An Introduction to Industrial Wastewater Collection and Treatment

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(Figures, Tables and Equations in this publication may at times be alittle difficult to read, but they are the best available. ***DO NOT PURCHASE THIS PUBLICATION IF THIS LIMITATION IS NOT ACCEPTABLE TO YOU.)***

1. OBJECTIVES. Industrial waste should be collected in a manner that avoids unsafe conditions to personnel, equipment, and facilities. Industrial wastes should either be pretreated sufficiently to be accommodated in a domestic wastewater collection and treatment system, or provided with a separate collection and treatment system. Bench scale or pilot plant treatability studies to evaluate the effectiveness of the proposed physical, chemical, or biological unit processes may be needed for design of industrial waste treatment facilities. These studies should be conducted on the waste stream, if available, or on an equivalent waste stream at another facility. As a minimum, jar tests should be conducted prior to chemical process design to determine the reactor design criteria, process control and operating strategy, sludge production, and sludge characteristics. Using new membrane technologies, consideration must be made for brine generation that can be nonhazardous and discharged directly to a publicly owned treatment works (POTW). Pilot and bench scale studies should simulate the complete series of proposed unit process treatment steps using the same wastewater sample. This will identify any adverse effects of upstream treatment processes on subsequent treatment steps.

2. INDUSTRIAL POLLUTANTS. Industrial wastewaters contain pollutants that can be divided into two types (conventional or toxic) depending on their degree of impact on the environment.

2.1 CONVENTIONAL POLLUTANTS. Conventional pollutants are BOD, TSS, pH, fecal coliform, oil, and grease.

2.2 TOXIC POLLUTANTS. Sixty-five specific compounds and families of compounds were identified as toxic by the EPA (Title 40 CFR, Part 403). The EPA must promulgate effluent limitations, pretreatment standards, and new source performance standards for 42 major industrial categories (Title 40 CFR, Part 403). Examples of toxic substances typically found in wastewater are heavy metals, cyanides, aqueous film-forming foam (AFFF), phenols and halogenated phenols, paint stripping agents, solvents, surfactants, and degreasers.

a) Contact local and state regulatory agencies for an updated list of priority pollutants.

b) If characteristics of industrial wastewater are unknown, obtain complete organic and inorganic analysis by an EPA certified laboratory.

2.3 EFFLUENT DISCHARGE LIMITS. Effluent discharge limits for industrial wastes are established by the EPA. The limits are specific to the industrial waste category (such as metal finishing or electroplating), the type of industrial facility (new or existing), and the point of discharge. Effluent discharge alternatives are presented below.

2.3.1 DIRECT DISCHARGE TO NAVIGABLE WATER. Direct discharge to a receiving water body would be regulated under the NPDES permit. Direct discharge will usually require an extensive treatment facility that is capable of producing low effluent pollutant levels for conventional pollutants and toxic pollutants.

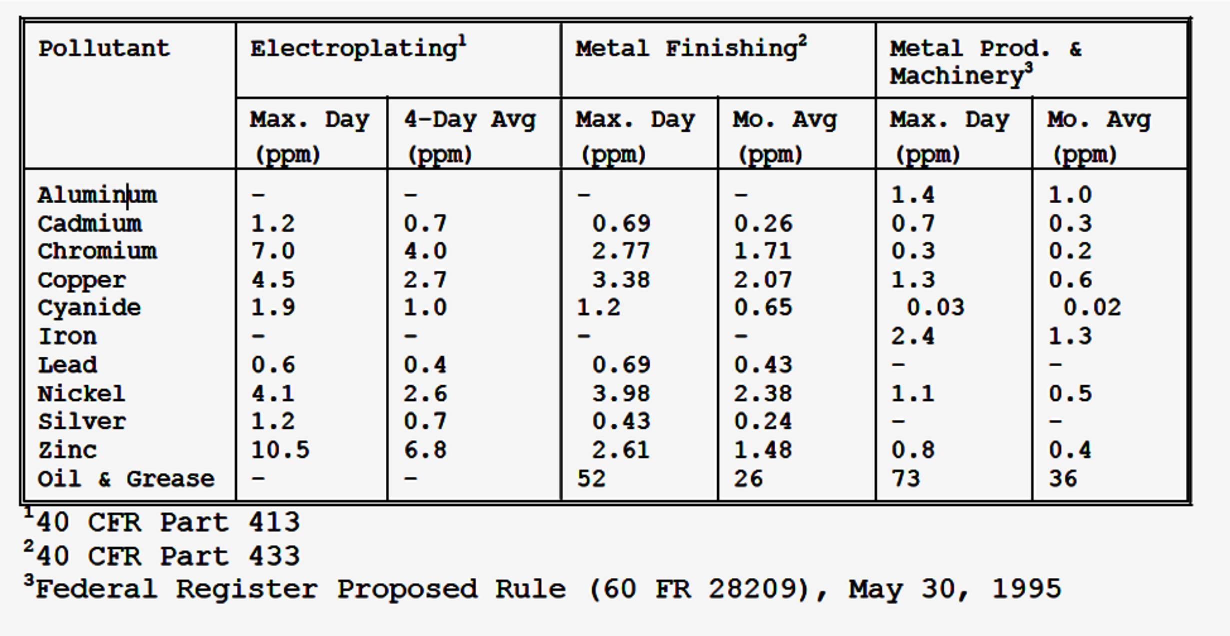
2.3.2 INDIRECT DISCHARGE. Indirect discharge to a receiving water body occurs by way of a sewerage collection system and a POTW. Indirect discharge does not require an NPDES permit for the industrial wastewater. The discharged wastewater characteristics, however, must satisfy the POTW's sewer use ordinance and pretreatment standards. A treatment facility that uses indirect discharge is designated herein as a pretreatment facility.

a) Indirect discharge levels for conventional pollutants will usually be higher and easier to satisfy than levels for direct discharge.

b) Indirect discharge levels for toxic substances may be greater than or equal to those for direct discharge depending on the POTW sewer ordinance.

Contact local officials for sewer use ordinances and EPA categorical discharge standards to determine applicable industrial category and discharge limits. These limits will establish the industrial treatment or pretreatment requirements prior to direct or indirect discharge, respectively.

2.3.3 PRETREATMENT REGULATIONS. Pretreatment standards for concentrations of pollutants that may be discharged to a POTW by industrial users are established by the EPA (Title 40 CFR, Part 403.6). Existing categorized pretreatment standards for the electroplating (40 CFR Part 413) and metal machinery category (40 CFR Part 433) are summarized in Table 2-1.



Pollutant	Electroplating[1]		Metal Finishing[2]		Metal Prod. & Machinery[3]	
	Max. Day (ppm)	4-Day Avg (ppm)	Max. Day (ppm)	Mo. Avg (ppm)	Max. Day (ppm)	Mo. Avg (ppm)
Aluminum	-	-	-	-	1.4	1.0
Cadmium	1.2	0.7	0.69	0.26	0.7	0.3
Chromium	7.0	4.0	2.77	1.71	0.3	0.2
Copper	4.5	2.7	3.38	2.07	1.3	0.6
Cyanide	1.9	1.0	1.2	0.65	0.03	0.02
Iron	-	-	-	-	2.4	1.3
Lead	0.6	0.4	0.69	0.43	-	-
Nickel	4.1	2.6	3.98	2.38	1.1	0.5
Silver	1.2	0.7	0.43	0.24	-	-
Zinc	10.5	6.8	2.61	1.48	0.8	0.4
Oil & Grease	-	-	52	26	73	36

[1] 40 CFR Part 413

[2] 40 CFR Part 433

[3] Federal Register Proposed Rule (60 FR 28209), May 30, 1995

Table 2-1

Selected Categorical Pretreatment Standards

2.4 PLANNING AND DESIGN PROCEDURES. See Figure 2-1 for an illustration of stepwise procedures for planning and design of an industrial waste treatment project.

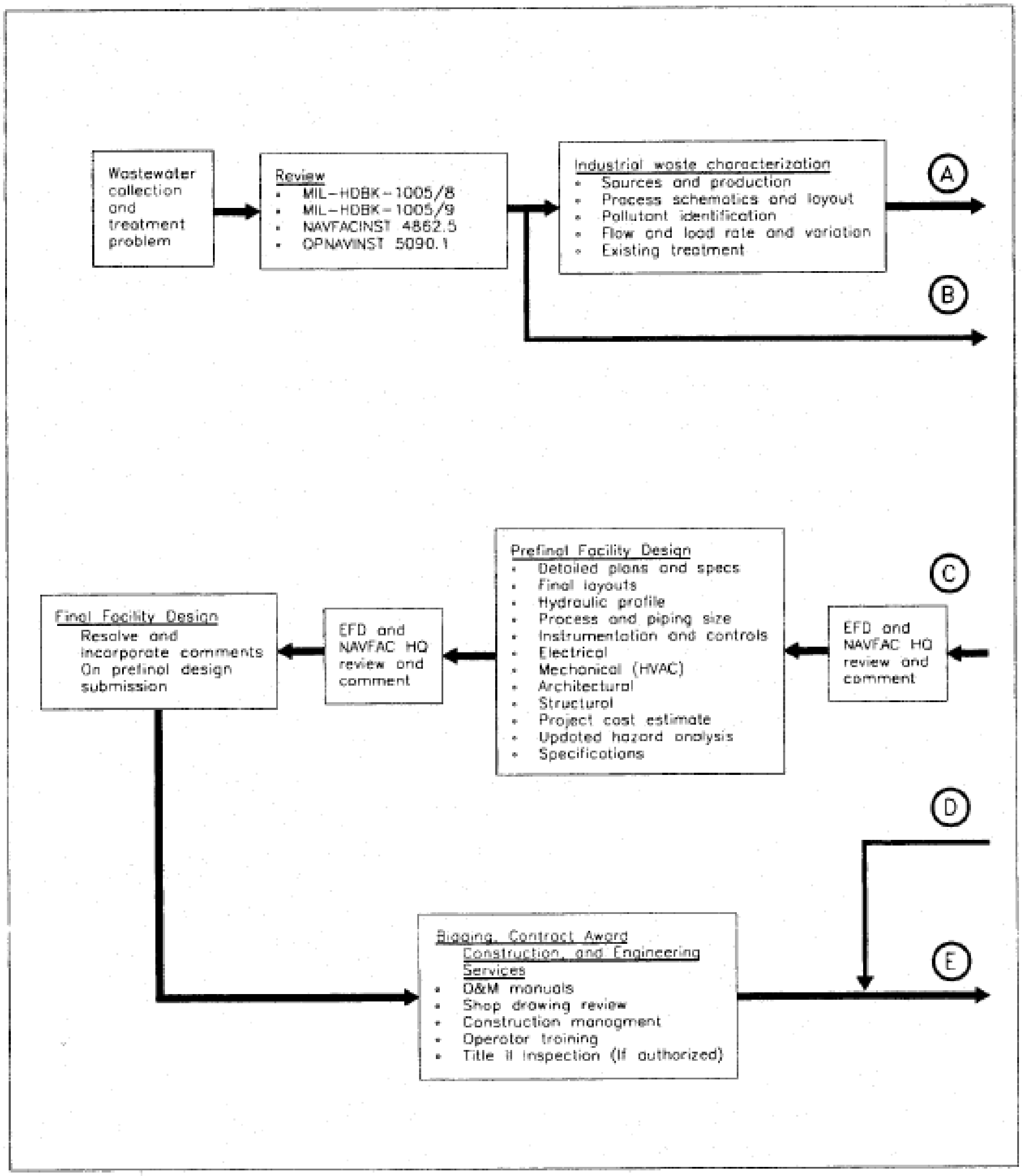


Figure 2-1

Planning and Design Steps for Industrial Waste Treatment Facility

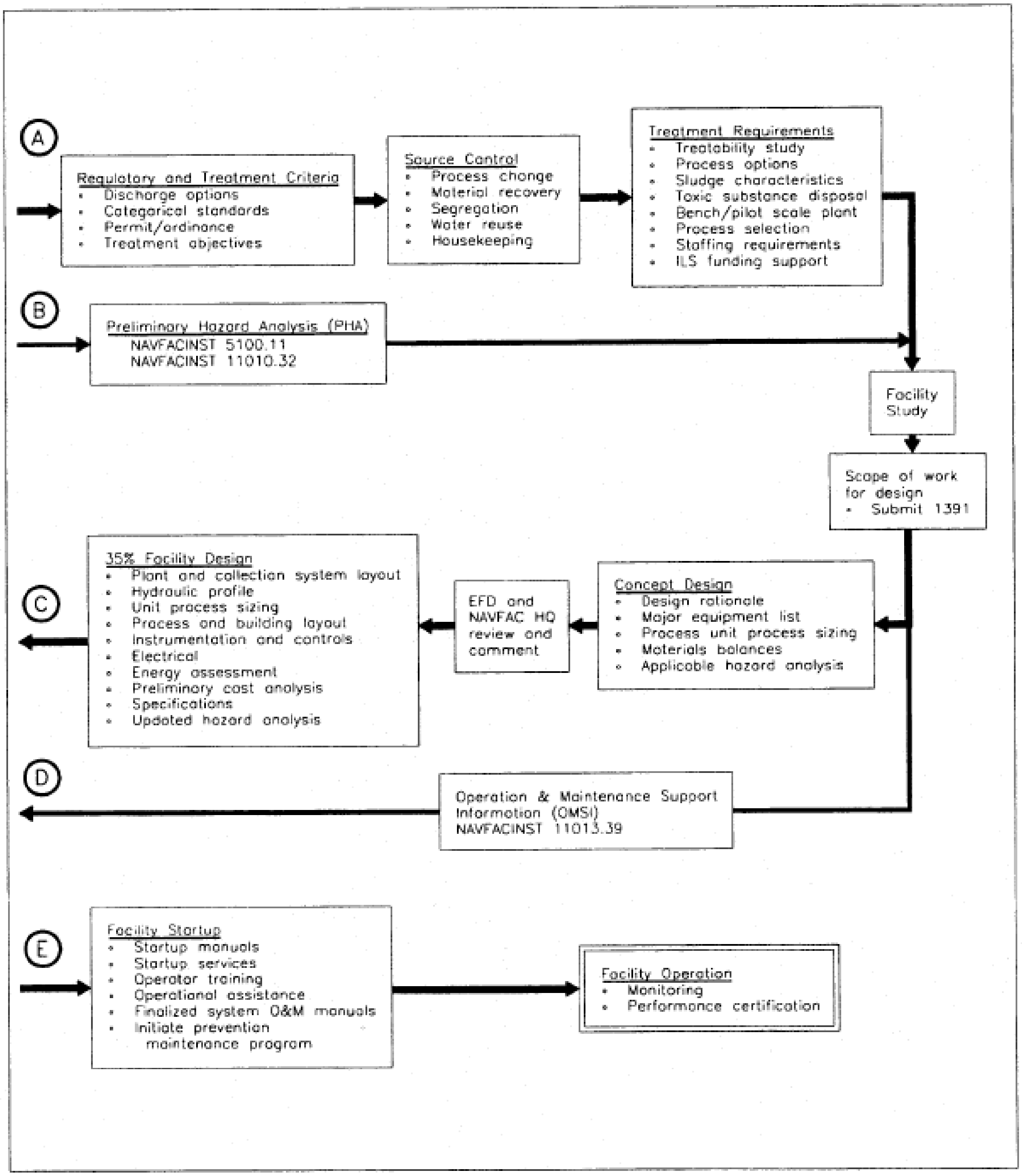


Figure 2-1 (continued)

Planning and Design Steps for Industrial Waste Treatment Facility

3. SOURCE CONTROL AND WASTE REDUCTION. Investigations should be undertaken to determine the characteristics of wastes, their sources, and potential means for reducing waste quantities prior to proceeding on any industrial waste collection and treatment project.

3.1 SOURCE CHARACTERIZATION. Identify wastewater sources using typical industrial waste survey techniques, sewer plans, process piping diagrams, and dye tracer methods. Develop complete and updated wastewater flow schematics and current and projected production rates.

3.2 PROCESS CHANGES. Evaluate the potential for reducing waste volume or strength through process changes such as changing cleanup operations from wet to dry methods; arranging plating operations for countercurrent rinsing or solution recovery; using wastewater from one process as a source of water for another process (when the second process does not have a high quality requirement); and recycling some wastewaters.

3.3 SOURCE SEPARATION. Separate uncontaminated flows, such as storm water inlets, roof drains, building subdrains, and uncontaminated cooling water from contaminated process flow, to minimize the volume requiring treatment. Consider combining separate waste flows that are compatible for co-treatment, such as neutralization by combining acid and alkaline flows. Separate process wastewaters containing pollutants whose individual treatment methods are not compatible or create hazardous conditions. Examples of wastewater to be separated are precipitation treatment of copper and lead (incompatible since optimum pH of precipitation of each metal is not equal) and acid reduction of hexavalent chrome in the presence of cyanide (hazardous as it produces toxic hydrogen cyanide gas).

3.3.1 METAL PLATING WASTES. Provide for isolation and separate collection system for chrome and phenol containing wastewaters, for cyanide containing wastewaters, and for mixed acid and alkaline-content wastewaters.

3.3.2 OILY WASTES. Used oils and solvents should be segregated at their source (if possible). Do not mix oily waste with aqueous waste streams containing metals and phenols.

3.3.3 COSTS. The additional cost of source isolation and separate collection systems is offset by reduced treatment process requirements, complexity, and cost and reduction in facility operational hazards.

3.4 RECOVERY. Consider the feasibility of recovering materials, such as semiprecious and precious metals, and chrome, from a metal plating waste stream for subsequent reuse by using electrolytic recovery units (ERUs).

3.5 GOOD HOUSEKEEPING. Investigate current process operating practices to determine if good housekeeping practices are employed, or if changes can be made to reduce wasted materials or use of excess water.

4. WASTEWATER FLOWS AND CHARACTERISTICS

4.1 TYPES OF WASTEWATER. Typical sources of wastewater from industrial facilities are plating operations, painting and stripping operations, graving dock operations, degreasing operations, firefighting schools, equipment operation and maintenance, and miscellaneous processes.

4.2 FLOWS

4.2.1 MONITORING. Each industrial waste should be surveyed and its flow should be established. Average conditions, as well as variations, should be identified. Flow rates should be correlated with process production rates to allow extrapolation to full load conditions.

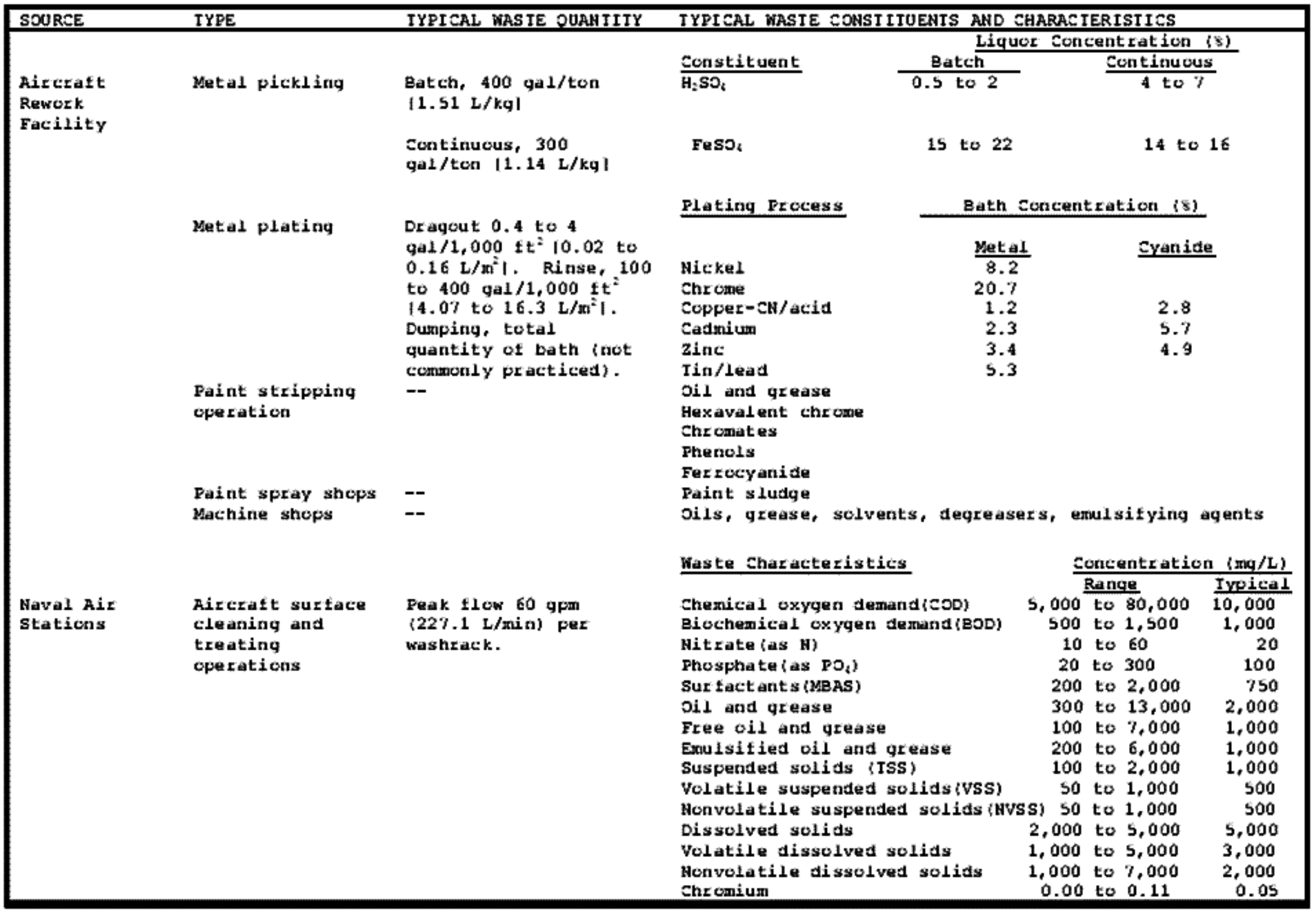
4.2.2 PEAK FLOWS. Peak flows will normally be higher during a specific 8-hour shift during the day (or during a specific day at single shift shops). The peak flow shift should be utilized as the basis for sizing treatment facilities.

4.3 FLOW CHARACTERISTICS

4.3.1 MONITORING. Determine industrial wastewater characteristics for design from a survey of the actual wastes involved or from knowledge of waste at similar facilities. Refer to the Environmental Protection Agency's (EPA) PB 259146, Handbook for Monitoring Industrial Wastewater for sampling and gaging techniques. Use of waste parameters from similar facilities is practical where monitoring of actual wastes may be difficult or costly; however, monitoring major flow contributions at a specific facility is the preferred method. Ensure that waste monitoring and characterization programs are adequate for full development of design criteria.

4.3.2 TYPICAL CHARACTERISTICS. Characteristics of discharges from some industries commonly associated with typical facilities are presented in Table 4-1. These characteristics are only for preliminary engineering analysis. Characteristics of wastes from other industrial processes at Navy facilities may be found in the technical literature. Daily and process-related variations in wastewater characteristics should be identified and related to production operations to facilitate development of control strategies.

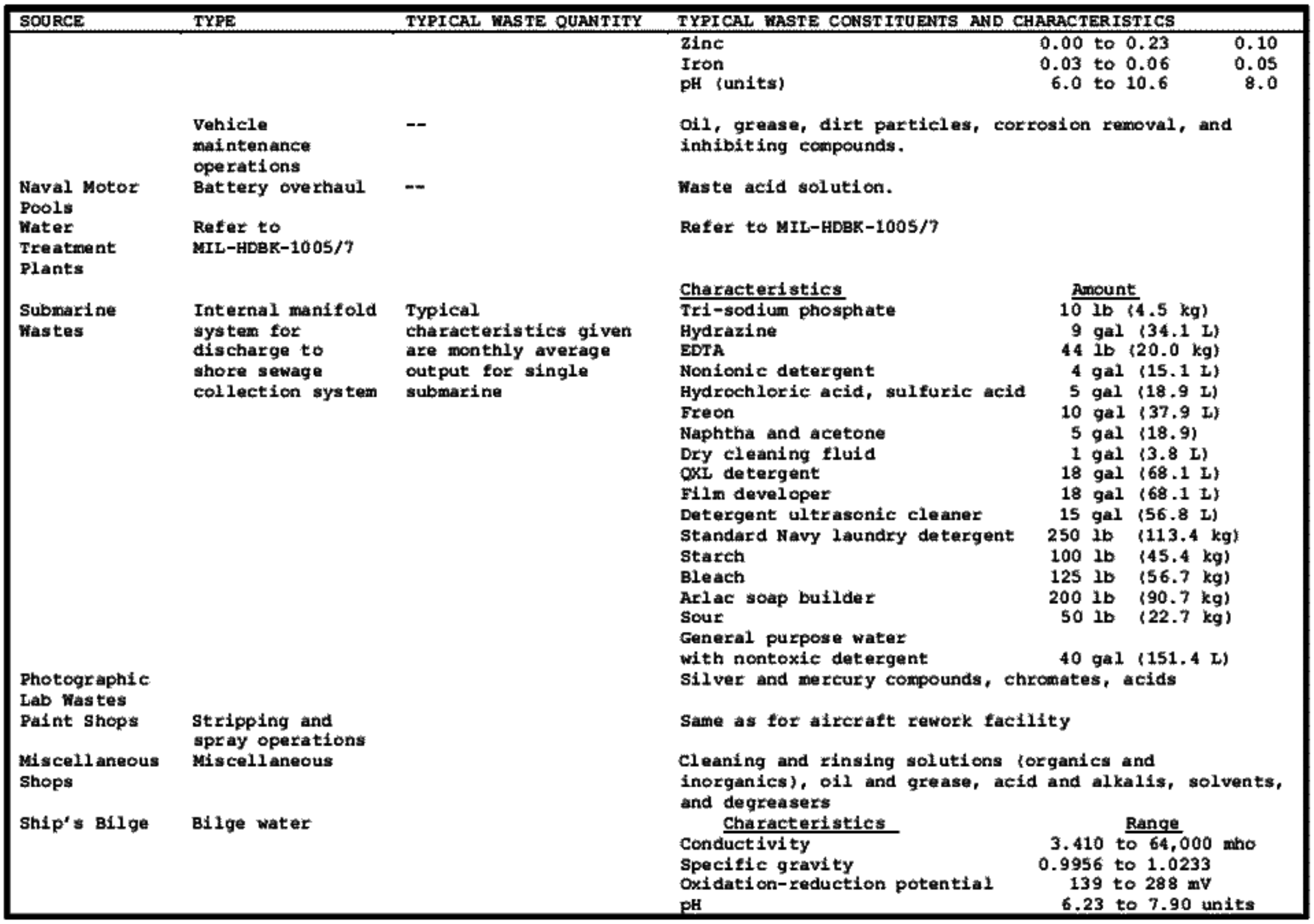
4.3.3 DISCHARGE CRITERIA. Identify effluent criteria applicable to discharge from a proposed industrial waste treatment plant for either NPDES permit or local pretreatment requirements or recycling to another process. Metal finishing and battery manufacturing (motor pool) are the only categorical industrial waste types listed in Table 4-1 that have final pretreatment and direct discharge limits established by EPA pretreatment standards. Refer to Title 40 CFR, Part 403, for metal finishing regulations and Title 40 CFR, Part 403, for battery wastes. None of the other listed waste types have established categorical standards. Consult local, state, and Federal regulatory agencies to determine applicable discharge standards for these waste types.



SOURCE	TYPE	TYPICAL WASTE QUANTITY	TYPICAL WASTE CONSTITUENTS AND CHARACTERISTICS		
				Liquor Concentration (%)	
			Constituent	Batch	Continuous
Aircraft Rework Facility	Metal pickling	Batch, 400 gal/ton [1.51 L/kg]	H_2SO_4	0.5 to 2	4 to 7
		Continuous, 300 gal/ton [1.14 L/kg]	$FeSO_4$	15 to 22	14 to 16
			Plating Process	Bath Concentration (%)	
	Metal plating	Dragout 0.4 to 4 gal/1,000 ft^2 [0.02 to 0.16 L/m^2]. Rinse, 100 to 400 gal/1,000 ft^2 [4.07 to 16.3 L/m^2]. Dumping, total quantity of bath (not commonly practiced).		Metal	Cyanide
			Nickel	8.2	
			Chrome	20.7	
			Copper-CN/acid	1.2	2.8
			Cadmium	2.3	5.7
			Zinc	3.4	4.9
			Tin/lead	5.3	
	Paint stripping operation	--	Oil and grease		
			Hexavalent chrome		
			Chromates		
			Phenols		
			Ferrocyanide		
	Paint spray shops	--	Paint sludge		
	Machine shops	--	Oils, grease, solvents, degreasers, emulsifying agents		
			Waste Characteristics	Concentration (mg/L)	
				Range	Typical
Naval Air Stations	Aircraft surface cleaning and treating operations	Peak flow 60 gpm (227.1 L/min) per washrack.	Chemical oxygen demand(COD)	5,000 to 80,000	10,000
			Biochemical oxygen demand(BOD)	500 to 1,500	1,000
			Nitrate(as N)	10 to 60	20
			Phosphate(as PO_4)	20 to 300	100
			Surfactants(MBAS)	200 to 2,000	750
			Oil and grease	300 to 13,000	2,000
			Free oil and grease	100 to 7,000	1,000
			Emulsified oil and grease	200 to 6,000	1,000
			Suspended solids (TSS)	100 to 2,000	1,000
			Volatile suspended solids(VSS)	50 to 1,000	500
			Nonvolatile suspended solids(NVSS)	50 to 1,000	500
			Dissolved solids	2,000 to 5,000	5,000
			Volatile dissolved solids	1,000 to 5,000	3,000
			Nonvolatile dissolved solids	1,000 to 7,000	2,000
			Chromium	0.00 to 0.11	0.05

Table 4-1

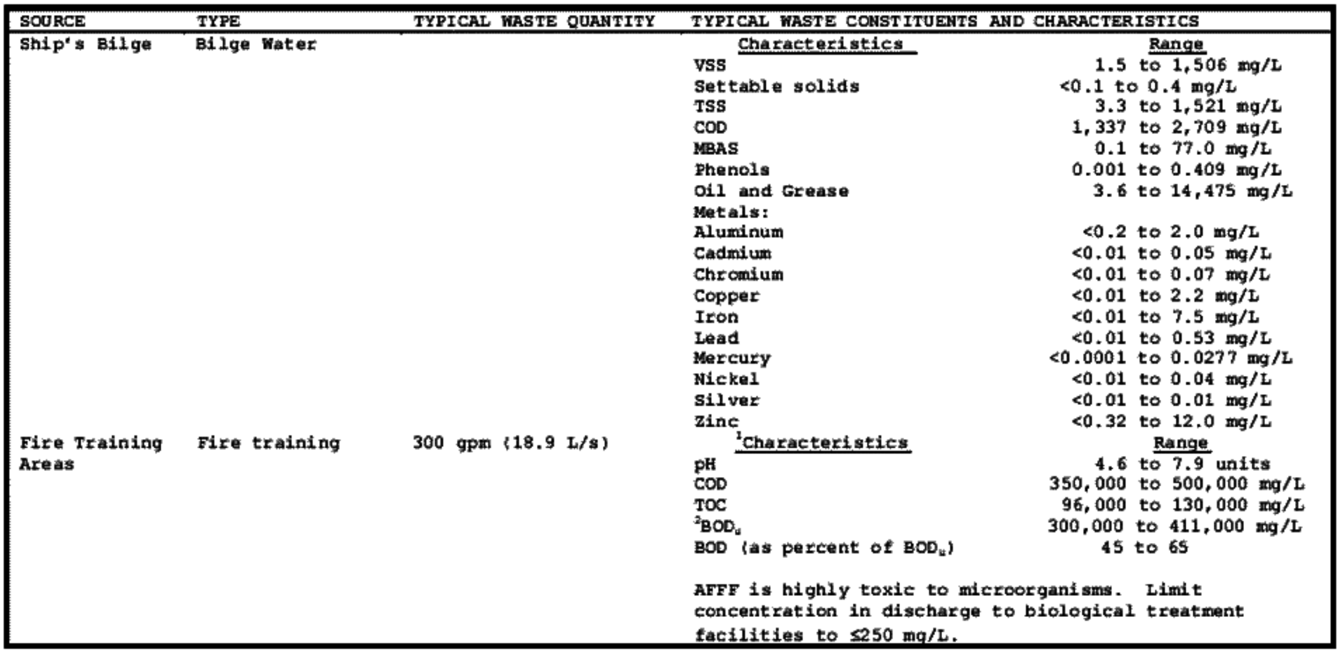
Characteristics of industrial wastes



SOURCE	TYPE	TYPICAL WASTE QUANTITY	TYPICAL WASTE CONSTITUENTS AND CHARACTERISTICS		
			Zinc	0.00 to 0.23	0.10
			Iron	0.03 to 0.06	0.05
			pH (units)	6.0 to 10.6	8.0
	Vehicle maintenance operations	--	Oil, grease, dirt particles, corrosion removal, and inhibiting compounds.		
Naval Motor Pools	Battery overhaul	--	Waste acid solution.		
Water Treatment Plants	Refer to MIL-HDBK-1005/7		Refer to MIL-HDBK-1005/7		
			Characteristics	Amount	
Submarine Wastes	Internal manifold system for discharge to shore sewage collection system	Typical characteristics given are monthly average output for single submarine	Tri-sodium phosphate	10 lb (4.5 kg)	
			Hydrazine	9 gal (34.1 L)	
			EDTA	44 lb (20.0 kg)	
			Nonionic detergent	4 gal (15.1 L)	
			Hydrochloric acid, sulfuric acid	5 gal (18.9 L)	
			Freon	10 gal (37.9 L)	
			Naphtha and acetone	5 gal (18.9)	
			Dry cleaning fluid	1 gal (3.8 L)	
			QXL detergent	18 gal (68.1 L)	
			Film developer	18 gal (68.1 L)	
			Detergent ultrasonic cleaner	15 gal (56.8 L)	
			Standard Navy laundry detergent	250 lb (113.4 kg)	
			Starch	100 lb (45.4 kg)	
			Bleach	125 lb (56.7 kg)	
			Arlac soap builder	200 lb (90.7 kg)	
			Sour	50 lb (22.7 kg)	
			General purpose water with nontoxic detergent	40 gal (151.4 L)	
Photographic Lab Wastes			Silver and mercury compounds, chromates, acids		
Paint Shops	Stripping and spray operations		Same as for aircraft rework facility		
Miscellaneous Shops	Miscellaneous		Cleaning and rinsing solutions (organics and inorganics), oil and grease, acid and alkalis, solvents, and degreasers		
Ship's Bilge	Bilge water		Characteristics	Range	
			Conductivity	3.410 to 64,000 mho	
			Specific gravity	0.9956 to 1.0233	
			Oxidation-reduction potential	139 to 288 mV	
			pH	6.23 to 7.90 units	

Table 4-1 (continued)

Characteristics of industrial wastes



SOURCE	TYPE	TYPICAL WASTE QUANTITY	TYPICAL WASTE CONSTITUENTS AND CHARACTERISTICS	
Ship's Bilge	Bilge Water		Characteristics	Range
			VSS	1.5 to 1,506 mg/L
			Settable solids	<0.1 to 0.4 mg/L
			TSS	3.3 to 1,521 mg/L
			COD	1,337 to 2,709 mg/L
			MBAS	0.1 to 77.0 mg/L
			Phenols	0.001 to 0.409 mg/L
			Oil and Grease	3.6 to 14,475 mg/L
			Metals:	
			Aluminum	<0.2 to 2.0 mg/L
			Cadmium	<0.01 to 0.05 mg/L
			Chromium	<0.01 to 0.07 mg/L
			Copper	<0.01 to 2.2 mg/L
			Iron	<0.01 to 7.5 mg/L
			Lead	<0.01 to 0.53 mg/L
			Mercury	<0.0001 to 0.0277 mg/L
			Nickel	<0.01 to 0.04 mg/L
			Silver	<0.01 to 0.01 mg/L
			Zinc	<0.32 to 12.0 mg/L
Fire Training Areas	Fire training	300 gpm (18.9 L/s)	^{1}Characteristics	Range
			pH	4.6 to 7.9 units
			COD	350,000 to 500,000 mg/L
			TOC	96,000 to 130,000 mg/L
			^{2}BOD$_u$	300,000 to 411,000 mg/L
			BOD (as percent of BOD$_u$)	45 to 65
			AFFF is highly toxic to microorganisms. Limit concentration in discharge to biological treatment facilities to ≤250 mg/L.	

Table 4-1 (continued)

Characteristics of industrial wastes

4.3.4 RADIOACTIVE WASTES. Wastes that have radioactivity are not covered in this discussion.

4.4 FLOW AND LOAD EQUALIZATION. Certain processes have short duration, and high flow and loading rates that can adversely impact the collection and treatment systems. At-the source equalization tanks may be advantageous to minimize these hydraulic and pollutant load surges. Equalization should be evaluated on a large scale for compatible wastes received at a treatment facility, or on a smaller scale for specific process line-waste discharges.

4.4.1 BASIN SIZING. Equalization basin volume may be controlled by either flow variations or load variations of the influent. The method of sizing should be selected based on the equalization objective (flow or load).

4.4.1.1 FLOW EQUALIZATION. If curve of inflow rate variations is available, apply mass diagram techniques to determine the required storage volume for desired outflow rate. In absence of the flow rate curve, determine the required storage volume by statistical methods and as outlined in the Statistical Design of Equalization Basins, the American Society of Civil Engineers (ASCE) Journal of the Environmental Engineering Division.

4.4.1.2 LOAD EQUALIZATION. Determine the effect of required volume for flow equalization of pollutant loads. Use the method presented in the Water and Sewage Works Journal, Developing a Methodology for Design of Equalization Basins, Ouano, 1977. If adequate power is not provided for complete mixing in the basin, size the basin on non-ideal flow pattern described by Ouano (1977). Consider the effects of variable and constant volume basin on equalization performance.

4.4.2 BASIN CONSTRUCTION. Use steel or concrete tanks with suitable liners to prevent ground water contamination. Earth embankment lagoons are not allowed unless permitted by Resource Conservation and Recovery Act (RCRA). Provide a protective liner compatible with wastewater characteristics. Consider frequency of basin use and solids deposition and clean-out when evaluating the need for liners.

4.4.3 MIXING CONDITIONS. Provide sufficient aeration or mixing conditions to maintain 1 mg/L of dissolved oxygen in tank contents. Some equalized wastes may exert no oxygen demand but will require mixing to maintain solids in suspension. Provide circulation velocity of at least 1.0 fps at locations over the floor of basin. Consult manufacturers as to circulation capacity of their aeration or mixing equipment for particular basin configuration. Provide for removal of deposited solids from basin, either by drainage and cleaning during off-peak hours or by cleaning without draining.

4.5 EFFECT OF INDUSTRIAL WASTES

4.5.1 COLLECTION SYSTEMS. The characteristics of industrial process wastewaters must be carefully evaluated so that damage or blockage of the collection system or safety hazards to workmen do not result. Waste acids and hydrogen sulfide can attack concrete and metal conduits. Flammable and explosive materials should be restricted from the sewer system as they may cause explosive conditions. Refer to Water Environment Federation (WEF), Manual of Practice (MOP) No. 3, Regulation of Sewer Use.

4.5.2 TREATMENT SYSTEMS. Structures and personnel at treatment facilities are subject to the same hazards noted for collection systems. In addition, certain industrial wastes can severely inhibit biological treatment performance and overload other unit processes. Evaluations of wastewater characteristics must be closely coupled with proposed treatment processes to ensure that treatment facilities and process performance are protected.

4.6 LIMITS ON BIOLOGICAL TREATMENT

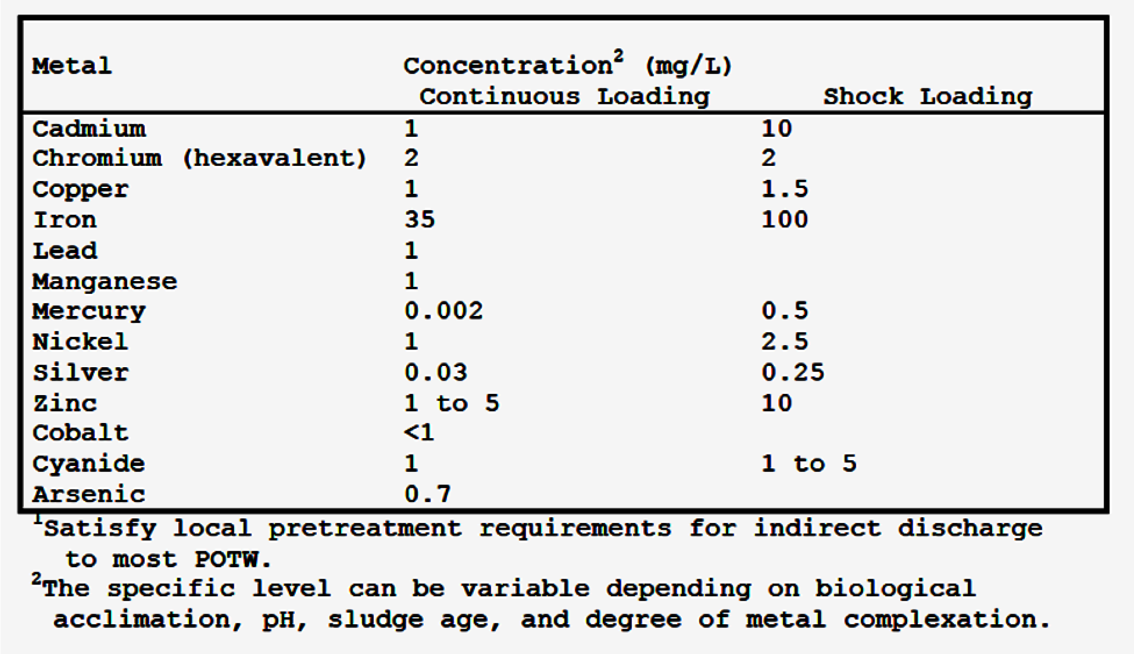
4.6.1 CONVENTIONAL POLLUTANTS. When toxic substances are absent, use loading criteria for conventional pollutants.

4.6.2 TOXIC SUBSTANCES. Toxic substances, such as heavy metals and certain organic compounds present in some industrial wastes, must be controlled to avoid upset or pass-through of biological treatment systems.

a) The levels of heavy metals that can usually be tolerated by biological treatment systems as both a continuous load and as a shock load are listed on Table 4-2. These levels should be used only for influent characterization to biological treatment at NOTW and pretreatment facilities. The NPDES permit establishes allowable effluent metal limits for direct discharge to navigable water. Allowable levels for indirect discharge are established by the POTW's sewer use ordinance and applicable pretreatment standards.

b) Some organic priority pollutants are also removed by conventional biological treatment systems. Removal mechanisms are biodegradation, volatilization (stripping), and adsorption. Other organic priority pollutants are not removed to any significant or reliable degree and pass through the treatment facility. The degree, methods, and costs of removal of the priority pollutants by conventional treatment processes have been determined by the EPA (refer to EPA 600/2-82-001 a-e, Treatability Manual, Vols. I-V). These treatability data should be used for guidance only. Actual removal performance depends on the operating characteristics (sludge age, mixed liquor suspended solids (MLSS)) of the treatment facility, the method of oxygenation, and the amount and nature of other compounds present in the wastewater. Bench or pilot scale treatability studies should determine removal performance. Refer to Industrial Water Pollution Control, by Eckenfelder and Ford (1988), for the procedure for conducting treatability studies.

4.6.3 OTHER POLLUTANTS. Some industrial wastes may not contain any listed priority pollutants but may still be toxic due to the presence of other compounds. These wastes should be evaluated using bioassay procedures to negotiate and establish pretreatment levels for discharge to POTW systems.



Metal	Concentration[2] (mg/L)	
	Continuous Loading	Shock Loading
Cadmium	1	10
Chromium (hexavalent)	2	2
Copper	1	1.5
Iron	35	100
Lead	1	
Manganese	1	
Mercury	0.002	0.5
Nickel	1	2.5
Silver	0.03	0.25
Zinc	1 to 5	10
Cobalt	<1	
Cyanide	1	1 to 5
Arsenic	0.7	

[1] Satisfy local pretreatment requirements for indirect discharge to most POTW.

[2] The specific level can be variable depending on biological acclimation, pH, sludge age, and degree of metal complexation.

Table 4-2

Threshold Concentrations for Heavy Metal Inhibition of

Biological Treatment Processes

4.6.4 NUTRIENTS. Certain minimum amounts of nutrients are required for efficient biological treatment. Normal proportions needed for active microbiological growth are typically about 1 pound (0.45 kg) of phosphorous (as P) and 5 pounds (2.25 kg) of nitrogen (as N) for each 100 pounds (45 kg) of BOD removed (requirements are somewhat lower for lightly loaded systems). Mixing industrial wastes with domestic sewage often avoids the need for supplemental nutrients since sewage contains excess amounts. However, nutrient levels must be evaluated for both separate and combined industrial waste treatment systems.

4.6.5 OTHER. Other wastewater characteristics (such as pH, dissolved solids, and nontoxic industrial organic chemicals) can inhibit biological treatment performance. The identification and allowable concentration of these characteristics can best be determined from treatment of similar wastes and from review of technical literature. If adequate data on treatability of these wastewaters are not available, conduct pilot or bench scale treatability tests.

4.7 BIOASSAY OF WASTEWATERS. Effluent limitations are based in part on limitations for individual chemicals or generic pollutant parameters: chemical oxygen demand (COD), BOD, or total organic carbon (TOC). Comprehensive physiochemical characterization of an effluent does not directly indicate any possible adverse effects on the ecosystem of the receiving stream. The collective effects of physical, chemical, and biological properties of the effluent are exhibited in the observed toxicity as measured by the bioassay procedure. Industrial process wastewater from naval installations may contain toxic compounds that exhibit none of the generic pollutant parameters or cannot be disclosed for security reasons. The monitoring of these effluents by bioassay techniques may be required by regulatory agencies.

4.7.1 STANDARD BIOASSAY PROCEDURES. A bioassay measures the concentration of pollutant at which a designated percentage of selected test organisms exhibits an observable adverse effect. The percentage is usually 50 percent, and the adverse effect is usually death or immobility. Concentrations (percent by volume) are expressed as LC5O for median lethal concentration and EC5O for median effective concentration.

4.7.1.1 TEST ORGANISMS. Effluent tests should be conducted with a sensitive species that is indigenous to the receiving water. The test organisms do not have to be taken from the receiving water. Refer to EPA 600/4-90-027F, Acute Toxicity – Freshwater and Marine Organisms, for a complete list of acceptable test organisms and temperatures.

4.7.1.2 METHODOLOGY. Refer to EPA 600/4-90-027F, for a complete description of required test equipment, laboratory and test procedures, sampling and analytical procedures, procedures for data gathering and reporting, and methods for data reduction and analysis to determine LC50 or EC50. Regulatory bioassay requirements and LC50 or EC50 are usually based on 48- or 96-hour tests using fish or invertebrates (for example minnows or Daphnia, respectively). These require extensive equipment, time, and test procedures, and do not provide a rapid assessment of effluent toxicity.

4.7.2 RAPID BIOASSAY PROCEDURE (RBP). The use of RBP should be considered by installations in lieu of standard procedures. RBP is a useful tool in effluent monitoring since inexpensive yet reliable toxicity data can be obtained quickly. The EPA has not approved RBP as an equivalent method. Check with a State regulatory agency for approval of RBP prior to developing a test program. A substantial database of toxicity of pure compounds, and of raw and treated industrial effluents has been developed using RBP (refer to Use of Rapid Bioassay Procedure for Assessment of Industrial Wastewater Treatment Effectiveness, presented at the 38th Purdue Industrial Waste Conference, May 1983). The RBP results have shown good reproducibility and correlation with results of the long-term standard procedure. The RBP is best conducted using one of the proprietary methods and equipment available from chemical instrumentation and equipment manufacturers (for example, the Beckman Microtoxä system, Beckman Instruments, Inc.).

5 WASTEWATER COLLECTION

5.1 GRAVITY AND PRESSURE SYSTEMS. Primary considerations in collecting industrial wastes are waste segregation and material selection. Protect pipes, pumps, and appurtenances coming in contact with the wastewater from damage that can be caused by solvents, corrosion, temperature, and pH characteristics of the wastes. Double-wall pipe with leak detection may be required in some application where the potential for soil contamination exist. Collection system modifications or pretreatment steps should be considered for industrial wastes with high solids or sludge content or for wastes that may react to produce solids and sludge deposits. Address the release and formation of toxic or explosive gases in the system design. The following limitations on discharge to industrial waste sewers should be observed.

5.1.1 STORM WATER. Storm water should not be carried in industrial waste sewers. Provide separate industrial and storm water collection systems.

5.1.2 UNCONTAMINATED WASTES. Segregate uncontaminated cooling waters and similar discharges from municipal and commercial establishments from polluted wastes and discharged to storm sewers or natural watercourses. Check with the local Engineering Field Division (EFD) or Engineering Field Activity (EFA) to determine if a discharge permit is required for such uncontaminated waters.

5.1.3 HAZARDOUS AND TOXIC WASTES. Exclude or pretreat wastes that can create a fire or explosion hazard, endanger lives, impair hydraulic capacity, cause corrosion, or carry toxic elements in sufficient quantities to impair downstream treatment processes. Refer to WEF MOP No. 3.

5.2 GRAVITY SEWERS. The design for gravity sewers is as follows:

5.2.1 DESIGN FLOWS. Design sewers for peak flow, except design main interceptor to treatment facility for 125 percent of peak flow.

5.2.2 FLOW FORMULA. Use the Manning formula (refer to WEF MOP No. FD-5, Gravity Sanitary Sewer Design and Construction) to design sewers to flow full, without surcharge, under peak flow (equivalent to design for flow at 0.8 depth under peak flow with friction factor constant). Use friction factor “n” of 0.013 for most smooth wall pipes; for corrugated wall pipes, use “n” of 0.025.

5.2.3 VELOCITY CONSTRAINTS. Design pipe slopes to ensure a velocity of at least 2.5 feet per second (fps) (0.76 meters per second [m/s]) when pipe is flowing full at peak flow. Velocity should not exceed 10 fps (3.05 m/s) for any flow in design range. Velocities as low as 2.0 fps (0.6 m/s) flowing fully are permitted where appreciable cost benefits can be realized.

5.2.4 MAINTENANCE OF ENERGY GRADIENT. Design to maintain the energy gradient when the diameter of the sewer changes. Set 0.8 depth point of each pipe at the same elevation to approximate this requirement.

5.2.5 PIPE DIAMETER. No sewers in the collection system (including laterals, interceptors, trunks, and mains) should be less than 8 inches (203 mm) in diameter. Other building service connections should be at least 6 inches (152 mm) in diameter.

5.2.6 DEPTH. Place sewers sufficiently deep to receive wastewater from basements and to prevent freezing. Depths greater than 15 feet (4.6 m) are usually uneconomical.

5.2.7 LAYOUT. Do not lay trunk lines under buildings. Consider maintenance in the system layout.

5.2.8 STRUCTURES AND APPURTENANCES. See Table 5-1 for applications and details of sewer structures.

5.2.9 PIPES. Guidelines for selection of sewer pipe material are given in Table 5-2. Requirements for pipe are given in NFGS-02530, Sanitary Sewerage, and in Tables 5-1 and 5-2.

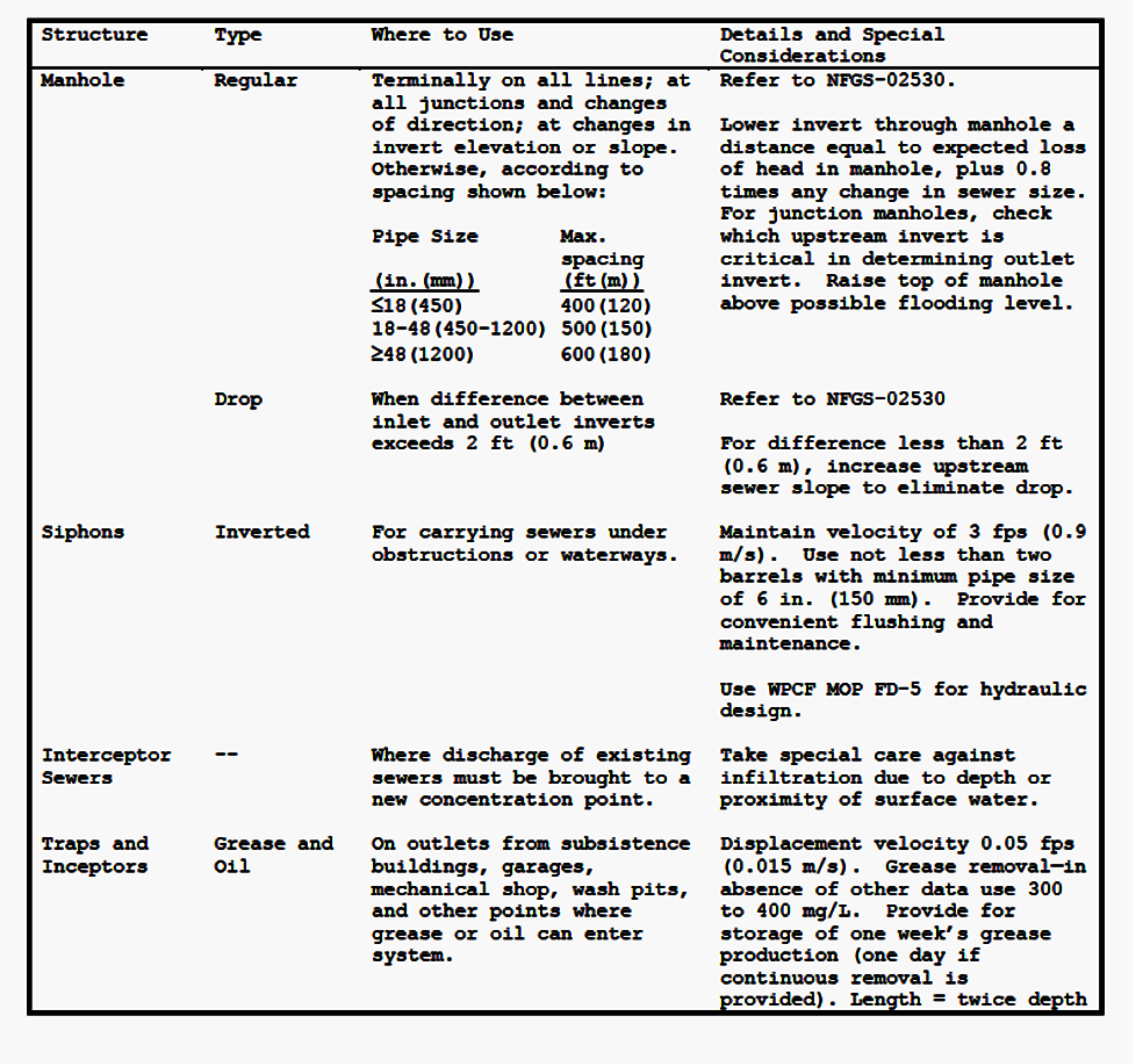
5.2.10 INSTALLATION. Installation requirements are given in NFGS-02530 or in Table 5-5.

a) Use WEF MOP FD-5 for criteria pertaining to trenching, foundations, laying, pipe cover, and loads.

b) For design criteria in cold regions, use appropriate criteria.

c) Design sewer lines located aboveground on structural supports in high wind areas to withstand expected wind velocities.

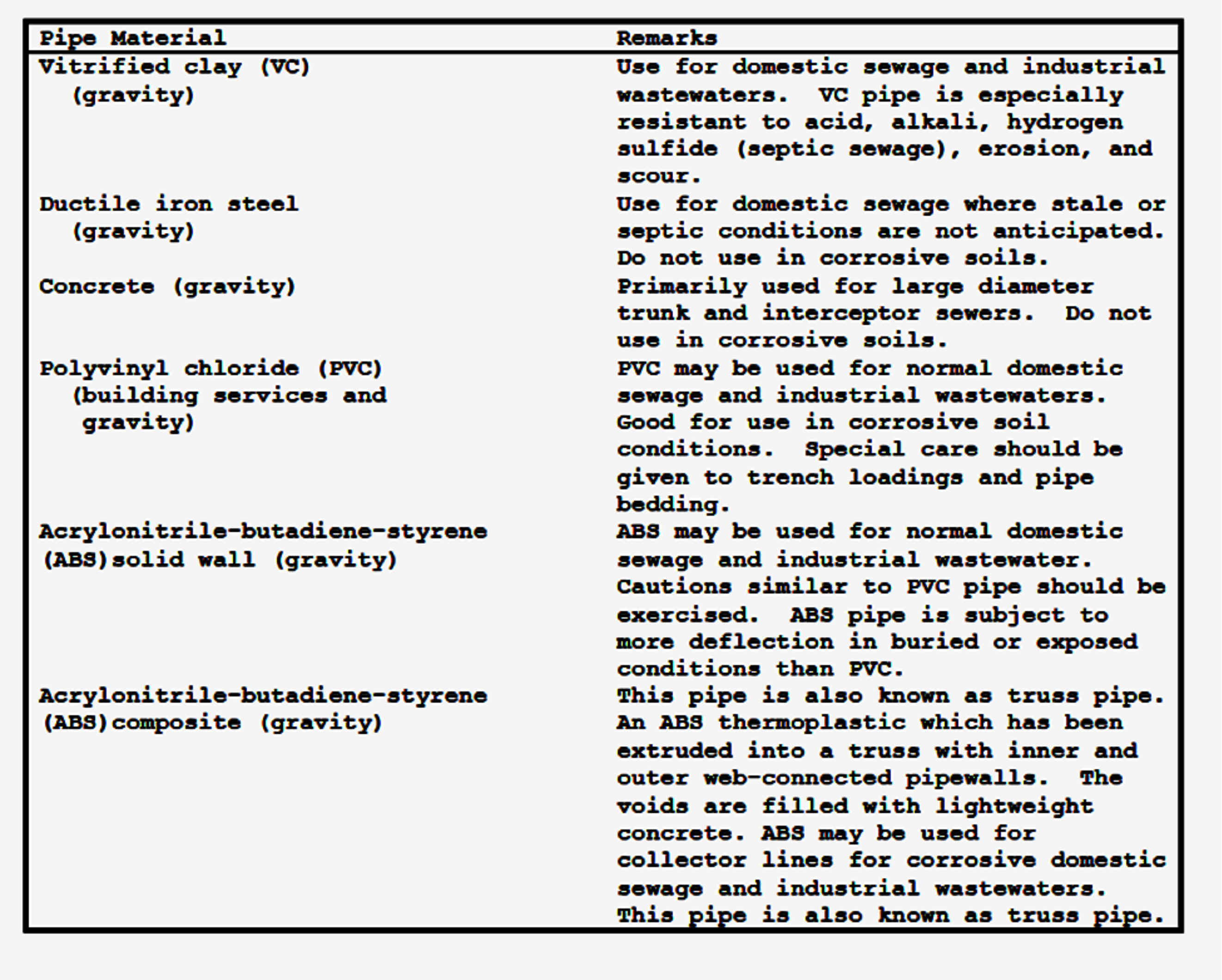
5.3 PUMPING. Use pumping only where a gravity system cannot serve hydraulically or where cost analysis shows a significant saving. Incorporate the following criteria for industrial wastewater systems.



Structure	Type	Where to Use	Details and Special Considerations
Manhole	Regular	Terminally on all lines; at all junctions and changes of direction; at changes in invert elevation or slope. Otherwise, according to spacing shown below: Pipe Size (in.(mm)) — Max. spacing (ft(m)) ≤18(450) — 400(120) 18-48(450-1200) — 500(150) ≥48(1200) — 600(180)	Refer to NFGS-02530. Lower invert through manhole a distance equal to expected loss of head in manhole, plus 0.8 times any change in sewer size. For junction manholes, check which upstream invert is critical in determining outlet invert. Raise top of manhole above possible flooding level.
	Drop	When difference between inlet and outlet inverts exceeds 2 ft (0.6 m)	Refer to NFGS-02530 For difference less than 2 ft (0.6 m), increase upstream sewer slope to eliminate drop.
Siphons	Inverted	For carrying sewers under obstructions or waterways.	Maintain velocity of 3 fps (0.9 m/s). Use not less than two barrels with minimum pipe size of 6 in. (150 mm). Provide for convenient flushing and maintenance. Use WPCF MOP FD-5 for hydraulic design.
Interceptor Sewers	--	Where discharge of existing sewers must be brought to a new concentration point.	Take special care against infiltration due to depth or proximity of surface water.
Traps and Inceptors	Grease and Oil	On outlets from subsistence buildings, garages, mechanical shop, wash pits, and other points where grease or oil can enter system.	Displacement velocity 0.05 fps (0.015 m/s). Grease removal—in absence of other data use 300 to 400 mg/L. Provide for storage of one week's grease production (one day if continuous removal is provided). Length = twice depth

Table 5-1

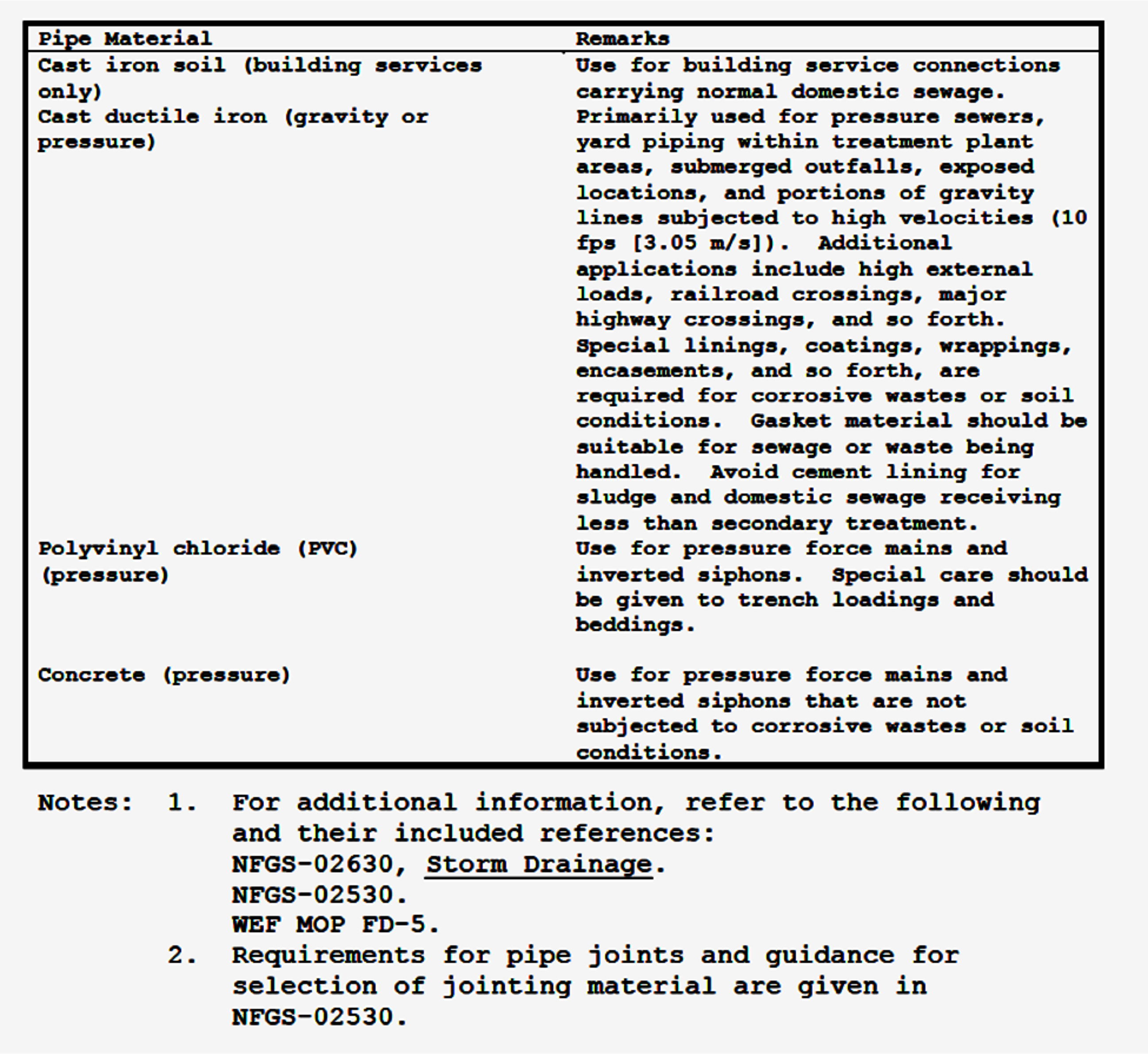
Sewer Structures



Pipe Material	Remarks
Vitrified clay (VC) (gravity)	Use for domestic sewage and industrial wastewaters. VC pipe is especially resistant to acid, alkali, hydrogen sulfide (septic sewage), erosion, and scour.
Ductile iron steel (gravity)	Use for domestic sewage where stale or septic conditions are not anticipated. Do not use in corrosive soils.
Concrete (gravity)	Primarily used for large diameter trunk and interceptor sewers. Do not use in corrosive soils.
Polyvinyl chloride (PVC) (building services and gravity)	PVC may be used for normal domestic sewage and industrial wastewaters. Good for use in corrosive soil conditions. Special care should be given to trench loadings and pipe bedding.
Acrylonitrile-butadiene-styrene (ABS) solid wall (gravity)	ABS may be used for normal domestic sewage and industrial wastewater. Cautions similar to PVC pipe should be exercised. ABS pipe is subject to more deflection in buried or exposed conditions than PVC.
Acrylonitrile-butadiene-styrene (ABS) composite (gravity)	This pipe is also known as truss pipe. An ABS thermoplastic which has been extruded into a truss with inner and outer web-connected pipewalls. The voids are filled with lightweight concrete. ABS may be used for collector lines for corrosive domestic sewage and industrial wastewaters. This pipe is also known as truss pipe.

Table 5-2

Sewer Pipe Selection Guide



Pipe Material	Remarks
Cast iron soil (building services only)	Use for building service connections carrying normal domestic sewage.
Cast ductile iron (gravity or pressure)	Primarily used for pressure sewers, yard piping within treatment plant areas, submerged outfalls, exposed locations, and portions of gravity lines subjected to high velocities (10 fps [3.05 m/s]). Additional applications include high external loads, railroad crossings, major highway crossings, and so forth. Special linings, coatings, wrappings, encasements, and so forth, are required for corrosive wastes or soil conditions. Gasket material should be suitable for sewage or waste being handled. Avoid cement lining for sludge and domestic sewage receiving less than secondary treatment.
Polyvinyl chloride (PVC) (pressure)	Use for pressure force mains and inverted siphons. Special care should be given to trench loadings and beddings.
Concrete (pressure)	Use for pressure force mains and inverted siphons that are not subjected to corrosive wastes or soil conditions.

Notes: 1. For additional information, refer to the following and their included references:
NFGS-02630, Storm Drainage.
NFGS-02530.
WEF MOP FD-5.
2. Requirements for pipe joints and guidance for selection of jointing material are given in NFGS-02530.

Table 5-2 (continued)

Sewer Pipe Selection Guide

5.3.1 LOCATION. Locate pump stations as far as possible from inhabited facilities, subject to the restriction that they be accessible by an all-weather road.

5.3.2 CAPACITY. Provide a total pumping capacity equal to the maximum expected flow with at least one of the largest pumps out of service. Install a minimum of two pumps in any station. In small stations with a maximum inflow of 500 gallons per minute (gpm) or less, normally provide only two pumps, each with maximum capacity.

An exception to this practice would be when this station is the only one pumping directly to a treatment plant. For larger stations, select pump number and capacities so that rates-of-inflow may be matched as nearly as possible. The inflow may be matched by varying sizes of pumps, selecting multiple speed pumps, or by variable speed pumping. Variable speed pumping may completely match inflow and may reduce the necessary wet-well storage volume. Variable speed pumps are the most desirable types to use when pumping directly into a treatment plant.

5.3.3 PUMPS. Submersible centrifugal pumps installed in a sump are the preferred approach. Pump controls should be automatic based on wet well level. The controls should perform the following functions: starting and stopping, sequencing, alternating, sounding alarms, and low-level shutoff.

5.3.4 FORCE MAINS. Force mains should be kept as short as possible. Check possibility of sulfide generation. Make provisions to control sulfide generation if necessary by injecting oxidizing chemicals such as chlorine, permanganate, or hydrogen peroxide. Consult suppliers of chemicals or generation and feed equipment on costs and expected performance.

a) Maintain minimum flow velocity of 3 fps (0.9 m/s).

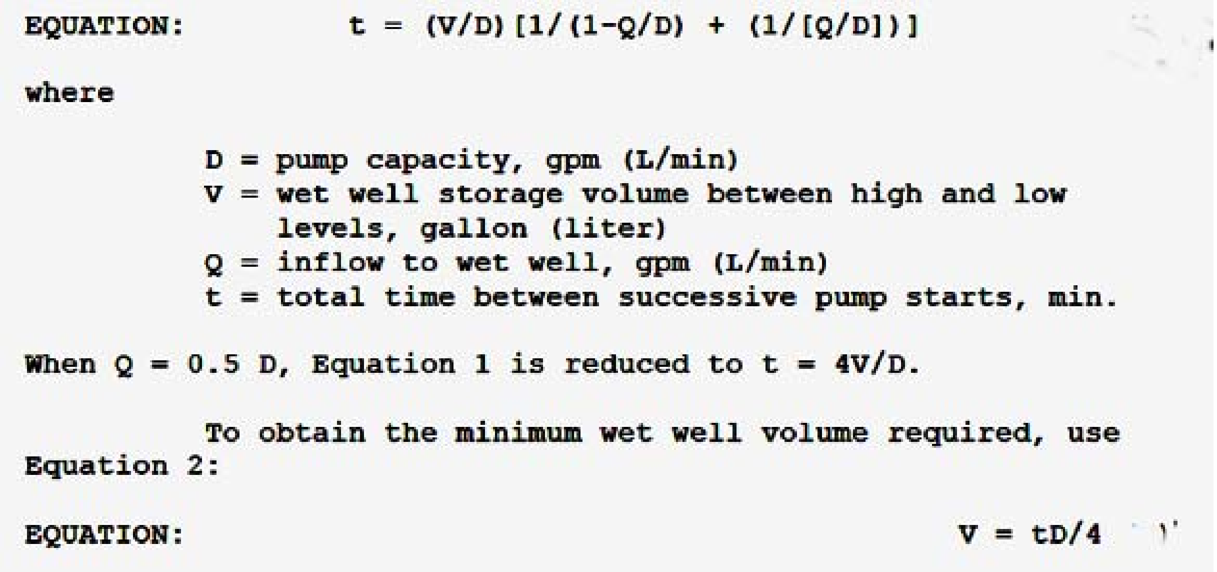
b) Provide clean-outs and air relief valves as required.

5.3.5 DEPENDABILITY. Use two separate and independent power sources with automatic switching equipment. Evaluate either two independent incoming powerlines or a standby engine-driven generator.

5.3.6 WET WELLS

5.3.6.1 SIZE. Wet wells should be as small as possible for economic reasons and to prevent settling out of suspended material. However, a wet well must be of adequate size to contain the pumps (for submersible pumps) to provide adequate depth for pump controls and to provide an adequate cycle time between successive motor starts to prevent overheating of the electric motors.

(1) Determine the length of cycle time by using the Equations 1 and 2 below:



EQUATION: $t = (V/D)[1/(1-Q/D) + (1/[Q/D])]$

where

D = pump capacity, gpm (L/min)
V = wet well storage volume between high and low levels, gallon (liter)
Q = inflow to wet well, gpm (L/min)
t = total time between successive pump starts, min.

When $Q = 0.5\ D$, Equation 1 is reduced to $t = 4V/D$.

To obtain the minimum wet well volume required, use Equation 2:

EQUATION: $V = tD/4$

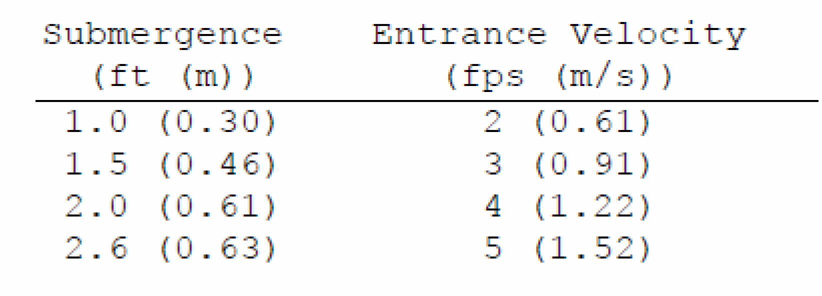
Provide pump operating-cycle of at least 6 minutes for pump units less than 50 horsepower. Check with motor manufacturer for recommended maximum number of cycles for motor specified.

5.3.6.2 BOTTOM SLOPE. Slope wet well bottom toward the pump suction.

(1) Use slope of 1.75 vertical to 1 horizontal (1.75:1).

(2) A minimum slope of 1:1 is permitted only where special justification exists.

5.3.6.3 SUCTION INLETS. Provide tapered inlet for vortex suppression. Determine required submergence above highest open point of suction inlet based on the entrance velocity. Interpolate from the following table. Limit entrance velocity to 5 fps (1.5 m/s).



Submergence (ft (m))	Entrance Velocity (fps (m/s))
1.0 (0.30)	2 (0.61)
1.5 (0.46)	3 (0.91)
2.0 (0.61)	4 (1.22)
2.6 (0.63)	5 (1.52)

5.3.6.4 VENTILATION. Provide a 4-inch (102-mm) minimum diameter vent with return bend and stainless steel bird screen.

5.3.7 DRY WELLS (for other than submersible pump stations).

5.3.7.1 SIZE. Keep dry wells to the minimum size consistent with safe and convenient operation and with allowance for possible expansion.

5.3.7.2 TYPE OF PUMP. Use vertical pumps to conserve space (unless special conditions dictate otherwise).

5.3.7.3 SUMPS. Provide the following:

(1) Minimum 20 gpm (1.3 L/s) capacity.

(2) Check valve in horizontal run.

5.3.7.4 HOISTING FACILITIES. Provide installed or portable hoisting facilities consistent with the size of the installation. Provide lifting eyes for a portable hoist.

5.3.7.5 VENTILATION. Provide positive ventilation.

5.3.7.6 PROVIDE POTABLE WATER (if available) to dry well for general maintenance use.

5.3.8 ALARMS. Provide both audible and visual alarms for wet well and pumps. Wet wells should have both high and low level alarms; provide pumps with flow switch alarms for pump failure conditions. Telemetering should be considered for large or remote stations or for locations where failure to react to alarm condition could cause substantial damage.

5.3.9 MAINTENANCE CONSIDERATIONS. For pumps and mechanical equipment, provide access for repair and means for removal. Facilitate maintenance and repair by planning for quick removal of vertical pumps installed in the wet well.

5.4 SPECIAL REQUIREMENTS FOR PIER AND WHARF SYSTEMS. For collection systems pertaining specifically to piers and wharfs, refer to the technical literature.

5.5 INNOVATIVE COLLECTION SYSTEMS. Vacuum sewers and pressure sewers are included in this category. A case by case determination of specific application to industrial and oily waste should be performed.

5.6 AIRCRAFT AND VEHICLE WASHRACKS, MAINTENANCE, AND SERVICE AREAS. Washrack, maintenance, and service areas require special attention as discussed below.

5.6.1 HOUSEKEEPING

a) Keep outdoor maintenance surfaces clean by regular flushing during dry weather (pass these flushings to the industrial sewer if available).

b) When outdoor washracks or maintenance areas are not being used, and just before it begins to rain, close the sluice gate in the diversion chamber so that storm runoff flows into the storm sewer system.

c) Carry out washing and maintenance operations in designated areas (which should be as compact as conveniently possible). Consider the use of non-emulsifying degreasers.

d) Use dry absorbent materials to clean up oil and gasoline spills on pavements served exclusively by storm water sewers.

5.6.2 APPURTENANCES

5.6.2.1 DIVERSION CHAMBER

(1) Construction. Construct a manhole with conventional inflow and outflow storm sewer pipe, incorporating a small gated outflow to allow diversion of dry weather flows and the first increment of runoff during storms (see Figure 5-1). This also prevents flushing of oil and sediment from the trap during storm conditions.

(2) Hydraulic design. Design the main inflow and outflow pipes to pass storm flows, taking care to ensure that velocities of dry weather flows are sufficient to prevent solids deposition. Design the gated outflow pipe to pass dry weather flows. The pipe diameter should not be less than 6 inches (152 mm).

5.6.2.2 GRIT REMOVAL. Provide for gravity separation, washing, and removal of grit where load may block sewer. Use velocity control channel type, either manually or mechanically cleaned, with a screw type agitated grit washer.

(1) Selection Basis. Use manually cleaned units for applications where grit load is less than 1 cubic ft (0.0283 cubic m) per day and use mechanically cleaned units for application where grit load is greater than 1 cubic ft/day.

(2) Design Basis. Provide at least two units sized to give 95 percent removal of P10 grit size at peak flow with units in service. Limit variations in flow velocity to a narrow range

and use high values of V/Vs (maximum 70). Refer to WEF MOP No. 8, Wastewater Treatment Plant Design.

5.7 PAINT SHOPS. The following special methods are applicable.

5.7.1 PAINT STRIPPING. Paint stripping operations are the source of the most polluted and difficult to treat industrial wastes. Most paint stripping operations use phenolic base strippers. The resulting wastewaters can contain high concentrations of phenols and substituted phenols, as well as chromate, hexavalent chrome, and ferrocyanide. If treatment experience on similar wastes is not available, conduct bench or pilot scale treatability studies. To reduce pretreatment requirements, emphasize source control measures:

a) Use gravity separator for control of paint solids prior to discharge to industrial sewer (if available). Remove paint solids periodically to offsite drying beds or containerize for direct landfill disposal. Establish hazardous or nonhazardous waste nature of solids by the toxicity characteristic leaching procedure (TCLP) (refer to Title 40 CFR, Part 261.24).

b) Use nonphenolic base strippers or dry stripping methods where possible.

5.7.2 PAINT BOOTHS. Where wet-type booths are utilized, water should be recirculated in a closed system provided with solids removal facilities. When discharge is required, the flow should be tested for TCLP and discharged accordingly. Solids should be removed and disposed. Establish hazardous or nonhazardous waste nature by the TCLP method. The use of paper or peel-off floor and wall coverings is recommended.

5.8 FIRE TRAINING AREAS. Wastewater from fire training areas contains unburned hydrocarbons, burn products, additives (purple-K-powder, AFFF), and sludges. Where AFFF is used, wastewater will have significant COD, TOC, BOD, and toxicity levels.

Flow and load equalization should be provided prior to pretreatment or discharged to a POTW system.

5.9 METAL PLATING OPERATIONS

5.9.1 SEPARATE COLLECTION SYSTEMS. Metal plating operations generate a variety of waste materials, including heavy metals, cyanides, oil and grease, solvents, degreasers, acids, and alkalies. Safety and cost-effectiveness of treatment dictate waste source isolation and separate collection systems for subsequent treatment or material recovery.

5.9.1.1 CYANIDE-BEARING WASTES. Keep separate from acid wastes to avoid cyanide conversion to toxic hydrogen cyanide gas.

5.9.1.2 CHROME-BEARING WASTES. Keep separate from cyanide containing wastes so that hexavalent chrome can be acid reduced prior to alkaline precipitation with other metal-bearing wastes.

5.9.1.3 MIXED CHEMICALS. Keep acids and bases isolated and separate from chrome and cyanide wastes.

5.9.2 VOLUME REDUCTION. Plating process changes should be evaluated to minimize the volume of wastewater to be treated. New or modified plating processes should use still rinses, dragout rinses, or double or triple countercurrent rinses to minimize water use and wastewater treatment. Advanced treatment systems using evaporative techniques with minimal discharge volume have been successfully used. Recycling of rinse water is also possible at certain plating shops. The extent of plating process modifications and water reuse depends on the quality of plating required.

5.10 DRYDOCKING FACILITIES

5.10.1 TREATMENT SYSTEMS

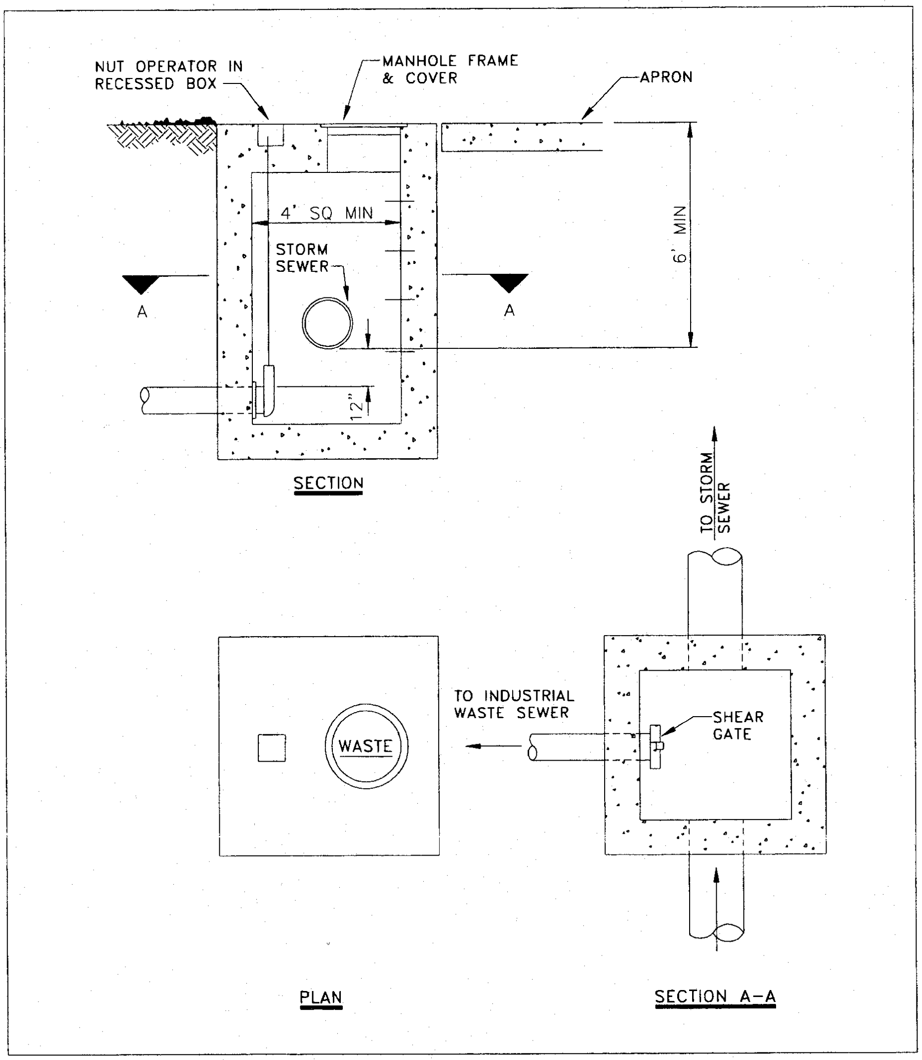


Figure 5-1

Wastewater diversion chamber

Principal pollutants in graving dock industrial wastewater are grit and suspended matter and heavy metals. Grit should be removed at the drydock facility using velocity control grit channel with an agitation-type grit washer. If flow and grit loads are small; pumping of discharge can be directly to grit washer. The need for heavy metal removal must be determined by wastewater monitoring on an individual-case basis considering local sewer ordinance and pretreatment requirements and drydock activities.

6. WASTEWATER TREATMENT

6.1 GENERAL DESIGN CONSIDERATIONS.

6.1.1 EFFLUENT LIMITS. Follow NPDES permit requirements for industrial wastes that are treated at a NOTW (refer to paragraph 2.5.2). For industrial wastes that discharge to a POTW, obtain the necessary sewer use ordinance from the municipality. Sewer use ordinances will define industrial wastewaters that must be restricted from entering the system and define the necessary levels of various constituents prior to entry into the system.

6.1.2 TREATMENT VERSUS PRETREATMENT. Where possible, it is preferable to provide pretreatment and discharge to a POTW, rather than providing separate treatment of wastes and then discharging into a water body. Separate treatment and discharge of industrial wastes should be considered only if a municipal system with sufficient capability to handle the waste is not located nearby, or if the surcharge costs levied by the municipality plus the cost for any pretreatment are excessive in comparison to separate collection and treatment. Pretreatment and discharge to a municipality versus separate treatment and discharge to a water body should be analyzed as a part of the preliminary engineering studies.

6.1.3 RECEIVING WATER. Present policy may be to use an outside contractor to haul difficult-to-treat wastes. In addition, deep well injection may be used for low-volume, difficult-to-treat industrial wastes, if permitted by regulatory agencies. Suitability of proposed substrata must be determined for each specific case.

6.1.4 SANITARY SEWER. Avoid discharging industrial waste materials that may damage the wastewater collection and treatment facilities and/or cause potential personnel safety problems (refer to WPCF MOP No. 3).

6.1.5 BATCH VERSUS CONTINUOUS TREATMENT. Batch treatment is preferable to continuous treatment of most industrial wastes. Batch treatment requires more tankage but allows greater process control than continuous treatment. The extra capital investment in providing holding and process tanks for batch treatment frequently offsets the cost of controls and operation and maintenance requirements for a continuous system. Batch treatment also provides additional reliability since unusual discharge conditions on industrial process lines are more easily accommodated. Use batch treatment except for large flows where continuous treatment offers significant advantages. Design for flexibility in unit treatment processes and total treatment systems. Provide interconnections within the treatment facility to allow transfer of separated waste streams to holding units or other treatment units. This will facilitate treatment when separate collection systems are contaminated.

6.1.6 DISPOSAL OF SLUDGES

6.1.6.1 PROCESS SELECTION. Sludge handling and disposal operations must be evaluated concurrently with wastewater treatment evaluations. Costs for sludge disposal can dictate process selection for the wastewater treatment system. Bench or pilot scale testing is recommended to establish design parameters for industrial sludges.

(1) Testing should establish sludge production rates, dewatering characteristics, volume and mass to disposal, and hazardous or nonhazardous nature of the sludge.

(2) Perform the Toxicity Characteristic Leaching Procedure on sludges produced by alternative physical-chemical treatment processes before making final treatment process selection. Use of different chemicals for treatment (such as lime versus caustic soda) can affect the results of the TCLP and the declaration of the sludge as a hazardous or nonhazardous material. Refer to Title 40 CFR, Part 261.24 and amendments for test procedure and criteria.

(3) For special treatment or waste generation circumstances that produce hazardous wastes, consider application to EPA for delisting of waste to nonhazardous status. Delisting requires demonstration that the waste does not exhibit hazardous or reactive characteristics. Proving the waste nontoxic requires proving that the sludge could not leach hazardous materials at harmful concentrations. Refer to Title 40 CFR, Part 260, Subpart C.

6.1.6.2 DISPOSAL REQUIREMENTS. Contact the State and Federal regulatory agencies to determine restrictions that may be applied to ultimate disposal of industrial wastewater sludges. Limitations can be expected for handling and disposing of metal-bearing sludges resulting from wastewater treatment (biological or physical-chemical). Refer to the paragraphs above for application of the TCLP to sludge generation and disposal requirements.

6.1.6.3 WASTE HAULER. For very small treatment operations, utilizing a private sludge hauler may be cost effective. Waste hauler capabilities and qualifications should be closely scrutinized since improper disposal of industrial sludges will create liabilities. The waste generator is responsible for ultimate disposal under the RCRA. Transportation of hazardous wastes is strictly regulated by the RCRA. Exclusion from some RCRA requirements has been allowed for waste generators producing less than 2,200 lb/mo. This upper limit applies to the total mass of waste (including water and nonhazardous components). Some recordkeeping, reporting, and waste manifest are not required for small generators but the waste must still be disposed in an approved site.

6.1.6.4 LANDFILL DISPOSAL. The preferred method for ultimate disposal of industrial sludges is to provide dewatering and disposal of the dewatered sludge in a properly located and designed landfill. Refer to EPA PB 80-2200546, Process Design Manual, Sludge Treatment and Disposal for design considerations.

6.1.6.5 LAND DISPOSAL. Some biological and chemical industrial sludges that are not defined as hazardous may be acceptable for land disposal depending upon the sludge characteristics, soil conditions, and intended use of the site (that is, use of the site for crop production versus a dedicated disposal site). Contact regulatory agencies for local requirements and for maximum allowable loads at dedicated land disposal sites.

6.1.6.6 RECYCLE. Some metal waste treatment systems, particularly those for hard chrome and precious metal plating operations, have the potential of recovering waste materials for subsequent reuse. Reuse and recovery can reduce raw material and ultimate sludge disposal requirements.

6.1.7 AIR POLLUTION CONTROL. Some industrial processes (chrome plating, storage battery reclamation, metal pickling, and fuel combustion) may emit metallic fumes and vapors, acid droplets, and metallic oxides and salts. A condenser should be used for low efficiency removal of vapors in moist air streams. For high efficiency removal of vapors, a scrubber should be used. Efficiency mist collectors should be incorporated in the scrubber design. Refer to EPA 625/3-77-009, Controlling Pollution from the Manufacturing and Coating of Metal Products, Metal Coating Air Pollution Control - I and Solvent Metal Cleaning Air Pollution Control - II.

6.2 REUSE/RECYCLE

6.2.1 COOLING WATER RECYCLE. The equipment and processes that utilize water for indirect (noncontaminating) cooling should be identified as a part of the preliminary engineering studies. Consideration should be given to utilizing “cascade” or direct recirculation systems for noncontaminated cooling waters, particularly in water short areas. In a cascade system, cooling water discharged from one unit may be utilized in another process where temperature of incoming water is not critical. Direct recirculation systems require a cooling tower to dissipate the net heat load.

6.2.2 RECLAMATION. There are a number of processes and equipment, most of them proprietary, that may be utilized for reclaiming metals in plating wastes or removing materials so that the reclaimed water can be reused. Manufacturers should be consulted for design criteria.

6.2.2.1 DEMINERALIZATION. The five methods available for demineralization of wastewaters are ion exchange, selective metal recovery using immobilized ligands, reverse osmosis, electrodialysis, and distillation. These processes are generally too costly to consider except where reuse is a necessity. Distillation appears to be the most feasible method for regenerating wastewaters in polar regions.

6.2.2.2 EVAPORATION. Evaporation systems, such as the waste heat or vapor compression evaporation process, can be used to recover heavy metals from plating solutions. Concentration and reuse using evaporation is particularly applicable to chromic acid solutions. The distilled water from evaporation can be reused as process rinse water, and the high purity water results in low rinse water use.

6.2.2.3 ION EXCHANGE. Ion exchange can be applied to chromium rinse waters with use of other membrane technologies. A system that contains a cation exchange bed followed by an anion exchange bed can remove the contaminants of concern from the chromium-bearing wastewater stream. The cation exchange resin will remove the metal ions under optimal conditions. The anion exchange resin under optimal conditions will remove the chromate ion (CrO_4) from the solution. With the addition of electrodialysis (ED) and advanced reverse osmosis (ARO), a closed looped system can be designed. Electrodialysis will recycle the H_2SO_4 to the cation exchange column while the metals are removed as sludge. The anion exchange column effluent will be separated by ED into NaOH and chromic acid, both of which are recycled. ARO will then separate the water to be recycled and brine salts for disposal.

6.2.2.4 METALLIC REPLACEMENT. Silver or copper recovery can be achieved by using the replacement process where a metal that is more chemically active than the metal to be recovered is placed into the waste solution. The more active metal goes into solution, thereby replacing the less active metal which precipitates (or plates) out and is recovered. Zinc or iron, in the form of either dust or finely spun wool, is often used to recover silver or copper. Unlike evaporation or ion exchange, relatively clean water is not recovered in this method.

6.2.2.5 ELECTRODEPOSITION. Electrolytic recovery can be used to recover valuable metals such as silver or copper. When a direct electrical current of the proper density is passed through the wastewater of a single plating process, the metal in the solution plates out in a pure form on the cathode.

6.2.2.6 OPERATING REQUIREMENTS. Most reclamation systems require sophisticated equipment; thus, the ability of the operating personnel and the manner in which the owner operates a specific facility may limit the use of some recycle processes.

6.3 HAZARDOUS AND TOXIC SUBSTANCES. Special handling, treatment, and disposal procedures are required for hazardous and toxic substances that may be encountered. Refer to the hazardous waste management plan of the facility.

6.4 PRETREATMENT PROCESS SELECTION. Wastewater from industrial facilities will be discharged to a POTW sewer system or to a separate NOTW system for receiving industrial waste. In either case, pretreatment will normally be required to either minimize the interference upon subsequent treatment processes or to provide more effective treatment on a special waste stream. Table 6-1 summarizes the common pretreatment operations, which must be considered at Naval facilities. Selection guidelines require that sufficient pretreatment be provided to satisfy local sewer use ordinances and EPA pretreatment requirements or to reduce contaminants to threshold limits which will not adversely affect biological treatment processes at NOTW. Threshold limits will generally be greater than local and pretreatment limits. Refer to Tables 4-1 and 4-2 for threshold limits of heavy metals.

6.5 PHYSICAL-CHEMICAL TREATMENT PROCESS SELECTION. Most industrial wastes that are collected separately will require physical-chemical treatment. The physical-chemical treatment processes that should be evaluated are summarized in Table 6-2. The following paragraphs discuss the basic physical-chemical treatment processes used for treatment of industrial wastes from many facilities.

6.5.1 NEUTRALIZATION. Neutralization is the reaction of compounds having active hydrogen or hydroxyl ions to form water and chemical salts. The degree of neutralization is measured by pH. Flow and load equalization tanks may necessarily precede the chemical neutralization process. Sludge production rates, settleability, and dewaterability should be considered in selection of neutralizing chemicals.

6.5.1.1 CHEMICALS. Lime, caustic soda, sulfuric acid, waste acid and alkali, carbon dioxide, sodium bicarbonate, limestone (beds), and combustion gases.

6.5.1.2 WASTE TYPES AND CHARACTERISTICS. Neutralization reactions may occur between a strong acid or base and a strong base or acid, respectively, or between a strong acid or base and a weak base or acid, respectively. The required amounts of neutralizing a chemical must be determined by laboratory testing and preparation of titration curves.

Purpose	Process	Selection Guide
Flow and load equalization	Balancing storage	Use prior to batch or semicontinuous treatment of industrial wastes to reduce design flow and load rate and provide controlled discharge of industrial wastes or ship discharges to sanitary sewers.
Removal of hexavalent chromium (Cr+6)	Chemical reduction followed by chemical precipitation	Pretreat before biological treatment (at NOTW) if hexavalent chromium concentration at plant influent exceeds EPA industry standards. Confirm treatability at NOTW with testing or pilot plant. For discharge to a POTW, check local sewer ordinance pretreatment limits and satisfy these stricter criteria. Eliminate at source, if possible.
Removal of heavy metals	Chemical precipitation (hydroxide or sulfide)	Use prior to biological treatment (at NOTW) of total heavy metals concentration exceeds EPA industry standards. Confirm treatability at NOTW with bench or pilot scale testing if possible. Pretreat before waste mixes with other components of flow to plant. For discharge to a POTW, check local sewer ordinance pretreatment requirements.
	Ion exchange	Use where recovery of metals is desired. Not recommended as a pretreatment process for metal removal without recovery by regeneration of the ion exchange column.
Removal of cyanide (CN-)	Chemical oxidation	Use prior to biological treatment if cyanide concentration at plant influent exceeds EPA industry standards. For discharge to POTW, check local sewer ordinance pretreatment requirements. Treat cyanide stream before it mixes with other waste streams.
	Electrolysis	Consider for low flow, high strength cyanide waste streams (such as batch dumps).
Removal of phenol (C_6H_5OH)	Biochemical oxidation Chemical oxidation	Need depends on discharge criteria. Where required, removal best accomplished in biological treatment plant with other biodegradable organic wastes. Use bench testing or pilot plant to determine removals (acclimation required). Use chemical oxidation where biological treatment is not available or is not possible because of toxicity problems or insufficient BOD.
pH adjustment	Neutralization	Use prior to biological treatment where pH is frequently less than 6.0 or greater than 9.0 (check treatability with bench scale or pilot plant). Treat highly acid or alkaline at source.
Removal of emulsified or dissolved oil. Emulsion breaking.	Acidification and/or coagulation with flotation. Adsorption on activated carbon.	Need depends on pretreatment criteria.
Removal of free oil	Gravity separation. Hydrocyclone separation.	Need depends on pretreatment criteria.
Removal of hydrogen sulfide (H_2S)	Aeration. Chemical oxidation.	Use if sulfides exceed 50 mg/L or if odor is a persistent problem or hazardous gas conditions occur. Eliminate at source, if possible.

Table 6-1

Process Selection Guide for Pretreatment of Industrial Wastewater

Purpose	Recommended Process	Recommended Chemical and Requirements	Reaction	Tankage Requirements	Recommended Process Control	Remarks
Destruction of cyanide (CN)	Alkaline chlorination	Chlorine and sodium hydroxide or lime. Determine requirements by experiment. Theoretical dosage = 6.8 lb Cl2/lb.	Two stages: (1)Oxidation of cyanide to cyanate (CNO). (2)Complete oxidation of cyanate to nitrogen gas (N2).	Provide at least 90-min detention for each stage. Equip each tank with propeller agitator to provide at least one turnover per min.	Use electronic recorder-controllers to maintain optimum conditions: 1 stage (CN®CNO): ORP: 350 to 400 mV pH: 10 to 11.5 2 stage (CNO®N2): ORP:600 mV pH: 8 to 8.5	Use common feed line for alkali and chlorine to avoid possibility of localized acid conditions. Bench testing required to determine dosage since oxidation of other waste components exerts Cl2 demand.
	Hydrogen peroxide (H2O2) oxidation	Hydrogen peroxide, trace catalyst metal (such as copper) and sodium hydroxide. Theoretical dosage = 1.3 lb H2O2/lb.	Two stages: (1)Oxidation of CN to CNO (2)Hydrolysis of CNO to carbon dioxide (CO2) and ammonia (NH3).	Mixing and reaction tank. See remarks	pH: 8.5 to 10	Bench scale testing required to determine H2O2 and catalyst dosage and reaction time since oxidation of other waste components exerts H2O2 demand.
	Exhaust ventilation equipment, heating and mixing equipment.	Destruction of cyanide at anode of electrolytic cell.	Destruction of cyanide at anode of electrolytic cell.	Tankage depends upon waste volume to current ratio and initial concentration of CN	T = 200°F (93.3°C). Anode current density from 30 to 80 amp/sq. ft (333 to 861 amp/m^2). 2.5 to 3.5 kWh/lb CN (5.5 to 7.7 kWh/kg).	Additional treatment may be necessary depending on effluent standards.
Destruction of phenols (C_6H_5OH)	Alkaline chlorination 1	Chlorine and sodium hydroxide. Determine requirements by experiment. Theoretical dosage = 10.5 lb Cl2/lb.	Complete oxidation possible.	Provide at least 4- h detention. Equip each tank with propeller agitator to provide at least one turnover per minute.	Use electronic recorder-controller to maintain optimum conditions: ORP: 250 to 300 mV pH: 7 to 10 T = 45°F (7.2°C)	Use high calcium lime for large flows. Consider use of chlorine dioxide or ozone as oxidant for high ammonia concentrations. May cause problems by formation of toxic chlorophenols.

Table 6-2

Physical-Chemical Treatment of Industrial Wastes

Purpose	Recommended Process	Recommended Chemical and Requirements	Reaction	Tankage Requirements	Recommended Process Control	Remarks
	Hydrogen peroxide (H_2O_2) oxidation1 . Potassium permanganate ($KMnO_4$) oxidation 1 .	Hydrogen peroxide and trace metal catalyst (such as ferrous sulfate). Theoretical dosage = 5.1 lb H_2O_2/lb. Potassium permanganate and sodium hydroxide. Determine requirements by experiment.	Complete oxidation possible; reaction rate declines rapidly outside pH 3 to 4 range. Complete oxidation possible. Optimum reaction rate at $9<pH<9.5$.	Mixing and reaction tank.	Use electronic recorder-controller to maintain optimum conditions of pH 3 to 4.	Bench scale testing required to define dosage and reaction time. Copper, aluminum, iron and chromium can serve as catalysts. Incomplete oxidation forms hydroquinone.
Removal of chromium (Cr)	Acid sulfonation followed by precipitation.	Sulfur dioxide, sodium metabisulfite or sodium sulfite; sulfuric acid; sodium hydroxide. Determine requirements by experiment.	Two stages: (1)Reduction of Cr^{+6} to Cr^{+3} at acid conditions. (2)Precipitation of Cr^{+3} as $Cr(OH)_3$ at alkaline conditions.	Mixing and reacting tank. Provide 1 to 3-h detention time. Filtration may follow for precipitate removal. 1st stage: Provide 4-h (1-h if continuous) Detention time. Equip tank with mixer to provide one turnover per minute. 2nd stage:See hydroxide precipitation of heavy metals (below).	Dosage on ration to phenol level. Use electronic recorder-controller to maintain pH at 9.0 to 9.5 and to maintain optimum conditions: 1st stage: ORP: 250 to 300 MV pH: 1.8 to 2.5 2nd stage: pH: 8.5	May create sludge difficulties. For large waste streams use high calcium lime and sulfur dioxide gas. Oxidizing agents (oxygen and ferric iron) increase required amount of reducing agent. Settling required to capture metal hydroxide sludge. Granular media filtration or DAF may be required for low effluent chrome limits.
Neutralization of alkali waste	Addition of acid	Acid wastes if available; otherwise sulfuric acid.	Experiment needed to define reaction rates, chemical feed requirements, and sludge production.	Mixing required	Pace acid feed rate to flow based on bench scale titration curves.	Design to minimize sludge production. Use stepwise batch neutralization for high alkalinity wastes to minimize exothermic reaction and improve process and effluent control.

Table 6-2 (continued)

Physical-Chemical Treatment of Industrial Wastes

Purpose	Recommended Process	Recommended Chemical and Requirements	Reaction	Tankage Requirements	Recommended Process Control	Remarks
Removal of heavy metals	Precipitation: hydroxide or sulfide	Select chemical based on flow rate, treatability, effluent limits, and sludge production rate and dewatering ability. Conduct treatability study to determine chemical requirements.	Experiment needed to define reaction rates, optimum operating points, sludge characteristics	Mixing and sedimentation required	Use electronic recorder-controller to maintain optimum pH conditions determined by experiment.	Ion exchange may be used to concentrate waste stream prior to treatment. Settling required to capture metal precipitation sludge. Filters required for low effluent metal limits.
Recovery of metals for reuse	Evaporation	For acid solutions, recover in small dip tanks immediately following the plating solution.	Evaporation and concentration.	Evaporators, concentrated solution holding tank.	Water salts may build up in recirculated rinse water.	Ion exchange can be used to pretreat solution to remove salts before evaporation.
Removal of phosphorous	Precipitation	High calcium lime and alum. Determine requirements by experiment (for estimate use: Ca:Al:P = 3:2:1).	Experiment needed to define reaction rate and sludge characteristics	Mixing, flocculation, and sedimentation required.	Use electronic recorder-controller to maintain optimum pH conditions determined by experiment.	Refer to EPA Process Design Manual, Phosphorous Removal. In activated sludge plant, chemicals can be added just prior to aeration tanks, eliminating need for separate flocculation and settling tanks.
Removal of colloids	Coagulation followed by sedimentation			Same as above	Same as above	Perform jar test experiments to determine mixing and flocculation reaction time and power gradients, sludge settleability and dewaterability.

Table 6-2 (continued)

Physical-Chemical Treatment of Industrial Wastes

Purpose	Recommended Process	Recommended Chemical and Requirements	Reaction	Tankage Requirements	Recommended Process Control	Remarks
Removal of emulsified oil. Emulsion breaking.	Coagulation followed by flotation. Acidification prior to coagulation may be required.			Mixing flocculation, and sedimentation with skimming of DAF. Acid mix tank may be required for breaking difficult emulsions.	Same as above	Avoid emulsion breaking by salting out with NaCl due to corrosion and ineffectiveness. Determine emulsion breaking chemical types and dosages by bench or pilot scale tests.
Removal of soluble, refractory organics	Granular-activated carbon		Adsorption. Conduct bench or pilot scale experiments to define adsorption characteristics and carbon adsorption capacity.	Contactor tanks	Refer to EPA PB 259147, Process Design Manual, Carbon Adsorption.	Consider using PAC with activated sludge where removal of refractory organics is needed (consult Zimpro, Inc. for proprietary system and performance data).
Removal of heat	Cooling towers or ponds	Tower capacity or pond size to dissipate required heat	Evaporative cooling	Depending on temperature change needed and mixing provided (for ponds).	If recycle system, makeup and blowdown to control dissolved solids.	Consult manufacturers for tower cooling capabilities. Consider use of waste heat to operate evaporator in metal recovery process.

Table 6-2 (continued)

Physical-Chemical Treatment of Industrial Wastes

6.5.1.3 SLUDGE PRODUCTION. Sludge production and disposal, and scaling must be considered in design of neutralization systems.

(1) Waste solutions with no suspended solids or dissolved solids at less than saturation concentration produce negligible sludge upon neutralization.

(2) Waste solutions with or without suspended solids, but saturated dissolved solids (such as $CaSO_4$) in the neutralized mixture, create sludge handling and significant scaling problems.

6.5.1.4 TREATMENT PROCESS ALTERNATIVES. The following treatment alternatives should be considered for neutralization.

(1) Lime addition. Use limestone ($CaCO_3$) as beds or pellets, quicklime (CaO), or hydrated lime ($Ca(OH)_2$).

(2) Limestone beds. Use upflow or downflow systems. Limit acid concentration to 0.3 to 0.6 percent to minimize bed coating with calcium sulfate. Use recirculation to reduce required bed depth. Load at less than 1 gpm/square ft (40 L/min/square m) for downflow beds. Higher rates may be used for upflow beds since solids and precipitate are carried out.

(3) Chemical Mixing. If mixing is required, provide 200 to 400 horsepower per million gallons of tank's capacity (mechanical-type mixer). Check pumping or turnover rate of mixing equipment.

(4) Acid neutralization. Use sulfuric or hydrochloric acid for strong acid neutralization of alkaline wastes. Use carbon dioxide, sodium bicarbonate, or fuel combustion gas for weak acid neutralization and final adjustment of pH.

(5) Process Staging. Provide at least two separate stages for dampening pH fluctuations in continuous flow systems. Additional stages are required for strong acid

and alkaline wastes and for fine tuning the pH to a desired effluent level. Use staged operation for batch treatment to complete neutralization in at least two steps. Use smaller pH increments (one to two units) for strong wastes.

6.5.1.5 PROCESS CONTROL. Use self-cleaning pH probes and control systems that allow feed forward, feed-back, proportional, and manual control options.

6.5.2 PRECIPITATION. Chemical precipitation involves alteration of the ionic equilibrium to produce insoluble precipitates that can be removed by sedimentation or granular media filtration. The process can be preceded by chemical oxidation (as for copper (Cu+) removal) or chemical reduction (as for chrome (Cr+6) removal) to change the oxidation state of the metal ions to a form that can be precipitated. The principle metal precipitates are metal hydroxides, metal sulfides, and metal carbonates.

6.5.2.1 METAL ION SOLUBILITY. Heavy metal ion solubility depends on the specific metal, system pH, temperature, and degree of chemical complexation with organic and inorganic ions. The effect of pH on solubility of selected heavy metal hydroxides and sulfides is shown in Figure 6-1. Solubility of metal carbonates is not shown since it is dependent on wastewater alkalinity. Listed metal sulfides are less soluble than the metal hydroxide at the same pH.

6.5.2.2 PRECIPITATION CHEMICALS. Use lime or caustic soda for pH adjustment for metal hydroxide precipitation. Use hydrogen sulfide, sodium sulfide, or sodium bisulfide for metal sulfide precipitation. Use sodium hydroxide with carbon dioxide for metal carbonate precipitation.

6.5.2.3 CO-MINGLED METAL SYSTEMS. Wastewaters that contain several metals in solution may not be treatable by adjustment to a single pH with a single chemical (for example, cadmium and zinc cannot be simultaneously precipitated at optimum pH for minimum metal hydroxide solubility). If these metals occur in the same wastewater, two-staged (or more) treatment is required. Alternatively, sulfide precipitation could be used at a selected pH to produce approximately equal low soluble metal levels. The solubilities presented in Figure 6-1 should be used for preliminary guidance only. Actual metal solubility will depend on ionic strength, temperature, and degree of chemical complexation. Bench scale or pilot plant testing must be conducted to determine actual metal removals at various adjusted wastewater pH values. Both soluble and total metal concentrations in the treated effluent should be measured during the testing program.

6.5.2.4 SLUDGE PRODUCTION. Determine volume, mass, settleability, and dewaterability of sludges produced during treatability study. Using TCLP, determine the toxicity for alternative chemical precipitants (selection of lime versus caustic soda can affect the results of TCLP).

6.5.2.5 COAGULANTS. Coagulants such as iron salts, alum, and polyelectrolytes may be required to enhance flocculation and settleability of the metal precipitates.

6.5.2.6 PROCESS DESIGN. Use batch treatment systems whenever possible. Provide reaction tankage for staged treatment with each stage capacity sufficient to treat total volume of wastewater expected during the treatment period. Use batch tank as reactor and preliminary settler. Expected batch treatment cycle is approximately 4 hours. If greater tankage volume is required to accommodate duration of wastewater flow, consider off-line storage of excess wastewater rather than continuous flow treatment.

6.5.2.6.1 HYDROXIDE PRECIPITATION. Provide mixed tank with feed and multiple supernatant drawoff lines or drawoff by telescoping valve (if batch reactor will also be used as settling basin). If sulfate concentration in waste is high, calcium sulfate scale will be a problem when lime is used. Consider caustic soda to avoid scaling.

6.5.2.6.2 SULFIDE PRECIPITATION. Provide mixed tank with sulfide (gas or Na_2S slurry) feed and multiple supernatant drawoff lines or drawoff by telescoping valve (if batch reactor will also be used as settling basin). Maintain reactor pH between 8 to 9.5 using a caustic to minimize formation of toxic hydrogen sulfide gas. Provide excess sulfide in reactor to drive precipitation reaction. Provide post-treatment aeration to oxidize excess sulfide to sulfate. Alternatively, use ferrous sulfide (FeS) slurry as the sulfide source to eliminate formation of hydrogen sulfide gas.

6.5.2.6.3 SEDIMENTATION. Sedimentation is required following precipitation reactions unless metal precipitate levels are low enough for direct filtration. Use direct filtration only if performance has been verified by pilot plant studies. Evaluate polymer conditioning to enhance sludge settleability. For continuous flow systems, use circular or rectangular clarifiers with or without inclined parallel plate (or tube) settling assistance. Provide a means for scum and float removal so that scum discharges to the sludge holding tank or returns to treatment process. Provide complete access for plant operator to manually scrape down plate settlers. Consider air agitation and scour beneath plate or tube settler to blowdown sludge plugging to underflow while clarifier effluent valve is temporarily closed. For batch settling processes, use either chemical reactor or separate clarifier tank. Provide multiple drawoff ports or telescoping valve for supernatant withdrawal.

6.5.2.6.4 FILTRATION. Filtration following sedimentation may be required to satisfy low discharge metal limits or if metal precipitate coagulates and settles poorly. Evaluate polymer and alum coagulation for enhanced settleability before using filters. Consider pH effect on cementation of filter media.

6.5.2.6.5 SLUDGE DEWATERING. Since metal sludge will usually be classified as a hazardous waste, select dewatering equipment to optimize cake solids concentration and to minimize volume and weight for ultimate disposal. Use fixed or variable volume plate and frame press for mechanical dewatering if cake disposal follows immediately. Consider centrifuge, vacuum filter, or belt filter press for thickening prior to dewatering on permitted sand drying beds.

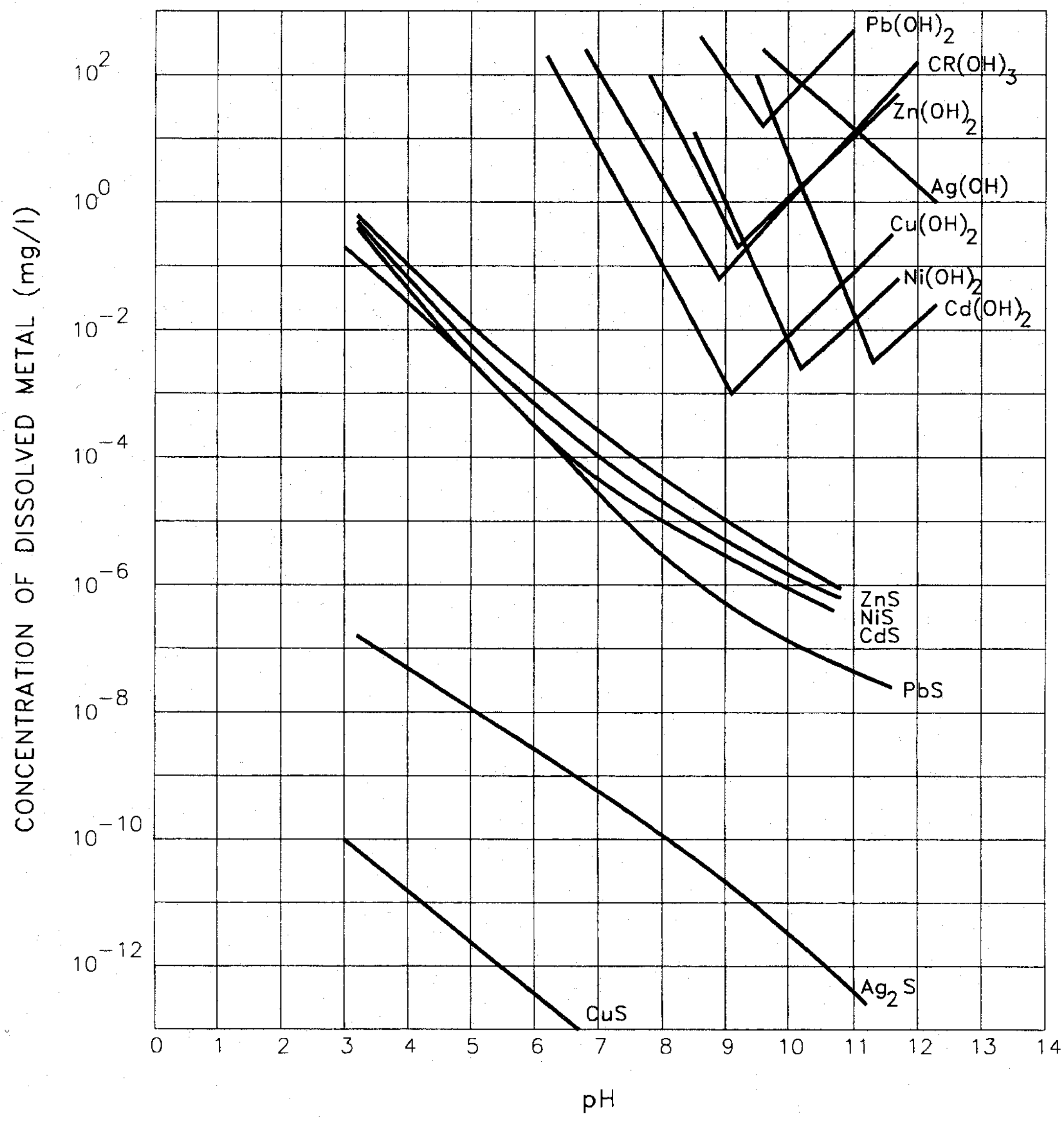


Figure 6-1

Solubility of metal hydroxides and sulfides as a function of pH

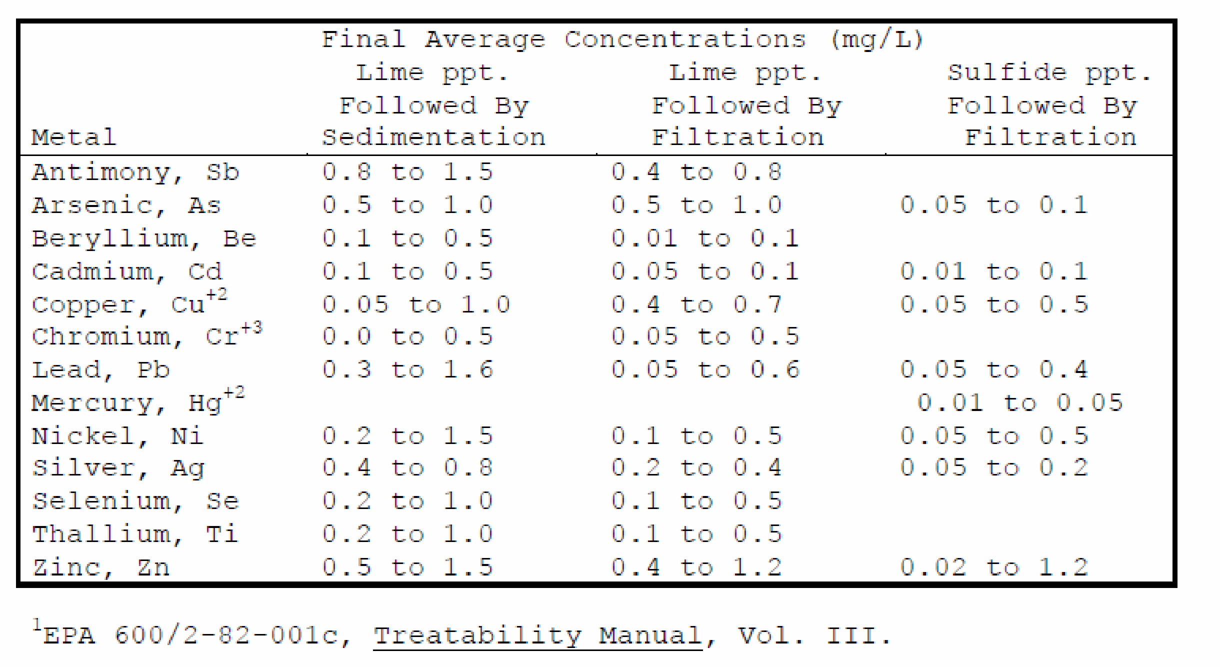
6.5.2.7 PROCESS CONTROL. Process pH control is absolutely essential for favorable performance. Use self-cleaning pH probes and oxidation-reduction potential (ORP) probes. Metal hydroxide precipitates will resolubilize if operating pH varies from optimum. Metal sulfide precipitates are less sensitive to loss of pH control and are less affected by metal chelates and metal complexes.

6.5.2.8 PROCESS PERFORMANCE. Hydroxide and sulfide precipitations are highly reliable if proper monitoring and control are maintained. Estimated achievable maximum 30-day average concentrations of several heavy metals under different chemical precipitation processes are shown in Table 6-3.

6.5.3 CHEMICAL OXIDATION. The primary purpose of chemical oxidation is to enhance the treatability of industrial wastes and to detoxify (if possible) hazardous wastes. Oxidation is accomplished by the addition of oxidizing agents, such as chlorine, permanganate and ozone. Examples of chemical oxidation of industrial wastes from Navy facilities are destruction of hydrogen sulfide, cyanide, and phenol, conversion of cuprous ion (Cu+) or ferrous ion (Fe+2) to the more treatable cupric ion (Cu+2) and ferric ion (Fe+3), respectively.

6.5.3.1 OXIDIZING AGENTS. Use chlorine gas or liquid, or solutions of hypochlorite salts, ozone, potassium permanganate, oxygen (by aeration), or hydrogen peroxide. See Table 6-2 for selection of oxidizing agent and for application guide. In absence of treatability data on similar waste, conduct bench or pilot scale tests to determine treatability, reaction rates, dosage, and catalyst requirements, and the formation of noxious or toxic reaction byproducts.

6.5.3.2 PROCESS DESIGN CONSIDERATION. Use batch treatment whenever possible. Provide for sufficient excess feed capacity of oxidizing agent to satisfy full expected range of contaminant and extraneous reducing agents. This should be determined by bench or pilot testing of wastewater spiked with appropriate reducing agents.



Metal	Final Average Concentrations (mg/L) Lime ppt. Followed By Sedimentation	Lime ppt. Followed By Filtration	Sulfide ppt. Followed By Filtration
Antimony, Sb	0.8 to 1.5	0.4 to 0.8	
Arsenic, As	0.5 to 1.0	0.5 to 1.0	0.05 to 0.1
Beryllium, Be	0.1 to 0.5	0.01 to 0.1	
Cadmium, Cd	0.1 to 0.5	0.05 to 0.1	0.01 to 0.1
Copper, Cu^{+2}	0.05 to 1.0	0.4 to 0.7	0.05 to 0.5
Chromium, Cr^{+3}	0.0 to 0.5	0.05 to 0.5	
Lead, Pb	0.3 to 1.6	0.05 to 0.6	0.05 to 0.4
Mercury, Hg^{+2}			0.01 to 0.05
Nickel, Ni	0.2 to 1.5	0.1 to 0.5	0.05 to 0.5
Silver, Ag	0.4 to 0.8	0.2 to 0.4	0.05 to 0.2
Selenium, Se	0.2 to 1.0	0.1 to 0.5	
Thallium, Ti	0.2 to 1.0	0.1 to 0.5	
Zinc, Zn	0.5 to 1.5	0.4 to 1.2	0.02 to 1.2

[1]EPA 600/2-82-001c, Treatability Manual, Vol. III.

Table 6-3

Estimated Maximum 30-Day Average

for Lime and Sulfide Precipitation

6.5.3.2.1 CHLORINE OXIDATION. Use chlorine gas or liquid (depending on dosage rate) with caustic or hypochlorite solution only for oxidation of cyanide (see Table 6-2 for operational conditions).

6.5.3.2.2 HYDROGEN PEROXIDE (H_2O_2) OXIDATION. Use for oxidation of cyanide at alkaline pH (8.5 to 10) in presence of trace concentration of copper catalyst. Use for oxidation of phenols at acidic pH (3 to 4) in presence of trace concentration of metal (Fe, Al, or Cu) catalyst. Since the intermediate reaction product (hydroquinone) is adsorbed and consumes adsorbent capacity that may be required for heavy metal removal, avoid incomplete oxidation of phenols if treatment is followed by granular-activated carbon.

6.5.3.2.3 POTASSIUM PERMANGANATE ($KMNO_4$) OXIDATION. Use for oxidation of hydrogen sulfide, mercaptans, and phenols. Retention times should be determined by bench or pilot scale testing and are typically 1 to 3 hours.

6.5.3.2.4 RESIDUALS. Oxidation can create precipitates that must be separated by subsequent clarification and filtration. Need for additional treatment should be determined during bench testing study.

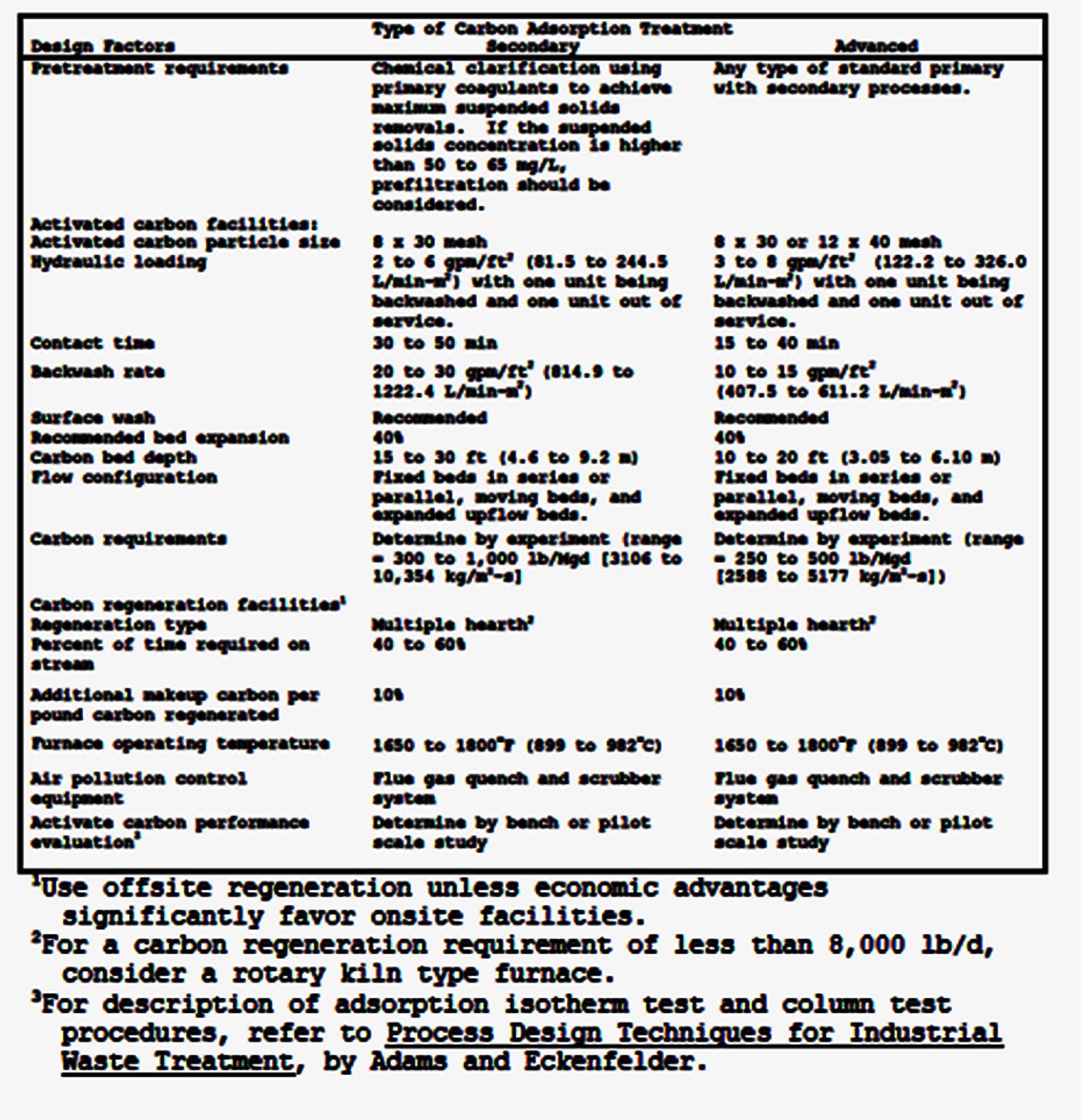
6.5.3.3 PROCESS CONTROL. Use electronic recorder-controllers with self-cleaning probes for pH and ORP.

6.5.4 ACTIVATED CARBON. Table 6-4 presents additional considerations for granular-activated carbon (GAC) which may be used to provide effluent polishing following treatment of specific industrial wastes.

a) GAC should be included in heavy metal waste treatment facilities only as a standby treatment unit for use during process upsets or outages for maintenance. GAC may be required for polishing effluent prior to direct discharge under a NPDES permit. It should not be required for continuous use as pretreatment prior to discharge to a POTW. GAC treatment economics dictate that precipitation, flocculation, and filtration processes be upgraded and controlled prior to installation of GAC columns.

b) Powdered-activated carbon (PAC) addition to activated sludge systems should be considered for treatment of wastewaters containing biorefractory organic compounds. However, adsorption of these compounds to PAC and subsequent discharge with waste-activated sludge may create a sludge that is a hazardous waste.

6.5.5 OTHER TREATMENT PROCESSES AND OPERATIONS. Other treatment processes that are applied to industrial wastes are sedimentation, coagulation, and flotation.



Design Factors	Type of Carbon Adsorption Treatment	
	Secondary	Advanced
Pretreatment requirements	Chemical clarification using primary coagulants to achieve maximum suspended solids removals. If the suspended solids concentration is higher than 50 to 65 mg/L, prefiltration should be considered.	Any type of standard primary with secondary processes.
Activated carbon facilities:		
Activated carbon particle size	8 x 30 mesh	8 x 30 or 12 x 40 mesh
Hydraulic loading	2 to 6 gpm/ft^2 (81.5 to 244.5 L/min-m^2) with one unit being backwashed and one unit out of service.	3 to 8 gpm/ft^2 (122.2 to 326.0 L/min-m^2) with one unit being backwashed and one unit out of service.
Contact time	30 to 50 min	15 to 40 min
Backwash rate	20 to 30 gpm/ft^2 (814.9 to 1222.4 L/min-m^2)	10 to 15 gpm/ft^2 (407.5 to 611.2 L/min-m^2)
Surface wash	Recommended	Recommended
Recommended bed expansion	40%	40%
Carbon bed depth	15 to 30 ft (4.6 to 9.2 m)	10 to 20 ft (3.05 to 6.10 m)
Flow configuration	Fixed beds in series or parallel, moving beds, and expanded upflow beds.	Fixed beds in series or parallel, moving beds, and expanded upflow beds.
Carbon requirements	Determine by experiment (range = 300 to 1,000 lb/Mgd [3106 to 10,354 kg/m^3-s]	Determine by experiment (range = 250 to 500 lb/Mgd [2588 to 5177 kg/m^3-s])
Carbon regeneration facilities[1]		
Regeneration type	Multiple hearth[2]	Multiple hearth[2]
Percent of time required on stream	40 to 60%	40 to 60%
Additional makeup carbon per pound carbon regenerated	10%	10%
Furnace operating temperature	1650 to 1800°F (899 to 982°C)	1650 to 1800°F (899 to 982°C)
Air pollution control equipment	Flue gas quench and scrubber system	Flue gas quench and scrubber system
Activate carbon performance evaluation[3]	Determine by bench or pilot scale study	Determine by bench or pilot scale study

[1] Use offsite regeneration unless economic advantages significantly favor onsite facilities.

[2] For a carbon regeneration requirement of less than 8,000 lb/d, consider a rotary kiln type furnace.

[3] For description of adsorption isotherm test and column test procedures, refer to *Process Design Techniques for Industrial Waste Treatment*, by Adams and Eckenfelder.

Table 6-4

Granular Carbon Adsorption Treatment Applications

6.6 CASE STUDY: AIRCRAFT MAINTENANCE FACILITY

6.6.1 OPERATIONS. Typical operations include metal surface cleaning, metal fabricating, metal finishing, metal plating, and aircraft paint stripping and spraying.

6.6.2 WASTEWATER CHARACTERISTICS. The wastewater generated from these operations contains numerous constituents including chromium, cyanide, phenol oil, and various heavy metals.

6.6.3 TREATMENT SYSTEM. Preliminary engineering studies should be conducted to establish the appropriate treatment processes to be applied to wastewater sources at these installations. Figure 6-2 shows a system schematic for treatment or pretreatment of wastewater. It assumes separate collection systems for mixed (acid and alkali) wastewater, phenolic wastes, cyanide wastes, and chrome bearing wastes. A separate treatment scheme is provided for each wastewater. The treatment systems, however, have piping and operational flexibility to treat any of the individual wastewaters in series in the event that cross-contamination (connection) occurs in the collection system. GAC columns are not shown in the schematic. GAC may be required for effluent polishing to remove metals or partially oxidized phenol. Treatment process schematics and control logic for batch chrome reduction, batch cyanide oxidation, and batch phenol oxidation are shown in Figure 6-3. Treatment process schematics and control logic for batch and continuous flow metal precipitation are shown in Figure 6-4. Concentrated oily wastewaters and wastewaters containing solvents and degreasers should be handled separately. Low levels of oil and grease can be accommodated by the systems shown in Figure 6-2.

6.7 CASE STUDY: AIRPORTS

6.7.1 OPERATIONS. Operations generating industrial wastes at a typical airport include washracks and service maintenance areas.

6.7.2 WASTEWATER CHARACTERISTICS. Wastes from washracks and maintenance and service aprons will predominantly consist of oils and solids.

6.7.3 TREATMENT SYSTEM. Preliminary engineering studies should be conducted to determine the appropriate treatment facilities. Treatment will usually consist of a collection sump with a diversion structure for bypassing storm water flow followed by a gravity oil-water separator. Clear water can be discharged to the POTW or to the industrial waste sewer (if available) depending on the concentration of metals and detergents.

6.8 CASE STUDY: SEAPORTS

6.8.1 OPERATIONS. Operations that generate industrial waste can be extensive and depend on the size of the facility. Wastes include metal working and plating, maintenance, paint spraying and stripping, and miscellaneous shop work.

6.8.2 WASTE CHARACTERISTICS. The predominant wastes are oils, solids, and heavy metals. Phenols will be present in wastewater from paint stripping operations.

6.8.3 TREATMENT SYSTEM. Wastewater from plating, paint stripping, paint spraying, maintenance, pipe shop, and other miscellaneous sources should be segregated at the source into waste streams indicated in Figure 6-2. Collection of such streams is recommended with treatment as shown in Figure 6-2. Wastes from drydock operations should be introduced to this treatment scheme after grit removal.

6.9 CASE STUDY: PAINT SPRAY AND STRIPPING SHOP

6.9.1 OPERATIONS. The primary operations include the use of stripping and washdown solutions for removing paint and spray booths for applying new paint.

6.9.2 WASTE CHARACTERISTICS. Paint stripping operations produce small volumes of heavily polluted wastewater that is difficult to treat. Paint booth wash waters accumulate metals from the captured aerosols and from the water curtain discharges of spray paint operations. Principal pollutants are common metals, hexavalent chromium, ferro-cyanide, and solvents (primarily phenols). Paint booth sludge is also generated intermittently when booths are cleaned. This sludge should be evaluated for its hazardous waste nature by the EP toxicity test. Some reduction in sludge volume can be achieved on drying beds if proper climatic conditions exist. This reduces the cost of ultimate sludge disposal.

6.9.3 TREATMENT SYSTEM. The wastewater can be pretreated onsite for phenol removal using the peroxide oxidation scheme shown in Figure 6-3. Since wastewater volumes are small, batch reactor tankage and onsite chemical storage requirements are small. The effluent can be pumped to a central treatment facility for removal of cyanide, hexavalent chrome, and other metals. Alternatively, since volumes are small, they could be hauled by a truck and stored at the central facility for subsequent treatment. Because of the characteristics of paint stripping wastes, limited or no onsite pretreatment is the preferred method of waste handling. Treatment should be conducted at a central facility.

6.10 MISCELLANEOUS SHOPS

6.10.1 OPERATION. These include a variety of miscellaneous operations. These can include machining, parts cleaning and overhaul, boiler operations, and vehicle and engine repair.

6.10.2 WASTE CHARACTERISTICS. Typically, the wastes from miscellaneous shop operations are low volume continuous discharges or periodic batch dumps. The materials generally included in the waste discharge are oily or of some petrochemical base (for example, degreasing operations, machining oils, cleaning solutions, and solvents).

6.10.3 TREATMENT SYSTEM. Most waste from miscellaneous shop operations can be handled in conjunction with other wastes previously described. Substitute chemicals or procedures should also be considered to minimize troublesome wastes from miscellaneous shops. For example, use of dry cleaning methods rather than wet cleaning procedures is an option.

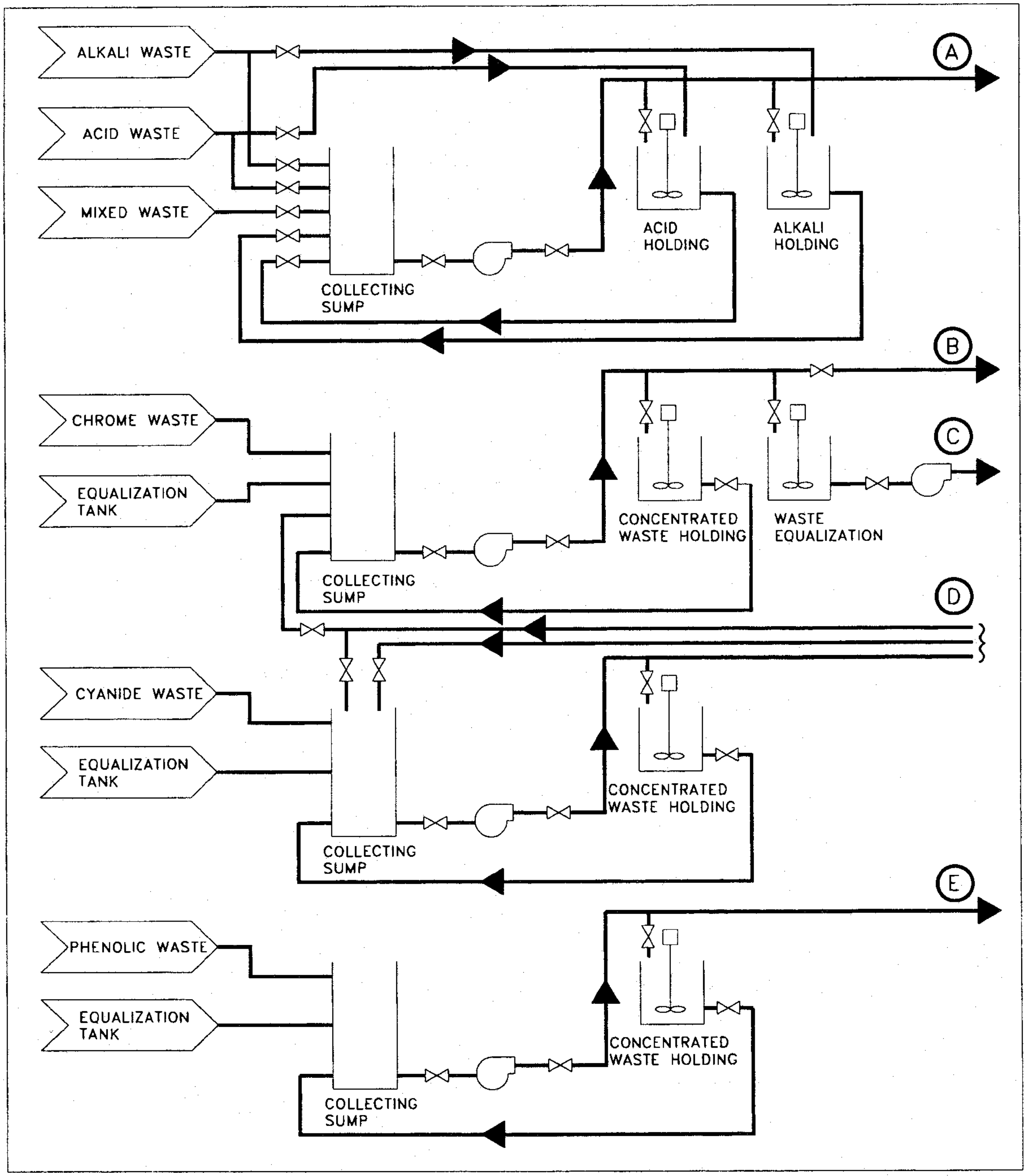


Figure 6-2A

Wastewater Treatment Flow Schematic

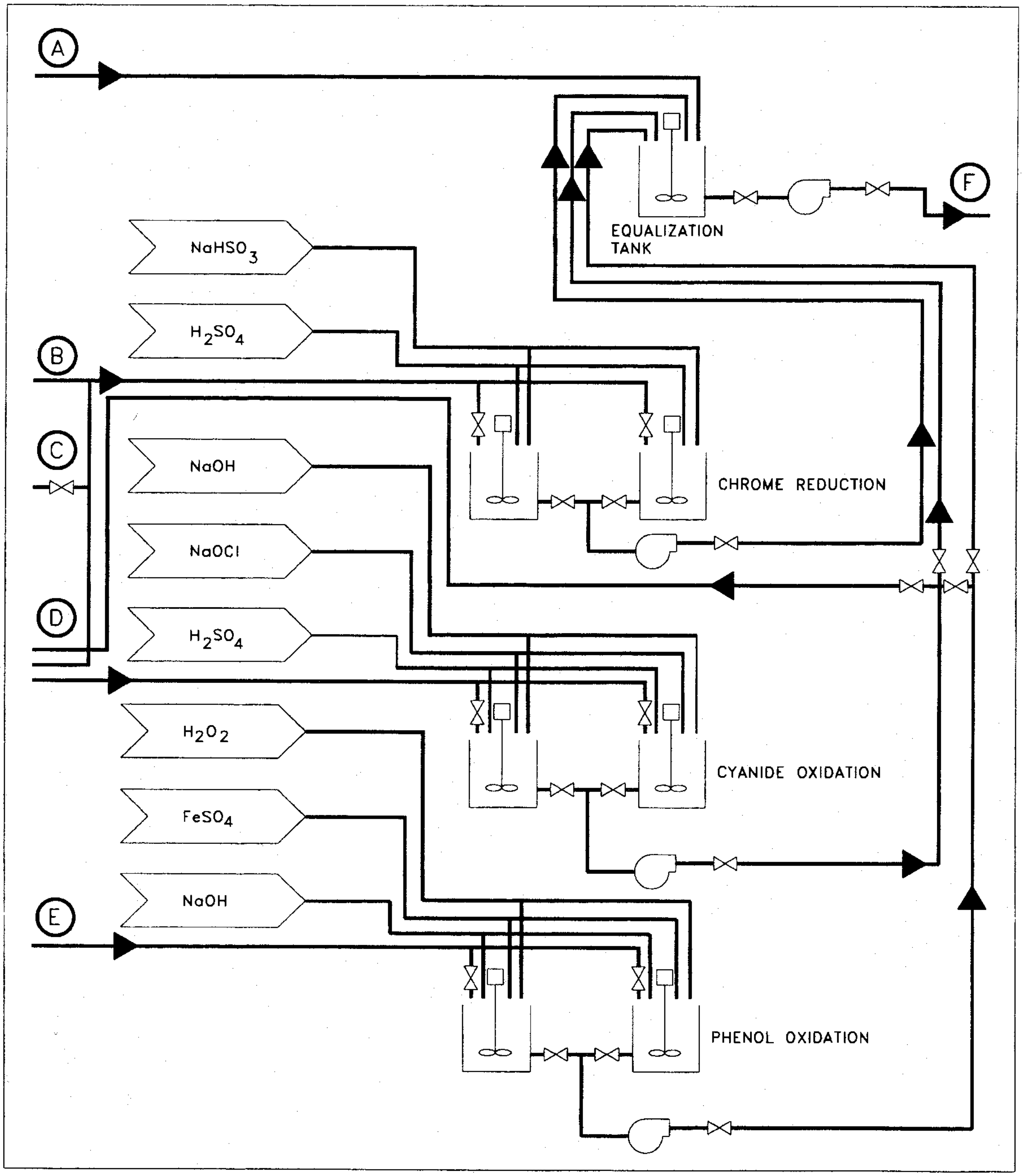


Figure 6-2B

Wastewater Treatment Flow Schematic

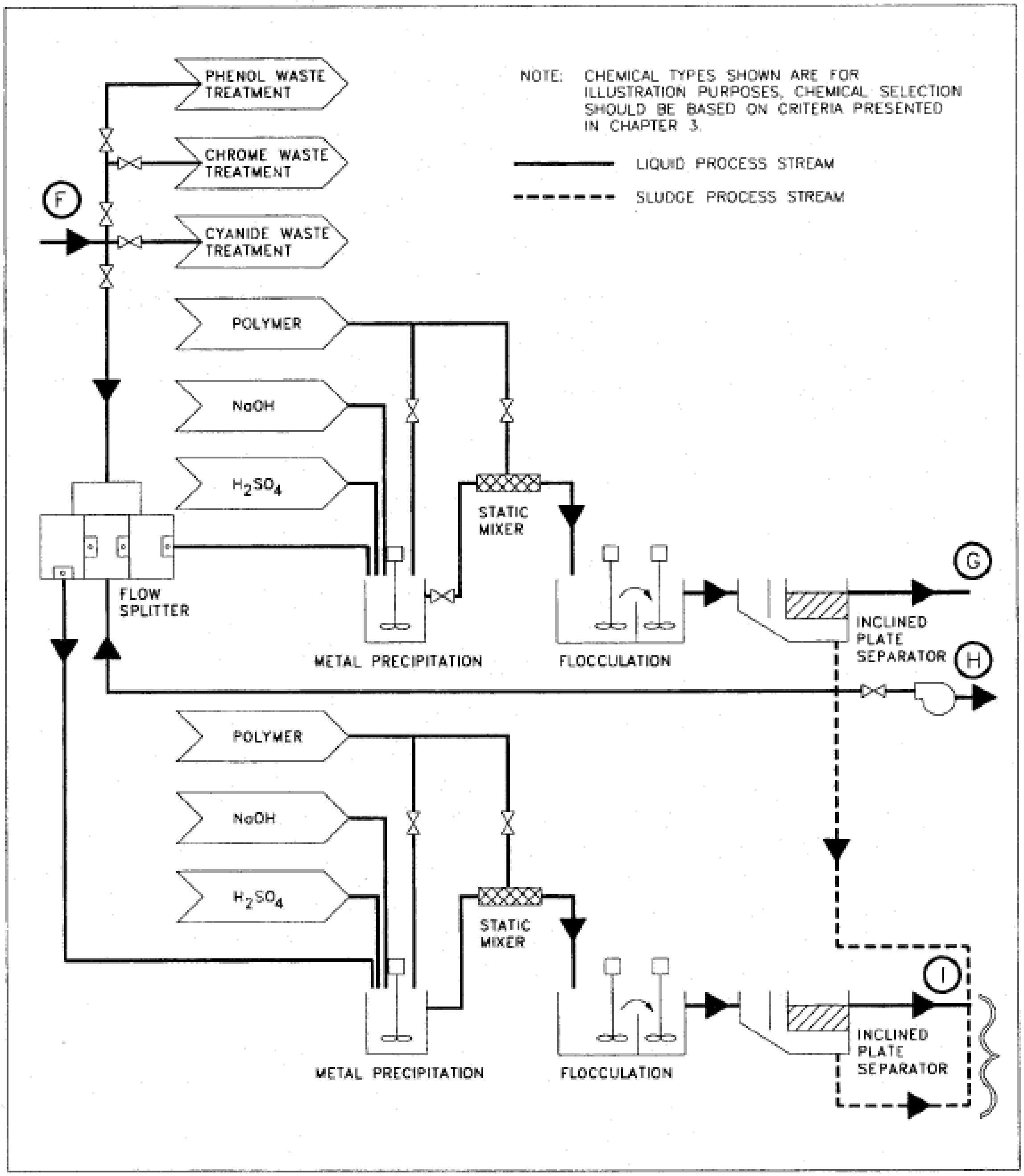


Figure 6-2C

Wastewater Treatment Flow Schematic

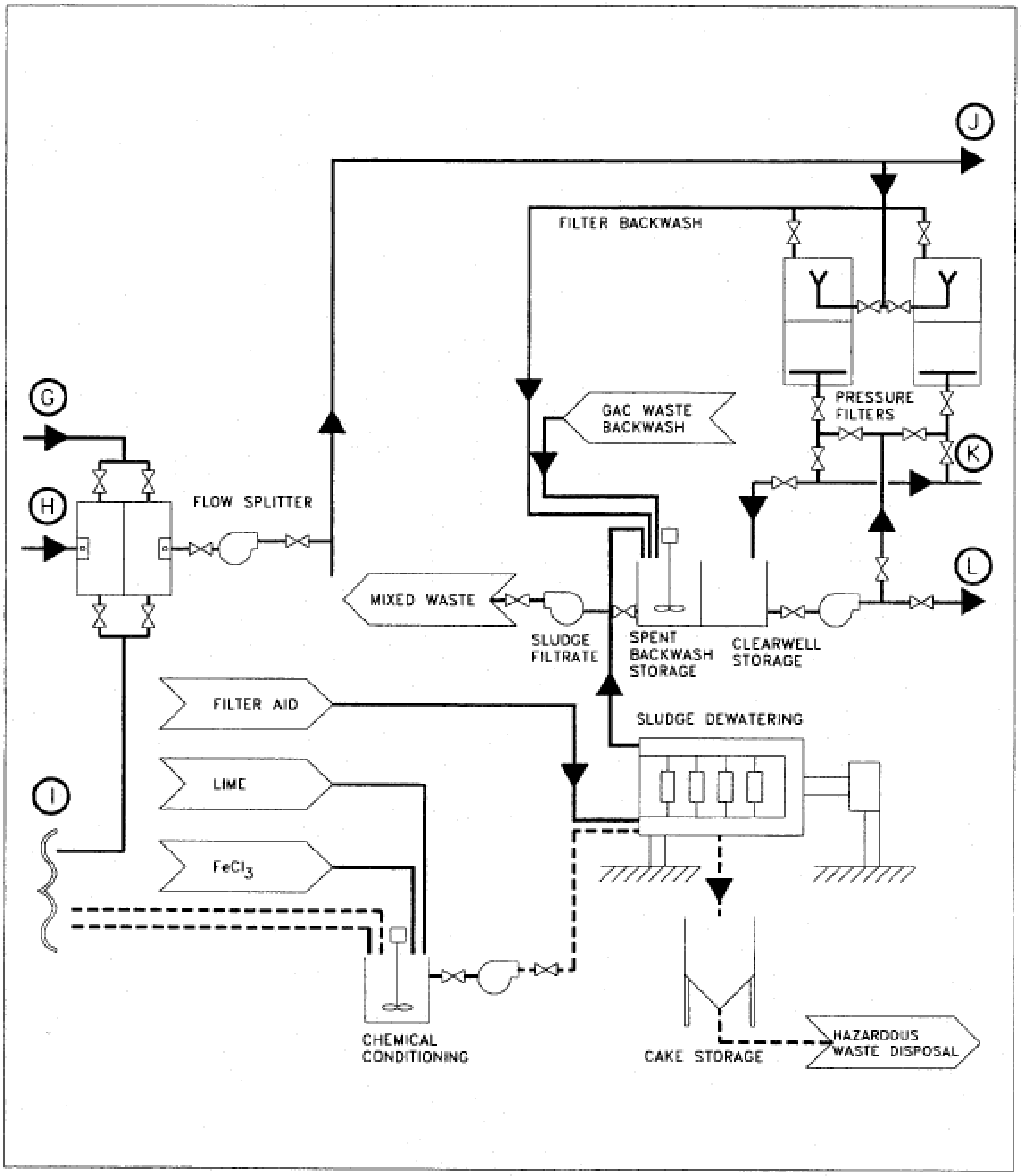


Figure 6-2D

Wastewater Treatment Flow Schematic

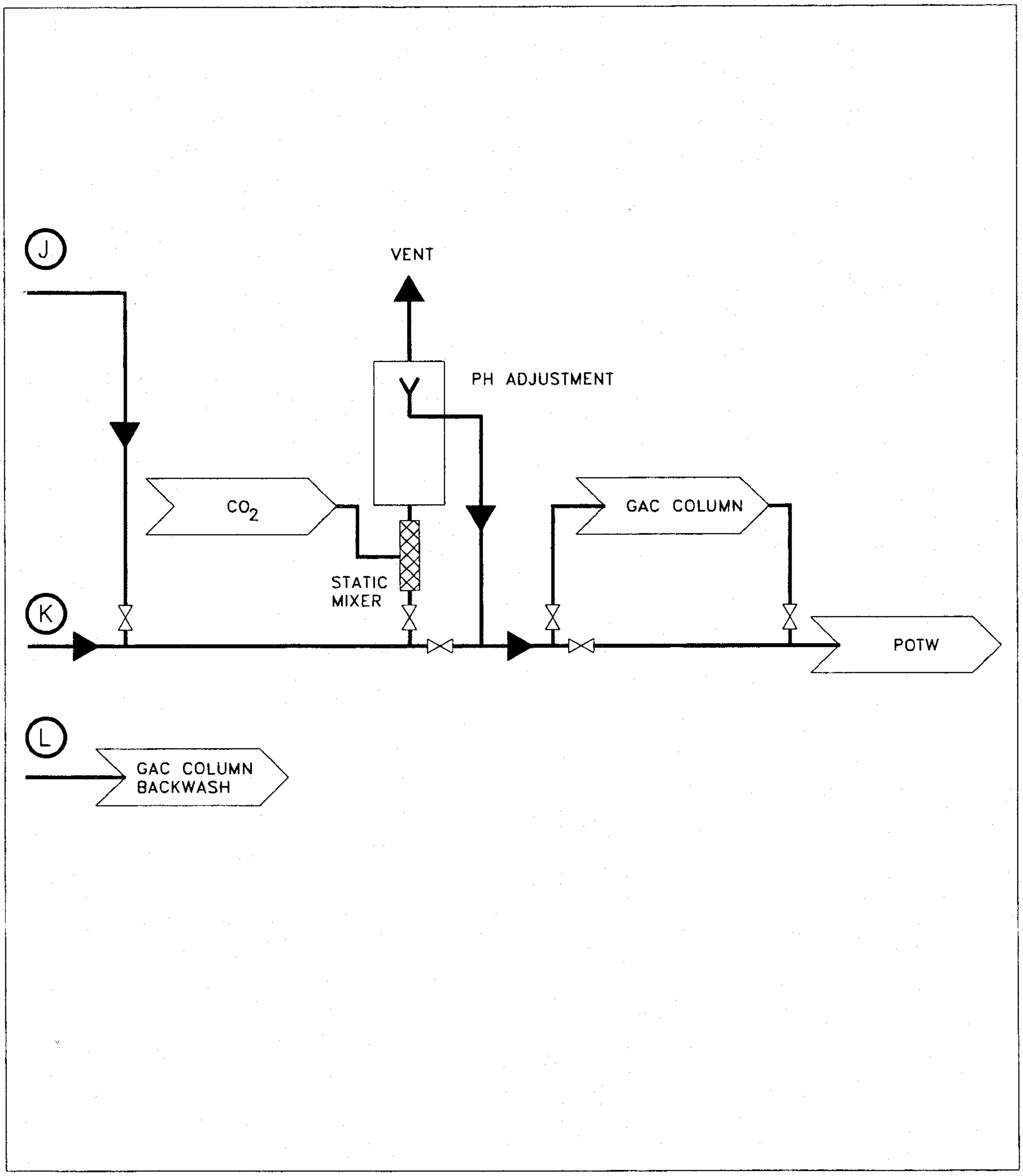


Figure 6-2E

Wastewater Treatment Flow Schematic

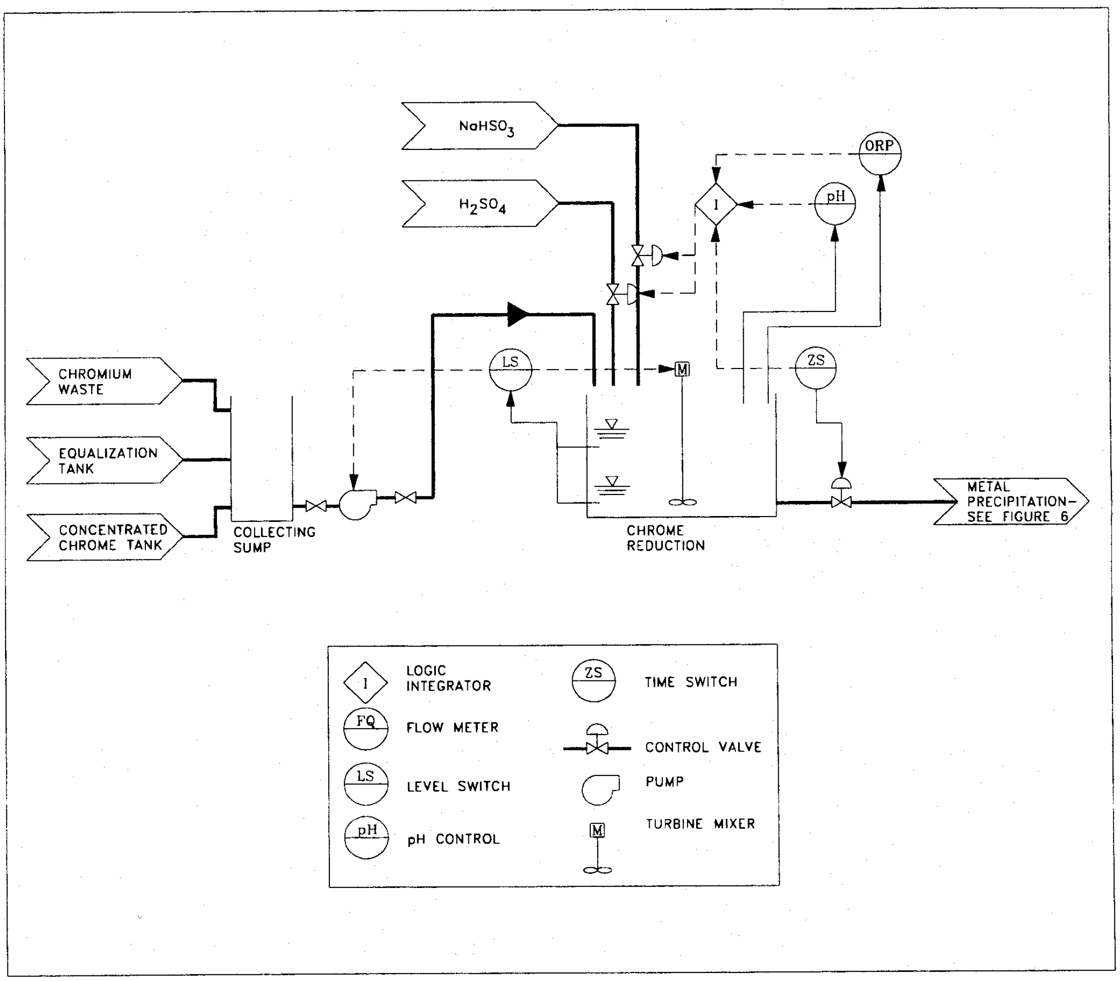


Figure 6-3A

Process Schematics for Chrome Reduction,

Cyanide Oxidation, and Phenol Oxidation

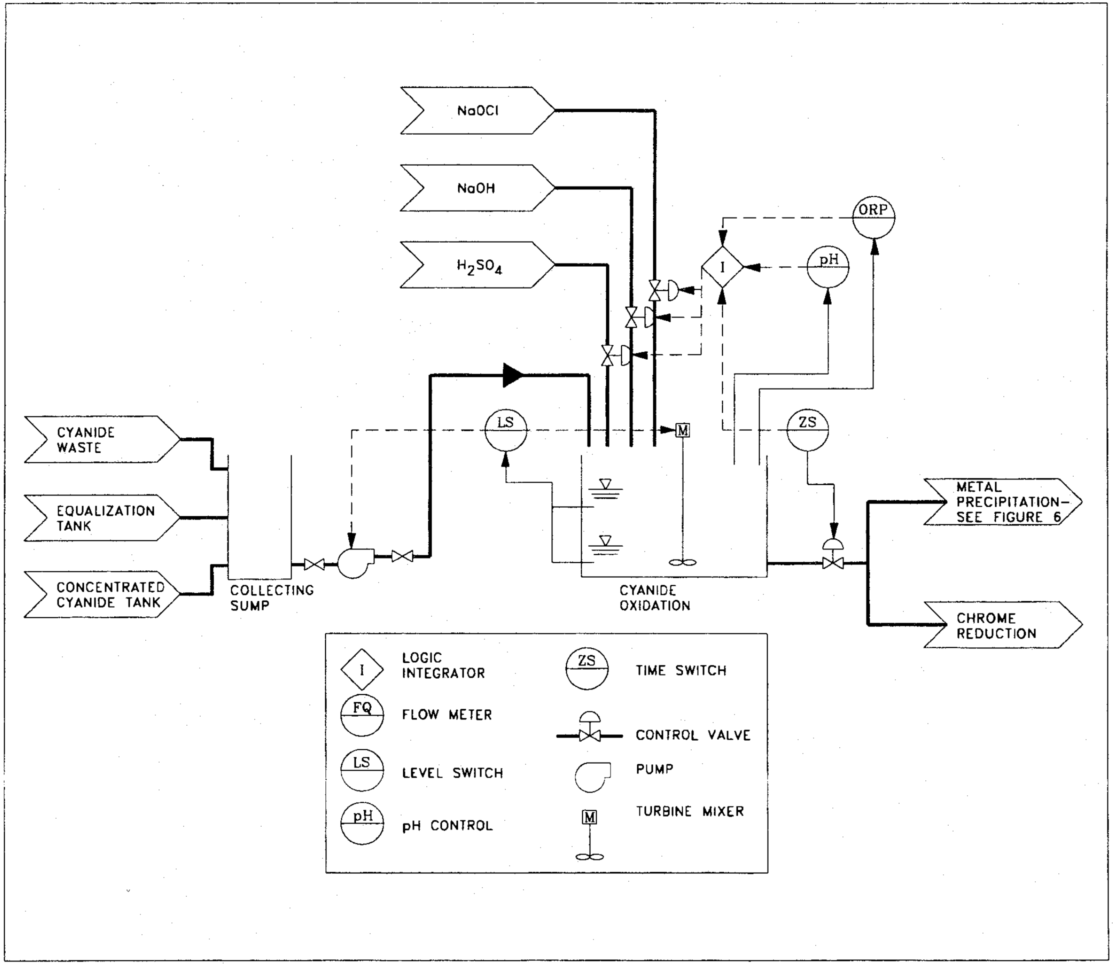


Figure 6-3B

Process Schematics for Chrome Reduction,

Cyanide Oxidation, and Phenol Oxidation

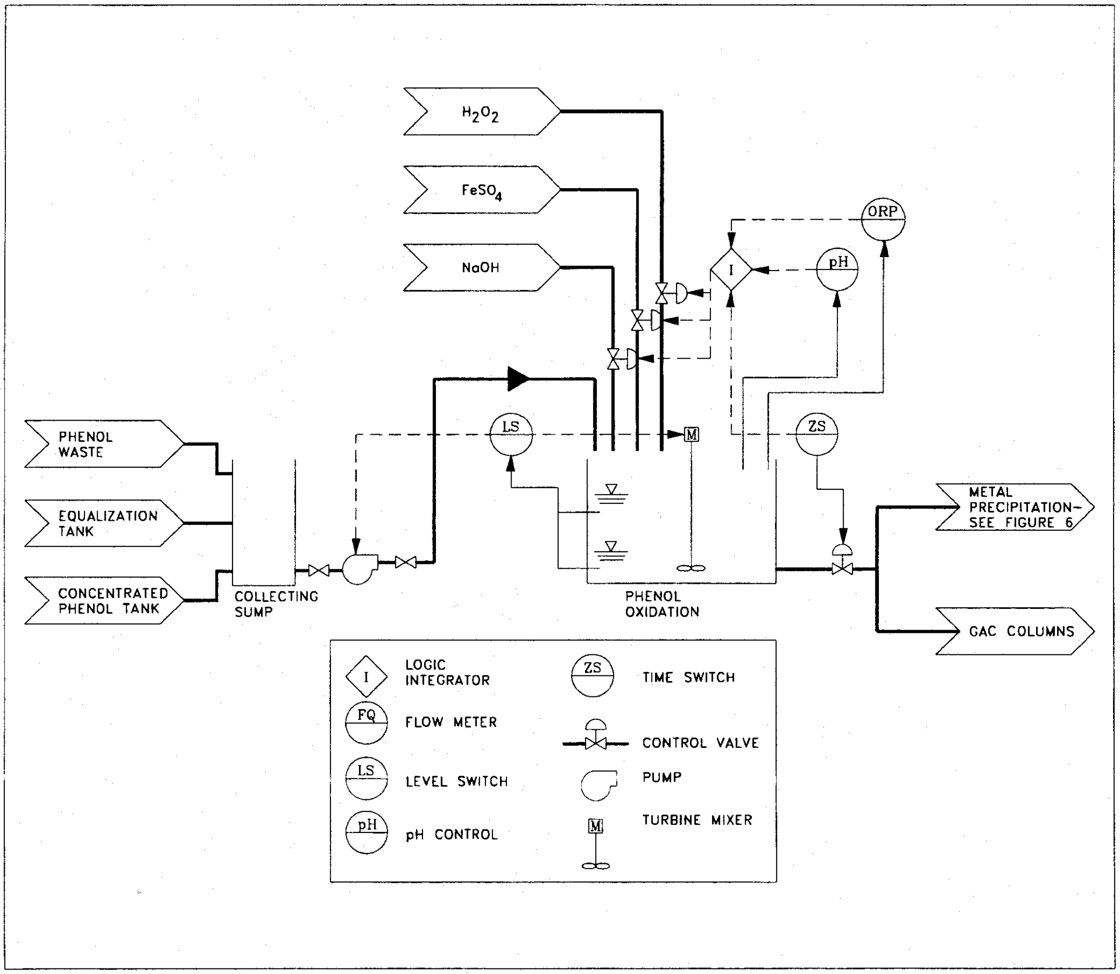


Figure 6-3C

Process Schematics for Chrome Reduction,

Cyanide Oxidation, and Phenol Oxidation

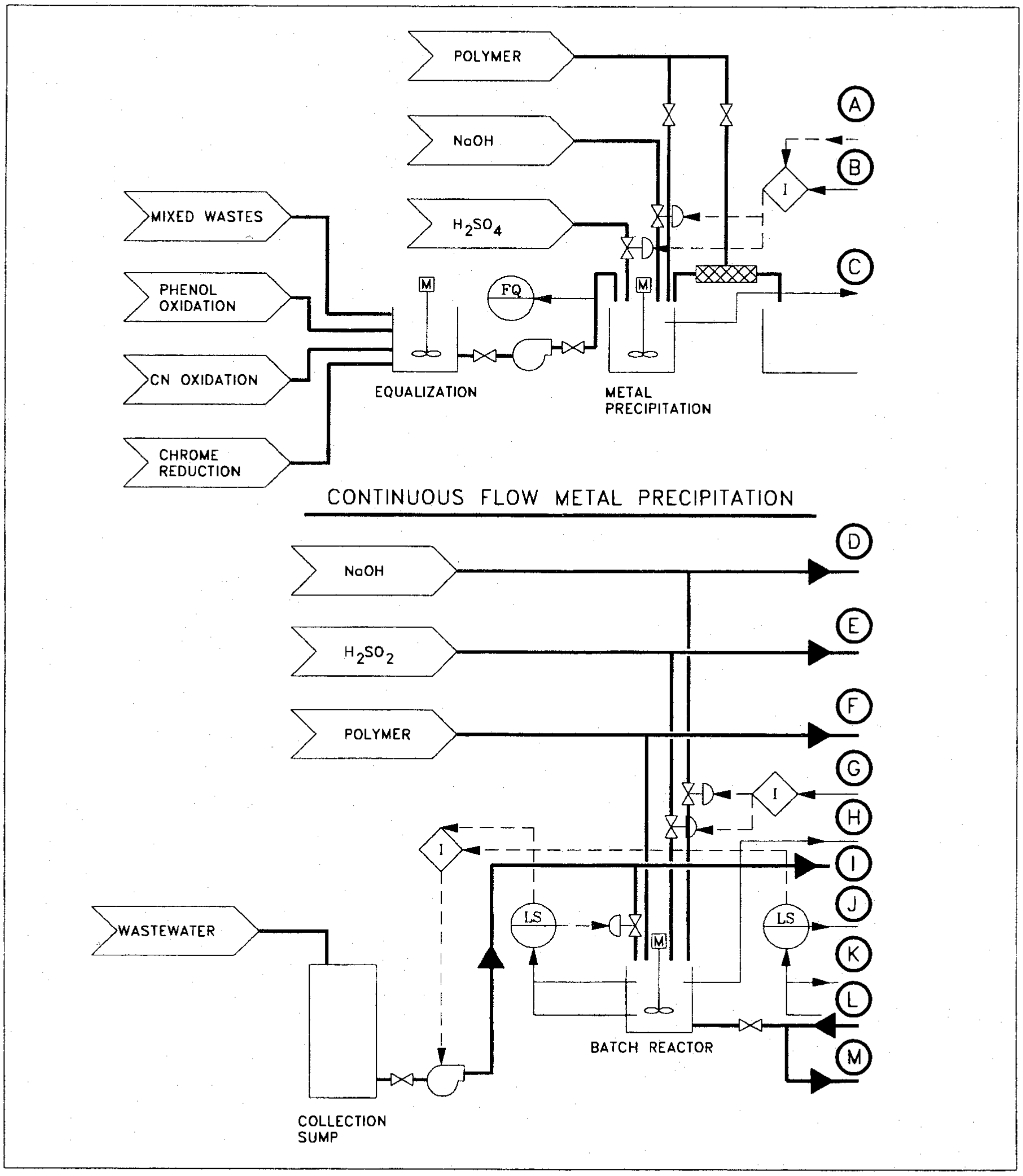


Figure 6-4A

Process Schematic for Batch and Continuous Flow Metal Precipitation

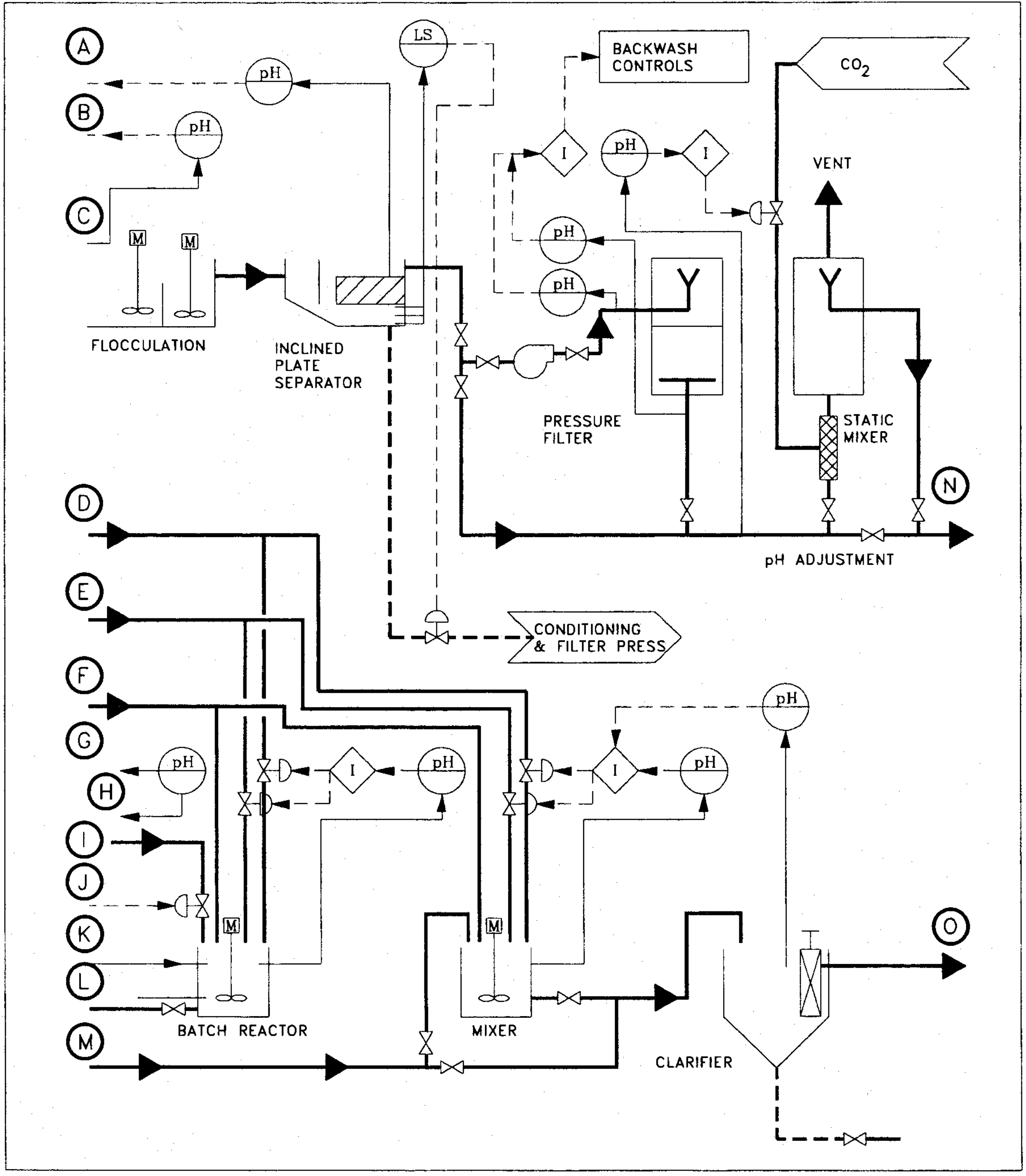


Figure 6-4B

Process Schematic for Batch and Continuous Flow Metal Precipitation

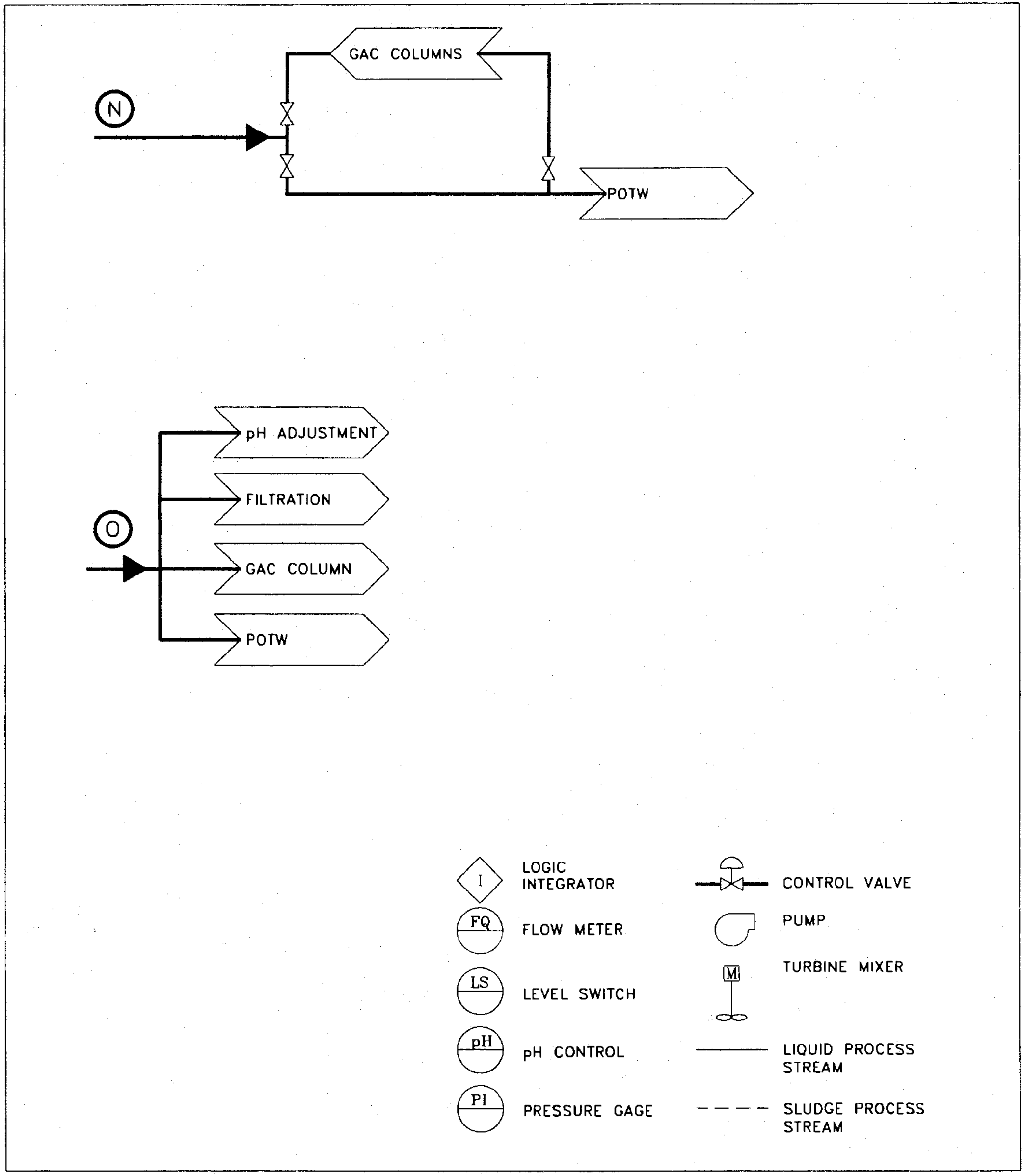


Figure 6-4C

Process Schematic for Batch and Continuous Flow Metal Precipitation

6.11 FACILITIES LAYOUT. Layout and plot size of new and upgraded industrial waste treatment facilities is frequently dictated by the space available at the base site. These local guidelines should be followed as long as the resulting facility layout does not create potentially hazardous or unsafe working and operating conditions. These conditions can result by placing cyanide waste treatment units too close to caustic neutralization units or acid storage, or in potential areas of leaking pipes and conduits. Adequate space should be allocated for satisfying chemical storage requirements and safety criteria for ventilation of fumes and clear space for pipe routes. Space for laboratory, office, and operating personnel support facilities should not be sacrificed for more treatment reactor space. A suggested layout diagram for a complete industrial waste treatment facility is shown in Figure 6-5. This layout is coordinated with the treatment schematic for shop wastewaters (Figure 6-2). It includes phenol and cyanide oxidation, chrome reduction, metals precipitation, and comingled waste treatment and sludge dewatering.

6.12 COLOR CODING OF PIPING SYSTEMS. The color code for identification of piping systems should comply with the American National Standards Institute (ANSI) A13.1, Scheme for the Identification of Piping Systems recommendations. The color scheme includes pipe fittings, valves, and pipe coverings, but excludes pipe supports, brackets, and other accessories, as well as conduits for solids carried in air or gas. Apply the following general color scheme to piping systems at waste treatment facilities. See Table 6-5 for recommended color coding for typical piping systems for industrial and domestic wastewater treatment facilities. These color coding schemes are applicable only for treatment facilities and do not affect the coding scheme recommended elsewhere.

6.12.1 FEDERAL SAFETY RED. This classification (ASA Class F-fire) includes sprinkler systems and other firefighting or fire protection equipment. Applications include sprinkler piping, identification and location of fire alarms and boxes, extinguishers, fire blankets, fire doors, hose connections, hydrants, and other firefighting equipment.

6.12.2 FEDERAL SAFETY YELLOW. This group includes materials that are inherently hazardous because they are flammable or explosive, toxic, or produce poisonous gas. Applications include flammable liquids such as gasoline, naphtha, fuel oil, chlorine gas, sulfur dioxide, ammonia, and steam.

6.12.3 FEDERAL SAFETY ORANGE. This classification includes ASA Class D dangerous materials such as corrosive liquids, acids, and alkalis. Applications include concentrated acid, caustic soda, lime slurry, or hydrogen peroxide solution piping.

6.12.4 FEDERAL SAFETY GREEN. This classification includes ASA Class S safe materials which involve little or no hazard to life or property in handling. Applications include low temperature and pressure, nonpoisonous and nonflammable liquids and gases, drinking water, service water, emergency showers, and eyewash facilities.

6.12.5 FEDERAL SAFETY BLUE. This classification includes ASA Class P protective materials. The materials used for washdown and for lawn watering are piped through plants for the express purpose of being available to prevent or minimize the hazards associated with dangerous materials. These materials are not typically used at naval wastewater treatment facilities.

6.12.6 OTHER. In addition to these recommended color codes, piping systems can be more specifically identified by applying color bands and by painting the name of the material on the pipe. Refer to ANSI A13.1 for specification details of legend marker. Pipes carrying hazardous materials should be further identified with flow directional arrows and operating pressures (for steam lines and other high-pressure systems).

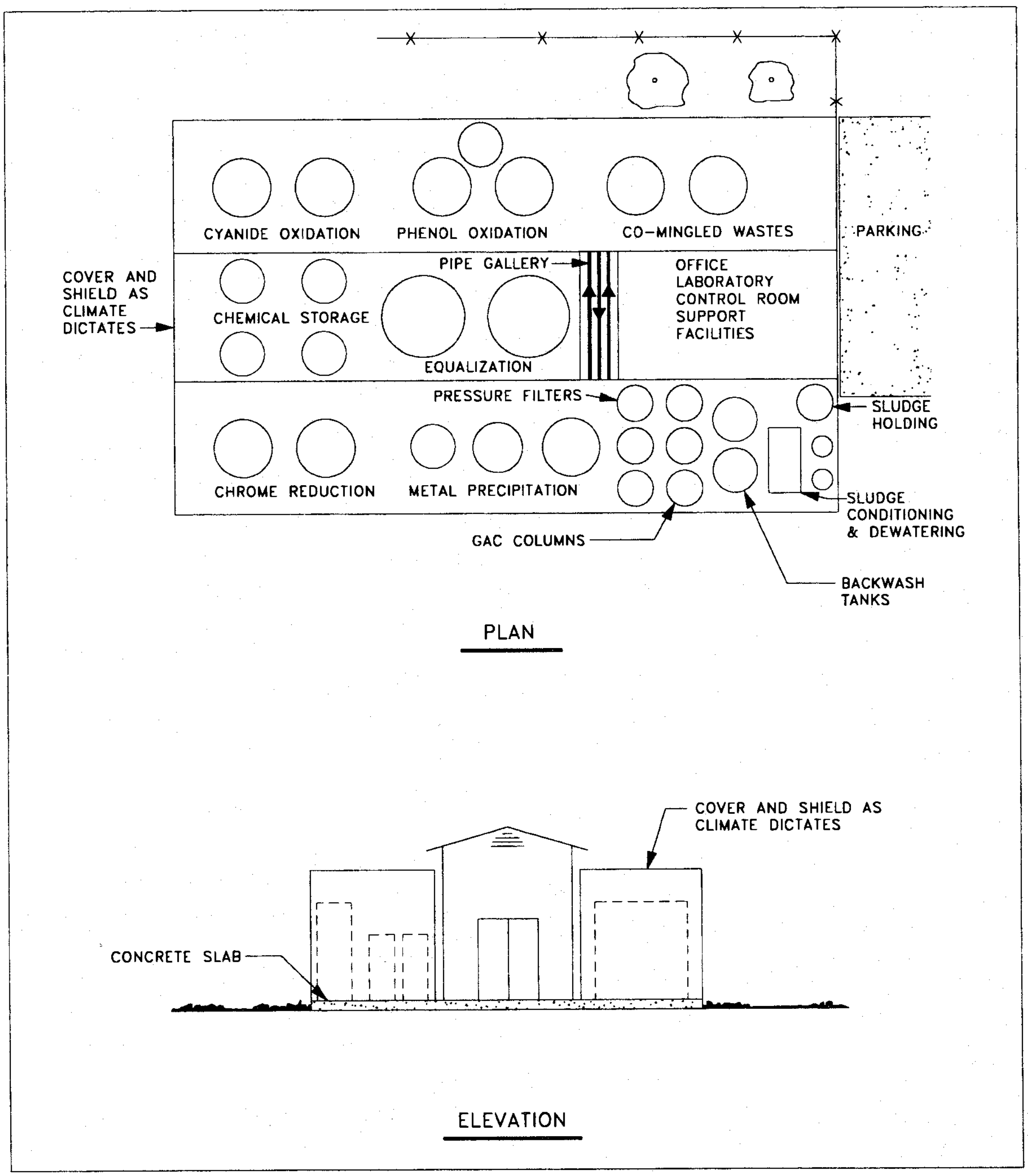
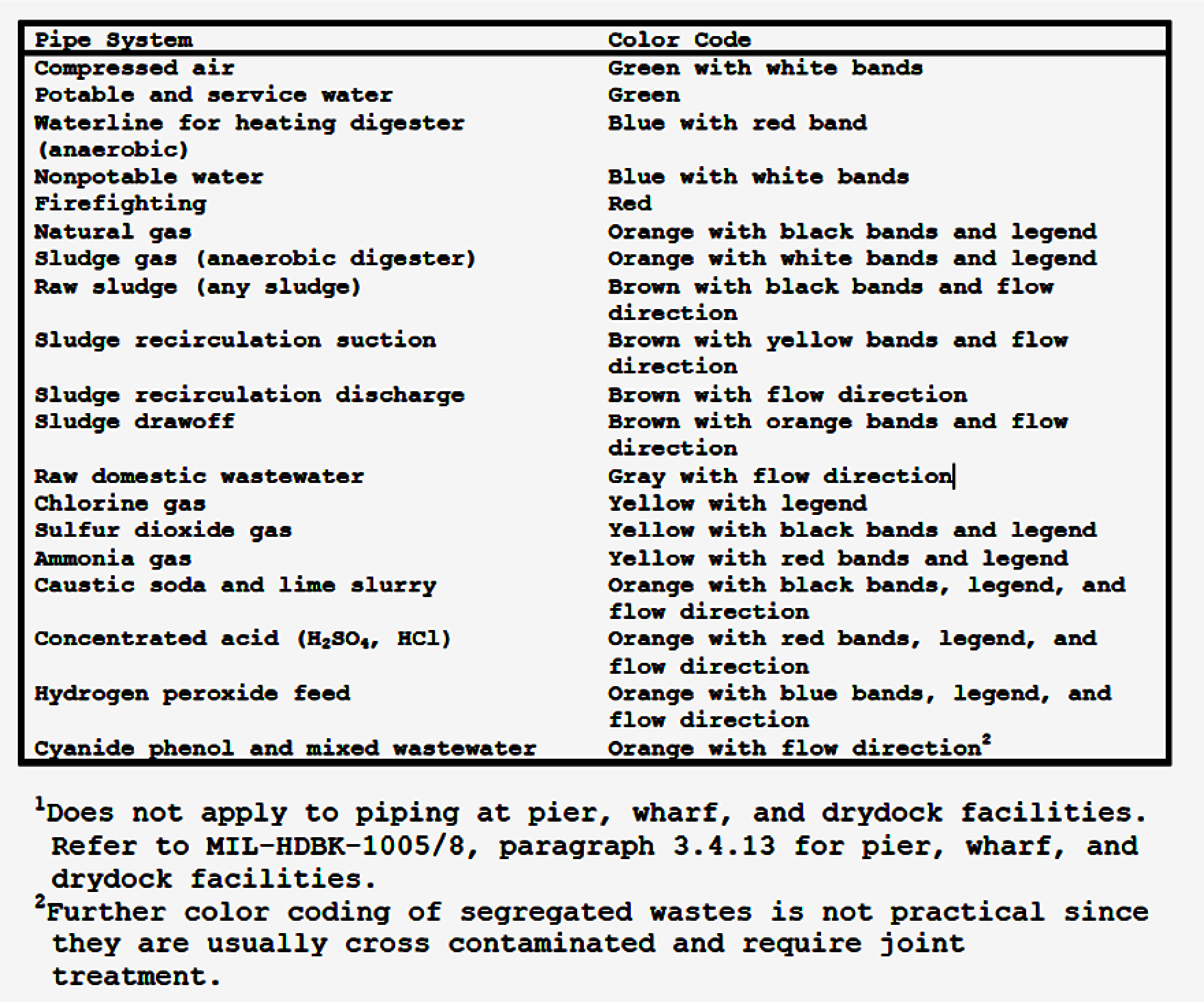


Figure 6-5

Layout for Industrial Waste Treatment Facility



Pipe System	Color Code
Compressed air	Green with white bands
Potable and service water	Green
Waterline for heating digester (anaerobic)	Blue with red band
Nonpotable water	Blue with white bands
Firefighting	Red
Natural gas	Orange with black bands and legend
Sludge gas (anaerobic digester)	Orange with white bands and legend
Raw sludge (any sludge)	Brown with black bands and flow direction
Sludge recirculation suction	Brown with yellow bands and flow direction
Sludge recirculation discharge	Brown with flow direction
Sludge drawoff	Brown with orange bands and flow direction
Raw domestic wastewater	Gray with flow direction
Chlorine gas	Yellow with legend
Sulfur dioxide gas	Yellow with black bands and legend
Ammonia gas	Yellow with red bands and legend
Caustic soda and lime slurry	Orange with black bands, legend, and flow direction
Concentrated acid (H_2SO_4, HCl)	Orange with red bands, legend, and flow direction
Hydrogen peroxide feed	Orange with blue bands, legend, and flow direction
Cyanide phenol and mixed wastewater	Orange with flow direction[2]

[1] Does not apply to piping at pier, wharf, and drydock facilities. Refer to MIL-HDBK-1005/8, paragraph 3.4.13 for pier, wharf, and drydock facilities.

[2] Further color coding of segregated wastes is not practical since they are usually cross contaminated and require joint treatment.

Table 6-5

Color Coding Criteria for Piping Systems at Wastewater Facilities

7 GUIDELINES FROM ACTUAL EXPERIENCE

7.1 POST OCCUPANCY EVALUATION REPORTS.

Post occupancy evaluation reports have identified numerous lessons that have been learned through actual experience. Previous designs specifying operational errors and omissions must not be repeated on any new or retrofitted facility. The following paragraphs summarize items that need to be considered. The guidelines have been grouped into four categories: design factors, operational factors, equipment selection, and material selection.

7.2 DESIGN FACTORS. The following points should be considered:

a) Effluent discharge limits set by regulatory agencies should be evaluated closely and renegotiated with the issuing agency (if there is sufficient justification) prior to proceeding on facility plant design.

b) Treatment operational requirements should be kept as simple as possible. Use instrumentation and controls only to reduce operating manpower requirements or hazard exposure. Highly automated control systems have not been successful at some facilities. The degree of automation should be optimized by balancing specific project factors. For example, a highly automated system that requires a few well trained operators and considerable instrument maintenance must be compared against a system with less automation but greater operator attention. The degree of automation must reflect the specific facilities staffing capabilities. In most instances, this will include automatic feed system, motorized valves, and other systems that minimize relatively simple treatment tasks.

c) Operational considerations must be closely coordinated with waste treatment plant design to achieve an efficient and reliable facility.

d) Collection sewers, pumping facilities, and treatment tanks for acids and cyanides should be located completely separate from each other to avoid severe safety hazards and mixing. Facilities should be separate and designed so that spills or leaks could not result in cross connection between the acid and cyanide operations.

e) Leakage of industrial wastes or sludges from any container or vessel such as tanks, pipes, and sand drying beds must be avoided. Provide emergency drains and spill containment area drains.

f) Waste treatment from plating operations should provide sufficient onsite storage capacity to allow for a minimum of 8 hours of plating operation during waste treatment shutdown periods.

g) Ventilation design as determined by the medical activity industrial hygienist must provide adequate air flow during normal and emergency conditions to ensure a safe environment for operating personnel. This is particularly crucial in plant areas that generate gases and vapors. Consider covers for large volume reactors and equalization basins.

h) Provide positive head on pump suctions.

i) Particular caution should be observed with chemical piping layout; for example, avoid entrapment areas for hydrogen peroxide that may cause valve and pipe eruption. Provide vacuum breaks in piping design to avoid undesirable back siphonage to pumps and tanks.

j) Provide adequate design of piping and equipment supports to avoid vibration that may lead to failure.

k) Provide for storage of process treatment chemicals in temperature and/or climate controlled areas as needed.

l) Consider the use of pneumatically controlled valves (rather than electric) in corrosive environments.

7.3 OPERATIONAL FACTORS. The following points should be considered:

a) Adequate operator training at facilities is mandatory. An O&M manual which specifically reflects the plant's requirements is required. Conduct on-the-job training at plant startup and continue until the entire treatment process runs continuously and satisfies design effluent discharge criteria for a minimum 30-day period.

b) Prepare operation and maintenance manuals for each equipment component in the plant. Prepare a system O&M manual to integrate and demonstrate how each component relates to the system. Operation and equipment manuals should be updated after the performance demonstration period to include equipment and plant modifications. New operational requirements should be implemented during the startup or performance demonstration period.

c) Plant equipment should be operated immediately upon installation. Equipment should not be allowed to sit idle and deteriorate from lack of usage. Equipment performance should be in demonstrated compliance with specifications and testing procedures.

d) Operator work requirements should be minimized by designing treatment chemicals in liquid form to be pumped, or in powder form to be automatically fed.

e) Use of computer control systems with total manual backup should be considered for larger installations.

f) After removing solids from the units, a steam line/wand or air supply should be provided for cleaning filter press gaskets and flanges.

g) Develop contingency plans for plant shutdown and chemical spills and treatment process performance failure.

7.4 EQUIPMENT SELECTION. The following points should be considered:

a) For solids separation following chemical precipitation (particularly plating waste), parallel plate or tube separators should be evaluated. Manual or automatic means of cleaning plugged plates or tubes must be provided.

b) Plate and frame filter presses have been particularly successful in dewatering chemical sludges for direct disposal and should be used unless special circumstances dictate otherwise.

c) Electrically powered agitators are preferred over air spargers.

d) Mixer shafts should be constructed of solid corrosion-resistant materials rather than coated.

7.5 MATERIAL SELECTION. The most critical factors that have caused unfavorable conditions at industrial waste facilities operated by the Navy have been material selection and protection from the corrosive environments. Careful selection of materials is necessary. The following points should be considered:

a) Concrete block or masonry buildings are preferred over steel to resist corrosion.

b) Exhaust and ventilation ductwork must be structurally sound. Ductwork must have the proper materials to resist corrosive fumes vented or a corrosive atmosphere on the exterior side. Roof fans and ventilators should be suitable for a corrosive atmosphere of a building air space.

c) Piping and conduit material should be resistant to the corrosive agents and operating conditions to which they may be exposed. Paint exposed metal that is nonresistant to corrosion with a corrosion-resistant paint. Consider the effect of a corrosive atmosphere on building interior roof and walls.

d) Tank materials (or liners) should be of proper corrosion-resistant material.

e) Materials for seals, connectors, and gaskets on piping and pumps exposed to corrosive materials should be carefully selected to avoid damage.

f) Pump housing should be corrosion resistant.

g) Provide overhead piping which carries corrosive type materials with a corrosion-resistant sleeve and directed to a safe area to avoid safety hazards from leaky piping. Provide emergency area floor drains.

h) Proper welding specifications and materials are necessary for constructing or repairing tanks and equipment which are exposed to corrosive materials.

i) Electrical boxes should be located away from corrosive environments. If located in corrosive operating areas, they should be sealed gasket types and corrosion resistant.

j) Protect other instruments and electrical equipment that may be exposed to a corrosive environment. Locate control consoles, panel-boards, and transformers within a closed and vented control room out of any corrosive atmosphere.

k) Concrete tanks or sewers exposed to corrosive materials should be constructed of acid-resistant concrete or provided with suitable liners.