ENGINEERING STANDARD

FOR

PROCESS DESIGN PLANT WASTE-WATER TREATMENT

AND RECOVERY SYSTEMS

ORIGINAL EDITION

DEC. 1997

CONTENTS : PAGE No.

FIGURES :

APPENDICES:

0. INTRODUCTION

"Design of Miscellaneous Processes in OGP Industries" are broad and contain various subjects of paramount importance including waste water treatment and recovery systems. Therefore, a group of Process Engineering Standards are prepared to cover this subject. This group includes the following Standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-700	"Process Design of Crude Oil Electrostatic Desalters"
IPS-E-PR-725	"Process Design of Plant Waste Water Sewer Systems"
IPS-E-PR-730	"Process Design of Plant Waste Water Treatment and Recovery Systems"
IPS-E-PR-735	"Process Design of Plant Solid Waste Treatment & Disposal Systems"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF PLANT WASTE WATER TREATMENT AND RECOVERY SYSTEMS"

The treatment of waste waters, involves a sequence of treatment steps. Every one of the waste water treatment processes involves the separation of solids from water in at least some part of the operation and removal of BOD in some extent. The end of pipe treatment sequence can be divided into the following elements. Primary or pretreatment, intermediate treatment, secondary treatment and tertiary treatment plus ancillary, sludge dewatering and disposal operations.

The key to optimize the treatment sequence for provision of maximum water treatment at minimum cost, is to identify the rule of each Unit operation and optimize that operation. Optimizing the performance of specific Unit operations, such as API Separator, Dissolved Air Flotation, Biological Treatment, etc. can best be achieved if:

a) the properties of influent streams are considered;

b) the chemical principles that are used in solids pretreatment are understood;

c) the variety of chemicals available for solids treatment is recognized;

d) the properties of effluent water are established based on the Local Environmental Regulations and final disposal;

e) the protocols for quantifying results are identified.

In general, most industries require water for processing or other purposes; much of this water after use is discharged either to public and/or natural water sources or directed to recycling purpose inside the industry. Such discharge, which may contain a wide variety of matter in solution or suspension should be controlled according to the requirements imposed by the final destination and/or Environmental Regulations.

A model sequence for the treatment of oil, gas and petrochemical industries waste waters is shown in Fig. 1.

1. SCOPE

This Engineering Standard Specification covers minimum requirements for the process design and engineering of the equipment and facilities pertaining to the waste water treatment Units of Oil and gas refineries, chemical plants, oil terminals, petrochemical plants and other facilities as required.

As far as Environmental Regulations are concerned, extent of application of all systems, facilities and/or methods as outlined in this Standard should be advised by the Company for each project.

Included in the scope are:

i) Liquid and solid disposal systems.

ii) Primary oil/solids removal facilities (API Separators).

iii) Further oil & suspended solids removal (secondary oil/solids removal) such as Dissolved-Air Flotation Unit.

Granular Media Filters and Chemical Flocculation Units.

iv) Chemical Addition Systems.

v) Biological Treatment.

vi) Filteration and/or other final polishing.

Excluded from the scope are:

i) Sewage system handling domestic and medical sanitary appliances of buildings.

ii) Drainage system carrying surface and rainwater.

iii) Waste water gathering systems.

iv) Clean water drainage, e.g., from buildings and paved areas.

v) Evaporation ponds and disposal by natural percolation into the subsoil in permeable ground.

vi) Sanitary sewage treatment.

vii) Sludge handling and treatment.

This Engineering Standard Specification shall be read in conjunction with the Standards Specifications listed below:

STANDARD CODE	STANDARD TITLE
IPS-E-CE-380	"Sewerage & Surface Water Drainage System"
IPS-E-CE-390	"Rain & Foul Water Drainage of Buildings"
IPS-E-CE-400	"Sewage Treatment"
IPS-C-CE-342	"Construction Works for Water Supply & Sewerage System"
IPS-M-CE-345	"Water Supply & Sewerage Equipment"
IPS-E-PI-240	"Plant Piping Systems"
IPS-E-SF-880	"Water Pollution Control"
IPS-E-PR-725	"Process Design of Plant Waste Water Sewer Systems"
IPS-E-PR-735	"Process Design of Plant Solid Waste Treatment & Disposal Systems"

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

API (AMERICAN PETROLEUM INSTITUTE)

API-RP-500A,	"Classification of Areas for Electrical Installations in Petroleum Refineries",4th. Ed., January 1982, Reaffirmed December 1987
API Publ. 420	"Monographs on Refinery Environmental Control, Management of Water Discharges, The Chemistry and Chemicals of Coagulation and Flocculation"., 1st. Ed., 1990
API Publ. 421	"Monographs on Refinery Environmental Control, Management of Water Discharges, Design and Operation of Water Separators", 1st. Ed., 1990
API Std. 650	"Welded Steel Tanks for Oil Storage", 8th. Ed., 1988

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

ASME Code, Section VIII, Div. 1

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

ASTM D-1888	"Test Methods for Particulate and Dissolved Matter, Solids, or Residue in Water.", Ed. 2, 1978
ASTM D-3921	"Test Method for Oil and Grease for Petroleum Hydrocarbons in Water"

DIN (DEUTSCHE INDUSTRIE-NORM)

DIN 997	"Tracing Dimensions for Bars and Rolled Steel Sections", Oct. 1970

EPA (UNITED STATE ENVIRONMENTAL PROTECTION AGENCY)

EPA-413.1	"Gravimetric Separation"
EPA-413.2	"Infrared Spectrophotometry"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-CE-380	"Sewerage and Surface Water Drainage System"
IPS-E-CE-390	"Rain & Foul Water Drainage of Buildings"
IPS-E-CE-400	"Sewage Treatment"
IPS-E-PR-725	"Process Design of Plant Waste Sewer Systems"
IPS-E-PR-735	"Process Design of Plant Solid Waste Treatment & Disposal Systems"
IPS-G-SF-130	"Solid Waste Disposal"

METCALF & EDDY, INC.

"Waste Water Engineering Treatment, Disposal, and Reuse", published by McGraw-Hill Company, 3rd., Ed., 1991

3. DEFINITIONS AND TERMINOLOGY

For definition of the particular terms/words of this Standard not outlined herein below, reference should be made to the latest revision of the following standards/publications:

API Vol. 1	"Manual on Disposal of Refinery Wastes, Liquid Wastes"
IPS-E-CE-380	"Sewerage and Surface Water Drainage System"
IPS-E-CE-390	"Rain & Foul Water Drainage System"
IPS-E-CE-400	"Sewage Treatment "
IPS-E-PR-725	"Process Design of Plant Waste Water Sewer Systems"

3.1 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is oxygen demand by microorganisms during stabilization of organic matter under scribed conditions, usually over a 5 day period, BOD_5 specifically denotes the oxygen demand over a 5 day period at 20°C.

3.2 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is the equivalent amount of oxygen consumed under specified conditions in the chemical oxidation of the organic and oxidizable inorganic matter contained in a waste water, corrected for the influence of chlorides. In practice, unless otherwise specified, the chemical oxidizing agent is hot acid dichromate.

3.3 Coagulant Aids

Materials added to enhance the action of coagulants, generally by affecting the electrical balance of the particles.

3.4 Coagulation and Coagulants

Coagulation is the formation of flocculate particles from added chemical. Coagulants are the materials added to the waste water to cause agglomeration of small particles to facilitate their separation.

3.5 Dissolved Oxygen (DO)

Dissolved Oxygen is the oxygen dissolved in sewage, water or other liquid, usually expressed in milligrams per liter (mg/L) or percent (%) of saturation.

3.6 Effluent

Effluent is (1) a liquid which flows out of a containing space, and/or (2) sewage, water or other liquid, partially or completely treated, or in its natural state, as the case be flowing out of a reservoir, basin, or treatment plant, or part thereof.

3.7 Effluent Limitation

Effluent limitation is any restriction (including schedules of compliance) established by a governmental authority on quantities, rates and concentration of chemical, physical, biological and other constituents which are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean.

3.8 Flocculation

The provision of retention time with gentle agitation to allow the floc particles or precipitate, associated with the impurities to increase in size by agglomeration.

3.9 Immediate Oxygen Demand (IOD)

Immediate Oxygen Demand (IOD) is the amount of oxygen that is utilized by the components of a waste water within 15 minutes (unless otherwise specified) after being introduced into water that contains dissolved oxygen.

3.10 Susceptibility to Separation (STS) Number

STS number is the oil contents in parts per million, of the suspend water after the specified settling period.

3.11 Surface Water

Surface water is natural rain water from the ground surface, paved areas and roofs plus occasional courtyard and car washing waste waters and incidental fire fighting water.

3.12 Total Organic Carbon (TOC)

TOC is a measure of the amount of carbon in a sample originating from organic matter only. The test is run by burning the sample and measuring the CO_2 produced.

4. SYMBOLS AND ABBREVIATIONS

Symbols and abbreviations referred to in this Standard are as follows:

SYMBOLS/ABBREVIATION	DESCRIPTION
ABS	Acrylonitrile Butadiene Styrene.
API	American Petroleum Institute.
ASCE	American Society of Civil Engineers.
ASTM	American Society for Testing and Materials.
BCME	Bis (chloromethyl)ether.
BOD_5	The 5 Day Biochemical Oxygen Demand at 20°C.
CMME	Methy chloromethyl methyl ether.
COD	Chemical Oxygen Demand.
CPI	Corrugated Plate Interceptor.
DAF	Dissolved Air Flotation.
DEA	di-Ethanolamine.
DGF	Dissolved Gas Flotation
DN	Diameter Nominal, in (mm).
DO	Dissolved Oxygen.
DP	Differential Pressure.

EFF	Efficiencies.
EPA	Environmental Protection Agency.
MBAC	Methylene Blau Active Substance.
MEA	mono-Ethanolamine.
MOCA	4,4’-methylene-bis (2-chloroaniline).
MPN	Maximum Possible Numbers.
OGP	Oil, Gas and Petrochemical.
OSHA	Occupational Safety and Health.
PCBs	Polychloro-biphenyls.
PPI	Parallel Plate Interceptor
ppm	Parts per million.
PVC	Poly-vinyl chloride.
SS	Suspended Solids.
STS	Suspectible To Separation.
SWD	Side Water Depth.
TDS	Total Dissolved Solids.
TOC	Total Organic Carbon.
USDA	United States Department of Agriculture.
USEPA	United States Environmental Protection Agency.
WPCF	Water Pollution Control Federation.
VOCs	Volatile Organic Compounds.

5. UNITS

This Standard is based on International System of Units, (SI) except Where otherwise specified.

6. WASTE-WATER TREATMENT

6.1 Nature of Waste-Waters

Suspended solids, biodegradable organics, nutrients, refractory organics, heavy metals, dissolved inorganic solids and pathogens are the important contaminants which may be found in the OGP industry’s waste waters. Appendix A presents a list of important waste water contaminants and reasons for their importance.

Suspended solids can be removed by physical treatment in some extent. Removal of biodegradable organics, suspended solids and pathogens is achieved through the secondary treatment operation Units. The more stringent standards are dealt with the removal of nutrients and priority pollutants (see Appendix B).When waste water is to be reused, standards normally include requirements for the removal of refractory organics, heavy metals, and in some case dissolved inorganic solids.

6.1.1 Suspended solids

The standard way of testing a waste water for suspended solids is to filter the waste water through a 0.45 µm porosity filter. Anything on the filter after drying at about 103°C is considered a portion of the suspended solids. Table 1 provides another classification system for the solids found in waste water.

TABLE 1 - GENERAL CLASSIFICATION OF WASTE WATER SOLIDS

PARTICLE CLASSIFICATION	PARTICLE SIZE, mm
Dissolved	Less than 10^{-6}
Colloidal	10^{-6} to 10^{-3}
Suspended	Greater than 10^{-3}
Settleable	Greater than 10^{-1}
Supracolloidal	10^{-3} to 10^{-1}

6.1.2 Biodegradable organics

The following procedures shall be utilized to estimate the oxygen-demanding potential of waste waters:

- Biochemical Oxygen Demand (BOD)Test.
- Chemical Oxygen Demand (COD) Test.
- Total Organic Carbon (TOC) Test.

6.1.3 Heavy metals

Any cation having an atomic mass (weight) greater than 23 (atomic mass of sodium) to be considered a heavy metal. See IPS-G-SF-130, "Solid Waste Disposal" for levels of various metals which are deemed permissible in fresh water.

6.1.4 Dissolved inorganic solids

The following procedure can be used to determine the inorganic dissolved solids in waste waters. A sample of waste water to be filtered through a 0.45 µm filter, collected the filterate, and vaporized first the water (at 103°C) and then the organic fraction (at 550°C) from the filterate. The amount of material left in the vessel after incineration at 550°C is referred to as the fixed or inorganic dissolved solids level.

6.1.5 Toxic organic compounds

Appendix C provides some organics compounds which are considered toxic and/or carcinogenic.

6.1.6 Surfactants

Surfactants or surface-active agents, are large organic molecules that are slightly soluble in water and cause foaming in waste water treatment plants and in the surface waters into which the waste effluent is discharged. During aeration of waste water, these compounds are collected on the surface of the air bubbles and thus create a very stable foam. The determination of surfactants is accomplished by measuring the color change in a standard solution of methylene blue active substance (MBAS).

6.1.7 Priority pollutants

Priority pollutants (both inorganic and organic) are selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of the organic priority pollutants are also classified as volatile organic compounds (VOCs). Representative examples of the priority pollutants are shown in Appendix B. Within a waste water collection and treatment system, organic priority pollutants may be removed, transformed, generated, or simply transported through the system unchanged. Five primary mechanical are involved; (1) volatilization (also gas stripping); (2) degradation; (3) adsorption to particles and sludge; (4) transporting through the entire system; (5) generation as result of chlorination or as byproducts of the degradation of precursor compounds.

6.1.8 Volatile organic compounds

Organic compounds that have a boiling point ≤ 100°C and/or a vapor pressure > 1 mm Hg (or 133.3 Pa) at 25°C are generally considered to be volatile organic compounds (VOCs), e.g., vinyl chloride. The release of these compounds in sewers and at treatment plants especially at the headworks, is of particular concern with respect to the health of collection system and treatment plant workers.

6.2 Treatment Stages

Generally, the term "preliminary" and/or "primary" referred to physical Unit operations; "secondary " referred to chemical and biological Unit Processes; and "advanced" or "tertiary " referred to combinations of all three.

Application and definition of the various stages of treatment and methods to perform specific functions are described in the following Articles.

6.2.1 Preliminary waste water treatment

Preliminary waste water treatment is defined as the removal of waste water constituents that may cause maintenance or operational problems with the treatment operations, processes, and ancillary systems. Screening and comminution for the removal of debris and rags, grit removal for the elimination of coarse suspended matter that may cause wear or clogging of equipment, and floatation for the removal of large quantities of oil and grease are examples of preliminary operations.

6.2.2 Primary waste water treatment

In primary treatment a portion of the suspended solids and organic matter is removed from the waste water. This removal is usually accomplished with physical operations such as screening and sedimentation.

The effluent from primary treatment will ordinarily contain considerable organic matter and will have a relatively high BOD. The principal function of primary treatment will continue to be as a precursor to secondary treatment.

6.2.3 Conventional secondary waste water treatment

Secondary treatment is directed principally toward the removal biodegradable organics and suspended solids. Disinfection is included frequently in the definition of conventional secondary treatment. Conventional secondary treatment is defined as the combination of processes customarily used for the removal of these constituents and includes biological treatment by activated sludge, fixed film reactors, or lagoon systems and sedimentation.

6.2.4 Nutrient removal or control

Nutrient removal or control is generally required for:

1) discharges to confined bodies of water where eutrophication may be caused or accelerated;

2) discharges to flowing streams where nitrification can tax oxygen resources or where rooted aquatic plants can flourish;

3) recharge of ground waters that may be used indirectly for public water supplies.

The nutrients of principal concern are nitrogen and phosphors and may be removed by biological , chemical, or a combination of these processes. In many cases, the nutrient removal processes are coupled with secondary treatment; for example biological denitrification may follow an activated sludge process that produces a nitrified effluent.

6.2.5 Advanced waste water treatment /waste water reclamation

Advanced waste water treatment or tertiary treatment is normally defined as the level of treatment required beyond conventional secondary treatment to remove constituents of concern including nutrients, toxic compounds, and increased amounts of organic material and suspended solids. In addition to the nutrient removal processes, Unit operations or processes frequently employed in advanced waste water treatment are chemical coagulation, flocculation, and sedimentation followed by filteration and activated carbon. Less used processes include ion exchange and reverse osmosis for specific ion removal or for the reduction in dissolved solids.

Advanced waste water treatment is also used in a variety of reuse applications where a quality water is required such as for industrial cooling water and ground water recharge.

6.2.6 Toxic waste treatment/specific contaminant removal

The removal of toxic substances and specific contaminants is a complex subject and the concentrations of toxic pollutants are usually controlled by pretreatment prior to discharge to the final treatment system. Many toxic substances such as heavy metals are reduced by some form of chemical-physical treatment such as chemical coagulation, flocculation, sedimentation, and filteration. Some degree of removal is also accomplished by conventional secondary treatment. Waste waters containing volatile organic constituents may be treated by air striping or by carbon adsorption. Small concentrations of specific contaminants may be removed by ion exchange. Table 2 presents a list of typical pollutants that have an inhibitory effect on the activated-sludge process.

6.2.7 Sludge processing

For the most part, the methods and systems reported in Table 3 are used to process the sludge removed from the liquid portion of the waste water.

TABLE 2 - THRESHOLD CONCENTRATIONS OF POLLUTANTS INHIBITORY TO THE ACTIVATED-SLUDGE PROCESS

POLLUTANT	CONCENTRATION, mg/L	
	CARBONACEOUS REMOVAL	NITRIFICATION
Aluminum	15-26	
Ammonia	480	
Arsenic	0.1	
Borate (Boron)	0.05-100	
Cadmium	10-100	
Calcium	2,500	
Chromium (hexavalent)	1-10	0.25
Chromium (trivalent)	50	
Copper	1.0	0.005-0.5
Cyanide	0.1-5	0.34
Iron	1,000	
Manganese	10	
Magnesium		50
Mercury	0.1-5.0	
Nickel	1.0-2.5	0.25
Silver	5	
Sulfate		500
Zinc	0.8-10	0.08-0.5
Phenols:		
Phenol	200	4-10
Cresol		4-16
2-4 Dinitrophenol		150

TABLE 3 - SLUDGE-PROCESSING AND DISPOSAL METHODS

PROCESSING OR DISPOSAL FUNCTION	UNIT OPERATION, UNIT PROCESS, OR TREATMENT METHOD
Preliminary Operation	Sludge pumping Sludge grinding Sludge blending and storage Sludge degritting
Thickening	Gravity thickening Flotation thickening Centrifugation Gravity belt thickening Rotary drum thickening
Stabilization	Lime stabilization Heat treatment Anaerobic digestion Aerobic digestion Composting
Conditioning	Chemical conditioning Heat treatment
Disinfection	Pasteurization Long-term storage
Dewatering	Vacuum filter Centrifuge Belt press filter Filter press Sludge drying beds Lagoons
Heat drying	Dryer variations Multiple effect evaporator
Thermal reduction	Multiple hearth incineration Fluidized bed incineration Co-incineration with solid wastes Wet air oxidation Vertical deep well reactor
Ultimate disposal	Land application Distribution and marketing Landfill Lagooning Chemical fixation

6.3 Treatment Processes

6.3.1 General

Contaminants in waste water should be removed by physical, chemical and/or biological means. unit operations and processes which may be commonly used in waste water treatment are listed in Table 4. The following instructions should be taken into consideration for the selection of treatment technologies:

a) Technologies should be categorized into those that work, those that have the potential to work, and those that have no place for the particular application.

b) Technologies should be evaluated based on their effectiveness (ability to reliably attain treatment goals), implementability (availability of materials and services), and costs (capital and operation and maintenance).

c) Viable technologies should be identified for each of the individual waste water streams. The streams that use the same technologies shall be combined to create composite waste treatment trains. The resulting waste water treatment trains shall be compared to the current manufacturing and waste treatment practices to identify possible candidates for waste segregation and independent treatment.

d) The level of waste water treatment and method of effluent discharge shall be established to protect the receiving body of water or water table and its usages.

Level of treatment of the facility to be designed shall be determined by the ability of the receiving waters to accept residual wastes and allocation set up by effluent standards. The degree of treatment can be determined by comparing the influent waste water characteristics to the required effluent waste water characteristics.

In case of waste water reuse applications, the quality of water used as make-up will govern the waste water treatment needed and the degree of reliability required for the treatment processes and operations. The reliability of the proposed treatment processes and operations must be evaluated to provide a continuous supply of water with consistent water quality.

e) All toxic and highly chemically active materials should be treated at the source and not be discharged in any active state into the sewers loading to the waste treatment plant. This may include removal of soluble and insoluble forms of metals such as lead, zinc, copper, or their derivatives and other similarly dangerous classified metals and their by-products.

It should be required that highly active metals inclusive of finely divided magnesium or aluminum alloys should not be discharged in the sewers but be treated and removed by special methods and equipment at the source.

It should be required that all highly toxic inorganic chemicals inclusive of cyanides, fluorides, and related objectionable anions must be treated and removed from the water at or near the source to the degree specified in the code regulations. This includes the chromates and other special complex anion derivatives.

Another group for exclusion from discharge of waste in the sewer should include highly acting oxidizing agents, particularly peroxides of organic and of inorganic structures. This group should also include the exclusion of other powerful oxidizing agents inclusive of chlorates, perchlorates, nitric acid, and other similar products.

The discharge of volatile organic materials into the waste should also be restricted and these materials should be isolated and treated at the source. This restriction is a must, because very disastrous explosion may occur in sewer systems where volatilization of the organic matter creates an explosive mixture or some other conditions set off chemical reactions.

In general all toxic materials particularly of the organic family that are known to be dangerous to plant, animal, or human life should be treated at the source.

All solutions containing radioactive products must also be kept isolated and treated at the source.

TABLE 4 - UNIT OPERATIONS, UNIT PROCESSES, AND SYSTEMS FOR WASTE-WATER TREATMENT

CONTAMINANT	UNIT OPERATION, UNIT PROCESS, OR TREATMENT SYSTEM
Suspended Solids:	Sedimentation Screening and comminution Filtration Flotation Chemical-polymer addition Coagulation/sedimentation Land treatment systems
Biodegradable organics:	Activated-sludge variations Fixed-film: trickling filters Fixed-film: rotating biological contractors Lagoon and oxidation pond variations Intermittent sand filtration Land treatment systems Physical-chemical systems
Pathogens:	Chlorination Hypochlorination Ozonation Land treatment systems
Nutrients: a) Nitrogen	Suspended-growth nitrification and denitrification variations Fixed-film nitrification and denitrification variations Ammonia stripping Ion exchange Breakpoint chlorination Land treatment systems
b) Phosphorus	Metal-salt addition Lime coagulation/sedimentation Biological-chemical phosphorus removal Land treatment systems
c) Nitrogen and phosphorus	Biological nutrient removal
Refractory organics:	Carbon adsorption Tertiary ozonation Land treatment systems
Heavy metals:	Chemical precipitation Ion exchange Land treatment systems
Dissolved inorganic solids:	Ion exchange Reverse osmosis Electrodialysis

6.3.2 Selection of treatment processes

6.3.2.1 General

a) Removing of the all waste water contaminants will be achieved only through the various treatment operation Units. Selection of most probable appropriate treatment sequences will provide more desirable treated waste water. Various combinations of Unit operations and processes and their interaction for treatment of refinery waste water are identified in Table 5A. Summary of treatment methods for petrochemical wastes are also presented in Table 5B.

The selection of a process train or alternative process trains should be made on the ability of the individual Unit processes to remove specific waste constituents.

b) The two general categories of approaches to develop the treated waste water are physical/chemical treatment and biological treatment. The essential difference between the capabilities of a physical. chemical process and a biological process is the ability of each to remove certain types of organic materials. The physical/chemical process is subject to apparent inefficiencies caused by a certain amount of non-adsorbable organics in the waste water. The biological process is subject to apparent inefficiencies as a result of non-biodegradable organics in the waste water. A selective listing of Unit processes and the waste constituents for which they are generally applied and/or are effective is shown in Table 6.

Assembling of the most applicable process train is based on the full knowledge of the waste water conditions and constituents.

In general, chemical/physical treatment is a suitable alternative:

- for low total organic strength wastes (BOD_5 less than 100mg/L);

- for a waste having a high particulate organic concentration, provided the soluble organic concentration, following chemical coagulation, sedimentation and filteration is less than 50 mg/L BOD_5;

- for waste water treatment systems where no influent flows will be received for substantial periods of time, for example batch treatment or systems experiencing significant flow variations;

- if land space is limited or toxic substances presented in the raw waste water.

Care should be exercised in the application of chemical-physical treatment systems on medium to high strength wastes (BOD_5 greater than 200 mg/L). For this situation, on-site pilot studies are desirable to determine obtainable effluent quality and to ascertian if the biological activity anticipated in the carbon column will be more of a detriment (odor, plugging) than asset (higher organic removal).

c) Land application of waste water is viewed as an alternative to other secondary treatment schemes or a final add-on step for liquid disposal and convenient water use. Alternative land disposal methods include various modes of surface and subsurface percolation and deep well injection.

Combination land disposal and waste water reclamation methods include infiltration-percolation, overland flow, irrigation, and ground water recharge.

d) Many treatment methods can be used for the treatment of toxic compounds. Because of the complex nature of toxicity, the treatment methods must consider the specific characteristics of the waste water and the nature of the toxic compounds.

Treatment processes used to remove some of the specific compounds or groups of compounds are summarized in Table 7.

TABLE 5A - REFINERY TREATMENT SEQUENCE OPTIONS

PRE-OR IN-PLANT TREATMENT	PRIMARY TREATMENT	INTERMEDIATE TREATMENT	SECONDARY TREATMENT	TERTIARY TREATMENT
OBJECTIVE				
Removal of phenolics, S^-, NH_3, RSH, F^-, acid sludge, oil, etc., water reuse; waste equalization	Removal of free oil suspended solids	Removal of emulsified oil, suspended and colloidal solids	Removal of dissolved organics,(Variable) produced biological sludge	
PROCESSES				
Unit separators Steam stripping Fuel gas stripping Air oxidation Neutralization Surge ponds Inhibitory contaminant surge control	API separators CPI, PPI separators ↓ Sludges	Chemical coagulation and air flotation Chemical coagulation and filtration pH control Reduction of intermediate oxygen demand Equalization of wastes ↓ Sludges	Trickling filter Activated Oxidation pond Aerated lagoon Rotating biological Contactors ↓ Sludges	Chemical coagulation and air flotation Chemical coagulation and filtration Carbon adsorption Carbon adsorption ↓ Sludges

Note:
CPI = corrugated plate interceptor:
PPI = parallel plate interceptor.

TABLE 5B - SUMMARY OF TREATMENT METHODS FOR PETROCHEMICAL WASTES CLASSIFIED BY PLANT PRODUCT

PLANT PRODUCT	PHYSICAL . TIRALAICNT								CHEMICAL TREATMENT			BIOLOGICAL TREATMENT			ULTIMATE DISPOSAL						
	SEDIMENIALTION	FILTRATION	FILTRATION	SEPARATORS (API)	STRIPING	AUSOURPTION AND EXTRACTION	EVAPORATION	SUBMERGED COMOUSION	PH ADJUSTMENT	CHEMICAL OXIDATION		BIOLOGICAL FILTERS	ACTIVATED SLUDGE	LAGOONS	CONTROLLED DILUTION TO STREAMS AND BAYS	AT SEA	ON LAND SURFACES	DUMPING OR BURIAL	DEEP WELES	INCINEKATION	SALVAGE
General chemicals	X				X	X			X	X				X							
Nylon								X				X					X		X	X	X
Nylon chemical intermediates	X	X			X		X			X		X		X	X					X	
Organic chemicals				X			X		X												
Oxygenated hydrocarbones													X								
Photochemicals		X									X	X									
Powders												X									
Resins						X						X		X							
Rocket fuels				X					X			X									
Rubber , textile , and plastics													X								
Synthetic rubber				X											X					X	

NOTE: processes being used are indicated by air X .

TABLE 6 - SELECTIVE LIST OF UNIT PROCESSES USED FOR PARTICULAR WASTE CONSTITUENTS

UNIT PROCESS	REMOVAL MECHANISM	WASTE CONSTITUENT
Sedimentation/flotation	Gravity	Solid phase organics/inorganics
Coagulation/sedimentation	Particle aggregation/gravity	Solid phase organics/inorganics
		Colloidal phase organics/inorganics
	Chemical bonding	Colloidal phase inorganics
Biological treatment	Particle aggregation/biological	Solid phase organics/inorganics
	Metabolism/gravity	Colloidal phase organics/inorganics Soluble phase biodegradable organics
Filtration	Entrapment	Solid phase organics/inorganics
	Particle aggregation/adsorption	Colloidabl phase organics/inorganics
Carbon adsorption	Adsorption	Soluble phase adsorbable organics/inorganics
	Entrapment	Solid phase organics/inorganics
	Particle aggregation/adsorption	Colloidal phase organics/inorganics

TABLE 7 - TREATMENT PROCESSES USED FOR THE REMOVAL OF TOXIC COMPOUNDS

PROCESS	REMOVAL APPLICATION
Activated-carbon adsorption	Natural and synthetic organic compounds including VOCs; pesticides; PCBs; heavy metals
Activated-sludge-powdered activated carbon	Heavy metals; ammonia; selected refractory priority pollutants
Air stripping	Volatile organic compounds (VOCs) and ammonia
Chemical coagulation, sedimentation, and filteration	Heavy metals and polychloro-biphenyls (PCBs)
Chemical oxidation	Ammonia; refractory and toxic halogenated aliphatic and aromatic compounds
Conventional biological treatment (activated-sludge, trickling filter)	Phenols; PCBs; selected hydrogenated hydrocarbons

6.3.2.2 Important factors in process selection

The most important factors that must be considered in evaluating and selecting Unit operations and processes are identified as below:

a) Process applicability

The applicability of a process should be evaluated on the basis of past experience, published data, data from full scale plants, and from pilot plant studies. If new or unusual conditions are encountered, pilot plant studies are essential.

b) Applicable flow range and flow variation

The process should be matched to the expected range of flow-rates. For example, stabilization ponds are not suitable for extremely large flow-rates. Most Unit operations and processes have to be designed to operate over wide range of flow-rates. Most processes work best at a relatively constant flow-rate. If the flow variation is too great, flow equalization is necessary. Table 8 identifies critical design and sizing factors for secondary treatment plant facilities and describes potential performance impacts of flow-rate and constituent mass-loading variations.

Design provisions for flow-rate variations, in-addition to flow equalization, may include flow splitting and Unit process bypassing under certain peak flow-rate conditions. Minimum treatment requirements, if permitted by regulatory authorities, may include primary treatment and disinfection of the entire flow and secondary treatment of a portion of the flow. Advantages of a Unit process flow-splitting and bypassing strategy are that:

1) the biomass the secondary treatment process can be preserved during peak storm conditions and not lost due to washout;

2) the quality of the treatment plant effluent can be restored shortly after the storm event; and;

3) the entire treatment facilities need not be oversized to handle unusual events.

A disadvantage for flow-splitting and bypassing is that the effluent quality may violate the discharge permit for short periods of time.

However, any treatment sequence designed for flow-splitting and Unit bypassing should be investigated in advance to comply with the Environmental Regulations requirements.

c) Influent waste water characteristics

The characteristics of the influent waste water affect the types of processes to be used (e.g., chemical or biological)and the requirements for their proper operation.

d) Inhibiting and unaffected constituents

It should be identified that:

- the constituents which are present;
- the constituents which may be inhibitory to the treatment processes;
- the constituents which are not affected during treatment.

e) Climatic constraints

Temperature affects the rate of reaction of most chemical and biological processes. Temperature also affect the physical operation of the facilities. Warm temperatures may accelerate odor generation and also limit atmospheric dispersion.

f) Reaction kinetics and reactor selection

Reactor sizing shall be based on the governing reaction kinetics. Data for kinetic expressions usually are derived from experience, published literature, and the results of pilot plant studies.

g) Performance

Performance is usually in terms of effluent quality, which must be consistent with the effluent discharge requirements.

h) Treatment residuals

The types and amounts of solid, liquid, and gaseous residual produced shall be known or estimated.

i) Sludge processing

If there are any constraints that would make sludge processing and disposal infeasible or expensive, should be identified. Extent of recycle loads from sludge processing which affect the liquid Unit operations or processes should also be clarified.

j) Environmental constraints and regulations

Environmental factors, such as prevailing winds, wind directions and proximity to residential areas, may restrict or affect the use of certain processes, especially where odors may be produced. Noise and traffic may affect selection of a plant site. Receiving waters may have special limitations, requiring the removal of specific constituents. Characteristics of treated water imposed by the final destination and/or Environmental Regulations will dictate special Unit operations and processes for treatment of waste water.

k) Chemical requirements

What resources and what amounts must be committed for a long period of time for successful operation of the Unit operation or process to be clarified. What effects might the addition of chemicals have on the characteristics of the treatment residuals and the cost of treatment should also be determined.

l) Energy requirements

The energy requirements, as well as probable future energy cost, must be known if cost-effective treatment systems are to be designed.

m) Operating and maintenance requirements

Special operating or maintenance requirements which is needed along with the necessary spare parts and their availability and cost shall be determined.

n) Reliability

What is the long-term reliability of the Unit operation or process under consideration, which has to be answered. Is the operation or process easily upset? Can it stand periodic shock loadings? If so, how do such occurrences affect the quality of the effluent? Because of the variations in effluent quality performance, a treatment plant should be designed to produce an average effluent concentration below the permit requirements.

o) Compatibility

The Unit operation or process should be used successfully with the existing facilities. The plant expansion should be accomplished easily.

p) Land availability

Sufficient space to be allocated to accommodate either the facilities currently under consideration or possible future expansion.

q) Equipment availability

Most of the equipment used in waste water treatment is custom manufactured, except for items such as small pumps, motors, and valves. Some items of equipment may require special manufacturing techniques or are proprietary and only available from limited sources. Therefore, it should be considered carefully the equipment components that make-up the process or system to determine their potential effects upon the design, construction, and operation and maintenance of the facilities.

r) Personnel requirements

The selection of a treatment process should consider not only the amount of operating and maintenance personnel needed but also the skills required.

The extent and complexity of the control systems and the staffing levels required have to be evaluated carefully.

TABLE 8 - EFFECT OF FLOWRATES AND CONSTITUENT MASS LOADINGS ON THE SELECTION AND SIZING OF SECONDARY TREATMENT PLANT FACILITIES

UNIT OPERATION OR PROCESS	CRITICAL DESIGN FACTOR(S)	SIZING CRITERIA	EFFECTS OF DESIGN CRITERIA ON PLANT PERFORMANCE
Waste Water pumping and piping	Maximum hour flowrate	Flowrate	Wetwell may flood, collection system may surcharge, or treatment units may overflow if peak rate is exceeded.
Screening	Maximum hour flowrate	Flowrate	Headlosses through bar rack and screens increase at high flowrates.
	Minimum hour Flowrate	Channel approach Velocity	Solids may deposit in approach channel at low flowrates.
Grit Removal	Maximum hour flowrate	Overflow rate	At high flowrates, grit removal efficiency decreases in flowthrough type grit chambers causing grit problems in other processes.
Primary Sedimentation	Maximum hour flowrate	Overflow rate	Solids removal efficiency decreases at high overflow rates; increases loading on secondary treatment system.
	Minimum hour flowrate	Detention time	At low flowrates, long detention times may cause the waste water to be septic.
Activated Sludge	Maximum hour flowrate	Hydraulic residence time	Solids washout at high flowrates; may need effluent recycle at low flowrates.
	Maximum daily organic load	Food/ microorganism ratio	High oxygen demand may exceed aeration capacity and cause poor treatment performance.
Tickling Filters	Maximum hour flowrate	Hydraulic loading	Solids washout at high flowrates may cause loss of process efficiency.
	Minimum hour flowrate	Hydraulic and organic loading	Increased recycle at low flowrates may be required to sustain process.
	Maximum daily organic load	Mass loading/ media Volume	Inadequate oxygen during peak load may result in loss of process efficiency and cause odors.
Secondary Sedimentation	Maximum hour flowrate	Overflow rate or detention time	Reduced solids removal efficiency at high overflow rates or short-detention times.
	Minimum hour flowrate	Detention time	Possible rising sludge at long-detention time.
	Maximum daily organic load	Solids loading rate	Solids loading to sedimentaion tanks may be limiting.
Chlorine-contact tank	Maximum hour flowrate	Detention time	Reduced bacteria kill at reduced detention time.

7. PHYSICAL UNIT OPERATIONS

Those operations used for the treatment of waste water in which change is brought about by means or through the application of physical forces are known as physical Unit operations.

The Unit operations most commonly used in waste water treatment and their applications are shown in Table 9.

7.1 Flow Measurement

Important criteria that must be considered in the selection of flow metering devices include type of application, proper sizing, fluid composition, accuracy, headloss, installation requirements, operating environment, and ease of maintenance.

The application and type of sensors or detectors used for the measurement of different flow streams in waste water treatment facilities are identified in Table 10. Because of rapid advances made in the metering device electronics and converters, current information should be obtained from meter manufacturers.

Among the important criteria that must be considered in the selection of flow metering devices accuracy and repeatability are critical, especially where the readings from the metering devices are to be used for process control. The estimated range, the repeatability and accuracy of the metering devices used in waste water treatment is presented in "Appendix D".

TABLE 9 - APPLICATIONS OF PHYSICAL UNIT OPERATIONS IN WASTE-WATER TREATMENT

OPERATION	APPLICATION
Flow metering	Process control, process monitoring, and discharge reports
Screening	Removal of coarse and settleable solids be interception (surface straining)
Comminution	Grinding of coarse solids to a more or less uniform size
Gravity separation	Settling of oil droplets or solid particles by relative density (specific gravity) differences
Flow equalization	Equalization of flow and mass loadings of BOD and suspended solids
Mixing	Mixing chemicals and gases with waste water, and maintaining solids in suspension
Flocculation	Promotes the aggregation of small particles into larger particles to enhance their removal be gravity sedimentation
Sedimentation	Removal of settleable solids and thickening of sludges
Flotation	Removal of finely divided suspended solids and particles with densities close to that of water. Also thickens biological sludges
Filtration	Removal of fine residual suspended solids remaining after biological or chemical treatment
Microscreening	Same as filtration. Also removal of algae from stabilization-pond effluent
Gas transfer	Addition and removal of gases
Volatilization and gas stripping	Emission of volatile and semi-volatile organic compounds from waste-waters

TABLE 10 - APPLICATION OF FLOW-METERING DEVICES IN WASTE WATER TREATMENT FACILITIES[a]

APPLICATION Process Metering device	Raw wastewater	Primary effluent	Secondary effluent	Primary sludge	Return sludge	Thickened sludge	Mixed liquor	water
For open channels								
Head/area								
Flume	t	t	t					t
Weir		t	t					t
Other								
Magnetic (insert type)								t
Velocity-head								
For closed conduits								
Head/pressure								
Flow tube	t[b]	t[b]	t	t[b]	t[b]	t[b,c]	t	t
Orifice								t
Pitot tube								t
Rotameter								t
Venturi	t[b]	t[b]	t	t[b]	t[b]	t[b]	t	
Moving fluid effects								
Magnetic (tube type)	t	t	t	t	t	t		t
Magnetic (insert type)								
Target								
Ultrasonic (doppler)	t			t	t	t[d]		
Ultrasonic (transmission)		t	t				t	t
Vortex shedding		t	t					t
Positive displacement								
Propeller								t
Turbine			t					t

[a] **Based on industry practice and engineering judgement.**

[b] **Flushing or diaphragm sealed connections recommended.**

[c] **Use with in-line reciprocating pumps not recommended.**

[d] **Solids content less than 4 percent.**

7.2 Screening

Suspended particles greater than 6 mm should be removed by screening. A screen should have openings of uniform size of any shape. The screening element should consist of parallel bars, rods or wires, wire mesh, grating or perforated plate. Adequate number of Units should be provided to facilitate the continuous screening with permission of maintenance type, size classification and application of screening devices shall be as following Table 11.

TABLE 11 - SCREENING DEVICES

TYPE OF SCREENING DEVICE	SIZE CLASSIFICATION	SIZE RANGE (mm)	APPLICATION
Bar rack	**Coarse**	**١٥-٣٥**	**Pretreatment**
Screens: Inclined (Fixed) Inclined (Rotary) Drum (Rotary)	 Medium Coarse Coarse Medium Fine	 0.25-2.5 0.76 × 2.29 × 50 2.5-5 0.25-2.5 6-35 µm	 Primary treatment Pretreatment Pretreatment Primary treatment Removal of residual secondary suspended solids
Rotary disk	Medium Fine	٠,٢٥-١٠ 0.025-0.5	Primary treatment Primary treatment
Centrifugal	Fine	٠,٠٥-٠,٥	Primary treatment, secondary treatment with settling tank, and the removal of residual secondary suspended solids

7.3 Comminution

As an alternative to racks or coarse screens, comminutors can be used to grind up the coarse solids without removing them from the flow.

Comminutors should be constructed with a bypass arrangement so that a manual bar screen is used in case flowrates exceed the capacity of the comminutor or in case there is a power or mechanical failure. Stop gates and provisions for draining should also be included to facilitate maintenance.

Manufacturer's data and rating tables for these units should be consulted for recommended channel dimensions, capacity ranges, upstream and downstream submergence, and power requirements. Because the manufacturer's capacity ratings are usually based on clean water, the ratings should be decreased by approximately 20 to 25 percent to account for partial clogging of the screen.

7.4 Grit Removal

Grit removal may be accomplished in grit chambers or by the centrifugal separation of sludge. The removal of grit is essential ahead of centrifuges, heat exchangers, and high pressure diaphragm pumps. For more information, on grit chambers, reference should be made to IPS-E-PR-735 and METCALF & EDDY, INC., "Waste Water Engineering Treatment, Disposal, and Reuse".

7.5 Gravity Separation

7.5.1 General

The gravity differential type separators are used to remove most of the oil from the plant waste water before discharging the water to the further treating Units. The oil-water separator is basically a holdup basin which reduce waste-water velocity and provides holdup time to allow the oil to rise to the surface, where it is removed by skimming.

In some special cases, oil traps, oil holding basins and/or water retention basins may be provided in order to lower final oil-water separator load.

The effectiveness of the treatment facility depends on the design flowrate, water temperature, density and size of the oil globules, and amount of the suspended matter. Furthermore, it also relies on the operating techniques, proper supervision and maintenance.

The gravity type separators will not separate or retain substances in solution and will not remove soluble BOD and also will not break stable emulsions and therefore should not be used for such applications. Oil-water separators will remove only free oil; the emulsified and dissolved oils are required additional treatment.

Oil-water separators covered in this Standard Specification are as follows:

a) The conventional, rectangular-channel Unit.

b) The parallel-plate separator.

c) Oil traps.

d) Oil holding basins.

Throughout this Standard Specification , the term conventional oil-water separator is used in place of the term API separator and refers to rectangular channel Units designed in accordance with the criteria published by API. Utilizing of any type of oil-water separators in OGP's Industries shall be in congruent with the Environmental Regulations and upon approval of the Company. For design of oil-water separators, API-421 latest edition shall be used in addition to the instructions stipulated in this Standard Specification.

7.5.2 Application

Oil-water separators are designed to remove free oil only. If emulsified or dissolved oil is present, an oil-water separator will not be able to remove it, and additional downstream treatment will be required. A principal function of the oil-water separator is to remove gross quantities of free oil before future treatment.

In this capacity, the oil-water separator protects more sensitive downstream treatment processes from excessive amounts of oil.

Parallel-plate separators require less space than do conventional oil-water separators and are theoretically capable of achieving lower concentrations of effluent oil.

In some applications, the oil-water separator is provided as a protective device for containment of spills and leaks (e.g., on once-through cooling water).

It should be stressed that whenever an oil-water separator is considered for an application where it must stand alone, the amount of emulsified and dissolved oils in the waste-water stream must be properly quantified, because these oils will not be removed by the separators.

7.5.3 Oil-Water separators general design considerations

The following requirements shall be taken into consideration in the design stage.

a) Location:

- safety distance;
- access from the road;
- prevailing wind (when applicable);
- possible future extensions.

b) Function:

- two way access /escape for operator;
- hand railing and grating;
- easy access to skimmers, pumps and filters;
- proper ventilation for depressed locations;
- lamp posts;
- surface drainage;
- kerbs around pump foundations;
- water supply for flushing and/or pump seal cooling;
- maintenance access for vacuum truck/mobile crane;
- signboard with Unit number and instructions;
- high level alarm in oil collecting sumps in the control room;
- heating coils in cold climate conditions.

c) Safety distances:

- distance to the edge of public roads: 30 m
- distance to the edge of main roads: 15 m
- distance to a fixed source of ignition: 15 m.

d) Air pollution control:

Effective means of control to be instituted to minimize losses of hydrocarbon and other contaminants such as sulfur Compounds to the atmosphere from the large exposed surface area of the separators if required by the Company and/or the Environmental Regulations.

Control of hydrocarbon or contaminants emissions from oil-water separators may be achieved by the covering of forebays or primary separator sections by either fixed roofs or floating roofs. The roof shall be vapor tight as much as possible.

e) Screening:

Screens shall be installed at the oily sewer outlet (oil-water separator influent) in order to stop and manually remove rags, stones and other debris which would interfere with the operation. The screens shall be equipped with hot dip galvanized steel frame, lateral rails, movable box for solid removal and stainless steel removable screen. Hoist for screen removal for cleaning operation should be provided.

7.5.4 Conventional, rectangular channel (API) separators

7.5.4.1 Basic design considerations

Minimum requirements for design of API separators shall be as per procedure outlined in API publication 421 latest edition and the following design notes:

7.5.4.1.1 A minimum of two parallel channels should be included, so that operation can be continued when one channel is removed from service for repair or cleaning. The separator shall be designed for design flow with all the channels in service.

7.5.4.1.2 Provision should be made for separator expansion to meet possible future requirements in design of separators for new installations.

The Unit shall be particularly amenable to expansion, such that additional channels can be added without interruption of service or major construction changes to the existing facility.

7.5.4.1.3 Design of the separators should be performed based on the worse ambient conditions(e.g., minimum ambient temperature, affects of wind velocity, etc.).

7.5.4.1.4 The main separators should be designed to guarantee outlet oil which is "Suspectible To Separation (STS)" in the range of 50-70 mg/L in worse ambient conditions. Maximum outlet oil content should be reduced to 50 mg/L for areas with minimum ambient temperature of about zero degree Celsius or higher. Effluent free oil concentration shall be 50 mg/L maximum for crude desalter oil-water separators for all areas.

The total oil and grease content (only free oil) of the streams concerned shall be determined by United State Environmental Protection Agency’s (EPA’s) Methods 413.1 " Gravimetric Separation"; and 413.2, "Infrared Spectrophotometry". ASTM Method of D-3921, "Test Method for Oil and Grease for Petroleum Hydrocarbons in Water" can also be used in absence of the EPA’s Methods. Method of EPA 413.1 is applicable for oil concentration range of (50-1000) mg/L and nonvolatile hydrocarbons, and method EPA 413.2 is applicable for oil concentration range of (0.2-1000) mg/L and volatile hydrocarbons.

7.5.4.1.5 Necessity for the covers of separators and type of coverage (fixed or floating) will be advised by the Company in accordance with the Environmental Pollution Regulations. However, special attention should be made for provision of the covers for oil-water separators which receive more than 800 liters per day of volatile organic compounds.

7.5.4.1.6 The separators shall be installed such that oily water from the industry oily water sewer can flow by gravity to the separators. Influents to the separators shall be below grade.

7.5.4.1.7 In order to minimize the emulsification of oil and the remixing of the separated oil in the waste water flow, pumping of separator influent should be avoided.

7.5.4.1.8 A hold-up basin shall be provided at upstream of the main separator (s) for dumping of sudden fluctuations in the receiving oily waters. The basin should be designed for a minimum capacity of 3 (three) hours hold-up of influent oily water to the separator(s) at maximum flow rate conditions.

The basin should be designed with a suitable coverage for Environmental Pollution Control purpose.

7.5.4.1.9 Each separator shall consist of either a preseparation or and entry flume and two parallel channels. The preseparation flume will be common to the both channels.

7.5.4.1.10 Provision of coalescers in the separators is not acceptable.

7.5.4.1.11 Effective length of the channels shall not be less than 40 meters for OGP's Industries main separator(s). However, the design should be based on separating oil droplets of sizes down to 100 micrometers (μm) in diameter for all oil-water separators.

In calculating separator length, corrections should be made for the turbulence and short circuiting that occur in real channels (see Appendix E). An ideal separator is assumed to have no short circuiting, turbulence or eddies.

7.5.4.1.12 The following characteristics of waste water should be evaluated for design of oil-water separators as minimum requirement:

- free oil;
- solids content;
- relative densities (specific gravities) of oil and water phases;
- absolute viscosity of waste water.

The relative densities (specific gravities) and viscosity should be evaluated at minimum design temperature.

7.5.4.1.13 The separators should be provided with floors (other than earth). Floors should allow the user of sludge scrapers, provide inleakage of ground water, and avoid contaminating the ground water.

7.5.4.1.14 In materials selection, consideration should be given to corrosion, leakage, structural strength, buoyancy (height with local water table vs. mass of separator), etc. All parts in contact with fluid shall be in dip galvanized steel and/or red wood.

Antispark material shall be used for metal to metal contacts in moving parts.

7.5.4.2 API separator's components

API and oil-water separators shall consist of , but not be limited to the following components:

7.5.4.2.1 Inlet section

Inlet section generally includes a preseparator flume, trash rack, oil skimmers, retention baffle, and forebay.

a) preseparator flume

The preseparator flume is the transition between the end of the inlet sewer and the separator forebay and will be common to both channels. It serves two functions: reduction of flow velocity and collection of floating oil.

The transition and separator sections of the preseparator flume have to be covered to reduce evaporation loss. For this the vapor space should be enclosed by a barrier or wall at the downstream end of the cover.

The transition between the sewer outlet and the preseparator section shall be designed to accomplish velocity reduction with a minimum of turbulence. The preseparator section shall be designed to reduce the horizontal flow velocity to about 3 to 6 meters per minute (m/min).

The preseparator section contains two kinds of equipment as minimum: a trash or bar screen and a floating oil skimmer.

a.1) Trash rack

Trash racks or bar screens which are provided to remove sticks, rags stones and other debris shall consist of a series bars or rods and shall be located at the entrance to each separator flume. Bars shall be 1 mm by 5 mm with clear openings of 1.9 mm to 2.5 mm. The bars shall be spaced on 25-50 mm centers, at an angle of 45 to 60 degrees from the horizontal, depending upon the depth of the flume and space availability. A pan or trough shall be provided at the top of the trash rack to receive the refuse when the trash rack is cleaned. The refuse pan should be perforated to allow liquid drainage back into the flume.

a.2) Oil skimmer

Oil skimmer to be installed at downstream of the trash rack for removal of oil from the inlet section. Both rotatable slotted-pipe skimmer (a.2.2 below) and floating type oil skimmer (a.2.1 below) shall be employed in the inlet section. Utilizing of any other type of oil skimmer not specified in this Standard shall be upon Company's approval.

a.2.1) Floating oil skimmers

Floating oil skimmers are applicable for installation in the presepartor section especially when the liquid level is expected to vary significantly. The specifications stipulated in Clause a.2.1.1 below is typical and should be followed for all other types of floating oil skimmers as applicable.

a.2.1.1) Floating vortex oil skimmer

Floating vortex oil skimmer which is installed in the preseparation flume shall be equipped with the vortex oil device and shall be furnished with the following characteristics:

- The vortex oil skimmers shall remove at least 85 percent of oil entering each basin.

- The vortex oil skimmers shall be of the floating type and each shall consist of a vortex generator and drive, generator support structure, float assembly, control station, pump and pump drive.

The vortex generator shall be equipped with a propeller set on a vertical axis driven by an electric motor to create a vortex to collect floating oil where it is then recovered by pumping.

Each Unit shall be equipped for automatic, unattended operation by addition of a simple reliable oil level indicator electrode control system which serves as an automatic switch to operate the pump when the vortex pocket contains oil. The vortex oil skimmers shall be capable of continuous operation.

- The vortex generator shall consist of a cylindrical skirt surrounding a vortex generating impeller. The impeller shall utilize a conical inlet section and lower zero pitched propeller. The bottom of the generator shall consist of a flat plate separated from the skirt section and forming with it an annular opening to flow through the generator.

The generator shall be mounted to afloat structure by three equally spaced support rods. The impeller, skirt and base plate shall be of carbon steel construction with two coat epoxy painted for corrosion resistance. A hollow steel pipe shall be provided to join the impeller to its drive motor. The pipe shall be seated at the base of the impeller in a Teflon bearing mounted on the base plate. The pipe shall be perforated at its upper end and fitted with a sleeve for control of flow level into the pipe. The flow into the pipe shall be directed through the base plate and piped laterally to the pump mounted on the generator skirt.

- The pump shall be a direct coupled centrifugal pump. Pump casing and bearing cover shall be of bronze construction. Impeller shall be of the enclosed standard type and shall be constructed of vacuum cast bronze. Impeller shall be dynamically balanced and keyed to the pump shaft. The pump shall have sufficient head to send the oil to the slops tanks.

- The float assembly shall consist of three fiberglass float structures attached to the vertical legs of the support structure. The fiberglass floats shall be adjustable in the vertical plane, to allow for proper skimming depth below the surface of the water. Changes in waste stream composition which will cause liquid density variations shall be taken into consideration in design of the float assembly.

- All electrical equipment and wiring shall be fabricated and installed for Class I, Group D Division 1 Area hazardous locations in accordance with API-RP - 500A, latest edition. All motors shall be furnished with drip covers and lifting lugs. Motor drain plugs shall be located at the lowest point so that accumulated moisture may be drained. Each motor shall be furnished with stainless steel nameplate.

Control panels shall be explosion-proof and suitable for installation within non-ventilated, 220 volts, 50 Hz motor control circuitry.

Space heaters or other means of heating shall be provided on both motors and the control panel. The space heating elements shall be independently controlled by integral thermostats set at predetermined temperatures to prevent excessive condensation within the control panels during periods of cold weather when the Unit is stored and not in use.

- All bolts, nuts, screws and other necessary connecting devices shall be stainless steel .

- Pump discharge shall be provided with 6 meters of DN 50 (2 inch) PVC hose with quick disconnect couplings. A rigid single point lifting fixture shall be attached to the assembly for permanent positioning and handling.

- The following requirements shall be guaranteed by Vendor when the equipment is operated in accordance with the written operating instructions:

  - The vortex oil skimmers shall remove not less than 85 percent of oil entering each basin.

  - The equipment shall be free from fault in design, workmanship and and material to fulfill satisfactorily the specified operating conditions.

a.2.1.2) Rotary drum oil skimmer

The rotary drum oil skimmer consists of a drum or unslotted pipe, mounted in a horizontal Position, partially submerged below the surface of the settled oil layer. The drum is rotated by an external motor; as the drum rotates it picks up a film of oil which adheres to the drum surface. The oil film is removed by doctor knife and directed to a trough.

Rotary drum oil skimmer may be used in the following applications:

- for continuous and automatic operation;
- for minimizing water skimmed off with the oil.

The rotary drum oil skimmer disadvantages are as follows:

- limited oil removed; cannot handle massive spills;
- has problems with heavy greases and heavy objects, which slide off;
- floating debris can interfere with oil pick-up;

- requires maintenance for rotating machinery;
- does not skim floatable solids.

The rotary drum skimmer should not be used if a large amount of oil is expected. When rotary drum skimmers are selected, variable speed drive and a Teflon wiper blade shall be provided.

a.2.1.3) Horseshoe-type floating skimmer

The horseshoe-type floating oil skimmer consists of a floating collecting pan buoyed up by hollow chambers on three sides (see API Publ.-421, Fig. 12). The fourth side is open, contains an oil-skimming weir, and faces in the upstream flow direction to skim on-coming oil. This skimmed oil flows out through a pipe or a hose to a sump or other reservoir.

Horseshoe-type floating skimmer advantages and disadvantages are as follows:

ADVANTAGES	DISADVANTAGES
- adjusts automatically	- submergence varies with the density of the liquid;
to changes in liquid level;	
- high capacity;	- removes water with the oil (large quantities of water to slop
	handling facilities);
- operates continuously and	-subject to fouling, which can upset buoyancy and trim and automatically.
cause undesirable performance.	

a.2.1.4) Self -adjusting floating oil skimmer

Self-adjusting floating oil skimmer, also known as the Baltimore skimmer consists of a floating tank with a portion of the front open near the top to form the oil-skimming weir. A hollow buoyancy chamber in effect a tank within the tank is included to float the skimmer at the proper level (see API Publ. 421, Fig. 13).

Advantages and disadvantages of the self-adjusting, floating oil skimmer are:

ADVANTAGES	DISADVANTAGES
- adjusts automatically to	- submergence varies with the
changes in liquid level;	density of the liquid;
- avoids skimming water	- requires watching and operator attending to determine
when no settled oil layer	when to operate the pump;
is present;	
- can handle large	- floating scum, solids, etc. would tend to enter the skimmer
oil spills.	but not be removed through the submerged pump suction line and may cause plugging.

a.2.2 Rotatable slotted-pipe skimmer

The slotted-pipe skimmer (see Fig. 2) shall be used either in the separator forebay or separator channels while the floating type oil skimmers as described in Clause a.2.1 above shall be utilized in the preseparation flume.

The slotted-pipe skimmer shall be located in the separator forebay, prior to entry into the channels to remove the oils not recovered by the floated type oil skimmer.

The pipe skimmer shall consist of a length of pipe with the 60 degrees slots cutted symmetrically about the vertical axis of the pipe with the edges of the slot serving as a weir over which the scum flows into the pipe when the pipe is rotated. The edges of the slot shall be parallel to the longitudinal axis of the pipe. Bands of the full pipe periphery shall be left at regular intervals to act as stiffeners. The pipe shall be mounted horizontally across the entire length of the channel and shall be supported at both ends. The skimmer should be capable of being rotated both backward and forward over a range of 180 degrees so that, the separated oil that is collected between the skimmer and the oil-retention baffle can be recovered. The operation can be automatically by providing the proper control and actuating equipment, but in general, due to unsatisfactory results is not recommended. The size of the pipe diameters depends upon the capacity required, the variation in liquid level, and the distance which skimmings must travel within the pipe. Minimum pipe diameter shall be DN 250 (10 inch) which should be used for runs up to 12m, and larger pipe for longer runs. The slotted pipe can be rotated by a simple lever arrangement, by a rack and pinion linkage, by worm gear, or by motor. The worm gear arrangement is recommended, since it allows more precise skimming. Skimmer pipes shall be galvanized after fabrication. Advantages and disadvantages of slotted-pipe oil skimmers are:

ADVANTAGES	**DISADVANTAGES**
- simple;	- requires manual operation;
- economical;	- removes relatively large amounts of water with the oil;
- low maintenance;	- usually not continuous;
- no utilities required;	- operated with only a limited variation in liquid level.
- high capacity;	
- can remove floatable solids in addition to oil.	

The slotted-pipe skimmer is normally the preferred type for separator channel sections. It has the capability of removing the large amount of oil that could be encountered in the event of a massive spill.

The recovered oil shall be drained to a slop oil pit at one side of the Unit.

b) Separator forebay

The preseparator flume discharges into the separator forebay, which distributes the influent to the separator channels. If an upstream grit collector is lacking, sludge is likely to be deposited in the forebay. In the absence of an upstream grit collector, means should be provided for removing or transferring the sludge to the separator for subsequent removal, particularly if a reaction-jet diffusion device is used. Water jets can be used to flush solids from the forebay into the separator zone. This practice can affect the quality of the effluent unless the separator channel is blocked off.

Alternatively, the reaction-jet diffusion device can be put at the floor level of the forebay to allow solids to be scoured out of the forebay to the separator channels for collection. Slotted-pipe skimmer to be provided in the forebay, depending on whether or not oil is trapped by the flow distribution devices.

b.1) Slotted-pipe oil skimmer (see Clause a.2.2 above)

b.2) Oil retention baffle

An oil retention baffle shall be located immediately at downstream of the slotted-pipe oil skimmer.

Spacing between the oil skimmer and baffle should not exceed 150 mm. The oil retention baffle should be high enough to prevent oil from flowing or splashing over it. Submergence of this baffle should not exceed 450 mm. The baffle should be extended to the top of the channel.

7.5.4.2.2 Separation section

a) Gateways

Each channel shall be provided with one or more sluice gates at its inlet to allow shutting off the flow to the channel when desired. Hoist shall be provided for gates removal. The gate frame and slots should be of suitable corrosion resistant and erosion resistant materials.

b) Velocity head diffusion devices

Immediately downstream of the inlet gateway shall be a diffusion device, to distribute the flow equally over the cross-sectional area of the channel and to reuse flow turbulence. Two types of diffusion devices are available: vertical slot baffles and reaction jets. Only reaction jet type should be used.

b.1) Vertical slot baffle

A vertical slot baffle is formed from vertical posts.

This type of distributor has suffered from severe fouling and should not be used.

b.2) Reaction jet inlet

The reaction jet inlet which is preferred diffusion device introduces and distributes the influent appropriately.

The reaction jet consists of a tube or orifice and a dished baffle; the concave surface of the baffle faces the tube or orifice. Water flows through the tube (orifice), is reversed by the baffle, and impinges on the inlet wall of the separator, dissipating the velocity head and distributing the flow. Orifices are generally used if the separator forebay is large and the normal direction of flow is toward the inlet wall . Tubes are used when approach velocities in directions not normal to the inlet wall exceed 9 meters per minute (9 m/min).

Reaction jets have a number of advantages:

- They are less subject to clogging than vertical slot baffles.
- They provide good distribution over a wide range of flow rates.
- They are cheaper than vertical slot baffles.
- They can be shut off easily, since they are relatively small orifices in solid barriers, thus obviating gates or dams for interrupting the flow for maintenance.
- They may result in less oil in the channel effluent, than with vertical slot baffles.

Reaction jet inlets should be designed on the following basis in addition to the requirements outlined in API-421.

- Reaction jets shall be made up of # 10 gage thick stainless steel plate formed to proper radius, and shall be completely mounted in front of inlet pipes.

- At least four reaction jets shall be provided for each API channel and two for each oil/water channel.

- Reaction jet wall sleeves and inlet guide vanes to mount the reaction jets to the influent wall shall be provided.

- Minimum tube diameter shall be DN 75 (3 inch).

- The maximum spacing between reaction jets shall be 1.5 meters.

c) Oil and sludge moving devices

The separator channels contain a mechanical device to move the separated oil and the sludge to the collecting area. The floating oil is moved to the downstream end of the separator and the settled sludge is moved to the upstream end. Two oil and sludge moving devices are available: the traveling bridge (span) type and the flight scraper or chain type.

c.1) Traveling bridge or span type

This type of moving device consists of one or two blades extending across the width of the channel hung from a beam or truss spanning the channel.

The span rests on wheels in a carriage arrangement; the wheels rise on rails at the sides of the channel and travel the length of the basin. The wheels are chain driven and the rails are located on top of the channel walls.

The blades are adjusted to sequentially skim oil on the downstream travel and scrape sludge on the upstream flight. The one-blade arrangement accomplishes this by adjusting the height of the blade to either oil level or channel bottom using a hoist or cam mechanism. The blade pivots on the underside of the bridge as height is changed. The two blade arrangement achieves the sequential movement of material by either of two means. During oil movement, the sludge blade can be moved out of the channel or it can be feathered parallel to the channel bottom. At the end of the downstream run, the oil moving blade is raised out of the water and the sludge-moving blade is properly positioned to move sludge upstream on the return trip.

Surface travel is typically on the order of 0.6 m per minute and bottom travel is on the order of 0.3 m per minute.

This device can span and operate in one or several channels. Operation can be manual or continuous; but is preferably automatic and actuated intermittently by a cycle time.

The traveling bridge type oil/sludge moving device offers the following advantages:

- the parts requiring lubrication are located above the water;

- it allows different travel speeds on the forward and reverse runs;

The disadvantages are as follows:

- more expensive than other types;

- requires a movable power cable; usually either a cable reel or a festoon system using a cable looped from a supporting wire;

- complicates covering the channels;

- the design is not common and has not been used on Units equipped with covers.

A design specification for a traveling bridge type device should include the following features:

- provide full width skimming;

- provide totally enclosed, explosion-proof, weather-proof drivers;

- provide overload protection;
- the current collector (3rd. rail) type of power supply is not acceptable;
- provide facilities for leveling the blades;
- provide means to raise blades out of the water for maintenance.

c.2) Flight scraper or chain type

The flight scraper type of oil and sludge moving device consists of two parallel endless chains, one at each side of the channel, with flights connected to the chains across the channel width. The assembly is moved at a flight speed on the order of 0.3 to 0.6 m per minute by motor driven sprockets .

Flights can be spaced uniformly along the entire length of the chains, but flights on only one-half of the chain length are usually sufficient and are preferred because the smaller the number of flights, the less the turbulence. The flights should span the entire width of the channel. Typically, flights are 200 mm high and spaced on 3 meters centers.

Only one oil/sludge moving device per channel should be installed. The motor and speed reducer assembly may be mounted directly on the concrete. Each oil/sludge moving device in a parallel channel installation shall have its own drive Unit operating independently of the others. Operation of these devices can be either automatic or manual.

Advantages of the flight scraper type oil/sludge mover are:

- lower initial cost;
- can be used on channels equipped with covers.

The disadvantages of this device are:

- requires underwater bearings;
- sludge can be accumulated on chain and sprockets;
- moves at the same speed on the top and the bottom of the separator;
- chain sag can redistribute oil beneath the water surface.

A design specification of flight scraper type oil/sludge moving devices should include the following features:

- provide full width skimming;
- provide totally enclosed, explosion-proof, weather-proof drivers;
- provide overload protection of driving sprocket;
- provide shaft aligning facilities ;
- provide flight leveling facilities;
- provide chain guards for personnel protection on chains above grade or near stairs, ladders, platforms, accessways, etc.
- provide chain tighteners;
- flight cleaner chains shall have an average ultimate strength of 18200 kg with the plain and attachment links assembled with DN 20 (¾ inch) heat treated high carbon steel pins and rivets. Attachments for scrapers shall be the full depth of the flight and be provided with four DN 10 (3/8 inch) attachment bolts each. Pivoted attachments shall be provided for at least two scrapers of each collector for positive cleaning of the basin (tank) corners.
- at least 5 links of each chain strand to be pin and cottered;
- provide angle tracks for supporting surface run of sludge collectors;
- flights to be spaced at 3 meters intervals and to be 200 mm high;

- provide squeegees of spark-proof construction on two flights for positive cleaning of the tank wall at the water surface and at the tank bottom;

- 25# tee rail (as per table 3 of DIN 997) shall be provided for each basin bottom;

- the flight cleaner shall consist of 75 mm × 203 mm (3 inch × 8 inch) nominal size heart redwood scrapers on two strands of chain. The flights shall be provided with wearing shoes to contact bottom rails;

- the chains shall run over four sets of sprocket wheels so as to clean sludge from the basin bottoms and move floating oil and material to the downstream end of the separator channel;

- the flight cleaner speed shall not exceed 36.6 m/h (10.15 mm/s).

- all flights shall be accurate drilled and notched at the factory and be carefully grouped and banded together for safe shipment and storage;

- provide rails flush with tank bottom for wear surfaces;

- use corrosion resistant anchor bolts;

- sprockets for drive and collector chains shall have a hardness of not less than 360 Brinell at the tooth bearing surfaces. All sprockets shall be stress relieved before machining. Sprocket shall be keyed firmly to the headshaft. All flight cleaner shall be of the double life type;

- all shafting shall be solid, cold finish steel, straight and true, shall extend across the full width of the basin, and shall be held in alignment with set screwed set collars. The shafting shall contain key ways with fitted keys where necessary and shall be of sufficient size to transmit the power required;

- all underwater bearings shall be babbitted, of water lubricated, ball and socket, self-aligning type, especially designed to prevent accumulation of settle solids in their surfaces. These bearings shall be bolted directly to the concrete walls in a manner which will permit their easy adjustment;

- each motor shall have ample power for starting and operating the cleaner mechanism without overloading. Each drive unit speed reducer shall be of the worm gear type, fully enclosed, running in oil and of approved make with antifriction throughout. The reducer unit and the electric motor shall be mounted as a common unit directly on the concrete.

d) Sludge collection and removal

A sludge hopper shall be provided independently for each channel at the downstream base of the inlet baffle. A screw conveyor for positive removal of the sludge shall be provided for each channel. The hoppers shall consist of inverted pyramids with sides sloped at least 45°. With an underdraw system, each hopper contains an exit pipe at the apex. The exits discharge into a sludge withdrawal pipe.

Screw conveyors shall include wet well type drive complete with helical gear reducer and a chain and sprocket, drive arrangement. The screw shall be at least 9.5 mm thick and shall run in water lubricated bearings and be supported by a suitable diameter pipe shaft. The sludge shall be directed to the sludge pit.

The sludge pit will be common for both separator channels. Accumulated sludge shall be removed by sludge pumps. The sludge pumps shall be started automatically when the level in the sump reaches to the high liquid level and shall be switched off when the level comes down to low liquid level. Two vertical sludge pumps (one operating and one spare) shall be provided.

High and low level alarms in control room shall also be provided for the sludge sump.

e) Skimmed oil collection

The skimmed oil from the main separator channels as well as from the forebay section shall be routed by gravity to a common sump. Both separator channels will have a common oil sump. The sump provides a reservoir for the pumpout pump, and in addition can be used to allow water to be separated from the oil. The sump shall be equipped with two vertical centrifugal pumps (one operating and one spare). The entire oil shall be pumped to the slops tank. Level controls of the float, electric probe, or air differential pressure type shall actuate the pumps at high level and switch them off at low level. High and low level alarms shall also be provided in the control room to guard against sump overflow and pump cavitation, respectively.

The sump and the pumps should be sized large enough to avoid continuous operation of the pumps, and should also be large enough to handle a large spill. The size of the sump pumps can be estimated on the following basis if data are unavailable:

- assume incoming oil can reach to 2000 ml/m³ (2000 ppm by volume) on dry weather separator influent;

- water withdrawn with the skimmed oil can be assumed to about seven times the skimmed oil volume when a slotted-pipe oil skimmer is used; and assume that water volume is the same as the skimmed oil volume when a rotary drum oil skimmer is used;

- provide about four hours hold-up time in the sump before pump-out;

- provide for sump pump-out of oil in 20 to 30 minutes and sump pump-out of water in ½ to 1½ hours (when the oil and water pumps are not the same) ;

- provide for sump pump-out of oil and water in one hour when the same pump serves to pump mixture of oil and to the slops tank.

f) Oil skimming device

A slotted -pipe oil skimmer shall be provided at the end of each separator channel. The requirements of the skimming device shall be as outlined in Clause a.2.2 above. The rotatable oil skimmer-pipes for each channel shall be connected end to end in a line that drain to a slop oil pit at one side of the Unit. Skin pipe shall be DN 300 (12 inch) minimum.

g) Oil retention baffle

An oil retention baffle shall be provided just downstream of the oil skimming device, spaced not more than 300 mm downstream of the skimming device. The baffle is installed with a maximum submergence of 55% of water depth. It should extend to the top of the channel.

h) Effluent weir

an effluent weir wall is located at downstream of the oil retention baffle, spaced not more than 600 mm downstream of the oil-retention baffle.

The weir wall extends from the channel floor to a height equal to the normal water depth minus the depth of normal flow over the crest (top edge) of the weir. The crest corresponds to the head on the weir. A sharp-crested or notched weir plate is attached to the downstream face of the weir wall along its top. Bolt holes in the plate should be elongated vertically so that the weir plate can be made absolutely level when installed and minor adjustments in elevations can be made.

Provision should be made to prevent leakage between the weir plate and the weir wall.

The liquid depth over a weir can be calculated by the methods presented in IPS-E-PR-725.

7.5.5 Parallel-Plate separators

7.5.5.1 General

In cases where available space for a separator is limited, the extra surface area provided by a more compact parallelplate unit makes the parallel-plate separator an attractive alternative to the conventional separator. The separator's surface area can be increased by the installation of parallels-plates in the separator chamber.

The resulting parallel-plate separator will have a surface area increased by sum of the horizontal projections of the plates added. Flow through a parallel-plate unit can be two to three times that of an equivalent conventional separator.

In addition to increasing separator surface area, the presence of parallel plates may decrease tendencies toward shortcircuiting and reduces turbulence in the separator, thus improving efficiency. Oil content in the effluent water can be up to 60 percent lower for parallel-plate systems with a higher proportion of small oil droplets recovered with respect to the conventional separators. This type of separator is not suitable for removing of emulsified or dissolved oils.

7.5.5.2 Design considerations

7.5.5.2.1 Design of the parallel plate separators should be in accordance with API-421 latest edition unless otherwise specified in this Standard.

7.5.5.2.2 An oil-globule diameter of 60 microns (60 μm) should be assumed for design of separator.

7.5.5.2.3 The relative density (specific gravity) and viscosity should be calculated based on the worse ambient conditions for either waste water or oil in design of separator.

7.5.5.2.4 Process problems such as oil and solids removal and clogging should be diagnosed and taken into account in equipment selection and separator design. The plate inclination and plate-to-plate spacing should be selected such that to avoid any clogging problem.

Solids-removal devices should be provided preceding the separator to avoid clogging.

7.5.5.2.5 Mechanical sludge-removal equipment should be provided to avoid raising the plate pack from the separator for sludge removal. The system should also include oil-drawoff equipment.

7.5.5.2.6 The plates should be corrugated type. However, necessary coordinations should be made with well-known Vendors for optimizing of the plates spacing and configuration.

7.5.5.2.7 In OGP's Industries on main oily water effluent, a minimum of two parallel separators with one inlet in combination with a flow diverter (sluice gate) and independent outlets should be provided, so that operation can be continued when one separator is removed from service for repair or cleaning. The separators shall be designed to handle design flow rate when all separators are in service.

7.5.5.2.8 Separator should be designed to guarantee outlet oil which is "Susceptible To Separation (STS) " to be 40 mg/L in worse ambient conditions. The total oil and grease content (only free oil) of the streams concerned shall be determined by the methods outlined in Para. 7.5.4.1.4 of this Standard.

7.5.5.2.9 The separators shall be installed such that oily water from the industry oily water sewer can flow by gravity to the separators. Pumping of separator influents should be avoided.

7.5.5.2.10 Pre-separator/pre-sedimentation basin is required unless otherwise specified by the Company.

Pre-separators are normally constructed in 2 bays and consist of an overflow weir, a retention baffle, a sedimentation zone and an overflow into the inlet channels of the parallels-plate separators.

Floating oil skimmers [(see 7.5.4.2.1 (a.2.1) above] shall be installed in front of the retention baffle, one per bay. The recommended overflow rate under maximum flow conditions is 10 mm/s. The retention time for the maximum flow rate should be about 15 minutes. It should be noticed that the composition of the effluent may vary per location. Samples should be taken and tested to verify the above flow and retention time values. The bottom slab of the pre-separator shall have a slope of 1:50 to simplify cleaning by vacuum truck.

7.5.5.2.11 The following paragraphs of this Standard are also applicable for this type of separator:

- para. 7.5.4.1.8;
- para. 7.5.4.1.14;
- para. 7.5.4.2.1 (a.2.1 & b.2);
- para. 7.5.4.2.2 (d & e) only for design of oil and sludge sumps and pumps.

7.5.6 Oil traps

7.5.6.1 General

An oil trap is a facility designed to retain floating oil only and should not be used for segregation of dispersed oil. The necessity of installing an oil trap shall be instructed by the Company. For a typical oil trap configuration see Appendix F. Oil trap can be used as:

a) an inlet to a storm water pond to keep the surface clean;

b) an outlet of e.g., a lagoon where separated oil is prevented from entering public waters.

7.5.6.2 Design

An oil trap construction consists of :

- an approach channel with a minimum length of 60 meters in which the velocity shall be limited to 0.25 m/s under normal conditions and 0.45 m/s during maximum rainfall;
- a transition part;
- a final weir section in which the velocity shall be limited to 0.20 m/s under normal conditions and 0.35 m/s during maximum rainfall. However, the velocity underneath the baffle shall not exceed 0.08 m/s and 0.15 m/s respectively.

For calculation purposes using the above velocities, a sediment layer with a depth of 0.30 m on the bottom of the complete oil trap shall be taken into consideration.

7.5.6.3 Construction

The weir section shall be constructed in a V-shape, each leg forming one compartment. However, depending on the throughput, construction of one leg only may be considered. In the transition part the cross section of the approach channel shall change gradually into the cross section(s) of the weir section. The underside of the baffle wall shall be at least 0.60 m below the water level in the oil trap.

The oil trap approach channel and transition part shall preferably be built in two bays in order to facilitate its cleaning and repair when required.

7.5.7 Oil holding basins

7.5.7.1 General

A holding basin shall be designed to hold the amount of oil spilled by a large accidental spillage. This amount of oil shall be assumed to be at least 100 cubic meter for one spillage. The holding basin shall be constructed at the end of an accidentally drainage system.

7.5.7.2 Design

The maximum velocity of effluent through the holding compartment shall not exceed 0.05 m/s under normal conditions and 0.075 m/s during maximum rainfall. The velocity underneath the baffle shall in no circumstances exceed 0.15 m/s. When calculating the velocities, a sediment layer of 0.30 m on the bottom of the entire holding basin shall be taken into consideration. The overflow rate, (i.e., the discharge quantity of the oil holding basin divided by its horizontal surface) shall be 0.005 m/s, unless otherwise specified. It is recommended to assume a theoretical design water depth of 1.20 m. The underside of the baffle shall be at least 0.60 m below the water level in the holding basin.

7.5.7.3 Construction

Holding compartment shall be preceded by an oil-retention baffle, oil skimmer and oil sump in the transition part in order to keep surface of the holding basin free from oil under normal conditions. The underside of the oil-retention baffle shall be 0.20 m below the water level. The holding compartment shall preferably be built in two or more bays in order to facilitate its cleaning and repair, when required.

7.5.8 Guarantee

The following requirements should be guaranteed by Contractor/Vendor:

- effluent rate and quality under conditions specified in the relevant job specification;

- equipment is free from any fault in design, workmanship and material and is of sufficient size to fulfill satisfactorily the specified operating conditions.

7.6 Flow Equalization

Flow equalization is used to overcome the operational problems caused by flowrate variations, to improve the performance of the downstream processes, and to reduce the size and cost of downstream treatment facilities.

7.6.1 Application and location

Flow equalization to be used for damping of flowrate variations so that a constant or nearly constant flowrate is achieved. The design of equalization basins must take into account both dry and wet weather flows, as well as variations caused by the operational problems. Sufficient mixing and aeration to be provided in the equalization basin (s) to equalize various waste water streams and prevent solids deposition, septicity and odor problems.

In order to achieve an equalized flow and a considerable amount of constituent concentration and flowrate damping, the equalization basin(s) shall be provided in the in-line arrangement so that, all of the flow passes through the basin(s). Depending on the type of treatment and the characteristics of the collection system and the waste water, detailed studies should be performed to locate the equalization basin(s) in the optimum location. In the refineries and petrochemical plants the appropriate location is downstream of the oil-water separators and upstream of the floatation Units. However, locating the basin(s) in any places or in the off-line arrangement should take into account all economical and operational points of views and shall be upon the Company's approval.

Application of flow equalization will result principally the following benefits:

- biological treatment is enhanced, because shock loadings are eliminated or can be minimized, inhibiting substances can be diluted, and pH can be stabilized;

- the effluent quality and thickening performance of secondary sedimentation tanks following biological treatment is improved through constant solids loading;

- effluent filtration surface-area requirements are reduced, filter performance is improved, and more uniform filter-backwash cycles are possible;

- in chemical treatment, damping of mass loadings improves chemical feed control and process reliability.

7.6.2 Volume requirements

The following factors shall be taken into account in determination of the required volume for equalization basin (s):

- sufficient depth of liquid in the basin(s) should be provided to allow continuous operation of aeration and mixing equipment;
- sufficient volume must be provided to accommodate the concentrated plant recycle streams that are expected;
- additional volume should be provided for unforeseen changes in diurnal flow and additional damping of the BOD mass-loading rate;
- the volume shall be sufficient to accommodate a minimum of 16 hours retention time for the all incoming waste water flowrates to the plant based on the daily average flows.

7.7 Mixing

7.7.1 Description and type

Mixing is an important Unit operation in many phases of waste water treatment, including:

- the mixing of one substance completely with another;
- the mixing of liquid suspensions;
- the blending of miscible liquids;
- flocculation;
- heat transfer.

Most mixing operations in waste water can be classified as:

a) Continuous rapid (30 seconds or less) mixing which is used most often where one substance is to be mixed with another.

b) Continuous mixing which is used where to maintain the contents of a reactor or holding tank or basin in a completely mixed state.

Typical mixers used in waste water treatment plants are:

- propeller mixer;
- turbine mixer;
- static in-line mixer;
- in-line turbine mixer;
- pneumatic mixer.

7.7.2 Application

Mixers to be selected on the basis of laboratory or pilot plant tests or similar data provided by manufacturers. Mixers with small impellers operating at high speeds are best for dispersing gases or small amounts of chemicals in waste water. Mixers with slow-moving impellers are best for blending two fluid streams for flocculation. Paddle mixers to be used as flocculation devices when coagulants, such as aluminum or ferric sulfate, and coagulant aids, such as polyelectrolytes and lime, are added to waste water or sludges. Mechanically, flocculation is promoted by gentle stirring with slow-moving paddles. A paddle-tip speed of approximately 0.6 to 0.9 m/s achieves sufficient turbulence without break-ing up the floc. In-line static mixers are commonly used for the mixing of chemicals, whereas over and under baffled channels are used for flocculation. In dissolved air-floatation Units, flocculation is achieved by introducing air bubbles in the bottom of the tank (pneumatic mixing).

7.8 Sedimentation

7.8.1 Application and type

Sedimentation is the separation from water, by gravitational settling, of suspended particles that are heavier than water. Sedimentation may be used for grit removal, particulate-matter removal in the primary settling basin, biological-floc removal in the activated-sludge settling basin, and chemical-floc removal when the chemical coagulation process is used. It is also used for solids concentration in sludge thickeners. However, in most cases, the primary purpose is to produce a clarified effluent. In designing sedimentation basins, consideration must be given to production of both a clarified effluent and a concentrated sludge.

On the basis of the concentration and the tendency of particles to interact, four types of settling can occur:discrete particle, flocculent, hindered (also called zone), and compression (see Appendix H for description of these settling phenomena).

7.8.2 Design considerations

a) Presedimentation basins may be constructed in excavated ground or out of steel or concrete. However, the basins shall be equipped with a continuous mechanical sludge removal apparatus. The minimum detention time for presedimentation shall be 4 hour. Chemical feed equipment should be provided ahead of presedimentation to provide prechlorination or partial coagulation.

b) Settling basins are usually provided for chemical coagulation or softening in a wide variety of shapes and flow mechanism. The selection of the particular form or shape for a given plant depends upon area available and conformity with adjacent structures. The basins should preferably be circular in shape and of reinforced concrete construction. However, rectangular or square basins can also be used upon space availability and the Company's approval.

c) The basins shall be provided with sloping bottoms to facilitate the removal of deposited sludge. The bottom slopes shall be 1% in rectangular tanks and 8% in circular or square tanks. The water depth is recommended to be in the range of 3.5 to 5.3 m. Length to width ratio for the rectangular basins should be in the range of 3:1 to 5:1.

d) To minimize the effects of short-circuiting and turbulent flow, care should be taken in the effective hydraulic design of inlet and outlet structures in all tanks. Inlet structures should be designed to:

1) uniformly distribute flow over the cross section of the settling zone;

2) initiate parallel or radial flow;

3) minimize large-scale turbulence;

4) preclude excessive velocities near the sludge zone.

e) Flow through a sedimentation basin normally enters at the top of the basin, but in the circular basins, the flow may enter a central flocculating chamber of the basin. Effluent flows vertically out over perimeter weirs. An efficiently designed vertical tank is more stable than a horizontal one.

The rating of a vertical tank as related to the bulk settling velocity is usually 1 to 3 m/h. The volumetric capacity can be increased with the introduction of inclined tubes into the basins.

f) Sedimentation processes shall be proceeded by coagulation and followed by filtration.

g) Each clarifier shall consist of scraped calrifier mechanism with a bridge with drive moving along the length/circumference (depending on the type of the basin) to scrape the accumulated scums on the surface of water. The rotating blades just above the clarifier floor shall be provided to collect the separated sludges from the mixed liquor. Each blade shall be provided with hard rubber squeegees that scrape the basin bottom one per revolution collecting the sludge towards the discharge hopper (for details of clarifier design see Section 8 of this Standard.

7.8.3 Number of basins

The following considerations shall be taken into account in the selection of the number of sedimentation basins:

1) the effect upon the production of treated waste water if one basin is removed from service for cleaning, repairs, or any other reason;

2) the largest size which can be expected to produce satisfactory result.

for any supply which requires coagulation and filtration for the production of safe water, a minimum of two basins should be provided.

7.8.4 Inlet arrangements

The inlets should be arranged such that to distribute the coagulated water uniformly among the basins and uniformly over the cross section of each sedimentation basin and avoid-short-circuiting through the basin. The permissible velocity range for any water and floc can be determined by tests, but the recommended velocities are between 0.20 and 0.55 m/s. Where inlet pipelines or flumes are required, the head loss at each opening should be large compared to the maximum difference of energy head available at the inlets. However, velocities must be maintained sufficiently low to prevent breaking up of floc.

7.8.5 Short-Circuiting

In arrangement of baffles in sedimentation basins for reduction of short-circuiting and improving settling efficiency special attention should be made to avoid forming dead spaces, producing eddy currents, and causing disturbance of the deposited solids.

7.8.6 Outlet arrangements

Water leaving the sedimentation basin should be collected uniformly across the width/circumference of the basin to prevent high velocities of approach and consequent lifting of the settled sludge over the weir. Weirs may e constructed across the basin, or slots or provided effluent ports. Combinations of effluent orifices ahead of the submerged weir provide efficient outlet arrangements and reduce short-circuiting. Special attention should be made to provision of the sufficient weir length in the construction of the basins to avoid excessive overflow rates and consequent high velocity of approach to the weir.

7.8.7 Detention time

The time theoretically required for a unit volume of water to flow through a mixing or sedimentation basin is called the detention time. It is equal to the time required to fill the basin at a given rate of flow and can be computed by dividing the volume of the basin by the rate of flow through it. Detention time must be distinguished from the retention time which is the minimum time required for a particle of water to pass through the basin. Depending on the purpose of the basin, detention time of 2 to 4 hours shall be applied. Detention time shall be higher where a high degree of suspended solids removal is desired.

7.8.8 Surface loading rate

The surface overflow rate for any given sedimentation tank could be determined by jar test studies wherein the best coagulant, optimum dosage, and the best flocculation are used. The maximum surface loading rate for suspended solids removal shall be 25 m^3/ day/m^2 while proper coagulant and flocculation are used.

7.9 Dissolved Air Floatation (DAF)

7.9.1 General

Dissolved Air Floatation (DAF) is a floatation process in which air is dissolved in the water at 350 to 750 kPa (ga), and subsequently released to atmospheric pressure in the floatation tank, where air bubbles precipitate upon particles of suspended matter and float them to the surface. In general, dissolved air floatation Unit is used to reduce the free oil and other suspended matter from waste water below that attainable in an API Separator.

Dissolved air floatation Unit should be designed such that to produce an effluent containing less than 15 mg/L (max.) of free oil with chemical aids. Reduction of oil content below the solubility level of hydrocarbons in water should not be expected in DAF Units.

Dissolved Gas Floatation (DGF) in which gas (such as natural gas) is employed instead of air can be applied to maintain a reducing action, or otherwise to avoid oxidation of waste material.

The primary purpose of further oil removals by DAF Units is to meet desired effluent quality and/or pretreatment for a downstream biological Units. DAF Units are normally located downstream of API Separators and upstream of biological oxidation Unit.

7.9.2 System configuration

The DAF Units shall be constructed in concrete tanks located partially or totally above grade. Minimum of two parallel Units, each designed for 50% of total design flowrate as fresh feed plus the pressurized recycle water flowrate shall be provided. The water recycled to each Unit shall be designed to be in the range of 50% to 75% of each DAF Unit design fresh feed flowrate. Multiple DAF Units shall be supplied when the dimension of a rectangular Unit would exceed 6 m width or 30 m length or when the diameter of a circular flotator would exceed 24 m.

Each Unit shall consist of, but not be limited to the following facilities:

- pressurized flow control system and pressure retention tank;
- flocculation chamber;
- control valves and instrumentation for effective control of all flow conditions throughout the recycle system;
- telescopic valves;
- scum skimmer including drive and supports;
- scum screw conveyor and scum trough;
- scum retention baffles;
- bottom sludge collector and drive;
- perforated recycle pipe and baffle for distribution of the pressurized recycle across the flotation channel;
- deflection baffle out of stainless steel;
- scum pit agitator and drive;
- effluent weir and scum retention baffles;
- all booster and pressurizing pumps, including motors and drivers;
- air compressors;
- inlet sluice gates of 0.1 square meter free area;

- adjustable outlet weirs.

7.9.3 Variables affecting DAF efficiency

a) Influent characteristics

Certain characteristics of the influent affect DAF efficiency such as globule size, pH, surface activity, and suspended solids concentration. Coagulation agents can significantly affect globule size, the chemicals used may alter surface activity and floating all the suspended solids can be achieved by introducing enough air bubbles through the water. The pH should be adjusted to within proper range prior to the addition of coagulating chemicals. The pH adjustment facilities should be provided upstream of DAF Units.

b) Design variables

The following major design variables shall be taken into account:

- overflow rate (rise rate);
- recycle rate;
- air pressure.

c) Operating variables

The Unit should be sized such that to provide sufficient operating flexibility to allow effluent quality to be maintained with the expected variations in influent characteristics. The operator should be able to adjust the following major operating variables:

- pH;
- coagulant type and dose;
- coagulant aid type and dose;
- air pressure;
- recycle rate.

7.9.4 Treatability testing

Studies should be made on the waste water to determine if it is amenable to be cleaned up by DAF process. If it is established that DAF is a suitable technique for the particular waste, pilot plant tests or laboratory bench -scale tests can be used to establish the following design parameters (refer to API, Manual on Disposal of Refinery Wastes, Volume on Liquid Wastes, 1969 for bench-scale treatability test procedures for the DAF process):

- Overflow rate or rate of particles of mass.
- Optimum recycle rate.
- Pressure level in the air-water mix drum.
- Type of chemical conditioning required such as:
    - type and number of chemicals;
    - optimum dosages of chemicals;
    - best points of chemicals;
    - best points of chemicals application;
    - flash-mix and flocculation detention times.

If the waste water cannot be tested before design, data from a similar refinery or plant when possible should be used.

7.9.5 Design considerations

7.9.5.1 System design

a) The system shall be designed for a continuous service and an uninterrupted operation of 2 years (minimum).

b) All equipment shall be suitable for unsheltered outdoor installation for the specified climatic zone.

c) Enclosure for electrical equipment shall be appropriate for the specific area classification and environment.

d) Effluent from the flocculation tank to the DAF Unit and the float/sludge from the DAF Unit to the receiver tank shall be by gravity.

e) Design retention time shall be minimum as follows:

- Neutralization tank: 3 minutes
- Flocculation tank: 20 min (influent feed)
- Floatation basin: 40 min (influent feed + recycle)
- Air/water mix drum: 3 min at maximum recycle rate.

f) Design flowrate shall be 1.5 L /s/m² (max.) based on the DAF flotation area.

g) A continuous supply of air to pressure retention tank shall be provided at a pressure not less than 500 kPa (ga) or more than 700 kPa (ga).

7.9.5.2 DAF section

a) Side Water Depth (SWD) shall be minimum 2.5 m and maximum 3.0 m. In addition to the water depth, 500 mm of free board shall also be provided.

b) A perforated recycle distribution pipe and baffle shall be provided to uniformly distribute the flow across the depth and width of the flotation compartment. The perforations shall be spaced and designed for proper flow distribution across the width of the chamber. The pipe shall be flanged at one end for connection to the recirculation piping.

c) The Unit shall be designed to remove floatable free oil and/or suspended solids with a rise rate of 7.2 m/h or greater when the Unit is working at design flowrate.

d) Fluid velocity in the flotation chamber shall not exceed 36 m/h.

e) The scum skimmer shall consist of two stands of chain running above the liquid surface over two sets of sprockets with pivoted skimming flights. The flights shall enter the floated material blanket at the effluent end of the tank and skim towards the influent end. The skimmer shall be driven by a suitable variable speed drive. Skimmer chains shall be supported where required.

Skimmer blade shall include a depth adjustment feature. Skimmer chains shall be provided with a self lubricating device for rectangular Units. For circular Units, blades shall be interconnected with transverse bracing to reduce potential for excessive blade horizontal deflection and rebound.

f) A helical flight screw conveyor shall be provided in the flotation basin to remove the floatable solids from the scum trough to a sump beyond the basin wall. The conveyor shall be 225 mm diameter with full pitch flights mounted on a standard mass (weight) steel pipe. The conveyor shall be driven by a suitable electric drive. An agitator and drive shall be provided at the scum sump to keep the slurry in suspension.

g) The bottom sludge collector shall consist of 50 mm × 152 mm nominal size redwood scraper, mounted on two strands of chain and not more than 3000 mm apart. The collector chains shall run over three sets of sprocket wheels and be driven by a suitable variable speed drive. The chains shall be C720, heavy pintle type with the plain and attachment links assembled with heat-treated high carbon steel pins and rivets. At least 25# tee rails (as per Table-3 of DIN 997) shall be provided for the tank bottom for the collector. Tracks for the return run of the scraper, where required, shall be made of 76 mm × 51 mm × 9.5 mm thick steel angles with 6.25 mm steel supporting brackets.

h) Skimmer/sludge scraper tip speed shall be maximum 0.025 m/s for circular Units and 0.015 m/s for rectangular Units.

i) The use of belt transmissions for skimmers and scrapers shall be approved by the Company. Limitations on the use of belt transmissions shall be as follows:

- maximum drive power rating : 110 kW;
- drive service factor : 1.5;
- belt type : jointed (multiple V-belt).

Belts shall be of heavy duty or premium quality with oil resistant, static conducting characteristics. Utilizing of variable speed transmissions shall be approved by the Company. Couplings shall be of forged steel, flexible type.

j) Float skimmer and sludge scraper shall have cycle timers with on/off switches. Remote torque indicator and manual torque lifting device shall be provided for circular scraper. If design load is reached, the drive motor shall shut-off and visual and audible alarms shall be actuated. A shear pin shall be furnished on the skimmer/scraper drive shaft.

k) Provisions should be included to remove settled sludge from the flotation tank. Generally, a number of hoppers or a trough at the inlet end of the tank may be provided. Settled sludge is usually scraped into the hoppers or trough and periodically removed either by pumping or by allowing the hydrostatic head in the flotation tank to pressure the sludge out.

l) The float/sludge receiving tank shall be sized to accommodate a minimum of 3 hours retention of a float production based on 0.5 volume percent of raw waste water feed. The tank shall include facilities for steam or air injection, or both. Float boxes shall be sized to accommodate the maximum amount of float produced. Minimum two numbers of float boxes shall be provided. Vendor’s design basis including number of boxes shall be approved by the Company.

m)Float/sludge transfer pumps shall have minimum the following characteristics:

- A minimum of two screw pumps (one operating and one spare)shall be provided. If single screw type pumps are used, spare stators shall be provided for each pump.
- Pump suction strainers shall be provided to screen out any solid particles which the pump cannot handle. Screen material shall be a copper alloy. Strainers shall be provided with flushing connections.

7.9.5.3 Neutralization/flocculation section

7.9.5.3.1 Neutralization section

a) Neutralization tank design shall be as follows:

- the tank shall be baffled;
- for circular tanks, liquid height shall be approximately equal to the diameter;

- for other than circular tanks, liquid volume shall have approximate cubical dimensions.

b) Feed stream inlet piping layout shall allow for a free fall of about 600 mm above liquid level to promote premix condition.

c) Influent and effluent connections shall be diametrically opposite each other. The effluent connection shall be per API 650 low type.

d) Acid and caustic injection into the neutralization tank shall be adjacent to raw waste water influent.

e) The mixer shall be propeller or axial flow type. Liquid pumping or moving capacity shall be 10 to 20 times feed flowrate with flow directed toward the bottom of the tank.

f) Neutralization facilities shall preferably be located downstream of the equalization basin.

g) The pH control system shall incorporate the following:

- at least proportional plus reset feedback control mode to be provided;

- the pH analyzer shall have a self-cleaning feature. The pH control probe shall be located on the neutralization tank effluent line as close as practicable to the tank;

- pH indicator and alarm high in the control room shall be provided;

- pH control system shall be automatic.

7.9.5.3.2 Flocculation section

The flocculation equipment shall be installed in an adequately sized compartment. A freeboard of 610 mm at the head of each Unit shall be provided. The equipment shall consist of a paddle wheel mounted on a shaft and driven by a suitable variable speed drive. Each paddle assembly shall consist of nominal size clear all heart redwood blades supported by steel angle arms.

Flocculation tank shall incorporate the following:

a) Circular tanks shall be baffled.

b) The mixer shall have maximum tip speed of 0.6 m/s.

c) The tank shall include an air sparger.

A manually operated rack and pinion scum collection pipe shall be installed in the flocculator compartment for the removal of floating material trapped in the coalescing area. The scum pipe shall be capable of being rotated backward as well as forward to insure the removal of scum between the pipe and the basin wall. A 60 degree slot shall be cut symmetrical about the vertical axis of the pipe with the edges of the slot serving as a weir over which the scum flows into the pipe when the pipe is rotated. A suitable watertight seal shall be provided for the open end of the pipe. The seal shall be renewable without removing the pipe from the supporting brackets and shall not bind or impede the smooth action of the revolving pipe.

7.9.5.4 Pressurized flow recycle system

a) Each pressurized flow recycle system shall consist of a pressurized tank, pressurizing pump, a flow meter, regulating valves for water and air and necessary instrumentation such as indicators, alarms, on/off valves, etc. Individual pressurized flow systems comprising of individual pressurized tank, flow meter, regulating valve, connecting piping, instrumentation, etc., shall be provided to serve each DAF Unit. When two DAF systems are provided, three numbers of pressurizing pumps shall be foreseen such that each pump to be capable to serve both DAF Units. In this case, each pressurized flow system should also be designed to be operable for both flotation basins. Each pressurized recycle system with all components such as pressurized tank, each pump, piping, etc., shall be designed to handle at least 75% of design fresh feed to each DAF Unit. The recycle pumps shall be horizontal centrifugal types.

b) The pressurized tank shall be designed to assure that a minimum of 80% saturation at operating conditions is achieved. Air sparger on the air inlet line and water spray nozzles on the water inlet line shall be provided. The equivalent liquid hold-up time shall be 3 minutes (min). Minimum one meter of outage should be provided between normal liquid level and the internals to allow for frothing and for the air to disengage. A means to drain the drum should be provided.

c) Float switches and solenoid valves mounted on the pressurized tank shall maintain the proper air-liquid ratio in the tank. The float switches shall activate an alarm provided in the event of high or low water level. The pressure tank shall also have a pressure gage, level gage, low pressure alarm, air vent with needle valve and pressure relief safety valve. Level and pressure control system proposed by Vendor shall be submitted to the Company for approval. Any proposed level control shall be external type.

d) Suitable packing shall be provided in the pressurized tank to increase the water surface and improve air solubility.

e) Material of the air-water mix drum shall be killed carbon steel with 3 mm corrosion allowance and a suitable coating or lining as specified in Article 7.9.10 below. The mechanical design pressure of the drum should be sufficiently high to permit future operation at a process pressure higher than that initially anticipated.

f) Back pressure (let-down valve) should be located as close to the flotation tank and to the influent stream as possible. The valve must be suitable for the mechanical design pressure of the system, should not be easily plugged by solids, and should minimize turbulence. The valve should not impart high shear in order to prevent breaking the floc. Downstream of the back pressure valve at entrance to the flotation chamber, proper inlet distributor with suitable sized nozzles shall be provided.

g) Injection of air to the suction and/or interstage of the recycle pump is not accepted. When the air is added to discharge side of the recycle pump, it should be injected through a porous diffuser.

h) Takeoffs for recycle and effluent shall be oriented to satisfy recycle feed water requirements so that upon loss of raw feed, the DAF Unit shall go into total recycle.

i) The recycle line should assure full flow so that air entrainment will not bind the pump. The recycle line should be fabricated of corrosion resistant material.

j) Air supply shall provide at least 0.12 Nm^3/m^3 of raw waste water feed. If plant air is unavailable and a separate compressor is included with the system, a 100% installed spare shall be furnished.

k) Final configuration of air-water mix drum control and instrumentation systems shall be approved by the Company.

7.9.5.5 Effluent chamber

Effluent water shall leave the effluent chamber by gravity. A common effluent chamber to be provided for the flotation Units. Minimum residence time for the chamber shall be 12 minutes. An adjustable weir plate at the end of each flotation chamber shall be provided to permit the regulation of the water level to control penetration of the skimmer blades into the scum blanket in the flotation area. A scum retention baffle shall be provided to prevent flotation solids from passing under and out of the flotation chamber. A wiper shall be provided to clean the skimmer blades. Recycle flow shall be designed to be delivered to the suction side of the pressurizing pump from the effluent chamber at a rate of equal to 50% to 75% of the design fresh feed to the flotation basin.

7.9.6 Instruments and control

a) All instrumentation for furnished equipment shall be suitable for the service and electrical area classification.

b) All instruments shall be tagged with identifying tag numbers which will be assigned by the Company. Stainless steel nameplate shall be furnished stamped or engraved with this tag number and permanently mounted with stainless steel drive screws.

c) The following instruments shall be provided in addition to the instruments specified in Section 7.9 of this Standard:

- flowrate recorder for fresh influent;
- ratio controllers to control chemical dosages;
- recycle flowrate meter;
- air flowrate meter (usually a rotameter);
- oil-in-water detector on effluent water;
- turbidity meter for effluent total suspended solids.

7.9.7 Piping

a) Gravity line(s) between flocculation tank and DAF shall be sized for a maximum velocity of 0.6 m/s.

b) Sample connections and relevant valves shall be DN 20 for the waste water lines, DN 50 for the sludge line, and DN 25 for the feed recycle sample line. Connections shall be located for easy accessibility.

c) Float and sludge line to the float/sludge receiver tank shall include rodding and flushing connections.

d) Facilities shall be provided for blow-down of the let-down system to the flotation tank with compressed air.

e) Drains shall be included for all vessels and tanks.

f) Corrosion allowances shall be specified.

g) All lines and accessories in contact with aerated water shall be carbon steel with corrosion resistant lining. The minimum acceptable lining for corrosion protection is coal tar epoxy.

7.9.8 Chemicals facilities

a) When feasible, the types and quantities of chemicals to be added to a DAF feed should be determined by tests before the chemicals facilities are designed.

b) In addition to the chemicals (acid, caustic, etc.) used for the neutralization section, chemical facilities shall be provided for at least two chemicals: a coagulant and a coagulant aid. Necessary equipment for chemicals storage, solution or dilution, addition, metering, flash mixing, and flocculation shall be provided. If solid chemicals are handled, suitable enclosure or shed to protect the solids and their addition facilities from the weather shall be provided.

c) The floc must not be pumped, and lines carrying the floc should be sized to avoid both break-up and settlement of the floc. Design for a velocity of about 0.6 m/s.

d) Flash-mixing drum shall be designed for a hold-up time of 4 to 5 minutes, and shall be provided with rapid agitation. The length to diameter ratio shall be about 1.0.

e) Flocculation tank shall be provided with gentle agitation by a slow-speed mixer with a maximum tip speed of 0.6 m/s.

f) Suitable shelter or building shall be provided to cover chemicals facilities.

7.9.9. Coverage

If covers are not specified by the Company for initial installation, the equipment shall be furnished with the necessary provisions to permit future installation of covers.

7.9.10 Material

Material of vessels, piping and all other equipment should be selected in accordance with the Company's relevant standards unless otherwise specified herein below:

a) Carbon steel tanks and vessels shall have at least 3 mm corrosion allowance and a protective coating system of 2 coats of coal tar-polyamide epoxy. Surface preparation for the protective coating shall be by White Metal Blast Cleaning. The nominal dry thickness for each coat shall be 200 micrometer (8 mils).

b) Carbon steel float/sludge receiver tank(s) which includes facilities for live steam shall be lined with gunite of 25 mm thickness. Coal tar-polyamide epoxy is not acceptable.

c) All internals of the vessels/tanks contacting aerated water shall be stainless steel.

d) Piping contacting aerated water shall be carbon steel with minimum corrosion allowance of 3 mm.

e) Rubber and plastic parts shall be resistant to attack by aromatic solvents.

f) Bolting for skimmer and weir adjustment shall be type 316 stainless steel.

g) Antispark material shall be used for metal to metal contacts in moving parts.

7.9.11 Guarantee

The following requirements shall be guaranteed by the Vendor/Contractor when the equipment is operated in accordance with the written operating instructions and based on the treating waste water composition as specified:

- Effluent rate and quality: Either free oil and grease contents or suspended solids of the effluent water shall not exceed 10 mg/L (average) and 15 mg/L (maximum) in any conditions.

- Equipment shall be free from fault in design, workmanship and material and shall be of sufficient size to fulfill satisfactorily the specified operating conditions.

7.10 Granular-Media Filters

7.10.1 General

Granular-media filters are facilities to separate undissolved (free) oil and solid suspended matter from the waste water by filtering the water through a bed of granular media such as sand. Granular-media filters do not remove phenol, H_2S, soluble BOD or other soluble constituents. They remove solids from the water stream by straining through the filter bed, and by other mechanisms such as sedimentation between the media particles and adsorption upon them.

As impurities are removed, bed pressure drop increases, thus, the filters shall periodically be taken out of service and backwashed in the up flow direction to reduce pressure drop. Backwashing shall be accomplished by expanding or fluidizing the bed with filter influent or effluent at a relatively high flowrate and injecting air to scour the particles. Occasionally, a detergent wash or steaming may be employed to more thoroughly clean the bed.

7.10.2 Filter types and applications

Granular-media filters are differentiated by:

- Mode of operation:

  a) downflow;

  b) upflow.

- Number of media:

  a) monomedia;

  b) mixed-media:

  b.1) dual-media (e.g., sand and anthracite);

  b.2) tri-media (e.g., garnet, sand and anthracite).

- Material of media:

  a) sand;

  b) anthracite;

  c) garnet or ilmenite.

- Driving force for flow:

  a) gravity;

  b) pressure.

- Depth of penetration:

  a) shallow-bed;

  b) deep-bed.

Granular-media filters can remove oil and suspended solids from a waste water with or without the use of chemicals. In chemical applications, a chemical flocculent is often added to the waste water prior to granular-media filtration, to enhance oil removal. Additionally, granular-media filters can be designed and operated as simple coalescers, without chemicals, causing the small oil droplets to coalesce into larger ones as they pass through the filter bed. When filters are operated in this manner, the oil is subsequently removed from the water by gravity separation. This technique can be used on oil-field produced water, but should not be used for refinery or petrochemical plant waste water. Use of gravity filters due to high water demand and large bed areas should be avoided.

When possible, the design basis contaminant removal efficiency for granular media filters should be determined by tests using the particular waste stream of interest. With an existing waste water stream, pilot plant work to establish effluent purity, cycle time, pressure drop, and pressure drop build-up, chemicals and dosages should precede design. For grassroots and/or other installations where tests cannot be conducted, the following typical contaminant removal efficiencies can be used for granular media filters:

FILTER LOCATION	API SEPARATOR EFF.	BIOLOGICAL EFF.
Residual oil level:	less than 20 mg/L residual	80 to 90% free oil removal
Susp. sol. removal:	80% to 90%	80% to 90%
5-day BOD removal:	30% (*)	---

(*) : **Based on the removal of insoluble BOD when the filter is used as a pretreatment process; this BOD reduction should not be expected when the filter is used for polishing. Granular-media filters do not remove soluble BOD or other soluble constituents.**

Deep-bed, downflow, sand filters produce about the same quality effluent as an upflow sand filter or a downflow, dualmedia filter, but with a shorter cycle time. Downflow filters can operate with more flowrate variation than upflow filters because the media will not fluidize at high flowrates. However, deep-bed downflow sand filters may not be feasible with flocculents because of the low solids retention capacity of these filters. Shallow-bed, downflow, gravity sand filters are conventionally used for polishing in domestic water treatment.

In general, in refinery or petrochemical plants, the following types of filters are preferred for waste water treating purposes. Utilizing of any other types should be approved by the Company:

- Deep-bed, pressure, downflow, sand filter.
- Deep-bed, pressure, upflow, sand filter.

7.10.3 Design considerations

7.10.3.1 System design parameters

a) The feed system shall be designed to minimize flow surges.

b) Multiple Units shall be provided to allow continuous operation at maximum design capacity with one Unit out of service for backwashing.

c) Units shall be designed for continuous service and uninterrupted operation for a period of minimum 2 years.

d) Type of filters shall be vertical cylindrical with dished head ends supported on 4 legs. However, in case of utilizing horizontal type filters (upon approval of the Company), the effective filtration area shall be the area of the interface between the underdrain systems and the bottom media.

e) All equipment shall be suitable for unsheltered, outdoor installation for the specified climatic zone.

f) Type of operation (manual or automatic) backwash as well as provision of automatic programmable controllers shall be specified by the Company.

g) Headers for feed water distribution, effluent collection, backwash water and air scour shall be provided.

h) Sufficient storage capacity with all necessary accessories shall be provided for backwashing purpose.

i) Deep-bed, pressure filters both upflow and downflow may be used either with or without chemical addition upon the quality requirements of the effluent water requested by the Company. However, utilizing of the chemicals shall be proposed by Vendor based on the effluent water quality and shall be approved by the Company.

7.10.3.2 Downflow sand filters

Downflow sand filters shall consist of a bed of sand supported on several layers of gravel resting on a backwash distributor which supports the entire bed. The sands shall be 1 to 2 mm in diameter. Minimum and maximum depth of sand bed shall be 1.2 m and 2 m respectively. The gravel layers shall be graded particle size, with the coarsest layer on the bottom (See Appendix I).

The backwash distributor shall be designed such that to support the gravel and allow proper simultaneous distribution of air and water during backwashing.

Down flow filters offer a more positive protection against breakthrough than do upflow filters. Down flow filters also offer the advantage of not fluidizing during filtration, and thus can operate with a relatively large temporary increase in flow.

7.10.3.3 Upflow sand filters

An upflow sand filter shall consist of a bed of sand supported by several layers of gravel of various size, resting on a bed support/distributor. A hold-down grid shall be located near the top of the bed to prevent fluidization during filtration. Use of open-top vessels are not acceptable. The filters shall be comprised of pressure vessels containing sands in 1 to 2 mm in diameter.

The filter bed support shall be designed such that to allow simultaneous addition and distribution of air and water during backwashing. The minimum and maximum depth of sand bed shall be 1.2 m and 2 m respectively.

The media in upflow sand filters shall be fine sand (fine relative to the other material in the filter) and shall consist of a layer of coarse sand and two layers of gravel, each of a different size. All of the media should be of the proper size and shape. The shape should approach spherical (spherically should be at least 0.8), to allow effective movement of the grains during backwashing. Uniformity coefficient (U) should be 1.2 minimum.

7.10.3.4 Backwashing considerations

a) The water used to backwash the filter must be clean. It can be a portion of the filtrate, or clean water from another source. When filtrate is used, a holdup tank shall be provided to retain the necessary amount. Alternatively, if there are enough filters and the pressure is sufficient, the backwash water can be taken directly from the filter effluent.

b) Two backwash pumps (one operated and one spare) shall be provided. The backwash water rate depends upon the size of the sand particles and the temperature of the water and should be advised by the Vendor. The recommended backwash water rate is 39 m^3/h per each m^2 of the filter bed.

c) A restriction orifice, sized for about 45 to 50 m^3/h per each m^2 of the filter bed should be provided in the back-wash water line to each filter to limit the quantity of backwash water to avoid washing the sand from the bed. One hand control valve with local indicator to be provided at the backwash pumps discharge line.

d) Air shall be injected during backwashing to cause movement, tumbling, and rotation of the media to scour off the retained material. Air rate will be advised by the Vendor. Air pressure should be at least 300 kPa(ga). No deliberate back pressure is maintained on the filter beds during air blowing or backwashing. If safety problems (explosivity) can be encountered during air blowing, due to the presence of light components, inert gas or nitrogen should be used in place of air.

e) If plant air is unavailable, air blowers (with 100% spare capacity) to supply air for air scour during backwash operation shall be provided.

f) Backwash storage tank shall have adequate capacity at least for 20 minutes working of the backwash pumps at design throughput.

g) When a bed is cleaned, the discharge from the backwash will contain the bulk of the contaminants and should be sent to the sludge removal facilities.

h) If automatic backwashing is desirable and required by the Company, the automated backwash should be actuated by a cycle timer, but should have overrides that activate the backwash procedure at high pressure drops across a filter and at low flow through one. Additional overrides for high oil content in the effluent water and for high effluent turbidity should also be considered.

7.10.4 Cycle time

On-stream filtration time depends upon the solids loading, oil content, and contaminant characteristics of the stream being filtered, and, when possible, should be determined by tests. Filtration run lengths on the order of 8 to 24 hours can be expected if chemicals are used; longer runs would be expected if chemicals are not used. Pressure drop may play a part in the retention of the oil and solids, so the flow to these filters should not be suddenly reduced or stopped and then increased or restarted, otherwise oil breakthrough or high pressure drops may ensue.

7.10.5 Vessels and appurtenances

a) The filter vessel must be high enough to accommodate the required depth of filter media and an inlet distributor, and to allow freeboard for bed expansion during backwashing. The manufacturer determines the space required under the inlet distributor. Filter media shall be minimum 1.2 m for vertical vessels.

Freeboard shall be a minimum of two thirds total bed depth, measured from the top of the filter media to the tangent line at the top of vessel but not less than 1.2 meters.

Filter media retainers shall be furnished above the bed of each filter vessel in upflow filters to prevent fluidization of the bed during filtration.

b) Sand filters not subject to steaming should be designed for a minimum mechanical design temperature of 93°C and mechanical design pressure of at least equal to shut-off pressure of either the filter feed pumps or backwash water circulation pumps, whichever is greater. If steam is connected to the filter, the mechanical design pressure and temperature of the steam system should also be considered in addition to the abovesaid conditions. Pressure vessels shall be designed and fabricated per ASME Code Section VIII Div. 1.

c) Filter bed shall rest on a perforated baffle. Holes in baffle shall be covered by devices to retain filter media in bed. Devices shall be equipped with slots or holes smaller than the particle dimension of the filter media.

d) Total required filtration area will be determined by dividing the flowrate to be filtered by the filter hydraulic loading (allowable filtration rate per unit of the area with one Unit out of service for backwashing). The maximum hydraulic loading for deep bed pressure, downflow type filter shall be 12.2 $m^3/h/m^2$ when one filter is in backwash operation.

e) Maximum media loss shall be 5 percent of media volume per year.

f) Filter media traps shall be furnished on the outlet of each pressure filter Unit to indicate loss of media in the event of underdrain failure. Maximum pressure drop through the trap shall be 35 kPa (ga) when the Unit is operating at maximum design flowrate.

g) Units 900 mm diameter and larger shall have one 500 mm manhole in the top head and one at the same size bellow the media support. Units smaller than 900 mm diameter shall have one 250 mm diameter handhole located in the top head and another one below the media support. Manholes, 500 mm (20 inch) minimum diameter, shall be provided for access to compartments of Units, as required. Manhole covers shall be equipped with handling davits. In any case, access for removal of the internals shall be provided.

h) A filter media discharge connection shall be furnished close to the vessel bottom. It shall be DN 150 (6 inch) minimum size and furnished with a blind flange.

i) Drains shall be provided to dewater each Unit. The minimum size of drains shall be DN 50 (2 inch) for Units up to 750 mm (30 inch) diameter and 75 mm (3 inch) for larger Units.

j) Cleaning connections shall be provided for each vessel.

k) Manual air relief valve for each vessel to be provided.

l) Sample valves shall be furnished on the inlet and the outlet of each vessel. Units operating above 65°C shall have a common sample cooler to cool the sample below 38°C.

m) A pressure safety valve for each pressure vessel shall be provided.

n) The filter vessels shall be constructed of killed carbon steel with minimum corrosion allowance of 3 mm. Where lining is required, the lining material shall be compatible with the water quality and media abrasiveness. Vendor's proposals for coatings and linings shall be submitted to the Company for approval. Vessel internals shall be stainless steel.

o) Winterizing shall be provided for filters if required by the site climatic conditions.

7.10.6 Instrumentation and controls

7.10.6.1 Pressure

a) A differential pressure gage, with an adjustable high pressure alarm announced in the control room, shall be furnished to monitor the DP across the combined inlet and outlet headers. Additional pressure gages are required on the inlet and the outlet backwash headers for use during backwashing.

b) For each vessel, facilities shall be provided to measure the pressure at the inlet and the pressure drop across the vessel during either filtration or backwashing operation. High DP alarm in the control room shall be provided for each vessel. These instruments will not show if a filter is plugged so individual flow instruments are also required (see Clause 7.10.6.2 below).

7.10.6.2 Flow

Adjustable flow controls and flow indicators shall be provided to control and indicate service, air scour or subsurface wash, backwash, and effluent flow from each vessel.

7.10.6.3 Level

A means (preferably sight glass) must be provided to detect water level in the vessels when they are drained to the top of the sand prior to backwashing.

7.10.6.4 Temperature

The means shall be provided to measure and control the temperature of the backwash water.

7.10.6.5 Venting

Air vents shall be DN 20 (¾ inch) minimum size, piped to the nearest drain. When Units are operated automatically, air vents shall also operate automatically. In addition, an auxiliary, manually operated vent valve shall be furnished. Automatically operated vent valves shall be installed with a block valve to permit removal of the vent valve without shutting down the Unit.

7.10.6.6 Analyzers

If specified by the Company, the following in-line analyzers with indication and high alarm in the control room shall be provided at the effluent water from the Unit:

- Turbidity analyzer (surface scatter type).
- Oil analyzer.

7.10.6.7 Programmable controller for automatic operation

If provision of programmable controller for automatic operation is specified by the Company, it shall be provided in accordance with the following requirements:

a) The number of programmable controllers required shall be specified.

b) The control mode (automatic/step/manual) shall permit selection and control of every step within the sequence of operation.

c) The control system shall provide for status selection (service/standby/power off) and identification.

d) Interlocks shall be provided to prevent:

- more than one Unit from backwashing simultaneously; and
- a filter backwash where the levels in either the clean or the dirty backwash storage tank are insufficient for complete backwash.

e) A means positively to verify that a step has been completed within a specified time shall be provided. If a step fails, an alarm shall be actuated and either the sequence stopped or another contingency step initiated.

f) Programmable controllers shall have provisions for manual operation from a locally mounted solenoid cabinet in the event of a programmable controller malfunction.

g) Local solenoid cabinets containing solenoids for manual operation of automatic valves shall be located adjacent to the Units. Operation of the solenoids shall be by means of switches mounted outside of the cabinet.Switches shall be protected by a hinged, weatherproof cover.

h) A remote interface shall be provided in the control room. This interface shall include graphics in the form of either a hard-wired graphics panel or displays presented on a video screen, as specified. Minimum graphics display for each Unit shall be as follows:

- Control mode (automatic/step/manual).
- Unit status (service/standby/power off).
- Programmable controller malfunction.
- Indication of each step of the backwash sequence.
- On/off indication of pumps and compressors.
- Position of each automatic valve.
- Valve malfunction during the sequence.
- A schematic of a filter Unit to display the status.

i) Programmable controller input and output circuits shall be individually isolated and protected against transitions in field wiring affecting the internal logic.

7.10.7 Performance guarantee

Filtrate oil and grease and suspended solids contents shall not exceed values specified by the Company. Test methods shall be as per the following:

a) Oil and grease: ASTM D3921.

b) Suspended solids: ASTM D1888.

8. CHEMICAL TREATMENT

8.1 Definition and Application

Those processes used for the treatment of waste water in which change is brought about by means of or through chemical reaction are known as chemical Unit processes. In the field of waste water treatment, chemical Unit processes are usually used in conjunction with the physical Unit operations and the biological Unit processes, to meet treatment objectives.

Applications of chemical Unit processes in waste water treatment are presented in Table-12 below. In considering the application of the following chemical Unit processes, the inherent disadvantages associated with most chemical processes (activated carbon adsorption is an exception), as compared with the physical Unit operations, is that they are additive processes and cause an increase in the total dissolved-solids concentration of the waste water. If the treated waste water is to be reused, this can be a significant factor. Another disadvantage of chemical Unit processes is that they are all intensive in operating costs.

TABLE 12 - APPLICATIONS OF CHEMICAL UNIT PROCESSES IN WASTE WATER TREATMENT

PROCESS	APPLICATION
- Chemical precipitation:	Removal of phosphorus and enhancement of suspended solids removal in primary sedimentation facilities used for physical-chemical treatment.
- Chemical flocculation:	Removal of free oil & suspended solids from waste water.
- Adsorption:	Removal of organic not removed by conventional chemical and biological methods. Also used for dechlorination of waste water before final discharge for treated effluent.
- Disinfection:	Selective destruction of disease-causing organisms (can be accomplished in various ways).
- Disinfection with chlorine:	Selective destruction of disease-causing organisms. Chlorine is the most used chemical.
- Dechlorination:	Removal of total combined chlorine residual that exists after chlorination (can be accomplished in various ways).
- Disinfection with chlorine:dioxide, bromine chloride, ozone or ultraviolet light	Selective destruction of disease-causing organisms.
- Other chemical applications:	Various other chemicals can be used to achieve specific objectives

For additional chemical applications in waste water collection, treatment, and disposal, reference can be made to Appendix J of this Standard Specification.

8.2 Chemical Precipitation

Chemical precipitation in waste water treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and to facilitate their removal by sedimentation. Chemical processes, in conjunction with the various physical operations, can be used in the secondary treatment of untreated waste water, including the removal of either nitrogen or phosphorus, or both. The most common chemicals used in waste water treatment are listed in Table 13. The degree of clarification obtained depends on the quantity of chemicals used and the care with which the process is controlled. It is possible by chemical precipitation to obtain a clear effluent, substantially free from matter in suspension or in the colloidal state. From 80 to 90 percent of the total suspended matter, 40 to 70 percent of the BOD5, 30 to 60 percent of the COD, and 80 to 90 percent of the bacteria can be removed by chemical precipitation. In comparison, when plain sedimentation is used, only 50 to 70 percent of the total suspended matter and 30 to 40 percent of the organic matter settles out.

TABLE 13 - CHEMICALS USED IN WASTE WATER TREATMENT

CHEMICAL	FORMULA	MOLECULAR MASS	DENSITY, (kg/m³)	
			DRY	LIQUID
Alum	$Al_2(SO_4)_3.18H_2O$ [a)] $Al_2(SO_4)3.14H_2O$ [a)]	٦٦٦,٧ 594.3	٩٦٠-١٢٠٠ 960-1200	١٢٥٠-١٢٨٠(٤٩%) 1330-1360(49%)
Ferric chloride	$FeCl_3$	١٦٢,١		١٣٤٥-١٤٩٠
Ferric sulfate	$Fe_2(SO_4)_3$ $Fe_2(SO_4)_3.\ 3H_2O$	٤٠٠ 454		 1120-1153
Ferrous Sulfate(copperas)	$FeSO_4.7H_2O$	٢٧٨,٠	٩٩٣-١٠٥٧	
Lime	$Ca(OH)_2$	٥٦ as CaO	٥٦٠-٨٠٠	

a) Number of bound water molecules will vary from 13 to 18.

8.3 Chemical Flocculation

8.3.1 Definition and applications

Chemical flocculation can be used to remove suspended matter and free oil from water. The coagulating agent hastens the settling of suspended material and often allows removal of solids not separated by conventional sedimentation.

Chemical flocculation consists of the following four steps:

- Coagulation

The formation of flocculent particles from added chemicals. This is sometimes termed flash-mixing or rapidmixing.

- Flocculation

The provision of retention time with gentle agitation to allow the floc particles or precipitate, associated with the impurities, to increase in size by agglomeration. This step is sometimes called slow-mix.

- Sedimentation

The gravity settling of the floc.

- Removal of the settled material

After coagulation, flocculation, and settling, the floc is removed as a sediment or sludge.

The chemical flocculation Units normally serve to protect a downstream biological oxidation Unit from excessive influxes of oil. Other potential uses for chemfloc are:

- To protect downstream carbon adsorption columns from excessive oil and solids.
- To increase the cycle time of downstream deep-bed sand or mixed media filters.
- To reduce the oil content of API separator effluent prior to final discharge.
- To reduce color and turbidity.
- To remove stabilized, fine oil droplets that are ineffectively removed by gravity separation.
- To remove some COD and BOD associated with the nondissoloved material (usually the BOD of the water is hardly affected by the chemical flocculation process).
- To reduce the concentration of sulfides (by using iron salts).

A chemical flocculation Unit shall consist at least of the following major items:

- chemicals storage, metering and addition;
- flash-mixing;
- flocculation;
- clarification;
- sludge handling, treatment and disposal.

Design contaminant removal efficiencies for a chemical flocculation Unit are shown in Table 14.

TABLE 14 - DESIGN CONTAMINANT REMOVAL EFFICIENCIES FOR CHEMICAL FLOCCULATION UNITS

- OIL	٥-٢٥ mg/L residual (depending on the pretreating facilities of the feed), measured by extraction and infrared analysis
- SUSPENDED SOLIDS	٥٠ to 80% removal with a minimum residual of 20 mg/L
- HYDROGEN SULFIDE	١٠% removal
- PHENOL	١٠% removal
- ٥-DAY BOD	١٠% removal (based on removal of insoluble BOD)

8.3.2 Design considerations

8.3.2.1 In addition to the requirements stipulated herein below, the design notes outlined in Clauses 7.9.5.3 and 7.9.8 of this Standard should also be taken into consideration.

8.3.2.2 A chemical flocculation Unit operating on refinery or petrochemical plant waste water should generally be preceded by pretreatment and by flow equalization. The type of pretreatment and the amount of flow equalization vary with the waste and with the installation, and must be studied for each case. Pretreatment should include at least sulfides and ammonia stripping facilities, and settling in API type or other gravity settler to remove oil and settleable solids.

8.3.2.3 Pumping of the flocculated water, or subjecting it to any other turbulence should be avoided.

8.3.2.4 Chemical types and chemical treatment requirements shall be according to API publication 420 and approved by the Company unless otherwise specified in this Standard.

8.3.2.5 Flocculation chamber shall contain a slow speed mixer which gently agitates the fluid. The mixer shall be of variable speed, mechanical agitator type.

8.3.2.6 High temperature can upset the clarifier, so a high temperature alarm in the control room on the sewer water to warn of excessive influent temperature shall be provided. In addition, provision of high temperature alarms on critical streams into the sewer shall be taken into consideration. pH swings can also upset the clarifier and therefore, meters to measure both alkalinity and free mineral acidity, or pH meters with attendant alarms on the sewer water shall be provided.

The alarms shall allow diversion to avoid excessive swings in temperature, acidity, alkalinity, or pH.

8.3.2.7 Chemicals addition equipment should be designed with sufficient flexibility to allow the addition of acids, alkali, coagulant, and coagulant aid over the range of rates expected.

8.3.2.8 Special attention should be made for covering the flocculation chamber if required by either air pollution regulations or Company’s instructions.

8.3.3 Clarifier

8.3.3.1 Design considerations

a) Design of clarifier basins shall be in accordance with the requirements outlined in Clause 7.8 above unless otherwise specified herein below.

b) Minimum two clarifiers shall be provided. Each clarifier shall be designed to operate under the following conditions:

- Total retention time shall not be less than two hours, including recycle.
- Clarifier overflow (rise) rate shall not be greater than 2.4 L/day/cm².
- OIL 5-25 mg/L residual (depending on the pretreating facilities of the feed), measured by extraction and infrared analysis
- SUSPENDED SOLIDS 50 to 80% removal with a minimum residual of 20 mg/L
- HYDROGEN SULFIDE 10% removal
- PHENOL 10% removal
- 5-DAY BOD 10% removal (based on removal of insoluble BOD)
- The system should be designed for a recycle flowrate of equal to 100% of the fresh feed to the clarifier.
- Sludge withdrawal shall be designed based on the continuous handling of a flowrate equal to 100% of the fresh feed.

c) The basins should preferably be circular in shape and of reinforced concrete construction with bottom slope of 8%. However, rectangular or square basins can also be used upon space availability and the Company's approval.

d) The minimum side water depth shall be 4.5 m. At least, 600 mm freeboard above the water depth shall be provided.

e) The Unit must be capable of effective operation at all rates from 40% of design to 100% of design.

8.3.3.2 Clarifier components

a) A conical hood shall be included in the center of circular clarifiers to separate flocculation chamber from the clarification chamber.

b) The outlet weirs should be level to promote even distribution. Level weirs and the capability of being leveled after installation should be specified. Submerged weirs should be specified where freezing problems are anticipated.Multiple weirs can be employed to reduce weir rate in both rectangular and circular clarifiers. In circular clarifiers, multiple weirs should be radial type and should be at least equivalent in length to a circumferential weir. Weirs should be arranged to uniformly collect the effluent over a substantial portion of the surface to promote full utilization of the settling area and reduce short-circuiting.

c) The which clarified water flows over the weir(s) into a collecting trough or launder which leads it to the outlet pipe. Peripheral effluent launders shall be flat-bottomed and sized to result in a velocity of around 0.6 m/s.

d) Sludge scrapers shall be provided to move the settled floc and contaminants to an outlet in the bottom of the tank. Scrapers in circular clarifiers shall move the sludge to a central outlet in the cone bottom of the tank. Sludge scrapers in circular Units shall be rotated from a central shaft. The rotary mechanism shall operate at a relatively low speed (tip speed of around 2.5 cm/s) to avoid disturbance of the settled solids. Circular sludge scrapers shall be designed for continuous operation and constant speed driven.

e) The sludge shall be removed from clarifiers by the hydrostatic pressure in the tank to a pit outside of the clarifier.

Sludge discharged from the clarifier is usually intermittent and shall be controlled by an automated blow-off valve. Provisions should be made in the sludge outlet for back-flushing with water under pressure prior to sludge discharge. The frequency and duration of the back-flush and blow-off can be automatically controlled by cycle timers. The sludge withdrawal rate to be frequently regulated by a manually set timing sequence. The setting shall be based on the amount of floc that is being formed and the amount of silt and dirt entering the chemfloc system. The accumulated sludge in the sludge sump shall be recycled back by the sludge pumps to the clarifier influent. 2 to 5% of the sludge shall be routed to the aerobic digester, sludge thickener and/or sludge basin.

f) The clarifier should be equipped with an oil skimmer, in conjunction with an oil moving device. When the chemfloc Unit is followed by a biox plant, it is particularly important to avoid sending large slugs of oil to the biox Unit. The oil moving device usually consist of slowly moving blades, which direct settled oil to the skimmer for removal. In circular clarifiers, the oil moving device shall be rotated by a common shaft with the sludge scraper. In rectangular clarifiers, the oil moving device shall be of the continuous, flight scraper type.

8.3.4 Chemical addition systems

8.3.4.1 Type of chemicals

- pH adjustment

Either a basic material or an acid should be consistently added for pH adjustment of the waste water. Liquid caustic is normally used to raise pH; sulfuric acid is often used to lower it. Acid is normally added with a metering pump, and acid addition rate is regulated by the pump speed or pump stroke, which is set by the pH controller. A pH meter/controller to control the addition of the basic or acidic material shall be provided. For design of system see Clause 7.9.5.3.1 above.

- Coagulants

Alum is the most commonly used coagulant. It can be used as a solid and as a water solution. If the alum solution requires dilution, it should be diluted to the optimum concentration (determined by testing) with the water to be treated. Dilution water should be added when delivered alum solution is being unloaded, in order to get good mixing. Alum is corrosive, and piping and equipment in alum solution service should be fabricated of corrosion resistant materials.

- Coagulant aids

Polyelectrolytes are the most commonly used coagulant aids. Jar tests should be performed to determine the most suitable form of polyelectrolyte (cationic, acidic, neutral) for a particular waste and contaminant. Activated silica may also be used as a coagulant aid. Utilizing of activated silica due to the extremely short self-life is not recommended. Facilities should be provided to add the coagulant aid to both the flash-mix and the slow-mix (flocculation chamber) sections.

8.3.4.2 Polyelectrolyte handling and mixing system

Polyelectrolyte handling and mixing system requirements shall be minimum as per following clauses. The requirements outlined herein below are also applicable to any other chemical handling system (where required).

a) The system shall be designed in order to use polyelectrolyte in solid form (powder) and/or liquid polyelectrolyte plus activator.

b) The polyelectrolyte shall be used as a coagulant aid at the influent of dissolved air flotation Unit and clarifier.

c) Equipment and facilities shall receive the input plant water from the plant source and polyelectrolyte from the concentrated polyelectrolyte containers for ratio balancing and transfer as separate streams to the tank and shall also include the control system and electrical terminals. The design concentration of the dilute polyelectrolyte solution shall be 1% mass (using liquid) and 0.2% mass (using dry powder).

d) Tanks shall be completed with gage glass, hinged cover, level control connections for drain and pump suction.

e) The control system shall be provided to sequence water and polyelectrolyte flush cycles to prevent undispersed polyelectrolyte from entering the system. Safety circuits shall be provided to monitor normal operating conditions and shut down Unit in the event of a component failure. Low level switch should also be provided on all tanks to stop the relevant pumps when the tank is in low level conditions.

f) The system shall be located inside a suitable shelter or building.

g) Suitable material to be used for all equipment and piping.

h) The system shall include but not be limited to the following equipment:

- water pumps(one operating and one spare);
- polyelectrolyte metering pumps (one operating and one spare);
- polyelectrolyte solution tank with minimum capacity of 3 m^3;
- activator supply tank with minimum capacity of 2 m^3;
- water tank with minimum capacity of adequate for 24 hours;
- polyelectrolyte inline static mixer(s);
- polyelectrolyte dosing screen conveyor;
- polyelectrolyte concentrate tank with minimum capacity of 60 liters (60 L);
- calibration pots on the activator metering pumps suction line;
- polyelectrolyte injection pumps to clarifier (one operating and one spare) including calibration pot on the suction line;
- polyelectrolyte injection pumps to DAF Unit (one operating and one spare) including calibration pot on the suction line;
- polyelectrolyte premix water pumps to DAF Unit (one operating and one spare);
- all necessary instrumentation including local control panel.

8.4 Disinfection

When all of the disease-causing organism are not destroyed during the process, disinfection should be used. In waste water treatment, disinfection should be accomplished through the use of chemical agents, physical agents, mechanical means, and radiation.

8.4.1 Chemical agents

Chemical agents that should be used as disinfectant, include alcohols, iodine, chlorine and its compounds, bromine, ozone, dyes, soaps and synthetic detergents, quaternary ammonium compounds, hydrogen peroxide and various alkalis and acids. Characteristics of an ideal chemical disinfectant is shown in Appendix K.

8.4.2 Mechanical means

Typical removal efficiencies for various treatment processes are listed in Table 15 below:

TABLE 15 - REMOVAL OR DESTRUCTION OF BACTERIA BY DIFFERENT TREATMENT PROCESSES

PROCESS	PERCENT REMOVAL
Coarse screens	٠-٥
Fine screens	10-20
Grit cambers	10-25
Plain sedimentation	25-75
Chemical precipitation	40-80
Trickling filters	90-95
Activated sludge	90-98
Chlorination or treated sewage	98-99

8.5 Chlorination

8.5.1 Application

The principal uses of chlorine and its compounds are listed in Table 16.

8.5.2 Chlorine dosages

Typical chlorine dosages for disinfection are shown in Table 17.

TABLE 16 - CHLORINATION APPLICATIONS IN WASTE WATER COLLECTION AND TREATMENT

APPLICATION	DOSAGE RANGE mg/L	REMARKS
Collection: Slime-growth control	1-10	Control of fungi and slime-producing bacteria
Corrosion control (H_2S)	2-9*	Control brought about by destruction of H_2S in sewers
Odor control	٢-٩*	Especially in pump station and long flat sewer
Treatment: Grease removal	2-10	Added before preparation
BOD reduction	٠,٥-٢ ≠	Oxidation of organic substance
Ferrous sulfate oxidation	♣	Production of ferric sulfate and ferric chloride
Filter-pounding control	١-١٠	Residual at filter nozzles
Filter-fly control	٠,١-٠,٥	Residual at filter nozzles, used during fly season
Sludge-bulking control	١-١٠	Temporary control measure
Digester supernatent Oxidation	٢٠-١٤٠	
Digester and Imhoff tank	٢-١٥	

* Per mg/liter of H_2S.

≠ Per mg/liter of BOD, destroyed.

♣ $6FeSO_4, 7H_2O + 3Cl_2 \rightarrow 2FeCl_3 + 2Fe_2(SO_4)_3 + 42H_2O$.

TABLE 17 - TYPICAL CHLORINE DOSAGES FOR DISINFECTION

EFFLUENT FROM	DOSAGE RANGE (mg/L)
Untreated waste water (prechlorination)	٦-٢٥
Primary sedimentation	٥-٢٠
Chemical-precipitation	٢-٦
Trickling-filter plant	٣-١٥
Activated-sludge plant	٢-٨
Multimedia filter following activated-sludge plant	١-٥

8.5.3 Design considerations

a) Each chlorinator Unit shall be furnished complete including a chlorinator, any necessary manifold valving for the chlorinator cylinders, an ejector, a chlorinator flowrate indicator and adjusting valve, strainer and all necessary solution feed and vacuum tubing, valves, adapters, check valves, etc.

b) Separate housing for the chlorination system with forced ventilation that has start-up bottom at room entrance shall be supplied.

c) Chlorine cylinders with handling equipment shall be provided.

d) Space heater shall be provided for the room.

e) The chlorinators shall be manually operated on an intermittent push-button start-up basis, with all vacuum gages and rotameter located on the front of the panel. The rate of chlorine feed shall remain constant until manually changed.

f) Chlorine feedrate, when set, shall be maintained within less than 3% accuracy. Operation shall be continuous and intermittent.

g) The chlorinator shall be equipped with an ejector assembly of the chlorine water solution type utilizing water pressure to produce the vacuum in the chlorine system. The ejector shall be constructed of corrosion resistant plastic and the ejector nozzle shall be of the fixed throat orifice type. The ejector nozzle shall be precisely engineered for given hydraulic conditions such that the chlorinator shall operate efficiently over the full range of its operating capacity. The ejector shall contain a diaphragm type check valve to prevent water from entering the chlorinating system when water flow is shut down.

h) The chlorinator shall be constructed of materials suitable for wet and dry chlorine gas service. All springs used in the chlorinator shall be of hastelloy C.

i) The cabinet shall be of plastic fiberglass, floor mounted self-supporting and suitable for indoor installation.

j) All necessary chlorine valves flexible connectors,fittings, etc. and any additional items as required for an operable Unit shall be provided. The basic instruments shall be minimum as follows:

- gas inlet pressure gage;
- outlet vacuum gage;
- rotameter (easily visible for flow adjustment from front of Unit);
- a spring loaded diaphragm actuated pressure relief valve (to operate if pressure is excessive or when excessive air develops);
- chlorine gas shut-off valve for interrupted water flow or loss of vacuum.

k) The chlorinator shall be provided with a heated trap.

l) The chlorinator shall be provided with an indicator in the cabinet to indicate when chlorine supply is exhausted or shut-off.

m) The following accessories shall be included:

- header valves and double unions at each chlorinator inlet;
- auxiliary valves, flexible connections and header valves at each chlorine container;
- in-line chlorine pressure switch with adjustable contacts.

8.5.4 Guarantee

Vendor shall guarantee the following:

- chlorine rate and capacity under conditions given in the job specification;
- equipment is of sufficient size to fulfill satisfactorily the specified operating conditions.

9. BIOLOGICAL TREATMENT

9.1 Objectives

The objectives of the biological treatment of waste water are to coagulate and remove the nonsettleable colloidal solids and to stabilize the organic matter. For domestic waste water, the major objective is to reduce the organic content and, in many cases, the nutrients such as nitrogen and phosphorus. In many locations, the removal of trace organic compounds that may be toxic is also an important treatment objective. For industrial waste water, the objective is to remove or reduce the concentration of organic and inorganic compounds. Pretreatment shall be required, because many of the compounds in the industrial waste water are toxic to microorganisms.

9.2 Biological Treatment Processes

The major biological processes used for waste water treatment are identified in Table 18. All of the biological processes used for the treatment of waste water as reported in Table 18, are derived from processes occurring in nature. By controlling the environment of the microorganisms, the decomposition of wastes is speeded up. Regardless of the type of waste, the biological treatment process consists of controlling the environment required for optimum growth of the microorganisms involved.

The principal applications of these processes are for:

- removal of the carbonaceous organic matter in waste water, usually measured as BOD, total organic carbon (TOC), or chemical oxygen demand (COD);
- nitrification;
- denitrification;
- phosphorus removal;
- waste stabilization.

Biological processes are affected by environmental conditions. The environmental conditions can be controlled by pH and/or temperature regulation, nutrient or trace element addition, oxygen addition or exclusion, and proper mixing. Biological processes are classified by the oxygen dependence of the primary microorganisms responsible for waste treatment. The processes are usually refereed to as aerobic, anaerobic or facultative.

a) Aerobic processes

The aerobic processes considered are activated sludge, trickling filter, and aerobic stabilization ponds. The activated sludge process shall be used almost exclusively in large Units.

TABLE 18 - MAJOR BIOLOGICAL TREATMENT PROCESSES USED FOR WASTE-WATER TREATMENT

TYPE	COMMON NAME	USE[a]
- Aerobic processes:		
Suspended-growth	Activated-sludge process	Carbonaceous BOD removal (nitrification)
	Conventional (plug-flow)	
	Complete-mix	
	Slop aeration	
	Pure oxygen	
	Sequencing batch reactor	
	Contact stabilization	
	Extended aeration	
	Oxidation ditch	
	Deep tank (27.5 m)	
	Deep shaft	
	Suspended-growth nitrification	Nitrification
	Aerated lagoons	Carbonaceous BOD removal (nitrification)
	Aerobic digestion	Stabilization, carbonaceous BOD removal
	Conventional air	
	Pure oxygen	
Attached –growth	Tricking filters	Carbonaceous BOD removal, nitrification
	Low-rate	
	High-rate	
	Roughing filters	Carbonaceous BOD removal
	Rotating biological contactors	Carbonaceous BOD removal (nitrification)
	Packed-bed reactors	Carbonaceous BOD removal (nitrification)
Combined suspended-and attached-growth processes	Activated biofilter process, trickling-filter solids-contact process, biofilter activated-sludge process, series trickling-filter activated-sludge process	Carbonaceous BOD removal (nitrification)
- Anoxic processes:		
Suspended-growth	Suspended-growth denitrification	Denitrification
Attached-growth	Fixed-film denitrification	Denitrification
- Anaerobic processes:		
Suspended-growth	Anaerobic digestion	
	Standard rate, single-stage	Stabilization, carbonaceous BOD removal
	High-rate, single-stage	Stabilization, carbonaceous BOD removal
	Two-stage	Stabilization, carbonaceous BOD removal
	Anaerobic contact process	Carbonaceous BOD removal
	Upflow anaerobic sludge-blanket	Carbonaceous BOD removal
Attached-growth	Anaerobic filter process	Carbonaceous BOD removal , waste stabilization (denitrification)
	Expanded bed	Carbonaceous BOD removal, waste stabilization
- Combined aerobic, anoxic, and anaerobic processes:		
Suspended-growth	Single- or multi-stage processes, Various proprietary processes	Carbonaceous BOD removal, nitrification, denitrification, phosphorus removal
Combined suspended-and attached-growth	Single-or multi-stage processes	Carbonaceous BOD removal, nitrification, denitrification, phosphorus removal
- Pond processes	Aerobic ponds	Carbonaceous BOD removal
	Maturation (tertiary) ponds	Carbonaceous BOD removal (nitrification)
	Facultative ponds	Carbonaceous BOD removal
	Anaerobic-ponds	Carbonaceous BOD removal (waste stabilization)

[a] Major uses are presented first; other uses are identified in parentheses.

The aerobic environment is achieved by the use of diffused or mechanical aeration. The reactor contents are referred to as the mixed liquor. Temperature dependence of the biological reaction-rate constant is very important in assessing the overall efficiency of a biological treatment process.

In aerobic photosynthetic ponds, the oxygen is supplied by natural surface aeration and by algal photosynthesis. Only a portion of the original waste is actually oxidized to low-energy compounds, such as NO_3, SO_4 and CO_2; the remainder is synthesized into cellular material.

The most important inorganic compound is ammonia, because its presence in the plant effluent can stimulate the lowering of the dissolved oxygen in the receiving stream through the biological process of nitrification. In nitrifical, ammonia is biologically oxidized to nitrite. The nitrite is then oxidized by another group of microorganisms to nitrate. Nitrate is the final oxidation state of the nitrogen compounds, and as such represents a stabilized product.

b) Anaerobic waste treatment

Anaerobic waste treatment shall be involved in the decomposition of organic and/or inorganic matter in the absence of molecular oxygen. The major application is in the digestion of the concentrated sewage sludges and in the treatment of some industrial wastes. Another application of anaerobic treatment is in anaerobic lagoons or ponds. The usual mode of operation of an anaerobic waste treatment Unit receiving a concentrated sewage sludge is by use of a complete-mix reactor system with minimum cellular recycle for the purpose of heating and mixing the tank contents.

c) Aerobic, anaerobic (facultative) waste treatment

Stabilization ponds of facultative bacteria are known as aerobic-anaerobic ponds. Such ponds have an aerobic upper layer and an anaerobic bottom layer. In practice, oxygen is maintained in the upper layer by the presence of algae or by the use of surface aerators. Where surface aerators are used, algae are not required.

9.3 Activated Sludge Units

9.3.1 Applications

The activated sludge process and its modifications, the extended-aeration activated sludge process and the oxygen activated sludge process, are used to decompose organic matter and stabilize soluble organic wastes in water. An activated sludge Unit achieves more BOD reduction than does a trickling filter, and it requires shorter liquid retention times and smaller plot areas than do stabilization ponds or lagoons. Equalization should be considered to stabilize Loads for waste waters with widely varying BOD. In general, the benefits from the biological treatment of waste waters are reduction of oxygen demand, reduction of oil content, reduction of toxicity to the aquatic life in receiving waters, improvement in odor, and improvement in appearance.

9.3.2 Effects of activated sludge

An activated sludge plant to be designed to produce an effluent with a total (soluble plus insoluble) BOD5 of 10 to 20 mg/L. However, the chemical oxygen demand (COD) of the effluent is usually considerably higher, because of the presence of compounds resistant to biological oxidation.

a) The residues from an activated sludge system can include the following:

a.1) Soluble BOD, this is composed of

- Any of the soluble BOD in the waste-water not removed by the process. The concentration of these residues decreases with retention time in the aeration basin.

- Organic byproducts produced by the microorganisms and not metabolized. These residues increase with retention time.

- Organic material produced by the decomposition of cells during endogenous respiration (auto-oxidation, oxidation by microorganisms of material from bacterial cells). A residual BOD_5 of 5 to 15 mg/L will persist from these residues as long as active cells are present in the system.

a.2) Biological solids

Although the biological solids (cells) are removed in the settler following aeration, the settling step is not perfect and some solids overflow with the clarifier effluent. These solids often hold some oil. In addition, these solids will contribute a BOD on the order of 0.3 to 0.7 mg BOD_5/mg suspended solids depending on the age of the sludge.

a.3) Non-biodegradable residues

Some soluble wastes are not biodegradable. These will exhibit a COD or TOC, but not a BOD. In addition, some solid metabolic byproducts which are non-biodegradable are produced.

a.4) Non-biological organic suspended material

Some of the insoluble organic material originally present in the waste water may carry through with the settled effluent. This unstabilized material could include oil, plastics, rubber, etc.

a.5) Inorganic, non-volatile suspended matter

Most of the inorganic suspended matter (e.g., silt) will settle with the floc and will be purged with wasted sludge. Some, however, may not settle and so may appear as non-volatile suspended solids in the clarifier effluent.

b) Free oil

An activated sludge Unit is designed to remove soluble organic compounds and not free oil. Free oil above about 50 mg/L must be first removed in a pretreatment step. The small amount of free oil remaining after pretreatment (5 to 20 mg/L) will be further reduced in the activated sludge Unit, primarily by adsorption onto the floc.

c) Ammonia

A small amount of ammonia (equal to 1 to 3% of the BOD_5 removed) can be removed from water by activated sludge treatment in the usual case where nitrification does not occur. Thus, activated sludge treatment is not a practical way to remove ammonia from waste water due to too small removal efficiency.

9.3.3 Feed composition

Certain materials in the feed and other environmental factors affect the operation of an activated sludge plant. Table 19 gives criteria for pretreatment of activated sludge feed. Pretreatment of feed to an activated sludge or extended-aeration plant should be provided when the feed is outside of the limits shown in Table 19. In addition to feed pretreatment, a holding basin to which the biox influent can be diverted in the event of toxic shocks or organic shocks is recommended.

a) Oil content

Pretreatment of the waste water to remove free oil should be provided if the oil content of the waste water to be treated in an activated sludge system is over 50 mg/L.

b) Nutrients

Any nutrient not already present in sufficient quantity should be supplied. Ammonia is most readily assimilated by bacteria in the form of nitrogen. The source of ammonia can be either free ammonia in the waste water or ammonia formed in the activated sludge Unit by the bio-degradation of organic nitrogen compounds such as MEA (mono-Ethanolamine) and DEA (di-Ethanolamine). Both refinery and petrochemical plant waste waters are usually deficient in phosphorus, although phosphorates enter the waste water from boiler and cooling tower blow-down and from spent phosphoric acid catalyst from polymerization Units.

The needs for nitrogen and phosphorus should be determined by pilot-plant testing. If this has not been done, an analysis of the feed waste water is required. Based on this analysis, the Contractor should provide nutrientaddition facilities, if necessary, to result in a ratio of N:P:BOD metabolized of 5:1:100, and in addition, provide for residual concentrations of 0.1 mg/L or the phosphate phosphorus (PO_4^{---}) and 0.5 mg/L ammonia nitrogen in the effluent.

c) Toxic and inhibitory materials

The presence of toxic materials in the waste water can seriously impair the performance of an activated sludge Unit and reduce its efficiency. Toxicants either kill microorganisms or inhibit their growth. The effect depends on concentration, contact time, and the environment (e.g., pH). A number of toxic materials are potentially present in refinery and petrochemical plant waste waters, including zinc, chromium, copper, cyanide, sulfide, biocides, furfural, and certain other organic compounds. In addition, highly alkaline or acid discharges may be toxic. Besides being toxic, sulfides preferentially consume oxygen and can create an anaerobic environment. Table 19 gives guidance on the limiting concentrations for certain materials. Heavy metals, in general, inhibit the activated sludge process. Dissolved heavy metal ions (cadmium, cobalt, copper, dichromate, ferric iron, lead, manganese, nickel, silver, vanadium, and zinc), above certain concentrations, impede biological metabolism. The effect of any particular concentration of these depends on the environment; therefore, it is not possible to give exact concentration limits for most of these heavy metals. Microorganisms can tolerate only 1 mg/L or less of some heavy metals (cadmium, copper, silver), but other metal ions (ferric iron, manganese, nickel, vanadium) have been successfully handled at 10 mg/L with little or no loss in efficiency.

Organic compounds which are toxic to the microorganisms will inhibit their utilization of other materials. Hence, intermittent slugs of many organic compounds or sudden, large changes in their concentration can disrupt the biological process. When feasible, laboratory studies to evaluate toxic limits should be made before wastes from a new process are introduced into an existing activated sludge system.

d) Organic compounds

Organic compounds differ in their biodegradability; some are readily degraded by the microorganisms normally present, some are degraded if the organisms have become acclimated to the compound, and others are practically non-biodegradable. Appendix L lists organic compounds that are biodegradable by acclimated organisms, and compounds generally resistant to biological degradation.

TABLE 19 - CRITERIA FOR PRETREATMENT OF ACTIVATED SLUDGE FEED(NOTES 1 & 2)

CONSTITUENT	LIMITING CONCENTRATION [3]	APPROPRIATE PRETREATMENT
Oil	۵۰ mg/L max.[4]	Dissolved-air flotation, granular media filtration, chemical flocculation
Sulfides	10 mg/L max.	Stripping, precipitation with iron salts
Ammonia	500 mg/L max.	Stripping, dilution
Phenols	500 mg/L max.[5 & 6]	Stripping
Chlorides	100% sea water max.[5 & 6]	Dilution, de-ionization[7]
Suspended Solids	150 mg/L max.	Sedimentation, granular media filtration, chemical floc., DAF Unit
Copper	1 mg/L max.	Precipitation, ion exchange[7]
Heavy Metals	1 to 10 mg/L max.	Precipitation, ion exchange[7]
Dissolved Salts	30000 mg/L max.[5 & 6]	Dilution, stream segregation
Cyanides	5 mg/L max.[5]	Stripping, oxidation (ozone, alkaline chlorination)
Thiocyanides	30 mg/L max.	Retention, equalization
Organic Load Variation (Based on 4 hour composite)	max. of 2 to 4 [8]	
pH	6.5 to 8.5	Neutralization
Alkalinity	max. of 0.2 kg alkalinity as $CaCO_3$ per 0.4 kg BOD removed	Neutralization
Free Mineral Acidity	zero free mineral acidity, maximum	Neutralization
Temperature	10 to 40°C[5] or 46 to 60°C[9]	Cool, dilute, heat

Notes:

1) Shock loads as well as continuous loads should be considered.

2) The values given are for satisfactory operation of the activated sludge Unit. Pretreatment may be required to reach more restrictive values to meet discharge requirements.

3) The limiting concentrations are given for guidance in the absence of test data. The values presented are the best estimates available at this time and are not given with complete confidence. Test measurements should be made when possible.

4) Varies with the solids retention time.

5) Although the activated sludge Unit will operate satisfactorily within the indicated range, the size will be affected by the indicated parameter. Determine if there is an economic incentive to provide pretreatment to adjust this parameter in order to reduce the cost of the activated sludge or extended-aeration plant.

6) The concentration given applies if the concentration is relatively constant. Only a lesser concentration can be tolerated if it occurs as a non steady variation.

7) De-ionization and ion exchange are seldom practical for refinery or petrochemical plant waste water.

8) Depends upon the waste water.

9) Avoid operation in the 40 to 46°C temperature range.

e) Organic shocks

An organic shock is a sudden increase in the organic content of the incoming waste water. Organic shocks can be caused by a number of materials including: phenols, alcohols, detergents, solvents, MEA, DEA, hydrocarbons, etc. The concentration of each component in the feed to an activated sludge Unit should not vary by more than 50% per hour. In any case, retention or equalization hold-up should be provided to avoid any organic shock.

f) Salt content

Rapid changes in salt concentration can devitalize the microorganisms; salt concentrations about 3000 mg/L (ppm) TDS (Total Dissolved Solids) retard sludge settling and any concentration of dissolved solids reduces the solubility of oxygen in water and increases the rate of transfer of oxygen to water. In any case, shock loads of salt, as from occasional releases of salt-water ballast, should be avoided.

g) Suspended solids

High concentrations of influent suspended solids decrease efficiency by reducing the fraction of active biological solids, create an excessive oxygen demand, and may result in a sludge less amenable to dewatering.

h) pH, alkalinity, and acidity

The pH of the aeration basin determines which microorganisms predominate in the system and also affects the rate of reaction. Facilities to adjust the pH of the feed to the activated sludge Unit should be provided. The pH of the aeration basin should be kept in the range of 6.5 to 8.5, the optimum pH range is 7 to 8. An aeration basin pH outside the range of 5 to 9 may result in destruction of microorganisms.

i) Temperature

The temperature in the aeration basin affects the reaction rate in the aeration basin and the settling characteristics of the sludge. Either of two ranges of temperature can be maintained in the aeration basin. The growth of a different type of microorganism predominates in each of these ranges: mesophilic microorganisms grow in the range of 10 to 40°C and thermophilic microorganisms grow in the range of 46 to 60°C. An activated sludge plant should not be designed to operate in the 40 to 46°C temperature range. Winterization facilities to be foreseen in cold climates. Temperature changes should be kept smaller than 10°C per hour so as not to retard performance. An activated sludge plant should not be designed to operate below 15°C.

j) Oxygen concentration

The design value for dissolved-oxygen concentration should be minimum 2 mg/L. This should be sufficient to maintain a minimum DO (Dissolved Oxygen) residual of 0.5 mg/L throughout the aeration chamber with normal fluctuations in incoming BOD and COD load. If shock BOD loads are expected, design should be made for more than 2 mg/L dissolved oxygen, to avoid a DO of less than 0.3 mg/L during or after the shock load period.

9.3.4 Process design

The biological oxidation Unit shall utilize the completely mixed recycle activated sludge process of treatment. For the design of the Unit, influent waste water specifications shall be based on either daily average or maximum figures extracted from the specified conditions. However, the Unit shall be checked for the expected maximum concentrations of the contaminants in the influent water in order to meet the guaranteed effluent waste water quality. The effluent from the aeration basin shall be routed to the activated sludge clarifier. A portion of the activated sludge from the clarifier underflow shall be recycled to the aeration basin and mixed with the influent waste. A portion of the clarifier underflow shall be wasted to the aerobic sludge digester to maintain proper concentration of mixed liquor suspended solids in the aeration basin. Floatable solids from scum trough in the clarifier shall flow to a scum pit. Effluent from the clarifier shall flow to a surge tank and shall be pumped to the deep bed filters for final treatment.

Effluent from the clarifier shall contain 10 mg/L(ppm) maximum of dissolved BOD_5 and 25 mg/L(ppm) maximum of total dissolved solids unless otherwise specified.

9.3.5 Design considerations

9.3.5.1 Biological oxidation basin(s)

Adequate numbers of aeration basins should be provided based on the optimum size of the basin and fresh feed design flowrate. Adequate hours retention time should be provided by each aeration basin. Basin walls shall have a 1.5 to 1 slope and a freeboard of not less than 500 mm. The basins should be surrounded by guard rails to prevent personnel from falling into the aeration basins.

The inlet line should allow the influent to be added to the aeration basin both at the head end of the basin and under each aerator. The recycle sludge should enter at the head end. The aeration basins should be designed so that the air is disengaged from the microbial floc and the skimming of foam, scum, or floating sludge is minimized in the discharge. An overflow weir and baffles extended 500 mm below and 300 mm above the water surface to be provided.

9.3.5.2 Mechanical aerators

Low speed mechanical aerators shall be provided for each aeration basin to supply oxygen required into the basin. The numbers will be determined based on the total oxygen requirement. The circles of influence of adjacent aerators should just touch but not overlap. The aerators shall be of the easily-adjusted, variable weir platform mounted type driven by a gear box consisting of a stationary base, ball race and internal gear. The latter shall be provided with mounting rim for attaching the drive shaft. The internal gear shall be rotated by a pinion, keyed to a first stage speed reducer, connected with an electric motor. The aerobic sludge digester aerator shall be of the floating type. Each Unit shall be complete with impeller shaft and assembly and all necessary anchor bolts and accessories for a complete Unit. Each Unit shall be ready for easy on-site assembly requiring only bolting the base plate to the appropriate platform or poles. A platform with vertical access ladder shall be provided to the aerobic sludge digester.

The drive assembly shall be designed for continuous duty and heavy shock loads. The impeller assembly shall be of suitable design to provide oxygen transfer and mixing, withstand design loads and be easily removable from drive assembly. Each impeller shall be statically balanced prior to shipment. The impeller shaft shall be of suitable material and of proper size to withstand all operating and static stresses.

9.3.5.3 Nutrient feed systems

The nutrient feed systems shall be designed to provide sufficient amount of nitrogen and phosphorous to substain growth of the biological mass in each aeration basin. The nutrients shall be injected to a single point up-stream of the aeration basin(s). Each nutrient feed system shall include chemical solution tank, agitator and two chemical feed pumps (one as spare). Chemical solution tank capacity shall be based on at least 24 hours of operation. The tank shall be equipped with level indicator, sight glass, bag breaker, necessary pump controls and agitator. The pumps shall have facilities to permit adjustment of capacity from 0 to 100% of the maximum specified. Accessories of the pumps shall include coupling guard and strainer.

9.3.5.4 Aerobic sludge digester

The aerobic sludge digester shall be of adequate size to provide minimum 16 days retention time based on a design input of at least 3 percent of sludge withdrawal rate from the clarifiers. Floating type low speed mechanical surface aerators shall be provided. The tank should be equipped with a platform (including ladder) and poles to fix the mechanical aerators. Vendor shall specify the oxygen requirement for the aerobic sludge digester.

9.3.5.5 Clarifier

Refer to Clause 8.3.3 of this Standard Specification.

9.3.5.6 Control and instrumentation

The design of the biological oxidation Units shall incorporate the necessary instrumentation for a minimum amount of operator observance. Alarms shall be installed on all critical water levels and for over-torque condition on the clarifiers. DO (Dissolved Oxygen) and TOC (Total Organic Content) analyzers shall be provided at appropriate locations in the biological oxidation Unit. The following instrumentation should be specified as minimum requirement:

- A flow controller (indicating or recording) on sludge recycle.
- A flow controller (indicating or recording) on sludge wastage.
- An indicator or recorder for dissolved oxygen in the aeration basin.

- An indicator or recorder for TOC of feed and effluent.
- A recorder of the pH of the feed.
- An indicator or recorder of the pH in the aeration basin.
- An indicator of the temperature of the influent and aeration basin.
- An indicator or recorder of dissolved oxygen in the final effluent.

9.3.6 Performance test

Performance test of the Units shall be conducted at the time of plant start-up with the Vendor's representative at the site. In the event equipment or auxiliaries fail to meet the specified performance, Vendor shall make whatever changes are necessary to meet the specified performance.

9.3.7 Guarantee

Vendor shall guarantee the following when the equipment is operated in accordance with the written operating instructions and treating waste water having composition as specified in the purchase order:

a) Effluent rate and quality under conditions given in the relevant job specification.

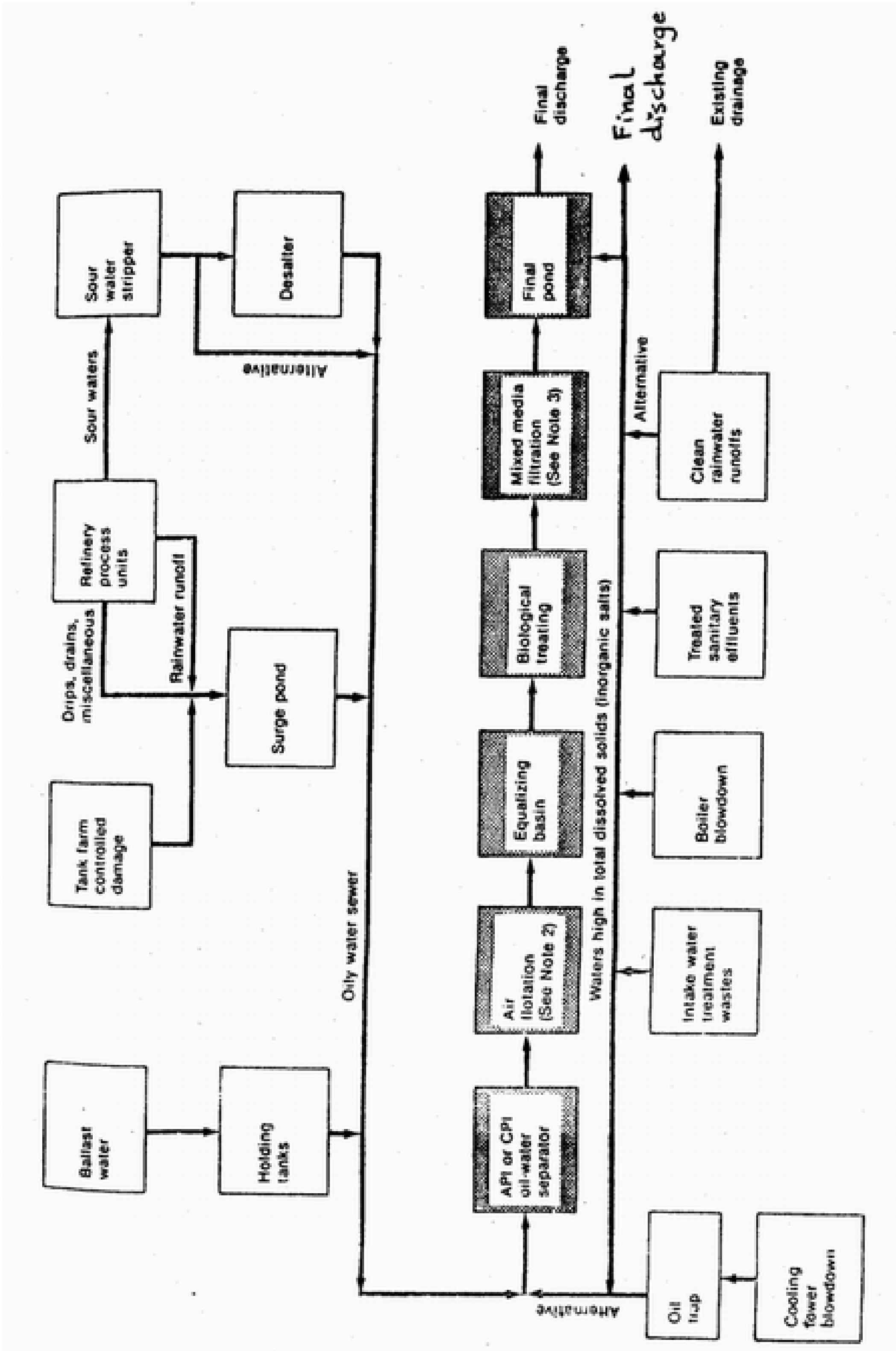
b) Oxygen transfer rate and mixing volume of each mechanical aerator.

c) Equipment is free from fault in design, workmanship and material and is of sufficient size and capacity and to fulfill satisfactorily the specified operating conditions.

10. EFFLUENT PERMISSIBLE CONCENTRATIONS

Maximum permissible concentration of the contaminants in effluents are presented in Appendix M according to Iranian Environmental Organization's Regulation as a guidance. However, the maximum concentrations of effluent contaminates shall be updated during execution of each project in accordance with the latest available information officially issued by the Iranian Environmental Organization's Regulation.

The figures indicated in Appendix M can be used only for the cases not covered in this Standard.



TYPICAL WASTE-WATER SOURCES AND WASTE-WATER MANAGEMENT

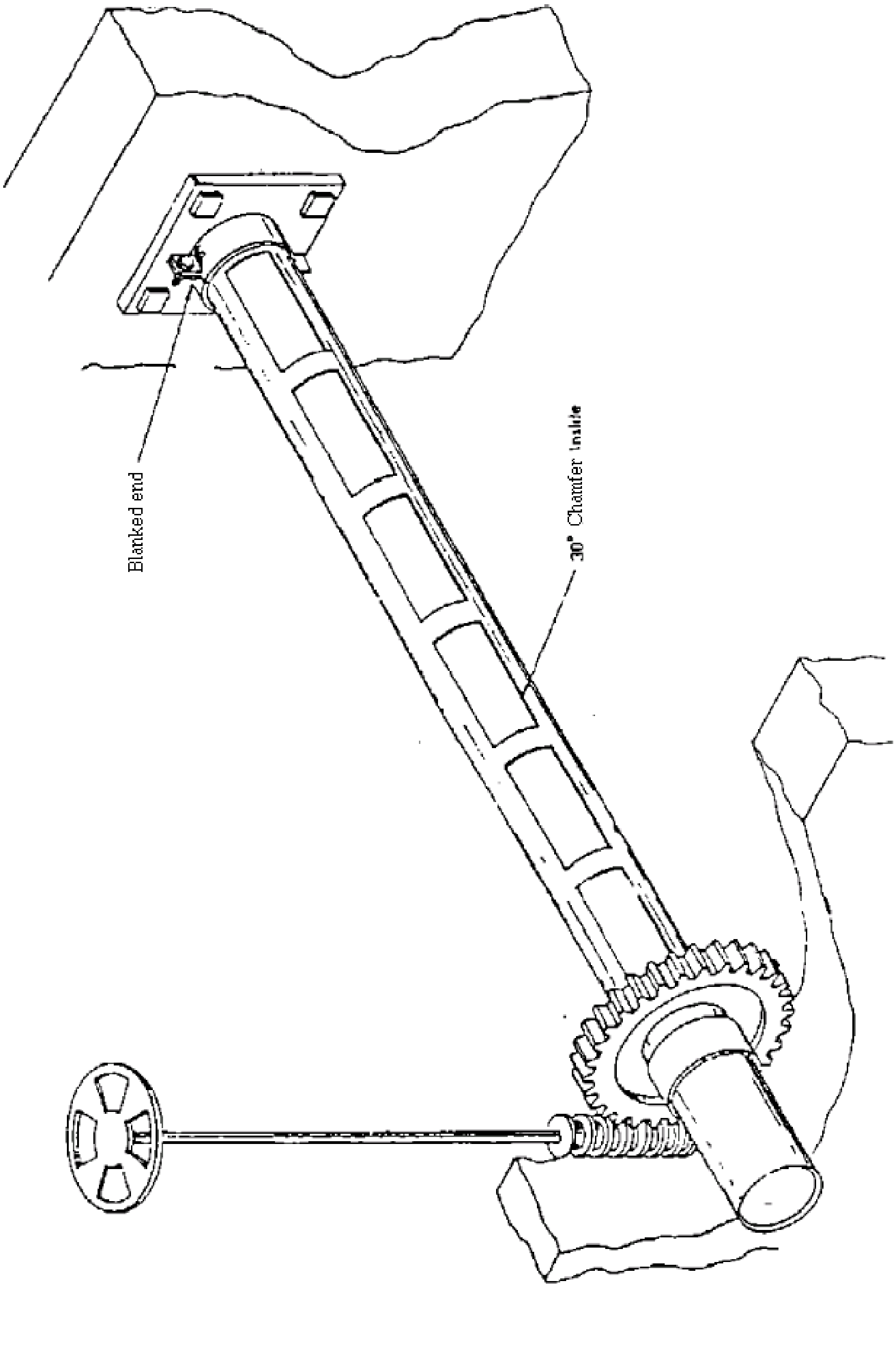
Fig. 1

Notes:

1) CPI = corrugated plate interceptor.

2) Or chemical coagulation and settling or filtration.

3) Or air floation.



SLOTTED PIPE OIL SKIMMER

Fig. 2

APPENDICES

APPENDIX A

CONTAMINANT IMPORTANCE IN WASTE-WATER TREATMENT

CONTAMINANTS	REASON FOR IMPORTANCE
Physical Suspended solids	Suspended solids are important for esthetic reasons and because they can lead to the development of sludge deposits and anaerobic conditions.
Chemical Biodegradable organics	Composed principally of proteins, carbohydrates,and fats, biodegradable organics are measured most commonly in terms of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). If discharged untreated to the environment, the biological stabilization of these materials can lead to the depletion of natural oxygen resources and to the development of septic conditions.
Nutrients	Carbon, nitrogen, and phosphorus are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.
Refractory organics	These organics tend to resist conventional biological methods of waste water treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Due to their toxic nature, certain heavy metals can negatively impact upon biological waste treatment processes and stream life.
Dissolved inorganic solids	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.
Biological Pathogens	Communicable diseases can be transmitted by the pathogenic organisms in wastewater.

APPENDIX B

TYPICAL WASTE COMPOUNDS CLASSIFIED AS PRIORITY POLLUTANTS

NAME (FORMULA)	CONCERN
Nonmetals:	
- Arsenic (As)	Carcinogen and mutagen. Long term sometimes cause fatigue and loss of energy; dermatitis.
- Selenium (Se)	Long term-red staining of fingers, teeth, and hair; general weakness; depression; irritation of nose and mouth.
Metals:	
- Barium (Ba)	Flammable at room temperature in powder form. Long term-increased blood pressure and nerve block.
- Cadmium (Cd)	Flammable in powder form. Toxic by inhalation of dust or fume. A carcinogen. Soluble compounds of cadmium are highly toxic. Long term-concentrates in the liver, kidneys, pancreas, and thyroid; hypertension suspected effect.
- Chromium (Cr)	Hexavalent chromium compounds are carcinogenic and corrosive on tissue. Long term-skin sensitization and kidney damage.
- Lead (Pb)	Toxic by ingestion or inhalation of dust or fumes. Long term-brain and kidney damage; birth defects.
- Mercury (Hg)	Highly toxic by skin absorption and inhalation of fume or vapor. Long term-toxic to central nervous system; may cause birth defects.
- Silver (Ag)	Toxic metal. Long term-permanent grey dis-coloration of skin, eyes and mucus membranes.
Organic compounds:	
- Benzene (C_6H_6)	A carcinogen. Highly toxic. Flammable, dangerous fire risk.
- Ethylbenzene ($C_6H_5C_2H_5$)	Toxic by ingestion, inhalation, and skin absorption; irritant to skin and eyes. Flammable, dangerous fire risk
- Toluene ($C_6H_5CH_3$)	Flammable, dangerous fire risk, Toxic by ingestion, inhalation, and skin absorption.
Halogenated compounds:	
- Chlorobenzene (C_6H_5Cl)	Moderate fire risk. Avoid inhalation and skin contact.
- Chloroethene (CH_2CHCl)	An extremely toxic and hazardous material by all avenues of exposure. A carcinogen.
- Dichloromethane (CH_2Cl_2)	Toxic. A carcinogen, narcotic.
-Tetrachloroethene (CCl_2CCl_2)	Irritant to eyes and skin.
Pesticides, Herbicides, Insecticides[(1)]	
- Endrin ($C_{12}H_8OCl_6$)	Toxic by inhalation and skin absorption, carcinogen.
- Lindane ($C_6H_6Cl_6$)	Toxic by inhalation, ingestion, skin absorption.
- Methoxychlor [$Cl_3CCH(C_6H_4OCH_3)_2$]	Toxic material
- Toxaphene ($C_{10}H_{10}Cl_8$)	Toxic by ingestion, inhalation, skin absorption.
- Silvex [$Cl_3C_6H_2OCH(CH_3)COOH$]	Toxic material; use has been restricted.

(1) Pesticides, herbicides, and insecticides are listed by trade name. The compounds listed are also halogenated organic compounds.

APPENDIX C

TOXIC ORGANIC COMPOUNDS OCCUPATIONAL EXPOSURE TO CARCINOGENIC SUBSTANCES

COMPOUND	SITE	COMMENT
١. Organic substances for which there is wide agreement on carcinogenicity		
٤- Aminodiphenyl	Bladder	A contaminant in diphenylamine
Benzidine	Bladder	Ingredient of aniline dyes, plastics, and rubber
Beta-naphthylamine (2-NA)	Bladder	Dye and pesticide ingredient; synonym, 2- naphthylamine exposed workers have 30 to 60 times as much bladder cancer
Bis (chloromethyl) ether	Lung	Used in making exchange resins; exposed workers have 7 times as much lung cancer; synonym, BCME
Vinyl chloride	Liver	Angiosarcoma cases among PVC workers
٢. Additional organic substances on USDA-OSHA cancer-causing substances list		
Alpha-naphthylamine (1-NA)	Bladder	Human case implicated; used in making dyes, herbicides, food colors, color film; an antioxidant
Ethyleneamine	Unknown	Carcinogenic in animals; used in paper and textile processing and making of herbicides, resins, rocket and jet fuels
٣،٣' - Dichlorobenzidine	Unknown	Carcinogenic in animal species; exposure accompanies benzidine and betanaphthylamine
Methyl chloromethyl methyl ether	Unknown	Carcinogenic in animals; synonym, CMME; BCME contaminants CMME;used in resin-making, textile, and drug production.
٤،٤' - Methylene bis (2-chloroaniline)	Unknown	Synonym MOCA. Tumorigenic in rats and mice. Skin absorption may be the hazard. Curing agent for iso-cyanate polymers.
٣. Industrial substances suspected of carcinogenic potential for humans		
Antimony trioxide production		Epichlorhydrin
Benzene (skin)		Hexamethyl phosphoramide (skin)
Benz(a) pyrene		Hydrazine
Beryllium		4,4' - Methylene bis (2-chloroaniline) (skin)
Cadmium oxide production		4,4' - Methylene dianiline
Chloroform		Monomethyl hydrazine
Chromates of lead and zinc		Nitrosamines
٣،٣' - Dichlorobenzidine		Propane sulfone
Dimethylcarbamyl chloride		Beta-propiolactone
١،١ - Dimethyl hydrazine		Vinyl cyclohexene dioxide
Dimethyl sulfate		

APPENDIX D

CHARACTERISTICS OF FLOW-METERING DEVICES USED IN WASTE-WATER TREATMENT FACILITIES[a]

METERING DEVICE	RANGE[b)]	ACCURACY,[b)] PERCENT OF ACTUAL RATE	REPEATABILITY[b)] PERCENT OF FULL SCALE	STRAIGHT UPSTREAM RUN IN PIPE DIAMETERS
For open channels:				
Head/area				
Flume	10:1-75:1[c)]	±5-10[d)]	±0.5	
Weir	500:1	±5	±0.5[g)]	
Other				
Magnetic (insert type)	10:1	±1-2[e)]	±0.5	
Velocity-head				
For closed conduits:				
Head/pressure				
Flow tube	4:1	±3	±0.5	4-10[f)]
Orifice	4:1	±1	±1	±5[g)]
Pitot tube	3:1	±3	±1[g)]	10[g)]
Rotameter	10:1	0.5-10	1[g)]	5[g)]
Venturi meter	4:1	±1	±0.5	4-10[f)]
Moving fluid effects:				
Magnetic (tube type)	10:1	±1-2[e)]	±0.5	5
Magnetic (insert type)	10:1	±1-2[e)]	±0.5	5
Target	10:1	±5	1[f)]	20
Ultrasonic (Doppler)	10:1	±3	±1	7-10
Ultrasonic (transmission)	10:1	±2	±1	7-10
Vortex shedding	15:1	±1	±0.5	10
Positive displacement:				
Propeller	10:1	±2	±0.5	5
Turbine	10:1	±0.25	±0.05	10[h)]

a) Based on industry practice and engineering judgement.

b) Based on both the primary element and primary conversion device.

c) Depends on the type of flume.

d) Parshall flumes ±5%, Palmer-Bowlus flume ±10%.

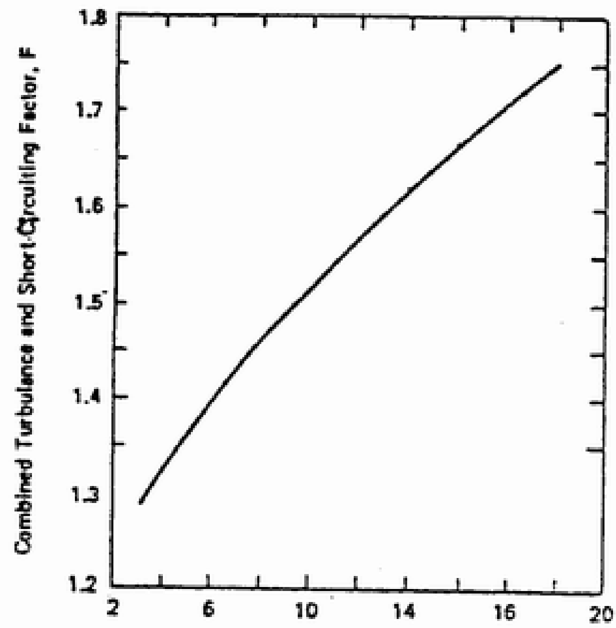
e) Of full scale.

f) Depends on the type of flow-disturbing obstruction.

g) Estimated.

h) Assuming that flow straightening is used (25 to 30 pipe diameters, otherwise).

APPENDIX E
OIL-WATER SEPARATOR CHANNEL LENGTH CORRECTIONS FOR TURBULENCE AND SHORT-CIRCUITING



$$F = F_t . F_s \quad \text{(Eq.E.1)} \qquad L = F\left(\frac{V_H}{V_t}\right)d \quad \text{(Eq.E.2)}$$

RECOMMENDED VALUES OF TURBULENCE FACTORS

V_H/V_t	Turbulence Factor, F_t
20	1.45
15	1.37
10	1.27
6	1.14
3	1.07

RECOMMENDED VALUE OF SHORT-CIRCUITING FACTOR

V_H/V_t	Short Circuiting Factor, F_s
All	1.2

Where:

V_H is superficial horizontal flow velocity, in (m/min), however V_H must not exceed 0.91 m/min;

V_t is rate of rise of oil globule, in (m/min);

L is the length of the separator channel between inlet distributor and oil retention baffle, in meter (m);

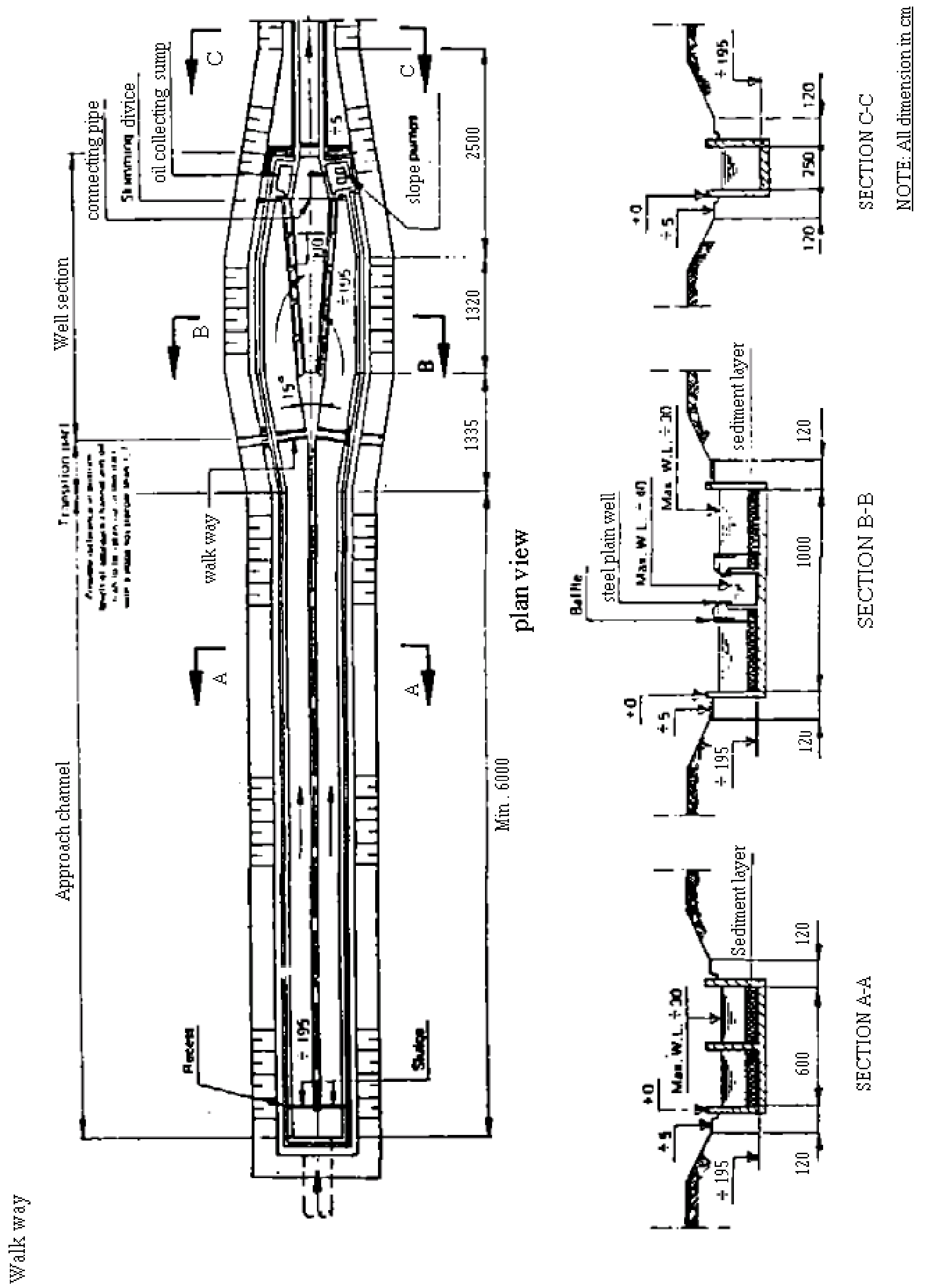
D is channel depth, in meter (m);

F_t is turbulence factor, (dimensionless);

F_s is short circuiting factor, (dimensionless).

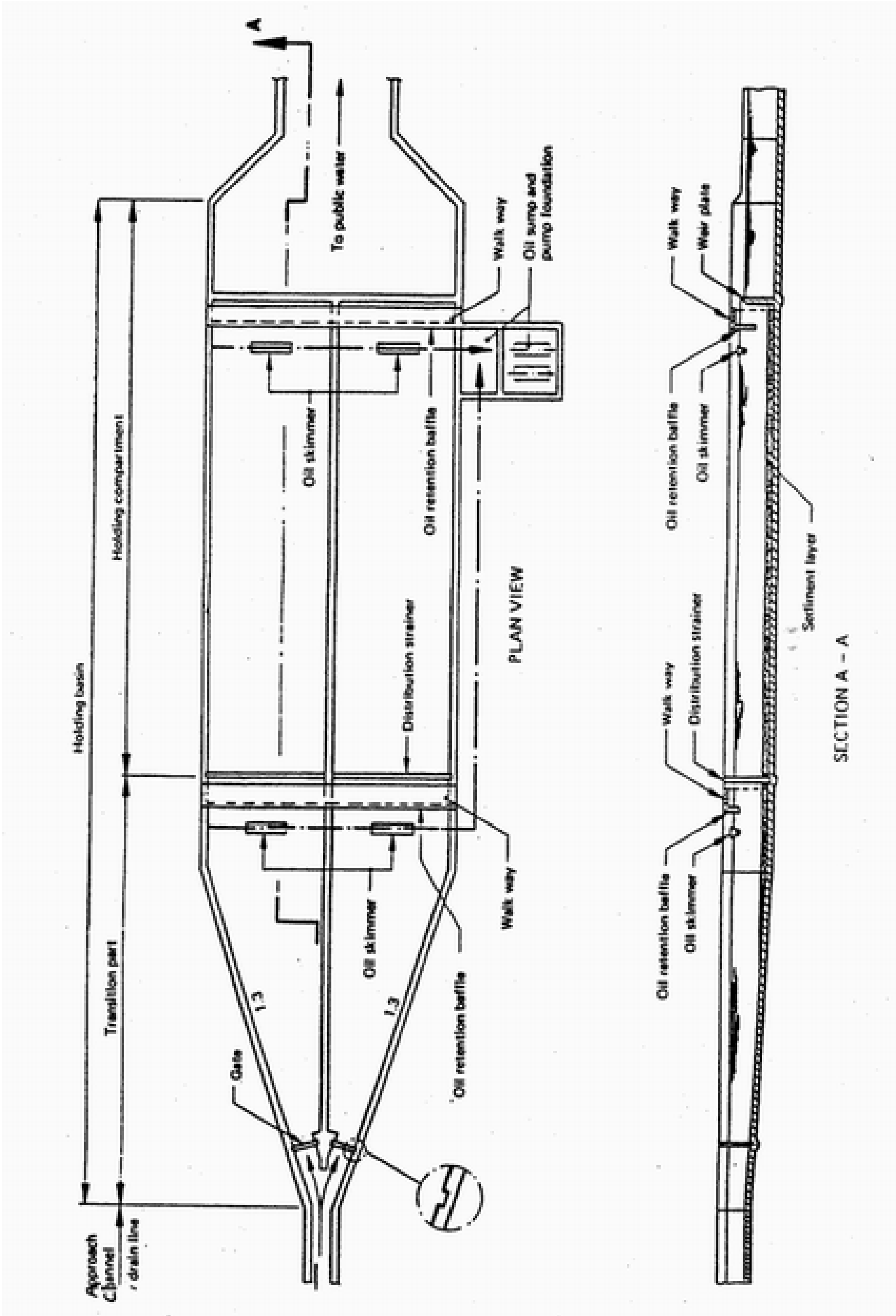
APPENDIX F

TYPICAL OIL TRAP



APPENDIX G

TYPICAL OIL HOLDING BASIN



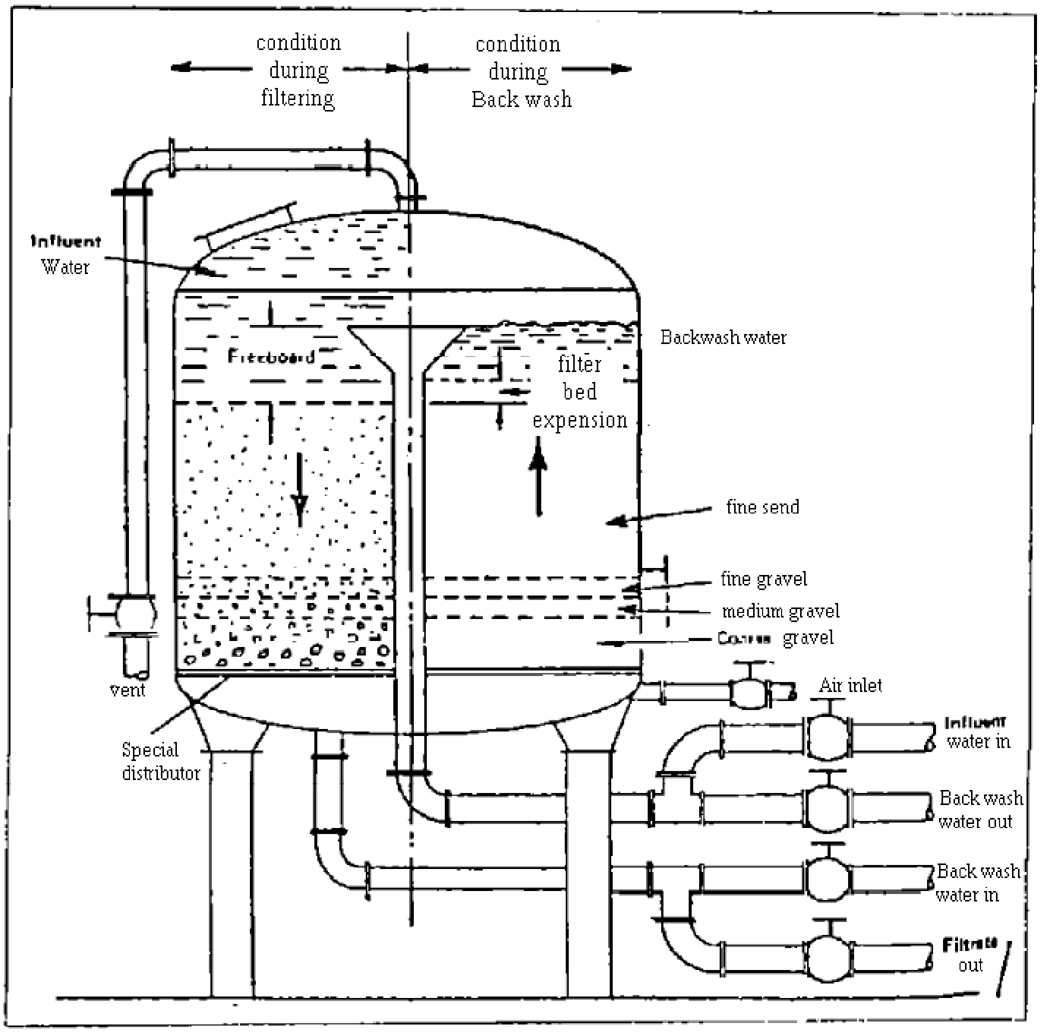
APPENDIX H

TYPES OF SETTLING PHENOMENA INVOLVED IN WASTE-WATER TREATMENT

TYPES OF SETTLING PHENOMENON	DESCRIPTION	APPLICATION/OCCURRENCE
Discrete particle (type 1)	Refers to the sedimentation of particles in a suspension of low solids concentration. Particles settle as individual entities, and there is not significant interaction with neighboring particles	Removes grit and sand particles from waste water
Flocculant (type 2)	Refers to a rather dilute suspension of particles that coalesce, or flocculate, during the sedimentation operation. By coalescing, the particles increase in mass and settle at a faster rate	Removes a portion of the suspended solids in untreated waste water in primary settling facilities, and in upper portions of secondary settling facilities. Also removes chemical floc in settling Tanks
Hindered, also called zone (type 3)	Refers to suspensions of intermediate concen-tration, in which interparticle forces are sufficient to hinder the settling of neighboring particles. The particles tend to remain in fixed positions with respect to each other, and the mass of particles settles as a unit. A solids-liquid interface develops at the top of the settling mass	Occurs in secondary settling facilities used in conjunction with biological treatment facilities
Compression (type 4)	Refers to settling in which the particles are of such concentration that a structure is formed, and further settling can occur only by compression of the structure. Compression takes place from the mass of the particles, which are constantly being added to the structure by sedimentation from the supernatant liquid	Usually occurs in the lower layer of a deep sludge mass, such as in the bottom of deep secondary settling facilities and in sludge-thickening facilities

APPENDIX I

DOWN FLOW SAND FILTER (TYPICAL)



APPENDIX J

ADDITIONAL CHEMICAL APPLICATIONS IN WASTE-WATER COLLECTION, TREATMENT, AND DISPOSAL

Application	Chemicals used[a]	Remarks
Collection		
Slime-growth control	Cl_2, H_2O_2	Control of fungi and slime-producing bacteria
Corrosion control (H_2S)	Cl_2, H_2O_2, O_3	Control brought about by destruction of H_2S in sewers
Corrosion control (H_2S)	$FeCl_3$	Control brought about by precipitation of H_2
Odor control	Cl_2, H_2O_2, O_3	Especially in pumping stations and long, flat sewers
Treatment		
Grease removal	Cl_2	Added before preaeration
BOD reduction	Cl_2, O_3	Oxidation of organic substances
pH control	KOH, $Ca(OH)_2$, NaOH	
Ferrous sulfate oxidation	Cl_2[b]	Production of ferric sulfate and ferric chloride
Filter-ponding control	Cl_2	Residual at filter nozzles
Filter-fly control	Cl_2	Residual at filter nozzles, used during fly season
Sludge-bulking control	Cl_2, H_2O_2, O_3	Temporary control measure
Digester supernatant oxidation	Cl_2	
Digester and imhoff tank foaming control	Cl_2	
Ammoniaoxidation	Cl_2	Conversion of ammonia to nitrogen gas
Odor control	Cl_2, H_2O_2, O_3	
Oxidation of refractory organic compounds	O_3	
Disposal		
Bacterial reduction	Cl_2, H_2O_2, O_3	Plant effluent, overflows, and stormwater
Odor control	Cl_2, H_2O_2, O_3	

a) Cl_2 = chlorine, H_2O_2 = hydrogen peroxide, O_3 = ozone, KOH = potassium hydroxide, $Ca(OH)_2$ = calcium hydroxide, NaOH = sodium hydroxide.

b) $6(FeSO_4 . 7H_2O) + 3Cl_2 \rightarrow 2FeCl_3 + Fe_2(SO_4)_3 + 42H_2O$.

APPENDIX K

CHARACTERISTICS OF AN IDEAL CHEMICAL DISINFECTANT

CHARACTERISTICS	REMARKS
Toxicity to microorganisms	Should have a broad spectrum of activity of high dilutions
Solubility	Must be soluble in water or cell tissue
Stability	Loss of germicidal action on standing should be low
Non-toxic to higher forms of life	Should be toxic to organisms and non-toxic to man and other animals
Homogeneity	Solution must be uniform in composition
Interaction with extraneous material	Should not be absorbed by organic matter
Toxicity at room temperature	Should be effective in environmental temperature range
Penetration	Should have the capacity to penetrate through surfaces
Non-corrosive and non-staining	Should not disfigure metals or stain clothing
Deodorizing ability	Should deodorize while disinfecting
Detergent capacity	Should have cleansing action to improve effectiveness of disinfectant
Availability	Should be available in large quantities and reasonably priced

APPENDIX L

RELATIVE BIODEGRADABILITY OF CERTAIN ORGANIC COMPOUNDS

BIODEGRADABLE ORGANIC COMPOUNDS[(1)]	COMPOUNDS GENERALLY RESISTANT TO BIOLOGICAL DEGRADATION
Acrylic acid	Diethanolamine
Aliphatic acids	Ethers
Aliphatic alchohols	Ethylene chlorohydrin
(normal, iso, secondary)	Insoluble oil
Aliphatic aldehydes	Isoprene
Aliphatic esters	Methyl vinyl ketone
Aromatic amines	Morpholine
Benzaldehyde	Polymeric compounds
Dichlorophenols	Selected hydrocarbons
Ethylene glycol	Aliphatics
	Aromatics
Ketones	Alkyl-aryl groups
Linear alkyl benzene sulfonates	Tertiary aliphatic alcohols
Methacrylic acid	Tertiary benzene sulfonates
Methyl methacrylate	Tetrapropylene and other polypropylene benzene sulfonates
Monochlorophenols	Trichlorophenols
Monoethanolamine	Triethanolamine
Nitriles	
Phenols	
Primary aliphatic amines	
Styrene	
Vinyl acetate	

[(1)] Some compounds can be degraded biologically only after an extended period of acclimation.

APPENDIX M
EFFLUENT PERMISSIBLE CONCENTRATIONS

MAXIMUM PERMISSIBLE CONCENTRATION OF CONTAMINANTS IN EFFLUENTS ACCORDING TO IRANIAN ENVIRONMENT ORGANIZATION'S REGULATION			
CONTAMINANTS	**DISCHARGE TO SURFACE RUNOFF (+)**	**DISCHARGE TO GROUND WATER (+)**	**IRRIGATION & AGRICULTURE USAGE (+)**
Al	۵	۵	۵
Ba	2	1	1
Be	0.1	1	0.1
B	2	1	1
Cd	1	0.01	0.01
Ca	75	---	---
Cr^{+6}	1	1	1
Cr^{+3}	1	1	1
Co	1	1	0.05
Cu	1	1	0.2
Fe	3	0.5	5
Li	2.5	2.5	2.5
Mg	100	100	100
Mn	1	0.5	0.2
Hg	0	0	0
Mo	0.01	0.01	0.01
Ni	1	0.2	0.2
Pb	1	1	1
Se	1	0.01	0.02
Ag	1	0.05	0.01
Zn	2	2	2
Sn	2	2	---
V	0.1	0.1	0.1
As	0.1	0.1	0.1
Cl^2	1	1	0.2
Cl^-	*	*	*
F	2.5	2	2
P	1	1	---
CN	0.2	0.02	0.02
C_6H_5OH	1	0	1
CH_2O	1	1	1
NH_4^+	2.5	0.5	---
NO_2^-	50	10	---
NO_3^-	50	1	---
SO_4^{2-}	300	300	500
SO_3^{2-}	1	1	1
TSS	30	30	100
SS	0	0	0
TDS	**	**	**
Oil & Grease	10	10	10
BOD	20	20	100
COD	50	50	200
DO	>2	>2	>2
ABS (detergent)	1.5	0.5	0.5
Turbidity	50	50	50
Color	***	75 unit of color	75 unit of color
Temperature	****	---	****
pH	6.5-8.5	5-9	5-9
Radio actives	0	0	0
Digestable Coliform	400/100 mL	400/100 mL	400/100 mL
MPN	1000/100 mL	1000/100 mL	1000/100 mL

Notes:

+ Unit of measurement is, in (mg/L).

*** Amount of chloride in industrial effluents should not exceed 250 mg/L (ppm) for fresh water.**

**** Total dissolved solids in industrial effluents should not increase the amount of these materials more than 10% in the underground water/river and any other sources in a distance of 200 m, in which effluent dumped.**

***** Color of source water should not exceed more than 16 standard units due to industrial effluent, dumped.**

****** Temperature of industrial effluent should not change the temperature of source water more than ±3°C in a distance of 200 m.**