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An Introduction to Oily Wastewater Collection and Treatment

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CONTENTS

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1. OBJECTIVES. Section 311(b)(3) of the FWPCA prohibits the discharge of oil in harmful quantities into or upon the navigable waters of the United States. As indicated in the Title 40 CFR Part 110, Discharge of Oil, discharges in quantities that violate applicable water quality standards and cause a visible sheen upon the water are considered harmful. Treatment of oil discharges or oily wastes is frequently required.

2 SOURCES. Oily waste originates in numerous locations. A typical source is shipboard oily waste. The design criteria presented herein have been primarily developed for treatment of oily wastes from ships.

2.1 PIERSIDE AND BARGE COLLECTION OF SHIPBOARD OILY WASTE. Wastewater collected in the bilges of ships normally contains about 1 percent oil and grease and some heavy metals and organic contaminants. This waste may not be directly discharged to public waters, and in many cases it is unsuitable for discharge to a POTW. Full treatment to direct discharge standards or pretreatment to reduce pollutants to acceptable levels for municipal sewer discharge is necessary. Bilge wastes are normally the primary influent, both in volume and contaminant concentration, to an oily waste treatment system. Occasionally, compensating ballast water is discharged from ships and barges directly overboard. Some activities are required by the local regulatory agencies to collect compensating ballast water during ship's refueling operations. This waste contains lower contaminant levels than bilge wastes but usually requires treatment before disposal.

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

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

2.4 TANK FARM OPERATIONS. The soil around large buried fuel or oil storage tanks is often dewatered by a perforated underdrain system. Fuel or oil may enter the soil by tank overflows or structural failure. It can seep into the surrounding soil and drainage system and create a potential ground water contamination problem. The movement of the fuel or oil through the soil to the drainage system is enhanced during periods of precipitation and/or the presence of a high water table. Contaminated soil should be removed and replaced with uncontaminated materials, and the drainage pipe cleaned. If not feasible, provide oily wastewater treatment system. Complexity of system will depend on required effluent quality. Provide containment facilities, such as skimming dams or diversion ponds for fuel or oil transfer areas to prevent spills from reaching surface water bodies and underground drainage systems. Containment area will require a chemical resistant, impermeable lining. Provide containment areas around storage tanks. Equip fuel and oil storage tanks and dispensing facilities with covers or other control devices to minimize dispersion of hydrocarbons into the air. New tanks should comply with Federal and state underground storage tank regulations. These regulations provide guidelines for the design, material of construction, and monitoring techniques as well as for any remedial action in case of leakage.

2.5 FIRE TRAINING AREA. Firefighting demonstrations that require disposal of unburned fuel and/or oil, burn products, AFFF, or protein foam are routinely scheduled. Design containment area to prevent uncontrolled runoff and percolation of fuel, oil, and foam into soil or open surface drains. Refer to Table 2 for wastewater characteristics from fire training area.

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

2.7 SHIP AND BARGE DEBALLASTING OPERATIONS. For design criteria refer to appropriate references.

2.8 OTHER SOURCES. Other sources of oily wastes include aircraft machine and paint shops, fuel transfer operations, and runway operations.
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2.8.1 AIRCRAFT MACHINE AND PAINT SHOPS. Aircraft machine and paint shop wastes include many types of lubricating and cutting oils, hydraulic fluids, paints, paint strippers, solvents, degreasers, washdown waters, and plating wastes. Do not discharge these wastes to a building drain system. Collect in separate systems and route to oily or industrial wastewater treatment systems. Check the compatibility of wastewater mixtures and the hazardous waste nature of the mixture.

2.8.2 FUEL TRANSFER OPERATIONS. Spills may occur during fuel transfer operations. If possible, use dry absorbents to pick up oil and dispose of them as solid waste material. Check flash point of the spent material for possible hazardous waste characteristics.

2.8.3 RUNWAY OPERATIONS. At airports subjected to cold weather, deicing fluids such as ethylene glycol are used to keep runways from icing over. Deicing fluids are generally washed off by rainfall or snowmelt into runway storm sewers.

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

	Concentration (mg/L)	
Characteristic	Average	Peak
Oil and grease	200 to 2,000	10,000 to 100,000
Suspended solids	50 to 500	5,000
pH	6 to 8 units	--
Copper	0.02 to 2	5 to 10
Lead	0.03 to 0.1	0.5
Mercury	Negligible	--
Nickel	0.01 to 0.2	0.5
Zinc	0.1 to 1	2
Phenolics	0.01 to 0.5	2
Sulfides	0 to 80	--

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

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

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

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

5 DISPOSAL OF OIL. Oils and oily sludges obtained from treatment or pretreatment systems may be disposed of by several methods. These are reuse/recovery, incineration, selling, waste hauler, landfill, and land disposal. Final disposal options must be evaluated concurrently with oil-water separation methods and environmental requirements to establish the most cost-effective total system.

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

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

5.3 WASTE HAULER. May be feasible when available.

5.4 LANDFILL OR LAND DISPOSAL. Dewatered oily sludge may be disposed of in a dedicated landfill site or in a landfill with other solid wastes. Oily sludge, with or without domestic wastewater sludge, can also be incorporated into the soil in a land application system. The landfill or land disposal site must be approved to accept the sludge. Oily sludge may be considered a hazardous waste based on RCRA criteria for flammability or the TCLP. Determine hazardous waste nature by TCLP test results and ignition point. Contact state regulatory agency for local handling, transport, and storage requirements.

6. EMERGENCY CONTAINMENT AND CLEANUP. Process and treatment operations at installations should be controlled to eliminate spills of oil to surface and ground waters. Equipment and procedures to effectively contain and remove accidental spills should be established as a part of the oily waste collection and treatment system.

7 OILY WASTEWATER CHARACTERISTICS

7.1 GENERAL. Establish wastewater flow rate and contaminant concentrations, when possible, through direct measurements and sampling. Use existing installations to forecast conditions for facilities to be constructed. Exercise caution with regard to the similarity of oily wastewater sources and collection systems. Length and configuration of collection system, liquid transport velocities, and associated appurtenances (pumping) can significantly influence wastewater characteristics.

3.7.2 CHARACTERISTICS. The types and concentrations of contaminants in oily wastes from different sources will vary greatly. The type of contaminant may be one or a combination of the following: various oils such as hydraulic, turbine, lubricating, cutting, and motor oil (which may be in the form of free, dispersed, emulsified, or dissolved oil); gasoline; heavy metals; emulsifying agents; solvents; oily sludge; seawater; and particulate matter (flotable and settleable) such as sand, soil, gravel, and paint skins.
Based on available data from analyses of shipboard discharges and composite influents to oily waste treatment systems, a general characterization of physical and chemical properties of untreated oily waste is as follows:

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Lead	0.03 to 0.1	0.5
Mercury	Negligible	--
Nickel	0.01 to 0.2	0.5
Zinc	0.1 to 1	2
Phenolics	0.01 to 0.5	2
Sulfides	0 to 80	--

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

7.3 FLOWS. Determine frequency and duration of maximum and average flows for ship-generated oily wastes by using the methods described in paragraph 3.8. Determine flow characteristics of other oily wastes by using the methods described.

7.4 SAMPLING. Collect, preserve, and analyze representative samples to determine the physical and chemical characteristics and concentrations. Conduct sampling program concurrently with a flow measuring program. Oily wastewater sources that are highly variable with regard to volume and constituent concentrations should be sampled continuously using flow weighted composites (refer to guidelines for sampling in EPA PB 259146).

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

7.6 TREATABILITY. Use benchscale and pilot plant studies as required to determine treatment processes that will provide the required effluent quality. Use benchscale experiments to determine design criteria for chemical dosage, optimum pH, suspended solids settling rate, temperature effects, emulsion breaking, oil separation, sludge generation, and allowable overflow rate. Refer to Process Design Techniques for
Industrial Waste Treatment by Adams and Eckenfelder for treatability test procedures. When considering gravity separation only, use column settling test at sample collection site, if practical, and immediately after collecting sample. Avoid column agitation and sunlight during test period. If chemical addition is required, use jar test to select optimum conditions and

column test to simulate gravity separation. Compare test results with most stringent applicable effluent quality regulations.

8. COLLECTION AND TRANSFER

8.1 SHIP OILY WASTEWATER GENERATION

8.1.1 SHIPS. Collection of ship's oily wastewater should be available at every berth. The collection may take the form of truck or barge transfer or facility pipelines. Coordinate with environmental requirements to determine the most life-cycle cost efficient, environmentally acceptable collection system.

8.1.1.1 SOURCES. Primary sources of ship-generated oily wastewater are bilges, oily waste holding tanks for collecting lubricating oils and water contaminated fuel, condensate lines, and tank cleaning water. Sonar dome pumping water is not normally collected as part of the oily waste collection system. The oil content in the bilge water normally varies from 0.01% (100 ppm) to 1.0% (10,000 ppm). The rest is mostly saltwater of unknown chloride content. The oil content of ship discharges overboard is limited to 20 ppm or less within 12 nautical miles of nearest land. In restricted ports, ballast water can be discharged from most ships (other than tankers) through large diameter piping directly overboard to a ship waste oily barges. Compensating ballast water can also be discharged directly to a pier collection system providing the liquid can gravity flow (from ship to pier connection) and back pressure kept to a minimum. Generally bilge water should be treated like any other waste. At the time of publishing, the states of California and New Jersey consider bilge water as a hazardous waste. Some states may also require the collection of compensating ballast water when refueling occur within the restricted waters (in port) of the United States.

8.1.1.2 SHIP-TO-SHORE OILY WASTEWATER TRANSFER. In 1970, a program to limit the discharge of oily waste from ships and crafts may parallel international, federal, state, and local regulations and agreements concerning oil pollution abatement. Various OPA equipment have been installed on ships in recent years to minimize oily waste pollutant discharges. Most ships have oil water separators, waste oil tanks (WOTs), oily waste holding tanks (OWHTs), and oily waste transfer pumps (OWTPs). A brief description of these equipment is presented below:

(1) An OWHT usually can contain the oily waste generated in one-half day by a ship in auxiliary mode. It holds at least 1,000 gallons.

(2) A WOT usually can contain the oily waste separated during a 60-day mission.

(3) A OWTP is normally a segregated electric driven pump that pumps bilge water to the OWHT and waste oil or oily waste to shore facilities. Some older ships use rotary vane pumps, but the newer ones use sliding shoe pumps. Pumps discharge at least at 10 psi pressure at the lowest weather deck of the ship. See Table 1 for discharge pressures for each class. These pumps normally have capacity of off-loading the OWHT in approximately 1 to 2 hours. The off-loading time may take up to 4 hours.

(4) Transfer is accomplished via standard ship deck discharge-risers connected by 2.5-inch (65-mm) flexible hose to standard pier risers (see Figure 1). A ship nested outboard normally will lay hoses across the deck of the inboard ship.

8.1.2 SHIP OILY WASTEWATER FLOWS. Treatment systems should be sized for the following flows. Ship bilge daily flow varies with the class of ship, shipboard operations, and condition of the ship's mechanical equipment. The three measures of ship's flow are average (Qave), peak (Qpeak), and additional from compensating fuel tanks (Qcomp). Estimated values for the ship flow (without the use of onboard OWS) for each ship class is listed on Table 2. These flows are used in various combinations (depending on facility size) to estimate the total daily oily waste flow (Qdaily) from a pier. Qcomp is determined based on the fueling capability of the facility. If no fuel capability exists on the pier, then this quantity is zero. Fuel capability may be in the form of piping, trucks or barges. If fueling capability exists, then this quantity is equal to the maximum fueling rate for one day. Qdaily is used to estimate ship utility charges and shoreside oily waste treatment plant capacity, operating costs, and operating schedule. Plants should normally be assumed to operate on a 40-hour work week. The size of the pier facility depends on the historical and pier berthing plan. Facility size and Qdaily are determined as per the following subparagraphs.

Ship Class[1]	Number of Oily Waste Transfer Pumps (OWTPs)	Capacity of Each Pump gpm(L/s)	Rated Pump Discharge Pressure[2] psig(kPa)	Design Deck Riser Pressure[3] psig(kPa)	Deck Riser Height above Waterline ft(m)
CV	2	200(12.6)	125(861.8)	80(551.6)	28(8.5)
CVN	2	200(12.6)			
CG 16	2	50(3.2)	40(275.8)	15(103.4)	22(6.7)
CG 47					
CGN 36	4	54(3.4)	110(758.4)	22(151.7)	21(6.4)
CGN 38					
DD 931	2	50(3.2)	60(413.7)	39(268.9)	11(3.4)
DD 963	2	90(5.7)	110(758.4)	33(227.5)	18(5.5)
DDG 51	2	50(3.2)	50(344.7)		
DDG 993	2	90(5.7)	110(758.4)	33(227.5)	18(5.5)
FF 1052	1	50(3.2)	60(413.7)	37(255.1)	13(4.0)
FFG 1	2	50(3.2)	60(413.7)	35(241.3)	17(5.2)
FFG 7	1	15(0.9)			
SSN 21	2	280(17.7)	(C)[4]	(C)	
SSN 637	1	230(14.5)	(C)	(C)	
SSN 688	1	230(14.5)	(C)	(C)	
SSBN 726	1	230(14.5)	(C)	(C)	
PHM					
LHA	5	4@ 18(1.1)	110(758.4)		
		1@ 54(3.4)			
LHD	3	54(3.4)	110(758.4)		
LPD 4	2	1@ 18(1.1)	110(758.4)	30(206.8)	34(10.4)
		1@ 90(5.7)			
LPD 17	1	54(3.4)	110(758.4)		
LPH	2	100(6.3)	60(413.7)	27(186.2)	31(9.4)
LKA	1	50(3.2)	50(344.7)	16(110.3)	40(12.2)
LSD 33	1	100(6.3)	60(413.7)	36(248.2)	24(7.3)
LSD 41					
LST	2	50(3.2)	50(344.7)	25(172.4)	28(8.5)
LCC	1	100(6.3)	50(344.7)	23(158.6)	22(6.7)
AE-21	1	50(3.2)	50(344.7)	24(165.5)	20(6.1)
AE-26	2	1@ 50(3.2)	60(413.7)	35(241.3)	20(6.1)
		1@ 15(0.9)			
AF	1	100(6.3)	60(413.7)	30(206.8)	25(7.6)
AO 143					
AO 177	2	100(6.3)	50(344.7)	19(131.0)	25(7.6)
AOE 1	1	100(6.3)	50(344.7)	13(89.6)	32(9.8)
AOE 6					

Table 1

Ship bilge pump data

Ship Class[1]	Number of Oily Waste Transfer Pumps (OWTPs)	Capacity of Each Pump gpm(L/s)	Rated Pump Discharge Pressure[2] psig(kPa)	Design Deck Riser Pressure[3] psig(kPa)	Deck Riser Height above Waterline ft(m)
AOR 1	1	100(6.3)	60(413.7)	29(199.9)	26(7.9)
MSO	2	15(0.9)	50(344.7)	35(241.3)	9(2.7)
MCM					
MCS					
MHC					
PC					
ACS					
AD-14	1	100(6.3)	60(413.7)	32(220.6)	26(7.9)
AD-37					
AD-41					
AR	1	100(6.3)	60(413.7)	33(227.5)	22(6.7)
ARS 6	2	15(0.9)	50(344.7)	29(199.9)	22(6.7)
ARS 50					
AS 31	2	100(6.3)	60(413.7)		
AS 33	2	100(6.3)	60(413.7)		
AS 40					
ASR					
ATS	1	15(0.9)	50(344.7)	33(227.5)	12(3.7)
T-AFS	2	50(3.2) 15(0.9)	60(413.7)	31(213.7)	31(9.4)
T-AG 193	1	50(3.2)	50(344.7)	18(124.1)	33(10.0)
T-AGM	2	600(37.9)	125(861.8)		22(6.7)
T-AGOS 1	1	10(0.6)	52(358.5)		15(4.6)
T-AGOS 19	2	20(1.3)	30(206.8)		
T-AGOS 23	2	18(1.1)	110(758.4)		30(9.1)
T-AGS 51	2	20(1.3)	50(344.7)		14(4.3)
T-AGS 60	1	20(1.3)	50(344.7)	10(68.9)	14(4.3)
T-AH (SYS 1)	2	425(26.8)	65(448.2)		40(12.2)
T-AH (SYS 2)	2	21(1.3)	50(344.7)		40(12.2)
T-AKR 287	2	110(6.9) 45(2.8)	64(441.3) 63(434.4)		30(9.1)
T-AKR 290	1	250(15.8)	100(689.5)		
T-AKR 295	2	50(3.2)			55(16.8)
T-AKR 296	2	50(3.2)		10(68.9)	55(16.8)

Table 1 (continued)

Ship bilge pump data

Ship Class[1]	Number of Oily Waste Transfer Pumps (OWTPs)	Capacity of Each Pump gpm(L/s)	Rated Pump Discharge Pressure[2] psig(kPa)	Design Deck Riser Pressure[3] psig(kPa)	Deck Riser Height above Waterline ft(m)
T-AKR 300	2	50(3.2)			55(16.8)
T-AKR 310	2	50(3.2)	60(413.7)		55(16.8)
T-AO 187	1	100(6.3)	60(413.7)	30(206.8)	22(6.7)
T-ATF 166	1	15(0.9)	60(413.7)	44(303.4)	9(2.7)
T-ARC	2	420(26.5)	25(172.4)		
AVB	1	30(1.9)	60(413.7)		30(9.1)

[1]Major Surface Ship Classes which will be generating oily waste to be processed ashore. Refer to SECNAVINST 5030.1, Classification of Naval Ships and Craft, for description of other classes.
[2]Rated discharge pressure at the flow capacity listed. Pump recirculating relief valve limits discharge pressure at zero flow to 125 percent of rated discharge pressure listed.
[3]Estimate of ship deck riser pressure for shoreside design.
[4](C) indicates that information is classified. Use 3-inch piping for laterals.

Table 1 (continued)

Ship bilge pump data

Ship Class	Estimated Daily Peak Oily Waste Flow, Q_{peak} gpd (L/day)	Estimated Daily Average Oily Waste Flow, Q_{ave} gpd (L/day)
CV	80,000 (302,832)	50,000 (189,270)
CVN	35,000 (132,489)	35,000 (132,489)
CG 16	12,000 (45,425)	3,000 (11,356)
CG 47	12,000 (45,425)	3,000 (11,356)
CGN 36	2,500 (9,464)	1,750 (6,624)
CGN 38	2,500 (9,464)	1,750 (6,624)
DD 931	3,500 (13,249)	1,000 (3,785)
DD 963	6,750 (25,551)	1,500 (5,678)
DDG 51	12,000 (45,425)	3,000 (11,356)
DDG 993	3,500 (13,249)	1,000 (3,785)
FF 1052	3,500 (13,249)	1,000 (3,785)
FFG 1	3,500 (13,249)	1,000 (3,785)
FFG 7	6,750 (25,551)	1,500 (5,678)
SSN 21	500 (1,893)	250 (946)
SSN 637	500 (1,893)	250 (946)
SSN 688	500 (1,893)	250 (946)
SSBN 726	500 (1,893)	250 (946)
PHM	100 (379)	50 (189)
LHA	21,000 (79,493)	6,400 (24,227)
LHD	21,000 (79,493)	6,400 (24,227)
LPD 4	21,000 (79,493)	6,400 (24,227)
LPD 17	21,000 (79,493)	6,400 (24,227)
LPH	21,000 (79,493)	6,400 (24,227)
LKA	21,000 (79,493)	6,400 (24,227)
LSD 33	4,800 (18,170)	2,700 (10,221)
LSD 41	4,800 (18,170)	2,700 (10,221)
LST	4,000 (15,142)	1,000 (3,785)
LCC	21,000 (79,493)	6,400 (24,227)
AE-21	4,800 (18,170)	2,700 (10,221)
AE-26	4,800 (18,170)	2,700 (10,221)
AF	15,000 (56,781)	3,500 (13,249)
AO 143	21,000 (79,493)	11,250 (42,586)
AO 177	21,000 (79,493)	11,250 (42,586)
AOE 1	21,000 (79,493)	11,250 (42,586)
AOE 6	21,000 (79,493)	11,250 (42,586)
AOR 1	21,000 (79,493)	11,250 (42,586)

Table 2

Estimated daily oily waste flows for facility design

Ship Class	Estimated Daily Peak Oily Waste Flow, Q_{peak} gpd (L/day)	Estimated Daily Average Oily Waste Flow, Q_{ave} gpd (L/day)
MSO	100 (379)	50 (189)
MCM	100 (379)	50 (189)
MHC	100 (379)	50 (189)
PC	100 (379)	50 (189)
ACS		
AD-14	15,000 (56,781)	10,000 (37,854)
AD-37	15,000 (56,781)	10,000 (37,854)
AD-41	15,000 (56,781)	10,000 (37,854)
AR	15,000 (56,781)	3,500 (13,249)
ARS 6	500 (1,893)	275 (1,041)
ARS 50	500 (1,893)	275 (1,041)
AS 31	15,000 (56,781)	10,000 (37,854)
AS 33	15,000 (56,781)	10,000 (37,854)
AS 40	15,000 (56,781)	10,000 (37,854)
ASR	100 (379)	100 (379)
ATS	3,500 (13,249)	3,250 (12,303)
T-AFS		
T-AG 193		
T-AGM		1,000 (3,785)
T-AGOR		
T-AGOS 1	100 (379)	50 (189)
T-AGOS 19	100 (379)	50 (189)
T-AGOS 23	100 (379)	50 (189)
T-AGS		
T-AH		
T-AK		
T-AKR 7		
T-AKR 287		
T-AKR 300		
T-AO 187	21,000 (79,493)	11,250 (42,586)
T-AOG 77		
T-AOT		
T-ATF 166		
T-ARC		
AVB		

Table 2 (continued)

Estimated daily oily waste flows for facility design

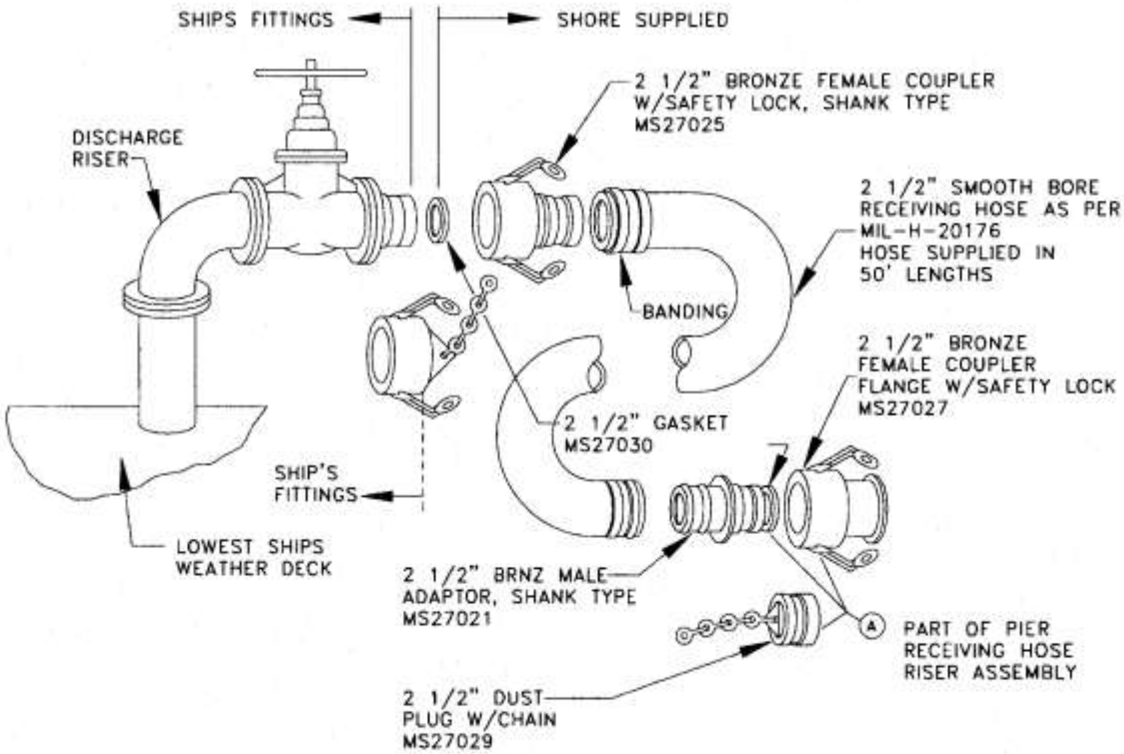


Figure 1

Ship-to-shore oily waste hose connection

a) Small Facilities. Defined as pier facilities with fewer than 15 homeported vessels. Qdaily is determined by:

$$Q_{daily} = Q_{comp} + \sum_{n=1}^{N} Q_{peak}$$

where

Q_{daily} = design daily flow for facility, gpd(L/day)

Q_{comp} = maximum fueling flow per day from shore to ships, gpd(L/day)

N = number of ships at piers during maximum holiday berthing or special peacetime exercise

Q_{peak} = peak daily flow from each ship, gpd(L/day) (see Table 12)

b) Large Facilities. Defined as pier facilities where more than 15 ships are homeported. Qdaily is determined by:

$$Q_{daily} = Q_{comp} + \left(1.33 \times \sum_{n=1}^{M} Q_{average}\right)$$

where

Q_{daily} = design daily flow for facility, gpd(L/day)

Q_{comp} = maximum fueling flow per day from shore to ships, gpd(L/day)

M = number of ships at piers during average daily berthing condition.

Q_{ave} = average daily flow from each ship, gpd(L/day)

Each facility should be capable of accommodating the maximum daily flow (Qmaximum) using overtime during holiday operations. Qmaximum is determined by:

$$Q_{maximum} = Q_{comp} + \sum_{n=1}^{N} Q_{avg}$$

where

$Q_{maximum}$ = maximum daily flow during holiday berthing, gpd(L/day)

Q_{comp} = maximum fueling flow per day from shore to ships, gpd(L/day)

N = number of ships at piers during maximum holiday berthing or special peacetime exercise

Q_{ave} = average daily flow from each ship, gpd(L/dav' ...

8.1.3 DESIGN FLOW FOR PIER OILY WASTE. Flow estimate for design of pier main and laterals and pump station capacity is determined as follows.

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

$$Q_{main} = 0.31 \sum_{i=1}^{S} (n_i)(q_i)$$

where

Q_{main} = design daily flow for pier main, gpm (L/s)

S = maximum number of ships at pier during holiday berthing condition, use ship mix that produces largest daily flow

q_i = discharge rate from each OWTP (assume one pump per riser), gpm(L/s)

n_i = total number of OWTP conn... ...d to same pier pressure main

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

$$Q_{lateral} = 0.31\sum_{i=1}^{P} (n_i)(q_i)$$

where

$Q_{lateral}$	=	design daily flow for pier lateral, gpm(L/s)
P	=	maximum number of ships connected to same lateral during holiday berthing condition, use ship mix that produces largest daily flow
q_i	=	discharge rate from each OWTP (assume one pump per riser), gpm(L/s)
n_i	=	total number of OWTP connected to same pier pressure main

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

8.2 SHORESIDE COLLECTION SYSTEMS

8.2.1 GENERAL. Lay out the system to segregate oily and non-oily wastewater sources to minimize oil-water separator hydraulic loading, minimize emulsification, and maximize oil and grease concentration. Combine similar wastewaters and route to most efficient treatment processes.

8.2.2 COLLECTION SYSTEM LAYOUT. The collection system consists of a 6-inch (150-mm)(minimum) pier pressure main with 4-inch (100-mm)(minimum) pressure laterals manifold to main. Main may be laid in center or alongside of pier. Facilities berthing some ships may use 3-inch lateral. Space lateral and pier riser at 150 feet (46 m). This relatively close spacing facilitates flexible berthing configurations. Mission change frequently and flexibility should be incorporated. Hose riser assemblies need not be provided at the end of piers unless specifically required by the activity. Use dual hose receivers to provide capability for nesting ships. Nesting may occur during major exercises and holidays and during periods when nearby berth are down because of damage or repair. Provide containment according to Title 33 CFR Part 154.530

(U.S. Coast Guard regulations). See Figure 2 for pier receiving hose riser assembly connection. Consider the following when laying out a pier collection pipeline:

a) Ships of same class type often berth together.
b) Locate a riser at the pier end for use by oil SWOB or service craft.
c) Install valves at head of each pier to allow for isolation in case of pier pipeline damage.
d) Allow for minimum slope toward free discharge to prevent liquid stagnation and freezing.
e) Use a minimum fluid velocity that will prevent settling of suspended solids and minimize emulsification.

8.2.3 PIPE MATERIALS. Specification of oily waste collection piping should include:

a) Minimum operating pressure of 150 psig (1,034 kPa).
b) Use mechanical joint, lined ductile iron for exposed locations where high impact resistance is important. Support exposed pipe per manufacturer's recommendations. In other exposed locations, for superior corrosion resistance, consider thermoplastic (high density polyethylene) pressure pipe with butt fusion joints. Plastic piping on pier and wharf systems should be protected from impact of floating debris and other hazards by placement in a specially designed utility trench. For buried lines, apply general sewer pipe selection guidelines.
c) Provide cathodic protection.

8.2.4 SPECIAL CONSIDERATIONS.

a) Provide freeze protection.
b) Provide cleanouts at junctions, directional changes, end of pipe run, and every 400 feet (122 m) of continuous runs.
c) For thrust support, hanger sizing, and spacing, consult manufacturer's design manual. Install pipelines inboard of pier fendering systems or preferably in utility tunnels. Protect pipelines from damage from below due to tide-carried debris. Consider composite type hanger system for increased durability in the marine environment.

d) Piping, manholes, and pump wells need not be double-walled or have secondary containment unless required by local regulations. Check local regulatory agencies for requirements.

8.3 PRESSURIZED PIER COLLECTION SYSTEM. Use pumping only when a gravity system cannot serve hydraulically, such as for wastewater collection lines at piers. For those pumping systems:

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

b) Use reciprocating positive displacement or screw pumps to transfer oily wastewater to treatment unit or equalization facility. Maximize size of wet well and select a number of pumps and an operating schedule to minimize surge effect of pump off-on cycle on downstream oil-water separators. Consider variable speed drives on transfer pumps.

c) If rotary displacement or centrifugal pump is used, design for low speed (< 900 rpm) to minimize mechanical emulsification. Maximize size of wet well and select the number of pumps and an operating schedule to minimize surge effect of pump off-on cycle on downstream oil-water separators. Consider the use of a pump control valve and a surge tank with control orifice to throttle discharge to oil-water separator. Consider variable speed drives on transfer pumps.

8.4 GRAVITY FLOW COLLECTION SYSTEM. Collection piping should be sized for the following flows. Procedures for design of ship oily waste collection pipelines are based on Qmain and Qlateral. The design objectives are to determine the diameter of pier laterals and the pier main. The design procedure is as follows:

8.4.1 FACILITY DAILY FLOW. For design purposes, determine if the activity is a "small" or "large" facility. Determine the number and classes of ships present during maximum holiday berthing and average daily berthing.

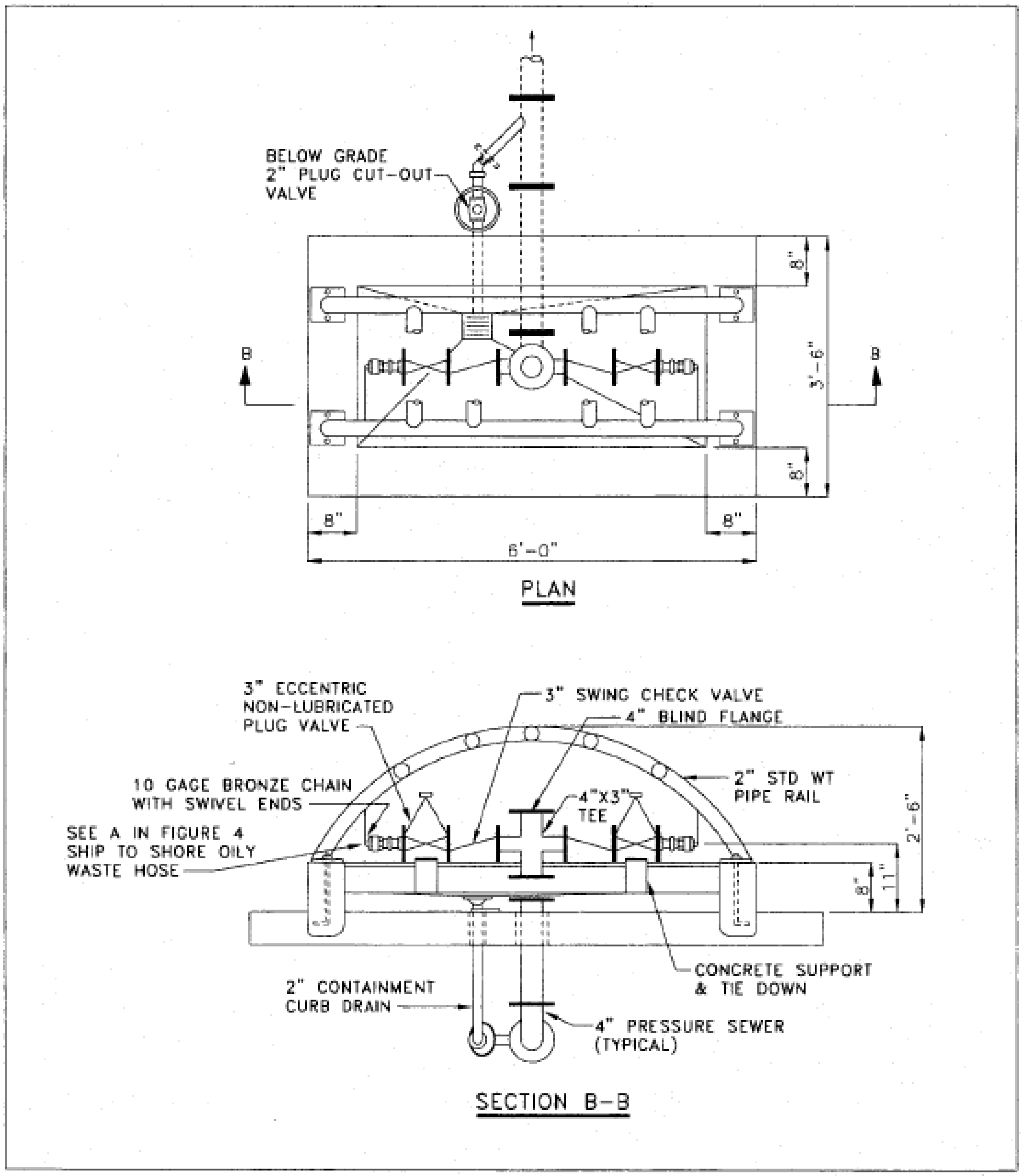


Figure 2

Pier receiving hose riser assembly

8.4.2 SIZING OF PIER MAIN AND LATERALS. Determine length of pier main, pier riser elevation, deck riser elevation, and ship discharge pressure for each ship class berthed at pier.

Determine the diameter of the pier main for Qmain flow rate at design velocity of 2 fps (0.6 m/s) for gravity system. Maintain pipe velocity less than scouring velocity recommended by pipe manufacturer. The minimum velocity will be zero since flow is intermittent. Pressurized systems should be sloped to drain to prevent freezing, fluid stagnation, and for cleaning purposes.

(1) Calculate the friction loss in the pier main at the Qmain flow rate using Equation 8 for flow of marine diesel fuel with viscosity at lowest expected ambient temperature.
(Note: Equation first appears in English (IP), then metric (SI)). Determine design viscosity from Figure 3. Assume Hm occurs at each main-lateral intersection as a back pressure against berthed ship's bilge pumps.

EQUATION (IP): $$H_m = [f(L/D)(Q_{main}/D_{main}^2)^2]/g$$

or

EQUATION (SI): $$H_m = [f(L/D)(Q_{main}/D_{main}^2)^2/g] \quad [79,217]$$

where

H_m = head loss in pier main, ft (kPa)
f = Darcy-Weisbach friction factor. See Figure IIIA-3 in Engineering Data Book by the Hydraulic Institute
L = length of pier main from pier end to free discharge point, ft (m)
D_{main} = pier main diameter, in. (cm)
g = 32.2 fps^2 (9.81 m/s^2)

(2) Calculate the maximum Qlateral for all ship types at maximum holiday berthing plan. Determine the diameter of the pier lateral at maximum Qlateral flow rate at design velocity of 5 to 7 fps (1.5 to 2.1 m/s). Maintain velocity less than the maximum scouring velocity recommended by pipe manufacturer.

8.4.3 HEAD LOSS DETERMINATION. Calculate the head loss across the pier riser assembly (Hr), the lateral (Hl), and the lateral-main intersection (Hlm) based on maximum Qlateral flow rate and design viscosity using equations noted. See Figure 4 for design nomenclature.

EQUATION (IP): $H_r = [K(Q_{lateral}/D^2)^2/2g][0.1669]$

or

EQUATION (SI): $H_r = [K(Q_{lateral}/D^2)^2/2g][1586.7]$

where

- H_r = head loss across pier riser assembly, ft (kPa)
- D = lateral diameter, in. (mm)
- $Q_{lateral}$ = as per Equation 7, gpm (L/s)
- g = 32.2 fps^2 (9.81 m/s^2)
- K = head loss coefficients for pier riser assembly. See Figure 8 for description of fittings in pier riser assembly.

EQUATION (IP): $H_l = [f(L/D)(Q_{lateral}/D^2)^2]/g$

or

EQUATION (SI): $H_l = [f(L/D)(Q_{lateral}/D^2)^2/g]$ [79,217]

where

- H_l = head loss through lateral from pier riser to lateral/main intersection, ft (kPa)
- L = length of lateral from pier riser to main, ft (m)

EQUATION (IP): $H_{lm} = [K(Q_{lateral}/D^2)^2/2g][0.1669]$

or

EQUATION (SI): $H_{lm} = [K(Q_{lateral}/D^2)^2/2g][1,586.7]$

where

- H_{lm} = head loss through total hose length from ship deck riser to pier riser, ft (kPa)
- K = loss coefficient for fitting at lateral/main intersection

For each ship in the berthing plan, determine the number of 50-foot (15.2-m) hose lengths and total hose length required to reach from the inboard ship deck discharge riser to the pier riser. Determine the head loss through the hose lengths by the equation noted.

EQUATION (IP): $H_h = (f[L/D][Q_{bilge}/D^2]^2)/g$

or

EQUATION (SI): $H_h = [(f[L/D][Q_{bilge}/D^2]^2)/g]$ [79,217]

where

H_h = head loss through total hose length from ship deck riser to pier riser, ft (kPa)

L = total hose length from ship deck riser to pier riser, ft (m)

Q_{bilge} = flow rate of one bilge pump, gpm (L/s) (see Table 11)

D = diameter of oily waste transfer hose, in. (mm)

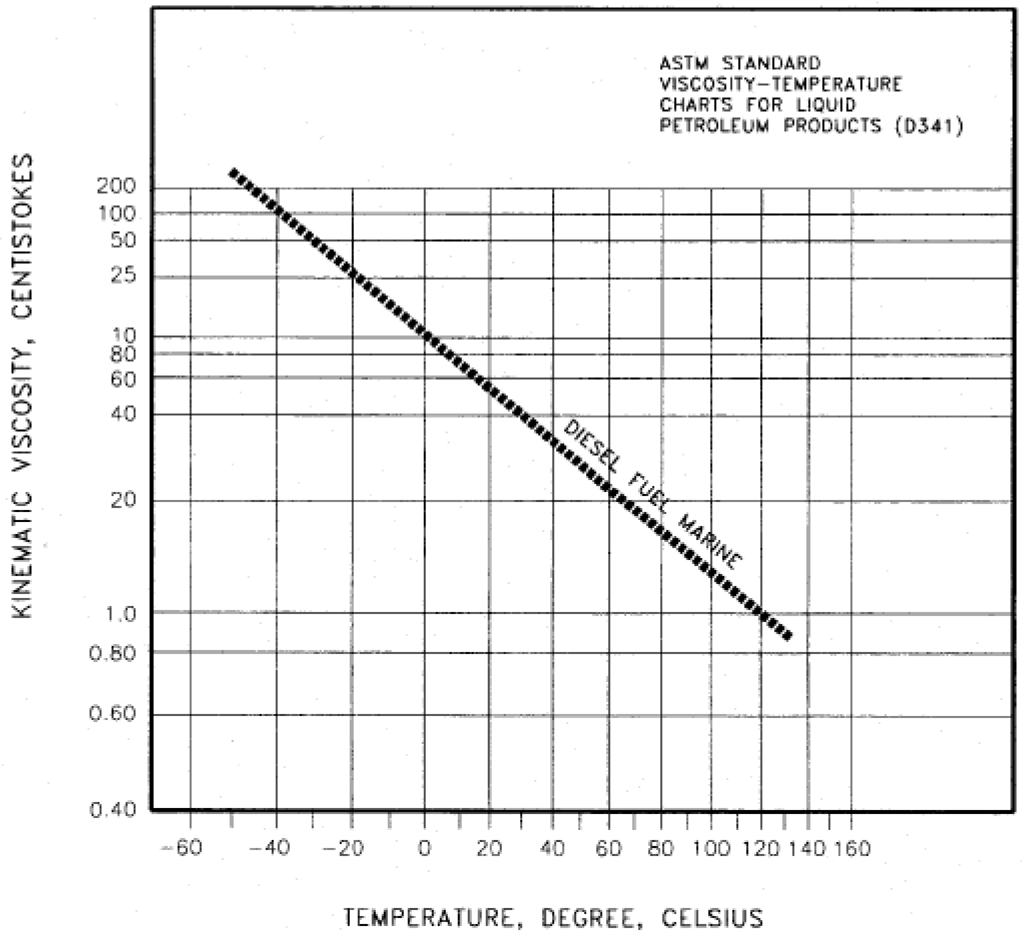
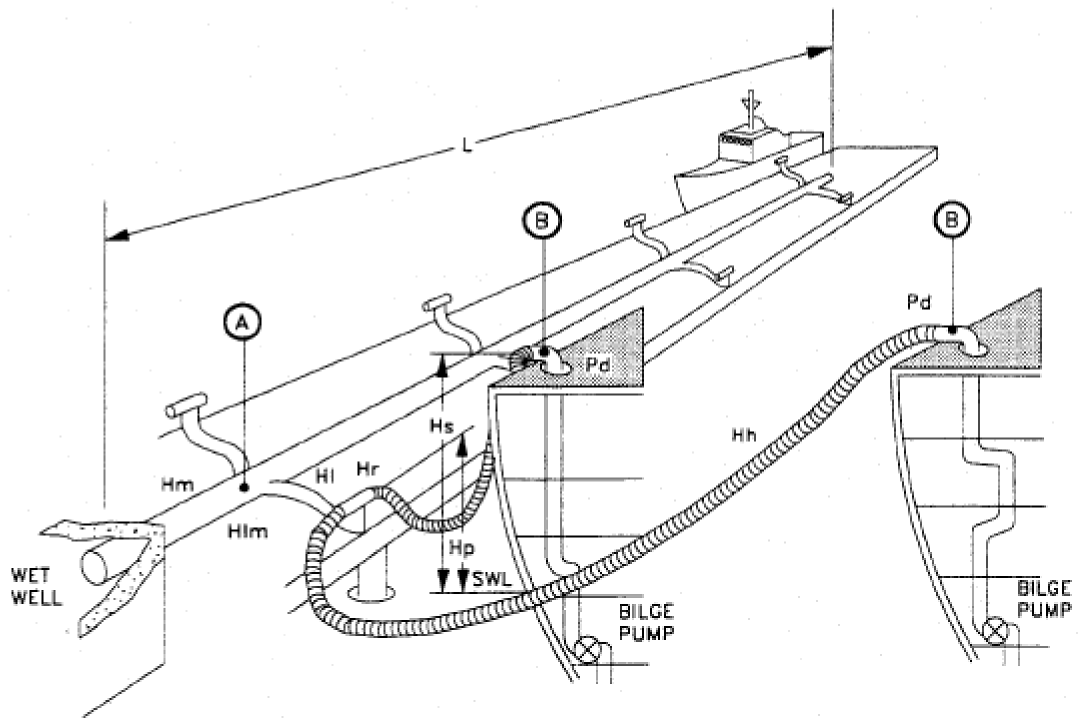


Figure 3

Viscosity-temperature relationship for marine diesel fuel



KEY

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

Figure 4

Oily waste collection pipeline – nomenclature

For each ship in the berthing plan and for each berth, sum the head losses due to flow and compare this sum with the ship deck discharge pressure using the equation below:

EQUATION (IP): $[H_m+H_r+H_l+H_{lm}+H_h+(H_p-H_s)]k < P_d$

or

EQUATION (SI): $[H_m+H_r+H_l+H_{lm}+H_h+(H_p-H_s)] < P_d$

where

H_m and H_l	=	head loss in pier main and lateral, respectively, ft (kPa)
H_r, H_h, H_{lm}	=	head loss in pier riser, ship's connecting hose, and lateral to main connection, respectively, ft (kPa)
(H_p-H_s)	=	elevation difference between pier riser, Hp, and ship's deck riser, Hs, ft (kPa). See Figure 11 for schematic
k	=	0.445 psig/ft
P_d	=	ship's deck riser discharge pressure, psig (kPa) (see Table 11)

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

8.5 PUMP STATIONS

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

8.5.1.1 WET WELL LINER. A protective rubberized liner or alternative protective coating should be provided to resist oil and grease and saltwater attack.

8.5.1.2 VENTILATION. Provide continuous ventilation with complete air changeover every 2 minutes.

8.5.1.3 INLET SCREENS. Provide basket or bar type screens on a pump inlet which can be removed and cleaned at the surface without personnel entry.

8.5.2 PUMP SELECTION. Determine pump capacity and operating cycle. Use positive displacement pumps with pressure relief valve, rather than centrifugal pumps, to reduce mechanical formation of emulsion at oily waste treatment plants. Pumps should pass solids having a diameter 0.125 inches (3 mm).

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

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

9. OILY WASTEWATER TREATMENT

9.1 GENERAL. No single treatment process or commercial device will remove all forms of oil (emulsified, free or dissolved) in oil-water mixtures. A series of treatment process units may be utilized to achieve the desired effluent quality. The degree of treatment required will be based on the most applicable discharge limit for a POTW or navigable water. Select oily wastewater treatment options from those presented in Table 3. In addition, sludge treatment and disposal must be considered.

9.2 TREATMENT REQUIREMENTS. The level of required treatment for oily wastewater depends on the discharge criteria (POTW or navigable water).

9.2.1 DISCHARGE TO PUBLICLY OWNED TREATMENT WORKS (POTW). Typical effluent quality requirements can be achieved by batch treatment gravity separation processes to remove free oil from wastewater. The oily waste is discharged into a short-term storage/separation tank referred to as a load equalization tank (LET). The waste is received for a predetermined number of days and then allowed to sit quiescently for about 24 hours to ensure optimum gravity separation. Free oil floats to the surface and is skimmed off. Settleable solids sink and are scraped to a hopper for withdrawal and disposal. Typical LET effluent contains less than 50 ppm of oil and grease. Multiple LETs should be provided for semicontinuous (fill and drawoff) operation of the facility. The pretreatment scheme is shown in Figure 5.

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

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

Treatment option	Description	Comments
Gravity separation		
Equalization basin	Separation of grease, oil, and settleable solids from water due to density differences. Tank or lined pond to dampen hydraulic and contaminant surges. If agitation is not employed, provide drain-off for floatables and settleables.	Effectiveness usually restricted to removal of free oil and settleable solids. Provide at least two basins operated in parallel as semi-continuous process. Fill period of 5-7 d and settling period of 2 d. Provide oil skimming and sludge scraping equipment. Design based on oil droplet diameter of 0.015 cm and is not necessarily typical of oil-water mixtures. Relatively inefficient and requires significant amount of space. Maintenance requirements are high if maximum treatment efficiency is to be attained. Avoid pumping influent oily wastewater to minimize mechanical emulsification. Use as pretreatment process preceding discharge to POTW or other onsite treatment process. Low capital and maintenance costs. Minimal space requirements. Operating requirements for cleaning plates and tubes may be high.
American Petroleum Institute (API) separator	Long, rectangular tank designed to provide sufficient hydraulic detention time to permit free and slightly emulsified (mechanical) oil to agglomerate and rise to the surface and suspended solids not entrapped in the oil to settle. Oil skimming and sludge raking required.	
Parallel plate separation	Tank equipped with inlet, oil coalescing, and outlet compartments to enhance separation of oil and suspended solids from oily wastewater. Number of coalescing plates or tube modules dependent on flow and characteristics of oil-water mixture.	
Vertical tube separator	See parallel plate separator.	See parallel plate separator.
Skimming dam	Low dam or weir placed in a flow through channel to pond water. Floating baffle retains floatables.	Utilize to impound contaminated surface runoff or spill for gross contaminant recovery and transfer to other treatment processes. Low capital, operating, and maintenance costs.
Thermal (cooker)	Heated vessel to accelerate liquid-liqui separation.	Oil reclamation process can be effective in breaking physical emulsions but increases solubility of oil. High operating costs, and inefficient for dilute oil-water mixtures.
Coalescing (mechanical)	Induced agglomeration of small oil droplets to aid gravity separation.	Effective in breaking physical emulsions when suspended solids do not interfere. Not effective in removing chemical emulsions.

Table 3

Guidelines for oily wastewater treatment

Treatment Option	Description	Comments
Filters	Oily wastewater applied to filter media either by gravity or by pumping. The reusable or disposable media is an oleophilic or hydrophobic packed, manufactured fibrous material or diatomaceous earth. Sand filters also used for effluent polishing.	High operating and maintenance costs. Efficiency decreases with low fluid temperatures and high oil concentrations. Wide variations in type and quantity of oil and grease reduces reliability of system. Pretreatment to remove suspended solids is usually required.
Dissolved or induced air flotation	Gravity separator using small air bubbles to lift oil globules to surface.	Effective in coalescing physical emulsions. High density suspended solids will decrease oil removal efficiency. Moderate capital and operating costs.
Ultrafiltration	Low-pressure (50-100 psig [345 kPA-689 kPA]) membrane process for separating emulsified oils. Oil droplets are retained by the membrane, concentrated and removed continuously. Usually preceded by an equalization tank and process tank.	In conjunction with gravity separation devices, effective in separating stable emulsions. High operating and maintenance costs and substantial pumping requirements.
Absorption	Penetration of one substance in one phase into the mass of another substance of a different phase.	May be effective as a tertiary process in removing low concentrations of highly emulsified or dissolved oil. High operation and maintenance costs. Highly sensitive to suspended solids.
Absorbent	Hydrophobic material with high affinity for specific oils.	For design guidance, refer to Water-Oil Separator for Fuel-Oil Handling Facilities, by Mootz.
Adsorption	Concentration or accumulation of a substance at the surface or interface of another substance.	May be effective as a tertiary process in removing soluble oil and chemically stable emulsions. Refer to EPA PB 259147.
Activated carbon	Utilize fixed, expanded, or moving carbon bed(s) to achieve desired treatment objectives.	Pretreatment usually required to reduce suspended solids. Proper section of carbon type and optimum operating parameters. The presence of other chemicals may diminish effectiveness of oil adsorption. High capital and operating costs.
Adsorbent resin	Effectiveness based on Van der Waals. Adsorption rather than coulombic ion exchange.	Same as for activated carbon.

Table 3 (continued)

Guidelines for oily wastewater treatment

Treatment option	Description	Comments
Biological	Oxidation by aerobic biological activity using fixed or suspended growth systems.	May be used as secondary treatment following primary processes that reduce suspended solids and most of free oil fraction. Requires that adequate nutrients be present and extended aeration period and mean cell residence time. Most applicable to existing biological treatment facilities.
Activated sludge, trickling filter or RBC	Refer to technical literature.	Use to remove soluble oil and break chemical emulsions. Can be utilized in combination with other treatment options discussed in this table.
Lagoon	Refer to technical literature.	Aerobic oxidation without mechanical aeration is minimal. Buildup of floating oil and sludge can promote anaerobic conditions that will result in the generation of undesirable gases. Not suitable for cold climate.
Chemical	Refer to technical literature.	Use to remove soluble oil and break chemical emulsions. Can be utilized in combination with other treatment options discussed in this table.
Emulsion breaking	System may include chemical storage and feed, flash mixing, flocculation, and settling. Chemicals used include sulfuric acid, alum, caustic soda, or activated alumina. Polyelectrolytes may be used as primary coagulant or as coagulant aid.	Usually used in conjunction with previous treatment options. Benchscale studies required for proper selection of best chemical(s), optimum dosages, and optimum pH. Use actual flow-weighted oily wastewater sample during laboratory studies to achieve best results. Polyelectrolyte use as primary coagulant may significantly reduce sludge production.

Table 3 (continued)

Guidelines for oily wastewater treatment

9.2.2 DISCHARGE TO NAVIGABLE WATER. To meet stringent effluent quality requirements for direct discharge, additional treatment is required after gravity separation in a LET. Depending on specific load requirements, 80 to 90 percent of the free and emulsified oil remaining after LET treatment must be removed by secondary and tertiary treatment steps. An NPDES permit would be required.

a) Batch treatment in a LET is the recommended primary unit operation. Secondary treatment such as a dissolved air flotation (DAF) or induced air flotation (IAF) unit will remove significant amounts of residual and some emulsified oil and grease. Normally, the effluent from a DAF/IAF unit will contain 10 to 50 mg/L of oil and grease. Based on treatability studies, it may be necessary to add coagulating and emulsion breaking chemicals to the DAF/IAF influent to optimize removal of contaminants. Sulfide control and metals removal may also be necessary to meet stringent discharge criteria.

b) To provide consistent direct discharge quality effluent, tertiary treatment is required. The recommended process is multimedia filtration with relatively fine graded media followed by carbon adsorption. In certain situations, primarily where flows are higher and space limitations prevent installation of a sufficient number or size of multimedia filters, coalescing filtration units should be considered. Coalescing filters are mechanically complex, but they perform reliably if operated and maintained properly. Figure 5 shows a schematic flow diagram for a treatment system to discharge to navigable waters.

c) Design guidelines and criteria for these unit processes are presented below.

9.2.3 REDUNDANCY. The design of an oily waste treatment system for either discharge criteria should provide 100 percent redundancy for critical process equipment. (Determination of criticality is based on the impact on effluent quality of loss of a component, and on a specific hazard analysis. It is important to avoid the loss of a key unit operation during either scheduled or unscheduled maintenance downtime for any piece of equipment. Guidelines for LET design require multiple units and redundant capacity for normal operation of the gravity separation process. It is also recommended that 100 percent redundancy be provided for downstream polishing treatment units, transfer pumping equipment, and effluent monitoring instrumentation.

9.3 SULFIDE CONTROL

9.3.1 SULFIDE FORMATION. The presence of sulfides in oily wastewater is primarily due to biological reaction involving anaerobic bacteria that use hydrocarbons as their energy source and convert sulfates to sulfides. The pH of wastewater affects the distribution of sulfide species. If low pH oily wastewater is exposed to the atmosphere, hydrogen sulfide (H_2S) gas is released causing severe odors and corrosion problems. At alkaline pH, the sulfide species do not escape to the atmosphere. Exposure to small concentrations of H_2S in the air is also a health hazard as it can affect the respiratory system. The time gap between the generation and treatment/ disposal of oily wastewater is a major factor for sulfide formation. During this time, oxygen is rapidly depleted causing a decrease in the ORP which favors the activity of sulfate reducing bacteria. This time should be kept at a minimum to limit sulfide production.

9.3.2 CONTROL TECHNIQUES. The principal physical and chemical methods for sulfite control at oily waste treatment plants include chemical oxidation, chemical precipitation, and wastewater aeration. Other techniques such as biological processes or adsorption have limited application at Navy oily waste treatment plants due to cost and operational requirements of these processes.

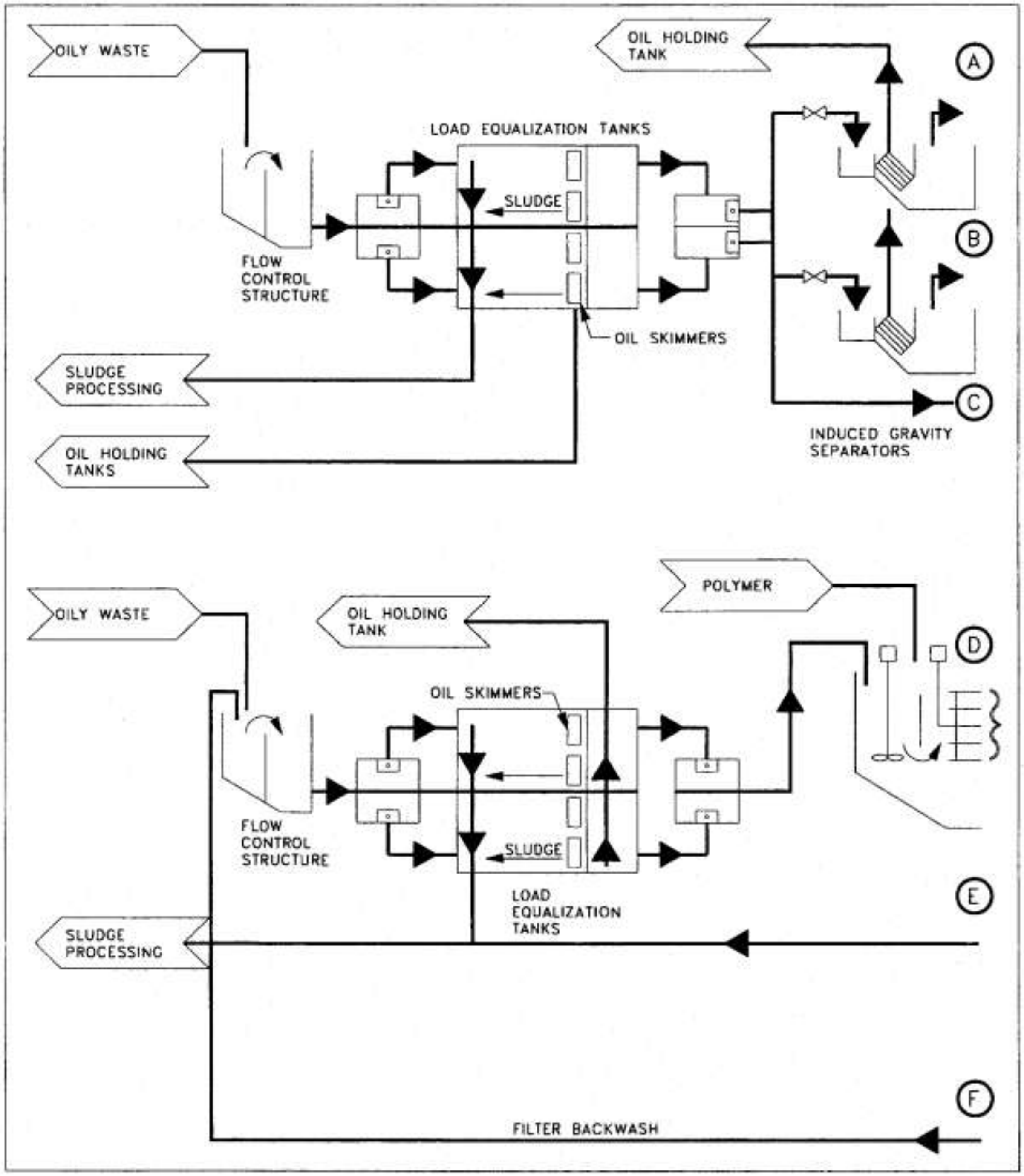


Figure 5A

Treatment system for discharge to POTW or navigable water

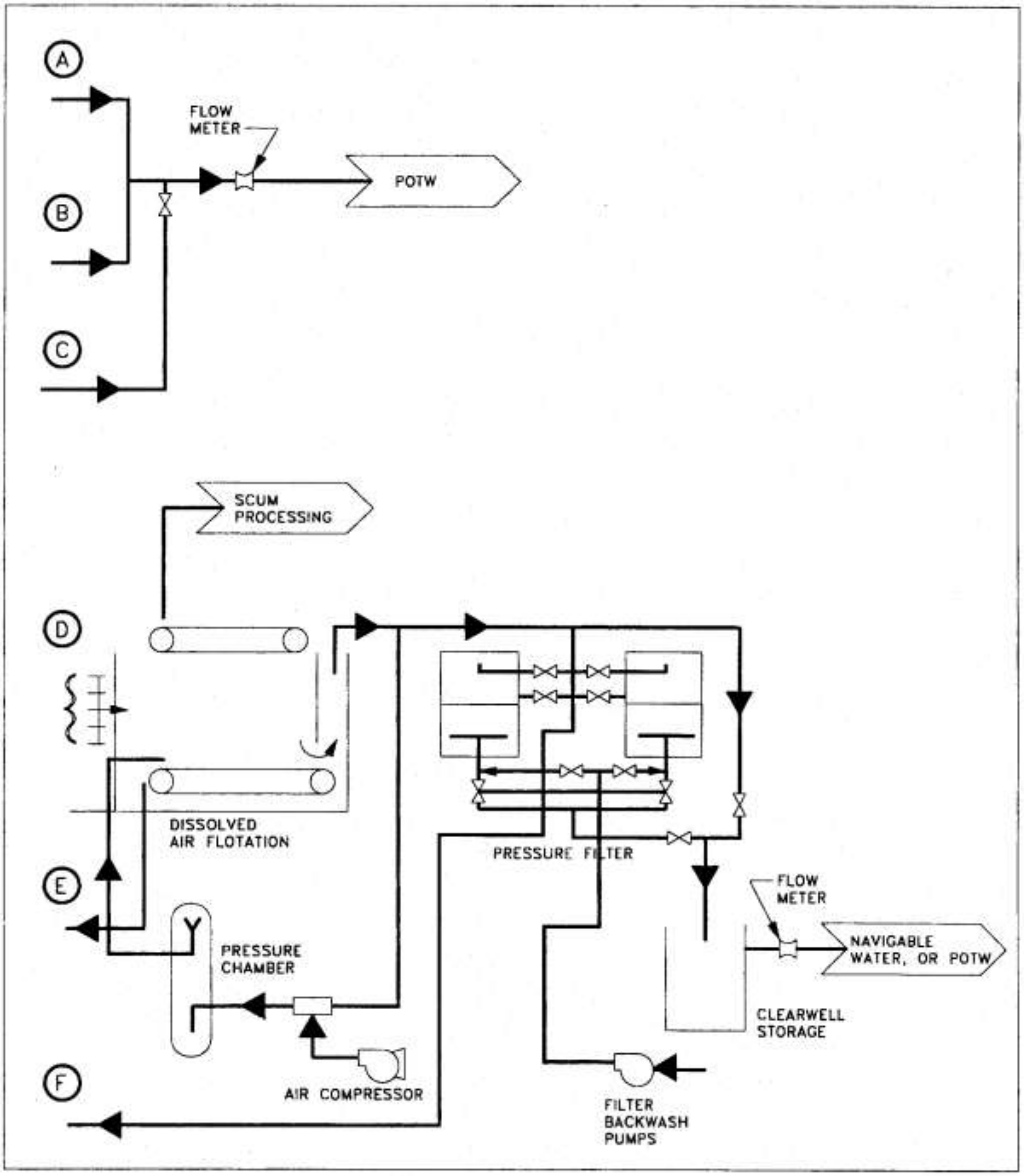


Figure 5B

Treatment system for discharge to POTW or navigable water

9.3.2.1 CHEMICAL OXIDATION. Treatment with agents such as hydrogen peroxide and chlorine or hypochlorite is effective in removing sulfides. The amount of chemical needed should be determined from laboratory investigation as the amount can vary significantly from stoichiometric requirements. Theoretically, one gram of hydrogen peroxide (H_2O_2) will oxidize one gram of hydrogen sulfide, but under actual operation the amount may vary by up to two to three times. Hydrogen peroxide is commercially available as either a 30, 50 or 70 percent solution by weight and the equipment required is relatively simple. For most oily wastewater plants, a package system in which peroxide is withdrawn directly from the container and applied with a metering pump will be adequate and is available from various suppliers. Peroxide is a strong oxidizing chemical and therefore tanks, pumps, and piping should be made with peroxide resistant materials. These include PVC, polyethylene, aluminum, or stainless steel. Hypochlorite and chlorine can also be used for sulfide control. For smaller plants, hypochlorite is recommended due to safety reasons and the simple hardware requirements. The actual amount of these chemicals needed to oxidize sulfides should be determined from laboratory experiments as the actual amount can vary significantly from the stoichiometric amount.

9.3.2.2 CHEMICAL PRECIPITATION. The removal of sulfides by precipitation should be used at plants where removal of emulsified oils from wastewater is desired due to common hardware and treatment requirements. Accurate pH control is required for this process to control sulfide equilibrium. Under alkaline conditions (pH about 8.5), sulfides will be removed by precipitation with dissolved metals in wastewater; whereas, at lower pH, the sulfides will escape into plant atmospheres as odorous hydrogen sulfide gas. Sodium hydroxide solution may be used to raise wastewater pH. This solution should be added in-line, prior to wastewater mixing to avoid sulfide release to the atmosphere. An in-line addition system, shown in Figure 6, consists of a storage tank, metering pump, and in-line mixing element. The addition of alkali can be controlled by simple instrumentation for pH control. The precipitated sulfides are removed during subsequent oil/water separation equipment such as DAF or IAF.

9.3.2.3 AERATION. Air injection into oily wastewater can prevent sulfides. In this technique, wastewater is aerated for an extended period of time, such as up to 24 hours to prevent ORP conditions. Aeration can cause release of existing sulfides due to mixing and should be avoided in enclosed areas. The sulfide formation during storage can also be prevented by the addition of a supplemental oxygen source, such as nitrate salts. The bacteria will consume nitrates instead of sulfates and sulfides will not be formed. The addition of nitrates has a disadvantage in that it enhances biological activity in wastewater and may significantly increase suspended solids loading.

9.4 DISSOLVED METALS REMOVAL

9.4.1 GENERAL. Oily wastewater may contain significant amounts of dissolved metals. The removal of the metals may be necessary due to discharge regulations particularly for direct discharging plants or for improved plant performance. Metals such as iron, zinc, lead, copper, and nickel can be reduced to low levels by chemical precipitation.

9.4.2 TREATMENT. The removal of dissolved metals can be accomplished by raising wastewater pH above 8 by adding lime or sodium hydroxide. At this pH, metals form highly insoluble precipitates. The minimum solubilities of different metals occur at different pH values as shown in Figure 7. Therefore, a laboratory investigation is essential to determine the optimum pH level. For plants using sulfide control by chemical precipitation, additional treatment for metals removal may not be necessary. As the alkaline solution is added for sulfide control, it will affect metals precipitation and metals will be co-precipitated as hydroxides and sulfides. The metal precipitates will be separated from wastewater in the oil-water separation equipment, such as the DAF or IAF. For improved removal of these precipitates, addition of polyelectrolytes may be necessary. The laboratory investigation should be conducted to select the type and amount of polyelectrolyte for simultaneous suspended solids (metals precipitates) and emulsified oil removal from wastewater.

9.5 EMULSIFIED OIL TREATMENT. Oily wastewaters contain varying amounts of emulsified oils and, unlike free oils, simple gravity settling is not effective for their removal.

Formation of oil emulsions should be minimized as much as possible by voiding excessive turbulence and the use of detergents or emulsifying agents. Segregate emulsions for special treatment wherever possible. Treatment of these segregated emulsions, which involves oil recovery, is discussed elsewhere. Emulsions are usually complex, and bench or pilot plant testing is generally necessary to determine an effective method for emulsion breaking. Common emulsion-breaking (demulsification) methods are a combination of physical and chemical processes. The most common approach to removing emulsified oils from wastewater is by the use of chemicals. These emulsions can be broken by chemicals which will balance or reverse interfacial surface tension, neutralize stabilizing electrical charges, or precipitate emulsifying agents and cause flocculation to form larger particles for subsequent removal. The effectiveness of various chemicals in breaking emulsions must be determined by laboratory testing. Refer to American Petroleum Institute (API), Manual on Disposal of Refining Wastes, Volume on Liquid Wastes for the testing procedure. Coalescence and flotation separation of oil and water phases follow chemical addition. Chemicals commonly used include alum, ferrous sulfate, ferric sulfate, ferric chloride, sodium hydroxide, sulfuric acid, lime, and polymers. The polymers or polyelectrolytes are large organic molecules that may be charged (cationic or anionic).

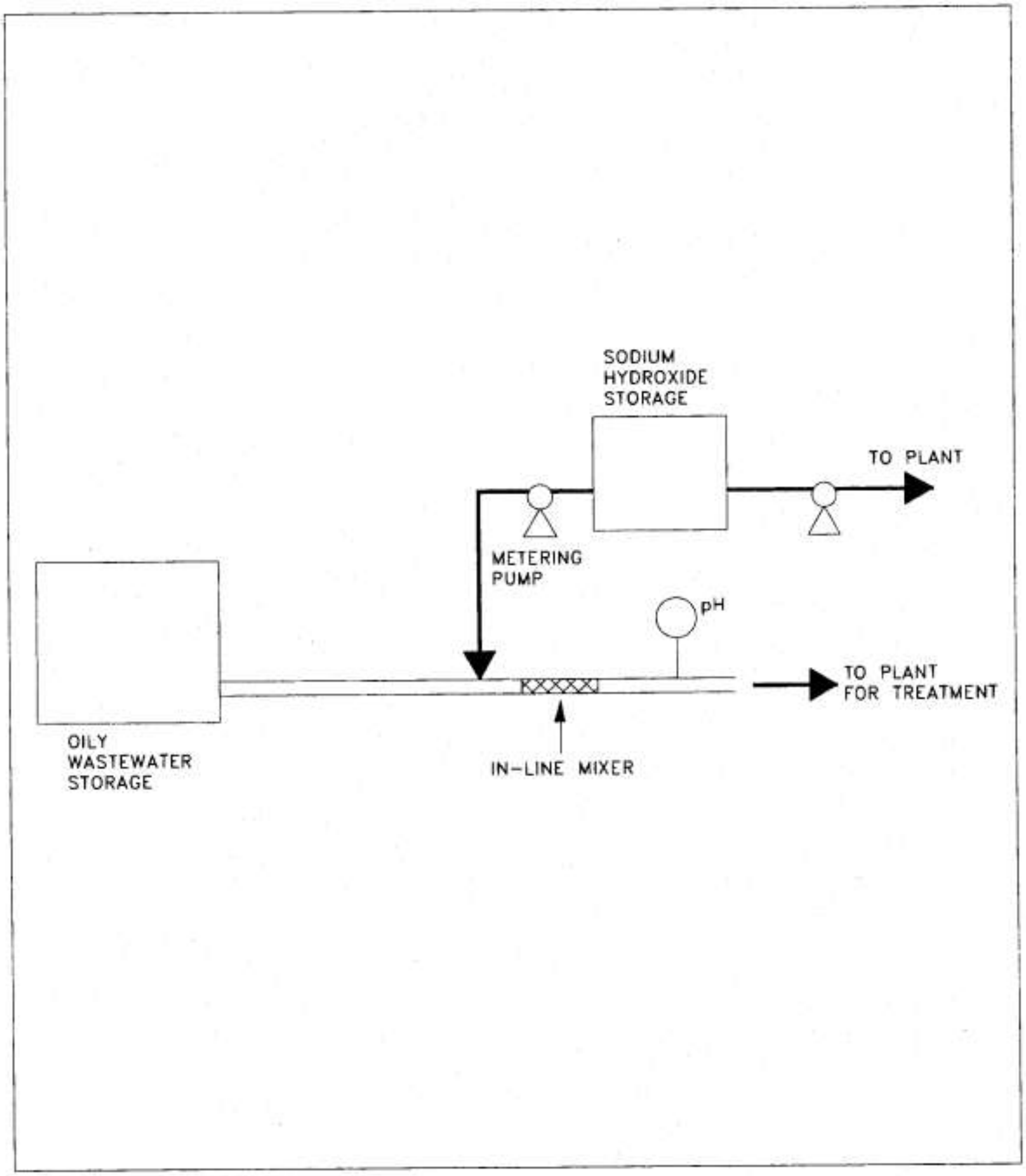


Figure 6

In-line chemical addition system

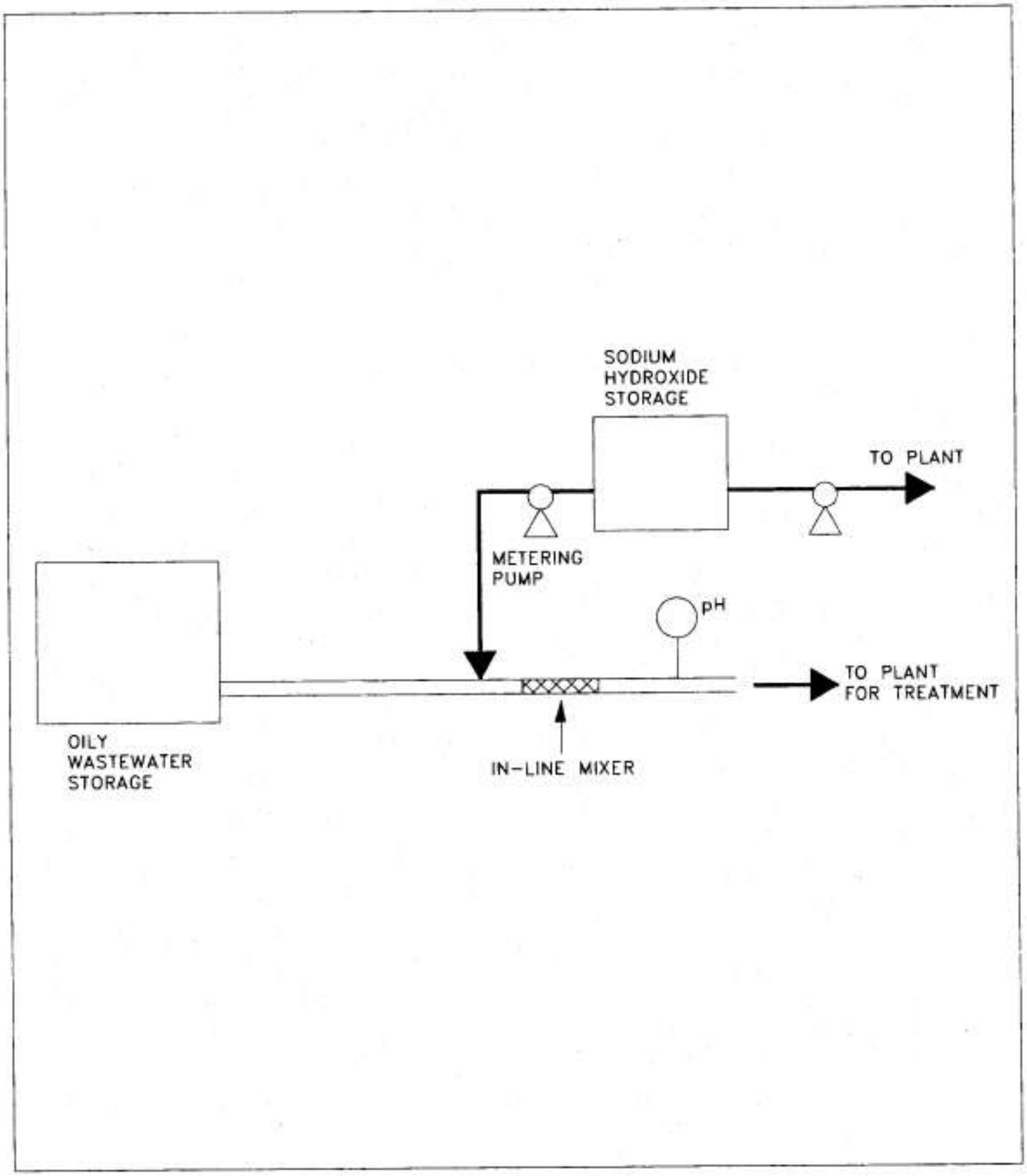


Figure 7

Solubilities of metal hydroxides as a function of pH

These molecules react with emulsified oils or colloidal material and form large floc particles. Sodium chloride (NaCl) is not recommended for "salting out" emulsions since it is slow, requires large amounts of NaCl (20 to 70 g/L), and results in a corrosive liquid product. For chemical handling and feeding details, refer to Section 4. General guidelines for the selection and application of chemicals is as follows:

9.5.1 COAGULANTS. Anionic and cationic surface-active agents are not compatible and tend to neutralize each other. Generally, reactive anions such as OH- and PO4
-2 will break water-in-oil emulsions; reactive cations, such as H+, Al+3 and Fe+3 will break oil-in-water emulsions. For oily wastewaters containing dissolved iron, addition of an inorganic coagulant may not be needed. This dissolved iron can function as a coagulant under alkaline pH conditions. An inorganic coagulant in combination with organic polymers can provide satisfactory demulsification for oily wastewater.

9.5.2 OPERATING PH. Chemical addition to form a heavy metal hydroxide flocculent precipitate can be used to break dilute oil-in-water emulsions. However, the best emulsion breakage effect by ferric chloride, ferric sulfate, and other salts is achieved in an acidic medium. Limited application exists at plants employing heavy metal or sulfide removal by precipitation, as slightly alkaline conditions are desired for these situations.

9.5.3 WETTING AGENTS. Wetting agents can break water-in-oil emulsions. However, correct dosage is critical, as overdosing will destroy the emulsion breaking action. Almost all organic polymer formulations contain wetting agents and therefore separate addition of these is not required.

9.5.4 POLYELECTROLYTES. Organic polymers can be used for breaking emulsions. A wide variety of polymers with varying molecular weight, charge, and different monomers that can be used for oily waste are available. Polymers such as polyamines, quaternary amines, and polyacrylamates are effective for emulsion breaking. The quaternary amine polymers and non-ionic polymers can be applied over a wide range of pH conditions and are compatible with processes for dissolved metals removal that employ pH adjustment followed by removal of precipitates.

9.5.5 CHEMICAL MIXING AND FLOCCULATION. A two-step procedure is required for chemical addition to wastewater. The first step is rapid mixing to provide a thorough and complete dispersal of chemical throughout the oily waste. A short detention times of less than 1 minute is usually adequate and inline or mechanical mixers can be used. The rapid mix stage is followed by slow mixing or flocculation to form larger floc particles. This is carried out in either a mechanically mixed tank or a baffled tank. A detention time of 10 to 30 minutes should be used for the formation of properly sized floc. The mixing speed is to be kept low to avoid floc shear.

9.5.6 FLOC SEPARATION. Separation of the flocculated oil and other solids from the water after chemical addition is the most vital operation in the treatment of emulsified oily wastes. Separation can be achieved in gravity settling, DAF or IAF. Design guidelines and criteria for these unit processes are presented elsewhere.

10. DESIGN CRITERIA FOR OIL-WATER SEPARATORS AND APPURTENANCES

10.1 GENERAL

10.1.1 PROCESSES. The basic process for removing oil from wastewater is the gravity type oil-water separator. The extent to which receiving waters or treatment works are impacted by separator effluent determines whether additional treatment is required. Treatment methods available for improving separator effluent are summarized in Table 2. Gravity separators alone will not remove emulsified oils. The methods described are required to break emulsions.

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

10.1.3 EQUALIZATION (SURGE TANK). Provide side holding tank or basin to equalize and store oily wastewater flows prior to oil-water separation. Holding facilities can be concrete or steel tanks. They should be covered or under a roof in a rainy climate or where wildlife is present.

10.1.4 GRIT REMOVAL. Use grit removal equipment to remove solids particles larger than 200 microns such as sand, metals, and rags prior to entering load equalization tanks.

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

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

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

10.2.1 BASIS OF SIZING. Estimates are required of the numbers and types of berthed ships discharging to the pierside collection system and SWOBs. Nominal shipboard oily waste generation rates are 50,000 gpd (189,270 L/d) for very large ships and 3,750 gpd (14,195 L/d) for other classes of ships. Estimates of barge and tank truck delivery volumes and frequencies should be compiled from historical records. Alternatively, LET size could be based on analysis of Q_{daily}, $Q_{maximum}$, and Q_{peak} established for design of pierside collection systems.

10.2.2 LAYOUT. Use rectangular, reinforced concrete tanks. The following guidelines for LET layout are suggested. See Figure 8 for a schematic of a LET.

	LET 7-Day Capacity	
Characteristic	0.1 to 0.5 Mgal	1.0 to 1.5 Mgal
Length:Width	3:1	5:1
Depth-ft (m)	10(3.05)	20(6.1)
Freeboard-ft (m)	1.5(0.5)	1.5(0.5)

At smaller installations, where LETs of less than 15,000 gallons (56,781 liters) are required, circular steel LET may be more cost-effective than a rectangular concrete LET. Based on the quantity of material required and local availability and cost of materials, the circular tank could be less expensive to fabricate. The circular tank design also may allow more efficient use of available ground for system layouts on smaller parcels of land. Secondary containment such as berm may be required to capture 100 percent of the capacity of the largest tank plus the maximum 24-hour rainfall in the last 25 years within its boundary. Premanufactured tanks should conform to Underwriters

Laboratories Inc. (UL) 142, Steel Aboveground Tanks for Flammable and Combustible Liquids, specifications. Refer to local regulations for complete list of tank system requirements. Where facility topography will permit, LETs should be located out of ground to facilitate gravity flow to downstream processes or the discharge point. Example Calculations 1 and 2 give further guidance on LET sizing.

a) Example Calculation 1 - LET sizing (calculation is given first in English units and then in metric (SI) units):

Given: Daily Discharge from Pierside Collection System, Q_{daily} = 70,000 gpd [264,970 L/d]

Required: LET to receive for 7 days.

LET Volume = (70,000 gpd)(7 days) = 490,000 gal
[(264,970 L/d)(7 days)= 1,854,852 L]

(490,000 gal)(1 ft^3/7.48 gal)= 65,508 ft^3
[(1,854,852 L)(1 m^3/1000 L)= 1,855 m^3

Use 10 ft [3.05 m] depth per guidelines:

65,508 ft^3/10 ft = 6,551 ft^2 surface area
[1,855 m^3/3.05 m = 608 m^2 surface area]

Use 3:1 length to width ratio per guidelines

$$(3w)(w) = 6{,}551\ ft^2\ [608\ m^2]$$
$$w^2 = 2{,}183.6\ ft^2\ [202.7\ m^2]$$
$$w = 46.7\ ft\ [14.2\ m]$$

Try 50 ft [15.2 m] width and try LET size.

50 ft [15.2 m] x 150 ft[45.7 m] x 10 ft[3.05 m] deep

Check total volume and freeboard at 7-day oily waste volume:

(50 ft)(150 ft)(10 ft)(7.48 gal/ft^3) = 561,000 gallons
[(15.2 m)(45.7 m)(3.05 m)(1000 L/m^3)= 2,123,609 L

Freeboard volume =

561,000 - 490,000 = 71,000 gallons
[2,123,609 L - 1,854,852 L] = 268,757 L

LET Volume per foot [meter] of depth =

(50 ft)(150 ft)(1 ft)(7.48 gal/ft^3) = 56,100 gal/ft
[(15.2 m)(45.7 m)(1 m)(1000 L/m^3)= 694,640 L/m]

Freeboard available:

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

[268,757 L/694,640 L/m = 0.384 m = 1.26 ft = 15 in.]

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

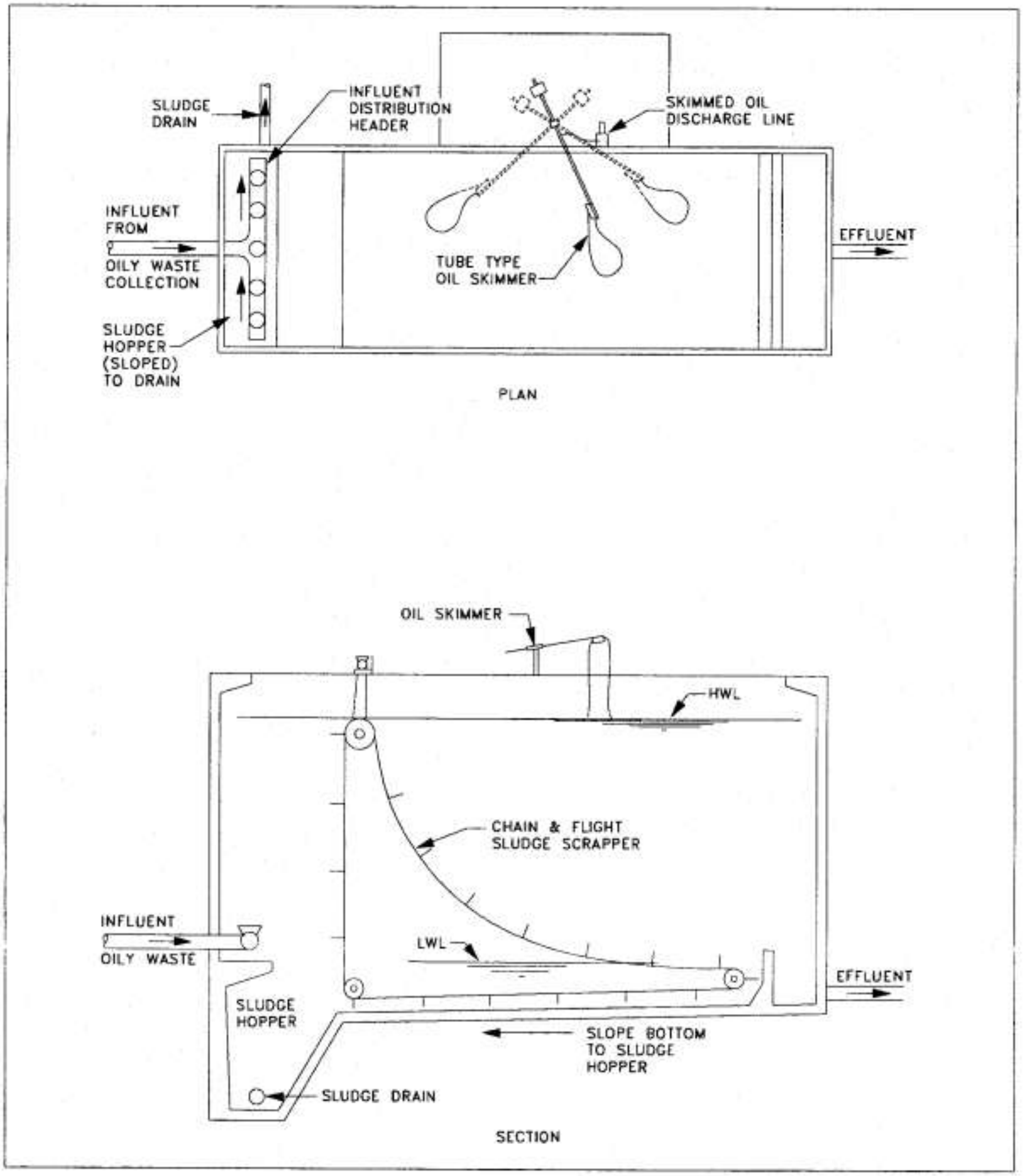


Figure 8

Load equalization tank (LET)

b) Example Calculation 2 - LET influent header outlets:

The recommended equation for determining the number of outlets on the distribution header is (first in English, then in SI units):

EQUATION: $N_o = 0.4085\ Q_{main}/(V_o)(D_o^2)$

$N_o = 21.2\ Q_{main}/(V_o)(D_o^2)$

where

N_o = number of outlets on distribution header

Q_{main} = instantaneous flow rate from pierside collection system pumping station, gpm (L/min)

V_o = desired velocity of flow from distribution header outlets, fps (m/s). Suggested value 0.5 fps (0.15 m/s) for first trial.

D_o = diameter of outlet openings in distribution header, in. (mm)

Use standard flare diameter based on header diameter for first trial.

In this example, Q_{main} is estimated from the average daily flow using an assumed peaking factor of 3. In actual design of a LET, Q_{main} would be available from the pierside pumping station design or the actual pumps used in an existing pierside pumping station. Q_{main} is determined by Equation 6.

For Example Calculation 1, LET daily discharge rate from pierside of 70,000 gpd [264,970 L/d].

Assumptions

Q_{main} = (70,000 gpd)(1 day/1,440 min)(3) = 146 gpm
[(264,970 L/d)(1 day/1,440 min)(3)= 552 L/min

V_o = 0.5 fps [0.1524 m/s]

D_o = 8 in. [203.2 mm]

N_o = [(0.4085)(146)]/[(0.5)(8)^2] = 1.86 English

= [(21.2)(552)]/[(0.1524)(203.2)^2] = 1.86 SI

Therefore, use two flared outlets.

10.2.3 SLOPING BOTTOM. The bottom of the LET should slope from the outlet end back to the inlet end at about 1/8 inch per foot (10.4 mm/m) of tank length. This will facilitate the transport of settled solids to a solids collection hopper at the inlet end of the LET. The collection hopper bottom should slope from side to side at about 1/4 inch per foot (20.8 mm/m), with a sludge withdrawal at the low side.

10.2.4 SLUDGE SCRAPING MECHANISM. Provide chain and flight sludge scraping mechanism. Fabricate major components from nonmetallic materials (such as nylon resins) to avoid corrosive effects of salt water in oily waste. Specify fiberglass flights spaced 6 to 10 feet (1.8 to 3.05 m) apart. Specify polyurethane wear shoes to protect edges of flights from abrasion damage by the tank bottom rails and tank side track angles. Specify carbon steel for drive chain, drive sprocket, shaft sprockets, and shafts. Drag chain may also be specified as a high strength nylon resin. Specify that carbon steel components be shopfinished as follows: blast clean in accordance with Steel
Structures Painting Council (SSPC), SP 5, Joint Surface Preparation Standard White Metal Blast Cleaning; and shop prime and finish coat with coal tar epoxy, similar to Carboline Carbomastic 3 and 14, 5 to 7 mils minimum dry thickness.

10.2.5 OIL SKIMMER. Provide means of removing oil from surface of load equalization tanks and discharging to waste oil storage tank. Mechanical simplicity and efficiency and waste oil characteristics are the most important equipment selection criteria. Two types of mechanical skimmers are described below. In most situations the flexible tube type skimmer is recommended for removal of floating oil. It requires little maintenance, can operate continuously and unattended, provides a high recovery efficiency, and can be variably positioned for optimum coverage of LET area.

10.2.5.1 FLEXIBLE TUBE SKIMMER. This unit provides excellent removal rates of all types of waste oils, greases, and floating sludges, and it minimizes the removal of water with the waste oil. The unit consists of a flexible, polyurethane collector tube which is long enough to enable 16 feet (4.9 m) of tubing to be in contact with the water surface at all times. Floating oil, grease, and sludge adhere to the surface of the tube and are thus skimmed from the surface. The tube is circulated through a drive unit where scrapers clean the surface and divert waste oil to storage. A typical installation features the drive unit mounted at the end of a beam that is cantilevered from a mounting post at the side of a tank or basin. The unit should be mounted near the discharge end of the LET. For tanks £ 20 feet (6.1 m) wide, one unit may be sufficient. Tanks over 20 feet wide should be provided with two units mounted on opposite sides of the tank. Operating 24 hours/day, these units can remove up to 240 gpd (908 L/d) for light oils, 600 gpd (2,271 L/d) for medium oils, and 1,440 gpd (5,450 L/d) for heavy oils. For cold climate installations, the drive head/skimming assembly should be enclosed, insulated, and heated. Figure 9 illustrates a flexible tube skimmer installation.

10.2.5.2 FLOATING WEIR SKIMMER. This skimmer type uses an adjustable weir to set the overflow depth below the oil layer surface. These units are best applied to installations where separated oil is allowed to accumulate for a number of days and is then skimmed in a single operation. This differs from the continuous or daily intermittent operating scheme for the tube or mop type skimmer. There is a greater potential for skimming significant amounts of water with the weir-type device. The floating, weir-type skimmer is usually connected to a pump with a flexible hose. This enables an operator to manually move and position the skimmer for optimum interception of pockets of accumulated oil, if the layer is not continuous or is disturbed by skimming turbulence. In some units, varying the pumping rate will change the submergence level of the weir. Thus, a higher pumping rate can be used for initial skimming operations, and as the oil layer decreases in thickness, the pumping rate can be reduced to raise the weir and minimize the potential for water carryover. Average pumping rates of 6 to 7 gpm (22.7 to 26.5 L/min) are suggested, with the maximum recommended rate at 10 gpm (37.9 L/min). Since they operate in contact with and are partially immersed in the oily waste, floating weir-type skimmers should be constructed of plastic or stainless steel. Figure 10 illustrates a floating weir skimmer installation.

10.2.6 SAMPLE TAPS. Provide sample taps along one wall of the LET, near the discharge end, spaced at 1-foot maximum depth intervals. For accessibility, they should be adjacent to and follow the incline of the tank top access stairway. Each tap should consist of a piece of 1-inch (25-mm) diameter PVC pipe, with length equal to the wall thickness plus 6 inches (152 mm), and with a 1-inch (25-mm) diameter PVC ball valve at the sampling end outside the tank. The through wall pipes should be set when the tank wall is formed and poured. The exterior surface of the pipe should be roughened prior to setting in the forms to ensure a good bond with the concrete and a grout ring should be provided at the midwall point as a precautionary obstruction to leakage along the pipe surface through the wall.

10.2.7 WATER SUPPLY. Provide a water supply with minimum delivery of 15 gpm (56.8 L/min) at 40 psig (276 kPa) around the top of the tank. At least two discharge points with hose bibb outlet controls should be provided on tanks less than 100 feet (30.5 m) long. For tanks longer than 100 feet, three or four outlet points should be provided. In areas subject to extremely cold weather, freezeless hydrants should be provided in lieu of hose bibbs. The water supply will be used for tank cleaning, foam control, and general housekeeping; therefore, potable quality is not essential. If a source of nonpotable, service water is available at a facility, it should be used for the LET supply. If it is necessary to tap the LET supply from the potable water system, a suitable backflow preventer must be installed in the LET supply line immediately downstream from the tapping point.

10.2.8 CORROSION PROTECTION. Apply protective coatings to both the interior and exterior wall surfaces to ensure long-term structural integrity of the LET. For interior surfaces, a coal tar epoxy coating system, similar to Carboline Carbomastic 14, is recommended. These coatings are typically two component mixtures with a curing agent added just prior to use. The coating should have a high build characteristic, allowing application thickness of 8 to 10 mils. Two coats should be applied for a total dry thickness of at least 16 mils. For exterior surfaces, a flexible epoxy-amine coating system, similar to Carboline 188, is recommended. The system should consist of two or three coatings: a primer and a high build finish coating; or a primer, an intermediate high build coating, and a finish coating. For either combination, the system should have a total dry film thickness of at least 10 to 11 mils.

10.3 API SEPARATOR. Use methods and criteria given in API Manual on Disposal of Refinery Wastes, Volume on Liquid Wastes, to design API separator, subject to the limitations presented in Table 4. For general arrangement and vertical slot inlet baffle detail, refer to the API Manual and Figures 11A and 11B.

10.4 INDUCED GRAVITY SEPARATOR. The induced gravity separator removes free and dispersed oil to produce an effluent that has 10 to 50 ppm oil. The oil is removed by passing water at laminar velocity through a pack of closely spaced plates on an incline of 45 to 55 degrees. The oil droplets rise and are trapped along the bottom of the plates. The oil droplets coalesce and gradually move upward along the bottom of the plates, eventually collecting at the surface of the tank. Suspended solids settle to the bottom. The separator should have adequate capacity in the sludge well to collect these solids and should have a sludge pump. An automatic valve, if sludge transfer is by gravity displacement, should be provided and operated frequently to avoid excessive buildup. Refer to Figure 12 for alternative types of induced gravity separators. Specific design features of induced gravity separators vary among manufacturers.

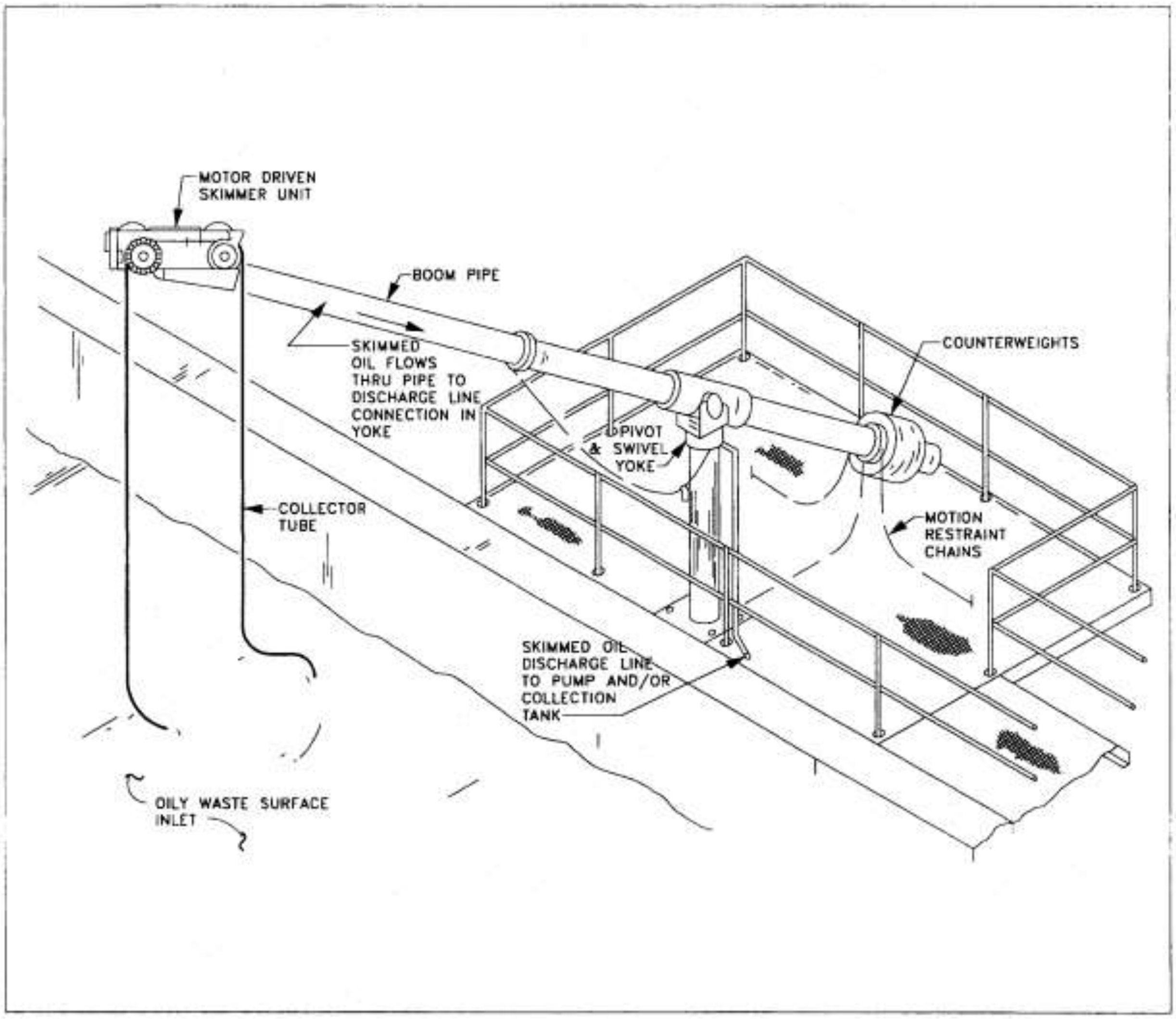


Figure 9

Tube type oil skimmer installation

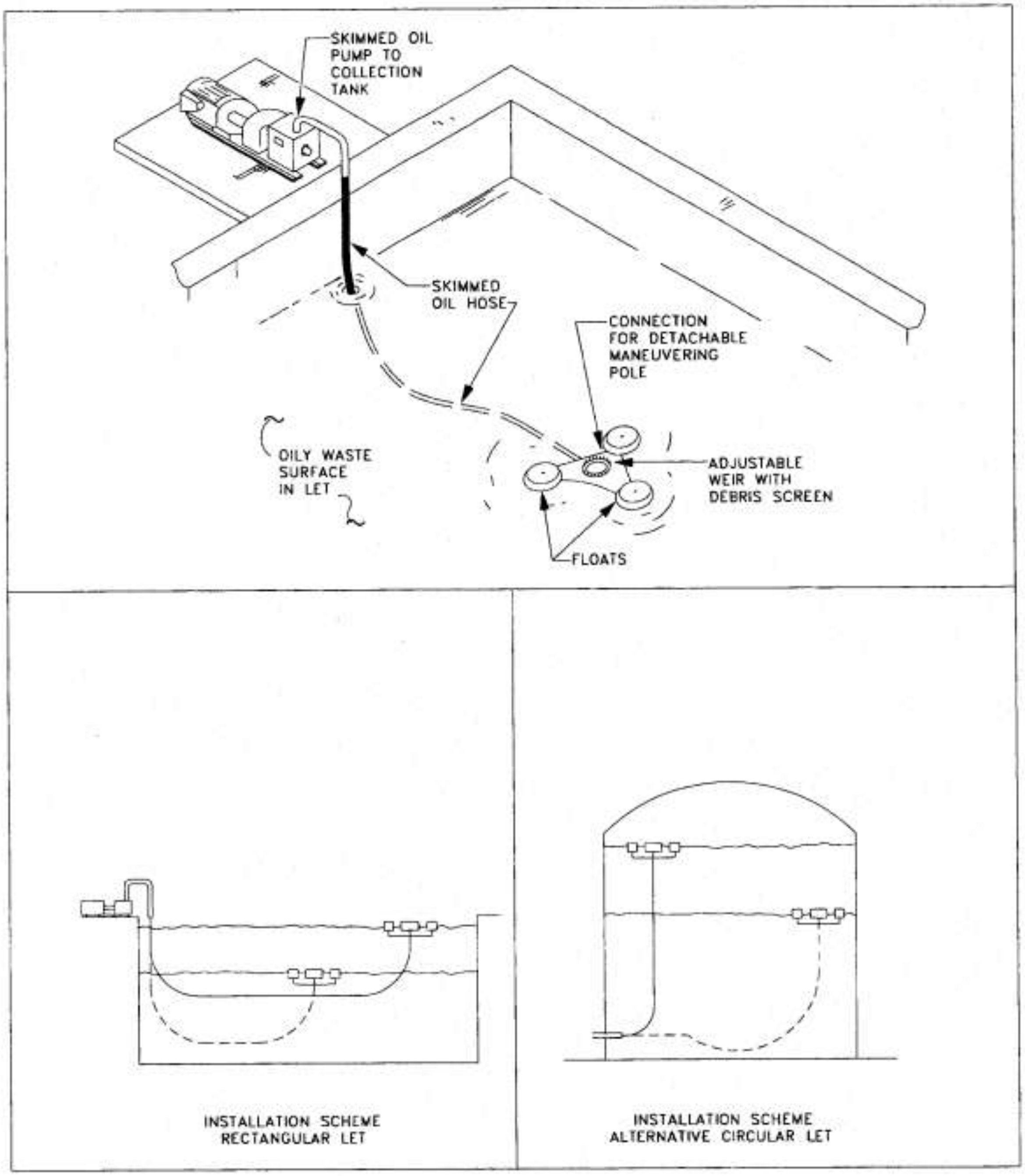


Figure 10

Floating weir type skimmer installation

Design Parameter	Design Flow Rate	
	<185 gpm (11.7 L/s)	>185 gpm (11.7 L/s)
[1]Maximum Surface Loading, gpd/ft^2 (L/s-m^2)	[2]1,000 to 2,000 (11.3 to 22.6)	1,000 (11.3)
Length:Width (minimum)	4:1	4:1
Depth:Width	1:1 (maximum)	0.3:1 to 0.5:1
[3]Maximum Depth, ft (m)	3 (0.9)	5 (1.5)
Maximum Horizontal Velocity, fpm (m/min)	2 (0.6)	2 (.06)

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

Table 4

API Separator design criteria

10.4.1 PARALLEL PLATE SEPARATOR. Use the wastewater characteristics developed elsewhere. Refer to design separator guidance for removal of free oil and, if required, suspended solids. Locate units above ground or partially buried. Protect buried units against flooding from surface runoff by locating a minimum of 8 inches (203 mm) above grade. Consider the following during design:

a) Tanks should be fabricated from carbon steel and coated inside and outside with coal tar epoxy. Preferred construction materials for plate packs are a frame of Type 304 stainless steel with individual plates of fiberglass. Refer to Table 5 for basic design data and Figure 12 for typical plate separator arrangement. The exact dimensions and orientation of the separator (crossflow inclined, crossflow horizontal, and downflow inclined) will vary with separator type and manufacturer.

b) Provide adequate cathodic protection.

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

d) Refer to the technical literature for additional design information.

e) Example Calculation 3 - Determination of required number of plates. Steps are performed first using English units, then using SI units (shown in brackets).

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

Given: (From Example Calculation 1 preceding):
LET Volume = 490,000 gal (1,854,846 L)

Assume LET contents must be processed through an induced gravity separator in 16 hours.

Influent flow rate to separator (Q_I)

Q_I = 490,000 gal/16 h X 1 h/60 min = 510.416 gpm

[Q_I = 1,854,846 L/16 h X 1 h/60 min = 1932.13 L/min]

Recommended Surface Loading Rate (Q_{SR}):

Q_{SR} = 200 gpd/ft^2 [8149.11 L/day·m^2]

Convert to gpm/ft^2 [L/min·m^2]:

200 gal/day·ft^2 X 1 day/1440 min = 0.1389 gpm/ft^2

[(8149 L/min·m^2) X 1 day/1440 min = 5.66 L/min·m^2

Plate Surface Area (A_p) normally available from manufacturer's data (manufacturer value not available for SI size):

A_p = 20 ft^2/plate [1.85 m^2/plate]

Determine:

Total Plate Area Required (A_t):

$A_t = Q_T/Q_{SR}$ = 510 gpm/(0.1389 gpm/ft^2) = 3,672 ft^2

[A_t = 1932 L/min/(5.66 L/min·m^2) = 338.9 m^2]

Number of Parallel Plates Required (N_p):

$N_p = A_t/A_p$ = 3,672 ft^2/(20 ft^2/plate) = 183.6

[$N_p = A_t/A_p$ = 338.9 m^2/(1.85 m^2/plate) = 183.6]

Use 184 plates, minimum.

10.5 SKIMMING DAM. Locate low dam or weir in drainage channel at least 50 feet (15.2 m) downstream from the nearest storm drain outlet to pond water; provide an open port in the dam to drain the pond in dry weather. Design a port to accommodate estimated dry weather flow. Refer to Figure 13 for details. Use float and boom to trap and divert floating oil and grease to the side of channel. Ensure that floating diversion boom extends at least 3 inches (76 mm) below surface of water. Provide a movable belt skimming device to skim oil to a collection hopper for storage. Design a channel for a maximum horizontal velocity of 12 fpm (3.7 m/min), based on rainfall intensity-duration-frequency curve data for a 1-year frequency storm at the specified geographical location. Contact Federal, State, and local regulatory agencies to determine the adequacy of this storm frequency interval. Consider surrounding topography and drainage basin characteristics when establishing channel dimensions; the minimum length of channel should be 50 feet (15.2 m). Avoid surcharging storm sewer outlets at high water level.

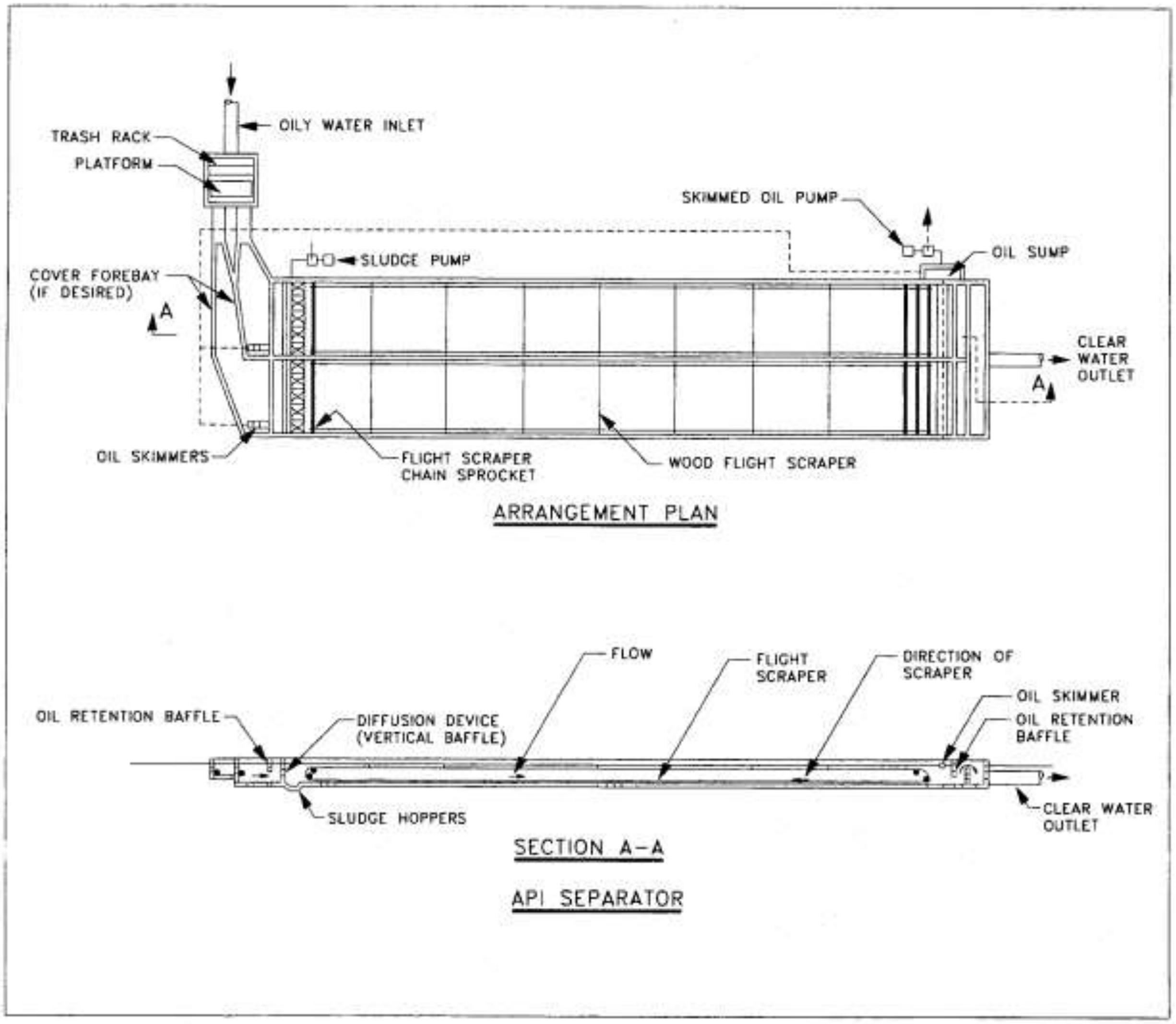


Figure 11A

API separator

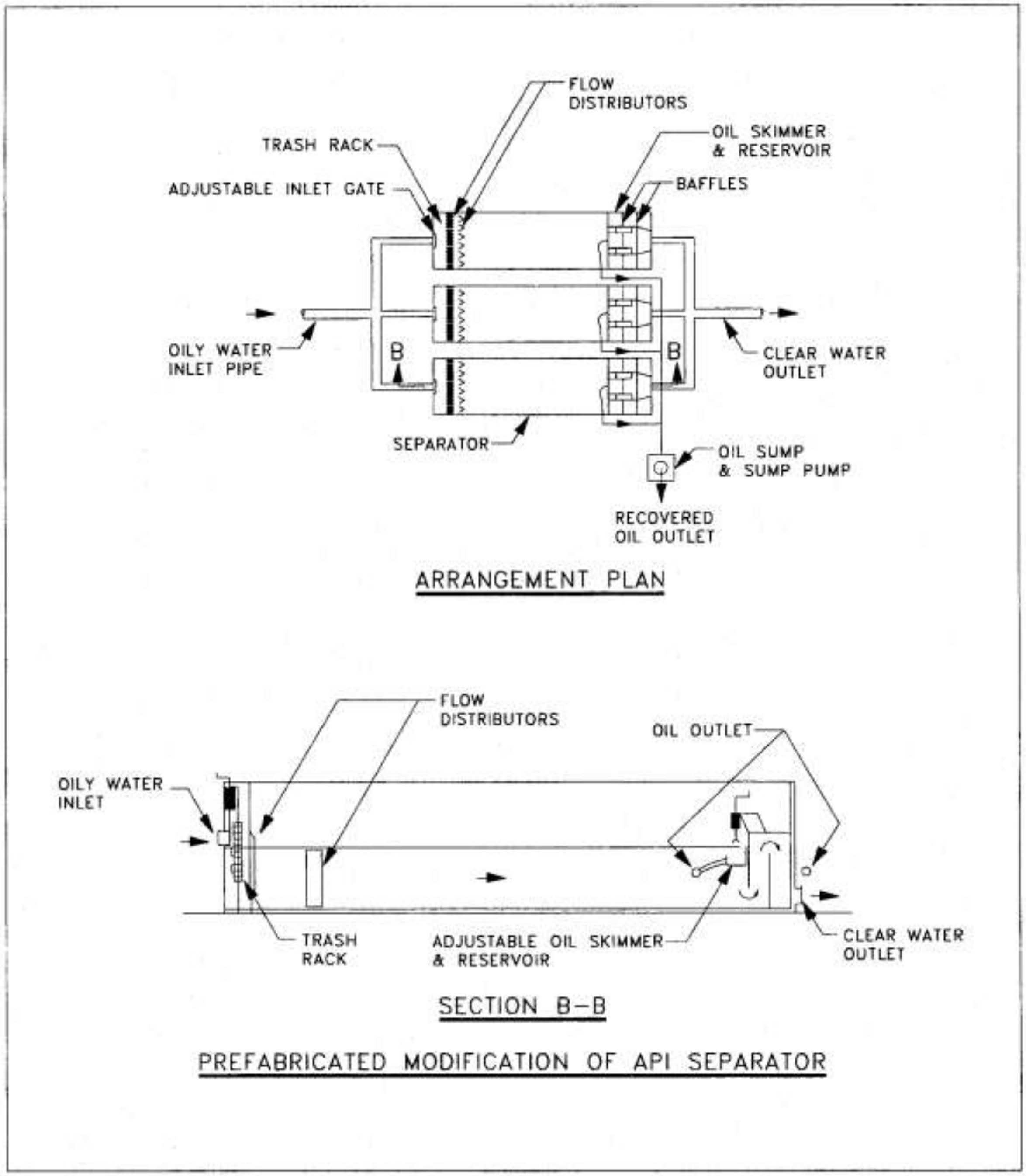


Figure 11B

API separator

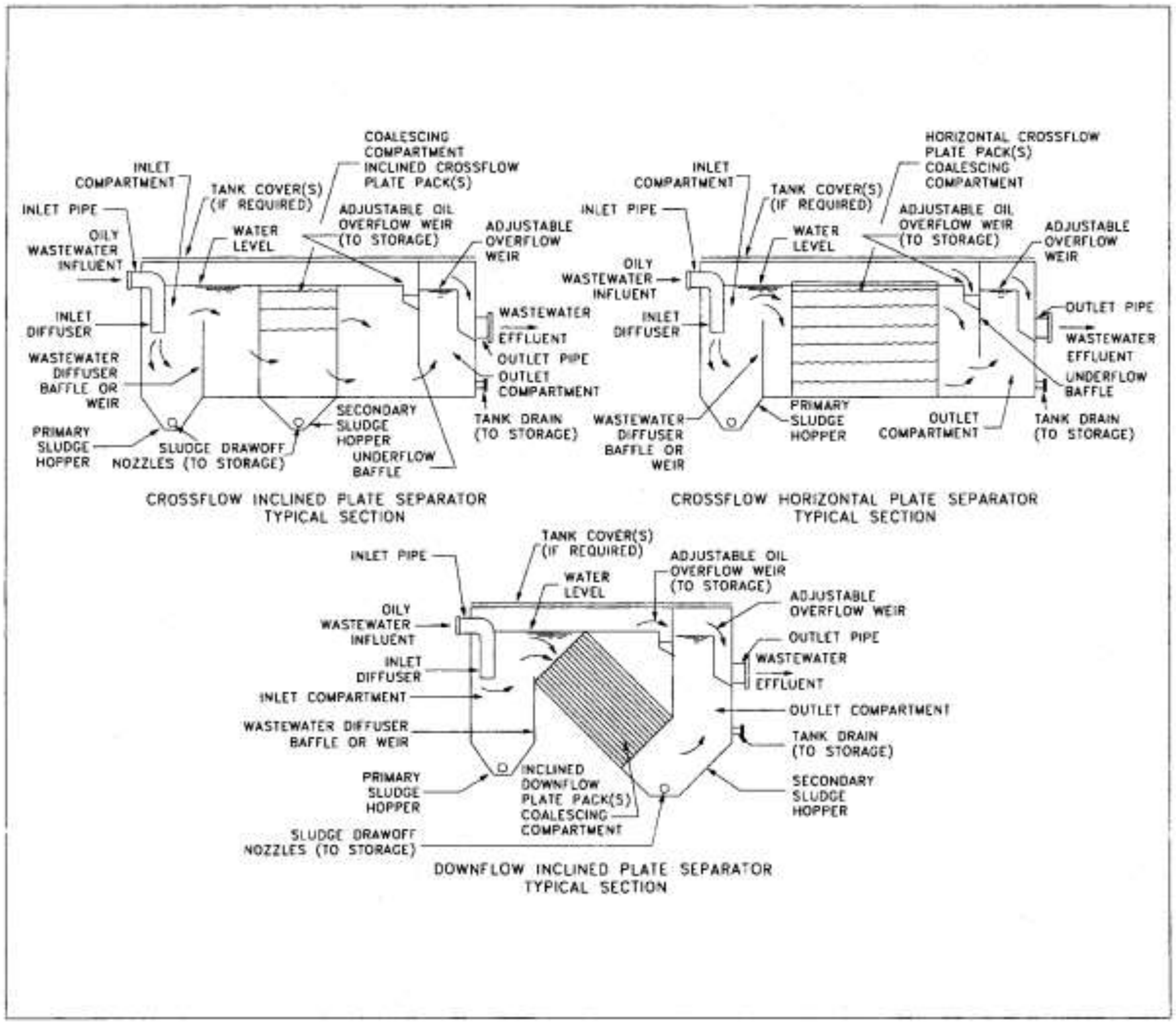


Figure 12

Induced gravity separator

Design Parameter	Description
Inlet pipe[2]:	
Diameter	6-in. (150-mm) minimum.
Velocity	Use minimum that will avoid suspended solids deposition in pipe. Approximately 2 fps (0.6 m/s) for grit-bearing wastewater.
Diffuser	By manufacturer. Reduce momentum to avoid short-circuiting.
Inlet compartment:	
Dimensions	A function of the flowrate and settleability of the suspended solids. Maximum surface loading rate of 1,000 gpd/ft^2 (28.3 L/min-m^2). Determine actual design surface loading in benchscale experiments.[3]
Primary sludge hopper	Optimum hopper angle of 55° (from horizontal). Do not use slope less than the angle of repose for material removed. Hopper volume determined by volume of suspended solids removed and sludge drawoff schedule. Provide ≥10% of compartment volume.
Primary sludge drawoff	4-in. (100-mm) minimum diameter connection with plug valve.
Diffuser baffle (weir)	By manufacturer. Distribute oily wastewater evenly across packed plate inlet.
Overflow weir	Sharp crested, vertically adjustable, length as necessary to establish laminar flow velocity to plate pack compartment.
Coalescing (plates) compartment:	
Inclined plates	
Plate type	Corrugated preferred.
Spacing	Range: 1/2 in.[4] to 1.0 in. (13 mm to 25 mm)
Angle	Range: 40° to 60° (from horizontal).
Plate pack orientation	Downflow preferred.
Effective separation area[5]	
Downflow	100 to 1000 ft^2 (9.3 to 92.9 m^2) per pack.
Crossflow	270 to 2220 ft^2 (25.1 to 206.2 m^2) per pack.
Loading rate	Determined from bench scale experiments and based on effluent quality requirements. Typically, 100 to 200 gpd/ft^2 (2.8 to 5.7 L/min-m^2).

Table 5

Parallel plate oil-water separator design data

Design Parameter	Description
Number of plates	See Example Calculation 3. Will vary slightly among manufacturers based on plate characteristics and standard pack sizes.
Horizontal plates[6]	
Spacing	1/2 in.[4] to 1.0 in. (13 mm to 25 mm)
Angle	Zero degrees (from horizontal).
Plate pack orientation	Crossflow with respect to corrugations.
Effective separation area	60 ft^2 (5.6 m^2) per pack.
Loading rate	Determined from benchscale experiments and based on effluent quality requirements. Typically, 100 to 200 gpd/ft^2 (2.8 to 5.7 L/min-m^2).
Oil overflow weir	Sharp crested vertically adjustable. If discharge is directly to outfall sewer, provide V-notch weir for flow measurement.
Secondary sludge hopper	Same as primary sludge hopper of inlet compartment.
Secondary sludge drawoff	
Nozzle	4-in. (100-mm) minimum diameter with plug valve.
Underflow baffle	Underflow velocity not to exceed 4 fpm (1.2 m/min)
Outlet compartment[2]:	
Overflow weir	Sharp crested vertically adjustable.
Secondary sludge hopper	Same as primary sludge hopper.
Secondary sludge drawoff	4-in. (100-mm) minimum diameter nozzle.
Underflow baffle	Underflow velocity not to exceed 4 fpm(1.2 m/min).

[1]Refer to manufacturer's product bulletin for equipment descriptions, exact dimensions, and location of appurtenances. Also, refer to NFGS-11311.
[2]Influent invert elevation established by collection system design. Set outlet invert elevation a minimum of 3 in. (76 mm) below inlet invert.
[3]Average rate to be used for preliminary unit sizing only. Supply manufacturer with oily wastewater flow and characterization data described previously in this section to determine actual design loading rate.
[4]Plate spacing <1/2 in. (13 mm) not recommended due to inherent presence of suspended solids.
[5]Actual effective separation area is a function of the plate angle, corrugation dimension, and plate dimension.
[6]Limited effectiveness in preventing reentrainment of suspended solids in wastewater stream since sludge storage hopper not an integral part of standard equipment.

Table 5 (continued)

Parallel plate oil-water separator design data

10.5.1 DIVERSION POND. A skimming dam does not remove oil immediately from the flow since it relies on the oil skimmers. It is sized for a relatively small storm event to minimize the backwater effect in the storm drainage channel. Use a separate diversion pond to accommodate potential large oily waste spills and more intense storm events. This prevents washout of the oil over the skimming dam before it can be removed. See Figure 14 for details.

10.6 DISSOLVED AIR FLOTATION (DAF) AND INDUCED AIR FLOTATION (IAF). The DAF unit removes emulsified oil and suspended solids through the use of chemical coagulants and rising air bubbles. The coagulants cause the minute oil droplets and solids to agglomerate into larger floc particles. The air bubbles adhere to these particles causing the floc to rise rapidly to the surface. The DAF unit is usually installed above ground and will often require pumping of influent flow. The DAF unit is divided into two sections. The influent enters a flocculator chamber where it is mixed with coagulant demulsifiers. The oily waste then flows into the flotation section. This section has a skimmer on the surface to remove the scum and an outlet to remove the settled sludge from the bottom by gravity displacement or pumping. Refer to Figure 15 for a schematic representation of a DAF unit. A similar system to the DAF is the IAF which will remove emulsified oil, heavy metals and suspended solids (agglomorates) from oilywaste water influent. This system produce ultra-fine gas bubbles much smaller than conventional mechanical and hydraulic flotation cells. The smaller bubbles liberated from relatively high gas intake volumes provide large surface area contacting potential for the agglomorates to rise to the liquid surface. The agglomorates laden froth is radially dispersed to the peripheral skim trough and then removed from the vessel on an intermittent cycle. The skid mounted system is compact in size and light weight which makes it more ideal for some applications.

10.6.1 PRESSURIZATION METHOD. Introduce dissolved air to the DAF or IAF by recycle and by pressurizing a portion of the effluent using infused air. Mix recycles with flotation tank contents.

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

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

C) RECYCLE. Recycle of a portion of the clarified effluent allows a larger quantity of air to be dissolved and dilutes the feed solids concentration. Dilution reduces the detention period necessary to achieve good separation.

10.6.2 DESIGN PARAMETERS. The principal design variables for DAF or IAF are shown below. Most of these parameters will be specified by the equipment manufacturer.

Design Parameter	Design Value
Pressure	40 to 60 psig (276-414 kPA)
Recycle ratio	30 to 70%
Feed solids concentration	0.5 to 5 lb/ft^2/h (2.0 to 20.1 kg/m^2/h)
Detention period	10-30 min.
Air-to-solids ratio	0.02:1 to 0.05:1
Hydraulic loading	1.0 to 3.0 gpm/ft^2(40.7 to 122.2 L/min·m^2)
Chemical aids	Determined by field testing
Depth to width or diameter ratio	0.4:1 to 0.8:1

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

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

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

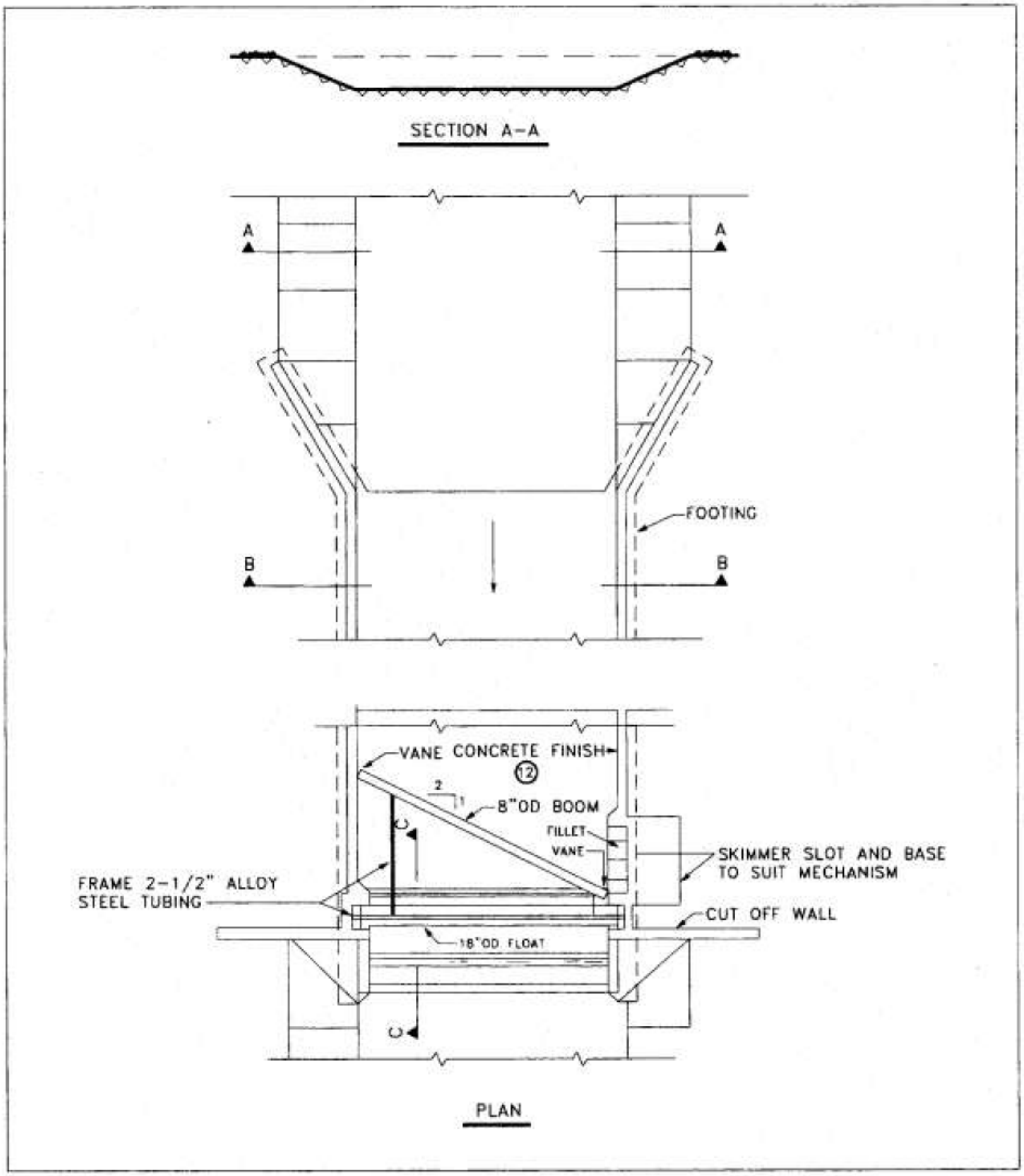


Figure 13A

Skimming dam details

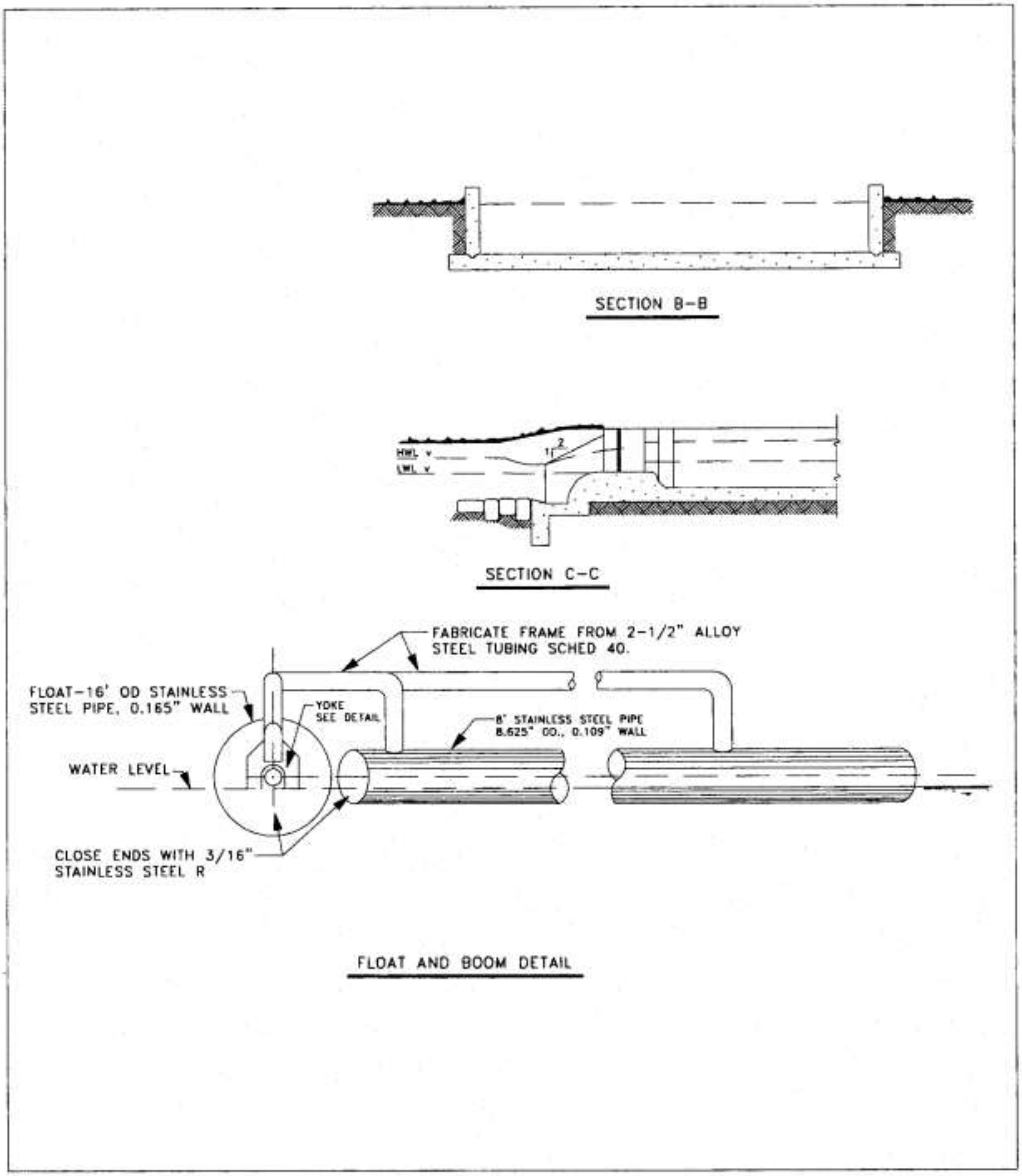


Figure 13A

Skimming dam details

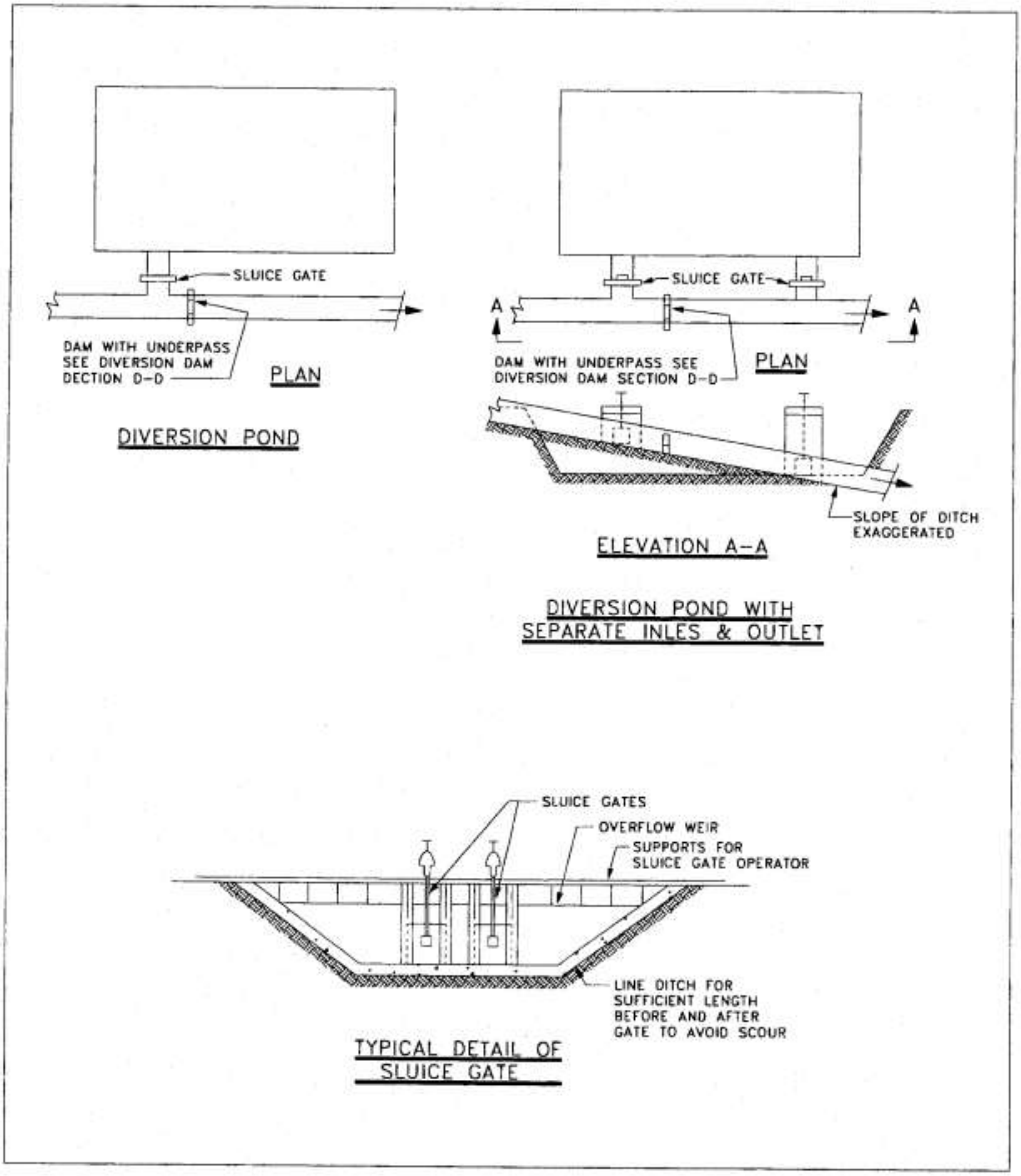


Figure 14A

Diversion pond details

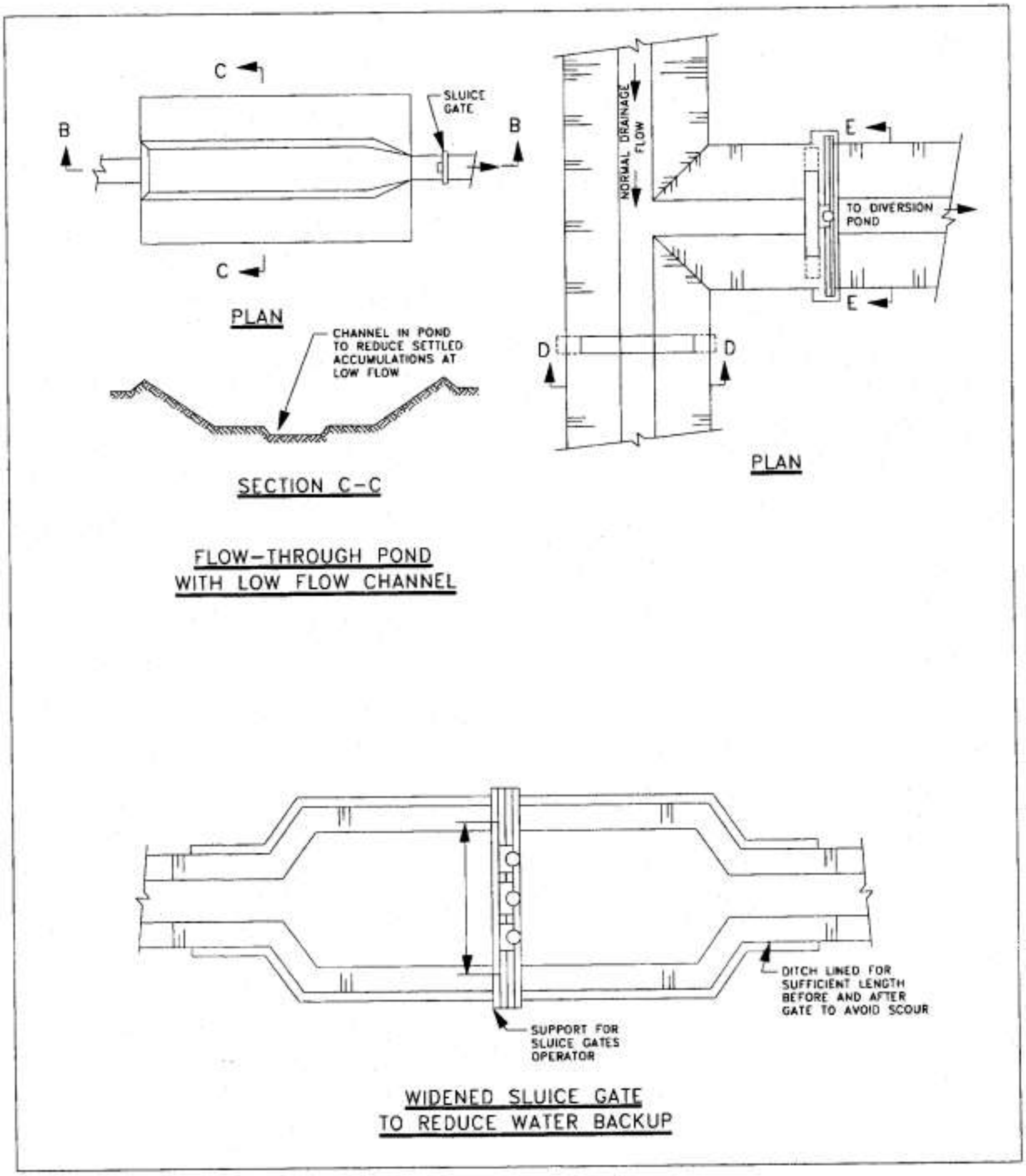


Figure 14B

Diversion pond details

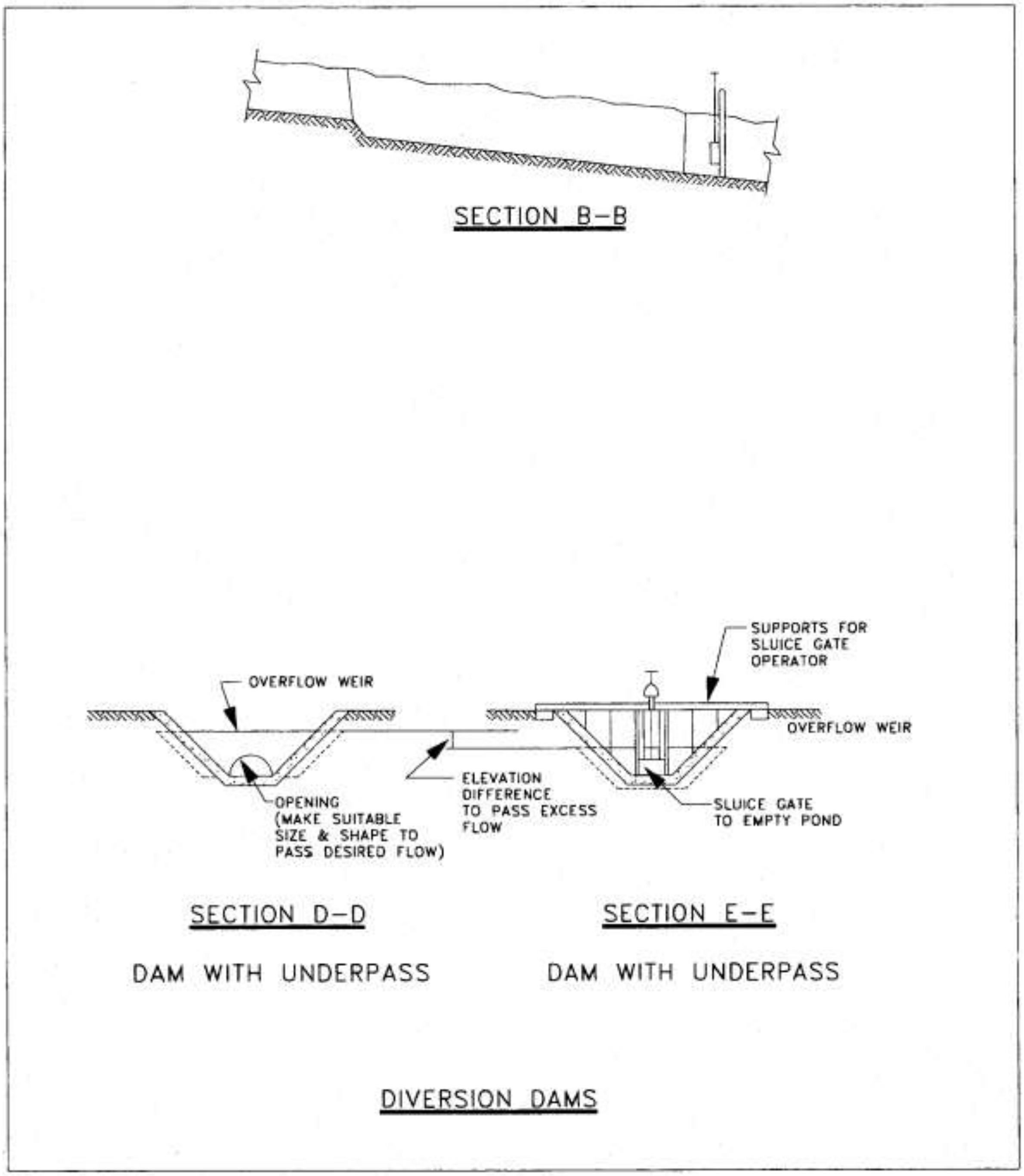


Figure 14C

Diversion pond details

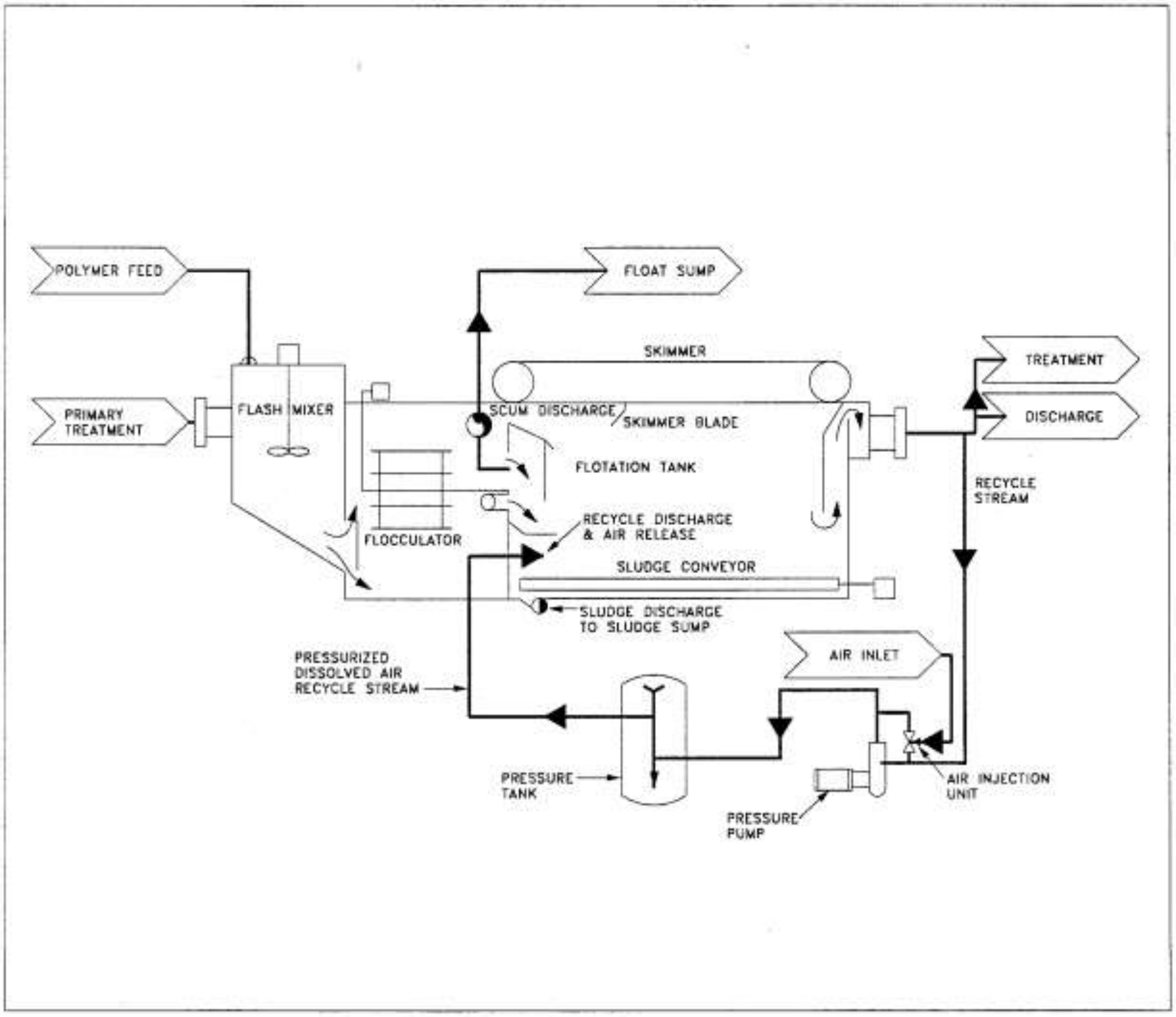


Figure 15

Schematic of dissolved air flotation oil-water separator

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

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

Design Parameter	Design Value
Bed depth	24-36 in. (610-914 mm)
Filtration rate	
Gravity	3-8 gpm/ft^2 (122-326 L/min·m^2)
Pressure	12-18 gpm/ft^2 (489-733 L/min·m^2)
Backwash rate	15-20 gpm/ft^2 (611-815 L/min·m^2)
Air scour flow rate (if necessary)	3-6 sft^3/min/ft^2 (0.9-1.8 m^3/min/m^2) @ 12 psig (83 kPa)
Filter media	Combination sand, gravel, anthracite (garnet optional)
Pressure drop	
Clean	2-4 psig (13.8-27.6 kPa)
Loaded	8-12 psig (55.2-82.7 kPa)
Filter solids loading	2-6 lb/ft^2/hr (9.8-29.3 kg/m^2·hr)

b) Pilot studies are essential in selecting the optimum filter. Design should be based on economic tradeoffs between filter size, operating head requirements, and run length for a specific effluent quality. Refer to EPA PB 214551, Process Design Manual, Suspended Solids Removal, for methodology for making this comparison.

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

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

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

10.7.3 ACTIVATED CARBON ADSORPTION. Polishing of oily wastewater by activated carbon adsorption produces effluence of high quality containing less than 10 mg/L oil and grease and low levels of dissolved organics. A large number of compounds listed as toxic on EPA's priority pollutants lost are amenable to removal by this treatment. The optimum use of carbon columns as a treatment process requires the development of design parameters from a detailed laboratory pilot-scale treatability investigation with the wastewater under consideration. Pilot scale studies should determine the necessary design parameters for sizing

of a carbon contact system. The design parameters include type of carbon, breakthrough and head loss characteristics, and pretreatment requirements. The main components of an adsorption system, as shown in
Figure 18, include two or three adsorption columns packed with activated carbon, liquid transfer pumps, valves, basic instrumentation for pressure and liquid flow monitoring, and backwashing provisions. Periodic backwashing is required to remove accumulated suspended solids. To minimize backwashing, the column influent should be pretreated to maintain suspended solids at less than 50 mg/L. These levels of suspended solids are normally achieved by polishing in multimedia filters prior to carbon adsorption. Periodic regeneration of activated carbon is necessary at the exhaustion of adsorption capacity. For most oily waste treatment plants, a vendor-provided regeneration service should be investigated. Onsite regeneration is economical for very large industrial or domestic wastewater plants where carbon usage is more than 1,000 pounds/day. For oily wastewater plants with continuous operation, supplying two or more columns instead of one large column capable of handling the entire flow should provide adequate redundancy. For batch operated plants, redundant capacity is not needed as maintenance or carbon replacement can be scheduled during plant shutdown. The contacting system can be pressurized or operated under gravity. The pressurized systems are generally more flexible and can be operated at a higher head loss.

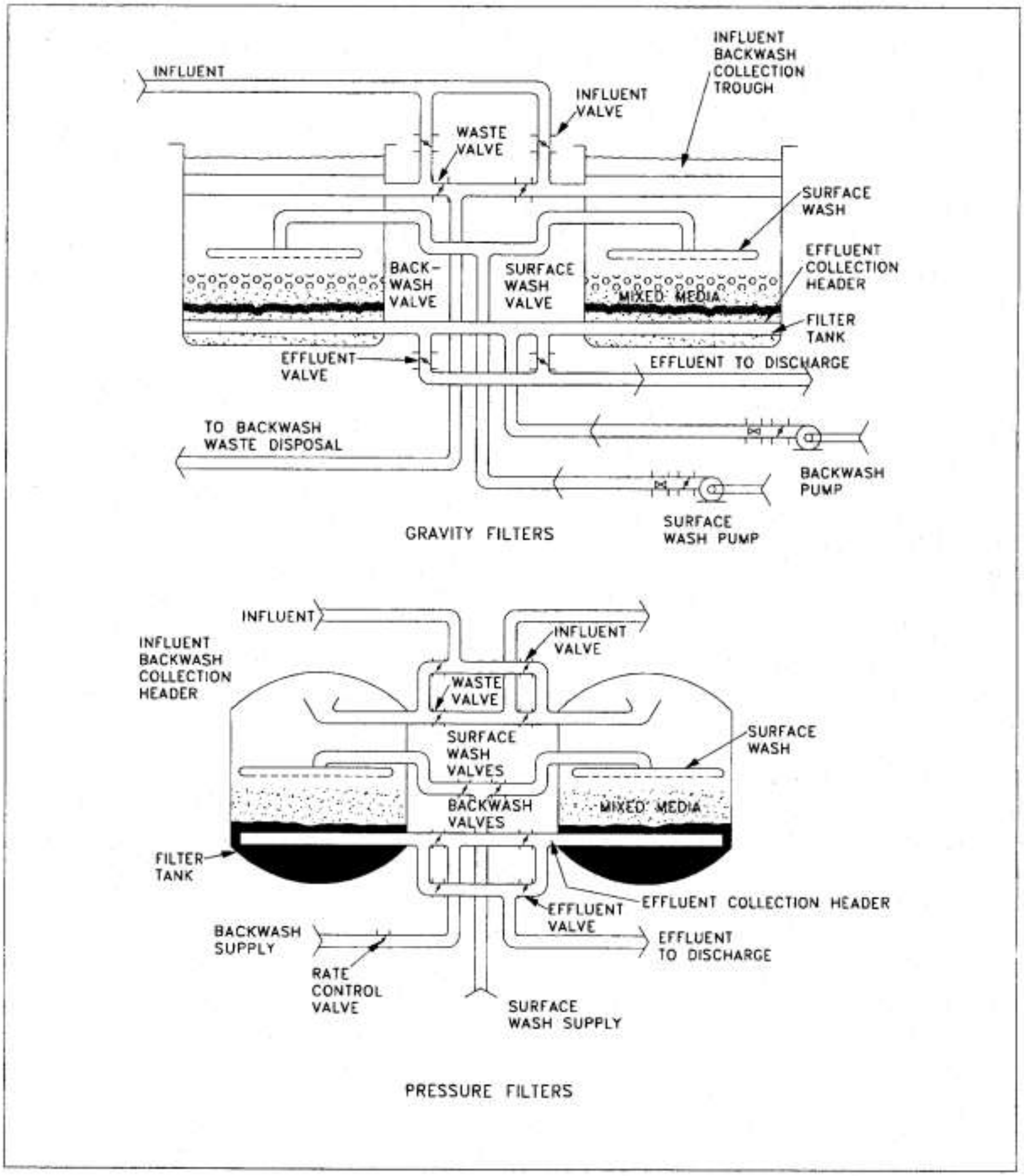


Figure 16

Mixed media filtration

Usually, carbon columns are designed with hydraulic loadings of 2 to 10 gpm/ft2 (81.5 to 407.5 L/min×m2) for carbon beds 10 to 30 feet (3.05 to 9.1 m) high. Bed height-to-diameter ratio varies from 1:1 to as high as 4:1. The higher rations are needed for columns operating without flow distribution systems.

10.8 SLUDGE DEWATERING AND DISPOSAL. The solids that settle to the bottom of the LETs, gravity separators, and DAF/IAF must be removed periodically. In addition, the scum that accumulates at the surface in the DAF/IAF must also be disposed. Oily sludges may contain considerable quantities of heavy metals and organic toxic chemicals. Inorganic coagulants such as lime and alum used in wastewater treatment also increase sludge generation. These sludges may be classified as toxic wastes and must be dewatered (regardless of toxicity) to minimize transportation and disposal costs and comply with typical disposal site criteria. Sludge drying beds or mechanical dewatering equipment are the preferred method of sludge dewatering. The efficiency of dewatering can be improved by sludge conditioning prior to dewatering. The common processes include chemical and thermal conditioning. Chemical conditioning by polyelectrolytes is more suitable for oily waste plants as it requires less capital and O&M costs and the process hardware is less complex as compared to thermal conditioning. However, chemical conditioning requires an investigation to select the type and feed rates of chemicals. Inorganic conditioning chemicals are also considered effective, but they increase the quantity of sludge and increase disposal cost as compared to organic polyelectrolytes. The water fraction from dewatering oily sludges is to be transferred to the LETs.

10.8.1 SLUDGE DRYING BEDS. Sludge drying beds are the preferred alternative if the treatment facility is located in a suitable climate. Sludge drying beds are considerably less expensive to design, construct, operate, and maintain as compared to mechanical dewatering devices. Their performance is not affected by variable solids/moisture content in sludges. Design and use of drying beds are influenced by: (1) meteorological and geological conditions; (2) sludge characteristics; and (3) use of sludge conditioning aids. Climatic conditions are the most important. The amount and rate of precipitation, percentage of sunshine, air temperature, relative humidity, and wind velocity are factors that determine the effectiveness of air drying. The following general design characteristics are recommended for drying beds:

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

10.8.1.2 BED CHARACTERISTICS. If available land is limited, consider use of premolded, polypropylene screen modules to replace sand bottom. These beds require 1/6 to 1/10 the area of sand beds. Alternatively, consider vacuum assist or solar assisted drying for conventional sand bottom beds. Drying beds usually consist of 10 to 30 cm of sand that is placed over 20 to 50 cm of graded gravel or stone. A recent study indicates 40 cm of sand to be preferred for mechanically cleared beds. The sand typically has an effective size of 0.3 to 1.2 mm and a uniformity coefficient of less than 5.0. Gravel is normally graded from up to 2 cm.

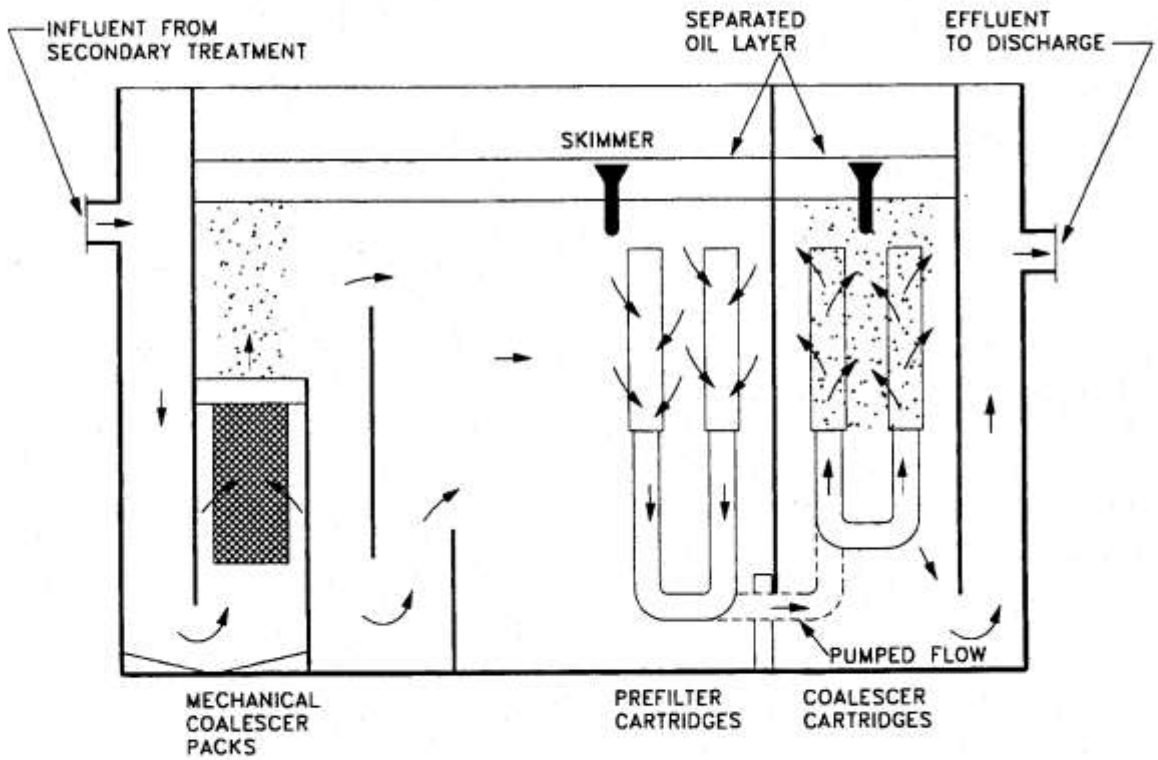


Figure 17

Schematic of coalescing filter

The top 3 inches (7.5 cm) of gravel should consist of 1/8 to 1/4 inch (0.3 to 0.6 cm) gravel. The gravel should extend at least 6 inches (15 cm) above the top of the underdrains. Drying beds have underdrains that are spaced from 10 to 26 feet (3 to 8 m) apart. Underdrain piping is often vitrified clay laid with open joints, has a minimum diameter of 10 cm, and has a minimum slope of about 1 percent. Collected filtrate is returned to the treatment plant. Bed walls should be watertight and extend 15 to 18 inches (38.1 to 45.7 cm) above and at least 6 inches (15 cm) below the surface. Outer walls should be curved to prevent soil from washing onto the beds. Pairs of concrete truck tracks at 20-foot (6.2-m) centers should be provided for beds. The influent pipe should terminate at least 12 inches (30 cm) above the surface with concrete splash plates provided at discharge points. A recent trend in handling sludge in drying beds is the increased use of mechanical lifting equipment for sludge handling. Chemical conditioning greatly aids the dewatering process. In many reported instances, flocculent chemicals have overcome problems in drying beds.

10.8.1.3 COVERS. Sand beds cab be enclosed by glass or other material where justifiable to protect the drying sludge from rain, to control odors and insects, and to reduce the drying periods during cold weather. Good ventilation is important to control humidity and optimize the evaporation rate. As expected, evaporation occurs rapidly in warm, dry weather. Adaption of sludge removal and handling equipment to enclosed beds is more difficult than to open drying beds.

10.8.2 DRYING LAGOONS. Drying lagoons are technically and operationally simple for sludge dewatering. The cost factor depends on land availability. Since there are a fair number of applicable regulations (such as mandatory monitoring of ground water) to be taken into consideration, there is a higher risk involved in choosing this method. Some common design criteria are: the soil must be reasonably porous, and the bottom of the lagoon must be at least 18 inches (45 cm) above the maximum ground water table. Surrounding areas must be graded to prevent surface water from entering the lagoon. The lagoon depth should not be more than 24 inches (61 cm). At least two lagoons should be provided. Sludge usually will not dewater in any reasonable period of time in lagoons (to the point that it can be lifted by a fork except in an extremely hot, arid climate). If sludge is placed in depths of 15 inches (36 cm) or less, it may be removed and dewatered in 3 to 5 months.

10.8.3 MECHANICAL DEWATERING AND DISPOSAL. Consider filter press equipment in locations where sludge drying beds cannot be used.

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

10.8.3.2 FILTER PRESS. For larger facilities with higher sludge production, consider a plate and frame (or diaphragm) filter press. A plate and frame press will require high lime dosage. As an alternate, select type and feed rate of organic polyelectrolyte. Use a diatomaceous earth precoat filter to minimize oil blinding of the filter fabric. Consider high pressure air or steam cleaning of the fabric in a regular operating cycle. Consider operational problems of media blinding and cake handleability in selection of the filter press, as for other mechanical dewatering equipment.

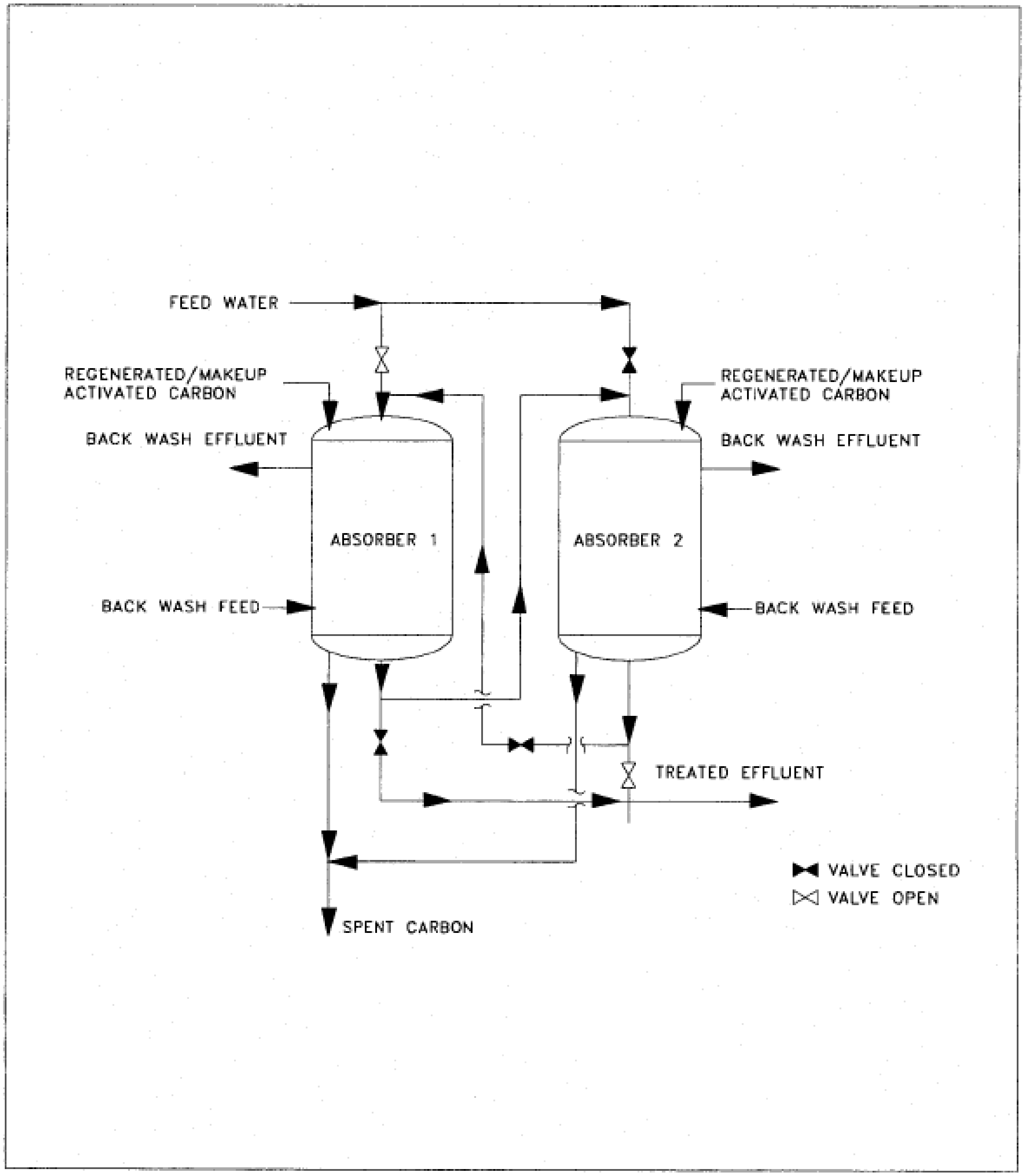


Figure 18

Two-vessel granular carbon adsorption system

A pressure filter consists of metal plates covered by a fabric filtering medium. The covered plates are hung in a frame equipped with both a fixed and a moveable head. The plates are forced together with a chamber left between the cloth surfaces. Sludge is pumped through a central opening in the plates to the cloth-lined chamber. Sludge is retained on the fabric and liquid is forced through the fabric to the plate surface where it drains away. At the end of the filtration cycle, the plates are separated, and the sludge cake is discharged from the unit. Feed pressures ranging between 80 and 225 psig are common. Filter presses achieve 40 to 50 percent solids concentration.

10.8.3.3 BELT FILTER PRESS. For larger facilities with higher sludge production consider a belt filter press. The performance of belt presses depends on factors such as conditioning, maximum pressure, and number of rollers. Determine polymer type and required dosage for sludge conditioning by bench scale or pilot plant tests. Consider the effect of oil blinding of media and methods and efficiency of media cleaning in equipment selection and specification. Consider handleability of sludge cake and cake discharge characteristics in equipment selection and specification. A belt type filter press will normally produce a sludge cake with 60 to 70 percent moisture content. The units are mechanically complex and require frequent maintenance attention to check and adjust roller clearances and lubricate roller bearings. However, full time operator attention is not required during operation. Since sludge cake is discharged continuously, a conveyor belt might be required to carry off the sludge to a storage area.

MIL-HDBK-1005/9A

170

10.8.3.4 VACUUM FILTRATION. There are three commonly used vacuum filtration units that may be considered: rotary drum, rotary belt, and coil filters. A typical rotary drum filter installation consists of a horizontal compartmented drum, which supports the filter media on its outer surface. The drum is rotated, partially submerged, in a tank containing the sludge. As each section of the drum passes through the tank, a vacuum pulls the liquid inward and the solids are retained as a thin cake on the filter media covering the outer drum surface. The belt vacuum filter represents a recent improvement in continuous rotary vacuum filtration. Rather than being fixed to the drum, the filter medium belt is wrapped around the face of the drum. The belt leaves the drum at approximately the two o'clock lock position and is transported over a roll and wash system which serves three purposes: cake washing, medium washing, and belt alignment (prior to its being placed back on the drum). The coil filter is similar in many respects to the belt filter except that metal coil springs are used in place of a filter belt. The metal coil springs are constructed of stainless steel and are arranged in two layers in corduroy fashion around the drum face. The coils, having approximately 10 percent open area, do not function as a filter medium, but as support for the filter medium developed from sludge solids. Vacuum filtration apparatus is a complex system that includes the following components: sludge feeding and conditioning components, vacuum pump and receiver, vacuum filter, and filtrate pump.

10.8.4 SLUDGE DISPOSAL. The toxic characteristics of oily sludges are specific to the oily waste treatment facility where they are generated. An increase in the types of these sludges is expected to be classified as hazardous due to the adoption of the more stringent TCLP method for sludge toxicity characterization. Consequently, these sludges will require handling and disposal under RCRA. The final disposal of these sludges must be in accordance with the applicable State and Federal regulations. One alternative for sludge disposal is by contract haul. It should be evaluated, particularly for small plants located close to the disposal sites. Other disposal techniques are as follows:

10.8.4.1 ULTIMATE DISPOSAL OPTIONS (CONVENTIONAL). Land applications and land-farming are current methods used for the disposal of oily sludge. The mineral and organic matter and microorganisms present in soil, chemically and biologically degrade oily sludges. Raw oily sludge is mechanically spread and worked into the soil for improved performance. These techniques require large land areas as the degradation process is slow. These processes are being subjected to increasingly stringent environmental regulations so it is necessary to check with local and Federal regulations when disposing of hazardous oily sludges in this manner.

10.8.4.2 ULTIMATE DISPOSAL OPTIONS (UNCONVENTIONAL). Less conventional methods for the ultimate disposal of hazardous wastes are likely to become more prevalent as rising costs of conventional disposal methods become prohibitive. These methods include encapsulation or solidification of sludge, followed by disposal in a conventional site rather than a hazardous waste site. Silicate materials, lime, cement, or gypsum are mixed with the sludge and are allowed to set for a short time. The setting time and the selection of the materials should be based on laboratory scale evaluation. High concentrations of sulfates in sludge may interfere with the process.

10.8.4.3 THERMAL DEGRADATION. Thermal degradation methods, such as incineration and co-firing, can be used for sludge disposal. Thermal degradation is not the ultimate method of disposal. It produces three secondary streams (effluents): flue gas (air), scrub water, and ash. Each effluent requires additional treatment. Thermal degradation methods are technically and operationally very complex, and associated costs are high. The hazardous waste reduction by thermal degradation methods is controlled by a series of Federal laws (RCRA, Clean Air Act, Clean Water Act, Toxic Substances Control Act (TSCA)) as well as State regulations and local ordinances. Currently, due to high cost, technical complexity, and extensive regulations, this is the last alternative to be considered.

10.9 OIL RECLAMATION. Oil is recovered in the LET and the induced gravity separator and should be reclaimed. Emulsified oil may also be reclaimed but requires further treatment to destabilize the emulsion. Oil reclaimed from oily waste treatment plants can be used for boiler fuel if it meets specifications.

10.9.1 DEMULSIFICATION. Oils contaminated with water, or heavily emulsified (usually water-in-oils emulsion, but may be oil-in-water) may be demulsified sufficiently to produce fuel oil reclaimed quality oil. The most common method is that of organic demulsifying agents or polymers used in conjunction with heat. Some emulsions respond better to various filtration techniques, such as the use of a precoated plate and frame filter. However, this technique often requires the emulsion to be pretreated with a “conditioner” for filtration to be a success. Bench scale tests are required to choose the most appropriate technique. This technique can feasibly separate out quality oil and produce a reduced amounts of sludge that is non-leachable (an important factor in determining how and where you will dispose of the sludge). Centrifugation has also proved to be a viable method, but tends to be more labor intensive and requires dedicated personnel to the operation and maintenance of the centrifuge itself. For larger quantities, this should be the last method considered.

10.9.1.1 CHEMICAL TREATMENT. This is usually carried out in smaller tanks (1,000 to 5,000 bbls) that provide heat. The demulsifier is transfer injected into the waste stream via a metering pump to ensure adequate mixing and proper dosage. The heat required is generally between 145°F and 165° F (62.8°C and 73.9°C) and may be provided with steam heating coils in the settling tank. The waste stream may be heated before demulsifier addition if convenient. A reclamation facility will typically have two holding tanks. The oil settles in one tank while it is collected in the other. Depending on the size of tank used, 3 to 7 days are required for optimum resolution of the emulsion. After settling, the bottom water is drawn off and returned to the LET for reprocessing. Figure 26 shows the treatment of an oil emulsion in a batch process.

10.9.1.2 FILTRATION. In filtration (precoat), the emulsion is filtered through a layer of diatomaceous earth, normally deposited on a continuously rotating drum filter. Precoat filtration is not normally recommended because of its high operating costs. For additional details, refer to the API Manual.

10.9.2 DEMULSIFIER SELECTION AND APPLICATION. Given the complexity and diversity of emulsions, an emulsion breaker is expected to perform many tasks. Ideally, a demulsifier should provide a rapid water break, clean oil that meets reuse specifications, a sharp interface and clear, oil-free water. Based on the above functions, no single-component chemical can do these jobs effectively. The different surface phenomena that occur in three different phases can only be addressed by a multi-component demulsifier. Therefore, when formulating a demulsifier, one has to consider incorporating a range of solubilities, surface activities, and wetting properties. An effective demulsifier may consist of two, three, or four components, preselected and blended in a specific order and in carefully controlled proportions.

The selection of demulsifiers requires practical experience. There follows, then, a trial and error narrowing of the choice according to activity and tolerance toward existing system variables. The identification of the best demulsifier and the optimum concentration range is best realized by the jar/bottle test. This is a standard technique (API Code 2500) accepted in the oil industry that has, for many decades, aided the operator in demulsifier selection.

10.10 PUMPS, VALVES, AND PIPING

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

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

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

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

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

10.10.3 PIPING. Aboveground wastewater and sludge piping should be designed using ductile iron or carbon steel pipe. Chemical feed piping and underground wastewater and sludge piping should be specified as PVC pipe. Due to the corrosiveness of both the oily waste, with a high seawater content, and the "salt air" atmosphere, corrosion resistant coating systems should be specified for both the interior and exterior surfaces of ductile iron and carbon steel pipe. In areas where seasonal temperatures fluctuate widely, adequate provisions for expansion and contraction must be provided to avoid pipe breakage. For ductile iron and carbon steel piping 4 inches (100 mm) in diameter and larger, cement lining or coal-tar epoxy coating of interior surfaces, and coal-tar epoxy exterior coating should be specified. For carbon steel piping smaller than 4 inches in diameter, polyethylene or Saran lining of interior surfaces and coal-tar epoxy exterior coating should be specified. Piping should be sized for a velocity of 6 to 8 fps (1.8 to 2.4 m/s).

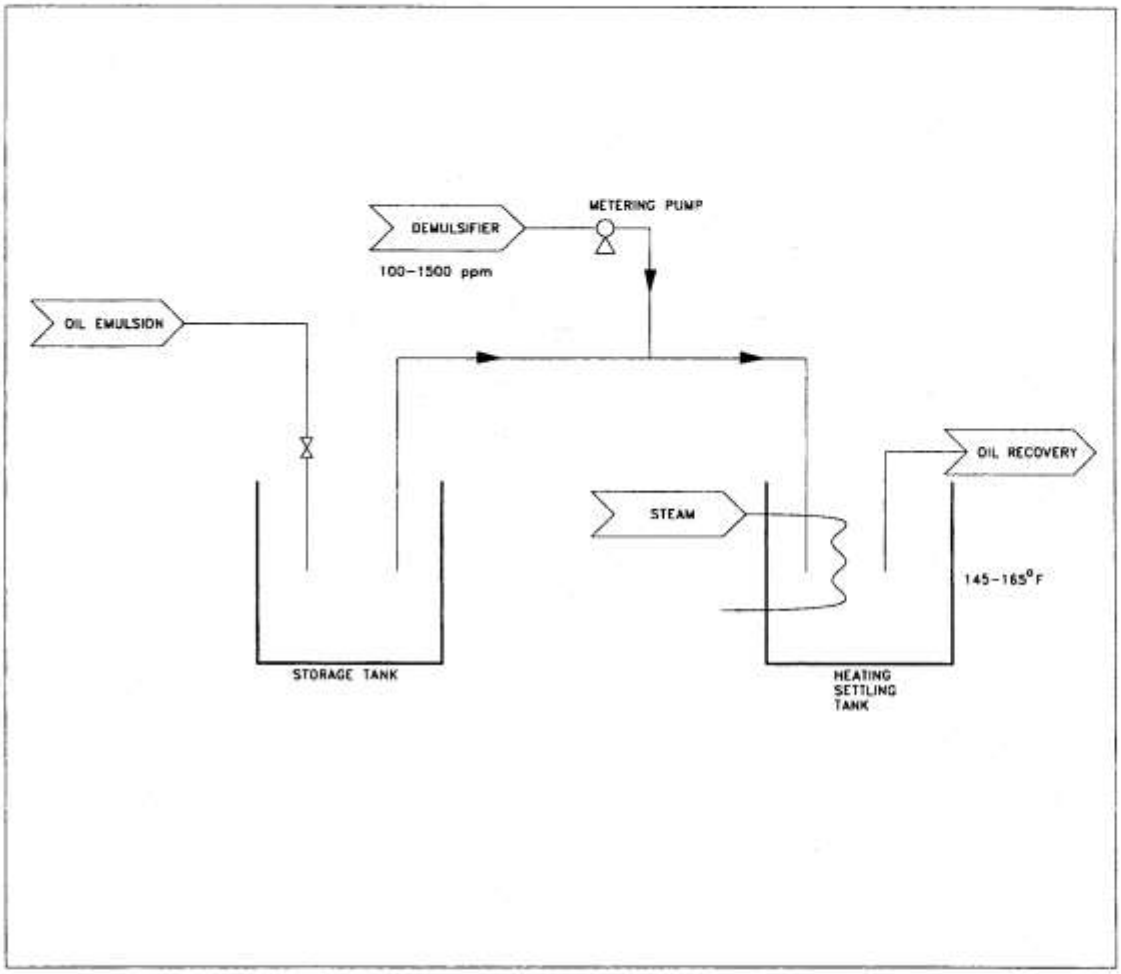


Figure 19

Oil emulsion treatment schematic

10.11 INSTRUMENTATION. Since the systems are intended to be run on a batch basis, manual control of treatment unit operations is recommended. Excessive automation should be avoided. Any automation provided must have full manual backup. Automatic backwash controls on filtration units and automatic start-stop control of polymer feed systems on sensing flow to a DAF/IAF unit are recommended. pH monitoring and automatic control for chemicals addition are also recommended. On direct discharge systems consider provision for automatic recycles of effluent to a LET if oil is detected at higher than permissible concentrations. Instrumentation should be provided to monitor influent and effluent flow and key effluent quality parameters. Monitoring instrumentation for facilities discharging to navigable waters should be provided in duplicate for 100 percent redundancy. Suggested parameter monitoring guidelines are presented in Table 6.

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

Table 6

Guidelines for oily waste treatment monitoring