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MILITARY HANDBOOK

INDUSTRIAL AND OILY WASTEWATER CONTROL

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ABSTRACT

This handbook presents design criteria for use by qualified engineers for design of collection, transport, treatment, and sludge handling facilities for industrial and oily wastewaters from Naval installations. The handbook also presents design criteria for metering instrumentation, controls, and chemical feeding devices for these facilities.

FOREWORD

This handbook has been developed in preparation of Naval facilities engineering and design criteria documents. This handbook uses, to the maximum extent feasible, national and institute standards in accordance with Naval Facilities Engineering Command (NAVFACENGCOM) policy. Deviations from these criteria for Navy criteria manual preparation shall not be made without prior approval of NAVFACENGCOM Headquarters Code 04.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commander, Naval Facilities Engineering Command, Naval Engineering Command Headquarters, Code 04, 200 Stovall Street, Alexandria, VA 22332-2300; telephone (703)325-0450.

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

CIVIL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	PA
DM-5.01	Surveying	LANTDIV
DM-5.02	Hydrology and Hydraulics	LANTDIV
DM-5.03	Drainage Systems	LANTDIV
DM-5.4	Pavements	PACDIV
DM-5.5	General Provisions and Geometric Streets, Design for Roads, Walks, and Open Storage Areas	HDQTRS
DM-5.6	Trackage	NORTHDIV
MIL-HDBK-1005/7	Water Supply Systems	SOUTHDIV
MIL-HDBK-1005/8	Domestic Wastewater Control	HDQTRS
MIL-HDBK-1005/9	Industrial and Oily Wastewater Control	HDQTRS
DM-5.10	Solid Waste Disposal	PACDIV
MIL-HDBK-1005/12	Fencing, Gates, and Guard Towers (Proposed)	WESTDIV
MIL-HDBK-1005/13	Hazardous Waste Storage Facilities	HDQTRS
DM-5.14	Groundwater Pollution Control	HDQTRS

NOTE: Design manuals, when revised, will be converted to military handbooks.

This handbook is issued to provide immediate guidance to the user. However, it may or may not conform to format requirements of MIL-HDBK-1006/3 and will be corrected on the next update.

INDUSTRIAL AND OILY WASTEWATER CONTROL

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Section 1: INTRODUCTION

1.1 Scope. This handbook contains design criteria for the collection, transport, and treatment of industrial and oily wastewater discharges from Naval facilities. Particular details covered include:

a) design procedures and guidelines;

b) industrial and oily wastewater characterization, collection, and treatment;

c) effluent disposal;

d) metering, instrumentation and control of wastewater processes;

e) chemical handling and feeding.

Emphasis has been placed on processes and equipment which have had wide application and for which there is significant design and operation experience. Systems particularly applicable to the size and type of facilities operated by the Navy are emphasized. Bracketed [ ] numbers following each reference mentioned in the text of this handbook are keyed to the REFERENCES list at the end of the handbook.

This manual does not cover systems for the control of exhaust emissions from internal combustion engines, boilers or air scrubbers; systems for the control of wastes from nuclear reactors; or systems for control, transport, and disposal of hazardous wastes.

1.2 Cancellation. This handbook cancels and supersedes NAVFAC DM-5.9, Metering, Instrumentation and Control, -and Chemical Feeding, October 1979.

1.3 Definitions

1.3.1 Pollution. Pollution is the condition resulting from discharge of chemical, physical, or biological agents which so alters or harms the natural environment that it creates an adverse effect on human health or comfort, fish and wildlife, other aquatic resources, plant life, or structures and equipment to the extent of producing economic loss, impairing recreational opportunity, or marring natural beauty.

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

1.4 Policy. The basic policy of the Navy regarding pollution control is that the Navy will cooperate with all other concerned agencies at the local, state, and Federal level. This policy is detailed in OPNAV Instruction (OPNAVINST) 5090.1, Environmental Protection/Engineering Program Ashore; Engineering Field Division Responsibilities for [1]. Also refer to Environmental Quality in MIL-HDBK-1190, Facility Planning and Design Guide, [2].

1.4.1 Guidelines. Refer to OPNAVINST 5090.1 [1]. Also refer to applicable United States Environmental Protection Agency (EPA) and state guidelines.

1.4.2 Standards. Consult the regional office of the EPA and appropriate state and local regulatory agencies for information on applicable regional or local standards.

1.4.3 Cooperation with Review Agencies. Submit project plans to EPA and local and state regulatory agencies for information and comment.

1.4.4 Environmental Impact Statements. These statements are normally not required for improvement projects for pollution abatement. Guidelines on when to submit statements are given in OPNAVINST 5090.1 [1].

1.4.5 Shore Disposal of Ship Sewage. See Naval Ship Engineering Center Directive, Ship-to-Shore Interface for Sewage Disposal System [3].

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

a) MIL-HDBK-1190 [2]

b) NAVFACINST 4100.5 of 5 March 1974 Techniques of Energy Conservation [2]

c) NAVFAC DM-3.03, Heating, Ventilating, Air Conditioning, and Dehumidifying Systems [2]

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

1.4.7 Water Conservation. It is the policy of the Navy to employ water conservation measures to an extent that is feasible and economical, particularly in arid regions. Such methods as reuse of wastewater on agricultural crops, application of wet sludge to cropland, and reuse of wastewater for industrial purposes should receive full consideration in facilities planning and design.

1.5 Operations and Maintenance Manual. The preparation and furnishing of an operations and maintenance (O&M) manual should be included in the scope of work of all Architect-Engineering (A-E) contracts for the design of industrial waste treatment plants, oily waste treatment plants, and associated pumping and wastewater transfer systems.

1.6 Special Provisions in Seismic Areas. Refer to NAVFAC P-355, Seismic Design for Buildings, Section 10, Mechanical and Electrical Elements; Section 11, Structures Other than Buildings; and Section 12, Utility Systems, for recommended provisions in seismic areas [2].

1.7 Design Manual Use

1.7.1 Purpose. This handbook is a general guide for designing industrial and oily wastewater collection and treatment facilities and air pollution control facilities not covered in the DM-3 Series on Mechanical Engineering [2]. The design criteria presented and referenced herein will assist the engineer in the design of Naval facilities.

1.7.2 Guidelines. This handbook presents extensive criteria for design and operation of pollution control systems. It also includes guidelines developed from past field experiences. These guidelines are the result of design deficiencies, operational problems, poor equipment selection, and poor materials specification. These guidelines are presented in para 2.7.

Section 2: INDUSTRIAL WASTEWATER COLLECTION AND TREATMENT

2.1. Objectives. Industrial waste should be collected in a manner which 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. Refer to NAVFACINST 4862.5C, Industrial Facilities Acquisition Projects Which Involve Complex Processes or Hazardous/Toxic Materials [2], before proceeding on an industrial wastewater control project. 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 Naval facility. As a minimum, jar tests should be conducted prior to chemical process design in order to determine the reactor design criteria, process control and operating strategy, sludge production, and sludge characteristics. 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.

2.2 Industrial Pollutants. Industrial wastewaters contain pollutants that can be divided into two types depending on their degree of impact on the environment:

2.2.1 Conventional Pollutants. These are Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), pH, fecal coliform, oil, and grease.

2.2.2 Toxic Pollutants. Sixty-five specific compounds and families of compounds were identified as toxic by the EPA. The EPA must promulgate effluent limitations, pretreatment standards and new source performance standards for 21 major industrial categories. The EPA list of "toxic pollutants" presently includes 186 specific compounds and will probably be expanded. Examples of toxic substances typically found in wastewater from Navy installations are heavy metals, organo-tin, aqueous film-forming-foam (AFFF), phenols and halogenated phenols, paint stripping agents, solvents, and degreasers.

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

b) If characteristics of industrial wastewater are unknown, obtain complete organic and inorganic analysis by an EPA certified laboratory. See Section 4 for sample collection and analytical procedures.

2.2.3 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 plating or battery manufacture), the type of industrial facility (new or existing), and the point of discharge. Discharge alternatives are:

2.2.3.1 Direct Discharge to Navigable Water. Direct discharge to a receiving water body that would be regulated by a National Pollutant Discharge Elimination System (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. A Naval treatment facility that discharges directly to a navigable water is designated herein as a Navy-Owned Treatment Works (NOTW).

2.2.3.2 Indirect Discharge. Indirect discharge to a receiving water body is by way of a sewerage collection system and a Publically Owned Treatment Works (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 Navy-owned 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.

2.2.3.3 Pretreatment Regulations. The EPA's Final Rule for general pretreatment regulations prior to indirect discharge to a POTW is presented in Federal Register Part II Vol. 46, No. 18, p. 9404 (Jan. 28, 1981) [4]. Specific pretreatment regulations for each industrial category are currently being established by EPA.

2.2.4 Planning and Design Procedures. See Figure 1 for illustration of stepwise procedures for planning and design of an industrial waste treatment project. See NAVFACINST 4862.5C for additional guidance [2].

2.3 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.

2.3.1 Source Characterization. Identify all 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.

2.3.2 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.

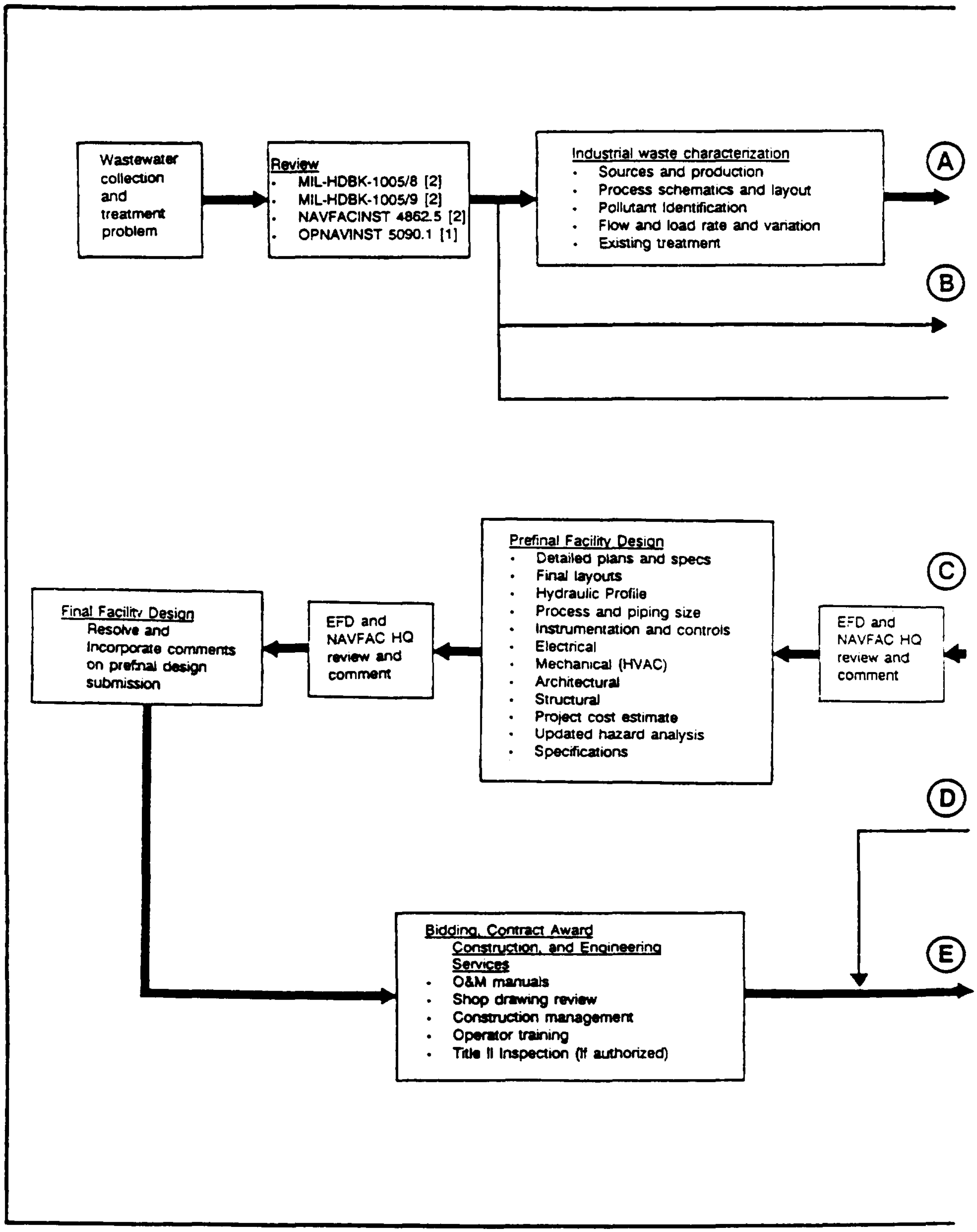


Figure 1
Planning and Design Steps for Industrial Waste Treatment Facility

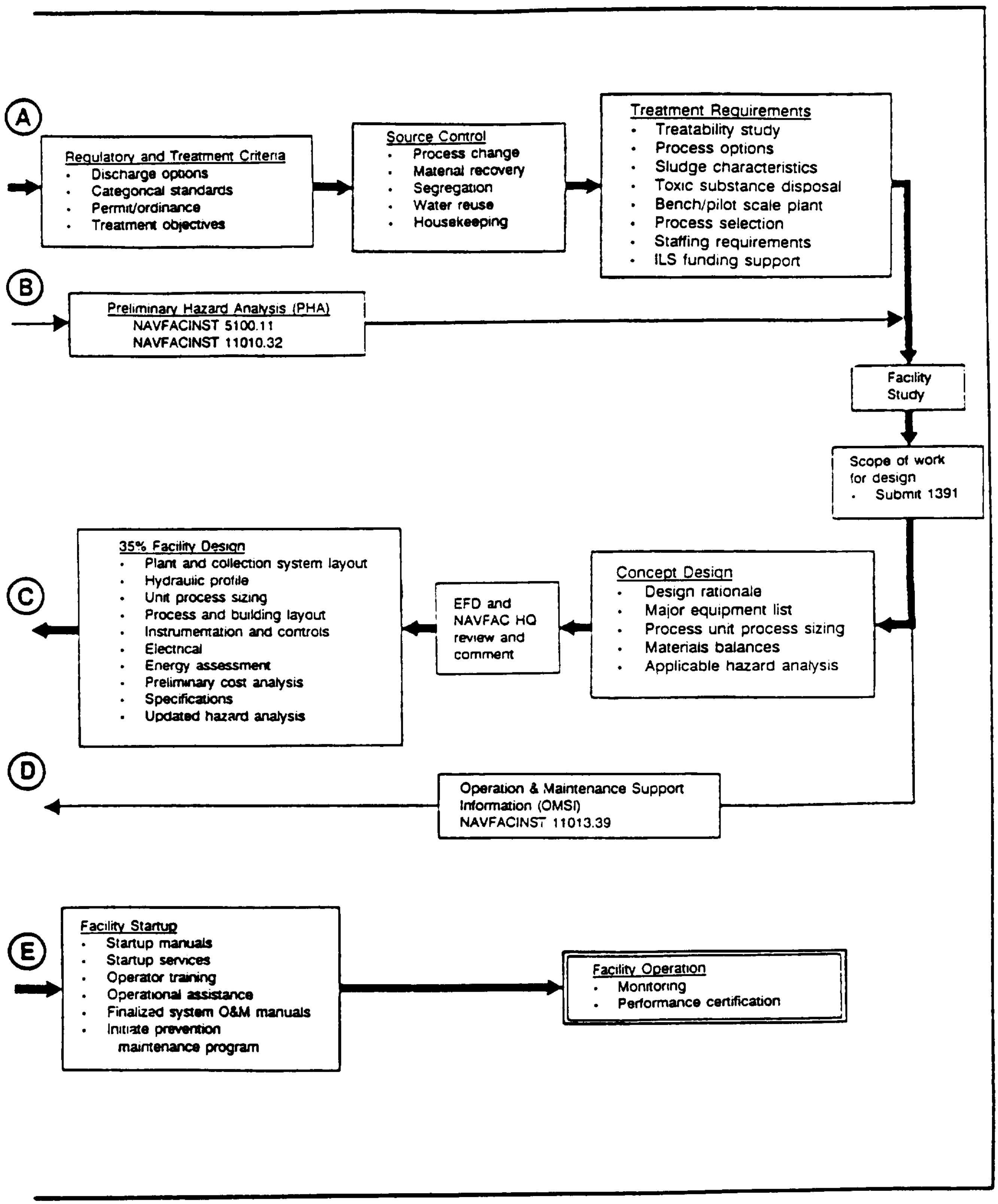


Figure 1 (Continued)
Planning and Design Steps for Industrial Waste Treatment Facility

2.3.3 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 cotreatment, 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).

2.3.3.1 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.

2.3.3.2 Oily Wastes. Used oils and solvents should be segregated at their source (if possible). Eliminate or minimize oily waste mixtures with metal and phenol containing wastewaters.

2.3.3.3 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.

2.3.4 Recovery. Consider the feasibility of recovering materials, such as semiprecious and precious metals, and chrome, from a metal plating waste stream for subsequent reuse.

2.3.5 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.

2.4 Wastewater Flows and Characteristics

2.4.1 Types of Wastewater. Primary sources of industrial wastes at Naval facilities are shipyards, air stations, and aircraft rework facilities. Primary sources of wastewater from these facilities are plating operations, painting and stripping operations, graving dock operations, degreasing operations, fire fighting schools, equipment operation and maintenance, and miscellaneous processes.

2.4.2 Flows

2.4.2.1 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.

2.4.2.2 Peak Flows. Peak flows will normally be higher during a specific 8-h 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.

2.4.3 Flow Characteristics

2.4.3.1 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 EPA Handbook for Monitoring Industrial Wastewater [5] 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.

2.4.3.2 Typical Characteristics. Characteristics of discharges from some industries commonly associated with Naval facilities are presented in Table 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.

Discharge Criteria. Identify effluent criteria applicable to discharge from proposed industrial waste treatment plant for either NPDES permit or local pretreatment requirements. Refer to para. 2.2.3.

a) Metal finishing and battery manufacturing (motor pool) are the only categorical industrial waste type listed in Table 1 that have final pretreatment and direct discharge limits established by EPA Pretreatment Standards. Refer to Federal Register Part III, Vol. 48, No. 137, p. 32462 (July 15, 1983) [4] for metal finishing regulations and Vol. 49, No. 48, p. 9108 (March 9, 1984) [4] 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.

2.4.3.4 Radioactive Wastes. Wastes which have radioactivity are not covered in this manual.

2.4.4. Flow and Load Equalization. Certain processes have short duration, and high flow and loading rates which 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 all compatible wastes received at a treatment facility, or on a smaller scale for specific process line waste discharges.

2.4.4.1 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).

a) Flow Equalization. If curve of inflow rate variations is available, apply mass diagram technique to determined required storage volume for desired outflow rate. In absence of flow rate curve, determine required storage volume by statistical methods developed by DiToro (see Statistical Design of Equalization Basins, in the American Society of Civil Engineers (ASCE) Journal of the Environmental Engineering Division, Volume 101, No. EE6, Proc. Paper 11782.) [6]

SOURCE	TYPE	TYPICAL WASTE QUANTITY	TYPICAL WASTE CONSTITUENTS AND CHARACTERISTICS		
				Liquor concentration %	
			Constituent	Batch	Continuous
Aircraft rework facility:	Metal pickling	Batch, 400 gal/ton. Continuous, 300 gal/ton.	H_2SO_4	0.5 to 2	4 to 7
			$FeSO_4$	15 to 22	14 to 16
			Plating process	Bath concentration %	
	Metal plating	Dragout 0.4 to 4 gal/1,000 ft^2. Rinse, 100 to 400 gal/1,000 ft^2. Dumping, total quantity of bath (not commonly practiced).		Metal	Cyanide
			Nickel	8.2	
			Chrome	20.7	
			Copper-CN	1.2	2.8
			Cadmium	2.3	5.7
			Zinc	3.4	4.9
			Tin	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 station:	Aircraft surface cleaning and treating operations.	Peak flow 60 gpm per washrack.	Chemical oxygen demand (COD)	5,000 to 80,000	10,000
			BOD	500 to 1,500	1,000
			Nitrate (as N)	10 5o 60	20
			Phosphate (as PO_4)	20 to 300	100
			Surfacants (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
			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, metal 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		

Table 1
Characteristics of Industrial Wastes

Submarine wastes:	Internal manifold system for discharge to shore sewage collection system.	Typical characteristics given are monthly average output for single submarine.	**Characteristics**	**Amount**
			Tri-sodium phospate	10 lb
			Hydrozine	9 gal
			EDTA	44 lb
			Nonionic detergent	4 gal
			Hydrochloric acid, sulfuric acid	5 gal
			Freon	10 gal
			Naphtha and acetone	5 gal
			Dry cleaning fluid	1 gal
			QXL detergent	18 gal
			Film developer	18 gal
			Detergent ultrasonic cleaner	15 gal
			Standard Navy laundry detergent	250 lb
			Starch	100 lb
			Bleach	125 lb
			Arlac soap builder	200 lb
			Sour	50 lb
			General purpose water with nontoxic detergent	40 gal
Photographic lab wastes:			Silver and mercury compounds, chormates, 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		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
			VSS	1.5 to 1,506 mg/L
			Settleable solids	<0.1 to 0.4 ml/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
Bilge water			**Characteristics**	**Range**
			Metals (mg/L)	
			Aluminum	<0.2 to 2.0
			Cadmium	<0.01 to 0.05
			Chromium	<0.01 to 0.07
			Copper	<0.01 to 2.2
			Iron	<0.01 to 7.5
			Lead	<0.01 to 0.53
			Mercury	<0.0001 to 0.0277
			Nickel	<0.01 to 0.04
			Silver	<0.01 to 0.01
			Zinc	<0.32 to 12.0
Fire training Areas:	Fire training	300 gpm	**Characteristics**[1]	**Range**
			pH	4.6 to 7.9 units
			COD	350,000 to 500,000 mg/L
			TOC	96,000 t 130,000 mg/L
			BOD_u[2]	300,000 to 411,000 mg/L
			BOD (as percent of BOD_u)	45 to 65
			AFFF is highly toxic to unacclimated microorganisms. Limit concentration in discharge to biological treatment facilities to ≤250 mg/L.	

1 Characteristics based on use of AFFF. Range values presented for DOD. BOD_u and BOD are for AFFF concentrate. The wastewater characteristics will depend on the AFFF content of the fire hose stream. Fire hose streams contain 3-6 percent AFFF depending on the proportioning equipment used.

2 Ultimate biochemical oxygen demand.

Table 1 (Continued)
Characteristics of Industrial Wastes

b) Load Equalization. Determine the effect of required volume for flow equalization of pollutant loads. Use the method presented in Water and Sewage Works Journal, Developing a Methodology for Design of Equalization Basin, Ouano, (Nov. 1977) [7]. If adequate power is not provided for complete mixing in the basin, size the basin on nonideal flow pattern described by Ouano. Consider the effects of variable and constant volume basin on equalization performance.

2.4.4.2 Basin Construction. Use earth embankment lagoons with suitable liners to prevent ground water contamination. Consider frequency of basin use and solids deposition and clean-out when evaluating need for concrete or asphaltic type liners.

For smaller basins or where site constraints require, use steel or concrete tanks. Provide protective liner compatible with wastewater characteristics.

2.4.4.3 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 all locations over 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. For further information on aeration equipment and installation, refer to para. 3.10.6.

2.4.5 Effect of Industrial Wastes

2.4.5.1 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 Pollution Control Federation (WPCF) Manual of Practice (MOP) No. 3, Regulation of Sewer Use [8].

2.4.5.2 Treatment Systems. Structures and personnel at treatment facilities are subject to the same hazards noted for collection systems in para. 2.4.5.1, above. 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.

a) Refer to para 2.1.1 for a discussion of treatability studies and industrial pretreatment requirements.

2.4.6 Limits on Biological Treatment

2.4.6.1 Conventional Pollutants. When toxic substances are absent, use loading criteria for conventional pollutants presented in MIL-HDBK-1005/8, Domestic Wastewater Collection and Treatment [2].

2.4.6.2 Toxic Substances. Toxic substances, such as heavy metals and certain organic compounds, present in some industrial wastes must be controlled to avoid upset or passthrough of biological treatment systems.

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

b) Organics. Some organic priority pollutants are also removed by conventional biological treatment systems. Removal mechanisms are bodegradation, 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 EPA. (refer to EPA Treatability Manual Vols. I-V, EPA-600/2-82-001a-e [5].) These treatability data should be used for guidance only. Actual removal performance depends on the operating characteristics (sludge age, MLSS) of the treatment facility, the method of oxygenation, and amount and nature of other compounds present in the wastewater.

Removal performance should be determined by bench or pilot scale treatability studies. See Water Pollution Control: Experimental Procedures for Process Design, by Eckenfelder and Ford [9], for the procedure for conducting treatability studies.

2.4.6.3 Other Pollutants. Some industrial wastes from Navy installations may not contain any listed priority pollutants but 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 (refer to para 2.4.7).

2.4.6.4 Nutrients. Certain minimum amounts of nutrients are required for efficient biological treatment. Normal proportions needed for active microbiological growth are typically about 1 lb of phosphorous (as P) and 5 lb of nitrogen (as N) for each 100 lb 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.

2.4.6.5 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.

TABLE 2
Threshold Concentrations for Heavy Metal
Inhibition of Biological Treatment Processes[1]

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

2.4.7 Bioassay of Wastewaters. Effluent limitations are based in part on limitations for individual chemicals or generic pollutant parameters: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (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 all 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.

2.4.7.1 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 LC50 and EC50 for median lethal concentration and median effective concentration, respectively.

a) 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 600/4-73-012, Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms [5], for complete list of acceptable test organisms and temperatures.

b) Methodology. Refer to EPA 600/4-73-012 [5], for complete description of required test equipment, laboratory and test procedures, sampling and analytical procedures, procedures for data gathering and reporting, and methods or data reduction and analysis to determine LC50 or EC50.

(1) Regulatory bioassay requirements and LC50 or EC50 are usually based on 48- or 96-h tests using fish or invertebrates (for example minnows or Daphnia, respectively). These require extensive equipment, time, test procedures, and do not provide a rapid assessment of effluent toxicity.

2.4.7.2 Rapid Bioassay Procedure (RBP). The use of RBP should be considered by Naval installations in lieu of standard procedures. RBP is a useful tool in effluent monitoring since inexpensive yet reliable toxicity data can be obtained quickly. RBP has not been approved by EPA as an "equivalent method." Check with a state regulatory agency for approval of RBP prior to developing test program.

A substantial data base of toxicity of pure compounds, and of raw and treated industrial effluents has been developed using RBP. See Use of Rapid Bioassay Procedure for Assessment of Industrial Wastewater Treatment Effectiveness, presented at the 38th Purdue Industrial Waste Conference (May 1983) [10]. 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 Microtox™ systems, Beckman Instruments, Inc.).

2.5 Wastewater Collection

2.5.1 Gravity and Pressure Systems. Primary considerations in collecting industrial wastes are waste segregation and material selection. All pipes, pumps, and appurtenances coming in contact with the wastewater shall be protected from damage that can be caused by solvents, corrosion, temperature, and pH characteristics of the wastes. Collection system modifications or pretreatment steps should be considered for industrial wastes with high solids or sludge content or for wastes which may react to produce solids and sludge deposits. Release and formation of toxic or explosive gases in the system shall be addressed in design. The following limitations on discharge to industrial waste sewers shall be observed.

2.5.1.1 Storm Water. Storm water shall not be carried in industrial waste sewers. Provide separate industrial and storm water collection systems.

2.5.1.2 Uncontaminated Wastes. Uncontaminated cooling waters and similar discharges from municipal and commercial establishments shall be segregated from polluted wastes and discharged to storm sewers or natural water courses. Check with local Engineering Field Division (EFD) to determine if a discharge permit is required for such uncontaminated waters.

2.5.1.3 Hazardous and Toxic Wastes. Wastes which 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 shall be excluded or pretreated. Refer to WPCF MOP No. 3, Regulation of Sewer Use [8].

2.5.2 Gravity Sewers. The design for gravity sewers is as follows.

2.5.2.1 Design Flows. Design sewers for peak flow, except design main interceptor to treatment facility for 125 percent of peak flow.

2.5.2.2 Flow Formula. Use the Manning formula (see WPCF FD-5, Gravity Sanitary Sewer Design and Construction [8]) 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.

2.5.2.3 Velocity Constraints. Design pipe slopes to insure a velocity of at least 2.5 feet per second (fps) when pipe is flowing full at peak flow. Velocity should not exceed 10 fps for any flow in design range. Velocities as low as 2.0 fps flowing full are permitted where appreciable cost benefits can be realized.

2.5.2.4 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.

2.5.2.5 Pipe Diameter. No sewers in the collection system (including laterals, interceptors, trunks, and mains) shall be less than 8 in. (203 mm) in diameter. All other building service connections shall be at least 6-in. (152 mm) diameter.

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

2.5.2.7 Layout. Do not lay trunk lines under buildings. Consider maintenance in the system layout.

2.5.2.8 Structures and Appurtenances. See Table 3 for applications and details of sewer structures.

2.5.2.9 Pipes. Guidelines for selection of sewer pipe material are given in Table 4. Requirements for pipe are given in NFGS-02722, Exterior Sanitary Sewer System [2], and in Tables 3 and 4.

2.5.2.10 Installation. Installation requirements are given in NFGS-02722 [2] or in Table 4.

a) Use WPCF MOP FD-5 [8] for criteria pertaining to trenching, foundations, laying, pipe cover, and loads.

b) For design criteria in cold regions, refer to Department of Army Corps of Engineers TM 5-852 Series on Arctic and Subarctic Construction [11].

TABLE 3
Sewer Structures

SOURCE	TYPE	TYPICAL WASTE QUANTITY	TYPICAL WASTE CONSTITUENTS AND CHARACTERISTICS	
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. — Max spacing ft 18 — 400 18-48 — 500 48 — 600	See NAVFAC NFGS-02722 [2]	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 exceed 2 ft.	See NAVFAC NFGS-02722 [2]	For difference less than 2 ft, increase upstream sewer slope to eleminate drop.
Siphons	Inverted	For carrying sewers under obstructions or waterways.	Manitain velocity of 3 fps. Use not less than two barrels with minimum pipe size of 6 in. Provide for convenient flushing and maintenance.	Use WPCF MOP FD-5, Gravity Sanitary Sewer Design and Construction [8], for hydraulic design.
Intercepting 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 interceptors	Grease and oil	On all outlets from subsistence buildings, garages, mechanical shop, wash pits, and other points where grease or oil can enter system.	Displacement velocity 0.05 fps. 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 4
Sewer Pipe Selection Guide

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.
Asbestos-cement (AC) (gravity)	Use for normal domestic sewage where stale or septic conditions are not anticipated. Do not use in corrosive soils. Lightweight and longer laying lengths are inherent advantages.
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.
Cast iron soil (building services only)	Use for building service connections carrying normal domestic sewage.

TABLE 4 (Continued)
Sewer Pipe Selection Guide

PIPE MATERIAL	REMARKS
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). 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 shall be suitable for sewage or waste being handled. Avoid cement lining for sludge and domestic sewage receiving less than secondary treatment.
Asbestos-cement (pressure)	Use for pressure force mains and inverted siphons that are not subjected to corrosive wastes or soil conditions.
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, see the following and their included references:

NAVFAC Guide Specification NFGS-02420 [2].
NAVFAC Guide Specification NFGS-02722 [2].
WPCF MOP FD-5 [8].

2. Requirements for pipe joints and guidance for selection of jointing material are given in NAVFAC Guide Specification NFGS-02722 [2].

c) Sewer lines located aboveground on structural supports in high wind areas shall be designed to withstand expected wind velocities, (refer to NAVFAC DM-2 Series, Structural Engineering [2]).

2.5.3 Pumping. Use pumping only where a gravity system cannot serve hydraulically or where cost analysis shows a significant savings. Incorporate the following criteria for industrial wastewater systems. Oily wastewater pumping is discussed in Section 3.

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

2.5.3.2 Capacity. Provide a total pumping capacity equal to the maximum expected flow with at least one of the largest pumps out of service. A minimum of two pumps shall be installed 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 type to use when pumping directly into a treatment plant.

2.5.3.3 Pumps. Submersible centrifugal pumps installed in a sump is 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.

2.5.3.4 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 injection of 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.

b) Provide cleanouts and air relief valves as required.

2.5.3.5 Dependability. Use two separate and independent power sources, with automatic switching equipment. Evaluate either two independent incoming powerlines or a standby engine-driven generator. Refer to EPA-430-99-74-001, Design Criteria for Mechanical, Electrical and Fluid System and Component Reliability [5], for additional details.

2.5.3.6 Wet Wells

a) 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 Equation (1) or (2).

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

Where: D = Pump capacity, gpm.
V = Wet well storage volume between high and low levels, gal.
Q = Inflow to wet well, gpm.
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: $$V = tD/4 \quad (2)$$

(2) Provide pump operating cycle of at least 6 min for pump units less than 50 hp. Check with motor manufacturer for recommended maximum number of cycles for motor specified.

b) 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.

c) 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.

SUBMERGENCE ft	ENTRANCE VELOCITY fps
1.0	2
1.5	3
2.0	4
2.6	5

d) Ventilation. Provide a 4-in. minimum diameter vent with return bend and stainless steel bird screen.

2.5.3.7 <u>Dry Wells</u>. For other than submersible pump stations.

a) Size. Keep dry wells to the minimum size consistent with safe and convenient operation and with allowance for possible expansion.

b) Type of Pump. Use vertical pumps to conserve space (unless special conditions dictate otherwise).

c) Sumps. Provide the following:

(1) Minimum 20 gpm capacity.

(2) Check valve in horizontal run.

d) Hoisting Facilities. Provide installed or portable hoisting facilities consistent with the size of the installation. Provide lifting eyes for a portable hoist.

e) Ventilation. Provide positive ventilation.

f) Provide potable water (if available) to dry well for general maintenance use.

2.5.3.8 Alarms. Provide both audible and visual alarms for wet well and pumps. Wet wells shall have both high and low level alarms; pumps shall be provided 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.

2.5.3.9 Maintenance Considerations. For all 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.

2.5.3.10 Equipment and Appurtenances. See MIL-HDBK-1005/8, Domestic Wastewater Control [2].

2.5.3.11 Cold Regions Design. For design criteria in cold regions, refer to Department of Army Corps of Engineers TM 5-852 Series on Arctic and Subarctic Construction [11].

2.5.4 Special Requirements for Pier and Wharf Systems. For collection systems pertaining specifically to piers and wharfs refer to MIL-HDBK-1005/8 [2].

2.5.5. Innovative Collection Systems. Vacuum sewers and pressure sewers are included in this category. Refer to MIL-HDBK-1005/8 [2] for discussion on applications of these innovative collection systems. A case by case determination of specific application to industrial and oily waste should be performed.

2.5.6. Aircraft and Vehicle Washracks, Maintenance, and Service Areas. Washrack, maintenance, and service areas require special attention as follows:

2.5.6.1 Housekeeping

a) Keep all outdoor maintenance surfaces clean by regular flushings 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 diverson chamber so that storm runoff flows into storm sewer system.

c) Carry out all washing and maintenance operations in designated areas (which shall be as compact as conveniently possible).

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

2.5.6.2 Appurtenances

a) 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 first increment of runoff during storms (see Figure 2). 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 (refer to NAVFAC DM-5.03, Drainage System [2]), taking care to ensure that velocities of dry weather flows are sufficient to prevent solids deposition. The gated outflow pipe shall be designed to pass dry weather flows. Pipe diameter shall not be less than 6 in. (152.3 mm).

b) 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 screw type agitated grit washer.

(1) Selection basis. Use manually cleaned units for applications where grit load is less than 1 ft^3/d (.0283 m^3) and use mechanically cleaned units for application where grit load is greater than 1 ft^3/d.

(2) Design basis. Provide at least two units sized to give 95 percent removal of P_{10} grit size at peak flow with all units in service. Limit variations in flow velocity to a narrow range and use high values of V/Vs (maximum 70). Refer to WPCF MOP No. 8, Wastewater Treatment Plant Design [8].

2.5.7 Paint Shops. The following special methods are applicable.

2.5.7.1 Paint Stripping. Paint stripping operations are the source of the most polluted and difficult to treat industrial wastes at Navy installations. Most Navy 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.

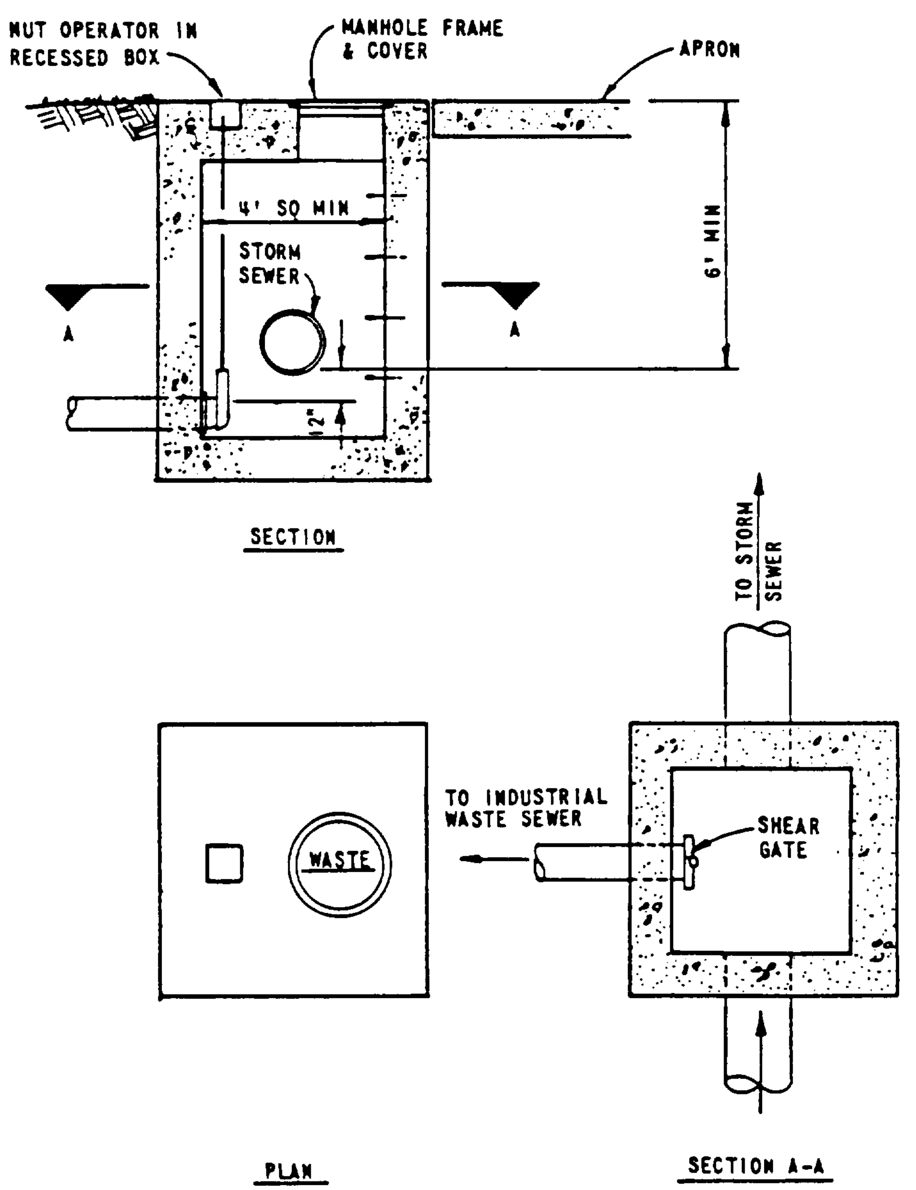


FIGURE 2
Wastewater Diversion Chamber

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 Extraction Procedure (EP) Toxicity Test (refer to the Federal Register, Vol 45, No. 98, p. 33122-7; May 19, 1980) [4].

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

2.5.7.2 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, flow shall be directed to the industrial sewer system, and care should be taken to ensure that paint solids and sludges are not discharged. Solids should be removed and disposed. Establish hazardous or nonhazardous waste nature by EP Toxicity Test. The use of paper or peeloff floor and wall coverings is recommended.

2.5.8 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. For wastewater collection and pretreatment recommendations, see NCEL TM M-54-78-06, Fleet Training Center Fire Fighting School [12] and NAVFAC DM-27 Series on Training Facilities [2].

2.5.9 Metal Plating Operations

2.5.9.1 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.

a) Cyanide-Bearing Wastes. Keep separate from acid wastes to avoid cyanide conversion to toxic hydrogen cyanide gas.

b) 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.

c) Mixed Chemicals. Keep acids and bases isolated and separate from chrome and cyanide wastes.

2.5.9.2 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 used at Navy facilities. Recycle 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. Contact NAVFAC Headquarters (Code 04BD) for operational performance of plating process modifications and advanced treatment systems prior to design.

2.5.10 Drydocking Facilities

2.5.10.1 Collection Systems. Refer to MIL-HDBK-1005/8 [2].

2.5.10.2 Wastewater Treatment. 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 agitation-type grit washer (Refer to para. 2.5.6.2). If flow and grit load are small, pump discharge may 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. NAVFAC headquarters (Code 04BD) shall be contacted regarding the control of organo-tin which may be present in drydock wastewaters.

2.6 Wastewater Treatment

2.6.1 General Design Considerations. Refer to MIL-HDBK-1005/8 [2] for guidance on many design considerations which are applicable to both domestic and industrial wastewater collection and treatment.

2.6.1.1 Effluent Limits. Follow NPDES permit requirements for industrial wastes which are treated at a NOTW (refer to para. 2.5.2). For industrial wastes which discharge to a POTW, obtain the necessary sewer use ordinance from the municipality. Sewer use ordinances will define industrial wastewaters which must be restricted from entering the system and define the necessary levels of various constituents prior to entry into the system (refer to para. 2.2).

2.6.1.2 Treatment Versus Pretreatment. Where possible, it is preferable to provide pretreatment and discharge to a POTW, rather than providing separate treatment of wastes from Navy facilities and then discharging into a waterbody. 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 waterbody should be analyzed as a part of the Preliminary Engineering Studies required in NAVFACINST 4862.5C [2].

2.6.1.3 Receiving Water. Present policy is 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.

2.6.1.4 Sanitary Sewer. Avoid discharging industrial waste materials which may damage the wastewater collection and treatment facilities and/or cause potential personnel safety problems (refer to para. 2.4.5 and WPCF MOP No. 3), Regulation of Sewer Use [8].

2.6.1.5 Batch Versus Continuous Treatment. Batch treatment is preferable to continuous treatment of most industrial wastes from Navy installations. 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.

2.6.1.6 Disposal of Sludges

a) Process Selection. Sludge handling and disposal operations must be evaluated concurrently with wastewater treatment evaluations. Costs for sludge disposal may dictate process selection for the wastewater treatment system. Refer to MIL-HDBK-1005/8 [2] for guidance on sludge processing operations. 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 EP Toxicity Tests 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 effect the results of the EP Toxicity Test and the declaration of the sludge as a hazardous or nonhazardous material. Refer to Hazardous Waste Management Systems: Identification and Listing of Hazardous Wastes, Federal Register, Vol. 45, No. 98, p. 33122-7 (May 19, 1980) [4] 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 Federal Register Vol. 45, No. 98, p. 33084-133 (May 19, 1980) [4].

b) Disposal Requirements. State and Federal regulatory agencies shall be contacted 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 para. 2.6.1.6 for application of EP Toxicity Test to sludge generation and disposal requirements.

c) 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 for the Navy. The waste generator is responsible for ultimate disposal under the Resource Conservation and Recovery Act (RCRA). Transportation of hazardous wastes is strictly regulated by 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 (includes 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.

Consult NAVFAC Code 112 for guidance on hauling and disposal of hazardous materials.

d) 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. See EPA Process Design Manual, Sludge Treatment and Disposal [5] for design considerations.

e) 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). Table 5 provides maximum limits for heavy metals where crops are to be grown on the land receiving the sludge (refer to EPA 430/9-80-001, Evaluation of Sludge Management Systems [5]). Contact regulatory agencies for local requirements and for maximum allowable loads to dedicated land disposal sites.

TABLE 5
Total Amount of Sludge Metals Allowed on Agricultural Land

METAL	SOIL CATION EXCHANGE CAPACITY milliquivalents/100 grams		
	0-5	5-10	>15
	MAXIMUM METAL LOAD (lb/acre)		
Lead	500	1,000	2,000
Zinc	250	500	1,000
Copper	125	250	500
Nickel	50	100	200
Cadmium	5	10	20

Reference: EPA 430/9-80-001, Evaluation of Sludge Management Systems [5].

(1) Values in Table 5 are the total amounts of metals which can be added to soils. For metal contaminated sludges, one of the loading criteria may be met with a single application, whereas multiple applications may be required for a domestic waste sludge.

(2) When values are reached, application must be stopped.

(3) Maintain soil pH $\geq$6.5 at all times to minimize metal mobility.

f) 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.

2.6.1.7 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 utilized. 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 [5].

2.6.2 Reuse/Recycle

2.6.2.1 Cooling Water Recycle. As a part of the Preliminary Engineering Studies required by NAVFACINST 4862.5C, [2] the equipment and processes which utilize water for indirect (noncontaminating) cooling should be identified. 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.

2.6.2.2 Reclamation. There are a number of processes and equipment, most of them proprietary, which 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. NAVFAC headquarters (Code 04BD) should be advised prior to proposed use of any reclamation system.

a) Demineralization. The four methods available for demineralization of wastewaters are ion exchange, 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 (see NCEL Sanitary Waste Disposal for Navy Camps in Polar Regions) [12].

b) 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.

c) Ion Exchange. Ion exchange can be applied in a recovery manner to rinse water containing chromium wastes. Mixed wastes of chromium and cyanide can be treated first by a cation exchanger to remove metal, to aid in the decomposition of complex metal cyanides, and to generate hydrogen cyanides. It is then treated by an anion exchanger to remove the liberated cyanide. The concentrated solution formed by regenerating the exchange resins can be a source of recovered product which can be reused in the plating operation.

d) Metallic Replacement. Silver or copper recovery can be achieved by using the replacement process where a metal which is more chemically active than the metal to be recovered is placed into the waste solution. The more active metal goes into solution, 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, a relatively clean water is not recovered in this method.

e) Electrodeposition. Electrolytic recovery can be used, like metallic replacement, to recover valuable metals such as silver or copper. When a direct electrical current of the proper density is passed through the wastewater solution, the metal in solution plates out in a pure form on the cathode.

f) Operating Requirements. Most reclamation systems require sophisticated equipment; thus, the ability of the operating personnel and the manner in which the Navy operates a specific facility may limit the use of some recycle processes.

2.6.3 Hazardous and Toxic Substances. Special handling, treatment, and disposal procedures are required for hazardous and toxic substances that may be encountered at Naval facilities. Refer to MIL-HDBK 1005/13, Hazardous Waste Storage and Transfer Facilities [2], and to the hazardous waste management plan of the facility. Consult NAVFAC Code 112, Environmental Quality Division, for guidance on hauling and disposal of hazardous materials.

2.6.4 Pretreatment Process Selection. Wastewater from Navy 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 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 Table 2 for threshold limits of heavy metals.

2.6.5 Physical-Chemical Treatment Process Selection. Most industrial wastes from Navy facilities which are collected separately will require physical-chemical treatment (refer to MIL-HDBK-1005/8 [2] for biological treatment alternatives which may be considered for certain organic containing industrial wastes following bench or pilot testing). The physical-chemical treatment processes which should be evaluated are summarized in Table 7.

TABLE 6
Process Selection Guide for
Pretreatment of Industrial Wastewater

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 2 mg/L (see Table 45). Confirm treatability at NOTW with bench testing or pilot plant. For discharge to a POTW, check local sewer ordinance and pretreatment limits and satisfy more strict criteria. Eliminate at source, if possible.
Removal of heavy metals	Chemical precipitation (hydroxide or sulfide).	Use prior to biological treatment (at NOTW) if total heavy metals concentration exceeds continuous loading values in Table 45. 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 and pretreatment requirements and satisfy more strict criteria.
	Ion exchange	Use where recovery of metals desired. Not recommended as a pretreatment process for metal removal without recovery.
Removal of cyanide (CN^-)	Chemical oxidation	Use prior to biological treatment (at Navy facility) if cyanide concentration at plant influent exceeds 1 mg/L as continuous load (see Table 45). For discharge to POTW, and satisfy more strict criteria. 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 not available, or 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. Refer to Section 4.
Removal of free oil	Gravity separation Hydrocyclone separation.	Need depends on pretreatment criteria. Refer to Section 4.
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 7
Physical-Chemical Treatment of Industrial Wastes

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 Cl_2/lb.	Two stages: (1) Oxidation of cyanide to cyanate (CNO). (2) Complete oxidation of cyanate to nitrogen gas (N_2).	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: 1st stage (CN -> CNO): ORP: 350 to 400 mV. pH: 10 to 11.5. 2nd stage (CNO -> N_2): 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 Cl_2 demand.
	Hydrogen peroxide (H_2O_2) oxidation	Hydrogen peroxide, trace catalyst metal (such as copper) and sodium hydroxide. Theoretical dosage = 1.3 lb H_2O_2/lb.	Two stages: (1) Oxidation of CN to CNO. (2) Hydrolysis of CNO to carbon dioxide (CO_2) and ammonia (NH_3).	Mixing and reaction tank. See remarks.	pH: 8.5 to 10.0	Bench testing required to determine H_2O_2 and catalyst dosage and reaction time since oxidation of other waste components exerts H_2O_2 demand.
	Electrolytic oxidation	Exhaust ventilation equipment, heating and mixing equipment.	Destruction of cyanide by electric current.	Tankage depends upon waste volume to current ratio, and initial concentration of CN.	T = 200° F. Anode current density from 30 to 80 amp/ft^2. 2.5 to 3.5 kWh/lb CN.	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 Cl_2/lb.	Complete oxidation possible.	Provide at least 4-h detention. Equip each tank with propeller agitator to provide at least one turn-over per minute.	Use electronic recorder-controller to maintain optimum conditions: ORP: 250 to 300 mV. pH: 7 to 10. T = 45° F.	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.
	Hydrogen peroxide (H_2O_2) oxidation[1] Potassium per-manganate ($KMnO_4$) 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 recorders-controllers to maintain optimum conditions of pH3 to 4.	Bench 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^{+3}, Cr^{+6})	Acid sulfonation followed by precipitation	Sulfur dioxide, sodium meta-bisulfite 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 reaction tank. Provide 1- to 3-h detention. 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 ratio to phenol level. Use electronic recorders-controllers to maintain pH at 9.0 to 9.5. Use electronic recorders-controllers 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.

TABLE 7 (Continued)
Physical-Chemical Treatment of Industrial Wastes

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 onbench 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.
Removal of heavy metals	Precipitation: hydroxide or sulfide	Select chemical based on flow rate, treatability, effluent limits, and sludge production rate and dewaterability. 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 as determined by experiment.	Ion exchange may be used to concentrate waste stream prior to treatment. Settling required to capture metal precipitate sludge. Filters required for low effluent metal limits.
Recovery of metals for reuse	Evaporation	For acid solutions, recover in still 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 phosphorus	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.	See EPA Process Design Manual, Phosphorous Removal [5]. 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.
Removal of emulsified oil. Emulsion breaking	Coagulation followed by flotation. Acidification prior to coagulation may be required.	Refer to para. 2.5.4 and Section 4		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 in effectiveness. Determine emulsion breaking chemical types and dosages by bench or pilot scale tests.
Removal of soluble, refractory organics.	Granular-activated carbon	See Table 9	Adsorption. Conduct bench or pilot scale experiments to define adsorption characteristics and carbon adsorption capacity.	Contactor tanks (see Table 9)	Refer to EPA Process Design Manual, Carbon Adsorption [5].	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	Dependent 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.

[1]Where possible, biochemical oxidation of phenols is preferable to chemical oxidation.

Guidance for chemical selection and feeding requirements is presented in Section 4. The following paragraphs discuss the basic physical-chemical treatment processes used for treatment of industrial wastes from Navy facilities.

2.6.5.1 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.

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

b) Waste Types and Characteristics. Neutralization reactions may occur between a strong acid or base and strong base or acid, respectively, or between a strong acid or base and a weak base or acid, respectively. The amounts of neutralizing chemical required must be determined by laboratory testing and preparation of titration curves.

c) 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.

d) 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/ft^2 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 pH to desired effluent level. Use staged operation for batch treatment to complete neutralization in at least two steps. Use smaller pH increments (1-2 units) for strong wastes.

e) Process Control. Use self-cleaning pH probes and control systems that allow feed forward, feed back, proportional, and manual control options.

2.6.5.2 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 as metal hydroxides, metal sulfides, and metal carbonates.

a) 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 on Figure 3. Solubility of metal carbonates is not shown since it is dependent on wastewater alkalinity. All listed metal sulfides are less soluble than the metal hydroxide at the same pH.

b) 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.

c) Mixed 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 3 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.

d) Sludge Production. Determine volume, mass, settleability, and dewaterability of sludges produced during treatability study. Determine EP toxicity for alternative chemical precipitants (selection of lime versus caustic soda can affect the results of the EP Toxicity Test).

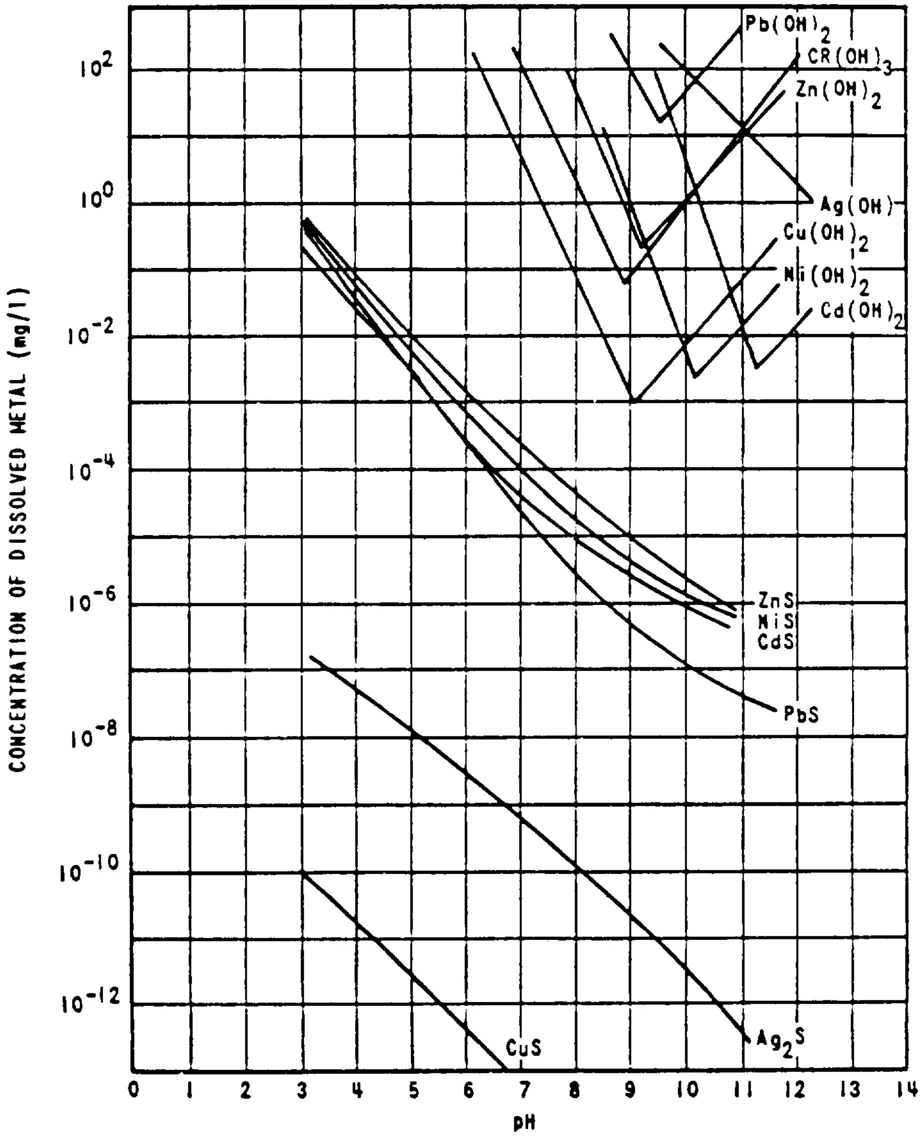


FIGURE 3
Solubility of Metal Hydroxides and Sulfides
as a Function of pH

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

f) 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 h. If greater tankage volume is required to accommodate duration of wastewater flow, consider off-line storage of excess wastewater rather than continuous flow treatment.

(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.

(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 posttreatment aeration to oxidize excess sulfide to sulfate. Alternatively, use ferrous sulfide (FeS) slurry as the sulfide source to eliminate formation of hydrogen sulfide gas.

(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.

(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.

(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 sand drying beds.

g) Process Control. Process pH control is absolutely essential for favorable performance. Use self-cleaning pH probes and 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 effected by metal chelates and metal complexes.

h) Process Performance. Hydroxide and sulfide precipitation are highly reliable if proper monitoring and control are maintained. Estimated achievable maximum 30-d average concentrations of several heavy metals under different chemical precipitation processes are shown in Table 8.

2.6.5.3 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 addition of oxidizing agents, such as chlorine, permangante 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.

TABLE 8
Estimated Maximum 30-Day Average for Lime and Sulfide Precipitation[1]

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	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 [5].

a) Oxidizing Agents. Use chlorine gas or liquid, or solutions of hypochlorite salts, ozone, potassium permanganate, oxygen (by aeration), or hydrogen peroxide. Refer to Table 7 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 by-products.

b) 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.

(1) Chlorine oxidation. Use chlorine gas or liquid (depending on dosage rate) with caustic or hypochlorite solution only for oxidation of cyanide (see Table 7 for operational conditions).

(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 which may be required for heavy metal removal, avoid incomplete oxidation of phenols if treatment is followed by granular-activated carbon

(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 h.

(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.

c) Process Control. Use electronic recorder-controllers with self-cleaning probes for pH and ORP.

2.6.5.4 Activated Carbon. Table 9 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.

Table 9
Granular Carbon Adsorption Treatment Applications

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 treatment 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 with one unit being back-washed and one unit out of service.	3 to 8 gpm/ft^2 with one unit being back-washed and one unit out of service
Contact time	30 to 50 min	15 to 40 min
Backwash rate	20 to 30 gpm/ft^2	10 to 15 gpm/ft^2
Surface wash	Recommended	Recommended.
Recommended bed expansion	40%	40%
Carbon bed depth	15 to 30 ft	10 to 20 ft
Flow configuration	Fixed beds in series or parallel, moving beds, and expanded upflow beds.	Fixed beds in series or parallel, moving beds, and expanded upflowbeds.
Carbon requirements	Determine by experiment (range = 300 to 1,000 lb/Mgd).	Determine by experiment (range = 250 to 5001b/Mgd.)
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 lb carbon regenerated	10%	10%
Furnace operating temperature	1,650 to 1,800° F	1,650 to 1,800°
Air pollution control equipment	Flue gas quench and scrubber system.	Flue gas quench and scrubber system.
Activated 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 regeration 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 [13].

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.

2.6.5.5 Other Treatment Processes and Operations. Other treatment processes that are applied to industrial wastes are sedimentation, coagulation, and flotation. Sedimentation and coagulation are discussed in MIL-HDBK-1005/8 [2]. Flotation for oily waste treatment is discussed in Section 3.

2.6.6 Naval Aircraft Rework Facility

2.6.6.1 Operations. Typical operations at Naval aircraft rework facilities (NARFs) include metal surface cleaning, metal fabricating, metal finishing, metal plating, and aircraft paint stripping and spraying.

2.6.6.2 Wastewater Characteristics. The wastewater generated from these operations contains numerous constituents including chromium, cyanide phenol oil, and various heavy metals.

2.6.6.3 Treatment System. Preliminary Engineering Studies should be conducted in accordance with NAVFACINST 4862.5C [2] to establish the appropriate treatment processes to be applied to wastewater sources at NARF installations. Refer to paras 2.1 and 2.2 for treatability study requirements. Figure 4 shows a system schematic for treatment or pretreatment of NARF 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 schematic.

They 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 on Figure 5. Treatment process schematics and control logic for batch and continuous flow metal precipitation are shown on Figure 6.

Concentrated oily wastewaters and wastewaters containing solvents and degreasers should be handled separately (refer to Section 3). Low levels of oil and grease can be accommodated by the systems shown in Figure 4.

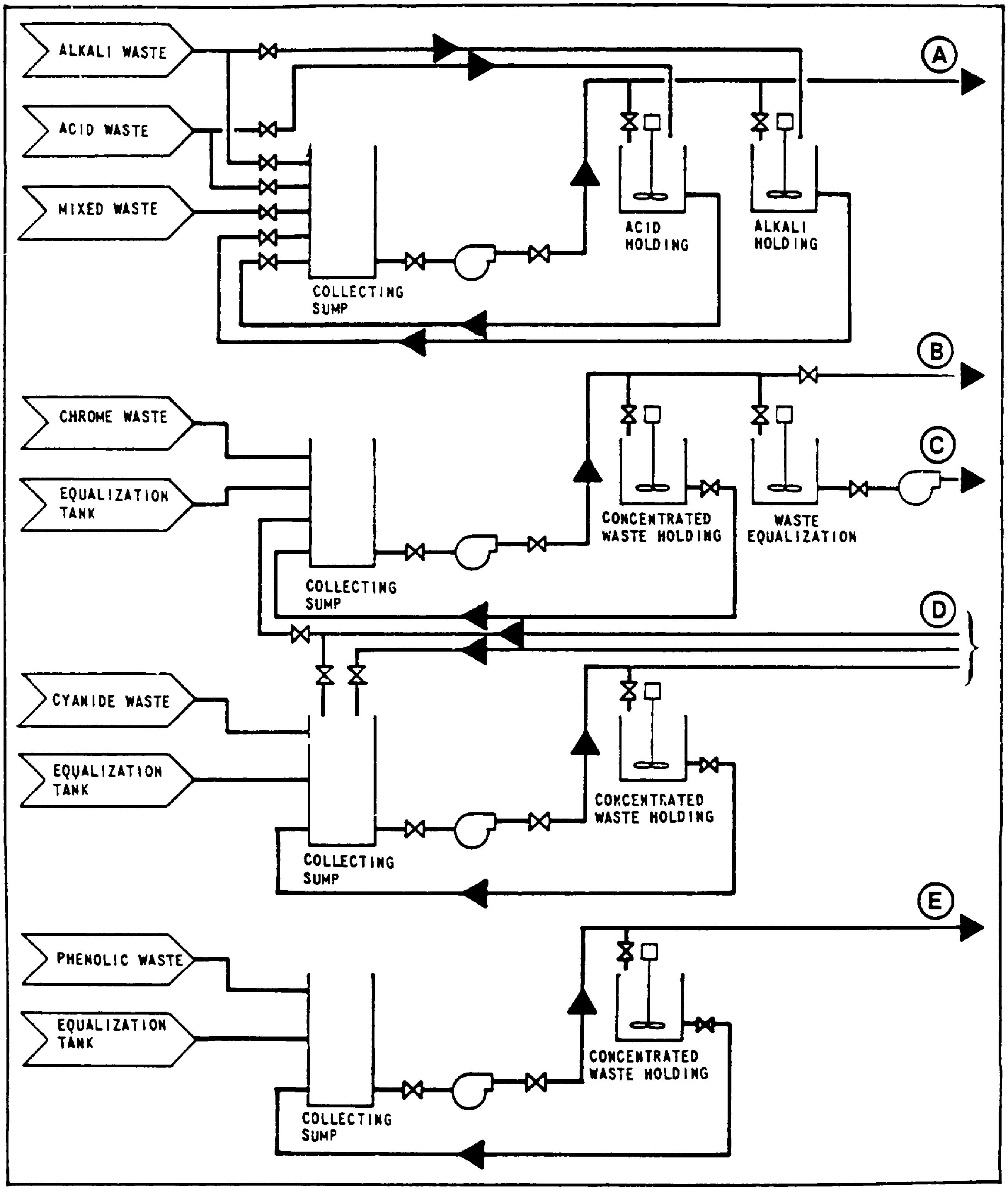


FIGURE 4A
NARF Wastewater Treatment Flow Schematic

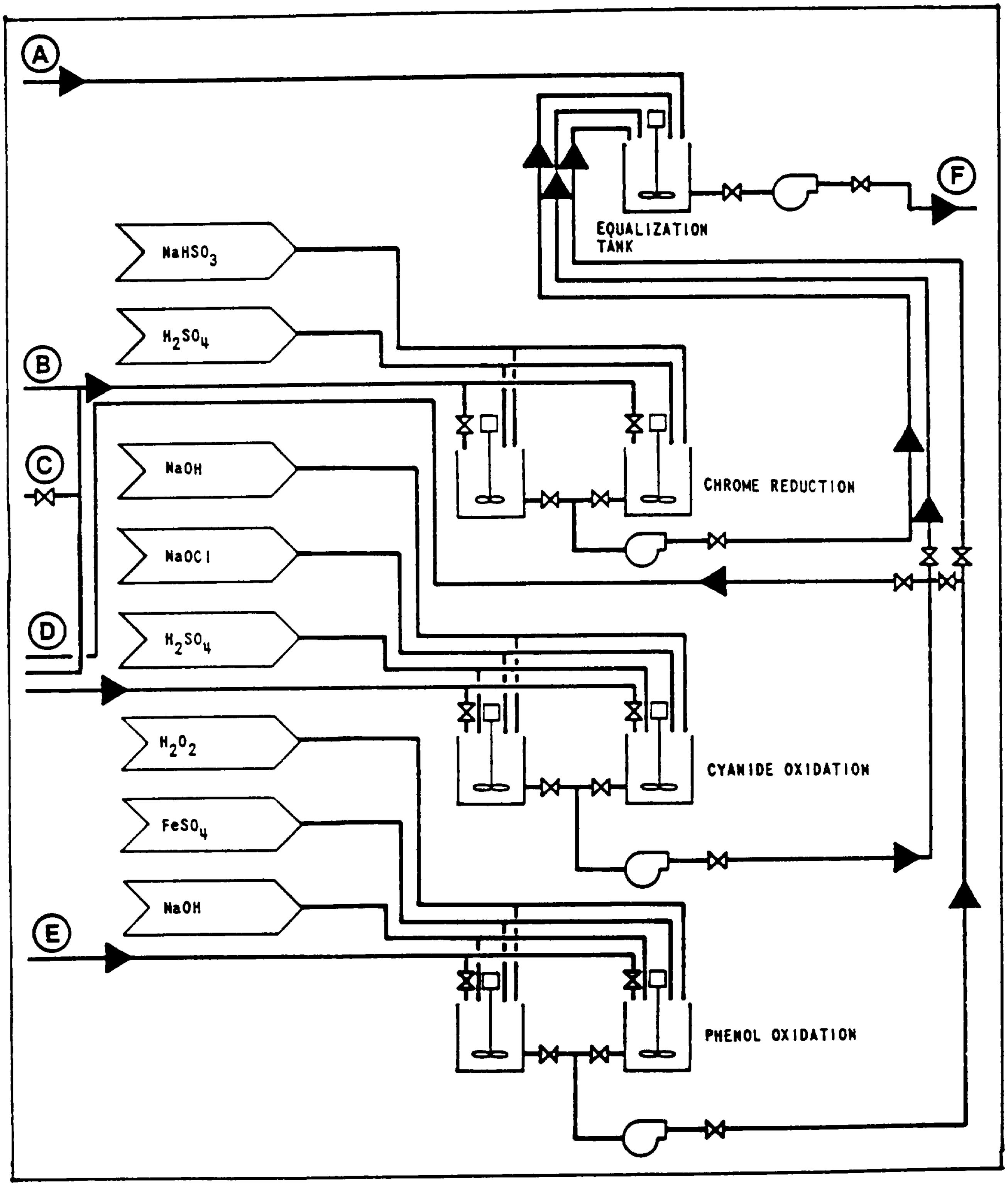


FIGURE 4B
NARF Wastewater Treatment Flow Schematic

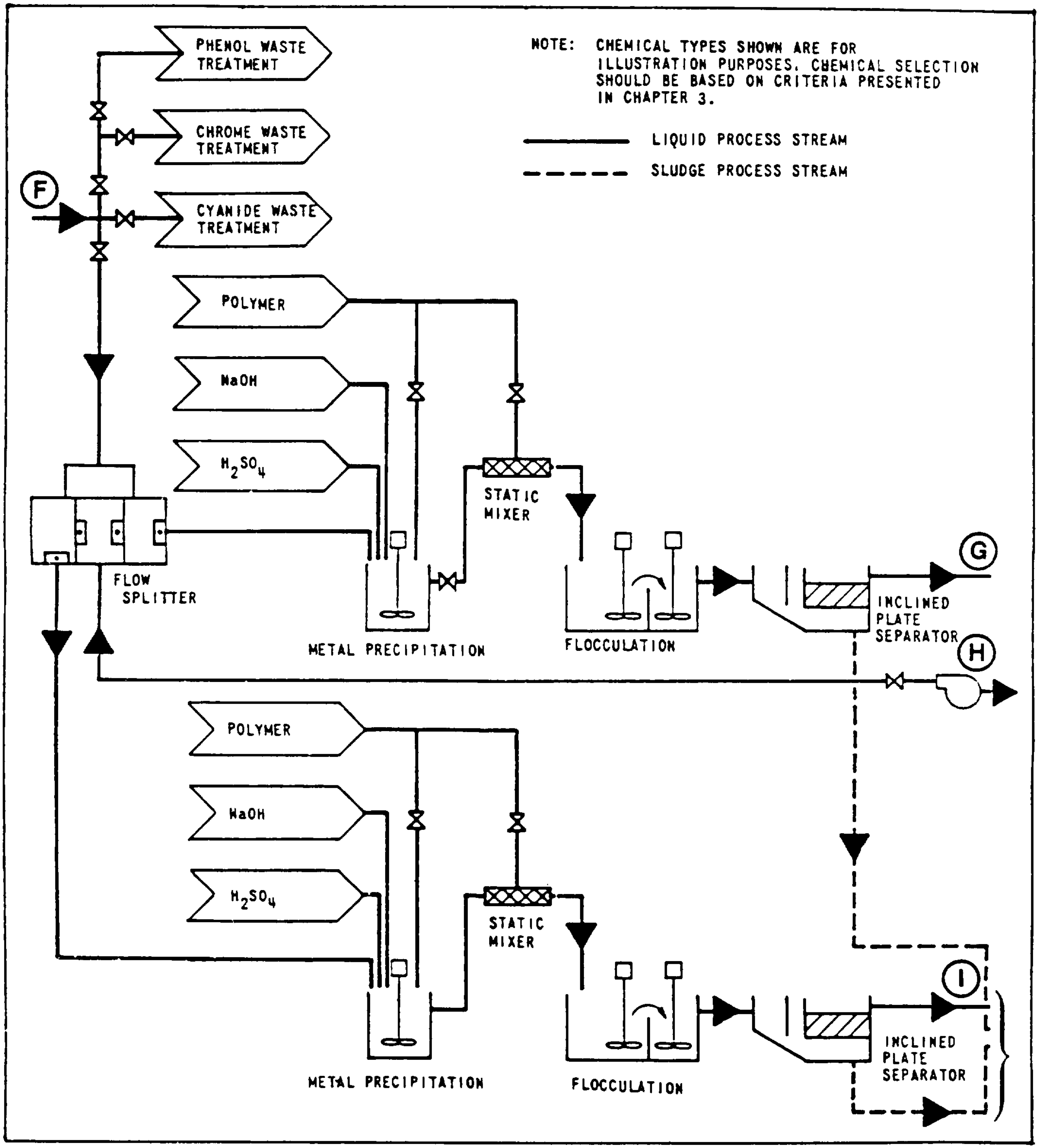


FIGURE 4C
NARF Wastewater Treatment Flow Schematic

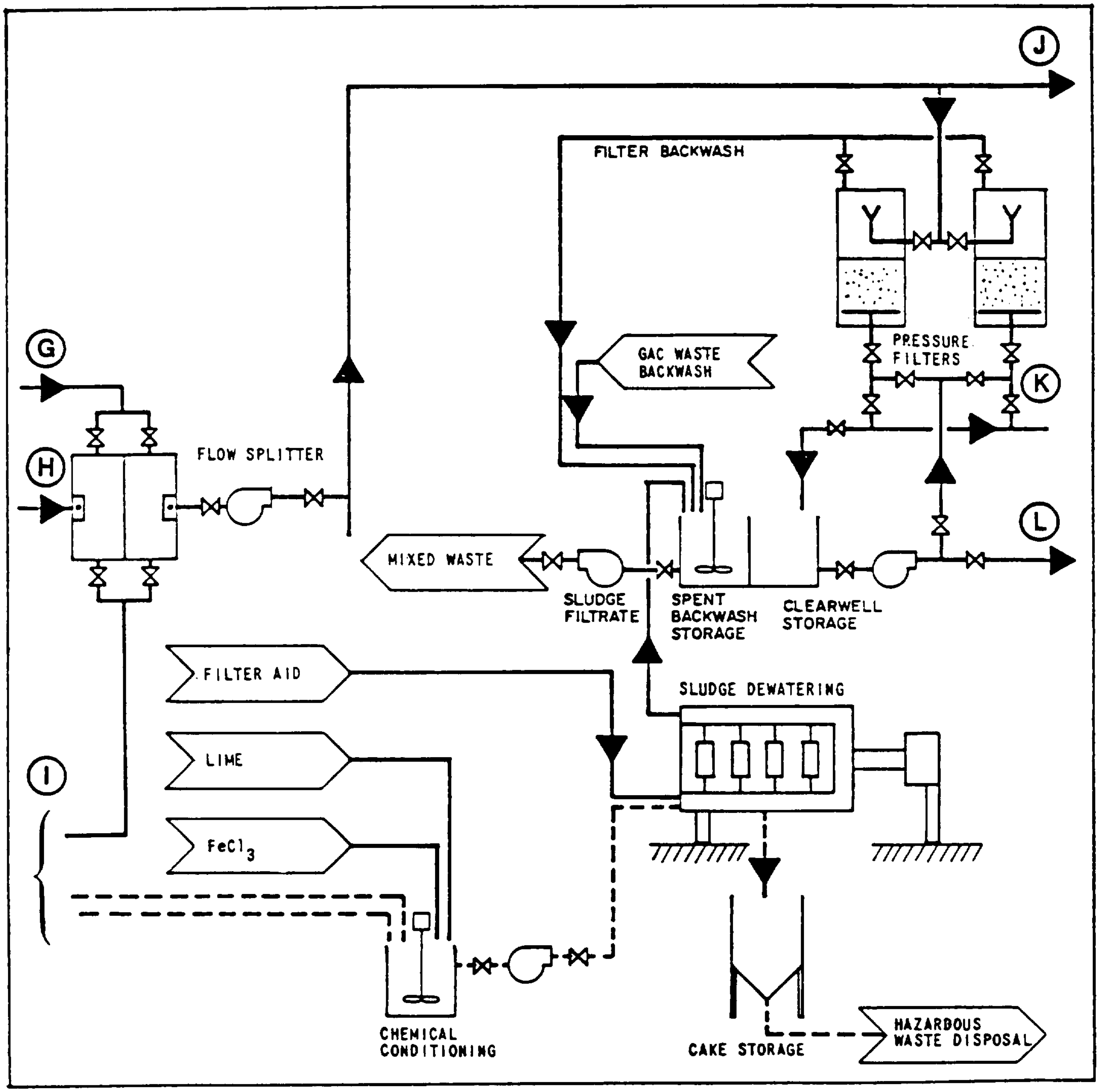


FIGURE 4D
NARF Wastewater Treatment Flow Schematic

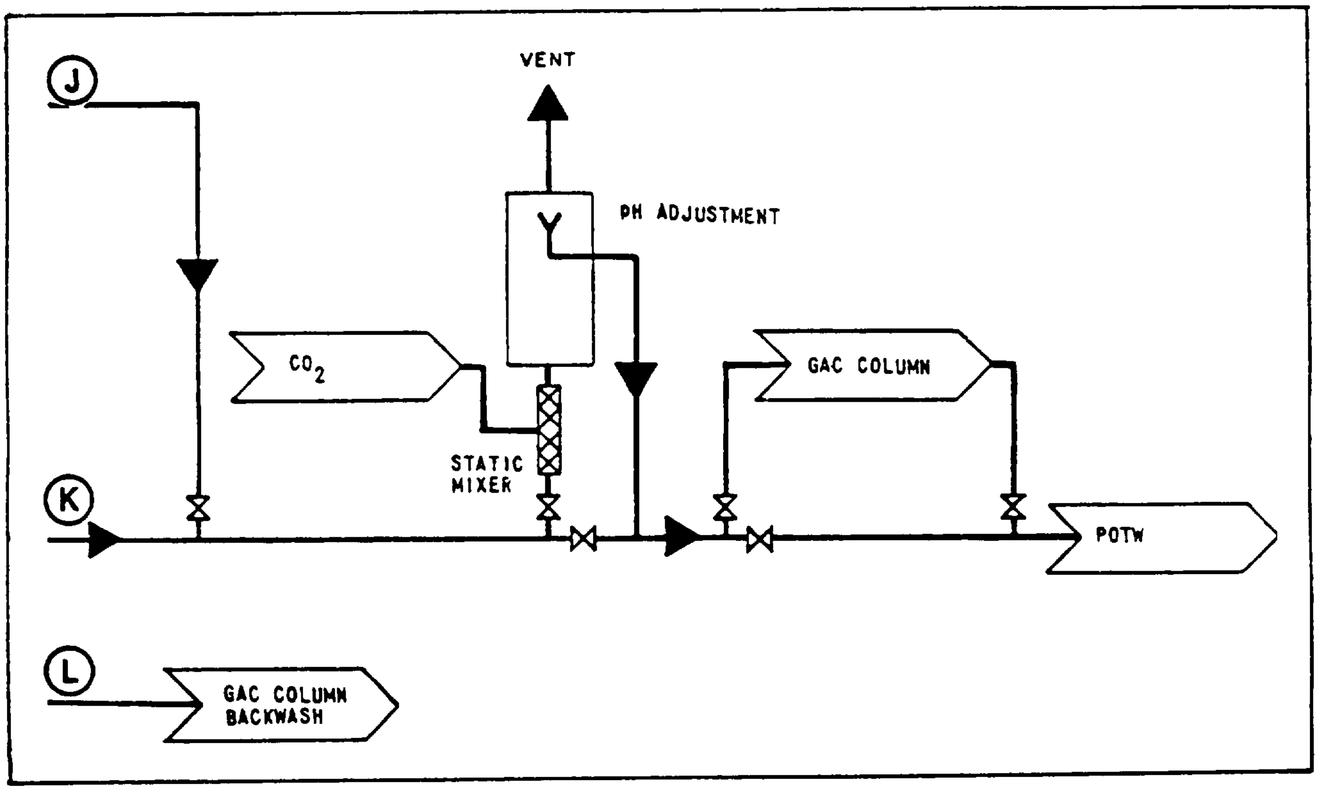


FIGURE 4E
NARF Wastewater Treatment Flow Schematic

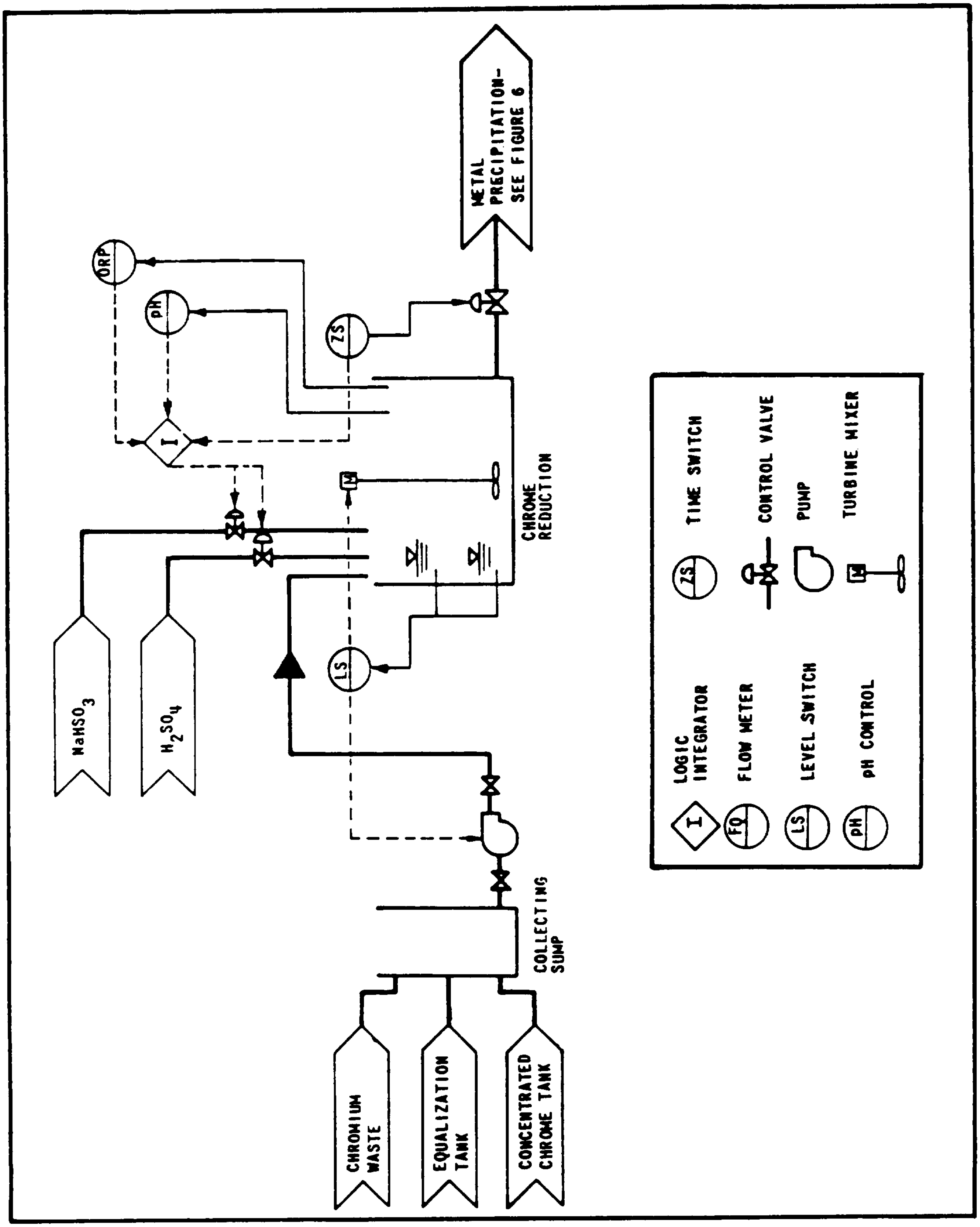


FIGURE 5A
Process Schematics for Chrome Reduction,
Cyanide Oxidation, and Phenol Oxidation

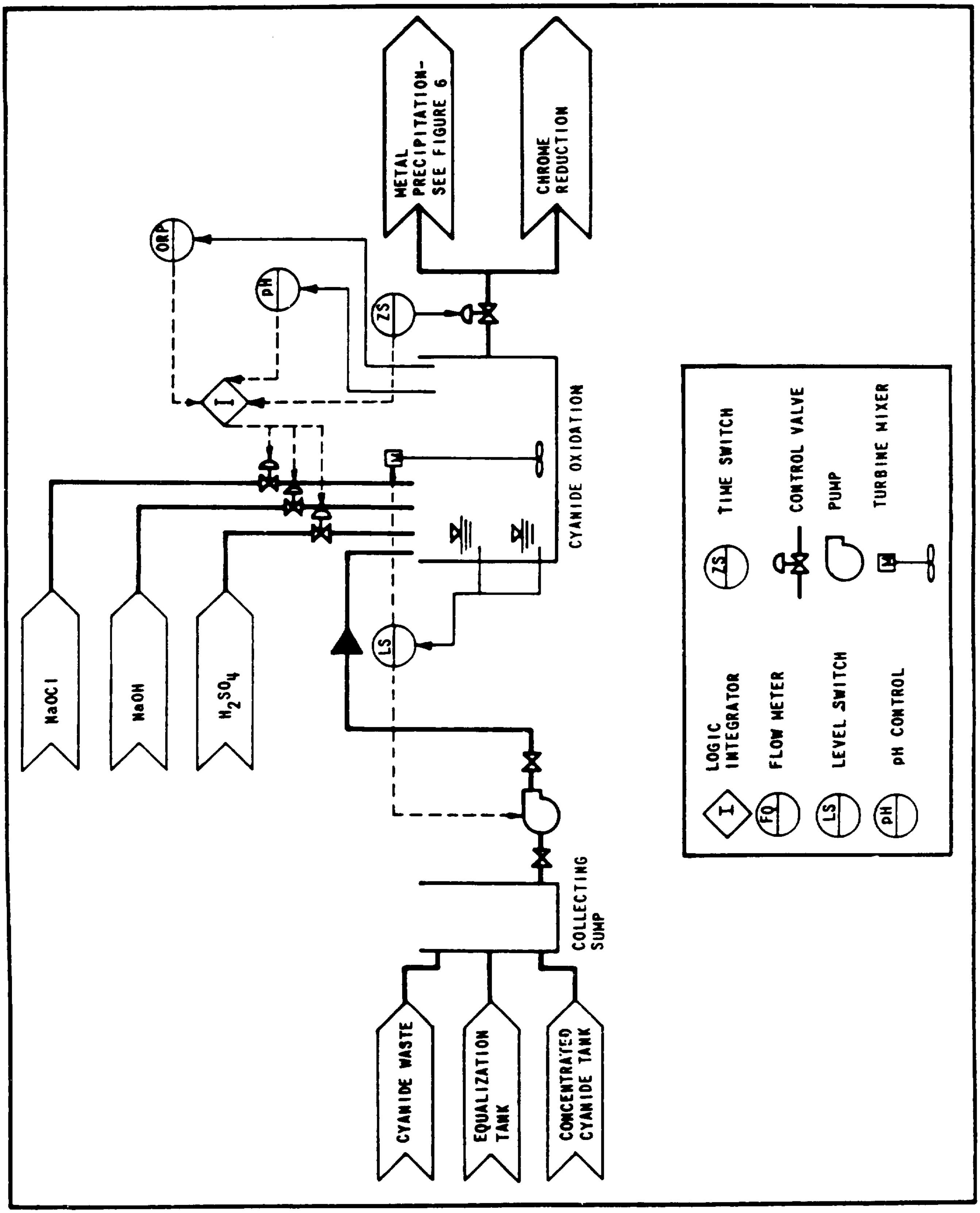


FIGURE 5B
Process Schematics for Chrome Reduction,
Cyanide Oxidation, and Phenol Oxidation

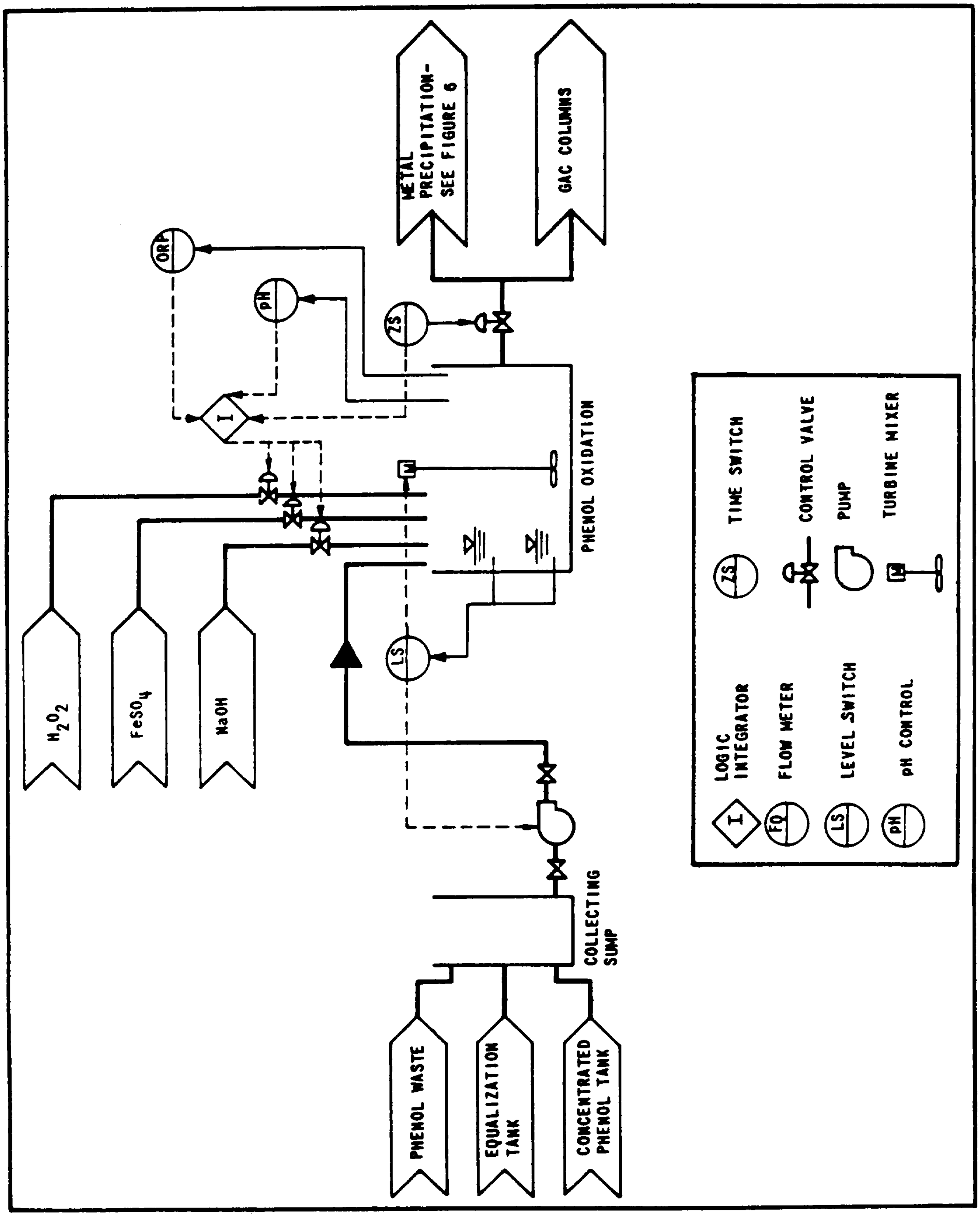


FIGURE 5C
Process Schematics for Chrome Reduction,
Cyanide Oxidation, and Phenol Oxidation

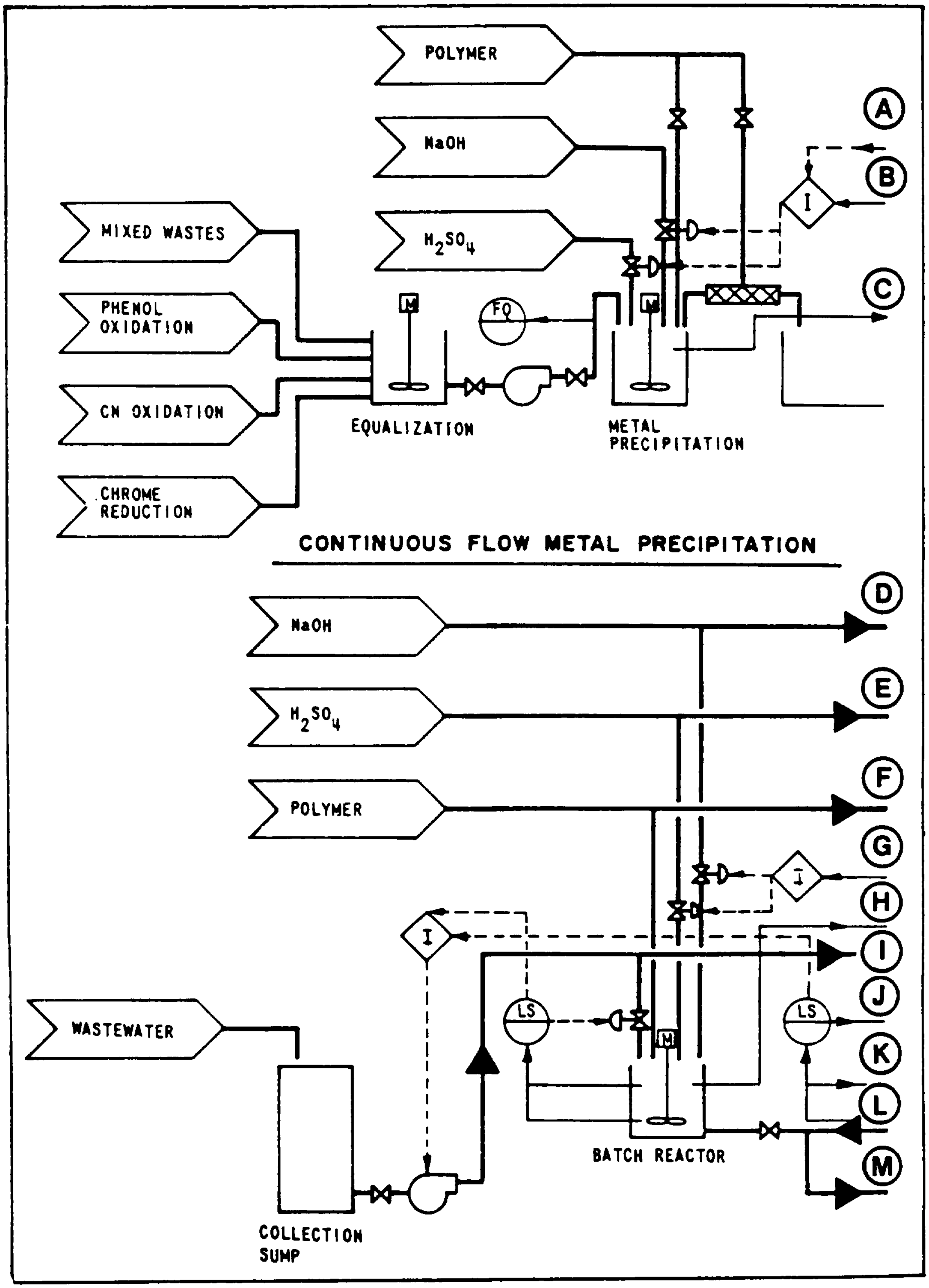


FIGURE 6A
Process Schematic for Batch and Continuous
Flow Metal Precipitation

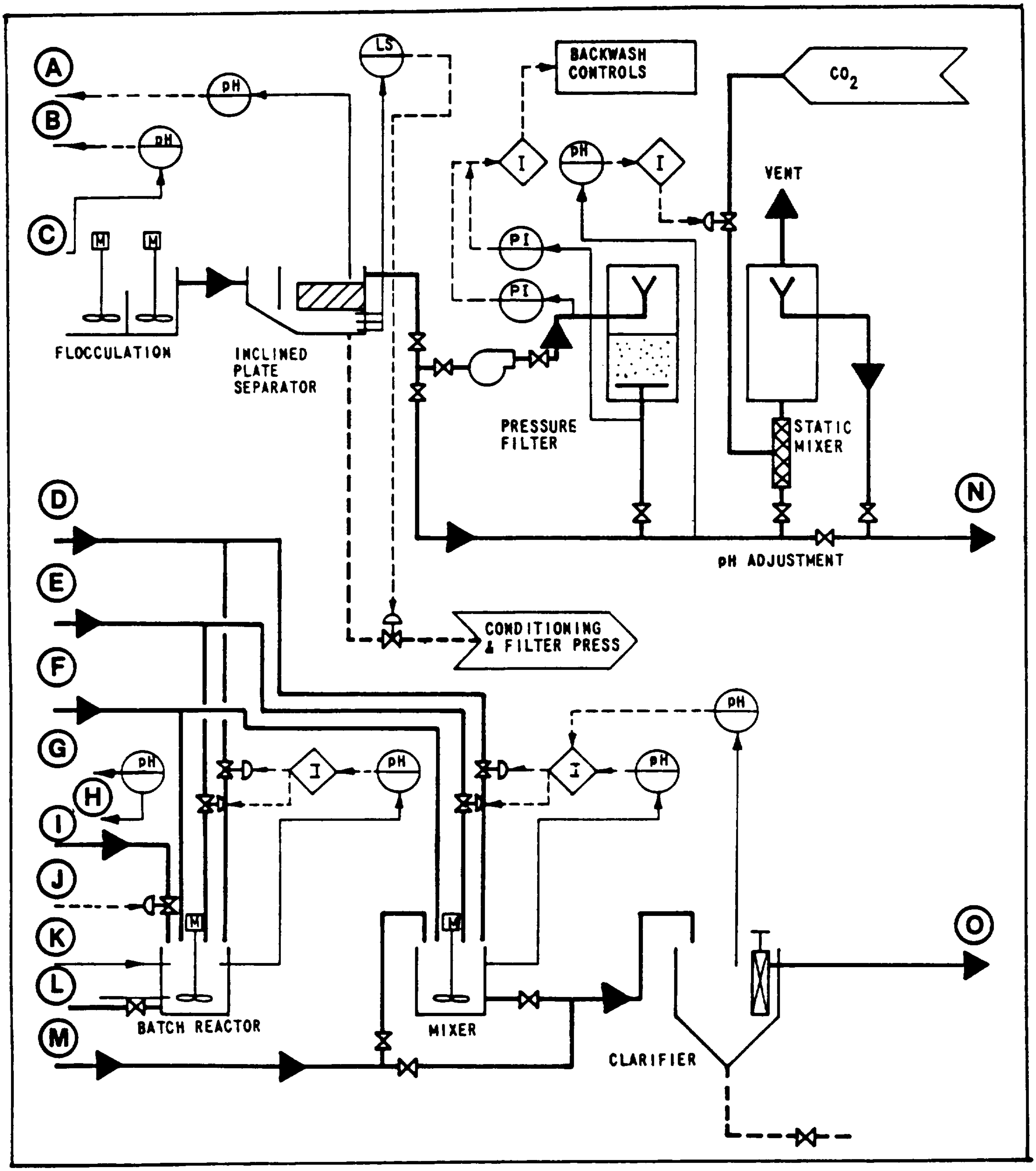


FIGURE 6B
Process Schematic for Batch and Continuous
Flow Metal Precipitation

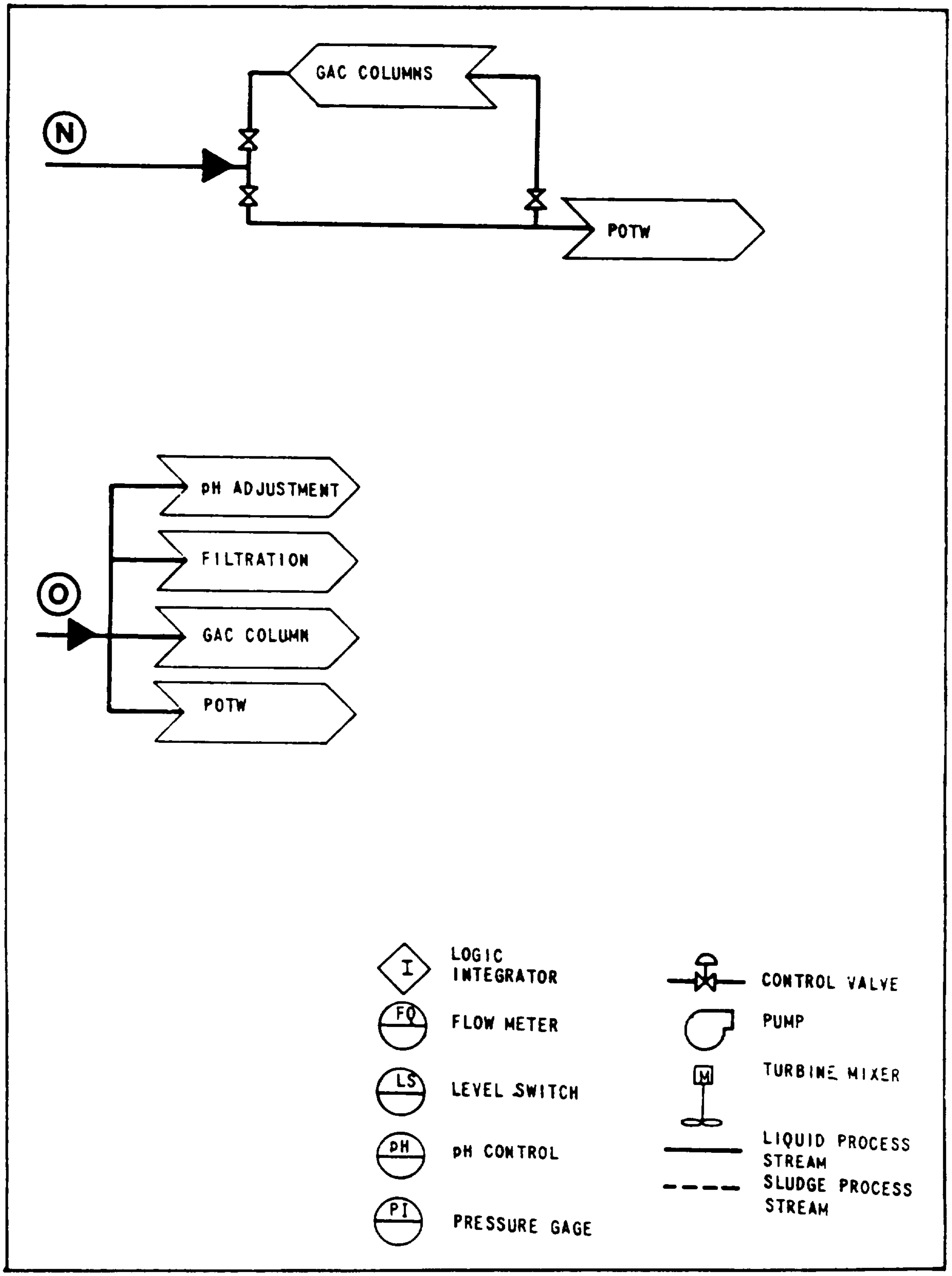


FIGURE 6C
Process Schematic for Batch and Continuous Flow Metal Precipitation

2.6.7 Naval Air Station

2.6.7.1 Operations. Operations generating industrial wastes at a typical air station include washracks and service maintenance areas. Other operations can include those found at NARF installations (refer to para. 2.6.6).

2.6.7.2 Wastewater Characteristics. Wastes from washracks and maintenance and service aprons will predominantly consist of oils and solids.

2.6.7.3 Treatment System. Preliminary Engineering Studies should be conducted in accordance with NAVFACINST 4862.5C [2] to determine the appropriate treatment facilities. Treatment will usually consist of a collection sump with a diversion structure for bypassing stormwater 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. Refer to Section 3 for additional information on oily waste treatment.

2.6.8 Naval Shipyard

2.6.8.1 Operations. Operations at Naval shipyards which generate industrial waste can be extensive and depend on the size of the yard. Wastes include metal working and plating, maintenance, paint spraying and stripping, and miscellaneous shop work.

2.6.8.2 Waste Characteristics. The predominant wastes are oils and heavy metals. Phenols will be present in wastewater from paint stripping operations.

2.6.8.3 Treatment System. For oily waste collection and treatment, refer to Section 3. Wastewater from plating, paint stripping, paint spraying, maintenance, pipe shop, and other miscellaneous sources should be segregated at the source into waste streams indicated for NARF installations in Figure 4. Collection of all such streams is recommended with treatment as shown in Figure 4. Wastes from drydock operation should be introduced to this treatment scheme after grit removal.

2.6.9 Paint Spray and Stripping Shop

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

2.6.9.2 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 sand drying beds if proper climatic conditions exist. This reduces the cost of ultimate sludge disposal.

2.6.9.3 Treatment System. The wastewater can be pretreated onsite for phenol removal using the peroxide oxidation scheme shown on Figure 5. 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 truck hauled 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. All treatment should be conducted at a central facility.

2.6.10 Miscellaneous Shops

2.6.10.1 Operation. Naval installations include a variety of miscellaneous operations. These include machining, parts cleaning and overhaul, boiler operations, and vehicle and engine repair.

2.6.10.2 Waste Characteristics. Typically, the waste 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).

2.6.10.3 Treatment System. Most waste from miscellaneous shop operations can be handled in conjunction with other wastes previously described in paras. 2.6.6 through 2.6.9. 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.

2.6.11 Facilities Layout. Layout and plot size of new and upgraded industrial waste treatment facilities are 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 all 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 on Figure 7. This layout is coordinated with the treatment schematic for NARF shop wastewaters (Figure 4). It includes phenol and cyanide oxidation, chrome reduction, metals precipitation, and mixed waste treatment and sludge dewatering.

2.6.12 Color Coding of Piping Systems. The color code for identification of piping systems shall comply with the American National Standards Institute ANSI A13.1-1982, Scheme for the Identification of Piping Systems [14] 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. The following general

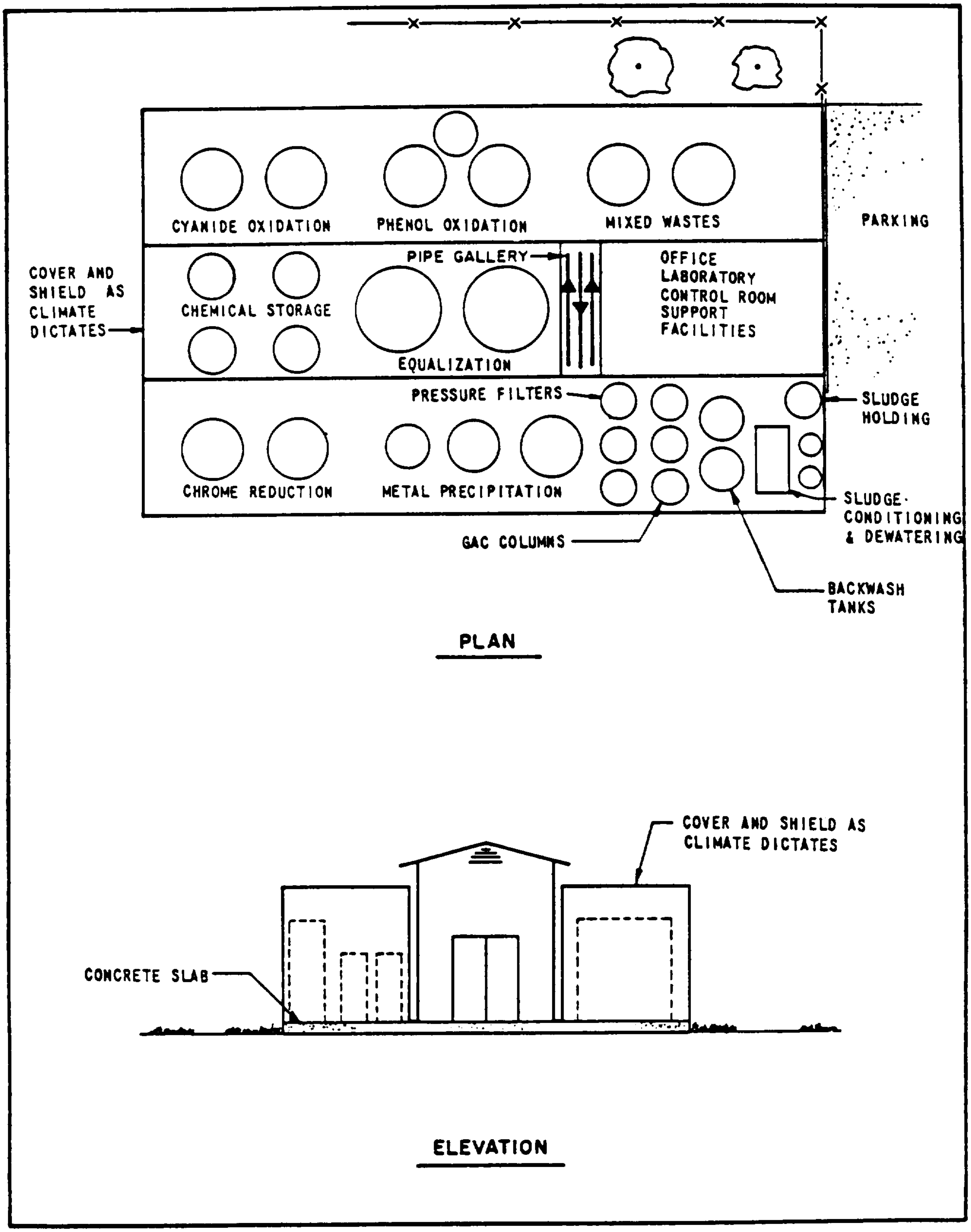


FIGURE 7
Layout for Industrial Waste Treatment Facility

color scheme shall be applied to piping systems at waste treatment facilities. See Table 10 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 in MIL-HDBK-1005/8 [2] for pier, wharf, and drydock utility connections.

2.6.12.1 Federal Safety Red. This classification (ASA Class F-Fire) includes sprinkler systems and other firefighting or fire protection equipment.

Applications. Sprinkler piping, identification and location of fire alarms and boxes, extinguishers, fire blankets, fire doors, hose connections, hydrants, and other firefighting equipment.

2.6.12.2 Federal Safety Yellow. This group includes materials which are inherently hazardous because they are flammable or explosive, toxic, or produce poisonous gas.

Applications. Flammable liquids such as gasoline, naphtha, fuel oil, chlorine gas, sulfur dioxide, ammonia, and steam.

2.6.12.3 Federal Safety Orange. This classification includes ASA Class D Dangerous Materials such as corrosive liquids, acids, and alkalis.

Applications. Concentrated acid, caustic soda, lime slurry, or hydrogen peroxide solution piping.

2.6.12.4 Federal Safety Green. This classification includes ASA Class S Safe Materials which involve little or no hazard to life or property in handling.

Applications. Low temperature and pressure, nonpoisonous, and nonflammable liquids and gases, drinking water, service water, emergency showers, and eyewash facilities.

2.6.12.5 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.

Applications. These materials are not typically used at Naval wastewater treatment facilities.

2.6.12.6 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 A13.1-1981 [14] for specification details of legend marker.

Pipes carrying hazardous materials shall be further identified with flow directional arrows and operating pressures (for steam lines and other high-pressure systems).

TABLE 10
Color Coding Criteria for Piping Systems at Wastewater Facilities[1]

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 para. 3.4.13 for pier, wharf, and drydock facilities [2].
[2]Further color coding of segregated wastes is not practical since they are usually cross contaminated and require joint treatment.

2.7 Guidelines From Actual Experience

2.7.1 Post Occupancy Evaluation Reports. In recent years, the Navy has had experience constructing and operating several industrial wastewater collection and treatment systems. The Post Occupancy Evaluation Reports have identified numerous lessons that have been learned through actual experience. Previous design, 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.

2.7.2 Design Factors. The following points shall 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 Navy facilities. The degree of automation should be optimized by balancing specific project factors. For example, a highly automated system which 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 Navy facilities staffing capabilities. In most instances, this will include automatic feed system, motorized valves, and other systems which minimize relatively simple treatment tasks.

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

d) Collection sewers, pumping facilities, and all treatment tanks for acids and cyanides should be located completely separate from each other to avoid mixing and severe safety hazards. Facilities shall 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. Emergency drains and spill containment area drains shall be provided.

f) Waste treatment from plating operations should provide sufficient onsite storage capacity to allow for a minimum of 8 h 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 assure a safe environment for operating personnel. This is particularly crucial in plant areas that generate gases and vapors. Covers for large volume reactors and equalization basins shall be considered.

h) Provide positive head on all pump suctions.

i) Particular caution should be observed with chemical piping layout; for example, avoid entrapment areas for hydrogen peroxide which 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 which may lead to failure.

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

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

2.7.3 Operational Factors. The following points shall be considered:

a) Adequate operator training at facilities is mandatory. An operation and maintenance manual which specifically reflects the plant's requirements is required. On-the-job training shall be conducted at plant startup and continued until the entire treatment process runs continuously and satisfies design effluent discharge criteria for a minimum 30-d period.

b) Operation and maintenance (O&M) manuals shall be prepared for each equipment component in the plant. A system O&M manual shall be prepared to integrate and demonstrate how each component relates to the system. Operation and equipment manuals shall be updated after performance demonstration period to include equipment and plant modifications and new operational requirements implemented during 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 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 shall be provided for cleaning filter press gaskets and flanges.

g) Contingency plans shall be developed for plant shutdown and chemical spills and treatment process performance failure.

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

2.7.5 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 shall be suitable for corrosive atmosphere of building air space.

c) All piping and conduit material should be resistant to the corrosive agents and operating conditions to which they may be exposed. All exposed metal which is nonresistant to corrosion shall be painted with a corrosion resistant paint. The effect of corrosive atmosphere on building interior roof and walls shall be considered.

d) Tank materials (or liners) shall 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) All pump housing shall be corrosion resistant.

g) All overhead piping which carries corrosive-type materials shall be provided 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 shall be sealed gasket types and corrosion resistant.

j) All other instruments and electrical equipment which may be exposed to corrosive environment shall be protected. Control consoles, panel-boards, and transformers shall be located within a closed and vented control room out of any corrosive atmosphere.

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

Section 3: OILY WASTEWATER COLLECTION AND TREATMENT

3.1 Objectives. Section 311(b)(3) of the Federal Water Pollution Control Act (FWPCA) prohibits the discharge of oil in harmful quantities into or upon the navigable waters of the United States. As indicated in the Code of Federal Regulation 40 CFR 110, Discharge of Oil, discharge in such quantities is generally considered to be concentrations greater than 10 mg/L or sufficient to cause a visible sheen. Treatment of oil discharges or oily wastes is frequently required at Naval installations.

3.2 Sources. Oily waste originates in numerous locations on board ships and throughout shore facilities. The largest (by volume) source is shipboard oily waste. The design criteria presented herein have been primarily developed for treatment of oily wastes from ships.

3.2.1 Pierside and Barge Collection of Shipboard Oily Waste. Wastewater collected in the bilges of ships normally contains about 1 percent oil and grease and some heavy metals and organic contaminants. This waste may not be directly discharged to public waters, and in many cases it is unsuitable for discharge to a POTW. Full treatment to direct discharge standards or pretreatment to reduce pollutants to acceptable levels for municipal sewer discharge is necessary. Bilge wastes are normally the primary influent, both in volume and contaminant concentration, to an oily waste treatment system. Occasionally, ballast water is discharged from ships and barges. This waste contains lower contaminant levels than bilge wastes but usually requires treatment before disposal.

3.2.2 Aircraft and Vehicle Maintenance Operations. Spills of piston, hydraulic, and turbine oils to building drains can occur. Route drains through oil-water separator to sanitary sewer or to industrial sewer if metal or organics removal is required. Implement oil use and recovery plans. Minimize working area for outside maintenance installations to minimize volume of contaminated surface runoff requiring treatment. The use of high-pressure water and/or detergents for cleanup of work area is not recommended because they increase emulsification and inhibit oil-water separation by gravity. For spill cleanup, use dry absorbents and sweep whenever possible. Dispose absorbents as solid waste material.

3.2.3 Aircraft Washracks and Rinse Areas. Equipment is usually cleaned with detergents, corrosion inhibitors, and other cleaning compounds by brushing and high-pressure water rinses to remove oil, dirt, and seawater. The most feasible alternative to remove free oil fraction would be pretreatment prior to discharging to the sanitary sewer. Outside areas located adjacent to runways usually employ a potable water rinse to remove salt as aircraft land. Rinse water may require treatment to prevent long-term buildup of oil and grease in the soil, which could result in contaminated surface runoff to receiving drainage systems or contaminated infiltration to groundwater supplies. Confirm treatment and groundwater monitoring requirements with regulatory agency.

3.2.4 Tank Farm Operations. The soil around large buried fuel or oil storage tanks is often dewatered by a perforated underdrain system. Fuel or oil may enter the soil by tank overflows or structural failure. It can seep into the surrounding soil and drainage system and create a potential ground water contamination problem. The movement of the fuel or oil through the soil to the drainage system is enhanced during periods of precipitation and/or the presence of a high water table. Contaminated soil should be removed and replaced with uncontaminated materials, and the drainage pipe cleaned. If not feasible, provide oily wastewater treatment system. Complexity of system will depend on required effluent quality. Provide containment facilities, such as skimming dams or diversion ponds for fuel or oil transfer areas to prevent spills from reaching surface water bodies and underground drainage systems. Containment area may require a chemical resistant, impermeable lining. Provide containment areas around storage tanks as described in NAVFAC DM-22 Series, Petroleum Fuel Facilities [2]. Equip fuel and oil storage tanks and dispensing facilities with covers or other control devices to minimize dispersion of hydrocarbons into the air.

3.2.5 Fire Training Area. Fire fighting demonstrations which require disposal of unburned fuel and/or oil, burn products, AFFF, or protein foam are routinely scheduled. Design containment area to prevent uncontrolled runoff and percolation of fuel, oil, and foam into soil or open surface drains. Refer to NAVFAC DM-27 Series on Training Facilities [2], for wastewater collection and treatment system design criteria. Refer to Table 1 for wastewater characteristics from fire training area.

3.2.6 Stormwater Runoff. Where feasible, segregate potentially contaminated runoff from uncontaminated runoff to minimize volume requiring treatment. Provide oily wastewater treatment facilities as required to achieve effluent quality. Suspended solids in runoff must be minimized to maximize effectiveness of the oil removal system. Sedimentation facilities could be required upstream of the oil-water separator. Use a temporary impoundment facility and a release to treatment system at a controlled rate to minimize the size of an oil-water separator.

3.2.7 Ship and Barge Deballasting Operations. For design criteria refer to NAVFAC DM-22 [2].

3.2.8 Other Sources. Other sources of oily wastes include aircraft machine and paint shops, fuel transfer operations, and runway operations.

a) Aircraft Machine and Paint Shops. Aircraft machine and paint shop wastes include many types of lubricating and cutting oils, hydraulic fluids, paints, paint strippers, solvents, degreasers, washdown waters, and plating wastes. Do not discharge these wastes to a building drain system. Collect in separate systems and route to oily or industrial wastewater treatment systems. Check the compatibility of wastewater mixtures and the hazardous waste nature of the mixture.

b) Fuel Transfer Operations. Spills may occur during fuel transfer operations. If possible, use dry absorbents to pick up oil and dispose of them as solid waste material. Check flash point of the spent material for possible hazardous waste characteristics.

c) Runway Operations. At airports subjected to cold weather, deicing fluids such as ethylene glycol are used to keep runways from icing over. Deicing fluids are generally washed off by rainfall or snow melt into runway storm sewers.

3.3 Discharge Criteria. Oily wastes must be treated in order to comply with Federal, state, and local regulations. The effluent from the oily waste treatment plant may be discharged to either navigable waters or to a POTW. The effluent quality requirements for discharge to navigable waters are determined by the NPDES permit. Effluent quality requirements for discharge to POTWs are determined by local and municipal authorities and, therefore, may vary from place to place. The effluent quality requirements most typically encountered, and for which treatment system design criteria are developed herein, are as follows:

PARAMETER	DISCHARGE TO NAVIGABLE WATERS	DISCHARGE TO POTW
Oil and Grease	10 mg/L	50-100 mg/L
Suspended Solids	15 mg/L	100-500 mg/L
pH	6-9	6-9

Regional and local authorities may impose additional effluent quality requirements. These requirements may restrict heavy metals and organic pollutants. In such cases, treatability studies shall be done to determine process additions or modifications necessary to the standard treatment system.

3.4 Point Source Control. Investigate point source controls to eliminate or reduce wastewater volume and contaminant concentrations. It may be more economical to implement point source controls rather than provide a wastewater treatment system. Consider point source control techniques such as process change or modification, material recovery, wastewater segregation, and water reuse.

3.4.1 Segregation and Recovery. Consider segregation of oily wastewater streams based on intended use of reclaimed oil; for example, lubricating oils may be re-refined instead of incinerated. Do not mix high flash oil with low flash oil, or halogenated solvents with nonhalogenated oil.

3.4.2 Process Change. Consider use of dry absorbents to minimize oils reaching a sewer. Dry absorbents may be collected and disposed of with solid waste materials. Evaluate flash point of spent absorbent for possible hazardous waste designation under RCRA guidelines.

3.5 Disposal of Oil. Oils and oily sludges obtained from treatment or pretreatment systems may be disposed of by several methods. These are reuse/recovery, incineration, selling by Defense Property Disposal Office (DPDO), waste hauler, landfill, and land disposal. Final disposal options must be evaluated concurrently with oil-water separation methods and environmental requirements to establish the most cost-effective total system.

3.5.1 Reuse/Recovery. Consider processes which will enable reusing separated oils for subsequent use. Additional water removal from gravity or flotation units may be necessary to utilize oils for combustion. Use of recovered oil for combustion with subsequent recovery of heat is recommended where justified.

3.5.2 Incineration. When other disposal methods are not practical or where toxic materials are contained in oily sludges, incineration should be considered. Determine air pollution control requirements from the controlling regulatory agency.

3.5.3 Waste Hauler. Refer to para. 2.6.1.6 c).

3.5.4 Landfill or Land Disposal. Dewatered oily sludge may be disposed of in a dedicated landfill site or in a landfill with other solid wastes. Oily sludge, with or without domestic wastewater sludge, can also be incorporated into the soil in a land application system. The landfill or land disposal site must be approved to accept the sludge.

a) Oily sludge may be considered a hazardous waste based on RCRA criteria for flammability or the EP Toxicity Test. Determine hazardous waste nature by EP test results and ignition point. Contact state regulatory agency for local handling, transport, and storage requirements.

3.6 Emergency Containment and Cleanup. Process and treatment operations at Navy installations should be controlled to eliminate spills of oil to surface and groundwaters. Equipment and procedures to effectively contain and remove accidental spills should be established as a part of the oily waste collection and treatment system. Refer to Code 1122, Environmental Quality Division; and NAVFAC P-908, Oil Spill Control for Inland Water and Harbors, [2] for specific guidance on procedures and techniques. See OPNAVINST 5090.1 [1] for overall guidance on responsibilities and management for oil spills.

3.7 Oily Wastewater Characteristics

3.7.1 General. Establish wastewater flow rate and contaminant concentrations, when possible, through direct measurements and sampling. Follow procedures in NAVFACINST 4862.5C [2] when conducting Preliminary Engineering Studies for industrial wastes. Use existing installations to forecast conditions for facilities to be constructed. Exercise caution with regard to the similarity of oily wastewater sources and collection systems. Length and configuration of collection system, liquid transport velocities, and associated appurtenances (pumping) can significantly influence wastewater characteristics.

3.7.2 Characteristics. The types and concentrations of contaminants in oily wastes from different sources will vary greatly. The type of contaminant may be one or a combination of the following: various oils such as hydraulic, turbine, lubricating, cutting, and motor oil (which may be in the form of free, dispersed, emulsified, or dissolved oil); gasoline; emulsifying agents; solvents; oily sludge; seawater; and particulate matter (floatable and settleable) such as sand, soil, gravel, and paint skins.

Based on available data from analyses of shipboard discharges and composite influents to oily waste treatment systems, a general characterization of physical and chemical properties of untreated oily waste is as follows:

CHARACTERISTIC	CONCENTRATION (mg/L) AVERAGE	PEAK
Oil and grease	200 to 2,000	10,000 to 100,000
Suspended solids	50 to 500	5,000
pH	6 to 8 units	--
Copper	0.02 to 2	5 to 10
Lead	0.03 to 0.1	0.5
Mercury	Negligible	--
Nickel	0.01 to 0.2	0.5
Zinc	0.1 to 1	2
Phenolics	0.01 to 0.5	2

In addition, oily wastewater and ballast water from ships contain a high concentration of dissolved solids. This can create operational, maintenance, and materials problems for the treatment and collection systems. Principal problems are process upsets, corrosion, and scale formation. Variations in wastewater flow rates occur due to discharge rates of different ship types.

3.7.3 Flows. Determine frequency and duration of maximum and average flows for ship-generated oily wastes by using the methods described in para. 3.8. Determine flow characteristics of other oily wastes by using the methods described in Section 4. Methods for estimating stormwater runoff are described in NAVFAC DM-5.02, Hydrology and Hydraulics [2]. Flow measuring locations should correspond with sampling locations.

3.7.4 Sampling. Collect, preserve, and analyze representative samples to determine the physical and chemical characteristics and concentrations. Conduct sampling program concurrently with a flow measuring program. Oily wastewater sources that are highly variable with regard to volume and constituent concentrations should be sampled continuously using flow weighted composites (see guidelines for sampling in EPA Handbook for Monitoring Industrial Wastewater [5]).

3.7.5 Analyses. The basic oily wastewater characterization program should include the minimum and maximum concentrations for the following: total solids, suspended solids, total and dissolved oil and grease (or petroleum hydrocarbon), specific gravity, temperature, total halogens and Btu value of the oil. Include the range for pH and the presence of corrosive materials such as solvents and acids for proper selection of construction materials. Perform metals analyses if they are potentially present in the oily wastewater system.

3.7.6 Treatability. Refer to NAVFACINST 4862.5C [2] for treatability study guidance. Use benchscale and pilot plant studies as required to determine treatment processes that will provide the required effluent quality. Use benchscale experiments to determine design criteria for chemical dosage, optimum pH, suspended solids settling rate, temperature effects, emulsion breaking, oil separation, sludge generation, and allowable overflow rate. See Process Design Techniques for Industrial Waste Treatment by Adams and Eckenfelder [13] for treatability test procedures. When considering gravity separation only, use column settling test at sample collection site, if practical, and immediately after collecting sample. Avoid column agitation and sunlight during test period. If chemical addition is required, use jar test to select optimum conditions and column test to simulate gravity separation. Compare test results with most stringent applicable effluent quality regulations.

3.8 Collection and Transfer

3.8.1 Collection

3.8.1.1 General. Lay out system to segregate oily and nonoily wastewater sources to minimize oil-water separator hydraulic loading, minimize emulsification, and maximize oil and grease concentration. Combine similar wastewaters and route to most efficient treatment processes. Refer to NAVFAC DM-5.02 [2], NAVFAC DM-5.03 [2], and para 2.5 for collection system design criteria. Use a minimum fluid velocity that will prevent settling of suspended solids and minimize emulsification. Refer to MIL-HDBK-1004/6 Lightning Protection [2], for cathodic protection, and NAVFAC DM-28 Series on Maintenance Facilities [2], for facility details. Applicable building codes and safety regulations shall govern when conflicts occur between these design criteria and the appropriate codes.

3.8.1.2 Ships. Ship's oily wastewater is collected for treatment by either pier pipelines or offloaded to doughnuts and Oil-SWOBs (Ship's Waste Offloading Barge).

a) Sources. Primary sources of ship-generated oily wastewater are bilges, oily waste holding tanks for collecting lubricating oils and water contaminated fuel, and ballast water. Oily ballast water can be discharged from most ships (other than tankers) through large diameter piping directly overboard or to doughnuts or Oil-SWOBs. Large naval bases may need permanently installed collection, storage, and treatment facilities for ballast water collected from tankers at fueling piers. For design criteria for ballast water collection and treatment, see NAVFAC DM-22 [2].

b) Pier Collection System Layout. The collection system consists of 6-in. (minimum) (152 mm) pier pressure main with 4-in. (101.5 mm) (minimum) pressure laterals manifold to main. Main may be laid in center or alongside of pier. Lateral and pier riser spacing shall be 150 ft (45.7 m). See Figure 8 for pier receiving hose riser assembly connection.

c) Ship to Shore Oily Wastewater Transfer. Positive displacement bilge pumps transfer oily wastes to standard ship deck discharge risers connected by 2.5-in. (63 mm) flexible hose to standard pier risers (see Figure 9). Discharge pressure at the pier riser depends on surface ship class, type of bilge pumps, and static lift. See Table 11 for bilge pump characteristics of major ship classes.

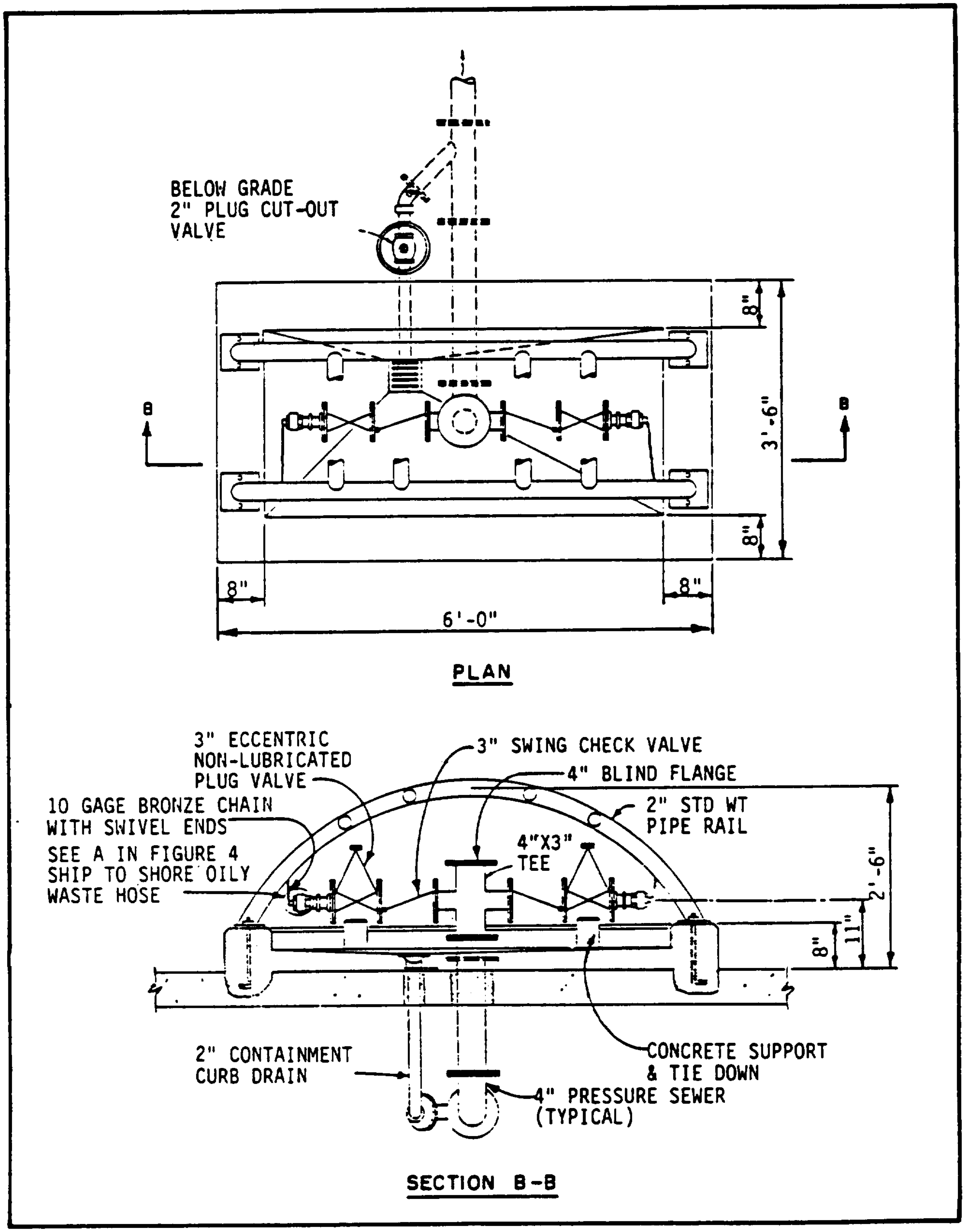


FIGURE 8
Pier Receiving Hose Riser Assembly

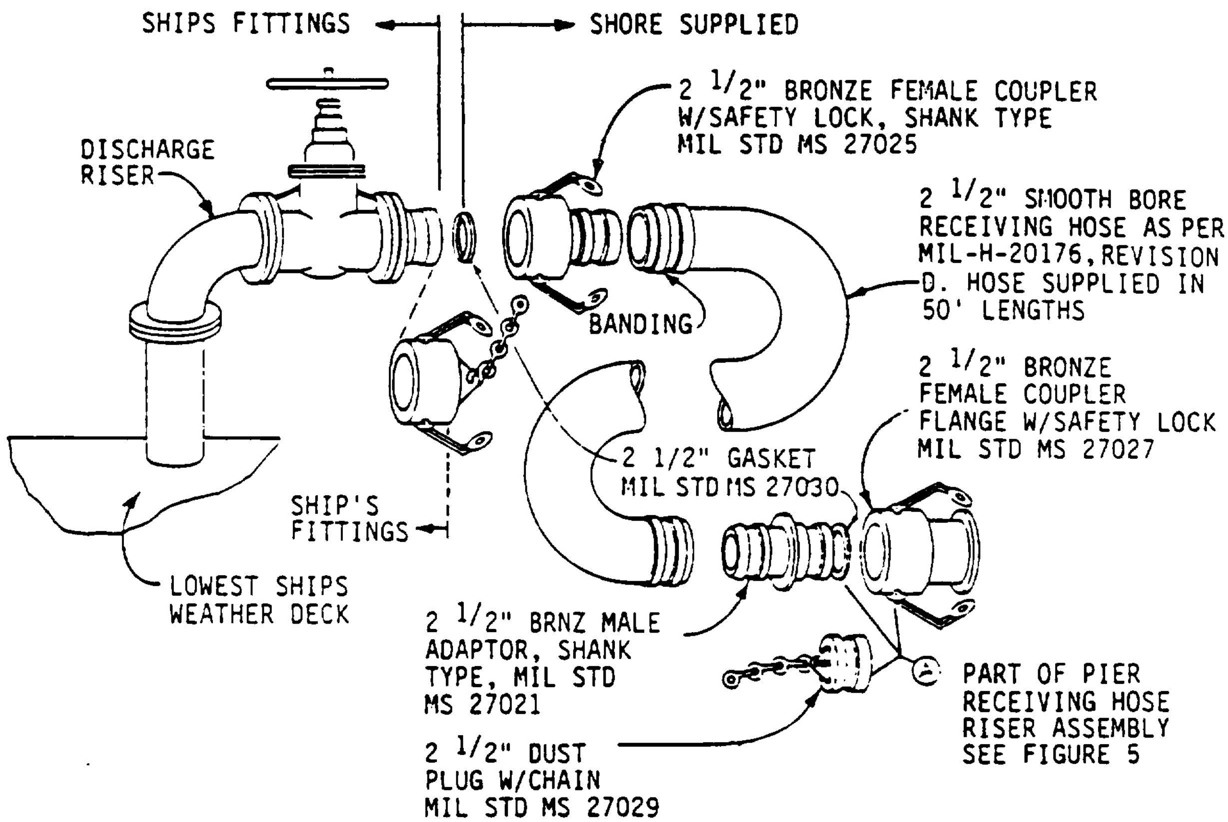


FIGURE 9
Ship-to-Shore Oily Waste Hose Connection

TABLE 11
Rotary Vane Positive Displacement Ship Bilge Pump Data

MAJOR SURFACE SHIP CLASS[1]	NO. OF PUMPS	CAPACITY EACH PUMP (gpm)	RATED DISCHARGE PRESSURE[2] (psig)	DESIGN DECK RISER PRESSURE[3] (psig)	DECK RISER HEIGHT ABOVE WATERLINE (ft)	SHIP BEAM[4] (ft)
AD	2	100	60	32	26	85
AE 21	1	50	50	24	20	72
AE 26	2	50	60	35	20	81
AF	1	100	60	30	25	72
AFS	1	50	60	31	31	79
AG 153	1	50	50	18	33	76
AO	1	100	60	30	22	75
AO 177	2	100	50	19	25	88
AOE	1	100	50	13	32	107
AOR	1	100	60	29	26	96
AR	1	100	60	33	22	73
ARS	2	15	50	29	22	39
AS	2	100	60	25	39	85
ASR	2	15	50	26	22	42
ATF	1	15	60	44	9	42
ATS	1	15	50	33	12	50
MSO	2	15	50	35	9	35
LCC	1	100	50	23	22	82
LKA	1	50	50	16	40	82
LPD	2	50	60	30	34	84
LSD	1	100	60	36	24	84
LST	2	50	50	25	28	70
LPH	2	100	60	27	31	84
CV'S	2	200	125	80	28	260
CG	2	50	40	15	22	67
CGN	2	50	50	22	21	74
DD931-950	2	50	60	39	11	45
DD 963	2	100	80	33	18	53
DDG	2	50	60	35	18	55
FF	1	50	60	37	13	47
FFG	2	50	60	35	17	45

[1]Major Surface Ship Classes which will be generating oily waste to be processed ashore. See SECNAVINST 5030.1K, Classification of Naval Ships and Craft, [15] for description of other classes.
[2]Rated discharge pressure at the flow capacity listed. Pump recirculating relief valve limits discharge pressure at zero flow to 125 percent of rated discharge pressure listed.
[3]Estimate of ship deck riser pressure for shoreside design.
[4]Use to estimate number of shore-supplied 50-ft hose lengths for nested ships.

3.8.1.3 Ship Oily Wastewater Flows. Ship bilge daily flow varies with the class of ship, shipboard operations, and condition of the ship's mechanical equipment. The three measures of ship's flow are average (Qave), maximum (Qmax), and peak (Qpeak). Table 12 lists the values for these flow terms for three ship types. These flows are used in various combinations (depending on facility size) to estimate the total daily oily waste flow (Qdaily) from a pier. Qdaily is used to estimate ship utility charges and shoreside oily waste treatment plant capacity, operating costs, and operating schedule. The size of the pier facility depends on the pier berthing plan and shoreside ship utilities (usually electrical hookups). Facility size and Qdaily are determined as per the following subparagraphs.

TABLE 12
Ship Bilge Flow Data

SURFACE SHIP CLASS[1]	FLOW RATE (gpd) Qave	Qmax	Qpeak
Type 1. All ship classes except Types 2 and 3	3,700	6,600	14,000
Type 2. Carriers and AOEs	50,600		135,000
Type 3. Service craft	50		100
Submarines (SS, SSBN, SSN)	100		1,000

[1]Reference: SECNAVINST 5030.1K, Classification of Naval Ships and Craft [15]

a) Small facilities. Defined as pier facilities with few berths or limited shoreside ship utilities. Qdaily is determined by Equation (3).

EQUATION: $$Qdaily = (N_1)(6{,}600) + (N_2)(Qpeak_2) + (N_3)(Qpeak_3) \quad (3)$$

Where: Qdaily = Design daily flow from single pier, gpd.
$N_{1,2,3}$ = Number of ships of type 1, 2, and 3, respectively, during maximum holiday berthing.
Qpeak = Peak daily flow from ship type 1, 2, and 3, respectively (gpd). See Table 12.

b) Large facilities. Defined as pier facilities where complete shoreside utilities are provided to ships at berth. Qdaily is determined by Equation (4).

EQUATION: $$Qdaily = (N_1)(Qave_1) + (N_2)(Qave_2) + (N_3)(Qave_3) \quad (4)$$

Where: $Qdaily$ = Design daily flow from single pier, gpd.
$N_{1,2,3}$ = Number of ships of type 1, 2, and 3, respectively, during average daily berthing.
$Qave_{1,2,3}$ = Average daily flow from ship type 1, 2, and 3, respectively, during average daily berthing, gpd. See Table 12.

c) Design Flow for Pier Oily Waste. Flow estimate for design of pier main and laterals and pump station capacity is determined as follows. (See Table 11 for ship's bilge pump characteristics.)

(1) Design flow for pier main is determined by Equation (5):

EQUATION: $$Qmain = \sum_{i=1}^{3} (0.31\ N_i n_i)(q_i) \quad (5)$$

Where: $Qmain$ = Design flow for pier main, gpm.
N_i = Number of ships of type "i" berthed at pier during maximum holiday berthing.
n_i = Number of bilge pumps aboard each ship of type "i." See Table 11.
q_i = Discharge rate from each bilge pump of type "i" ship, gpm. See Table 11.

(2) Design flow for pier laterals is determined by Equation (6):

EQUATION: $$Qlateral = \sum_{i=1}^{3} (0.31\ N_i n_i^*)(q_i) \quad (6)$$

Where: $Qlateral$ = Design flow for all pier laterals, gpm.
n_i^* = Total number of bilge pumps aboard all ships of type "i" connected to same pier riser during maximum holiday berthing.
q_i = As defined for Equation (5).

Total design flow from multiple parallel piers or multiple parallel pier mains on a single pier are assumed to be additive.

3.8.1.4 <u>Collection System Design Procedure</u>. Procedures for design of ship oily waste collection pipelines are based on Qmain and Qlateral. The design objectives are to determine the diameter of pier laterals and the pier main. The design procedure is as follows:

a) Pier Daily Flow. For design purposes, determine if the activity is a "small" or "large" facility. Determine the number and classes of ships present during maximum holiday berthing and average daily berthing. Determine Qdaily by Equation (3) or (4).

b) Sizing of Pier Main and Laterals. Determine L, Hp, and Hs (see Figure 10) and Pd (see Table 11) for each ship class berthed at pier. Determine the diameter of the pier main for Qmain flow rate at design velocity of 5 to 7 fps. Maintain pipe velocity less than scouring velocity recommended by pipe manufacturer. The minimum velocity will be zero since flow is intermittent.

(1) Calculate the friction loss in the pier main at the Qmain flow rate using Equation (7) for flow of marine diesel fuel with viscosity at lowest expected ambient temperature. Determine design viscosity from Figure 11. Assume Hm occurs at each main-lateral intersection as a back pressure against berthed ship's bilge pumps.

EQUATION: $$Hm = [f(L/D)(Qmain/Dmain^2)^2]/g \quad (7)$$

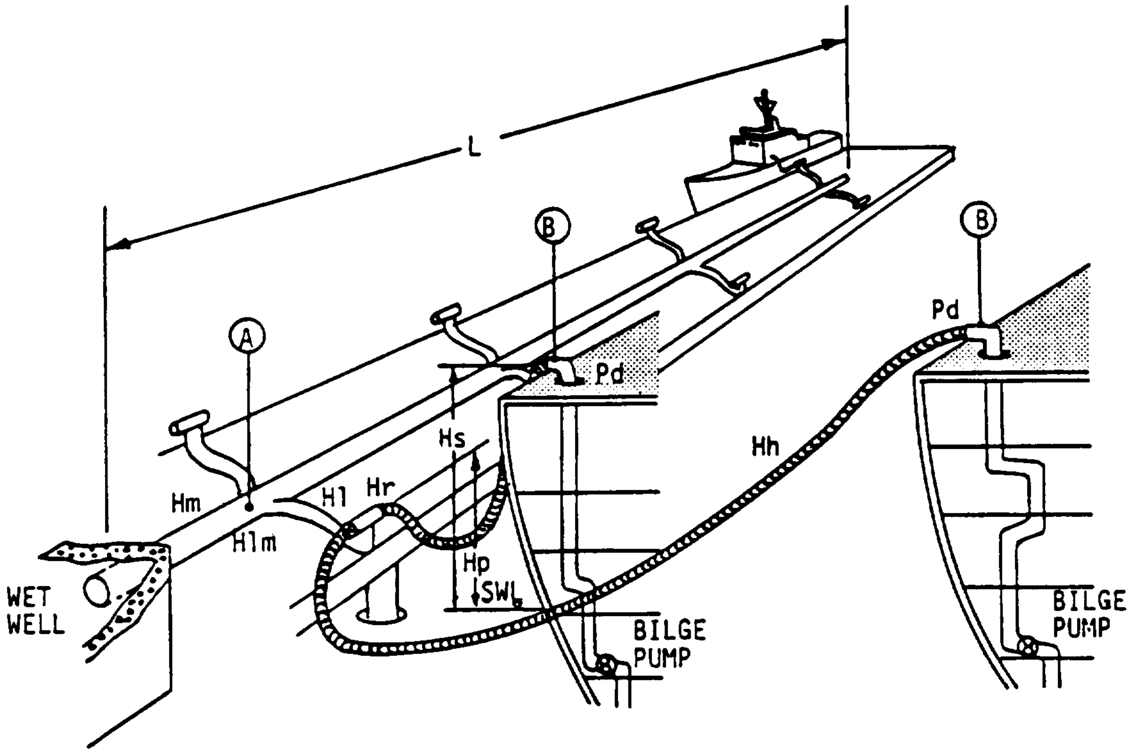
Where:	Hm	=	Head loss in pier main, ft.
	f	=	Darcy-Weisbach friction factor. See Figure IIIA-3 in Engineering Data Book by The Hydraulic Institute [16].
	L	=	Length of pier main from pier end to free discharge point, ft.
	Dmain	=	Pier main diameter, in.
	Qmain	=	As determined by Equation (5).
	g	=	32.2 fps^2.

(1) Calculate the maximum Qlateral for all ship types at maximum holiday berthing plan. Determine the diameter of the pier lateral at maximum Qlateral flow rate at design velocity of 5 to 7 fps. Maintain velocity less than the maximum scouring velocity recommended by pipe

c) Head Loss Determination. Calculate the head loss across the pier riser assembly (Hr), the lateral (Hl), and the lateral-main intersection (Hlm) based on maximum Qlateral flow rate and design viscosity using Equations (8), (9), and (10), respectively. See Figure 10 for design nomenclature.

EQUATION: $$Hr = [K(Qlateral/D^2)^2/2g][0.1669] \quad (8)$$

Where:	Hr	=	Head loss across pier riser assembly, ft.
	D	=	Lateral diameter, in.
	Qlateral	=	As per Equation 3-4, gpm.
	g	=	32.2 fps^2.
	K	=	Head loss coefficients for pier riser assembly. See Figure 8 for description of fittings in pier riser assembly.



KEY

L = LENGTH OF PIER MAIN
Hm = HEAD LOSS IN PIER MAIN
H1m= HEAD LOSS IN LATERAL MAIN CONNECTION
H1 = HEAD LOSS IN LATERAL
Hr = HEAD LOSS ACROSS PIER RISER
Hs = ELEVATION OF DECK RISER ABOVE SWL
Hp = ELEVATION OF PIER RISER ABOVE-MEAN LOW SWL)
Hh = HEAD LOSS IN HOSE(S)
Pd = SHIP DISCHARGE PRESSURE

FIGURE 10
Oily Waste Collection Pipeline - Nomenclature

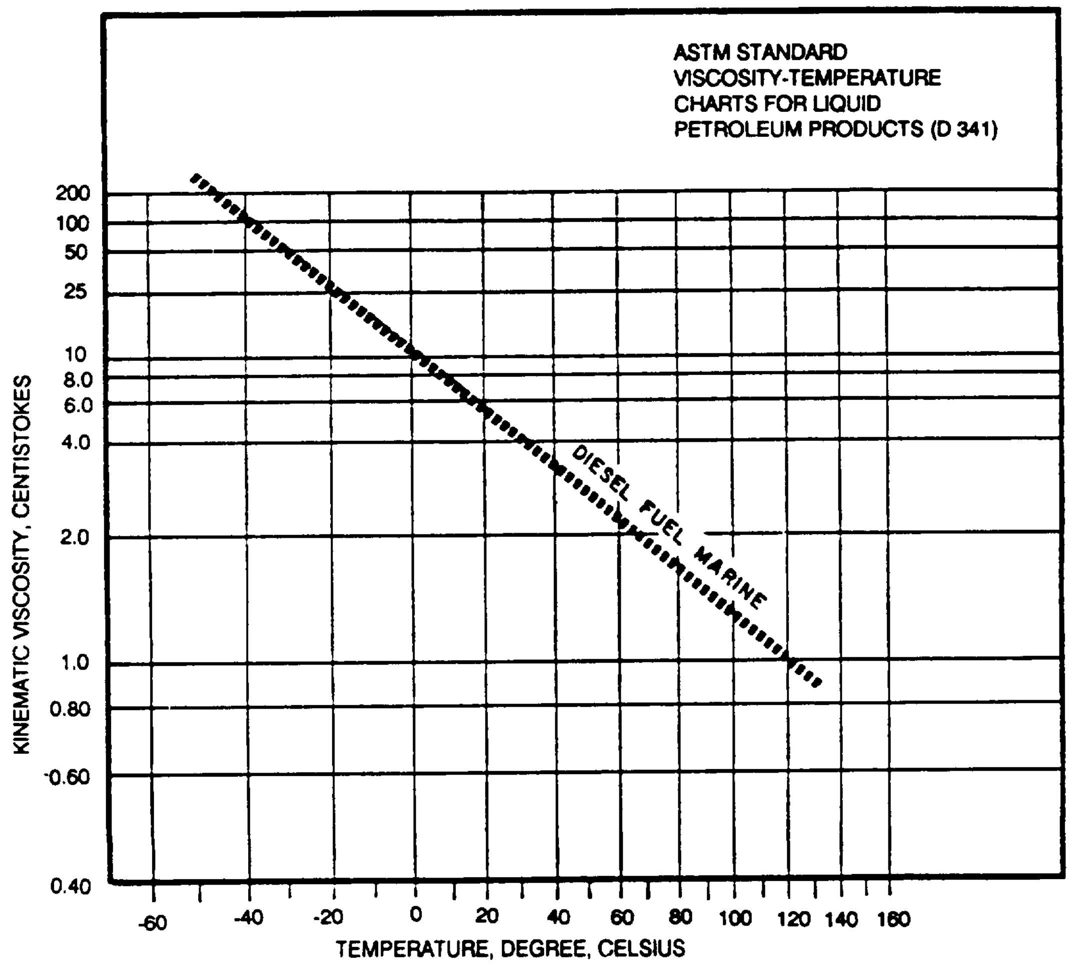


FIGURE 11
Viscosity-Temperature Relationship
for Marine Diesel Fuel

EQUATION: $$Hl = (f[L/D][Qlateral/D^2]^2)/g \quad (9)$$

Where: Hl = Head loss through lateral from pier riser to lateral/main intersection, ft.
L = Length of lateral from pier riser to main, ft.

EQUATION: $$Hlm = [K(Qlateral/D^2)^2/2g][0.1669] \quad (10)$$

Where: Hlm = Head loss across lateral/main intersection, ft.
K = Loss coefficient for fitting at lateral/main intersection.

For each ship in the berthing plan determine the number of 50 ft hose lengths and total hose length required to reach from the inboard ship deck discharge riser to the pier riser. Determine the head loss through the hose lengths by Equation (11).

EQUATION: $$Hh = (f[L/D][Qbilge/D^2]^2)/g \quad (11)$$

Where: Hh = Head loss through total hose length from ship deck riser to pier riser, ft.
L = Total hose length from ship deck riser to pier riser, ft.
Qbilge = Flow rate of one bilge pump, gpm. See Table 11.
D = Diameter of oily waste transfer hose, in.

For each ship in the berthing plan and for each berth, sum the head losses due to flow and compare this sum with the ship deck discharge pressure using Equation (12).

EQUATION: $$[Hm+Hr+Hl+Hlm+Hh+(Hp-Hs)]k < Pd \quad (12)$$

Where: Hm and Hl = Head loss in pier main and lateral, respectively, ft.
Hr, Hh, Hlm = Head loss in pier riser, ship's connecting hose, and lateral to main connection, respectively, ft.
(Hp-Hs) = Elevation difference between pier riser, Hp, and ship's deck riser, Hs, ft. See Figure 10 for schematic.
k = 0.445 psig/ft.
Pd = Ship's deck riser discharge pressure, psig. See Table 11.

If the inequality is not satisfied for a ship at any berth, reiterate the calculations first for an assumed larger main diameter and then for a larger main and lateral diameter, if necessary.

3.8.1.5 <u>Collection System Layout</u>. Consider the following when laying out a pier collection pipeline.

a) Ships of same class type often berth together.

b) Locate a riser at the pier end for use by oil SWOB or service craft.

c) Install valves at head of each pier to allow for isolation in case of pier pipeline damage.

d) Allow for minimum slope toward free discharge to prevent freezing.

3.8.1.6 Pipe Materials. Specification of oily waste collection piping should include:

a) Minimum operating pressure of 150 psig.

b) Use mechanical joint, lined ductile iron for exposed locations where high impact resistance is important. Support exposed pipe per manufacturer's recommendations. In other exposed locations, for superior corrosion resistance, consider thermoplastic (high density polyethylene) pressure pipe with butt fusion joints. Plastic piping on pier and wharf systems should be protected from impact of floating debris and other hazards by placement in a specially designed utility trench. For buried lines, apply general sewer pipe selection guidelines.

3.8.1.7 Special Considerations

a) Freeze protection. For design criteria in cold regions, refer to Department of Army Corps of Engineers TM 5-852 Series on Arctic and Subarctic Construction [11].

b) Cleanouts. Provide cleanouts at junctions, directional changes, end of pipe run, and every 400 ft (122 m) of continuous runs.

c) For thrust support, hanger sizing and spacing, consult manufacturer's design manual. Install pipelines inboard of pier fendering systems or preferably in utility tunnels. Protect pipelines from damage from below due to tide-carried debris.

3.8.2 Transfer

3.8.2.1 General. Use pumping only when a gravity system cannot serve hydraulically, such as for wastewater collection lines at piers. For those pumping systems:

a) Locate pumps as close to oily wastewater source as possible to maximize detention time between pumping and treatment and minimize impact of mechanical emulsification; or, as an alternative, use equalization facility. If equalization is employed, avoid detention times which may result in odor and gas production. Use vapor controls as required by applicable environmental regulations.

b) Use reciprocating positive displacement or screw pumps to transfer oily wastewater to treatment unit or equalization facility.

Maximize size of wet well and select a number of pumps and an operating schedule to minimize surge effect of pump off-on cycle on downstream oil-water separators. Consider variable speed drives on transfer pumps.

c) If rotary displacement or centrifugal pump is used, design for low speed (≤900 rpm) to minimize mechanical emulsification.

(1) Maximize size of wet well and select the number of pumps and an operating schedule to minimize surge effect of pump off-on cycle on downstream oil-water separators.

(2) Consider the use of a pump control valve and a surge tank with control orifice to throttle discharge to oil-water separator. Consider variable speed drives on transfer pumps.

3.8.2.2 Ships

a) Design. Design pump stations to handle the cumulative Qmain for all piers served assuming that individual pier main flows occur simultaneously. Package pump stations are acceptable for oily wastes if the following are considered:

(1) Wet well liner. A protective rubberized liner or, alternative protective coating should be provided to resist oil and grease and saltwater attack.

(2) Ventilation. Provide continuous ventilation with complete air changeover every 2 minutes.

(3) Inlet screens. Provide basket or bar type screens on a pump inlet which can be removed and cleaned at the surface without personnel entry.

b) Pump Selection. Determine pump capacity and operating cycle as in para. 2.4.

Use positive displacement pumps with pressure relief valve, rather than centrifugal pumps, to reduce mechanical formation of emulsion at oily waste treatment plants. Pumps should pass solids having a diameter ≤0.125 in.

c) Pump Controls. Provide controls suitable for Class I, Division 1, Group D safety classification. Use float or sonic type mechanisms, not air bubblers, for pump control and alarm. Provide discharge pump control valve to minimize surge effect on equalization basins at oily waste treatment plants. (Not applicable for positive displacement pumps.) Provide an alarm system for overflow or power failure. Provide manual override of all pump controls but not of low level alarms.

d) Metering. Specify the following to monitor station activity: accumulating flowmeter, elapsed time meter for pumps and ventilator, and pump suction and discharge pressure gages with oil-filled diaphragm and cutoff valves.

3.9 Oily Wastewater Treatment

3.9.1 General. No single treatment process or commercial device will remove all forms of oil (emulsions, free and dissolved oil) in oil-water mixtures. A series of treatment process units may be utilized to achieve the desired effluent quality. The degree of treatment required will be based on the most applicable discharge limit for a POTW or navigable water. Select oily wastewater treatment options from those presented in Table 13. In addition, sludge treatment and disposal must be considered (refer to MIL-HDBK-1005/8 [2] for sludge handling systems).

3.9.2 Free Oil Treatment. The level of required treatment for oily wastewater depends on the discharge criteria (POTW or a navigable water).

3.9.2.1 Discharge to POTW. Typical effluent quality requirements can be achieved by batch treatment gravity separation processes. The pretreatment scheme is shown in Figure 12. The oily waste is discharged into a short-term storage/separation tank referred to as a Load Equalization Tank (LET). The waste is received for a predetermined number of days and then allowed to sit quiescently for about 24 h to insure optimum gravity separation. Free oil floats to the surface and is skimmed off. Settleable solids sink and are scraped to a hopper for withdrawal and disposal. Typical LET effluent contains less than 50 ppm of oil and grease. Multiple LETs should be provided for semicontinuous (fill and drawoff) operation of the facility.

a) An induced gravity separator should be provided for additional treatment when LET effluent contains more than 50 ppm of oil and grease. Provide a bypass around the induced gravity separator. In an induced gravity separator, total flow is distributed through numerous flow paths and formed by inclined plates or tubes at laminar velocity. This increases suspended solids contact, and it aids solids separation by improving the flotation and settling characteristics of the enlarged particles.

b) Design guidelines and criteria for these unit processes are presented in para. 3.10.

3.9.2.2 Discharge to Navigable Water. To meet effluent quality requirements for direct discharge, additional treatment is required after gravity separation in a LET. Depending on specific load requirements, 80 to 90 percent of the free and emulsified oil remaining after LET treatment must be removed by secondary and tertiary treatment steps.

a) Batch treatment in a LET is the recommended primary unit operation. Secondary treatment in a dissolved air flotation (DAF) unit will remove significant amounts of residual and some emulsified oil and grease. Normally, the effluent from a DAF unit will contain 10 to 20 mg/L of oil and grease. Based on treatability studies, it may be necessary to add coagulating and emulsion breaking chemicals to the DAF influent to optimize removal of contaminants.

b) To provide consistent direct discharge quality effluent, tertiary treatment is required. The recommended process is multimedia filtration with relatively fine graded media. In certain situations, primarily where flows are higher and space limitations prevent installation of a sufficient number or size of multimedia filters, coalescing filtration units should be considered. Coalescing filters are mechanically complex, but they perform reliably if operated and maintained properly. Figure 12 shows a schematic flow diagram for a treatment system to discharge to navigable waters.

c) Design guidelines and criteria for these unit processes are presented in para. 3.10 following.

3.9.2.3 Redundancy. The design of an oily waste treatment system for either discharge criteria should provide 100 percent redundancy for all "critical" process equipment. (Determination of criticality is based on the impact on effluent quality of loss of a component, and on a specific hazard analysis. Also refer to NAVFACINST 4862.5C [2].) It is important to avoid the loss of a key unit operation during either scheduled or unscheduled maintenance downtime for any piece of equipment.

Guidelines for LET design require multiple units and redundant capacity for normal operation of the gravity separation process (refer to para. 3.10.2). It is also recommended that 100 percent redundancy be provided for all downstream polishing treatment units, transfer pumping equipment, and effluent monitoring instrumentation.

3.9.3 Emulsified Oil Treatment. Formation of oil emulsions should be minimized as much as possible. Segregate emulsions for special treatment wherever possible. Emulsions are usually complex, and bench or pilot plant testing is generally necessary to determine an effective method for emulsion breaking. Common emulsion-breaking (demulsification) methods are a combination of physical and chemical processes, preferably operated in a batch treatment mode.

3.9.3.1 Physical Methods. Physical methods are ultrasonic radiation and precoat filtration. Ultrasonic radiation is not suitable for application to typical oily wastes from Naval installations. Heating of an emulsion will not in itself break the emulsion since it only increases the kinetic energy of both the water phase and the oil globules. The application of heat and pressure, however, will improve the separating effect achieved by the addition of caustic or acid.

Some stable emulsions can be broken by filtration. The emulsion is filtered through a layer of diatomaceous earth normally deposited on a continuously rotating drum filter. Precoat filtration is not normally recommended because of its high operating costs. For additional details, refer to the American Petroleum Institute (API) Manual on Disposal of Refining Wastes, Volume on Liquid Wastes [17].

3.9.3.2 Chemical Methods. Emulsions can be broken by chemicals which will balance or reverse interfacial surface tension, neutralize stabilizing electrical charges, or precipitate emulsifying agents. The effectiveness of various chemicals in breaking emulsions must be determined by laboratory testing. See API Manual on Disposal of Refining Wastes, Volume on Liquid Wastes [17] for the testing procedure. Coalescence and separation of oil and water phases follow chemical addition. Chemicals commonly used include alum, ferrous sulfate, ferric sulfate, ferric chloride, sodium hydroxide, calcium chloride, sulfuric acid, lime, sodium silicate, borax, sodium sulfate, and

TABLE 13
Guidelines for Oily Wastewater Treatment

TREATMENT OPTION	DESCRIPTION	COMMENTS
Gravity separation:	Separation of grease, oil, and settleable solids from water due to density differences.	Effectiveness usually restricted to removal of free oil and settleable solids.
Equalization basin	Tank or lined pond to dampen hydraulic and contaminant surges. If agitation is not employed, provide drainoff for flotables and settleables.	Provide at least two basins operated in parallel as semi-continuous process. Fill period of 5-7 d and settling period of $\leq$2 d. Provide oil skimming and sludge scraping equipment.
American Petroleum Institute (API) separator	Long, rectangular tank designed to provide sufficient hydraulic detention time to permit free and slightly emulsified (mechanical) oil to agglomerate and rise to the surface and suspended solids not entrapped in the oil to settle. Oil skimming and sludge raking required.	Design based on oil droplet diameter of 0.015 cm and is not necessarily typical of all oil-water mixtures. Relatively inefficient and requires significant amount of space. Maintenance requirements are high if maximum treatment efficiency is to be attained. See Figure 18 for details. Avoid pumping influent oily wastewater to minimize mechanical emulsification. Use as pretreatment process preceding discharge to POTW or other onsite treatment process. Low capital and maintenance costs. Minimal space requirements.
Parallel plate separation	Tank equipped with inlet, oil coalescing, and outlet compartments to enhance separation of oil and suspended solids from oily wastewater. Number of coalescing plates or tube modules dependent on flow and characteristics of oil-water mixture.	Operating requirements for cleaning plates and tubes may be high. Refer to Figure 19 for additional details. Also, refer to NAVFAC NFGS-11301, Packed, Gravity Flow Oil Water Separator [2].
Vertical tube separator	See parallel plate separator.	See parallel plate separator.
Skimming dam	Low dam or weir placed in a flowthrough channel to pond water. Floating baffle retains flotables.	Utilize to impound contaminated surface runoff or spill for gross contaminant recovery and transfer to other treatment processes. Low capital, operating, and maintenance costs.
Thermal (cooker)	Heated vessel to accelerate liquid-liquid separation.	Oil reclamation process can be effective in breaking physical emulsions but increases solubility of oil. High operating costs and are inefficient for dilute oil-water mixtures.
Coalescing (mechanical)	Induced agglomeration of small oil droplets to aid gravity separation.	Effective in breaking physical emulsions when suspended solids do not interfere. Not effective in removing chemical emulsions.
Filters	Oily wastewater applied to filter media either by gravity or by pumping. The reusable or disposable media is an oleophilic or hydrophobic packed, manufactured fibrous material or diatomaceous earth. Sand filters also used for effluent polishing.	High operating and maintenance costs. Efficiency decreases with low fluid temperatures and high oil concentrations. Wide variations in type and quantity of oil and grease reduces reliability of system. Pretreatment to remove suspended solids is usually required.
Dissolved or induced air flotation	Gravity separator using small air bubbles to lift oil globules to surface.	Effetive in coalescing physical emulsions. High density suspended solids will decrease oil removal efficiency. Moderate capital and operating costs.

TABLE 13 (Continued)
Guidelines for Oily Wastewater Treatment

Ultrafiltration	Low-pressure (50-100 psig) membrane process for separating emulsified oils. Oil droplets are retained by the membrane, concentrated and removed continuously. Usually preceded by an equalization tank and process tank.	In conjunction with gravity separation devices, effective in separating stable emulsions. High operating and maintenance costs and substantial pumping requirements.
Absorption	Penetration of one substance in one phase into the mass of another substance of a different phase.	May be effective as a tertiary process in removing low concentrations of highly emulsified or dissolved oil. High operation and maintenance costs. Highly sensitive to suspended solids.
Absorbent	Hydrophobic material with high affinity for specific oils.	For design guidance, refer to Water-Oil Separator for Fuel-Oil Handling Facilities [21], by Mootz, Chemical Engineering.
Absorption	Concentration or accumulation of a substance at the surface or interface of another substance.	May be effective as a tertiary process in removing soluble oil and chemically stable emulsions. Refer to EPA Process Design Manual, Carbon Adsorption [5].
Activated carbon	Utilize fixed, expanded, or moving carbon bed(s) to achieve desired treatment objectives.	Pretreatment ususally required to reduce suspended solids. Proper section of carbon type and optimum operating parameters. The presence of other chemicals may diminish effectiveness of oil adsorption. High capital and operating costs.
Adsorbent resin	Effectiveness based on van der Waals' adsorption rather than coulombic ion exchange.	Same as for activated carbon.
Biological	Oxidation by aerobic biological activity using fixed or suspended growth systems.	May be used as secondary treatment following primary processes that reduce suspended solids and most of free oil fraction. Requires that adequate nutrients be present and extended aeration period and mean cell residence time. Most applicable to existing biological treatment facilities.
Activated sludge, trickling filter or RBC	See MIL-HDBK-1005/8 [2] for design guidelines.	Use to remove soluble oil and break chemical emulsions. Can be utilized in combination with other treatment options discussed in this table.
Lagoon	See MIL-HDBK-1005/8 [2] for design guidelines.	Aerobic oxidation without mechanical aeration is minimal. Buildup of floating oil and sludge can promote anaerobic conditions that will result in the generation of undesirable gases. Not suitable for cold weather climate.
Chemical	Refer to Section 2 and Table 7.	Use to remove soluble oil and break chemical emulsions. Can be utilized in combination with other treatment options discussed in this table.
Emulsion breaking	System may include chemical storage and feed, flash mixing, flocculation, and settling. Chemicals used include sulfuric acid, alum, caustic soda, or activated alumina. Polyelectrolytes may be used as primary coagulant or as coagulant aid.	Usually used in conjunction with previous treatment options. Laboratory benchscale studies required for proper selection of best chemical or combination of chemicals, optimum chemical disages, and optimum pH conditions. Use actual flow-weighted oily wastewater sample during laboratory studies to achieve best results. Polyelectrolyte use as primary coagulant may significantly reduce sludge production.

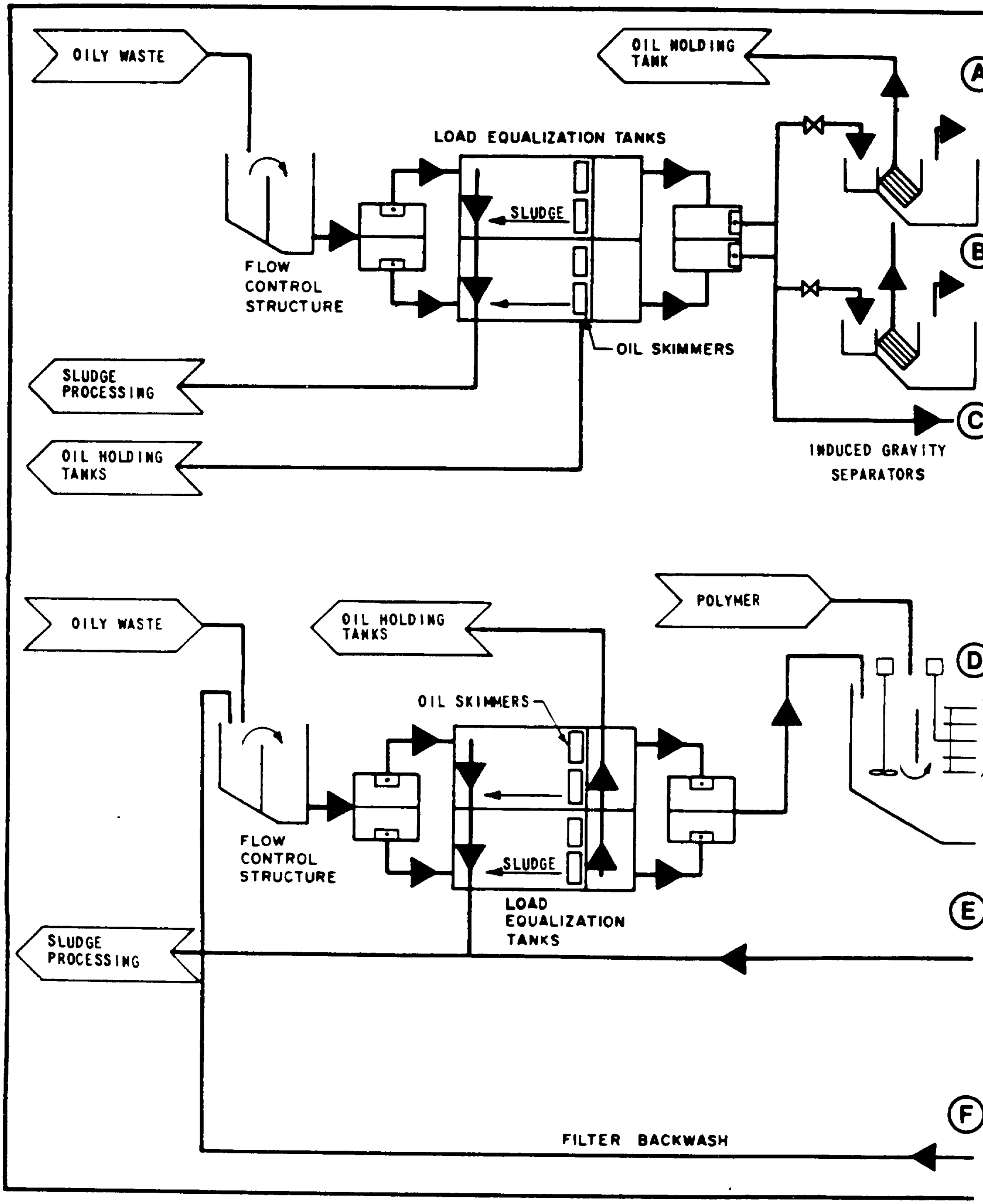


FIGURE 12A
Treatment System for Discharge to
POTW or Navigable Water

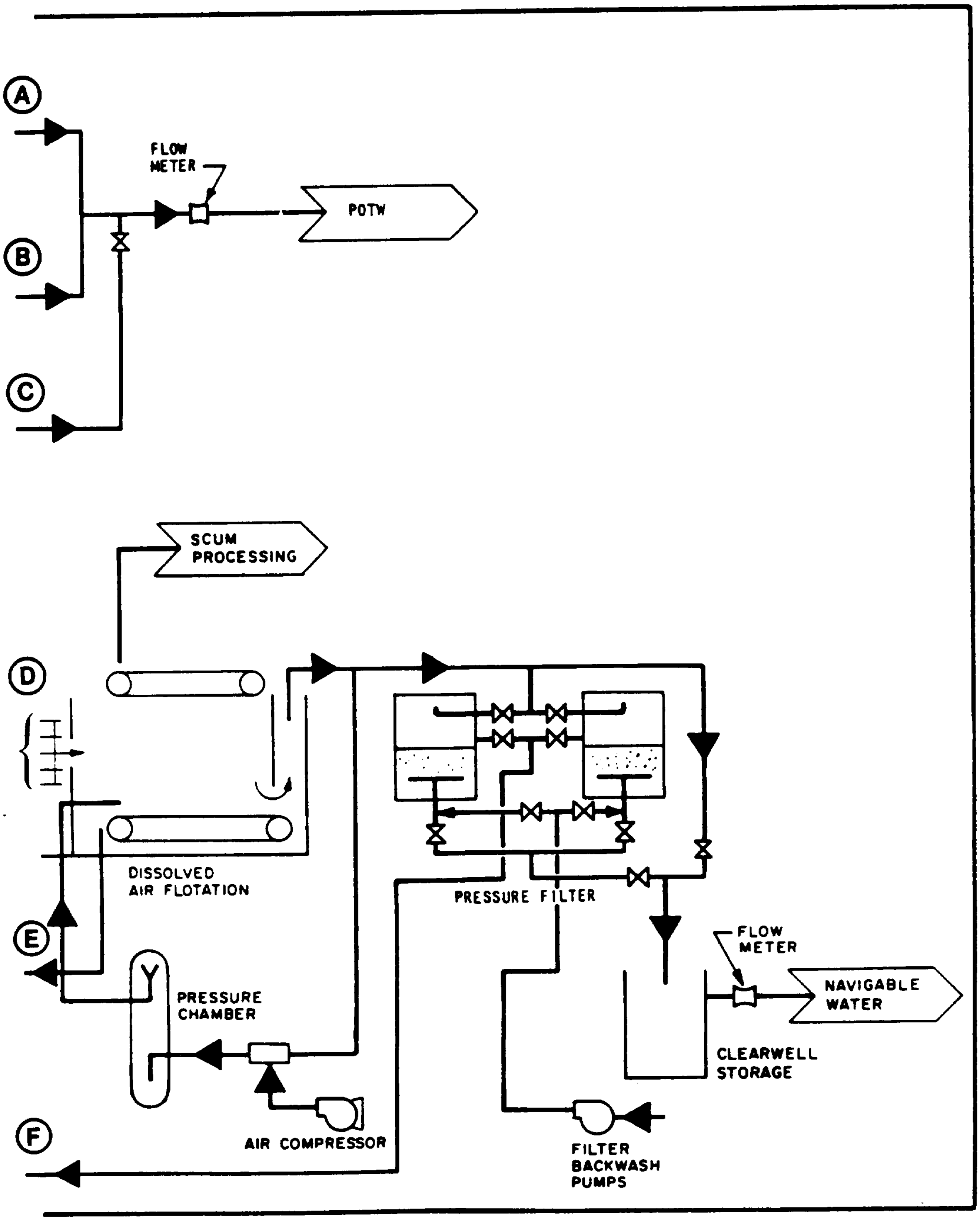


FIGURE 12B
Treatment System for Discharge to
POTW or Navigable Water

polymers. Sodium chloride (NaCl) is not recommended for "salting out" emulsions since it is slow, requires large amounts of NaCl (20-70 g/L), and results in a corrosive liquid product. For chemical handling and feeding details see Section 4.

a) Coagulants. Anionic and cationic surface-active agents are not compatible and tend to neutralize each other. Generally, reactive anions such as OH^- and PO_4^{-2} will break water-in-oil emulsions; reactive cations, such as H^+, Al^{+3}, and Fe^{+3} will break oil-in-water emulsions.

b) Operating pH. Chemical addition to form a heavy metal hydroxide flocculent precipitate can be used to break dilute oil-in-water emulsions. However, the best emulsion breakage effect by ferric chloride, ferric sulfate, and other salts is achieved in an acidic medium.

c) Wetting Agents. Wetting agents can break water-in-oil emulsions. However, correct dosage is critical as overdosing will destroy the emulsion breaking action.

d) Polyelectrolytes. Organic polymers can be used for breaking water-in-oil emulsions.

3.9.3.3 Separation of Demulsion. Separation of the oil droplets from the water after breaking the emulsion is the most vital operation in the treatment of emulsified oily wastes. Separation can be achieved in gravity settling tanks and oil separators but requires a long detention time (24-48 h). The separation process can be intensified using centrifugation, heat, filtration, or flotation.

3.9.3.4 Treatment Schemes. Alternative treatment schematics for demulsification employing gravity settling and flotation are shown on Figure 13 (batch treatment) and Figure 14 (continuous treatment).

a) Sedimentation Process. This scheme is operated as a batch process. Oily wastewater is fed to a reactor where sulfuric acid (or coagulant demulsifier) is added. Mixing is either mechanical or by injection of compressed air. To intensify demulsification and separation the reactor is heated (90-95° C) by injection of steam (if available). After sedimentation for 24-48 h the demulsified oils float to the surface of the reactor and are displaced over a peripheral weir into an oil collection and holding tank by injecting service water into the lower part of the chemical reactor. Water phase effluent has a pH of 1-2 (if sulfuric acid is used) and is neutralized with lime slurry before discharge or further treatment. See Figure 13 for treatment schematic.

(1) Advantage of this method is simplicity of equipment and technology.

(2) Disadvantages of this method are the duration of batch treatment time, consequent large unit size, and only moderate efficiency.

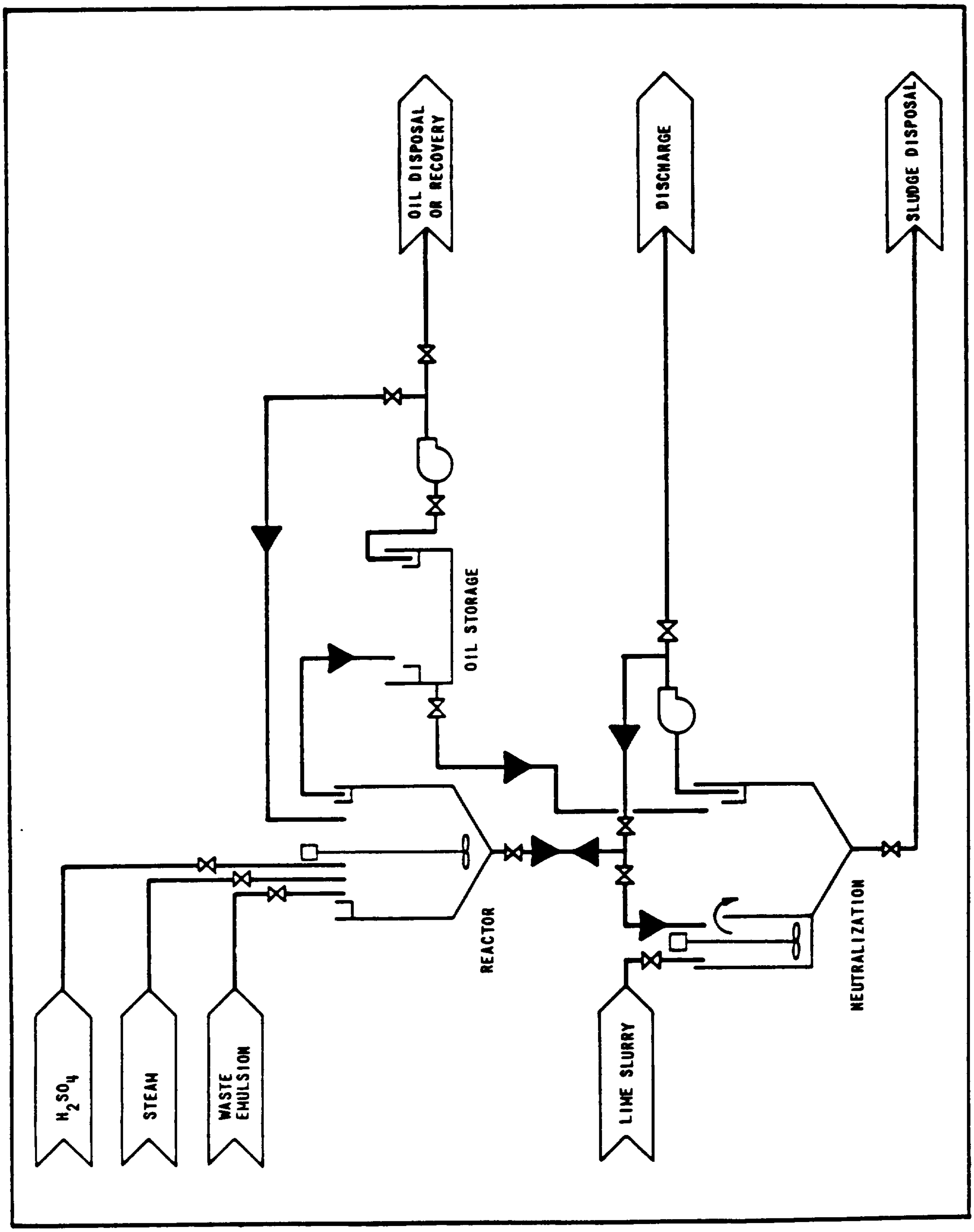


FIGURE 13
Oil Emulsion Treatment Schematic - Batch Process

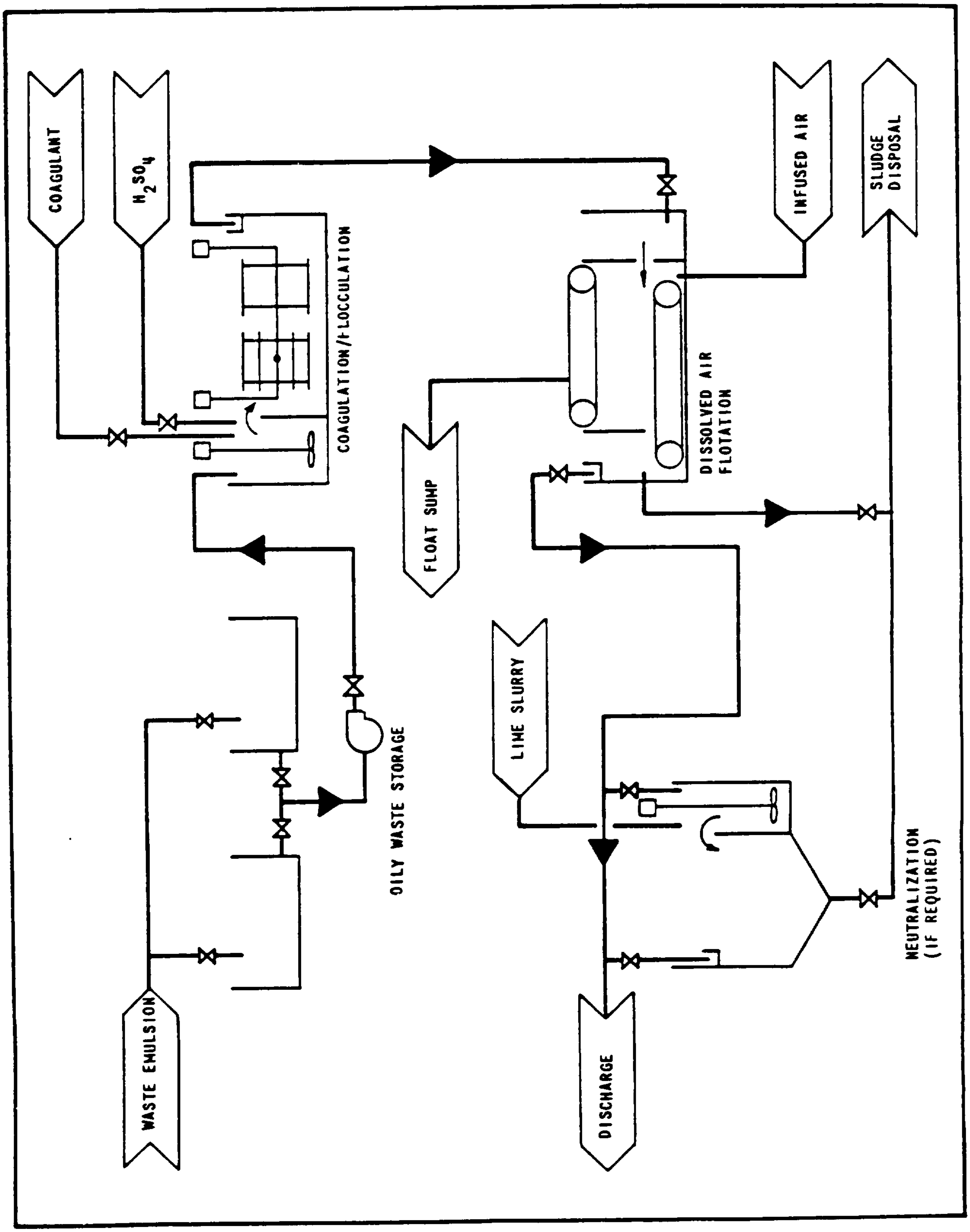


FIGURE 14
Oil Emulsion Treatment Schematic - Continuous Process

b) Pressure Flotation Process. This process is operated as a continuous flow demulsification process. Reagents may be sulfuric acid, lime slurry, iron and aluminum salts, or a combination of these depending on laboratory test results. Oily waste emulsion is fed from holding tanks to mechanically stirred chemical conditioning tanks having a 5- to 30-min contact time. Overflow is to a dissolved air flotation process. Flotation time is 5- to 15-min for practically complete oil-water separation. Underflow (water phase) is neutralized and discharged or directed to further treatment. Float (oil phase) is discharged to holding tanks, or directly to a dewatering process. See Figure 14 for treatment schematic.

(1) Advantages of the method are high efficiency (99-99.9 percent oil removal), high treatment capacity and resulting smaller unit size no heating requirement, low operational attention and cost.

(2) Disadvantages of the method are the potentially high salt content and corrosivity of the effluent.

3.10 Design Criteria for Oil-Water Separators and Appurtenances

3.10.1 General

3.10.1.1 Processes. The basic process for removing oil from wastewater is the gravity type oil-water separator. The extent to which receiving waters or treatment works are impacted by separator effluent determines whether additional treatment is required. Treatment methods available for improving separator effluent are summarized in Table 13. Gravity separators alone will not remove emulsified oils. The methods described in para. 3.9.3 are required to break emulsions.

3.10.1.2 Equipment. Consider wastewater flowrate, oil droplet size and distribution, the concentration of oil and grease and suspended solids, differences in specific gravities of wastewater components and operating temperatures in selection and specification of equipment. Gravity separators are usually used as pretreatment unit processes since effluent quality fluctuates significantly due to large variances in the quality of the influent wastewater. Construct separators in parallel to provide continuity of operation during individual unit repair, cleaning, or inspection. If waste volumes are small and adequate off-line holding tank capacity is provided, a single separator may be used.

3.10.1.3 Equalization (Surge Tank). Provide side holding tank or basin to equalize and store oily wastewater flows prior to oil-water separation. Holding facilities can be concrete or steel tanks or lined ponds. They should be covered or under roof in rainy climate and to control wildlife.

3.10.2 Load Equalization Tank (LET). The LET is a batch operated, gravity oil-water separator. Oily wastes are discharged to the LET for a predetermined collection period. Wastes are settled, the oil skimmed off to storage, and sludge withdrawn for further processing and disposal. Clarified water is passed on for additional treatment or discharge.

a) Provide at least two LETs for sequential fill and draw operation. Each tank should have a capacity equal to the average flow for 7 d. Typical settling time is 24 h. Sludge should be withdrawn daily. Longer LET operating periods or large volume upstream receiving tanks should not be used since they promote anaerobic conditions and H_2S gas production. These conditions will corrode metal and concrete, cause odor problems, and create potential health hazards when H_2S concentration exceeds 10 ppm.

b) Under certain circumstances, provision of a third LET should be considered. At larger naval installations subject to periodic surges in ship traffic in port, the capability to process sudden, abnormally high oily waste flows may warrant extra reserve capacity. At smaller naval installations where available land area imposes layout restrictions, three, reduced volume LETs may be necessary to provide operating flexibility for normal peak flow occurrences and for tank cleaning downtime. Due to the different characteristics of shore waste, a third LET should be considered for treatment of shore-generated oily waste at shore facilities where large volumes of shore-generated oily waste are to be treated with ship oily waste.

3.10.2.1 Basis of Sizing. Estimates are required of the numbers and types of berthed ships discharging to the pierside collection system or to doughnuts and SWOBs. Nominal shipboard oily waste generation rates are 50,000 gpd for aircraft carriers and 3,750 gpd for all other classes of ships. Estimates of barge and tank truck delivery volumes and frequencies should be compiled from historical records.

Alternatively, LET size could be based on analysis of Qdaily, Qmax, and Qpeak established for design of pierside collection systems. Refer to para, 3.8.1.3 for methodology for determining these flow rates.

3.10.2.2 Layout. Use rectangular, reinforced concrete tanks. The following guidelines for LET layout are suggested. See Figure 15 for a schematic of a LET.

	LET 7-DAY CAPACITY	
CHARACTERISTIC	0.1 to 0.5 Mg	1.0 to 1.5 Mg
Length:Width	3:1	5:1
Depth (ft)	10 ft	20 ft
Freeboard (ft)	1.5 ft	1.5 ft

At smaller naval installations, where LETs of less than 15,000 gal capacity are required, a circular steel LET may be more cost-effective than a rectangular concrete LET. Based on the quantity of material required and local availability and cost of materials, the circular tank could be less expensive to fabricate. The circular tank design also may allow more efficient use of available ground for system layouts on smaller parcels of land.

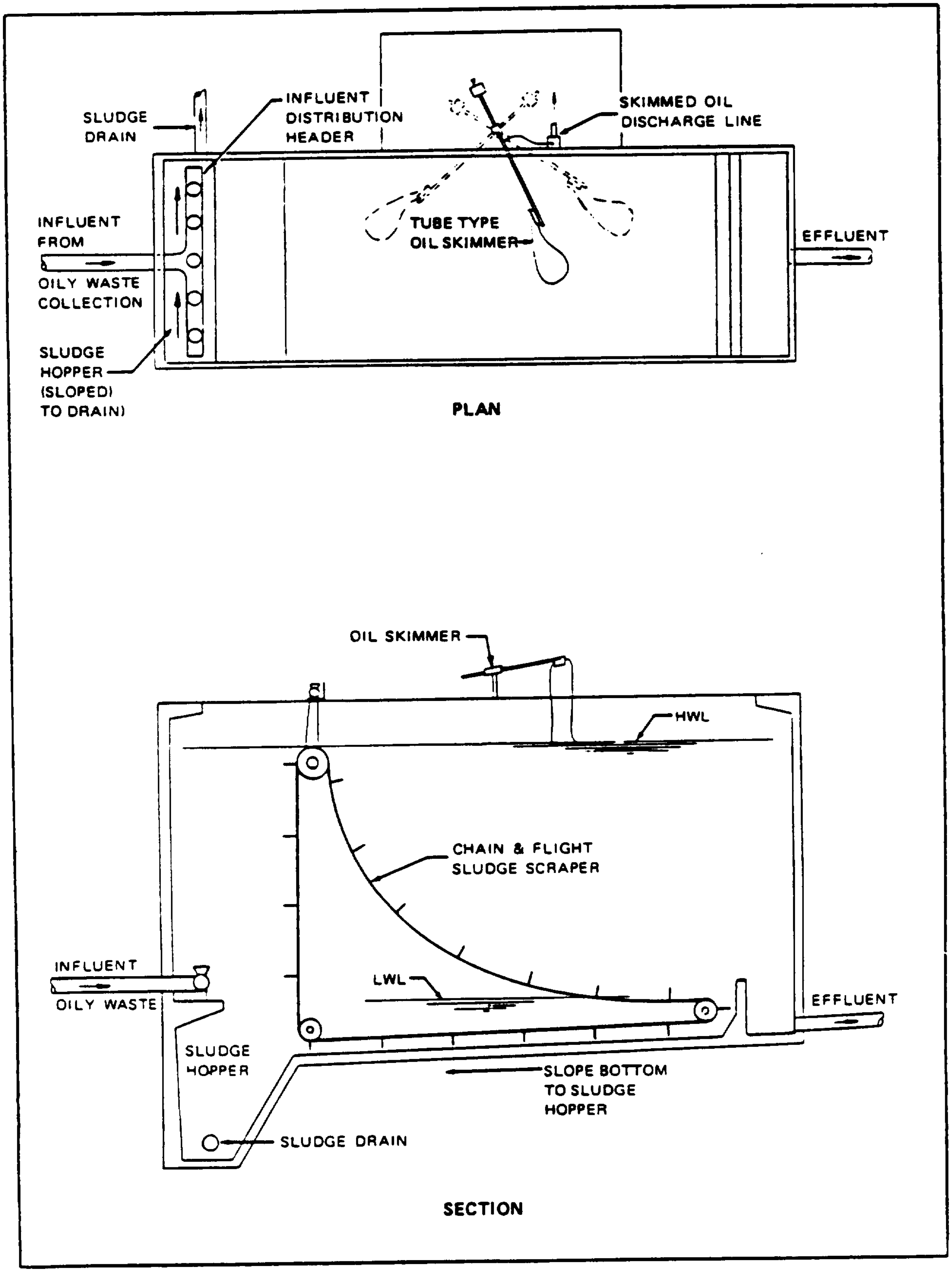


FIGURE 15
Land Equalization Tank (LET)

Where facility topography will permit, LETs should be located out of ground to facilitate gravity flow to downstream processes or the discharge point.

Example Calculations 1 and 2 give further guidance on LET sizing.

a) Example Calculation 1 - LET Sizing.

Given: Daily Discharge from Pierside Collection System, Qdaily = 70,000 gpd

Required: LET to receive for 7 days.

LET Volume = (70,000 gpd)(7 days) = 490,000 gal
(490,000 gal)(1 ft^3/7.48 gal) = 65,508 ft^3

Use 10 ft depth per guidelines
65,508 ft^3/10 ft = 6,551 ft^2 surface area

Use 3:1 length to width ratio per guidelines
$(3w)(w) = 6{,}551\ ft^2$
$w^2 = 2{,}183.6$
$w = 46.7$ ft; try 50 ft width

Try LET size 50 ft x 150 ft x 10 ft deep

Check total volume and freeboard at 7-day oily waste volume -
(50 ft)(150 ft)(10 ft)(7.48 gal/ft^3) = 561,000 gallons

Freeboard volume = 561,000 - 490,000 = 71,000 gallons
LET Volume per foot of depth
(50 ft)(150 ft)(1 ft)(7.48 gal/ft^3) = 56,100 gal/ft

Freeboard available
71,000 gal/56,100 gal/ft = 1.26 ft = 15 in.

Therefore, use LET size 50 ft wide by 150 ft long by 10 ft deep.

(2) Example Calculation 2 - LET Influent Header Outlets:

The recommended equation for determining the number of outlets on the distribution header is:

EQUATION: $$No = .4085\ Qmain/Vo\ (Do^2) \qquad (13)$$

Where: No = Number of outlets on distribution header.
Qmain = Instantaneous flowrate from pierside collection system pumping station, gpm.
Vo = Desired velocity of flow from distribution header outlets, fps. Suggested value 0.5 fps for first trial.
Do = Diameter of outlet openings in distribution header, in. Use standard flare diameter based on header diameter for first trial.

In this example, Qmain is estimated from the average daily flow using an assumed peaking factor of 3. In actual design of a LET, Qmain would be available from the pierside pumping station design or the actual pumps used in an existing pierside pumping station. Qmain is determined by Equation (5).

For Example Calculation 1 LET daily discharge rate from pierside of 70,000 gpd.

Assume Qmain = (70,000 gpd)(1 day/1,440 min)(3-peaking factor)
= 146 gpm
Vo = 0.5 fps
Do = 8 in.
No = $[(.4085)(146)]/[(1.5)(8)^2]$

No = 1.86

Therefore, use two flared outlets.

3.10.2.3 Sloping Bottom. The bottom of the LET shall slope from the outlet end back to the inlet end at about 1/8 in. per ft (10.4 mm/m) of tank length. This will facilitate the transport of settled solids to a solids collection hopper at the inlet end of the LET. The collection hopper bottom shall slope from side to side at about 1/4 in. per ft (20.8 mm/m), with a sludge withdrawal at the low side.

3.10.2.4 Sludge Scraping Mechanism. Provide chain and flight sludge scraping mechanism. Fabricate major components from nonmetallic materials (such as nylon resins) to avoid corrosive effects of salt water in oily waste. Specify fiberglass flights spaced 6 to 10 ft (1.8 to 3.05 m) apart. Specify polyurethane wear shoes to protect edges of flights from abrasion damage by the tank bottom rails and tank side track angles. Specify carbon steel for drive chain, drive sprocket, shaft sprockets, and shafts. Drag chain may also be specified as a high strength nylon resin such as Delrin. Specify that carbon steel components be shop-finished as follows: blast clean per Steel Structures Painting Council Procedure SP-5; shop prime and finish coat with coal tar epoxy, similar to Carboline Carbomastic 3 and 14, 5 to 7 mils minimum dry thickness.

3.10.2.5 Oil Skimmer. Provide means of removing oil from surface and discharging to waste oil storage tank. Mechanical simplicity and efficiency and waste oil characteristics are most important equipment selection criteria.

Two types of mechanical skimmers are described in subparagraphs a) and b). In most situations the flexible tube type skimmer is recommended for removal of floating oil. It requires little maintenance, can operate continuously and unattended, provides a high recovery efficiency, and can be variably positioned for optimum coverage of LET area.

a) Flexible Tube Skimmer. This unit provides excellent removal rates of all types of waste oils, greases, and floating sludges, and it minimizes the removal of water with the waste oil. The unit consists of a flexible, polyurethane collector tube which is long enough to enable 16 ft (4.9 m) of tubing to be in contact with the water surface at all times. Floating oil, grease, and sludge adhere to the surface of the tube and are thus skimmed from the surface. The tube is circulated through a drive unit where scrapers clean the surface and divert waste oil to storage. A typical installation features the drive unit mounted at the end of a beam that is cantilevered from a mounting post at the side of a tank or basin. The unit should be mounted near the discharge end of the LET. For tanks ≤20 ft (6.1 m) wide, one unit may be sufficient. Tanks over 20 ft wide should be provided with two units mounted on opposite sides of the tank. Operating 24 h/d, these units can remove up to 240 gpd (908.4 Lpd) for light oils, 600 gpd (2271 Lpd) for medium oils, and 1,440 gpd (5450 Lpd) for heavy oils. For cold climate installations, the drive head/skimming assembly should be enclosed insulated, and heated. Figure 16 illustrates a flexible tube skimmer installation.

b) Floating Weir Skimmer. This skimmer type uses an adjustable weir to set the overflow depth below the oil layer surface. These units are best applied to installations where separated oil is allowed to accumulate for a number of days and is then skimmed in a single operation. This differs from the continuous or daily intermittent operating scheme for the tube or mop type skimmer. There is a greater potential for skimming significant amounts of water with the weir-type device. The floating, weir-type skimmer is usually connected to a pump with a flexible hose. This enables an operator to manually move and position the skimmer for optimum interception of pockets of accumulated oil, if the layer is not continuous or is disturbed by skimming turbulence. In some units, varying the pumping rate will change the submergence level of the weir. Thus, a higher pumping rate can be used for initial skimming operations, and as the oil layer decreases in thickness, the pumping rate can be reduced to raise the weir and minimize the potential for water carryover. Average pumping rates of 6 to 7 gpm (23 to 26.5 Lpm) are suggested, with the maximum recommended rate at 10 gpm (38 Lpm). Since they operate in contact with and are partially immersed in the oily waste, floating weir-type skimmers should be constructed of plastic or stainless steel. Figure 17 illustrates a floating weir skimmer installation.

3.10.2.6 Sample Taps. Sample taps shall be provided along one wall of the LET, near the discharge end, spaced at one ft maximum depth intervals. For accessibility, they should be adjacent to and follow the incline of the tank top access stairway. Each tap should consist of a piece of 1-in. (25.38 mm) diameter PVC pipe, with length equal to the wall thickness plus 6 in. (152.3 mm), and with a 1-in. diameter PVC ball valve at the sampling end outside the tank. The through wall pipes should be set when the tank wall is formed and poured. The exterior surface of the pipe should be roughened prior to setting in the forms to ensure a good bond with the concrete, and a grout ring should be provided at the midwall point as a precautionary obstruction to leakage along the pipe surface through the wall.

3.10.2.7 Water Supply. A water supply with minimum delivery of 15 gpm (57 Lpm) at 40 psig (276 kPa) shall be provided around the top of the tank. At least two discharge points with hose bibb outlet controls should be provided on tanks less than 100 ft (30.5 m) long. For tanks longer than 100 ft, three or four outlet points should be provided. In areas subject to extremely cold weather, freezeless hydrants shall be provided in lieu of hose bibbs. The water supply will be used for tank cleaning, foam control, and general housekeeping; therefore, potable quality is not essential. If a source of nonpotable, service water is available at a facility, it should be used for the LET supply. If it is necessary to tap the LET supply from the potable water system, a suitable backflow preventer must be installed in the LET supply line immediately downstream from the tapping point.

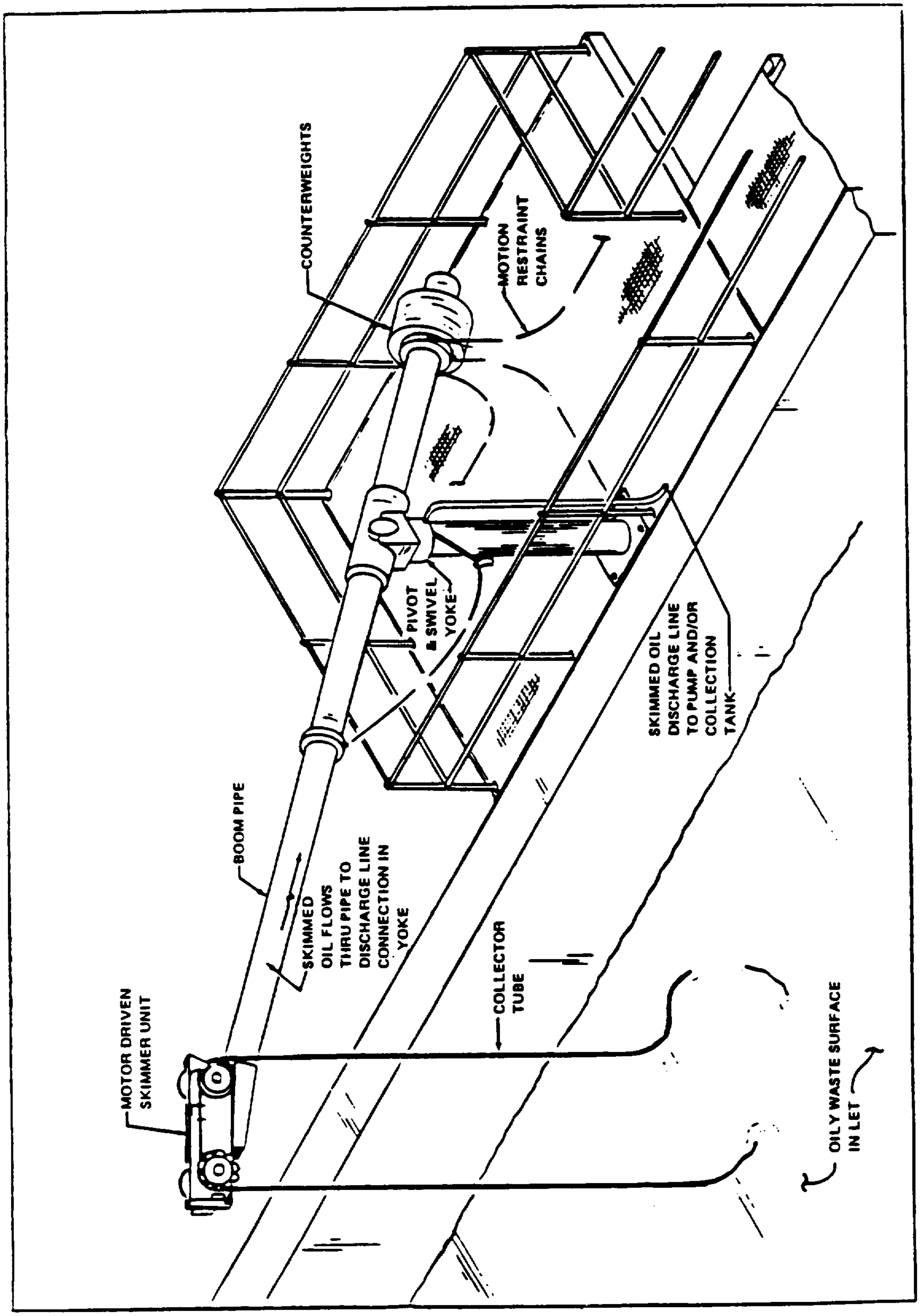


FIGURE 16
Tube Type Oil Skimmer Installation

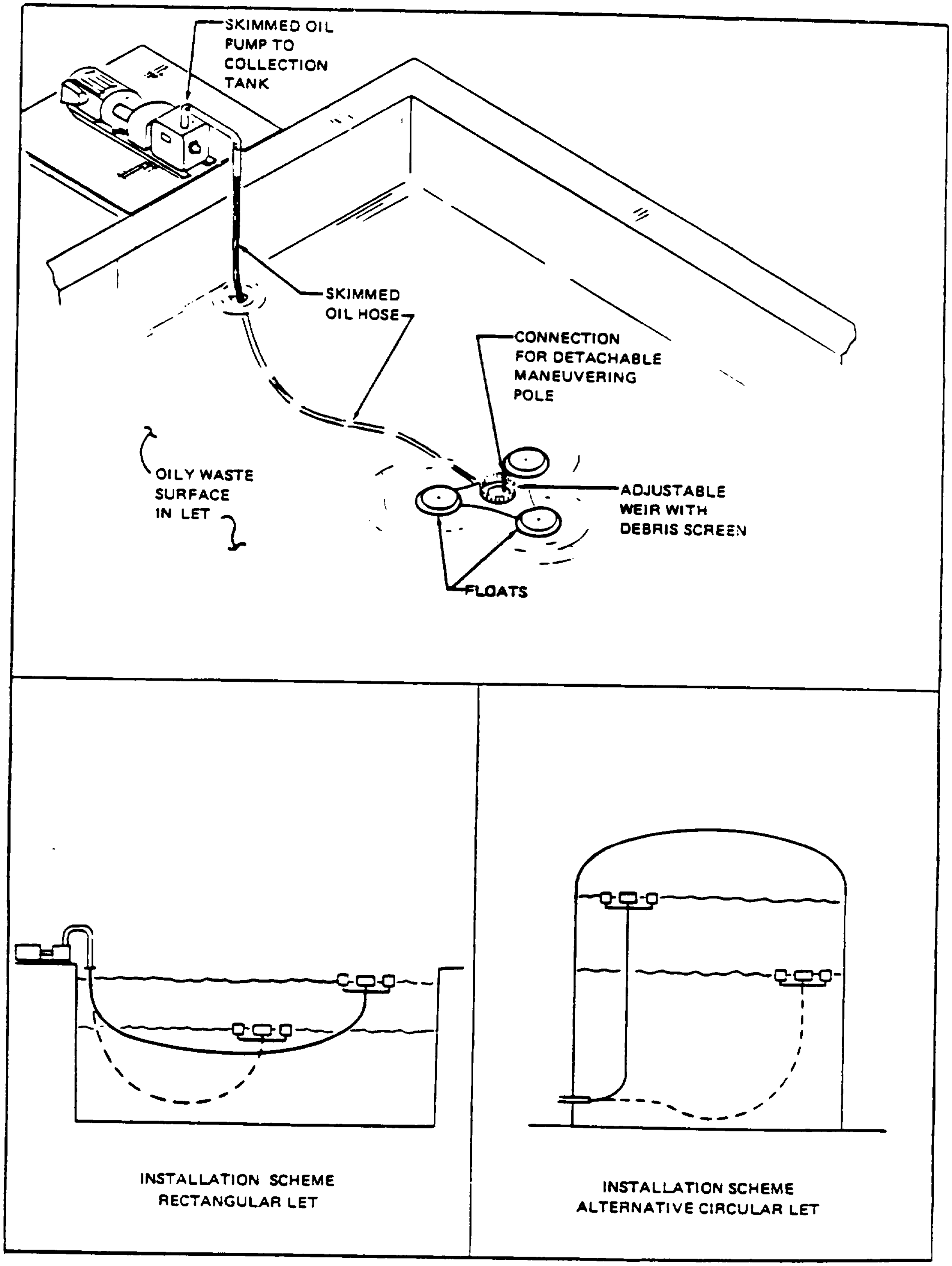


FIGURE 17
Floating Weir Type Skimmer Installation

3.10.2.8 Corrosion Protection. To ensure long-term structural integrity of the LET, protective coatings shall be applied to both the interior and exterior concrete wall surfaces. For interior surfaces, a coal tar epoxy coating system, similar to Carboline Carbomastic 14, is recommended. These coatings are typically two component mixtures with a curing agent added just prior to use. The coating should have a high build characteristic, allowing application thicknesses of 8 to 10 mils. Two coats should be applied for a total dry thickness of at least 16 mils.

For exterior surfaces, a flexible epoxy-amine coating system, similar to Carboline 188, is recommended. The system shall consist of two or three coatings: a primer and a high build finish coating; or a primer, an intermediate high build coating, and a finish coating. For either combination, the system should have a total dry film thickness of at least 10 to 11 mils.

3.10.3 API Separator. Use methods and criteria given in API Manual on Disposal of Refinery Wastes, Volume on Liquid Wastes [17], to design API separator, subject to the limitations presented in Table 14. For general arrangement and vertical slot inlet baffle detail, refer to API Manual on Disposal of Refinery Wastes, Volume on Liquid Wastes [17], and Figure 18.

TABLE 14
API Separator Design Criteria

DESIGN PARAMETER	DESIGN FLOW RATE (gpm) ≤185	DESIGN FLOW RATE (gpm) >185
Maximum surface loading, gpd/ft^2(1)	1,000(2) to 2,000	1,000
Length:Width (minimum)	4:1	4:1
Depth:Width	1:1 (maximum)	0.3:1 to 0.5:1
Minimum depth, ft(3)	3	5
Maximum horizontal velocity, fpm	2	2

[1]Based on maximum 24-h flow with one tank out of service.
[2]Use lower value if separator is only form of treatment. Use higher value if separator is a pretreatment or intermediate component of a multi-unit treatment system or if effluent quality complies with POTW discharge regulations.
[3]Increase depth to provide oil and sludge storage volume as required.

3.10.4 Induced Gravity Separator. The induced gravity separator removes free and dispersed oil to produce an effluent that has 25 to 50 ppm oil. The oil is removed by passing water at laminar velocity through a pack of closely spaced plates on an incline of 45° to 55°. The oil droplets rise and are trapped along the bottom of the plates. The oil droplets coalesce and gradually move upward along the bottom of the plates, eventually collecting at the surface of the tank. Suspended solids settle to the bottom. The separator should have adequate capacity in the sludge well to collect these solids and should have a sludge pump. An automatic valve, if sludge transfer

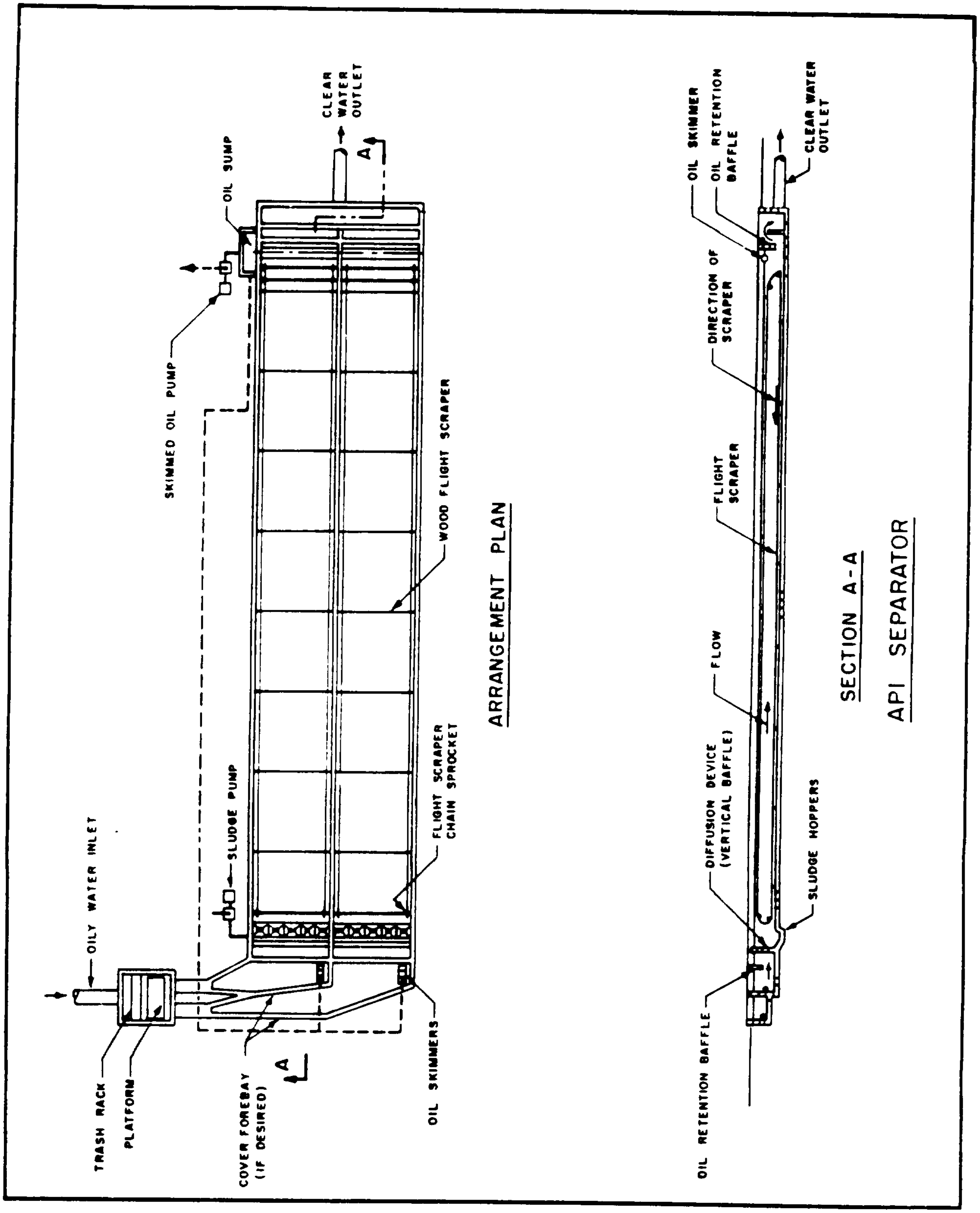


FIGURE 18A
API Separator

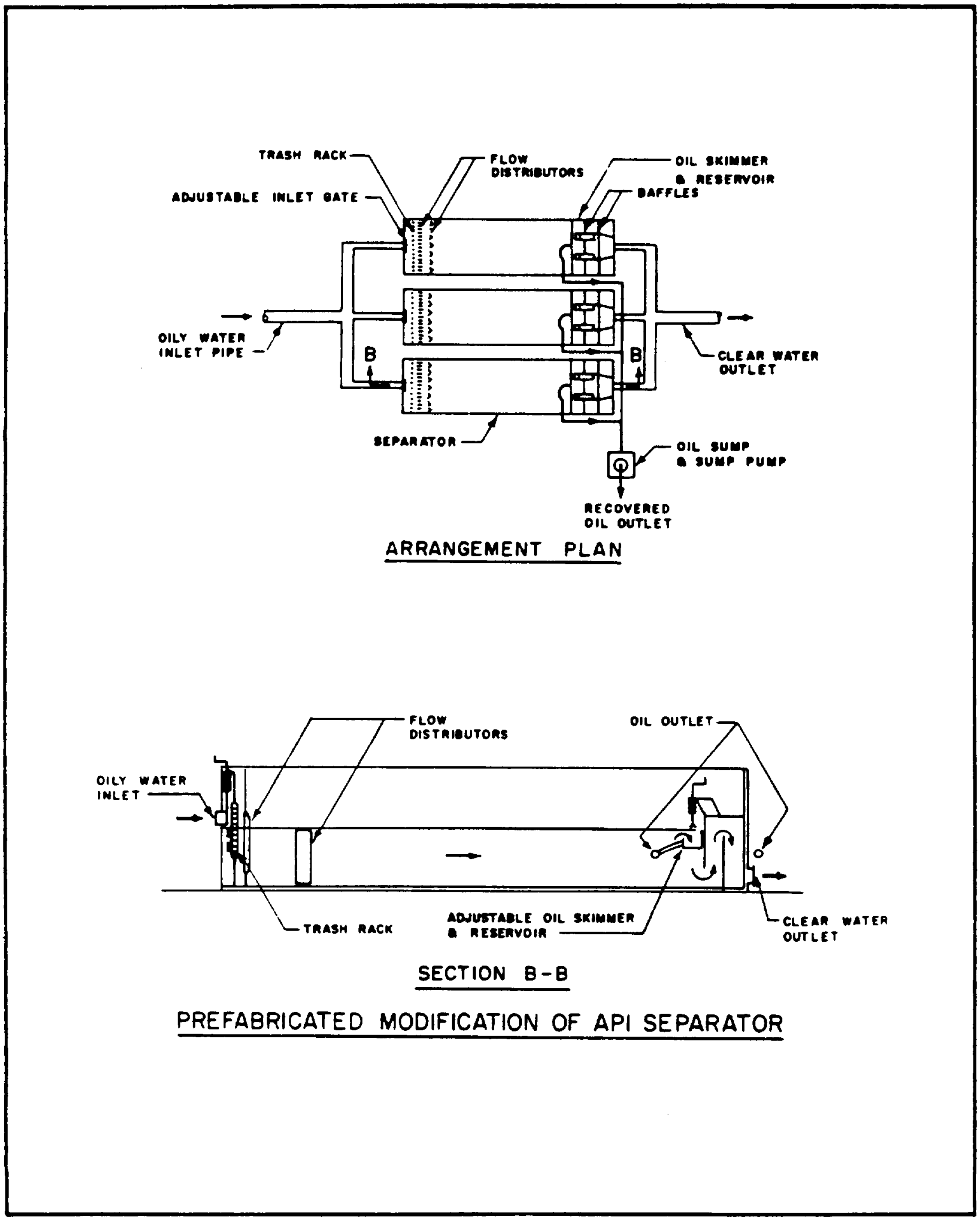


FIGURE 18B
API Separator

is by gravity displacement, should be provided and operated frequently to avoid excessive buildup. Refer to Figure 19 for alternative types of induced gravity separators. Specific design features of induced gravity separators vary among manufacturers.

3.10.4.1 Parallel Plate Separator. Use the wastewater characteristics developed in accordance with Section 3. Refer to paras. 3.7.2 and 2.7.4 to design separator for removal of free oil and, if required, suspended solids. Locate units above ground or partially buried. Protect buried units against flooding from surface runoff by locating a minimum of 8 in. (203 mm) above grade. Consider the following during design:

a) Tanks should be fabricated from carbon steel and coated inside and outside with coal tar epoxy. Preferred construction materials for plate packs are a frame of type 304 stainless steel with individual plates of fiberglass. Refer to Table 15 for basic design data and Figure 19 for typical plate separator arrangement. The exact dimensions and orientation of the separator (crossflow inclined, crossflow horizontal, and downflow inclined) will vary with separator type and manufacturer.

b) Provide adequate cathodic protection.

c) Minimize hydraulic surge effect on separator by use of variable speed pumps, flow control valves, or by an upstream surge tank with gravity feed through an upstream control orifice.

d) Refer to NAVFAC NFGS-11301, Packed, Gravity Oil/Water Separator [2], for additional design information.

e) Example Calculation 3 - Determination of Required Number of Plates.

Determine required number of theoretical plates and number of plate packs as follows:

Given: (From Example Calculation 1 preceding):
LET Volume = 490,000 gal
Assume LET contents must be processed through an induced gravity separator in 16 hours.

Influent Flowrate to Separator (Q_I)

$$Q_I = 490{,}000 \text{ gal/16h} \times \text{1h/60 min} = 510 \text{ gpm}$$

Recommended Surface Loading Rate (Q_{SR}):

$$Q_{SR} = 200 \text{ gpd/ft}^2$$

Convert to gpm/ft^2

$$200 \text{ gal/(day/ft}^2) \times 1 \text{ day/1440 min} = 0.1389 \text{ gpm/ft}^2$$

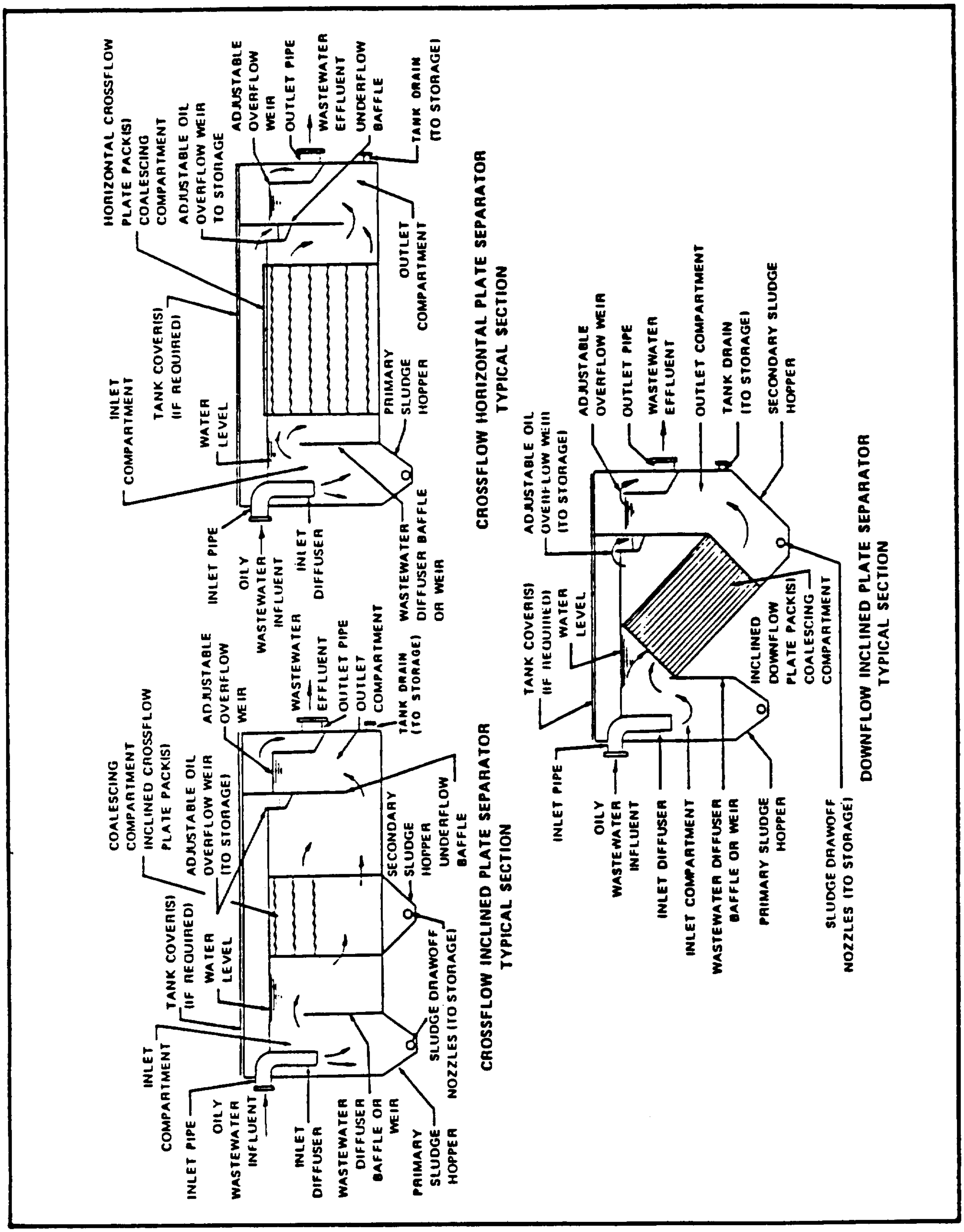


FIGURE 19
Induced Gravity Separators

TABLE 15
Parallel Plate Oil-Water Separator Design Data[1]

DESIGN PARAMETER	DESCRIPTION
Inlet pipe:[2]	
Diameter	6-in. minimum.
Velocity	Use minimum that will avoid suspended solids deposition in pipe. Approximately 2 fps for grit-bearing wastewater.
Diffuser.	By manufacturer. Reduce momentum to avoid short-circuiting.
Inlet compartment:	
Dimensions	A function of the flowrate and settleability of the suspended solids. Maximum surface loading rate of 1,000 gpd/ft^2. Determine actual design surfaceloading in benchscale experiments.[3]
Primary sludge hopper	Optimum hopper angle of 55° (from horizontal). Do not use slope less than the angle of repose for material removed. Hopper volume determined by volume of suspended solids removed and sludge drawoff schedule. Provide $\geq$10% of compartment volume.
Primary sludge drawoff	4-in. minimum diameter connection with plug valve.
Diffuser baffle (weir)	By manufacturer. Distribute oily wastewater evenly across packed plate inlet.
Overflow weir	Sharp crested, vertically adjustable, length as necessary to establish laminar flow velocity to plate pack compartment.
Coalescing (Plates) compartment:	
Inclined plates	
Plate type	Corrugated preferred.
Spacing	Range: 1/2-in.[4] to 1.0-in.
Angle	Range: 40° to 60° (from horizontal).
Plate pack orientation	Downflow preferred.
Effective separation area[5]	
Downflow	100 to 1,000 ft^2 per pack.
Crossflow	270 to 2,220 ft^2 per pack.
Loading rate	Determined from benchscale experiments and based on effluent quality requirements. Typically, 100-200 gpd/ft^2.
Number of plates	See Example Calculation 3. Will vary slightly among manufacturers based on plate characteristics and standard pack sizes.
Horizontal plates[6]	
Spacing	1/2-in.[4] to 1.0-in.
Angle	Zero degrees (from horizontal).
Plate pack orientation	Crossflow with respect to corrugations.
Effective separation area	60 ft^2 per pack.
Loading rate	Determined from benchscale experiments and based on effluent quality requirements. Typically, 100-200 gpd/ft^2.
Oil overflow weir	Sharp crested vertically adjustable. If discharge is directly to outfall sewer, provide V-notch weir for flow measurement.
Secondary sludge hopper	Same as Primary Sludge Hopper of Inlet compartment.
Secondary sludge drawoff nozzle	4-in. minimum diameter with plug valve.
Underflow baffle	Underflow velocity not to exceed 4 fpm.
Outlet compartment:[2]	
Overflow weir	Sharp crested vertically adjustable.
Secondary sludge hopper	Same as Primary Sludge Hopper.
Secondary sludge drawoff	4-in. minimum diameter nozzle
Underflow baffle	Underflow velocity not to exceed 4 fpm.

[1]Refer to manufacturer's product bulletin for equipment descriptions, exact dimensions, and location of appurtenances. Also, see NFGS-11301 [2].
[2]Influent invert elevation established by collection system design. Set outlet invert elevation a minimum of 3 in. below inlet invert.
[3]Average rate to be used for preliminary unit sizing only. Supply manufacturer with oily wastewater flow and characterization data described previously in this section to determine actual design loading rate.
[4]Plate spacing <1/2-in. not recommended due to inherent presence of suspended solids.
[5]Actual effective separation area is a function of the plate angle, corrugation dimension, and plate dimension.
[6]Limited effectiveness in preventing reentrainment of suspended solids in wastewater stream since sludge storage hopper not an integral part of standard equipment.

Plate Surface Area (A_p) normally available from manufacturer's data

$$A_p = 20 \text{ ft}^2/\text{plate}$$

Determine:

Total Plate Area Required (A_t)

$$A_t = Q_I/Q_{SR} = 510/(0.1389 \text{ gpm/ft}^2)$$

$$A_t = 3{,}672 \text{ ft}^2$$

Number of Parallel Plates Required (N_p)

$$N_p = A_t/A_p = 3672 \text{ ft}^2/(20 \text{ ft}^2/\text{plate})$$

$$N_p = 183.6$$

Use 184 plates, minimum

3.10.5 Skimming Dam. Locate low dam or weir in drainage channel at least 50 ft (15.2 m) downstream from the nearest storm drain outlet to pond water; provide an open port in the dam to drain the pond in dry weather. Design a port to accommodate estimated dry weather flow. Refer to Figure 20 for details. Use float and boom to trap and divert floating oil and grease to the side of channel. Ensure that floating diversion boom extends at least 3 in. (76 mm) below surface of water. Provide a movable belt skimming device to skim oil to a collection hopper for storage. Design a channel for a maximum horizontal velocity of 12 fpm (3.66 m/min), based on rainfall intensity-duration-frequency curve data for a 1-year frequency storm at the specified geographical location. Contact Federal, state, and local regulatory agencies to determine the adequacy of this storm frequency interval. Consider surrounding topography and drainage basin characteristics when establishing channel dimensions; the minimum length of channel should be 50 ft. Avoid surcharging storm sewer outlets at high water level.

3.10.5.1 Diversion Pond. A skimming dam does not remove oil immediately from the flow since it relies on the oil skimmers. It is sized for a relatively small storm event to minimize the backwater effect in the storm drainage channel. Use a separate diversion pond to accommodate potential large oily waste spills and more intense storm events. This prevents washout of the oil over the skimming dam before it can be removed. See Figure 21 for details.

3.10.6 Dissolved Air Flotation (DAF). The DAF unit removes emulsified oil through the use of chemical coagulants and rising air bubbles. The coagulants cause the minute oil droplets to agglomerate into larger floc particles. The air bubbles adhere to these particles causing the oil to rise rapidly to the surface. The DAF unit is usually installed above ground and will often require pumping of influent flow. The DAF unit is divided into two sections. The influent enters a flocculator chamber where it is mixed with coagulant. The oily waste then flows into the flotation section. This section has a skimmer on the surface to remove the scum and an outlet to remove the settled sludge from the bottom by gravity displacement or pumping. Refer to Figure 22 for a schematic representation of a DAF unit.

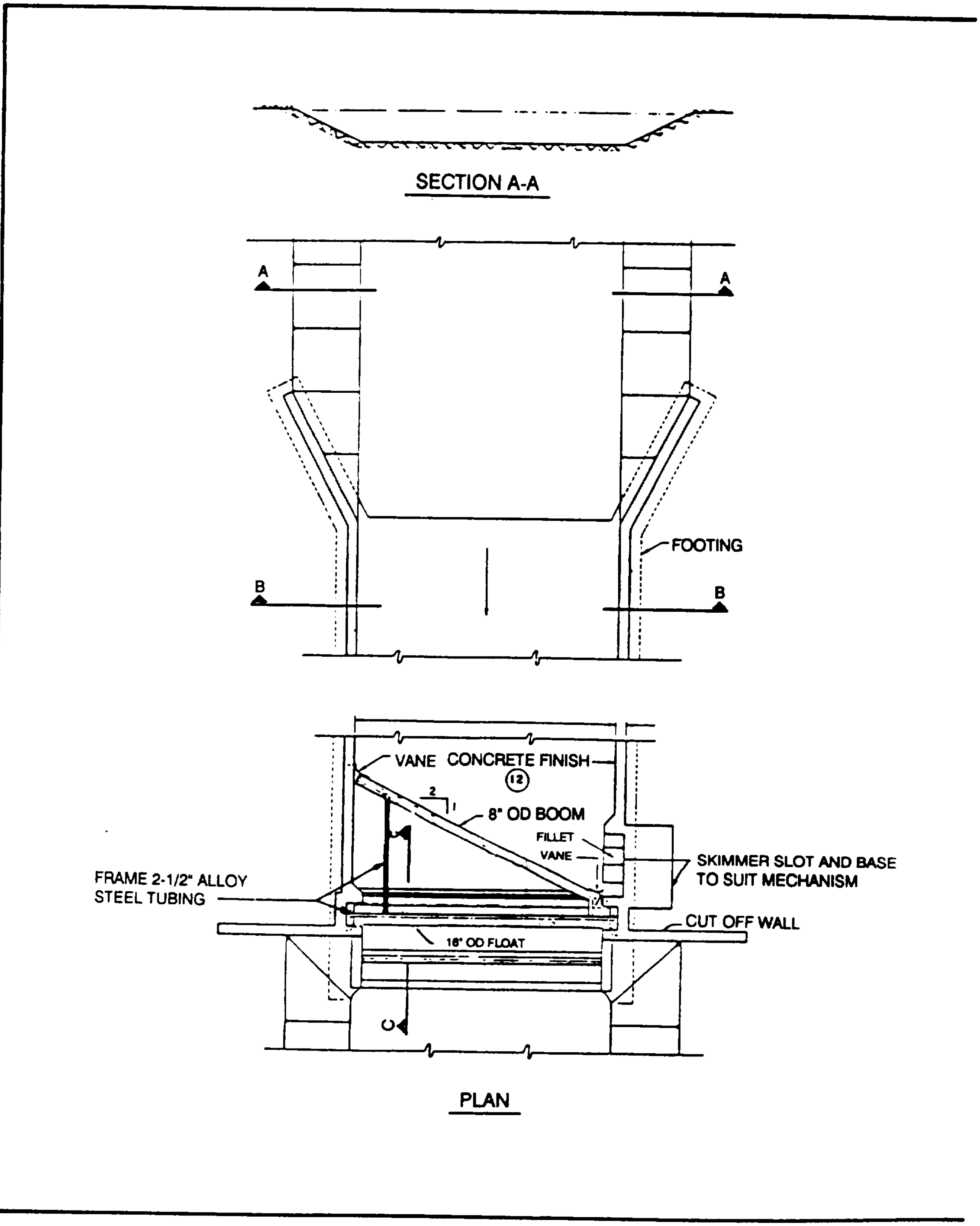


FIGURE 20A
Skimming Dam Details

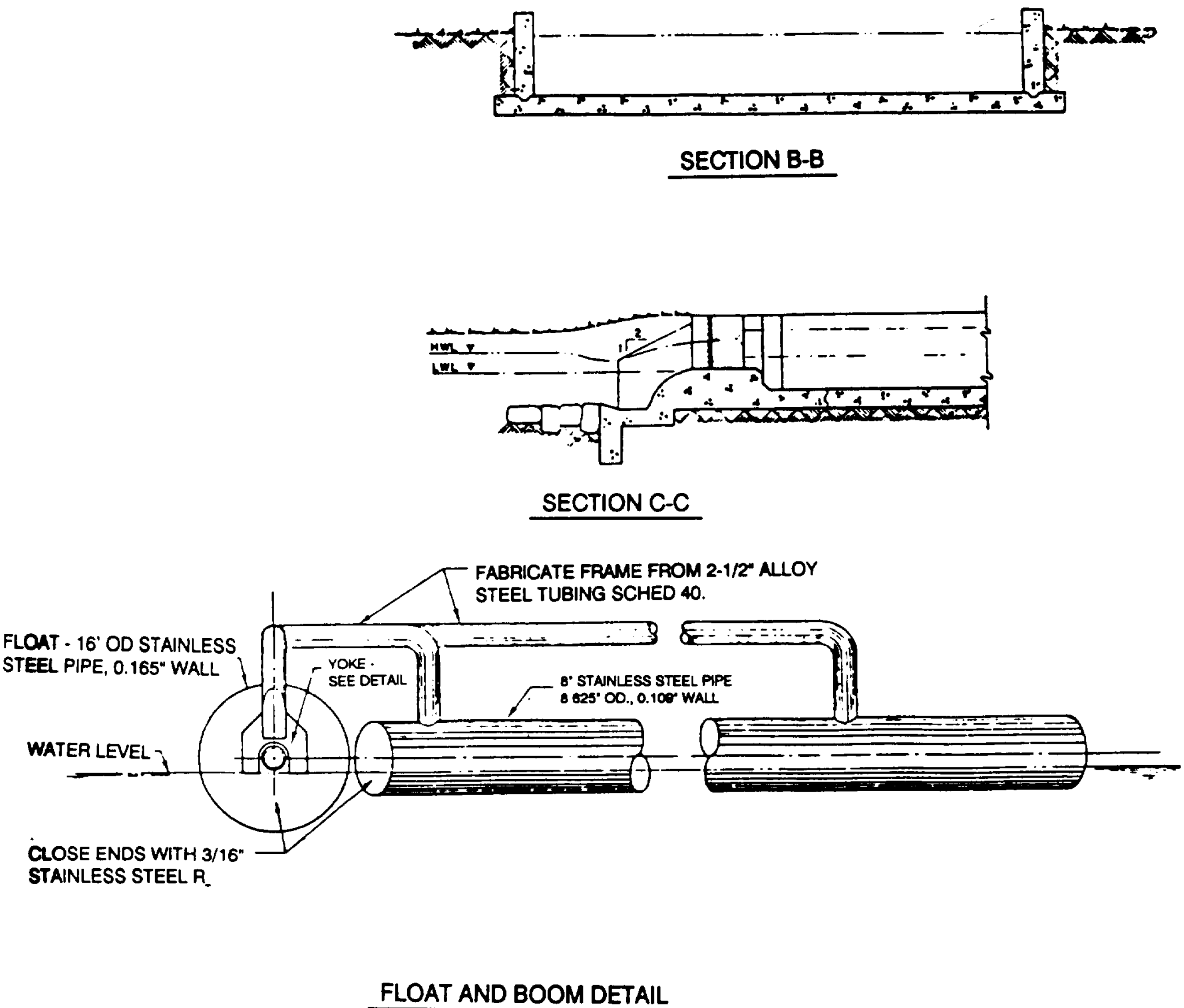


FIGURE 20B
Skimming Dam Details

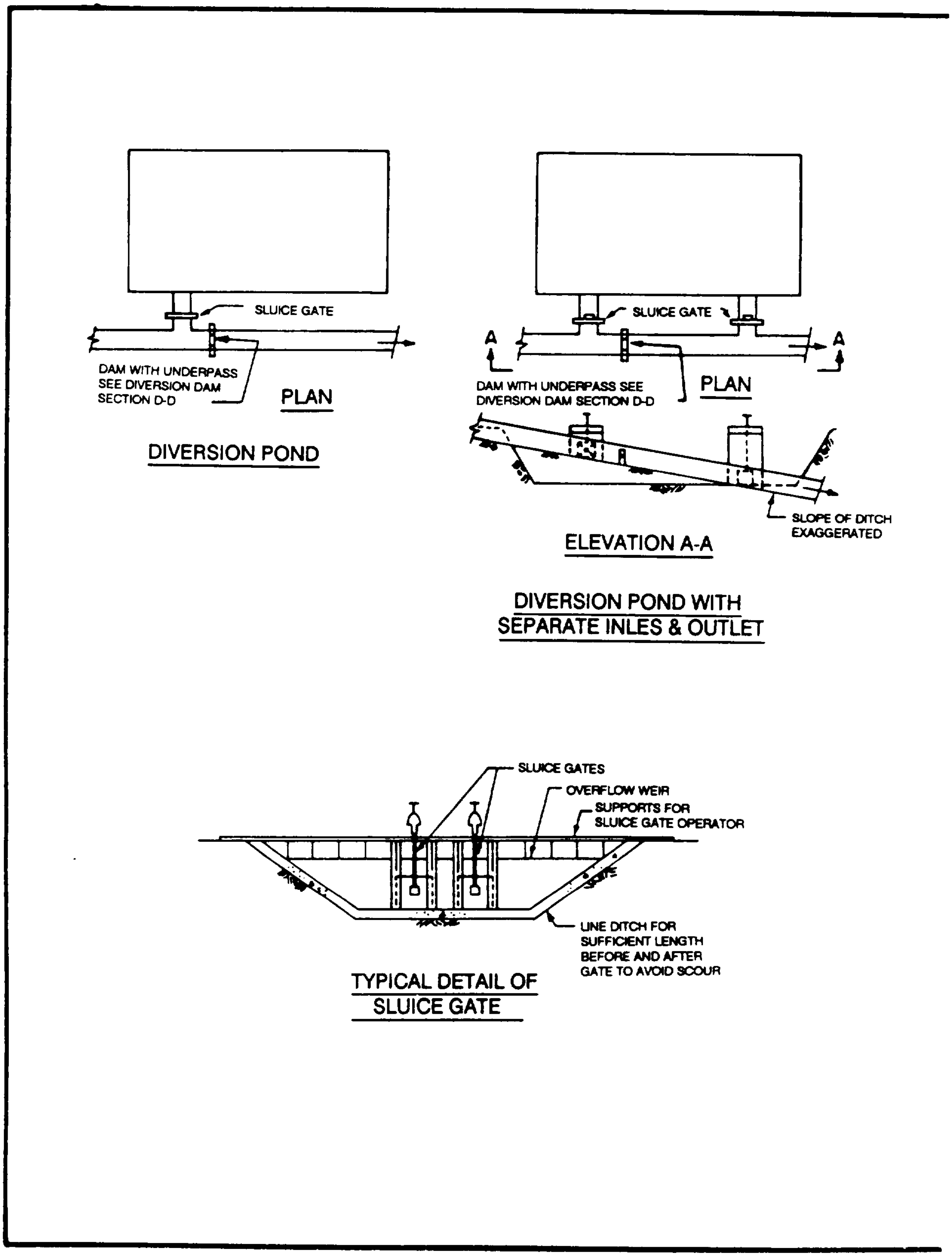
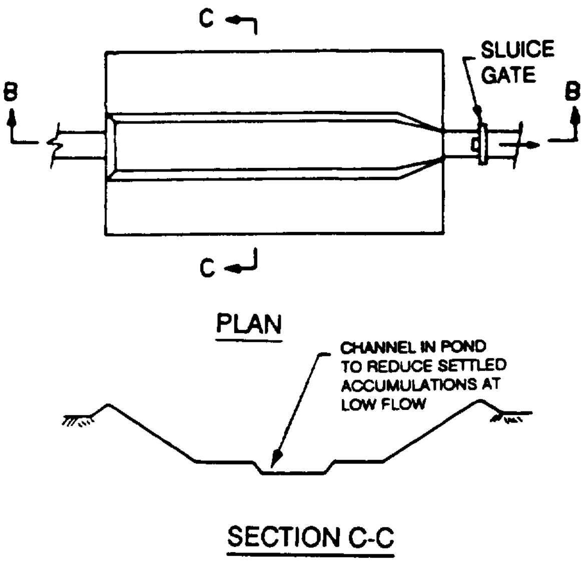
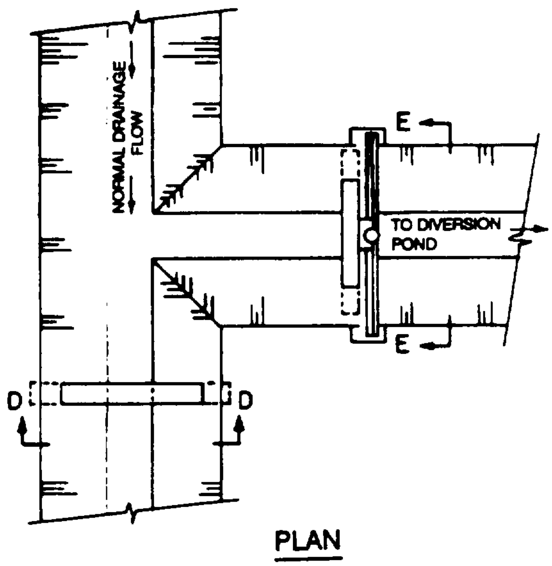
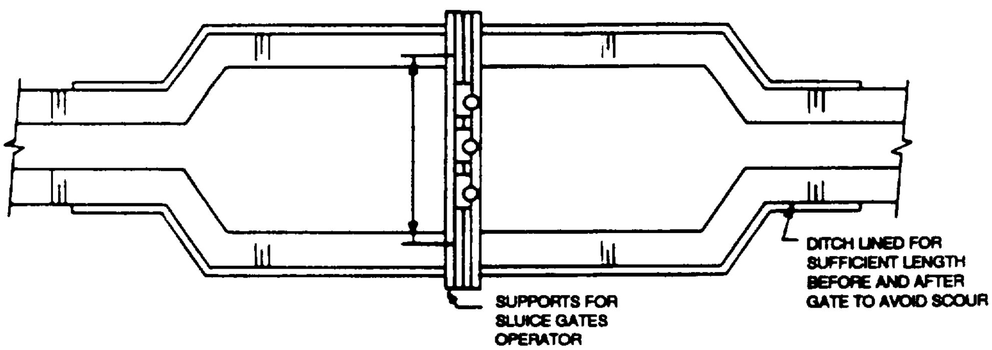


FIGURE 21A
Diversion Pond Details



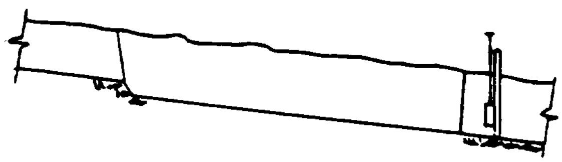


FLOW-THROUGH POND
WITH LOW FLOW CHANNEL

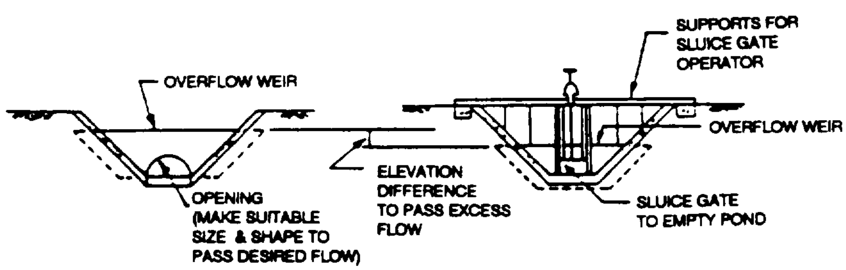


WIDENED SLUICE GATE
TO REDUCE WATER BACKUP

FIGURE 21B
Diversion Pond Details



SECTION B-B



SECTION D-D

DAM WITH UNDERPASS

SECTION E-E

DAM WITH SLUICE GATE

DIVERSION DAMS

FIGURE 21C
Diversion Pond Details

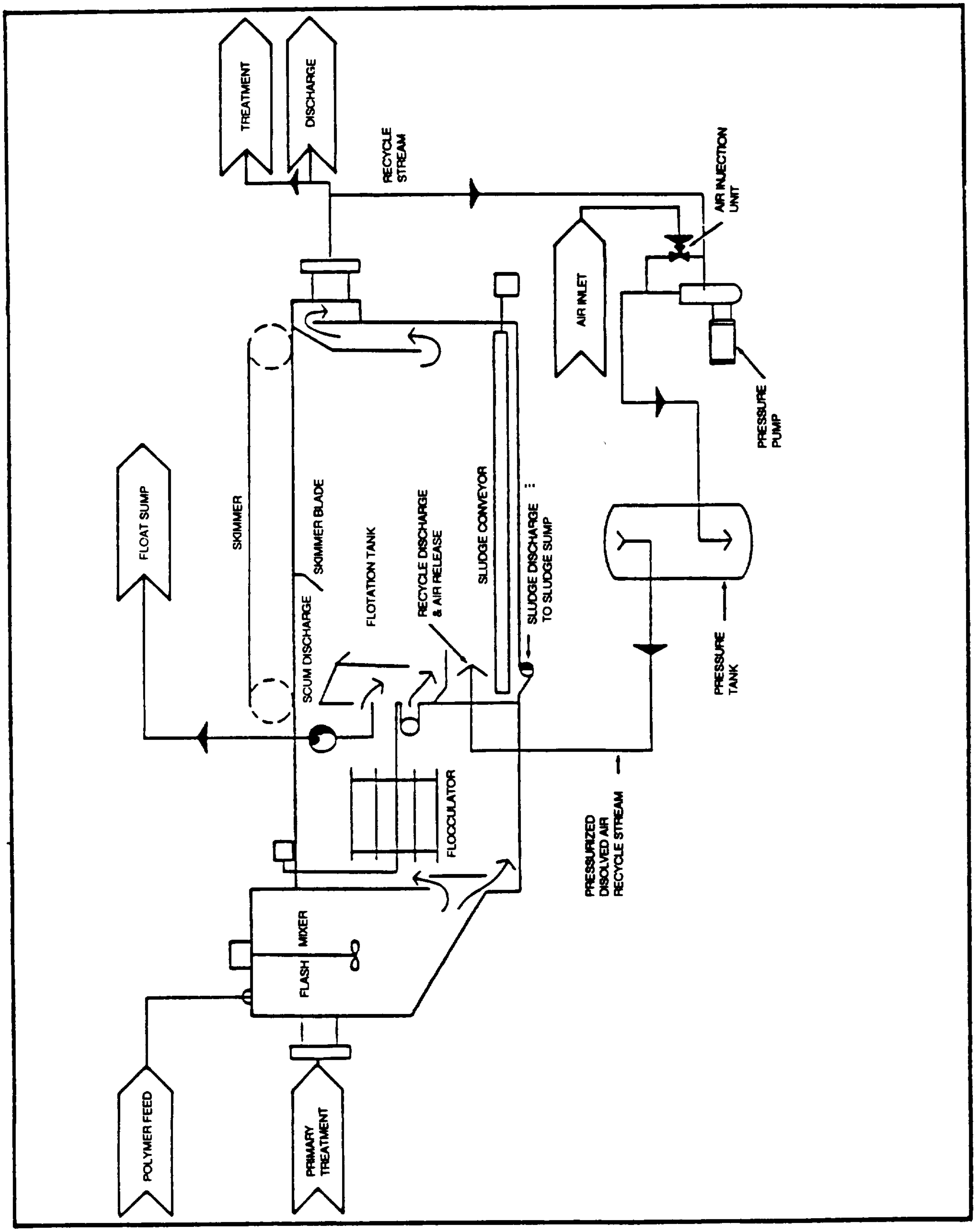


FIGURE 22
Schematic of Dissolved Air Flotation Oil - Water Separator

3.10.6.1 Pressurization Method. Introduce dissolved air to the DAF by recycle and by pressurizing a portion of the effluent using infused air. Mix recycle with flotation tank contents.

a) Equipment. Use a back pressure inductor to infuse air into the recycle stream. The flow through the inductor creates a partial vacuum in a side port drawing in atmospheric air. This system is mechanically simpler and lower in maintenance and operating cost than a compressed air system.

b) Bubble Size. The air pressure used in flotation determines the size of the air bubbles formed. Air bubbles <100 µm in size are the most suitable for being adsorbed and entrapped by the chemical floc and oil globules. An excessive amount of air can destroy the fragile floc formed in the flocculator, resulting in poor performance.

c) Recycle. Recycle of a portion of the clarified effluent allows a larger quantity of air to be dissolved and dilutes the feed solids concentration. Dilution reduces the effect of particle interference on separation rate. Detention period and air-to-solids ratio are also interrelated. The air-to-solids ratio influences the sludge rise rate. An increased rise rate reduces the detention period necessary to achieve good separation.

3.10.6.2 Design Parameters. The principal design variables for DAF are shown below. Most of these parameters will be specified by the equipment manufacturer.

DESIGN PARAMETER	DESIGN VALUE
Pressure	40-60 psig
Recycle ratio	30-70%
Feed solids concentration	0.5 to 5 $lb/ft^2/h$
Detention period	10 to 30 min
Air-to-solids ratio	0.02:1 to 0.05:1
Hydraulic loading	1.0-3.0 gpm/ft^2
Chemical aids	determined by field testing
Depth to width or diameter ratio	0.4:1 to 0.8:1

a) Performance. Specify performance of DAF unit to include oil removal efficiency and effluent oil concentration at expected unit operating conditions (air, solids, hydraulic loading, pressure, detention period) with or without chemical addition.

3.10.6.3 Chemical Conditioning. Chemical aids, or coagulants, are used to allow individual droplets of emulsified oil to agglomerate into a larger floc, which is more easily separated from the water. Materials used as coagulants include alum, ferric chloride, sulfuric acid, lime, organic polyelectrolytes, and combinations of inorganic and organic polyelectrolytes. Organic coagulants generally produce a better quality effluent, often require lower dosages, and reduce the amount of sludge generated by 50 to 75 percent. Bench scale studies should be performed to identify the optimum coagulant or combination of coagulants and determine dosage rate.

3.10.7 Polishing Treatment Alternatives. The purpose of the polishing step is to reduce the oil content to less than 10 ppm so that the effluent can be discharged to navigable waters. Multimedia filtration is the most practical process. Coalescing filtration units require less surface area per increment of flow capacity and may be preferred for site specific land constraints. This may be especially true in colder climate areas where much of the treatment system equipment will be installed indoors and building size must be minimized. Since the polishing step is critical to meeting effluent requirements, duplicate units for 100 percent redundancy must be provided.

3.10.7.1 Multimedia Filtration. Systems are available that operate by gravity or under pressure. Select equipment on basis of operating costs and the availability of space for installation. Pressure filters operate at higher loading rates and require less installation area than gravity units with comparable capacity. In colder climates, consider enclosing the system indoors. The system shall have automatic backwashing capabilities, initiated by sensing a predetermined head loss across the filter bed. Treated effluent is normally recycled for surface wash and backwash water supply. A suitably sized reservoir should be provided downstream from the filtration unit to hold the required volume of effluent for the backwashes. Backwash wastewater should be recycled to either the LET or the DAF unit. Depending on the desired flow configuration, adequate capacity must be included in either the LET or the DAF unit to receive the periodic backwash recycle flows. Refer to Figure 23 for typical sections of gravity and pressure multimedia filtration units, respectively.

a) The principal design variables for multimedia filter design for oily waste treatment are as follows:

DESIGN PARAMETER	DESIGN VALUE
Bed depth	24-36 in.
Filtration rate	
Gravity	3-8 gpm/ft^2
Pressure	12-18 gpm/ft^2
Backwash rate	15-20 gpm/ft^2
Air scour flow rate (if necessary)	3-6 sft^3/min/ft^2 @ 12 psig
Filter media	Combination sand, gravel, anthracite (garnet optional)
Pressure drop	
Clean	2-4 psig
Loaded	8-12 psig
Filter solids loading	2-6 lb/ft^2/hr

b) Pilot studies are essential in selecting the optimum filter. Design should be based on economic tradeoffs between filter size, operating head requirements, and run length for a specific effluent quality. See EPA Process Design Manual, Suspended Solids Removal [5] for methodology for making this comparison.

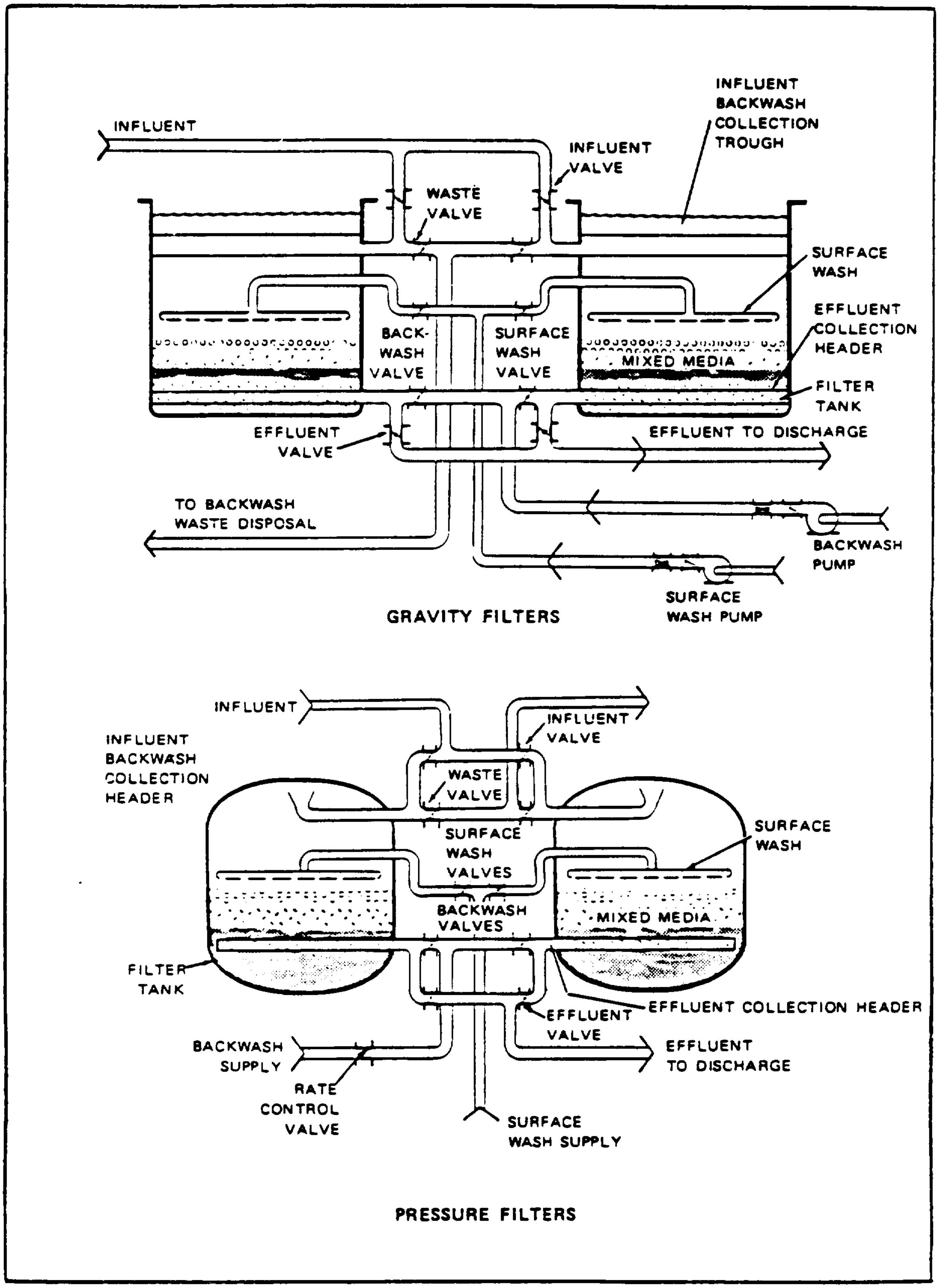


FIGURE 23
Mixed Media Filtration

c) Gravity filter tanks can be constructed of either reinforced concrete or carbon steel. Pressure filters are normally prefabricated package units built in carbon steel pressure tanks. Carbon steel tanks shall be specified to have both interior and exterior surfaces blast cleaned, prime coated, and finish coated with a coal-tar epoxy.

3.10.7.2 Coalescing Filtration. A coalescer system consists of a prefilter followed by two stages of coalescer elements. The prefilter removes free oil and solids and can be either a mechanical pack or disposable cartridges. The coalescing elements, often cartridges, remove dispersed and some emulsified oil to below 10 ppm. Eventually, the elements become blinded and must be replaced.

a) Equipment. Coalescing filtration units are available as prefabricated package units. Specify tankage fabricated of carbon steel with interior and exterior surfaces blast cleaned, prime coated, and finish coated with a coal tar epoxy system. Specify maximum use of stainless steel for internal components including mechanical coalescer packs, piping, and cartridge and filter supports or brackets. Prefilter and coalescer cartridges are manufactured from a variety of synthetic, noncorrosive materials. Figure 24 shows a typical arrangement of components for a coalescing filtration unit.

3.10.8 Sludge Dewatering and Disposal. The solids that settle to the bottom of the LETs, gravity separators, and DAF must be removed periodically. In addition, the scum which accumulates at the surface in the DAF must also be disposed. These sludges may be classified as toxic wastes and must be dewatered (regardless of toxicity) to minimize transportation and disposal costs and comply with typical disposal site criteria. Sludge drying beds or mechanical dewatering equipment are the preferred method of sludge dewatering.

3.10.8.1 Sludge Drying Beds. Sludge drying beds are the preferred alternative if the treatment facility is located in a suitable climate. Sludge drying beds are considerably less expensive to design, construct, operate, and maintain as compared to mechanical dewatering devices. Their performance is not affected by variable solids/moisture content in sludges.

a) Basis of Sizing. Provide at least 1.5 ft^2 (0.14 m^2) of drying bed per 1,000 gpd (3785 Lpd) of oily waste flow. Provide duplicate units for 100 percent redundancy. Individual bed area should not exceed 2,000 ft^2 (186 m^2). If more than 2,000 ft^2 is required, provide two beds each with 50 percent of the required design area and two equally sized beds for redundancy requirement.

b) Bed Characteristics. If available land is limited, consider use of premolded, polypropylene screen modules to replace sand bottom. These beds require 1/6 to 1/10 the area of sand beds. Alternatively, consider vacuum assist or solar assisted drying for conventional sand bottom beds.

c) Covers. In areas subject to extreme cold or wet climate, consider covering drying beds to improve year round performance.

3.10.8.2 Mechanical Dewatering and Disposal. Consider filter press equipment in locations where sludge drying beds cannot be used.

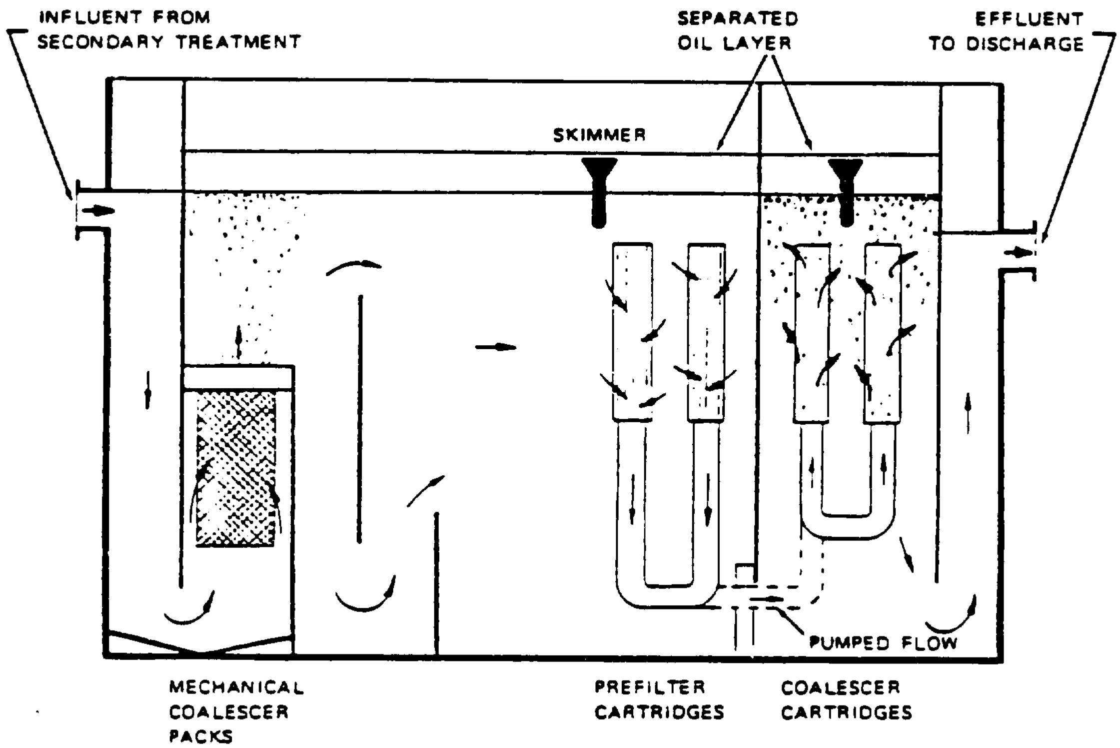


FIGURE 24
Schematic of Coalescing Filter

a) Bag Filters. In smaller facilities, where sludge production is low, bag type filter presses should be considered. They dewater by moisture displacement under pressure from influent liquid sludge. Bag type filter presses generally dewater to about 50 percent moisture content. They are mechanically simple and require little maintenance other than periodic cleaning. The operation is normally manual and requires continuous operator attention to start and stop the process, and to empty and replace the filter bag. They are small, portable, and require little floor space for a permanent installation.

b) Filter Press. For larger facilities with higher sludge production consider plate and frame (or diaphragm) filter press. Plate and frame press will require high lime dosage. Use diatomaceous earth precoat filter to minimize oil blinding of filter fabric. Consider high-pressure steam and/or detergent cleaning of fabric in regular operating cycle. Other types of sludge dewatering equipment should be considered, but bench or pilot scale demonstration of dewatering performance may be required. Consider operational problems of media blinding and cake handleability in selection of dewatering equipment.

c) Belt Filter Press. For larger facilities with higher sludge production consider belt filter press. Determine polymer type and required dosage for sludge conditioning by benchscale or pilot plant tests. Consider the effect of oil blinding of media and methods and efficiency of media cleaning in equipment selection and specification. Consider handleability of sludge cake and cake discharge characteristics in equipment selection and specification.

A belt type filter press will normally produce a sludge cake with 60 to 70 percent moisture content. The units are mechanically complex and require frequent maintenance attention to check and adjust roller clearances and lubricate roller bearings. However, full time operator attention is not required during operation. Since sludge cake is discharged continuously, a conveyor belt might be required to carry off the sludge to a storage area.

3.10.8.3 Sludge Disposal. The toxic characteristics of oily sludges are specific to the oily waste treatment facility that generates them. The toxic or hazardous waste characteristics of any oily sludge must be determined before a disposal method is selected. Refer to NCEL TM54-83-13-CR, April 1983, Oily Sludge Disposal Practice at Naval Installations [12]. For nonhazardous sludges, evaluate landfill disposal or agricultural land application. For sludges designated hazardous, use contract haul and disposal.

3.10.9 Oil Reclamation. Oil is recovered in the LET and the induced gravity separator and should be reclaimed. A reclamation facility will typically have two holding tanks. The oil settles in one tank while it is collected in the other. The tanks are sized to provide 3 to 7 d of settling time. After settling, the bottom water is drawn off and returned to the LET for reprocessing.

Oil reclaimed from oily waste treatment plants can be used for boiler fuel. The Navy Petroleum Office specification should be used to produce a standard quality boiler fuel from recovered oils collected at oily waste treatment facilities. Military Specification MIL-F-24951, Fuel Oil Reclaimed [2], allows an activity to substitute fuel oil reclaimed (FOR) for burner fuel oil (Federal Specification VV-F-815D, Fuel Oil, Burner [2]), either directly or as a blend in stationary boilers.

3.10.10 Pumps, Valves, and Piping

3.10.10.1 Pumps. Primary emphasis should be placed on arranging treatment units for gravity flow operation. Where gravity flow is not feasible or there is a need to control feed rates into treatment units, pumping should be used. Pumps specified for transfer of oily waste should not shear emulsions or mechanically emulsify free oil.

a) Use progressive cavity pump or recessed impeller vortex pump. Progressive cavity pumps require that influent be fine screened to remove any solids large enough to jam the cavity between the stator and rotor components. Pump selection should be based on low speed operation of 700 to 1,100 rpm. Provide a pressure relief system to protect the pumps and discharge piping from being overpressurized if the pump discharge line becomes blocked.

b) A conventional centrifugal pump with high efficiency, fully enclosed impeller and operating speed <1,750 rpm is recommended to pump treated effluent to a discharge point.

c) Facility designs should provide 100 percent redundancy in all pump installations to preclude total plant shutdown on loss of a single pump.

3.10.10.2 Valves. Plug valves and ball valves are recommended. Their self cleaning tendency when operated reduces the possibility of flow port blockage by debris in the oily waste. They operate simply and quickly with 90° action full closed to full open and seal tightly when closed.

c. Piping. Above ground wastewater and sludge piping should be designed using ductile iron or carbon steel pipe. Chemical feed piping and underground wastewater and sludge piping should be specified as PVC pipe. Due to the corrosiveness of both the oily waste, with a high seawater content, and the "salt air" atmosphere at many Naval bases, corrosion resistant coating systems should be specified for both the interior and exterior surfaces of ductile iron and carbon steel pipe. In areas where seasonal temperatures fluctuate widely, adequate provisions for expansion and contraction must be provided to avoid pipe breakage.

For ductile iron and carbon steel piping 4-in. (101.5 mm) diameter and larger, cement lining or coal tar epoxy coating of interior surfaces, and coal tar epoxy exterior coating should be specified. For carbon steel piping smaller than 4-in. diameter, polyethylene or Saran lining of interior surfaces and coal tar epoxy exterior coating should be specified. Piping should be sized for a velocity of 6 to 8 fps (1.8 to 2.4 mps).

3.10.11 Instrumentation. Since the systems are intended to be run on a batch basis, manual control of treatment unit operations is recommended. Excessive automation should be avoided. Any automation provided must have full manual backup. Automatic backwash controls on filteration units and automatic start-stop control of polymer feed systems on sensing flow to a DAF unit are recommended. On direct discharge systems consider provision for automatic recycle of effluent to a LET if oil is detected at higher than permissible concentrations. Instrumentation should be provided to monitor influent and effluent flow and key effluent quality parameters. Monitoring instrumentation for facilities discharging to navigable waters should be provided in duplicate for 100 percent redundancy.

Suggested parameter monitoring guidelines are presented in Table 16.

TABLE 16
Guidelines for Oily Waste Treatment Monitoring

PARAMETER	EFFLUENT TO POTW	EFFLUENT TO NAVIGABLE WATERS
Influent flow	Continuously monitor using magnetic type meter with chart recorder.	Continuously monitor using magnetic type meter with chart recorder.
Effluent oil content	Analysis of grab samples taken at intervals required by permit.	Continuously monitor using ultraviolet transmission/ fluorescence detection type meter with chart recorder. Verify with laboratory analysis of daily grab or composite samples.
Effluent pH	Periodic checks taken at intervals required by permit.	Continuously monitor using submerged probe/remote analyzer type meter with chart recorder.
Effluent flow	Continuously monitor using magnetic, turbine, or overflow weir/float type meter with chart recorder.	Continuously monitor using magnetic, turbine, or overflow weir/float type meter with chart recorder.

Section 4: METERING, INSTRUMENTATION AND CONTROL, AND CHEMICAL FEEDING

4.1 Scope. This chapter contains criteria on metering, instrumentation, controls, and chemical feeding devices used in wastewater disposal systems.

4.2 Related Criteria. Certain criteria related to the subject matter of this Section appear elsewhere in this handbook. Refer to Sections 2 and 3 for instrumentation, control, and chemical feeding for selected wastewater treatment unit processes and operations.

4.3 Use of Criteria. These criteria indicate simple recommended practices applicable to plants with up to 5 Mgd average flow.

4.3.1 Special Cases. Specific design problems may require departures from these practices; therefore, use these criteria with discretion. For example, use of computers and microprocessors for data logging, indication, and process control is considered an emerging technology. This technology is presently primarily applicable to large wastewater treatment plants with adequately trained staff to maintain the hardware (greater than 10 Mgd size). However, improvements in electronics, hardware, software, and sensing devices (primarily sensing elements) will make this technology more desirable for smaller plants. Detailed information is not included for such emerging technology because of its state of rapid change and because additional development and application experience needs to occur before application to the smaller Naval facilities is justified.

4.3.2 Letters in Tables. To further clarify terms in the tables, the letters (E), (O), and (S) are used to mean:

(E) = Essential	Items described are required wherever particular applications occur.
(O) = Optional	Items described may be required (contingent on specific plant needs).
(S) = Special Cases	Items are sometimes used in large installations or where process variable control is critical.

4.4 Policies. Devices and systems shall be as simple as possible. In any installation or facility, equipment procurement shall be limited to the smallest practicable number of manufacturers.

4.4.1 Primary Measurement. Provide elements to measure any function essential to proper operating control and evaluation of plant performance.

4.4.2 Instrumentation. Provide remote readouts only where operating convenience and cost savings outweigh added maintenance needs or where hazardous wastes are being treated. Record functions that significantly affect public health, the environment, or economy of operation. Consider data logging devices where cost can be offset by reduced operating manpower needs.

4.4.3 Controls. Consider automatic controls where significant improvement in performance will result or where cost can be offset by reduced operating manpower needs or where treating hazardous wastes; otherwise, keep controls as simple as possible. Wherever feasible, use fixed or manual controls (for example, weirs, launders, siphons, or throtting valves) in preference to mechanical devices. Use direct acting controls (for example, float valves) in preference to electrically or pneumatically actuated devices. Always consider the effects of possible control malfunctions.

4.4.4 Standardization. Equipment shall be standardized wherever possible. Use identical or similar components to the maximum extent. Instrumentation, control, and feeding equipment should be homogeneous (that is, all self-powered, all pneumatic, and so forth).

4.4.5 Equipment Accuracy. Equipment accuracy tolerances shall be as low as possible and consistent with the functions desired.

4.4.6 Equipment Ranges. Before selecting equipment such as meters or feeders, the required maximum and minimum capacities shall be computed, and ranges shall be kept as narrow as possible for any piece of equipment.

4.4.7 New Products. New products and applications are constantly being developed. Approval or advice on their uses shall be requested from NAVFACENGCOM.

4.5. Information Required. Obtain the following information to assist in equipment selection:

a) Type of treatment.

b) Chemical, physical, and bacteriological qualities of raw wastewater, treated wastewater, and permissible discharge limits.

c) Variations of flow rate for raw wastewater.

d) Ranges of other related variables.

e) Size of treatment plant.

f) Effluent disposal conditions.

4.6 Wastewater Treatment Systems

4.6.1 Primary Measuring Devices

4.6.1.1 Location and Purpose. Primary measuring devices are required at critical locations in wastewater treatment systems to sense and measure flow, pressure, elevation, temperature, weight, and physical and chemical characteristics of process streams. For type of device, refer to Table 17. For examples of location of measuring devices and types of measurements for industrial waste treatment systems, refer to Table 18.

TABLE 17
Types of Measuring Devices Applicable to Wastewater Treatment Systems

PRIMARY MEASUREMENT AND TYPE OF DEVICE	USE EXAMPLES	GENERAL	CAPACITY	RANGE
Open Channel Flow:		Accuracy is dependent on piping configuration. Consult vendor data on specific device.		
Flume (Parshall or Palmer-Bowlis)	Plant influent, bypass lines	Suspended matter does not hinder operation. More costly than wier.	10 gpm and up	75:1
Weir	Plant influent, plant effluent.	Requires free fall for discharge and greater head loss than flume. Influent wiers may plug.	0.5 gpm and up	100:1 and up
Pressure Pipeline Flow:				
Differential producers	Filled lines. Fluids under positive head at all times. Not generally for water supply service.			
Venturi tube or flow tube	Most fluid lines where solids build up and scale will not be a problem.	Long laying length required. Costly in large pipe sizes.	5 gpm and up for liquid; 20 ft^3/min and up for gas.	10:1
Orifice plate	Air and gaslines, water except filter effluent.	Clean fluids only.	5 gpm and up for liquid; 20 ft^3/min and up for gas.	5:1
Flow nozzle	Water except filter effluent	Clean fluids only.	Determined by pipe sizes.	3:1
Average pitot tube	Water, air, gas			
Displacement meters	Plant water and distribution system service connections. Plant gaslines, sludge gaslines. Chemical addition lines.	Different types available. Maximum flow volume somewhat limited. May be in conjunction with chemical feed pump. Clean fluids only.	0.1 to 9,000 gpm for liquid; 0 to 100 ft^3/min for gas.	10:1
Target meters	Plant effluent, sludge, dirty fluids.	Suspended matter does not hinder operation.	0.07 gpm and up.	10:1
Velocity meters, Propeller meter	Water, clean liquids.	Insertion turbine or full bore types available.	0.001 to 40,000 gpm for liquids, to 10,000,000 ft^3/min for gas.	10:1 to 50:1
Magnetic meter, sonic or ultrasonic meter	Plant influent, sludge, clean to dirty liquids, plant effluent.	No obstruction in flow stream. Well suited for suspended matter and solids. Sonic meters are subject to interference by air bubbles. Suitable for confined piping systems.	0.001 to 500,000 gpm.	10:1

TABLE 17 (Continued)
Types of Measuring Devices Applicable to Wastewater Treatment Systems

PRIMARY MEASUREMENT AND TYPE OF DEVICE	USE EXAMPLES	GENERAL	CAPACITY	RANGE
Vortex shedding meter	Heat exchanger water lines.		3 to 5,000 gpm.	15:1
Variable area rotameter	Gas and gas solution feeders, chemical dilution systems, influent lines to ion exchange units, water and clean liquids.	Available in very small to very large flow rates at lowest cost for flow indicator.	0.01 mL/min to 4,000 gpm for liquids, to 1,300 ft^3/min gas.	5:1 to 12:1
Openflow nozzle	Plant influent or effluent, sludge.	Requires free fall from end of pipeline.	5 to 11,000 gpm.	5:1 to 10:1
Level:				
Staff gauge	Wet wells, floating cover digesters, water supply intake.	Indication only.	Unlimited.	100:1
Float	Wet wells, sumps.	Indication near tank, has moving parts	Unlimited.	100:1
Capacitance probes, RF probes	Wet wells, elevated tanks, tanks, most level applications.	Many types immune to conductive build-up and coating on probe. Continuous or on/off available.	Unlimited.	100:1
Sonic or ultrasonic meters	Wet wells, supply intake, batch tanks.	Continuous type does not contact the liquid, may not be suitable for foaming liquids. Gap type for on/off applications.	Unlimited.	50:1
Differential pressure	Batch tanks, chemical tanks	Specific gravity should be fairly constant. Build-up may be a problem.	Unlimited.	20:1
Bubble tube	Water supply wells.	Requires air supply for automatic. Manual (hand pump type) available for indication only.	Depth limited by air pressure if automatic.	10:1
Pressure:				
Pressure gauge	Pump discharge, transmission mains, elevated tanks, digester gas, aeration air.	Seals or diaphragms may be required to prevent corrosion or plugging of pressure impulse connections.	Vacuum to 1,500 psig.	10:1
Loss of head gauge	Gravity filters		Unlimited.	3:1
Temperature:				
Thermometer or resistance thermal device	Plant influent, clearwell, atmosphere, digester, digester heating system.			
Analytical Instruments:	Plant influent or effluent, pH precipitator, neutralization, oxidation or reduction processes.		0 to 14 units.	

TABLE 17 (Continued)
Types of Measuring Devices Applicable to Wastewater Treatment Systems

PRIMARY MEASUREMENT AND TYPE OF DEVICE	USE EXAMPLES	GENERAL	CAPACITY	RANGE
Oxidation on Reduction Potential (ORP)	Precipitator, oxidation, or reduction processes.	May also be used for free residual chlorine.	-400mV to +400 mV[1]	
Dissolved oxygen	Mixed liquor, aerobic digester, aeration basin, plant effluent.		0 to 20 mg/L	
Turbidity	Filter influent/effluent. Settling basin effluent.		0 to 1,000 NTU	
Residual chlorine, residual ozone	Treatment unit effluent		0 to 2 mg/L[1]	
Specific ion electrodes	Treatment unit effluent		0 to 2 mg/L[1]	
Ultraviolet photometer	Oil treatment unit influent or effluent.		0 to 50 mg/L	
Sand Expansion:				
Float	Gravity filter		Unlimited.	20:1
Weight:				
Scales	Chemical feed and storage equipment, grit chamber, sludge cake conveyor.	Weighing devices may be integral to gravimetric feeders.	1 to unlimited.	12:1
Gas Concentration:				
Concentration indicator or alarm	Chlorine rooms, digester operating room, wet wells, lift stations.		0 to 100%	
Time:				
Elapsed time meter (ETM)	Motors requiring periodic service, motors driving principal pumps.		0 to 10,000 h.	100,000:1
Revolutions:				
Counter	Positive displacement sludge pumps.	May be used for primary metering of sludge flow.	0 to 100 million.	100 million:1
Electric Power Use:				
Watt-hour meter	Plant power.	Public utility may have governing requirements	Unlimited.	10,000:1

[1]Depends on actual effluent requirements.

TABLE 18
Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

LOCATION AND USE	TYPE OF MEASUREMENT	TYPE OF INSTRUMENT READOUT	RANGE OF MEASUREMENT AND/OR READOUT	CONTROLS	
				ITEM REGULATED	TYPE
Pumping:					
Lift station discharge	Flow	Indicator (O) Totalizer (E) Recorder (O)	Minimum to maximum pumping capacity		
	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure		
Suction	Pressure	Indicator (O)	Full vacuum to 1.5 times static suction head.		
Transfer pumps suction	Pressure	Indicator (O)	Full vacuum to 1.5 times static suction head.		
Transfer pump discharge	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure		
Major pumps	Temperature	Indicator (O)	32° to 200° F		
	Running time	Totalizer (O)	At least 2 times maintenance period.		
Surge Tank:	Level	Indicator (E)	Depth of tank	Lift pumps	Automatic (E)
Batch Treatment Tank:	Level	Indicator (E)	Depth of tank	Transfer pump	Manual (O)
Chrome or cyanide waste	pH	Indicator (E) Recorder (O)	0 to 14 units	Chemical addition	Automatic (E) Automatic (O)
	ORP	Indicator (E) Recorder (O)	-200 to +200 mV	Chemical addition	Manual (E) Proportional-automatic (O)
Metal waste	pH	Indicator (E) Recorder (O)	0 to 14 units.	Chemical addition	Manual (E) Proportional-automatic (O)
Neutralization Tank:					
(batch type)	Level	Indicator (E)	Depth of tank		
	pH	Indicator (E)	0 to 14 units	Chemical addition	Automatic (O)
Clarified Water Storage:	Level	Indicator (E)	Depth of tank		
Filters:					
Influent line to each filter	Flow	Indicator (E)	1 to 4	Filtration rate	Manual (E)
Individual filters	Pressure differential.	Indicator (E)	1 to 3	Backwash frequency	Manual (E) Automatic (S)
Backwash pump	Flow	Indicator (E)	1 to 4	Backwash rate	Manual (E)
Spent backwash storage tank	Level	Indicator (E)	Depth of tank		
Sludge Storage Tank:	Level	Indicator (E)	Depth of tank		
Gas Feeder:					
Chlorine or sulfur dioxide	Flow	Indicator (E)	1 to 10	Application rate	Manual (E) Proportional-automatic (O)
On-line chlorine cylinder or on-line sulfur dioxide cylinder	Weight	Indicator (E)	3 times full cylinder weight	Chlorine supply	Manual (E)
Chemical bulk storage	Level	Indicator (E)	Depth of tank	Chemical supply	Manual (E)
	Temperature	Indicator (O)	Depends on chemical	Tank heater (if required)	Automatic (E)
Chemical day tanks	Level	Indicator (O)	Depth of tank	Day tank supply	Manual (E)
Oil emulsion breaking tank	Temperature	Indicator (E)	1 to 10	Tank content temperature.	Automatic (E)

4.6.1.2 Use Limitations. Different types of measuring devices are available for each application. The listed "capacity" of a device includes most sizes and types of the device that are available. The "range" is the useful turndown-ratio of a particular device.

4.6.1.3 Discrete vs. Analog Devices. Alarm functions and many control functions require only the presence or absence of a process variable input for their operation. For example, a sump pump may start if the liquid level is above a certain point or a tank heater may start if the temperature is below a selected point. Control these functions by discrete devices such as flow switches, temperature switches, level switches, and pressure switches. If the actual status of the process variable is required, rather than on/off for indication or control, an analog primary device should be used. Some alarm switches are not included in the tables; for example, clarifier torque switches, speed switches, and other equipment protection switches that are normally supplied with the equipment.

4.6.1.4 Special Considerations. Primary measuring devices for wastewater systems must meet more rigorous operational requirements than those for water supply systems. Select devices constructed of materials impervious to the corrosive effects of the wastewater. Consider plugging of impulse or sampling lines and buildup of solids and grease on analytical probes when specifying these devices.

4.6.1.5 Ship Sewage. In the design of pier sewage collection systems to receive sewage from ships, facilities to meter the total flow through the collection system should be included. The designer should consult activity's Public Works Department for metering needs. The location of meters necessary to provide the needed information will be determined by the layout of the collection system, but in no case should this exceed one meter at the shore end of each pier. There is no necessity to meter the flow from individual ships.

4.6.2 Instrumentation. Instrumentation covers all secondary instruments (such as gages, indicators, recorders, or totalizers) needed for efficient operation of wastewater treatment systems. Information sensed by a primary device is translated by instruments into an operator usable form called "readout." Most analog primary devices require secondary instruments, although a few (such as displacement meters) contain built-in counters.

4.6.2.1 Use Limitations. Instruments may be obtained in any combination of totalizing, indicating, or recording of information developed by primary devices. Other more sophisticated forms of instruments (such as summation and multiplication of variables) are possible, but are not normally needed.

4.6.2.2 Transmission. Select means of transmitting information from primary measuring devices to secondary instruments from the following:

a) Mechanical. Transmission distance is limited to a few feet. Consider the effects of corrosion, wear, or icing on mechanical linkages.

b) Pneumatic. Transmission distance can be up to 1,000 ft (304.8 m). Reaction time of pneumatic loops is relatively long if transmission distance is long.

c) Electrical. There is no limitation on distance. Analog signals may require amplification for transmission distances greater than 1,000 ft.

4.6.2.3 Remote Indication. Remote indicators should provide the operator with the status of any function necessary for remote operation of the plant. Panel lights should indicate the on/off status of pumps or other discrete devices, alarm functions, and operator-actuated functions (for example, initiate backwash, fill day tank).

4.6.3 Controls. Controller devices are needed to regulate the functions of equipment throughout the process. Controls may be classified by the degree of automation.

4.6.3.1 Manual. Use this type where the operator will start, stop, or adjust rates of operations based on instrument observations, laboratory tests, or indicated conditions.

4.6.3.2 Automatic. Use this type to automatically start, stop, or regulate rates of operations in response to changes in a measured variable or other input. All equipment must also have manual control to override automatic control regardless of the degree of automation provided.

4.6.3.3 Design Considerations. Many controls combine manual and automatic operations. The operator may initiate an automatic-timed cycle backwash system, or adjust set points of a proportional controller based on instrument observation. Controls that seldom require adjustment (rate of flow to filters, for example) should be manual. Controls requiring frequent adjustment (starting sump pumps, proportional chemical feeding) should be automatic. Whether the automation is on/off-timed cycle, or proportional, must be based on analysis of plant requirements.

4.7 Chemical Handling and Feeding

4.7.1 Introduction. Refer to Table 19 for function of chemicals used for cyanide, oil, and metal removal. Sections 2 and 3 recommend specific chemicals for wastewater applications encountered in Navy facilities. Refer to Table 20 for the usual chemical strengths and other data on chemicals.

4.7.2 Chemical Handling and Feeding

4.7.2.1 Handling. See Table 20 for handling precautions. Provide the following:

a) Roofed unloading platforms.

b) Mechanical handling aids for unloading and transporting chemicals to the storage area, feed hoppers, and solution tanks.

c) Dust control equipment for dry, dusty chemicals.

d) Washdown and cleanup. Facilities for dry and liquid chemical spills.

TABLE 19
Function of Chemicals for Industrial and Oily Wastewater Treatment

CHEMICAL	CYANIDE REMOVAL		METAL REMOVAL					OIL REMOVAL	
	pH	O	A	pH	R	PR	C	pH	C
1. Activated Carbon			X						
2. Aluminum Sulfate (alum)							X		X
3. Calcium Carbonate (limestone)				X					
4. Calcium Hydroxide (hydrated lime)	X			X		X		X	
5. Calcium Oxide (quick lime)	X			X		X		X	
6. Calcium Hydrochlorate (HTH, perchloran)		X							
7. Chlorine		X							
8. Chlorine Dioxide		X							
9. Ferric Chloride							X		
10. Ferrous Sulfate							X		X
11. Ferrous Sulfide						X			
12. Hydrochloric Acid	X			X				X	
13. Hydrogen Peroxide		X							
14. Ozone		X							
15. Polymers (polyelectrolytes)							X		X
16. Sodium Carbonate				X		X			
17. Sodium Chlorite		X							
18. Sodium Hypochlorite		X							
19. Sodium Hydroxide	X			X		X		X	
20. Sodium Meta Bisulfite					X				
21. Sulfur Dioxide					X				
22. Sulfuric Acid	X			X				X	

Key: A = Adsorbtion
C = Coagulation
O = Oxidizing Agent
pH = pH Adjustment
PR = Precipitant
R = Reducing Agent

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TABLE 20
Data on Chemicals for Wastewater Treatment

Chemical	Available form	Shipping container	Bulk weight lb/ft^3	Commercial strength	Water solubility lb/gal
1. Activated Carbon					
C	Powder	Bags, bulk	Varies		Insoluble
	Granular	Bags, bulk	20 to 35		
2. Aluminum Sulfate (alum)					
$Al_2(SO_4)_3 \cdot 14H_2O$	Slab, lump, powder.	Bags (100-200 lb), drums	60 to 75	17% Al_2O_3	5.2 @ 32° F 5.5 @ 50° F 5.9 @ 68° F
	Liquid	Bulk	10.71 lb /gal	5.8 to 8.5% Al_2O_3.	Complete
3. Calcium Carbonate					
$CaCO_3$	Powder, crushed (various sizes).	Bags, barrel, bulk	Powder, 48 to 71; crushed, 70 to 110.		Nearly insolu able.
4. Calcium Hydroxide					
$Ca(OH)_2$	Powder, granules.	Bags (50 lb) bulk.	25 to 50	Normally 13% $Ca(OH)_2$.	Nearly insol-uble
5. Calcium Oxide					
CaO	Lump, pebble, ground.	Bags (80 lb), barrels, bulk.	40 to 70	75 to 99% normally 90% CaO.	Nearly insoluble
6. Calcium Hypochlorite					
$Ca(OCl)_2 \cdot 4H_2O$	Granules, tablets.	Cans (5 lb), drums (100, 300, 800 lb).	50 to 55	70% available chlorine.	1.8% @ 32° F
7. Chlorine					
Cl_2	Liquified gas.	Cylinders (100, 150, 200 lb), bulk.	Liquid-91.7. Gas-0.19 @ 60° F and atm. press.	99.8%	0.12 @ 32° F 0.047 @ 87° F

TABLE 20 (Continued)
Data on Chemicals for Wastewater Treatment

Feeding form	Feeder type	Accessory equipment	Suitable handling materials	Comments
Dry or slurry.	Volumetric metering pump.	Slurry tank, dust control devices.	Dry-iron, steel.	Combustible dust.
Static or fluidized bed.			Wet-rubber, plastic, stainless steel.	
Dry or solution.	Volumetric metering pump.	Dissolver or solution tank.	Dry-iron, steel, concrete.	
Solution.	Metering pump.	Solution tank.	Wet-lead, rubber, plastic.	
Dry slurry used in fixed beds.	Volumetric metering pump	Slurry tank	Iron, steel	
Dry or slurry.	Volumetric metering pump.	Slurry tank.	Iron, steel, plastic, rubber hose.	
Dry or slurry (must be slaked to $Ca(OH)_2$) bed.	Dry-volumetric Wet-slurry (centrifugal pump).	Slurry tank, slaker.	Iron, steel, plastic rubber hose.	Provide means for cleaning slurry transfer pipes.
Solution or dry.	Solution-metering pump. Dry-tablet contact feeder.	Solution tank.	Glass, plastic, rubber.	Soft water required for solution.
Water solution of gas.	Vacuum chlorinator with water ejector.	Scales, switch over devices, leak detector.	Sched. 80 steel for gas under pressure. Plastic or rubber-lined for gas under vacuum or water solution.	Provide gas masks for emergency use. Irritant to eyes and lungs. Toxic and corrosive.

TABLE 20 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available form	Shipping container	Bulk weight lb/ft^3	Commercial strength	Water solubility lb/gal
8. Chlorine Dioxide					
ClO_2	Gas	Prepared on site using chlorine and sodium chlorite, solution pump, and contactor column.			0.07 @ 60° F 0.04 @ 100° F
9. Ferric Chloride					
$FeCl_3$	Powder	Drums (135, 350 lb).	175	98%	4.6 @ 32° F
	Liquid	Bulk	87 to 94	39 to 45%	5.8 @ 55° F
10. Ferrous Sulfate					
$FeSO_4$ $.7H_2O$	Crystals, powder, lumps	Bags (50, 100 lb) Drums (55 gal), bulk	62 to 66	55 to 58%	
	Liquid	Bulk	Varies. Consult producer	Varies. Consult producer	
11. Ferrous Sulfide FeS	Liquid solution	Prepared on site by mixing ferrous sulfate, a soluble sulfide and lime.			Nearly insoluable.
12. Hydrochloric Acid					
HCl	Liquid	Barrels, drums, bulk	27.9%– 0.53 lb/ gal 31.45%– 9.65 lb/ gal	27.9%, 31.45%, 35.2%	Complete
13. Hydrogen Peroxide					
H_2O_2	Liquid	Drums (30, 55 gal), bulk	35%–9.4 lb/gal 50%–10 lb/gal. 70%–10.8 lb/gal	35%, 50%, 100%	Complete
14. Ozone					
O_3	Gas	Generated on site from air or oxygen			Gas solution

TABLE 20 (Continued)
Data on Chemicals for Wastewater Treatment

Feeding form	Feeder type	Accessory equipment	Suitable handling materials	Comments
Water solution of gas.	Chlorinator plus sodium chlorite solution pump.	Scales, switch over devices, leak detectors, reactor tower.	Sched. 80 steel for gas under Plastic or rubber-lined for gas under vacuum or water solution.	
Liquid	Metering pump.	Solution tank.	Glass, rubber, plastic.	Dilution limited due to iron hydrolosis.
Liquid	Metering pump.			
Liquid	Metering pump	Solution tank	Glass, rubber, plastic.	Dilution limited due to iron hydrolysis.
Liquid	Metering pump			
Slurry	Metering pump			
Liquid	Metering pump	Dilution tank	Hastellory A, selected plastic and rubber types.	
Liquid	Metering pump		Type 304 stainless steel, polyethylene	Strong oxidizing agent
Consult	Unplasticized	equipment supplier	Toxic, irritant PVC, stainless steel	

TABLE 20 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available form	Shipping container	Bulk weight lb/ft^3	Commercial strength	Water solubility lb/gal
15. Polymers	Liquid, powder	Drums bulk	The various cationic, anionic and nonionic polymers vary in composition, density and other characteristics. Consult supplier for data.		
16. Sodium Carbonate					
Na_2CO_3	Powder	Bags (100 lb) Bulk	34 to 62	99.2%	0.58 @ 32° F. 1.04 @ 50° F. 1.79 @ 68° F. 3.33 @ 86° F.
17. Sodium Chloride					
NaCl	Rock, evaporated	Bags, barrels, bulk.	50 to 70	Varies	2.97 @ 32° F. 2.97 @ 50° F. 3.00 @ 68° F. 3.02 @ 86° F.
18. Sodium Hypochlorite					
NaOCl	Liquid	Carboys (5, 13, 59 gal), bulk (1,300, 2,000 gal), truckload		12 to 15% available chlorine	Complete
19. Sodium Hydroxide					
NaOH	Solid flake, ground flake, liquid	Drum (735 lb) Drums (100 lb) Drums (450 lb)	Varies	98%	3.5 @ 32° F 4.3 @ 50° F 9.1 @ 68° F 9.2 @ 86° F
20. Sodium Metabisulfite					
$Na_2S_2O_5$	Lump, ground.	Bags (100 lb). Drums (100 and 300 lb).	84 to 95		2,3 @ 68° F.
21. Sulfur Dioxide					
SO_2	Liquified gas	Cylinder (150, 2,000 lb)	Liquid-89.6 Gas @ 32° F and 1 atm.-0.183	99%	1.0 @ 60° F
22. Sulfuric Acid					
H_2SO_4	Liquid	Carboys, drums (825 lb) Bulk	106 114	60°Be-77.7% 66°Be-93.2%	Complete

Notes:

[1] Polyelectrolytes have relatively short periods of chemical potency once mixed and diluted. Most manufacturers will advise mixing no more than a 1 to 3 day supply in the solu-

TABLE 20 (Continued)
Data on Chemicals for Wastewater Treatment

Feeding form	Feeder type	Accessory equipment	Suitable handling materials	Comments
Solution		Storage and dilution tanks	Consult supplier	See Note 1
Dry	Volumetric feeder	Dissolving	Iron, steel	Can cake
Liquid	Metering pump			
Solution	Pump	Dissolving tank.	Plastic, iron steel	
Solution	Metering pump	Solution tank	Plastic, glass, rubber	
Solution	Metering pump	Solution tank	Iron, steel	Dissolving solid forms generates much heat
Solution	Metering	Solution	Plastic, Type 316 stainless steel.	
Water solution of gas	Vacuum-sulfur-meter with	Scales, switch over devices	Dry-316 stainless steel Wet and low pressure plastic, rubber	Provide gas masks for emergency use
Liquid	Metering pump			Provide for spill cleanup and neutralization

tion feed tank. Therefore, a protected area must be provided for storage of sealed bags or containers of dry polyelectrolyte or sealed containers of concentrated liquid polyelectrolyte.

4.7.2.2 Storage. See Table 21 for space criteria and Table 22 for type criteria. Refer to American Concrete Institute, Concrete Sanitary Engineering Structures [18], for criteria on protection of concrete against chemicals.

a) Store materials in original containers in dry rooms on boards or pallets.

b) Locate storage for dry chemicals at the level of feed hopper inlets if possible.

c) Do not exceed safe floorload limits.

d) For liquified gas cylinders, provide cool, dry, well-ventilated, aboveground storage rooms of noncombustible construction, remote from heat sources, walkways, elevators, stairways, and ventilating system intakes.

e) Determine compatibility of all chemicals stored. Store incompatible chemicals separately.

f) Refer to para. 4.7.2.5 for personnel safety precautions.

TABLE 21
Chemical Storage Space Criteria

CLASS OF CHEMICALS	NONINTERRUPTIBLE	INTERRUPTIBLE
Examples of class	All chemicals used for disinfection. Chemicals used for coagulation in treatment plants where raw water is polluted. Softening chemicals.	Chemicals used for corrosion control. Taste and odor, fluoridation.
Minimum stock to be maintained, in days.[1]	30	10
Additional allowance based on shipping time, in days.[1,2]	2 times shipping time.	1-1/2 times shipping time.

[1]Based on maximum use expected for total consecutive days plus additional allowance.
[2]Additional allowance must be large enough to accommodate maximum expected size shipping equipment (truckload, carload, fractional shipload).

TABLE 22
Chemical Storage Type Criteria

TYPE OF STORAGE	DRY	WET
Handling requirements	Allow for access corridors between stacks of packaged chemicals.	Provide agitation for slurries such as carbon or lime (not less than 1 hp mixing for 100 ft^3).
	Palletize and use fork-lift truck only in large installations.	Check manufacturers of feed and mixing equipment for pumps, pipe sizing, and materials selection.
Safety and corrosion requirements	Provide separated storage spaces for combustibles and for toxic chemicals, such as carbon or chlorine gas.	Doublecheck corrosion resistance of bulk storage linings, pipe, mixing, and pumping materials.
	Provide ample space between stores of materials that may interact, such as ferrous sulfate and lime.	Isolate hazardous or toxic solutions such as fluosilicic acid.
		Prefer below-ground or outdoor storages.

4.7.2.3 On-Site Generation and Feeding Equipment

a) Ozone. Ozone can be generated from air or from high-purity oxygen.

(1) Generation from air requires the air to be filtered and dried to a dew point less than -58° F (-50° C) by desiccation and refrigeration.

(2) When using oxygen for the production of ozone, refrigeration and desiccation are not required except when recycling is used. Use oxygen for the generation of ozone where savings are indicated. Power consumption is halved when oxygen is used to generate ozone, but oxygen must be recycled or used for aeration to achieve overall economy.

(3) For ozone feeding equipment, use porous diffusers, injectors, or emulsion turbines to ensure optimum contact.

b) Hypochlorite. Compare the cost of hypochlorite generated from brine with cost of purchased hypochlorite solution delivered to site.

Generation is generally cheaper and may compare favorably with the cost of gaseous chlorine.

c) Chlorine Dioxide. Chlorine dioxide can be generated using a solution of sodium chlorite ($NaClO_2$) and a solution feed-type gas clorinator.

(1) Solutions are fed through packed media reactor for generation of chlorine dioxide in solution.

(2) Optimum operating conditions are pH ≤ 4; chlorine solution ≥ 500 milligram per liter (mg/L); 1:1 weight ratio of pure chlorite to chlorine; and reaction time ≥ 1.0 minute.

(3) Reactor effluent will contain approximately 70 percent hypochlorite and 30 percent chlorine dioxide. Approximate yield is 0.4 lb ClO_2/lb Cl_2. Near 100 percent conversion to chlorine dioxide can be achieved by available recycle equipment. (Yield = 1.0 lb ClO_2/lb Cl_2)

(4) Practical dosage range of 6:1. System operating as flow-proportional should provide acid injection directly upstream from the chlorinator injector to maintain optimum pH.

(5) Chlorine dioxide solutions are unstable in open vessels. All solution lines and diffusers must be designed so there is minimum possibility of chlorine dioxide coming out of solution.

4.7.2.4 Chemical Feeders. See Table 23 for applications of various types of feeders.

a) Dry Feeder Accessories. Dry feeders may require specific auxiliary equipment or accessories when the chemical to be fed has unusual characteristics. Accessories and the conditions under which they are used are as follows:

ACCESSORY	CHARACTERISTIC OF MATERIAL REQUIRING USE OF ACCESSORY
Agitator	Arches in hoppers.
Rotolock mechanism	Tends to flood.
Dissolving chamber	To be fed in solution.
Dust collector	Dusty.
Vapor collector	Noxious or irritating fumes.

b) Feeder Construction. Mechanisms of feeders must be constructed out of materials resistant to substances to be handled. See Table 20 for guidance on materials selection.

TABLE 23
Types of Chemical Feeders for Wastewater Treatment Systems

TYPE OF FEEDER	USE	LIMITATIONS: GENERAL	LIMITATIONS: CAPACITY ft^3/hr	LIMITATIONS: RANGE
Dry Feeder:				
Volumetric:				
Oscillating plate	Any material, granules or powder		0.01 to 35	40 to 1
Oscillating throat (universal)	Any material, any particle size		0.002 to 100	40 to 1
Rotating disc	Moist materials including NaF, granules or powder.	Use disc unloader for arching.	0.01 to 1.0	20 to 1
Rotating cylinder (star)	Any material, granules or powder		8 to 2,000	or 10 to 1
Screw	Dry, free flowing material, powder or granules.		0.05 to 18	20 to 1
Ribbon	Dry, free flowing material, powder, granules, or lumps.		0.0006 to 0.16	10 to 1
Belt	Dry, free flowing material up to 1-1/2-in. size, powder or granules.		0.01 to 3,000	10 to 1 or 100 to 1
Gravimetric:				
Continuous-belt and scale	Dry, free flowing, granular material, or floodable material.	Use hopper agitator to maintain constant density.	0.02 to 2	100 to 1
Loss in weight	Most materials, powder, granules or lumps.		0.02 to 80	100 to 1
Solution Feeder:				
Nonpositive Displacement:				
Decanter (lowering pipe)	Most solutions or light slurries		0.01 to 10	100 to 1
Orifice	Most solutions	No slurries	0.16 to 5	10 to 1
Rotometer (calibrated valve)	Clear solutions	No slurries	0.005 to 0.16 0.01 to 20	or 10 to 1 10 to 1
Loss in weight (tank with control valve)	Most solutions	No slurries	0.002 to 20	10 to 1
Eductor	Most solutions	No slurries	For batch or continuous rate of feed only.	
Positive Displacement:				
Rotating dipper	Most solutions or slurries		0.01 to 30	100 to 1
Proportioning Pump:				
Diaphragm	Most solutions. Special unit for 5% slurries[1].		0.004 to 0.15	100 to 1
Piston	Most solutions, light slurries		0.01 to 170	20 to 1
Gas Feeders:				
Solution feed	Chlorine		8,000 lb/day maximum	20 to 1
	Ammonia		2,000 lb/day maximum	20 to 1
	Sulfur dioxide		7,600 lb/day maximum	20 to 1
Direct feed	Chlorine		300 lb/day maximum	10 to 1
	Ammonia		120 lb/day maximum	7 to 1

[1]Use special heads and valves for slurries.

c) Feeder Accuracy. The accuracy of feeders should be in these ranges:

(1) Volumetric feeders, accuracy of ±3 percent.

(2) Gravimetric feeders, accuracy of ±1 percent. Gravimetric feeders are more expensive than volumetric feeders.

4.7.2.5 Safety Precautions. Provide the following safety factors as a minimum:

a) First aid kits.

b) Continuous toxic gas monitors with alarms and pressure demand self-contained breathing apparatus (SCBA) for emergency gas situations.

c) A readily accessible potable water supply to wash away chemical spills. Emergency deluge shower and eyewash facilities shall be located where they are easily accessible to those in need.

d) Special handling clothing and accessories, such as gloves, goggles, aprons, and dust masks.

e) Adequate ventilation as determined by the medical activity industrial hygienist.

f) No electrical convenience outlets in activated carbon storage or feeding rooms. Store activated carbon in a separate room with adequate fire protection.

g) Entry into confined spaces will require adherence to a gas-free engineering program.

4.7.2.6 Chemical Feeder Capacity and Standby Requirements. Base feeder capacity on maximum expected instantaneous flow and dosage. Essential (noninterruptible) chemical feeders such as disinfection units must have a standby unit having capacity equal to the largest unit. The need for standby units on other treatment processes depends on raw water quality and the specific treatment scheme. Where two chemical feed systems could use the same spare chemical feeder, one standby unit to serve both is adequate. See EPA-430-99-74-001, Design Criteria for Mechanical Electrical and Fluid System and Component Reliability [5].

4.7.3 Sampling. Institute sampling programs only as needed to obtain data for the design and operation of wastewater treatment facilities, or to determine compliance with standards and the effect of waste streams (both raw and treated) on receiving waters. Refer to American Society for Testing and Materials publication ASTM D-3370, Practices for Sampling Water [19] for general discussion of sampling water and wastewater.

4.7.3.1 Sampling Techniques

a) Collection Point. Collect all samples in conduits or channels, at point where flow is highly turbulent. Collect sample from process tank only if tank contents are well mixed. Consider width, length, and depth when selecting sampling point from process tank.

b) Type of Sample. Use samples composited on basis of time and flow, but take single grab samples when:

(1) Wastewater stream is intermittent or concentration is highly variable.

(2) Obtaining information for which time between collection and analysis of sample must be minimized (for example, sampling for dissolved oxygen, temperature, pH, chlorine demand, and residual chlorine; these cannot be composited).

(3) Ascertaining characteristics at extreme conditions.

(4) Samples for oil and grease may be manually composited. Automatic sampling is not normally accurate.

c) Method of Sampling. Use widemouthed containers to take grab samples. At small plants (up to 1 Mgd), take composite samples manually by combining a series of regularly collected grab samples, such that the contribution from a particular grab sample is proportional to the flow at the time it was taken. At large plants and industrial wastes use automatic sampling devices which can be programmed for desired sampling method, that is, grab, continuous or flow proportional composite.

4.7.3.2 Sample Volume and Preservation. Volume and preservation requirements depend on: (1) the analytical determinations to be carried out on the sample, and (2) the time between sample collection and analysis. Refer to Table 24 for recommendations for sampling and sample preservation. Refer to American Public Health Association (APHA) Standard Methods for the Examination of Water and Wastewater [20] and EPA Manual of Methods for Chemical Analysis of Water and Wastes [5], for specific recommendations regarding sample containers, volumes, and methods of sample preservation for each analytical measurement.

4.7.4 Analytical Methods. Analytic methods available for quantitative determination of physical, biological, inorganic chemical, and organic chemical characteristics of wastewater samples are summarized in Table 25. Refer to APHA Standard Methods for the Examination of Water and Wastewater [20] for detailed laboratory procedures.

4.7.4.1 Routine Testing During Plant Operation. A routine sampling and analysis program to maintain plant operability and performance is required. This program is unique to the individual industrial and oily wastewater treatment facilities and a general program cannot be developed by this manual.

The program shall be fully developed in the Operations and Maintenance Manual and revised accordingly after plant startup and the 30-d performance certification period. The program shall include the following: sample locations and method, sample type (grab or composite), sampling frequency and analyses required per sample. The Operations Manual shall also identify minimum reporting requirements for regulatory compliance and shall provide operating log sheets for recording operating data.

TABLE 24
Recommendations for Sample Collection and Preservation According to Measurement

MEASUREMENT	VOLUME mL	CONTAINER[1]	PRESERVATIVE	HOLDING TIME[2]
Physical Properties:				
Color	50	P,G	Cool, 4° C	24 h
Conductance	100	P,G	Cool, 4° C[3]	24 h
Hardness	100	P,G	Cool, 4° C HNO_3 to pH <2[4]	6 mo
Odor	200	G only	Cool, 4° C	24 h
pH	25	P,G	Det. on site	6 h
Residue:				
Filterable	100	P,G	Cool, 4° C	7 d
Nonfilterable	100	P,G	Cool, 4° C	7 d
Total	100	P,G	Cool, 4° C	7 d
Volatile	100	P,G	Cool, 4° C	7 d
Settleable Matter	1,000	P,G	None required	24 h
Temperature	1,000	P,G	None	No holding
Turbidity	100	P,G	Cool, 4° C	7 d
Metals:				
Dissolved	200	P,G	Filter on site HNO_3 to pH <2[4]	6 mo
Suspended	200	P,G	Filter on site	6 mo
Total	100	P,G	HNO_3 to pH <2[4]	6 mo
Mercury:				
Dissolved	100	P,G	Filter on site HNO_3 to pH <2[4]	38 d (glass) 13 d (hard plastic)
Total	100	P,G	HNO_3 to pH <2[4]	38 d (glass) 13 d (hard plastic)
Inorganics, Nonmetallics:				
Acidity	100	P,G	None required	24 h
Alkalinity	100	P,G	Cool, 4° C	24 h
Bromide	100	P,G	Cool, 4° C	24 h
Chloride	50	P,G	None required	7 d
Chlorine	200	P,G	None	No holding
Cyanides	500	P,G	Cool, 4° C NaOH to pH 12	24 h

See footnotes 1, 2, 3, and 4.

TABLE 24 (Continued)
Recommendations for Sample Collection and Preservation
According to Measurement

MEASUREMENT	VOLUME mL	CONTAINER[1]	PRESERVATIVE	HOLDING TIME[2]
Fluoride	300	P,G	None required	7 d
Iodine	100	P,G	Cool, 4° C	24 h
Nitrogen:				
Ammonia	400	P,G	Cool, 4° C H_2SO_4 to pH <2	24 h
Total Kjeldahl	500	P,G	Cool, 4° C H_2SO_4 to pH <2	24 h[5]
Nitrate plus Nitrite	100	P,G	Cool, 4° C H_2SO_4 to pH <2	24 h[5]
Nitrate	100	P,G	Cool, 4° C	24 h
Nitrite	50	P,G	Cool, 4° C	48 h
Dissolved Oxygen:				
Probe	300	G only	None	No holding
Winkler	300	G only	Fix on site	4 to 8 h
Phosphorus:				
Orthophosphate, dissolved	50	P,G	Filter on site	24 h
Hydrolyzable	50	P,G	Cool, 4° C H_2SO_4 to pH <2	24 h[5]
Total	50	P,G	Cool, 4° C H_2SO_4 to pH <2	24 h[5]
Total, dissolved	50	P,G	Filter on site Cool, 4° C H_2SO_4 to pH <2	24 h[5]
Silica	50	P only	Cool, 4° C	7 d
Sulfate	50	P,G	Cool, 4° C	7 d
Sulfide	500	P,G	2 ml zinc acetate	24 h
Sulfite	50	P,G	None	No holding
Organics:				
BOD	1,000	P,G	Cool, 4° C	24 h
COD	50	P,G	H_2SO_4 to pH <2	7 d[5]

See footnotes 1, 2, and 5.

TABLE 24 (Continued)
Recommendations for Sample Collection and Preservation
According to Measurement

MEASUREMENT	VOLUME mL	CONTAINER[1]	PRESERVATIVE	HOLDING TIME[2]
Oil & Grease	1,000	G only	Cool, 4° C H_2SO_4 or HCl to pH <2	24 h
Organic carbon H2S04 or HCl	25	P,G	Cool, 4° C H_2SO_4 or HCl to pH <2	24 h
Phenolics	500	G only	Cool, 4° C H_2PO_4 to pH <4 1.0 g $CuSO_4$/1	24 h
MBAS	250	P,G	Cool, 4° C	24 h
NTA	50	P,G	Cool, 4° C	24 h

[1]Plastic (P), Glass (G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.
[2]Recommended holding times for properly preserved samples based on currently available data. Extension or reduction of these times may be possible for some sample types and measurements. Where shipping regulations prevent the use of proper preservation techniques or the holding time is exceeded, reported analytical data should indicate the variation in recommended procedures.
[3]If the sample is preserved, it should be warmed to 25° C for measurement or temperature correction made and results reported at 25° C.
[4]Where HNO_3 cannot be used because of shipping restrictions, the sample may be initially preserved by icing and immediately shipped to the laboratory. Upon receipt in the laboratory, the sample must be acidified to a pH <2 with HNO_3 (normally 3 mL 1:1 HNO_3/L is sufficient). At the time of analysis, the sample container should be thoroughly rinsed with 1:1 HNO_3 and the washings added to the sample. A volume correction may be required.
[5]Data from National Enforcement Investigations Center, Denver, Colorado, support a 4-week holding time for this parameter in sewerage systems (SIC 4952).

TABLE 25
Analytical Methods

CHARACTERISTICS	METHOD OF ANALYTIC DETERMINATION
Physical Parameters:	
Color	Photometric
Odor	Physiological
Temperature	Thermometric
Turbidity	Nephelometric
Total suspended solids	Gravimetric
Specific conductance	Conductivity meter
Biological Parameters:	
Total coliform bacteria	Fermentation tube or membrane filter
Fecal coliform bacteria	Fermentation tube or membrane filter
Inorganic Chemical Parameters:[1]	
Alkalinity	Potentiometric or colorimetric titration
Ammonia nitrogen	Spectrophotometric, or titrametric
Arsenic	AA spectroscopy
Boron	Colorimetric
Cadmium	AA spectroscopy
Chloride	Titrametric
Chlorine residual	Colorimetric or potentiometric titration
Hexavalent chromium	AA spectroscopy
Copper	AA spectroscopy
Fluoride	Colorimetric or ion selective probe
Hardness	Titrametric
Iron	Colorimetric or AA spectroscopy
Lead	AA spectroscopy
Manganese	Colorimetric
Mercury	AA spectroscopy
Nitrates	Colorimetric or ion selective probe
Nitrites	Spectrophotometric
pH	Electrometric
Phosphorous	Colorimetric
Selenium	AA spectroscopy
Silver	AA spectroscopy
Sulfate	Gravimetric or nephelometric
Sulfide	Colorimetric
Total dissolved solids	Gravimetric
Zinc	AA spectroscopy
Organic Chemical Parameters:	
Cyanide	Colorimetric
Methylene blue active substances	Spectrophotometric
Oil and grease	Hexane extraction or freon extraction
Pesticides	Solvent extraction plug gas chromatographic analysis
Phenols	Photometric
Biochemical oxygen demand	BOD_5 test, respirometric
Chemical oxygen demand	Chemical oxidation

[1]Atomic absorption spectroscopy and flame emission photometry are recommended for most metals analyses. These are designated "AA spectroscopy."

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