yes
* Watts	4	120-160	Continuous	2-3	2	C/U	15	As Needed
Rhodium	1	100-120	As Required	1-2	1-2	U/U	5	Periodic
Silver Cyanide	12	70-120	Continuous	2	2	C/U	5	Periodic
Tin Acid	0.5	70	As Needed	1	1	U/U	15	As Needed
* Alkaline	12	140-180	As Needed	3	3	C/U	30	No
Tin-Lead (solder)	0.5	100	Continuous	1	1	U/U	15	Periodic
Zinc Acid Chloride	5-6	70-140	Continuous	2	4	U/U	15	As Needed
* Alkaline	14	75-100	As Needed	2-3	3	U/U	30-50	Optional
* Cyanide	14	75-90	Continuous	2-3	3	C/U	30-100	No

\*Of tank volume with good cleaning cycle. With high dirt load, increase by 50 to 100%.

C-Cotton

U-Polypropylene

S-Corrosion Resisting Steel

Depending on tank size and space, select appropriate in-tank or out-of-tank pump with non-metallic solution contact.

Either seal-less magnetic or mechanical seal pumps are most common. For electroless plating solutions, a water flushed double mechanical seal pump is best.

10.6.2 Hood Design. Hoods should be designed to contain the contaminant as completely as possible, while providing access and working space to the tank. Air will move in all directions toward a suction opening, and must be directed in a manner that will provide the proper capture velocity while minimizing total airflow. Typical hoods are as specified in paras. 10.6.2.1 through 10.6.2.3.

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10.6.2.1 Canopy Type Hoods. They are not often used in plating shops because the operator is subjected to the fumes under the hood, and access to the working space is restricted. Such hoods may be used only for uncontaminated vapor or nontoxic fumes generated under the canopy.

10.6.2.2 Lateral Exhaust Hoods. They may be one side, two sides, or wrap-around type; arranged for updraft or downdraft; with duct takeoff at one end or in the center; or in the case of hoods over 6 ft (1.8 m) long, with multiple takeoffs. Side hoods are preferred for use where parts are to be dried after removal from baths.

10.6.2.3 Lateral Exhaust Hood With Push-Pull System. A push-pull system is essentially one in which air is blown on one side of the tank and is exhausted on the opposite side of the tank. This directs the entrainment of fumes to the exhaust inlet. The following considerations should be heeded in the design of push-pull systems:

a) Push-pull systems are not effective when major obstructions, such as elevated portions of or attachments to the work, or large anode bars, prevent a free flow of air across the tank. If operator access is interfered with then a push-pull system shall not be used.

b) Systems must be designed to provide means of adjustment of air supply and exhaust for satisfactory results.

c) Because of the high evolution of mist particles during chromium plating, push-pull systems are not as effective as two-sided lateral exhaust systems.

10.6.3 Ductwork. Ducts from hoods to fans and to ultimate point of discharge should be as short and direct as possible. They should be sloped toward drainage points, and drains should be provided at all low points. They should be located for easy access for cleaning and maintenance. Access doors should be provided for cleanout purposes. Special considerations to be given include:

a) At branch connections to hoods provide a damper for adjustment of airflow and to shut off exhaust from tanks not in use. Dampers may be of the quadrant type of compatible material or the sliding blast gate type. Balanced duct design is the preferred method of airflow adjustment, but if blast gates are used, they shall be tamper-proof.

b) Construction of PVC ducts should conform to ASTM D3299, Filament-Wound Glass-Fiber--Reinforced Resin Chemical-Resistant Tanks, ASTM D4021, Glass-Fiber-Reinforced Polyester Underground Petroleum Storage Tanks, ASTM D4097, Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks, and ASTM D2996, Filament-Wound Reinforced Thermosetting Resin Pipe. Ductwork should be designed for segregation of incompatible fumes or vapors.

c) Cyanide fumes should never be mixed with acid fumes in any duct system because of the toxic hazard. Fumes and mists from chromium plating should be kept separate to promote removal and reclaim of the chromic acid

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solution. Most other fumes may be mixed in common ducts except where segregation is required for scrubbers or waste treatment purposes.

d) Isolation from structures to prevent transmission of vibration to the building shall be designed into the duct system.

10.6.4 Materials for Ventilation/Exhaust Systems. Hoods and ducts should be constructed of one of two basic types of materials: plastics, or FRP. Steel should be used only for temporary or minimal installations because of its poor resistance to corrosion even when coated.

10.6.4.1 Plastic. PVC, or rigid (unplasticized) PVC is a thermoplastic material, supplied in sheet form or extrusions. The sheeting should conform to ASTM D1927, Rigid Poly (Vinyl Chloride) Plastic Sheet Type 1, Grade 2. The plastic surfaces are made to adhere by hot-air welding using PVC plastic rods. PVC is resistant to most chemicals, is readily fabricated or repaired if fractured, but is brittle, subject to mechanical damage and to stress failure. Furthermore, the welds are less structurally sound than the material. Also, it tends to soften above 140 degrees F (60 degrees C).

PVC is normally the first choice for hoods if not in direct contact with temperatures above 140 degrees F because it is less expensive than FRP. Rigid PVC is preferred to FRP for chromic acid mists. When PVC is used, guards shall be installed to prevent damage to duct work. Do not use PVC outside of buildings or where PVC can be exposed to ultraviolet light.

10.6.4.2 Fiberglass Reinforced Polyester/Epoxy (FRP). FRP is a thermosetting plastic, compounded with fiberglass fibers, mesh, or fabric in combination with various resins. It is light and strong, formed in various shapes, and resins are formulated to suit the specific application. It is readily worked in the field with solvent cement joints, usually with a fiberglass and resin wrapping for a permanent joint.

FRP, especially for chromium plating, must be specified as resin rich, with no exposed fibers to prevent the phenomenon known as wicking, or migration of moisture into the fibers. Furthermore, the resin must be vinylester to resist attack by concentrated chromic acid.

Furthermore, FRP should be specified as fire-retardant grade. FRP is in some cases slightly less chemical resistant than PVC, but is more resistant to breakage and mechanical damage.

10.6.5 Fans. Fans are of two basic types, axial and centrifugal, with a number of variations in each category, and other special types. Special considerations to be given in the design and selection are:

a) All parts of fans exposed to the air stream should be of corrosion resisting material, either solid plastic or metal with heavy plastisol coating, not thinner than 60 mils. Exterior frame should be of steel, coated with a suitable epoxy coating properly applied.

b) All fans to have a drain, an access door, OSHA approved belt, and drive guard.

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- c) All fans to be AMCA tested and rated.

10.6.6 Makeup Air. Air exhausted from the plating room must be replaced and should be supplied mechanically at a rate approximately equal to the rate of exhaust or slightly less. Makeup air must be heated in cold weather and cooled and dehumidified in hot weather in addition to being filtered.

An excess of makeup air in the plating room will produce a positive pressure tending to disperse the contaminated air to other parts of the building, while an excessive negative pressure will tend to pull drafts and dust through doors and windows, reduce the efficiency of the exhaust system, and increase contamination of the plating solution in the tanks. A slight negative pressure of 10 percent of atmospheric will help prevent migration of fumes to other areas, and is recommended.

Makeup air should be supplied by roof-mounted air handling units fired with gas or steam for heating. The tempered air produced should be distributed in the plating room in a manner that will not create drafts for personnel or disturb the exhaust system.

#### 10.6.7 Air Pollution Control

10.6.7.1 Introduction. Stack exhaust systems, particularly those from local ventilation, are subject to national and regional air pollution control requirements. For that reason the emissions resulting from those systems must meet limits imposed on hazardous and toxic compounds. In addition, there is a problem with corrosive fumes affecting nearby structures and automobiles in nearby parking lots. Those hazardous and toxic emissions have to be abated. The carryover of chromic acid from the exhausting of gases from chromium plating baths and the attack by that acid on automobile surfaces is a well known example of the damages brought about by corrosive fumes.

Meeting the "Permissible Exposure Limits" (PEL) for the safety of human beings inside a plating room by proper forced ventilation does not necessarily result in acceptable stack emissions, based on ambient air levels. These depend on whether the contaminants have high, moderate, or low toxicity. Highly and moderately toxic air contaminants are animal carcinogens or other substances posing a health risk to humans. Low toxicity air contaminants are not carcinogenic but are known to be irritants. As an example, the ambient air levels in the absence of specific values are determined in the State of New York by dividing the PEL-TWA's (time-weighted average concentrations for a normal 8-hour workday and a 40-hour workweek) by 300 for highly and moderately toxic contaminants, and by 50 for low toxicity contaminants.

Among the gases or fumes that are removed by ventilation of plating facilities, including integrated wastewater systems, are oxides of nitrogen, hydrogen chloride, hydrogen cyanide, cyanogen chloride, sulfur dioxide, hydrogen fluoride, chlorine, chlorinated hydrocarbons, and hexavalent chromium aerosols.

10.6.7.2 Scrubbers. Corrosive fumes are normally removed by scrubbers, while toxic organic compounds may be removed by either scrubbing or by adsorption on activated carbon or by both methods. Scrubbers should be

designed such that there is no contamination of the environment from spillage into the environment.

For corrosive fume scrubbing which includes all of the compounds mentioned above, except the chlorinated hydrocarbons, the most common equipment used are:

- a) packed towers,
- b) spray towers,
- c) plate towers,
- d) venturi scrubbers, and
- e) fluidized bed absorbers.

In brief, characteristics of the scrubber equipment are:

a) Packed Towers. The common type of packed tower consists of a cylindrical shell containing an inert material. These towers generally operate with countercurrent fluid flow. A large amount of gas-liquid contact area is available in packed towers and this results in efficient mass-transfer operations. Countercurrent flow in vertical packed towers has performed well in the field and is preferred more when packed towers are used.

b) Spray Towers. These are not as efficient as packed towers because they have considerably less interfacial contact area. They are, however, used for cooling gas streams and gross removal of particles.

c) Plate Towers. These provide large interfacial areas because the gas is converted to very small size bubbles by having to pass through small orifices or Venturi inlets. Lower liquid rates than in packed towers are normally required.

d) Venturi scrubbers. These utilize impingement and diffusion by utilizing the energy of the airstream to cause the formation of minute droplets in the liquid stream, thus increasing the interfacial area and also increasing the chances of collision between the gas bubbles and the liquid droplets.

e) Fluidized bed. The fluidized bed absorber utilizes plastic polypropylene spheres in single or multiple stages. Concurrent flow rather than countercurrent flow is normally used. Higher gas rates can be used than in fixed packing. A restraining grid must be used to prevent the spheres from leaving the tower. Where scaling results from the reaction between the contaminants in the gas and the absorbing liquid, the fluidized or floating bed is preferable to fixed packed beds, because the attrition of the moving spheres will break up the scale.

In a number of cases the scrubbing medium should be followed by a demister which removes most of the entrainment. Among the requirements to be met by scrubbers are:



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- (1) Low initial equipment and installation cost
- (2) Excellent corrosion resistance
- (3) Simplicity
- (4) Low water consumption
- (5) Ease of maintenance
- (6) High efficiency, and
- (7) Low energy consumption.

For the design of a workable scrubber it is necessary to know the airflow, the water and air temperature, the types and concentrations of fumes to be scrubbed, and the required emission quality. Mist prevention at the tanks may be accomplished by:

- (1) Floating plastic balls, and
- (2) Foaming agents (compatible surfactants).

10.6.7.3 Removal Of Chromate Mist From Air. This can be removed by properly designed entrainment separators or demisters. The contaminant load on the separator can be decreased if hollow plastic balls are installed on the surface of the chromium bath, when this does not interfere with water evaporation. Among the media used for the removal of entrained droplets are: knitted wire, static packing, fiber demisters and reversed airflow baffles. If hydrogen fluoride is emitted from the baths, knitted metal wire would not be recommended because of possible corrosion to the metal. Glass fiber would also be affected.

Knitted plastic mesh is capable of removing more than 90 percent of the entrained particles if the gas velocity is sufficiently low or about 10 ft/sec. Higher velocities may result in reentrainment. The thickness of the demister pads is normally 3 to 6 in. (76.2 to 152.4 mm). Most demisters are not provided with sprays. If sprays are used (normally for the removal of particulate matter that would have the tendency to plug the demister) they should be applied only to the bottom thickness of the demister pad. Most manufacturers of entrainment separators can provide data on the efficiency of their equipment as a function of particle size and air velocity.

The mists removed may be returned to the baths to conserve materials.

10.6.7.4 Removal Of Dry Airborne Particulates. The removal of dry particulate matter from air would only be applicable in the areas where abrasive or impact blasting is performed. Should the integral dust collection and recovery system not be operable or not be available, external means would have to be provided.

Particles can be removed by employing the following equipment:

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- a) Filters
- b) Electrostatic precipitators
- c) Wet scrubbers

In plating installation application, the equipment choices would be between a filter and a wet scrubber. The initial cost of a filter will probably be greater than that of a wet scrubber. However, the pressure drop will be considerably less in the former than in the latter, the departure becoming greater as the particle sizes to be removed become smaller.

## 10.7 Other Design Considerations

10.7.1 Housekeeping. Proper selection and handling of process solutions and proper maintenance of metal finishing equipment are required to reduce wastewater loads to the treatment system. Good housekeeping techniques prevent premature or unnecessary dumps of process solutions. Examples of good housekeeping features include:

- a) Frequent inspection of plating racks for loose insulation prevents excessive drag-out of process solutions. Also, periodic inspection of the condition of tank liners and the tanks themselves reduces the chance of a catastrophic failure which would overload the treatment system.
- b) Steps should be taken to prevent the formation of hard-to-treat wastes. Separation of cyanide wastes from nickel or iron wastes is advisable to avoid formation of cyanide complexes. Proper tank linings in steel tanks prevent the formation of ferrocyanides.
- c) Periodic inspection should be performed on all auxiliary metal finishing equipment. This includes inspection of sumps, filters, process piping, and immersion steam heating coils for leaks. Filter replacement should be done in curbed areas or in a manner such that solution retained by the filter is dumped to the appropriate waste stream.
- d) Chemical storage areas should be isolated from high hazard fire areas and arranged such that if a fire or explosion occurs in the storage area, loss of the stored chemicals due to deluge quantities of water would not overwhelm the treatment facilities. All shelves should be labeled for appropriate location of materials.
- e) To prevent microbiological buildup on equipment, sump walls and circulatory systems should be sterilized at regular intervals. Centralized cooling systems are self-cleaning to some extent, but physical and biological cleaning are required. The physical cleaning entails the removal of metallic fines, oxidized oil and other sludge forming matter. Biological cleaning involves the use of antiseptic agents, detergents, germicides, and fungicides.
- f) Chip removal from machining operations should include oil recovery and salvage provisions.
- g) A lubrication program schedule keeps track of leakage and contamination. By analyzing records of consumption, it is possible to

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identify high consumption equipment. Premature drain intervals may indicate abnormal system contamination which should be corrected:

h) A general accounting of oils and fluids throughout their life cycle (purchasing, storage, application, cleaning, and disposal) will lead to oil and fluid conservation.

i) It is important that proper lubricants are employed in a particular piece of machinery. Marking each piece of equipment with the product type required is practiced throughout the industry. This helps prevent the use of an improper oil and the subsequent premature dumping of that oil.

j) Training and educating the operators of production equipment and waste treatment equipment can prevent unnecessary waste.

10.7.2 Wastewater Segregation. Raw waste streams generated by operations within the facility may include oily waste, metals waste, and cyanide waste. Segregation of waste streams is necessary in order to facilitate efficient handling and treatment of these wastes.

Many different types of oils and related fluids are common in oily wastes including cutting oils, fluids, lubricants, greases, solvents, and hydraulic fluids. Segregation of these oily wastes from other wastewaters reduces the expense of both the wastewater treatment described in MIL-HDBK-1005/9, and the oil recovery process by minimizing the quantity and number of constituents involved. In addition, segregated oily wastes are appropriate for hauling to disposal/reclamation by a contractor in lieu of on-site treatment.

Likewise, process baths which are to be sent to waste treatment rather than being shipped out should be segregated from one another. Mixing together of process solutions may form compounds which are very difficult to treat or create unnecessarily large volumes of water requiring specialized treatment such as chromium reduction or cyanide oxidation.

10.7.3 Surge Storage Facilities. Segregated holding tank facilities are provided for minimizing the impact of sudden changes caused by the electroplating operations. It will provide for balancing the flow or pollutant load on the downstream waste treatment plant. This design feature provides for better management and treatment of wastes. Furthermore, such holding facilities also aid in storing the waste during periods when the waste treatment plant is unavailable for treating the waste.

10.7.4 Regulatory Compliances. The environmental, safety, and health related regulations are a continuously evolving process and they occur at federal, state, and local levels of government. These regulations must be taken into consideration in the design of planned facilities along with the future regulations that will be in effect at the time when the permitting processes are initiated. The EPA, OSHA, and related state agencies must be contacted to determine the regulatory requirements in effect and all compliance requirements.

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## APPENDIX A

## MILL FINISHES OF CORROSION RESISTING STEEL

Sheet - Distinctions are made in the finishes of stainless steel sheet by a system of numbers:

No. 1 is a very dull finish produced by hot rolling the steel on hand sheet mills to specified thicknesses, annealing, and descaling. It is used in industrial applications for resistance to heat or corrosion, where smooth finish is not of particular importance.

No. 2D is a dull finish produced on either hand sheet mills or continuous mills by cold rolling to the specified thickness, annealing, and descaling. The dull finish may result from the descaling operation or may be developed by a final light cold roll pass on dull rolls. This finish is favorable to the surface retention of lubricants in deep drawing operations. It generally is used in forming deep drawn articles that may be polished after fabrication.

No. 2B is a bright, cold rolled finish commonly produced in the same way as No. 2D, except that the annealed and descaled sheet receives a final light cold roll pass on polished rolls. It is a general-purpose finish used for all but exceptionally difficult deep drawing applications. This finish is more readily polished than No. 1 or No. 2D.

No. 3 is an intermediate polished finish for use where a semifinished polished surface is required and a further finishing operation follows fabrication. For sheets or articles that will not be subject to additional finishing or polishing, No. 4 finish is recommended.

No. 4 is a general-purpose polished finish widely used for architectural panels and trim, and for dairy, restaurant, and kitchen equipment. Following initial grinding with coarser abrasives, sheets are finally finished with lubricated 120- to 150-mesh abrasive belts.

No. 6 is a dull satin finish having lower reflectivity than No. 4. It is produced by tampico brushing No. 4 finished sheets in a medium of abrasive and oil and is used for architectural applications and ornamentation where a high luster is undesirable. It also is used to contrast with brighter finishes.

No. 7 is a finish with a high degree of reflectivity, produced by buffing a finely ground surface without removing the grit lines. It is used chiefly for architectural and ornamental purposes.

No. 8 is the most reflective finish and is obtained by polishing with successively finer abrasives and buffing extensively with very fine buffing rouges. The surface is essentially free of grit lines from preliminary grinding operations. This finish is most widely used for press plates, as well as for small mirrors and reflectors. Sheets can be produced with one or both sides polished. When polished on one side only, the other side may be rough ground in order to obtain the necessary flatness. The relationship between abrasive grit numbers and surface roughness in terms of microinches is sometimes a basis for specification. The values are approximately as follows:

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## APPENDIX A (Continued)

ABRASIVE GRIT NO.	SURFACE ROUGHNESS	
	mm	in.
500	0.10 to 0.25	4 to 10
320	0.15 to 0.38	6 to 15
240	0.20 to 0.51	8 to 20
180	0.64 max	25 max
120	1.14 max	45 max
60	3.56 max	140 max

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## APPENDIX B

## DEPTH OF DISTURBANCE BY MECHANICAL PROCESSES ON CARBON STEEL

FINISHING METHOD	FATIGUE STRENGTH, % OF VALUE FOR MECHANICAL POLISHING	DEPTH OF COLD WORK		SURFACE COMPRESSIVE STRESS	
		mm	in.	MPa	ksi
Mechanical polishing	100	<0.050	<0.002	620	90
Electropolishing	70-90	None	None	None	None
Lathe turning	65-90	0.50	0.02	---	---
Milling	---	0.18	0.007	---	---
Grinding	80-140	Up to 0.25	Up to 0.01	760	110
Surface rolling	115-190	1.00	0.04	900	130
Shot peening	85-155	0.50	0.02	1030	150

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## APPENDIX C

## PLATING BATH FORMULATIONS

While typical or prototype plating bath formulations and conditions of operation are presented in Appendix C and Table 17, it is recognized that most Navy (as well as industry) plating installations use proprietary processes. These are based on closely-held formulations, sometimes secret and sometimes patented, so the user may or may not be given the precise makeup of a solution. For the sake of safety in handling and use, it is imperative that those who design plating facilities have in hand U.S. Department of Labor, Occupational Safety and Health Administration Material Safety Data Sheets (MSD) for each chemical to be stored and used in a facility being designed. This form is required under the U.S. Department of Labor Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917). The form used is Form OSHA-20, as illustrated in Figure B-1. While proprietors of plating chemicals and processes have MSD's available, they usually furnish them only on request. It should be required that contractors request these forms before a chemical or process is adopted for use. Materials which are hazardous should be controlled as shown in NAVSUPINST 5100.27 (Navy Hazardous Material Control Program) and Code of Federal Regulation 29 CFR 1910.1200 (Hazard Communication Standard).

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U.S. DEPARTMENT OF LABOR Occupational Safety and Health Administration		Form Approved OSHA No. 10-11267
<b>MATERIAL SAFETY DATA SHEET</b>		12-8-75 (WRC)
Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1918, 1917)		
<b>SECTION I</b>		
MANUFACTURER'S NAME <b>The Parker Company</b>		EMERGENCY TELEPHONE NO. <b>313 583-9300</b>
ADDRESS (Number, Street, City, State, and ZIP Code) <b>P.O. Box 20201, Detroit, Michigan 48220</b>		
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS <b>PARCO CLEANER 143 (00451)</b>	
CHEMICAL FAMILY	FORMULA	
<b>SECTION II - HAZARDOUS INGREDIENTS</b>		
PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Usual)
PIGMENTS		BASE METAL
CATALYST		ALLOYS
VEHICLE		METALLIC COATINGS
SOLVENTS		FILLER METAL PLUS COATING OR CORE FLUX
ADDITIVES		OTHERS
OTHERS		
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES		%
		TLV (Usual)
<b>SECTION III - PHYSICAL DATA</b>		
BOILING POINT (°F.)	<b>212°F.</b>	SPECIFIC GRAVITY (vs. H <sub>2</sub> O @ 1)
VAPOR PRESSURE (mm Hg.)		PERCENT. VOLATILE BY VOLUME (%)
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (vs. H <sub>2</sub> O @ 1)
SOLUBILITY IN WATER	<b>100%</b>	
APPEARANCE AND ODOR	<b>Light amber liquid, slight odor of ammonia.</b>	
<b>SECTION IV - FIRE AND EXPLOSION HAZARD DATA</b>		
FLASH POINT (Method used)	<b>None</b>	FLAMMABLE LIMITS
EXTINGUISHING MEDIA	<b>Water</b>	Low
SPECIAL FIRE FIGHTING PROCEDURES	<b>None</b>	High
UNUSUAL FIRE AND EXPLOSION HAZARDS	<b>None</b>	

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(Continued on reverse side)

Form OSHA-28  
Rev. 10-77

Figure C-1  
Illustration of a Material Safety Data Sheet



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## Parco Cleaner 143

SECTION V - HEALTH HAZARD DATA	
THRESHOLD LIMIT VALUE	
EFFECTS OF OVEREXPOSURE May tend to remove oil from skin.	
EMERGENCY AND FIRST AID PROCEDURES EYES - flush thoroughly with water for 15 minutes. EXTERNAL - wash thoroughly with water. INTERNAL - drink large quantities of milk or water and induce vomiting.	

SECTION VI - REACTIVITY DATA			
STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATIBILITY (Materials to avoid)			
HAZARDOUS DECOMPOSITION PRODUCTS None			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII - SPILL OR LEAK PROCEDURES	
STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Flush to sewer with water.	
WASTE DISPOSAL METHOD	

SECTION VIII - SPECIAL PROTECTION INFORMATION			
RESPIRATORY PROTECTION (Specify type)			
VENTILATION	LOCAL EXHAUST	X	SPECIAL
	MECHANICAL (General)		OTHER
PROTECTIVE GLOVES None		EYE PROTECTION Not required	
OTHER PROTECTIVE EQUIPMENT None			

SECTION IX - SPECIAL PRECAUTIONS	
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE Normal handling. We recommend storage in a chemical storage area.	
OTHER PRECAUTIONS	

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MPS 12-68Form OSHA-38  
Rev. May 78Figure C-1  
Illustration of a Material Safety Data Sheet (Continued)

## MIL-HDBK-1015/1

## 1. COPPER

(1) Strike. Typical range of bath compositions is as follows:

	<u>Rochelle Strike Bath (oz/gal)</u>	<u>Cyanide Strike Bath (oz/gal)</u>
Copper	1.0 - 3.5	2.5 - 3.5
Free cyanide	0.8 - 1.5	0.7 - 1.4
Rochelle salt	2.0 - 5.0	-----
Sodium carbonate	2.0 - 8.0	2.0 - 8.0

(2) Cyanide. Typical copper acid bath formulations are as follows

	<u>General (oz/gal)</u>	<u>Printed Circuits (oz/gal)</u>
Copper sulfate	27 - 32	8 - 15
Sulfuric acid	6 - 10	24 - 35

## 2. SILVER

(1) Strike. Typical range of bath compositions are as follows:

	<u>Substrates</u>	
	<u>Ferrous (oz/gal)</u>	<u>Non-Ferrous (oz/gal)</u>
Potassium silver cyanide, KAg(CN) <sub>2</sub>	0.4	0.7 - 1.3
Copper cyanide, CuCN	1.14 - 1.36	-----
Potassium cyanide, KCN	10.00 - 12.0	10.0 - 12.0

(2) Cyanide. Typical range of bath compositions are as follows:

	<u>Conventional (oz/gal)</u>	<u>High-Speed (oz/gal)</u>
Potassium silver cyanide KAg(CN) <sub>2</sub>	6 - 8	20 - 30
Potassium cyanide, KCN	4 - 6	15 - 20
Potassium carbonate, K <sub>2</sub> CO <sub>3</sub>	4 - 12	2 - 10

(3) Non-Cyanide. Formulations for silver iodide baths will be inserted here.

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## 3. NICKEL

(1) Strike. Nominal bath compositions are as follows:

	Strike (Watt's) <u>(oz/gal)</u>	Low pH <u>(oz/gal)</u>	All Sulfate <u>(oz/gal)</u>	Strike (Wood's)* <u>(oz/gal)</u>
Nickel sulfate (NiSO <sub>4</sub> .6H <sub>2</sub> O)	44	26	40	---
Nickel chloride (NiCl <sub>2</sub> .H <sub>2</sub> O)	6	23	---	32
Boric acid	5	5.3	5.3	---
Wetting agents	0.06	0.06	0.06	---

\*Hydrochloric acid is added to maintain 12.5 percent HCl by volume.

(2) Sulfamate. Typical bath formulations are as follows:

	Chloride- Free <u>(oz/gal)</u>	Chloride- Containing <u>(oz/gal)</u>	High-Speed <u>(oz/gal)</u>
Nickel sulfamate, (Ni(NH <sub>2</sub> SO <sub>3</sub> ) <sub>2</sub> )	60	40	92
Nickel chloride, (NiCl <sub>2</sub> .H <sub>2</sub> O)	---	2	1.7
Boric acid, H <sub>3</sub> BO <sub>4</sub>	4	5	5.4
Wetting agent	0.05	0.05	0.05

(3) Bright. Typical bath formulations used for bright nickel plating are Watt's nickel baths modified by the addition of class 1 brighteners, class 2 brighteners, control agents and ductilizers, as shown below:

<u>Addition Agents</u>	<u>Function</u>	<u>Compounds</u>
Class 1 brighteners (Carriers)	Refine grain structure and increase brightness	Saccharin Paratoluene Benzene sulfonate Benzene monosulfonate Sodium orthobenzaldehyde Naphthalene 1, 3, 6 trisulfonate (sodium salt)
Auxiliary brighteners used for barrel and rack plating	Augment luster obtained from brighteners	Sodium allylsulfonate
Class 2 brighteners	Increased ductility brightness and leveling	Reduced fuchsin Phenosafranin Thiourea N-allyl quinolium bromide 1, 4-aminobenzimidazole- thiol-2

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The above compounds are formulated carefully by producers into commercially available, proprietary bath materials and are to be used as specified by these producers to provide bright nickel baths.

(4) Electroless Nickel. A typical electroless nickel formulation is as follows:

	<u>Molar</u>
Nickel sulfate	0.09
Sodium hypophosphite	0.045
Sodium chloride	0.18
Sodium succinate	0.06

## Acid Bath

	<u>g/L</u>
Nickel chloride	30
Sodium glycollate	50
Sodium hypophosphite	10

## Alkaline Bath

	<u>g/L</u>
Nickel chloride	30
Sodium citrate	100
Ammonium chloride	50
Sodium hypophosphite	10

(5) Special Purpose Nickel Coatings. Typical bath formulations are as follows:

	Barrel (g/L)	Nickel worn- parts (g/L)	Zinc die castings (g/L)	Wear Resistance Phosphorous (g/L)		
					<u>Low</u>	<u>High</u>
Nickel sulfate	36	24	10 - 25	23.2	2.0	
Nickel chloride	9	---	---	6.7	6.0	
Ammonium chloride	---	3.3	2 - 5	---	---	
Sodium sulfate (anhydrous)	---	---	10 - 15	---	---	
Magnesium sulfate	---	---	---	---	---	
Boric acid	5.4	4.0	2	---	---	
Phosphoric acid	---	---	---	6.7	6.7	
Phosphorus acid	---	---	---	0.17	5.3	

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## 4. CHROMIUM

(1) Hard. Typical hard-chromium bath compositions are as follows:

	Concentration	
	<u>Low</u>	<u>High</u>
Chromic acid, CrO <sub>3</sub>		
g/L	250	400
oz/gal	33	53
Sulfate		
g/L	2.5	4.0
oz/gal	0.33	0.53
Ratio CrO <sub>3</sub> to SO <sub>4</sub>	80 to 100	80 to 100

(2) Decorative. Typical decorative chromium bath compositions are as follows:

	<u>General</u>	<u>Bright Crack-free</u>
	Chromic acid, CrO <sub>3</sub>	
g/L	250	250-300
oz/gal	33	35-40
Ratio of CrO <sub>3</sub> to SO <sub>4</sub>	100:1 to 125:1	150 to 1

(3) Microcracked. Typical microcracked bath compositions are as follows:

	<u>First Plating</u>		<u>Second Plating</u>	
	Steel	Zinc	Steel	Zinc
Chromic acid				
g/L	338-375	375-413	165-195	210-233
oz/gal	45-50	50-55	22-26	28-31
Fluoride				
g/L	---	---	1.5-2.25	1.9-6.23
oz/gal	---	---	0.2-0.3	0.25-0.35
Chromic acid to sulfate ratio	100:1	140:1	180:1	180:1

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5. ZINC. Typical bath for barrel and rack plating is as follows:

	<u>oz/gal</u>
Zinc cyanide, Zn(CN) <sub>2</sub>	8.0 - 11.0
Sodium cyanide, NaCN	2.5 - 10.0
Sodium hydroxide, NaOH	10.0 - 15.0
Metallic zinc	4.5 - 6.0

6. CADMIUM. Typical bath compositions are as follows:

	<u>Still (Rack) Plating oz/gal(g/L)</u>	<u>Barrel High- Speed Plating oz/gal(g/L)</u>
Cadmium metal	3 (22.5)	2.4 (18)
Sodium cyanide	16.5 (124)	16.2 (121)
Sodium carbonate	2.6 (19.5)	2.0 (15)
Brightener		

7. TIN-LEAD ALLOYS. For 7 percent tin - 93 percent typical bath compositions are as follows:

<u>Component</u>	<u>oz/gal(g/L)</u>	<u>oz/gal(g/L)</u>
Stannous tin	0.8 (6)	2.0 (15)
Lead	11.8 (88)	1.3 (10)
Fluoboric acid minimum	13.0 (100)	53.4 (400)
Boric acid	3.4 (25)	3.4 (25)
Peptone (dry basis)	0.7 (5)	0.7 (5)

Rate of Electrodeposit:

<u>Current Density</u>		<u>Thickness of Electrodeposit</u>			
<u>A/m<sup>2</sup></u>	<u>(A/ft<sup>2</sup>)</u>	<u>2.5 micron 0.1 mil minutes</u>	<u>7.5 micron 0.3 mil minutes</u>	<u>12.5 micron 0.5 mil minutes</u>	<u>25 micron 1.0 mil minutes</u>
0.93	10	4.5	13.5	22.0	45.0
1.4	15	3.0	9.0	15.0	30.0
1.9	20	2.3	6.8	11.3	22.5
2.3	25	1.8	5.4	9.0	18.0
2.8	30	1.5	4.5	7.5	15.0

The following information will be added:

Lead bath formulations for meeting specifications such as Military Specification MIL-L-13808 and AMS 2414.

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8. GOLD. Typical bath compositions in grams per liter(g/L) are as follows:

Ingredient	<u>Strike Baths</u>		<u>Alkaline Baths</u>		<u>Acid Baths</u>		<u>Neutral Baths</u>	
	Alkaline Finish	Acid Finish	Mat Finish	Bright Finish	Mat Finish	Bright Finish	Mat Finish	Bright Finish
Potassium gold cyanide, $\text{KAu}(\text{CN})_2$	0.75-3	0.75-6	3-17.5	6-23.5	3-23.5	6-17.5	6-23.5	3-15
(Gold as Metal)	0.5-2	0.5-4	2-12	4-6	2-16	4-12	4-16	2-10
Potassium cyanide, KCN	15-90	0	15-45	15-90	-	-	-	-
Potassium phosphate, $\text{K}_2\text{HPO}_4$	15-45	0	-	-	-	-	-	-
Potassium phosphate, $\text{KH}_2\text{PO}_4$	0	0-45	0-45	0-45	0-100	0-100	0-90	0-9
Potassium carbonate	-	-	0-45	0-30	-	-	-	-
Potassium hydroxide	-	-	10-30	10-30	-	-	-	-
Chelates	-	-	-	-	10-200	10-150	15-90	50-150
Brightners	-	-	0	0.1-10	0	0.1-20	0	0.1-30
Secondary Brightners	-	-	-	-	0-10	0.1-10	-	-

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9. PLATINUM. Typical bath compositions are shown as follows:

Source of Pt	Ammonia "P" Salt	Acid "P" Salt	$H_2Pt(NO_2)_2SO_4$	$K_2Pt(OH)_2$	$H_2PtCl_6$
Pt, as metal, g/L	10	40	5	12	20
Ammonium nitrite, $NH_4NO_2$ , g/L	100	-	-	-	-
Sodium nitrite, $NaNO_2$ , g/L	10	-	-	-	-
Ammonia, $NH_3$ , 28%, g/L	40	-	-	-	-
Sulfamic acid, $NH_2SO_3H$ , g/L	-	80	-	-	-
Sulfuric acid, $H_2SO_4$	-	-	to pH2	-	-
Potassium hydroxide, KOH, g/L	-	-	-	15	-
Hydrochloric acid, HCl, g/L	-	-	-	-	300

10. RHODIUM. Typical bath compositions are shown as follows:

Source of Rh metal	Phosphate Bath	Sulfate Bath	Phosphate Sulfate Bath	Barrel Sulfate Bath
	$PO_4^{3-}$ concentrate	$SO_4^{--}$ concentrate	$PO_4^{3-}$ concentrate	$SO_4^{--}$ concentrate
Rh, as metal, g/L	2.0	1.3-2.1	1.0	2.5-5
Phosphoric acid, $H_3PO_4$ , 85%, g/L	40-80	-	-	-
Sulfuric acid, $H_2SO_4$ , g/L	-	25-80	80	160



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## APPENDIX D

## SPECIFIC GRAVITY OF ELECTROLYTES

ELECTROLYTE	SPECIFIC GRAVITY
Concentrated Sulfuric Acid	1.83
Aluminum Electropolishing	1.70 to 1.75
Copper Electropolishing	1.70 to 1.81
Nickel Stripping Solution (50 to 55° Baume)	1.52 to 1.56
Concentrated Nitric Acid	1.52
Corrosion-Resisting Steel Electropolishing	1.30 to 1.42
Solutions other than those specified	>120
Hydrochloric Acid Pickle	1.05 to 1.06
Acid Copper Electroplating	1.16 to 1.20
Chromium Electroplating (54 oz/gal)	1.44 to 1.54
Chromium Electroplating (30 oz/gal)	1.15 to 1.20

## MIL-HDBK-1015/1

## APPENDIX E

## STANDARDIZATION DOCUMENTATION

INDEX OF STANDARDS AND SPECIFICATIONS  
FOR METALLIC AND INORGANIC COATINGS<sup>1</sup>

The American Society for Testing and Materials (ASTM), Society of Automotive Engineers (SAE), International Organization for Standardization (ISO), and Federal government agencies are listed below. The individual documents for similar coatings often contain different requirements for procurement purposes. They should not be construed as an acceptable alternative unless all requirements of the specified document are met. Documents may be obtained from the following sources:

- ASTM - American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103
- AMS - Aerospace Materials Specifications, available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096
- ISO - American National Standards Institute, 1430 Broadway, New York, New York 10018
- Fed - Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402
- Mil - Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120

FEDERAL AND MILITARY STANDARDS AND SPECIFICATIONS RELATED TO  
METALLIC AND INORGANIC COATINGS  
NUMERIC SEQUENCE

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
<u>Federal Specifications</u>		
O-N-335		Nickel Salts, Electroplating
QQ-A-671	A	Anodes, Cadmium
QQ-A-673	B	Anodes, Copper
QQ-A-677	A	Anodes, Nickel
QQ-C-320	B	Chromium Plating (Electrodeposited)
QQ-N-290	A	Nickel Plating (Electrodeposited)
QQ-P-35	B (1)	Passivation Treatment for Austenitic, Ferritic and Martensitic Corrosion Resisting Steels (Fastening Devices)

<sup>1</sup>Current to 15th July 1986.

<sup>2</sup>Corrected to 15th July 1986. Users should determine level in effect at time of use. Alphabetical revision level indicates the number of updates. The highest alphabetical order shows the latest revision.

<sup>3</sup>Issue controlled, request by others than DoD Activities must be submitted via the Preparing Activity of the Specification.

## MIL-HDBK-1015/1

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
<u>Federal Specifications</u>		
QQ-P-416	D (2)	Plating, Cadmium (Electrodeposited)
QQ-S-365	D	Silver Plating (Electrodeposited) General Requirements for
TT-C-490	C	Cleaning Methods and Pretreatment of Ferrous Surfaces for Organic Coatings
<u>Military Specifications</u>		
MIL-F-495	D	Finish, Chemical, Black, for Copper Alloys
MIL-M-3171	C (1)	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-C-4607	D (1)	Heater, Engine and Shelter, Ground Type H-1
MIL-S-5002	C (1)	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-C-5541	C	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-W-6712	C	Wire, Metallizing
MIL-F-7179	F (1)	Finish Coatings and Sealants for Protection of Aerospace Weapons Systems
MIL-C-7460	A	Chromium Plating, Porous Channel Type Aircraft Engine Cylinders, General Specification for
MIL-I-8474	C	Inspection of Aluminum Alloy Parts, Anodizing Process for
MIL-A-8625	D	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-C-8837	B (1)	Coating, Cadmium (Vacuum Deposited)
MIL-G-9954	A (2)	Glass Beads, for Cleaning and Peening
MIL-C-10578	D (1)	Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base)
MIL-T-10727	B	Tin Plating; Electrodeposited or Hot-Dipped, for Ferrous or Nonferrous Metals
MIL-S-12515	C	Surface Hardening, Flame and Induction (of Ferrous Alloys)
MIL-T-12879	A	Treatment, Chemical, Prepaint and Corrosion Inhibitive for Zinc Surfaces
MIL-S-13165	B (2)	Shot Peening of Metal Parts
MIL-T-13291	E	Tank, Hot-Dip, Directly and Indirectly Heated
MIL-L-13762	B	Lead Alloy Coatings, Hot-Dip (for Iron and Steel Parts)
MIL-L-13808	B	Lead Plating (Electrodeposited)
MIL-I-13857	B (1)	Impregnation of Metal Casting
MIL-F-14072	C	Finish for Ground Electronic Equipment
MIL-C-14538	C	Chromium Plating, Black (Electrodeposited)
MIL-C-14550	B (2)	Copper Plating (Electrodeposited)

## MIL-HDBK-1015/1

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
<u>Military Specifications</u>		
DOD-P-16232	F	Phosphate Coatings, Heavy, Manganese or Zinc Base (for Ferrous Metals)
MIL-C-17711	B	Coatings, Chromate, for Zinc Alloy Castings and Hot-Dip Galvanized Surfaces
MIL-A-18001	J	Anode, Corrosion Preventive Zinc, Slab Disc and Rod Shaped
MIL-P-18317		Plating, Black Nickel (Electrodeposited) on Brass, Bronze or Steel
MIL-P-19419	A	Plating, Chromium, Electrodeposited (on the Interior Surfaces of 20 mm Mark II Gun Barrels)
MIL-C-20218	F	Chromium Plating, Electrodeposited, Porous
MIL-P-21415	C	Protective Finish and Painting for Polaris Fleet Ballistic Missile
MIL-C-23217	B (1)	Coating, Aluminum, Vacuum Deposited
MIL-P-23408	B	Plating, Tin-Cadmium (Electrodeposited)
MIL-C-23422	D	Chromium Plating, Electrodeposited <sup>3</sup>
MIL-C-26074	C (1)	Coating, Electroless Nickel, Requirements for Magnesium Alloy, Anodic Treatment of
MIL-M-45202	C	Gold Plating, Electrodeposited
MIL-G-45204	C (2)	Gold Plating, Electrodeposited
MIL-P-45209	B	Palladium Plating (Electrodeposited)
MIL-L-46064	A	Lead Tin Alloy Coating (Electrodeposited)
MIL-R-46085	B	Rhodium Plating, Electrodeposited
MIL-C-46110	B	Coating Compound, Oxide Black
MIL-P-47184		Plating, Nickel Tungsten, Electrodeposit on Aluminum Alloys, by Selective (Brush) Method
MIL-C-47267	notice 2	Cleaning and Surface Treatment
MIL-P-50002	B	Phosphate Coating Compounds, for Phosphating Ferrous Metals
MIL-N-55392	A	Nickel Carbon, Porous, Electrodeposited, for Camouflage
MIL-C-60536	notice 1	Coating, Anodic, Hard, for Aluminum and Aluminum Alloys
MIL-C-60539	notice 1	Coating, Anodic, Conventional, for Aluminum and Aluminum Alloys
MIL-D-80118	B	Deposition System, Vacuum Evaporation

## MIL-HDBK-1015/1

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
<u>Military Specifications</u>		
MIL-T-80144	B	Tank, Electroplating and Anodizing
MIL-P-80249	A	Plating Unit, Selective (Brush), Portable
MIL-C-81302	D	Cleaning Compound, Solvent, Trichlorotrifluoroethane
MIL-C-81562	B	Coating, Cadmium and Zinc (Mechanically Deposited)
MIL-C-81706	(5)	Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys
MIL-P-81728	A (1)	Plating, Tin-Lead (Electrodeposited)
MIL-C-81740		Coating, Aluminum and Aluminum Alloys (Metallic Compound Decomposition)
MIL-C-81751	B	Coating Metallic-Ceramic
MIL-C-81769		Chemical Milling of Metals, General Specification for
MIL-C-81797		Coating, Inorganically Bonded Aluminum (Electrophoretically Deposited)
MIL-A-81801		Anodic Coatings for Zinc and Zinc Alloys
MIL-W-81840		Wheels, Peening, Rotary Flap
MIL-R-81841		Rotary Flap Peening of Metal Parts
MIL-T-81955	notice 2	Tin Plating, Immersion, for Copper and Copper Alloys
MIL-T-81985	(1)	Peening of Metals
MIL-C-83488	C	Coating, Aluminum, Ion Vapor Deposited
MIL-C-87115		Coating, Immersion Zinc Flake/Chromate Dispersion
<u>Federal Standards</u>		
FED-STD-141	B (2)	Paint, Varnish, Lacquer and Related Materials, Methods of Inspection
FED-STD-151	B (2)	Metals, Test Methods
FED-STD-791	B (4)	Lubricant, Liquid Fuel and Related Products, Methods of Testing
<u>Military Standards</u>		
MIL-STD-101	B	Color Code for Pipelines and for Compressed Gas Cylinders
MIL-STD-105	D (2)	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-171	D (3)	Finishing of Metal and Wood Surfaces
MIL-STD-186	D (3)	Protective Finishing Systems for Rockets, Guided Missiles, Support Equipment and Related Materials
MIL-STD-193	J (2)	Finishing Procedures, Tactical Vehicles (Tracked and Wheeled)
MIL-STD-414	(1)	Sampling Procedures and Tables for Inspection, and Testing for Surface Passivation
MIL-STD-753	B	Corrosion-Resistant Steel Parts, Sampling, Inspection by Variables for Percent Defective
MIL-STD-808	A	Finish, Protective and Codes for Finishing Schemes for Ground and Ground

## MIL-HDBK-1015/1

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
MIL-STD-865	A (2)	Brush Plating, Electrodeposition
MIL-STD-866	B	Grinding of Chrome Plated Steel and Steel Parts Heat Treated to 180,000 psi or Over
<u>Military Specifications</u>		
MIL-STD-868	A	Nickel Plating, Low Embrittlement, Electrodeposition
MIL-STD-869	B	Flame Spraying
MIL-STD-870	A	Cadmium Plating, Low Embrittlement, Electrodeposition
MIL-STD-871	A	Electro-chemical Stripping of Inorganic Finishes
MIL-STD-889	B (1)	Dissimilar Metals
MIL-STD-1216		Preventive Compounds, Phosphate Coatings and Inhibitors
MIL-STD-1235	B	Single and Multilevel Continuous Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-1500	A (1)	Cadmium-Titanium Plating, Low Embrittlement, Electrodeposition
MIL-STD-1501	B	Chromium Plating, Low Embrittlement, Electrodeposition
MIL-STD-1503	A	Preparation of Aluminum Alloys for Electroplating
MIL-STD-1504	A	Abrasive Blasting
MIL-STD-1516		Coating for Aircraft and Missiles
MIL-STD-1568	A	Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems
MIL-STD-1587	B	Material and Process Requirements for Air Force Systems
MIL-STD-1687A		Thermal Spray Processes for Naval Ship Machinery and Ordnance Applications
<u>Military Handbooks</u>		
MIL-HDBK-HID		Cross-Index of Chemically Equivalent Specifications and Identifications Code (Ferrous and Nonferrous Alloys)
MIL-HDBK-5A		Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-132		Protective Finishes
MIL-HDBK-205		Phosphatizing and Black Oxide Coatings of Ferrous Metals
MIL-HDBK-721		Corrosion and Corrosion Protection of Metals
MIL-HDBK-724		The Stress Corrosion Cracking and Hydrogen Stress Cracking of Metals

MIL-HDBK-1015/1

NAVAL FACILITIES ENGINEERING COMMAND  
GUIDE SPECIFICATIONS

NFGS-09310	Ceramic Tile, Quarry Tile, and Paver Tile Lining System, Interior, for Concrete Storage Tanks or Petroleum Fuels
NFGS-09871	
NFGS-09815	High Build Glaze Coatings
NFGS-15361	
NFGS-15362	Carbon Dioxide Fire Extinguishing Systems (High Pressure)
NFGS-15362	
NFGS-15400	Carbon Dioxide Fire Extinguishing Systems (Low Pressure)
NFGS-15411	
	Plumbing
	Compressed Air Systems (Non-Breathing Airtype)

## MAINTENANCE MANUAL

MO-110	Painting of Buildings
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AEROSPACE MATERIAL SPECIFICATIONS (AMS), ISSUED BY THE  
SOCIETY OF AUTOMOTIVE ENGINEERS, RELATED TO  
THIS DOCUMENT NUMERICAL SEQUENCE

NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
2400	R	Cadmium Plating
2401	C	Cadmium Plating, Low Hydrogen Content Deposit
2404	C	Electroless Nickel Plating
2405	B	Electroless Nickel Plating, Low Phosphate
2409*	E	Tin Plating, Immersion
2410*	G	Silver Plating, Nickel Strike, High Bake
2411	C	Silver Plating, For High Temperature 2413*C Silver and Rhodium Plating
2414	C	Lead Plating
2415*	E	Lead and Indium Plating
2417*	D	Nickel-Zinc Alloy Plating
2418	A	Copper Plating
2419*	A	Cadmium-Titanium Alloy Plating
2422	C	Gold Plating for Electronic Applications
2424*	C	Nickel Plating, Ion Vapor Deposition
2425*	C	Gold Plating for Thermal Control
2426	A	Cadmium Plating, Vacuum Deposition
2430*	J	Shot Peening
2436	B	Coating--Aluminum Oxide Detonation Deposition
2437	A	Coating Plasma Spray Deposition
2450	E	Sprayed Metal Finish--Aluminum
2468	C	Hard Coating Treatment of Aluminum Alloys
2470	H	Anodic Treatment of Aluminum Base Alloys, Chromic Acid Process
2471	D	Anodic Treatment of Aluminum Base Alloys, Sulfuric Acids Process, Undyed Coating

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NUMBER	REVISION LEVEL <sup>2</sup>	TITLE
2472	C	Anodic Treatment of Aluminum Base Alloys, Sulfuric Acid Process, Dyed Coating
2474	B	Chemical Treatment for Aluminum Base Alloys, Low Electrical Resistance Coating
2476	A	Electrolytic Treatment of Magnesium Base Alloys, Acid Type, Full Coat
2480	C	Phosphate Treatment, Paint Base
2481	D	Phosphate Treatment, Anti-Chafing
2485	G	Black Oxide Treatment
2486	A	Conversion Coating of Titanium Alloys-- Fluoride-Phosphate Tape
2506	B	Coating of Fasteners, Aluminum Filled, Ceramic Bonded Coating
2550	C	Treatment of Sheet Metal Parts, Corrosion Resistant

\*DoD Adopted

American Society for Testing and Materials  
Specifications and Standards Related  
to This Document

## Alphanumerical Sequence

Annual Book of ASTM Standards, Section 2, Nonferrous Metal Products,  
Volume 01.05, Metallic and Inorganic Coatings; Metal Powders  
Sintered; Powder Metal Structural Parts

A269-83	Seamless and Welded Austenitic Stainless Steel Tubing for General Service, Specification for
A380-78	Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems, Recommended Practice for
B39-79	Nickel, Specification for
B68-80	Seamless Copper Tube, Bright Annealed, Specification for
B110-45(73)	Dielectric Strength of Anodically Coated Aluminum, Test for
B117-73(79)	Salt Spray (Fog) Testing
B136-77	Stain Resistance of Anodic Coatings on Aluminum, Measurement of
B137-45R9E	Weight of Coating on Anodically Coated Aluminum, Measurement of
B177-68(84)	Chromium Electroplating on Steel for Engineering Use, Recommended Practice
B183-79	Low-Carbon Steel for Electroplating, Practice for, Preparation of
B200-76	Electrodeposited Coatings of Lead and Lead-Tin Alloys on Steel and Ferrous Alloys, Specification for
B201-80	Chromate Coatings on Zinc and Cadmium Surfaces, Recommended Practice for Testing
B242-54(79)	High-Carbon Steel for Electroplating, Recommended Practice for Preparation of
B244-79	Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Non magnetic Basis



## MIL-HDBK-1015/1

B251-81 Wrought Seamless Copper and Copper-Alloy Tube, Specification for General Requirements for

B252-69(77) Zinc-Alloy Die Castings for Electroplating, Recommended Practice for Preparation of

B253-83 Preparation of and Electroplating on Aluminum Alloys by the Zincate Process, Recommended Practice for

B254-79 Preparation of and Electroplating on Stainless Steel, Recommended Practice for

B281-82 Copper and Copper-Base Alloys for Electroplating, Recommended Practice for Preparation of

B287-74(80) Acetic Acid-Salt Spray (Fog) Testing

B319-84 Lead and Lead Alloys for Electroplating, Guide Preparation of

B320-60(79) Iron Castings for Electroplating, Recommended Practice for Preparation of

B322-68(79) Cleaning Metals Prior to Electroplating, Recommended Practice for

B342 Electrical Conductivity by Use of Eddy Currents, Test for

B368-68R8E Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)

B374-80 Electroplating, Definitions of Terms Relating to

B380-65(78) Corrosion Testing of Decorative Chromium Electroplating by the Corrodkote Procedure

B431-79 Processing of Mandrels for Electroforming Recommended Practice for

B440-83 Cadmium Metal, Specification for

B449-67(82) Chromate Treatments on Aluminum, Recommended Practice for

B450-79 Engineering Design of Electroformed Articles, Recommended Practice for

B454-76 Mechanically Deposited Coatings of Cadmium and Zinc on Ferrous Metals, Specifications for

B456-79 Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium, Specification for

B457-67(80) Impedance of Anodic Coatings on Aluminum, Measurement of

B480-68(80) Magnesium and Magnesium Alloys for Electroplating, Recommended Practice for Preparation of

B481-68(79) Titanium and Titanium Alloys for Electroplating, Recommended Practice for Preparation of

B482-68(79) Tungsten and Tungsten Alloys for Electroplating, Recommended Practice for Preparation of

B487-79 Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section, Measurement of

B488-80 Electrodeposited Coatings of Gold for Engineering Uses, Specifications for

B489-68(79) Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals, Practice for

B490-68(80) Micrometer Bend Test for Ductility of Electrodeposits, Recommended Practice for

B499-75(80) Coating Thicknesses by the Magnetic Method: Non metallic Coatings on Magnetic Basis Metals, Measurement of

B503-69(84) Copper and Nickel, Electroplating Solutions for Electroforming, Recommended Practice for Use of

B504-82 Thickness of Metallic Coatings by the Coulometric Method, Measurement of

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- B507-70(79) Design of Articles to Be Electroplated on Racks with Nickel, Practice of
- B530-75(80) Coating Thicknesses by the Magnetic Methods: Electrodeposited Nickel Coatings on Magnetic and Non magnetic Substrates, Measurements of
- B532-79 Appearance of Electroplated Plastic Surfaces, Specifications for the
- B533-79 Peel Strength of Metal Electroplated Plastics, Measurement of
- B537-70(81) Rating of Electroplated Panels Subjected to Atmospheric Exposure, Recommended Practice for
- B538-70(79) FACT (Ford Anodized Aluminum Corrosion Test) Testing
- B545-83 Electrodeposited Coatings of Tin, Specification for
- B553-79 Thermal Cycling of Electroplated Plastics, Test for
- B554-78 Thickness of Metallic Coatings on Non metallic Substrates, Recommended Practice for Measurement of
- B555-75(80) Electrodeposited Metallic Coating Thicknesses by the Dropping Test, Guidelines for Measurement of
- B556-84 Thin Chromium Coatings by the Spot Test, Guidelines for Measurement of
- B567-79A Coating Thicknesses by the Beta Backscatter Method, Measurement of
- B568-79 Coating Thicknesses by X-Ray Spectrometry, Measurement of
- B571-79 Adhesion of Metallic Coatings, Test for
- B578-80 Microhardness of Electroplated Coatings, Measurement of
- B580-79 Anodic Oxide Coatings on Aluminum, Specification for
- B583-83 Porosity in Gold Coatings on Metal Substrates, Test for
- B588-75(81) Thickness of Transparent or Opaque Coatings by Double-Beam Interference Microscope Technique, Measurement of
- B602-84 Inspection of Electrodeposited Metallic Coatings and Related Finishes, Sampling Procedures for
- B604-80 Decorative Electroplated Coatings of Copper/Nickel/Chromium on Plastic, Specification for
- B627-79 Electrolytic Corrosion Testing (EC Test)
- B629-77 Preparation of Molybdenum and Molybdenum Alloys for Electroplating, Practice for
- B630-83 Preparation of Chromium for Electroplating with Chromium, Practice for
- B634-79 Electrodeposited Coatings of Rhodium for Engineering Use, Specification for
- B635-83 Coatings of Cadmium-Tin Mechanically Deposited on Iron and Steel, Specification for
- B636-84 Internal Stress of Plated Metallic Coatings with the Spiral Contractometer, Measurement of
- B650-78 Electrodeposited Engineering Chromium Coatings on Ferrous Substrates, Specification for
- B651-83 Measurement of Corrosion Sites in Nickel Plus Chromium or Copper plus Nickel Plus Chromium Electroplated Surfaces with Double-Beam Interference Microscope
- B656-84 Autocatalytic Nickel Deposition on Metals for Engineering Use, Practice for
- B659-79 Measuring Thickness of Electrodeposited and Related Coatings, Practice for
- B733-84 Autocatalytic Nickel-Phosphorous Coating of Metals, Specifications for

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B734-84	Electrodeposited Copper for Engineering Uses, Specification for
D1193-77(83)	Reagent Water, Specification for
D1732-67/R73	Preparation of Magnesium Alloy Surfaces for Painting, Recommended Practices for
D1888-78	Particulate and Dissolved Matter in Water, Test Methods for
E112-83	Average Grain Size of Metals, Estimating the
F326-78	Electronic, Hydrogen Embrittlement Test for Cadmium Electroplating Processes
F519-77	Electronic Hydrogen Embrittlement Test for Cadmium Electroplating Processes

## American National Standards Institute (ANSI)

Standards

B30.11	Monorails and Underhung Cranes
B30.16	Overhead Hoists
H27.1-1981	Underhung Cranes and Monorail Systems

## Electronics Industries Association (EIA)

RS-232C	Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange (August 1969)
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## Hoist Manufacturers Association (HMI)

HMI-100-74	Electric Wire Rope Hoists
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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) RECOMMENDATIONS  
AND STANDARDS, RELATED TO METALLIC AND INORGANIC COATINGS  
NUMERICAL SEQUENCE

NUMBER	CURRENT ISSUE <sup>2</sup>	TITLE
ISO 1456	1974	Metallic Coatings--Electroplated Coatings of Nickel Plus Chromium
ISO 1457	1974	Metallic Coatings--Electroplated Coatings of Copper Plus Chromium on Iron or Steel
ISO 1458	1974	Metallic Coatings--Electroplated Coatings of Nickel
ISO 1459	1973	Metallic Coatings--Protection Against Corrosion by Hot Dip Galvanizing--Guiding Principles
ISO 1460	1973	Metallic Coatings--Hot Dip Galvanized Coatings on Ferrous Materials--Determination of the Mass per Unit Area--Gravimetric Method
ISO 1461	1973	Metallic Coatings--Hot Dip Galvanized Coatings on Fabricated Ferrous Products--Requirements
ISO 1462	1973	Metallic Coatings--Coatings Other Than Those Anodic to the Basis Metal--Accelerated Corrosion Tests-- Method for the Evaluation of the Results

## MIL-HDBK-1015/1

NUMBER	CURRENT ISSUE <sup>2</sup>	TITLE
ISO 1463	1973	Metal and Oxide Coatings--Measurement of Thickness by Microscopic Examination of Cross-Sections
ISO 1878	1974	Classification of Instruments and Devices for Measurement and Evaluation of the Geometrical Parameters of Surface Finish
ISO 1879	1974	Instruments for the Measurement of Surface Roughness by the Profile Method--Vocabulary
ISO 1880	1979	Instruments for the Measurement of Surface Roughness by the Profile Method--Contact (Stylus) Instruments of Profile Transformation--Profile Recording Instruments
ISO 2064	1980	Metallic and Other Non-Organic Coatings--Definitions and Conventions Concerning the Measurement of the Thickness
ISO 2079	1973	Surface Treatment and Metallic Coatings--General Classification of Terms
ISO 2080	1973	Metallic Coatings--Electroplating and Related Processes--Vocabulary
ISO 2081	1973	Metallic Coatings--Electroplated Coatings of Zinc on Iron or Steel
ISO 2082	1973	Metallic Coatings--Electroplated Coatings of Cadmium on Iron or Steel
ISO 2085	1976	Surface Treatment of Metals--Anodisation of Aluminum and Its Alloys--Check of Continuity of Thin Coatings--Copper Sulphate Test
ISO 2093	1973	Metallic Coatings--Electroplated Coatings of Tin
ISO 2106	1976	Surface Treatment of Metals--Anodisation (Anodic Oxidation) of Aluminum and Its Alloys--Measurement of the Mass of the Oxide Coatings--Gravimetric Method
ISO 2128	1976	Surface Treatment of Metals--Anodisation (Anodic Oxidation) of Aluminum and Its Alloys--Measurement of Thickness of Oxide Coatings--Non-Destructive Measurement by Light Section Microscope
ISO 2135	1976	Surface Treatment of Metals--Coloured Anodisation of Aluminum and Its Alloys--Determination of the Light Fastness of Coloured Anodised Aluminum
ISO 2143	1971	Surface Treatment of Metals--Anodisation of Aluminum and Its Alloys--Estimation of the Loss of Absorptive Power by Colorant Drop Test with Prior Acid Treatment
ISO 2177	1972	Metallic Coatings--Measurement of Coating Thickness--Coulometric Method by Anodic Dissolution
ISO 2178	1972	Non-Magnetic Metallic and Vitreous or Porcelain Enamel Coatings on Magnetic Basis Metals, Measurement of Coating Thickness, Magnetic Method
ISO 2179	1972	Electroplated Coatings of Tin-Nickel Alloy
ISO 2360	1972	Non-Conductive Coatings on Non-Magnetic Basis Metals--Measurement of Coating Thickness--Eddy Current Method

## MIL-HDBK-1015/1

NUMBER	CURRENT ISSUE <sup>2</sup>	TITLE
ISO 2361	1972	Electrodeposited Nickel Coatings on Magnetic and Non-Magnetic Substrates--Measurement of Coating Thickness--Magnetic Method
ISO 2376	1972	Anodization (Anodic Oxidation) of Aluminum and Its Alloys--Insulation Check by Measurement of Breakdown Potential
ISO 2767	1973	Surface Treatments of Metals--Anodic Oxidation of Aluminum and Its Alloys--Specular Reflectance at 45°--Total Reflectance--Image Clarity
ISO 2819	1980	Metallic Coatings on Metallic Substrates--Review of Methods Available for Testing Adhesion--
ISO 2859	1974	Electrodeposited and Chemically Deposited Coatings Sampling Procedures and Tables for Inspection by Attributes
Addendum I ISO 2931	1975	Anodizing of Aluminum and Its Alloys--Assessment of Quality of Sealed Anodic Oxide Coatings by Measurement of Admittance or Impedance
ISO 2932	1973	Anodizing of Aluminum and Its Alloys--Assessment of Sealing Quality by Measurement of the Loss of Mass After Immersion in Acid Solution
ISO 3210	1974	Anodizing of Aluminum and Its Alloys--Assessment of Sealing Quality by Measurement of the Loss of Mass After Immersion in Phosphoric-Chromic Acid Solution
ISO 3211	1977	Anodizing of Aluminum and Its Alloys--Assessment of Resistance of Anodic Coatings to Cracking by Deformation
ISO 3497	1976	Metallic Coatings--Measurement of Coating Thickness--X-ray Spectrometric Methods
ISO 3613	1980	Chromate Conversion Coatings on Zinc and Cadmium--Test Methods
ISO 3768	1976	Metallic Coatings--Neutral Salt Spray Test (NSS Test)
ISO 3769	1976	Metallic Coatings--Acetic Acid Salt Spray Test (ASS Test)
ISO 3770	1976	Metallic Coatings--Copper-Accelerated Acetic Acid Spray Test (CASS Test)
ISO 3868	1976	Metallic and Other Non-Organic Coatings--Measurement of Coating Thickness--Fizeau Multiple Beam Interferometry Method
ISO 3882	1976	Metallic and Other Non-Organic Coatings--Review of Methods of Measurements of Thickness
ISO 3892	1980	Conversion Coatings on Metallic Materials--Determination of Mass per Unit Area--Gravimetric Methods
ISO 4516	1980	Metallic and Related Coatings--Vickers and Knoop Microhardness Tests
ISO 4518	1980	Metallic Coatings--Measurement of Coating Thickness--Profilometric Method

## MIL-HDBK-1015/1.

NUMBER	ISSUE <sup>2</sup>	TITLE
ISO 4519	1980	Electrodeposited Metallic Coatings and Related Finishes--Sampling Procedures for Inspection by Attributes
ISO 4538		Metallic Coatings--Thioacetamide Corrosion Test (TAA Test)
ISO 4539	1980	Electrodeposited Chromium Coatings--Electrolytic Corrosion Testing (EC Testing)
ISO 4540	1980	Metallic Coatings--Rating of Electrodeposited Test Specimens Subjected to Corrosion Tests--Coatings Cathodic to the Substrate
ISO 4541	1978	Metallic and Other Non-Organic Coatings--Corrodokote Corrosion Test (CORR Test)

## NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATES (NEMA)

3-304 Programmable Controllers (September 1978)

\*Listed in the Department of Defense Index of Specification and Standards (DODISS)

## STANDARD DOCUMENTS FOR METALLIC AND INORGANIC COATINGS

DESIGNATION	ASTM	GOVERNMENT	AMS	ISO
<u>Materials and Equipment</u>				
Anodes	B 39, B 440	QQ-A-660, QQ-A-671, QQ-A 673, QQ-A-677, MIL-C-3309, MIL-A-18001, MIL-C-22045	---	---
Chemicals	---	O-N-335, MIL-C-6151, MIL-P-50002, MIL-C-81706, MIL-STD-1216, MIL-C-46110	---	---
Equipment	---	MIL-T-13291, MIL-D-80118, MIL-F-80144, MIL-STD-944	---	---
<u>Preparation and Processing</u>				
Metal Preparation	B 177, B 183, B 242, B 252, B 253, B 254, B 281, B 319, B 320, B 343, B 480, B 481, B 482, B 588, B 629, B 630	QQ-P-35, MIL-T-12879, MIL-S-13165, MIL-P-47040, MIL-C-81769, MIL-R-81840, MIL-P-81985, MIL-STD-1503	2430	---
Cleaning	B 322	TT-C-490, MIL-STD-871, MIL-C-47267	---	---

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DESIGNATION	ASTM	GOVERNMENT	AMS	ISO
Processing	B 431, B 503	MIL-S-12515, MIL-P-47141, MIL-M-46080, MIL-STD-865, MIL-STD-866, MIL-STD-1504, MIL-HDBK-205	2550	---
Surface Finishing	---	ANSI B46.1	---	1878, 1879, 1880

Electrodeposited Metallic Coatings

Cadmium	A 165	QQ-P-416, MIL-STD-870	2400, 2401	2082
Cadmium-Titanium	---	MIL-STD-1500	2419*	---
Chromium	B 456, B 604, B 650, B 177	QQ-C-320, MIL-P-14538, MIL-P-19419, MIL-C-20218, MIL-C-23422, MIL-STD-1501	2406, 2407	---
Copper	---	MIL-C-14550	2418	---
Gold	B 488	MIL-G-45204	2422, 2425*	---
Lead, Lead and Indium	B 200	MIL-L-13808	2414, 2415*	---

Electrodeposited Metallic Coatings

Nickel	B 456, B 604	QQ-N-290, MIL-P-18317, MIL-P-27418, MIL-STD-868	2403, 2423, 2424*	1458
Nickel Plus Chromium	B 456, B 604	---	---	1456, 1457
Nickel-Cadmium	---	---	2416	---
Nickel-Carbon	---	MIL-N-55392	---	---
Nickel-Tungsten	---	MIL-P-47184	---	---
Nickel-Zinc	---	---	2417*	---
Palladium	---	MIL-P-45209	---	---
Rhodium	B 634	MIL-R-46085	---	---
Silver, Silver Rhodium	---	QQ-S-365	2410*, 2411, 2412*, 2413*	---
Tin	B 545*	MIL-T-10727, QQ-T-435	2408	2093
Tin-Cadmium	---	MIL-P-23408	---	---
Tin-Lead	B 579	MIL-L-46064, MIL-P-81728	---	---
Tin-Nickel	B 605	---	---	2179
Zinc	A 164, B 633*	QQ-Z-325	2402	2081

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DESIGNATION	ASTM	GOVERNMENT	AMS	ISO
<u>Non-Electrodeposited Metallic Coatings</u>				
Aluminum	---	MIL-G-23217, MIL-A-40147, MIL-G-81740, MIL-C-81797, MIL-C-83488	2420*, 2427 2450	---
Cadmium	B 454	MIL-C-8837, MIL-C-81562	2426	---
Copper	---	MIL-P-47226	---	---
Lead	---	MIL-L-13762	---	---
Magnesium	---	---	2421*	---
Metallic-Ceramic	---	MIL-C-81751	2506, 3126	---
Molybdenum	---	---	2465*	---
Nickel	B 656	MIL-C-26074	2399, 2404, 2405	---
Tin	B 656	MIL-T-81955	2409*	---
Tin-Cadmium	B 635	MIL-C-81562	---	---
Zinc	B 454	MIL-C-81562	---	---
Zinc Flake	---	MIL-C-87115	---	---

Non-Metallic Coatings and Treatments

Aluminum, Anodic Oxides on:	B 580	MIL-A-8625, MIL-C-60536, MIL-C-60539	2436, 2468, 2469*, 2470, 2471, 2472	---
Aluminum, Conversion Coatings on:	B 449	MIL-C-5541, MIL-C-81706,	2473, 2474	---
Black Oxide	---	MIL-C-13924	2485	---
Cadmium, Conversion Coating on:	B 201	---	---	---
Copper, Chemical Black on Magnesium	---	MIL-F-495 MIL-C-3171, MIL-S-47042	2475, 2476, 2478, 2479	---
Phosphates	---	TT-C-490, MIL-P-16232	2480, 2481	---
Tungsten Carbide	---	---	2435*	---



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DESIGNATION	ASTM	GOVERNMENT	AMS	ISO
Titanium, Anodic Oxides on:	---	---	2488	---
Titanium, Conversion Coatings on:	---	---	2486	---
Zinc, Anodic Oxides on:	---	MIL-A-81801	---	---
Zinc, Conversion Coatings on:	B 201	MIL-C-17711	---	---
<u>Test Methods</u>				
Adhesion	B 571	---	---	---
Chromate Coatings	B 201	---	---	3613, 3892
Coating Weight	B 137*	---	---	2106, 2932, 3210
Corrosion Sites	B 651	---	---	---
Dielectric Strength	B 110	---	---	2376
Ductility	B 489, B 490	---	---	3211
Dye Stain	B 136	---	---	2135,
Electrolytic Corrosion	B 627	---	---	4539
Hydrogen Embrittlement	F 326, F 519	---	---	---
Impedance	B 457	---	---	2931
Microhardness	B 578	---	---	4516
Panel Rating	B 537	---	---	4540
Phosphate Coatings	---	---	---	3892
Plastic Surfaces	B 532, B 533, B 553	---	---	---
Porosity	B 583	---	---	---
Spray (Fog) Tests	B 117, B 287, B 368, B 380, B 538	---	---	2085, 3768, 3769, 3770
Standard Test Methods	---	MIL-L-8474, Fed-Std-141, Fed-Std-151, MIL-STD-753	2350	1462, 3882
Stress	B 636	---	---	---

## MIL-HDBK-1015/1

DESIGNATION	ASTM	GOVERNMENT	AMS	ISO
Thickness	B 244*, B 487, B 499*, B 504*, B 529*, B 530*, B 554, B 555, B 556, B 567*, B 568*, B 588, B 659	---	---	1463, 2128, 2177, 2178, 2360, 2361, 3497.
<u>Miscellaneous</u>				
Definition of Terms:	B 374	---	---	2064, 2079, 2080
Electroformed Articles, Engineering Design:	B 450	---	---	---
Impregnation of Metals	---	MIL-I-13857	---	---
Plasma Spray	---	MIL-M-6874	---	---
Metal Spray	---	MIL-W-6712	2437	---
Flame Spray	---	MIL-STD-869	---	---
Thermal Spray	---	MIL-STD-1687	---	---
Rack Plating, Design of Article:	B 507	---	---	---
Sampling Procedures	B 602	MIL-STD-105, MIL-STD-414	---	2859* Addendum 4519
Surface Treat- ments, Coatings	--- 2819/1	MIL-S-5002, MIL-F-7179,	---	---
Corrosion and Corrosion Protection		MIL-F-14072, MIL-P-21415, MIL-STD-171, MIL-STD-186, MIL-STD-193, MIL-STD-808, MIL-STD-889, MIL-STD-1235, MIL-STD-1516, MIL-STD-1568, MIL-STD-1587, MIL-HDBK-132, MIL-HDBK-721, MIL-HDBK-724		

\*Listed in the Department of Defense Index of Specification and Standards (DODISS).

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Electroplating Engineering Handbook (4th Edition), Lawrence I. Durney, Editor, Van Nostrand Reinhold Company, 7625 Empire Drive, Florence, KY 41042.

Eletroplating (Fundamentals of Surface Finishing) (1978), By Frederick A. Lowenheim, McGraw-Hill Book Company, 1221 Avenue of the Americas, New York, NY 10030.

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Phosphatizing with Non-Crystalline Coatings, by Samuel Spring and K. Woods, Vol. 78, No.9, p. 31 (1980).

Selection of a Paint Pretreatment System, by K. Woods and Samuel Spring, Vol. 78, No. 6, p. 17 (1980).

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Preparation of Metals for Painting (1965), Samuel Spring, Van Nostrand Company, 7625 Empire Drive, Florence, KY 41042.

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Steel Structures Painting Manual (Vol. 1, 1982), Good Painting Practice, Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.

Surface Treatment and Finishes for Aluminum (1972), Samuel Wernick and R. Pinner; Robert Draper, Ltd., Teddington, England.

## MIL-HDBK-1015/1

## REFERENCES

NOTE: Unless otherwise specified in the text, users of this handbook should utilize the latest revisions of the documents cited herein.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS:

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise indicated, copies are available from Commanding Officer, Naval Publications and Forms Center, ATTENTION: NPODS, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

## SPECIFICATIONS

## FEDERAL

QQ-A-671	Anodes, Cadmium
QQ-P-416	Plating, Cadmium (Electrodeposited)
TT-C-490	Cleaning Methods for Ferrous Surfaces and Pretreatments for Organic Coatings

## MILITARY

MIL-M-3171	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-C-4607	Heater, Engine and Shelter, Ground Type H-1
MIL-C-5541	Chemical Conversion Coatings on Aluminum Alloys
MIL-W-6858	Welding, Resistance, Spot and Seam
MIL-G-9954	Glass Beads for Cleaning and Peening
MIL-C-10578	Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base)
MIL-S-13165	Shot Peening of Metal Parts
MIL-I-17433	Inhibitor, Hydrochloric Acid Descaling and Pickling Solutions
MIL-C-17711	Coatings, Chromate, for Zinc Alloy Castings and Hot-Dip Galvanized Surfaces
MIL-M-45202	Magnesium Alloy, Anodic Treatment of
MIL-G-45204	Gold Plating, Electrodeposited

## MIL-HDBK-1015/1

MIL-R-46085	Rhodium Plating, Electrodeposited
MIL-P-80249 MIL-C-81302	Plating Unit, Selective (Brush), Portable Cleaning Compound, Solvent, Trichlorotrifluoroethane
MIL-C-81706	Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys
MIL-C-87936	Cleaning Compounds Aircraft Exterior Surfaces, Water Dilutable

## STANDARDS

## FEDERAL

FED-STD-791	Lubricants, Liquid Fuels, and Related Products; Methods of Testing
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## MILITARY

MIL-STD-101	Color Code for Pipelines and for Compressed Gas cylinders
MIL-STD-865	Selective (Brush Plating) Electrodeposition
MIL-STD-882	System Safety Program Requirements

## HANDBOOKS

MIL-HDBK-205	Phosphatizing and Black Oxide Coating of Ferrous Metals
MIL-HDBK-1003/17	Industrial Ventilation Systems
MIL-HDBK-1005/8	Domestic Wastewater Control
MIL-HDBK-1005/9	Industrial and Oily Wastewater Control
MIL-HDBK-1005/13	Hazardous Waste Storage Facility
MIL-HDBK-1190	Facility Planning and Design Guide

## NAVFAC GUIDE SPECIFICATIONS

NFGS-09310	Ceramic Tile, Quarry Tile, and Paver Tile
NFGS-09815	High-Build Glaze Coatings
NFGS-09910	Painting of Buildings (Field Painting)
NFGS-15361	Carbon Dioxide Fire Extinguishing System (High Pressure)

## MIL-HDBK-1015/1

NFGS-15362	Carbon Dioxide Fire Extinguishing System (Low Pressure)
NFGS-15400	Plumbing
NFGS-15411	Compressed Air Systems (Non-Breathing Air Type)

NAVY MANUALS, DRAWINGS, P-PUBLICATIONS, AND MAINTENANCE OPERATING MANUALS:

Available from Commanding Officer, Naval Publications and Forms Center (NPFC), 5801 Tabor Avenue, Philadelphia, PA 19120-5099. To Order these documents: Government agencies must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP); the private sector must write to NPFC, ATTENTION: Cash Sales, Code 1051, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

MO-110	Paints and Protective Coatings
P-355	Seismic Design for Buildings

NAVY DEPARTMENTAL INSTRUCTIONS: Available from Commanding Officer, Naval Publications and Forms Center, ATTENTION: Code 3015, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

NAVFACINST 4862.5C	Industrial Facilities Acquisition Projects which Involve Complex Processes or Hazardous/Toxic Materials
NAVSUPINST 5100.27 C15	Navy Hazardous Material Control Program (August 1985)
OPNAVINST 5090.1	Environmental and Natural Resources Protection Manual (May 1983)
OPNAVINST 5100.24	Navy Systems Safety Program

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

The following Government documents and publications form a part of this document to the extent specified herein.

## DEPARTMENT OF DEFENSE

DoD 4145.19-R-1	Storage and Handling of Hazardous Materials
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(Unless otherwise indicated, copies are available from Office of the Secretary of Defense (OASD) (P & L) SD, Pentagon Room 3B724, Washington D.C. 20301-8000 Telephone (703) 695-2207.)

## EXECUTIVE BRANCH

Executive Order No. 12003, 20 July 1977	Energy Policy & Conservation
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MIL-HDBK-1015/1

(Copies available at any public library classified as a Federal Depository Library which lists it in the Weekly Compilation of Presidential Documents.)

DEPARTMENT OF HEALTH AND HUMAN SERVICES

NIOSH, Good Work Practices for Electroplaters

(Unless otherwise indicated, copies are available from National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226, Telephone (513) 533-8287.)

DEPARTMENT OF LABOR

29 CFR 1910 (Labor OSHA Reg 2206), OSHA Safety and Health Standards for General Industry. (Refer to Department of Commerce PB-2737803.)

Guidelines for Energy Conservation in New Building, Interim Design Criteria, January, 1975

(Unless otherwise indicated, copies are available from Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington DC 20210.)

NON-GOVERNMENT PUBLICATIONS

The following publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the Department of Defense Index of Specification & Standards (DODISS).

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENE (ACGIH)

ACGIH 2080 Industrial Ventilation, A Manual of Recommended Practice, Feb. 1989

ACGIH 4710 Occupational Health Hazard of Solvents

(Unless otherwise indicated, copies are available from American Conference of Governmental Industrial Hygiene, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45221, Telephone (513) 661-7881.)

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI-A13.1 Scheme for Identification of Piping

ANSI-B30.11 Safety Standards for Monorail Systems and Underhung Cranes

ANSI-B30.16 Safety Standards for Overhead Hoists

ANSI-MH27.1 Specifications for Underhung Cranes and Monorails

ANSI-X3.4 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)

## MIL-HDBK-1015/1

ANSI-Z358.1

Eyewash Shower Equipment, Emergency, June  
1981

(Unless otherwise indicated, copies are available from American National Standards Institute, 1430 Broadway, New York, NY 10018, Telephone (212) 354-3300).

## AMERICAN SOCIETY FOR METALS

Metals Handbook, 9th edition (1987), Katherine Mills, Editor

Volume 4, Heat Treating

Volume 5, Surface Cleaning, Finishing, and  
Coating

(Unless otherwise indicated, copies are available from American Society for Metals, Metals Park, OH 44073, Telephone (216) 338-5841.)

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A269	Tubing, Stainless Steel, Seamless and Welded Austenitic, for General Service (DoD adopted)
ASTM A380	Cleaning & Descaling Stainless Steel parts, Equipment, & Systems (DoD adopted)
ASTM B68	Seamless Copper Tube, Bright Annealed (DoD adopted)
ASTM B251	Alloy (Nickel Silver) Copper Nickel Zinc & Copper Nickel Rod & Bar (DoD adopted)
ASTM B488	Electrodeposited Coatings of Gold for Engineering Uses (DoD adopted)
ASTM B630	Preparation of Chromium for Electroplating with Chromium
ASTM D1193	Reagent Water, Specifications for (DoD adopted)
ASTM D1730	Standard Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting
ASTM D1732	Preparation of Magnesium alloy Surfaces for Painting (DoD adopted)
ASTM D1888	Particulate and Dissolved Matter in Water, Test Methods for
ASTM D1927	Rigid Poly (Vinyl Chloride) Plastic Sheet



MIL-HDBK-1015/1

ASTM D2092	Standard Practice for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting
ASTM D2996	Filament-wound Reinforced Thermosetting Resin Pipe (DoD adopted)
ASTM D3299	Filament-Wound Glass-Fiber Reinforced Resin Chemical-Resistant Tanks
ASTM D4021	Glass-Fiber-Reinforced Polyester Underground Petroleum Storage Tanks
ASTM D4097	Contact-Molded Glass-Fiber-Reinforced Thermostat Resin-Chemical-Resistant Tanks
ASTM E112	Determining Average Grain Size (DoD adopted)

(Unless otherwise indicated, copies are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 Telephone (215) 299-5400.)

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C506	Backflow Prevention Devices--Reduced Pressure Principle and Doublecheck Valve Type
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(Unless otherwise indicated, copies are available from American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235, Telephone (303) 794-7711.)

ELECTRONIC INDUSTRY ASSOCIATION (EIA)

EIA RS-232C	Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data to Interchange (Aug. 1969) (DoD adopted)
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(Unless otherwise indicated, copies are available from Electronic Industry Association, 2001 Eye St. NW, Washington, DC 20006, Telephone (202) 457-4900.)

HOIST MANUFACTURERS INSTITUTE (HMI)

HMI-100-74	Electrical Wire Rope Hoists
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MIL-HDBK-1015/1

(Unless otherwise indicated, copies are available from Hoist Manufacturers Institute, c/o Material Handling Institute, 8720 Red Oak Blvd., Suite 201, Charlotte, NC 23217, Telephone (704) 522-8644.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 3-304                      Programmable Controller  
(Sept. 1978)

(Unless otherwise indicated, copies are available from National Electrical Manufacturers Association (NEMA), 2101 L St. NW, Suite 300, Washington, D.C. 20037, Telephone (202) 457-8400.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE J444-84                      Cast Shot and Grit Size  
Specifications for Peening and Cleaning,  
Recommended Practice

AEROSPACE MATERIAL SPECIFICATIONS (AMS):

AMS-2474                      Chemical Treatment for Aluminum Alloys Low  
Electrical Resistance Coating

AMS-2476                      Electrolytic Treatment for Magnesium Base  
Alloys, Alkaline Type, Full Coat

(Unless otherwise indicated, copies are available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096, Telephone (412) 776-4841.)

## MIL-HDBK-1015/1

## GLOSSARY

GLOSSARY. These definitions correspond to interpretations used within the electroplating and related processes and not necessarily to definitions used in other areas. They are based upon ASTM Designation B.374-80 American Society for Testing and Materials, 1910 Race Street, Philadelphia, Pennsylvania 19103, and F. Lowenheim, Electroplating Fundamentals of Finishing, (1st edition) McGraw-Hill Publications Company, 1221 Avenue of the Americas, New York, New York 10020, 1978.

ABRASIVE - A substance used in grinding, honing, lapping, polishing, pressure blasting, and barrel finishing operations. Abrasives include materials such as silicates, garnet, emery, glass, corundum, diamond, aluminum oxide, silicon carbide, and boron carbide.

ABRASIVE BLASTING - A process of cleaning or finishing by means of an abrasive material directed at high velocity against the workpiece.

ACID - A substance which yields hydrogen ions to a base in a chemical reaction; an acid tastes sour, turns blue litmus red, produces free hydrogen ions, and, when mixed with a base, forms a salt.

ACIDITY - The measure of hydrogen ion concentration of a solution.

ACTIVATED CARBON - A specially treated, porous form of carbon or charcoal having a large surface area capable of absorbing large quantities of gases, vapors, and colloidal solids.

ACTIVATION - Elimination of a passive condition on a surface.

ACTIVE - Capable of reacting chemically.

ADDITION AGENT - A material added to a plating solution for the purpose of modifying the character of the deposit or solution.

A/ft<sup>2</sup> - Amperes per square foot.

A/m<sup>2</sup> - Amperes per square meter.

ADHESION - The attractive force that exists between an electrodeposit and its substrate. The ability of a deposit to cling to the basis metal due to strong atomic or molecular attraction between the two.

AGITATION - Shaking or stirring a solution to insure a homogeneous mixture.

ALKALI - A substance capable of producing hydroxyl ions in solution. A base.

ALKALINE CLEANING - Cleaning by means of an alkaline solution.

ALLOY - A substance having metallic properties composed of two or more elements at least one of which must be a metal.

MIL-HDBK-1015/1

ALLOY PLATE - A deposit containing two or more metals so intimately mixed or combined as not to be distinguishable to the unaided eye.

ALLOY PLATING - Codeposit of two or more metals.

AMORPHOUS - Noncrystalline or devoid of regular structure.

AMPERE - The unit for measuring electrical current. It represents the passage of one coulomb per second.

AMYL NITRATE - Amyl nitrate is used as an antidote for cyanide gas poisoning.

ANION - A negatively charged ion.

ANNEAL - Heating or cooling a substance slowly to prevent brittleness.

ANODE - The positive electrode. The electrode at which current enters or electrons leave the solution.

ANODE BAG - A fabric bag that completely encloses the plating anode to keep sludge that forms at the anodes from entering the plating solution.

ANODE CORROSION - The electrochemical reaction with soluble anodes that causes the metal ions to go into solution at the positive electrode.

ANODE EFFICIENCY - The ratio of the actual metal that goes into solution at the anode to that which is theoretically possible with a given current density.

ANODE FILM - The portion of solution in immediate contact with the anode.

ANODE SLUDGE - Compounds formed on the anode due to impurities in the anodes or by reaction with substances in the bath.

ANODIC OR REVERSE CLEANING - Electrolytic cleaning in which the work is the anode.

ANODIC COATING - A protective, decorative, or functional coating, formed by conversion of the surface of a metal in an electrolytic oxidation process.

ANODIZING - An electrolytic oxidation process in which the surface of a metal, when anodic, is converted to an oxide film having desirable protective, decorative or functional properties.

ANTI-PITTING AGENT - A substance added to a plating solution for the specific purpose of preventing the formation of pits or large pores in the deposit.

ATOMIC WEIGHT - The weight of an atom of any element.

AVOIRDUPOIS OUNCE - A unit of weight equal to 1/16 pound, 0.911 troy ounce or 28.35 grams.

## MIL-HDBK-1015/1

**BACK EMF** - The potential set up in a electrolysis cell which opposes the flow of current, caused by such factors as concentration, polarization and electrode films.

**ARREL PLATING** - Electroplating done in a mechanically rotating barrel that operates as a self-contained unit or in a standard still plating tank. The method is especially suited for plating large numbers of small parts.

**BASE METAL** - A metal that readily oxides or dissolves to form ions. The opposite of noble metal.

**BASIS METAL** - The material upon which coatings are deposited.

**BATH** - The solution used for cleaning or plating.

**BAUME' OR BE** - A specific gravity or solution density scale.

**BOND** - The action by which a deposited metal is held to a basis metal by molecular forces.

**BRIGHTNESS** - Brightness is the luminous intensity of any surface in a given direction per unit of projected area of surface as viewed from that direction. In common usage the term brightness is a perceptual term denoting the apparent absolute amount of light perceived. For metallic surfaces, it is the surface property, which permits the reflectance of light and depends on grain size and shape on the metallic surface.

**BRIGHT DIP** - A solution used to produce a bright surface on a metal.

**BRIGHT PLATING** - A process which produces an electrodeposit having a high degree of specular reflectance in the as-plated condition.

**BRIGHT PLATING RANGE** - The range of current densities within which a given plating solution produces a bright plate.

**BRIGHTENER** - An addition agent used in plating solutions to produce a denser, more reflective plate over that which is obtained without its use. Brighteners are not authorized for Air Force due to difficulties encountered as the result of their use.

**BRUSH PLATING** - A method of plating in which the plating solution is applied with a pad or brush within which is an anode and which is moved over the cathode to be plated.

**BUFFER** - A substance which, when added to a solution, causes it to resist any change in hydrogen ion concentration upon addition of acid or alkali.

**BUILDING UP** - Electroplating for the purpose of increasing the dimensions of an article.

**BUILD-UP** - Overplating or undesirable building up of deposit on corners or edges during plating. Also referred to as "treeing."

## MIL-HDBK-1015/1

**BURNT DEPOSIT** - A rough, noncoherent, or otherwise unsatisfactory deposit produced by the application of an excessive current density or solution imbalance and usually containing oxides or other inclusions.

**BUS (BUS BAR)** - A rigid conducting section for carrying current to the anode and cathode bars.

**CARBURIZING** - Heat treatment of metal to increase the carbon content of the surface layer.

**CATHODE** - The negative electrode. The electrode through which current leaves, or electrons enter, the solution. In electroplating, the electrode which receives the deposit.

**CATHODE EFFICIENCY** - The ratio of actual metal deposited on the cathode to that which is theoretically deposited based on current density.

**CATHODE FILM** - The layer of solution in contact with the cathode that differs in composition from that of the bulk of the solution.

**CATHODIC OR DIRECT CLEANING** - Electrolytic cleaning in which the work is the cathode.

**CATION** - A positively charged ion.

**CHEMICAL PICKLING** - The removal of the surface layer on a metal by chemical means.

**CHLORINE** - Chlorine is used as an oxidant in the waste treatment process of cyanide.

**CHROMATE** - A salt of chromic acid.

**CHROME** - Chromium.

**CLEANING** - The removal of foreign materials from the surface of an item.

**CONCENTRATION** - Strength or relative intensity of dissolved materials.

**CONDUCTANCE** - The capacity of a medium for transmitting electrical current. The reciprocal of resistance.

**CONDUCTING SALT** - A salt added to a solution to increase its conductivity.

**CONDUCTIVITY** - The ability of a solution to convey electrical current.

**CONTACT (GALVANIC) COATING** - The coating of a metal without the use of an outside source of current, by immersion of the work in a solution in contact with another metal.

**CONVERSION** - A coating produced by chemical or electrochemical treatment of a metallic surface that gives a superficial layer containing a compound of the metal.

## MIL-HDBK-1015/1.

**CORROSION** - The gradual destruction of a material usually by solution, oxidation, or other means attributable to a chemical process; also products formed as the result of this chemical action.

**COULOMB** - The quantity of electricity that is transmitted past a point in an electric circuit in one second if the current in the circuit is one ampere. The quantity of electricity that will deposit 0.0011180 grams of silver.

**COVERING POWER** - The ability of a plating solution to evenly deposit metal in low current density areas.

**CRITICAL CURRENT DENSITY** - Any value of the current density at which a variable exhibits a sudden change in value.

**CROCUS** - Powdered iron oxide used for cleaning or polishing.

**CURRENT DENSITY** - Amount of current per unit area; total current divided by total area of electrode in the solution.

**CURRENT EFFICIENCY** - The proportion of the current used in depositing or dissolving metal; the proportion of current that is effective in carrying out a given process in accordance with Faraday's law.

**CYANIDE (COMBINED)** - The amount of cyanide in chemical combination with a platable metal.

**CYANIDE (FREE)** - The difference between combined and total cyanide.

**CYANIDE (TOTAL)** - The combined, plus free cyanide, present in a solution.

**DEGREASING** - The removal of grease and oils from a surface by immersion of the item in liquid solvent or solvent vapors.

**DEIONIZATION** - The removal of ions from a solution by ion exchange.

**DEIONIZED WATER** - Water that has been processed through synthetic resin beds to remove undesirable mineral ions.

**DENSITY** - Mass per unit volume.

**DETERGENT** - A surface active agent that possesses the ability to clean soiled surfaces.

**DISTILLED WATER** - Nearly pure water; water that has been produced by evaporation and subsequent condensation of water, leaving any dissolved solid impurities behind.

**DRAG-IN** - The water or solution that adheres to or that is entrapped in the objects introduced into a bath.

## MIL-HDBK-1015/1

**DRAG-OUT** - The solution that adheres to or that is entrapped in the objects removed from a bath.

**DUCTILITY** - The ability of a material to deform plastically without fracturing.

**DUMMY** - A cathode in a plating solution which is used to work the solution but which is not to be made use of after plating. Often used for removal or decomposition of impurities.

**DUMMYING** - Plating with dummy cathodes.

**ELECTROCHEMICAL PROCESS** - A process involving a change in composition of a surface, or deposition of a coating upon a surface as the result of the use of electrical current.

**ELECTROCLEANING** - The removal of foreign materials from the surface of an item, submerged in a solvent or detergent solution, while passing an electric current through the item. If the item is made the anode, then anodic cleaning occurs. If the item is made the cathode, then cathodic cleaning occurs.

**ELECTRODE** - A conductor through which current enters or leaves an electrolytic cell, at which there is a change from conduction by electrons to conduction by charged particles of matter, or vice versa.

**ELECTRODEPOSITION** - The process of depositing a substance upon an electrode by electrolysis.

**ELECTROLESS PLATING** - Deposition of a metallic coating by a controlled chemical reduction, which is catalyzed by the metal or alloy being deposited.

**ELECTROLYTE** - A conducting medium in which the flow of current is accompanied by movement of matter; a substance which when dissolved in a solvent produces a conducting medium.

**ELECTROLYSIS** - Production of chemical changes by the passage of current through an electrolyte.

**ELECTROMOTIVE SERIES** - A table that lists in order the standard electrode potentials of specified electrochemical reactions.

**ELECTROPLATING** - The electrodeposition of an adherent metallic coating upon an electrode for the purpose of obtaining a surface with properties or dimensions different from those of the basis metal.

**EQUIVALENT WEIGHT** - One gram atomic weight of an element divided by its valence.

**ETCH** - To remove metal or roughen the surface of an item by chemical or electrolytic action.

**FARADAY** - The number of coulombs (96,490) required for an electrochemical reaction involving one chemical equivalent.



## MIL-HDBK-1015/1

**FILTER AID** - An inert, insoluble material, more or less finely divided, used as a filter medium or to assist in filtration by preventing excessive packing of the filter cake.

**FLASH (FLASH PLATE)** - A very thin electrodeposit of metal.

**FORMULA WEIGHT** - The weight, in grams, obtained by adding the atomic weights of all elemental constituents in a chemical formula.

**GALVANIC CELL** - An electrolytic cell capable of producing electrical energy by electrochemical action.

**GASSING** - The evolution of gases from one or more of the electrodes during electrolysis.

**HARD CHROMIUM** - Chromium plated for engineering rather than decoration purposes. Not necessarily harder than the latter.

**HARD WATER** - Water containing calcium and/or magnesium ions in solution, which will form insoluble curds with soaps.

**HEAT TREATMENT** - An operation, or combination of operations, involving the heating and cooling of a metal part for the purpose of obtaining certain desirable conditions such as hardness and ductility.

**HIGH CARBON STEEL** - Steel having a carbon content greater than 0.6 percent characterized by the property of brittleness.

**HULL CELL** - A trapezoidal box of nonconducting material with electrodes arranged to permit observation of cathodic or anodic effects over a wide range of current densities.

**HYDROGEN EMBRITTLEMENT** - Embrittlement of a metal caused by absorption of hydrogen during a pickling, cleaning, or plating process.

**HYDROGEN OVERVOLTAGE** - Overvoltage associated with the liberation of hydrogen gas.

**IMMERSION PLATE** - A metallic deposit produced by a displacement reaction in which one metal displaces another from solution.

**INDICATOR (pH)** - A substance which changes color when the pH of the medium is changed.

**INERT ANODE** - An anode which is insoluble in the electrolyte under the conditions prevailing in the electrolysis.

**INHIBITOR** - A substance used to reduce the rate of a chemical or electrochemical reaction.

**INTERFACE** - The boundary between two phases.

**ION** - An atom or group of atoms which has lost or gained one or more electrons, thereby acquiring an electrical charge.

## MIL-HDBK-1015/1

ION EXCHANGE - A reversible process by which ions are interchanged between a solid and a liquid with no substantial structural changes of the solid.

ITEM - An item is a unit of work which is an assembly handled as a single unit of work.

KARAT - A twenty-fourth part by weight; 0.2 grams.

LEVELING ACTION - The ability of a plating solution to produce a surface smoother than that of the basis metal.

LIMITING CURRENT - The maximum current density at which satisfactory deposits can be obtained.

MATTE FINISH - A dull finish.

MECHANICAL PLATING - A plating operation in which the cathodes are moved mechanically during the deposition.

MIL - One-thousandth of an inch (0.001 inch).

MILL SCALE - The heavy oxide layer formed during hot fabrication or heat treatment of metals.

MOTOR GENERATOR - A motor driven generator which delivers direct current of appropriate amperage and voltage necessary for electroplating operations.

NITRIDING - Formation of nitrides of metals by heat treatment in special atmospheres.

NOBLE METAL - A metal that does not readily tend to furnish ions, and; therefore, does not dissolve readily nor easily enter into such reactions as oxidation, etc. The opposite of base metal.

NODULE - A small knot or rounded projection formed on a cathode during electroplating.

NONFERROUS - Not containing iron; any metal or alloy other than iron.

NORMAL (N) SOLUTION - A solution which contains one gram equivalent weight (molecular weight divided by the hydrogen equivalent) of a specific substance (solute) per liter of solution.

OHM - The unit of electrical resistance.

OHM'S LAW - The current (I) in an electric circuit is directly proportional to the electromotive force (E) in the circuit.  $E = IR$ .

OPERATING LEVEL - The height at which a solution in a processing tank should be maintained while parts are being treated in the tank.

ORANGE PEEL - A finish resembling the dimpled appearance of an orange peel.

## MIL-HDBK-1015/1

**OVERVOLTAGE** - The irreversible excess of potential required for an electrochemical reaction to proceed actively at a specific electrode over and above the reversible potential characteristics of that reaction.

**OXIDATION** - A reaction in which electrons are removed from a reactant (an increase in the positive valence of an element); the combination of a reactant with oxygen.

**OXIDE** - A chemical compound of a metal and oxygen.

**OXIDIZING AGENT** - A compound that causes oxidation, thereby itself becoming reduced.

**PASSIVITY** - The condition of a metal that retards its normal reaction in a specified environment and associated with the assumption of a potential more noble than its normal potential.

**PEELING** - The detachment or partial detachment of a plated metal coating from the basis metal.

**PERIODIC REVERSE** - A method of cleaning or plating in which the direction of electric current within the electrical system is reversed periodically.

**pH** - A measure of the acidity or basicity of a solution; the logarithm, to the base 10, of the reciprocal of the concentration of hydrogen ion content of an aqueous solution.

**PICKLE** - An acid solution used to remove oxide or other compounds from the surface of a metal by chemical or electrochemical action.

**PICKLING** - The removal of oxides or other compounds from a metal surface by means of a pickle.

**PIT** - A small depression or cavity produced in a metal surface during plating or by corrosion.

**PLATING RANGE** - The current density range over which a satisfactory electroplate can be deposited.

**POLARIZATION** - A reverse potential set up during electroplating that tends to resist the flow of current; more precisely, the change in the potential of an electrode during electrolysis such that the potential of an anode always becomes more noble and that of a cathode less noble than their respective static potentials.

**PORE** - A minute cavity or channel extending all or part way through a coating.

**POROSITY** - A condition of a deposit in which microscopic openings or pores are present.

**PRECIPITATE** - An insoluble substance which separates from a solution, produced by chemical reaction of two or more substances dissolved in the solution.

## MIL-HDBK-1015/1

**PRIMARY CURRENT DISTRIBUTION** - The distribution of the current over the surface of an electrode in the absence of polarization.

**PROCESS CONTROL** - The adjustment, addition, or deletion of the significant variables of any process before or during the utilization of the process to assure that each operation accomplishes its intended purposes.

**QUENCHING** - Cooling of metal by plunging it into oil, water, etc.

**RACK** - A frame for holding or suspending items and conveying current to items during electroplating and related operations.

**RACKING** - The process and procedure of placing parts on a rack.

**REDUCING AGENT** - A compound that causes reduction, thereby itself being oxidized.

**REDUCTION** - A reaction in which electrons are added to a reactant (a reduction in the positive valence of an element); the addition of hydrogen or the abstraction of oxygen.

**RESISTANCE** - Opposition to the flow of electrical current.

**REVERSE CURRENT** - The reverse of the usual direction of electrical current required for electroplating; the part is made the anode.

**RIPPLE (d-c)** - Regular modulations in the d-c output wave of a rectifier unit or a motor generator, originating from the harmonics of the a-c input system in the case of a rectifier, or from the harmonics of the induced voltage of a motor generator set.

**ROBBER** - An auxiliary cathode so placed as to divert to itself some current from portions of the work which would otherwise receive too high a current density.

**ROCHELLE SALTS** - Common name for Potassium Sodium Tartrate  $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ .

**ROUGHNESS** - Roughness is the measure of relatively finely spaced surface irregularities: the height, width, and direction of which establish the predominant surface pattern.

**SACRIFICIAL PROTECTION** - The form of corrosion protection wherein the coating corrodes rather than the basis metal even though the latter may be exposed to the corroding medium through pores, scratches, etc.

**SALTING OUT** - The precipitation of a substance from a solution, by the action of added salts.

**SATIN FINISH** - A surface finish that behaves as a diffuse reflector and which is lustrous but not mirrorlike.

**SCALE** - An adherent oxide coating that forms on a metal surface.

## MIL-HDBK-1015/1

**SEALING OF ANODIC COATING** - A process, which by absorption, chemical reaction, or other mechanism, increases the resistance of an anodic coating to staining and corrosion, improves the durability of colors produced in the coating, or imparts other desirable properties.

**SEQUESTERING AGENT** - An agent that forms soluble complex compounds with or sequesters a simple ion, thereby suppressing the activity of that ion.

**SHIELD** - A nonconducting medium for altering the current distribution or path on an anode or cathode.

**SILVER NITRATE** - Silver nitrate is used to titrate for cyanide.

**SLURRY** - A suspension of solids in water such as glass beads in water.

**SMOOTHNESS** - Smoothness is freedom from irregularities. The inverse of roughness.

**SOAK CLEANING** - Cleaning by immersion without the use of current.

**SOLUTION CONTROL OR MAINTENANCE** - The detection, measurement, and evaluation of and the adjustment to the constituents contained within a processing solution to insure each is maintained within specified limits.

**SOLUTE** - The substance dissolved in a solution; the substance dissolved by the solvent.

**SOLVENT** - A liquid capable of dissolving other substances; the medium that dissolves the solute; also refers to organic fluids used to dissolve grease or oil from the surface of metal.

**SPECIFIC GRAVITY** - The ratio of the weight or mass of a given volume of a substance to that of an equal volume of another substance (water for liquids and solids; air or hydrogen for gases).

**SPECIFIC HEAT** - The ratio of the amount of heat required to raise the temperature of a unit mass of a substance one degree to the amount of heat required to raise the temperature of the same mass of water one degree.

**SPOTTING OUT** - The delayed appearance of spots and blemishes on plated or finished surfaces.

**STALOGOMETER** - An apparatus for determining surface tension. The mass of a drop of a liquid is measured by weighing a known number of drops or by counting the number of drops obtained from a given volume of the liquid.

**STANDARD** - A solution whose concentration is accurately known; a standard which solutions of unknown concentrations is compared against.

**STILL PLATING** - That form of plating in which the cathode remains stationary during electrodeposition.

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**STOP-OFF (MASKANT)** - A material applied to a part of a cathode or plating rack to render the surface nonconductive; a material applied to a part of the surface of an article to prevent reaction of metal from that area during chemical or electrochemical processes.

**STOPPING OFF** - The application of a stop off to any part of an electrode or rack.

**STRAY CURRENT** - Current through paths other than the intended circuit, such as through heating coils, the tank or from other work pieces.

**STRESS** - Force exerted upon a body that tends to strain or deform its shape. The intensity of such force is usually measured in pounds per square inch.

**STRESS RELIEVING** - The process of heating an object to a prescribed temperature and maintaining that temperature long enough to eliminate or reduce residual stress and then cooling slowly to minimize the development of new stresses.

**STRIKE** - A thin film of material to be followed by subsequent coatings; a solution used to deposit a strike coating.

**STRIP** - A process or solution used for the removal of a coating from a basis metal or an undercoat.

**SUBSTRATE** - The basis metal.

**SURFACE ACTIVE AGENT** - A substance that affects markedly the interface or surface tension of solutions even when present in very low concentrations.

**SURFACE TENSION** - That property, due to molecular forces, that exists in the surface film of all liquids and tends to prevent the liquid from spreading.

**SURFACE TREATMENT** - Any chemical or physical process which affects only the surface on an object.

**TANK VOLTAGE** - The total voltage between the anode and cathode of a plating bath or electrolytic cell during electrolysis. It is equal to the sum of (a) the equilibrium reaction potential, (b) the IR drop, and (c) the electrode polarizations.

**TARNISH** - The dulling, staining, or discoloration of metals due to superficial corrosion. The film so formed.

**TEMPER** - The state of a metal with regard to the degree of hardness and resiliency.

**TENSILE STRENGTH** - The force per unit area required to break a material, usually measured in pounds per square inch (psi).

**THIEF** - See ROBBER.

**THROWING POWER** - The ability of a plating solution to deposit metal successfully in low current density areas such as right angles, crevices, etc.

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**TITRATION** - An analytical process for determining the quantity of a solution component by measuring the quantity of some reagent (liquid or solution) which reacts quantitatively with it.

**TOTAL CYANIDE** - The sum of both the combined and free cyanide content of a solution.

**TRANSFERENCE** - The movement of ions through the electrolyte associated with the passage of the electric current.

**TREES** - Branched or irregular projections of metal formed on a cathode during electrodeposition, especially at the edges or other high current density areas.

**TRIPOLI** - Friable or dustlike silica used as an abrasive.

**TRIVALENT CHROMIUM** - Chromium ion formed by reduction of chromic acid through chemical action or during electrolysis.

**TUMBLING** - see BARREL PLATING.

**VACUUM DEPOSITION** - A process of depositing a coating by the evaporation of a metal or a metal compound and the subsequent condensation of vapors from these materials on the surface of the work (substrate). This process is carried out in a vacuum.

**VAPOR BLASTING** - A process of cleaning or finishing by means of a slurry of abrasive in water directed at high velocity against the work piece.

**VAPOR DEGREASING** - Removal of grease or oil from a metal surface by allowing the vapors of a solvent to condense on the metal and drain off, taking the grease with it.

**VOLTAGE EFFICIENCY** - The ratio of the equilibrium reaction potential in a given electrochemical process to the bath voltage.

**VOLUMETRIC ANALYSIS** - The method of analysis which depends upon measurement of the volume of standard solution consumed in a titration.

**WATER BREAK** - A surface area not covered by a film of water, signifying nonuniform wetting and usually associated with surface contamination. An indication of insufficient cleaning.

**WETTING AGENT** - A substance that reduces the surface tension of a liquid, thereby causing it to spread more readily on a solid surface.

**WHISKER** - A microscopic crystalline metallic filament growing out from the surface of a metal, sometimes formed during electrodeposition and sometimes spontaneously during storage or service, after finishing.

**WORK** - The item being plated or otherwise finished.

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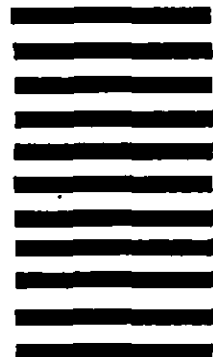
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