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MILITARY HANDBOOK

DOMESTIC WASTEWATER CONTROL

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ABSTRACT

This handbook provides basic design guidance developed from extensive reevaluation of facilities. It is intended for use by experienced architects and engineers. The contents cover the design of collection, transport, treatment, and sludge handling facilities for domestic wastewater from Navy installations. The handbook also presents design criteria for metering instrumentation, controls, chemical feeding devices, sampling, and analyzing for these facilities.

FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design, and construction of Naval shore facilities, cannot be made without prior approval of the NAVFACENGCOM Criteria Office, Code 15C.

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 Commanding Officer (Code 423), Naval Facilities Engineering Service Center, 1100 23rd Avenue, Port Hueneme, CA 93043-4370; telephone (805) 982-4984, DSN 551-4984.

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, Civil Engineering	LANTDIV
MILL-HDBK-1005/2	Hydrology	LANTDIV
MIL-HDBK-1005/3	Drainage Systems	LANTDIV
DM-5.4	Pavements	PACDIV
DM-5.5	General Provisions and Geometric Designs for Roads, Streets, Walks, and Open Storage Areas	NAVFAC
MIL-HDBK-1005/6	Trackage	NORTHDIV
MIL-HDBK-1005/7	Water Supply Systems	SOUTHDIV
MIL-HDBK-1005/8	Domestic Wastewater Control	NAVFAC
MIL-HDBK-1005/9	Industrial and Oily Wastewater Control	NAVFAC
DM-5.10	Solid Waste Disposal	PACDIV
DM-5.12	Fencing, Gates, and Guard Towers	WESTDIV
MIL-HDBK-1005/13	Hazardous Waste Storage Facilities	NAVFAC
DM-5.14	Groundwater Pollution Control	NAVFAC

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

DOMESTIC WASTEWATER CONTROL

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Section 1: INTRODUCTION

1.1 Scope. This handbook contains design criteria for the collection, transport, and treatment of domestic wastewater discharges from Navy facilities. Particular details covered include design procedures and guidelines; domestic wastewater characterization, collection, and treatment; effluent disposal; treatment and disposal of wastewater residuals; and air pollution control for wastewater processes. 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.

This handbook 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 Cancellations. This handbook cancels and supersedes NAVFAC MIL-HDBK-1005/8, Domestic Wastewater Control, September 1988.

The following definitive drawings are cancelled and are superseded by figures in this handbook:

Drawing Number	Title
1311352	Ballast Water Treatment and Disposal System
1311357	Oil-Water Separation for Oil Contaminated Water Treatment
1402880	Wastewater Treatment Systems Activated Sludge Plants Flow Diagram Plot
1402881	Wastewater Treatment Trickling Filter Plant Flow Diagram Plot Plan
1402882	Wastewater Treatment Packaging Plant Installations Flow Diagrams and Plot
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1402884	Wastewater Treatment Chemical Treatment Special Naval Aviation Rework Facility (NARF) Shop Wastes Process
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1402893	Wastewater Treatment Units Chlorination Buildings and Contact Tanks
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1403325	Wastewater Collection System - Shore Facilities for Receiving Ship Sewage - II

1.3 Definitions. The following definitions shall apply to this handbook.

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 an adverse effect is created 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 or constructed or manufactured for lease to the Department of the Navy.

1.4 Policy. The basic policy of the Navy in regard to 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 Office of the Chief of Naval Operations Instruction (OPNAVINST) 5090.1B, Environmental and Natural Resources Program Manual. Also, refer to Environmental Quality in NAVFAC Military Handbook MIL-HDBK-1190, Facility Planning and Design Guide.

1.4.1 Guidelines. Refer to OPNAVINST 5090.1B. 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 5090.1B.

1.4.5 Shore Disposal of Ship Sewage. Refer to NAVFAC MO-340, Ship-to-Shore Hose Handling Operations Manual.

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 shall be considered during the design process):

a) MIL-HDBK-1190

b) Chief of Naval Education and Training (CNET) 4100.4B, Energy Technology Application Program

c) NAVFAC MIL-HDBK-1003/3, Heating, Ventilating, Air Conditioning, and Dehumidifying Systems

In addition to full use 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 the extent 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 Overview of the Clean Water Act. The Clean Water Act is a major Federal law that addresses the release of pollutants to surface waters of the United States, such as lakes, streams, estuaries, oceans, and bays. Last amended in 1987, the Clean Water Act provides legislation for many water pollution issues. The amendments of the Clean Water Act make up six titles. The first title states the objective of the Act and establishes programs to improve the water quality and remove pollutants from the Great Lakes and the Chesapeake Bay. Second, the Act provides funding for construction of publicly owned treatment works. Perhaps most important are the third and fourth titles which address enforcement of the Act through standards and permits. The fifth title addresses judicial review and procedures for workers who report a violation of the Act. Finally, the sixth title gives the EPA the authority to provide states with grants to establish pollution control funds and also decide how they will use these funds. All Federal facilities are subject to the provisions of the Clean Water Act and must make appropriate changes to comply.

Enforcement of the Clean Water Act through standards and permits is an essential way to ensure that the objectives of the Act are met. The Clean Water Act imposes effluent limitations upon direct industrial dischargers based on national technology-based standards and water quality based standards. Technology-based standards establish minimum treatment levels for direct industrial dischargers without regarding water quality of the public waterways receiving the waste. These standards are based on treatment technologies that have been developed and are capable of being utilized by an entire industry. Water quality standards are applied in order to ensure that the water quality of specific bodies of water is protected and that the body of water can support its intended use.

Water quality standards provide the basis for establishing discharge limits in the National Pollutant Discharge Elimination System (NPDES). The NPDES is the regulatory mechanism for the Clean Water Act. The NPDES requires anyone discharging pollutants from a point source into waters of the

United States to obtain a permit. Permits obtained through the NPDES are legally enforceable.

1.5.1 Water Quality Based Standards. All U.S. waters have adopted water quality based standards in order to restore and maintain the chemical, physical, and biological integrity of the waters so that the propagation of fish and wildlife can be protected. Water quality standards consist of two essential components: designated uses and specific water quality criteria. A designated use describes the value of the water body and how it is used. Under Section 303 of the Clean Water Act, all states are required to establish designated uses for the water bodies in their jurisdiction. The designated uses can be as specific as is needed for the individual water body through use of subcategories or naming individual species of aquatic life that require protection. Water bodies which are affected by naturally occurring pollutants or have low flow water levels can have designated uses which are not attainable. In these cases, the water quality is at a lower level than is necessary to protect the water body's designated use. The naturally occurring pollutants make protection through permits and regulations difficult. Instead, it is more realistic to modify the designated use to one that is more easily attainable.

The second component of water quality standards is water quality criteria. Under Section 303 of the Clean Water Act, states are also required to adopt water quality criteria. Water quality criteria describe the water quality which will support a water body's designated use. This criteria can be expressed in numeric or narrative form based on the latest scientific findings regarding the effects of pollutants on aquatic life and human health.

Other important parts of water quality standards are the anti-degradation policies. These policies are formed in order to conserve, maintain, and protect existing uses of water bodies. When water quality of a water body is above and beyond that required to protect the designated use, the anti-degradation policy works to maintain the present condition of the water body. Anti-degradation policies also protect outstanding national resource waters, such as waters in national and state parks and wildlife refuges.

Water quality standards must be reviewed and updated at least once every 3 years. Revisions or new standards may be necessary under several circumstances: new scientific and technical information becoming available, improvements being made in the water quality, changes being made to the regulations, or environmental changes occurring in the ecological structure of the water body or its surroundings. Water quality standards play an important role in protecting the waters being affected by the pollutants.

1.5.2 *Technology-Based Standards*. Technology-based standards establish minimum amounts of pollutants allowed to be discharged from industrial facilities. When determining the limits, these standards do not take into consideration the water bodies being affected. All industrial facilities that discharge wastewater directly into public waterways instead of into publicly owned treatment facilities are subject to technology-based standards. The standards are established and applied evenly throughout all facilities within an industry. Each industry may have its own unique standards based upon the pollutants that are discharged and the best treatment technology available for the entire industry. However, subcategories within industries may be developed to take into account differences in raw materials used, manufacturing processes, age of the facilities, types of wastewater, and type of product produced.

Limitations that are established focus on conventional, nonconventional, and toxic pollutants. Conventional pollutants are biochemical oxygen demand, total suspended solids, pH, oil and grease, and fecal coliform. Nonconventional pollutants are all pollutants that are not, by definition, conventional or toxic. There are over 400 toxic pollutants. Similar to the water quality standards, the Clean Water Act requires revision to the limitations. However, these revisions should be performed on an annual basis in order to reflect current and improved technologies.

Every 2 years an "Effluent Guidelines Plan" is published in the Federal Register identifying industrial sources that discharge nonconventional and toxic pollutants and do not yet have guidelines. Effluent guidelines (incorporating technology-based standards) are established based on the amount of effluent limitation reduction possible for toxic and nonconventional pollutants by the Best Available Technology Economically Achievable (BAT) method. Best conventional pollutant control technology is the technical standard for conventional pollutants. When the EPA has not established technology-based limitations, Best Professional Judgment (BPJ) is used to determine effluent guidelines. Industries built after the publication of regulations are considered "new sources" and are subject to more stringent effluent standards. As long as compliance is met, industries have the freedom to choose among different manufacturing processes and equipment.

1.5.3 *National Pollutant Discharge Elimination System*. The NPDES is the regulatory mechanism for the Clean Water Act. The NPDES requires anyone discharging pollutants from a point source (pollutants discharged through confined and discrete carrying devices) into waters of the United States to have a permit. Some of the regulations that are controlled through permits include the disposal of sewage sludge, dredge and fill activities into navigable water and wetlands, discharge of pollutants into ocean waters, and discharge of stormwater. NPDES permits can subject a direct discharge industrial facility or a publicly owned treatment work to many terms and conditions. In order to ensure compliance with their NPDES permits, publicly owned treatment works enforce pretreatment standards which industrial users must follow before discharging into sewers.

In addition to effluent limitations, the permit can require monitoring and reporting requirements. Monitoring requirements include descriptions of how the sampling of the effluent should be conducted, how frequently the samples should be taken, and the type of monitoring required. The results of monitoring (including any noncompliance) are recorded on a Discharge Monitoring Report and are reported regularly to the EPA and state authorities. Water quality standards are also enforced through the NPDES. If any standard is not sufficient to protect the waters, then more stringent limitations are included in the permit.

NPDES permits are administered by either the U.S. EPA or a state that has been delegated by the EPA to be a permitting authority. Permits are valid for 5 years and only under certain circumstances may be modified, revoked, reissued, transferred, or terminated. Failure to disclose facts when applying for a permit, failure to comply, or the closing of a facility will all justify the termination of a permit. Modifications can be made to the permit when there are changes to the facility, when new information is available, or when regulations are changed. Permits can be issued only after opportunity has been given for a public hearing.

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

1.7 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.

Section 2: DOMESTIC WASTEWATER COLLECTION AND TREATMENT

2.1 Wastewater Flow and Characteristics. The five major components of wastewater carried by sanitary sewers at Navy installations are:

Type	Origin
Domestic flow	Homes, mess halls, recreation and entertainment facilities, clubs, commercial stores, laundry facilities, barracks, offices, institutions, and sanitary flow from shops and industrial installations.
Ship discharge	Holding tanks on Navy ships.
Industrial flow	Process wastes from Navy facilities such as shipyards, air stations, aircraft rework facilities, shops, laundries, and laboratories.
Infiltration	Unavoidable leakage of groundwater into sewers through joints, manholes, foundation drains, and damaged or defective sewer pipes.
Inflow	Unavoidable leakage of surface drainage into sewers through manhole covers, roof drains, and other surface drainage connections.

2.2 Flow Data on Variations and Estimates of Flow. Flow rates vary seasonally, daily, and hourly. To properly accommodate these variations, apply the following measures of flow:

Flow Measure	Explanation	Design Application
Average 24-hr flow	Annual average of daily flows (gallons per day (gpd) [liters per second (L/s)])	Estimate of annual operating costs (chemicals, power, etc.)
Maximum 24-hr flow	Highest 24-hr flow	Design of process units, during year such as settling tanks, and aeration basins

Flow Measure	Explanation	Design Application
Minimum flow	Least instantaneous flow	Design of sewers and plant conduits to avoid deposition problems at low flows
Peak flow	Highest instantaneous flow	Design of sewers and hydraulic elements of treatment plant (such as pipes, weirs, and channels)

2.2.1 Flow Estimates. A general approach to estimating flow is to:

a) Determine unit peak and minimum flows from analyses of actual wastewater discharge from the facilities being studied. Where actual measurements cannot be obtained, use data given in this section for individual flow components.

b) Apply unit flows to design population, production, or other applicable parameter of installation size.

c) Add maximum coincident flows from different sources to determine total peak flow. Consider peak discharges from pumping stations to be coincident with peak flows in the receiving system, unless a program of pumping is used to ensure that peaks do not coincide. If station is equipped with flow-paced variable speed pumps, the area upstream may be combined with downstream, and peak calculated from the combined average flow.

d) Determine unit flows, and peak and minimum flows, for minimum, normal, and maximum deployment conditions.

2.2.1.1 Domestic Flows for Design Regulations. To determine the design population for treatment facilities, multiply the authorized resident and transient population of installation by applicable growth factor from Table 1. For collection system design, use tributary portion of authorized population of installation.

Table 1
Growth Factors for Treatment Facilities

Authorized Population of Installation (resident plus nonresident)	Treatment Facility Growth Factor
5,000	1.50
10,000	1.25
20,000	1.15
30,000	1.10
40,000	1.05
50,000	1.00

2.2.1.2 Domestic Flows, Annual Average. To determine the annual average 24-hour flow per capita perform the following:

a) For estimating flow, use:

Resident population = 120 gallons per capita per day (gpcd) (454 liters per capita per day (Lpcd))

Transient workers = 30 gpcd (114 Lpcd)

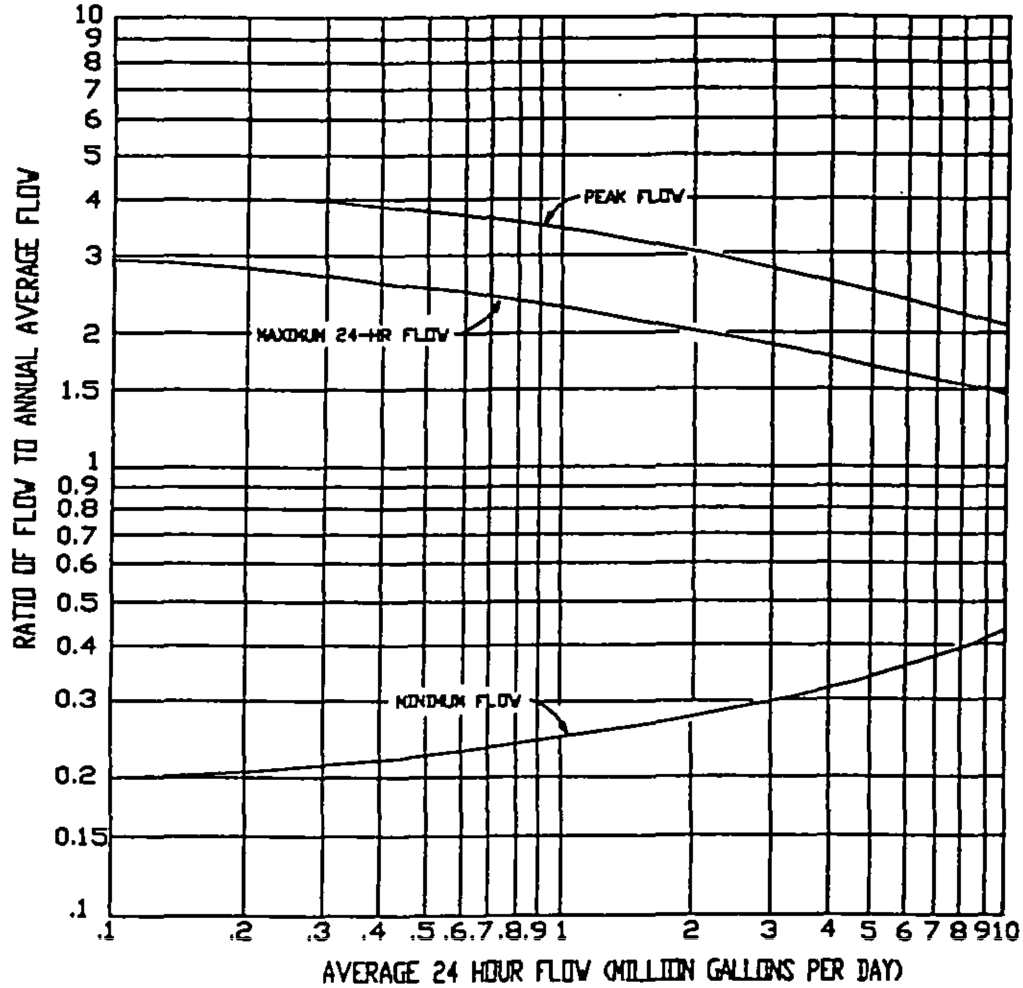
2.2.1.3 Domestic Flows, Maximum 24-Hour Flow. To determine the maximum 24-hour flow:

a) Multiply annual average 24-hour flow by ratio from the appropriate curve in Figure 1.

b) Add to maximum 24-hour flows from any other sources.

2.2.1.4 Domestic Flow, Peak Flow. To determine the peak flow for a resident population, multiply the annual average flow by ratio from the appropriate curve in Figure 1; consider coincident peaks from other sources. For transient workers, assume peak flow of three times the average is coincident with resident peak flow (that is, daily contribution uniform over 8-hour shift). For installation where average domestic flow for transients will exceed 0.4 million gallons per day (Mgd) (1.5 million liters per day [ML/d]) or constitute more than 20 percent total average flow, investigate flow variations from transients in the actual facility or in a facility similar to the one proposed.

2.2.1.5 Domestic Flows, Minimum Flow. To determine the minimum flow for resident population, multiply annual average flow by ratio from the appropriate curve in Figure 1; for transient workers, assume minimum flow is zero.



NOTE:
PEAK & MINIMUM FLOW CURVES ARE FOR RESIDENT POPULATION

Figure 1
Ratio of Extreme Flow to Average Daily Flow for
Domestic Sewage at Navy Facilities

2.2.1.6 Ship Discharges. Table 2 lists the daily flow, pump capacity, number of pumping stations, number of discharge connections, and design ship discharge for selected ship types. For ships not listed in Table 2, ship types equivalent to those listed are shown in the tabulation below. Where a destroyer or submarine is nested next to a tender, and the tender is berthed at a pier, the nested ships will discharge into the tender and the tender will discharge to the pier at the rate listed for the tender.

Flow rates are determined as follows:

a) Average 24-hour flow. Select values from Table 2 according to ship type. Calculate for maximum planned berthing. The average 24-hour flow shown in Table 2 is computed on the basis of 60 gpcd (227 Lpcd) using the maximum ship's complement.

b) Maximum 24-hour flow. Use average flow.

c) Minimum flow per ship. The flow is zero.

d) Peak flow. The peak flow shall be determined by Equation (1):

EQUATION: $$Q_{peak} = Q_{max} + (4)(Q_{avg}) \qquad (1)$$

where

Q_{peak} = design peak flow

Q_{max} = the discharge rate of the ship at berth having the highest discharge rate at a connection (see Table 2)

Q_{avg} = the average 24-hour flow of the remaining ships at berth, but not less than the flow rate of the largest single ship's sewage pump

$(4Q_{avg} \geq = Q_{max})$

Athwartship piping from port to starboard discharge connections will be installed in destroyer type ships which will reduce peak flows from nests.

2.2.1.7 Industrial Flows. Refer to NAVFAC MIL-HDBK-1005/9, Industrial and Oily Wastewater Control.

Table 2
Ship Sewage Discharge Rates[1]

Ship[2] Class or Ship	Max. Ship's Complement (without troops or air wing)	Average 24-Hour Flow[3] (gpm [L/s])	Maximum Discharge of One Pump (gpm [L/s])	No. of Pumping Stations	Total Number of Pumps	Number and Location of Discharge Connections[4]
AD 37, 38	1350 1680+340=2020	85 (5.4)	225 (14.2)	4	8	2 (1P,1S)
AD 40, 41, 43	1680+340=2020	85 (5.4)	225 (14.2)	5	10	3 (1P,1S,1A)
AD 44	1680+340=2020	85 (5.4)	225 (14.2)	3	6	2 (1P,1S)
AE	383	20 (1.3)	150 (9.46)	1	2	2 (1P,1S)
AGF	440	20 (1.3)	150 (9.46)	3	6	2 (1P,1S)
AO	225	10 (0.6)	100 (6.31)	1	2	2 (1P,1S)
AOE	667	30 (1.9)	100 (6.31)	2	4	2 (1P,1S)
ARS	100	5 (0.3)	100 (6.31)	1	2	2 (1P,1S)
AS 33	915	40 (2.5)	100 (6.31)	3	6	1 (1A)
AS 36	915	40 (2.5)	100 (6.31)	3	6	1 (1A)
AS 39	915	40 (2.5)	100 (6.31)	5	10	3 (1P,1S,1A)
CG	358	15 (1.0)	100 (6.31)	3	6	4 (2P,2S)
CGN	625	30 (1.9)	100 (6.31)	2	4	4 (2P,2S)

Table 2 (Continued)
Ship Sewage Discharge Rates[1]

Ship[2] Class or Ship	Max. Ship's Complement (without troops or air wing)	Average 24-Hour Flow[3] (gpm [L/s])	Maximum Discharge of One Pump (gpm [L/s])	No. of Pumping Stations	Total Number of Pumps	Number and Location of Discharge Connections[4]
CV	3000[5]	125 (7.9)	150 (9.46)	8	16	4 (2P,2S)
CVN	3300[5]	125 (7.9)	400 (25.24)	7	14	6 (3P,3S)
DD & DDG 993	340	15 (1.0)	9 (0.57)	2	2	2 (1P,1S)
DDG	323	8	9	2	2	2
DDG 51	341	15 (1.0)	40 (2.52)	2	8	4 (2P,2S)
DDG 52-78	341	15 (1.0)	40 (2.52)	2	4	4 (2P,2S)
DDG 79	380	20 (1.3)				
FFG	210	10 (0.6)	100 (6.31)	1	2	2 (1P,1S)
LCC	1010[5]	45 (2.9)	150 (9.46)	2	4	4 (2P,2S)
LHA	937[5]	40 (2.5)	100 (6.31)	3	6	6 (2P,2S)
LHD	1104[5]	50 (3.2)	20 (1.26)	2	4	4 (2P,2S)
LPD 4	510[5]	25 (1.6)	150 (9.46)	3	6	4 (2P,2S)
LPD 17	165	20 (1.3)				
LPH	1420[5]	60 (3.8)	100 (6.31)	3	6	6 (3P,3S)
LSD	375[5]	20 (1.3)	100 (6.31)	2	4	2 (1P,1S)

Table 2 (Continued)
Ship Sewage Discharge Rates[1]

Ship[2] Class or Ship	Max. Ship's Complement (without troops or air wing)	Average 24-Hour Flow[3] (gpm [L/s])	Maximum Discharge of One Pump (gpm [L/s])	No. of Pumping Stations	Total Number of Pumps	Number and Location of Discharge Connections[4]
MCM, MHC	81	5 (0.3)				
SSBN	155	10	-	-	-	-
SSN	133	10 (0.6)				

[1]For wastewater disposal systems aboard ships, refer to DTRC/SME-91/53, Catalog of Shipboard Pollution Abatement Systems.
[2]For more information on U.S. Naval Vessels, refer to NAVSEA S0300-A4-MAN-A1C/(U), Naval Vessel Register/Ships Data Bank.
[3]Based on maximum ship's complement at 60 gpcd (227 Lpcd). Flows raised to next highest 5 gpm (19 Lpcd).
[4]P = discharge connection on the port side of the ship; S = discharge connection on the starboard side of the ship; A = discharge connection on the stern side of the ship.
[5]The following ships carry additional air wing troops:
CV: 2500, CVN: 2800, LHA: 1700, LHD: 1900, LPD: 930, LPH: 1560, LSD: 450, LCC: 700.

2.2.1.8 Infiltration. Adequate allowance for infiltration is included in the per capita flows of domestic and ship sewage. This allowance is 500 gallon-per-day per inch diameter mile (gpd/in.-mi) [46 liters-per-day per millimeter diameter kilometer (Lpd/mm-km)] of sewer. For existing systems, estimate infiltration by comparing measured wastewater flow with water use. Also check variations of flow with weather conditions. If infiltration is greater than 3000 gpd/in.-mi (278 Lpd/mm-km), evaluate system renovation to eliminate infiltration.

2.2.1.9 Inflow. Surface drainage or runoff is normally very large in relation to sanitary flow. Surface drainage or inflow should be kept out of sanitary sewers by rational design procedures, adequate construction specifications and inspection, and by enforced regulation or command. Manhole covers can be a large source of inflow. Use of solid covers with half-depth pickholes in areas subject to overflow by surface drainage can reduce the problem significantly. Use of bolted and gasketed manhole covers in areas subject to flooding can also reduce the problem.

Existing sewer systems should be evaluated for inflow by the designer of new intercepting sewers, trunk sewers, collector sewers, or treatment facilities fed by the existing sewers. If inflow is significant, sources should be determined by inspecting manhole covers, roof and other drainage connections, smoke testing, and internal televised inspection of sewers. All inflow that is cost effective to remove should be eliminated by rehabilitation of the sewer system. This will prevent oversizing of new sewers and wastewater treatment facilities. Refer to EPA 430/9-75-021, Handbook for Sewer System Evaluation and Rehabilitation.

2.3 Characteristics. The base design on the expected maximum 24-hour pollutant loadings expressed in pounds per day (lb/d) [kilograms per day (kg/d)]. Where possible, determine loadings from analysis of the waste to be treated (refer to Section 4 for methods of analysis). Otherwise, determine the maximum 24-hour loadings by applying typical concentrations shown in the following paragraphs to maximum 24-hour flow.

For mixed wastes from distinct sources, calculate range of concentrations based on expected flow rates. Where ship discharges containing seawater are involved, determine the magnitude of chloride concentrations under expected ship discharge.

2.3.1 Domestic Wastes. Navy domestic wastewater tends to be stronger and more greasy than municipal domestic sewage. It is usually fresh when it arrives at the treatment plant, settles well, and is amenable to biological treatment. Typical concentrations are as follows (values are for collection area without garbage grinders; for effect of garbage grinders, refer to paragraph 2.3.5):

Characteristic	Concentration (mg/liter)
Total solids	800
Volatile solids	420
Fixed solids (highly variable)	380
Total suspended solids	200
Volatile suspended solids	144
Fixed suspended solids	56
Floatable solids (such as oil and	25-40
grease)	200
BOD_5 at 20 degrees C[1]	32
Total Kjeldahl nitrogen (as N)	16
Organic nitrogen (as N)	16
Ammonia nitrogen (as N)	12
Total phosphorus (as P)	

Hereafter, BOD will be used to represent the 5-day biochemical oxygen demand at 20 degrees C as represented by BOD_5. If an incubation time or temperature other than these are used, they shall be specifically identified.

2.3.2 Ship Sewage. Ship sewage settles well and is amenable to biological treatment, but may be septic. Typical concentrations are as follows (wastes from shipboard industrial activities are not included):

Characteristic	Concentration (mg/liter)
Total suspended solids	600
Total dissolved solids	20,000
Chlorides	11,000
Sulfates	1,500
Sodium	6,200
Other dissolved solids	1,300
BOD	400

The high dissolved solids, chloride, sulfates, and sodium concentrations apply when seawater flushing or ballast systems are used. For more information on ship sewage, see NAVSEA S9086-T8-STM-010/CH-593, Naval Ships' Technical Manual.

2.3.3 Industrial Wastes. Determine industrial wastewater characteristics used in design from a survey of the actual wastes involved, or from knowledge of wastes at similar facilities. Detailed information or characteristics of discharges from industries commonly associated with Navy facilities, along with additional references, are provided in MIL-HDBK-1005/9.

2.3.4 Residue Quantities

a) Sludge. Refer to paragraph 7.2.

b) Screenings. In the absence of local data, allow for 6 ft^3 per million gallons (ft^3/Mg) [0.045 cubic meters per million liters (cu m/ML)], based on maximum 24-hour flow.

c) Scum. In the absence of local data, allow for 6 ft^3/Mg (0.045 cu m/ML), based on maximum 24-hour flow.

d) Grit. Determine design quantities and design values of specific gravity and size distribution by sampling grit settled from actual sewage at overflow rates low enough to ensure complete capture.

(1) In the absence of existing local data, estimate maximum 24-hour and peak grit load by multiplying respective flow by the following allowances:

Flow	Allowance
Maximum 24-hour	6 ft^3/Mg (0.045 cu m/ML)
Peak	24 ft^3/Mg (0.18 cu m/ML)

(2) Consider the need for higher average allowances in systems with garbage grinders, unpaved roads, loose sandy soil, or leaky sewers, manholes, and covers; and higher maximum 24-hour or peak allowances in systems with combined sewers on very flat grades.

(3) For design of grit facilities, determine effective size (P_{10}) of grit from analysis. (P_{10} is equal to maximum particle diameter of smallest 10 percent, by weight, of the grit particles.) If sampling is not feasible, assume P_{10} equals 200 mesh (Tyler sieve) and specific gravity equals 2.65.

2.3.5 Effect of Ground Garbage. Where garbage grinders are used throughout the domestic sewage collection system or on board ships, increase allowances for strength of sewage as follows:

Characteristic	Average Increase (%)
Total suspended solids	50-85
BOD	30-65
Grit	40-80
Primary sludge (dry sludge solids)	Up to 85
Scum (dry solids)	Up to 50

Where garbage grinders are used in only parts of the system, allow proportionately smaller increases.

Section 3: WASTEWATER COLLECTION SYSTEMS

3.1 Sanitary Sewers. This section presents criteria for the design of collection systems carrying sanitary wastes. The following limitations on discharge to sanitary sewers shall be observed.

3.1.1 Storm Water. Storm water shall not be carried in sanitary sewers. Provide separate sanitary and storm water collection systems.

3.1.2 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 EFD to determine if discharge permit is required for such uncontaminated waters.

3.1.3 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 Water Pollution Control Federation (WPCF) MOP 3, Regulation of Sewer Use.

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

3.2.1 Design Flows. Refer to paragraph 2.2. Design sewers for peak flow, except design main interceptor to treatment plant for 125 percent of peak flow.

3.2.2 Flow Formula. Use the Manning formula (refer to WPCF MOP FD-5, Gravity Sanitary Sewer Design and Construction) to design sewers to flow full, without surcharge, under peak flow (equivalent to design for flow at 0.8 depth under peak flow with friction factor constant). Use friction factor "n" of 0.013 for concrete pipes. For cast iron pipes, vitrified clay pipes, and fiberglass reinforced pipes use "n" of 0.01.

3.2.3 Velocity Constraints. Design pipe slopes to ensure a velocity of at least 2.5 feet per second (fps) [0.76 meters per second (m/s)] when pipe is flowing full at peak flow. Velocity should not exceed 10 fps (3 m/s) for any flow in design range. Velocities as low as 2.0 fps (0.6 m/s) flowing full are permitted where appreciable cost benefits can be realized.

3.2.4 Maintenance of Energy Gradient. Design to maintain energy gradient when diameter of sewer changes. Set 0.8 depth point of each pipe at the same elevation to approximate this requirement.

3.2.5 Pipe Diameter. No sewers in the collection system (including laterals, interceptors, trunks, and mains) shall be less than 8 inches (200 mm) in diameter. Service connections for single family dwellings or equivalent shall be at least 4 inches (100 mm) in diameter. All other building service connections shall be at least 6 inches (150 mm) in diameter.

3.2.6 Depth. Place sewers sufficiently deep to receive sewage from basements. Depths greater than 15 feet (4.57 m) are usually uneconomical.

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

3.2.8 Structures and Appurtenances. Refer to Table 3 for applications and details of sewer structures.

3.2.9 Pipes. Guidelines for selection of sewer pipe material are given in Table 4. Requirements for pipes, pipe joints, and guidance for selection of jointing material are given in NAVFAC NFGS-02730K, Exterior Sanitary Sewer System.

3.2.10 Installation. Installation requirements are given in NFGS-02730K or in Table 4. Refer to WPCF MOP FD-5 for criteria pertaining to trenching, foundations, laying, pipe cover, and loads.

Sewer lines located aboveground on structural supports in high wind areas shall be designed to withstand expected wind velocities, refer to MIL-HDBK-1002/1, Structural Engineering General Requirements.

3.3 Pumping. Use pumping only where a gravity system cannot serve hydraulically or where cost analysis shows a significant savings. Incorporate the following criteria.

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

3.3.2 Capacity. Design each station to handle peak flow with one of its largest pumps out of service. Refer to paragraph 3.4 for special requirements for pump stations in pier and wharf systems.

Table 3
Sewer Structures

Structure	Type	Where to Use	Details	Requirements
Manhole	Regular	Terminally on all lines; at all junctions and changes of direction; at changes in invert elevation or slope. Otherwise, according to spacing shown below: Pipe Size (in. [mm]) — Max Spacing (ft [m]) 18 (450) or less — 400 (120) 18-48 (450-1200) — 500 (150) 48 (1200) and greater — 600 (180)	See NAVFAC Guide Spec NFGS-02730	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 man-holes, 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 (0.6 m)	See NAVFAC Guide Spec NFGS-02730	For difference less than 2 ft (0.6 m), increase upstream sewer slope to eliminate drop.
Siphons	In-verted	For carrying sewers under obstructions or waterways.	Maintain velocity of 3 fps (0.9 m/s). Use not less than two barrels with min. pipe size of 6 in. (150 mm). Provide for convenient flushing and maintenance.	Use WPCF MOP FD-5, for hydraulic design.

Table 3 (Continued)
Sewer Structures

Structure	Type	Where to Use	Details	Requirements
Inter-cepting 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 inter-ceptors	Grease and oil	On all outlets from subsistence bldgs, garages, mechanical shop, wash pits, and other points where grease or oil can enter system.	Displacement velocity 0.05 fps (0.015 m/s). Grease re-moval - in absence of other data use 300 to 400 mg/L. Provide for storage of 1 week's grease production (1 day if continuous removel is provided). Length = twice depth.	

Table 4
Sewer Pipe Selection Guide

Pipe Material	Remarks
Vitrified clay (VC) (gravity)	Use for domestic sewage and industrial wastewater. VC pipe is especially resistant to acid, alkali, hydrogen sulfide (septic sewage, erosion, and scour.
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 wastewater. Good for use in corrosive soil conditions. Special care should be given to trench loadings and pipe bedding.
Acrylonitrile-butadiene-styrene (ABS) composite (gravity)	ABS may be used for normal domestic sewages 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 pipe walls. The voids are filled with lightweight concrete. ABS may be used for collector lines, for corrosive domestic sewage, and for industrial wastewater.
Cast iron soil (building services only)	Use for building service connections carrying normal domestic sewage.
Cast ductile iron (gravity or pressure)	Primarily used for pressure sewers, yard piping within treatment plant areas, submerged outfalls, exposed locations, and portions of gravity lines subjected to high velocities (10 fps [3 m/s]). Additional applications include high external loads, railroad crossings, major highway crossings, and so forth. Special linings, coatings, wrappings, encasements, and so forth, are required for corrosive wastes or soil conditions. Gasket material shall be suitable for sewage or waste being handled. Avoid cement lining for sludge and domestic sewage receiving less than secondary treatment.

Table 4 (Continued)
Sewer Pipe Selection Guide

Pipe Material	Remarks
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: For additional information, refer to the following and their included references:

NFGS-02730
WPCF MOP FD-5

In small stations with a maximum inflow of 500 gpm (31.5 L/s) 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.

3.3.3 Pumps. 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. Refer to paragraph 5.7 for guidelines on pump selection and controls.

3.3.4 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. Refer to WPCF MOP FD-5 for rational methods to predict sulfide generation rates and methods of control.

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

b) Provide cleanouts and air relief valves as required.

c) Check valves must be provided at pump stations.

3.3.5 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, for additional details.

3.3.6 Wet Wells

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

a) Determine the length of cycle time by Equation (2) or (3).

EQUATION: $$t = V/D[1/(1-Q/D) + 1/Q/D] \quad (2)$$

where

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

when

Q = 0.5 D Equation (2) is reduced to t = V/D.

To obtain the minimum wet well volume required, use Equation (3).

EQUATION: $$V = tD/4 \quad (3)$$

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

3.3.6.2 Bottom Slope. Slope wet well bottom toward the pump suction.

a) Use slope of 1.75 vertical to 1 horizontal (175:100).

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

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

Submergence (ft [m])	Entrance Velocity (fps [m/s])
1.0 (0.3)	2 (0.6)
1.5 (0.5)	3 (0.9)
2.0 (0.6)	4 (1.2)
2.6 (0.8)	5 (1.5)

3.3.6.4 Ventilation. Provide 4-inch (100-mm) minimum diameter vent with return bend and bird screen.

3.3.7 Dry Wells

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

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

3.3.7.3 Sumps. Sumps shall be provided with the following:

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

b) Check valve in horizontal run.

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

3.3.7.5 Ventilation. Provide positive ventilation.

3.3.7.6 Potable Water. Provide potable water (if available) to dry well for general maintenance use.

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

3.3.9 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.

3.3.10 Equipment and Appurtenances. Refer to paragraph 3.4.9 for details on equipment and appurtenances.

3.4 Special Requirements for Pier and Wharf Systems. The ship sewage collection system on piers or on shore shall be designed for the peak flow from the maximum planned berthing with the sewer flowing full. Sewage collection systems special requirements are as defined in paragraphs 3.4.1 through 3.4.13.

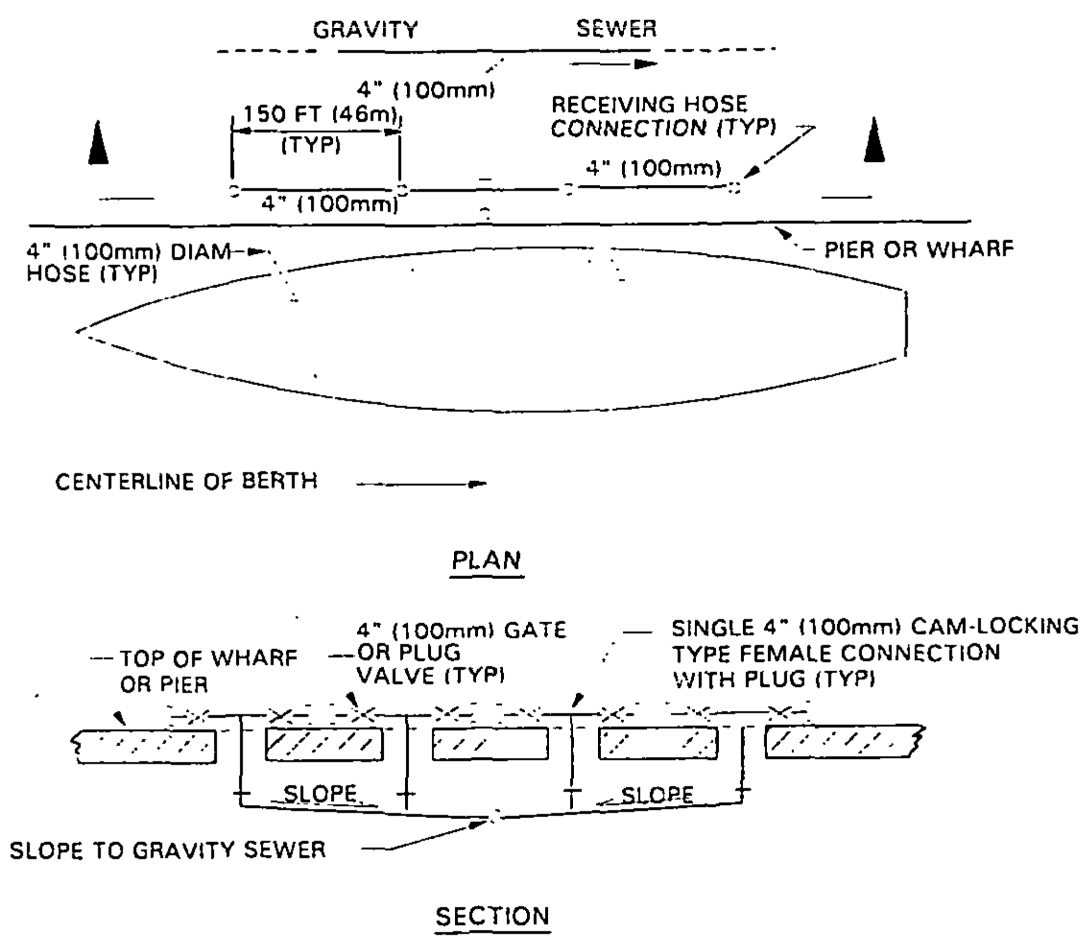
3.4.1 Pipe. Mechanical joint, lined ductile iron shall be used for exposed locations where high impact resistance is important. Support exposed pipe per manufacturer's recommendations. In other exposed locations, for superior corrosion resistance, consider thermoplastic (high density polyethylene) pressure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

3.4.2 Layout. A pressure manifold connected to the gravity sewer by a single 4-inch (100-mm) diameter pipe shall be used for the collection system at each berth. The manifold shall have four, single 4-inch (100-mm) receiving connections spaced 150 feet (46-m) apart on a 4-inch (100-mm) diameter pressure sewer (see Figure 2). This layout has the following advantages:

a) It provides large reduction in peak flows by combining multiple discharges from a ship or nested ships into a single stream, thereby increasing the head on the ship's pumps.

b) By reducing peak flow, it allows berthing of other ship types (other than shown on the design berthing plan) at the design berth.

c) It is self-regulating and self-cleaning, and avoids failure or maintenance problems inherent in regulating valves or other devices.



NOTE: DESIGN RECEIVING HOSE CONNECTIONS FOR 3000 LB (13,000 PULL IN ANY DIRECTION.

Figure 2
Pressure Manifold Schematic
Pier and Wharf

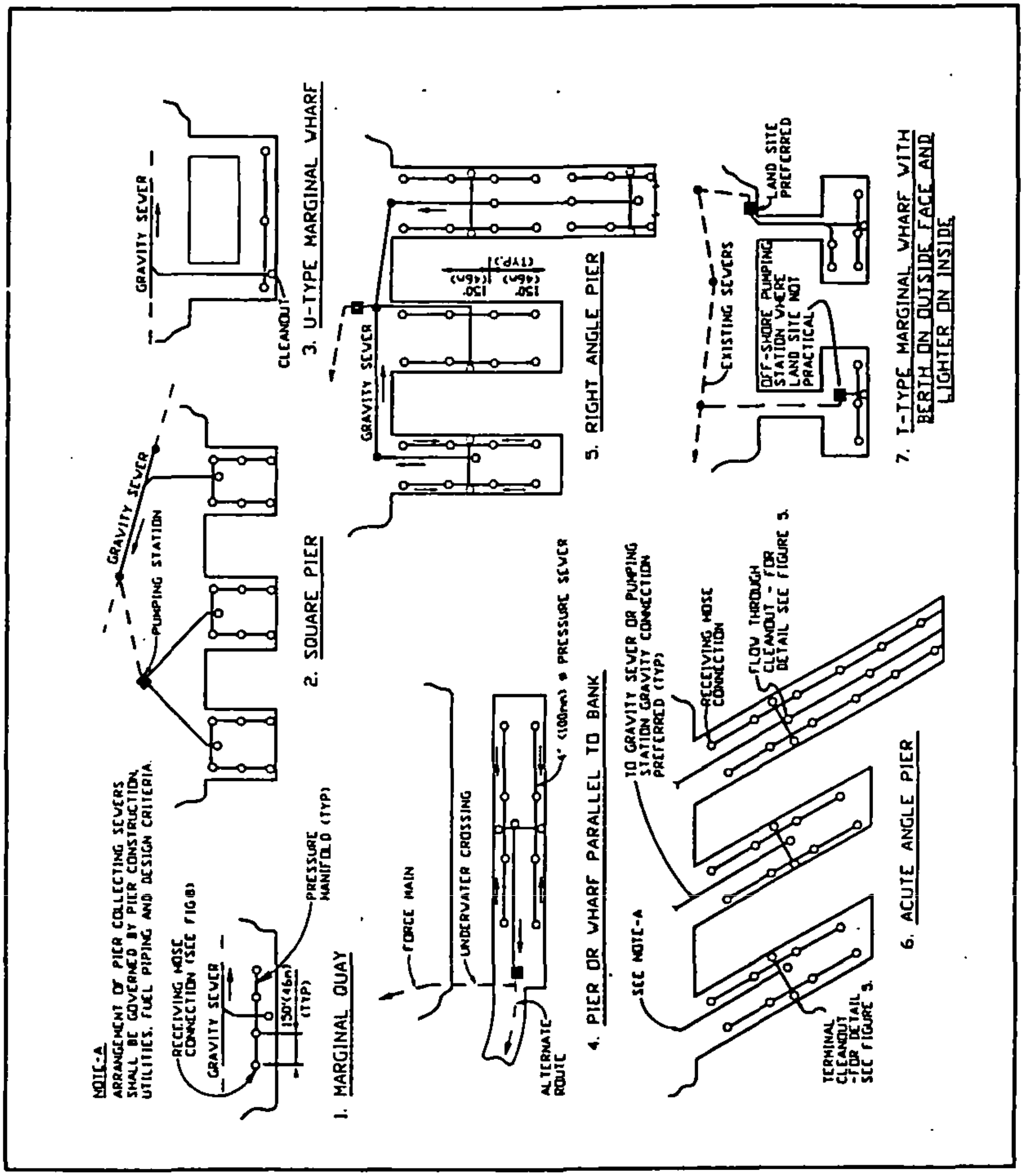


Figure 3
Collecting Sewer Layout for Alternative Pier Types

To prevent pumping from one berth into another and to allow ships with lower head pumps to discharge into the pier sewer, each berthing space must be isolated by providing one separate manifold at each berth connected to the gravity pier sewer. Where the berthing space is less than 600 feet (183 m), the number of outlets shall be reduced to fit the space available. In such cases, it may be necessary to reduce the 150-foot (46-m) spacing between outlets. For carrier berths, two standard 4-inch (100-mm) manifolds, each with four 4-inch (100-mm) outlets, shall be used. See Figure 3 for typical collection sewer layouts on different pier types.

3.4.3 Location. Locate all collecting sewers behind the permanent wharf or pier construction, away from the fender, to avoid impact loads and damage. Locate pump stations off the pier, behind the bulkhead lines. If location along the pier deck is required, do not restrict working area on the pier. Lines behind wharves should always be buried. See Figures 4 and 5 for typical installation on piers and quay walls. For design of new piers and quay walls, consider locating sewers in utility tunnels. Reduced external corrosion and improved maintainability of sewers may offset higher construction cost.

3.4.4 Pump Station Capacity. Make capacity equal to that of incoming sewers whenever this exceeds the expected peak flow. For pump station design for transfer of ship's oily wastewater, refer to MIL-HDBK-1005/9.

3.4.5 Control of Septicity, Odors, and Hydrogen Sulfide. Slope sewers as much as possible to minimize detention time and provide aeration. Refer to paragraph 3.3.4 for control measures in force mains. Aerate holding tanks unless detention time is less than 3 hours at average 24-hour flow.

3.4.6 Corrosion. For ship-to-shore connections, ductile iron sewer pipe, pier castings, and all submerged and nonsubmerged exposed metal such as structural steel members, gratings, angles, pipe support hangers, fastening devices, and other appurtenances, use a two coat coal-tar epoxy coating, conforming to Steel Structures Painting Council Paint No. 16, applied to a total minimum dry film thickness of 16 mils (0.4 mm). For alternative corrosion protection coatings for different environments, refer to NAVFAC MO-110, Paints and Protective Coatings. Brush bare steel surface to remove all mill scale prior to the application of the protective coating. Follow the manufacturer's instructions for the surface preparation and application to other materials. Evaluate need for cathodic protection.

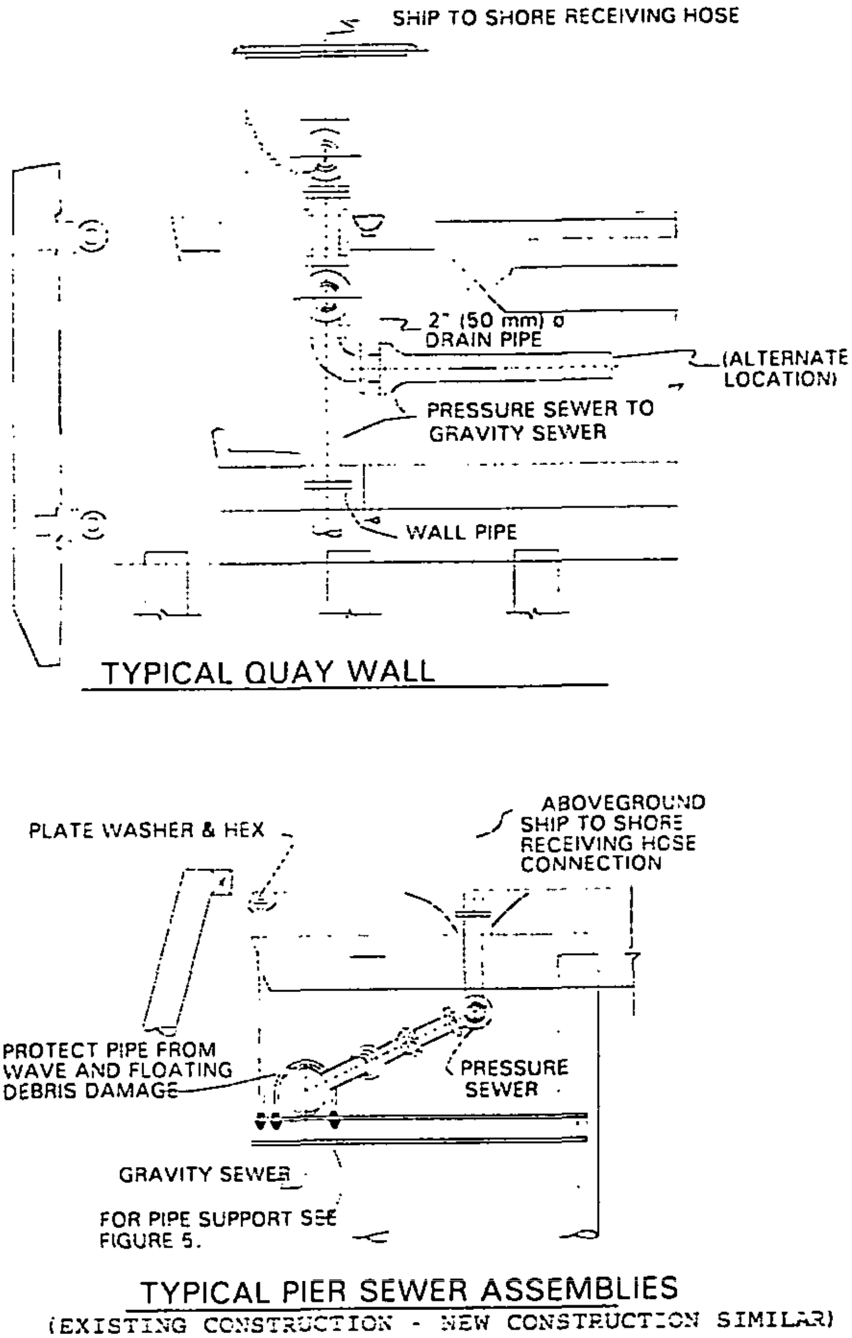
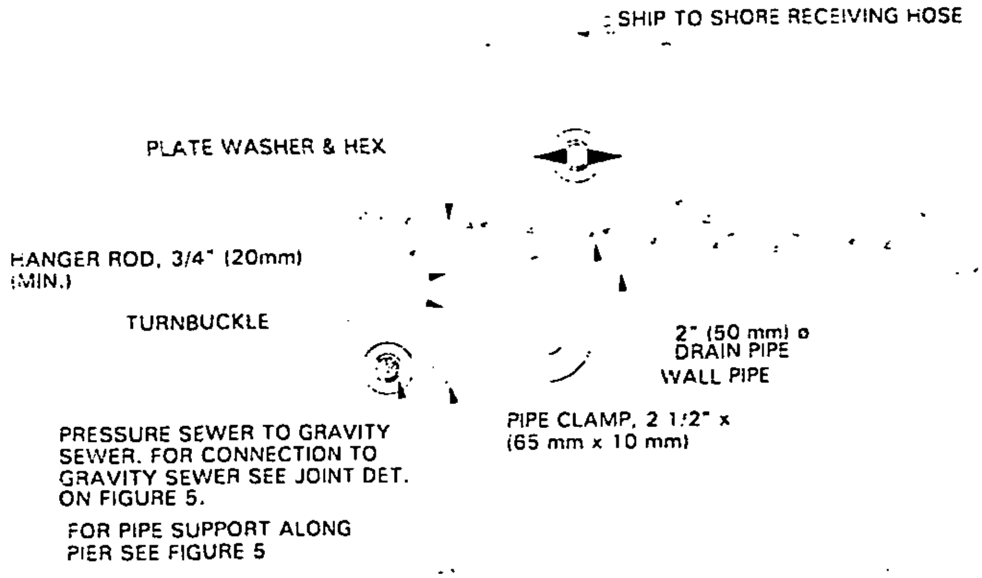
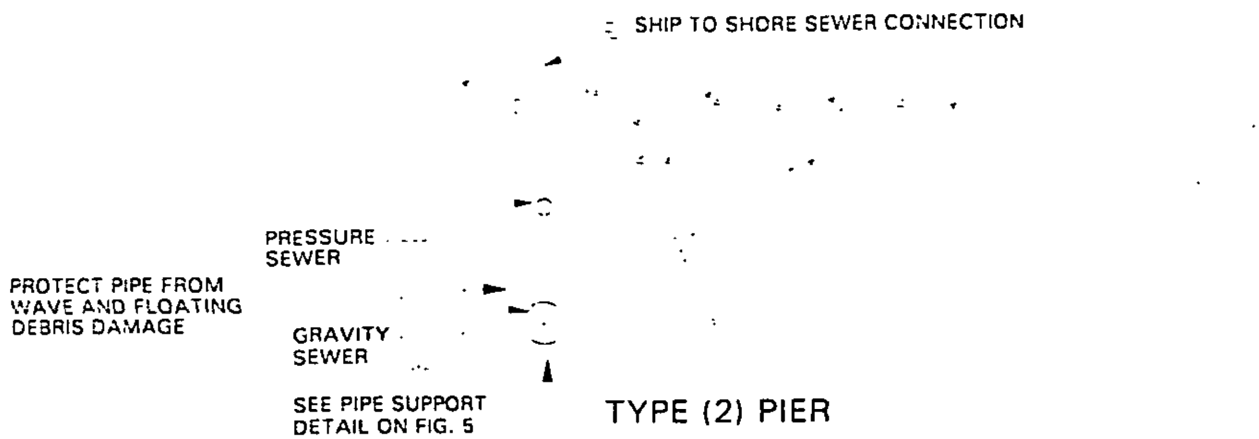


Figure 4
Typical Shore Collection Facilities for Receiving Ship's Sewage



ALTERNATE PIER SEWER ASSEMBLY



TYPE (2) PIER

Figure 4 (Continued)
Typical Shore Collection Facilities for Receiving Ship's Sewage

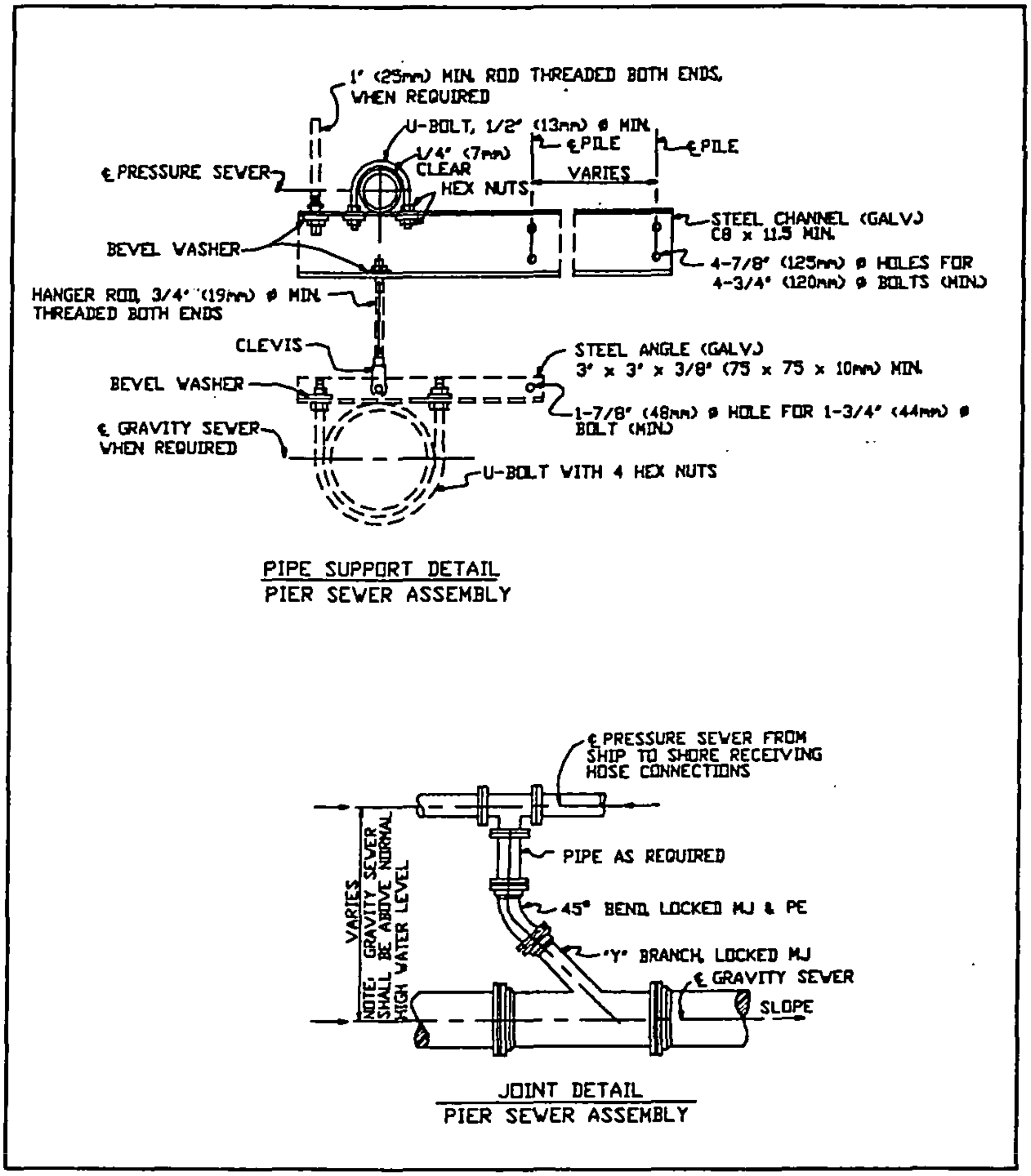
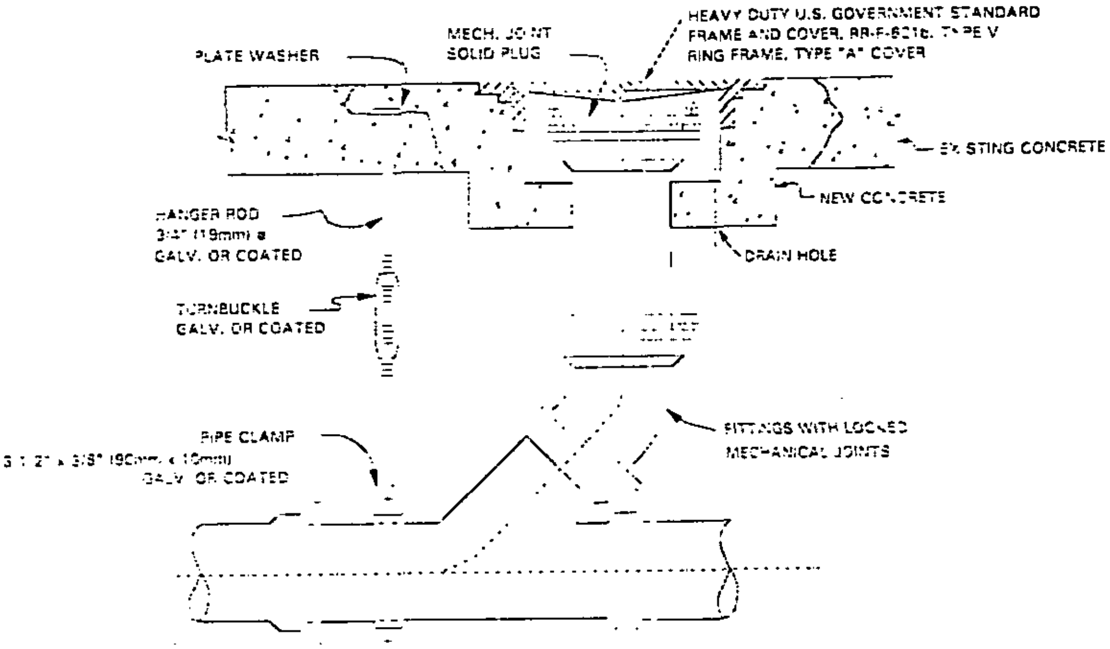


Figure 5
Details for Shore Collection Facilities Receiving Ship's Sewage



FLOW THROUGH CLEANOUT DETAIL

CONCRETE DECK INSTALLATION

CLEANOUT SPACING

400' (120m) MAX. FOR PIPES 15" (375mm) &

500' (150m) MAX. FOR PIPES 18" (450mm) &

NOTE: FOR TERMINAL CLEANOUT USE 90° ELBOW IN PLACE OF LATERAL.

Figure 5 (Continued)

Details for Shore Collection Facilities Receiving Ship's Sewage

References for cathodic protection are:

a) MO-306, Maintenance and Operation of Cathodic Protection Systems

b) MO-307, Corrosion Control

c) NFGS-16641, Cathodic Protection by Galvanic Anodes

d) NAVFAC ltr 11012, Cathodic Protection Systems, Interim Technical Guidance

3.4.7 Freeze Protection. See Figure 6 and refer to Naval Civil Engineering Laboratory (NCEL) Report No. R-593, Freeze Protection for Freshwater and Sanitary Piping Under Open Piers. Pipes installed under piers or wharfs in any geographic location must be protected from wave action and floating objects. If freeze protection is provided, protective jacketing of the insulation using aluminum, stainless steel, or coal-tar epoxy coated steel must be provided. Provide structural protection for entire length of pipe run in addition to jacketing. Use steel cage of fabricated shapes or a catwalk for both access and piping protection.

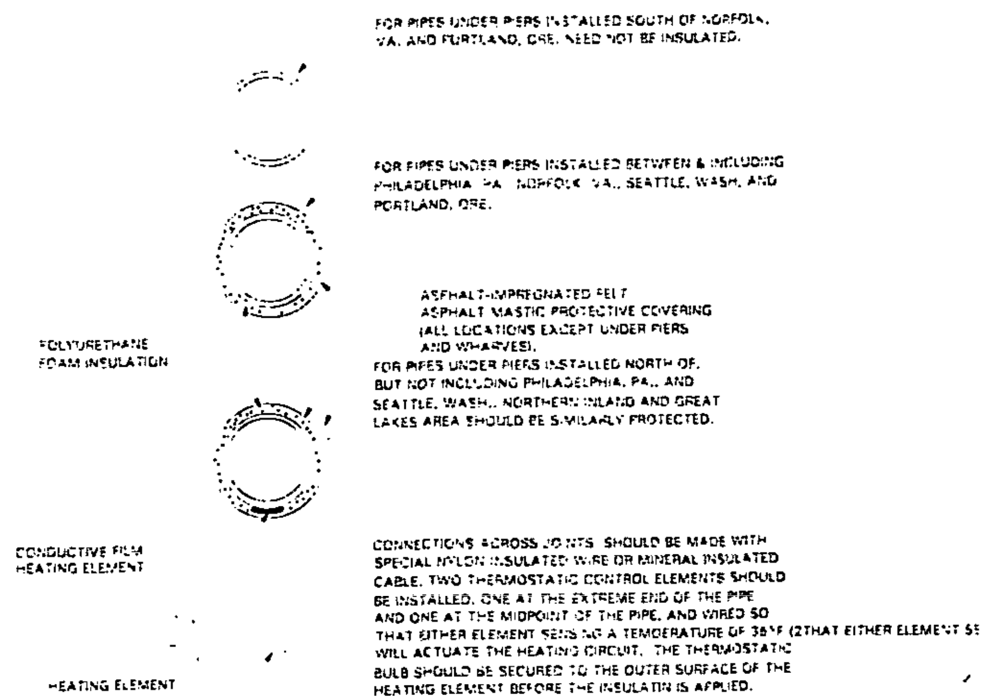
a) Pipes installed under piers north of Philadelphia, PA, and Seattle, WA, Northern inland and Great Lakes area: install with conductive mineral film electric heating elements and polyurethane foam insulation.

b) Pipes installed under piers between and including Philadelphia, PA; Norfolk, VA; Seattle, WA; and Portland, OR: install with polyurethane foam insulation. Refer to NCEL Report No. R-593 for flushing requirements.

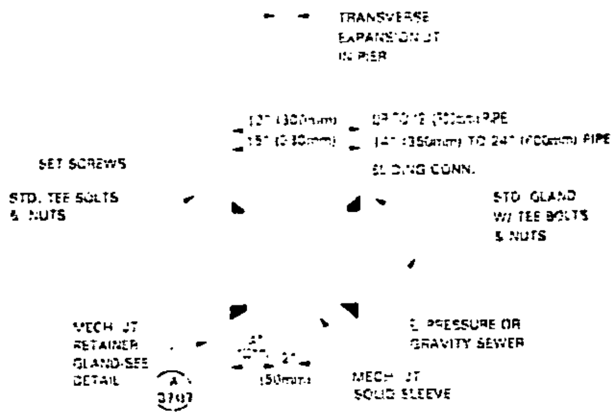
c) Pipes installed South of Norfolk, VA, and Portland, OR: no insulation required. See NCEL Report R-593 for flushing requirements.

d) Refer to Figure 6 and NCEL Report R-593 for details of heating element installation.

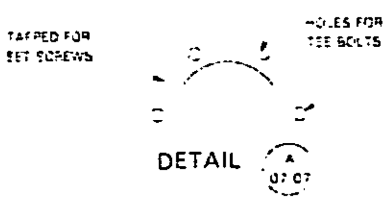
3.4.8 Sewage Transfer Hoses and Receiving Connections. Facilities should be provided for washing the end couplings and the exterior of the hose with hot potable water containing a standard stock detergent. Caps for each end of the hose should be provided and installed after washing. Clean hose should be stored dry in racks. See Figure 7 for transfer hose detail and Figure 8 for receiving hose connection. For further information, refer to NAVFAC MO-340, Ship-to-Shore Hose Handling Operations Manual.



FREEZE PROTECTION REQUIREMENTS



EXPANSION JOINT DETAIL



DETAIL A

Figure 6
Piping Details for Shore Collection Facilities Receiving Ship's Sewage

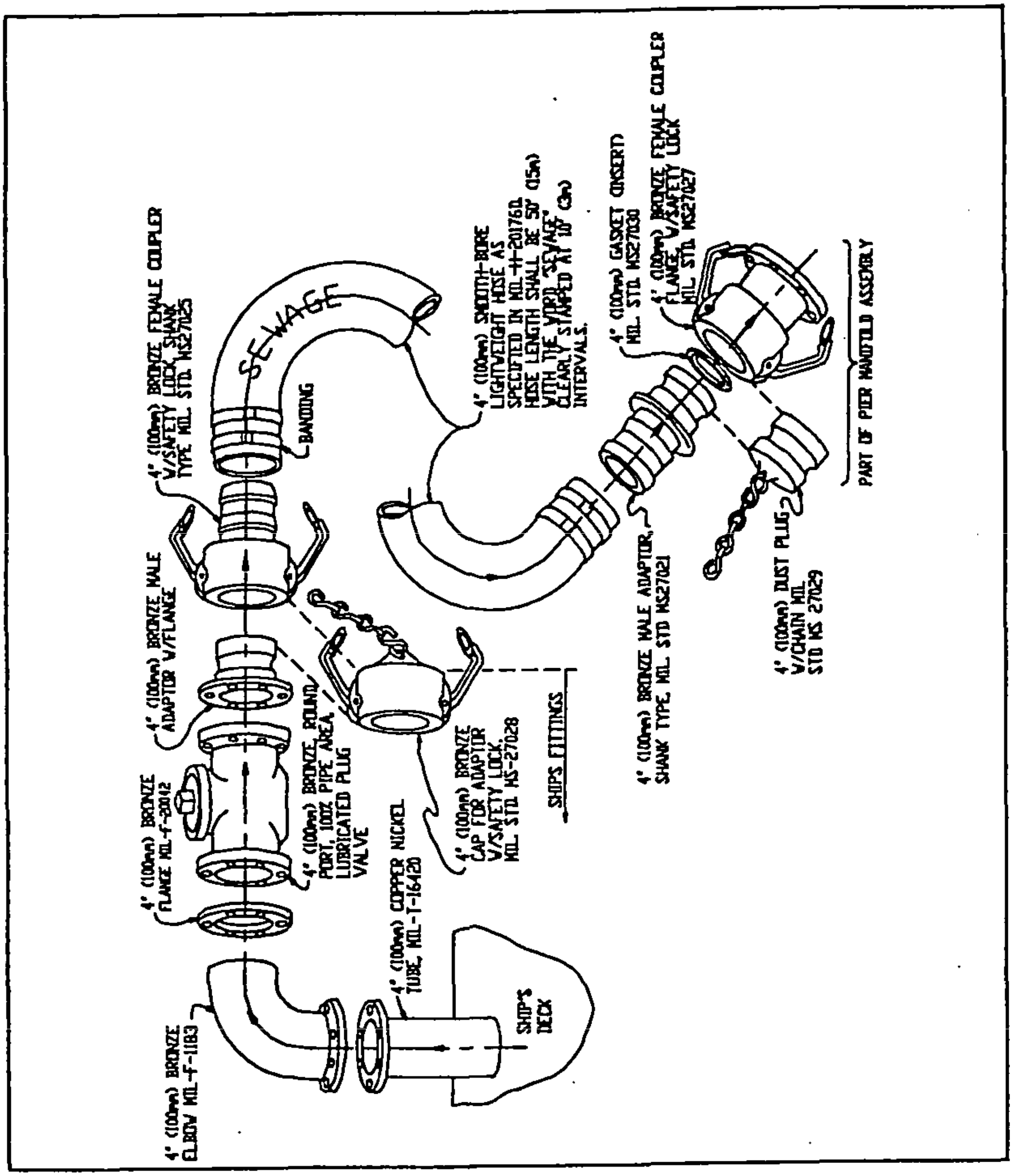


Figure 7
Ship-to-Shore Sewage Hose Components

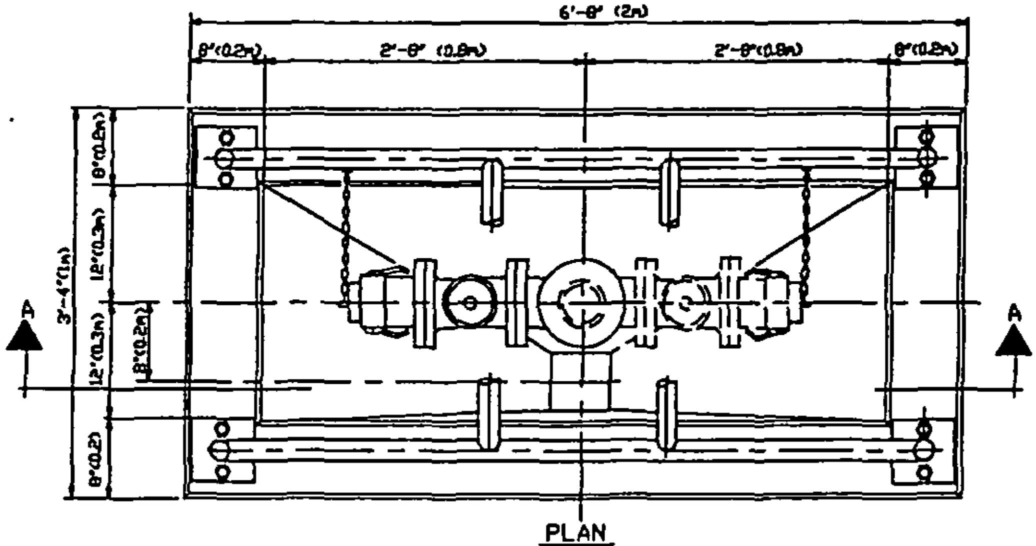


Figure 8
Aboveground Receiving Hose Connection

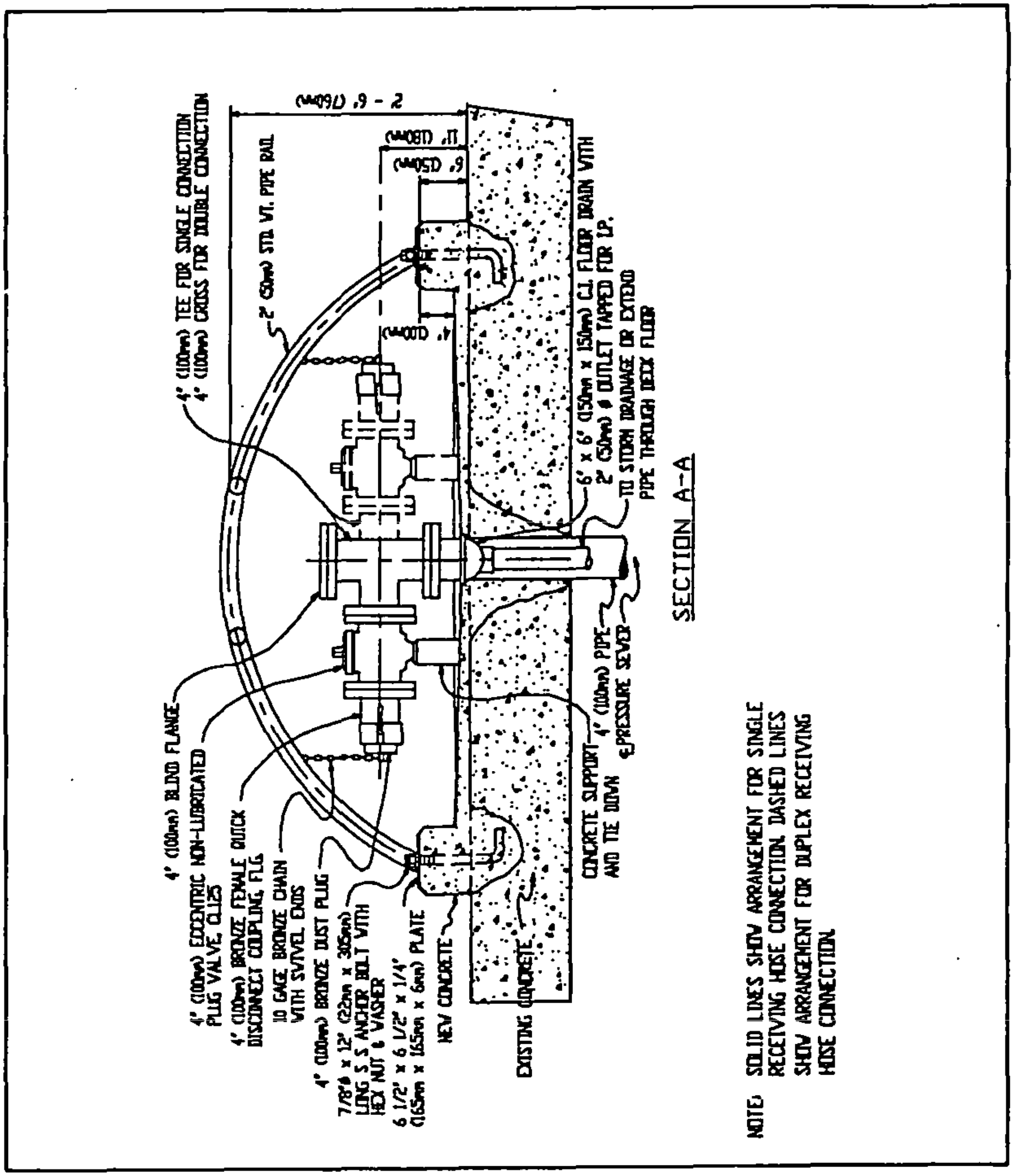


Figure 8 (Continued)
Aboveground Receiving Hose Connection

Design receiving hose connection for 3,000-pound (13,350-N) pull in any direction.

3.4.9 Special Pier Structures and Appurtenances. Refer to Table 5 and see Figures 4 to 8.

3.4.10 Metering Requirements. For metering requirements, refer to Section 10.

3.4.11 Ship Waste Offload Barge. Ship waste offload barges (SWOBs) outfitted for sewage are used to service ships anchored away from shore and to transport sewage to offload berth. For discharge, standard ship-to-shore sewage receiving connections can be used. A special SWOB berth may be provided, if needed, at the end of a pier or at a quay wall. A pier fire main 2.5-inch (65-mm) hose connection is required for tank and hose cleaning after offloading. If a fire main connection is not available, a portable fire pump taking suction off the pier can be used. Backup shore power (maximum load: 440 volts, three-phase, 45 horsepower) is recommended for onboard diesel generator.

3.4.12 Ship's Oily Wastes. For design of collection and transfer systems for ship's oily wastewater, refer to MIL-HDBK-1005/9.

3.4.13 Utility Service Connections. To ensure safety, shore-to-ship utility service connections at Navy shore facilities shall use the standardized color codes as a secondary identifier on waterfront wharf and pierside connections and shore-to-ship hose assemblies. The primary identifiers shall be plain language tags, nameplates, or labels. The color code for shore-to-ship service connections is as follows:

Shore Service	Color	Federal Standard 595(a) No. Fed. Spec TT-E-489 No.
Potable Water (40 to 81 psig [4053 to 8207 kPa])	Blue, Dark	15044
Nonpotable Water (100 to 175 psig [10,132 to 17,732 kPa])	Red	11105
Sewer	Gold	17043

Notes:
1. The above colors are used to identify ends of hose assemblies, pier-side valves, handwheels, or operating levers, and adjacent deck, curb, standpipe, or guard.
2. Color coding for shore-to-ship utility connections shown above may vary from color coding for pier distribution piping or other shore piping systems. MIL-STD-101, Color Codes for Pipelines and for Compressed Gas Cylinders, governs the color codes used on pier distribution piping and other shore piping systems.
3. Pressures shown are nominal pressures and represent average conditions.

3.5 Drydock Facilities. The collection system for the graving dock shall be designed for the peak flow from the maximum planned docking pattern with the sewer flowing full. Drydock collection systems shall consider the following:

a) Separation of hydrostatic leakage from drydock wastewater. The water is generally not contaminated and can be discharged directly to storm sewers or open water depending on regulatory conditions.

b) Separation of ship's domestic wastes from the industrial wastes generated by drydock activities. These industrial wastes include leakage, precipitation runoff, and washdown that carries sandblasting residue and paint.

3.5.1 Layout. Ships fitted with collection-holding-transfer (CHT) should be connected to dock side sanitary sewers for CHT discharge. Ships without CHT should use scuppers and manifold connections to ship's discharge points for transfer to sanitary sewer system in floor of drydock. See Figure 9 for typical collection system layout in drydock facilities to collect from CHT systems. Receiving connection on pressure manifolds connected to gravity sewers shall be used.

3.5.2 Pump Station Capacity. Make capacity equal to that of maximum combined ship's discharge rate of ships in drydock. Furnish portable auxiliary pumping facilities when required. Refer to MIL-HDBK-1029/1, Graving Drydocks.

Install air release valves at high point of force main. Use manual valves for raw sewage applications or where clogging by grease can occur.

Table 5
Special Pier Structures and Appurtenances

Structure or Appurtenance	Where to Use	Details	Requirements
In-line cleanout	At junctions and changes of direction and when required according to spacing shown in details under Regular Manholes (Table 3)	See Figure 5	
Terminal cleanout	Terminally on all pier collection systems	See Figure 5	Locate where it will not interfere with other operations on the pier or other utilities.
Receiving hose connections		See Figures 7 and 8	Connection designed to receive the discharge from ships
Pier collection sewer supports	Support collecting sewer under piers	See Figures 4 and 5	

3.5.3 Sewage Receiving Connections. See Figure 10 for underground drydock receiving hose connections. See Figure 8 for aboveground drydock receiving hose connections. Aboveground receiving hose connections should be used whenever possible.

3.5.4 Special Structures and Appurtenances. See Figure 5 for typical cleanout detail for drydock sewers.

Locate cleanouts in main sewer at a maximum spacing of 300 feet (91 m).

3.6 Other Collection Systems. Vacuum sewers and pressure sewers are included in this category. These collection systems must be justified before employment in Navy facilities.

3.6.1 Vacuum Sewers

a) Vacuum sewage collection systems have been patented and in use in the United States and foreign countries for many years. Several manufacturers provide equipment. Performance experiences have been quite variable.

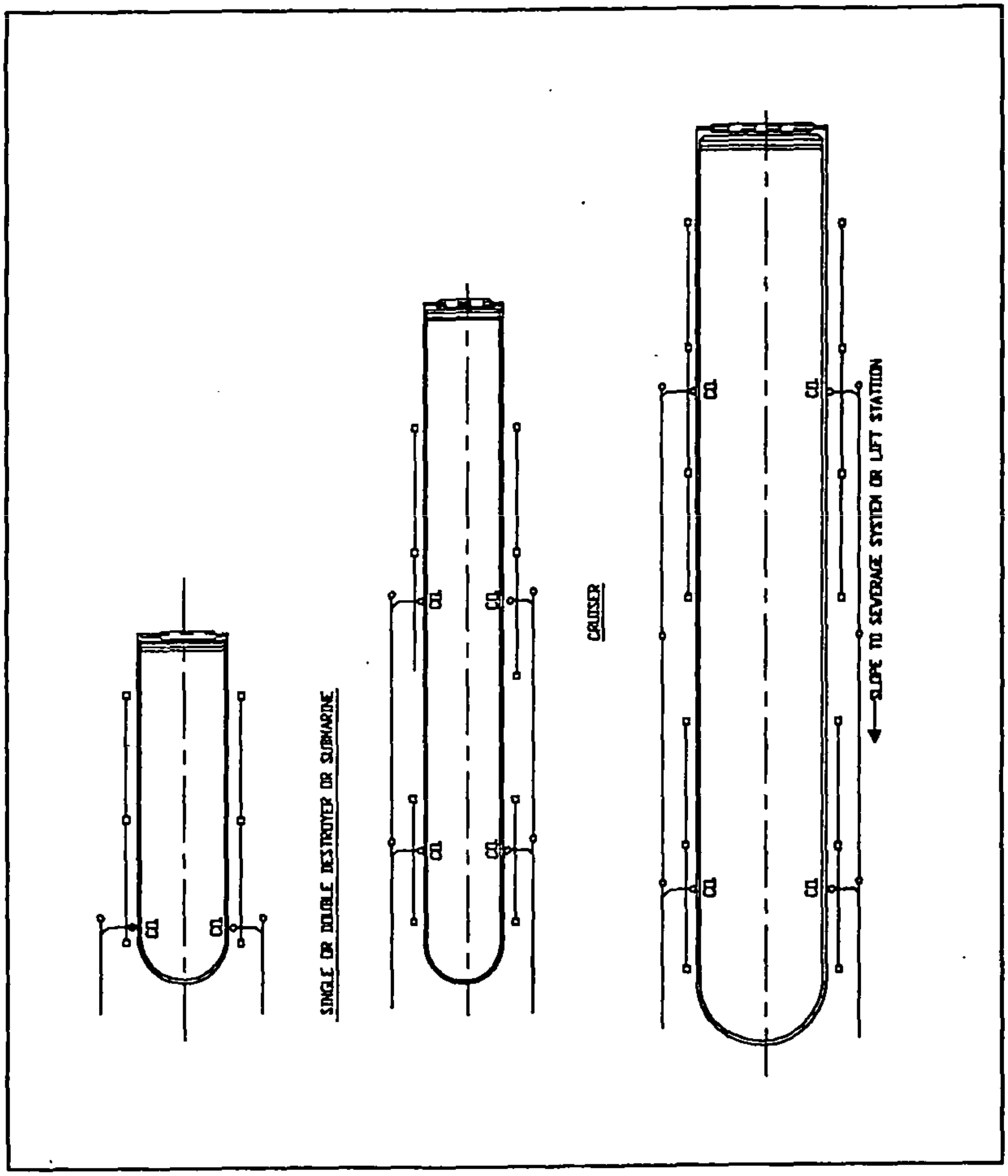


Figure 9
Typical Sewage Collection System Layouts for Drydock Facilities

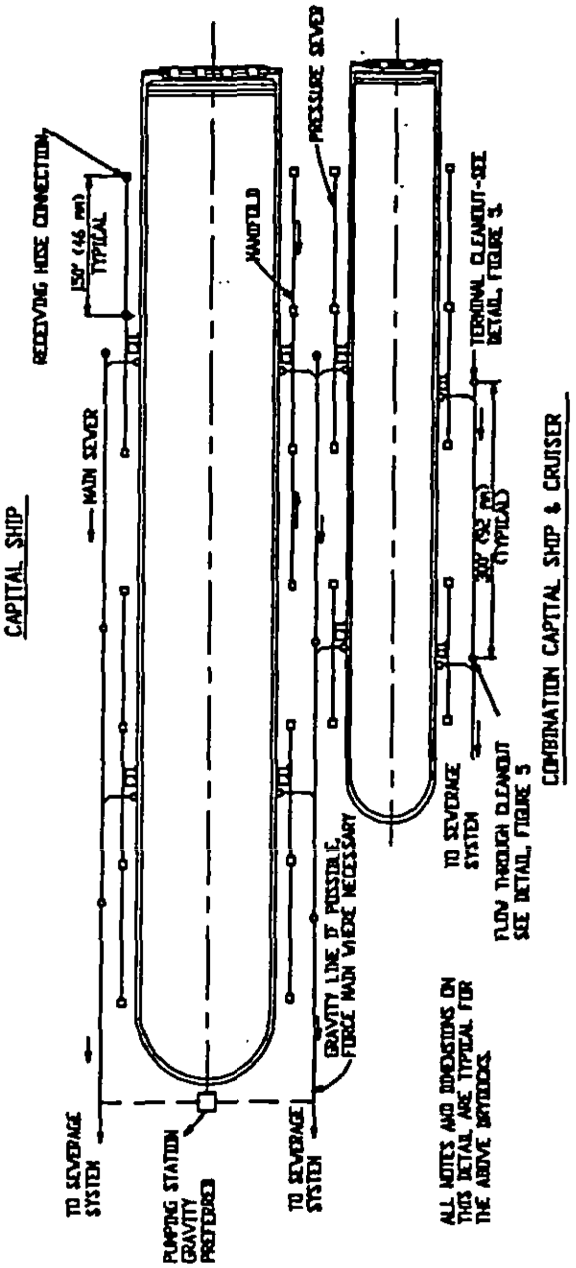


Figure 9 (Continued)
Typical Sewage Collection System Layouts for Drydock Facilities

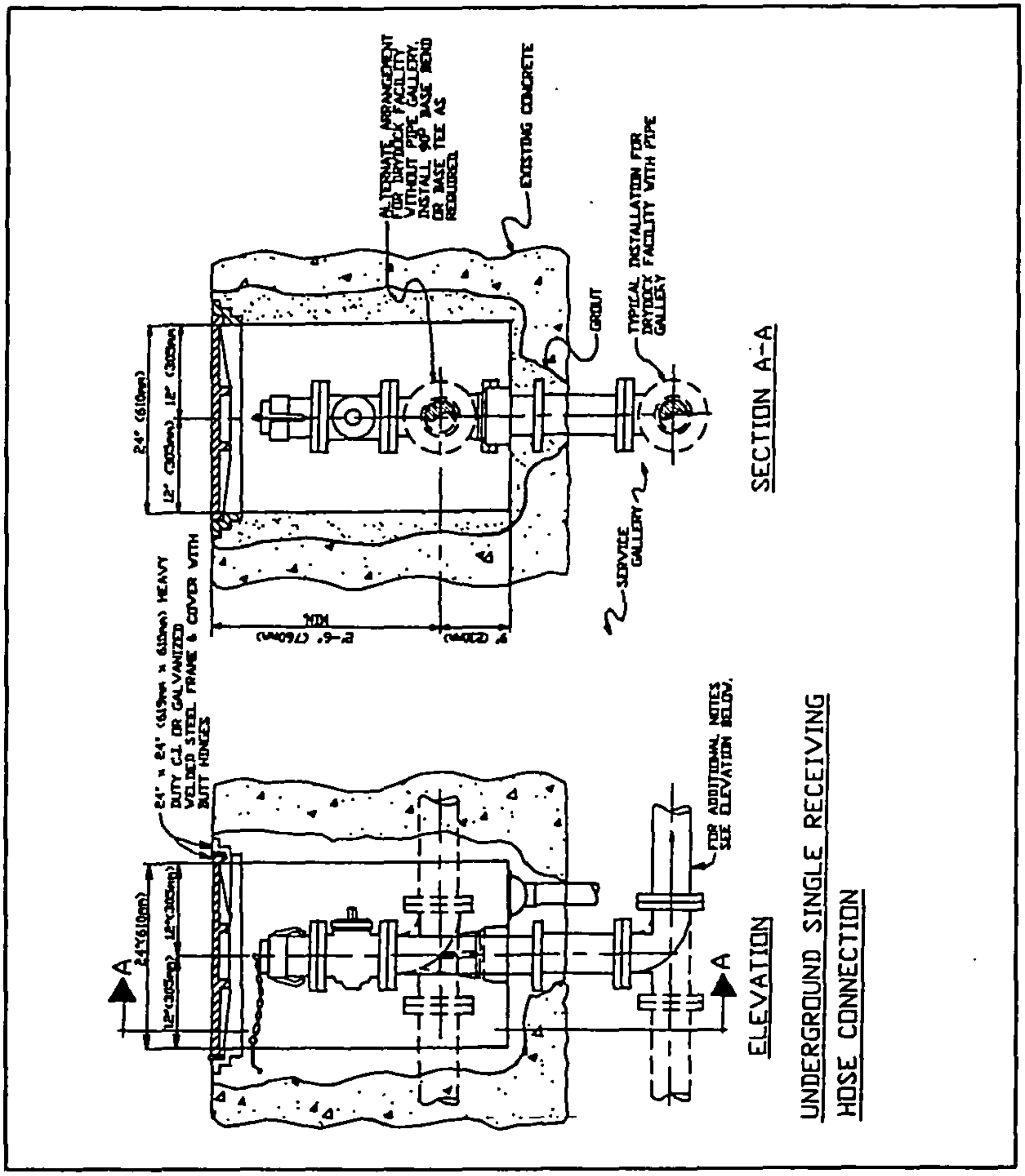


Figure 10
Underground Receiving Hose Connections for Drydock Facilities

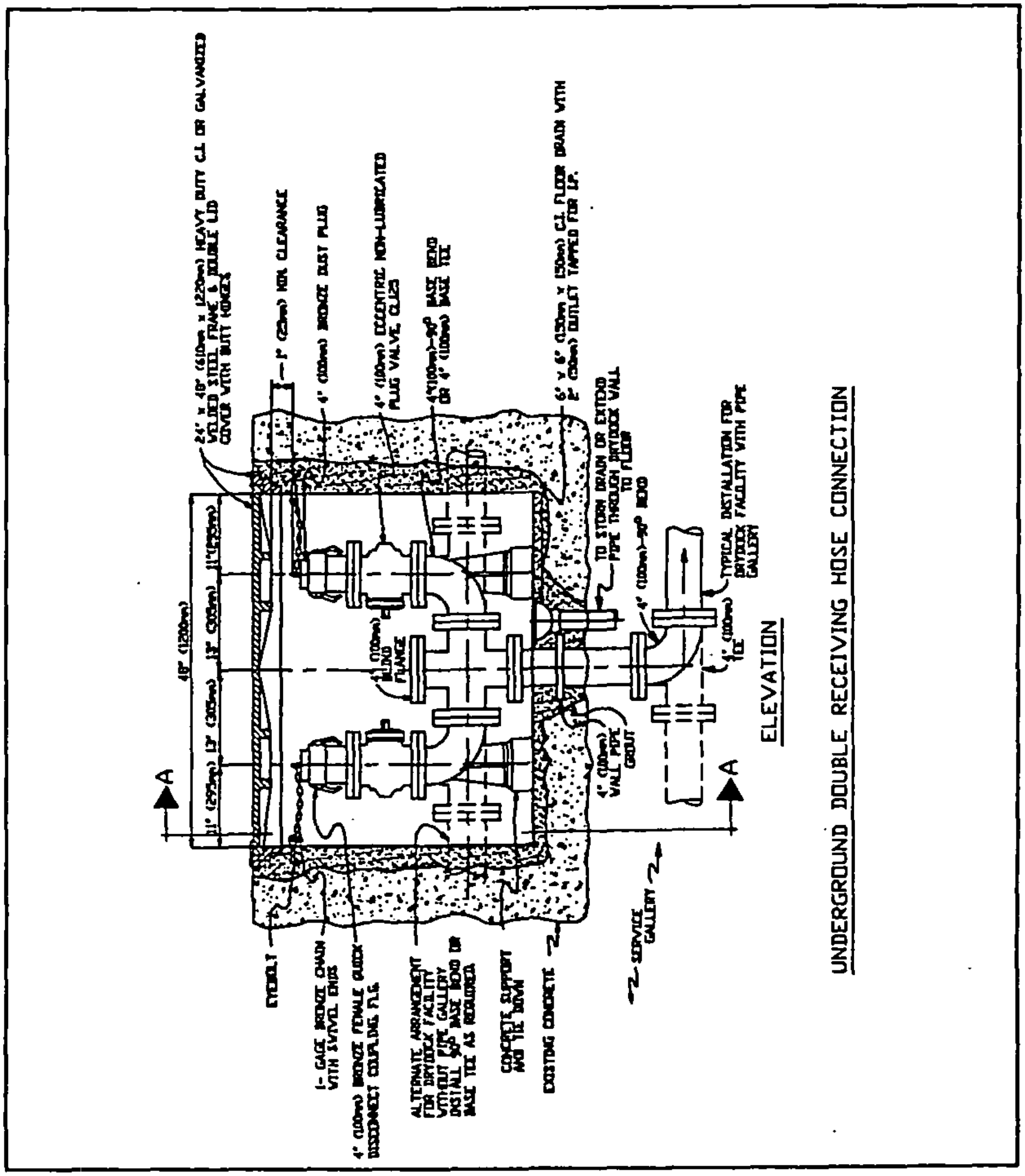


Figure 10 (Continued)
Underground Receiving Hose Connections for Drydock Facilities

b) Vacuum sewage collection systems have been used by the Navy, mostly on ships, but performance experiences have often been less than satisfactory.

c) Vacuum sewage collection is still considered a developing technology. It is most advantageous for servicing sparsely populated areas, and where natural ground profile, high groundwater, or soil conditions (such as rock or unstable material) make deeper excavation for gravity sewers uneconomical. Such systems must be well justified before employment in Navy facilities.

d) Where vacuum sewage collection is employed, care in design and specification of equipment is of utmost importance. Gravity building sewers connecting to the vacuum collection system must be adequately vented, both inside the building and outside the building before connection to the vacuum system.

e) Vacuum sewage collection systems may include separate black water (toilet wastes generated at a vacuum toilet) and gray water (discharges into the vacuum system through a vacuum valve) collection mains. The separate collection mains transport the gray and black water to vacuum collection stations.

f) Vacuum sewage collection systems may collect both black and gray water in a single system of collection mains for transporting to vacuum collection stations. Components of these systems include a vacuum valve preceded by a small buffer or holding tank at each building connection, the vacuum mains, and the vacuum collection stations with vacuum collection tank, vacuum pump, and sewage pump.

g) Vacuum collection mains are generally laid to conform with existing ground profiles, but on a sawtooth profile. manholes are not required. Since exfiltration is eliminated, vacuum sewers may be installed in the same trench as water mains. High scouring velocities are attained, reducing the risk of pipe blockage.

h) For additional information see the following:

(1) Vacuum Sewer Technology, by Cooper and Rezek, 1977.

(2) Vacuum Wastewater Collection: The Alternative Selected in Queen Anne's County Maryland, by Hassett and Starnes, 1981.

(3) EPA/625/R-92/005, Wastewater Treatment/Disposal for Small Communities.

3.6.2 Pressure Sewers. Pressure sewers consist of force mains laid in conformance with natural ground profile, and with pumps located at each building service connection, to force wastewater into the pressurized force main. The two major types of pressure sewer systems are the grinder-pump (GP) system and the septic tank effluent pumping (STEP) system.

Pressure sewer systems are most advantageous in areas of low population density, in areas where soil conditions make deeper excavation for gravity sewers uneconomical, and in areas where natural ground profiles require very deep excavations for gravity sewers.

3.6.2.1 GP Systems. GP systems shall meet the following criteria:

a) The GP system includes sumps to collect flows from gravity sewers in buildings. A sump provides a small amount of storage (to accommodate pump cycling, power outages, or equipment malfunction). Submersible centrifugal grinder pumps may be located in a sump, with ball check valves and discharge piping connected to the pressure sewers. Alternatively, progressive cavity grinder pumps may be used.

b) Grinder pumps, collection sumps, valves, and controls are normally provided by a single manufacturer or supplier. Several companies provide these components.

c) In more densely populated areas, such as multiple dwelling building units or office buildings, a single collection sump (probably with two full-sized grinder pumps for standby capacity) may be applicable.

d) Storage, overflow containment, or standby power should be considered particularly at larger or important installations. Consideration should be given to flushing connections where feasible.

3.6.2.2 STEP Systems. This system pumps effluent from septic tanks into pressure sewers. The STEP system reduces the minimum sewer size requirement because large solids are removed in a septic tank. Grinder pumps are not required. Submersible, wet pit, or dry pit type centrifugal pumps can be used. Submersible pumps are usually more economical.

Pressure sewer systems require pumps at every connection to the sewer system. This is an inherent disadvantage in that many separate pieces of mechanical equipment must be maintained to keep the system functional. Refer to Status of Pressure Sewer Technology, J.F. Kreisel, 1977, for additional details on pressure sewer systems.

Section 4: POLLUTION CONTROL METHODS AND TREATMENT PROCESS SELECTION

4.1 Water Pollution Control. Basic data and requirements for water pollution control are as follows:

a) Determine characteristics of all separate raw wastewaters.

b) Select appropriate disposal for effluent from treatment of each wastewater.

c) Investigate water quality regulations relevant to ultimate effluent disposal method.

d) Determine effluent quality requirements to meet water quality regulations.

e) Determine processes capable of treating raw wastewater to the degree necessary to meet effluent requirements.

f) For potential treatment processes, determine requirements for sludge treatment and disposal, air pollution control, and land area.

g) Select from among suitable processes on the basis of total present worth or least annual cost, including amortization, operation, and maintenance of total facility for treatment and disposal. If it appears likely that water quality standards will be tightened in the near future, consider effect of additional treatment requirements.

Refer to current publications of the EPA and technical societies for generalized construction and operating cost data on unit processes. Refer to EPA-430/9-75-002, Guide to the Selection of Cost-Effective Wastewater Treatment Systems.

Where cost comparison is inconclusive, favor the system that is simplest to operate.

4.2 Effluent Quality Requirements

4.2.1 Effluent Limits. Normally, owners of discharges to streams in the United States and its territories are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit before construction of the pollution control facilities. The NPDES permit is issued by the state regulatory agency or by the EPA, depending on jurisdiction. The NPDES permit sets effluent criteria for a specific discharge, based on water quality modeling studies carried out by the regulatory agency.

4.2.2 Receiving Waters. Where possible, use flowing surface waters (such as streams, estuaries, and oceans) for effluent disposal. Avoid disposal to lakes and reservoirs. Design to meet effluent standards set by the regulatory agency. In general, a minimum of secondary treatment will be required. Request discharge effluent criteria from the state or local regulatory authority before beginning process selection. Where effluent criteria are not established, conduct a stream study to determine effluent concentrations which will not violate water quality regulations. Consult the regulatory agency to determine treatment methods it will accept.

4.2.3 Groundwater. Domestic wastes from very small installations (up to about 30 people) in rural or remote locations may often be discharged indirectly to groundwater through soil absorption systems. Small discharges with industrial wastes containing heavy metals or toxic materials may not be amenable to treatment in soil absorption systems preceded by septic tanks. Also, soil absorption systems may be precluded where fractured or fissured limestone or shale occurs near the ground surface where impermeable soils exist, or the groundwater table is high.

4.2.4 Beneficial Uses. Treated effluents can be used for industrial purposes, irrigation, or flushing. Evaluate reuse alternatives and determine requirements by special studies, if applicable. Check with local health authorities.

4.3 Wastewater Treatment System Selection

4.3.1 Alternative Treatment Schemes. Refer to EPA-430/9-75-002 for descriptions and schematic diagrams of treatment systems capable of satisfying various effluent criteria. Environmental engineering textbooks and design manuals are available for detailed information on arrangement and performance of methods of wastewater treatment.

4.3.2 Process Sidestreams. Process design should account for recycled solids, BOD, TKN, phosphorous, and nitrates from sludge handling unit processes, especially where processes with low solids, organics, and nutrient capture (such as anaerobic digestion) are used. This can be critical in larger plants and for advanced wastewater treatment plants, particularly for sizing sludge handling facilities.

4.3.3 Pretreatment of Industrial Wastes. Eliminate or pretreat industrial wastes which would harm collection or treatment facilities or upset biological treatment processes (refer to MIL-HDBK-1005/9).

4.4 Unit Process Selection

4.4.1 Preliminary and Primary Treatment. See Table 6 for selection of unit processes.

4.4.2 Disinfection. Disinfection of plant effluents is normally mandatory but the state regulatory agency should be contacted to determine local requirements. Chlorination or ozonation may be used. In process selection consider:

a) Cost. Chlorination is significantly less expensive.

b) Stream limits on discharge of chlorine residuals or chlorinated compounds. These may require added cost of dechlorination or require use of ozonation or a suitable alternative disinfectant.

4.4.3 Secondary Treatment. Use a secondary process selected from Table 7.

4.4.4 Advanced Treatment. Use depends upon effluent standards. See Table 8 for selection of process.

4.5 Disposal of Residues

4.5.1 Disposal Guide. See Table 9.

4.5.2 Residue Treatment

a) Sludge. See Table 10.

b) Screenings. If wastewater is screened, dispose of screenings with sludge cake or dispose of them directly to landfill.

c) Grit. If grit is separated from wastewater or sludge, dispose of it directly to landfill.

d) Scum. Mix scum with sludge prior to stabilization or dewatering. Otherwise mix scum uniformly with dewatered sludge and dispose of it directly to landfill.

4.5.3 Other Residue Treatment Processes. These processes are not normally applicable to Navy facilities:

a) Heat Treatment. Heat treatment operates by thermal conditioning or low-temperature low-pressure wet air oxidation. These processes are normally too capital-intensive, too complex to operate, and can be energy-intensive. Under present conditions, they can rarely be economically justified.

Table 6
Preliminary and Primary Wastewater Treatment Unit Processes

Purpose	Process	Selection Guide
Protection of screens and comminutors	Trash rack	Omit if investigation shows that selected screen or comminutor units will operate satisfactorily without racks upstream. Normally used only with combined sewer systems where equalization does not precede mechanically cleaned screen or communitor or for large pumping installations.
Elimination of coarse solids	Comminutor or screening	Use mechanically cleaned bar screen(s) or comminutor(s). Use screens where commi-nuted material may cause difficulties in subsequent sludge treatment processes. Manually cleaned bar screens are acceptable for small plants.
Grit removal	Sedimentation with provision for separation of grit from other settled solids	Provide ahead of units not specifically designed to handle grit laden flows. Separation step may be omitted if handling and disposal of grit-sludge mixture will create no nuisance.
Removal of suspended solids	Sedimentation	Generally required. Primary settling tank may be omitted in plants under 1 Mgd (3.8 ML/d) or if raw wastewater suspended solids concentration is <100 mg/liter. Extended aeration and contact stabilization-activated sludge plants do not require sedimentation.
	Coagulation with sedimentation	Use in physical-chemical plants. Use in biological plants if pilot studies indicate economy for special purposes.
Removal of floatables	Skimming separators	Provide skimming on primary and secondary settling tanks. If total floatables exceed 50 mg/liter, use separator at source of oily waste, or design primary tanks on basis of oil removal.
Flow and load equalization	Balancing storage	Use prior to biological treatment where peak to average flow ratio is more than twice that given in Figure 1, or where shock BOD loads are anticipated.
Odor control	Chlorination, aeration, hydrogen peroxide, potassium, permanganate	Use in sewers or ahead of plant where plant or sewage flow takes over 12 hours to reach rational computations to indicate a potential hydrogen sulfide problem.

Table 6 (Continued)
Preliminary and Primary Wastewater Treatment Unit Processes

Purpose	Process	Selection Guide
Freshening of septic waste	Aeration, hydrogen peroxide	Use where dissolved oxygen content of waste stream is depleted, especially prior to force mains.
Measure flow	Various methods	Refer to Section 10.

Table 7
Secondary Wastewater Treatment Processes[1]

Purpose	Process	Selection Guide
Removal of soluble and colloidal organics (measured as BOD)	Biological treatment	Use for domestic wastes where advanced treatment is not necessary. Otherwise, evaluate biological treatment with advanced treatment versus physical-chemical processes.
	A. Suspended growth processes	Applicable to small package plants as well as large plants. Generally lower in capital costs but higher in operating costs than attached growth (fixed film) processes.
	1. Activated Sludge a. Conventional b. Step aeration c. Contact stabilization d. Completely mixed e. Extended aeration f. Oxidation ditch	Selection of specific process modification depends on wastewater characteristics and variability, presence of industrial wastes, treatment plant size, available land area, and other factors.
	2. Lagoons a. Aerated lagoons b. Facultative lagoons c. Stabilization ponds	Generally applicable to low wastewater flows and organic loads, with relatively large land areas available in undeveloped surrounding areas. Generally lower in capital costs and operating costs than activated sludge. Continuous sludge handling not normally required.
	B. Attached growth (fixed film) processes	Generally simpler process operation than suspended growth process.
	1. Trickling filters	Generally lower energy requirement than suspended growth processes, higher energy requirement than RBC process.
	a. Stone media	Not normally used in new plants due to high construction costs and relatively large land area requirement with no advantage over packed tower.

Table 7 (Continued)
Secondary Wastewater Treatment Processes[1]

Purpose	Process	Selection Guide
Removal of soluble and colloidal organics (measured as BOD) (Cont'd)	b. Packed tower	Low land area requirement, higher construction cost than activated sludge, lower operating cost and energy requirement than activated sludge. Higher energy requirement than RBC but lower construction cost than RBC.
	2. Rotating biological contactor (RBC)	Generally highest capital cost, but lowest energy cost of biological treatment processes. Land area requirement greater than packed tower and similar to activated sludge.
	C. Dual growth mode processes 1. Packed towers preceding activated sludge w/o intermediate clarification 2. Activated Bio-filter Process (ABF)	Generally less land area required than activated sludge, but more land area required than packed towers. Higher capital cost than activated sludge and somewhat lower operating costs; depends on wastewater condition and process design. Generally most applicable to high strength wastewaters and for expansion of existing trickling filter or activated sludge plants.
	D. Land application	May be used to treat primary effluent in isolated locations that have restricted public access. Effluent quality is generally better than secondary. Cost depends on relative locations of treatment sites. Often attractive in arid regions.

[1]Regulatory authority will define secondary treatment. Secondary treatment processes designed in accordance with criteria herein will achieve a minimum of 80 percent removal of BOD and suspended solids, with a critical unit out of service. Removals of 85 to 95 percent will be achieved with all units in service. Check with regulatory agency to ensure this is adequate. Lagoons will achieve less than 80 percent suspended solids removal, but are considered by EPA to meet requirements for secondary treatment in most cases.

Table 8
Advanced Wastewater Treatment Processes

Purpose	Process	Selection Guide
Conversion of ammonia to nitrates	Biological nitrification or land application	Need depends on effluent standards for oxygen demand and/or ammonia toxicity
Removal of ammonia	Air stripping, selective ion exchange or break-point chlorination/ dechlorination	Need depends on effluent standards
Removal of nitrogen	Biochemical denitrification or land application	Need depends on effluent standards
Removal of phosphorus	Chemical precipitation or land application	Need depends on effluent standards
Removal of dissolved inorganic salts	Demineralization	For special reuse applications only
Removal of residual soluble organics (measured as BOD)	Aerobic biological oxidation (holding pond) land application, or carbon absorption	Use if secondary treatment cannot produce sufficiently low BOD
Removal of dissolved trace organics	Carbon absorption or ozonation	For special reuse applications or effluent standards
Removal of fine solids	Filtration, microscreening, or coagulation and sedimentation	Selection depends on effluent standards
Cooling	Effluent cooling towers or ponds	Need depends on effluent standards. Where required, use after biological treatment

Table 9
Disposal Guide for Residues From Wastewater Treatment

Type of Disposal	Selection Guide
To local municipal treatment plant	Use wherever available unless higher costs significantly exceed benefits of ease of operation and disposal.
To ocean[1]	Discouraged under state and Federal policies. Consider only if savings appear significant based on sludge treatment requirements established by agreement with regulatory authorities for particular case.
Application to land surface[1]	Consider where suitably isolated adequate land area is available. Water pollution from sludge must be prevented by runoff control, groundwater monitoring, harrowing sludge into soil, and so forth. Sludge must be free of excessive concentrations of heavy metals and other toxic materials deleterious to long-term crop production and groundwater quality at required application rates, except for lands dedicated specifically to sludge disposal.
Lagooning[1]	Consider under same conditions and restrictions as for land application, but only where eventual restoration of lagoon area to other uses will be possible. Provide for return of any supernatant or surface liquid from lagoons to treatment plant.
Sanitary landfill of sludge, cake, grit, screen-ings, or scum	Consider where satisfactory landfill site is available. Refer to NAVFAC DM-5.10, Solid Waste Disposal. Evaluate possible effects on leachate quality from landfill in determining treatment needs. (Effects of grit, screening, and scum are small in relation to sludge.)

[1]For stabilized sludge and clean grit only. See Table 10 for Sludge Treatment Selection Guide.

Table 10
Sludge Treatment Selection Guide

Type of Treatment	Where Needed	Available Processes	Selection Guide
Thickening	Use separate thickening process if significant savings can be expected because of reduction in size or operating costs of subsequent sludge treatment units.	Gravity thickening, flotation, or centrifugation.	Gravity thickening is usually best for primary and secondary sludge. Consider separate flotation or centrifuge thickening of activated sludge where large quantities are experienced.
Stabilization	Use prior to surface land disposal, ocean disposal, or lagooning. Evaluate (versus sterilizing conditioning) prior to sanitary landfill.	Anaerobic digestion[1], aerobic digestion, or chemical stabilization with lime or other alkali.	Anaerobic digestion is higher in capital cost, more complex to operate and more easily upset than aerobic digestion, but has a lower operating cost. Aerobic digestion is preferable at plants that only have stabilizing waste activated sludge (e.g., in plant with no primary tanks), and at smaller plants. Chloride concentrations must be kept below 5,000 mg/L for anaerobic digestion, and 10,000 mg/L for aerobic digestion.
Conditioning	Use prior to dewatering and for disinfection.	Chemical conditioning.	Choice of chemical depends on performance (from full-scale operation or pilot studies) and economics. Generally choose between lime and/or ferric chloride and polymer conditioning.

Table 10 (Continued)
Sludge Treatment Selection Guide

Type of Treatment	Where Needed	Available Processes	Selection Guide
Condition-ing (Cont'd)			Polymer conditioning required for belt filter press dewatering. Lime conditioning tends to give a higher sludge cake solids concentration, but also may add appreciably to quantity of solids for disposal. High lime treatment (pH >12 for 2 h) may be needed to disinfect sludge before land application (check with regulatory agency).
Dewatering	Use prior to sanitary landfill or prior to land surface disposal where dewatering and application of sludge cake is less expensive than application of liquid sludge or where liquid sludge application is restricted.	Vacuum filtration, centrifugation, sand beds, lagooning, belt filter press, plate and frame or diaphragm press.	Sand beds are preferable for digested sludge to be disposed of in landfill (where high cake dryness is desirable). Generally choose between belt filter press and centrifugation for undigested sludge. Do not use centrifuge with gritty sludge. Vacuum filters and belt presses present more odor control and cleanliness problems than centrifuges. The belt filter press has become more prevalent than the vacuum filter for new installations. Consider sludge only lagooning for dewatering digested in isolated areas where temperature averages above 60 degrees F (16 degrees C). Use plate and frame press only where cake solids content greater than 40%

Table 10 (Continued)
Sludge Treatment Selection Guide

Type of Treatment	Where Needed	Available Processes	Selection Guide
Dewatering (Cont'd)			is required for subsequent processing or disposal.
Sludge storage	Use prior to mechanical dewatering where standby equipment is not provided, and prior to ultimate disposal.		

[1]Anaerobic digestion yields a by-product liquor (supernatant) with high ammonia content and BOD. This requires treatment either separately or by recirculation through wastewater treatment units. Where there are nitrogenous oxygen demand or nutrient restrictions on the plant effluent, the supernatant may create sufficient problems to render anaerobic digestion impractical or uneconomical.

b) Incineration. This process is capital- and energy-intensive. Normally, it can be economically justified only for very large plants (greater than 10 Mgd [38 ML/d]) where landfill disposal sites are very limited or long distances from the plant, or where industrial wastes require destruction of volatiles or organic toxics in sludge before disposal. Choices include multiple hearth, fluidized bed, and wet air oxidation. Wet air oxidation is the most complex and requires dewatering of the treated residue.

c) Heat Drying. This process is energy-intensive and should be considered only when a refuse incinerator or coal-fired boiler system is available for sludge incineration, and as a heat source. Even under these conditions, other methods may be more economical.

d) Elutriation. This process is used to reduce costs of chemical conditioning prior to dewatering anaerobically digested sludge. It is normally economical only for very large plants (greater than 10 Mgd [38 ML/d]) using lime and/or ferric chloride sludge conditioning prior to vacuum filtration or pressure filtration with plate and frame press. Elutriation requires treatment of washwater separately, or in plant wastewater treatment processes; is environmentally objectionable because of odors; and is rarely used in new plants.

e) By-Product Recovery. This process is not practical under present separation technology except for residue from specific industrial wastewater. Heat dried or otherwise stabilized and disinfected sludge can be sold or given away to local gardeners. Sludge pelletization can be viable at large plants where a market exists for the sludge.

4.6 Air Pollution Control. Design all waste collection and treatment systems to minimize emission of air pollutants:

a) Eliminate use of open fires or refuse dump burning.

b) Design waste collection and treatment system components to inhibit odors (this is achieved by design criteria set forth in this handbook). Evaluate need to install emergency odor control equipment at critical points.

4.6.1 Control Equipment Application. Where necessary to ensure that emissions will comply with air quality standards, install control devices as recommended in Table 11 (odor control data is specified in Table 12).

4.6.2 Detailed Design Criteria. Refer to WPCF MOP 22, Odor Control for Wastewater Facilities.

4.7 Hazardous and Toxic Substances. Some chemical substances considered hazardous and toxic will either not be removed by conventional processes or will interfere with selected treatment systems. Regulatory agencies should be consulted to determine the substances of concern. Pretreatment of hazardous and toxic wastes prior to entry into the collection system is normally the most cost-effective approach.

4.8 Energy Conservation. Energy considerations in wastewater treatment facilities include:

4.8.1 Basic Terms

a) Primary Energy. The energy required to operate the treatment facility.

b) Secondary Energy. The energy required to manufacture chemicals and other consumable materials used to operate the treatment facility.

c) Energy Quality. A measure of the usefulness and transportability of energy. Energy forms of the highest quality can be used in most applications and are most economical to handle and transport. Fuel oil and natural gas are high quality energy forms, while internal combustion engine jacket cooling water is a much lower quality energy form.

Table 11
Selection of Air Pollution Control Devices

Polluting Characteristics	Origin	Control Process	Selection Guide
Aerosols: Particulate matter	Feeding powdered chemicals	Baghouse	Use for up to 99% removal efficiency of fine particles in a dry airstream.
	Combustion of fuels or residues	Electrostatic precipitator	Use for high efficiency removal of fine particles in dry airstream and for removal of fine liquid particles in moist airstream.
		Scrubber	Use for removal of fine particles in dry or wet airstream and for combined removal of fine particles and odorous gases. Particularly applicable to situations where dry collection would form sticky or gummy materials.
Gases and vapors: Organic gases (usually odorous)	Septic sewage, anaerobic sludges	Air stripping	May be used to remove dissolved odorous gases from liquids for subsequent collection and treatment or dispersion.
		Chemical oxidation	Use to control odors arising from handling of sewage.
		Adsorption by activated carbon	Use for low moisture airstream where significantly less expensive than chemical oxidation.

Table 11 (Continued)
Selection of Air Pollution Control Devices

Polluting Characteristics	Origin	Control Process	Selection Guide
Inorganic gases SO_2; NO_x	Combustion of fuels or residues	Absorption	Absorption in water or chemical solution, depending upon gases to be removed, and efficiency designed. In some cases recovery is possible. Used to control NO_x in boilers or incinerators.
H_2S	Septic sewage, anaerobic sludges	Oxidation by combustion	Use where boiler or furnace available and heat generated can be used or provide specific fume incineration.
		Activated carbon treatment of off-gases (absorption)	For general use. Activated carbon may be regenerated by sodium hydroxide.
		Potassium permanganate treatment of off-gases (chemical oxidation)	Determine applicability by testing. May be less successful than activated carbon.
Vapors	Cleaning with organic solvents	Oxidation by combustion	Use where recovery not economical. If vapor heavy, pretreat with condenser.
	Evaporation from petroleum	Adsorption	

Table 12
Odor Control by Chemical Oxidation

Type of Contact System	Oxidant	System Characteristics
Gas-gas	Ozone (O_3) gas Air or oxygen	Consult manufacturer for latest design criteria. Power requirements: 2.5 to 4 kWh/liter O_3 generated. Capacity range: 0.5 to 78.6 lb O_3/d (0.2 to 35.6 kg O_3/d) depending on unit size.
Gas-liquid	Chlorine, chlorine dioxide, or potassium permanganate solutions	Orifice-type scrubber used to apply oxidant. Recirculation rates: up to 20 gpm/1,000 ft^3/min (2.7 L/s per 1,000 L/s) of gas. Pressure range: 2- to 8-in. (0.5- to 2-kPa) water gauge. Consult oxidant manufacturer for required detention times.
Liquid-liquid	Chlorine or hypochlorite solutions	Acts as oxidant and bacteriocide. Normally applied with solution feed chlorinator or meter jump.
Gas-solid	"Purafil" pellets	Polluted air passes through pellets made from 3% aqueous potassium permanganate solution impregnated into an activated alumina substrate. Consult manufacturer for further design criteria.
	Activated carbon	May be regenerated with heat or impregnated and regenerated with caustic, which improves efficiency of H_2S oxidation. Use where less expensive than oxidation by other chemicals.

4.8.2 Basic Principles. Principles of energy conservation include:

a) Minimizing energy use by eliminating or not initiating unnecessary energy-using functions.

b) Use of the least amount of energy necessary to accomplish a given specific purpose.

c) Use of the lowest quality of energy necessary to accomplish a given specific purpose.

These principles have variable priority of application, depending on the specific circumstances. For instance, if low quality energy which would otherwise be wasted has limited use in a treatment facility, conservation or maximizing use of that energy form may not be economically attractive.

4.8.3 Energy Use Factors. Energy use in wastewater treatment is controlled by the following factors described in paragraphs 4.8.3.1 through 4.8.3.5.

4.8.3.1 Degree of Treatment Required. Generally, the higher the degree of treatment, or the better the effluent quality required, the more energy that will be consumed. Regulatory agencies can minimize energy requirements by setting effluent criteria to require no higher degree of treatment than necessary to ensure that stream water quality criteria will not be violated. In the past, many state regulatory agencies have set effluent criteria based on a "worst case" stream assimilative capacity expected to occur statistically once in 10 years or a 7-day period. These effluent criteria were then applied to treatment facilities on a continuous, year-around basis, even though the stream had assimilative capacity for lower effluent quality most of the time.

On some projects with advanced wastewater treatment, state agencies have allowed seasonal advanced treatment operation, with only secondary treatment required in the cold weather. Seasonal operation can significantly reduce operating costs and can reduce size and capital costs for biological treatment processes, such as nitrification, because the processes can be designed for warmer operating temperatures.

4.8.3.2 Type of Processes Employed. Available processes to provide a given degree of treatment can have greatly differing energy requirements. For biological secondary treatment and nitrification, fixed film processes, such as trickling filters or rotating biological contactors, have generally lower energy requirements for the same degree of treatment as activated sludge. Anaerobic digestion stabilizes sludge and produces methane gas, while aerobic sludge digestion also stabilizes sludge but consumes power for aeration. Anaerobic digestion also provides greater solids reduction than aerobic digestion, reducing energy requirements for subsequent processing and disposal.

4.8.3.3 Efficiency of Equipment Used. Proper selection and application of equipment can greatly influence wastewater treatment plant energy consumption. Oversizing of electric motors results in low operating efficiency. The extra cost of high efficiency motors is often justified when their operation is continuous. For diffused aeration in activated sludge, fine bubble diffusers may double the overall energy efficiency of coarse bubble diffusers. Use of variable speed drives for pumping, or other applications where constant speed could be used, increases capital costs and energy requirements. Also, there are large differences in efficiencies of available variable speed drives. Pumps and air blowers should be selected and specified to operate at best efficiencies feasible under normal operating conditions.

4.8.3.4 Sources and Types of Energy Used. Heating for anaerobic digesters and buildings can often be supplied from waste heat sources, such as engine jacket and exhaust cooling water or from heat pumps using treated plant effluent as a heat sink. Solar energy can be used to heat buildings and anaerobic digesters. Excess digester gas can be used in a central plant hot water heating system to heat the digesters and buildings. Digester gas can also be used in place of gasoline as a fuel source for sludge disposal or other vehicles in large plants.

4.8.3.5 Additional Information. For additional information on energy-use factors, refer to:

a) EPA's FED MCD-32, Energy Conservation in Municipal Wastewater Treatment.

b) WPCF MOP FK-2, Energy Conservation in the Design and Operation of Wastewater Treatment Facilities.

c) WPCF M0030, Energy Conservation at Wastewater Treatment Plants.

4.9 Value Engineering (VE). PL 104450, section 4306, enacted as part of the National Defense Authorization Act for Fiscal Year 1996 requires that "Each executive agency shall establish and maintain cost-effective value engineering procedures and processes." It defines the term value engineering to be an analysis of the functions of a program, project, system, product, item of equipment, building, facility, service, or supply performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety, and life cycle costs. OMB Circular A131, dated 21 May 1993 requires the application of Value Engineering through formal study where appropriate in the procurement cycle and it requires its consideration on all projects $1 million and higher. In the facility arena, the services have established compliance with varying selection criteria determining the basis of project selection. The U.S. Army Corps of Engineers, from a facility perspective, applies VE to all projects over $2 million. The Naval Facilities Engineering Command applies the $1 million threshold but expects to achieve a 10:1 return on investment. The Department of the Air Force, CE, applies the $1 million threshold expecting to achieve a 10:1 return for projects under $10 million and applying VE to all projects over $10 million.

The Value Engineering effort may be initiated at the project's start using function analysis to establish user needs and concept thereby establishing "best value" at the initiation of design or it may be applied at a progress level of design using a peer group second team review. The VE effort is not used as simply a cost cutting tool or method to reduce quality. In either of the foregoing approaches the team, from a function standpoint, is developing best value directed at recommendations which maintain or improve performance, reliability, and quality on a life cycle cost basis.

Section 5: WASTEWATER TREATMENT PLANT GENERAL LAYOUT AND DESIGN CONDITIONS

5.1 Site Selection. Locate plants as far as possible from inhabited areas. Use minimum distance of 1,000 feet (305 m) for uncovered plants and 2,000 feet (610 m) for limit of spray irrigation of effluent. Greater separation distance is recommended if possible.

5.1.1 Wind Direction. Locate plants downwind from habitation where a definite wind direction prevails.

5.1.2 Foundation Conditions. Evaluate possible difficulties with foundation conditions or high groundwater. Obtain soil borings; qualified geotechnical engineer shall prepare foundation report with recommendations for structural design.

5.1.3 Elevation. Evaluate elevation in relation to the need for sewage pumping, and for dikes around the site. Protect facilities against damage from the once-in-100-year flood. Design to maintain operation and access during the once-in-25-year flood.

5.1.4 Effluent Disposal. Evaluate distance and possible pumping requirements to point of effluent disposal. Check effluent pumping requirements at flood elevations of receiving stream. Design outfall sewer for protection against flood waters and other hazards to ensure structural stability and freedom from stoppage.

5.1.5 Topography. To protect the plant against flooding, use flow associated with 100-year storm as basis for design of dikes and similar facilities. Design to minimize damage from more extreme storms. To a feasible extent, conform hydraulic profile through plant to natural topography to minimize grading and wastewater pumping.

5.1.6 Land Requirements. The following requirements shall be used for preliminary engineering estimates:

Treatment Method	Acres Per Mgd of Capacity (Hectares Per ML/d Capacity)
Activated sludge and RBC plants	2 (0.2)
Trickling filter plants	3 (0.3)
Aerated lagoons	16 (1.7)
Stabilization basins	20 (2.1)

Include possible expansion in estimate of treatment capacity. Provide 50 percent additional land (if available) for buffer zone. Base final land requirements on detailed design.

5.2 Design Flows. Refer to paragraph 2.2 for design flow estimation. Provide hydraulic capacity through plant for peak flows. Refer to Sections 6 and 8 for flow basis for sizing process units.

5.3 Reliability. The treatment plant must operate during emergencies, power failures, and during maintenance work on treatment units. Provide two alternative sources of power (for example, two utility sources from two separate substations, or one utility source with standby generator) with automatic switching at facilities without continuous attendance, or where time delay to manually transfer power could result in failure to meet effluent limitations, failure to treat peak flow, or damage to equipment. Provide standby process capacity, pumps, chemical feed equipment, electrical equipment, and similar items, to ensure that loss of single unit will not jeopardize the plant or its operation. Provide physically-separated transformers for each utility power source. Vital components of the same type shall be divided as equally as possible between at least two motor control centers. Design criteria given in Sections 6, 7, and 8 define spare capacity needed for process units. Refer to EPA 430-99-74-001, Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability for additional information.

5.4 Dewatering. Provide for dewatering (draining) of all tanks and channels, using a gravity system wherever possible. Slope tank bottoms a minimum of 1 percent toward drains. Design drains to empty tanks in 6 hours or less.

a) Take advantage of bottom sludge drawoffs from tanks for drainage connections.

b) Use portable pumps for tanks or channels not to be connected to the drainage system. Provide sumps in tank and channel floors large enough to accommodate pump suction hoses.

5.5 Flow Through Plant. Control the distribution of flow between multiple units by controlling the loss of head and providing adjustable control boxes with symmetrical division of flow.

5.5.1 Conduits and Pipeline Location. Where possible, locate lines parallel and adjacent to one another to minimize laying costs, and lay out units to minimize crossing pipes and conduits.

5.5.2 Control of Solids Separation. Limit solids deposition and scum accumulation in conveyance facilities to avoid septic conditions, odors, or flow stoppages.

5.5.2.1 Tanks. Incorporate efficient sludge and scum removal systems. Provide convenient access for cleaning and adequate flushing facilities.

5.5.2.2 Conduits and Channels. Eliminate dead spots. Provide cleaning access and flushing facilities at points of likely solids deposition or scum accumulation such as wet wells. Limit velocity variations over flow range (multiple pipes or variable channel depths may be necessary). Size conduits and channels to satisfy one of the following criteria:

a) Maintain minimum suspension velocity required to keep all particles in suspension at lowest flows (refer to Table 13). Channels may be aerated to meet this criterion.

b) Ensure that minimum scouring velocities to resuspend particles (refer to Table 13) are exceeded at average 24-hour flows.

Table 13
Minimum Velocities in Plant Conduits and Channels

Item	Minimum Suspension Velocity (fps [m/s])	Minimum Scouring Velocity (fps [m/s])
Raw sewage	2.5 (0.8)	3.5 (1.1)
Grit tank effluent	2.0 (0.6)	2.5 (0.8)
Flocculated sewage	NA*	NA*
Primary settling tank effluent	1.5 (0.5)	2.0 (0.6)
Mixed liquor or trickling filter effluent	1.5 (0.5)	2.0 (0.6)
Secondary settling tank effluent	0.5 (0.2)	1.0 (0.3)

*NA = Not applicable. Refer to paragraph 6.6.

5.5.2.3 Manifolds. For distribution of flow to multiple ports (for example, inlets to rectangular settling tanks, or outfall diffusers), design manifold conduits as follows to limit variations of flow between ports to 10 percent.

a) Design conduit with tapered width to maintain constant approach velocity at each port for any given flow (see Figure 11). Select size based on velocity of 5 to 8 fps (1.5 to 2.4 m/s) at maximum flow.

b) Select number of ports. Assume square ports with bottoms flush with bottom of conduit. Determine trial port size, assuming ratio of port velocity to conduit velocity (Vp/V) is 1.0.

c) Estimate variation in head (h) along conduit as multiple velocity head, ($V^2/2g$). Use Manning formula to estimate friction losses. See Figure 12 to estimate head losses passing ports (negative values indicate gain in head).

d) Use of adjustable gates can eliminate the need for precise sizing of ports.

5.6 Outfalls. Consult regulatory authorities as to specific requirements on dispersion, extension of outfall, and similar conditions. For methods of calculation of dispersion and for density effects in diffuser discharging to large open water body, refer to Design of Municipal Wastewater Treatment Plants, T.R. Camp, 1992. For outfall diffuser arrangement and design, refer to Wastewater Engineering: Treatment, Disposal, and Reuse, Metcalf and Eddy, 1991. The following general guidelines apply to outfall design, except where local requirements are more stringent.

5.6.1 Capacity. Design outfalls to discharge peak flow against the maximum stage of receiving waters.

5.6.2 Extension. Extend outfall at least 25 feet (7.6 m) beyond the low water contour and at least 30 feet (9.1 m) beyond the pierhead line. Where the outfall is hung below a pier, it may be terminated at the pierhead if the current is sufficient to ensure rapid dispersion. Check minimum extension guidelines by rational computation for diffusion requirements as described in the above references.

5.6.3 Depth. Locate crown of outfall at the following minimum depths below mean low water surface.

a) In navigation channels: Maintained channel depth plus 7 feet (2.1 m).

b) Other locations: 3 feet (0.9 m).

Check minimum depth guidelines by rational computations for diffusion requirements as described in above references.

5.6.4 Backflow Control. Provide backflow control where the level of receiving waters may rise above the outfall hydraulic grade line.

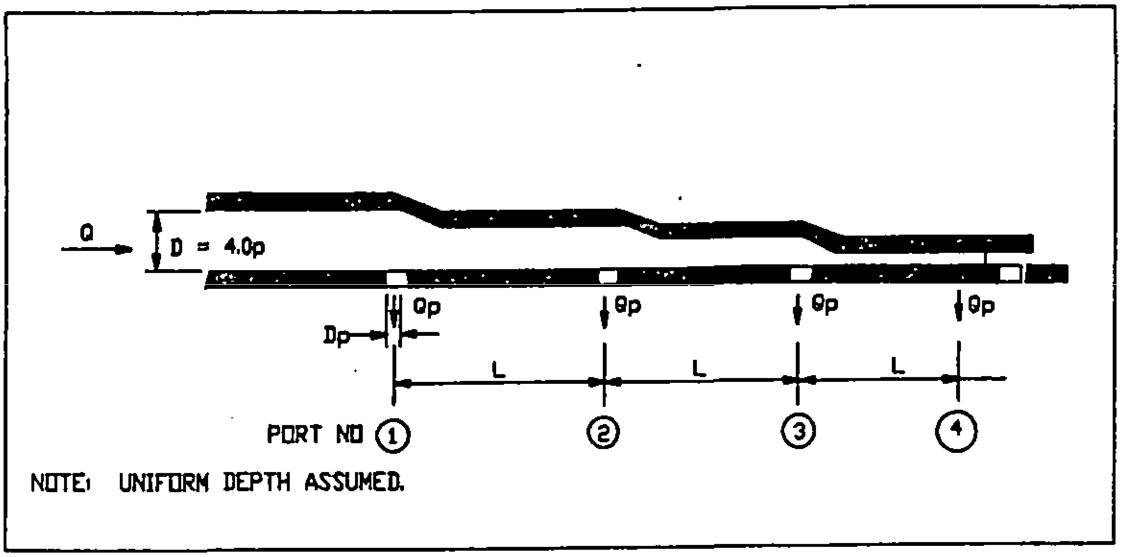


Figure 11
Tapered Manifold Conduit

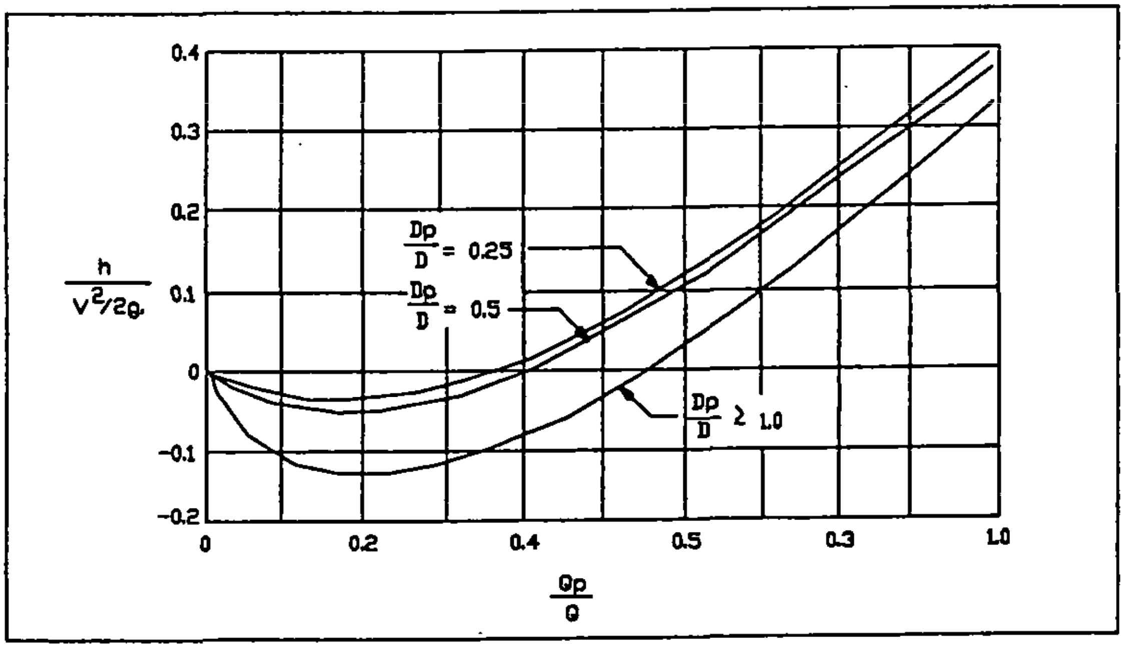


Figure 12
Head Losses **in Manifold Passing Parts**

5.6.5 Subaqueous Piping. Use ball-jointed ductile iron, steel (with effective corrosion protection), concrete, or high density polyethylene pipe. Anchor the pipe to prevent movements by currents.

5.6.6 High Wind. Outfalls located above ground on structural supports shall be anchored to withstand wind velocities specified for the design of structures (see MIL-HDBK-1002/1).

5.6.7 Protection. Provide riprap or other adequate protection against floating debris and erosion by wave action.

5.7 Pumps

5.7.1 Selection. General recommendations are given in Table 14.

5.7.2 Drives. Use polyphase electric motors, with enclosures conforming to recommendations outlined in NAVFAC DM-3.10, Noise and Vibration Control for Mechanical Equipment. Flexible connections between drives and pumps are desirable. Use variable speed drives only when it is not possible to choose single-speed equipment to cover all operation conditions, or where significant savings can be shown.

5.8 Pressure Piping. General design criteria are given in Table 15 with the friction multiplier shown separately in Table 16. Refer to Table 4 for piping material selection guide.

5.8.1 Friction Loss. Refer to Table 16 for friction loss multipliers for different flow velocities and sludge solids concentrations. These multipliers are applicable only to short pumping distances found in treatment plants (1,000 feet [305 m]). For greater sludge pumping distances, refer to Pipeline Friction Losses for Wastewater Sludges, M.C. Mulbarger, et al., 1981.

5.9 Valves. General recommendations are given in Table 17.

5.10 Buildings. Refer to Table 18 for criteria covering the provision of building space.

5.11 General Construction Criteria

a) Use dense reinforced concrete for all walls and slabs or below grade.

b) Walls requiring watertightness should not be less than 12 inches (300 mm) thick, and should have heavy-duty water stops at all construction joints.

Table 14
Pump Selection

Type of Material Being Pumped	Occurrence	Type of Pump		Capacity and Standby Requirements	On-Off Control	Remarks
		Recommendations	Exceptions			
Raw sewage	Lift station in collecting system. Lifting influent to plant.	>50 gpm (3 L/s): Pneumatic ejector or grinder pumps. >50 to 200 gpm (3 to 13 L/s): Sub-mersible nonclog centrifugal in wet well may be used, but end-suction nonclog centrifugal in dry well prefer-able. >200 gpm (13 L/s): End-suction nonclog centrifugal in dry well.	Below 50 gpm (3 L/s), may use nonclog centrif-ugal, recycling part of flow so that pump can operate above 50 gpm (3 L/s). Screw pump should be considered for low head high volume flows.	Pneumatic ejector: Provide for peak flow. Use duplex unit with two air compressors. Pumps: Provide capacity for peak flow with one or largest pumps out. Consider effect of pumping increments on flow rates through subsequent treatment units.	Use automatic control based on water level in wet well, with high level alarm. Multiple pump installations should alternate operation but be capable of simultaneous operation as well.	Nonclog pumps should not be operated above 1,800 rpm. Water-stuffing boxes are preferable. Sewage pumps must be protected against trash by screens or communitors. For pump station design criteria, refer to paragraph 3.3.
Settled sewage	Recirculation within plant (e.g., trickling filter). Lifting effluent to discharge point.	<500 gpm (32 L/s): End-suction nonclog centrifugal in dry well. >500 gpm (32 L/s): Vertical axial or mixed flow centrifugal in wet well.	Plant layout may permit influent pumps to handle recycle.	Provide for peak flow with one of largest pumps out.	Same as for raw sewage.	Pumps should not be operated above 1,800 rpm.
Primary sludge. Thickened sludge. Digested sludge.	Transferring sludge	Plunger pump in dry well.	Recessed impeller or screw feed centrifugals or rotary positive displacement pump may be considered for thin or well digested sludges.	Provide capacity to expected daily sludge pump sludge volumes in about 2 h, with one of the largest pumps out. (If unit may be down for several days w/o hindering operation standby requirement may not be needed.)	Use program control system (usually timer). Allow for switchover to manual control.	Plunger pumps should have air chambers on suction and discharge. Use totaling counter on each pump to record strokes. Pump should be operated with positive suction head.

Table 14 (Continued)
Pump Selection

Type of Material Being Pumped	Occurrence	Type of Pump		Capacity and Standby Requirements	On-Off Control	Remarks
		Recommendations	Exceptions			
Secondary sludge	Pumping from secondary tanks. *Usually continuous.*	End-suction nonclog centrifugal or mixed flow in *dry well or submersible* unit installed in sump.	For return sludge in small activated sludge *plants, air lifts should be* considered.	Refer to paragraph 7.2	Provide variable speed drive with manual speed adjustment.	Pumps should not be operated above 1,800 rpm.
Scum	Pumping from primary and secondary tanks. Usually intermittent. Scum control in digesters. Usually *continuous.*	Plunger pump in dry well. Recessed impeller in dry well.	Screw feed centrifugal may be considered for small installations.	Provide capacity to expected daily scum pump volume in about 2 h. As above.	Same as for primary sludge. Same as for primary sludge.	Piping often arranged to allow primary sludge pump to also scum. Piping may be arranged to combine digested sludge pumping and scum control.
Grit	Lifting grit from grit chamber hopper. Usually intermittent.	Recessed impeller centrifugal of special design in dry well.	Pneumatic ejector may be used. For short runs, screw conveyor rake or bucket elevator may be preferable.	Same as for primary sludge.	Same as for primary sludge.	Provide water jet agitation at pump inlet of grit chamber hopper.
Building drainage	Dry well and basement sumps.	Submersible centrifugal installed in sump.		Two pumps, sized for peak drainage condition (minimum 20 gpm [1.3 L/s]).	Use automatic control based on water level in sump. Alternate pumps.	Provide high water alarm.
Plant water	Pumping from plant effluent to provide *water for flushing,* spray foam control.	Centrifugal in dry well or submersible installed in *sump. Strainer on suction.*	Municipal water may be more economical in *smaller plants. (Provide* positive backflow protection.)	Provide for peak demand with one of largest pumps out.	Automatic control to maintain a desired pressure.	Provide loss of system pressure alarm.

NOTE: All flows mentioned in this table are average flows.

Table 15
Pressure Piping Criteria

Type of Material Being Pumped	Minimum Diameter[1]	Velocity Constraints[2] (fps [m/s])	Head Losses: Friction Loss[3]	Head Losses: Fitting and Valve Loss	Remarks
Raw sewage	4 in. (100 mm) 2 in. (50 mm) for small systems where grinder pumps are used.	Degritted: $v>3$ (0.9) at average flow. $v<10$ (3) at peak flow. Undegritted: $v>8$ (2.4) at highest flow reached regularly each day. ($v>8$ [2.4] only if $v<10$ [3] at peak flow).[3]	Use Hazen-Williams coefficient C = 100 for ductile iron. For other materials obtain manufacturer's recommendation.	Use K values as for water, taken from Hydraulics Institute, Engineering Data Book.	Avoid high spots which can trap air. If air binding unavoidable, vent. Provide backflow and surge protection. Discharge horizontally into headers. Minimize bends.
Settled sewage	No restriction.	$v>2$ (0.6) at average flow. $v<10$ (3) at peak flow.	As for raw sewage.	As for raw sewage.	As for raw sewage.
Primary sludge Thickened sludge Digested sludge (de-gritted or undegritted)Grit slurry	4 in. (100 mm)	$4<v<10$ ($1.2<v<3$) for all flows.	<2% solids: as for raw sewage. 2% to 8% solids: use friction loss for raw sewage multiplied by factor taken from Table 16. >8% solids: allow 0.5-ft (1.5-kPa) head loss per foot of pipe length.	As for raw sewage.	Use cleanout elbows, crosses, or capped tees or wyes at direction changes. Provide flushing connections (1.5-in. [40-mm] hose gates with quick coupling) at ends of long lines. (Provide positive backflow prevention if city water used.) See also remarks for raw sewage.
Secondary sludge	4 in. (100 mm)	As for raw sewage.	As for raw sewage.	As for raw sewage.	See remarks for raw sewage.
Scum	6 in. (150 mm)	As for primary sludge.	As for raw sewage.	As for raw sewage.	See remarks for primary sludge.

Table 15 (Continued)
Pressure Piping Criteria

Type of Material Being Pumped	Minimum Diameter[1]	Velocity Constraints[2] (fps [m/s])	Head Losses		Remarks
			Friction Loss[3]	Fitting and Valve Loss	
Building drainage	No restriction	As for settled sewage.	As for raw sewage.	As for raw sewage.	See remarks for raw sewage.
Plant water	No restriction	As for settled sewage.	As for raw sewage.	As for raw sewage.	See remarks for raw sewage.

[1]Minimum diameter criterion takes precedence where it conflicts with minimum velocity constraints.
[2]If velocity constraints are not practical for small pumping facilities, flushing connections or cleanout should be provided, but velocity should be >5 fps (1.5 m/s) at highest flow reached regularly each day.
[3]Values given for guidance only. Design must allow for range of variation from these values.

Table 16
Friction Loss Multiplier for Sludge

Pipe Velocity (fps [m/s])	Multiplier at Sludge Concentration (%)						
	2	3	4	5	6	7	8
4 (1.2)	2.0	3.0	3.4	3.8	4.4	4.9	5.4
5 (1.5)	1.5	2.1	2.4	2.7	3.0	3.5	3.9
6 (1.8)	1.4	1.8	2.0	2.2	2.5	3.0	3.4
7 and 8 (2.1 and 2.4)	1.3	1.6	1.7	1.9	2.4	2.9	3.2

Table 17
Valves and Operators

Type of Material Flowing	Backflow Prevention	
	Recommended Valve	Exceptions
Sewage	Swing check with outside lever and weight.	
Primary sludge Thickened sludge Digested sludge Scum Grit	Ball check (plunger pump)	Swing check with outside lever and weight (centrifugal pump)
Settled effluent	Swing check	Rubber-seated butterfly

Type of Material Flowing	Shutoff		Exceptions
	Recommended Valve	Recommended Operator[1]	
Sewage	<12 in. (300 mm): eccentric plug, knife gate. >12 in. (300 mm): double-disc gate, knife gate.	>8 in. (200 mm): lever. 8 to 12 in. (200 to 300 mm): gear. Handwheel.	For service above 150 psig (15,200 kPa), use lubricated plug. Gearing and bypass may be needed on larger sizes. (Consult with manufacturer.)
Primary sludge Thickened sludge Digested sludge Scum Grit	Eccentric plug 8 to 12 in. (200 to 300 mm): gear.	<8 in. (200 mm): lever.	
Settled effluent	8 in. (200 mm): lever. >8 in. (200 mm): gear.	For service above 150 psig (15,200 kPa), use double-disc gate.	

[1]For automatic control use pressure cylinder (motor-operated with gear reducer) for all valves.

Table 18
Provision of Building Space

Facility	Plant Size[1]	Criteria for Housing the Facility
Sewage pumping units	Small	Package pumping or pneumatic ejector stations.
	Medium	Vertical units located in an underground prefabricated steel structure with separate wet well.
	Large	Vertical pumps located in a concrete dry well with motors located indoors at grade. Wet well adjoins dry well.
Other pumping units	Small	Except for foam control pumping units, all other units located in control building.
	Medium and large	Located in control building.
Chlorination equipment	Small	Located in control building. Located in separate room with separate outside entrance.
	Medium and large	Located in control building. Provide separate rooms for chlorine cylinders in use and chlorinators, instruments, and controls.
Screening, comminution. Grit collectors, settling tanks, and thickeners	Any	Except to prevent freezing in extreme climates and/or for odor control, housing for these facilities not ordinarily justified even at largest plants of Navy installations. Except for clean grit, provide closed containers for material removed from sewage.
Aeration tanks	Any	Not housed except for special process variations. Avoid in extremely cold climates where housing would be essential. Use local heating as needed to avoid ice buildup on surfaces.
Trickling filters	Any	Housed in cold climates or if odor from industrial waste sources are potential problems.

Table 18 (Continued)
Provision of Building Space

Facility	Plant Size[1]	Criteria for Housing the Facility
Rotating biological contactors	Any	Housed for freeze protection in temperate climates.
Chemical feeders, vacuum filters, centrifuges, blowers. Sludge dewatering equipment	Any	Normally housed, except in warm climates, only rain protection may be required.
Anaerobic digester control (sludge heat exchanger and such)	Any	Housed in building located between digesters.
Office	Small and medium	Provide desk, telephone, file, and similar items in laboratory-office room of control building.
	Large	Same but provide additional space for record storage. Provide separate office from laboratory. Consider providing a separate lunchroom.
Laboratory[2]	Small and medium	Allow 150 ft^2 (14 sq m) of laboratory floor space in the laboratory-office room. Provide furnishings and equipment for plant classification C as given in U.S. Army Corps of Engineers TM 5-814-3, Domestic Wastewater Treatment.
	Large	Allow 300 ft^2 (28 sq m) of floor space in a separate room from office. Provide furnishings and equipment for plant classification A as given in TM 5-814-3.
Lavatory	Any	Provide wash basins, urinals, commodes, showers, and lockers.
Shops and general storage	Any	Provide on basis of analysis of expected operation.
Chemical storage	Any	As required by process and delivery methods.

Table 18 (Continued)
Provision of Building Space

Facility	Plant Size[1]	Criteria for Housing the Facility
Generators	Any	Unless indoor space is available in structures required for other purposes or in extremely cold climates, provide outdoor installation with adequate climate protection.
Instrument and controls	Any	Located in control or chlorination buildings.

[1]Small: Less than 1.0-Mgd (4-ML/d) nominal plant capacity; no full shift attendance.
Medium: 1.0- to 3.0-Mgd (4- to 11-ML/d) nominal plant capacity; at least 40 hours per week attendance, daily inspection.
Large: Over 3.0-Mgd (11-ML/d) nominal plant capacity; 24-hour attendance probable.
[2]Treatment plants for predominantly industrial wastes may require greater laboratory space for analytical services and instrumentation necessary for plant operation.

c) Refer to American Concrete Institute (ACI), Concrete Sanitary Engineering Structures for further criteria and details for obtaining dense watertight concrete resistant to chemicals and conditions expected in service.

d) For walls above grade, refer to criteria given for construction in MIL-HDBK-1001/1, Basic Architectural Requirements and Design Considerations.

e) Provide finishes as follows (refer to MIL-T-704K, Treatment and Painting of Material).

Space	Floor	Wall
Laboratory and office	Vinyl or rubber tile	Paint
Storage	Hardened concrete	Paint
Washrooms	Vinyl or rubber tile	Cement enamel or ceramic tile (lower wall) Paint
General work	Hardened concrete	Paint or cement
Screen and grit chambers	Hardened concrete	Paint
Pump rooms	Hardened concrete	Paint or cement enamel
Sludge dewatering	Hardened concrete	

f) Protect process tanks against flotation when they are emptied. Use combination of:

(1) Deadweight.

(2) Holddown piles.

(3) Groundwater relief drains. Drains may discharge into tank if normal water table is usually low enough that tank can be dewatered. Provide flap valves.

(4) Dewatering wells or well points.

g) For additional criteria, refer to MIL-HDBK-1190.

5.12 Equipment and Appurtenances. Criteria for plant piping layout, lighting, service water, tankage drains, and equipment installation are given in Table 19.

5.13 Heating and Ventilating. Refer to Table 20.

5.14 Hazards and Special Safety Criteria. Refer to Table 21.

5.15 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 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 color scheme shall be applied to piping systems at waste treatment facilities. Refer to Table 22 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 effect the coding scheme recommended in paragraph 3.4, for pier, wharf, and drydock utility connections.

5.15.1 Federal Safety Red (ASA Class F-FIRE). This classification includes sprinkler systems and other firefighting or fire protection equipment. The applications are sprinkler piping, identification and location of fire alarms and boxes, extinguishers, fire blankets, fire doors, hose connections, hydrants, and other firefighting equipment.

Table 19
Plant Equipment and Appurtenances

Item	Feature or Location	Criteria
Equipment installations	Clearances	Provide minimum passageways 3 ft (0.9 m) wide around equipment - greater allowances where operation is frequent. Allow vertical clearance sufficient to permit lifting of equipment from mounting.
	Removal for servicing	Allow door and aisle widths for lateral passage of largest equipment likely to be removed or brought in for maintenance. Provide hatches or open wells for removal of equipment below grade. Consider need for cranes, trolleys, hoists, and lifting eyes in interior installations of equipment.
Piping	Color coding	Paint interior piping with distinctive colors according to coding system given in Table 22.
	Layout	Locate piping along walls and overhead (7-ft [2.1-m] minimum clearance from floor). Avoid "headknockers."
Illumination	All locations	Refer to "Load Factors and Their Application" in WPCF MOP 8, Design of Municipal Wastewater Treatment Plant.
	Digester control building roof; and other outside locations where nightwork may be frequent.	Provide illumination of 2 footcandles (fc) [22 lux (lx)]. Avoid reliance on portable equipment.

Table 19 (Continued)
Plant Equipment and Appurtenances

Item	Feature or Location	Criteria
Drainage and flushing provisions	Pump dry wells; screening and grit removal buildings; digester control and sludge control and sludge processing buildings; lavatories.	Provide floor drains on minimum basis of one per 400 ft^2 (37 sq m) of floor area. Pitch floor to drains at slope of 1/16 in./ft (0.5:100). Provide hose bibs on minimum basis of one per 5,000 ft^2 (464 sq m) or one per room minimum.
	Below grade	Run drains or pitch floor to sump equipped with sump pumps.
Water supply	Yard supply	Provide flushing water hydrants adjacent to all units handling sewage or sewage materials. Size piping to give 50 gpm (3.2 L/s) at 40 psig (276 kPa).
	Building service	Base size on tabulation of estimated water needs for each building. Include sanitary uses, flushing, cooling equipment operation and treatment processes, sprinkling. Provide service (1-in. minimum) [25-mm minimum] for all buildings except those used only for storage.
	Service water (effluent)	Cautions required for sanitary reasons limit use: pipe only to special points of use; use clearly identified piping and signs.
	Cross connections	None. Refer to "Cross Connections With Nonpotable Supplies" in MIL-HDBK-1005/7, Water Supply Systems.
	Fire protection	Refer to MIL-HDBK-1005/7.

Table 19 (Continued)
Plant Equipment and Appurtenances

Item	Feature or Location	Criteria
Chemical feeding	Methods and characteristics	Refer to MIL-HDBK-1005/7.
	Location of equipment	Make physically separate, but visible from main operating area.

5.15.2 Federal Safety Yellow. This group includes materials which are inherently hazardous because they are flammable or explosive, toxic, or produce poisonous gas. The applications are flammable liquids such as gasoline, napthas, fuel oil, chlorine gas, sulfur dioxide, ammonia, and steam.

5.15.3 Federal Safety Orange. This classification includes ASA Class D Dangerous Materials such as corrosive liquids, acids, and alkalis. The applications are concentrated acid, caustic soda, lime slurry, or hydrogen peroxide solution piping.

5.15.4 Federal Safety Green. This classification includes ASA Class S Safe Materials which involve little or no hazard to life or property in handling. The applications are low temperature and pressure, nonpoisonous and nonflammable liquids and gases, drinking water service water emergency showers, and eyewash facilities.

5.15.5 Federal Safety Blue. This classification includes ASA Class P Protective Materials. These materials are piped through plants for the express purpose of being available to prevent or minimize the hazards associated with dangerous materials, for washdown and for lawn watering. These materials are not typically used at Navy wastewater treatment facilities.

5.15.6 Other Color Codes. 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 A13.1-1982 for specification details of legend marker.

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

Table 20
Plant Heating and Ventilating

Location	Criteria (see Notes 1-6)		
	Air Changes/h	Temperature to Maintain	Heating Source
Pipe tunnels	6	60°F (15.5°C)	H&V unit
Basement areas	6	Ambient	H&V unit
Chlorine storage and chlorine feed rooms	6 (normal); 60 (emergency)	60°F (15.5°C)	H&V unit
Thickener area	12	60°F (15.5°C)	H&V unit
Wet well (attended)	12	60°F (15.5°C)	Depending on job conditions
Grit and screening area (intermittent)	30		
Pump station	6 (continuous); 24 (intermittent)	50°F (10°C)	H&V unit
Chemical room, shop, and such	6	60°F (15.5°C)	H&V unit or unit heaters
Sludge treatment units	6+ (minimum	60°F (15.5°C)	H&V unit
Motor or generator rooms	Combustion air (see Note 5)	(Note 5)	(Note 5)
Boiler-mechanical room	20+ combustion air	60°F (15.5°C)	H&V unit
Toilet and locker area	12	70°F (21°C)	H&V unit
Showers	20	70°F (21°C)	Duct reheater
Offices, laboratories, control rooms	6 to 12 or air conditioned with 15% to 20% outside air.	Summer 78°F (25.5°C), 45% humidity. Winter 70oF (21°C).	Perimeter radiation and H&V unit

Table 20 (Continued)
Plant Heating and Ventilating

[1]H&V unit refers to heating coil within ventilating ducts.
[2]Normally where an area requires both air supply and exhaust, increasing discharge temperature of the air supply unit will compensate for the transmission losses of the room or area.
[3]Duct work fabricated of stainless steel or other noncorrosive material shall be used in wet well, grit, screenings, and thickener areas.
[4]Consider need for odor control on exhaust from enclosed thickeners, wet wells, grit or screenings handling areas.
[5]For economy, design ventilating system to provide required heat dissipation with a difference of at least 10°F (5.5°C) and preferably 15°F (8.5°C) between maximum outside temperature and design inside ambient temperature. Provide higher class motor insulation where not practical to limit temperature to ambient rating of normal insulation.
[6]For garages, refer to NAVFAC MIL-HDBK-1003/3.

5.16 Equipment Specifications. Refer to NFGS series.

5.17 Personnel Requirements. Minimum personnel requirements for efficient treatment plant operation are as follows:

Minimum Operating Personnel Requirement
for Given Plant Size[1]

Position	0 to 1.0 Mgd (0 to 4 ML/d)	1.0 to 5.0 Mgd (4 to 19 ML/d)	5.0 to 10 Mgd (19 to 38 ML/d)
Plant superintendent	1 (6 h/d)	1	1
Plant operator	1-2	2-4	4
Plant chemist	0	1	1
Plant laborer	1	2	2
Plant maintenance person	0	1	2
Laboratory technician	0	0	2

[1]Treatment plants for industrial or mixed domestic-industrial wastes may require greater staff requirements or special positions regardless of plant capacity.

Table 21
Hazards and Special Safety Criteria

Hazard	Location	Criteria
Falling	Stairs, open access wells, tank and channel exterior walls, walkways over tanks.	Where possible, avoid need for exterior railings on tanks or channels by setting grade 3.5 ft (1 m) below tops of walls. Where applicable, cover well or hatch opening with grating. In all other locations, provide railings consisting of 1.5-in. (40-mm) tubing or pipe, screwed or welded; rails at heights of 1.5 ft and 3.5 ft (0.5 mm and 1 m) above floor; and posts at 6- to 8-ft (1.8- to 2.4-m) spacing.
	Stairs (see also above)	Provide stairs rather than ladders or manhole steps for access to all areas which are attended daily. Use straight, in preference to circular, stairs. Use nonslip treads. Limit slop to 10 vertical on 12 horizontal.
Gas (asphyxiation and explosion)	Wet wells, screenings and grit removal buildings, digesters, thickeners, and their control buildings.	Provide portable explosive-gas and oxygen-deficiency indicators to test air when hazard appears to exist. Provide installed ventilation for exhausting. Provide warning signs. Use explosion-proof electrical fixtures. Locate fuel burning equipment at grade, with separate outside entrance. Provide chlorine leak detectors for all chlorination facilities. Provide chlorine container emergency repair kits for appropriate chlorine application. (Chlorine Institute Emergency Kit A for 150-lb. (68-kg) cylinders; Emergency Kit B for 1-ton (1- tonne) containers.)
Mechanical	Around any equipment with exposed moving parts.	Provide working clearance of at least 3 ft (0.9 m). Furnish guards on moving parts of machinery, especially belts, gears, chain drives, and shafts.

Table 21 (Continued)
Hazards and Special Safety Criteria

Hazard	Location	Criteria
Fire	Any	Provide extinguishers at locations of special hazard and a minimum of one extinguisher per building. (For electrical gear and oil storage or use, provide CO_2 type extinguishers.) Locate fuel storage with clearances in accordance with NAVFAC DM-22, Petroleum Fuel Facilities. Serve engines or furnaces by pump or day tank. Avoid gravity flow from a storage tank.
Electrical	Wherever electrical equipment is installed.	Make all control panels of dead front and dead rear type. Place rubber mats in front of panels. Use moisture-proof electrical equipment for below grade installations. Ensure adequate insulation and grounding. Refer to MIL-HDBK-1004/1, Electrical Engineering Preliminary Design Considerations.
Drowning	Open tanks	In addition to railings, provide each tank with egress ladder and life preserver with throw line.
Sanitary	Various	Provide potable water supply for drinking and washing. Provide washrooms with adequate supply of hot water. Furnish washrooms with swinging doors and metal door plates to avoid contamination from door knobs. Use foot-operated plumbing fixtures.
	Water seals on sewage or sludge pumps; pump priming systems; meter flushing; elutriation; screenings grinders; spray water foam control; pipe flushing.	Allow no cross connections. For prevention of cross connections, refer to MIL-HDBK-1005/7.

Table 21 (Continued)
Hazards and Special Safety Criteria

Hazard	Location	Criteria
Contamination of water supply	Potable water connections.	Provide backflow prevention device.
Marking of hazardous areas		Refer to MIL-HDBK-1001/1, Basic Architectural Requirements and Design Considerations.

Table 22
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 black 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 paragraph 3.4.13, preceding for pier, wharf, and drydock facilities.
[2]Further color coding of segregated wastes is not practical since they are usually cross-contaminated and require joint treatment.

Section 6: PHYSICAL-CHEMICAL PROCESSES

6.1 Trash Racks, Comminutors, and Screens. Avoid deep pits and locate out-of-doors unless enclosure is justified by criteria in Table 18.

6.1.1 Trash Racks. Trash racks shall conform to the following criteria.

6.1.1.1 Size of Openings. Openings shall be slightly less than the size of the solid which can be passed by pump being protected, but not greater than 6 inches (150 mm). Use 6-inch (150-mm) opening before comminutor.

6.1.1.2 Method of Cleaning. Manual method of cleaning shall be used for installations less than 2 Mgd (8 ML/d). Provide automatic mechanical cleaning at larger installations.

6.1.1.3 Standby. None are required.

6.1.1.4 Head Loss. Design to accommodate at least 6-inch (1.5-kPa) head loss through trash rack without surcharging upstream sewers.

6.1.2 Comminutors. At least two comminutors shall be provided (one standby) each capable of operating satisfactorily over the entire flow range for small plants. Additional units of fractional capacity may be required for larger plants. Location downstream of grit chambers will prolong the life of the unit in wastewater with a substantial grit load. Location upstream of grit chamber may be a cost effective alternative to a bar screen. Follow manufacturer's recommendations for head loss allowances and installation details. Consider grinder pumps as an in-line alternative to comminutors.

6.1.3 Bar Screens. Two bar screens shall be provided, including one standby. Each shall be capable of operating satisfactorily over the entire flow range. Bar screens shall meet the following criteria.

6.1.3.1 Size of Opening. The size of the opening shall be 1 inch (25 mm).

6.1.3.2 Hydraulic Design. Limit maximum velocity through screen to 3 fps (0.9 m/s) at flow range normally anticipated. Provide flume or other hydraulic control to maintain minimum water surface elevation as high as possible. Use Equation (4) to calculate head loss through a clean screen:

EQUATION: $h = 0.006 \; (V_2^2 - V_2^2)$ (4)

where

h = head loss (ft [m])
V_1 = velocity through screen (fps [m/s])
V_2 = velocity in channel just upstream of screen (fps [m/s])

6.1.3.3 Method of Cleaning. Provide mechanical cleaning with automatic timer control (1-hour cycle with on-off control adjustable to nearest minute) and high water level timer override. Consider use of two timers allowing day and night cleaning cycles to be set. Screens will generally need to be cleaned less frequently at night. Determine optimum cleaning cycles in field.

6.1.3.4 Alarm. Provide local audio and visual alarms if cleaning device jams and for high water condition.

6.2 Grit Removal. Design for 95 percent removal of P_{10} grit size at peak flow.

6.2.1 Selection of Grit Separation Units. Refer to Table 23.

6.2.2 Sizing Criteria for Grit Tanks or Channels. Size grit tank and channels according to methods presented in Metcalf and Eddy, 1991. Use grit specific gravity of 2.65 and grit particle size of 0.074 mm (200 mesh Tyler sieve) unless specific grit characteristics are known. Refer to paragraph 2.3.4d for additional information on grit analysis.

6.2.3 Grit Storage and Handling. Grit storage and handling shall meet the following criteria:

a) Avoid multiple handling by performing the following:

(1) Utilize inclined rake or screw type washers to convey grit to discharge point wherever possible.

(2) Where grit has to be hauled from plant, discharge directly from dewatering units to the containers in which it will be carried.

(3) Where grit must be moved a significant distance horizontally or vertically to a point of discharge, consider pumping grit slurry and placing washing and dewatering facilities at that point.

Table 23
Grit Separation Units

Type of Unit	Selection Basis	Design Basis	Remarks and Additional Requirements
Grit tanks	Use for separation of grit from main sewage flow in all plants except: 1. Those where grit can be settled more economically in primary tanks (also known as detritus tanks), or 2. Small plants where manually cleaned velocity control grit channels are used.	Provide at least two units sized to give 95% removal P_{10} grit size at peak flow with all units in service. Apply sizing criteria in para. 6.1.2. Limit V/v_s to <10 under any flow conditions.	Provide reseparation of grit from tank underflow using hydraulic cyclone agitation-type washers. Where grit flow is pumped to washer or cyclone provide: 1. Continuous pumping at rate which will limit grit and sewage solids concentration each to 1%. 2. Effluent water jets in tank hoppers to resuspend grit if needed. 3. Connections for backflushing drawoff lines.
Velocity control grit channels: Manually cleaned	Use only in small plants where grit load is less than 1 ft^3/d (0.03 cu m/d).	Same as for grit tanks except use high values of V/v_s (max. 70) and limit variations of velocity to a narrow range.	Effluent control structure should vary depth with flow to hold channel velocity as constant as possible. Refer to WPCF MOP 8.
Mechanically cleaned with chain and flight or screw conveyor type mechanism	Use only in small plants (<1 Mgd [4 ML/d]) where grit load is greater than 1 ft^3/d (0.03 cu m/d).	Same as for manually cleaned.	Same as for manually cleaned.
Primary settling tanks	Separate grit from main sewage flow in primary tanks only if plant includes sludge thickener which can accept primary sludge and if more economical than use of grit tanks.	See Table 24.	Same as for grit tanks except use hydraulic cyclones for separation of grit from primary organic solids.
Agitated grit tank (manual or air)	Consider only where data are available to demonstrate that desired removals will be obtained under entire range of flows expected.	Consult manufacturers for design and performance data.	For evaluation, require performance data that measure removals in relation to amount and size of grit present in raw wastewater. Consider odor problems from air-agitated tanks.
Hydraulic cyclones	Use in plants for reseparation of grit from primary settling tank underflow.	Consult manufacturers for design and performance data. Variations of flow to units must be minimized to avoid disrupting performance.	

Table 23 (Continued)
Grit Separation Units

Type of Unit	Selection Basis	Design Basis	Remarks and Additional Requirements
Agitated type grit washers (includes reciprocating rake screw type)	Use of reseparation of grit from settling tank underflow or for dewatering of cyclone underflow.	Consult manufacturers for design and performance data.	May be installed directly in grit tank, serving as combined conveyor-washer for grit removed from tank.
Static screen	Not normally used in Navy facilities.		
Swirl concentrator	Not normally used in Navy facilities.		

b) Size grit handling facilities to handle peak grit load at peak flow.

6.3 Flow Equalization. If curve of inflow variations is available, apply mass curve technique to determine storage required for desired maximum outflow rate. For more details on flow equalization, refer to WPCF MOP 8.

6.3.1 Construction. Use earth embankment lagoons, except in small sizes where steel or concrete tanks prove more economical. Line earthen lagoons as needed to prevent contamination of ground water. Consider frequency of lagoon use when evaluating need for earthen lagoon liner.

6.3.2 Aeration and Mixing. Provide sufficient aeration to maintain 1 mg/liter of dissolved oxygen, based on maximum expected exertion of influent BOD. For calculation method, refer to WPCF MOP 8. In the absence of specific data, assume BOD rate constant $R_1 = 0.38\ d^{-1}$ (natural log basis). Provide circulation velocity of least 0.5 fps (0.15 m/s) (preferably 1.5 fps [0.45 m/s]) at all locations over floor of basin.

Consult manufacturers as to circulation capacity of their aeration 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 paragraph 7.2.

6.4 Load Equalization. Determine the effect of flow retention on equalization of pollutant loads using the method developed by Ouano (refer to Developing a Methodology for Design of Equalization Basins, Water and Sewage Works Journal, November 1977). If adequate power is not provided for complete mixing in the basin, size the basin based on nonideal flow pattern described therein. Use larger of two basin volumes as sized for flow equalization and load equalization (refer to paragraph 6.3). Consider the effects of variable and constant volume basin on equalization performance.

6.4.1 Construction. Refer to paragraph 6.3.1 for guidance on construction of equalization basins.

6.4.2 Aeration and Mixing. Refer to paragraph 6.3.2 for guidance on aeration and mixing.

6.5 Sedimentation. Criteria presented below address both primary and secondary sedimentation applications. Use criteria in Table 24 to design conventional settling tanks in plants treating wastewater which is predominantly domestic. Primary settling tanks designed according to these criteria will remove 60 percent of total suspended solids (TSS) and 30 percent of BOD. For wastewater containing a substantial industrial waste contribution determine optimum surface loadings by settling column test and apply remaining criteria in Table 24. Refer to Water Pollution Control: Experimental Procedures for Process Design, by Eckenfelder and Ford, for experimental procedures. For solids contact units, refer to paragraph 6.6.6. For activated sludge settling units, sizing criteria is also based on sludge withdrawal capabilities and solids loading rates. Refer also to paragraph 7.2.

6.5.1 Selection of Configuration. Selection of type of unit depends on type of sludge to be removed, land availability, and operation preference.

6.5.1.1 Rectangular Tank. The rectangular tank allows common wall construction; it can reduce land required. It is generally used for primary sedimentation. The chain and flight collectors are used for primary sludge. Traveling bridge collectors are used for secondary sludge (not commonly used).

6.5.1.2 Circular Tank. The circular tank is applicable to all sludge types. It allows more rapid sludge collection. The following is applicable to the circular tank:

a) Center feed. Center feed types of circular tanks are widely used and the equipment is available from multiple suppliers.

Table 24
Design Criteria for Sedimentation Tanks for
Domestic Wastewater Treatment

Item	Circular Primary	Circular Final	Rectangular Tanks
Maximum surface loading:[1]			
At maximum 24-hr flow with all units in service[2].	1,200 gpd/ft^2 (49,000 Lpd/sq m)	800 gpd/ft^2 (33,000 Lpd/sq m)	Same as circular.
At peak flow with all units in service.	2,000 gpd/ft^2 (82,000 Lpd/sq m)	1,200 gpm/ft^2 (49,000 Lpd/sq m)	Same as circular.
At peak flow with one unit out of service[3].	4,000 gpd/ft^2 (163,000 Lpd/sq m)	1,500 gpd/ft^2 (61,000 Lpd/sq m)	Same as circular.
For activated sludge nitrification facilities:			
At maximum 24-hr flow with all units in service.		400-600 gpd/ft^2 (17,000-25,000 Lpd/sq m)	Same as circular.
At peak flow with all units in service.		800-1,000 gpd/ft^2 (33,000-41,000 Lpd/sq m)	Same as circular.
At peak flow with one unit out of service.		1,200 gpd/ft^2 (49,000 Lpd/sq m)	Same as circular.
Minimum side water depth: Activated sludge secondary process.	Does not apply	12 ft (4 m)	12 ft (4 m)
Other secondary processes.	Does not apply	12 ft (4 m)	12 ft (4 m)
Primary process.	8 ft (2 m)	Does not apply	8 ft (2 m)
Maximum number of bays per tank			4
Maximum width of bay			20 ft (6 m)
Minimum length to width ratio for bay			4:1
Maximum forward velocity (at peak flow)			4 ft/min (0.02 m/s)
Minimum pitch of tank floor toward sludge hopper	1 in./ft (8:100)	1 in./ft (8:100)	1/16 in./ft (0.5:100)
Minimum angle between hopper wall and horizontal plane	60 degrees	60 degrees	60 degrees
Type of outlet weir	Adjustable V-notch plate[4]		Adjustable V-notch plate
Maximum discharge per foot of weir length (at maximum 24-hr flow with all units operating). Provide full peripheral weir.	70,000 gpm (265,000 Lpd)	15,000 gpd (57,000 Lpd). Locate cantilevered effluent launders of center feed units at 0.25 to 0.33 radius from tank wall.	Same as circular.

Table 24 (Continued)
Design Criteria for Sedimentation Tanks for
Domestic Wastewater Treatment

Item	Circular Primary	Circular Final	Rectangular Tanks
Inlet baffle (design to prevent trapping of scum)	Use concentric baffle around central inlet pipe or peripheral feed zone. Extend 3 to 6 ft (1 to 2 m) below surface. Diameter of central inlet baffle should be 15 to 20 percent clarifier diameter.		Provide lateral baffle to dissipate inlet velocity and provide uniform flow distribution over tank width. Extend baffle to at least 1/2 tank depth to prevent short-circuiting.
Sludge collection	In activated sludge plants, use multiple gravity overflow type collection for final tanks larger than 35-ft (11-m) diameter. For all other applications, use rotary scraper collector with 5- to 8-fpm (0.03- to 0.04-m/s) peripheral velocity. Use plows to move sludge to central hopper or channel and a blade to move sludge within the hopper or channel.		Longitudinal chain and flight collector (2 fpm [0.01 m/s] for primary settling, 5 fpm [0.03 m/s] for other applications) to move sludge to hopper(s) at influent end of tank. Pump sludge from hopper. Use cross collector (4 fpm [0.02 m/s] or other applications) or multiple hoppers to limit hopper depth in wide tanks. Other sludge hopper locations may provide more hydraulically efficient sedimentation, and should be considered.
Minimum freeboard	18 in. (0.5 m)		18 in. (0.5 m)
Maximum allowable solids loading (with all units in service)	30 $lb/d/ft^2$ (146 kg/d/sq m) at maximum 24-hour flow. 50 $lb/d/ft^2$ (244 kg/d/sq m) at peak hour flow.		
Scum skimming (to be provided on all settling tanks except in tertiary treatment)	Use rotating skimming arms and pivoted blade to skim scum from liquid surface and deposit it in elevated skimming box. Equip tanks with effluent scum baffles, extending 9 to 12 in. (0.2 to 0.3 m) below water surface. Provide skimming arm on sludge. Provide radiant heating for metal skimming boxes exposed frequently to freezing temperatures.		Use flights of collector mechanism to skim liquid surface, moving scum toward manually operated slotted-pipe, dipping-weir skimmer. Equip tanks with effluent scum baffles, four-shaft chain and flight sludge and scum collectors, and manually cperated tilting pipe skimmers[5]. (Applies to chain and flight type collectors only.)

[1]Size settling tanks according to the surface loading criteria requiring the largest surface area. Check maximum solids loading rate.

[2]In final settling tanks for activated sludge systems, solids loading rate may control unit area required.

[3]Reduce expected primary removals (BOD & TSS) in proportion to fraction of capacity out of service. Allow for this added load in sizing subsequent treatment units.

[4]Weir plates to be set level to accuracy of 0.001 ft (0.0003 m). High point in effluent launder to be 180 degrees from effluent pipe.

Table 24 (Continued)
Design Criteria for Sedimentation Tanks for
Domestic Wastewater Treatment

[5]Discharge scum from skimmers as follows: (1) For secondary tanks in plants with primary settling, return scum to plant influent or wet well ahead of primary tanks. Use continuous gravity return if possible. If pumping is necessary, provide suction well at settling tank to receive discharge from skimming mechanism. Include provision for dilution of scum in well. (2) For other applications, discharge scum to decanting type containers in which it can be hauled to disposal. In larger plants where scum is to be processed on site (digestion, dewatering), consider pumping dilute scum to decant tank located at the processing unit.

b) Peripheral feed. These reportedly have a superior flow pattern; there are a limited number of manufacturers and some proprietary design aspects of this type.

c) Plow-type collector. Plow-type collectors are applicable generally to heavier sludges.

d) Hydraulic-type collector. Applicable to lighter, more flocculent sludges. When directly connected to pumped withdrawal, allows more control on sludge removal rate.

6.6 Coagulation and Flocculation. Data and requirements for coagulation and flocculation are as provided in paragraphs 6.6.1 through 6.6.6.

6.6.1 Selection of Coagulants. The jar test procedure shall be used to determine the best coagulant, required dosages, and optimum pH conditions for particular treatment objective. Refer to Eckenfelder and Ford.

6.6.2 Velocity Gradient Calculations. Calculate the velocity gradients for the mixing, flocculation units, and conduits carrying flocculated wastewater as follows:

6.6.2.1 Tanks With Mechanical Mixing

EQUATION: $$G = (W/u)^{0.5} \quad (5)$$

where

G = velocity gradient (s^{-1})
W = 550P/V (745.7P/V) = power per unit volume ($ft\text{-}lb/s/ft^3$ [L/s/cu m])
u = viscosity of water ($lb\text{-}s/ft^2$ [Pa-sec])

P = water hp
V = volume of tank (ft^3 [cu m])

Refer to American Water Works Association (AWWA), Water Treatment Plant Design, for chart of G versus W and values of u at different temperatures. Apply Equation (5) for high G values not covered by the reference.

6.6.2.2 Conduits (Equations below appear first in English, then in SI)

EQUATION: $G = (62.4\ sv/u)^{0.5}$ or $G = (9800\ sv/u)^{0.5}$ (6)

where

s = slope of hydraulic gradient for conduit
v = conduit flow velocity (fps [m/s])
G and u = as for Equation (5)

6.6.2.3 Baffled Channels

EQUATION: $G = (62.4QH/Vu)^{0.5}$ or $G = (Q\ H/Vu)^{0.5}$ (7)

where

Q = volumetric flow rate (ft^3/s [cu m/s])
H = head loss through channel (ft [Pa])
V, G, and u = as for Equation (5)

Head loss (H) through the channel is between 0.5 and 2.0 feet (1.5 and 6 kPa) and velocities vary from 0.5 to 1.5 fps (0.15 to 0.5 m/s). For (n-1) equally spaced over-and-under or around-the-end baffles, the head loss is:

EQUATION: $H = (nv_1^2/64.4) + (n-1)v_2^2/64.4 + hf$ or (8)

$$H = 500\ (nv_1^2) + (n-1)\ 500\ v_2^2 + hf$$

where

v_1 = velocity of flow in channel (fps [m/s])
v_2 = velocity of flow at baffle slot (fps [m/s])
hf = normal channel friction loss (ft [Pa])

6.6.2.4 Ports. Calculate as for conduits, allowing for entrance contraction in determining velocity.

6.6.3 Flash Mixing. To rapidly disperse applied chemicals throughout wastewater, use either commercially available in-line blenders or rapid mix tanks ahead of flocculation. Refer to Table 25 for design criteria.

6.6.4 Flocculation. Refer to Table 25 for design criteria. Design values of detention and velocity gradient apply only for flocculation of easily coagulated wastes which produce strong well settling flocs (for example, normal domestic sewage prior to settling). If jar tests indicate that a waste may be difficult to coagulate and will produce a weak, poorly settling floc, a pilot study should be conducted to develop suitable design values.

6.6.5 Flow Between Flocculation and Settling Tanks. Design to ensure that the velocity gradients in ports, channels, and conduits between flocculation and settling tanks do not exceed the maximum velocity gradient in the flocculation tanks.

6.6.6 Solids Contact Units. The high solids concentrations in these units speed reaction rates for flocculation, reducing required volume and cost. With wastewater, long solids detention may cause operation problems. Use only after pilot work to ensure performance and establish design criteria, such as optimum overflow rates and recirculation ratios. These units are not suitable for treatment systems that have frequent shutdown periods of any duration since the bed of flocculated solids must be reestablished at each startup.

6.7 Straining and Filtering Processes. Microstraining, diatomaceous filter, and deep bed filtration requirements are as follows.

a) Microstraining. Microstraining shall conform to the following criteria:

(1) Application. Use as a tertiary unit process for filtering secondary effluents.

(2) Available Screen Sizes: 23 to 60 micrometers.

(3) Maximum Allowable Head Loss Across Clean Screen: 6 inches (152 mm).

(4) Total Head Loss Across Unit: 12 to 18 inches (3 to 4.5 kPa).

(5) Continuous Backwash Rate. 1 to 5 percent of total throughout volume.

(6) Hydraulic Loading. 10 to 20 gpm/ft^2 (7 to 14 L/s/sq m) of effective submerged area, for maximum 24-hour flow with one unit out of service. Consult manufacturer for recommendation for particular waste.

(7) Materials for Construction. Carbon steel frame; plastic or stainless steel fabric.

(8) Head Loss. Refer to EPA 625/1-75-0030, Process Design Manual, Suspended Solids Removal, for relation between head loss, hydraulic loading drum speed, and influent characteristics.

Table 25
Design of Mixing and Flocculating Tanks

Items	Mixing	Flocculating
No. of units	Two units (rapid mix tank and in-line blender, or two in-line blenders).	Minimum of two units. All normally in operation.
Detention	In-line blenders: 1 s at maximum 24-hour flow. Rapid mix tank: 30 s at maximum 24-hour flow.	Minimum of 30 minutes with one unit out of service.
Compartments	Single with baffled inlet and outlets.	Minimum of three with baffles to reduce dead spots and short circuiting.
Mean velocity gradient (G)	In-line blenders: 3,000/s. Rapid mix tank: 800 to 1200/s.	Taper from 100/s in first compartment to 25/s in last (at maximum speed).
Mechanisms	Turbine or propeller mixer.	Rotary mechanical flocculator. Maximum tip speed of blades or paddles 2 fps (0.6 m/s).
Drives	Use constant speed motors with gear reducer that permits gear changes to alter output speed.	Use variable speed motors or fluid or V-belt speed variations with 4:1 output speed range. Use interchangeable drive units for all compartments.

(9) Typical Performance. Suspended solids removal, 40 to 85 percent; biochemical oxygen demand (BOD) removal depends on BOD in suspended solids removed. Consult manufacturer for laboratory or pilot testing units for the determination of the filterability index of the wastewater.

6.7.1 Granular Media Filtration. Typical design parameters for sizing filters for domestic wastes are given in Table 26. For selection of media for package filters, consult with manufacturers. Generally, sand or sand with anthracite are economical alternative media for domestic wastewater. Refer to EPA 625/1-75-0030 for further data.

Table 26
Granular Media Filter Parameters for Domestic Wastewater

Item	Design Data
Type of filter	Downflow, static bed[1]
Depth	3 to 8 ft (0.9 to 2.5 m)
Maximum surface loading at maximum 24-hour flow with one unit out of service	4 to 8 gpm/ft^2 (2.7 to 5.4 L/s/sq m) 1 to 3 gpm/ft^2 (0.7 to 2.1 L/s/sq m) of bed surface, at 50 to 100 psig (345 to 690 kPa)
Surface wash (intermittent)	2 to 5 ft ^{3}/min/ft^2 (10 to 25 L/s/sq m) of bed surface
Air scour (prior to backwash)	15 to 30 gpm/ft^2 (10 to 20 L/s/sq m)
Backwash (intermittent)	24 to 50 hours to maximum head loss of 8 to 15 ft (24 to 45 kPa), depending on configuration.
Average filter run	Coagulation and flocculation optional following biological treatment. Coagulation and flocculation required when treating raw sewage.
Pretreatment requirements	Filtration following secondary biological treatment will produce effluent with 5 to 10 mg/liter TSS.
Typical performance	Filtration following chemical clarification of raw sewage will produce effluent with 2 to 10 mg/liter TSS.

[1]For operating data for upflow filtration with single media, and moving bed filters, refer to EPA 625/1-75-0300.

6.7.1.1 Filter Type Selection. Gravity filters are generally preferred for large plants, 5 Mgd (19 ML/d) or greater. Pressure filters are advantageous where high terminal head loss is expected and where plant hydraulics would otherwise require filter influent and effluent pumping. Shallow bed filters with continuous or intermediate cleaning should be considered when available head limits equipment selection. See Figure 13 for typical gravity granular media filtration system layout. See Figure 14 for typical pressure filtration system layout.

6.7.1.2 Design Details. The design details for granular media filtration shall meet the following criteria:

a) Provide mudwell for backwash water collection; minimum capacity of two backwash volumes.

b) Provide minimum two backwash and two mudwell pumps.

c) Provide for simultaneous operation of air scour and backwash pump.

d) Provide high level alarm for mudwell.

e) Consider throttling control valve for mudwell pump discharge to control blend of backwash water with filter influent.

6.8 Chlorination. For purposes and dosages, refer to Table 27. For example layout of chlorination building and contact tanks, refer to Figures 15 and 16. Refer to WPCF MOP FD-10, Wastewater Disinfection, for additional details.

6.8.1 Effluent Contact Tanks. Provide a minimum of 15-minute detention at peak flow. Use two tanks (total volume satisfying detention requirement) to allow periodic cleaning. Minimize short-circuiting with inlet baffles and end-around baffling within the tank. Provide minimum length-to-width ratio of 40:1 in serpentine tanks. Provide complete mixing of chlorine solution with wastewater using injector, mechanical mixing or hydraulic jump as dissolution device. Provide mean velocity gradient of 750 to 1,000 s^{-1} for adequate chlorine-wastewater mixing.

Table 26
Granular Media Filter Parameters for Domestic Wastewater

Item	Design Data
Type of filter	Downflow, static bed[1]
Depth	3 to 8 ft (0.9 to 2.5 m)
Maximum surface loading at maximum 24-hour flow with one unit out of service	4 to 8 gpm/ft^2 (2.7 to 5.4 L/s/sq m) 1 to 3 gpm/ft^2 (0.7 to 2.1 L/s/sq m) of bed surface, at 50 to 100 psig (345 to 690 kPa)
Surface wash (intermittent)	2 to 5 ft ^{3}/min/ft^2 (10 to 25 L/s/sq m) of bed surface
Air scour (prior to backwash)	15 to 30 gpm/ft^2 (10 to 20 L/s/sq m)
Backwash (intermittent)	24 to 50 hours to maximum head loss of 8 to 15 ft (24 to 45 kPa), depending on configuration.
Average filter run	Coagulation and flocculation optional following biological treatment. Coagulation and flocculation required when treating raw sewage.
Pretreatment requirements	Filtration following secondary biological treatment will produce effluent with 5 to 10 mg/liter TSS.
Typical performance	Filtration following chemical clarification of raw sewage will produce effluent with 2 to 10 mg/liter TSS.

[1]For operating data for upflow filtration with single media, and moving bed filters, refer to EPA 625/1-75-0300.

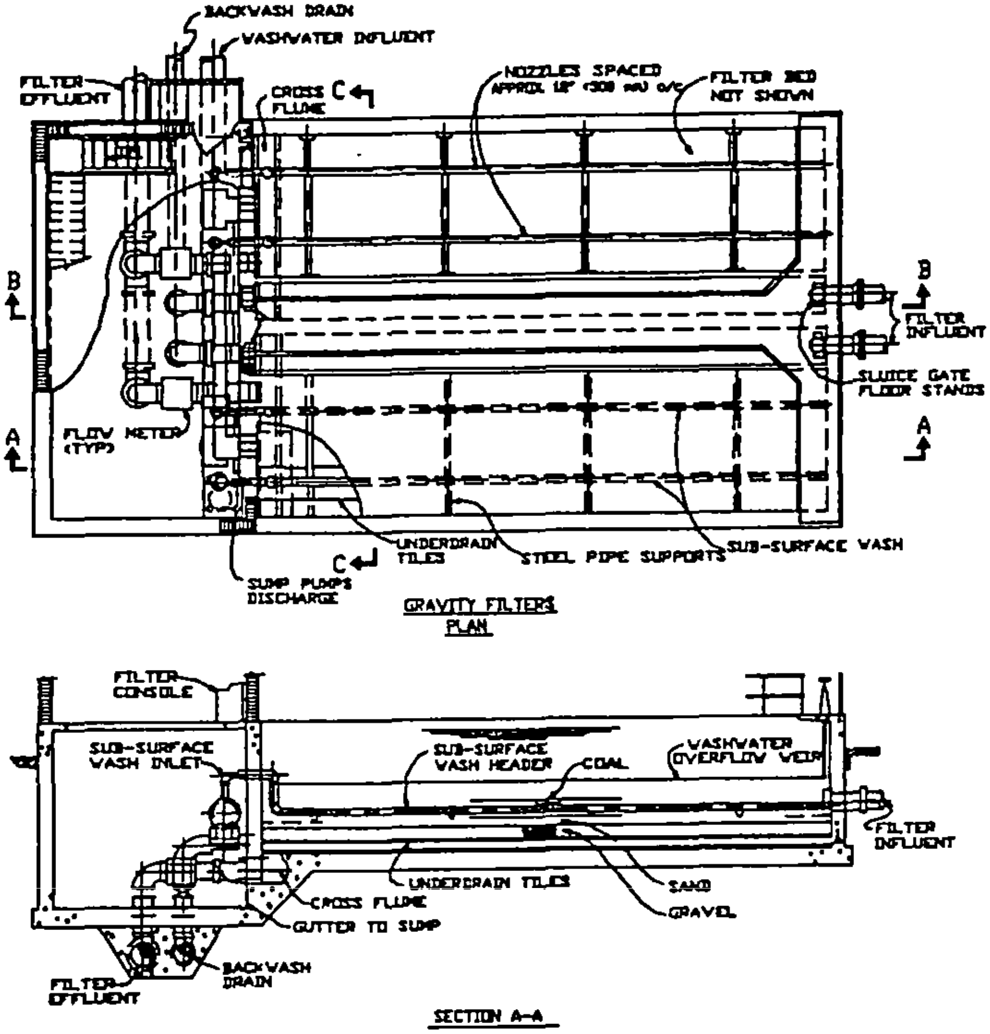


Figure 13
Granular Media Gravity Filter

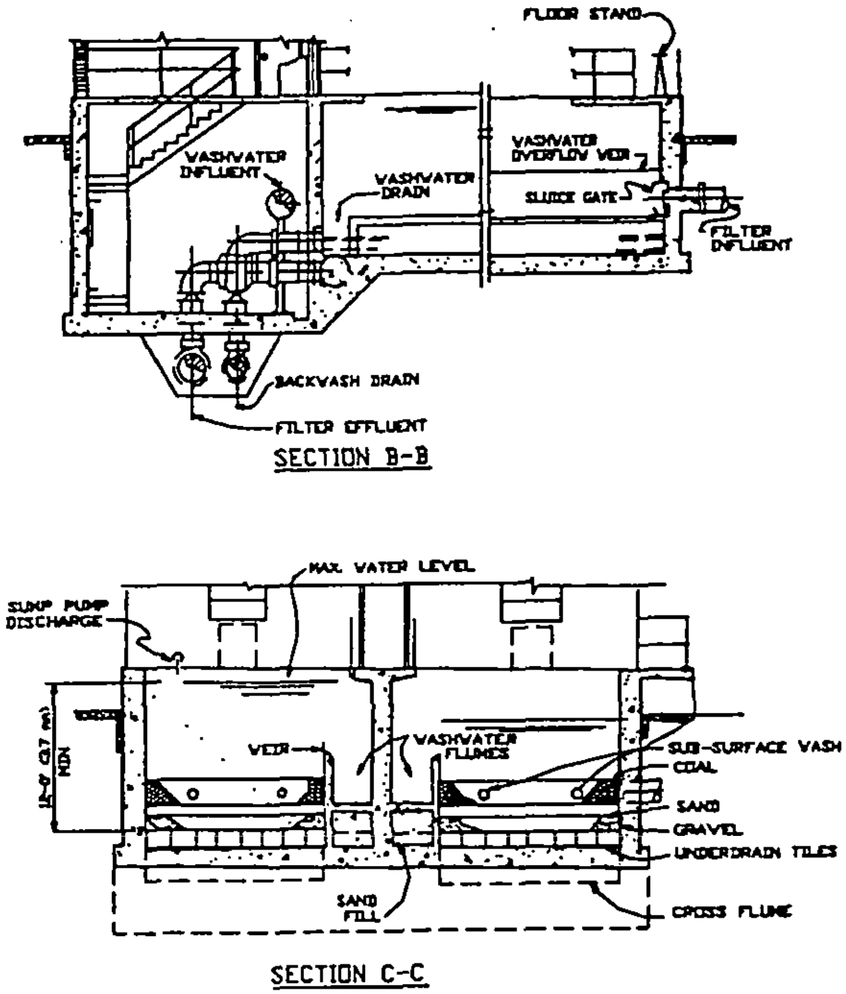


Figure 13 (Continued)
Granular Media Gravity Filter

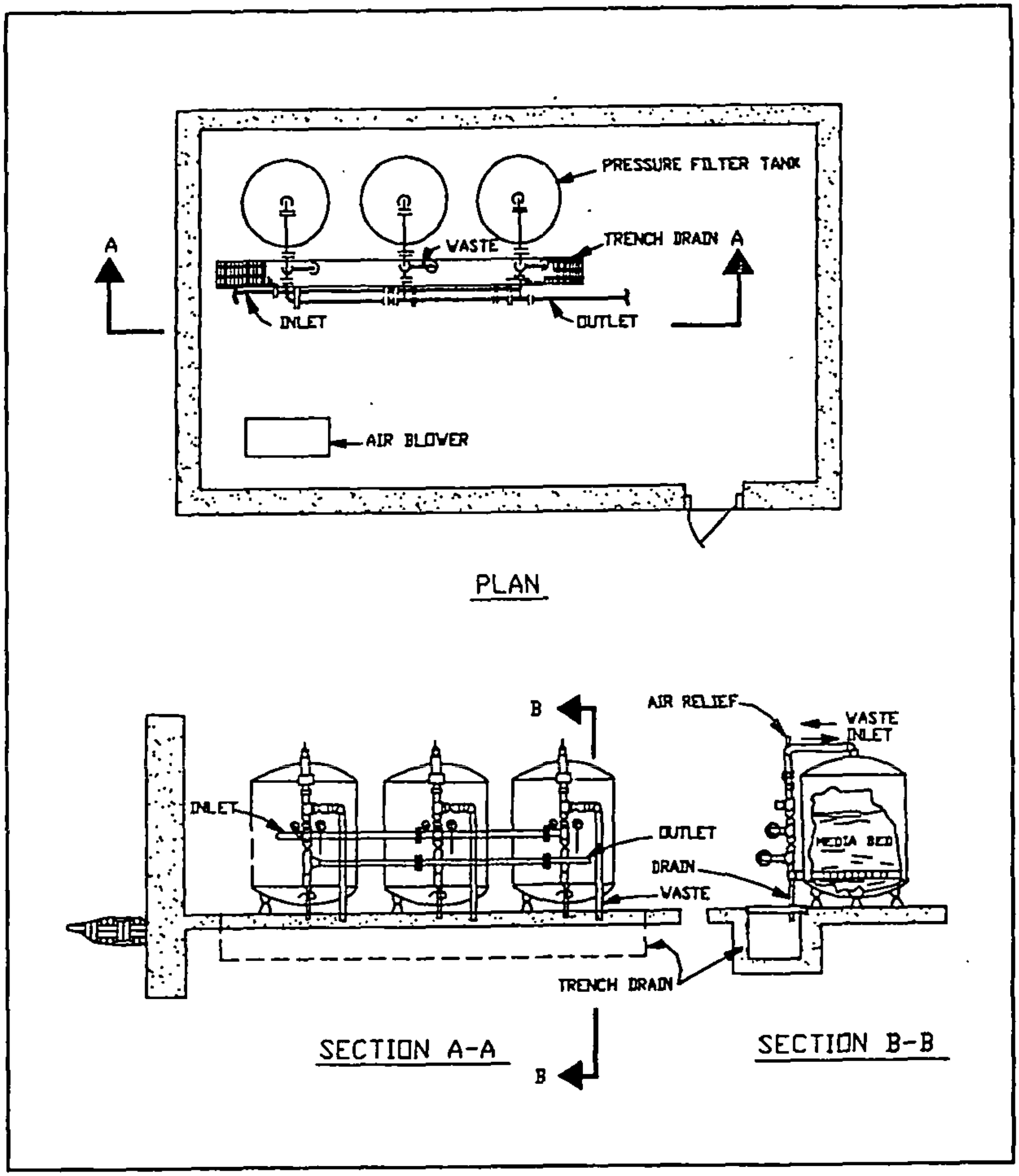


Figure 14
Pressure Filtration System

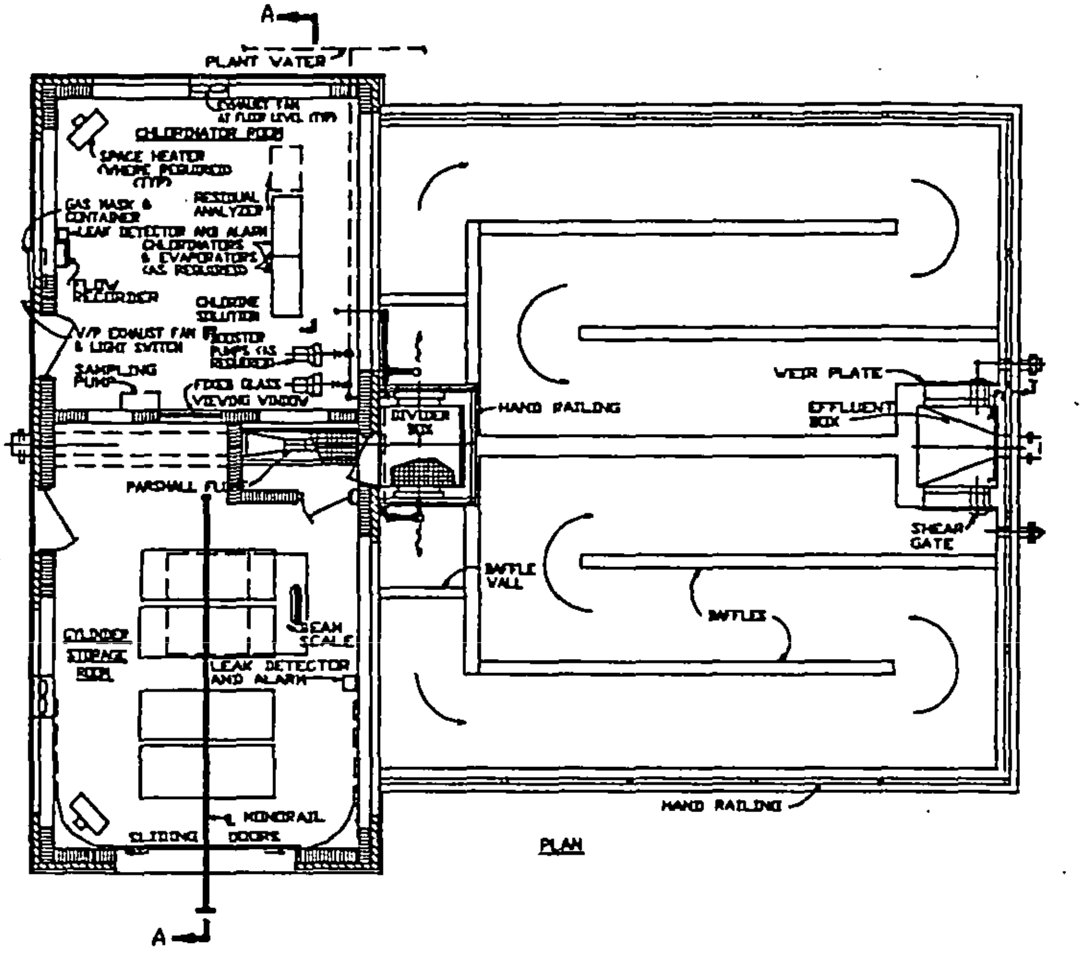


Figure 15
Chlorination Facilities for Large Installations (>80 lb/d [>36 kg/d])

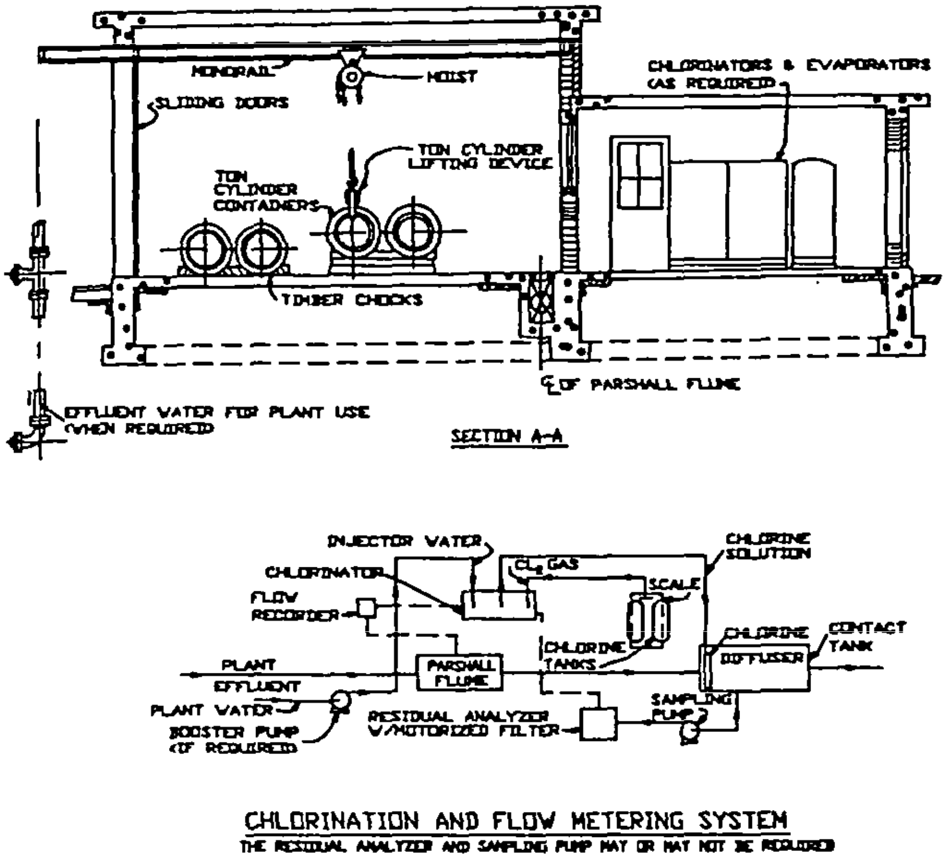


Figure 15 (Continued)
Chlorination Facilities for Small Installations (>80 lb/d [>36 kg/d])

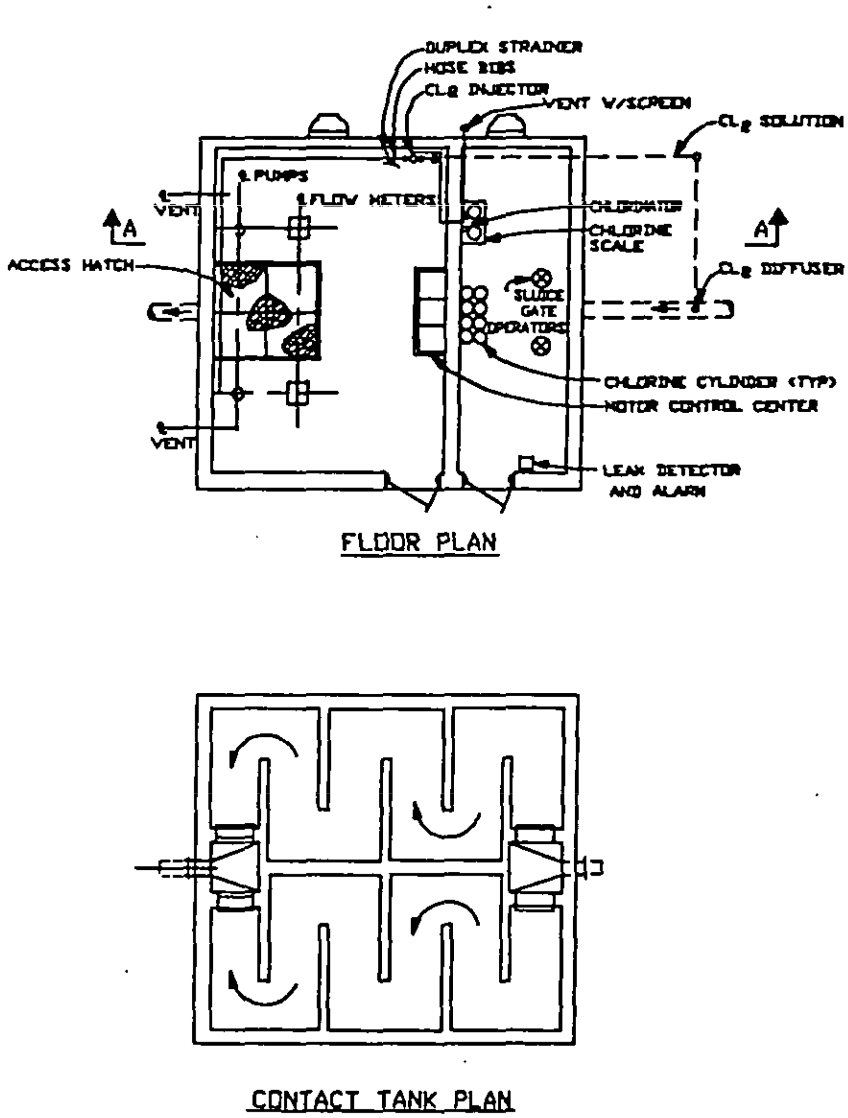
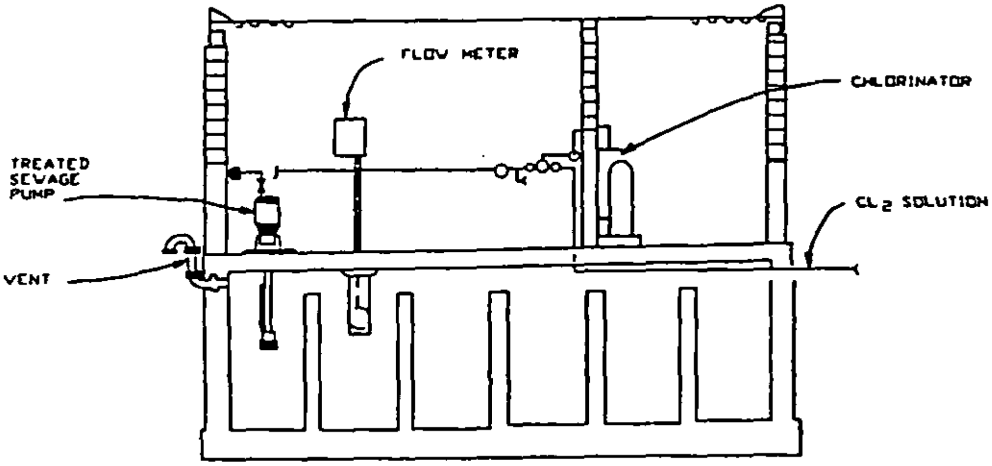


Figure 16
Chlorination Facilities for Small Installations (<80 lb/d [<36 kg/d])



SECTION A-A

Figure 16 (Continued)
Chlorination Facilities for Small Installations (<80 lb/d [<36 kg/d])

6.8.2 Chemical Handling, Instrumentation, and Controls. For guidance on chemical handling, instrumentation, and controls, refer to Section 10. Provide two feed systems (one as standby), each capable of handling the maximum required dosages. Use two 150-pound (68-kg) chlorine cylinders manifold to chlorinator for installations requiring less than 80 lb/d (36 kg/d). For larger installations, use ton cylinder manifold to chlorinator. For installations requiring more than 1500 lb/d (680 kg/d), provide chlorine evaporator. Leak detection and alarm equipment are required in chlorination building.

6.8.3 Hazards and Safety Precautions. Refer to paragraph 5.14 (Table 21).

6.9 Dechlorination. Dechlorination prior to surface water discharge may be required to satisfy regulatory criteria for maximum effluent chlorine residual. Use sulfur dioxide (sulfonation process) for dechlorination.

6.9.1 Requirements. Sulfonation requires one part by weight of SO_2 for one part by weight of chlorine residual. Excess SO_2 consumes dissolved oxygen and supplemental aeration should be considered prior to discharge.

6.9.2 Mixing and Contact Time. Mixing and contact requirements for sulfonation are not as rigorous as for chlorination. They may be accomplished in a hydraulic pump at a Parshall flume, an in-line static mixer, a submerged solution diffuser and conduit, or a mechanical mixer.

6.9.2.1 Mixing. Provide complete mixing within 45 to 60 seconds.

6.9.2.2 Contact Time. If mixing is complete, the dechlorination reaction will be complete in less than 3 minutes. Separate contact chambers are not usually required.

6.9.2.3 SO_2 Injection System. Provide solution SO_2 concentration of 3,500 to 4,000 mg/liter. Design SO_2 injection including pumps, meters, vacuum lines, and gauges same as for chlorine injection system. Design vacuum line to injector for 1.5-inch (38-mm) Hg total pressure drop at maximum SO_2 flow rate and 23-inch (584-mm) Hg vacuum level.

6.9.2.4 SO_2 Diffusers. Design SO_2 solution line diffuser system same as for chlorine solution diffuser.

Table 27
Chlorine Applications

Purpose	Dosage (mg/liter)	Point of Application	Remarks
Disinfection:	Based on residual 0.2-1:	Ahead of contact chamber	Effectiveness increases with removal of organics and settleable particles of which exert chlorine demand and shield organisms from attack.
Settled raw sewage (fresh)	5 to 40	Ahead of contact chamber	
Settled raw sewage (stale)	12 to 40	Ahead of contact chamber	
Chemically precipitated sewage	3 to 10	Ahead of contact chamber	
Trickling filter effluent	3 to 10	Ahead of contact chamber	
Activated sludge effluent	3 to 10	Ahead of contact chamber	
Sand filter effluent	1 to 5		
BOD reduction	1/2 of BOD concentration to be removed (maximum of 25% removal)	Ahead of contact chamber	Cost limits this to emergency measure or to relieve short-term overload.
Odor control	4 to 6	Up-sewer from plant or ahead of particular problem unit.	Residual generally not required.
Corrosion control	2 to 10 depending on staleness.	Upstream of long conduits where conditions favor sulfide production.	

Table 27 (Continued)
Chlorine Applications

Purpose	Dosage (mg/liter)	Point of Application	Remarks
Activated sludge bulking control	5 to 50	To return sludge 2 to 3 min ahead of reentry to aeration tank.	
Trickling filter operation:	To produce residual at distributor:	Trickling filter influent	Lower doses continued until condition corrected.
To control ponding with filter in operation	1 to 2	Trickling filter influent	
To cause complete unloading	20 to 50	Trickling filter influent	Unloading treatment used for about 8-hour duration.
To prevent septicity and rising of sludge during thickening	5 to 10	To thickener influent	

6.9.3 <u>SO_2 Supply System</u>. Use ton cylinders, rail car tanks, or separate site storage tanks filled from tank trucks based on usage rate. Use gas withdrawal from ton cylinders for rates at 250 lb/d (113 kg/d). Operate gas phase systems at tank temperatures than 100 degrees F (38 degrees C). Application of heat directly to SO_2 cylinder is acceptable. Provide air or nitrogen padding system to SO_2 cylinder to ensure proper movement of SO_2 and complete removal of SO_2 from tank.

6.9.3.1 <u>Materials of Construction</u>. Same as for chlorine system.

6.9.3.2 <u>Other Design Details</u>. Refer to <u>Disinfection of Wastewater and Water for Reuse</u>, by G. C. White, 1978.

6.9.4 <u>SO_2 Control System</u>. Control of SO_2 feed system should be based on chlorine residual measurement using compound loop feedback control. Use either single- or two-stage dechlorination process with compound loop control as described by G.C. White, 1978.

6.9.5 Safety Equipment. Similar to chlorine system including breathing apparatus and emergency container kits. Provide permanent SO_2 leak detector in chemical storage and feed room capable of sensing atmospheric SO_2 concentrations at $\geq$1.0 ppm (by volume).

6.9.6 Alarms. Monitor supply system for leaks and low pressure indicating imminent supply loss. Provide sulfonator with high and low vacuum sensing devices. Installations with evaporators require high and low water sensing devices. Installations with compressed air padding should have a high humidity alarm on dried compressed air. Chlorine residual analyzers for zero residual monitoring should have high residual alarm.

6.10 Ozonation. Published pilot studies for wastewater indicate disinfection requirements of 10 to 50 mg/liter with 5-minute detention at peak flow; this should be checked for a particular waste. There is insufficient experience in the use of ozone for tertiary treatment to provide dosage criteria. If ozone is considered for disinfection or chemical oxidation, its effectiveness should be demonstrated by bench scale or on-site pilot plant studies.

6.10.1 Chemical Handling, Instrumentation, and Controls. Refer to Section 10. Provide two feed systems, each capable of handling the maximum required dosages.

6.10.2 Hazards and Safety Precautions. Refer to paragraph 5.14 (Table 21).

Section 7: BIOLOGICAL TREATMENT PROCESSES

7.1 General Requirements. The criteria in this section shall be applied to selection and design of particular biological treatment processes. Base selection for particular application on comparison of costs and operating convenience among processes capable of meeting objectives. Consider total costs, capital and operating, including costs of residue disposal. Specific criteria are given for design of secondary treatment systems for essentially domestic wastewater. For other wastewater or for exceptionally high removal efficiencies, apply design relationships and parameter values from Metcalf and Eddy, 1991. For experimental procedures for determining parameters, refer to the report by Eckenfelder and Ford. For wastewater containing significant quantity of industrial wastes, refer to MIL-HDBK-1005/9.

7.1.1 Nutrient Requirements. For efficient biological treatment, nutrients must be supplied by the wastewater in the normal proportions needed for active microbiological growth. This is typically about 1 pound (0.45 kg) of phosphorus (as P) and 5 pounds (2.27 kg) of nitrogen (as N) for each 100 pounds (45.4 kg) of BOD removed. Requirements are somewhat lower for lightly loaded systems. Domestic sewage contains an excess of nitrogen and phosphorus and ample concentrations of minor nutrients for biological treatment. For wastewater containing significant carbonaceous industrial waste components, check the need for supplemental feed of nitrogen and phosphorous to the treatment process. Refer to Water Quality Engineering for Practicing Engineers, W.W. Eckenfelder, Jr., for relationships to calculate amounts of nitrogen and phosphorous incorporated in waste sludge.

7.1.2 Performance Characteristics and Process Applications

a) For application of biological processes to removal of carbonaceous BOD, refer to Table 28. Where industrial wastes are significant, consult technical literature or conduct treatability studies on the actual or similar wastes to estimate performance of the processes under consideration.

b) For application to oxidation of nitrogen (nitrification), refer to Table 29.

c) Do not rely only on biological removal of phosphorous beyond the quantities incorporated in biological growth and removed as waste sludge. Consider chemical addition and source reduction if additional phosphorous removal is required.

d) Except where noted in Table 28, assume suspended solids removals parallel those for BOD.

7.1.3 Effect of Wastewater With High Seawater Content

7.1.3.1 Performance. High concentrations of seawater tend to slightly inhibit biological treatment. Process inhibition is related to the chloride (Cl) concentration of the wastewater.

a) New designs. In absence of pilot plant data or treatment data from similar wastewaters, compensate for high seawater content according to data presented in Table 29.

b) In analyzing capacity of existing treatment facilities to receive ship's sewage, if figures determined as in Table 29 indicate overloading solely due to chloride inhibition, conduct pilot plant tests before planning any expansion.

c) Sudden changes in chloride concentration may upset biological processes. Consider equalization storage to limit chloride variation at the treatment plant to 200 mg/liter/h at chloride concentrations in excess of 5,000 mg/liter.

7.1.3.2 Maintenance. High seawater content in sewage will aggravate incrustation problems. Avoid fine bubble air diffusion systems, and design orifices in trickling filter flow distributors or in aeration devices to facilitate periodic cleaning of mineral deposits. Use care in selection of construction and equipment materials.

7.1.4 Process Combinations

7.1.4.1 Multiple Biological Processes or Biological With Physical-Chemical Process. Consider wherever treatment requirements for particular wastewater can be met most economically by multiple stages employing different processes; for example, biological nitrification- denitrification for nitrogen removal.

7.1.4.2 Package Units. These units combine processes such as aeration, settling, and sludge treatment in single multicompartment tank. Potential savings result from design standardization and factory production.

a) Selection of type. See Table 30 for classification according to biological process employed and other characteristics. Select type according to biological process. See Figure 17 for typical treatment plant layout and flow diagram incorporating secondary activated sludge package unit.

Table 28
Biological Treatment Processes - Application to Removal of Carbonaceous BOD

Type of Process	Limits of BOD Removal[1] (%)	Volumetric BOD Loadings[2] (lb/d/1,000 ft^3 [kg/d/1,000 cu m])	Relative Capital Cost	Relative Energy Requirement[3] (hp-hr/1,000 gal [hp-hr/1,000 L]) Treated	Sensitivity of Performance Temperature	Application Guide and Remarks
Suspended Growth Processes: Activated sludge (AS): Conventional Step Aeration (step feed) Contact stabilization Completely mixed High purity oxygen[4]	85 to 95 (for all modifications).	40 to 150+ (640 to 2,400) (refer to para. 7.2)	Intermediate	0.75 (0.2)	None to low	Consider activated sludge for general application in secondary treatment. Refer to para. 7.2 for selection of individual process variations.
Modified aeration	70 to 75	400 (6,400)	Low	0.50 (0.13)	None to low	Use modified aeration only when followed by other processes to bring overall removal up to secondary or pretreatment standards.
Extended aeration	85 to 95	10 to 20 (160 to 320)	Low-intermediate	0.9 (0.24)	Low to moderate depending on aeration method.	Extended aeration and oxidation ditch may not require further stabilization of waste-activated sludge.
Oxidation ditch	85 to 95	10 to 20 (160 to 320)	Low-intermediate	0.9 (0.24)	Same as extended aeration.	Oxidation ditch may offer mixing energy savings over conventional extended aeration.
Aerated lagoons	<80 of total; <90 of soluble	3 to 30 (48 to 480)	Low (2/3 of activated sludge)	>0.01 hp/1,000 gal/h (0.003 hp/1,000 L/h) of detention time (sufficient to keep solids in suspension).	High	Apply at higher volumetric loadings (10 to 30 lb/d/1,000 ft^3 [160 to 480 kg/d/1,000 cu m] only for partial treat-ment).

Table 28 (Continued)
Biological Treatment Processes - Application to Removal of Carbonaceous BOD

Type of Process	Limits of BOD Removal[1] (%)	Volumetric BOD Loadings[2] (lb/d/1,000 ft³ [kg/d/1,000 cu m])	Relative Capital Cost	Relative Energy Requirement[3] (hp-hr/1,000 gal [hp-hr/1,000 L]) Treated	Sensitivity of Performance Temperature	Application Guide and Remarks
Aerated facultative lagoons	80 to 85	0.5 to 3.0 (8 to 48)	Low (2/3 of activated sludge).	<0.01 hp/1,000 gal/h (0.003 hp/1,000 L/h) of detention time. Sufficient to keep dissolved oxygen distributed uniformly. Some solids will settle in basin.	High	May be used where effluent quality is adequate (considering temperature effects and removals in any added stages of treatment) and sufficient suitable land area is available. Significant operating economy results because sludge settles and decomposes within lagoon and hence need not be handled separately on continuous basis. Higher loadings apply only in warm climates or with strange wastes.
Facultative lagoons	80 to 85	0.01 to 0.5 (1.6 to 8)	Lowest	None	High	Same as for aerated facultative lagoons.
Attached Growth Processes: Trickling filters (TF):						Consider trickling filters for general application in treatment. Operating requirements are simpler than activated sludge. Used packed tower for new and upgraded facilities. Refer to para. 7.7.
Stone media	65 to 90+	25 to 150 (400 to 2,400)	Intermediate	0.06 to 0.18[5] (0.02 to 0.05[5])	Moderate	
Packed tower (random dump or stacked plastic media in deep or shallow bed)	65 to 90+	50 to 400 (800 to 6,400)	Generally higher than activated sludge for 85 to 90% BOD removal.	0.2 to 0.6[5] (0.05 to 0.16[5])		

Table 28 (Continued)
Biological Treatment Processes - Application to Removal of Carbonaceous BOD

Type of Process	Limits of BOD Removal[1] (%)	Volumetric BOD Loadings[2] (lb/d/1,000 ft^3 (kg/d/1,000 cu m))	Relative Capital Cost	Relative Energy Requirement[3] (hp-hr/1,000 gal (hp-hr/1,000 L)) Treated	Sensitivity of Performance Temperature	Application Guide and Remarks
Rotating biological contactor (RBC)	65 to 95 (depending on loading).	50 to 500,[6] (800 to 8,000[6])	Highest	Varies from 0.09 (0.02) for high loading to 0.3 (0.08) for low loading. Higher if supplemental aeration is used.	Low	High loadings apply for strong wastes only and generally require supplemental aeration. Operating simplicity gives advantage in small package plant applications.
Intermittent sand filter	50 of applied load	<1	Moderate	<0.06 (0.02)		Use only for "polishing" secondary effluents.
Dual Growth Mode Process: Activated biofiltration (ABF) or packed tower/activated sludge without intermediate settling	90 to 95	Up to 20% higher than intermediate TF for same performance.	High	Intermediate between TF and conventional-activated sludge.	Low to moderate	Consider for improving performance of existing units.
Rotating biological contactor with recycle of sludge	90 to 95	Up to 20% higher than highest RBC for same performance. Supplemental aeration required.	High	Similar to RBC at low loading rates.	Low to moderate	Not normally used because of added cost of required supplemental aeration.

[1]For domestic sewage, removal of suspended solids will generally parallel those of BOD except as follows: Type of process - facultative lagoons and stabilization ponds and aerated lagoons; Expected concentration of effluent suspended solids - 50 to 100 mg/L depending on settling allowed.
[2]Based on maximum 24-hr BOD except for lagoons and stabilization ponds. For these use highest average loading over the detention period.
[3]Based on domestic primary effluent.
[4]Not normally appropriate for Navy facilities.
[5]For two stages with recirculation ratio between 0 and 2.
[6]Volumetric loading is not a design criterium for RBD process. Consult manufacturer and independent research data for applicable loading rates.

Table 29
Biological Nitrification

Process	Maximum Cl Concentration for No Inhibition	Concentration for Chlorides in Excess of Maximum Level[1]
Trickling filters and RBCs	5,000 mg/liter	Referring to appropriate design loading curve, decrease loading an amount corresponding to one percentage point of removal efficiency per 1,000 mg/liter of chlorides in excess of 5,000 mg/liter.
Activated sludge	5,000 mg/liter	Decrease loading by 2% per 1,000 mg/liter chlorides in excess of 5,000 mg/liter.
Aerobic and facultative lagoons	8,000 mg/liter	Increase detention time by 2% per 1,000 mg/liter chlorides in excess of 8,000 mg/liter.

[1]Highest average Cl concentration expected over 24 hours.

b) Evaluation of particular packages. For most types, competitive packages are available from different manufacturers. Evaluate proprietary features and performance based on cross checking with manufacturers and with operators at actual installation. Use package plants certified by the National Sanitation Foundation. Refer to Naval Civil Engineering Laboratory (NCEL) CR-70.11, Analysis of Wastewater Treatment and Disposal Systems for Advanced Bases.

c) Performance certification. Specify requirements based on evaluation above. Specify method of operation and performance testing and penalties for failure to comply, including conditions requiring removal or replacement.

7.2 Activated Sludge. For process variations refer to Table 31. See Figure 18 for typical plant flow diagram and hydraulic profile. See Figure 19 for typical facilities layout.

Table 30
Characteristics of Package Biological Treatment Units

Biological Process	Units Processed Included in Package	Solids Disposal	Aeration Method	Sludge Return	Approximate Population Served and Flow[3]	Application
Extended aeration[1] (activated sludge)	Aeration and final settling. Chlorine contact tank may also be included.	Digested sludge to holding tank for truck disposal or to dewatering facilities.	Diffusion. Mechanical surface aerator.	By airlift or pump.	Up to 1,000 per unit. 0.12 Mgd (0.45 ML/d) per unit.	Most advantageous for low population load and where only periodic attention can be given to equipment.
Complete mixing (activated sludge)	Primary settling, aeration and final settling. In smaller units, chlorine contact tank and aerobic digester may be included in package.	To digesters if not combined in treatment unit. Digested sludge to holding tank for disposal or dewatering.	Diffusion. Mechanical surface aerator. Turbine aerator.	By airlift or pump.	Up to 10,000 per unit. 1.2 Mgd (4.5 ML/d) per unit.	Larger plants (see Table 31).
Step aeration[1] (activated sludge)	Aeration, final settling and aerobic digester. Chlorine contact tank may also be included.	Same as extended aeration.	Diffusion	By airlift.	Up to 5000 per unit. 0.6 Mgd (2.3 ML/d) per unit.	Higher degree of treatment.
Contact stabilization[1] (activated sludge)	Same as step aeration.	Same as extended aeration.	Diffusion	By airlift.	Up to 5000 per unit. 0.6 Mgd (2.3 ML/d) per unit.	Do not use.

Table 30 (Continued)
Characteristics of Package Biological Treatment Units

Biological Process	Units Processed Included in Package	Solids Disposal	Aeration Method	Sludge Return	Approximate Population Served and Flow[3]	Application
Biofiltration	Primary and secondary settling, two-stage trickling filtration, and digestion.	Digested anaerobically in lower compartment of unit.	Natural ventilation.		Up to 500 per unit 0.06 Mgd (0.23 ML/d) per unit.	Same as extended aeration.
Rotation biological contactor[2]	RBC with final settling tank.	To separate digestion unit, or to primary settling tank.	Disc rotation under partial submergence.	None.	Up to 1000 per unit. 0.12 Mgd (0.45 ML/d) per unit.	Simplicity makes very advantageous for small units. Entire package is operated by one motor.
Rotating biological contactor[2]						

[1]Separate primary settling generally not required.
[2]Primary settling generally installed separate from package unit.
[3]Flow rates shown are based upon average 120-gpcd (450-gpcd) flow rate.

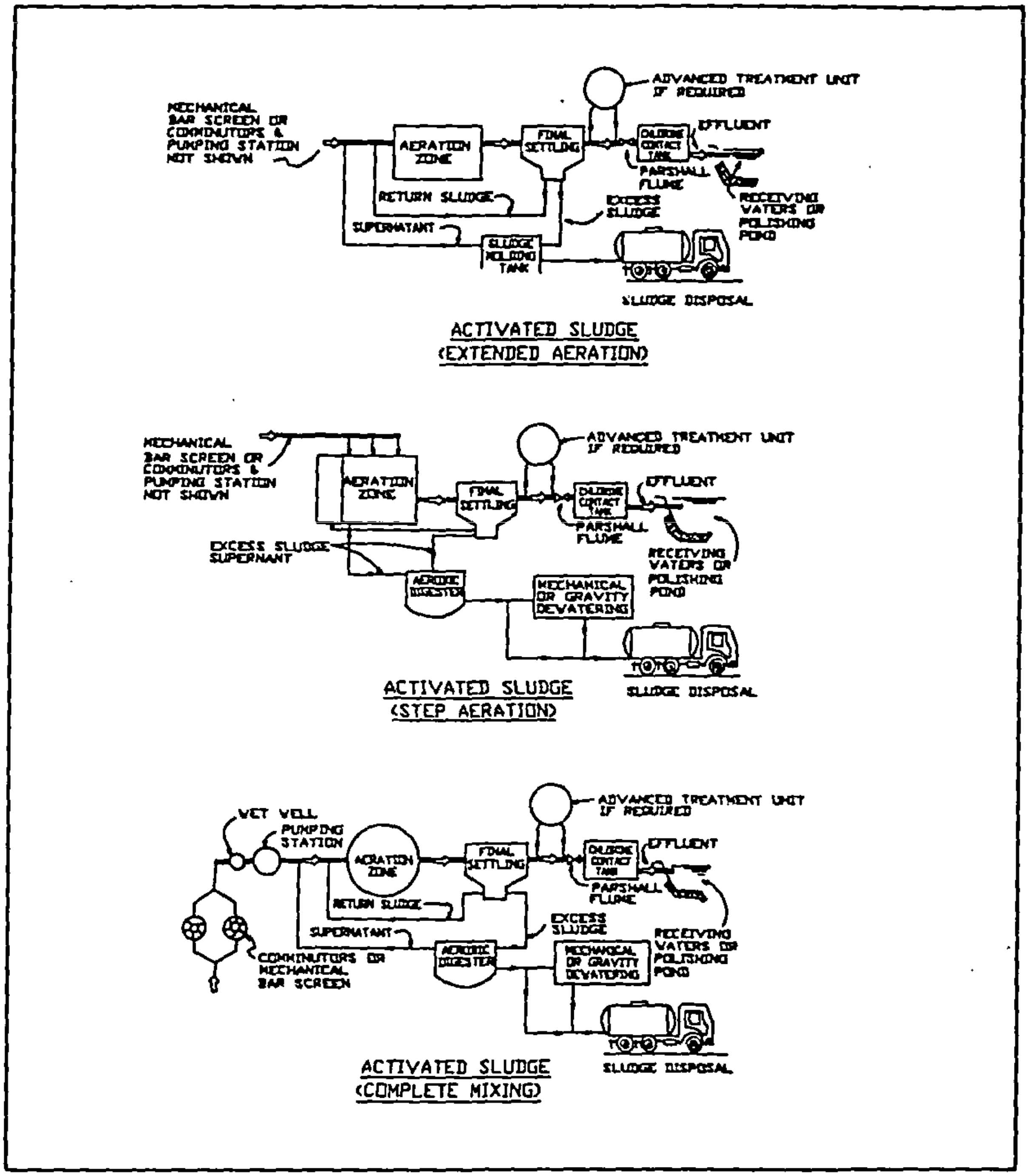
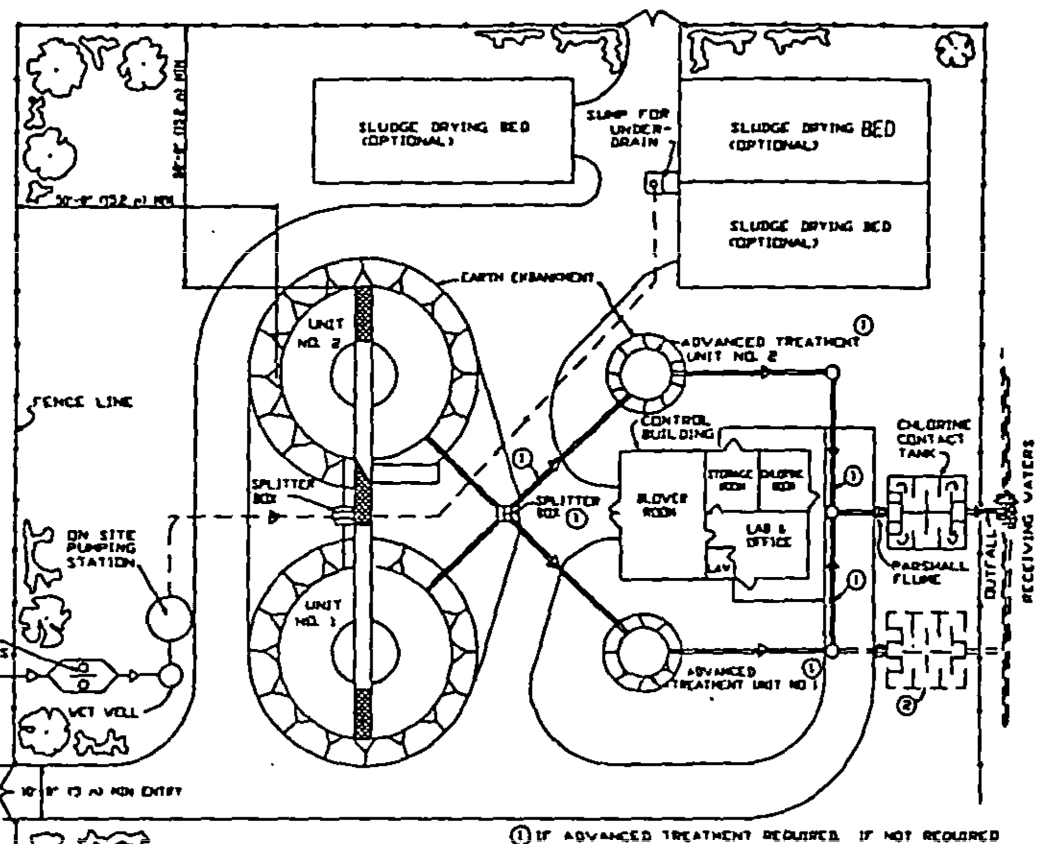


Figure 17
Activated Sludge Package Plant Installations



① IF ADVANCED TREATMENT REQUIRED. IF NOT REQUIRED USE MANHOLE INSTEAD OF SPLITTER BOX
② LOCATION WITHOUT ADVANCED TREATMENT UNITS

TYPICAL LAYOUT

Figure 17 (Continued)
Activated Sludge Package Plant Installation

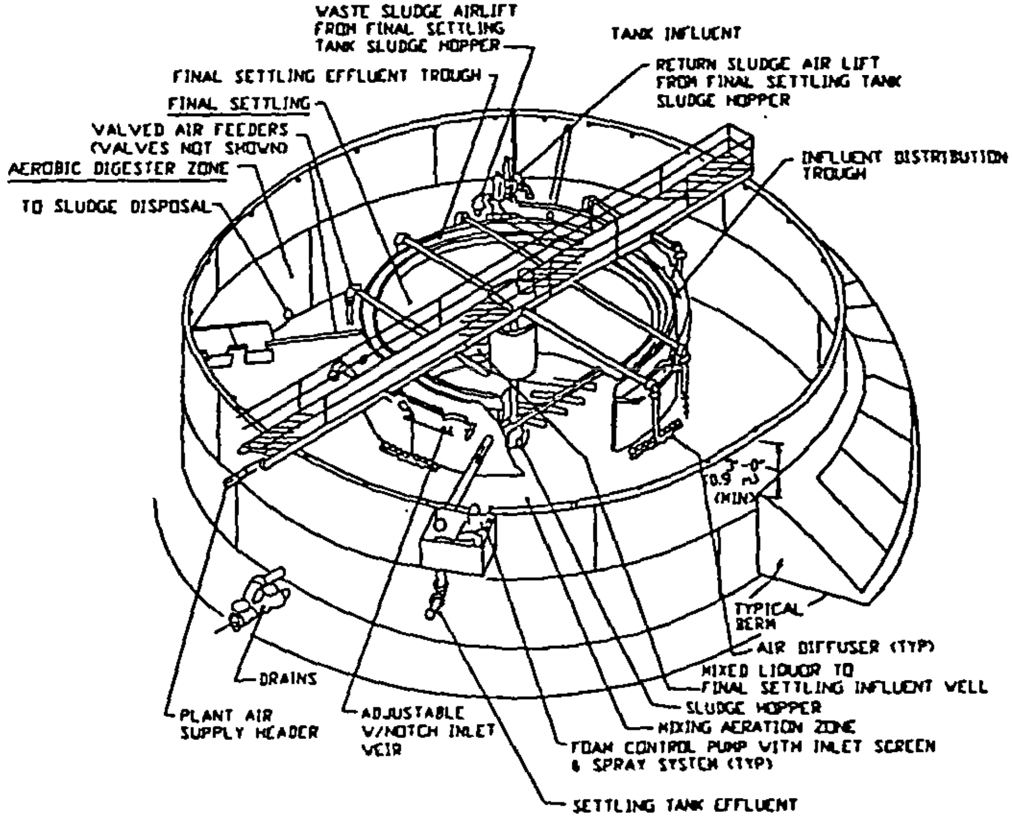


Figure 17 (Continued)
Activated Sludge Package Plant Installation

Table 31
Selection and Design Guidelines for Activated Sludge Process Variations

Process Variation[1]	Allowable Loading[2]		Oxygen Requirements[3] (lb/lb [kg/kg])	Application Guide and Remarks
	Volumetric (lb/d/1,000 ft^3 [kg/d/1,000 cu m])	F/M (lb/d/lb [kg/d/kg]) MLSS		
Conventional	40 (640)	0.35	1.1	Do not use for new designs. Consider step aeration or completely mixed instead.
Step aeration (or step feed)	60 (960)	0.4 (average)	1	For general application in secondary treatment.
Contact stabilization	70[4] (1120[4])	0.50	1.0	Do not use. Operation not stable except in larger plants with small diurnal flow variations.
Completely mixed	60 (960)	0.5	1.0	For general application in secondary treatment.
Completely mixed with high rate sludge recirculation	60+ (see remarks)	0.5+	1.0	May be selected for economy based both on higher loadings and elimination of separate return sludge pumping. Before applying at loadings above 0.5 lb/d/lb (kg/d/kg) MLSS or 60 lb/d/1,000 ft^3 (960 kg/d/1,000 cu m), designer should verify reliable operation in existing plants treating similar wastes at proposed

Table 31 (Continued)
Selection and Design Guidelines for Activated Sludge Process Variations

Process Variation[1]	Allowable Loading[2] Volumetric (lb/d/1,000 ft^3 [kg/d/1,000 cu m])	Allowable Loading[2] F/M (lb/d/lb [kg/d/kg]) MLSS	Oxygen Requirements[3] (lb/lb [kg/kg])	Application Guide and Remarks
Completely mixed with high rate sludge recirculation (cont'd)				loading, giving particular attention to ability to operate with poorly settling sludges.
High rate (high purity oxygen)	Up to 150 (2,400)	0.7 to 0.9	0.9	Generally applicable to secondary treatment. Consult equipment manufacturer for complete details. Not normally economical for plants less than 10 Mgd (40 ML/d) capacity. Do not use for new designs at Navy facilities.
Modified aeration	400 (6,400)	4.0	0.7	Consider only as part of multiple stage treatment.
Extended aeration and oxidation ditch	20 (320)	0.1	1.5	Consider for small plants (up to 5,000 population) where eliminating separate sludge treatment would be advantageous.

[1]For flow diagrams, refer to WPCF MOP 8.
[2]Based on maximum 24-hour BOD load. Expressed as pounds BOD applied per day per 1,000 cubic feet (kilograms BOD applied per day per 1,000 cubic meter) aeration tank volume (volumetric) and as pounds BOD applied per day per pound MLSS (kilograms BOD applied per day per pound MLSS) under aeration (F/M).
[3]Expressed as pound O_2 supplied per pound BOD applied.
[4]Based on total volume of reaeration plus contact basins.

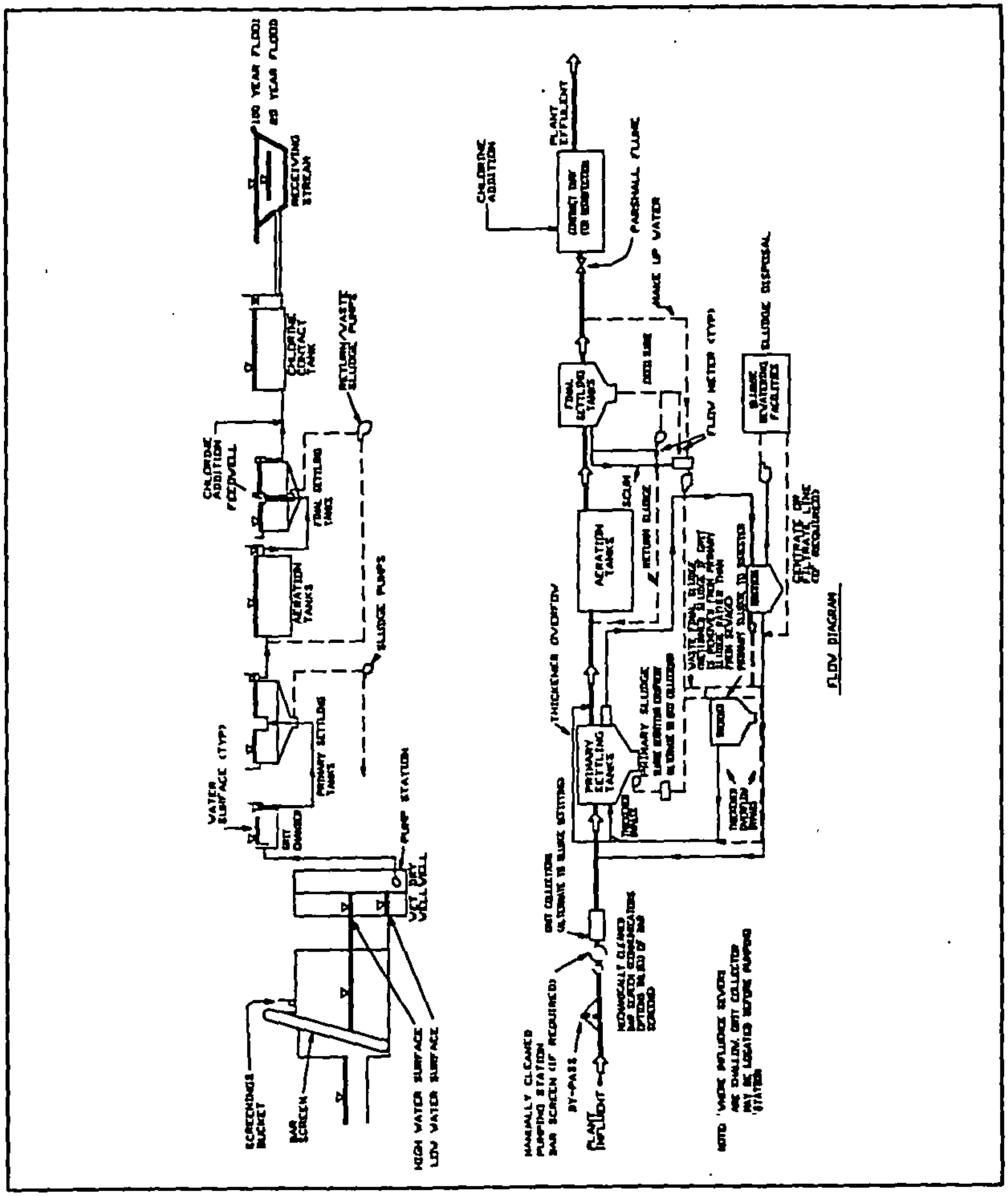


Figure 18
Activated Sludge Plant - Flow Diagram and Hydraulic Profile

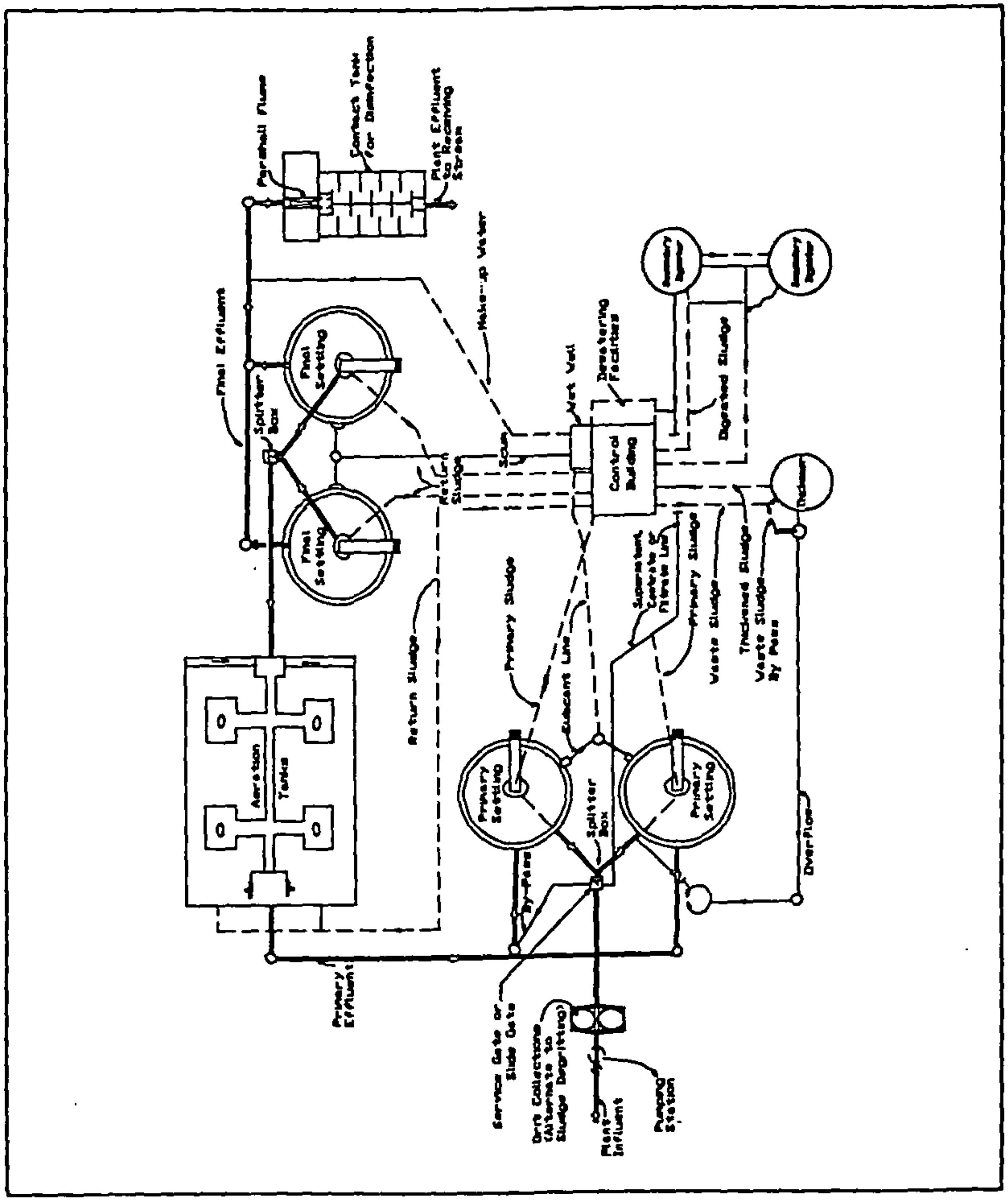


Figure 19
Activated Sludge Plant Layout

7.2.1 Sizing Basis. Base on maximum 24-hour BOD loading. Determine sizing, standby requirements, and oxygenation capacity as described in paragraph 7.2.1.1.

7.2.1.1 Design Loadings. For ordinary secondary treatment of domestic wastewater, size aeration tanks for allowable volumetric BOD loadings or F:M ratios given in Table 31. Size final settling tanks according to hydraulic and solids loading limits as described in paragraph 6.5 of Section 6 (Table 24).

7.2.1.2 Oxygen Transfer Requirements. For methods of aeration and selection guides, refer to Table 32. See Figure 20 for typical arrangement of diffused aeration system in aeration basin. See Figure 21 for arrangement of platform-mounted mechanical aerators in aeration basin. The following criteria applies to design of oxygen transfer requirements:

a) If pilot plant data are available, determine oxygen transfer requirements from observed peak oxygen uptake rates and the maximum design concentration of MLVSS. Oxygen uptake rates are expressed as mg oxygen per hour per gram of MLVSS (mg/h/g MLVSS).

b) In the absence of pilot plant data, determine the required maximum Standard Oxygen Transfer Rate (STR) based on 1.5 times the annual maximum 24-hour BOD times the oxygen requirement ratios from Table 31.

c) Determine the Actual Oxygen Transfer Rate (ATR), that is, field condition oxygen transfer rate according to Equation (9).

EQUATION: $$ATR = STR\ (C_{SW} - C_L)(alpha)(1.028)^{(T-20)}/9.2 \qquad (9)$$

where

STR = standard oxygen transfer rate from paragraph 7.2.1.2b preceding (lb/d [kg/d]).

ATR = actual oxygen transfer rate at design operating aeration tank conditions (lb/d [kg/d]).

C_{SW} = oxygen saturation concentration for wastewater (mg/liter). Use C_{SW} equal to 95 percent of oxygen saturation concentration for clean water at design waterway temperature. Refer to American Public Health Association (APHA), Standard Methods for the Examination of Water and Wastewater for oxygen saturation concentrations of clean water at wastewater temperature.

C_L = operating oxygen concentration of mixed liquor (mg/liter). Use C_L = 2.0 mg/liter tanks for complete mix tanks. Use 1.0 mg/liter for inlets of plug flow tanks. Use C_L = 3.0 mg/liter for nitrification systems.

alpha= ratio of oxygenation rate or efficiency in wastewater to standard oxygenation rate or efficiency in clean water. Use alpha = 0.8 except at influent end of step aeration systems use alpha = 0.6 unless another value has been determined by test of actual wastewater.

T = design wastewater temperature (degrees C). Consider oxygen transfer rate at both maximum and minimum operating wastewater temperature.

d) For diffused aeration systems, determine flow rate of standard air required for transfer of ATR according to Equation (10) which appears first in English, then in SI:

EQUATION: $$SAFR = (4.03)ATR/E_O \text{ or} \quad (10)$$

$$SAFR = (3.87)ATR/E_O$$

where

SAFR = standard air flow rate (ft^3/min [L/s]).

E_O = standard oxygen transfer efficiency of diffuser (%). In the absence of other data, use values from Table 32.

Typical depths for placement of diffused aerators is 12 to 18 feet (3.7 to 5.5 m). Use depth ≥ 15 feet (4.6 m) for plants of 1 Mgd (4 ML/d) size or greater. The value of SAFR will have to be adjusted for very deep aeration tanks, high altitudes, and extreme ambient air and wastewater operating temperatures.

e) Allow for variation in oxygen uptake rates between aeration tank compartments in series or along the lengths of plug flow tanks. Use length:width ≥ 4:1 for plug flow. In the absence of other data, the following values may be used for activated sludge treatment of essentially domestic wastewater with MLVSS = 0.75 MLSS: 80 mg/h/g MLVSS at sewage feed points tapered to a minimum of 20 mg/h/g MLVSS at tank outlet or in final compartment. Use 20 mg/h/g MLVSS for sludge reaeration compartments.

Table 32
Recommended Methods of Aeration

Oxygenation Method [1,2]	Standard Transfer Efficiency, E_O (%)	Mass Transfer Rate, N_O (lb/bhp-h [kg/bhp-h])	Application and Remarks
Diffused Air[3] Fine Bubble Diffusers[4]:			Suitable for all applications except oxidation ditches. Generally use fine bubble diffused air in large systems where oxygen transfer is prime consideration. Use coarse bubble diffused air for small systems, where mixing operations are primary consideration. Distributing diffusers over basin floor gives highest transfer efficiency, but location of diffusers along side walls facilitates maintenance. Consult manufacturers for unit sizing and layout to ensure solids suspension and optimum oxygen transfer.
Ceramic tube	13	3.3 (1.5	
Ceramic dome or plate	20	5.1 (2.3)	
Synthetic cloth socks	13	3.3 (1.5)	
Plastic would tubes	13	3.3 (1.5)	
Coarse Bubble Diffusers:			
Sparger	8	2.0 (0.9)	
Perforated tubing	18	4.6 (2.0)	
Jet aeration	15	3.4 (1.5)	Not normally used in lagoons. Applicable to most other systems.
Static tube aeration	8 to 10	1.8 to 2.6 (0.8 to 1.2)	Best suited to aerated lagoons in cold temperatures.

Table 32 (Continued)
Recommended Methods of Aeration

Mechanical aerator		3.2 to 3.6 (1.4 to 1.6)	Use where significantly less expensive than diffused air. Use floating mechanical aerators in large lagoons or when there are significant variations in elevation of liquid surface. Otherwise, use fixed mounted mechanical aerators (brush type aerators are applicable to oxidation ditches). Properly baffle mechanical aerators to prevent swirling of tank contents and short circuiting of flow. Use draft tubes where lagoon depths require. Limit surface aerator tip speed to 30 fps (9 m/s). Consult manufacturers for unit sizing and layout to ensure solids suspension and optimum oxygen transfer. Obtain performance guarantees on transfer rate and power requirements under stated test conditions, but do not restrict type of equipment unnecessarily. Check for icing problems in cold climates.
Sparged turbine aerator		2.5 (1.1)	Use where high capacity aerator required. Consult manufacturers for unit sizing and layout to ensure solids suspension and optimum oxygen transfer.

Table 32 (Continued)
Recommended Methods of Aeration

[1]Standard oxygenation rates vary with equipment layout, mechanical efficiency and basin configuration. Listed values should be used only as guidelines. For equipment and layout details, refer to WPCF FD-13, Aeration. Consult manufacturers for site specific recommendations.
[2]Transfer efficiencies and rates are generally for 13.5-foot (4-m) submergence, 20 degrees C, zero initial dissolved oxygen, and diffusers mounted at the side wall. Typical air rates: tubes or socks - 5 $ft^3/min/ft^2$ (25 L/s/sq m) of projected plan area; plates or domes - 2 $ft^3/min/ft^2$ (10 L/s/sq m) of plan area; spargers - 12 $ft^3/min/unit$ (6 L/s/unit); perforated tubing - 0.0025 $ft^3/min/perforation$ at 10-foot submergence (0.0012 L/s/perforation at 3-m submergence). Blower wire hp efficiency - 0.61. Mass transfer rates for mechanical and turbine aerators are expressed in units of pounds O_2 per brake horsepower hour (lb/bhp-h) (kgs O_2 per brake horsepower hour [kg/bhp-h]).
[3]Rotary positive displacement blowers preferred only for small installations. Centrifugal blowers are to be used elsewhere.
[4]Prefilter air for fine bubble diffusers with electrostatic agglomerator and fiberglass bag air filters to reduce dirt to less than 0.1 mg/100 ft^3 (3.5 mg/100 cu m) of air. Air cleanliness is less critical for coarse bubble diffusers; consult manufacturer for filtration requirements.

7.2.1.3 Standby Requirements. Standby treatment capacity is required to protect the process from long-term upset and ensure discharge compliance during reasonable unit outage for maintenance.

a) Provide a minimum of two hydraulically separate aeration tanks.

b) Determine required tank volume (V) based on allowable design BOD loading or F:M ratio (see Table 31) with all tanks in service.

c) Increase the calculated by step 7.2.1.3b above aeration tank volume according to Equation (11).

EQUATION: $$V_D = V(N/N-P) \qquad (11)$$

where

- V = required aeration tank volume from step 7.2.1.3b.
- V_D = design aeration tank volume.
- N = number of aeration tanks.
- P = decimal fraction of oxygen transfer capacity in any aeration tank that is lost when single

mechanical aerator or single diffuser header is out of service. If tank must be taken out of service for maintenance of aeration equipment, P = 1.0.

d) Increase the ATR and SAFR values (if diffused aeration system) calculated by Equations (9) and (10) as follows:

EQUATION: $$ATR_D = ATR\ (1 + P) \quad (12)$$

EQUATION: $$SAFR_D = SAFR\ (1 + P) \quad (13)$$

where

ATR_D = design oxygen transfer rate at field conditions (lb/d [kg/d]).

$SAFR_D$ = design standard air flow rate at field conditions (ft^3/min [L/s]).

ATR, SAFR, and P = as for preceding equations.

7.2.1.4 Power Requirements. Determine required horsepower (hp) to supply ATR_D as follows:

a) For mechanical aeration systems use Equation (14):

EQUATION: $$HP = 0.042\ ATR_D/(N_o e_m) \quad (14)$$

where

HP = wire horsepower required (hp).
N_o = mass transfer rate (lb/bhp-h [kg/bhp-h]). See Table 32.
e_m = motor efficiency as decimal fraction. In absence of other data, use e_m = 0.93.
ATR_D = from Equation (12).

b) For diffused aeration systems, use Equation (15) (Equation 15 first appears in English, then in SI):

EQUATION: $$HP = (0.0154)(SAFR_D)(G_1)(T_{in}/T_o)[(G_2 G_1)^{0.283}-1]/e_{bm} \quad (15)$$

or

$$HP = (0.15)(SAFR_D)(G_1)(T_{in}/T_o)[(G_2 G_1)^{0.283}-1]/e_{bm}$$

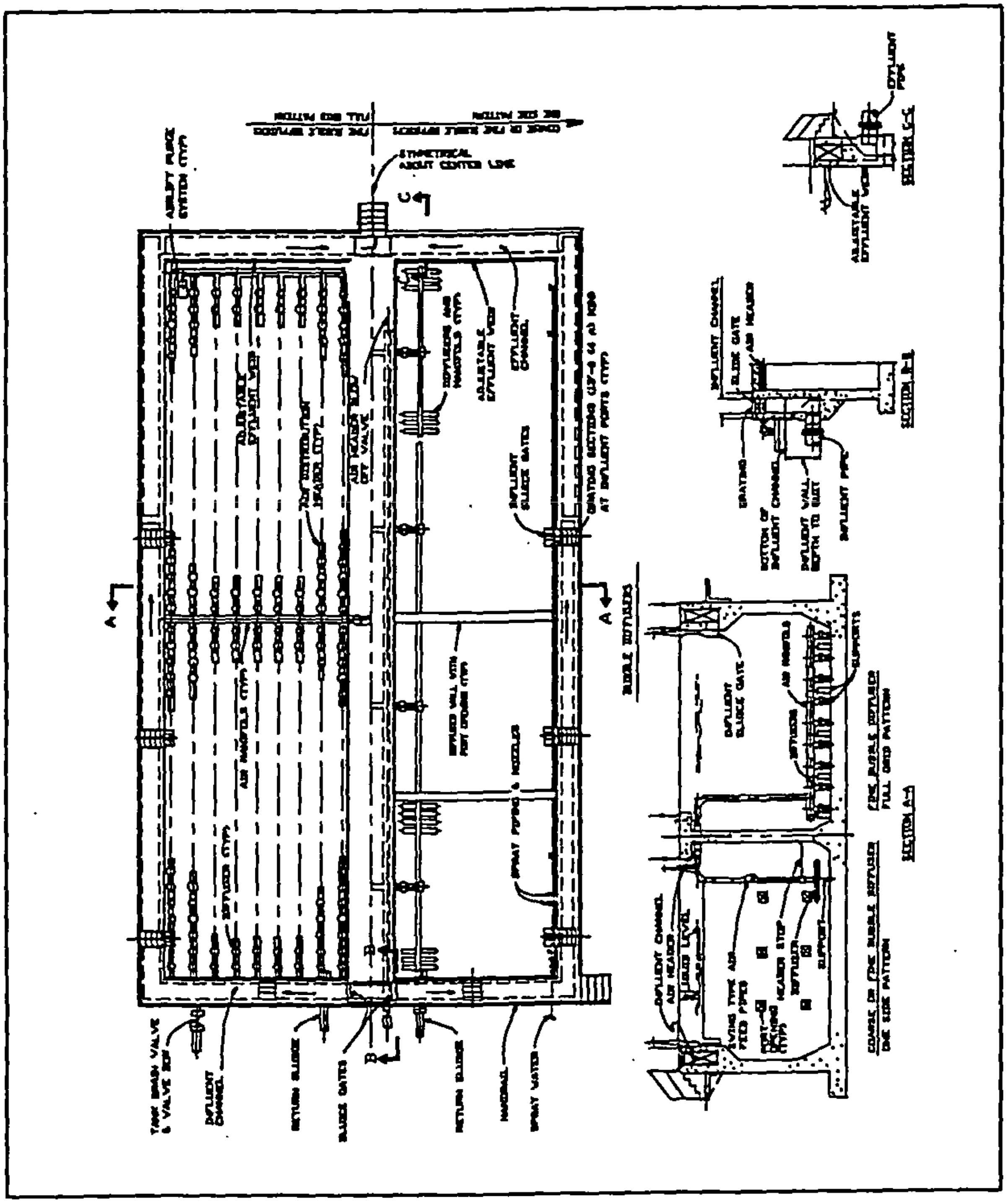


Figure 20
Diffused Aeration System Layouts

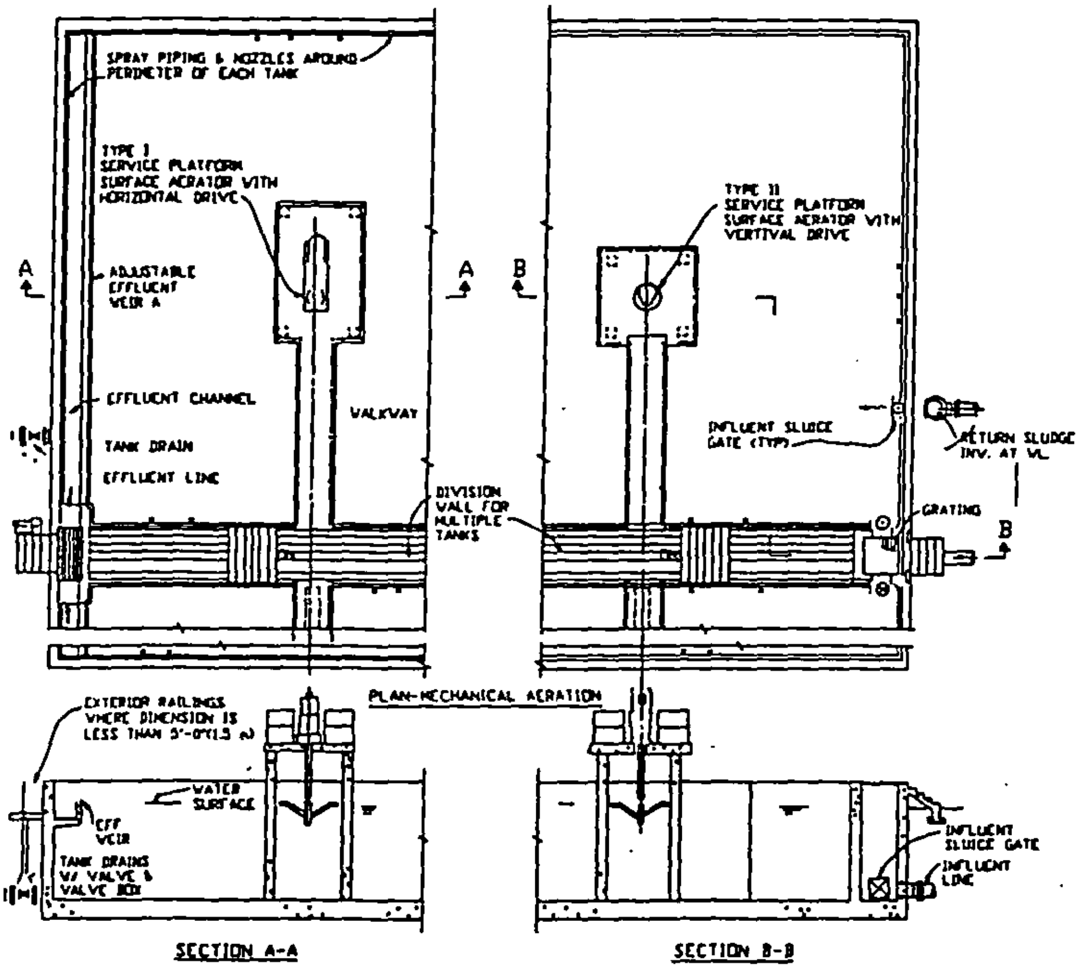


Figure 21
Mechanical Aeration Systems

where

G_1 = absolute ambient air pressure (psia [kPa]).
G_2 = absolute pressure at point of diffuser discharge (psia [kPa]).
T_{in} = absolute temperature of ambient air at blower intake, ER.
T_o = absolute temperature of standard air, ER. T_o is usually taken to be 492ER.
e_{bm} = combined efficiency of air compressor plus coupler and motor. Use e_{bm} = 0.61 in absence of other data.
HP and $SAFR_D$ = as for preceding equations.

7.2.1.5 Mixing. Aeration equipment should have a mixing capacity sufficient to produce velocities which will keep solids in suspension along aeration floor. Check with manufacturers to determine optimum aeration system layout and minimum aeration requirements (in power or airflow) to achieve minimum velocities along aeration unit floor of 0.6 fps (0.2 m/s). Use 1.0 fps (0.3 m/s) in oxidation ditches.

7.2.1.6 Sludge Production. In absence of pilot plant or equivalent data, for normal secondary treatment of essentially domestic wastes, use the following values for sludge production by secondary biological treatment systems:

System without primary settling = 1.2 lb SS/lb BOD applied (1.2 kg SS/kg BOD applied).

System with primary settling = 0.8 lb SS/lb BOD applied (0.8 kg SS/kg BOD applied).

7.2.1.7 Return Sludge System. The return sludge system shall conform to the following criteria:

a) For step aeration or completely mixed systems treating domestic sewage, with aeration tank sized based on allowable volumetric loadings in Table 31, provide the largest required pumping capacity as determined below:

Treatment Process	Return Sludge Rate
Step aeration	25% of peak hour wastewater flow or 60% of annual peak day wastewater flow.
Completely mixed: Systems with separate return sludge pumps	40% of peak hour wastewater flow. 75% of annual peak day wastewater flow.
High sludge recirculation units where pumping action is built in (typically package units)	At least 200% of peak day flow. Check with suppliers of units.

b) For other designs, provide sufficient return sludge pumping capacity to handle peak solids load on final clarifier at minimum expected underflow concentration. Determine limiting solids loading on final tanks by methods presented by Metcalf and Eddy, 1991. Determine required final tank area in accordance with Table 24.

c) Where separate pumps are required, provide at least two units. Consider variable speed drives to match influent flow variations. Size to provide the required pumping capacity with largest unit out of service. Refer to paragraph 5.7 and Table 14 for pump types.

7.2.1.8 Waste Sludge System. Waste sludge system shall conform to the following:

a) When needed, size pumps, piping and related items to waste at least two times the estimated average quantities of excess sludge at minimum expected underflow concentration.

b) For plants without gravity thickeners, design to waste a metered portion of the final clarifier underflow. Increase the final clarifier return sludge pumping capacity as required. Calculate average waste flow based on expected normal return sludge concentration (assume 0.8 percent underflow solids in absence of other data).

c) For plants with gravity thickeners, waste the final clarifier underflow or the aeration tank mixed liquor directly to the thickeners. Provide dual pumps or other appropriate means to blend in final effluent or final clarifier underflow as needed to maintain constant liquid flow and to control waste solids flux.

d) Where separate pumping is required, provide at least two pumping units. Size to provide required capacity with one unit out of service. Refer to paragraph 5.7 (Table 14) for pump types and selections.

7.2.1.9 Foam Control. A spray water system shall be provided for foam control; add defoaming agents only if spray system proves inadequate. The following criteria shall apply to foam control:

a) Base the spray water supply on allowance of 0.02 gpm/ft^2 (0.014 L/s/sq m) of tank surface.

b) Space the nozzles at about 4-foot (1.2-m) intervals on lines where foam will collect. Generally this will be along tank walls where circulating mixed liquor is descending. Spacing should be decreased at corners (if any exist) to 1-foot (0.3-m) intervals.

c) Allow at least 18 inches (0.5 m) of tank freeboard.

7.2.2 Nitrification. Use loadings given in Table 29 for a separate nitrification activated sludge stage.

7.2.2.1 Minimum Sludge Ages. Minimum sludge ages at which substantially complete nitrification may be expected in an activated sludge system are indicated in EPA PB259149, Process Design Manual for Nitrogen Control. In design, apply a safety factor based on the wastewater TKN peaking factor (peak 8-hour TKN load/average day TKN load).

7.2.2.2 Oxygen Requirements. Estimate oxygen requirements for nitrification on the basis of 4.6 pound (2.1 kg) oxygen per pound of NH_3-N oxidized. Consider TKN hydrolysis in determination of NH_3-N oxidized. In a single-stage system combining nitrification with BOD removal, deduct NH_3-N taken up by activated sludge BOD removal before calculating additional oxygen required for nitrification.

7.2.2.3 pH Control. Consider need for pH control if pH of waste varies outside the range of 7.2 to 8.4. Refer to EPA PB259149 for pH effects on nitrification. Raw wastewater must have sufficient alkalinity to provide 7.14 mg/liter of alkalinity per mg/liter NH_3-N oxidized, with 50 mg/liter minimum residual alkalinity. CO_2 formed in carbonaceous BOD removal also consumes alkalinity depending on stripping ability of aeration system. Consider CO_2 production and aeration system type in determining total alkalinity requirement.

7.2.2.4 Final Settling Tanks

a) Design for a maximum overflow rate of 800 gpd/ft^2 (32,500 L/d/sq m) based on peak hour flow with one tank out of service, or 400 to 600 gpd/ft^2 (16,000 to 24,000 L/d/sq m) at maximum 24-hour flow with all units in service, whichever requires the largest area. Consider economy of multiple tanks.

b) Use suction type sludge withdrawal equipment.

c) Provide means for recycling final clarifier skimmings to aeration tank in case sludge floats.

7.2.2.5 Return Sludge. Provide return sludge capacity equal to at least 75 percent of annual peak day wastewater flow assuming one of the largest pumps is out of service.

7.2.2.6 Excess Sludge Disposal. Dispose of any waste sludge from separate nitrification stage with other plant sludges. Waste sludge quantities will not add significantly to total plant sludge load.

7.2.2.7 Two-Stage Nitrification Facilities. In two-stage nitrification facilities (separate carbonaceous and nitrogenous aeration), provide means of transferring first stage sludge and/or primary effluent directly to second stage nitrification basin in order to maintain adequate nitrification mixed liquor.

7.2.3 Oxidation Ditch. An oxidation ditch is a type of extended aeration process and has the same design limits for allowable volumetric loading and F:M ratio (refer to Table 31). The method of aeration and the tank configuration are different. The oxidation ditch should be strongly considered for small wastewater flows (2 Mgd [7.5 ML/d]) with or without nitrification requirements. See Figure 22 for typical flow schematics.

7.2.3.1 Aeration Equipment. Evaluate brush, jet, and draft tube type. Consult equipment suppliers for standard oxygen transfer data and performance certification. Consider cold weather effects on aerator operation and mechanical problems. Provide means of varying oxygen transfer rate to match average and peak flows and loads. See Figures 23 and 24 for layout and details of alternative oxidation ditch aeration equipment.

7.2.3.2 Aeration Basin Configuration. Provide means for operating basin with zones of aerobic and anoxic conditions to promote nitrification and denitrification.

7.2.3.3 Nitrification and Denitrification. Provide installed aeration capacity for peak oxygen demand under completely aerobic conditions. Do not take a design oxygen credit for denitrification. Consider denitrification credit in determining annual power costs and alkalinity requirements.

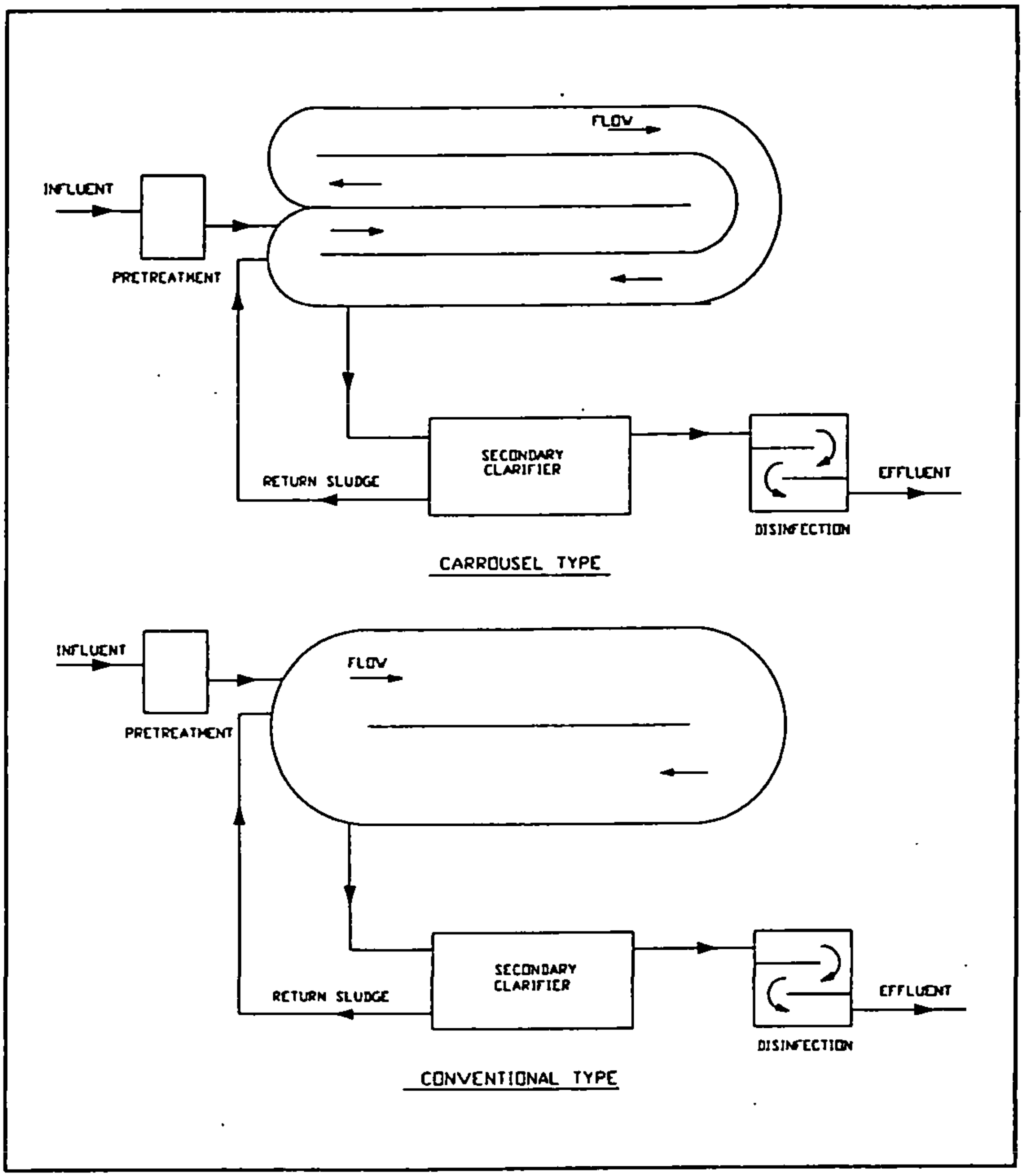


Figure 22
Alternative Oxidation Ditch Flow Schematics

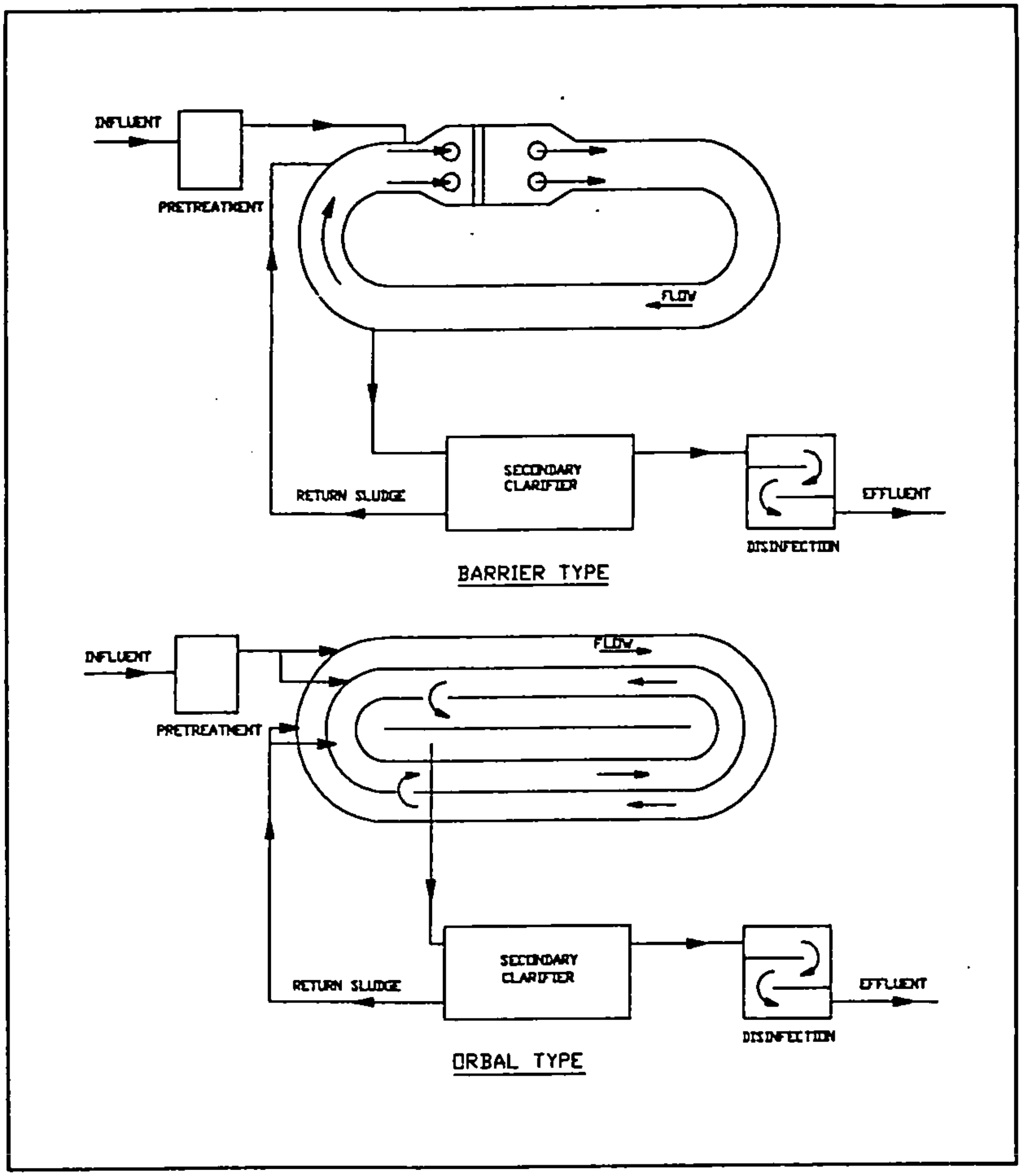


Figure 22 (Continued)
Alternative Oxidation Ditch Flow Schematics

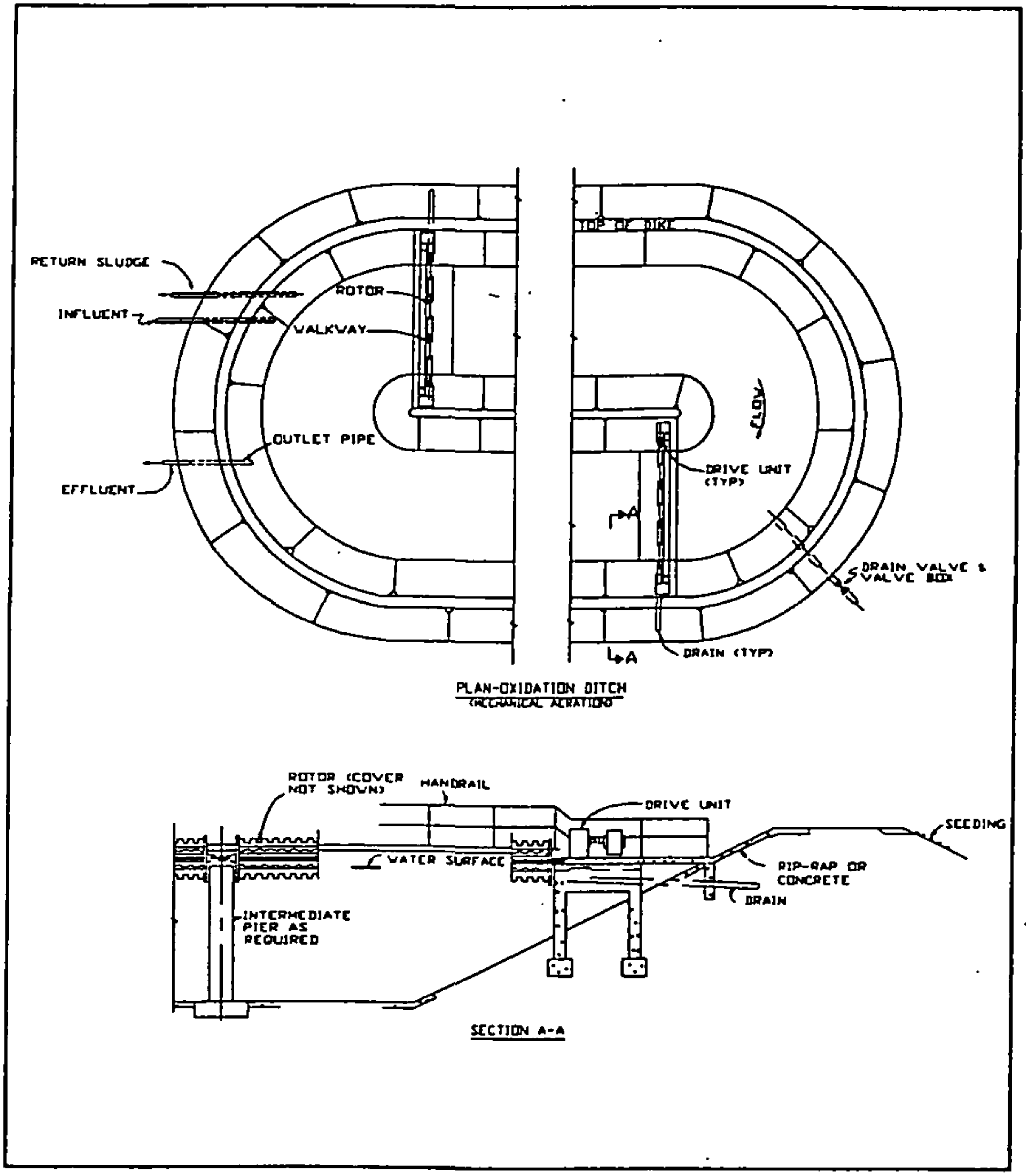


Figure 23
Oxidation Ditch with Brush or Jet Aeration

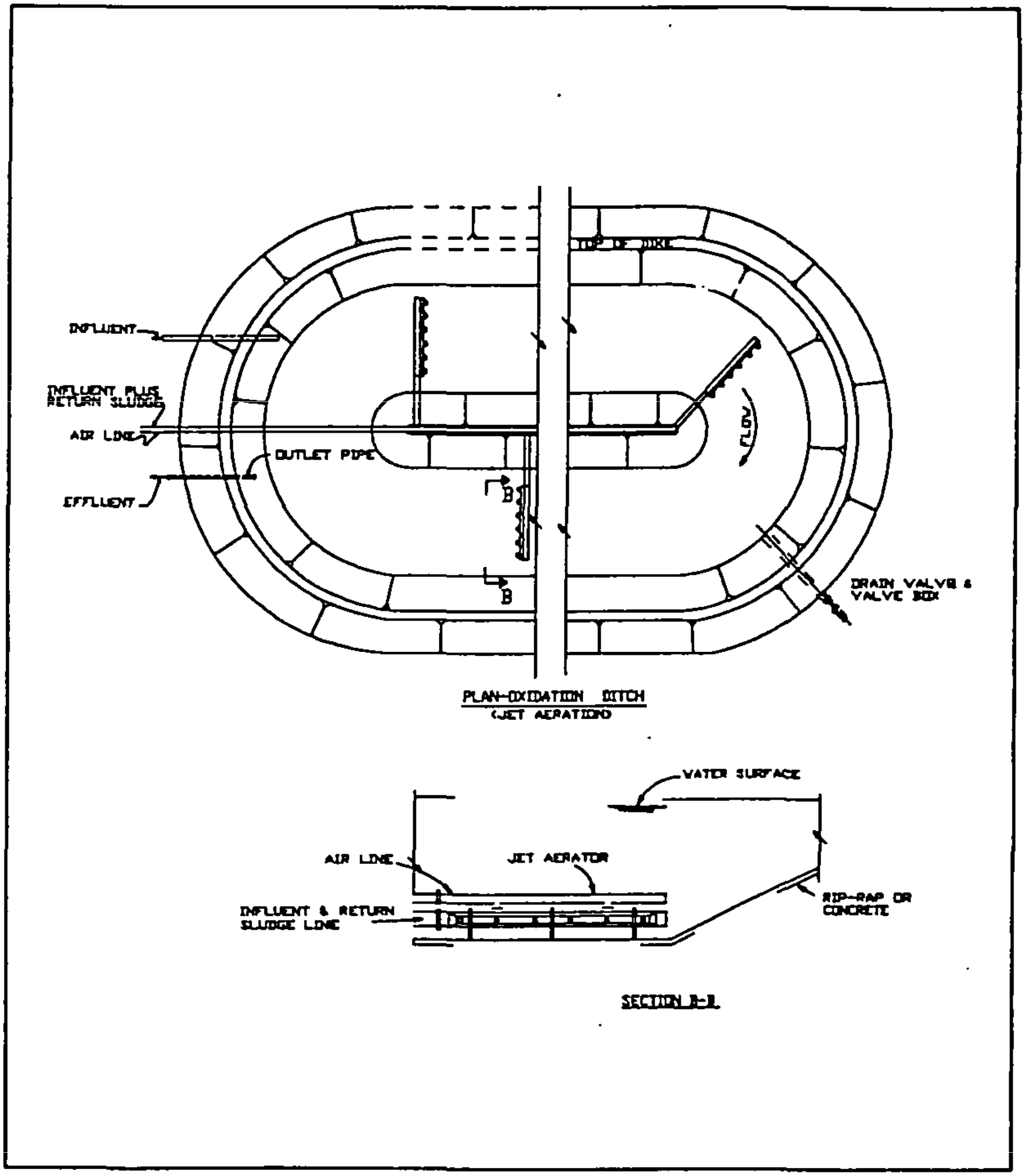


Figure 23 (Continued)
Oxidation Ditch With Brush or Jet Aeration

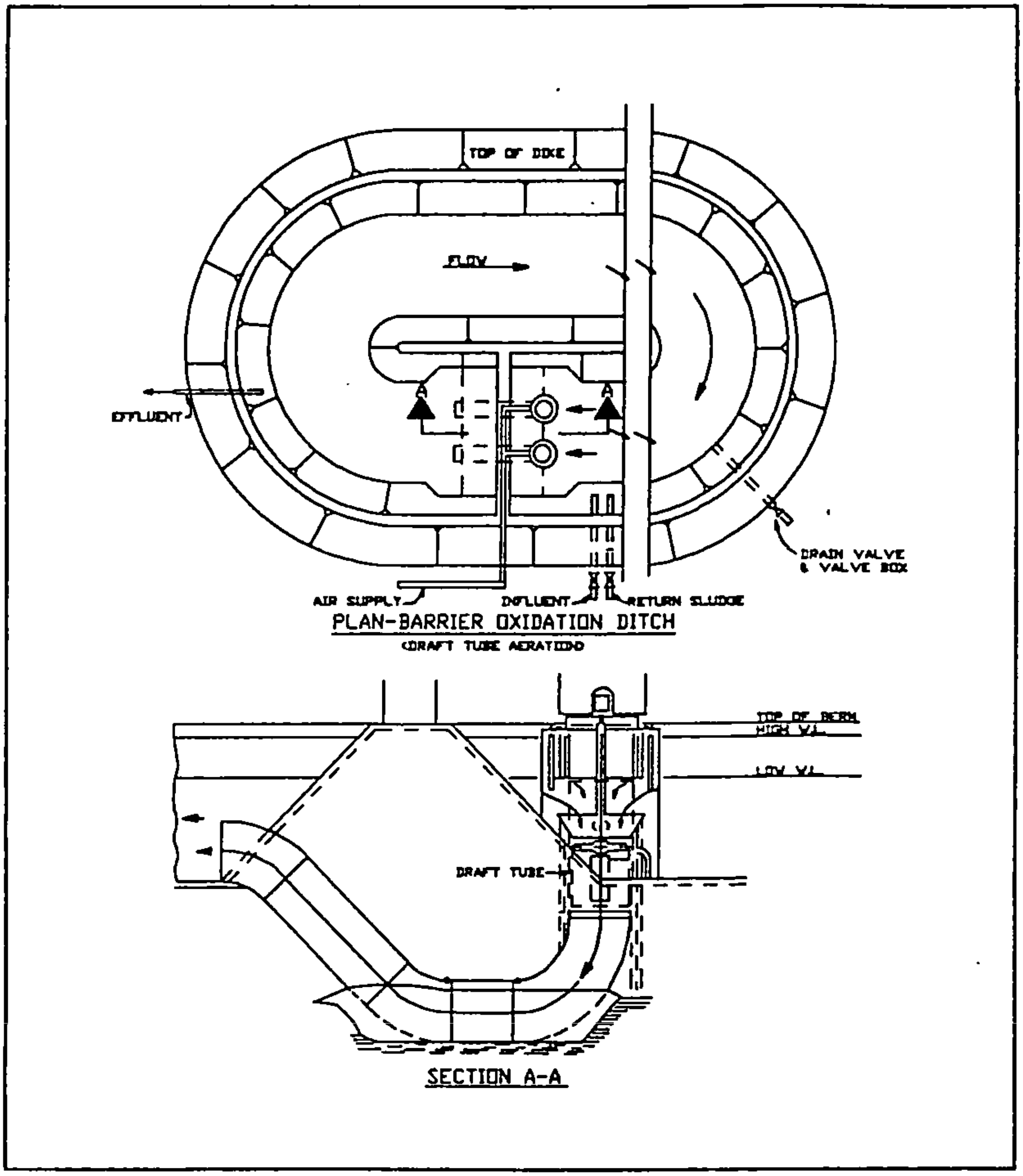


Figure 24
Barrier Oxidation Ditch with Draft Tube Aeration

7.2.3.4 Return Sludge Rate. Provide at least 75 percent of annual peak day flow.

7.3 Aerated Lagoons. Aerated lagoons are oxygenated through the action of surface or diffused air aeration. For process characteristics and method of aeration, refer to Tables 28 and 32, respectively. Because the solids are maintained in suspension in an aerated lagoon the detention time required for BOD removal will be less than for a facultative lagoon. The power requirement, however, will be greater and a settling pond for the aerated lagoon effluent will be required to remove suspended solids. The aerated lagoon is operated as a complete mix mechanically stirred with no recycle system. Because of their low capital and operating cost and ease of operation, aerated lagoons should be strongly considered for use at Navy installations where adequate land area is available and discharge limits are not strict.

7.3.1 Sizing Basis

7.3.1.1 Number of Equally Sized Basins. Provide at least two hydraulically separate and aerated basins and a third basin for solid-liquid separation. Aerated basins should be designed to operate either in series or in parallel flow patterns.

7.3.1.2 Design Conditions. Use the more critical of the following conditions:

a) Summer conditions. Maximum BOD load for detention period; design removal as required for receiving water; normal summer wastewater temperatures; and one basin out of service.

b) Winter conditions. Same design load as summer; minimum wastewater temperature; removal as required for receiving water; and all basins in service.

7.3.1.3 Performance and Operating Requirements

a) Detention time. Determine required total detention time for "n" complete mix ponds in series operation using Equation (16). It can be assumed that dissolved effluent BOD is 50 percent of total effluent BOD, that is, effluent TSS contribute 50 percent of total BOD.

EQUATION: $t = (n/K_T)[(S_o/S_e)^{1/n} - 1]$ (16)

where

t = total hydraulic detention time (d). Divide t equally among number of aerated basins.

n = number of aerated basins operated in series.

S_o = influent total BOD (mg/liter).

S_e = effluent dissolved BOD (mg/liter).

K_T = first order reaction rate at operating lagoon temperature (d^{-1}).

Determine rate constant from data for actual or similar wastes and operating conditions. If this is not practical, use K = 2.5/d for normal domestic wastewater at 20EC (K_{20}). Adjust K_{20} to expected operating lagoon temperature using Equations (17)and (18).

Increasing the number of ponds in series (n) decreases the required total detention time (t).

b) Lagoon temperature. Lagoon temperature is affected by the influent waste and ambient air temperature, basin geometry, and mixing conditions. The equilibrium temperature can be approximated by Equation (17):

EQUATION:
$$Tw = \frac{A\ f\ Ta + Q\ Ti}{A\ f + Q}$$

where

Ti = influent waste temperature, degrees F (degrees C)
Tw = lagoon waste temperature, degrees F (degrees C)
Ta = ambient air temperature, degrees F (degrees C)
f = proportionality factor 12 (500)
A = surface area, ft^2 (m^2)
Q = wastewater flow rate, gal/day (L/d)

For more details refer to Industrial Waste Treatment in Aerated Lagoons in Advances in Water Quality Improvement, Mancini and Barnhart, 1968.

c) Temperature correction. Use Equation (18) for temperature correction of the rate constant:

EQUATION:
$$K_T = K_{20} 2^{(TL-20)} \qquad (18)$$

where

θ = 1.085 for aerobic lagoons
K_{20} = rate constant at 20 degrees C (d^{-1})
K_T = rate constant at TL (d^{-1})
TL = temperature of lagoon contents (degrees C)

d) Oxygen requirements. For treatment of normal domestic sewage in aerobic lagoons, use a value of 1.3 lb O_2/lb BOD applied (1.3 kg O_2/kg BOD applied). Where aerobic lagoons must meet low effluent BOD requirements, consider use of perforated pipe grid-air diffusion system. Air bubble curtain effect with this type of system minimizes short-circuiting and maximizes effectiveness of lagoon volume. Consult system supplier for performance data. Alternatively, consider multistaged lagoons and effluent recycle.

e) Mixing requirement. There is no rational method available to determine the power input necessary to keep solids suspended. Consult equipment manufacturers to determine zone of influence or complete mixing. For lagoon depths of 8 to 18 feet (2.4 to 5.5 m) and suspended solids concentrations of 1,000 to 5,000 mg/liter provide 60 to 120 hp/mg of basin volume. At depths greater than 12 feet (3.7 m), draft tubes may be required. For lesser depths and solids level, provide at least 30 hp/mg of basin volume. Locate individual surface aerators for overlap of zone of influence. Use several small units rather than fewer large units to minimize effect of downtime.

f) Sludge production and buildup. Estimate production based on settleable solids (SS) removed plus sludge yield from BOD removal. For domestic sewage, use 1.2 pounds SS produced per pound of BOD applied (1.2 kg SS produced per kg of BOD applied). Estimate sludge buildup in final settling lagoon based on 50 percent destruction of volatile solids in anaerobic decomposition, and accumulated sludge solids concentration of 10 percent. Provide means of periodic removal unless sludge storage volume is adequate for useful life of the lagoon. In determining lagoon depth, allow for solids accumulation to depth of at least four times the average.

7.3.2 Layout. See Figure 25 for alternative layouts employing multiple lagoons in series and parallel operation.

7.3.3 Construction. Earth embankment with impervious synthetic liner or natural soil layer to prevent leakage. See Figure 26 for details of aerated lagoon. Refer to paragraph 7.3.7 for discussion of liner and sealing requirements.

7.3.4 Dimensions. The following dimensions are minimum values:

a) Length to width ratio: 1:1 to 4:1.

b) Depth: 10 to 20 feet (3 to 6 m) (with mixing provision).

c) Freeboard: 3 feet (0.9 m).

7.3.5 Inlets and Outlets. Locate inlet at maximum distance from outlet; discharge near aeration devices so diffusion will be rapid. Provide for submerged drawoff to avoid floating material in effluent.

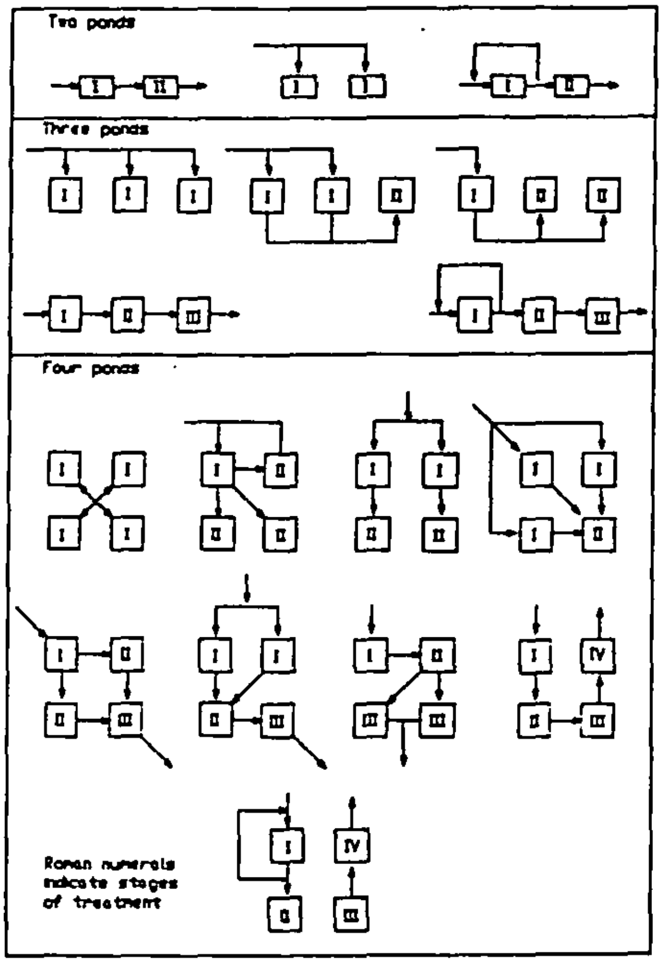


Figure 25
Alternative Lagoon Flow Schematics

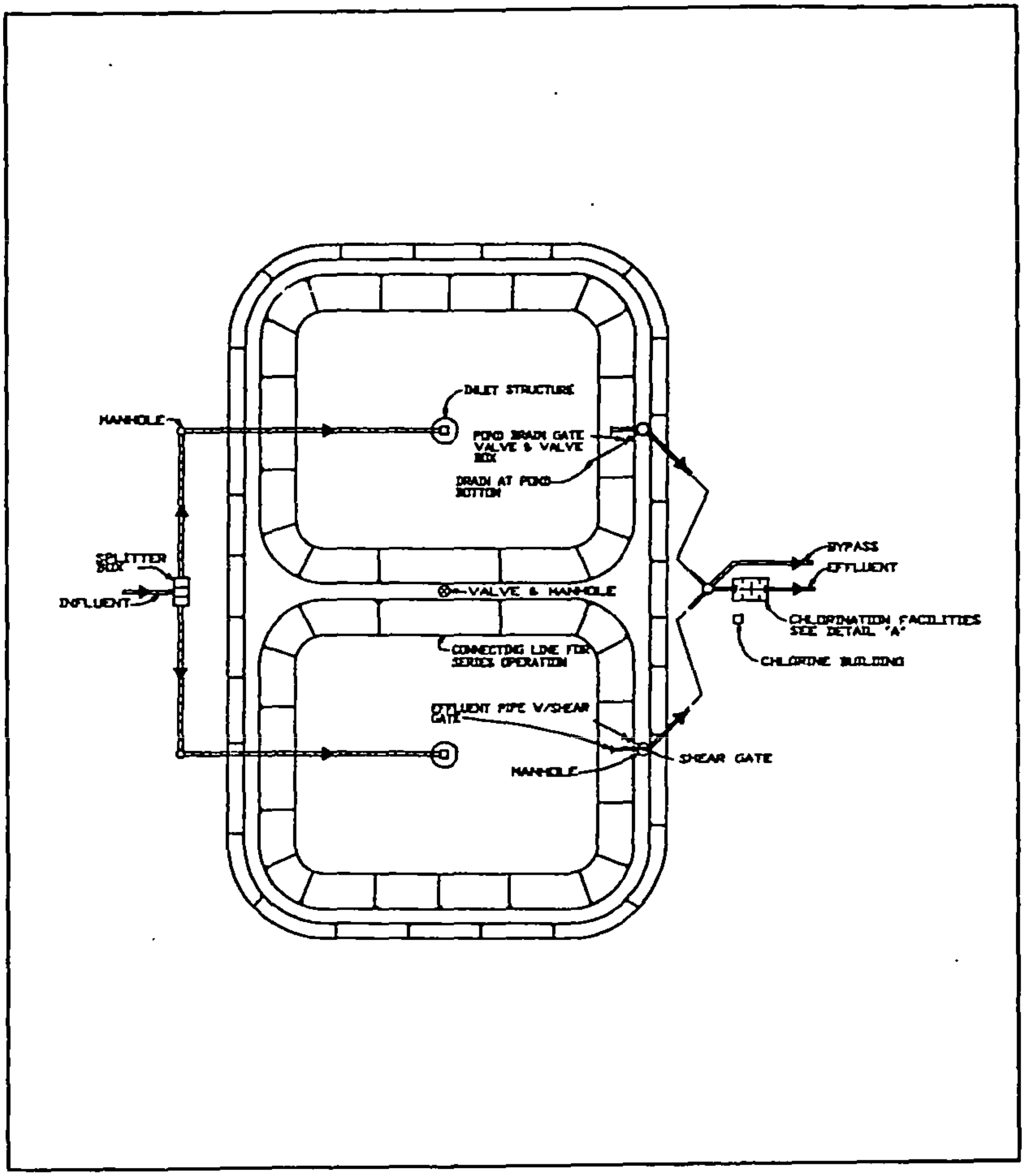


Figure 26
Facultative Lagoon and Mechanically Aerated Lagoon

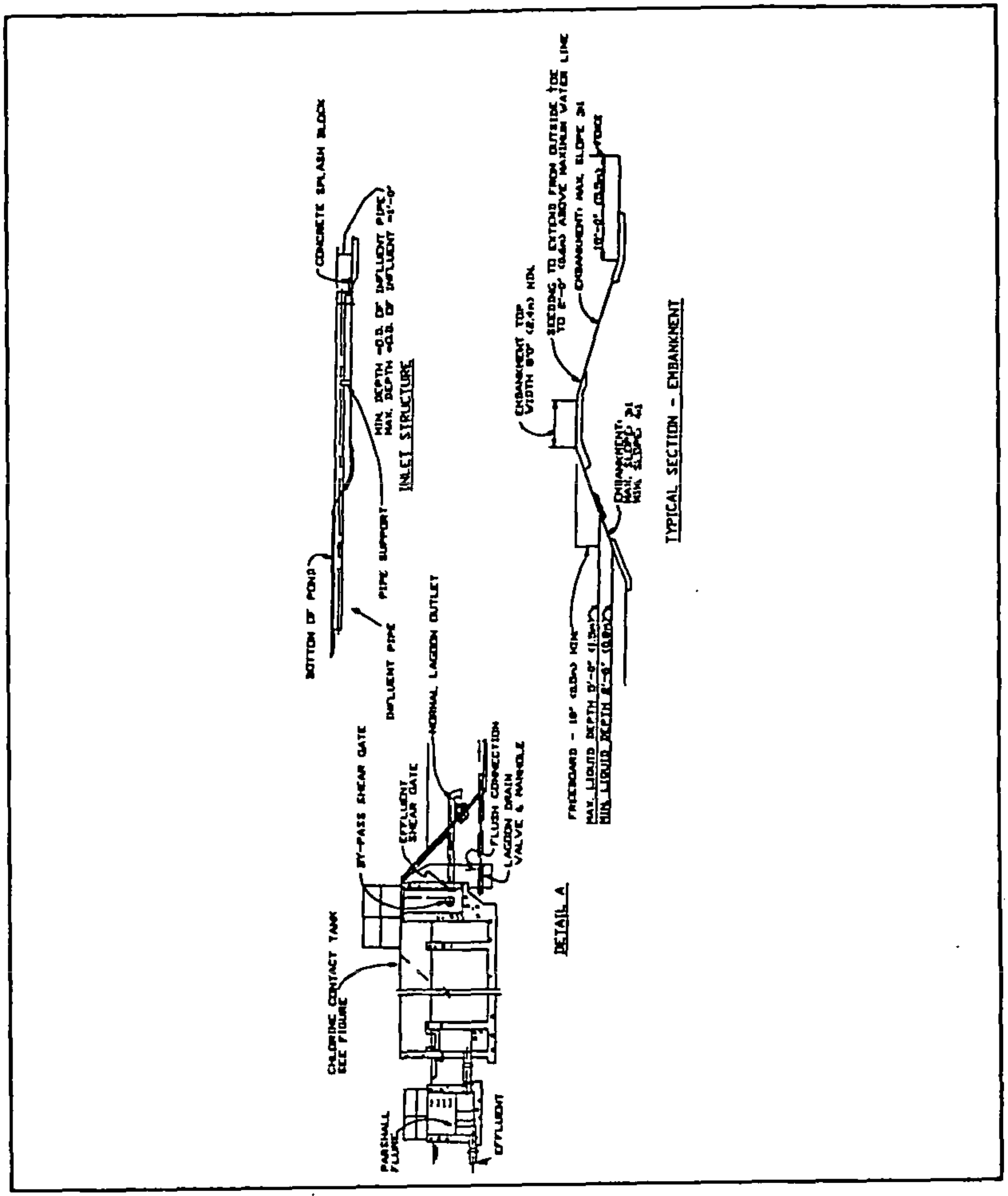


Figure 26 (Continued)
Facultative Lagoon and Mechanically Aerated Lagoon

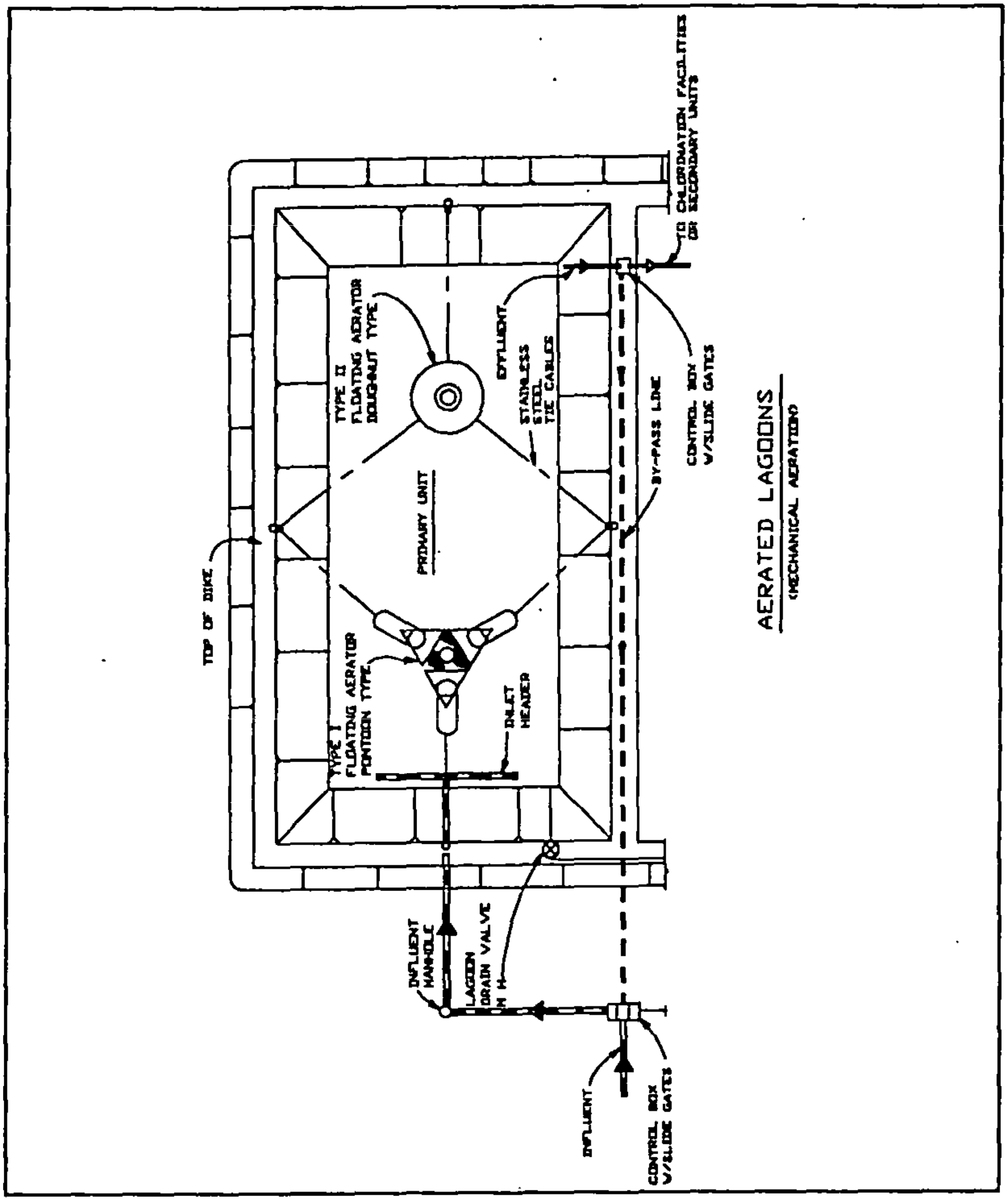


Figure 26 (Continued)
Facultative Lagoon and Mechanically Aerated Lagoon

7.3.6 Protection. Provide scour pads beneath mechanical aerators to avoid any possibility of membrane liners being pulled into aerator rotors. Provide splash blocks at inlet discharges. Riprap banks at water surface.

7.3.7 Lagoon Sealing. Lagoons are sealed to minimize seepage and resulting adverse impact on ground water quality and treatment performance. Pond sealers are classified into three categories: synthetic and rubber liners, earthen and cement liners, and natural and chemical treatment sealers. Natural sealing occurs due to physical clogging of soil pores by settled solids, chemical clogging of pores by ion exchange and precipitation, and biological clogging due to microbial growth. Natural sealing depends on wastewater characteristics and should not be relied on for satisfying design seepage criteria. Chemical treatment sealers change the nature of the bottom soil.

Contact state regulatory agency for design seepage rate and ground water monitoring requirements at lagoon site. Typical design seepage rate is 10^{-6} cm/sec (0.021 gpd/ft^2 [0.86 L/d/sq m]) for domestic wastewater lagoons. Industrial waste impoundments may require lower seepage rates or double liners for redundancy.

7.3.7.1 Bentonite Admixtures. Bentonite is a sodium-type montmorillonite clay that exhibits a degree of swelling, imperviousness, and low stability in the presence of water. It can be applied as a water slurry and incorporated with in-situ soils or as a sand-bentonite slurry (8:1 volume ratio) that is subsequently covered with soil.

a) Organic polyelectrolytes can be mixed with bentonite and soil to decrease the permeability of the admixture. Contact bentonite suppliers for further information and test procedures.

b) The performance of bentonite linings is greatly affected by the quality of the bentonite. Bentonite characteristics that should be specified in preparation of admixtures include sodium adsorption ratio (SAR); percent of silt, sand, and clay impurities; moisture content; particle size; and gradation.

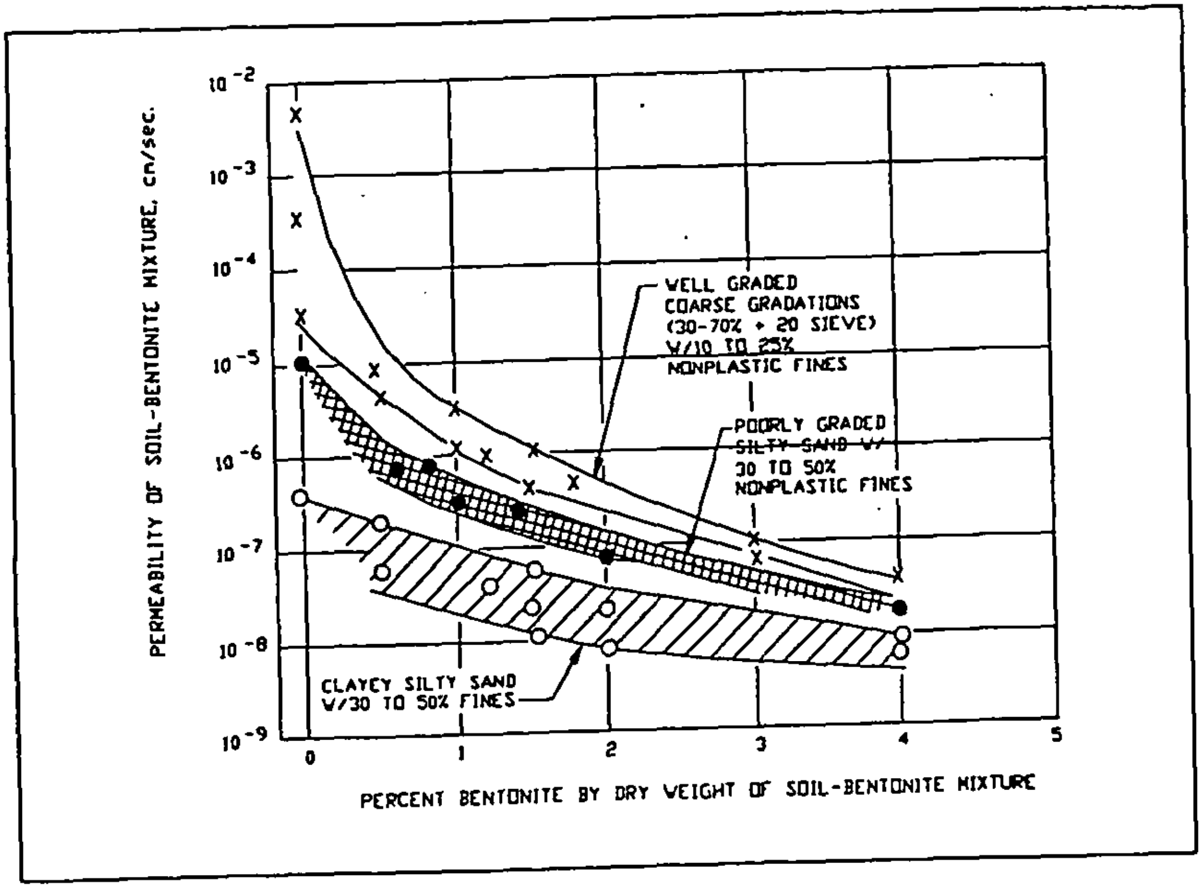


Figure 27
Relationship Between Permeability and Quantity of Bentonite in Soil Mixture

c) Determine the required amount of bentonite in the bentonite-soil mixture based on field soil sampling and laboratory tests by sealant suppliers. Use Figure 27 for guidance only and for review of laboratory results.

7.3.7.2 Asphalt and Cement Linings. Asphalt linings may be buried on the surface and composed of asphalt or a prefabricated asphalt with or without admixtures (bentonite or fiberglass). Soil cement sealant is best when used with sandy, well graded soil. Avoid use of bentonite and asphalt liners in areas of high weed growth.

7.3.7.3 Thin Membrane Liners. These liners include plastic and elastomeric membranes and are best used for sites requiring essentially zero permeability. For further information, refer to EPA's FED MCD-54, Wastewater Stabilization Pond Linings.

7.4 Facultative Lagoon. The facultative lagoon is the most common type of waste treatment for small flows. It has an anaerobic lower zone, a facultative middle zone, and an aerobic upper zone maintained by photosynthesis and natural surface reaeration. This type of biological process is also called an oxidation pond or a stabilization pond. It should be strongly considered for Navy installations with available land area because it is simple to operate, stable to flow and load variations, and has low capital and operating costs.

7.4.1 Sizing Basis - Loadings for Raw Sewage. Select values between maximum and minimum listed below depending on severity of freezing, ice cover, and available sunshine. Check lagoon size for detention time as listed.

Climate	Minimum BOD Loading (lb/day/acre [kg/day/ha])		Detention (d)
	Minimum	Maximum	
Cold (extended ice cover)	15 (17)	20 (22)	150 - 180
Temperate (short ice cover)	20 (22)	50 (56)	40 - 150
Subtropical (no significant ice cover)	50 (56)	100 (112)	10 - 40
Tropical	100 (112)	200 (224)	10

For facility layout with multiple ponds in series or parallel, limit first stage pond to 40 lb/day/acre (45 kg/day/ha) for odor control. Proportion the remainder of the total required area based on BOD loading equally among remaining cells.

7.4.1.1 Depth. Provide a 6-foot (1.8-m) operating depth with provision for varying depths between 3 to 8 feet (0.9 to 2.4 m) for flow and load variations and insect and weed control.

7.4.1.2 Design Equations. Refer to EPA 625/1-83-015, Design Manual on Municipal Wastewater Stabilization Ponds, for discussion and application of rational design equations.

7.4.2 Location. Locate the lagoon at least 0.25 mile (0.4 km) downwind from populated areas if pond receives ice cover through winter. This requirement may be reduced in accordance with paragraph 5.1, to take advantage of favorable topography.

7.4.3 Exposure. Choose site to give maximum sun and wind exposure.

7.4.4 Inlets and Outlets. For circular or square-shaped lagoons, the inlet should be near the center. For rectangular lagoons, place inlet at one-third point. Locate outlet to minimize short circuiting. Provide outlet with capability of drawoff at multiple depths.

7.4.5 Construction. Provide levees with 6- to 8-foot (1.8- to 2.4-m) minimum top-width with interior and exterior slope ratio of 2:1 to 6:1. Provide natural impervious soil liner (bentonite clay) to minimize exfiltration to ground water. Use of synthetic material lining will probably make this treatment process uneconomical. See Figure 26 for details of facultative lagoon. Refer to paragraph 7.3.7 for lagoon sealing requirements.

7.4.6 Layout. Use square, rectangular, or circular basins. For small installations (5,000 gpd [19,000 L/day]), single lagoons are acceptable. Use multiple lagoons for larger installations and arrange for series or parallel operation. See Figure 25 for alternative lagoon flow schematics. Recirculation can be employed to increase operational flexibility and treatment efficiency. Recirculation returns active algae cells and increases oxygenation capacity and dilutes influent BOD load. Recirculation ratio should be ≤ 2.

7.4.7 Performance. Recent changes in EPA effluent discharge criteria allow the use of facultative lagoons for equivalent secondary treatment. Effluent TSS will vary seasonally (especially in cold climates) between 50 and 350 mg/liter and contain 10 to 100 mg/liter of algae cells. BOD removal efficiency will vary seasonally between 70 and 95 percent. Odors may be a transient problem during spring season in cold climates where lagoon surface freezes over.

7.5 Anaerobic Lagoons. Anaerobic lagoons are deep lagoons that receive high strength biodegradable organic wastes such that anaerobic conditions prevail throughout the lagoon depth. This lagoon type is used only for treatment of industrial wastes and is not applicable to wastewater generated at Navy facilities.

7.6 Aerobic Lagoons. The aerobic lagoon type is most applicable to domestic waste treatment in subtropical and tropical climates. It utilizes shallow ponds (<3-foot depth [<1-m depth]) in which oxygenation is maintained by photosynthesis throughout the depth. It should be strongly considered for Navy installations with suitable land area and climate because it is simple to operate and has low capital and operating costs. Aerobic lagoons for continuous year-round use should be restricted to areas where the visible solar radiation is greater than 1.0 million calories per square meter per day ($cal/m^2/d$), 90 percent of the time and freezing conditions never persist for an extended period of time.

7.6.1 Sizing Basis

7.6.1.1 Loading. BOD removal for settled sewage (primary effluent) by an aerobic lagoon can be determined using Equation (19) (the Equation appears first in English, then in SI):

EQUATION:

$$\Delta \text{BOD} = \frac{21.872}{d} \left[\ln \left(I_o/24\right)\right] \qquad (19)$$

$$\Delta \text{BOD} = \frac{6.66}{d} \left[\ln \left(I_o/258\right)\right]$$

Δ BOD = BOD removed by lagoon (mg/liter)

d = lagoon mid-depth (≤ 1.5 ft [≤ 0.5 m])

I_o = light intensity at lagoon surface (footcandles [lux])

In absence of necessary solar radiation data, determine total required lagoon volume based on BOD surface loading rate of 60 (subtropical) to 120 (tropical) lb/day/acre [67 (subtropical) to 134 (tropical) kg/day/ha]. These loadings should provide detention time of 2 to 6 days. Proportion total required volume equally among multiple lagoons in series or parallel operation.

7.6.1.2 Depth. Operating depth should be 1 to 2 feet (0.3 to 0.6 m) and not exceed 3 feet (0.9 m) to ensure light penetration and photosynthetic activity for full lagoon depth.

7.6.1.3 Applications. Refer to EPA 625/1-83-015 for further discussion of aerobic and nondischarging lagoons and application of design equations.

a) Location. Refer to paragraph 7.4.2.

b) Exposure. Refer to paragraph 7.4.3.

c) Inlet and Outlet. Refer to paragraph 7.4.4 for rectangular ponds.

d) Construction. Refer to paragraphs 7.3.7 and 7.4.5.

e) Layout. Use multiple, rectangular lagoons in series or parallel operation with length-to-width ratios of 2:1 to 3:1. Individual lagoon area should be less than 10 acres (4 ha) to minimize short circuiting caused by wind action. Recirculation may be used to increase oxygenation capacity and seed influent sewage with algae cells. Recirculation ratios are 0.2 to 2.0 and average 0.5. See Figure 25 for alternative lagoon flow schematics.

f) Performance. Performance criteria for aerobic lagoons are similar to facultative lagoons except algae concentrations are higher (100 to 200 mg/liter for aerobic lagoons). Refer to paragraph 7.4.7. Aerobic lagoons should be preceded by primary treatment for removal of settleable organic solids. These solids will not undergo anaerobic destruction in an aerobic lagoon and will gradually fill the lagoon with solids. For more details on the use of lagoons for wastewater treatment, refer to WPCF MOP FD-16, Natural Systems for Wastewater Treatment.

7.7 Trickling Filters. Because of their ease of operation and reliable performance at variable loading conditions, trickling filters should be strongly considered for Navy facilities.

7.7.1 Media Types. For process variations and selection, the following media types are available:

a) Rock or artificial media in shallow tanks (random dump or stacked plastic media or redwood slats may be used as media for new tanks, or as replacement media for upgrading of existing installations).

b) Packed tower containing plastic media or redwood slats. Base selection on analysis of cost effectiveness and land area required for desired performance. Higher costs of redwood and plastic media are offset by the higher loadings made possible by the high specific surface areas (25 to 30 ft^2/ft^3 [82 to 98 sq m/cu m] for plastic media versus about 13 ft^2/ft^3 [43 sq m/cu m] for filter stone) and the greater practicable bed depths. Presently, plastic or redwood media are normally lower in total system construction cost for similar degree of treatment than rock media. Rock media systems normally use less energy due to lower filter depths, but this factor is often offset by greater recycle requirements.

c) Evaluate random dump or stacked plastic media for upgrading existing shallow bed, rock media trickling filters, or new shallow bed installations.

7.7.2 Flow Diagrams. See Figures 28 and 29 for typical flow diagram and hydraulic profile applicable to both packed towers and shallow bed filters. Refer to WPCF MOP 8 for other flow diagrams that have been used for rock filters. Base choice of recirculation ratio and flow pattern on the following considerations:

a) Maximum economy where performance and cost effects of different recirculation ratios and flow patterns can be determined.

b) Advantages of recirculation as discussed in WPCF MOP 8.

c) Factors affecting performance and design as discussed in WPCF MOP 8.

7.7.3 Hydraulic Loading and Effluent Recirculation

7.7.3.1 Rock Filters. Maintain minimum hydraulic loading of 120 gpd/ft^2 (5000 L/day/sq m) based on average flow without recirculation. Maintain sufficient minimum flow with recirculation to drive rotary distributors where used. Performance is related to recirculation ratio (R) as indicated in paragraph 7.7.4.1. Calculate the recirculation ratio as follows:

For constant recirculation rate, Q_R,

$$R = Q_R/Q_{24}$$

where

Q_R = recirculation flow rate (Mgd [ML/d])
Q_{24} = maximum 24-hour flow to plant (Mgd [ML/d])
Limit $R \le 2.0$

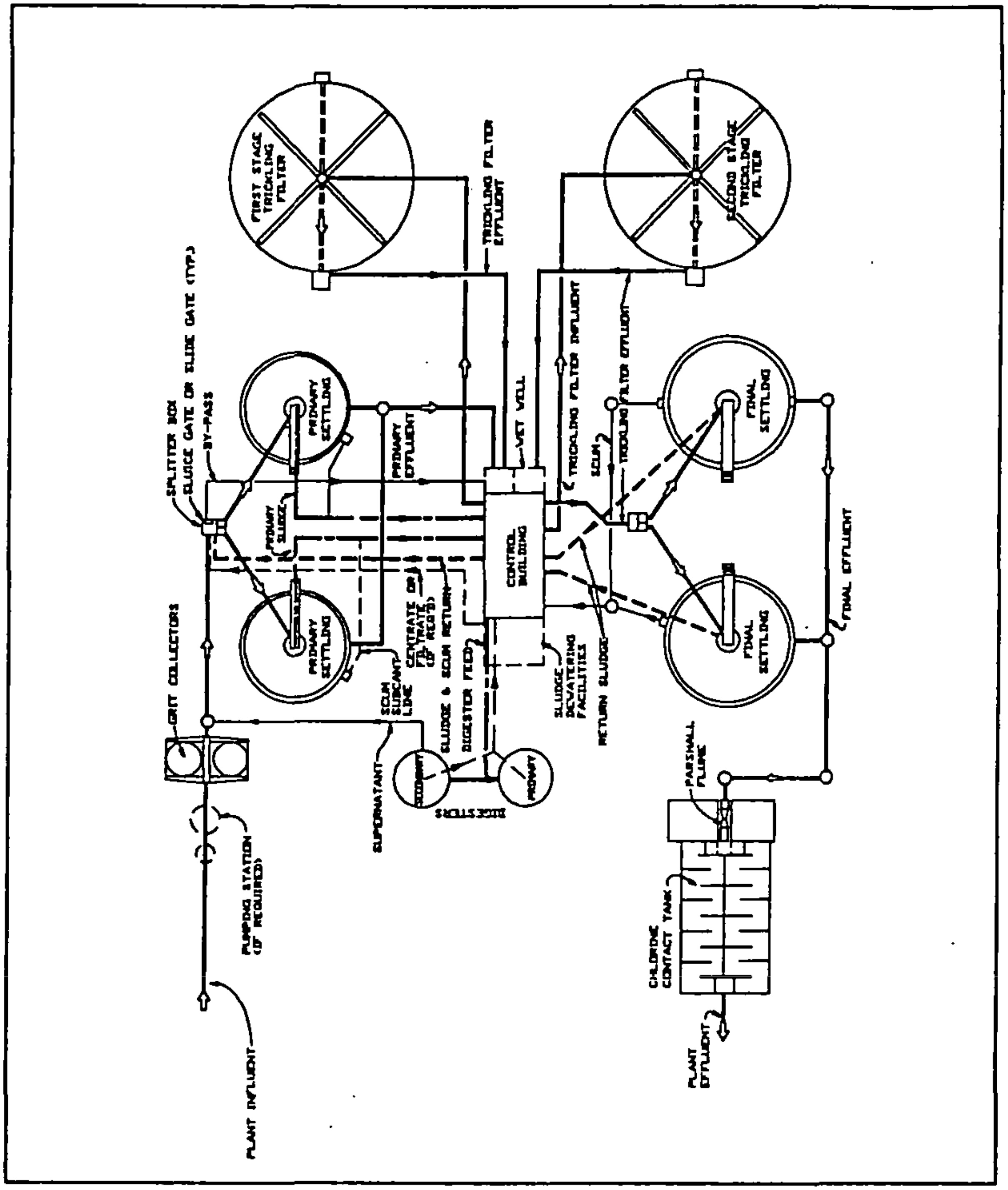
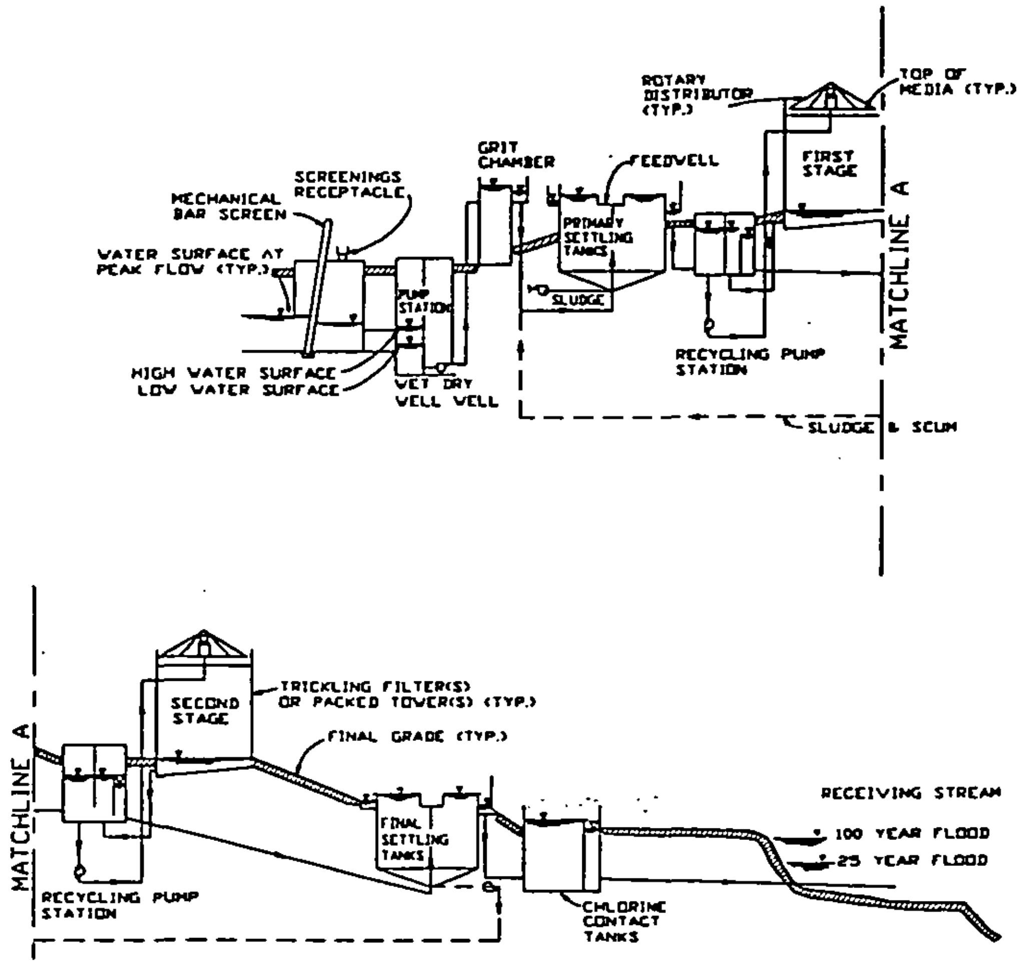


Figure 28
Trickling Filter Plant Layout



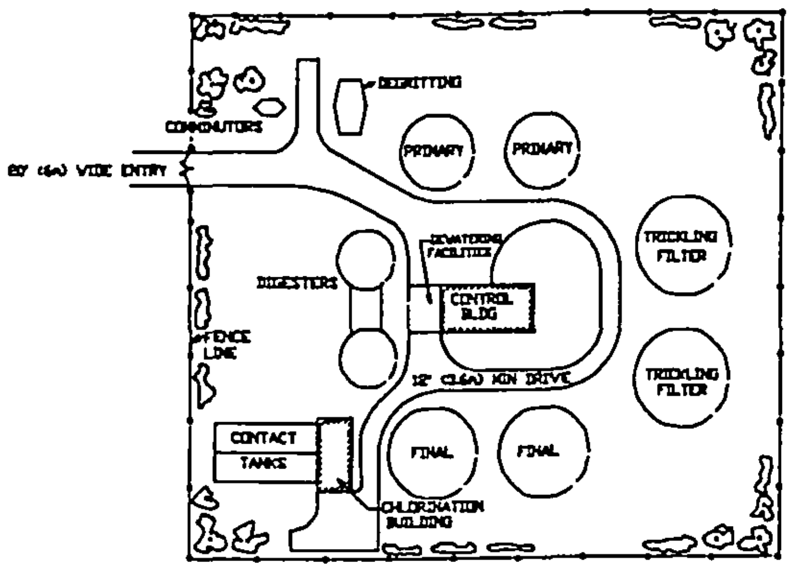
TYPICAL HYDRAULIC PROFILE

NOTES:

1. FOR PACKED TOWERS. USE OF SECOND STAGE TOWER IS SELDOM REQUIRED FOR SECONDARY TREATMENT OF DOMESTIC WASTEWATER.

2. FOR NITRIFICATION INTERMEDIATE SETTLING BETWEEN FIRST AND SECOND STAGE PACKED TOWERS IS REQ'D. IF HIGH DENSITY MEDIA IS USED IN SECOND STAGE PACKED TOWER. ALSO CONSIDER GRANULAR MEDIA FILTRATION IN LIEU OF FINAL SETTLING PLANTS FOR NITRIFICATION EMPLOYING 2-STAGE PACKED TOWERS WITH INTERMEDIATE SETTLING.

Figure 29
Trickling Filter Plant Hydraulic Profile and Plot Plan



TYPICAL PLOT PLAN

Figure 29 (Continued)
Trickling Filter Plant Hydraulic Profile and Plot Plan

For constant flow to filter, Q_F,

$$R = (Q_F/Q_{24}) - 1$$

where

Q_F = total flow to filter (Mgd [ML/d]). Q_F must be greater than maximum 24-hour flow (refer to paragraph 2..2.1)

Q_{24} = maximum 24-hour flow to plant (Mgd [ML/d])

7.7.3.2 Packed Towers. Maintain a minimum hydraulic loading including recirculation, of 960 gpd/ft^2 (39,000 L/d/sq m). Except for maintenance of minimum flows, recirculation is not critical to performance for packed towers treating settled domestic sewage. Hence, in general lower values of R are used than for rock media filters. Ensure hydraulic loading is no greater than 4.0 gpm/ft^2 (2.7 L/s/sq m).

7.7.3.3 Shallow Bed With Plastic Media. Refer to paragraph 7.7.3.2.

7.7.4 Sludge Recirculation. Consider recirculation of underflow from final settling tanks through packed tower filters on the same basis as other variations in paragraph 7.7.2. Consult media suppliers for data on performance improvements of towers with recirculation of sludge.

7.7.4.1 Basis for Sizing

a) Spare Units and Design Load Basis. Provide a minimum of two filters arranged to operate either in series or parallel. Base sizing on maximum 24-hour BOD load and minimum acceptable BOD removal (at least 85 percent for overall plant) with one unit out of service. Maximum efficiency for series operation is achieved when filter volumes and recirculation ratios are equal.

b) Performance Versus Loading

(1) Rock media filters. Use Equations (20) and (21) to relate BOD removal to loading and recirculation. For single-stage filters and final clarifier or for first-stage filters with intermediate clarifiers, use Equation (20) (Equations (20), (21), and (23) appear first in English, then in SI):

EQUATION:

$$E_1 = \frac{1.0}{1 + 0.0571\ [W_1/(V_1F_1)]^{0.5}} \qquad (20)$$

or

$$E_1 = \frac{1.0}{1 + 0.0119\ [W_1/(V_1F_1)]^{0.5}}$$

For second-stage filters with final clarifier, use Equation (21):

EQUATION:

$$E_2 = \frac{1.0}{1 + 0.0561\ [W_2/V_2F_2(1-E_1)^2]^{0.5}} \qquad (21)$$

or

$$E_2 = \frac{1.0}{1 + 0.0117\ [W_2/V_2F_2(1-E_1)^2]^{0.5}}$$

where

E_1 and E_2 = decimal fraction BOD removal through filter plus clarifier at 20 degrees C (68 degrees F)

W_1 and W_2 = BOD applied to filter (lb/d [kg/day])

V_1 and V_2 = filter media volume (1,000 ft^3 [1000 cu m])

F_1 and F_2 = recirculation factor of each filter defined as:

$F = (1 + R)/(1 + 0.1R)^2$

R = recirculation ratio for specific filter

$R = Q_R/Q_{24}$

Subscripts 1 and 2 = parameter at filter 1 and 2 in series operation.

For BOD removal efficiency at wastewater temperature other than 20 degrees C (68 degrees F) (E_T) adjust E_1 and E_2 as follows:

EQUATION: $E_T = (E_{20})(1.035)^{T-20}$ (22)

where

E_{20} = removal efficiency of filter at 20 degrees C by Equation (20) or (21).

E_T = removal efficiency of filter at wastewater temperature, T degrees C.

(2) Packed Towers. Use Equation (23) to relate BOD removal to loading and recirculation for stacked or random dump plastic media.

EQUATION:

$$\frac{S_e}{S_a} = \frac{(\exp)\ (-K_T D/Q^n)}{(1 + R) - R[(\exp)(-K_T D/Q^n)]} \qquad (23)$$

or

$$\frac{S_e}{S_a} = \frac{(\exp)\ (-2.7K_T D/Q^n)}{(1 + R) - R[(\exp)(-2.7K_T D/Q^n)]}$$

where

S_e = effluent soluble BOD(mg/liter). Effluent total BOD is approximately equal to $2S_e$

S_a = BOD of influent to filter including effect of recycle (mg/liter)

S_a = $(So + RS_e)/(1 + R)$

R = recirculation ratio

S_o = primary effluent total BOD (mg/liter)

K_T = treatability constant at operating temperature(min^{-1})

Q = hydraulic loading rate including recycle (gpm/ft^2 [L/s/sq m])

D = filter depth (ft [m])

n = constant for media type

In absence of other data, use n= 0.5 and K_{20} = 0.05/min for domestic wastewater using a 20-foot deep synthetic media having specific surface = 27 ft^2/ft^3 (88 sq m/cu m). Adjust K_{20} to temperature other than 20 degrees C as follows:

$$K_T = K_{20} (1.035)^{T-20}$$

c) Shallow Bed With Plastic Media. Use Equation (23) to relate BOD removal to loading and recirculation. Consult media supplier to determine appropriate value of "n" and K_{20} for media of choice in shallow bed application.

7.7.4.2 Materials and Construction. Materials and construction shall conform to the following criteria:

a) Rock Media Filters:

(1) Subfloor slab: concrete. Design structurally for loadings from filter block, media, and water load, if flooding is to be practiced. Slope toward drain channel at 0.5 percent or more.

(2) Walls: concrete.

(3) Floor: Type 1H perforated clay blocks meeting American Society for Testing and Materials (ASTM) C159, Standard Specification for Vitrified Clay Filter Block.

(4) Ventilation pipes: materials acceptable for sewer pipe, preferably impact resistant.

(5) Media: use cubical-shaped crushed rock sized to pass 4-inch (100-mm) screen and be retained on 2.5-inch (62.5-mm) screen. Specify characteristics and placement methods as outlined in WPCF MOP 8. Apply durability tests as follows:

Test	Maximum Loss	Reference
Sodium sulfite soundness 20 cycles	10%	ASTM C88, Standard Test Methods for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
Los Angeles rattler test 500 revolutions	20%	ASTM C131, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion Impact in the Los Angeles Machine

(6) Tank shape and depth: round with 6 to 8 feet (1.8 to 2.4 m) of media depth. Extend walls 0.75 foot (0.25 m) (minimum) above media.

b) Packed towers. See Figure 30 for details of packed tower applicable to stacked or random dump plastic media.

(1) Floors, drain channels, and media support piers: concrete. Design for weight of media plus wet slime growths, but without allowance for flooding. Include grating weight for random dump media.

(2) Walls. Use steel or plastic shell or provide exterior framed structure with plastic, wood, precast concrete, or masonry panels. Interior wall surface must be watertight if freezing could damage wall structures. Exterior framed structure must withstand wind load conditions when standing free of media.

(3) Media and supports. Support media on grating, framing, or directly on piers. Consult manufacturers for material characteristics and recommendations for support of particular media. Use corrosion-resistant materials for supports. Grating for dumped plastic media should be stainless steel, aluminum, PVC, or fiberglass reinforced plastic.

(4) Packed tower shape and depth. Shape depends on structural design. Media depth: 12 to 24 feet (3.6 to 7.3 m), walls to extend 3 to 4 feet (0.9 to 1.2 m) above media.

c) Shallow bed with plastic media. Same as for rock media filters.

7.7.4.3 Dosing Equipment. Dosing equipment shall meet the following criteria:

a) Rock filters. Use rotary distributors. (Refer to WPCF MOP 8 for features and NAVFAC NFGS-11365D, Trickling Filter.

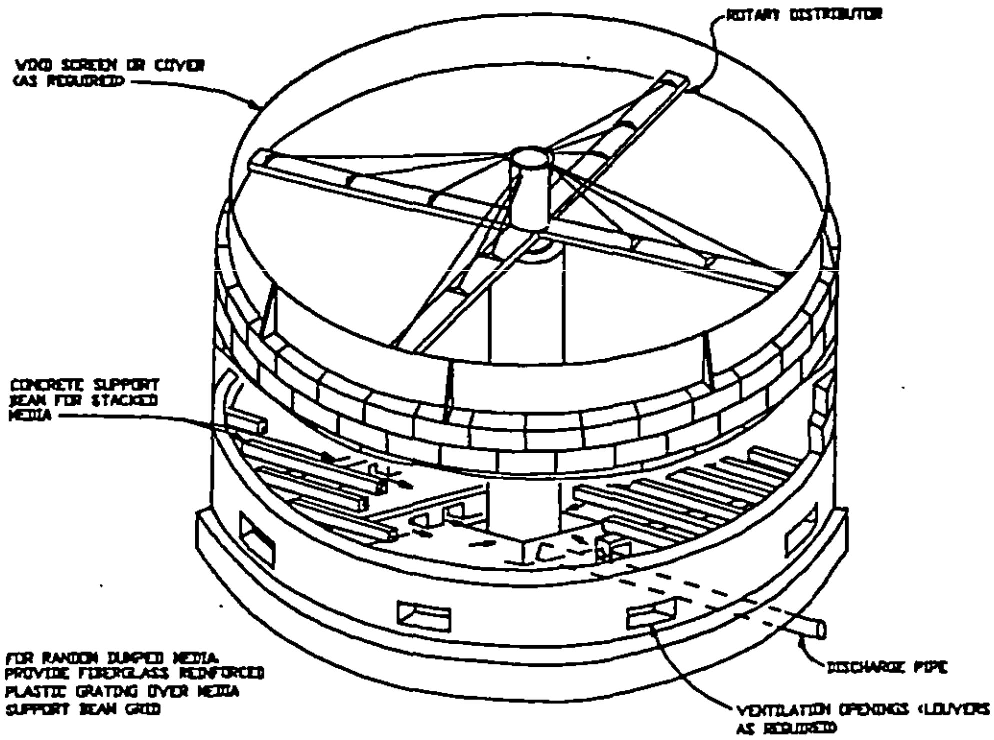
(1) Consult manufacturers for head requirements. Specify guaranteed maximum and minimum.

(2) Use reaction-driven type, except consider motor-driven units where head is limited.

(3) Use of mercury seals is prohibited.

b) Packed towers. For packed towers, consider rotary distributors, fixed nozzles, or impingement devices.

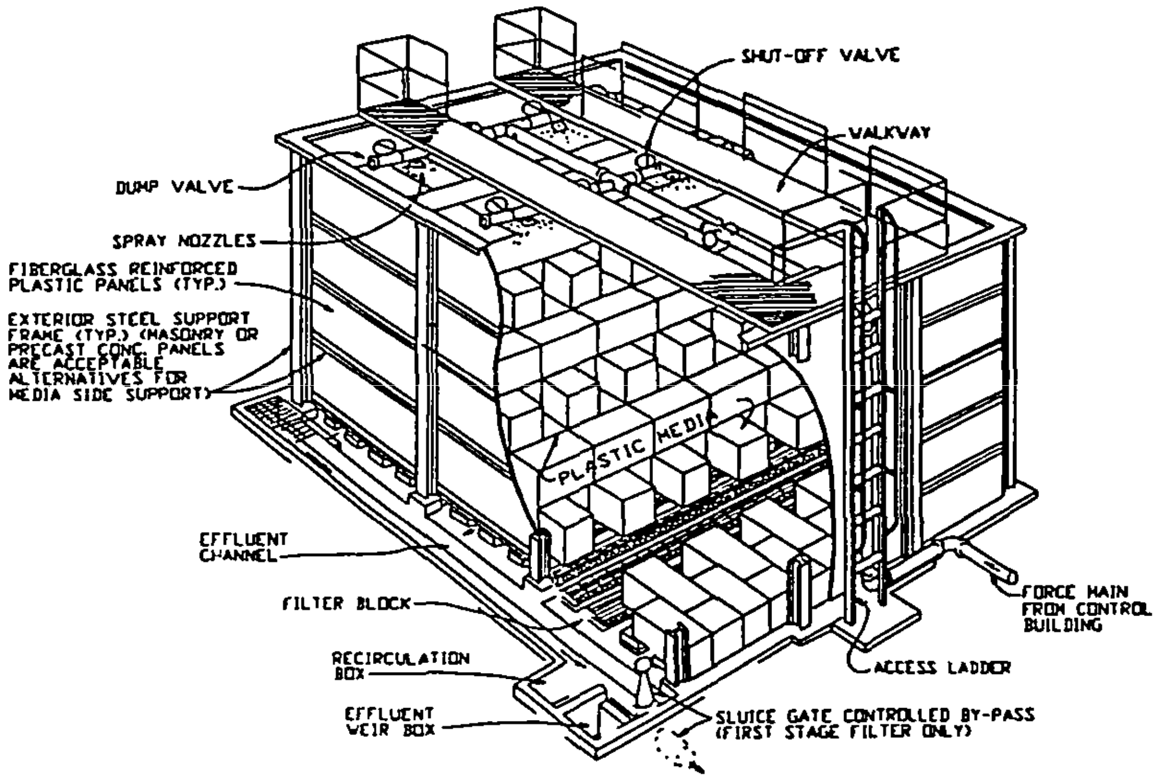
(1) Obtain recommendations of manufacturers for particular media.



NOTES:

1. FEED FOR ROTARY DISTRIBUTORS SHALL BE THROUGH CONSTANT HEAD BOX OR DIRECT PUMPING.
2. FILTER BLOCK SHOWN FOR RECTANGULAR TOWER MAY ALSO BE USED FOR MEDIA SUPPORT AND UNDERDRAIN SYSTEM.
3. PRECAST CONCRETE PANELS, FIBERGLASS REINFORCED PLASTIC PANELS WITH EXTERIOR STEEL SUPPORT FRAME, OR CIRCULAR BOLTED STEEL TANK WITH FUSED GLASS COATING (AWWA D-100) MAY BE USED FOR MEDIA SIDE SUPPORT IN LIEU OF MASONRY CONSTRUCTION SHOWN.
4. CONSULT MANUFACTURER FOR MAXIMUM MEDIA DEPTHS WITHOUT INTERMEDIATE SUPPORT SYSTEM.

Figure 30
Packed Media or Random Dumped Media Trickling Filter



NOTES:
1. REINFORCED CONCRETE BEAM SUPPORT SYSTEM AND CONCRETE SLAB SLOPING AT 05% MINIMUM TO CENTRAL COLLECTION BOX OR CHANNEL MAY BE USED AS SHOWN ON CIRCULAR TOWER IN LIEU OF FILTER BLOCK.
2. CONSULT MANUFACTURER FOR MAXIMUM MEDIA DEPTHS WITHOUT INTERMEDIATE SUPPORT SYSTEM.

Figure 30 (Continued)
Packed Media or Random Dumped Media Trickling Filter

(2) For high liquid application rates, rotary distributors may require multiple arms.

c) Shallow Bed With Plastic Media. Use rotary distributors as for rock filters.

7.7.4.4 Ventilation. Ventilation shall meet the following criteria:

a) Rock Filters. Inlet openings into the underdrains shall have gross area of at least 1 percent of the filter area. If filters are covered, provide at least 1 ft^2 (1 sq m)) of roof ventilation openings per 100 ft^2 (100 sq m) of filter area.

b) Packed Towers. Provide underdrain ventilation openings equal to at least 3 percent of the filter area or 2 ft^2/1,000 ft^3 (7 sq m/1000 cu m) of media volume, whichever is greater. If filters are covered, provide at least 3 percent of the filter area or 2 ft^2/1000 ft^3 (7 sq m/1000 cu m) of media as roof ventilation openings. Provide louvers on underdrain ventilation openings to allow control of amount of air flow and cooling effects.

c) Shallow Bed With Plastic Media. The same ventilation requirements as for rock filters if BOD loadings are the same. If BOD loadings are similar to those of packed tower facilities, provide ventilation equal to packed tower requirements.

7.7.4.5 Filter Fly Control. Positive control is needed unless hydraulic application rates are high enough to limit growth (at least 0.75 gpm/ft^2 [0.5 L/s/sq m] of plan area including recirculation). The filter fly control shall meet the following criteria:

a) Rock Filters. Provide gates on drain outlet and design walls and floors to permit periodic flooding.

b) Packed Towers. Provide for screening of ventilation openings.

7.7.4.6 Underdrain Hydraulics. Underdrain hydraulics shall meet the following criteria:

a) Rock Filters:

(1) Provide diametrical collection channel to flow at a velocity of at least 2 fps (0.6 m/s) at average flow, with flow line at peak flow plus recycle at mid-height of filter block channels.

(2) Specify the following hydraulic characteristics for filter blocks: (a) area of top perforations equal to 20 percent of gross filter surface area, and (b) maximum flow line including recycle less than 50 percent of depth of channel in block.

b) Packed Towers. Slope floor and collection channels at a minimum of 0.5 percent to provide drainage velocity of at least 2 fps (0.6 m/s) at average flow.

c) Shallow Bed With Plastic Media. If used as a retrofit of rock media, existing underdrain hydraulics may limit application rate to plastic. If used as new installation with loading rates typical of packed towers, use underdrain criteria for packed towers.

7.7.4.7 Access. Provide manhole steps for interior access to the control structures. Provide for safe access to top of packed towers.

7.7.4.8 Nitrification. A reliable basis for predicting nitrification in trickling filters has not been established. Check latest EPA Technology Transfer publications and media manufacturers for current performance data. Special attention is needed for nitrification by packed towers in cold climates. Refer to EPA-R2-73-199, Application of Plastic Media Trickling Filters for Biological Nitrification.

7.8 Rotating Biological Contactors (RBC). Equipment available from United States manufacturers may consist of:

a) shafts, discs, and drives for installation in tanks constructed on-site, or

b) package plants consisting of shafts, discs, rotary sludge scraper, and drive mounted in compartmented semicircular tank (axis horizontal).

Site installed equipment consists of a shaft 6 to 25 feet (1.8 to 7.6 m) long and disc diameters of 11.5 to 12 feet (3.5 to 3.7 m). Disc media is high-density polyethylene and is of two types -- standard media and high-density media. The effective surface areas are approximately 100,000 ft^2 (9300 sq m) and 150,000 ft^2 (14,000 sq m), respectively on a 25-foot (7.7-m) shaft with 12-foot (3.7-m) diameter discs.

7.8.1 Rotating Speed. The disc tip rotating speed is usually 60 fpm (0.305 m/s) or 1.6 revolutions per minute (rpm) for a 12-foot (3.7-m) diameter disc. Higher tip speeds increase oxygenation capacity and allowable loading rate but are not used since disc drive power required increases as the third power of rotational speed.

Both air drives and mechanical drives are available. Aeration in contactor tank below RBC units does not significantly increase BOD removal capacity but does reduce biological film thickness and live load on shafts. Aeration may be required to maintain allowable live structural load on RBC shafts at influent end of staged process. Consult equipment manufacturer for allowable live load or total allowable weight of operating shaft. Provide load cells on shafts to measure load.

7.8.2 Basis for Sizing

7.8.2.1 Media Volume. Provide at least two hydraulically independent units sized so that, with one out of service, the plant is able to provide minimum overall BOD removal (at least 85 percent) for the maximum 24-hour BOD load.

a) Provide primary treatment by settling or fine screening (static type) ahead of contactors.

b) Base loading-removal-temperature relations on data verified for installations treating wastes similar to those to be treated (consult equipment manufacturer for source of data). Locate independent research data.

c) In general, treatment efficiency is greater when a given total volume of media is divided into stages operated in series. Use parallel treatment trains as required to avoid overloading first stage units. Overloading can cause structural failure of RBC shafts and media and process failure.

7.8.2.2 Power

a) Power requirements increase as the third power of rotational speed. Motor ratings are typically 7.5 horsepower per 25-foot (7.6-m) by 12-foot (3.7-m) diameter shaft for mechanically driven units operating at 1.6 rpm. Air drive units require 7 to 9 horsepower (blower plus motor) per shaft. Blower discharge pressure is about 3 psig (21 kPa) using coarse bubble diffusers at air flow rates of 50 to 250 ft^3/min (24 to 118 L/s) to provide a rotational speed of 1.2 to 1.6 rpm. Variable speed drives are not used because of excessive power consumption.

b) Treatment efficiency at higher organic loads decreases if rotational speed is too low to oxygenate the full thickness of biological film on the media.

c) Obtain detailed data from equipment manufacturers and independent tests of units in operation at comparable organic loading rates. Refer to EPA PB85180545, Review of Current RBC Performance and Design Procedures.

7.8.2.3 Sludge Recirculation. Sludge recirculation is not normally cost-effective since supplemental aeration must be installed.

7.8.3 Covering. Covers used in practice are predominantly quonset-shaped structures consisting of opaque fiberglass reinforced plastic designed to withstand local weather conditions and prevent ultraviolet degradation of the media. Covers must have adequate ventilation, access doors large enough to permit replacement of electrical equipment, and sufficient insulation from 1/8-inch (3.2-mm) polyester resin to 1/2-inch (13-mm) urethane foam to protect the biological process during cold winter months. Avoid enclosure of RBC treatment trains in buildings unless adequate ventilation and corrosion protection of building are provided.

7.8.4 Contactor Tanks. Most contactor tanks are poured in place, semicircular, or trapezoidal in cross section, depending on equipment manufacturer, size, and arrangement of shaft installation. Rotation of discs keeps solids in suspension. Discs may also be installed in primary settling tanks equipped with sludge scrapers to increase primary BOD removal (consult manufacturer).

7.8.5 Flow Pattern. Flow pattern through the RBC systems may be perpendicular or parallel to the shaft. Parallel-to-shaft flow is baffled within the contactor tank. Perpendicular to shaft flow is baffled by the contactor tank itself. Multiple shafts and contactor tanks may be "staged" by arrangement in series flow pattern. Staging may require that more shafts and media be provided at the inlet end of the treatment process than the effluent end to reduce the organic and structural load on the first-stage shafts. Alternatively, influent flow splitting could be used to reduce first stage and increase contactor tank detention time.

7.8.6 Nitrification. Refer to paragraph 7.7.4.8. Consult manufacturer and independent research data for current nitrification performance in multistage contactors.

7.8.7 Equipment Selection. Obtain information from manufacturer and independent testing sources regarding structural design of shafts and media in service at various loading conditions. Shaft and media failures have occurred in the past due to inadequate structural design and fabrication practices, and biologically overloaded process conditions. Biological loads on first stage shafts are critical for this reason.

7.8.8 Performance Testing. Except for very small plants (less than 0.25 Mgd [1 ML/day]), using very conservative loading rates, require shaft performance and replacement guarantee in bidding or purchasing documents for specific design loading conditions. If plant is not loaded at full process design rates, provide for testing at design conditions by taking some shafts out of service, provision of parallel treatment trains, or other means. During testing, shaft end loads should be measured by a fabricated shaft bearing yolk and hydraulic jack and load cell to support the undriven end of the rotating RBC. Terminal jack pressure measurements can be used to compute load as a function of jack bearing area. Shaft allowable bending stress should be determined using a recognized code, such as American Welding Society (AWS) D1.1, Structural Welding Code: Steel, and considering total number of stress reversals (shaft rotations) during the design life of the shafts. Actual shaft bending stress can be determined by assuming the shaft is a simply supported beam, computing maximum moment from shaft end load, and dividing by the shaft section modulus. Such a test is most applicable to the influent end shafts of larger plants with shafts mounted perpendicular to direction of flow through the tanks.

7.9 Granular Beds. Data and requirements for granular beds are as follows:

7.9.1 Intermittent Sand Filters. These filters are sand beds which receive settled or more highly treated effluent intermittently. Rest periods permit reaeration of biological slime coating on the sand.

7.9.1.1 Application. Used to provide secondary or tertiary treatment where very high removals are necessary. Land and manual labor requirements generally limit their use to small installations (<5,000 population) except where required only for tertiary treatment. Low cost land and local supply of filter sand make this method more attractive.

7.9.1.2 Design Criteria

a) Location. Provide a minimum distance from dwellings of 1000 feet (300 m) (no restriction if filters are housed).

b) Depth. Provide a depth of 5 feet (1.5 m) from bed surface to discharge invert.

c) Loadings. For dosing with secondary effluent, use 9 to 11 gpd/ft^2 (370 to 450 L/day/sq m).

d) Dosing. Control dosing by automatic airlock siphon giving preferably two, up to four, dosings per day, with average siphon discharge about 90 gpm per 1000 ft^2 (61 L/s/1000 sq m) of filter. Allow 5-foot (15-kPa) head for siphon operation.

e) Surface distribution. Use center upflow pipe discharging at concrete apron on the same level as the bed.

f) Construction. Construct similar to the sludge drying beds shown in Figure 32 (which appears in Section 8 of this document), except increase sand layer to 30 inches (760 mm).

g) Overall removals, including preceding stages. 95+ percent BOD and TSS removal, and 99 percent bacteria removal.

7.10 Septic Tanks. Consider septic tanks only for temporary installations serving complements of fewer than 50 persons. Refer to EPA 625/1-80-012, Onsite Wastewater Treatment and Disposal Systems, for design and sizing criteria. In order to protect effluent disposal system (such as soil absorption systems), sewage must be periodically removed by pumping from septic tanks. Normal interval is 1 to 3 years, depending on loading.

7.10.1 Soil Absorption Systems. The following types of soil absorption systems are available for disposal of septic tank effluent.

7.10.1.1 Trenches, Beds, Seepage Pits. These systems are most commonly used and are addressed in EPA 625/1-80-012.

7.10.1.2 Mound Systems. The mound system is a soil absorption system that is elevated above the natural soil surface with a suitable fill material. The following conditions can preclude the use of trenches and beds or seepage pits, and favor the use of mound systems:

a) Slowly permeable soils.

b) Shallow, permeable soils over creviced or porous bedrock.

c) Permeable soils with high water tables.

7.10.1.3 Fill System. If surface soils overlying sands or sandy loams are very slowly permeable, and the underlying permeable soils have inadequate depth to bedrock or water table for a trench or bed system, fill systems should be considered. With a fill system, the slowly permeable overlying soil is stripped away and is replaced with a sandy fill material to provide 2 to 4 feet (0.6 to 1.2 m) of unsaturated soil. A trench or bed system is then constructed within the fill.

7.10.1.4 Artificially Drained Systems. Where a high water table limits the use of trenches or bed systems, the water table can sometimes be lowered artificially to permit use of these disposal methods, and avoid the extra cost of mound systems. Vertical drains, curtain drains and underdrains are commonly used artificial drainage techniques. Soil and site conditions will determine selection and applicability.

7.10.2 Applications and Design Criteria. For applications, design criteria, and sizing information on mound systems, fill systems, artificially drained systems, and other soil absorption systems, refer to EPA 625/1-80-012.

7.11 Land Application. Land treatment is the controlled application of wastewater onto the land surface to achieve a designed degree of treatment through natural physical, chemical, and biological processes within the plant-soil-water matrix. Land treatment is presently encouraged by EPA, where applicable, as a means of reducing capital and operating costs while achieving very high degrees of treatment. In many instances, land treatment avoids costs and problems associated with sludge handling and disposal. Land treatment should be rigorously considered for all new Navy facilities.

7.11.1 Effluent Quality. Typical effluent quality of treated water from land treatment processes is as follows (variation depends on treatment process used):

Characteristic	Concentration Range (mg/liter)
BOD	<2 to 15
TSS	<1 to <20
NH_3-N	<0.5 to <8
Total Nitrogen (as N)	3 to <20
Total Phosphorous (as P)	<0.1 to <6
Fecal Coliforms	0 to <2000/100 ml

7.11.2 Alternative Land Treatment Methods

7.11.2.1 Slow Rate Process. Apply wastewater to a vegetated land surface, with the wastewater being treated as it flows through the plant-soil matrix.

7.11.2.2 Rapid Infiltration Process. Wastewater is applied to moderately and highly permeable soils (such as sands and loamy sands) by spreading in basins or by sprinkling. Treatment is by percolation through the soil matrix. Vegetation is usually not planned, but emergency of grass and weeds usually does not cause problems. Underflow from the spreading basins may percolate to the groundwater or be recovered by an underdrain system or recovery wells.

7.11.2.3 Overland Flow Process. Wastewater is applied at the upper reaches of grass-covered slopes and allowed to flow over the vegetated surface to run off collection ditches. This process is primarily applicable to relatively impermeable soils on flat to moderate slopes, not exceeding 8 percent.

7.11.3 Preapplication Treatment. For domestic wastewater, pretreatment requirements are typically limited to preliminary treatment, such as screening, or primary treatment. Additional treatment levels may be required depending on site location, crops grown, land treatment process used, and effluent quality required.

7.11.4 Design Criteria. For detailed guidance and design procedures, refer to EPA 625/1-81-013, Land Treatment of Municipal Wastewater.

Section 8: SLUDGE TREATMENT AND DISPOSAL

8.1 General Requirements. Procedures on sludge quantities and disposal of liquid wastes are required as described in paragraphs 8.1.1, 8.1.2, and 8.1.3

8.1.1 Sludge Quantities

8.1.1.1 Weights and Volumes. Where sludge quantities are not known, use Table 33 for typical sludge production of major wastewater treatment processes for domestic sewage. For wastewater containing a large industrial waste component, calculate sludge production for specific treatment processes by methods presented in the report by Eckenfelder.

8.1.1.2 Volatile Matter. When characteristics of a particular sludge have not been determined, assume that primary and secondary sludges are comprised as follows:

a) 72 percent of total suspended solids is volatile.

b) 50 percent of total dissolved solids is volatile.

8.1.2 Disposal of Liquid Wastes From Residue Treatment Processes. Return all liquid wastes, i.e., overflow from gravity thickener; subnatant from floatation unit; centrate, filtrate; elutriate (not normally present in new Navy facilities); underdrainage from sand beds; supernatant from lagoons and digesters; and liquor from thermal conditioning and wet oxidation processes (not normally present in the new Navy facilities) to the plant influent, at an appropriate place ahead of biological treatment. Avoid pumping if possible.

Point of return should consider solids and oxygen demand load, septicity and potential odor of recycle stream. Ensure that this increased load does not upset subsequent wastewater treatment processes. Consider separate physical or biological treatment of high strength residue treatment liquid wastes prior to recirculation. Consider equalization storage of recycle liquid wastes for return during low flow periods.

8.1.3 Miscellaneous Sludges. Includes screenings, grit, scum, and sewage.

a) For treatment of screenings, grit, scum, refer to paragraph 4.5.

Type of Sludge	Underflow Concentration (%)
Primary	5 to 10
Trickling filter sloughings	3 to 6
Waste-activated sludge	1.5 to 3
RBC or packed tower sloughings	2 to 5
Primary w/chemical addition	4 to 12
Primary and trickling filter sloughings	5 to 9
Primary and waste-activated sludge	4 to 7
Primary and RBC or packed tower sloughings	5 to 8

b) Sewage is the partially digested mixture of liquid and solid material that is periodically removed from septic tanks. Discharge sewage to wastewater treatment plant. Provide holding tanks for sewage so that sewage can be gradually added to the influent wastewater stream to avoid upset of treatment plant processes.

8.2 Sludge Thickening. Sludge thickening processes are by gravity, flotation, and centrifuge as described in paragraphs 8.2.1, 8.2.2, and 8.2.3.

8.2.1 Gravity Thickening. Well operated mechanically stirred gravity thickeners will achieve 90 to 95 percent solids capture, and thicken sludges to the following concentrations:

8.2.1.1 Design Criteria. Refer to Table 34 and EPA 625/1-79-011, Process Design Manual, Sludge Treatment and Disposal.

8.2.2 Flotation Thickening. Use flotation thickening for light sludges such as waste-activated, RBC, and trickling filter sloughings. Heavy sludges such as primary sludges and combinations of primary and secondary sludges are handled best by gravity thickening. Flotation thickening will generally achieve 90 percent solids capture.

Table 33
Typical Characteristics of Domestic Sewage Sludge[1]

Source of Sludge	Solids Content of Wet Sludge (%)	Dry Solids[2] (lb/d/capita [kg/d/capita])	Fuel Value Dry Solids (Btu/lb [kJ/kg])
Primary settling tank	4 to 6	0.12 (0.05)	10,000 to 12,000 (23,000 to 28,000)
Primary settling tank with chemical addition for phosphorus removal	5 to 10	0.25 (0.11)	7000 (16,000)
Trickling filter secondary	1 to 3	0.04 (0.02)	8000 to 10,000 (19,000 to 23,000)
Mixed primary and trickling filter secondary	4 to 6	0.16 (0.07)	9000 to 11,000 (21,000 to 26,000)
Waste-activated sludge secondary	0.5 to 1.5	0.07 (0.03)	8000 to 10,000 (19,000 to 23,000)
Mixed primary and waste-activated sludge secondary	1.5 to 4	0.19 (0.09)	9000 to 11,000 (21,000 to 26,000)
RBC or packed tower secondary nitrification (separate stage) (negligible solids load)	1 to 3	0.05 (0.02)	6000 (14,000)

[1]Values based on removal efficiencies of well-operated treatment processes.
[2]Average 24-hour values. To estimate maximum 24-hour values, multiply given values by ratio of maximum 24-hour flow to average 24-hour flow, as determined from Figure 2.

8.2.2.1 Solids Loading Rate. Typical solids loading rates with and without polymer addition are shown below. Increasing the solids loading rate generally decreases the float solids concentration. The addition of polymer usually allows the solids loading rate to increase.

Type of Sludge	Solids Loading Rate[1] (lb/h/ft^2 [kg/h/sq m])		Float Concentration (%)
	W/O Polymer	W/Polymer	
Primary	0.8 to 1.25 (3.9 to 6.1)	<2.5 (12.2)	4 to 6
Waste-activated sludge	0.4 to 1.0 (2.0 to 4.9)	<2.0 (9.8)	3 to 5
Trickling filter sloughings	0.6 to 1.0 (2.9 to 4.9)	<2.0 (9.8)	4 to 5
RBC sloughings	0.6 to 1.0 (2.9 to 4.9)	<2.0 (9.8)	4 to 5
Primary plus waste-activated sludge	0.6 to 1.25 (2.9 to 6.1)	<2.0 (9.8)	3.5 to 6
Primary plus trickling filter or RBC sloughings	0.8 to 1.25 (3.9 to 6.1)	<2.5 (12.2)	4.5 to 6

[1]Expressed as pounds of dry solids per hour per square foot of thickener area (kilograms of dry solids per hour per square meter of thickener area).

8.2.2.2 Hydraulic Loading Rate. Check hydraulic loading rate on flotation thickener to ensure that solids will reach the sludge blanket before they reach the effluent end of the tank. Typical overflow rates are 1200 gpd/ft^2 (13,000 L/d/sq m) with polymer addition and 240 gpd/ft^2 (10,000 L/d/sq m) without polymer addition.

Table 34
Design Criteria for Gravity Thickening Tanks

Design Item	Criteria
Required overflow rate[1]	200 to 800 gpd/ft^2 (8,000 to 32,000 L/d/sq m)
Maximum solids loading[2]:	
Primary sludge	22 lb/d/ft^2 (107 kg/d/sq m)
Trickling filter sloughings	8 lb/d/ft^2 (39 kg/d/sq m)
Waste-activated sludge	4 lb/d/ft^2 (19.5 kg/d/sq m)
RBC sloughings	8 lb/d/ft^2 (39 kg/d/sq m)
Primary w/chemical addition	6 to 12 lb/d/ft^2 (29 to 59 kg/d/sq m)
Primary plus trickling filter sloughings	15 lb/d/ft^2 (73 kg/d/sq m)
Primary plus waste-activated sludge	8 lb/d/ft^2 (39 kg/d/sq m)
Primary plus RBC or packed tower sloughing	13 lb/d/ft^2 (63 kg/d/sq m)
Shape	Circular
Minimum side water depth	10 ft (3 m)
Minimum detention time	6 hours
Minimum floor slope	2:8:1 to 12:1 (vert:horiz)
Minimum number of tanks[3] (unless alternate means are available for thickening or storing sludge)	2
Minimum angle between hopper wall and horizontal plane	60 degrees
Type of outlet weir	V-notch plate (adjustable-set level to accuracy of 0.001 ft (0.3 mm).
Inlet baffle (design to prevent trappings of scum)	Use concentric baffle and extend 3 to 6 ft (0.9 to 1.8 m) below surface around central inlet pipe.
Minimum freeboard	18 in. (450 mm).
Sludge collection and stirring mechanism	Use rotary scraper collector with pickets on arms (tip speed as recommended by manufacturer). Consider variable speed drive.

Table 34 (Continued)
Design Criteria for Gravity Thickening Tanks

[1]Solids loading is the more critical design parameter.
[2]Expressed as pounds of dry solids per day per square foot of thickener tank area ($lb/d/ft^2$ [kg/d/sq m]). To achieve maximum solids concentration in thickener underflow, feed to the thickener should be dilute (concentration of primary plus secondary sludge not exceeding 3500 to 5000 mg/liter).
[3]Design thickener to accommodate total solids load with one thickener out of service.

Table 35
Centrifuge Thickening Performance of Waste-Activated Sludge

Type of Centrifuge	Maximum Flow Rate (gpm [L/s])	Solids Capture (%)	Maximum Cake Solids Content (%)	Remarks
Disc w/nozzle discharge	200 to 300 (12.6 to 18.9)	85 to 90	5 to 6	Needs prescreening to limit incoming particles to 60 mesh or smaller.
Imperforate basket w/knife	50 (3.2)	85 to 90	9 to 11	Automated batch operation.
Solid bowl scroll type	100 to 150 (6.3 to 9.5)	85 to 90	4 to 9	Concurrent and counter-current flow types available. Polymer use can be minimized w/recent designs.

8.2.2.3 <u>Other Design Details</u>. In cold climates provide cover for thickener and insulate thickener walls (buried tank, foam, or equivalent) to minimize freezing problems and conserve energy in subsequent anaerobic digester heating. Provide means of diluting feed sludge with service water or provide chlorine addition to thickener feed to control sludge floating and odors. Provide means of removing scum from thickener and return to treatment process or direct waste to sludge digestion or sludge disposal. For additional design criteria, consult WPCF MOP 8 and EPA 625/1-79-011.

8.2.3 Centrifuge Thickening. Typical performance of thickening waste-activated sludge by centrifuge is given in Table 35. Determine optimum design criteria by pilot testing, in consultation with the manufacturer. Refer to EPA 625/1-79-011.

8.3 Stabilization. Methods of stabilization by anaerobic digestion, aerobic digestion, lime stabilization, composting, and other processes are described in paragraph 8.3.1.

8.3.1 Anaerobic Digestion. A well operated anaerobic digester will achieve 40 to 50 percent volatile solids reduction, producing a stable sludge of 5 to 8 percent solids which dewaters readily on sand beds, but may be difficult to dewater mechanically.

8.3.1.1 Design Criteria. Provide two tanks, each designed as a high rate digester (see Table 36 for design criteria). Operate in series, with primary operating as high rate digester and secondary operating without heating or mixing to provide gas and supernatant separation and gas and sludge storage. Secondary tanks without heating and mixing should be considered where at least two primary digester tanks are required (larger installations). Secondary digester volume should be equal to primary digester volume. In this situation, fixed covers on primary digester tanks should be considered, but floating or gas holder covers should be provided on secondary tanks. For larger plants (>5 Mgd [19 ML/d]) where gas storage is required, consider using separate gas storage vessel in lieu of gas holder covers. Economics will dictate choice.

8.3.1.2 Heating

a) Requirements. Provide sufficient heat to maintain design temperature. Insulate digester to minimize heat losses. Use methods of calculation outlined in WPCF MOP 8.

b) Method. Use external sludge heat exchanger, either with self contained water heater or in conjunction with a boiler. Design boiler exchanger system to temper boiler output 180 to 190 degrees F (82 to 88 degrees C) with recycled, spent heating water to give 140 to 145 degrees F (60 to 63 degrees C) water temperature in exchanger.

c) Fuels. Use digester gas as primary fuel source (unless this is unreliable or uneconomical) with a fuel oil or natural gas standby source.

Table 36
Design Criteria for Anaerobic Digesters

Design Item	Criteria
Allowable average 24-hour solids loading	0.13 lb VSS/ft^3/day (2 kg VSS/cu m/day).
Primary digester retention time	15 to 20 d at 4% or greater feed solids concentration and maximum solids load.
Depth: diameter ratio	Consult mixing equipment manufacturer.
Mixing	Design to provide complete mixing. Choose between internal gas mixing, internal mechanical mixing, and external pumped circulation.
Operating temperature	Design to maintain digester contents at 90 to 95 degrees F[1] (32 to 35 degrees C).
Cover	Use floating cover with liquid level indicator and high and low level alarms.
Minimum freeboard	2 ft (0.6 m), if diameter <50 ft (<15 m); otherwise 2.5 ft (0.8 m).
Number of manholes in cover (30-in. diam [760-mm diam])	2, if diameter <40 ft (<12 m); otherwise 3. One shall be large enough to permit use of grit removal equipment inside tank.
Number of sampling wells	2, if diameter <50 ft (<15 m); otherwise 3.
Minimum slope of tank bottom	1:4 (vert:horiz).
Number of supernatant drawoff pipes (digester to be operated as secondary)	3.
Character of raw sludge	Thoroughly mixed, not less than 4% solids.
Location of sludge inlet	Provide one inlet if digesters <25 ft (<7.6 m) diameter and two inlets for larger tanks. Discharge raw sludge to zone of most active digestion and mixing. In unmixed digesters, feed sludge above high water level to break up scum.
Sampling	Provide connections for sampling all supernatant and sludge drawoffs. Also provide connection to sample raw sludge.
Flushing	Provide flushing water connection near bottom of tank.
Access	Provide 30-in. (760-mm) diameter manhole in tank sidewall, with cover. Provide two or three gastight and watertight access manholes on top of tank.
Overflow	Provide a positive overflow.

[1]Where lower design temperature is used, increase digester volume by 25% for each 10 degrees F (3 degrees C) reduction in design temperature.

8.3.1.3 Gas Utilization. Average gas production will vary from 0.7 to 1.0 ft^3/c/d (0.02 to 0.03 cu m/c/d) or 16 to 18 ft^3/lb (1 to 1.1 cu m/kg) of VSS destroyed, depending on the type of treatment, the degree of digestion, and the volatile solids in the raw sludge. Where garbage grinding is practiced, production will increase in proportion to the increase in suspended solids. Use an average fuel value of 640 Btu/ft^3 (24,000 kJ/cu m). For systems using gas as fuel for heating and power generation, refer to MIL-HDBK-1003/6, Central Heating Plants and MIL-HDBK-1003/7, Steam Power Plants - Fossil Fueled. Gas collection and transmission design data are as follows:

a) Pressure. Maintain the system pressure at least 2 inches of water above atmospheric pressure. Provide pressure and vacuum relief valves in the digester cover. Set the limits below the inward and outward design pressures used for designing covers, piping, and similar items.

b) Gas Piping. For interior and exterior gas piping criteria, see MIL-HDBK-1003/8A, Exterior Distribution of Steam, High Temperature Hot Water, Chilled Water, Natural Gas, and Compressed Air. Arrange piping and gas storage so that when digester liquid volume is changed, air will not be drawn into digester and gas will not be lost by displacement.

c) Sediment Traps. For separating contaminants carried from the digester with the gas, provide at least one trap between the digester and the rest of the gas system. Locate a trap at the lowest point in adjacent lines.

d) Condensate Traps. Supply condensate traps as adjuncts to sediment traps and at all low spots in piping. Manually-operated drip traps are mandatory. Float-operated drip traps are not acceptable.

e) Flame Traps. Use traps to separate digesters, and all points of use and waste gas burners, from the gas piping system.

f) Pressure Regulators. Provide pressure regulators before the flame trap assembly on the plant utilities service gasline.

g) Pressure Reliefs. Provide these ahead of each required flame trap. Vent to the outside atmosphere.

h) Meters. Provide for metering gas production even if the gas is wasted. Gas production is an indicator of digester conditions. Meter standby gas source.

i) Gas Domes. Position the domes high enough to provide clearance of 24 inches (600 mm) between the gas drawoff and the surface of the digester contents.

j) Waste Gas Burner. Use pilot operated type of burner with adjustable shutter type air intake for proper air/gas mixture.

k) Pressure Relief and Vacuum Breaker Valve With Flame Arrestor. Provide a valve on top of the digester cover for protection against excessive pressure and vacuum and to eliminate accidental ignition of sludge gas within the digester.

l) Flame Check. Use a flame check to prevent flashback on small pipelines carrying flammable gases (install in pilot lines of waste gas burners).

m) Back-Pressure Check Valves. Use for low pressure gaslines where minimum pressure drop and maximum flow capacity are required. Install downstream of meters and at other locations such as bypass lines where backflow of gas is detrimental to the operation of the system.

n) Pressure Indicators. Use manometer pressure gauges to indicate gas pressures in lines from digesters and lines leading to utilities and waste gas burner.

o) Gas Purifier. Install a purifier immediately downstream of the digester to remove corrosive and odorous hydrogen sulfide from sewage gas.

p) Explosion Relief Valves. Use valves to provide emergency excess pressure relief in gaslines leading to waste gas burners and boilers.

q) Location. Where possible, segregate gas equipment piping and appurtenances in a separate structure at ground level with an outside entrance only. Waste gas burner stack should be higher than and away from adjacent structures. Locate burner at least 50 feet (15 m) away from digester cover or gas holder.

8.3.2 Aerobic Digestion. Well-operated digesters will achieve 40 to 50 percent volatile solids reduction, producing a stable sludge of 2 to 3 percent solids which exhibits no obnoxious odors and dewaters readily on sand beds, but may be difficult to dewater mechanically. See Figure 31 for details.

8.3.2.1 Design Criteria. Refer to Table 37. Design tankage and sludge age requirements should consider extent and severity of cold weather operations and resulting digester mixed liquor temperature.

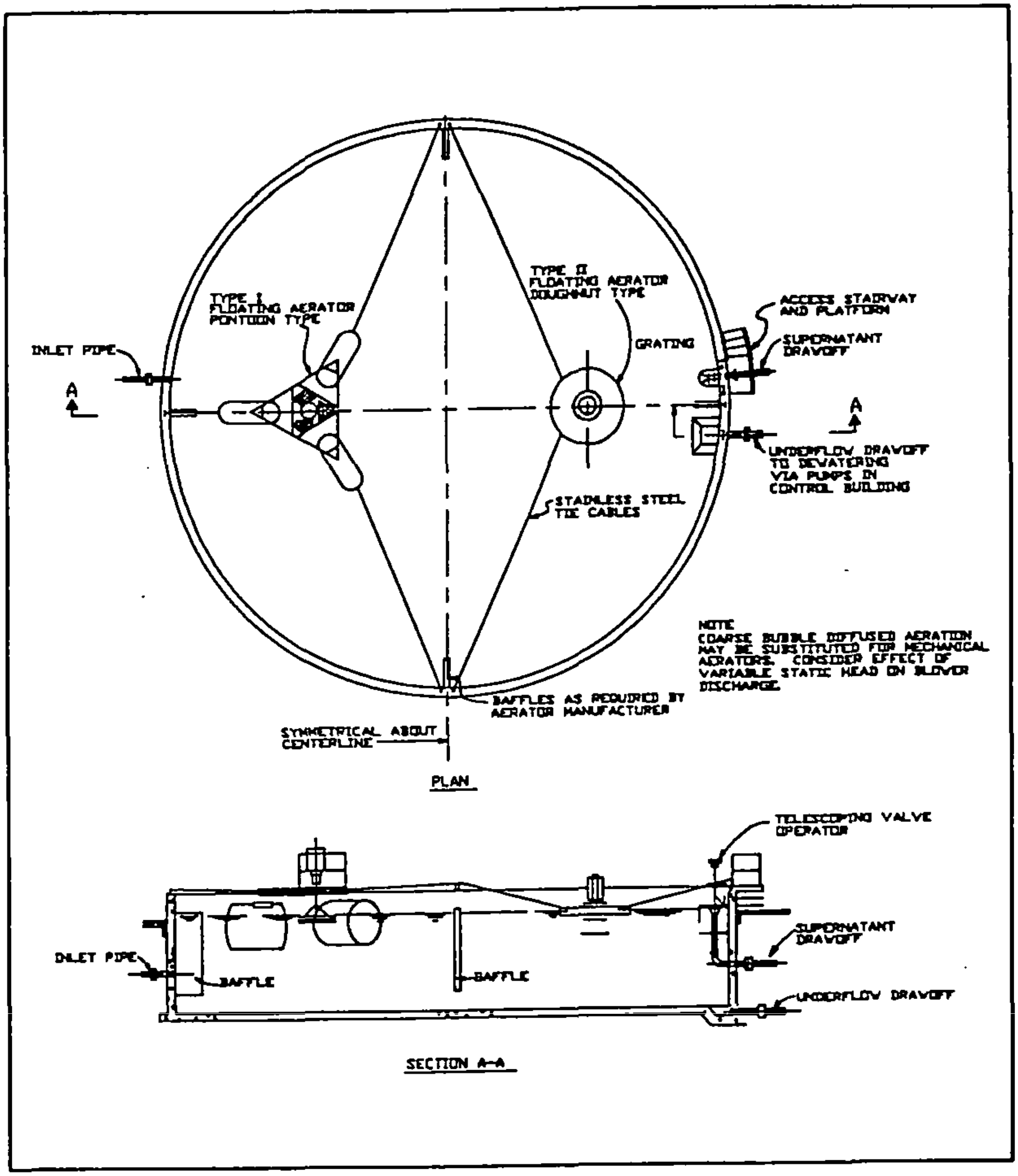


Figure 31
Aerobic Sludge Digestion

Design sludge age values for digestion of waste-activated sludge only or waste-activated sludge from systems without primary clarification, extended aeration and contact stabilization, should consider the operating sludge age of the mixed liquor to determine degree of stabilization in the aerobic digester. Extended aeration plans, operated at high sludge age (>30 d) may not require separate sludge stabilization.

8.3.2.2 Standby. Mechanical requirements are the same as for aerators except that a single tank may be used.

8.3.2.3 Method of Decanting. For small digesters, decant intermittently by shutting off air for 1 or 2 hours and siphon off supernatant or withdraw by telescoping valves. On large tanks, use automatic decant and separate thickening with sludge recycle.

8.3.2.4 Additional Considerations. For additional design considerations, see EPA 625/1-79-011.

8.3.3 Lime Stabilization. Lime stabilization reduces odors and odor production potential, reduces pathogen levels, and alters dewatering, settling, and chemical characteristics of sludges. Lime stabilization can be applied to raw primary or secondary sludge, digested sludge, or sewage.

a) Design Criteria. Perform bench scale or pilot plant studies to determine design criteria for lime dosage. The design objective is to maintain pH 12, more or less, for 2 hours, and pH 11, more or less, for several days, to allow sufficient time for disposal.

b) Lime Characteristics. For feeding and handling, refer to Section 10.

c) Mixing Tank. Design the tank to operate as a batch process, and provide at least a 30-minute contact time.

d) Reference. For additional design considerations, refer to EPA 625/1-79-011.

8.3.4 Composting. Composting reduces sludge organic constituents to relatively stable humus-like material and eliminates pathogenic organisms. Composted sludge is a good soil conditioner. Design and operating parameters vary with the nature of sludge material to be composted and the type of equipment used. Composting techniques include window, aerated static pile, or confined processes (rotating drums, towers, or tanks). Consult the manufacturer for design details. For additional information, refer to EPA 625/1-79-011.

Table 37
Design Criteria for Aerobic Digesters

Design Item	Mixture of Primary and Biological Sludges[1]	Waste-Activated Sludge
Allowable maximum 24-hour solids loading	0.10 lb VSS/ft^3/d (1.6 kg VSS/cu m/d)	0.12 lb VSS/ft^3/d (1.9 kg VSS/cu m/d)
Volumetric detention time[2]	20 days	15 days
Sludge age[3]	25 to 30 days	15 to 20 days
Solids concentration in digester (by weight)	3 to 6%	0.5 to 1.0%
Maximum tank depth	15 ft (4.6 m)	15 ft (4.6 m)
Air requirements[4]	2.0 lb O_2/lb VSS (2 kg O_2/kg VSS) destroyed	2.0 lb O_2/lb VSS (2 kg O_2/kg VSS) destroyed
Method of aeration	Diffused air or mechanical (see Table 31)	Diffused air or mechanical (see Table 31)

[1]Waste-activated or trickling filter sludge.
[2]Ratio of digester volume to sludge volume added daily.
[3]Ratio of weight of volatile solids in digester to weight of volatile solids removed daily.
[4]Normally 25 to 30 ft^3/min/1000 ft^3 (400 to 500 L/s/1000 cu m) of digester volume is minimum air requirement for mixing. Design aeration system to provide this air rate as a minimum.

8.3.5 <u>Other Processes</u>. Other methods for stabilizing sludges include thermal stabilization, chlorine stabilization, and high energy irradiation. These processes are generally not practical for Navy facilities and should only be considered when definite treatment and economic advantages can be realized.

8.3.5.1 <u>Thermal Stabilization</u>. Applying heat to sludge can effectively reduce the number of pathogenic organisms as well as stabilize, improve treatability, and reduce sludge mass. Thermal stabilization is very energy intensive.

8.3.5.2 Chlorine Stabilization. Chlorine stabilization reduces putrescibility and pathogen concentration. The process consumes large amounts of chlorine, requires special safety and handling facilities, and produces a low pH, stabilized sludge that may require neutralization because of its corrosive nature, depending on final disposal.

8.3.5.3 High Energy Irradiation. Wastewater sludges can be disinfected by beta rays (high energy electrons) or gamma rays (high energy photons). High energy radiation of sludge is presently considered a developing technology.

8.4 Conditioning. Alternative means for conditioning sludge prior to dewatering and disposal area are defined in paragraphs 8.4.1 and 8.4.2.

8.4.1 Chemical Conditioning. Polymers are more expensive than metal salt coagulants, but polymers are preferable because they create fewer chemical handling problems. Use polymers for chemical conditioning of sludges whenever field, pilot plant, or bench test experience support their performance. Use ferric chloride or lime prior to vacuum filtration or pressure filtration. Use polymers for centrifuge belt filter press dewatering of sludge and for enhancing sand bed dewatering. Consult with polymer manufacturers for recommendation on polymers for a particular sludge. Estimate alternative polymer types and dosages by laboratory tests, and determine optimum polymer and dosage when plant is in operation. Typical chemical dosages for preliminary evaluation of centrifuge or vacuum filter operation are given in Table 38. Maximum dosages may be 50 to 100 percent greater. Polymer dosages for belt filter press dewatering are listed in Table 41 of paragraph 8.5.3. Refer to paragraph 8.5 for chemical feeding and handling.

8.4.2 Other Conditioning Processes. Other conditioning processes available are thermal conditioning, elutriation, freeze-thaw, and mechanical screening and grinding. These processes are generally not practical for Navy facilities and should only be considered where definite treatment and economic advantages can be realized.

8.4.2.1 Thermal Conditioning. This process involves heating of wastewater sludges to temperatures of 350 to 400EF (177 to 204EC) in a reaction vessel under pressures of 250 to 400 psig (1,700 to 2,800 kPa). This process is complex to operate, capital costs are high, and highly concentrated sidestreams (liquids and gases) are produced which require further treatment.

Table 38
Typical Chemical Requirements for Centrifuge and Vacuum Filter Dewatering[1]

Type of Sludge	Ferric Chloride[2]	Lime[2]	Polymer[3]
Raw primary	20 to 80 (10 to 40)	0 to 200 (0 to 100)	2 to 5 (1 to 2.5)
Raw waste-activated sludge	120 to 200 (60 to 100)	0 to 320 (0 to 160)	8 to 25 (4 to 12.5)
Mixed raw primary and trickling filter secondary[4]	40 to 160 (20 to 80)	0 to 300 (0 to 150)	4 to 10 (2 to 5)
Mixed raw primary and activated sludge secondary	50 to 160 (25 to 80)	0 to 320 (0 to 160)	4 to 15 (2 to 7.5)
Digested primary	40 to 100 (20 to 50)	60 to 260 (30 to 130)	3 to 10 (1.5 to 5)
Digested mixed primary and trickling filter secondary[4]	80 to 160 (40 to 80)	100 to 350 (50 to 175)	6 to 15 (3 to 7.5)
Digested mixed primary and activated sludge secondary	80 to 200 (40 to 100)	100 to 420 (50 to 210)	5 to 20 (2.5 to 10)

[1]Expressed as pound of chemical per ton of feed sludge dry solids (lb/tds) [kg of chemical per ton of feed sludge dry solids (kg/tonne)].
[2]Prior to vacuum filter.
[3]Prior to centrifuge only. Not applicable to vacuum filter.
[4]RBC and trickling filter sloughings have approximately the same chemical conditioning requirements.

8.4.2.2 Elutriation. Elutriation involves washing anaerobically digested sludge prior to inorganic chemical conditioning and dewatering to reduce alkalinity and chemical conditioning requirements and enhance dewaterability. The process is not used as extensively as it had been because a high percentage of the digested solids (10 to 45 percent) can be washed from the incoming sludge stream and returned to the treatment process. The process is not applicable to sludges conditioned with polymer.

8.4.2.3 Freeze-Thaw. Freeze conditioning of sludges has not been popular in the United States. The process is expensive to operate because of the energy costs involved.

8.4.2.4 Mechanical Screening and Grinding. Screening and grinding can be beneficial to some sludge handling processes. Screening will remove large solids and fibrous material that could clog dewatering equipment. Grinding of a thick sludge stream reduces viscosity making the slurry easier to pump.

8.5 Dewatering. Design criteria for vacuum filter, centrifuge, belt filter press, sand bed, and lagoon dewatering are presented below. For additional design details, refer to EPA 625/1-87-14, Dewatering Municipal Wastewater Sludges.

8.5.1 Vacuum Filter. Vacuum filters achieve high solids capture (90 to 99 percent, depending on filter media and conditioning). Dewatering depends on sludge feed concentration and the filter rate. Typical dewatering performance of a well operated vacuum filter is given in Table 39.

8.5.1.1 Design Criteria

a) Filter Media. Choose between cloth and coil spring filter media.

b) Filter Rate. Consult with the manufacturer. Where sludge samples are available, run filter leaf tests to determine optimum conditioning chemical and dosage and filter yield.

c) Operating Time. Limit running time to 30 hours per week (h/wk) based on 5 days at 6 hours per day to allow for daily cleanup and maintenance.

d) Standby Provision. For small plants, use single filter and provide sludge storage capacity to cover a 7-day outage of filter. Otherwise, use two filters, together capable of handling total sludge load when running 30 h/wk.

8.5.1.2 Appurtenances. Vacuum pumps, receivers, and filtrate pumps will be supplied by the filter manufacturer. Provide two vacuum and two filtrate pumps (one of each as standby). Standby pump may be an uninstalled unit if an installed unit can be easily removed and replaced.

Check head and storage required for recycle of filtrate to wastewater treatment system.

Table 39
Typical Vacuum Filter Performance

Type of Sludge	Sludge Feed Concentration (%)	Filter Yield[1]		Cake Solids Concentration (%)
		Coil Spring Filter Media (lb/h/ft^2 [kg/h/sq m])	Cloth Filter Media (lb/h/ft^2 [kg/h/sq m])	
Raw primary	4.5 to 10	6.5 to 8 (32 to 39)	3.5 to 8 (17 to 39)	27 to 35
Raw waste-activated sludge	2.5 to 4.5	2 (10)	1 to 3 (5 to 15)	13 to 20
Raw trickling filter secondary[3]	4 to 6	6 to 8 (29 to 39)	3 to 5 (15 to 24)	20 to 28
Mixed raw primary and trickling filter secondary[3]	4 to 8	6 to 8 (29 to 39)	3 to 6 (15 to 29)	23 to 30
Mixed raw primary and activated sludge secondary	3 to 7	2.5 to 4 (12 to 19.5)	2.5 to 6 (12 to 29)	18 to 27
Digested primary	4 to 8	4 to 8 (19.5 to 39)	3 to 7 (15 to 34)	25 to 32
Digested mixed primary and trickling filter secondary[3]	5 to 10	4 to 6 (19.5 to 29)	3.5 to 8 (17 to 39)	20 to 27
Digested mixed primary and activated sludge secondary	3 to 7	3.5 to 4.5 (17 to 22)	2 to 5 (10 to 24)	18 to 25

Table 39 (Continued)
Typical Vacuum Filter Performance

[1]Expressed as pounds of dry cake solids per hour per square foot of media area (lb/h/ft^2) [kilograms of dry cake solids per hour per square meter of media area (kg/h/sq m)].
[2]Use cloth media.
[3]RBC and trickling filter sloughings have approximately same dewatering characteristics.

a) Cake Handling. Provide for the loading of trucks to carry cake to the disposal site. Use one of the following methods:

(1) an elevated storage hopper, with sludge raised by belt, bucket elevator, or tubular conveyors (maximum inclination on belt conveyors, 25 degrees);

(2) an elevated filter discharging directly to the hopper; or

(3) dump boxes, to be dropped off and picked up by a self-loading vehicle.

b) Wash Water. Consult manufacturer for wash water requirements.

c) Chemical Handling and Feed System. Refer to Section 10.

8.5.2 Centrifuge. Typical centrifuge performance is given in Table 40. Solid bowl centrifuges typically have better dewatering performance than imperforate basket centrifuges.

8.5.2.1 Design Criteria

a) Loading. Consult manufacturer for optimum loading. Specify guaranteed performance for cake solids and polymer requirements.

b) Operating Time. Limit running time to 30 h/wk based on 5 days at 6 hours per day to allow for maintenance and cleanup.

c) Standby Provision. For small plants, use single centrifuge and provide sludge storage capacity sufficient to cover a 7-day outage of the centrifuge. Otherwise, use two or more centrifuges, together capable of handling total load when running 30 h/wk. Backup unit may be uninstalled if installed unit can be easily removed and replaced.

Table 40
Typical Centrifuge Dewatering Performance

Type of Sludge	Typical Operating Results			
	Solid Bowl		Imperforate Basket	
	Cake Solids[1] (%)	Solids Recovery (%)	Cake Solids[1] (%)	Solids Recovery (%)
Raw primary	25 to 36	90 to 95	25 to 30	95 to 97
Raw water-activated sludge	8 to 12	85 to 90	8 to 10	90 to 95
Mixed raw primary and trickling filter secondary[2]	20 to 26	80 to 95	7 to 9	94 to 97
Anaerobically digested mixed primary and trickling filter secondary[2]	15 to 22	85 to 90		
Mixed raw primary and activated sludge secondary	18 to 25	90 to 95	12 to 14	90 to 95
Anaerobically digested mixed primary and activated sludge secondary	15 to 20	90 to 95	8 to 12	85 to 95
Anaerobically digested primary	25 to 35	95+	16 to 25	
Aerobically digested activated sludge secondary	8 to 10	90 to 95	8 to 14	90 to 95

[1]Expressed as percent by dry weight of cake.
[2]RBC and trickling filter sloughings have approximately same dewatering characteristics.

8.5.2.2 Appurtenances. Most appurtenances will be supplied by the manufacturer.

a) Cake Handling. Refer to paragraph 8.5.1, Vacuum Filter.

b) Wash Water. Consult manufacturer for wash water requirements. Provide for wash water return to treatment processes.

c) Chemical Handling and Feed Systems. Refer to Section 10.

8.5.3 Horizontal Belt Filters. Belt filter presses employ continuous single or double moving belts to dewater sludges and can achieve high solids capture of 90 to 99 percent. Values greater than 95 percent should not normally be used for design purposes unless supported by pilot plant studies. Typical belt filter performance is given in Table 41. Variations in performance are wide because of differences in equipment design. See manufacturer equipment literature for details of specific belt filter presses.

8.5.3.1 Design Criteria

a) Loading. Consult manufacturer for optimum loading. Specify guaranteed performance for filter yield, cake solids, percent solids capture, and polymer dosage. Conduct on-site pilot plant or bench scale dewatering tests.

b) Operating Time. Limit running time to 30 h/wk (5 days at 6 h/day) to allow for maintenance and cleanup.

c) Standby Provision. For small plants, use a single centrifuge and provide a sludge storage capacity sufficient to cover a 7-day outage of the filter. Otherwise, use two or more filters which together are capable of handling total load when running 30 h/wk.

8.5.3.2 Appurtenances. Most appurtenances will be supplied by the manufacturer.

a) Cake Handling. Refer to paragraph 8.5.1, Vacuum Filter.

b) Wash Water. Consult manufacturer for wash water requirements.
Provide for wash water return to treatment processes.

c) Chemical Handling and Feed Systems. Refer to Section 10.

Table 41
Typical Horizontal Belt Filter Performance

Type of Sludge	Feed Solids (%)	Cake Solids[1] (%)	Polymer Dose[2] (lb/tds [kg/tonne])
Raw primary	3 to 10	28 to 44	2 to 9 (1 to 4.5)
Raw waste-activated sludge	1 to 3	12 to 28	2 to 4 (1 to 2)
Mixed raw primary and activated sludge secondary	3 to 6	20 to 35	2 to 10 (1 to 5)
Mixed raw primary and trickling filter secondary[3]	3 to 6	20 to 40	3 to 10 (1.5 to 5)
Anaerobically digested primary	4 to 10	26 to 36	2 to 6 (1 to 3)
Anaerobically digested mixed primary and activated sludge secondary	3 to 9	12 to 25	4 to 9 (2 to 4.5)
Anaerobically digested mixed primary and trickling filter secondary[3]	3 to 9	20 to 35	3 to 9 (1.5 to 4.5)

[1]Expressed as percent by dry weight of cake.
[2]Expressed as pound of chemical per ton of feed sludge dry solids (lb/tds) [kilogram of chemical per tonne of feed sludge dry solids (kg/tonne)].
[3]RBC and trickling filter sloughings have approximately the same dewatering characteristics.

8.5.4 Pressure Filter (Filter Press). Pressure filtration is applicable to sludges that dewater poorly (such as waste-activated sludge) or when it is necessary to dewater a sludge to greater than 30 percent solids (such as for incineration, long cake hauling distances, or stringent landfill disposal moisture requirements). Do not consider pressure filters except under these above conditions. Two types of filter presses are available: the fixed volume, recessed plate filter press and the variable volume, diaphragm filter press. Both types require batch operation which can be automated for large plants. Typical dewatering performance for both types of pressure filters is given in Table 42. Capital costs for filter press installations are very high. Conditioning chemical requirements (usually lime and ferric chloride) are 5 to 20 percent of feed solids and are usually a significant percentage of cake volume and dry weight for haul and disposal. Polymer conditioning instead of lime and iron salts conditioning significantly reduces cake production but has not generally been successful and is not recommended at Navy installations.

8.5.4.1 Design Criteria. Consult technical literature of the equipment manufacturer for details and specifications.

a) Loading. Consult manufacturer for optimum loading and conditioning chemical requirements. Perform on-site pilot plant or bench scale testing. Specify guaranteed performance for filter yield, cake solids content, and chemical conditioning requirements.

b) Operating Time. Limit running time to 30 h/wk (5 days at 6 h/day) to allow for maintenance and cleanup.

c) Standby Provision. For small plants, use single filter press and provide sludge storage capacity sufficient to handle a 7-day outage of the pressure filter. Otherwise, use two or more pressure filters which are together capable of handling the total design load when running 30 h/wk.

d) Chemical Conditioning. Use lime or ferric chloride.

8.5.4.2 Appurtenances. The feed pump systems and their appurtenances will normally be supplied by the manufacturer.

a) Cake Handling. Refer to paragraph 8.5.1.2. Cake must normally be broken by falling against wire rope. Bucket elevators or tubular conveyors may not be applicable unless cake is pulverized.

b) Wash Water. Consult manufacturer for wash water requirements.

c) Chemical Handling and Feed Systems. Refer to Section 10.

Table 42
Typical Pressure Filter Performance

Type of Sludge	Cake Solids[1]		
	Feed Solids (%)	Fixed Volume Filter (%)	Diaphragm Filter (%)
Raw primary	3 to 10	40 to 50	45 to 55
Raw waste-activated sludge	1 to 3	30 to 35	32 to 42
Mixed raw primary and activated sludge secondary	3 to 6	32 to 42	38 to 47
Mixed raw primary and trickling filter secondary[2]	3 to 6	35 to 50	40 to 50
Anaerobically digested mixed primary and activated sludge secondary	3 to 6	32 to 45	36 to 50
Anaerobically digested mixed primary and trickling filter[2]	3 to 6	35 to 45	38 to 48

[1]Expressed as percent by dry weight of cake (includes conditioning chemicals).
[2]RBC and trickling filter sloughings have approximately same dewatering characteristics.

8.5.5 Sludge Drying Beds. Sludge drying beds may be classified as conventional sand media type or filter plate (wedgewire) type. Filter plate beds may be used with or without vacuum assist to drying. Advantages of filter plate type beds are less clogging of media, higher sludge loading rates, easier cleaning and maintenance, better performance on difficult to dewater sludges such as aerobically digested sludge, and less susceptible to poor climatic conditions. The need for covers on sludge drying beds should be determined by climatic conditions.

8.5.5.1 Conventional Sand Media Type. Performance depends on climate and operation, but dry cake solids generally exceed 35 percent by weight. Consider covers or passive solar assistance for sand bed applications in cold climate. See Table 43 for design criteria and appurtenances. See Figure 32 for bed details.

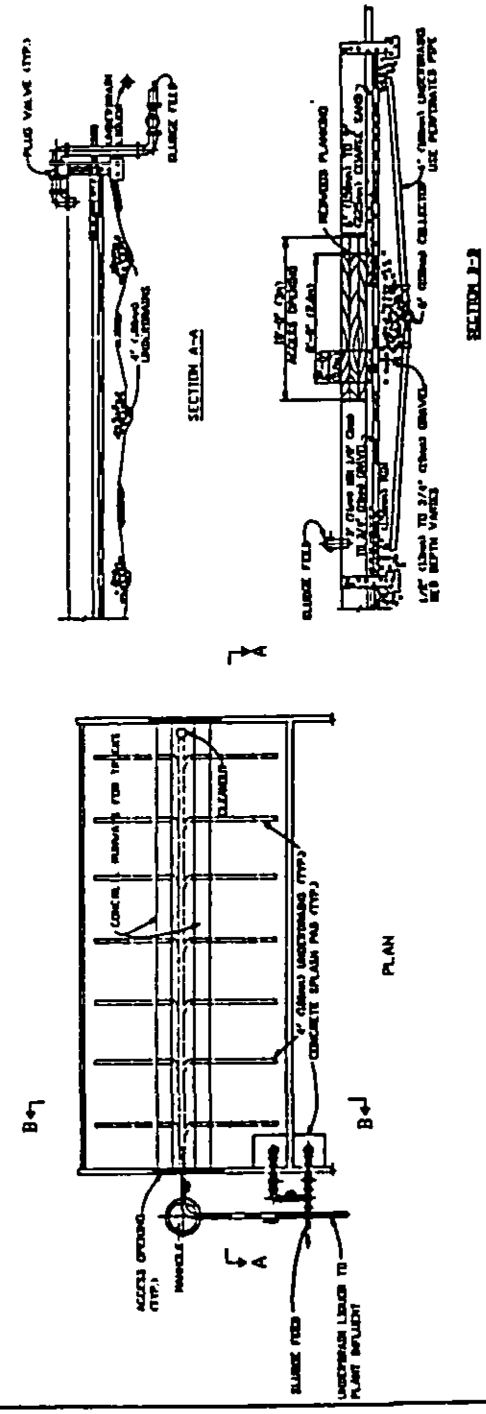


Figure 32
Sand Drying Bed

Table 43
Design Criteria for Sand Drying Beds

Item	Feature	Criteria	Specific Requirements
Location	Proximity to dwellings Proximity to other plant units Truck access Elevation of site	Min 300 ft (91 m) Locate to minimize length of lines Provide where hauling Secure head for gravity discharge to beds (5 ft [15 kPa]), if possible, and from underdrains to plant.	
Rational design (bed area)	Solids quantity (annual) Sludge concentration Depth of application Applications per year	Estimate Estimate Usually 8 in. (200 mm) Average value 8	Based on solids removed in treatment times solids reduction in digestion. Varies widely with local evaporation potentials.
Per capita allowances (bed area, ft^2/c [sq m/c])	Treatment: Primary Trickling filter Activated sludge Chemical coagulation	Open beds: Covered beds: 1.00 (0.09) 0.75 (0.07) 1.50 (0.14) 1.15 (0.11) 2.00 (0.18) 1.50 (0.14) 2.00 (0.18) 1.50 (0.14)	Based on latitudes 40° to 45°. For north of 45°, add up to 50%. South of 40°, deduct up to 50%. With garbage grinding, increase in proportion to the increase in sewage suspended solids allowed, according to criteria in Section 11.
Number of beds	For population: Up to 2,000 2,000 to 5,000 5,000 to 10,000 Over 10,000	Primary treatment: Higher degree treatment: 2 3 4 6 8 12 Minimum as for 5,000 to 10,000 otherwise let bed size govern.	
Media	Graded sand (4-9 in. [100-225 mm]) over graded gravel (8-18 in. [200-450 mm])	Sand effective size = 0.012-0.050 in. (0.3-1.25 mm). Sand uniformity coefficient <5.	

Table 43 (Continued)
Design Criteria for Sand Drying Beds

Item	Feature	Criteria	Specific Requirements
Dimensions	Length	50 to 100 ft (15 to 30 m)	
Construction	Sidewalls, underdrains, gravel, sand, splash block	Refer to NAVFAC P-272, <u>Definitive Designs for Navy and Marine Corps Shore Facilities</u>	
Cake removal	For populations up to 5000.	Use wheelbarrows or end loader on concrete runways.	
	For larger populations.	Provide monorail, track, or runway to permit loading of cars or buckets from anywhere on bed.	
Piping	Slope	1% minimum	
	Size	4 in. (100 mm) minimum	
	Flow control	Use shear gates at discharge	
	Disposal of underflow	Return to plant	
	Underdrain spacing	20 ft (6 m) maximum	
Enclosures	Wall height	About 18 in. (450 mm)	
	Ventilation	Use two rows of side sash windows with lower row opening in and upper row opening out.	
	Material	Glass or fiberglass	Fiberglass is considerably more expensive but is unbreakable.
	Dimensions	Request bids on general area requirements and approximate dimensions desired. Adopt successful bidder's standard width, length, truss spacing, and so forth.	

8.5.5.2 <u>Filter Plate Type</u>. Filter plates have openings of about 0.01 inch (25 mm) to retain solids. Sludge is applied directly to filter plate. Drainage may be by gravity or with vacuum assist. Contact media/plate manufacturer for design sludge loading rates and expected performance for sludge type and climate. See Figure 33 for details of vacuum assisted filter plate drying bed.

As a minimum, provide dual vacuum pumps and filtrate pumps for each unit capable of handling the design flow. Oversize the vacuum pumps to allow for small air leaks in the vacuum collection system. Provide vacuum gauge and check valve on vacuum side of pump. Vacuum pumps should be positive displacement type capable of handling liquid and soft solid carryover.

8.5.6 Lagooning. Performance depends on climate and operations, but cake solids generally in excess of 25 percent by weight. For design criteria, refer to EPA 625/1-79-011.

8.6 Sludge Storage. Criteria for storing sludge in lagoons, in concrete tanks, and within the wastewater and sludge treatment processes are listed in paragraphs 8.6.1, 8.6.2, and 8.6.3.

8.6.1 Lagoon Storage

8.6.1.1 Location. Adjacent to treatment operation to minimize pumping requirements.

8.6.1.2 Design Criteria

a) Annual loading rate. Less than 20 lb VSS/1,000 ft^2/d (98 kg VSS/1000 sq m/day).

b) If sludge is to be reused, provide 2- to 3-year storage for adequate pathogen die-off.

c) Surface agitation. Provide surface agitation equipment to maintain scum free surface conditions.

d) For further design considerations, refer to EPA 625/1-79-011.

8.6.2 Concrete Storage Tank

a) Location. Adjacent to treatment operation to minimize pumping requirements.

b) Type. Use cylindrical tanks.

c) Sizing. Provide 4-day minimum detention.

d) Bottom slope. Minimum of 1 to 4.

e) Side water depth. Minimum of 8 feet (2.4 m).

f) Freeboard. Provide a minimum of 1.5 feet (0.5 m).

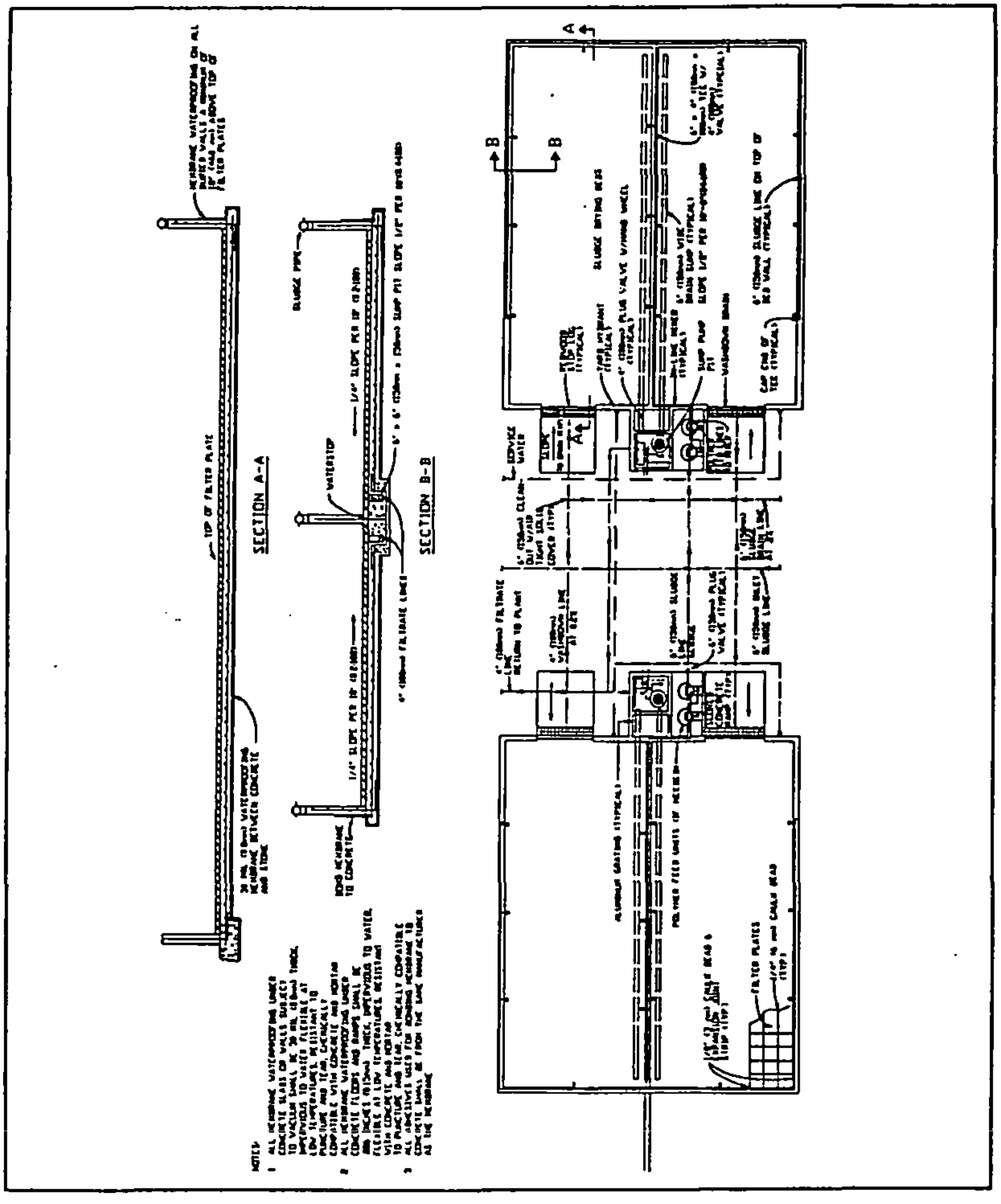


Figure 33
Vacuum-Assist Filter Plate Type Drying Beds

g) Cover. Provide floating cover where gas release would be objectionable.

h) Mechanical mixing. Provide prior to mechanical dewatering operations.

i) Decant lines. Provide decant lines where mixing is not required.

8.6.3 In-Plant Storage. Wastewater and sludge treatment facilities can also be utilized for limited sludge storage. The use of in-plant storage must not impair the treatment capabilities of the wastewater and sludge treatment facilities. Table 44 lists the treatment processes that can be used for sludge storage. For additional information, consult EPA 625/1-79-011.

Table 44
In-Plant Sludge Storage Alternatives

Method of Storage	Storage Period[1]			Comments
	Equalizing	Short-Term	Long-Term	
Storage within wastewater treatment processes:				Use of wastewater treatment processes for storage must not adversely affect treatment efficiency.
Grit removal tanks	X	N/A	N/A	Storage time depends on sewer system grit loading to plant.
Primary clarifiers	X	N/A	N/A	Temperature sensitive. Storage for over 24 hours may cause odors and floating sludge and require chemicals.
Aeration basins	X	X	N/A	Storage within extended aeration systems (oxidation ditches) can exceed 3 weeks if sludge settles well and secondary clarifier thickening criteria are not exceeded.
Secondary clarifiers	X	N/A	N/A	Sensitive to temperature and secondary treatment process type. Storage for over 8 hours requires chemical addition and is not recommended.
Imhoff tanks	X	X	X	Lightly loaded systems can store for 6 months. Most systems will require solids removal every 4 to 6 weeks.

Table 44 (Continued)
In-Plant Sludge Storage Alternatives

Method of Storage	Storage Period[1] Equalizing	Short-Term	Long-Term	Comments
Community septic tanks	-	-	X	Sludge from many septic tanks is removed only once in several years.
Wastewater Lagoons:				
Aerated	X	X	N/A	Aerated lagoons operate like activated sludge aeration reactors and storage is limited to equalizing and short term. Other lagoon process types use two-phase system (aerobic and anaerobic) and can store solids for extended periods.
Aerobic	X	N/A	N/A	
Facultative	X	X	X	
Storage within sludge treatment process				Use of sludge treatment processes for storage must not adversely affect sludge treatment efficiency.
Gravity thickeners	X	N/A	N/A	Temperature sensitive. Usually not used for storage of waste-activated sludge. Storage for over 24 hours may cause odors and floating sludge and require chemicals.

Table 44 (Continued)
In-Plant Sludge Storage Alternatives

Method of Storage	Storage Period[1]			Comments
	Equalizing	Short-Term	Long-Term	
Anaerobic digesters	X	X	X	Floating covers allow for displacement storage. Two-phase concentration storage impracticable if waste-activated sludge separates. Single-phase concentration storage is possible if digester is operated in conjunction with primary clarifier underflow solids concentration changes.
Aerobic digesters	X	X	X	Decanting can limit storage capacity. Short-term storage possible if digesters operated in conjunction with sediment concentration. Displacement storage requires digester aeration system which will operate with variable level (such as floating mechanical aerator).
Composting	-	X	X	Evaporation within process accomplishes two-phase concentration. Processed solids not normally removable for 3 to 4 weeks.
Drying beds	-	X	X	Initial settling accomplishes two-phase concentration. Processed solids not normally removable for 3 to 4 weeks.

[1]Equalizing = 3 to 4 days. Short-term = 10 to 20 days. Long-term = 30 days.

8.7 Sludge Transportation. Sludge transportation for treatment, storage, or disposal can be accomplished by pumping, conveyors, or hauling equipment. All sludge transporting enclosures accessible to personnel or subject to accumulation of explosive gases must be well ventilated.

8.7.1 Process Transport

a) Pumping. Refer to paragraph 5.7 and Table 14 for pumps, valves, and piping guidelines.

b) Conveyors. Use belt, tubular, or screw conveyors for transporting dewatered or dried sludges. Consult manufacturer for design information.

8.7.2 Long Distance Transport. Transport dewatered sludge by truck. Analyze cost effectiveness of transporting liquid sludge by truck versus dewatered cake by truck versus liquid pipeline transfer. Generally, trucking is the least expensive mode for one way distances of 20 miles (32 km) or less and annual sludge volumes less than 10 to 15 Mgal (38 to 57 ML). Pipeline transport is least expensive when annual sludge volume is greater than approximately 30 to 70 Mgal (114 to 265 ML). Cost of cake haul depends on sludge dewaterability, chemical costs and haul distance.

8.7.2.1 Truck. Consult local and state highway and health regulations for sludge hauling.

a) Dried or dewatered sludge. Haul in covered dump-body trucks. Schedule hauling to coincide with dewatering operation.

b) Liquid sludge. Haul in tank-body trucks. Where direct land application is utilized, trucks can be equipped with specifically designed spreaders, auger beaters, subsoil injectors, and other special application apparatus. Consult manufacturer for equipment needed. Schedule hauling and provide storage to accommodate disposal operation.

8.7.2.2 Pipeline

a) Refer to paragraph 5.7.1, Table 14, for pumps, valves, and piping guidelines.

b) If digestion is part of sludge treatment system, pump sludge after digestion.

c) Provide two pipes or use a single pipe and provide sludge storage capacity to cover a 4-day outage of piping system.

d) Design pipeline and appurtenances for inserting and removing a cleaning tool, such as a pig or go-devil.

e) Provide for adding controlled amounts of water for sludge dilution or pipeline flushing. Flushing water should flow at 3 fps (0.9 m/s) minimum.

f) Install air or gas relief valves at high points. Use manual blowoff valves. Use automatic valves with manual blowoff backup for pumping digested sludge only where careful attention will be given to pumping operation and maintenance.

8.8 Ultimate Disposal. Ultimate disposal of wastewater sludge may be by land application, landfill, dedicated land disposal, and product utilization.

8.8.1 Land Application. Sludge can be applied on agricultural land, forested land, or reclaimed land. Liquid sludge can be spread by tank truck, sprayed, injected, or applied by ridge and furrow techniques. Dewatered sludges are applied by conventional fertilizer spreading equipment. Consult state and local environmental regulations for disposal requirements.

a) Apply only stabilized sludge to land.

b) Consult state and local regulations for land application requirements.

c) For site investigation, application rates, preapplication treatment, application mode, storage, and operation guidelines, refer to EPA 625/1-79-011.

d) For sludge containing some industrial wastes from metal plating operations, evaluate allowable metal loading limits for land applications. Refer to MIL-HDBK-1005/9.

8.8.2 Landfill. Sludge landfill methods include sludge-only trench fill, sludge-only area fill, and codisposal with refuse.

a) Consult state and local regulations for landfill regulations.

b) For sludge-only landfills, concentrate sludge to at least 15 percent solids before landfilling. Conform to additional requirements of landfill operator.

8.8.3 Dedicated Land Disposal. Dedicated land disposal is the application of heavy sludge loadings to a defined land area which has limited public access and has been set aside for the disposal of wastewater sludge. Liquid sludge is typically applied to dedicated sites.

a) Apply only stabilized sludge to land.

b) Consult state and local regulations for land application requirements.

c) For guidelines for site selection, storage, application rate and mode, and operation refer to EPA 625/1-79-011.

8.8.4 Product Utilization. Beneficial uses of wastewater sludges include recovery of waste treatment chemicals, landfill toppings, industrial raw materials, and soil conditioning. Sludge product utilization is site specific and sludge specific and its application is very limited.

Section 9: NONWATER CARRIAGE SYSTEM

9.1 Types of Systems. Nonwater carriage systems are primarily applicable to small, isolated facilities where conventional wastewater collection and treatment systems are uneconomical or water supply is severely limited. Types of nonwater carriage systems are listed below. Consult manufacturers for details and design requirements.

9.1.1 Electric Incinerating Toilet. Normally used for single toilet installations. Uses electric power to evaporate and incinerate urine and fecal material.

9.1.2 Chemical Toilets. Used for single or multiple toilet installation. Black water is flushed with chemicals and discharged to a tank which disinfects and retards biological decomposition. The mixture of black water and chemicals is hauled away periodically.

9.1.3 Mineral Oil Type Waterless Flushing Toilet System. These toilets utilize a clear, odorless, nonreactive fluid for flushing. This liquid is used repeatedly for carrying black water to a sealed tank, where wastes are separated from the flushing liquid and stored. Filters and coalescers clean the recycled flushing liquid during recirculation.

9.1.4 Composting Toilet. This type of toilet is waterless and can accept human wastes and other organic matter, such as food wastes. The wastes are contained and composted in a tank or compartment below each toilet. The compartment is vented through the building or enclosure roof by a small fan, which promotes aerobic conditions and removes odors. The composted material is removed periodically and can be used as a soil conditioner.

Section 10: METERING, INSTRUMENTATION AND CONTROL, AND CHEMICAL FEEDING

10.1 Introduction. This section contains criteria on metering, instrumentation, controls, and chemical feeding devices used in wastewater disposal systems. Certain criteria related to the subject matter of this chapter appear elsewhere in this handbook. Refer to Sections 2 through 9 for instrumentation, control, and chemical feeding for selected wastewater treatment unit processes and operations. These criteria indicate simple recommended practices applicable to plants with up to 5 Mgd (19 ML/d) average flow.

10.1.1 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 [38 ML/d] 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 Navy facilities is justified.

10.1.2 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.

10.2 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.

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

10.2.2 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.

10.2.3 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 a simple as possible. Wherever feasible, use fixed or manual controls such as weirs, launders, siphons, or throttling valves, in preference to mechanical devices, and direct acting controls such as floating valves, in preference to electrically or pneumatically actuated devices. Always consider effects of possible control malfunctions.

10.2.4 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.

10.2.5 Equipment Accuracy. Equipment accuracy tolerances shall be as low as possible but consistent with the functions desired.

10.2.6 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.

10.2.7 New Products. New products and applications are constantly being developed. Approval or advice on their uses shall be requested from Naval Facilities Engineering Command Headquarters (NAVFACENGCOMHQ).

10.3 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.

Section 11: WASTEWATER TREATMENT SYSTEMS

11.1 Primary Measuring Devices

11.1.1 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 45. Refer to Table 46 for examples of location of measuring devices and types of measurements for domestic waste treatment systems.

11.1.2 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.

11.1.3 Discrete Versus 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.

11.1.4 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.

11.1.5 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.

Table 45
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-Bowlus)	Plant influent, bypass lines.	Suspended matter does not hinder operation. More costly than weir.	10 gpm (0.6 L/s) and up.	75:1
Weir	Plant influent, plant effluent.	Required free fall for discharge and greater head loss than flume. Influent weirs may plug.	0.5 gpm (0.03 L/s) and up.	100:1 and up
Pressure Pipeline Flow: Differential producers	Filled lines. Fluids under positive heat at all times. Not generally for water supply service.	Impulse lines may clog if used with suspended matter. Consider automatic purging if device must be used in suspended matter.		
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 (0.3 L/s) and up for liquid; 20 ft^3/min (9.4 L/s) and up for gas.	10:1
Orifice plate	Air and gaslines, water except filter effluent.	Clean fluids only. Head loss greater than flow tubes.	0.5 gpm (0.03 L/s) and up for liquid; 5 ft^3/min (2.4 L/s) and up for gas.	4:1
Flow nozzle	Water except filter effluent.	Clean fluids only.	5 gpm (0.3 L/s) and up for liquid; 20 ft^3/min (9.4 L/s) for gas.	5:1
Average pitot tube	Water, air, gas.	Clean fluids only.	Determined by pipe sizes.	3:1
Displacement meters	Plant water and distribution service connection. Plant 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 (0.006 to 568 L/s) for liquid; 0 to 100 ft^3/min (0 to 47 L/s) for gas.	10:1
Target meters	Plant effluent, sludge, dirty fluids.	Suspended matter does not hinder operation.	0.07 gpm (0.004 L/s) and up.	10:1
Velocity meters, propuller meter	Water, clean liquids.	Insertion turbine or full bore types available.	0.001 to 40,000 gpm (0.00006 to 2,500 L/s) for liquids to 10,000,000 ft^3/min (5,000,000 L/s) for gas.	10:1 to 50:1

Table 45 (Continued)
Types of Measuring Devices Applicable to Wastewater Treatment Systems

Primary Measurement and Type of Device	Use Examples	General	Capacity	Range
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.	0.01 to 500,000 gpm (0.0006 to 32,000 L/s).	10:1
Vortex shedding meter, variable area rotameter	Heat exchanger water lines. Gas and gas solution feeders, chemical dilution systems, influent lines to ion exchange units, water and clean liquids.	Suitable for confined piping systems. Available in very small to very large flow rates at lowest cost for flow indicator.	3 to 5,000 gpm (0.2 to 315 L/s). 0 to 4,000 gpm (0 to 252 L/s) for liquids, to 1,300 ft^3/min (610 L/s) for gas.	15:1 5:1 to 12:1
Openflow nozzle	Plant influent or effluent, sludge.	Requires free fall from end of pipeline.	5 to 11,000 gpm (0.3 to 694 L/s).	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, chemical storage tanks, batch tanks, most level applications.	Many types immune to conductive buildup and coating on probe. Continuous or on/off available.		
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. Buildup 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.	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.		-80 to 1,000EF (-60 to 500EC).	10:1
Analytical Instruments: pH	Plant influent or effluent, precipitator, neutralization, oxidation or reduction processes.		0 to 14 units.	

Table 45 (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.	-400 mV to +400 mV.	
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/ozone	Treatment unit effluent.		0 to 2 mg/L.	
Specific ion electrodes	Treatment unit effluent.		0 to 2 mg/L.	
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%.	12:1
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

Table 46
Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout[1]	Range of Measurement	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.		
Lift station wet well	Level	None	Depth of wet well.	Pump on/off.	Automatic (E)
Lift pumps	Running time	Totalizer (O)	At least 2 times maintenance period.	Pump selection.	
Grit Removal:	Weight	Indicator (S)	Estimated grit load in 3 days.		
Primary Treatment:					
Plant influent or effluent	pH	Indicator (O)	0 to 14 units		
	Temperature	Indicator (O)	32 to 100EF (0 to 38EC)	None	
	Flow	Indicator (E) Totalizer (E) Recorder (E)	1 to 4	Chemical feed, recycle flow, disinfection.	Manual (E), proportional-automatic (O).
Bypass lines	Flow	Indicator (E) Recorder (O)	1 to 10		
Influent to individual settling tanks	Flow	Indicator (O)	1 to 4	Influent flow rate.	Manual (O)[2].
Positive displacement sludge pumps	Revolution counter.	Totalizer (O) (E for main sludge disposal stream).	Estimated revolutions in 2 months.		
	Flow	Totalizer (E or O). Recorder (O)	1 to 4		
Disinfection:[3]					
Chlorine solution feeder	Flow	Indicator (E)	1 to 10	Application rate.	Manual (E), proportional-automatic (O).
	Residual	Indicator (O) Recorder (S)	1 to 10	Application rate.	Proportional-automatic (O).
Hypochlorite solution	Flow	Indicator (E)	1 to 10	Application rate.	Manual (E), proportional-automatic (O).
	Residual	Indicator (O) Recorder (S)	1 to 10	Application rate.	Proportional-automatic (O).

Table 46 (Continued)
Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout[1]	Range of Measurement	Controls: Item Regulated	Controls: Type
On-line chlorine cylinder	Weight	Indicator (E)	3 times full cylinder weight.	Chlorine supply.	Manual (E)
Trickling Filters:					
Influent to each filter	Flow	Indicator (E)	1 to 4	Flow rate.	Manual (E)[2]
Final clarifier sludge pumps	Running time	Totalizer (O)	At least 2 times maintenance period.	Pump selection.	Manual (E)
Recirculation lines	Flow	Indicator (E)	1 to 4	Recirculation flow rate.	Manual (E)
Activated Sludge:					
Influent line to each aeration tank	Flow	Indicator (E)	1 to 4	Flow rate.	Manual (E)[2]
Return sludge lines to each aeration tank	Flow	Indicator (E)	1 to 4	Sludge flow rate.	Manual (E)
Waste-activated sludge lines	Flow	Indicator (E) Totalizer (E) Recorder (O)	1 to 4	Sludge flow.	Manual (E)
Recycle and waste sludge pumps	Running time	Totalizer (O)	At least 2 times maintenance period.	Pump selection.	Manual (E)
Aeration Systems:					
Air line to each aeration tank (diffused air system)	Flow	Indicator (E)	1 to 4	Air flow to tank.	Manual (E)
Master air line	Flow	Indicator (E)	1 to 4	Main air flow.	Manual (E)
Mixed liquor dissolved oxygen	Concentration	Indicator (O)	0 to 10 mg/L.	Air flow.	Manual (E) Automatic (S)
Mechanical aerators	Electric current	Indicator (E) Totalizer (O)	Maximum motor rating.	Oxygen transfer.	Manual (E) Automatic (S)
Blowers	Electric current	Indicator (E) Totalizer (O)	Maximum motor rating.	Air flow.	Manual (E) Automatic (S)

Table 46 (Continued)
Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout[1]	Range of Measurement	Controls: Item Regulated	Controls: Type
Aerobic Sludge Digestion:					
Digested sludge drawoff line	Flow	Indicator (O) Totalizer (O)	1 to 4	Sludge volume.	Manual (E)
Supernatant drawoff line	Flow	Indicator (O) Totalizer (O)	1 to 4	Supernatant volume.	Manual (E)
Dissolved oxygen	Concentration	Indicator (O)	0 to 10 mg/L	Air flow rate.	Manual (E)
Anaerobic Sludge Digestion:					
Digested sludge drawoff line	Flow	Indicator (O) Totalizer (S)	1 to 4	Sludge volume.	Manual (E)
Supernatant drawoff line	Flow	Indicator (O) Totalizer (S)	1 to 4	Supernatant volume.	Manual (E)
Gas takeoff line from digester	Flow	Indicator (O) Totalizer (S)	1 to 4	Gas to heater.	Manual (E)
Gasline to sludge heater[4]	Flow	Indicator (O) Totalizer (S) Recorder (S)	1 to 4	Heat to exchanger.	Manual (E) Automatic (O)
Heating waterline to heat exchanger[4]	Flow	Indicator (O)	1 to 4	Heat to digester.	Manual (E) Automatic (O)
Circulating line, heat exchanger to digester	Flow	Indicator (O)	1 to 4		Manual (E) Automatic (O)
Circulating line, heat exchanger from digester	Temperature	Indicator (E)	+30 to 200°F (-1 to 93°C).		
Digester contents	Temperature	Indicator (E)	+30 to 200°F (-1 to 93°C).		
Mechanical Sludge Dewatering:[5]					
Dewatered sludge cake conveyor	Weight of conveyed solids.	Indicator (O) Totalizer (O) Recorder (S)	1 to 4		
Filtrate or centrate liquor line	Flow	Indicator (O) Recorder (S)	1 to 4		

Table 46 (Continued)
Metering, Instrumentation, and Control Requirements for Industrial Wastewater Treatment Systems

Location and Use	Type of Measurement	Type of Instrument Readout[1]	Range of Measurement	Controls: Item Regulated	Controls: Type
Miscellaneous:					
Plant water supply line	Flow	Totalizer (E)	Estimated consumption in 6 months.		
Potable water supply line, if separate	Flow	Totalizer (E)	Estimated consumption in 6 months.		
Plant gas supply line	Flow	Totalizer (E)	Estimated consumption in 6 months.		
Plant electric power supply line	Use of electric power.	Totalizer (E)	Estimated consumption in 6 months.		
Plant fuel-oil	Level	Indicator (E)	Depth of tank.		
Ambient air	Temperature	Indicator (O)	-40 to +120°F (-40 to 49°C).		
Chlorine storage and feed rooms	Gas concentration.	None		Concentration alarm.	Automatic (E)
Digester operating room	Methane	Indicator (O)	10 to 60% lower explosive limit.	Concentration alarm.	Automatic (E)
Wet wells and confined areas where gases may accumulate	Methane, hydrogen sulfide, and oxygen deficiency.	Indicator (O)	10 to 60% lower explosive limit, 10 to 100 mg/l H_2S, 16 to 22% oxygen.	Concentration alarm.	Automatic (E)

[1]E = Essential; O = Optional; S = Special cases.
[2]Flow may be self-regulating, and controls not required.
[3]Measuring devices normally are integral with the feeders.
[4]Provide only when sludge gas is burned for heating.
[5]Some measuring devices may be integral with mechanical dewatering equipment.

11.2 Instrumentation. Instrumentation covers all secondary instruments (such as gauges, 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.

11.2.1 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.

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

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

11.2.2.2 Pneumatic. Transmission distance can be up to 1,000 feet (300 m). Reaction time of pneumatic loops is relatively long if transmission distance is long.

11.2.2.3 Electrical. There is no limitation on distance. Analog signals may require amplification for transmission distances greater than 1,000 feet (300 m).

11.2.3 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).

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

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

11.3.2 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.

11.3.3 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.

Section 12: CHEMICAL HANDLING AND FEEDING

12.1 Domestic Wastewater Treatment

12.1.1 Introduction. Refer to Table 47 for function of chemicals used for domestic wastewater treatment. Section 6 recommends specific chemicals for wastewater applications encountered in Naval facilities. Refer to Table 48 for the usual chemical strengths and other data on chemicals.

12.2 Chemical Handling and Feeding

12.2.1 Handling. Refer to Table 48 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.

12.2.2 Storage. Refer to Table 49 for space criteria and Table 50 for type criteria. Refer to ACI, Concrete Sanitary Engineering Structures, 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 paragraph 12.2.5 for personnel safety precautions.

Table 47
Function of Chemicals for
Industrial and Oily Wastewater Treatment

BIOLOGICAL WASTEWATER TREATMENT

CHEMICAL	C	N	pH	PO	D	SL	DN	A	OC
1. Activated Carbon								X	X
2. Aluminum Sulfate (alum)	X			X					
3. Ammonia (aqua or gas)		X	X						
4. Ammonium Sulfate		X							
5. Calcium Hydroxide (hydrated lime)	X		X	X		X			
6. Calcium Oxide (quick lime)	X		X	X		X			
7. Calcium Hydrochlorate (HTH, perchloran)				X				X	
8. Chlorine					X				X
9. Chlorine Dioxide					X				X
10. Ferric Chloride	X			X		X			
11. Ferric Sulfate (ferrifloc)	X			X					
12. Ferrous Sulfate	X			X					
13. Hydrochloric Acid			X						
14. Hydrogen Peroxide			Special Oxidant						X
15. Methanol							X		
16. Ozone					X				
17. Polymers (polyelectrolytes)	X					X			
18. Phosphoric Acid		X							
19. Potassium Permanganate						X			X
20. Sodium Aluminate	X								
21. Sodium Bicarbonate			X						
22. Sodium Chlorite					X				
23. Sodium Hypochlorite					X				
24. Sodium Hydroxide			X						
25. Sulfur Dioxide					X				
26. Sulfuric Acid			X						

Key:
A = Adsorption
C = Coagulation
D = Disinfection
DN = Dentrification
N = Nutrient
pH = pH Adjustment
PO = Phosphorus Removal
SL = Sludge Conditioning
OC = Odor Control

Table 48
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Activated Carbon C	Powder	Bags, bulk	Varies		Insoluble	Dry or slurry	Volumetric metering pump	Slurry tank, dust control devices	Dry-iron, steel	Combustible dust
	Granular	Bags, bulk	20 to 35 (320 to 560)			Static or fluidized bed			Wet-rubber, plastic, stainless steel	
Aluminum Sulfate (alum) $Al_2(SO_4)_3 \cdot 14H_2O$	Slab, lump, powder	Bags (100-200 lb [45-90 kg]), drums	60 to 75 (960 to 1,200)	17% Al_2O_3	5.2@32°F (0.6@0°C) 5.5@50°F (.65@10°C) 5.9@68°F (0.7@20°C)	Dry or solution	Volumetric metering pump	Dissolver or solution tank	Dry-iron, steel, concrete	
	Liquid	Bulk	10.71 lb/gal (1.3 kg/L)	5.8 to 8.5% Al_2O_3	Complete	Solution	Metering pump	Solution tank	Wet-lead, rubber, plastic	
Ammonia NH_3	Liquified gas	Cylinders (100, 150 lb [45, 70 kg]), bulk. Carboys, drums, bulk.		99 to 100%	3.9@32°F (0.5@0°C)	Gas			Dry-steel, iron	
				15 to 30%	3.1@60°F (0.4@15°C)	Solution	Metering pump	Solution tank	Wet-stainless steel	
Ammonium Sulfate $(NH_4)_2SO_4$	Crystals	Bags (100 lb [45 kg])	54 (865)		5.9@32°F (0.7@0°C) 6.1@50°F (.73@10°C)	Solution	Metering pump	Solution tank	Plastic	

Table 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Calcium Hydroxide $Ca(OH)_2$	Powder, granules	Bags (50 lb [22 kg]) bulk	25 to 50 (400 to 800)	Normally 13% $Ca(OH)_2$	Nearly insoluble	Dry or slurry	Volumetric metering pump	Slurry tank	Iron, steel, plastic, rubber hose	
Calcium Oxide CaO	Lump, pebble, ground	Bags (80 lb [36 kg]), barrels, bulk	40 to 70 (640 to 1120)	75 to 99% normally 90% CaO	Nearly insoluble	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
Calcium Hypochlorite $Ca(OCl)_2 \cdot 4H_2O$	Granules, tablets	Cans (5 lb [2 kg]) drums (100, 300, 800 lb [45, 136, 362 kg])	50 to 55 (800 to 880)	70% available chlorine	1.8% @32°F (0°C)	Solution or dry	Solution-metering pump Dry-tablet contact feeder	Solution tank	Glass, plastic rubber	Soft water required for solution
Chlorine Cl_2	Liquified gas	Cylinders (100, 150, 200 lb [45, 68, 90 kg]) bulk	Liquid 91.7 (1470) Gas 0.19 @60°F (3@16°C) and atm. pressure	99.8%	0.12@32°F (0.014 @0°C) 0.047@87°F (0.006 @31°C)	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 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Chlorine Dioxide ClO_2	Gas	Prepared on site using chlorine and sodium chlorite, solution pump, and contactor column.			0.07@60°F (0.008 @16°C) 0.04@100°F (0.005 @38°C)	Water solution of gas	Chlorinator plus sodium chlorite solution pump	Scales, switch over devices, leak detectors, reactor tower	Sched. 80 steel for gas under pressure. Plastic or rubber-lined for gas under vacuum or water solution.	
Ferric Chloride $FeCl_3$	Powder	Drums (135, 350 lb [61, 159 kg])	175 (2800)	98%	4.6@32°F (0.55@0°C)	Liquid	Metering pump	Solution tank	Glass, rubber, plastic	Dilution limited due to iron hydrolysis
	Liquid	Bulk	87 to 94 (1390 to 1500)	39 to 45%		Liquid	Metering pump			
Ferric Sulfate $Fe(SO_4)_3$ $.xH_2O$	Powder	Bags (50, 100, 175 lb [23, 45, 79 kg])	70 to 72 (1120 to 1150) soluble iron	21%	5.8@55°F (0.7@13°C) Very soluble	Liquid pump	Metering tank	Solution plastic	Glass, rubber	Dilution limited due to iron hydrolysis
Ferrous Sulfate $FeSO_4$ $.7H_2O$	Crystals, powder, lumps	Bags (50, 100 lb [23, 45 kg]). Drums (55 gal [208L]), bulk	62 to 66 (990 to 1060)	55 to 58%		Liquid	Metering pump	Solution tank	Glass, rubber, plastic	Dilution limited due to iron hydrolysis
	Liquid	Bulk	Varies Consult producer	Varius Consult producer		Liquid	Metering pump			

Table 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Hydrochloric Acid HCl	Liquid	Barrels, drums, bulk	27.9% - 0.53 lb/gal (0.06 kg/L) 31.45% - 9.65 lb/gal (1.16 kg/L)	27.9%, 31.45%, 35.2%	Complete	Liquid	Metering pump	Dilution	Hastelory A, selected plastic and rubber types	
Hydrogen Peroxide H_2O_2	Liquid	Drums (30, 55 gal [113, 208 L]), bulk	35%-9.4 lb/gal (1.13 kg/L) 50%-10 lb/gal (1.2 kg/L) 70%-10.8 lb/gal (1.3 kg/L)	35%, 50%, 100%	Complete	Liquid	Metering pump		Type 304 stainless steel, polyethylene	Strong oxidizing agent
Methanol CH_3OH_2	Liquid									
Ozone O_3	Gas	Generated on site from air or oxygen				Gas solution		Consult equipment supplier	Unplasticized PVC, stainless steel	Toxic, irritant

Table 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Polymers	Liquid, powder	Drums bulk	See Note 1			Solution		Storage and dilution tanks	Consult supplier	See Note 2
Phos-phoric Acid H_3PO_4	Liquid	Carboys, barrels, kegs, bulk	75%-13.1 lb/gal (1.6 kg/L)	75%	Complete	Liquid	Metering pump		Type 316 or Alloy 20 stain-less steel, selected plastics	
Potassium Permang-anate $KMnO_4$	Crystals	Drums (110, 220, 550 lb [50, 100, 250 kg])	100 (1600)	95 to 99%	0.52@68°F (.06@20°C)	Liquid pump	Metering tank	Dissolv-ing	Iron, steel, PVC	
Sodium Aluminate $NaAlO_2$	Powder	Bags (100, 150, 250, 440 lb [45, 68, 113, 200 kg]) Drums	50 to 60 (800 to 960)	72 to 90%	2.4@32°F (0.3@0°C) 2.8@50°F (.34@10°C)	Dry	Volu-metric	Dissolv-ing tank	Wet or dry-iron, steel	
	Liquid	Bags	Varies	Varies	3.1@68°F (.37@20°C)	Liquid	Metering pump			
Sodium Bicarb-onate $NaHCO_3$	Granular, powder	Bulk	44 to 55 (705 to 880)	99.8%	3.3@86°F (0.4@30°C)	Dry	Volu-metric feeder	Dissolv-ing tank	Iron, steel, stainless steel	Tends to decompose and absorb moisture
					0.57@32°F (0.07@0°C) 0.68@50°F (.08@10°C) 0.80@68°F (.10@20°C)	Liquid	Metering pump			

Table 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight, (lb/ft^3 [kg/cu m])	Commercial strength	Water Solubility (lb/gal [kg/L])	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Sodium Chlorite $NaClO_2$	Flake Liquid	Drums (100 lb [45 kg]) Drums, bulk	Varies	Varies		Solution	Metering pump	Dissolving tank	Plastic (avoid cellulose)	Use to produce chlorine dioxide
Sodium Hypochlorite NaOCl	Liquid	Carboys (5, 13, 59 gal [19, 49, 223 L]), bulk (1,300, 2,000 gal [4920, 7570 L]), truckload		12 to 15% available chlorine	Complete	Solution	Metering pump	Solution tank	Plastic, glass, rubber	
Sodium Hydroxide NaOH	Solid flake, ground flake, liquid	Drum (735 lb [333 kg]) Drums (100 lb [45 kg]) Drums (450 lb [204 kg])	Varies	98%	3.5@32°F (0.4@0°C) 4.3@50°F (0.5@10°C) 9.1@68°F (1.09 @20°C) 9.2@86°F (1.10 @30°C)	Solution	Metering pump	Solution tank	Iron, steel	Dissolving solid forms, generates much heat
Sulfur Dioxide SO_2	Liquified gas	Cylinder (150, 2,000 lb [68, 907 kg])	Liquid-89.6 (1435) Gas @32°F and 1 atm.-0.183 (0°C and 101kPa-2.9)	99%	1.0@60°F (0.014 @16°C)	Water solution of gas	Vacuum-sulfurmeter	Scales, switch over devices	Dry-316 stainless steel Wet and low pressure plastic, rubber	Provide gas masks for emergency use

Table 48 (Continued)
Data on Chemicals for Wastewater Treatment

Chemical	Available Form	Shipping Container	Bulk Weight (lb/ft^3 (kg/cu m))	Commercial strength	Water Solubility (lb/gal (kg/L))	Feeding Form	Feeder Type	Accessory Equipment	Suitable Handling Materials	Comments
Sulfuric Acid H_2SO_4	Liquid	Carboys, drums (825 lb (374 kg)). Bulk	106 (1700) 114 (1830)	77.7% 93.2%	Complete	Liquid	Metering pump			Provide for spill cleanup and neutralization

[1]The various cationic, anionic and nonionic polymers vary in composition, density and other characteristics. Consult supplier for data.

[2]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 solution 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.

Table 49
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 of 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 50
Chemical Storage Type Criteria

Type of Storage	Dry	Wet
Handling requirements	Allow for access corridors between stacks of packaged chemicals. Palletize and use forklift truck only in large installations.	Provide agitation for slurries such as carbon or lime - not less than 1 hp mixing for 100 ft^3 (3 cu m). 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. Provide ample space between stores of materials that may interact, such as ferrous sulfate and lime.	Double check corrosion resistance of bulk storage linings, pipe, mixing, and pumping materials. Isolate hazardous or toxic solutions such as fluosilicic acid. Prefer below ground or outdoor storages.

12.2.3 On-Site Generation and Feeding Equipment

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

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

b) 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.

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

12.2.3.2 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.

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

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

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

c) Reactor effluent will contain approximately 70 percent hypochlorite and 30 percent chlorine dioxide. Approximate yield is 0.4 lb ClO_2/lb Cl_2 (0.4 kg ClO_2/kg 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 [1.0 kg ClO_2/kg Cl_2].)

d) 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.

e) 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.

12.2.4 Chemical Feeders. See Table 51 for applications of various types of feeders.

Table 51
Types of Chemical Feeders for Wastewater Treatment Systems

Type of Feeder	Use	Limitations: General	Limitations: Capacity (ft^3/hr [cu m/hr])	Limitations: Range
Dry Feeder:				
Volumetric:				
Oscillating plate	Any material, granules or powder.	-	0.01 to 35 (0.0003 to 1)	40 to 1
Oscillating throat (universal)	Any material, any particle size.	-	0.02 to 100 (0.0006 to 2.8)	40 to 1
Rotating disc powder	Moist materials, including NaF, granules for arching.	Use disc unloader.	0.01 to 1.0 (0.0003 to 0.028)	20 to 1
Rotating cylinder (star)	Any material, granules or powder.	-	8 to 2,000 (0.2 to 56.6) or 7.2 to 300 (0.2 to 8.5)	10 to 1 or 100 to 1
Screw	Dry, free flowing material, powder or granules.	-	0.05 to 18 (0.0014 to 0.5)	20 to 1
Ribbon	Dry, free flowing material, powder, granules, or lumps.	-	0.002 to 0.16 (0.00006 to 0.004)	10 to 1
Belt	Dry, free flowing material up to 1-1/2-in. (40 mm) size, powder or granules.	-	0.1 to 3,000 (0.003 to 85) or 100 to 1 (2.8 to 0.028)	10 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 (0.0006 to 0.06)	100 to 1
Loss in weight	Most materials, powder, granules or lumps.	-	0.02 to 80 (0.0006 to 2.3)	100 to 1
Solution Feeder:				
Nonpositive Displacement:				
Decanter (lowering pipe)	Most solutions or light slurries.	-	0.01 to 10 (0.0003 to 0.28)	100 to 1
Orifice	Most solutions.	No slurries.	0.16 to 5 (0.004 to 0.14)	10 to 1
Rotometer (calibrated valve)	Clear solutions.	No slurries.	0.005 to 0.16 (0.00014 to 0.004) or 0.01 to 20 (0.00028 to 0.6)	10 to 1
Loss in weight (tank with control valve)	Most solutions.	No slurries.	0.002 to 0.20 (0.00006 to 0.006)	10 to 1
Eductor	Most solutions.	No slurries.	For batch or continuous rate of feed only.	
Positive Displacement:				
Rotating dipper	Most solutions or slurries.	-	0.1 to 30 (0.003 to 0.85)	100 to 1
Proportioning Pump:				
Diaphragm	Most solutions. Special unit for 5% slurries[1].	-	0.004 to 0.15 (0.0001 to 0.004)	100 to 1
Piston	Most solutions, light slurries.	-	0.01 to 170 (0.00028 to 4.8)	20 to 1

Table 51 (Continued)
Types of Chemical Feeders for Wastewater Treatment Systems

Type of Feeder	Use	Limitations		
		General	Capacity (ft^3/hr [cu m/hr])	Range
Gas Feeders: Solution feed	Chlorine	-	8,000 lb/day (3,630 kg/day) maximum	20 to 1
	Ammonia	-	2,000 lb/day (917 kg/day) maximum	20 to 1
	Sulfur dioxide	-	7,600 lb/day (3,450 kg/day) maximum	20 to 1
Direct feed	Chlorine	-	300 lb/day (136 kg/day) maximum	10 to 1
	Ammonia	-	120 lb/day (55 kg/day) maximum	7 to 1

[1]Use special heads and valves for slurries.

12.2.4.1 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
Rotoclock mechanism	Tends to flood
Dissolving chamber	To be fed in solution
Dust collector	Dusty
Vapor collector	Noxious or irritating fumes

12.2.4.2 Feeder Construction. Mechanisms of feeders must be constructed out of materials resistant to substances to be handled. See Table 48 for guidance on materials selection.

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

a) Volumetric feeders, accuracy of "3 percent.

b) Gravimetric feeders, accuracy of "1 percent. Gravimetric feeders are more expensive than volumetric feeders.

12.2.5 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.

12.2.6 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. Refer to EPA-430-99-74-001.

12.3 Sampling. Institute sampling programs only as needed to obtain data for the design and operation of wastewater treatment facilities, and to determine compliance with standards and the effect of waste streams (both raw and treated) on receiving waters. Refer to ASTM D 3370, Practices for Sampling Water, for general discussion of sampling water and wastewater.

12.3.1 Sampling Techniques

12.3.1.1 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.

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

a) Wastewater stream is intermittent, or concentration is highly variable.

b) 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).

c) Ascertaining characteristics at extreme conditions.

d) Samples for oil and grease (may be composited manually; automatic sampling not normally accurate).

12.3.1.3 Method of Sampling. Use widemouthed containers to take grab samples. At small plants (up to 1 Mgd [4 ML/d]), 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.

12.3.2 Sample Volume and Preservation. Volume and preservation requirements depend on:

a) the analytical determinations to be carried out on the sample, and

b) the time between sample collection and analysis.

Refer to Table 52 for recommendations on sampling and sample preservation. Refer to APHA Standard Methods for the Examination of Water and Wastewater and EPA PB84128677, Manual of Methods for Chemical Analysis of Water and Wastes for specific recommendations regarding sample containers, volumes, and methods of sample preservation for each analytical measurement.

12.4 Analytical Methods. Analytic methods available for quantitative determination of physical, biological, inorganic chemical, and organic chemical characteristics of wastewater samples are summarized in Table 53. Refer to APHA Standard Methods for the Examination of Water and Wastewater for detailed laboratory procedures.

12.4.1 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 domestic wastewater treatment facilities and a general program cannot be developed by this manual. The sampling program shall be fully developed in the operations and maintenance manual and revised accordingly after plant startup and the 30-day 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 and maintenance manual shall also identify minimum reporting requirements for regulatory compliance and shall provide operating log sheets for recording operating data.

Table 52
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 hours
Conductance	100	P,G	Cool, 4°C[3]	24 hours
Hardness	100	P,G	Cool, 4°C HNO_3 to pH<2[4]	6 months
Odor	200	G only	Cool, 4°C	24 hours
pH	25	P,G	Det. on site	6 hours
Residue:				
Filterable	100	P,G	Cool, 4°C	7 days
Nonfilterable	100	P,G	Cool, 4°C	7 days
Total	100	P,G	Cool, 4°C	7 days
Volatile	100	P,G	Cool, 4°C	7 days
		P,G	Cool, 4°C	
Settleable Matter	1,000	P,G	None required	24 hours
Temperature	1,000	P,G	None	No holding
Turbidity	100	P,G	Cool, 4°C	7 days
Metals:				
Dissolved	200	P,G	Filter on site HNO_3 to pH<2[4]	6 months
Suspended	200	P,G	Filter on site	6 months
Total	100	P,G	HNO_3 to pH<2[4]	6 months
Mercury:				
Dissolved	100	P,G	Filter on site HNO_3 to pH<2[4]	38 days (glass) 13 days (hard plastic)
Total	100	P,G	HNO_3 to pH<2[4]	38 days (glass) 13 days (hard plastic)
Inorganics, Nonmetallics:				
Acidity	100	P,G	None required	24 hours
Alkalinity	100	P,G	Cool, 4°C	24 hours
Bromide	100	P,G	Cool, 4°C	24 hours
Chloride	50	P,G	None required	7 days
Chlorine	200	P,G	None	No holding
Cyanides	500	P,G	Cool, 4°C NaOH to pH 12	24 hours
Fluoride	300	P,G	None required	7 days
Iodine	100	P,G	Cool, 4°C	24 hours

Table 52 (Continued)
Recommendations for Sample Collection and Preservation
According to Measurement

Measurement	Volume (mL)	Container[1]	Preservative	Holding Time[2]
Nitrogen:				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH<2	24 hours
Total Kjeldahl	500	P,G	Cool, 4°C H_2SO_4 to pH<2	24 hours[5]
Nitrate plus Nitrite	100	P,G	Cool, 4°C	24 hours[5]
Nitrate	100	P,G	H_2SO_4 to pH<2	24 hours
Nitrite	50	P,G	Cool, 4°C	48 hours
Dissolved Oxygen:			Cool, 4°C	
Probe	300	G only		No holding
Winkler	300	G only	None	4 to 8 hours
Phosphorus:			Fix on site	
Orthophosphate, dissolved	50	P,G		24 hours[5]
Hydrolyzable	50	P,G	Filter on site	24 hours[5]
Total	50	P,G	Cool, 4°C H_2SO_4 to pH<2	24 hours[5]
Total, dissolved	50	P,G	Cool, 4°C H_2SO_4 to pH<2 Filter on site	24 hours[5]
Silica	50	P only		7 days
Sulfate	50	P,G	Cool, 4°C	7 days
Sulfide	500	P,G	H_2SO_4 to pH<2 Cool, 4°C	24 hours
Sulfite	50	P,G	Cool, 4°C	No holding
Organics:			2 ml zinc acetate	
BOD	1,000	P,G		24 hours
COD	50	P,G	None	7 days[5]
Oil and Grease	1,000	G only		24 hours
			Cool, 4°C H_2SO_4 to pH<2	
Organic carbon	25	P,G		24 hours
			Cool, 4°C H_2SO_4 or HCl to pH<2	
Phenolics	500	G only		24 hours
			Cool, 4°C H_2SO_4 or HCl to pH<2	
MBAS	250	P,G		24 hours
NTA	50	P,G		24 hours
			Cool, 4°C H_2SO_4 to pH<4 1.0 g $CuSO_4$/1	
			Cool, 4°C	
			Cool, 4°C	

Table 52 (Continued)
Recommendations for Sample Collection and Preservation According to Measurement

Notes:

[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 degrees C for measurement or temperature correction made and results reported at 25 degrees 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 no NHO_3 (normally 3 mL 1:1 HNO_3/liter is sufficient). At the time of analysis, the sample container should be thoroughly rinsed with 1:1 HNO_3 and 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 sewage systems (SIC 4952).

Table 53
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
Nitritates	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

Table 53 (Continued)
Analytical Methods

Characteristics	Method of Analytic Determination
Pesticides	Solvent extraction plus 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."

Section 13: REUSE APPLICATIONS

13.1 Introduction. Executive Order 12856 expanded coverage of the Pollution Prevention Act and the Emergency Planning and Community Right to Know to Federal facilities. As a result, more facilities will be examining the possibilities of water reuse. One or a combination of the following factors would prompt activities to examine water reuse:

a) Public policy requiring implementation of water reuse. If the wastewater is reused there will be less change for an NPDES permit violation.

b) Water reuse is the most cost effective means for effluent disposal.

c) Availability of good quality wastewater effluent, and high cost of freshwater supply.

This section will cover the planning considerations for water reuse, water reuse applications, and the wastewater reuse treatment processes.

13.2 Water Reuse Planning and Management. There are several steps that need to be taken to determine the feasibility of a water reuse project. The steps will be discussed in the following sections.

13.2.1 Objective of the Water Reuse Project. The activity needs to know whether the wastewater reuse program is initiated for one or both of the following reasons:

a) Limited freshwater sources.

b) Meeting more stringent discharge standards.

13.2.2 Gather Background Data. The activity should collect background data on all water users. The database should include information on the quality of water needed by each user, the price of water, the present and future needs of water, and the willingness to use reclaimed water.

13.2.3 Identify Potential Users. The base should then develop a list of existing and potential users and their water quantity and quality needs. Refer to paragraph 13.3 for more information on potential reuse applications. The potential uses should be grouped based on volume of water needed for certain periods, economic considerations, and water quality required.

13.2.4 Determine Requirements for Reuse. Depending on the use category determined in paragraph 13.2.3, a list of reuse requirements should be developed. The list includes health and water pollution control requirements, treatment requirements, dual distribution system requirements, on site facility modifications, and use control areas. In order to determine storage requirements, daily and seasonal changes in demand should be considered.

13.3 Reuse Applications. The category of the planned reuse will determine the requirements for the degree of treatment, and the treatment process selected. There are several reuse applications: agricultural and landscape irrigation, groundwater recharge, industrial reuse, recreational, and potable reuse.

13.3.1 Agricultural and Landscape Irrigation. Reclaimed water can be used for irrigating golf courses, greenbelts, etc. For more information on the water quality for irrigation, refer to Irrigation with Reclaimed Municipal Wastewater - A Guidance Manual, Pettygrove and Asano, 1985.

13.3.2 Groundwater Recharge. Groundwater recharge is used to augment groundwater supplies. There are two types of groundwater recharge that utilize reclaimed water: surface spreading or percolation, and direct injection river bank or stream bed infiltration as a result of stream flow augmentation. Pathogens, total minerals, heavy metals, and stable organic substances are the four quality factors that are important in groundwater recharge, refer to California Department of Health Services, State of the Art Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge.

13.3.3 Industrial Reuse. In many cases, industrial water quality requirements are less than drinking water quality standards. Water reuse has a great potential to supplement or replace the potable and freshwater demands from industries. The main water reuses in industrial activities are:

a) Cooling systems. Refer to California State Water Resource Control Board, Industrial Water Recycling.

b) Washdown water for cleaning cars and trucks.

c) Once through cooling (pumps, compressors, bearing cooling, turbine exhaust condensing, etc.).

d) Process water and boiler feed. The quality requirements for water used in industrial processes vary depending on the particular industrial application involved. For more information refer to California State Water Resource Control Board, Industrial Water Recycling..

e) Miscellaneous uses (site irrigation, fire protection, and dust control).

Although the quality requirements for the various industrial water uses are variable, several general requirements can be identified. The wastewater needs to go through secondary treatment and disinfection. Table 54 presents the treatment technology for wastewater reclamation as an industrial water supply.

Table 54
Treatment Technology for Wastewater
Reclamation as an Industrial Water Supply

Industrial Water Use	Treatment Process		
	Nitrification	Chemical Precipitation	Filtration
Cooling tower makeup	Normally	Yes	Yes
Equipment cooling	Yes	Yes	Yes
Process water	Yes	Yes	Yes
Boiler feedwater[1]	Yes	Yes	Yes
Washdown water	Sometimes	Seldom	Yes
Site irrigation	No	No	Normally

[1]Water reused for boiler feedwater would also require carbon absorption, iron exchange, or reverse osmosis.

13.3.4 Recreational/Environmental Enhancement. Reclaimed water can be used for a variety of recreational applications:

a) Recreational lakes used for fishing, boating, or swimming.

b) Aesthetic settings as in the case of a lake without public access.

c) Flow augmentation in natural streams.

d) Wildlife habitats and wetlands.

The water quality criteria for recreational use varies depending on the type of use. Phosphorous and nitrogen level should be kept low. Phosphorous should be kept below 0.1 mg/L as P, and ammonium hydroxide concentrations should be kept below 2 mg/L. For more information on water quality criteria for recreational water reuse, refer to Water Quality Criteria, McKee and Wolf.

13.3.5 Potable Reuse. There are two kinds of potable reuse: direct and indirect. Direct potable reuse is the incorporation of reclaimed water into a potable water supply system. Indirect potable reuse incorporates reclaimed wastewater into raw water. Water reuse for drinking represents the most rigorous and demanding application of water reuse. For more information on potable water reuse, refer to Potable Water Reuse, Linstedt and Rothberg, 1982.

13.4 Treatment Processes and Systems. This section covers the pretreatment, conventional treatment, advanced waste treatment, disinfection, land treatment, and aquatic treatment processes that can be used for wastewater reuse.

13.4.1 Pretreatment. Refer to Section 6.

13.4.2 Conventional Treatment. Refer to Section 7.

13.4.3 Advanced Wastewater Treatment

13.4.3.1 Suspended Growth Nitrification. Ammonia-nitrogen removal is of primary concern because of the oxygen demand exerted when the compound is released to the environment. The operation of a suspended growth nitrification system is the same as for conventional activated sludge systems. The nitrification process depends largely on the pH, temperature, alkalinity, and dissolved oxygen. These factors will have to be closely monitored. For more information, refer to EPA 625/R-93/010. Table 55 presents the suspended growth nitrification average process removal.

Table 55
Suspended Growth Nitrification Average Process Removal

Constituent	Performance, Average Percent Removal from Secondary Effluent
BOD	75
COD	56
TSS	61
NH_3-N	97
Phosphorous	50
TOC	73

13.4.3.2 Suspended Growth Denitrification. Denitrification is a biological process in which nitrate-nitrogen is reduced to nitrogen gas. Carbon source is usually added to the reactor to accelerate denitrification. Denitrification takes place in an anoxic (oxygen-free) environment. Denitrification occurs best at 20EC, and at a pH range of 7 to 7.5. For more information, refer to EPA 68-03-3055, Emerging Technology Assessment of Phostrip, A/O, and Bardenpho Processes for Biological Phosphorous Removal. Table 56 presents the suspended growth denitrification average process removal.

Table 56
Suspended Growth Denitrification Average Process Removal

Constituent	Performance, Average Percent Removal from Secondary Effluent
BOD	47
COD	35
TSS	42
NH_3-N	32
NO_3-N	89
Phosphorous	52
TOC	22

13.4.3.3 Fixed Growth Denitrification. Denitrification can also be accomplished in a fixed growth media. In fixed growth denitrification, the media can be either low porosity (sand and other granular media), or high porosity (berl saddles, pall rings). Table 57 shows the typical removal rates for fixed growth denitrification.

Table 57
Typical Removal Rates for Fixed Bed

Type of Reactor	Removal Rate (kg of nitrogen/cu m d)
Gas-filled reactor	1.6 to 1.8
Liquid filled - high porosity	0.1 to 0.12
Liquid filled - low porosity	0.2 to 0.4
Fluidized bed reactor - high porosity	5 to 16

13.4.3.4 Coagulation-Sedimentation. The coagulation-sedimentation process adds chemicals to enhance sedimentation of solids, precipitate pollutants, and/or removal of phosphorous. The coagulation-sedimentation process involves the following:

a) Rapid mixing to disperse the chemicals in the wastewater.

b) Slow mixing to promote the formation of large settleable flocs.

c) Settling in clarifiers.

Alum or ferric chloride can be added as coagulants. Lime is used to raise the pH. Polymers or polyelectrolytes are added as settling aids. Other coagulant aids include bentonite and activated silica. Table 58 presents the coagulation-sedimentation process removal.

Table 58
Coagulation-Sedimentation Typical Process Removal

Constituent	Performance, Average Percent Removal from Secondary Effluent
BOD	81
COD	81
TSS	91
Phosphorous	96
Alkalinity	69
TOC	22

13.4.3.5 Filtration. Filtration produces a high quality effluent. It combines both physical and chemical processes to remove solids from the waste stream. Filtration involves passing wastewater through a bed where the solids will be removed. Table 59 shows typical removal by filtration in various physical/chemical treatment processes.

13.4.3.6 Recarbonation. Lime addition raises the pH to 10-11. At this level, the water is unstable, and calcium carbonate will precipitate. Recarbonation is used to lower the pH of the effluent water to around pH 7. Recarbonation does not remove any contaminants.

Table 59
Filtration Following Physical/Chemical Treatment
Average Process Removal

Constituent	Performance, Average Percent Removal from Chemically Clarified Secondary Effluent
BOD	36
COD	22
TSS	42
TOC	26

13.4.3.7 Activated Carbon Adsorption. Activated carbon is used to lower the level of TOC in the effluent. Carbon is available in two forms. Powdered activated carbon can be handled as a slurry to be added to the process flow and subsequently removed by settling. Granular activated carbon is used as a filter medium.

13.4.3.8 Ammonia and VOC Stripping. Air stripping is used to remove ammonia-nitrogen and VOCs from wastewater. It takes place in a packed stripping tower with counter-current air and water flow. The conversion of ammonium ion to ammonia gas occurs at pH 11. Therefore, ammonia stripping is suitable after lime treatment because the pH of the wastewater has already been raised. VOC stripping has two problems. The first problem is that as the temperature drops, ammonia becomes more soluble and more difficult to remove. The second problem is the deposition of calcium carbonate scale on the tower medium.

13.4.3.9 Breakpoint Chlorination for Ammonia Removal. Breakpoint chlorination is used to remove the ammonia nitrogen in the wastewater effluent. Chlorine is added to convert ammonia to chloramines and then to oxidize the chloramines to nitrogen gas. Dechlorination may be necessary before discharging the effluent.

13.4.3.10 Selective Ion Exchange. Clinoptilolite (a zeolite) can be used to selectively remove ammonium. Pressure vessels, similar to those used for filtration, act as the exchange reactors. The process is useful to the bases requiring year-round high level removal of nitrogen, and where the effluent TDS is of major concern. Although the effluent TDS is increased by the process, the overall increase is much less than for the breakpoint chlorination process. Table 60 shows typical removal by selective ion exchange.

Table 60
Selective Ion Exchange Removal Following Chemically Clarified Secondary Effluent

Constituent	Performance, Average Percent Removal from Chemically Clarified Secondary Effluent
BOD	40
COD	28
TSS	62
NH_3-N	84
TOC	0

13.4.3.11 Membrane Systems. Semipermeable membranes are used for demineralization of water for domestic and industrial uses. The membrane process systems consists of applying pressure on the concentrated side of the membrane which has a high osmotic pressure. This results in pure water flowing to the less concentrated side. Therefore, we produce pure water, and the impurities are left behind. Table 61 shows typical average removal by reverse osmosis.

Table 61
Reverse Osmosis Average Process Removal

Constituent	Percent Removal		
	Activated Sludge Effluent	Activated Carbon Treated Activated Sludge Effluent	Chemically Clarified Primary Effluent
Calcium	99.6	99.6	99.6
Magnesium	99.5	99.6	99.3
Sodium	94.0	92.6	92.5
Potassium	94.7	93.0	91.5
Ammonia-N	95.1	96.7	90.2
Chloride	94.6	93.2	90.4
Sulfate	99.5	99.7	99.8
Phosphate	99.7	99.9	99.4
COD	96.1	91.3	65.6
TDS	95.2	95.3	93.3

13.5 Disinfection. Wastewater disinfection destroys the pathogens, and provides a barrier to possible waterborne disease before the wastewater is released to the environment. The most important factor in considering disinfection requirements is the protection of public health and the aquatic environment. The other factors to be evaluated are effectiveness, cost, and practicality.

13.5.1 Chlorination. Chlorine can be used at various stages of the treatment process. For more information on chlorination and dechlorination refer to paragraphs 6.8 and 6.9. Table 62 shows typical chlorine dosages for disinfection for water reuse.

Table 62
Typical Chlorine Dosages for Disinfection

Treatment Process	Dosage (mg/L)
Primary sedimentation	5-20
Chemical precipitation	2-6
Trickling filter plant effluent	10
Activated sludge plant effluent	8
Tertiary filtration effluent	6
Nitrified effluent	6

13.5.2 Ozonation. Refer to paragraph 6.10.

13.5.3 Ultraviolet Light. Ultraviolet light is very effective in destroying bacteria and viruses. Radiation at a wavelength of 254 nm penetrates the cell wall and is absorbed by the cellular nuclei acids. The advantages of the UV light are its simplicity, lack of impact on the environment and aquatic life, and minimal space requirements.

13.6 Land Treatment. Land treatment systems combine the objectives of wastewater treatment and water reuse. For more information on land treatment of wastewater, refer to paragraph 7.11.

13.7 Selecting and Combining Processes. Treatment processes can be combined in a number of ways to achieve the desired treatment level prior to reuse. Table 63 presents the treatment achieved by applying advanced wastewater treatment processes to the secondary effluent from the activated sludge process. Table 64 presents the treatment achieved by applying advanced treatment processes to the secondary effluent from the trickling filter process.

With current technology, almost any degree of wastewater treatment can be achieved. However, with the increased level of treatment, the construction costs, Operations and Maintenance (O&M) costs, and sludge production also rise. Generally, construction costs double from primary to secondary treatment, and rise by 50 percent from secondary treatment to advanced treatment. Operation and maintenance costs will double from primary to secondary treatment, and double from secondary to advanced treatment. Sludge production can increase by 50 percent from primary to secondary treatment, and by 15 percent from secondary treatment to advanced treatment. For more information on water reuse and advanced wastewater treatment processes, refer to Water Environment Federation (WEF) MOP SM-3, Water Reuse.

Table 63
Treatment Achievable With Activated Sludge and Advanced Wastewater Treatment Processes

Advanced Treatment Process	Typical Effluent Quality				
	SS (mg/L)	BOD (mg/L)	COD (mg/L)	Total-N (mg/L)	PO_4 as P (mg/L)
None	20-30	15-25	40-80	20-60	6-15
Granular filtration	5-10	5-10	30-70	15-35	4-12
Granular filtration, carbon columns	3	1	5-15	15-30	4-12
Coagulation settling	5	5-10	40-70	15-30	1-2
Coagulation settling, granular filtration	1	5	30-60	15-30	0.1-1
Coagulation settling, granular filtration, ammonia stripping	1	5	30-60	2-10	0.1-1
Coagulation, settling, granular filtration, ammonia stripping, carbon columns	1	1	1-15	2-10	0.1-1

Table 64
Treatment Achievable With Trickling Filter and Advanced Wastewater Treatment Processes

Advanced Treatment Process	Typical Effluent Quality				
	SS (mg/L)	BOD (mg/L)	COD (mg/L)	Total-N (mg/L)	PO_4 as P (mg/L)
None	20-40	15-35	40-100	20-60	6-15
Granular filtration	10-20	10-20	30-70	15-35	6-15
Coagulation, settling, granular filtration	5-10	5-10	30-60	15-35	4-12

REFERENCES

NOTE: THE FOLLOWING REFERENCED DOCUMENTS FORM A PART OF THIS HANDBOOK TO THE EXTENT SPECIFIED HEREIN. USERS OF THIS HANDBOOK SHOULD REFER TO THE LATEST REVISIONS OF CITED DOCUMENTS UNLESS OTHERWISE DIRECTED.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS:

Unless otherwise indicated, copies are available from the DODSSP, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

HANDBOOKS

MIL-HDBK-1001/1	Basic Architectural Requirements and Design Considerations
MIL-HDBK-1002/1	Structural Engineering General Requirements
MIL-HDBK-1003/3	Heating, Ventilating, Air Conditioning, and Dehumidifying Systems
MIL-HDBK-1003/6	Central Heating Plants
MIL-HDBK-1003/7	Steam Power Plants - Fossil Fueled
MIL-HDBK-1003/8	Exterior Distribution of Steam, High Temperature Hot Water, Chilled Water, Natural Gas, and Compressed Air
MIL-HDBK-1004/1	Electrical Engineering Preliminary Design Considerations
MIL-HDBK-1005/7	Water Supply Systems
MIL-HDBK-1005/9	Industrial and Oil Wastewater Control
MIL-HDBK-1029/1	Graving Drydocks
MIL-HDBK-1190	Facility Planning and Design Guide

SPECIFICATIONS

MIL-T-704	Treatment and Painting of Material
NAVSEA S9AA0-AA-SPN-010/GEN-SPEC	General Specifications for Ships of the United States Navy

STANDARDS

MIL-STD-101	Color Codes for Pipelines and for Compressed Gas Cylinders
NFGS-02730	Exterior Sanitary Sewer System
NFGS-16641	Cathodic Protection by Galvanic Anodes
NFGS-11365	Trickling Filter

NAVY MANUALS, P-PUBLICATIONS, AND MAINTENANCE OPERATING MANUALS:

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MANUALS

DM-3.10	Noise and Vibration Control for Mechanical Equipment
DM-5.10	Solid Waste Disposal
DM-22	Petroleum Fuel Facilities
NAVSEA S9086-T8-STM-010/CH-593	Naval Ships' Technical Manual (Chapter 593 Pollution Control)
NAVSEA S0300-A4-MAN-A1B	Naval Vessel Register/Ships Data Book

P-PUBLICATIONS

P-272	Definitive Designs for Navy and Marine Corps Shore Facilities
P-355	Seismic Design for Buildings

MAINTENANCE OPERATING MANUALS

MO-110	Paints and Protective Coatings
MO-306	Maintenance and Operation of Cathodic Protection Systems
MO-307	Corrosion Control

MO-340	Ship-to-Shore Hose Handling Operations Manual
MO-910	Sewage Ship Waste Offload Barge (SWOB)

NAVY DEPARTMENT INSTRUCTIONS:

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CNET 4100.4B	Energy Technology Application Program
OPNAVINST 5090.1	Environmental and Natural Resources Program Manual
SECNAVINST 5030.1	Classification of Naval Ships and Craft
NAVFAC 4858.1	Naval Facilities Engineering Command Value Engineering Program
NAVFAC LTR 11012	Cathodic Protection Systems, Interim Technical Guidance

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

EPA 430/9-75-001 (FED MCD-11)	Guide to the Selection of Cost-Effective Wastewater Treatment Systems
EPA 430/9-75-021	Handbook for Sewer Systems Evaluation and Rehabilitation
EPA 430-99-74-001 (FED MCD-05)	Design Criteria for Mechanical, Electrical, and Fluid System and Component Reliability
EPA 625/1-75-0030	Process Design Manual for Suspended Solids Removal
EPA 625/1-79-011	Process Design Manual for Sludge Treatment and Disposal
EPA 625/1-80-012	Onsite Wastewater Treatment and Disposal Systems
EPA 625/1-81-013	Land Treatment of Municipal Wastewater
EPA 625/1-83-015	Design Manual on Municipal Wastewater Stabilization Ponds
EPA 625/1-87-014	Dewatering Municipal Wastewater Sludges

EPA 625/R-92/005	Wastewater Treatment/Disposal for Small Communities
EPA 625/R-93/010	Process Design Manual for Nitrogen Control
EPA 68-03-3055	Emerging Technology Assessment of Phostrip, A/O, and Bardenpho Processes for Biological Phosphorous Removal
EPA R2-73-199	Application of Plastic Media Trickling Filters for Biological Nitrification
FED MCD-32	Energy Conservation in Municipal Wastewater Treatment
FED MCD-54	Wastewater Stabilization Pond Linings
PB259149	Process Design Manual for Nitrogen Control
PB84128677	Manual of Methods for Chemical Analysis of Water and Wastes
PB85180545	Review of Current RBC Performance and Design Procedures

(Unless otherwise indicated, copies are available from U.S. Environmental Protection Agency, Office of Water Program Operations, Washington, DC)

NCEL CR-70.11	Analysis of Wastewater Treatment and Disposal Systems for Advanced Bases
NCEL R-593	Freeze Protection for Freshwater and Sanitary Piping Under Open Piers

(Unless otherwise indicated, copies are available from Naval Facilities Engineering Service Center, Port Hueneme, CA 93043-4328)

DTRC/SME-91/53	Catalog of Shipboard Pollution Abatement Systems

(Unless otherwise indicated, copies are available from David Taylor Research Center, Bethesda, MD 20084-5000)

ARMY TM 5-814-3	Domestic Wastewater Treatment

(Unless otherwise indicated, copies are available from the U.S. Army Corps of Engineers, Washington, DC)

Industrial Water Recycling

(Unless otherwise indicated, copies are available from the California State Water Resource Control Board, Office of Water Recycling)

State of the Art Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge

(Unless otherwise indicated, copies are available from the California Department of Health Services, State Water Resources Control Board, Department of Water Resources, Sacramento, CA)

NON-GOVERNMENT PUBLICATIONS:

AMERICAN CONCRETE INSTITUTE (ACI)

Concrete Sanitary Engineering Structures

(Unless otherwise indicated, copies are available from the American Concrete Institute (ACI), 22400 W. 7-Mile Rd., Box 19150, Redford Station, Detroit, MI 48219)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI A13.1	Scheme for the Identification of Piping Systems

(Unless otherwise indicated, copies are available from the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018)

AMERICAN PUBLIC HEALTH ASSOCIATION

Standard Methods for the Examination of Water and Wastewater

(Unless otherwise indicated, copies are available from the American Public Health Association, Washington, DC)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM C88	Standard Test Methods for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion Impact in the Los Angeles Machine

ASTM C159	Standard Specification for Vitrified Clay Filter Block
ASTM D3370	Practices for Sampling Water

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AMERICAN WATER WORKS ASSOCIATION (AWWA)

Water Treatment Plant Design

(Unless otherwise indicated, copies are available from the American Water Works Association (AWWA), 6666 West Quincy Ave., Denver, CO 80235-9984)

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1	Structural Welding Code: Steel

(Unless otherwise indicated, copies are available from the American Welding Society (AWS), 559 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135)

WATER POLLUTION CONTROL FEDERATION (WPCF)

WPCF M0030	Energy Conservation at Wastewater Treatment Plants
WPCF MOP 3	Regulation of Sewer Use
WPCF MOP 8	Design of Municipal Wastewater Treatment Plant
WPCF MOP 22	Odor Control for Wastewater Facilities
WPCF MOP FD-5	Gravity Sanitary Sewer Design and Construction
WPCF MOP FD-10	Wastewater Disinfection
WPCF MOP FD-13	Aeration
WPCF MOP FD-16	Natural Systems for Wastewater Treatment
WPCF MOP FK-2	Energy Conservation in the Design and Operation of Wastewater Treatment Facilities
WPCF MOP SM-3	Water Reuse

(Unless otherwise indicated, copies are available from Water Pollution Control Federation (WPCF), 601 Wyeth St., Alexandria, VA 22314)

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3. DOCUMENT TITLE DOMESTIC WASTEWATER CONTROL

4. NATURE OF CHANGE (identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

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