4.0 DESIGN PRACTICES

This section provides practical information for engineers and technical personnel to establish a planning and design approach for industrial wastewater treatment at their facility. There are four discreet steps of the planning and design process for a wastewater treatment plant, as shown in Figure 4-1.

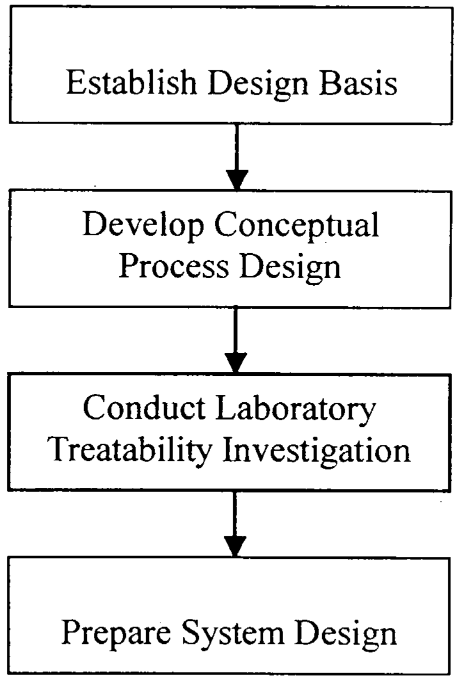


Figure 4-1 Typical Planning and Design Process

Each of these components of the planning and design process is discussed in the following subsections.

4.1 Establish Design Basis

The first step in the treatment plant design process is to understand the given conditions and the requirements the new treatment system must achieve. These data form the basis of initiating treatment plant design. The engineer must assemble relevant information on the type and quantity of the wastewater to be generated, and understand the regulatory discharge limits for treated effluent to establish. This information is essential to identify potentially applicable treatment approaches for site-specific conditions. The discharge criteria may be provided by local and national regulations, or may be specified by an objective of wastewater reuse at the facility itself.

Wastewater characteristics can be obtained in two ways.

- Conducting an analysis of existing conditions at an operating facility
- Developing assumptions on projected conditions for a new facility using information from similar manufacturing operations.

Wastewater analysis shall be conducted in accordance with analytical standard methods. The following methods are commonly used to ensure high-quality data are obtained:

- Standard Methods for the Examination of Water and Wastewater - 20th Edition on CD-ROM, 1999
- EPA Methods and Guidance for Analysis of Water (CD-ROM), 1997

In addition to understanding wastewater characteristics, data regarding flow conditions must be established. Wastewater flow rates can vary significantly throughout an operating shift, or between shifts. Information for the following flow conditions are needed as part of establishing the design basis:

- Normal or average conditions
- Maximum conditions
- Minimum conditions
- Facility start-up/shutdown conditions
- Facility maintenance/turn-around conditions

If the new wastewater treatment plant is to be designed for an existing facility, a sampling and analysis plan must be established to collect wastewater samples that are representative to the range of conditions normally encountered at the facility. This will require preparing a detailed sewer map of the facility to understand the location of the various discharge points and the source of wastewater in each discharge line. Depending on the type of facility, wastewater characteristics may be similar in the various wastewater streams generated. In this case a sampling and analysis plan will allow fewer samples at strategic times of the manufacturing operation. However, if there are several different manufacturing processes in the facility that generate wastewater with significantly different chemical characteristics, a more detailed sampling and analysis plan will be needed. This is critical if certain wastewater streams at the facility are high-strength versus other lower-strength wastewater. Opportunities for segregating wastewater streams the exhibit variable-strength may be important for the treatment plant design.

In the case of a grass-roots facility the exact wastewater characteristics are not known. Therefore specific assumptions must be made regarding wastewater composition using information obtained in literature and from other similar manufacturing facilities. In this case the facility process engineer shall compile relevant data that represents the anticipated conditions for the new facility. This information will form the design basis and will include:

- Flow rates (normal/maximum/minimum/frequency)
- Discharge amount for equipment maintenance
- Major chemical components and their concentrations
- pH values for the various wastewater streams expected.

One method to obtain basic information on wastewater strength (i.e., BOD and COD values), the theoretical oxygen demand (ThOD) can be estimated using data for various chemicals as summarized in Table 4-1. The engineer can estimate quantities of specific chemicals that will be present in the wastewater to obtain ThOD value for the combined waste stream.

The following example calculates ThOD for glycine ($CH_2(NH_2)COOH$) as adapted from Metcalf and Eddy (1991). Relevant assumptions regarding glycine stabilization include:

1. In the first step, the organic carbon and nitrogen are converted into carbon dioxide (CO_2) and ammonia (NH_3), respectively.
2. In the second and third steps, the ammonia is oxidized sequentially to nitrite and nitrate.
3. The ThOD is the sum of the oxygen required for all three steps.

The steps used to calculate the oxygen demand are:

1. Write the balanced reaction for the carbonaceous oxygen demand.

$CH_2(NH_2)COOH + 3/2O_2 \rightarrow NH_3 + 2CO_2 + H_2O$

2. Write balanced reactions for the nitrogenous oxygen demand.

(a) $NH_3 + 3/2O_2 \rightarrow HNO_2 + H_2O$

(b) $\underline{HNO_2 + 1/2O_2 \rightarrow HNO_3}$

$NH3 + 2O_2 \rightarrow HNO_3 + H_2O$

3. Determine the ThOD

ThOD = (3/2+4/2) mol-O_2/mol-glycine

= 3.5 mol-O_2 / mol-glycine * 32 g/mol-O_2

= 112 g-O_2/mol-glycine

= 1.43 g-O_2/g-glycine

Table 4-1 Chemical and its Oxygen Demand

Chemical		Boiling point (deg.C)	ThOD (g/g)	COD(Cr) (g/g)	COD(Mn) (g/g)	BOD (g/g)
Formic Acid	$HCOOH$	100.80	0.348	0.343	0.049	0.240
Acetic Acid	CH_3COOH	117.80	1.070	1.010	0.074	0.760
Propeonic Acid	CH_3CH_2COOH	140.80	1.510	1.460	0.130	1.220
Butyric Acid	$CH_3(CH_2)_2COOH$	163.50	1.820	1.780	0.079	-
Valerate	$CH_3(CH_2)_3COOH$	187.00	2.040	1.900	0.079	-
Stearic Acid	$C_{17}H_{35}COOH$	238.00	2.930	2.700	0.000	-
Isobutyric Acid	$(CH_3)_2CHCOOH$	154.50	1.820	1.760	0.120	1.030
Isovalerate	$(CH_3)_3CHCH_2COOH$	176.50	2.040	1.900	0.086	-
Lactic Acid	$CH_3CH(OH)COOH$	-	1.070	0.937	0.420	-
Malic Acid	$HOOC-CH_2CH(OH)COOH$	-	0.716	0.684	0.550	-
Tartaric Acid	$C_4H_6O_6$	-	0.533	0.519	0.490	-
Citric Acid	$C_6H_8O_8$	-	0.686	0.543	0.400	-
Formalin	$HCHO$	-21.00	1.070	0.499	0.490	0.300
Acetaldehyde	CH_3CHO	20.20	1.820	0.853	0.150	0.650
Acetone	CH_3COCH_3	56.30	2.210	1.830	0.000	0.460
Methyl ethyl ketone	$CH_3COC_2H_5$	79.60	2.410	1.900	0.008	0.320
Ether	$(C_2H_5)_2O$	34.38	2.590	0.840	0.010	0.000
Methanol	CH_3OH	64.65	1.500	1.430	0.400	1.020
Ethanol	C_2H_5OH	78.30	2.090	1.930	0.230	1.600
1-Propanol	$CH_3CH_2CH_2OH$	97.15	2.400	2.240	0.310	1.540
1-Butanol	$CH_3(CH_2)_3OH$	117.50	2.590	2.400	0.280	-
2-Propanol	$(CH_3)_2CHOH$	82.40	2.400	2.240	0.064	-
2-Butanol	$CH_3CH_2CH(OH)CH_3$	98.50	2.590	2.290	0.240	-
Glycerin	$C_3H_5(OH)_3$	290.00	1.220	1.170	0.630	0.810
Ethyl acetate	$CH_3COOC_2H_5$	76.82	1.820	1.420	0.075	0.970
iso-Butyl acetate	$CH_3COOCH_2CH(CH_3)_2$	108.00	2.210	1.870	0.018	0.400
Benzene	C_6H_6	80.13	3.080	0.526	0.000	0.000
Toluene	$C_6H_5CH_3$	110.80	3.130	0.679	<1.000	0.020
Phenol	C_6H_5OH	182.20	2.380	2.350	1.49-1.73	1.860
Aniline	$C_6H_5NH_2$	184.55	2.410	3.090	2.07-2.60	0.070
Benzoic acid	C_6H_5COOH	-	1.970	1.950	0.035	1.250
Cresol (mixed)	$CH_3C_6H_4OH$	191～203	2.520	2.470	1.260	1.290
Glucose	$C_6H_{12}O_6$	-	1.070	1.050	0.630	0.610
Saccharose	$C_{12}H_{22}O_{11}$	-	1.120	1.080	0.830	0.660

Source: Kondoh and Yamazaki, 7th Gesuidoh kenkyuu happyou kouenshu 216 @Sendai 1970

In addition to understanding the wastewater strength of the various waste streams, a system mass balance must be prepared. The facility engineer must consider the flow rate fluctuation at the plant. This will be based on knowledge of the expected manufacturing levels for the new facility and anticipated flow rates. Information from other similar plants will be needed to assist in preparing these expected flow rates.

Since many industrial wastewater streams consist of variable flow rates during operations and highly variable wastewater characteristics, flow equalization is an important component to a treatment facility. For biological treatment plants care must be taken to maintain continue operation during shut-down periods in order to successfully re-start the treatment operation.

4.2 Conceptual Design

Information collected to develop the design basis is used to initiate the conceptual design process. By identifying the wastewater characteristics, flow rates, and effluent requirements a process flow diagram can be prepared. Several considerations regarding the treatment process must be made, including:

(1) Wastewater segregation
(2) Pre-treatment requirements
(3) Treatment system type (e.g., physical/chemical, biological treatment)
(4) Tertiary treatment requirements
(5) Process residuals and sludge management
(6) Other considerations (e.g., odor generation and control)

4.2.1 Wastewater Segregation

As part of the wastewater characterization step a determination will be made on the relative strength and chemical concentrations in the facility wastes. Wastewater segregation may be warranted under the following conditions:

- Recovery of by-products is desired (e.g., metals of value)
- Lower costs can be achieved by treating a concentrated wastewater stream
- Detoxification is required prior to biological treatment
- Optimization of biological treatment can be achieved.

Industrial wastewater often contains chemicals that will inhibit biological treatment. Table-4-2 summarizes maximum allowable concentrations of selected inorganic and organic chemicals for an activated sludge process. Table 4-3 summarizes the effect of metal species most commonly encountered in industrial wastewater on the activated sludge process.

Table 4-2
Inhibition of Chemicals on Activated Sludge

Chemical		Tolerable Concentration (mg/l)
Chlorine	Cl_2	0
Arsenic	As	> 0.7
Sulfide	S^{2-}	5 - 25
Cyanide	CN	1 - 1.6
Thiocyanate	KSCN	36
Formaldehyde	HCHO	800
Ethanol	C_2H_5OH	15,000
Phenol	C_6H_5OH	> 250
Resorcin	$C_6H_4(OH)_2$	2,500
Pyrogallol	$C_6H_3(OH)_3$	500
Aniline	$C_6H_5NH_2$	Not noxic
Non-ionic detergent	-	500
Benzene	C_6H_6	> 500
Toluene	$C_6H_5CH_3$	> 500
Hexane	$CH_3(CH_2)_4CH_3$	> 500

Adapted from "Mizushori-gijutsu" Vol. 10 No. 10, 1969

Table 4-3
Inhibition of Metals on Activated Sludge Processes

Classification		Element	Concentration at 50% Inhibition (mg/l)	Concentration at 100% Inhibition (mg/l)
A	Extremely toxic	Cd	0.125	> 10
A	Extremely toxic	Cu	0.175	1.0
A	Extremely toxic	Ag	0.22	0.4
A	Extremely toxic	Hg	1.25	1.8
B	Toxic	Co	55	115
B	Toxic	Ni	83	185
B	Toxic	F (as KF)	90	160
B	Toxic	V	93	200
B	Toxic	Cr	142	260
B	Toxic	Be	240	350
C	Slightly toxic	Se	400	500-600
D	Slightly toxic	Pb, Fe, Zn, Al, W, Mn, Cl		
D'	Not toxic	Sr, Ba, U, Cs		
E	Necessary elements	Mg, K, Na, Ca, S, P, C, H, O, N		

Adapted from "Application of Microbiology" Hichi-miya

In order to eliminate the inhibitory influence dilution of the raw wastewater with lower-strength waste streams may be performed. Biological treatment systems must often become acclimatized to the specific wastewater characteristics, and may require several weeks before optimum treatment performance is achieved. Wherever possible, affects of the wastewater on biological treatment processes should be confirmed through experimental data.

4.2.2 Pre-Treatment Requirements

Based on the characterization and flow data collected to establish the design basis, pre-treatment steps may be required. Depending upon the specific waste types, the following technologies may be used for pre-treatment.

- Equalization
- Screening
- Grit Removal
- Oil and Grease Removal
- Neutralization
- Cooling

One or more of these technologies may be specified to ensure effective performance of the main treatment performance.

4.2.3 Treatment System Selection

After identifying the possible pre-treatment steps, process technologies needed to achieve the desired treatment levels must be considered. Both physical/chemical and biological technologies are evaluated for their applicability to the wastewater.

Depending on the wastewater characteristics, physical/chemical process may serve as an intermediate or final stage of treatment. The primary functions for this stage of treatment include:

- Precipitating toxic or undesirable metals and salts
- Removing oils in emulsions
- Reducing BOD and COD levels by reducing the SS levels through clarification

Physical-chemical treatment requires maintaining pH levels within a relatively narrow optimum range. Automatic pH control within the system is the most common technique used. Depending on wastewater characteristics, physical/chemical treatment may incude the following;

- Filtration
- Neutralization
- Oxidation or Reduction

Biological Treatment methods may also be considered for treatment depending on the biodegradability of wastewater. Degradability is specific to wastewater chemical characteristics. Factors that will influence the applicability include:

- Nutrient concentrations in the wastewater. Addition of N and P is often required.
- High mineral salts concentrations will inhibit microbial metabolism.
- The ability to maintain pH, temperature, and dissolved oxygen concentration.

Initiating biological treatment with either suspended growth or attached growth processes will require seed inoculation from an existing biological treatment plant. Attached growth processes can reduce the plot area required for conventional activated sludge systems. Treatment system layout using the area available and approximate sizes needed for each unit operation and process may direct the type of treatment technology selected.

In cases where potential inhibitory compounds may be present in the wastewater, the microbes used for inoculating the new system may require acclimatization to the wastewater before the system can effectively meet the desired treatment levels. For activated sludge systems the process will be controlled using either the F/M ratio or the MCRT. Adjustments to sludge return and wasting rates and DO levels in the aeration system are the primary techniques for controlling the system performance.

4.2.4 Tertiary Treatment Requirements

Tertiary treatment may be needed to meet the discharge limits. This level of treatment is most often specified when the treatment system must achieve relatively low concentrations of a particular pollutant, or if wastewater is intended for reuse at the facility. Technologies used for this type of treatment can include the following:

- Filtration
- Coagulation/Sedimentation
- Activated Carbon adsorption
- Oxidation (high-temperature and pressure oxygen, chlorine, ozone, UV, etc)
- Membrane Filtration

4.2.5 Sludge Treatment

Sludge treatment will be required to handle the solids generated during treatment. Sludge types include those from both biological and physical/chemical processes, and often have significantly different characteristics. Biological sludge will require stabilization to reduce the concentration of pathogenic organisms. Stabilization can be accomplished using aerobic or anaerobic means. Aerobic stabilization often requires greater energy, however the process is more stable than anaerobic processes and requires a lower level of operator attention. Following digestion, sludge dewatering is performed, most commonly with belt filter pressing techniques.

Sludge from physical/chemical processes typically has a higher solids concentration initially, and is more readily dewatered using simple sludge thickening and pressing in a plate and frame type press. Sludge thickening and dewatering requirements shall be determined based on the sludge characteristics. For inorganic sludge handling special attention should be paid to selecting compatible materials of construction for the dewatering equipment.

4.2.6 Other Considerations

Odors are a common result of biological treatment operations that are not operating properly. Origins of many odors are amines, ammonia, sulfide, mercaptans, phenolic compounds, and fermentation products. Process control to maintain proper levels of DO and solids in the treatment unit based on the original design should be evaluated to make necessary adjustments and reduce odor levels. However, since the strength of some industrial wastes can vary during the facility operating schedule, other measures may be needed for odor control, including using scrubbing or GAC treatment processes.

4.3 Conduct Laboratory Treatability Investigation

To design a wastewater treatment plant, the design basis and conceptual process information is used to develop key design criteria. Many unit processes will require laboratory studies to evaluate the process effectiveness as well as specific design data, such as reaction kinetics and sludge production rates. Several types of treatability studies are described in this section.

Coagulation/Sedimentation Test

The objective of this study is to determine the nature and dosages of reagents used to treat wastewater to achieve the desired treatment levels

:

- Kinds of coagulants and flocculants
- Injection rate of chemicals
- optimum pH range
- Solids production rate
- Size of clarifier

Figure 4-2 shows a typical laboratory arrangement of a coagulation/sedimentation study.

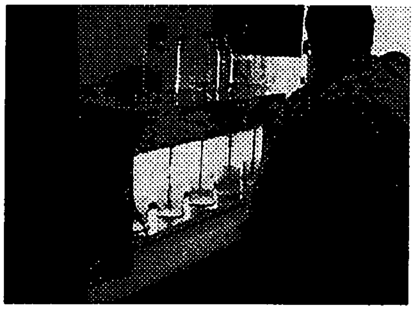


Figure 4-2
Laboratory Jar Test Arrangement

The following items are needed for this test.

- Beaker
- Jar Tester Stirrer
- Chemicals
- pH analyzer

Example test results are depicted graphically in Figure 4-3, and include:

(1) Optimum pH range: 7.5

(2) Optimum coagulant concentration (Fig. 4-3)

- PAC: 46 mg/L as Al_2O_3
- Aluminium Chloride: 12 mg/L as Al_2O_3
- Aluminium Sulfate: 15 mg/L as Al_2O_3
- Ferric Chloride: 18 mg/L as Al_2O_3

(3) Optimum polymer concentration: 2 mg/L

(4) Solids production: Much solids production in higher pH.

(5) pH adjustment reagents requirement

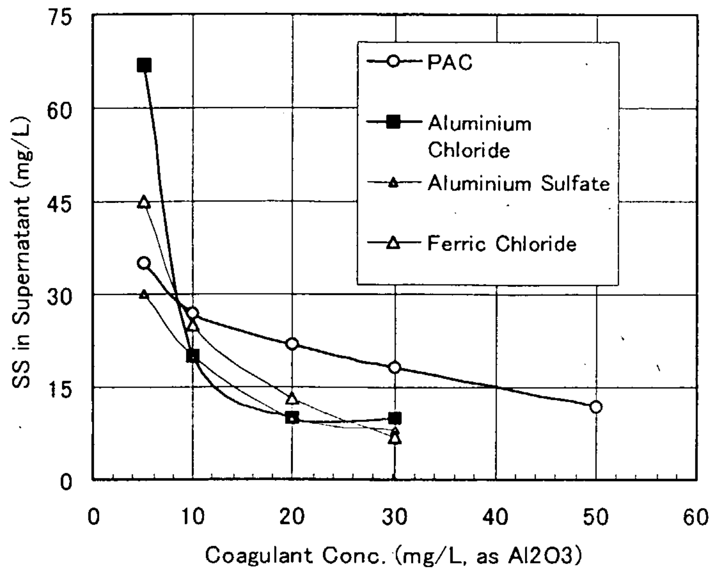


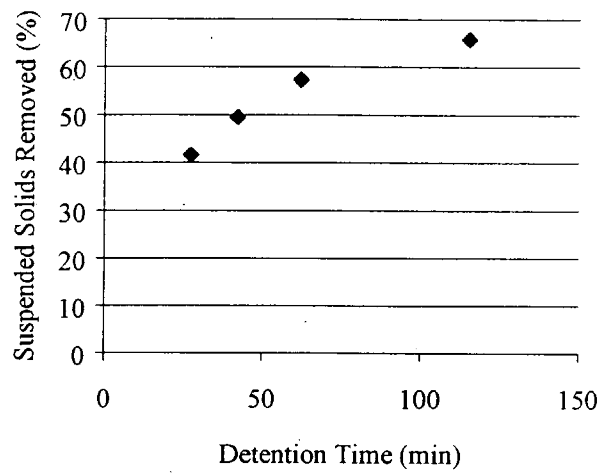
Figure 4-3
Effect of Various Coagulants (Sample)

Table 4-4 presents sample laboratory data from jar testing for use in sizing a clarifier. For this example an assumed suspended solids concentration of 150 mg/l will be specified.

Table 4-4
Sample Solids Settling Data

Time (min)	Suspended Solids Removed (%)	Overflow Rate ($m^3/m^2 \cdot d$)
27.5	41.6	96
42	49.5	63
62	57.3	43
115	65.8	23

Based on this laboratory settling data, a graph can be prepared that shows suspended solids removal as a function of detention time and of the overflow rate. Figure 4-4 shows the graph of the data given in Table 4-4.



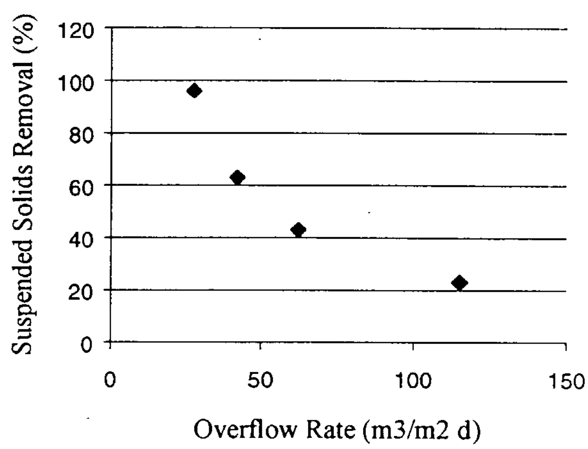


Figure 4-4 Solids Removal (Sample)

To ensure a maximum of 150 mg/L suspended solids in the effluent, this corresponds to a removal rate of 62% solids from the influent of 393 mg/L. For a 62% solids removal this corresponds to a detention time of approximately 74 minutes, and an overflow rate of approximately 31 $m^3/m^2 \cdot d$). Using the average daily flow expected for the clarifier, the area can be calculated using this overflow rate as determined experimentally. The desired effluent suspended solids concentration will depend on whether additional unit operations, such as polishing filters, are used at the facility. Improved settling performance can be achieved by increasing detention times, or using polymers to aid in the flocculation formation. The same process for sizing the clarifier would be made using laboratory data.

Batch Biological Treatment Test

The purpose of a batch biological treatment test is:

- To evaluate the organic removal limit of biological methods.
- To obtain approximately organic removal rates.

A list of the items required for the test is as follows:

- Beaker (2 to 3 l)
- Air pump
- Glass Ball Filter
- Vinyl Tube
- Water Bath with temperature control
- Thermometer
- pH meter
- KH_2PO_4
- Activated Sludge (From Sewage Treatment plant)
- Filter
- Analyzers (COD, TOC, etc)

The COD concentration of the untreated wastewater is measured. A sample aliquot of the wastewater is then inoculated with activated sludge from an existing treatment plant. Air is supplied to the system to maintain a pre-set DO concentration for the test duration. Samples of wastewater are collected during the test and analyzed for COD concentrations. A plot of COD levels as a function of time can be prepared using this data.

Example results from this test process are presented in Figure 4-5.

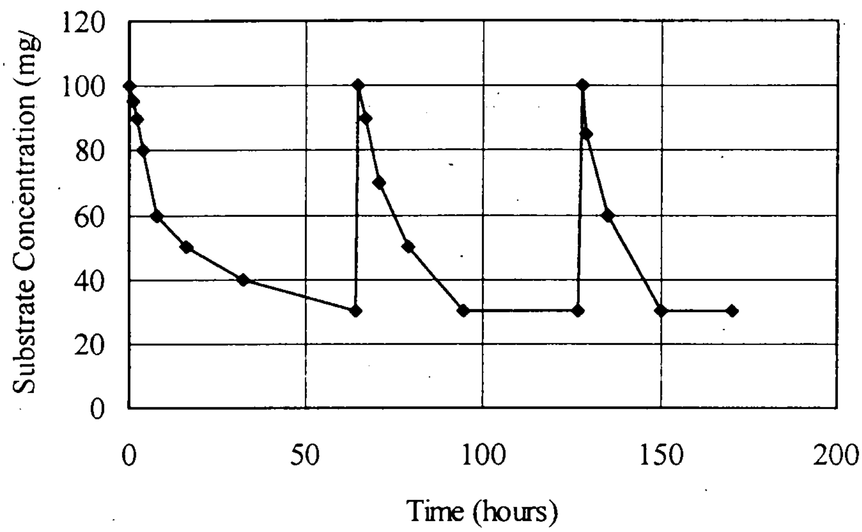


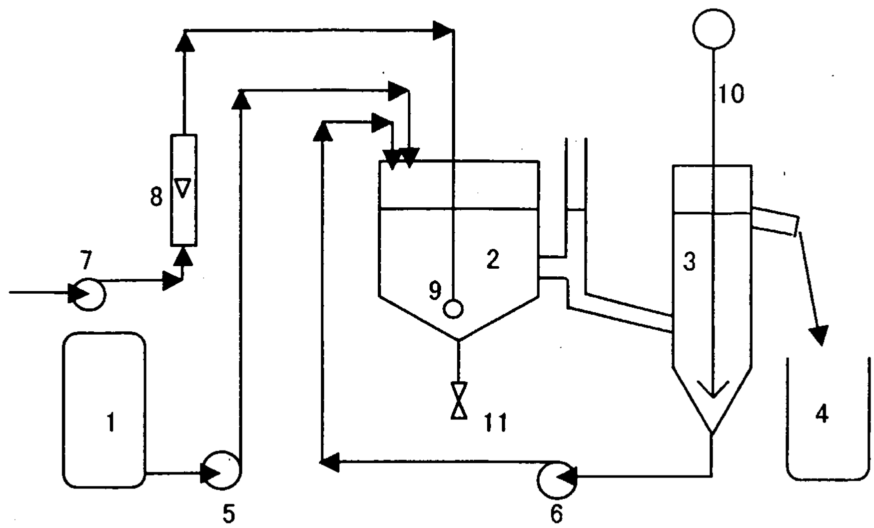
Figure 4-5
Substrate Concentration Changes

Two important conclusions can be observed from the data plotted in Figure 4-5:

The activated sludge requires 3 batches to become acclimatized to the wastewater.
COD removal limit is 30 mg/L, which represents the non-biodegradable portion of the wastewater.

<u>Bench Scale Biological Test</u>

To obtain additional design data for biological treatment of a given wastewater, a continuous operation reactor can be used where air is supplied and recycling of settled sludge is performed. This type of test will yield data such as microbial kinetics, effects of nutrients on the process, recycle rates required, as well as the ability to observe sludge settling properties. As part of this type of test the pH is monitored and preferably controlled, and chemical parameters such as COD, BOD, MLSS, pH, TOC, and DO are monitored as a function of time. Figure 4-6 shows the arrangement of a suitable laboratory apparatus for bench-scale biological testing.



1: Raw water tank
2: Aeration tank
3: Clarifier
4: Treated water tank
5: Raw water pump
6: Recycle pump
7: Air pump
8: rotameter
9: Diffuser (Glass ball filter)
10: Rake
11: Drain valve

Figure 4-6
Laboratory Bench-Scale Biological Test Apparatus

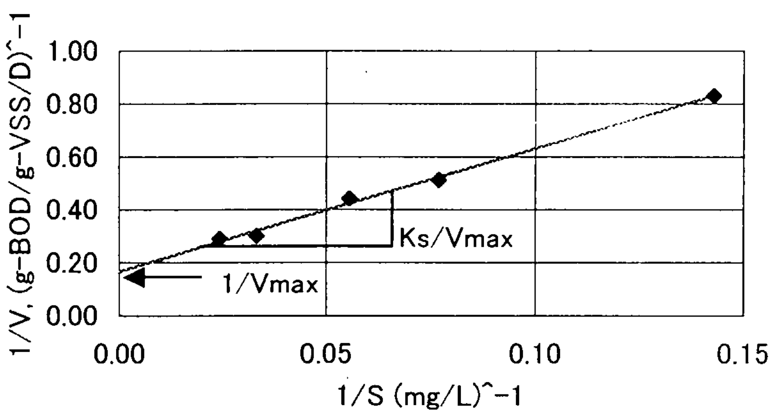
As previously mentioned, biological treatment is not immediately effective for certain industrial wastewater types. In such cases gradual acclimatization of the microbes for 10-60 days is necessary. Depending on the wastewater strength dilution of the raw wastewater is necessary. Another significant factor influencing biological treatment effectiveness is the concentrations of nitrogen and phosphorus in the wastewater. In some cases addition of nutrients is required to sustain effective treatment levels. The approximate ratio of waste strength and nutrient levels for successful biological treatment is BOD:N:P = 100: 5:1

By stepwise uploading, kinetic parameters can be obtained.
Data-handling example is shown below.

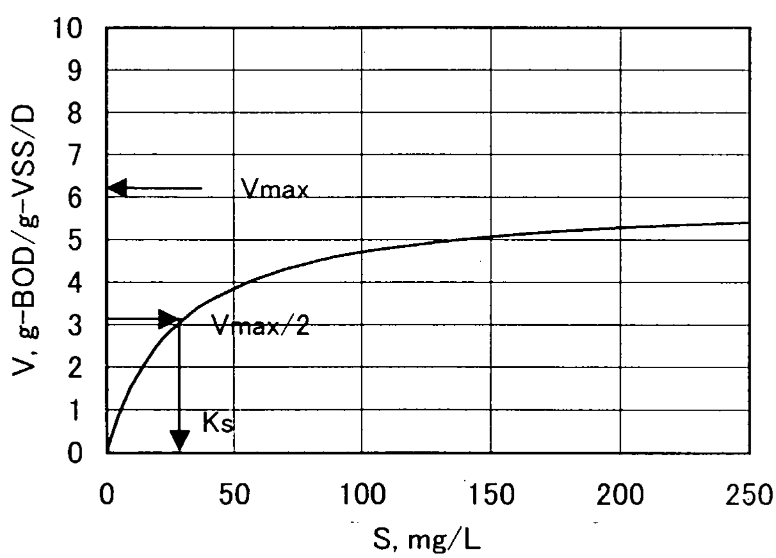
Determination of Kinetic Coefficients

Reactor Volume= 3.0 L

Data obtained from Experimental Results					Calculation		
Run No.	SR	S	Q	X	V	1/S	1/V
	BOD in RW	BOD in TW	Flow rate	MLVSS	BOD Removal Rate		
	mg/l	mg/l	L/D	mg/l	(g-BOD/g-VSS/D)	(mg/L)^-1	(g-BOD/g-VSS/D)^-1
1	500	7	0.9375	128	1.20	0.14	0.83
2	500	13	1.5	125	1.95	0.08	0.51
3	500	18	1.875	133	2.27	0.06	0.44
4	500	30	2.727273	129	3.31	0.03	0.30
5	500	41	2.727273	121	3.45	0.02	0.29



Ks/Vmax= 4.643 ("LINEST" function in MS-Excel)
1/Vmax 0.166 ("INTERSEPT" function in MS-Excel)
R^2 = 0.995 ("RSQ" function in MS-Excel)
Vmax= 6.0148 g-BOD/g-VSS/D
Ks= 27.9 mg/l



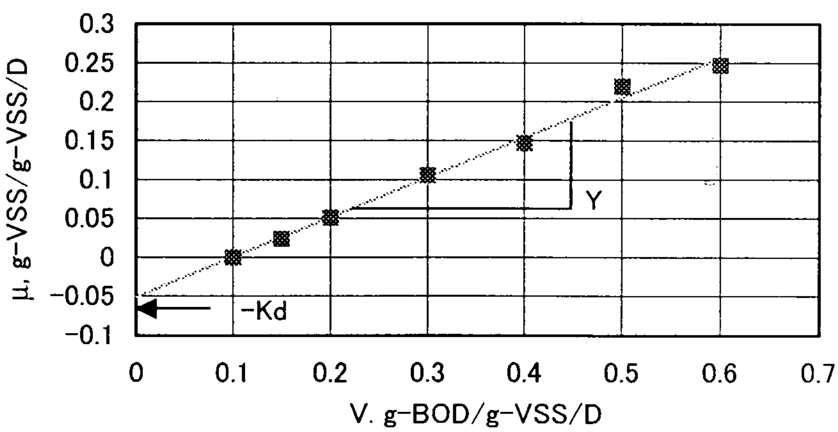
Growth Profile

Run	V BOD Removal Rate (g-BOD/g-VSS/D)	μ Specific Growth rate (g-VSS/g-VSS/D)
1	0.1	0
2	0.15	0.024
3	0.2	0.051
4	0.3	0.105
5	0.4	0.147
6	0.5	0.22
7	0.6	0.247

Specific Growth Rate is obtained from changes in MLVSS.
In the operation of bench plant, sludge management is very important.

- Dairy analysis of MLSS
- Maintain the MLSS concentration by solids withdrawing from the bottom of the clarifier.

Y=	0.512 g-VSS/g-BOD	("LINEST" function in MS-Excel)
-Kd=	−0.051 g-VSS/g-VSS/D	("INTERSEPT" function in MS-Excel)
Kd=	0.051	
R^2=	0.993	("RSQ" function in MS-Excel)



4.4 Prepare System Design

Once the information compiled as part of the design basis, conceptual design review, and treatability testing has been assembled, the process design can be prepared. The steps used to prepare the treatment process design include:

- developing a complete material and water balance for the system
- performing equipment sizing calculations
- performing system hydraulic calculations
- preparing a system layout diagram.

<u>Material/Water Balance</u>

The first step of the basic design is to establish the material balance based on determined treatment performance. Spreadsheet software programs such as Microsoft Excel are useful tools to establish the material balance. An example material balance calculation is shown below.

Calculation Sheet for Conventional Activated Sludge

Performance Parameters

Substrate removal Constant		
Vmax	0.2	kgSub./kgSS/d
Km	0.05	kg/m3
Sludge Production Constant		
Yield	0.25	kgSS/removed Sub.

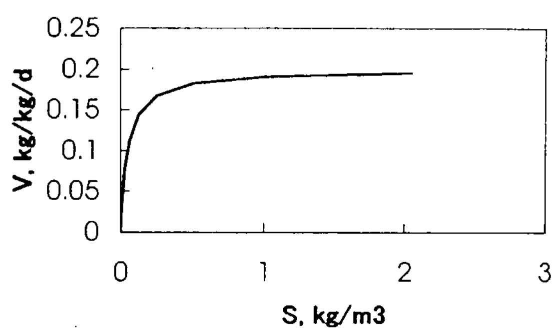
Wastewater conditions

Raw Water		
Substrate conc.	2000	mg/l
SS conc.	20	mg/l
Quantity	20	m3/h

Operating Conditions

Reactor Volume	2,500	m3
MLSS	3,000	mg/l
Sludge conc. in the Clarifier bottom	12,000	mg/l

Kinetic characteristics

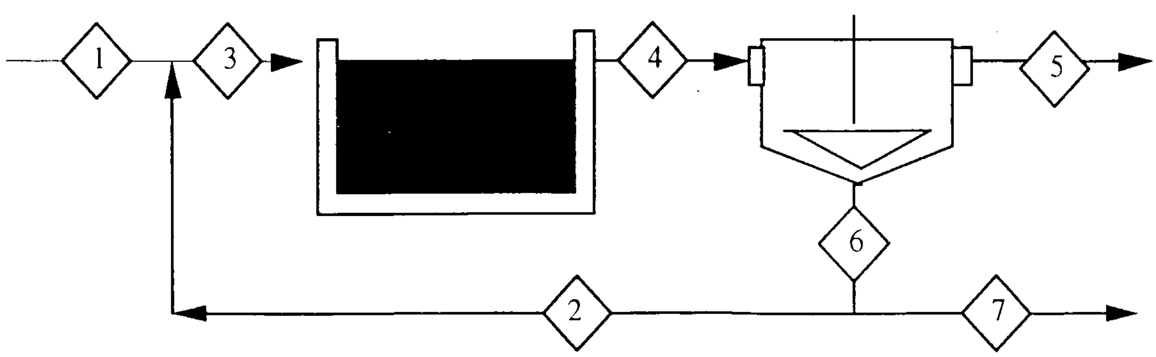


Results

Substrate in TW	48	mg/l	Substrate/SS loading	0.128	kg/kg/d
Sludge Production	244	kg/d	Sub. vol. loading	0.384	kg/m3/d
Sludge Recycle	6	m3/h	Removed substrate	937	kg/d
HRT	125.00	hours			

Material Balance

Item	Unit	1	2	3	4	5	6	7
Q	m3/h	20.00	5.54	25.54	25.54	19.15	6.38	0.85
Sub.	kg/m3	2.000	0.048	1.577	0.048	0.048	0.048	0.000
BOD	kg/h	40.000	0.265	40.265	1.223	5.000	0.306	0.000
SS	kg/m3	0.020	12.000	2.618	3.000	0.000	12.000	12.000
SS	kg/h	0.40	66.45	66.85	76.61	0.00	76.61	10.16



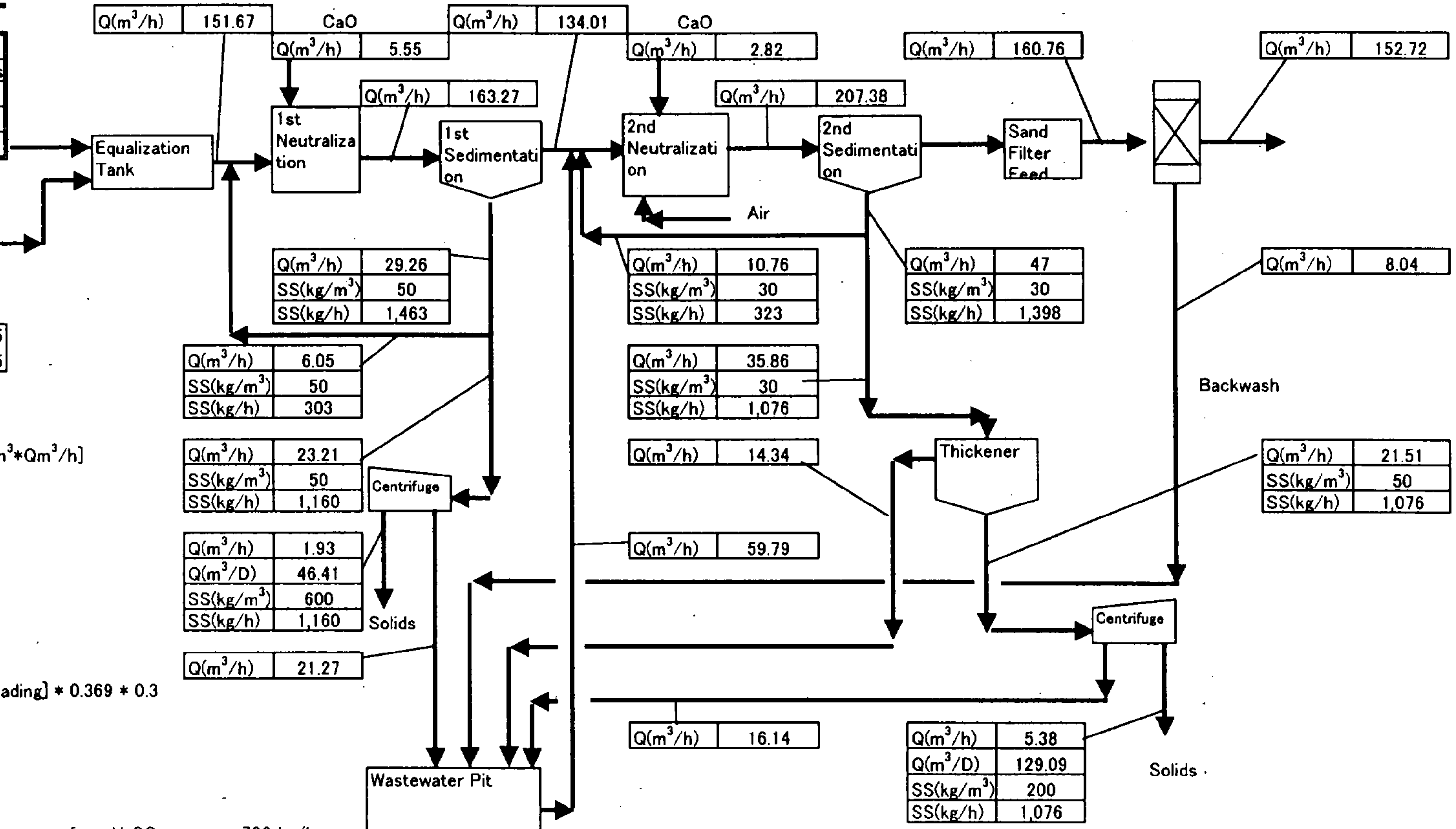
CHEMICAL REACTION and WATER BALANCE

Case 1 Base Case

Acid Wash Water	for Solids	Hydraulics
$Q(m^3/h)$	150	170
$H_2SO_4(kg/m^3)$	2.5	
$FeSO_4(kg/m^3)$	3.5	

Waste Acid	
$Q(m^3/h)$	1.67
$H_2SO_4(kg/m^3)$	120
$FeSO_4(kg/m^3)$	180

H_2SO_4 loading (kg/h)	575
$FeSO_4$ loading (kg/h)	825



Solids Production Unit

Gypsum from H_2SO_4

[H_2SO_4 loading] * 1.755 − [2.0 kg/m³*Qm³/h]

$Fe(OH)_3$

[$FeSO_4$ loading] * 0.704

Gypsum from $FeSO_4$

[$FeSO_4$ loading] * 1.133

Others

[0.1 kg/m³ * Q m³/h]

Lime Requirement as CaO

1st stage

[H_2SO_4 loading] * 0.572 + [$FeSO_4$ loading] * 0.369 * 0.3

2nd stage

[$FeSO_4$ loading] * 0.369 * 0.7

Solids Production

1st stage total 1,160 kg/h	1st stage gypsum from H_2SO_4	706 kg/h
	1st stage $Fe(OH)_3$	174 kg/h
	1st stage gypsum from $FeSO_4$	280 kg/h
2nd stage total 1,076 kg/h	2nd stage $Fe(OH)_3$	406 kg/h
	2nd stage gypsum from $FeSO_4$	654 kg/h
	2nd stage others	15 kg/h
1st + 2nd total 2,236 kg/h 53,666 kg/D		

Molecular weight	
H_2SO_4	98.1
$CaSO_4 \cdot 2H_2O$	172.2
$FeSO_4$	151.9
$Fe_2(SO_4)_3$	399.9
$Fe(OH)_3$	106.9
CaO	56.1
$Ca(OH)_2$	74.1

Lime Requirement as CaO

1st stage 420 kg/h

2nd stage 213 kg/h

Lime Solution:
10% as $Ca(OH)_2$
= 7.57% as CaO

1st + 2nd total
633 kg/h
15201 kg/D

4,176 kg/1000m³-wastewater

Gypsum Poduction from Influent H_2SO_4

$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 \cdot 2H_2O \downarrow$

Done in 1st stage.

Iron Oxidation and Gypsum Production

$FeSO_4 + 5H_2O + 1/2O_2 \rightarrow Fe(OH)_3 \downarrow + H_2SO_4$

$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 \cdot 2H_2O \downarrow$

30 % in 1st stage, 70 % in 2nd stage.

Equipment Sizing and Hydraulic Calculations

Based on the material/water balance, equipment sizes are calculated. Design values required to calculate the equipment sizes will be based on experimental results, as well as past similar experience. Suitable factors of safety should be provided to accommodate fluctuations in flow or waste loads. Some useful design information is included in the appendices includes:

- Hydraulics
- Blower calculation
- Property of Wastewater treatment chemicals
- Material selection guideline

Treatment System Layout

After the equipment is selected and the critical dimensions are calculated, a system layout diagram is prepared. This will allow an evaluation of how the equipment may be arranged at the facility to maximize the use of available space. Example layout diagrams for several industrial wastewater treatment systems are provided in the case studies in Section 5.

5.0 CASE STUDIES

This section presents summary information regarding the process design for wastewater treatment plants at selected industrial facilities. The information presented here represents a range of industrial wastewater treatment practices currently being used at manufacturing plants. Such information can be used to assist in the planning process for selecting and sizing key unit operations and unit processes for a new wastewater treatment plant.

Table 5-1 summarizes wastewater characteristics for selected industries. This information can be used as a guide to establish which are the major pollutants encountered in wastewater from various industries. This information can be used in conjunction with descriptions of the various treatment technologies presented in Section 3 and the case studies described in this section to identify a potentially applicable treatment scheme for a specific type of wastewater.

Table 5-1 Raw Wastewater Profiles for Selected Industries

	Industry*									
Contaminants	Aluminium	Automotive	Chemical	Coke	Food	Minig	Paper	Petroleum	Steel	Textile
Suspended solids	M	M	C	M	M	M	M	C	M	C
Salinity	C	C	C	M	V	M	C	C	C	C
pH variations	C	M	M	M	V	M	M	C	C	C
Oil and grease	C	M	M	M	V	V	I	M	M	C
Settable solids	M	M	C	M	M	M	M	C	M	C
BOD	V	M	M	M	M	C	M	M	V	M
COD	V	M	M	M	M	I	M	M	V	M
Heat	C	I	V	C	C	V	C	C	M	M
Color	V	I	V	M	C	V	M	I	I	M
Odor	I	I	C	C	C	I	C	C	I	C
Heavy Metals	C	C	V	I	I	M	V	V	M	I
Cyanides	I	V	V	M	I	V	I	C	V	I
Thiocyanites	I	I	V	M	I	I	I	C	V	I
Chromates	C	C	C	I	I	I	I	C	V	V
Phosphates	I	C	V	I	V	V	V	V	I	V
Fluorids	C	I	V	V	I	V	I	V	V	I
Ammonia	C	I	V	M	V	I	V	C	V	I
Organics (general)	I	M	M	M	M	I	M	M	V	M
Phenolics	I	I	V	M	I	I	V	C	V	I
Pestcides, biocides	I	I	V	I	I	I	C	C	I	I
Surfactants	V	M	V	I	C	V	V	C	I	C

*M: major factor
C: contributes to the problem
I: insignificant
V: varies in the industry, may contribute.

5.1 Wastewater Treatment in Food Industry

Two examples of wastewater from food processing operations are presented in this section. The first is a high-strength wastewater from a sugar-beet and vegetable canning operation. The second is a high-strength wastewater from a cake and confectionery facility.

5.1.1 Sugar Beet Processing Facility

A sugar-beet and vegetable canning processing facility located in Slovakia.

Wastewater to be treated

1) Sugar-beet wash and fluming water
2) pulping water
3) pressing water
4) lagoon pretreatment effluent
5) condenser water
6) sanitary wastewater from plant and adjacent small village.

Wastewater Flow Rate

1) Normal flow rate: 115 m^3/hr (95 m^3/hr from sugar beet processing; 14 m^3/hr from vegetable canning; 6 m^3/hr from sanitary sources)
2) Maximum flow rate: 172 m^3/hr, one time per day

Factory Operation

24 hours per day for 100 days per year during sugar-beet processing; 24 hours per day for 90 days per year during vegetable canning processing

Wastewater Treatment Operation

24hours/day

Sugar-Beet and Vegetable Canning Water Quality Summary

	Raw wastewater	Treated Water Target	Discharge Regulation
pH	6 to 8	6 to 9	6 to 9
BOD (mg/l)	5,000 to 5,300	200	200
COD (mg/l)	7,200 to 7,500	60	60
SS (mg/l)	1,300	50	50

Treatment Flow Scheme

Preliminary Treatment:	Screen, primary clarification, flow equalization
Primary Treatment:	Anaerobic Biological Treatment (UASB), Flocculation, lamella clarification
Secondary Treatment:	Activated sludge, with clarification
Sludge Treatment:	Gravity thickening

For detailed flow scheme, refer the attached flow diagram.

Design Parameters

Inlet Centrifuge:	Flow Rate = 30 to 120 m^3/hr
Primary Clarifier:	Holding Time = 4 hours
Equalization Pit:	Holding Time = 8 hours
UASB Reactor	Loading = 4.25 kg COD/m^3/day
Biological Teatment:	Loading = 1.3 kg BOD/m^3/day
Sludge Production:	Yield = 0.15
Clarifier:	Surface Loading = 2.3 $m^3/m^2/h$
Sludge Thickener:	Holding Time = 1.5 hours

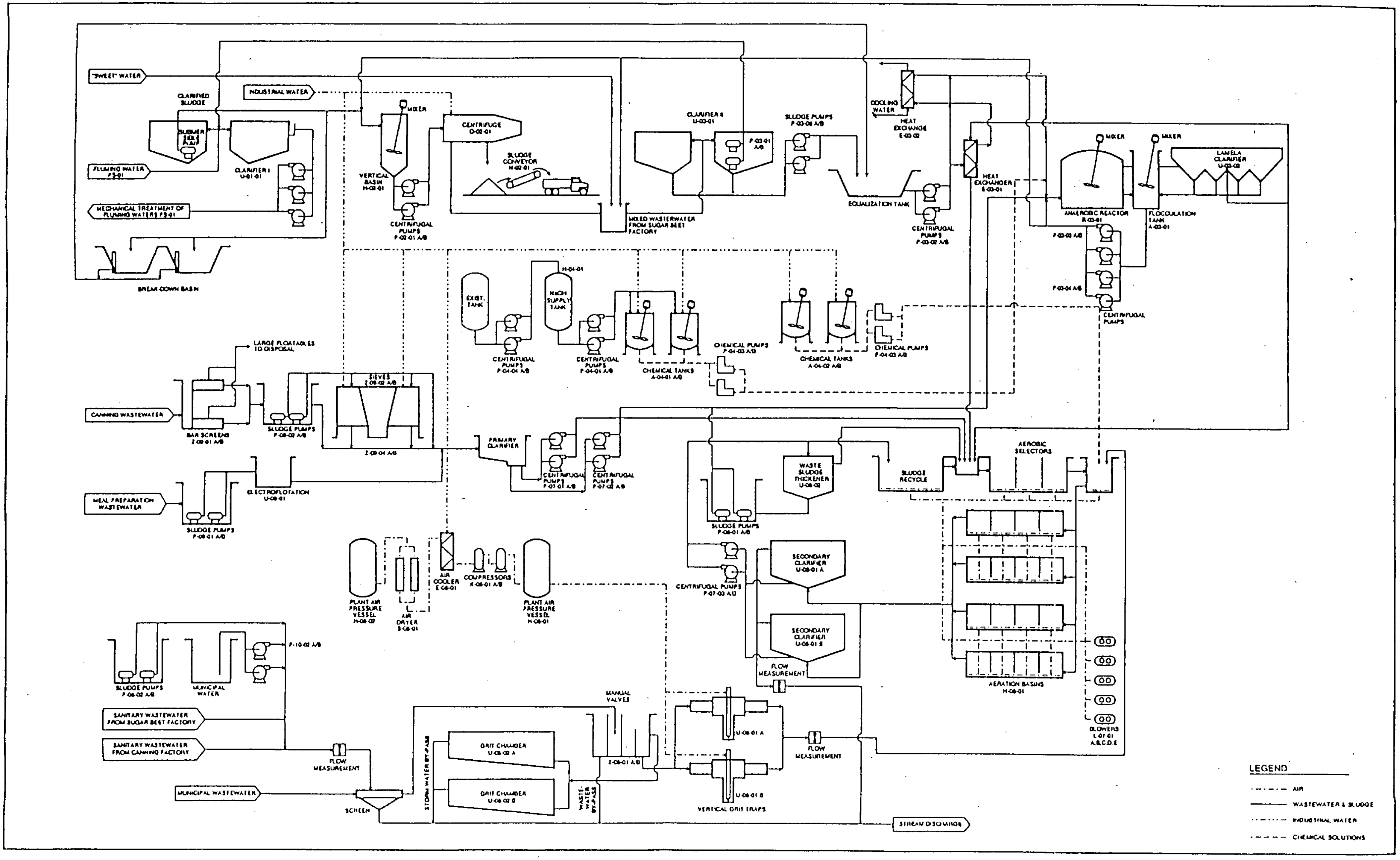


Figure 5-1 Wastewater Process Flow Diagram for Beet-Sugar Processing Facility

5.1.2 Cake and Confectionery Manufacturing Facility

A cake and confectionery manufacturing facility located in Japan.

Wastewater to be treated

7) Food processing wastewater
8) Effluent from the sewage septic tank

Wastewater Flow Rate

3) Normal flow rate: 160 m^3/day (Food processing wastewater 125m^3/day; sewage effluent 35 m^3/day)
4) Maximum flow rate: 73 m^3/2 hours (15:00 to 17:00)

Factory Operation

8:00 to 17:00

Wastewater Treatment Operation

24hours/Day

Cake and confectionery Water Quality

	Raw wastewater	Treated Water Target	Discharge Regulation
PH (-)	4 to 5	5.8 to 8.6	
BOD (mg/l)	1,100 to 1,300	20	30
COD_{Mn} (mg/l)	900 to 1,100	20	30
SS (mg/l)	500 to 700	20	30
Hexane extract (mg/l)	130 to 170	10	20
T-N (mg/l)	40 to 50	15	20
T-P (mg/l)	3 to 7	1.5	2

Treatment Flow Scheme

Preliminary Treatment:	Screen, and Neutralization
Primary Treatment:	Anaerobic/Aerobic Biological Treatment (Attached Growth type)
Secondary Treatment:	Coagulation/Sedimentation
Tertiary Treatment:	Filtration and Activated Carbon Adsorption
Sludge Treatment:	Dehydration

For detailed flow scheme, refer the attached flow diagram.

Design Parameters

Neutralization Unit:	Holding Time = 15 min.
Primary Sedimentation:	Holding Time = 4 hours
Equalization Pit:	Holding Time = 24 hours
Blower for Equalization Pit	Air Feed rate = 0.5 $m^3/m^3/h$
Biological Teatment:	Loading = 1.0 kgBOD/m^3/Day
Sludge Production:	Yield = 0.15
Mixing Pit:	Holding Time = 20 min.
Coagulation Pit:	Holding Time = 20 min.
Clarifier:	Surface Loading = 0.5 $m^3/m^2/h$
Sand Filter:	LV = 7.0 $m^3/m^2/h$
Activated Carbon Tower:	LV = 5.0 $m^3/m^2/h$
Back wash Pump:	LV = 50 $m^3/m^2/h$
Disinfection Pit:	Holding Time = 15 min.

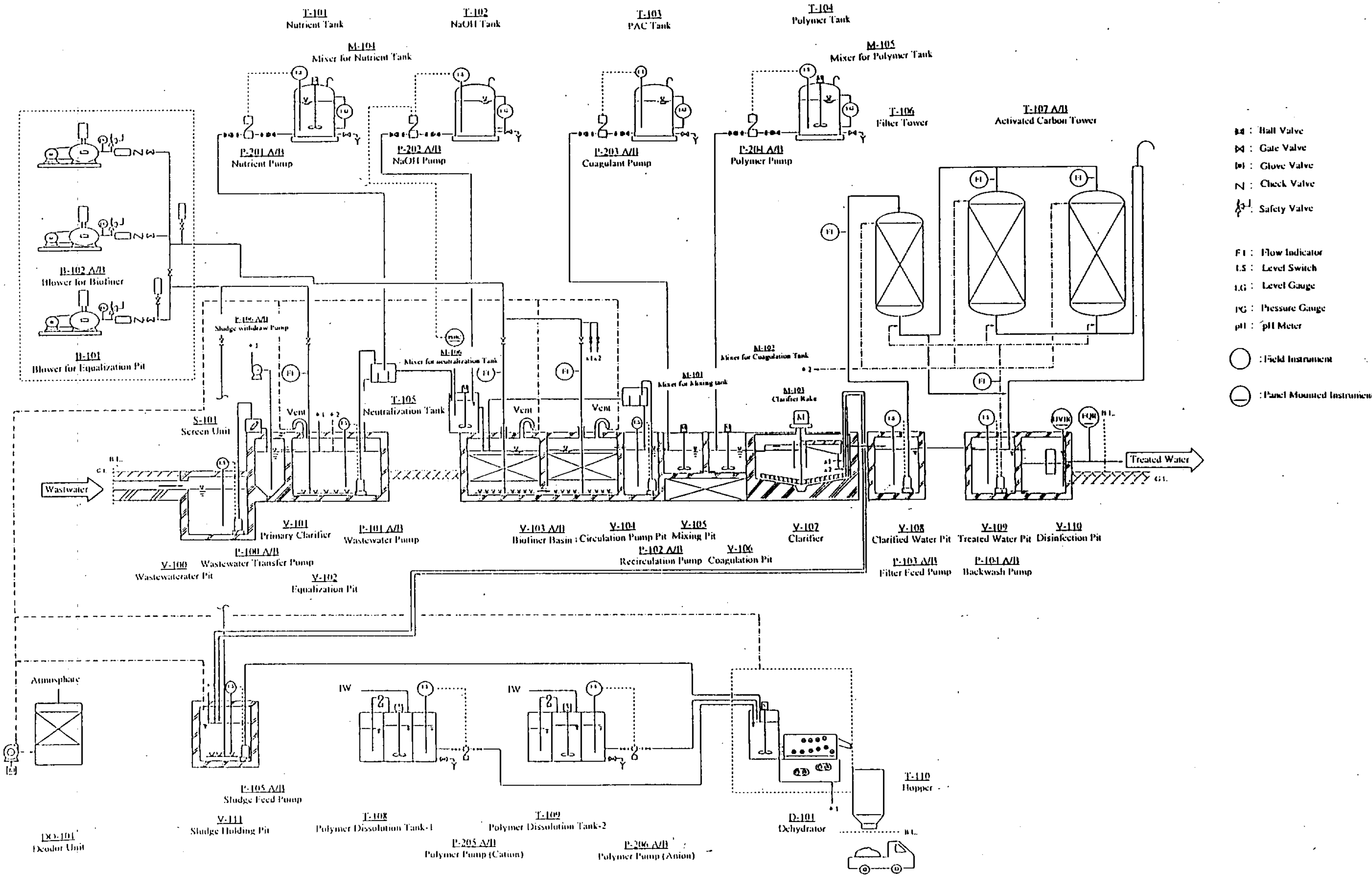


Figure 5-2 Wastewater Process Flow Diagram for Cake and Confectionery Processing Facility

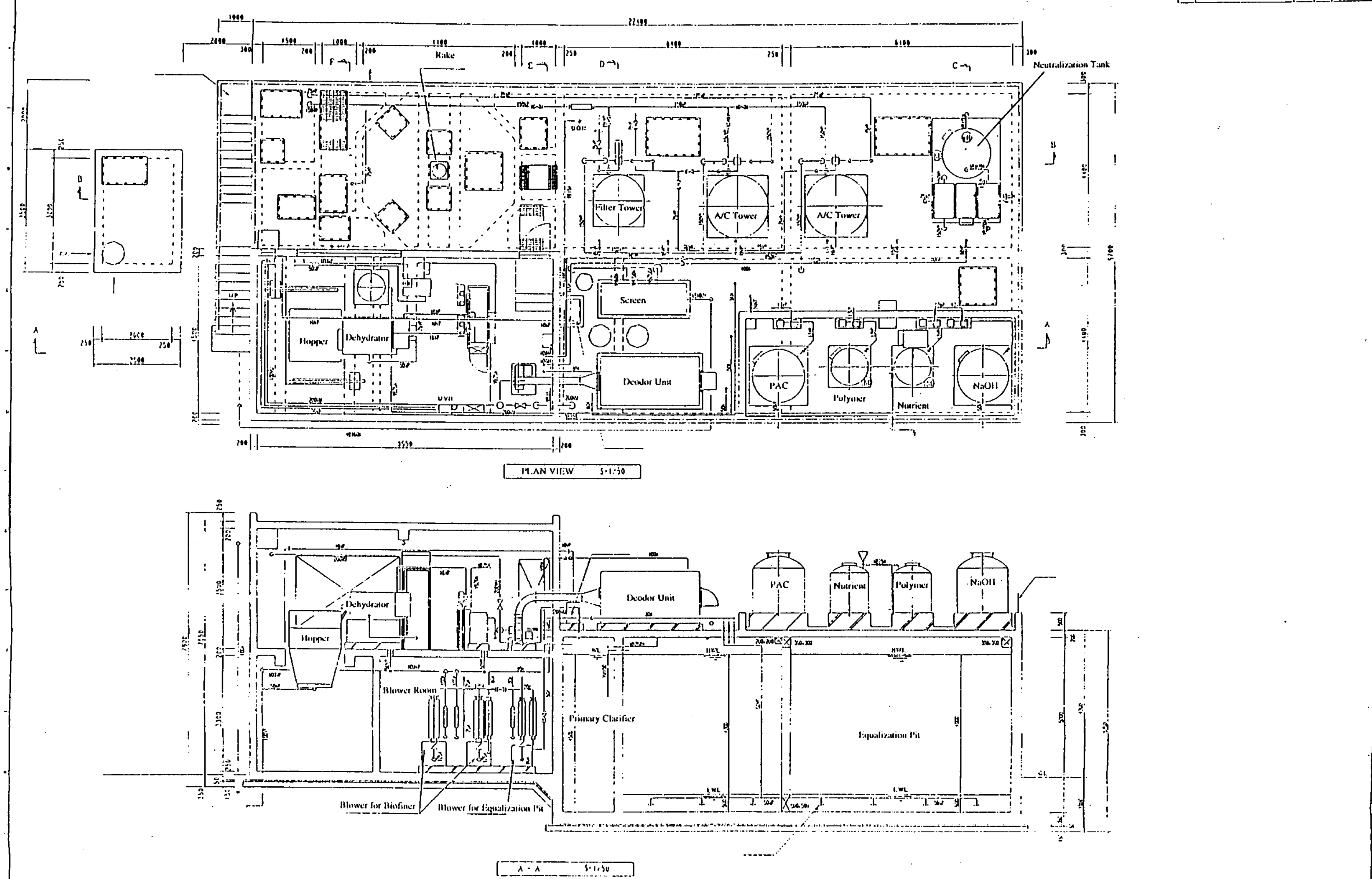


Figure 5-3 Plot Plan for Cake and Confectionery Processing Wastewater Facility

Equipment List for Food industry II

Equipment No.	Service	Number of	Type of Equipment	Size	Material	Remarks
V-100	Wastewaterater Pit	1	Rectangular	2,000W* 3,000L*800H, 4.8m^3	RC	
V-101	Primary Clarifier	1	Rectangular	1,500W*4,400L*4,500H, 29.7m^3	RC	
V-102	Equalization Pit	1	Rectangular	4,400W*6,400L*4,000H, 113m^3	RC	
V-103 A/B	Biofiner Basin	1	Rectangular	4,400W*4,600L*4,000H, 80m^3	RC	
V-104	Circulation Pump Pit	2	Rectangular	4,400W*6,400L*4,000H, 225m^3	RC	
V-105	Mixing Pit	1	Rectangular	1,000W*1,330L*3,500H, 7.7m^3	RC	
V-106	Coagulation Pit	1	Rectangular	1,000W*1,500L*2,500H, 3.75m^3	RC	
V-107	Clarifier	1	Rectangular	4,400W*4,400L*3,000H, 48m^3	RC	
V-108	Clarified Water Pit	1	Rectangular	1,000W*1,600L*2,900H, 4.6m^3	RC	
V-109	Treated Water Pit	1	Rectangular	1,500W*2,000L*4,000H, 12m^3	RC	
V-110	Disinfection Pit	1	Rectangular	1,000W*1,600L*3,600H, 7.93m^3	RC	
V-111	Sludge Holding Pit	1	Rectangular	1,500W*2,300L*4,500H, 14.9m^3	RC	
T-101	Nutrient Tank	1	Cylindrical	1,106ϕ*1,420H, 1m^3	PE	
T-102	NaOH Tank	1	Cylindrical	1,420ϕ*1,820H, 2m^3	PE	
T-103	PAC Tank	1	Cylindrical	1,420ϕ*1,820H, 2m^3	PE	
T-104	polymer Tank	1	Cylindrical	1,106ϕ*1,420H, 1m^3	PE	
T-105	Neutralization Tank	1	Cylindrical	1,420ϕ*1,820H, 2m^3	PE	
T-106	Filter Tower	1	Cylindrical	1,500ϕ*1,500H, 1.77m^3	SS + Tar Epoxy	
T-107 A/B	Activated Carbon Tower	2	Cylindrical	1,800ϕ*2,500H, 2.5m^3	SS + Tar Epoxy	
T-108	Polymer Dissolution Tank-1	1	Rectangular	500W*400L*500H	SUS	
T-109	Polymer Dissolution Tank-2	1	Rectangular	500W*400L*500H	SUS	
T-110	Hopper	1	Rectangular	1,500W*1,500L*1,000H, 2m^3	SS + Tar Epoxy	
P-100 A/B	Wastewater Transfer Pump	1+1	Centrifugal, Submergible	90 m^3/h * 10mH * 7.5kw	CS	
P-101 A/B	Wastewater Pump	1+1	Centrifugal, Submergible	12 m^3/h * 10mH * 1.5kw	CS	

1 / 2

Equipment List for Food industry II

Equipment No.	Service	Number of	Type of Equipment	Size	Material	Remarks
P-102 A/B	Recirculation Pump	1+1	Centrifugal, Submergible	21 m^3/h * 10mH * 1.5kw	CS	
P-103 A/B	Filter Feed Pump	1+1	Centrifugal, Submergible	12 m^3/h * 15mH * 2.2kw	CS	
P-104 A/B	Backwash Pump	1	Centrifugal, Submergible	150 m^3/h * 15mH * 11kw	CS	
P-105 A/B	Sludge Feed Pump	1+1	Centrifugal, Submergible	1.8 m^3/h * 10mH *0.75kw	CS	
P-106 A/B	Sludge withdraw Pump	1	Centrifugal, Holizontal	1.8 m^3/h * 10mH *1.5kw	CS	
P-201 A/B	Nutrient Pump	1+1	Diaphragm	60 cc/min. * 15 kg/cm^2 * 0.03kw	PVC	
P-202 A/B	NaOH Pump	1+1	Diaphragm	60 cc/min. * 15 kg/cm^2 * 0.03kw	PVC	
P-203 A/B	Coagulant Pump	1+1	Diaphragm	60 cc/min. * 15 kg/cm^2 * 0.03kw	PVC	
P-204 A/B	Polymer Pump	1+1	Diaphragm	60 cc/min. * 15 kg/cm^2 * 0.03kw	PVC	
P-205 A/B	Polymer Pump (Cation)	1+1	Diaphragm	720 cc/min. * 15 kg/cm^2 * 0.2kw	PVC	
P-206 A/B	Polymer Pump (Anion)	1+1	Diaphragm	720 cc/min. * 15 kg/cm^2 * 0.2kw	PVC	
M-101	Mixer for Mixing tank	1	Vertical	blade: 500mm, 120 rpm * 0.75kw	SUS	
M-102	Mixer for Coagulation Tank	1	Vertical	blade: 750mm, 62 rpm * 0.75kw	SUS	
M-103	Clarifier rake	1	Vertical	blade: 4,400mm, 0.1 rpm * 0.4kw	SUS	
M-104	Mixer for Nutrient Tank	1	Vertical	blade: 200mm, 375 rpm * 0.2kw	SUS	
M-105	Mixer for Polymer Tank	1	Vertical	blade: 250mm, 375rpm * 0.4kw	SUS	
M-106	Mixer for neutralization Tank	1	Vertical	blade: 250mm, 375rpm * 0.2kw	SUS	
B-101	Blower for Equalization Pit	1	Roots	2.5 $m^3/min.$ * 0.5 kg/cm^2 * 5.5kw	CS	
B-102 A/B	Blower for Biofiner	1+1	Roots	7.0 $m^3/min.$ * 0.5 kg/cm^2 * 11kw	CS	Invertor motor
D-101	Dehydrator	1	Filter Press	20 kg-Dry Solids/hr, 4.1 kw		
S-101	Screen Unit	1	Automatic	110m^3/h * 1 mm, 0.04kw		
DO-101	Deodor Unit	1		0.4kw		

5.2 Wastewater Treatment in the Textiles Industry

A textile finishing facility located in the southeastern United States. Plant activities include bleaching, dyeing, finishing, cutting, sewing, and screen printing of cotton broad-woven fabrics.

Wastewater to be treated

1) Boiler blowdown water
2) Cooling tower water
3) Slashing wastewater
4) Dyeing wastewater
5) Bleaching wastewater
6) Printing wastewater
7) Sanitary wastewater

Wastewater Flow Rate

1) Normal flow rate: 3,740 m^3/day (3,729 m^3/day processing wastewater; 11 m^3/day sanitary wastewater)
2) Maximum flow rate: 5,180 m^3/day

Factory Operation

24 hours/day

Wastewater Treatment Operation

24hours/day

Textile Water Quality Summary

	Raw wastewater	Treated Water Target	Discharge Regulation
pH	8.2 to 11.4	7.9 to 8.2	7.9 to 8.2
BOD (mg/l)	419 to 920	5.5	5.5
COD (mg/l)	2,095 to 3,460	148	148
SS (mg/l)	138 to 268	16	16
NH_3 (mg/l)	-	3	3
T-P (mg/l)	-	1.4	1.4

A dash indicates the information is not available.

Treatment Flow Scheme

Preliminary Treatment:	Screening, Neutralization, and Equalization
Primary Treatment:	Activated Sludge (oxidation ditch process)
Secondary Treatment:	Effluent Sand Filtration
Sludge Treatment:	Sludge Thickening

For detailed flow scheme, refer the attached flow diagram.

Design Parameters

Neutralization Unit:	Holding Time = 15 min.
Equalization Pit:	Holding Time = 8 hours
Biological Teatment:	Loading = 1.42 kg COD/m^3/day
Sludge Production:	Yield = 0.15
Mixing Tank:	Holding Time = 20 min.
Flocculation Tank:	Holding Time = 20 min.
Clarifier:	Surface Loading = 0.5 $m^3/m^2/h$
Sand Filter:	Hydraulic loading = 7.0 $m^3/m^2/h$
Back wash Pump:	Hydraulic loading = 21 $m^3/m^2/h$

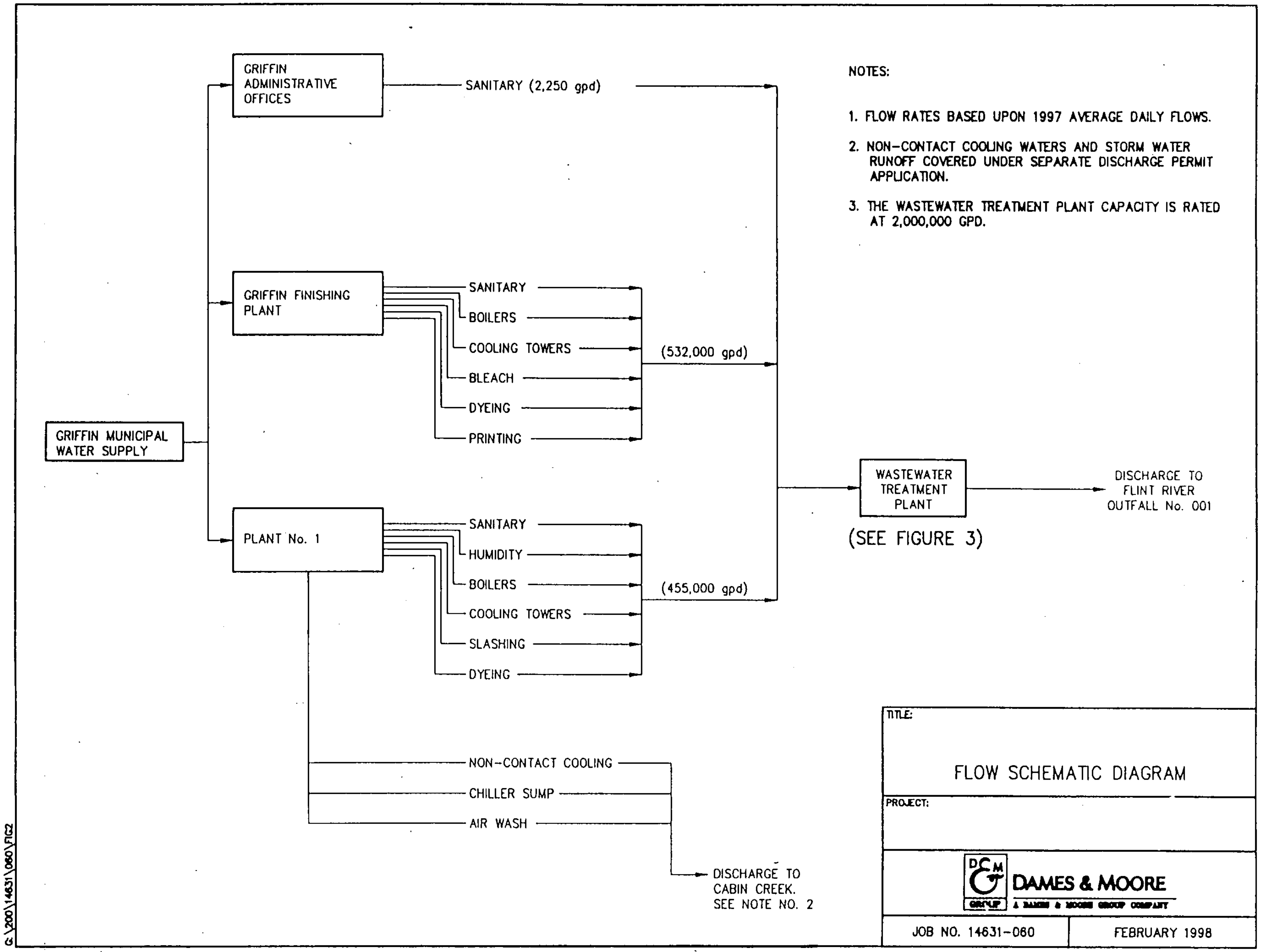


Figure 5-4 Wastewater Collection Flow Diagram for the Textile Industry

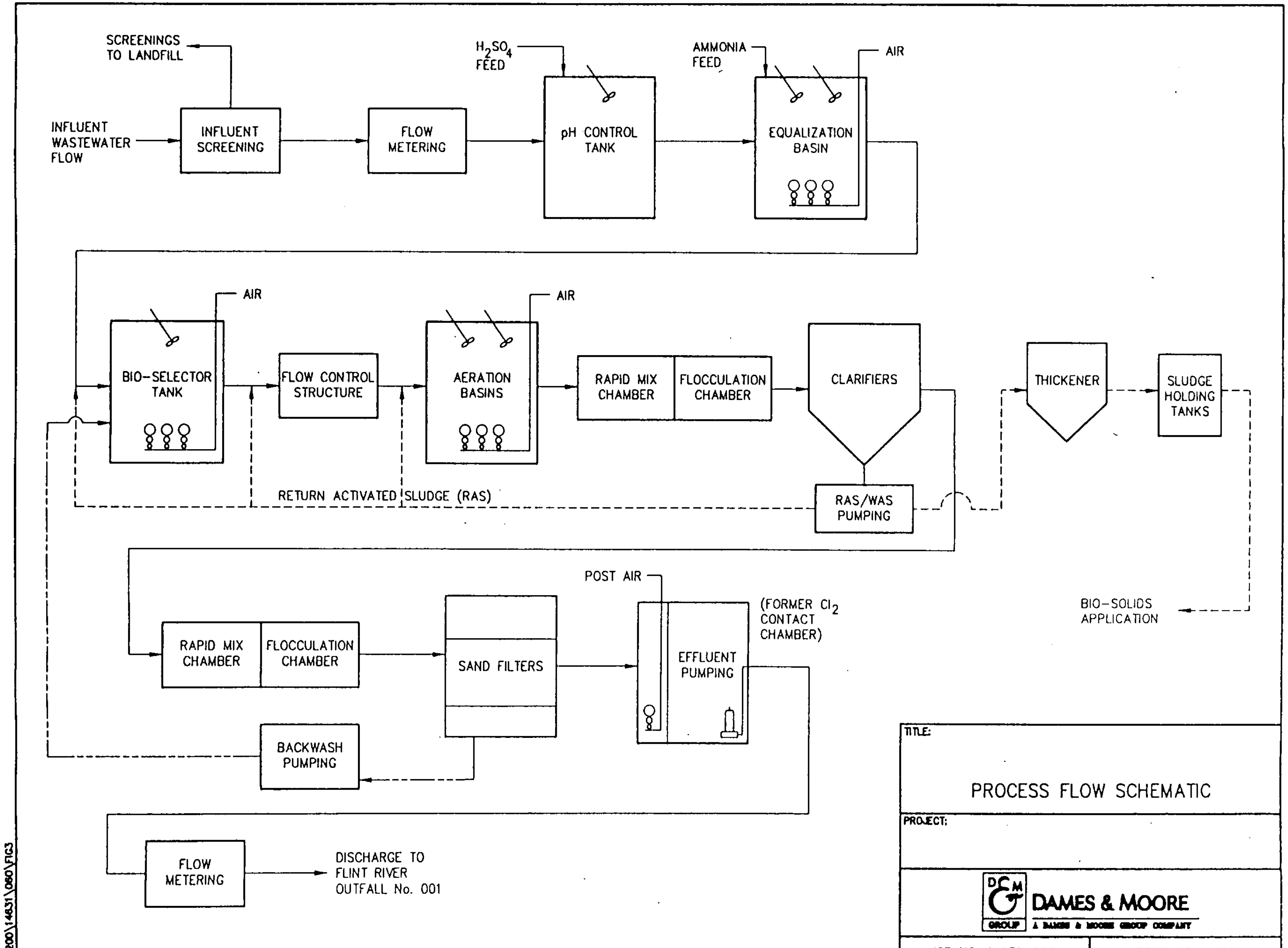


Figure 5-5 Process Flow Diagram for a Textile Wastewater Facility

5.3 Wastewater Treatment and Reuse in the Petroleum Industry

A natural gas sweetening facility in the western United States. Facility operations include removing H_2S from natural gas, which generates geologic formation water containing H_2S, oil and grease, and dissolved solids. Wastewater to be reused as boiler water make-up.

Wastewater to be treated

1) Geologic formation water
2) Boiler water blowdown

Wastewater Flow Rate

1) Normal flow rate: 560 m^3/day
2) Maximum flow rate: 560 m^3/day

Factory Operation

24 hours/day

Wastewater Treatment Operation

24hours/day

Gas Plant Water Quality Summary

	Raw wastewater	Treated Water Target	Discharge Regulation[a]
pH	3 to 8	6 to 8	6 to 8
BOD (mg/l)	1,100 to 1,300	< 20	< 20
COD (mg/l)	900 to 1,100	< 25	< 25
SS (mg/l)	100 to 200	< 5	< 5
TDS (mg/l)	1,500 to 2,000	< 10	< 10
Oil & Grease (mg/l)	25 to 60	< 2	< 2

a Water quality required for reuse in boiler system, not discharge

Treatment Flow Scheme

Preliminary Treatment:	Equalization and Aeration
Primary Treatment:	Dual-media, GAC, and cartridge filtration
Secondary Treatment:	Reverse Osmosis
Tertiary Treatment:	Ion Exchange
Sludge Treatment:	None

For detailed flow scheme, refer the attached flow diagrams.

Design Parameters

Equalization and Aeration:	Detention Time = 43 days
Dual Media Filtration:	Hydraulic Loading = 13.6 $m^3/m^2/h$
GAC Filtration:	Hydraulic Loading = 13.6 $m^3/m^2/h$
Reverse Osmosis:	Flow Rate = 265 lpm at 3,450 kPa
Ion Exchange:	Hydraulic Loading = 13.6 $m^3/m^2/h$
RO Back wash Pump:	Flow Rate = 1,020 lpm at 6.1 m head

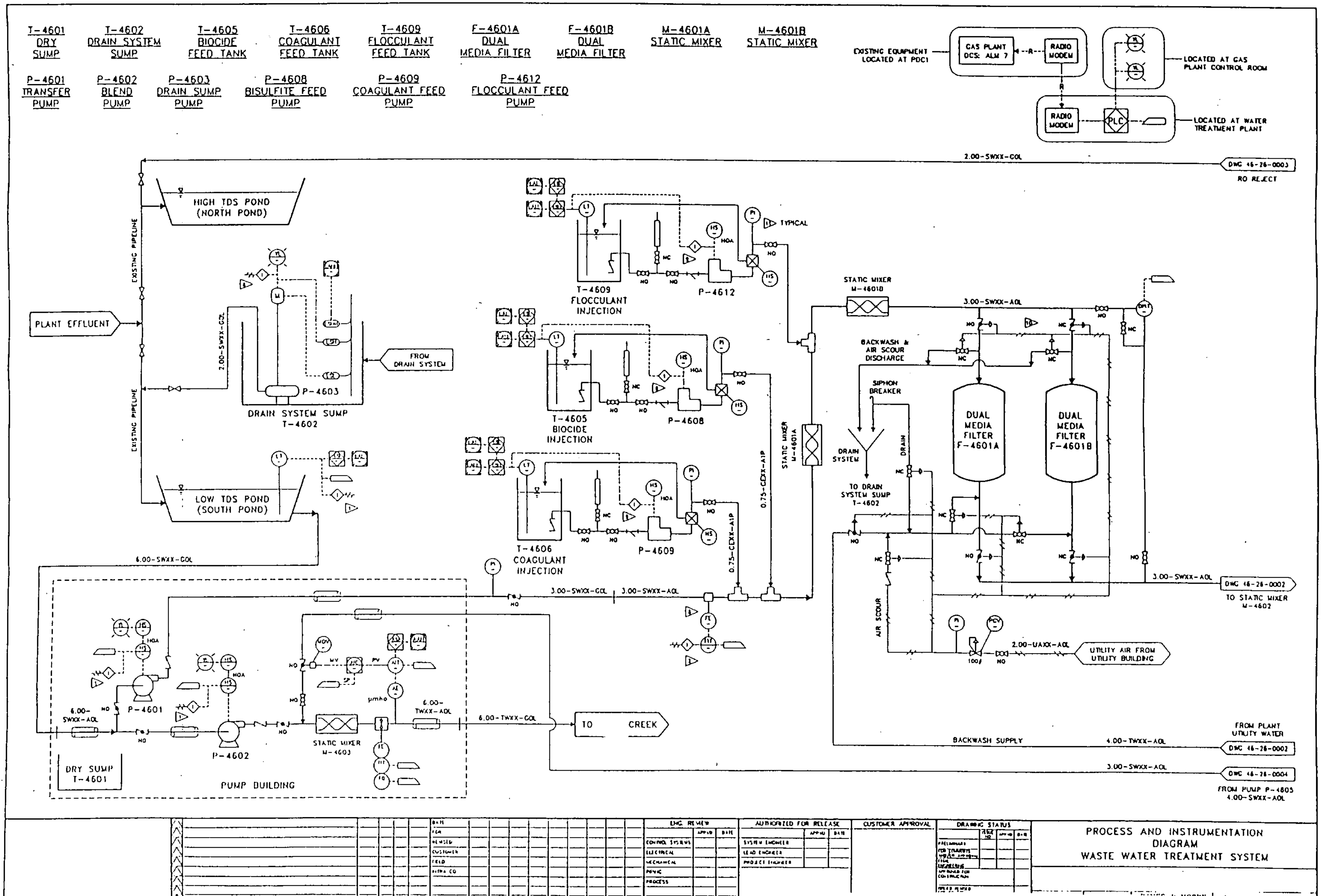
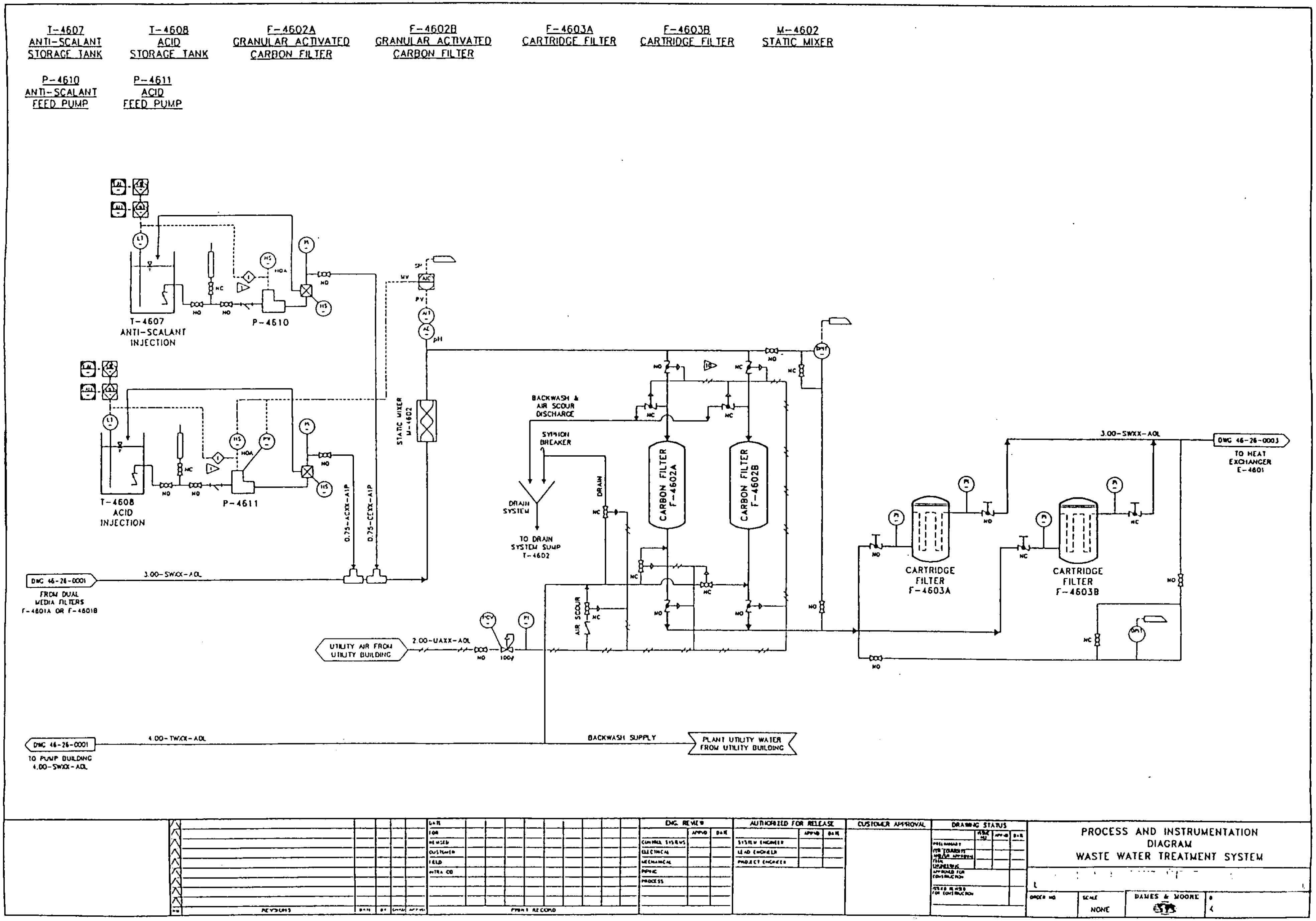
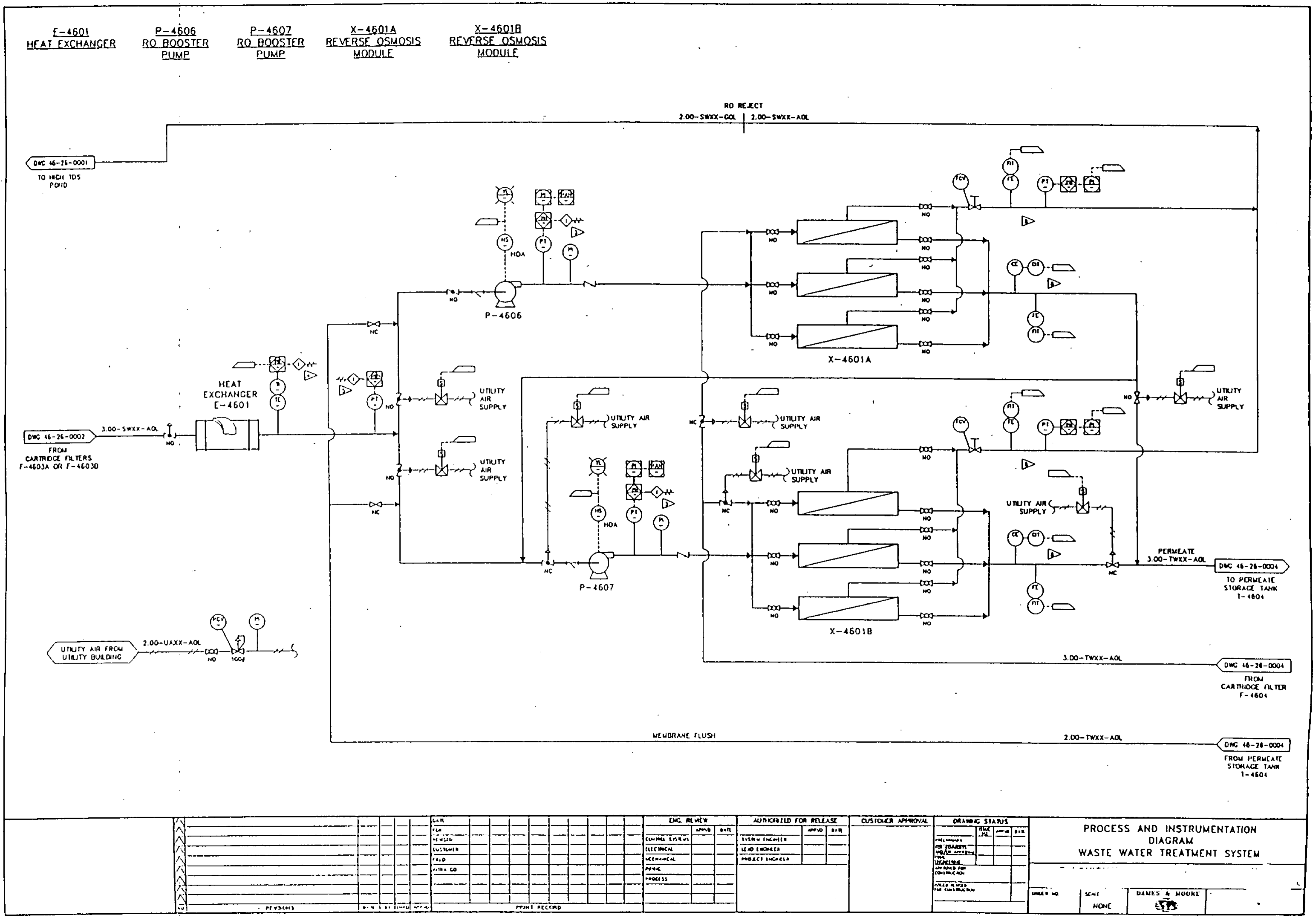


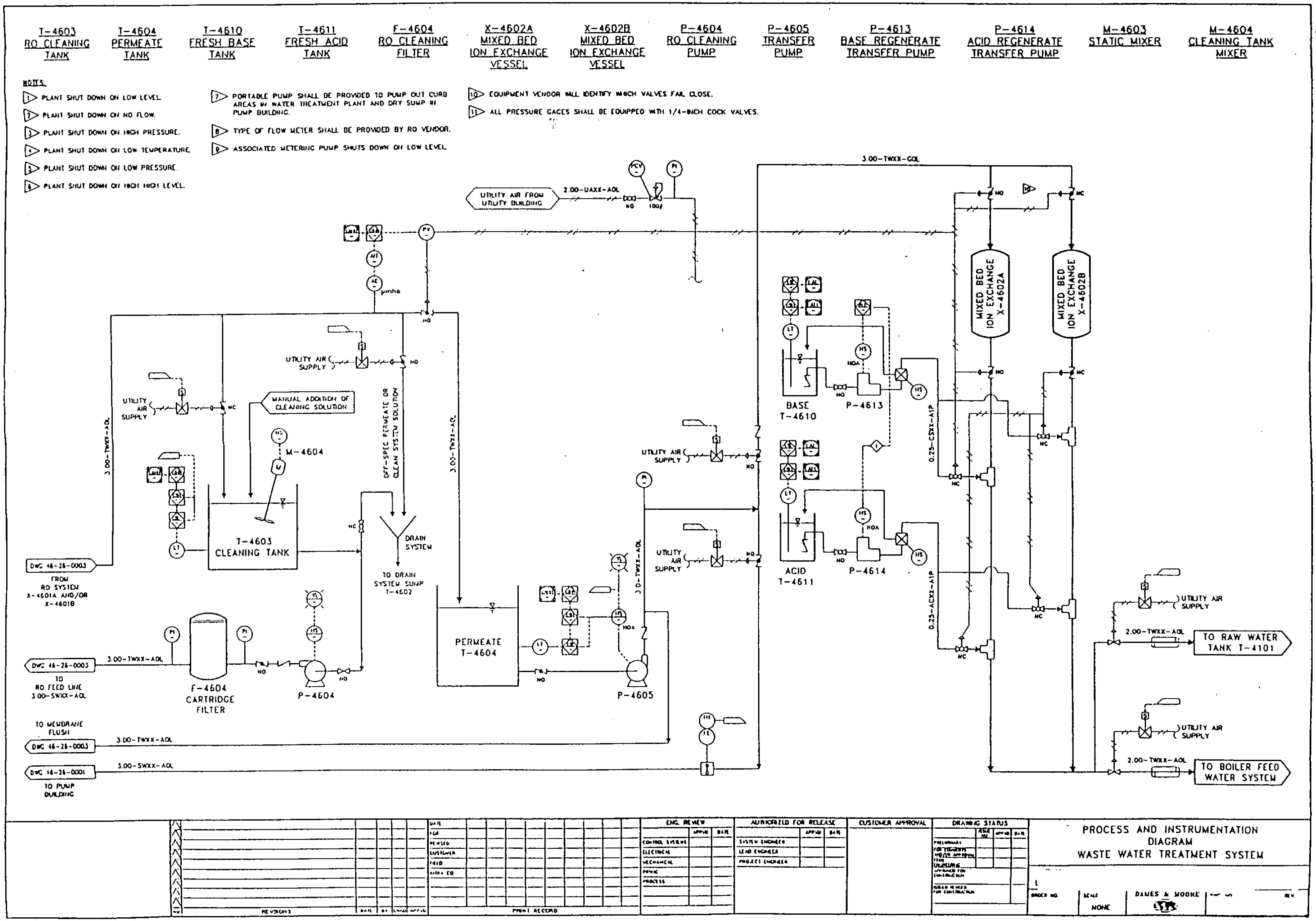
Figure 5-6 P&ID for Wastewater Treatment and Reuse in the Petroleum Industry



T-4607
ANTI-SCALANT
STORAGE TANK
T-4608
ACID
STORAGE TANK
F-4602A
GRANULAR ACTIVATED
CARBON FILTER
F-4602B
GRANULAR ACTIVATED
CARBON FILTER
F-4603A
CARTRIDGE FILTER
F-4603B
CARTRIDGE FILTER
M-4602
STATIC MIXER
P-4610
ANTI-SCALANT
FEED PUMP
P-4611
ACID
FEED PUMP
T-4607
ANTI-SCALANT
INJECTION
P-4610
T-4608
ACID
INJECTION
P-4611
0.75-ACXX-A1P
0.75-CEXX-A1P
STATIC MIXER
M-4602
DWG 46-26-0001
FROM DUAL
MEDIA FILTERS
F-4601A OR F-4601B
3.00-SWXX-AOL
BACKWASH &
AIR SCOUR
DISCHARGE
SYPHON
BREAKER
DRAIN
SYSTEM
TO DRAIN
SYSTEM SUMP
T-4602
DRAIN
AIR SCOUR
CARBON FILTER
F-4602A
CARBON FILTER
F-4602B
UTILITY AIR FROM
UTILITY BUILDING
2.00-UAXX-AOL
CARTRIDGE
FILTER
F-4603A
CARTRIDGE
FILTER
F-4603B
3.00-SWXX-AOL
DWG 46-26-0003
TO HEAT
EXCHANGER
E-4601
DWG 46-26-0001
TO PUMP BUILDING
4.00-SWXX-AOL
4.00-TWXX-AOL
BACKWASH SUPPLY
PLANT UTILITY WATER
FROM UTILITY BUILDING
PROCESS AND INSTRUMENTATION
DIAGRAM
WASTE WATER TREATMENT SYSTEM
DAMES & MOORE
SCALE
NONE



E-4601
HEAT EXCHANGER
P-4606
RO BOOSTER PUMP
P-4607
RO BOOSTER PUMP
X-4601A
REVERSE OSMOSIS MODULE
X-4601B
REVERSE OSMOSIS MODULE
RO REJECT
2.00-SWXX-GOL
2.00-SWXX-AOL
DWG 46-26-0001
TO HIGH TDS POND
DWG 46-26-0002
FROM CARTRIDGE FILTERS F-4603A OR F-4603B
3.00-SWXX-AOL
HEAT EXCHANGER E-4601
UTILITY AIR SUPPLY
P-4606
P-4607
HOA
X-4601A
X-4601B
PERMEATE
3.00-TWXX-AOL
DWG 46-26-0004
TO PERMEATE STORAGE TANK T-4604
3.00-TWXX-AOL
DWG 46-26-0004
FROM CARTRIDGE FILTER F-4604
MEMBRANE FLUSH
2.00-TWXX-AOL
DWG 46-26-0004
FROM PERMEATE STORAGE TANK T-4604
UTILITY AIR FROM UTILITY BUILDING
2.00-UAXX-AOL
ENG. REVIEW
AUTHORIZED FOR RELEASE
CUSTOMER APPROVAL
DRAWING STATUS
PRINT RECORD
REVISIONS
PROCESS AND INSTRUMENTATION DIAGRAM
WASTE WATER TREATMENT SYSTEM
SCALE
NONE
DAMES & MOORE


T-4603 RO CLEANING TANK
T-4604 PERMEATE TANK
T-4610 FRESH BASE TANK
T-4611 FRESH ACID TANK
F-4604 RO CLEANING FILTER
X-4602A MIXED BED ION EXCHANGE VESSEL
X-4602B MIXED BED ION EXCHANGE VESSEL
P-4604 RO CLEANING PUMP
P-4605 TRANSFER PUMP
P-4613 BASE REGENERATE TRANSFER PUMP
P-4614 ACID REGENERATE TRANSFER PUMP
M-4603 STATIC MIXER
M-4604 CLEANING TANK MIXER
NOTES
1 PLANT SHUT DOWN ON LOW LEVEL.
2 PLANT SHUT DOWN ON NO FLOW.
3 PLANT SHUT DOWN ON HIGH PRESSURE.
4 PLANT SHUT DOWN ON LOW TEMPERATURE.
5 PLANT SHUT DOWN ON LOW PRESSURE.
6 PLANT SHUT DOWN ON HIGH HIGH LEVEL.
7 PORTABLE PUMP SHALL BE PROVIDED TO PUMP OUT CURB AREAS IN WATER TREATMENT PLANT AND DRY SUMP IN PUMP BUILDING.
8 TYPE OF FLOW METER SHALL BE PROVIDED BY RO VENDOR.
9 ASSOCIATED METERING PUMP SHUTS DOWN ON LOW LEVEL.
10 EQUIPMENT VENDOR WILL IDENTIFY WHICH VALVES FAIL CLOSE.
11 ALL PRESSURE GAGES SHALL BE EQUIPPED WITH 1/4-INCH COCK VALVES.
UTILITY AIR FROM UTILITY BUILDING
2.00-UAXX-AOL
3.00-TWXX-COL
MIXED BED ION EXCHANGE X-4602A
MIXED BED ION EXCHANGE X-4602B
UTILITY AIR SUPPLY
MANUAL ADDITION OF CLEANING SOLUTION
M-4604
OFF-SPEC PERMEATE OR CLEAN SYSTEM SOLUTION
3.00-TWXX-AOL
T-4603 CLEANING TANK
DRAIN SYSTEM
TO DRAIN SYSTEM SUMP T-4602
BASE T-4610
P-4613
ACID T-4611
P-4614
0.25-CSXX-AIP
0.25-ACXX-AIP
DWG 46-26-0003 FROM RO SYSTEM X-4601A AND/OR X-4601B
DWG 46-26-0003 TO RO FEED LINE 3.00-SWXX-AOL
F-4604 CARTRIDGE FILTER
P-4604
PERMEATE T-4604
P-4605
TO MEMBRANE FLUSH
DWG 46-26-0003
3.00-SWXX-AOL
DWG 46-26-0001 TO PUMP BUILDING
2.00-TWXX-AOL
TO RAW WATER TANK T-4101
TO BOILER FEED WATER SYSTEM
REVISIONS
PRINT RECORD
ENG. REVIEW
AUTHORIZED FOR RELEASE
CUSTOMER APPROVAL
DRAWING STATUS
PROCESS AND INSTRUMENTATION DIAGRAM
WASTE WATER TREATMENT SYSTEM
SCALE NONE
DAMES & MOORE

5.4 Wastewater Treatment in the Steel Industry

A finish hot-rolled steel manufacturing facility located in the southeastern United States.

Wastewater to be treated

1) Contact cooling water from metal rolling, cutting, and forming operations
2) Miscellaneous utility wash water

Wastewater Flow Rate

1) Average flow rate: 32 m^3/day
2) Maximum flow rate: 2 m^3/hour, one time per day

Factory Operation

0700 to 1800

Wastewater Treatment Operation

8 hours/day

Steel Rolling Mill Water Quality

	Raw wastewater	Treated Water Target	Discharge Regulation
PH	7.5 to 9	6 to 9	6 to 11
BOD (mg/l)	40 to 80	30	30
Oil & Grease (mg/l)	25 to 40	< 30	30
SS (mg/l)	50 to 150	< 10	30
Ni (mg/l)	8 to 15	0.05	0.05
NH_3 (mg/l)	5 to 10	0.5	0.5
Zinc (mg/l)	10 to 20	0.015	0.015

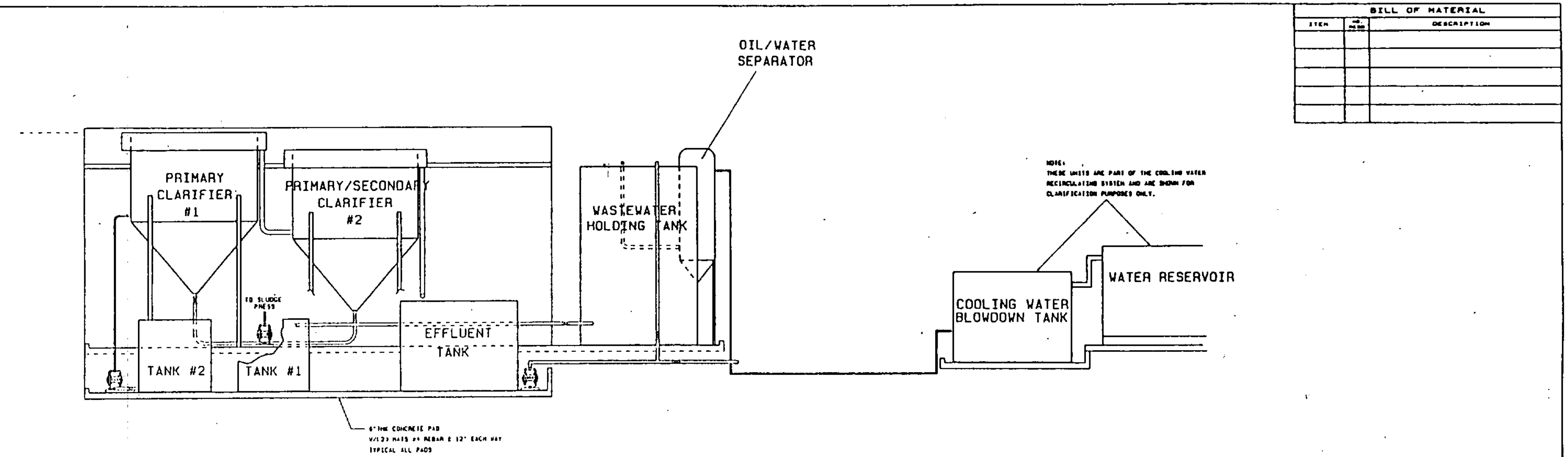
Treatment Flow Scheme

Preliminary Treatment:	Oil/Water Sepataion, Equalization
Primary Treatment:	Chemical Precipitation, coagulation, flocculation
Secondary Treatment:	Two-stage clarification
Sludge Treatment:	Plate & Frame Press

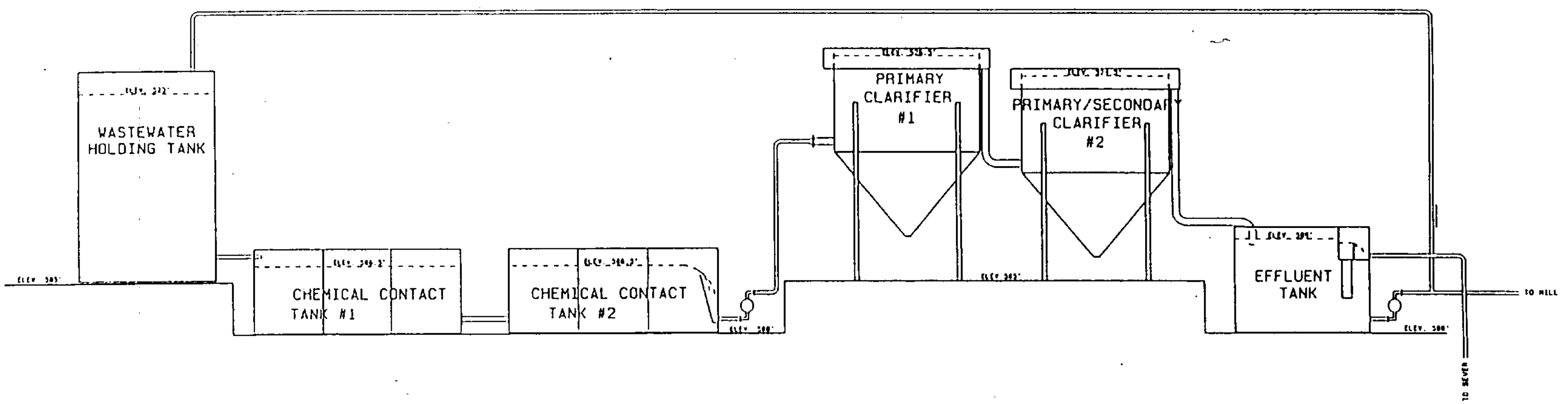
For detailed flow scheme, refer the attached flow diagram.

Design Parameters

Equalization Tank:	Holding Time = 1.8 hours
Coagulation/flocculation:	Reaction Time = 2.5 hours
Primary Clarifier:	Surface Loading = 1.3 $m^3/m^2/h$
Secondary Clarifier:	Surface Loading = 1.3 $m^3/m^2/h$



ELEVATION VIEW



HYDRAULIC GRADIENT ELEVATIONS

Figure 5-7 Wastewater Treatment Diagram for Steel Industry

BILL OF MATERIAL		
ITEM	NO. REQD	DESCRIPTION

LEGEND:

P-1, P-2, P-3, P-4 } SANDPIPER DIAPHRAM PUMPS #SB-2-A TM-2CI
BF --- BUTTERFLY VALVES
BALL --- BALL VALVES
PLUG --- 4"PLUG VALVE
SV --- 6"SQUEEZE VALVE
MAN --- MANUAL VALVE
AUTO --- AUTOMATIC CONTROLLED VALVE
LC-1 --- LEVEL CONTROL
SIGNET ULTRASONIC MODEL 121X
HIGH/LOW CONTROL
LC-2 --- LEVEL CONTROL
SIGNET ULTRASONIC
LOW/HIGH/HIGH CONTROL
FM --- ISCO MODEL 3210
ULTRASONIC FLOW METER/RECORDER
PH-1, PH-2 } PH SENSOR/CONTROLLER
SIGNET #MK-712 SENSOR
SIGNET #MK-710 CONTROLLER
MP-1, MP-2, MP-3, MP-4, MP-5 } METERING PUMPS
CW --- CITY WATER

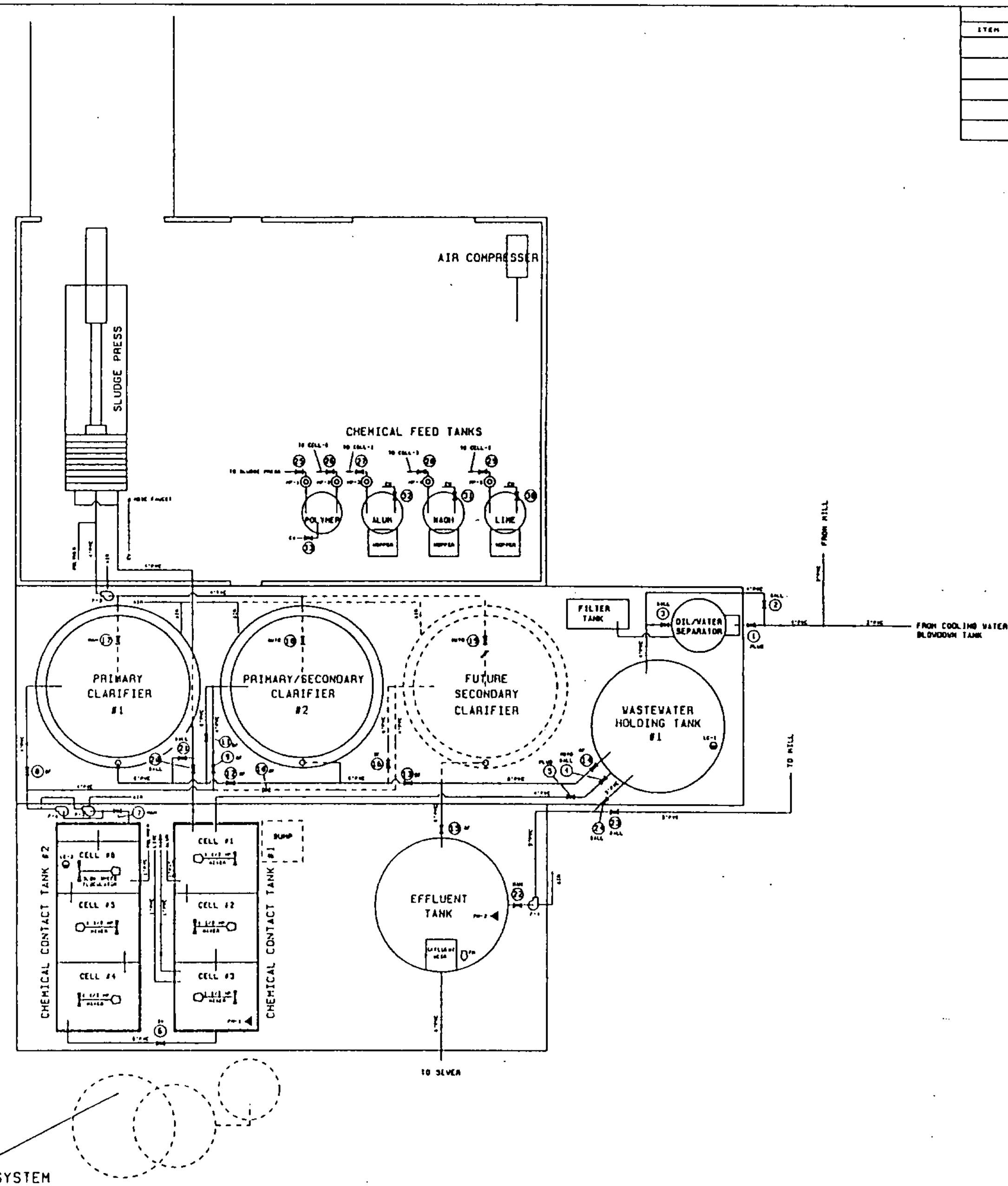


Figure 5-8 Plot Plan for Steel Industry Wastewater Facility

5.5 General Manufacturing Wastewater Case Study

An automobile parts manufacturing facility located in the mid-western United States. Wastewater is generated from paint electro-coating, copper coil manufacturing, and aluminum coil manufacturing.

Wastewater to be treated

1) Electro-coat wastewater
2) Flux braze wastewater

Wastewater Flow Rate

1) Normal flow rate: 280 m^3/Day (electro-coat processing wastewater = 76 m^3/day; flux braze wastewater = 204 m^3/day)
2) Maximum flow rate: 204 m^3/day

Factory Operation

16 hours/day

Wastewater Treatment Operation

19 hours/day

General Manufacturing Water Quality

	Raw wastewater	Treated Water Target	Discharge Regulation
pH (-)	1.5 to 9.1	5.5 to 9	5.5 to 10
SS (mg/l)	100 to 2,100	< 300	300
Oil & Grease (mg/l)	2 to 50	< 100	100
Chromium (mg/l)	0.02 to 5.4	1.20	1.20
Copper (mg/l)	0.05 to 5.42	0.50	0.50
Lead (mg/l)	0.01 to 0.66	0.22	0.22
Nickel (mg/l)	0.02 to 0.21	1.67	1.67
Zinc (mg/l)	110 to 1,050	1.04	1.04

Treatment Flow Scheme

Preliminary Treatment:	Equalization and Primary Clarification (clarification for alkaline concentrates only)
Primary Treatment:	Coagulation/flocculation and Clarification
Secondary Treatment	Clarifier Effluent Polishing Filtration
Tertiary Treatment:	Ion Exchange
Sludge Treatment:	Thickening and Plate & Frame Press

For detailed flow scheme, refer the attached flow diagram.

Design Parameters

Equalization Unit:	Holding Time = 12 hours
Coagulation/flocculation:	Reaction time = 30 minutes, both tanks
Secondary Clarification:	Hydraulic Loading = 0.66 $m^3/m^2 \bullet hr$
Effluent Polishing:	Hydraulic Loading = 9.7 $m^3/m^2 \bullet hr$
Ion Exchange:	Hydraulic Loading = 4.85 $m^3/m^2 \bullet hr$
PrimarySludge Production:	83 m^3/day at 0.5% solids
Thickened Sludge:	27 m^3/day at 1.5% solids
Sludge Press:	16 m^3/day at 2.5% solids

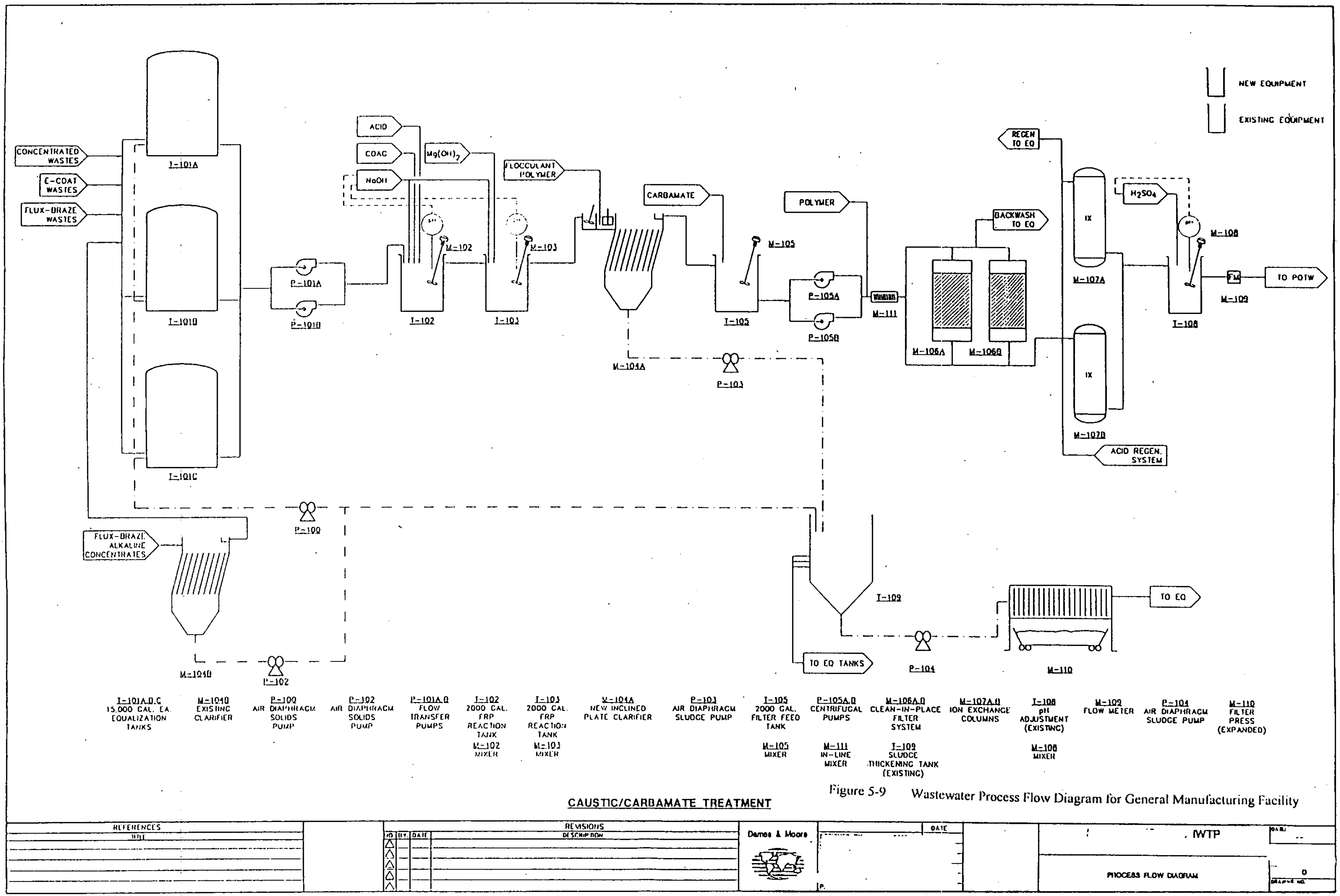
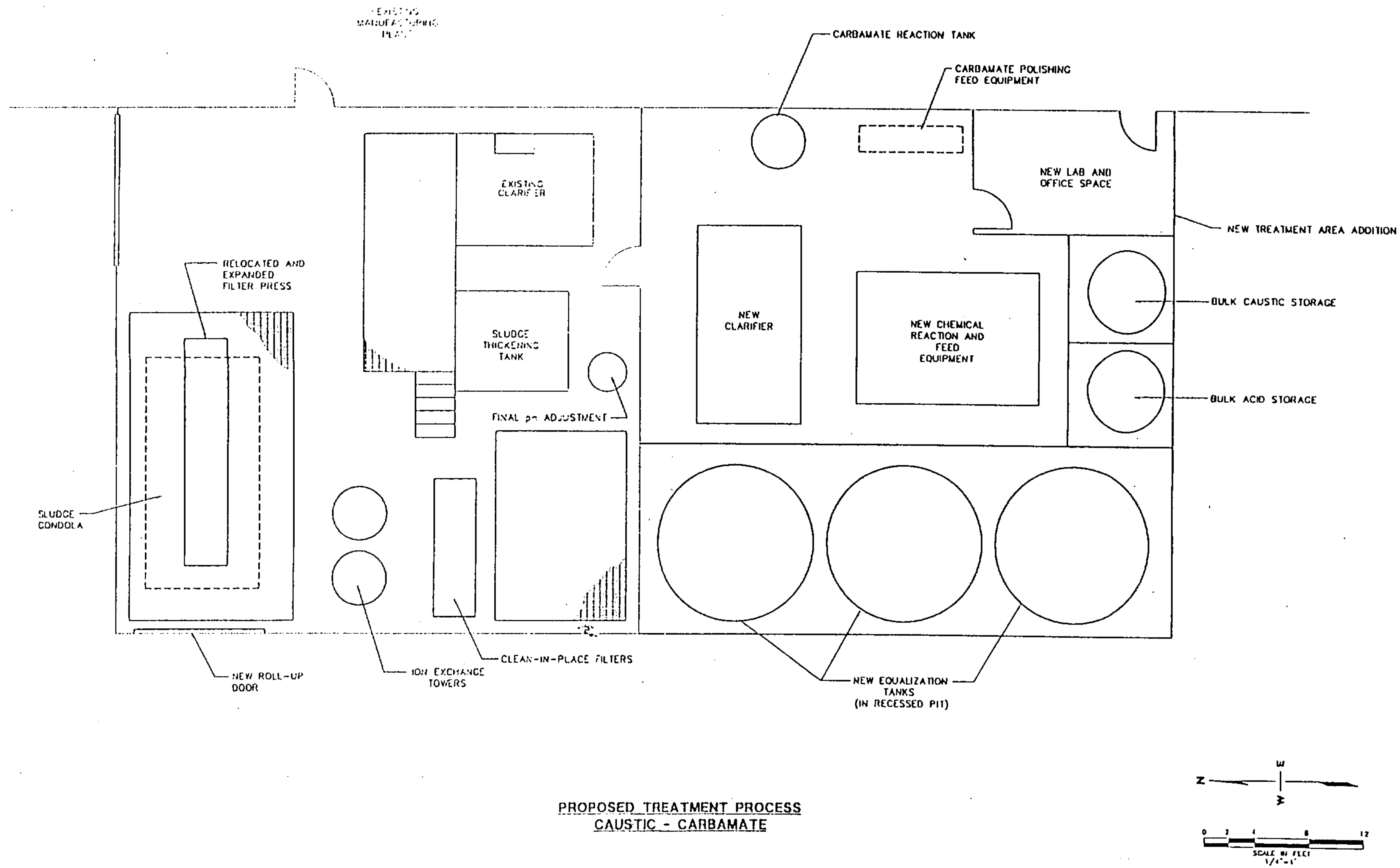


Figure 5-9 Wastewater Process Flow Diagram for General Manufacturing Facility



PROPOSED TREATMENT PROCESS
CAUSTIC - CARBAMATE

Figure 6.4

REFERENCES	REVISIONS	Dames & Moore	Figure 5-10 Plot Plan for General Manufacturing Wastewater Facility
TITLE	NO BY DATE DESCRIPTION		EQUIPMENT ARRANGEMENT PLAN

6.0 REFERENCES

ASCE Manual and Report on Engineering Practice No. 76, 1992, Design of Municipal Wastewater Treatment Plants, pp. 79 and 681.

Degremont, Water Treatment Handbook, 1991

Great Lakes-Upper Mississippi River Board of State Sanitary Engineers: Recommended Standards for Sewage Works (*Ten States Standards*), 1978.

W. W. Eckenfelder, Jr., Industrial Water Pollution Control 2nd Edition, McGraw-Hill, 1989

Metcalf & Eddy, Inc.,1991, Wastewater Engineering: Treatment Disposal Reuse.

The Nalco Water Handbook 2nd edition, McGraw-Hill, 1987.

Viessman, W., and M.J. Hammer, Water Supply and Pollution Control, 4th Edition, Harper & Row Publishers, 1985.

Yousui-Haisui Binran 2nd edition (in Japanese)

Appendix

- Glossary
- Potentially useful websites
- Relationship between metals solubility and pH
- Solubility Product of Metal Hydroxide
- Summary of carbon Adsorption Capacities
- Chemical Property of Wastewater Treatment Chemicals
- Figure for Line Sizing
- Pressure Drop by Piping Components
- Reference for Material Selection

Source: Nalco Water Handbook 2nd Edition
McGraw-Hill Book Company 1987

GLOSSARY

Absorption: Assimilation of molecules or other substances into the physical structure of a liquid or solid without chemical reaction.

Acidity: Theoretically, in water, an excess of H^+ ions over OH^- ions that occurs at a pH below 7. In water analysis, an excess of H^+ ions that is measurable by titration where the pH is less than 4.2 to 4.4, where M alkalinity disappears (at the methyl orange endpoint).

Activated sludge: An aerobic biological process for conversion of soluble organic matter to solid biomass, removable by gravity or filtration.

Adsorption: Physical adhesion of molecules or colloids to the surfaces of solids without chemical reaction.

Aerobic organism: An organism that requires oxygen for its respiration.

Aerosol: A colloidal system involving liquid or solid particulates dispersed in air.

Agglomerate: To gather fine particulates together into a larger mass.

Algae: Simple plants containing chlorophyll. Many are microscopic, but under conditions favorable for their growth they grow in colonies and produce mats and similar nuisance masses.

Alkalinity: By definition, total alkalinity (also called M alkalinity) is that which will react with acid as the pH of the sample is reduced to the methyl orange endpoint—about pH 4.2. Another significant expression is P alkalinity, which exists above pH 8.2 and is that which reacts with acid as the pH of the sample is reduced to 8.2.

Amphoteric: Capable of reacting in water either as a weak acid or as a weak base. For example, aluminum salts hydrolyze in water to produce a compound that may be considered a weak base, $Al(OH)_3$, or a weak acid, H_3AlO_3. A property of certain oxides makes them reactive both with acids and bases. Al_2O_3 is an example:

1. $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$
2. $Al_2O_3 + 2NaOH \rightarrow Na_2Al_2O_4 + H_2O$

Anaerobic organism: An organism that can thrive in the absence of oxygen.

Anion: A negatively charged ion resulting from dissociation of salts, acids, or alkalies in aqueous solution.

Anionic: The condition of a polymer, colloid, or large particle having exchangeable cations on its surface and an opposite, negative charge on the substrate.

Anode: In electrolysis or electrochemical corrosion, a site where metal goes into solution as a cation leaving behind an equivalent of electrons to be transferred to an opposite electrode, called a cathode.

Anodizing: The treatment of a metal surface whereby the metal is made anodic.

API gravity: An index of specific gravity defined by the American Petroleum Institute.

API separator: A simple gravity separator meeting the design standards of the American Petroleum Institute for separation of oil and solids from wastewater.

Aquifier: A porous, subsurface geological structure carrying or holding water, such as a well.

Avogadro's number: The number of molecules in a gram-molecular weight of any substance, 6.02×10^{23}.

Bacteria: Microscopic single-cell plants which reproduce by fission or by spores, identified by their shapes: coccus, spherical; bacillus, rod-shaped; and spirillum, curved.

Base: An alkaline substance.

Biocide: A chemical used to control the population of troublesome microbes.

Biota: All living organisms of a region or system.

Black liquor: Kraft cooking liquor recovered from brown stock washers in the pulp mill.

Blast furnace: A furnace producing iron from ore by reduction wtih coke.

Blowdown: The withdrawal of water from an evaporating water system to maintain a solids balance within specified limits of concentration of those solids.

Blowpit: The vessel receiving cooked wood pulp from the digester.

BOD: Biochemical oxygen demand of a water, being the oxygen required by bacteria for oxidation of the soluble organic matter under controlled test conditions.

Broke: Trim or excess sheet from paper manufacture returned to a pulping device for recovery.

BS&W (bottom sediment and water): A measure of oil quality based on the volume percent of sediment and water that can be centrifuged from a sample.

Buffer: A substance in solution which accepts hydrogen ions or hydroxyl ions added to the solution as acids or alkalies, minimizing a change in pH.

Bulk density: The measured density/volume ratio for a solid including or not corrected for the voids contained in the bulk of material, in lb/ft^3 or kg/m^3.

Bulking: Production of a light, fluffy biomass, usually due to the presence of filamentous organisms.

Cake: A term applied to a dewatered residue from a filter, centrifuge, or other dewatering device.

Carbonate hardness: That hardness in a water caused by bicarbonates and carbonates of calcium and magnesium. If alkalinity exceeds total hardness, all hardness is carbonate hardness; if hardness exceeds alkalinity, the carbonate hardness equals the alkalinity.

Carryover: The presence of boiler water in steam caused by foaming or entrainment.

Catalysis: Addition of a material (catalyst) that does not take a direct part in a chemical reaction but increases the rate of the reaction.

Cathode: In electrolysis or electrochemical corrosion, a site on a surface where cations in solution are neutralized by electrons to become elements that either plate out on the surface or react with water to produce a secondary reaction.

Cation: A positively charged ion resulting from dissociation of molecules in solution.

Cationic: The condition of a polymer, colloid, or large particle having exchangeable anions on its surface and an opposite, positive charge on the substrate.

Caustic soda: A common water treatment chemical, sodium hydroxide (lye).

Centrate: The liquid remaining after removal of solids as a cake in a centrifuge.

Chelating agents: Organic compounds having the ability to withdraw ions from their water solutions into soluble complexes.

Coagulation: The neutralization of the charges on colloidal matter (sometimes also considered to be flocculation).

Coalescence: The gathering together of coagulated colloidal liquid particles into a single continuous phase.

COD: Chemical oxygen demand, a measure of organic matter and other reducing substances in water.

Coliform bacteria: Bacteria found in the intestinal tract of warm-blooded animals and used as indicators of pollution if found in water.

Colloids: Matter of very fine particle size, usually in the range of 10^{-5} to 10^{-7} cm in diameter.

Concentration: The process of increasing the dissolved solids per unit volume of solution, usually by evaporation of the liquid; also, the amount of material dissolved in a unit volume of solution.

Concentration cell: The connection of two solutions of the same composition but different concentrations by a metal conductor to produce current flow through the circuit.

Concentration ratio: In an evaporating water system, the ratio of the concentration of a specific substance in the makeup to its concentration in the evaporated water, usually measured in the blowdown.

Condensate: Water obtained by evaporation and subsequent condensation.

Conduction: The transfer of heat through a body by molecular motion.

Conductivity: The ability of a substance to conduct heat or electricity. Electrical conductivity is usually expressed in microsiemans per centimeter.

Connate water: Fossil water produced with oil.

Consistency: In the pulp/paper industry, a term for the density in percent by weight dry matter, of a slurry of pulp.

Contaminant: Any foreign component present in another substance; e.g., anything in water that is not H_2O is a contaminant.

Convection: The transfer of heat through a fluid by circulating currents.

Coordinated phosphate: A boiler treatment scheme using phosphate buffers to avoid the presence of hydroxyl alkalinity.

Cracking: An oil-refining process that breaks large molecules into smaller ones.

Critical pressure: The pressure at the critical temperature above which the fluid no longer has the properties of a liquid, regardless of further increase in pressure.

Cupola: A furnace for melting scrap or pig iron with coke.

Cycles of concentration: Concentration ratio.

Dealkalization: Any process for reducing the alkalinity of water.

Decantation: An elutriation process, where the supernatant liquor contains recoverable leaching chemical.

Deinking: The process of removing ink from secondary fibers.

Deionization: Any process removing ions from water, but most commonly an ion exchange process where cations and anions are removed independently of each other.

Demineralization: Any process used to remove minerals from water; however, commonly the term is restricted to ion exchange processes.

Desalination: The removal of inorganic dissolved solids from water.

Desalting: The removal of salt from crude oil.

Detackify: Treatment of solids from a paint spray booth to eliminate their sticky properties.

Dewater: To separate water from sludge to produce a cake that can be handled as a solid.

Dialysis: A separation process that depends on differences in diffusion rates of solutes across a permeable membrane.

Diatoms: Organisms related to algae, having a brown pigmentation and a siliceous skeleton.

Disinfection: Application of energy or chemical to kill pathogenic organisms.

Dispersant: A chemical which causes particulates in a water system to remain in suspension.

Donnan effect: The rejection of diffusion of external ions by a semipermeable membrane because of a high internal concentration of ions of the same charge.

Drift: Entrained water in the stack discharge of a cooling tower.

Economizer: A heat exchanger in a furnace stack that transfers heat from the stack gas to the boiler feedwater.

EDTA: Ethylenediaminetetraacetic acid. The sodium salt is the usual form of this chelating material.

Electrolyte: A substance that dissociates into two or more ions when it dissolves in water.

Elution: The process of extracting one solid from another. Often used incorrectly to describe the regeneration of an ion exchanger.

Elutriation: The washing of a sludge with water to free it of its mother liquor.

Emulsion: A colloidal dispersion of one liquid in another.

Endothermic: Absorbing heat.

Enthalpy: The total heat content of a body.

Entrainment: The transport of water into a gas stream. In a boiler, this is carryover; in a cooling tower, drift.

Entropy: A mathematical expression applying to the limits to the availability of energy; a measure of the random motion of matter.

Enzyme: As applied to water, a chemical produced by living cells having the ability to reduce large organic molecules to units small enough to diffuse through the cell membrane.

EPA: Environmental Protection Agency.

Equalization: Minimization of variations in flow and composition by means of a storage reservoir.

Equivalent weight: The weight in grams of a substance which combines with or displaces one gram of hydrogen; it is usually obtained by dividing the formula weight by the valence.

Eutrophication: Enrichment of water, causing excessive growth of aquatic plants and an eventual choking and deoxygenation of the water body.

Exothermic: Evolving heat.

Facultative organisms: Microbes capable of adapting to either aerobic or anaerobic environments.

FDA: Food and Drug Administration.

Fermentation: The conversion of organic matter to CO_2, CH_4, and similar low-molecular weight compounds by anaerobic bacteria.

Filler: Clay, calcium carbonate, or other minerals added to cellulose fiber in the production of certain grades of paper or board.

Filtrate: The liquid remaining after removal of solids as a cake in a filter.

Filtration: The process of separating solids from a liquid by means of a porous substance through which only the liquid passes.

Fission: In biology, the process of reproduction by cell splitting.

Flash: The portion of a superheated fluid converted to vapor when its pressure is reduced.

Flocculation: The process of agglomerating coagulated particles into settleable flocs, usually of a gelatinous nature.

Flotation: A process for separating solids from water by developing a froth in a vessel in such fashion that the solids attach to air particles and float to the surface for collection.

Flume: A raceway or channel constructed to carry water or to permit flow measurements.

F/M ratio: Food-to-mass or food-to-microorganism ratio used to predict the phase of growth being experienced by the major microbial populations in a biological digestion process.

Fourdrinier: A design of paper machine using a continuous wire for forming the sheet.

Freundlich isotherm: The plot of test data related to the removal of colloidal matter from water showing the process to be adsorption.

Fumes: An aerosol with solids as the dispersed colloids.

Fungi: As applied to water, simple, one-celled organisms without chlorophyll, often filamentous. Molds and yeasts are included in this category.

Galvanic couple: The connection of two dissimilar metals in an electrolyte that results in current flow through the circuit.

Gangue: The earthy material remaining from ore beneficiation.

Grains per gallon: A unit of concentration. 1 gr/gal = 17.1 mg/L.

Green liquor: The liquor resulting from dissolving molten smelt from the kraft recovery furnace in water.

Hardness: The concentration of calcium and magnesium salts in water. Hardness is a term originally referring to the soap-consuming power of water; as such it is sometimes also taken to include iron and manganese. "Permanent hardness" is the excess of hardness over alkalinity. "Temporary hardness" is hardness equal to or less than the alkalinity. These are also referred to as "noncarbonate" or "carbonate" hardness, respectively.

Heat rate: An expression of heat-conversion to power, given in Btu/kWh. Theoretical conversion is 3413 Btu/kWh.

Henry's law: An expression for calculating the solubility of a gas in a fluid based on temperature and partial pressure.

Hindered settling: A stage of settling where the accumulated settled solids have compacted to an extent that egress of water from the mass is hindered and, therefore, settling is slowed.

Humidification: The addition of water vapor to air.

Hydrophilic: Having an affinity for water. Its opposite, non-water-wettable, is hydrophobic.

Infiltration: Inleakage of groundwater into sewage piping.

Inhibitor: A chemical that interferes with a chemical reaction, such as corrosion or precipitation.

Ion: An atom or radical in solution carrying an integral electric charge, either positive (cation) or negative (anion).

Ion exchange: A process by which certain undesired ions of given charge are absorbed from solution within an ion-permeable absorbent, being replaced in the solution by desirable ions of similar charge from the absorbent.

Ionic strength: A measure of the strength of a solution based on both the concentrations and valences of the ions present.

Kraft: An alkaline chemical pulping process, using salt cake as makeup.

Langelier index: A means of expressing the degree of saturation of a water as related to calcium carbonate solubility.

Leakage: The presence in the effluent of a species of ions in the feed to an ion exchanger.

Lignin: The major noncellulose constituent of wood.

Lime: A common water treatment chemical. Limestone, $CaCO_3$, is burned to produce quicklime, CaO, which is mixed with water to produce slaked, or hydrated, lime, $Ca(OH)_2$.

Lipophilic: Having an affinity for oil. The opposite of hydrophilic (i.e., hydrophobic).

Membrane: A barrier, usually thin, that permits the passage only of particles up to a certain size or of special nature.

Metabolize: To convert food, such as soluble organic matter, to cellular matter and gaseous by-products by a biological process.

Microorganism: Organisms (microbes) observable only through a microscope; larger, visible types are called *macroorganisms.*

Mineral: Any inorganic or fossilized organic material having a definite chemical composition and structure found in a natural state.

Miscibility: The ability of two liquids, not mutually soluble, to mix.

Mist: An aerosol with liquids as the dispersed colloids.

Mole: A unit weight or volume of a chemical corresponding to its molecular weight. A mole of water weighs 18 g, and its vapor occupies 22.4 L at standard temperature and pressure.

Monomer: A molecule, usually an organic compound, having the ability to join with a number of identical molecules to form a polymer.

Neutralization: Most commonly, a chemical reaction that produces a resulting environment that is neither acidic nor alkaline. Also, the addition of a scavenger chemical to an aqueous system in excess concentration to eliminate a corrosive factor, such as dissolved oxygen.

Noncarbonate hardness: Hardness in water caused by chlorides, sulfates, and nitrates of calcium and magnesium.

Noncondensibles: Gaseous material not liquefied when associated water vapor is condensed in the same environment.

NPDES permit: The National Pollution Discharge Elimination System permit required by and issued by EPA.

NSSC: The neutral sulfite, semichemical pulping process.

NTA: Nitrilotriacetic acid, a chelant with the sodium salt being the usual form.

Occlusion: An absorption process by which one solid material adheres strongly to another, sometimes occurring by coprecipitation.

Opacity: The percentage of light transmission through a plume.

Ore: A mineral containing useful substances which can be extracted.

Orifice: An opening through which a fluid can pass; a restriction placed in a pipe to provide a means of measuring flow.

ORP: Oxidation Reduction Potential. See "Redox potential."

Osmosis: The passage of water through a permeable membrane separating two solutions of different concentrations; the water passes into the more concentrated solution.

Oxidation: A chemical reaction in which an element or ion is increased in positive valence, losing electrons to an oxidizing agent.

Packing: The fill in a confined space in a stripping vessel, ranging from simply shaped units such as rocks or slats to complex shapes that provide large surface area per unit volume.

Pasteurization: A process for killing pathogenic organisms by heat applied for a critical period of time.

Pathogens: Disease-producing microbes.

Periodic chart: An arrangement of the elements in order of increasing atomic number that illustrates the repetition (or periodicity) of key characteristics.

Permeability: The ability of a body to pass a fluid under pressure.

pH: A means of expressing hydrogen ion concentration in terms of the powers of 10; the negative logarithm of the hydrogen ion concentration.

Photosynthesis: The process of converting carbon dioxide and water to carbohydrates, activated by sunlight in the presence of chlorophyll, liberating oxygen.

Pickle liquor: Acid used in treating steel for removal of oxide scale.

Plankton: Small organisms with limited powers of locomotion, carried by water currents from place to place.

Polarize: In corrosion, to develop a barrier on the anodic or cathodic surface, disrupting the corrosion process.

Pollutant: A contaminant at a concentration high enough to endanger the aquatic environment or the public health.

Polyelectrolyte: A polymeric material having ion exchange sites on its skeleton.

Polymer: A chain of organic molecules produced by the joining of primary units called *monomers*.

Polyphosphate: Molecularly dehydrated orthophosphate.

Precipitate: An insoluble reaction product; in an aqueous chemical reaction, usually a crystalline compound that grows in size to become settleable.

Protozoa: Large, microscopic single-cell organisms higher on the food chain than bacteria, which consume bacteria.

Pulp: Fibrous matter.

Radiation: In a furnace, the transfer of heat by energy waves, much like other forms of electromagnetic waves (e.g., light and radio waves).

Rag: Debris that accumulates at an oil-water interface.

Rankine cycle: The successive changes in heat content and temperature as water is converted to steam, expands through a prime mover, condenses, and returns to the boiler.

Recovery furnace: A furnace which burns black liquor from the kraft pulping process, to recover the cooking chemicals as smelt.

Red mud: The gangue from bauxite processing.

Redox potential: Reduction-oxidation potential measured against a standard electrode.

Reduction: A chemical reaction in which an element or compound gains electrons, being reduced in positive valence.

Regenerative heating: In utility stations, a scheme for reducing heat losses to the main condenser in the cycle by using steam extracted from the turbine to heat feedwater. In engineering designs, the use of a heat exchanger to preheat the feed to a process by extracting heat from the product.

Reheater: A heat exchanger located in a furnace to increase the temperature of steam extracted from a turbine for reinjection.

Resolution: The breaking of an emulsion into its individual components.

Reverse osmosis: A process that reverses (by the application of pressure) the flow of water in the natural process of osmosis so that it passes from the more concentrated to the more dilute solution.

Reversion: The return of molecularly dehydrated phosphate (polyphosphate) to its hydrated origin (orthophosphate).

Ringlemann test: A method of comparing the opacity of a stack plume to an arbitrary set of standard disks of increasing degrees of discoloration.

Salinity: The presence of soluble minerals in water.

Salt-splitting: The ability of an anion exchanger to convert a salt solution to caustic; the ability of a cation exchanger to convert a salt solution to acid.

Saturation index: The relation of calcium carbonate to the pH, alkalinity, and hardness of a water to determine its scale-forming tendency.

Saveall: A general term for several designs of devices used to recover fiber from white water and clarify the water for reuse.

Scale: The precipitate that forms on surfaces in contact with water as the result of a physical or chemical change.

Scale pit: A collection chamber alongside a rolling mill that receives roll cooling water containing metallic scale.

Scouring: The removal of surface debris from raw textile fibers.

Secondary fibers: In the paper industry, fibers reclaimed from waste paper.

Sedimentation: Gravitational settling of solid particles in a liquid system.

Seed: A particle or particles, usually crystalline, added to a supersaturated solution to induce precipitation.

Selectivity: The order of preference of an ion exchange material for each of the ions in the surrounding aqueous environment.

Sensible heat: Heat measurable by temperature alone.

Sequester: To form a stable, water-soluble complex.

Sewage: Waste fluid in a sewer.

Silt density index: A measure of the tendency of a water to foul a reverse osmosis membrane, based on timed flow through a membrane filter at constant pressure.

Sinter: A clinker-like material produced in a special furnace from a mixture of coal and recovered iron-bearing materials, such as scale pit solids, used as charge for a blast furnace.

Sizing: A surface finish, such as starch, applied to paper and textile fibers.

Slag: In metallurgical processing, the impurities separated from molten metal during refining; in boiler furnaces, the noncombustible ash which has reached fusion temperatures.

Slop oil: A general term in oil refining applying to tramp oil discharge to the oily sewer during shutdown and startup or through abnormal operation.

Sludge volume index: An inverse measure of sludge density.

Slurry: A water containing a high concentration of suspended solids, usually over 5000 mg/L.

Smelt: Molten slag; in the pulp industry, the cooking chemicals tapped from the recovery boiler as molten material and dissolved in the smelt tank as green liquor.

Soda ash: A common water-treatment chemical, sodium carbonate.

Sodium absorption ration (SAR): In irrigation water, a relationship between sodium and hardness used to predict acceptability for both the plant and soil being irrigated.

Softening: The removal of hardness (calcium and magnesium) from water.

Sour water: Waste waters containing malodorous materials, usually sulfur compounds.

Spore: A reproductive cell, or seed, of algae, fungi, or protozoa.

Stability index: An empirical modification of the saturation index used to predict scaling or corrosive tendencies in water systerms.

Stickwater: The distillate produced in the cooking of meat or in the rendering of fat and scraps.

Stiff-Davis index: An index used to predict the stability of brackish waters, such as those used in waterflooding.

Stoichiometric: The ratio of chemical substances reacting in water that corresponds to their combining weights in the theoretical chemical reaction.

Stokes' law: An expression for calculating the rate of fall of particles through a fluid based on densities, viscosity, and particle size.

Superheater: A heat exchanger located in a furnace to increase the temperature of steam leaving the boiler drum.

Supernate: The liquid overlying the sludge layer in a sedimentation vessel.

Surfactant: A surface active agent: usually an organic compound whose molecules contain a hydrophilic group at one end and a lipophilic group at the other.

Synergism: The combined action of several chemicals which produces an effect greater than the additive effects of each.

Synfuels: Liquid or gaseous fuels produced from coal, lignite, or other solid carbon sources.

Tailings: The residue from separation of useful values from an ore.

Thermocline: The layer in a lake dividing the upper, current-mixed zone, from the cool lower stagnant zone.

Threshold treatment: The control of scale or deposits by application of sub-stoichiometric dosage of treatment chemical.

Transpiration: Respiration of plants.

Tuberculation: A corrosion process that produces hard mounds of corrosion products on the metal surface, increasing friction and reducing flow in a water distribution system.

Turbidity: A suspension of fine particles that obscures light rays but requires many days for sedimentation because of the small particle size.

Turnover: The mixing of lower and upper layers in a lake in spring and fall caused by temperature and density equalization.

USDA: United States Department of Agriculture.

USGS: United States Geological Survey, Department of the Interior.

Venturi: A device for measuring fluid flow, including a short converging cone succeeded on the same axis by a long diverging cone. This device is also used in gas scrubbing.

Waterflooding: A process of displacing oil from underground formations with water and returning it to the surface for recovery.

Weir: A spillover device used to measure or control water flow.

White liquor: Cooking liquor from the kraft pulping process produced by recausticizing green liquor with lime.

White water: The filtrate from a paper- or board-forming machine, usually recycled for density control.

Yield: The rate of production of cake from a dewatering device.

Zeta potential: The difference in voltage between the surface of the diffuse layer surrounding a colloidal particle and the bulk liquid beyond.

POTENTIALLY USEFUL WEBSITES

http://www.awwa.org	American Water Works Association
http://www.cleanh2o.com	Wastewater Treatment Virtual Library
http://www.eic.or.jp/eanet/	Japan Environment Agency
http://www.enviro-engrs.org	American Academy of Environmental Engineers
http://www.epa.gov	U.S. Environment Protection Agency
http://www.iawq.org.uk	International Water Association
http://www.nalco.com	Nalco Chemical Company
http://www.pollutionsolutions.com	Environmental Solutions Inc.
http://www.wef.org	Water Environment Federation
http://www.webdirectory.com	Environmental Organization Web Directory
http://www.wsscc.org/interwater	interWATER Gateway to Water and Sanitation Information
http://www.wwinternational.com	Water and Wastewater International

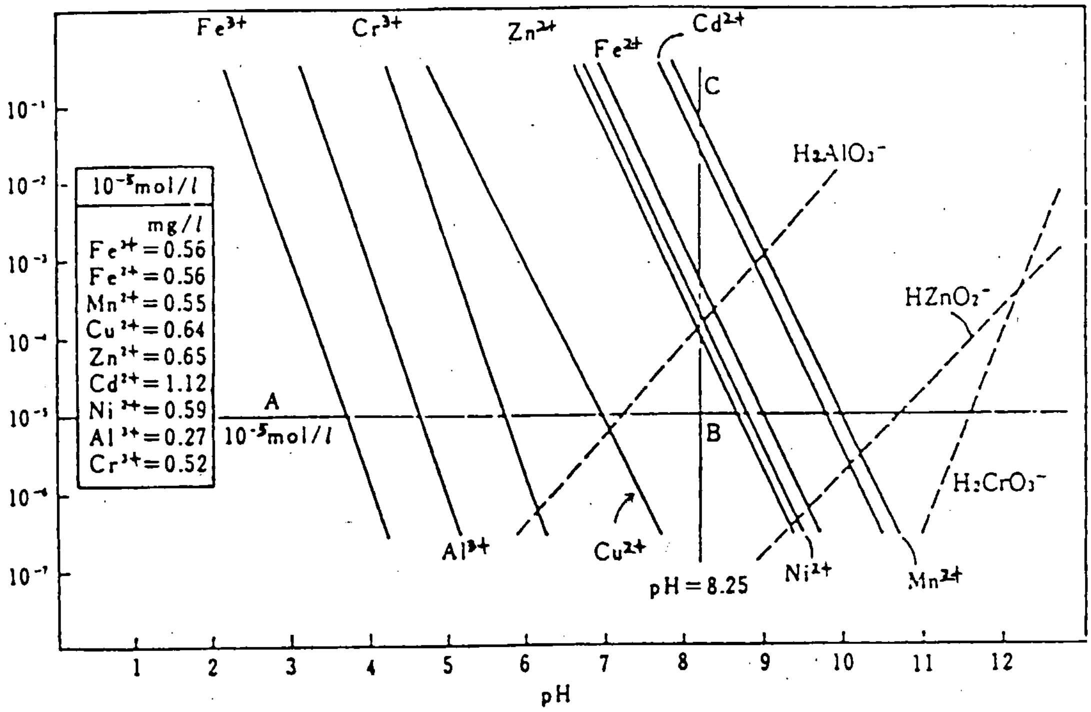


Figure Relationship between metals solubility and pH

Table Solubility Product of Metal Hydroxide

Hydroxide	Ksp	Hydroxide	Ksp
$Al(OH)_3$	$1.1 * 10^{-33}$	$Fe(OH)_3$	$7.1 * 10^{-40}$ *1 $4.8 * 10^{-28}$ *2
$Ca(OH)_2$	$5.5 * 10^{-6}$	$Mg(OH)_2$	$1.8 * 10^{-11}$
$Cd(OH)_2$	$3.9 * 10^{-14}$	$MN(OH)_2$	$1.9 * 10^{-13}$
$Co(OH)_2$	$2.0 * 10^{-16}$	$Ni(OH)_2$	$6.5 * 10^{-18}$ *3
$Cr(OH)_3$	$6.0 * 10^{-31}$	$Pb(OH)_2$	$1.6 * 10^{-7}$ *4
$Cu(OH)_2$	$6.0 * 10^{-20}$	$Sn(OH)_2$	$8.0 * 10^{-29}$
$Fe(OH)_2$	$8.0 * 10^{-16}$	$Zn(OH)_2$	$1.2 * 10^{-17}$

*1 $Fe(OH)_3 = Fe^{3+} + 3OH^-$

*2 $Fe(OH)_3 = Fe(OH)_2^+ + OH^-$

*3 $Ni(OH)_3 \sim 10^{-37}$

*4 PbO: $1.2 * 10^{-15}$

Source: Kougaiboushi-no-Gijutsu-to-Houki

TABLE SUMMARY OF CARBON ADSORPTION CAPACITIES

Compound	Adsorption[a] Capacity, mg/g	Compound	Adsorption[a] Capacity, mg/g
bis(2-Ethylhexyl) phthalate	11,300	Phenanthrene	215
Butylbenzyl phthalate	1,520	Dimethylphenylcarbinol*	210
Heptachlor	1,220	4-Aminobiphenyl	200
Heptachlor epoxide	1,038	beta-Naphthol*	200
Endosulfan sulfate	686	alpha-Endosulfan	194
Endrin	666	Acenaphthene	190
Fluoranthene	664	4,4' Methylene-bis-(2-chloroaniline)	190
Aldrin	651	Benzo(k)fluoranthene	181
PCB-1232	630	Acridine orange*	180
beta-Endosulfan	615	alpha-Naphthol	180
Dieldrin	606	4,6-Dinitro-o-cresol	169
Hexachlorobenzene	450	alpha-Naphthylamine	160
Anthracene	376	2,4-Dichlorophenol	157
4-Nitrobiphenyl	370	1,2,4-Trichlorobenzene	157
		2,4,6-Trichlorophenol	155
Fluorene	330	beta-Naphthylamine	150
DDT	322	Pentachlorophenol	150
2-Acetylaminofluorene	318	2,4-Dinitrotoluene	146
alpha-BHC	303	2,6-Dinitrotoluene	145
Anethole*	300	4-Bromophenyl phenyl ether	144
3,3-Dichlorobenzidine	300	p-Nitroaniline*	140
2-Chloronaphthalene	280	1,1-Diphenylhydrazine	135
Phenylmercuric Acetate	270	Naphthalene	132
Hexachlorobutadiene	258	1-Chloro-2-nitrobenzene	130
gamma-BHC (lindane)	256	1,2-Dichlorobenzene	129
p-Nonylphenol	250	p-Chlorometacresol	124
4-Dimethylaminoazobenzene	249	1,4-Dichlorobenzene	121
Chlordane	245	Benzothiazole*	120
PCB-1221	242	Diphenylamine	120
DDE	232	Guanine*	120
Acridine yellow*	230	Styrene	120
Benzidine dihydrochloride	220	1,3-Dichlorobenzene	118
beta-BHC	220	Acenaphthylene	115
N-Butylphthalate	220	4-Chlorophenyl phenyl ether	111
N-Nitrosodiphenylamine	220	Diethyl phthalate	110

TABLE SUMMARY OF CARBON ADSORPTION CAPACITIES (cont.)

Compound	Adsorption[a] Capacity, mg/g	Compound	Adsorption[a] Capacity, mg/g
2-Nitrophenol	99	Bromoform	20
Dimethyl phthalate	97	Carbon tetrachloride	11
Hexachloroethane	97	bis(2-Chloroethoxy) methane	11
Chlorobenzene	91	Uracil*	11
p-Xylene	85	Benzo(ghi)perylene	11
2,4-Dimethylphenol	78	1,1,2,2-Tetrachloroethane	11
4-Nitrophenol	76	1,2-Dichloropropene	8.2
Acetophenone	74	Dichlorobromomethane	7.9
1,2,3,4-Tetrahydro-naphthalene	74	Cyclohexanone*	6.2
Adenine*	71	1,2-Dichloropropane	5.9
Dibenzo(a,h)anthracene	69	1,1,2-Trichloroethane	5.8
Nitrobenzene	68	Trichlorofluoromethane	5.6
3,4-Benzofluoranthene	57	5-Fluorouracil*	5.5
1,2-Dibromo-3-chloro-propane	53	1,1-Dichloroethylene	4.9
Ethylbenzene	53	Dibromochloromethane	4.8
2-Chlorophenol	51	2-Chloroethyl vinyl ether	3.9
Tetrachloroethene	51	1,2-Dichloroethane	3.6
o-Anisidine*	50	1,2-trans-Dichloroethene	3.1
5 Bromouracil	44	Chloroform	2.6
Benzo(a)pyrene	34	1,1,1-Trichloroethane	2.5
2,4-Dinitrophenol	33	1,1-Dichloroethane	1.8
Isophorone	32	Acrylonitrile	1.4
Trichloroethene	28	Methylene chloride	1.3
Thymine*	27	Acrolein	1.2
Toluene	26	Cytosine*	1.1
5-Chlorouracil*	25	Benzene	1.0
N-Nitrosodi-n-propylamine	24	Ethylenediaminetetra-acetic acid	0.86
bis(2-Chloroisopropyl) ether	24	Benzoic acid	0.76
Phenol	21	Chloroethane	0.59
		N-Dimethylnitros-amine	6.8×10^{-5}

TABLE SUMMARY OF CARBON ADSORPTION CAPACITIES (cont.)

NOT ADSORBED

Acetone cyanohydrin	Adipic acid
Butylamine	Choline chloride
Cyclohexylamine	Diethylene glycol
Ethanol	Hexamethylenediamine
Hydroquinone	Morpholine
Triethanolamine	

*Compounds prepared in "mineralized" distilled water containing the following composition:

Ion	Conc., mg/l	Ion	Conc., mg/l
Na^+	92	$PO_4^{\equiv}$	10
K^+	12.6	$SO_4^{=}$	100
Ca^{++}	100	Cl^-	177
Mg^{++}	25.3	Alkalinity	200

(a) Adsorption capacities are calculated for an equilibrium concentration of 1.0 mg/l at neutral pH.

R.A. Dobbs and J.M. Cohen
EPA-600/8-80-023
CARBON ADSORPTION ISOTHERMS FOR TOXIC ORGANICS
1980

Hydrochloric Acid (20°C)

Bé	Specific Gravity	HCl (%)	HCl (g/l)	Bé	Specific Gravity	HCl (%)	HCl (g/l)
0.5	1.0032	1	10.03	14.2	1.1083	22	243.8
1.2	1.0082	2	20.16	15.4	1.1187	24	268.5
2.6	1.0181	4	40.72	16.6	1.1290	26	293.5
3.9	1.0279	6	61.67	17.7	1.1392	28	319.0
5.3	1.0376	8	83.01	18.8	1.1493	30	344.8
6.6	1.0474	10	104.7	19.9	1.1593	32	371.0
7.9	1.0574	12	126.9	21.0	1.1691	34	397.5
9.2	1.0675	14	149.5	22.0	1.1789	36	424.4
10.4	1.0776	16	172.4	23.0	1.1885	38	451.6
11.7	1.0878	18	195.8	24.0	1.1980	40	479.2
12.9	1.0980	20	219.6				

Nitric Acid (20°C)

Bé	Specific Gravity	HNO_3 (%)	HNO_3 (g/l)	Bé	Specific Gravity	HNO_3 (%)	HNO_3 (g/l)
0.5	1.0036	1	10.01	34.8	1.3160	51	671.2
1.3	1.0091	2	20.18	35.3	1.3219	52	687.4
2.1	1.0146	3	30.44	35.8	1.3278	53	703.7
2.9	1.0201	4	40.80	36.3	1.3336	54	720.1
3.6	1.0256	5	51.28	36.7	1.3393	55	736.6
4.4	1.0312	6	61.87	37.2	1.3449	56	753.1
5.2	1.0369	7	72.58	37.6	1.3505	57	769.8
5.9	1.0427	8	83.42	38.1	1.3560	58	786.5
6.7	1.0185	9	91.37	38.5	1.3614	59	803.2
7.5	1.0543	10	105.4	38.9	1.3667	60	820.0
8.2	1.0602	11	116.6	39.3	1.3719	61	836.9
9.0	1.0661	12	127.9	39.7	1.3769	62	853.7
9.8	1.0721	13	139.4	40.1	1.3818	63	870.5
10.5	1.0781	14	150.9	40.4	1.3866	64	887.4
11.3	1.0842	15	162.6	40.8	1.3913	65	904.3
12.0	1.0903	16	174.4	41.1	1.3959	66	921.3
12.8	1.0964	17	186.4	41.5	1.4001	67	938.3
13.5	1.1026	18	198.5	41.8	1.4018	68	955.3
14.2	1.1088	19	210.7	42.1	1.4091	69	972.3
15.0	1.1150	20	223.0	42.4	1.4134	70	989.4
15.7	1.1213	21	235.5	42.7	1.4176	71	1006
16.4	1.1276	22	248.1	43.0	1.4218	72	1024
17.1	1.1340	23	260.8	43.3	1.4258	73	1041
17.9	1.1404	24	273.7	43.6	1.4298	74	1058
18.6	1.1469	25	286.7	43.9	1.4337	75	1075
19.4	1.1531	26	299.9	44.1	1.4375	76	1093
20.0	1.1600	27	313.2	44.4	1.4413	77	1110
20.7	1.1666	28	326.6	44.7	1.4450	78	1127
21.4	1.1733	29	340.3	44.9	1.4486	79	1144
22.1	1.1800	30	351.0	45.1	1.4521	80	1162
22.8	1.1867	31	367.9	45.4	1.4555	81	1179
23.5	1.1931	32	381.9	45.6	1.4589	82	1196
24.2	1.2002	33	396.1	45.8	1.4622	83	1214
24.9	1.2071	34	410.4	46.1	1.4655	84	1231
25.6	1.2440	35	424.9	46.3	1.4686	85	1248
26.2	1.2205	36	439.4	46.5	1.4716	86	1266
26.8	1.2270	37	454.0	46.7	1.4745	87	1283
27.5	1.2335	38	468.7	46.8	1.4773	88	1300
28.1	1.2399	39	483.6	47.0	1.4800	89	1317
28.7	1.2463	40	498.5	47.2	1.4826	90	1334
29.3	1.2527	41	513.6	47.4	1.4850	91	1351
29.8	1.2591	42	528.8	47.5	1.4873	92	1368
30.4	1.2655	43	544.2	47.6	1.4892	93	1395
31.0	1.2719	44	559.6	47.8	1.4912	94	1402
31.6	1.2783	45	575.2	47.9	1.4932	95	1419
32.1	1.2847	46	591.0	48.0	1.4952	96	1435
32.7	1.2911	47	606.8	48.2	1.4974	97	1452
33.2	1.2975	48	622.8	48.4	1.5008	98	1471
33.8	1.3040	49	639.0	48.7	1.5056	99	1491
34.3	1.3100	50	655.0	49.2	1.5129	100	1513

Sulfuric Acid (20°C)

Bé	Specific Gravity	H_2SO (%)	H_2SO_4 (g/l)	Bé	Specific Gravity	H_2SO_4 (%)	H_2SO_4 (g/l)
0.7	1.0051	1	10.05	41.8	1.4049	51	716.5
1.7	1.0118	2	20.24	42.5	1.4148	52	735.7
2.6	1.0181	3	30.55	43.2	1.4248	53	755.1
3.5	1.0250	4	41.00	44.0	1.4350	54	774.9
4.5	1.0317	5	51.59	44.7	1.4453	55	794.9
5.4	1.0385	6	62.31	45.4	1.4557	56	815.2
6.3	1.0453	7	73.17	46.1	1.4662	57	835.7
7.2	1.0522	8	84.18	46.8	1.4768	58	856.5
8.1	1.0591	9	95.32	47.5	1.4875	59	877.6
9.0	1.0661	10	106.6	48.2	1.4983	60	789.9
9.9	1.0731	11	118.0	48.9	1.5091	61	920.6
10.8	1.0802	12	129.6	49.6	1.5200	62	942.4
11.7	1.0874	13	141.4	50.3	1.5310	63	964.5
12.5	1.0947	14	153.3	51.0	1.5421	64	986.9
13.4	1.1020	15	165.3	51.7	1.5533	65	1010
14.3	1.1094	16	177.5	52.3	1.5646	66	1033
15.2	1.1168	17	189.9	53.0	1.5760	67	1056
16.0	1.1243	18	202.4	53.7	1.5874	68	1079
16.9	1.1318	19	215.0	54.3	1.5989	69	1103
17.7	1.1394	20	227.9	55.0	1.6105	70	1127
18.6	1.1471	21	240.9	55.6	1.6221	71	1152
19.4	1.1548	22	254.4	56.3	1.6338	72	1176
20.3	1.1626	23	267.4	56.9	1.6456	73	1201
21.1	1.1704	24	280.9	57.5	1.6574	74	1226
21.9	1.1783	25	294.6	58.1	1.6692	75	1252
22.8	1.1862	26	308.4	58.7	1.6810	76	1278
23.6	1.2942	27	322.4	59.3	1.6927	77	1303
24.4	1.2023	28	336.6	59.9	1.7043	78	1329
25.2	1.2102	29	351.0	60.5	1.7158	79	1355
26.0	1.2185	30	365.6	61.1	1.7272	80	1382
26.8	1.2267	31	380.3	61.6	1.7383	81	1408
27.6	1.2349	32	395.2	62.1	1.7491	82	1434
28.4	1.2432	33	410.3	62.6	1.7594	83	1460
29.1	1.2515	34	425.5	63.0	1.7693	84	1486
29.9	1.2599	35	441.0	63.5	1.7786	85	1512
30.7	1.2684	36	456.6	63.9	1.7872	86	1537
31.4	1.2769	37	472.5	64.2	1.7951	87	1562
32.2	1.2855	38	488.5	64.5	1.8022	88	1586
33.0	1.2941	39	504.7	64.8	1.8087	89	1610
33.7	1.3028	40	521.1	65.1	1.8144	90	1633
34.5	1.3116	41	537.8	65.3	1.8195	91	1656
35.2	1.3205	42	554.6	65.5	1.8340	92	1678
35.9	1.3294	43	571.6	65.7	1.8279	93	1700
36.7	1.3384	44	588.9	65.8	1.8312	94	1721
37.4	1.3476	45	606.4	65.9	1.8337	95	1742
38.1	1.3569	46	624.2	66.0	1.8355	96	1762
38.9	1.3663	47	642.2	66.0	1.8364	97	1781
39.6	1.3758	48	660.4	66.0	1.8361	98	1799
40.3	1.3854	49	678.8	65.9	1.8342	99	1816
41.1	1.3951	50	697.6	65.8	1.8305	100	1831

Phosphoric Acid (20°C)

Bé	Specific Gravity	H_2PO_4 (%)	H_3PO_4 (g/l)	P_2O5 (%)	P_2O_5 (g/l)
0.6	1.0038	1	10.04	0.72	7.271
1.3	1.0092	2	20.18	1.4	14.62
2.8	1.0200	4	40.80	2.9	29.56
4.3	1.0309	6	61.85	4.3	44.81
5.8	1.0420	8	83.36	5.8	60.39
7.3	1.0532	10	105.3	7.2	76.29
8.8	1.0647	12	127.8	8.7	92.55
10.3	1.0764	14	150.7	10.1	109.2
11.8	1.0884	16	174.1	11.6	126.1
13.3	1.1008	18	198.1	13.0	143.5
14.8	1.1131	20	222.7	14.5	161.3
16.3	1.1263	22	247.8	15.9	179.5
17.8	1.1395	24	273.5	17.4	198.1
19.2	1.1529	26	299.8	18.8	217.1
20.7	1.1665	28	326.6	20.3	236.6
22.2	1.1805	30	351.2	21.7	256.5
25.8	1.216	35	425.6	25.4	308.3
29.4	1.254	40	501.6	29.0	363.4
32.9	1.293	45	581.9	32.6	421.5
36.4	1.335	50	667.5	36.2	483.5
39.9	1.379	55	758.5	39.8	549.4
43.3	1.426	60	855.6	43.5	619.5
46.7	1.475	65	958.8	47.1	691.5
50.0	1.526	70	1068	50.7	773.8
53.2	1.579	75	1181	51.3	857.9
56.2	1.633	80	1306	58.0	946.4
59.2	1.689	85	1436	61.6	1040
762	1.746	90	1571	65.2	1138
63.1	1.770	92	1628	66.6	1180
64.2	1.794	94	1686	68.1	1222
65.3	1.819	96	1746	69.5	1265
66.4	1.814	98	1807	71.0	1309
67.5	1.870	100	1870	72.4	1355

Sodium Chloride (20°C)

Bé	Specific Gravity	NaCI (%)	NaCI (g/l)
0.8	1.0053	1	10.05
1.8	1.0425	2	20.25
3.8	1.0268	4	41.07
5.8	1.0413	6	62.48
7.7	1.0559	8	84.47
9.6	1.0707	10	107.1
11.5	1.0857	12	130.3
13.3	1.1009	14	154.1
15.1	1.1162	16	178.6
16.9	1.1319	18	203.7
18.7	1.1478	20	229.6
20.4	1.1640	22	256.1
22.2	1.1804	24	283.3
23.9	1.1972	26	311.3

Sodium Sulfite (19°C)

Bé	Specific Gravity	Na_2SO_3 (%)	Na_2SO_3 (g/l)
1.1	1.0078	1	10.08
2.5	1.0172	2	20.31
5.1	1.0363	4	41.45
7.6	1.0556	6	63.34
10.1	1.0751	8	86.01
12.6	1.0918	10	109.5
14.9	1.1146	12	133.8
17.2	1.1516	14	158.8
19.4	1.1549	16	184.8
21.7	1.1755	18	211.6

Sodium Carbonate (20°C)

Bé	Specific Gravity	Na_2CO_3 (%)	Na_2CO_3 (g/l)	$Na_2CO_3 \cdot 10H_2O$ (%)	$Na_2CO_3 \cdot 10H_2O$ (g/l)
1.2	1.0086	1	10.09	2.70	27.23
2.7	1.0190	2	20.38	5.40	55.02
5.6	1.0398	4	41.59	10.80	112.3
8.3	1.0606	6	63.64	16.20	171.8
10.9	1.0816	8	86.53	21.60	233.6
13.5	1.1029	10	110.3	27.00	297.7
16.0	1.1244	12	134.9	32.40	361.3
18.5	1.1463	14	160.5	37.80	433.3

Sodium Phosphate Monobasic (25°C)

Density	NaH_2PO_4 (%)
1.0045	1
1.0120	2
1.0270	4
1.0422	6
1.0575	8
1.0730	10

Sodium Phosphate Dibasic (18°C)

Specific Gravity	Na_2PO_4 (%)
1.009	1
1.020	2
1.043	4
1.067	6

Sodium Phosphate Tribasic (15°C)

Specific Gravity	Na_3PO_4 (%)
1.0092	1
1.0194	2
1.0405	4
1.0624	6
1.0850	8
1.1083	10

Sodium Bicarbonate (18°C)

Specific Gravity	$NaHCO_3$ (%)
1.0059	1
1.0132	2
1.0206	3
1.0280	4
1.0354	5
1.0429	6
1.0505	7
1.0581	8

Sodium Silicate (20°C)

Bé	Specific Gravity	Na_2O+ 3.9 SiO_2 (%)	Na_2O+ 3.9 SiO_2 (g/l)	Bé	Specific Gravity	Na_2O+ 3.9 SiO_2 (%)	Na_2O+ 3.9 SiO_2 (g/l)
0.9	1.006	1	10.06	0.9	1.006	1	10.06
2.0	1.014	2	20.28	2.0	1.014	2	20.28
4.2	1.030	4	41.2	4.2	1.030	4	41.20
6.4	1.046	6	62.76	6.5	1.047	6	62.82
8.6	1.063	8	85.04	8.9	1.065	8	85.20
10.7	1.080	10	108.0	11.1	1.083	10	108.3
12.9	1.098	12	131.8	13.3	1.101	12	132.1
14.6	1.116	14	156.2	15.5	1.12	14	156.8
17.1	1.131	16	181.4	17.7	1.239	16	182.2
19.2	1.153	18	207.5	19.9	1.159	18	208.6
21.3	1.172	20	231.4	22.0	1.179	20	235.8
23.3	1.191	22	262.0	24.2	1.200	22	264.0
25.3	1.211	24	290.6	26.3	1.222	24	293.3
27.3	1.232	26	320.3	28.4	1.244	26	323.4
29.3	1.253	28	350.8	30.6	1.267	28	354.8
31.3	1.275	30	382.5	32.6	1.290	30	387.0
33.3	1.298	32	415.4	31.7	1.314	32	420.5
				36.7	1.339	34	455.3
				38.8	1.365	36	491.4
				40.9	1.393	38	529.3

Sodium Hydroxide (20°C)

Bé	Specific Gravity	NaOH (%)	NaOH (g/l)
1.4	1.0095	1	10.10
2.9	1.0207	2	20.41
4.5	1.0318	3	30.95
6.0	1.0428	4	41.71
7.4	1.0538	5	52.69
8.8	1.0648	6	63.89
10.2	1.0758	7	75.31
11.6	1.0869	8	86.95
12.9	1.0979	9	98.81
14.2	1.1089	10	110.9
16.8	1.1309	12	135.7
19.2	1.1530	14	161.4
21.6	1.2751	16	188.0
23.9	1.1972	18	215.5
26.1	1.2191	20	243.8
28.2	1.2411	22	273.0
30.2	1.2629	24	303.1
32.1	1.2848	26	334.0
34.0	1.3064	28	365.8
35.8	1.3279	30	398.4
37.5	1.3490	32	431.7
39.1	1.3696	34	465.7
40.7	1.2900	36	500.4
42.2	1.4101	38	535.8
43.6	1.4300	40	572.0
45.0	1.4491	42	608.7
46.3	1.2685	44	646.1
47.5	1.4873	46	684.2
48.8	1.5065	48	723.1
49.9	1.5253	50	762.7

Ammonia (20°C)

Bé	Specific Gravity	NH_3 (%)	NH_3 (g/l)
10.9	0.9939	1	9.939
11.5	0.9895	2	19.79
11.7	0.9811	4	39.24
13.9	0.9730	6	58.38
15.1	0.9651	8	77.21
16.2	0.9575	10	95.75
17.3	0.9501	12	114.0
18.5	0.9430	14	132.0
19.5	0.9362	16	149.8
20.6	0.9295	18	167.3
21.7	0.9229	20	184.6
22.8	0.9164	22	201.6
23.8	0.9101	24	218.4
24.9	0.9040	26	235.0
25.9	70.098	28	251.4
27.0	0.8920	30	267.6

Ammonia (15°C, measured in closed tube)

Bé	Specific Gravity	NH_3 (%)	NH_3 (g/l)
34.9	0.849	45	382.1
38.3	0.832	50	416.0
41.8	0.815	55	448.3
45.9	0.796	60	477.6
50.4	0.776	65	504.4
55.4	0.755	70	528.5
61.0	0.733	75	549.8
66.9	0.711	80	568.8
73.5	0.688	85	584.8
80.5	0.665	90	598.5
88.1	0.642	95	609.9
96.5	0.618	100	618.0

Potassium Hydroxide (15°C)

Bé	Specific Gravity	KOH (%)	KOH (g/l)
1.2	1.0083	1	10.08
2.5	1.0175	2	20.35
3.8	1.0267	3	30.80
3.0	1.0359	4	41.44
6.3	1.0452	5	52.26
7.5	1.0544	6	63.26
8.7	1.0637	7	74.46
9.9	1.0730	8	85.84
11.0	1.0824	9	97.42
12.2	1.0918	10	109.2
13.3	1.1013	11	121.1
14.5	1.1108	12	133.3
15.6	1.1203	13	145.6
16.7	1.1299	14	158.2
17.8	1.1396	15	170.9
18.8	1.1493	16	183.9
19.9	1.1590	17	197.0
20.9	1.1688	18	210.4
22.0	1.1786	19	223.9
23.0	1.1884	20	237.7
24.0	1.1984	21	251.7
25.0	1.2083	22	265.8
27.0	1.2184	23	280.2
27.0	1.2285	24	294.8
27.9	1.2387	25	309.7
28.9	1.2489	26	324.7
29.8	1.2592	27	340.0
30.8	1.2695	28	355.5
31.7	1.2800	29	371.2
32.6	1.2905	30	387.2
33.6	1.3010	31	403.3
34.5	1.3117	32	419.7
35.4	1.3224	33	436.4
36.2	1.3331	34	453.3
37.1	1.3440	35	470.4
38.0	1.3549	36	487.8
38.8	1.3659	37	505.4
39.7	1.3769	38	523.2
40.5	1.3879	39	544.3
41.4	1.3991	40	559.6
42.2	1.4103	41	578.2
43.0	1.4215	42	597.0
43.8	1.4329	43	616.1
44.6	1.4443	44	635.5
45.4	1.4558	45	655.1
46.2	1.4673	46	675.0
47.0	1.4790	47	695.1
47.7	1.4907	48	715.5
48.5	1.5025	49	736.2
49.2	1.5143	50	757.2
50.0	1.5262	51	778.4
50.7	1.5382	52	799.9

Lime

CaO (g/l)	CaO (%)	$Ca(OH)_2$ (%)	Density (20°C/20°C)
10	0.99	1.31	1.0085
20	1.96	2.59	1.017
30	2.93	3.87	1.0245
40	3.88	4.81	1.0315
50	4.18	5.13	1.039
60	5.74	6.36	1.046
70	6.65	7.58	1.0535
80	7.54	8.79	1.0605
90	8.43	9.96	1.0675
100	9.30	11.14	1.075
110	10.16	12.29	1.0825
120	11.01	13.43	1.0895
130	11.86	14.55	1.0965
140	12.68	15.67	1.104
150	13.50	16.76	1.111
160	14.30	17.84	1.1185
170	15.10	18.90	1.1255
180	15.89	19.95	1.1325
190	16.67	21.00	1.140
200	17.43	22.03	1.1475
210	18.19	24.04	1.1515
220	18.91	25.03	1.1615
230	19.68	26.01	1.1685
240	20.41	26.96	1.176
250	21.12	27.91	1.1835
260	21.84	28.86	1.1905
270	22.55	29.80	1.1975
280	23.24	31.71	1.205
290	23.92	31.61	1.2125
300	24.60	32.51	1.2195

Ferrous Sulfate (18°C)

Bé	Specific Gravity	$FeSO_4$ (%)	FeSO (g/l)	$FeSO_4 \cdot 7H_2O$ (%)	$FeSO_4 \cdot 7H_2$ (g/l)
0.1	1.0007	0.2	2.001	0.366	3.663
0.4	1.0028	0.4	4.011	0.732	7.341
0.7	1.0046	0.6	6.028	1.10	11.03
0.9	1.0065	0.8	8.052	1.46	14.74
1.2	1.0085	1.0	10.09	1.83	18.46
2.6	1.0180	2	20.36	3.66	37.26
5.2	1.0375	4	41.50	7.32	75.95
7.9	1.0575	6	63.45	11.0	115.1
10.6	1.0785	8	86.28	14.6	157.9
13.2	1.1000	10	110.0	18.3	201.3
15.8	1.1220	12	131.6	22.0	246.4
18.3	1.1445	14	160.2	25.6	293.3
20.8	1.1675	16	186.8	29.3	341.9
23.2	1.1905	18	214.3	32.9	392.2
25.5	1.2135	20	242.7	36.6	444.2

Ferric Sulfate (17.5°C)

Bé	Specific Gravity	$Fe_2(SO_4)_3$ (%)	$Fe_2(SO_4)_3$ (g/l)
1.0	1.007	1	10.07
2.3	1.016	2	20.32
4.7	1.033	4	41.32
6.9	1.050	6	63.00
9.1	1.067	8	85.36
11.2	1.084	10	108.4
13.5	1.103	12	132.4
15.8	1.122	14	157.1
17.9	1.141	16	182.6
20.1	1.161	18	209.0
22.2	1.181	20	236.2
28.2	1.241	25	310.3
31.1	1.307	30	392.1
39.6	1.376	35	481.6
44.9	1.449	40	579.6
50.1	1.582	45	687.6
55.1	1.613	50	806.5
59.9	1.703	55	936.7
64.4	1.798	60	1079

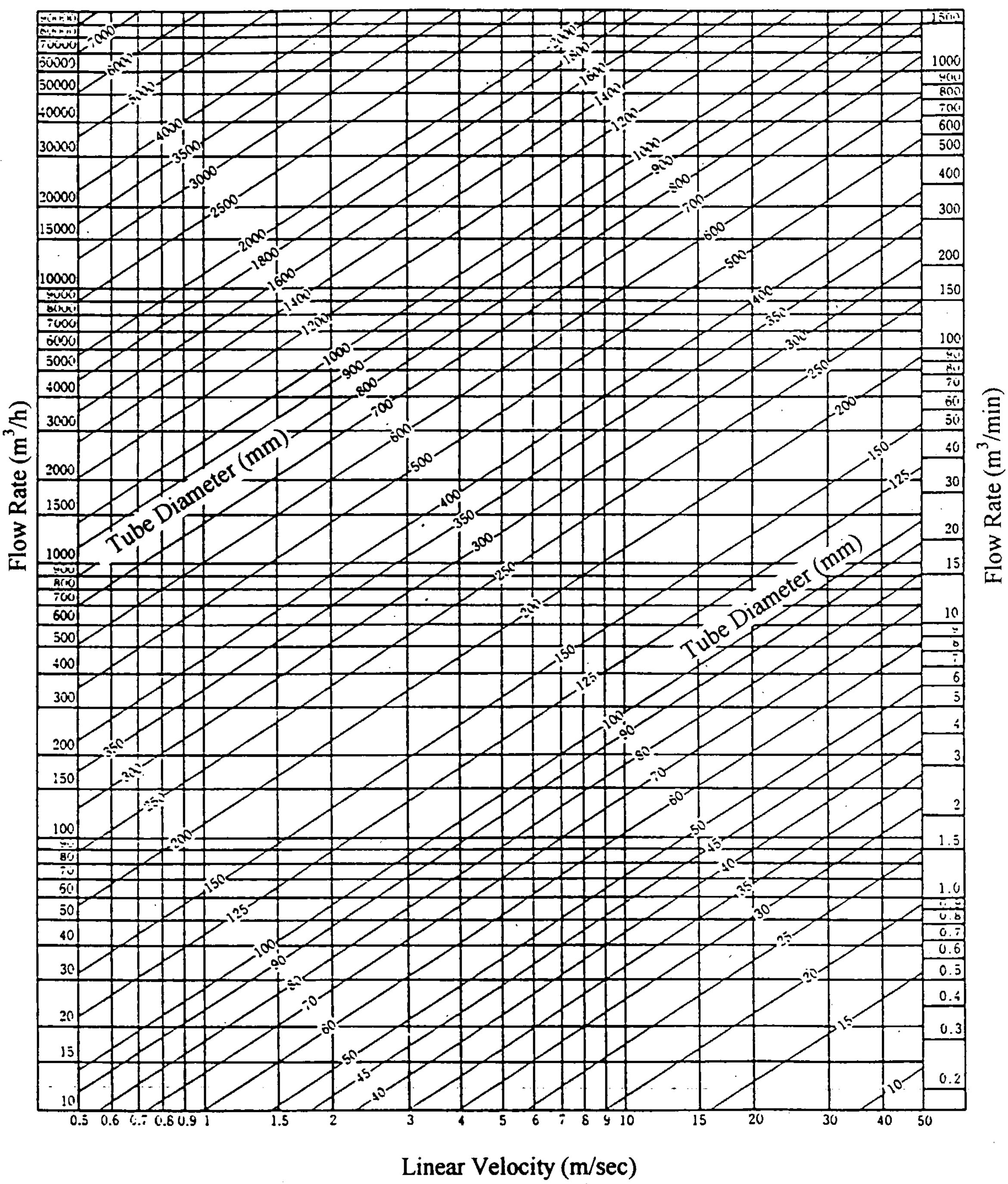
Aluminium Sulfate (15°C)

Bé	Specific Gravity	$Al_2(SO_4)_2$ (%)	$Al_2(SO_4)_2$ (g/l)	$Al_2(SO_4)_2 \cdot 18H_2O$ (%)	$Al_2(SO_4)_2 \cdot 18H_2O$ (g/l)
1.3	1.0093	1	10.09	1.948	19.66
2.8	1.0195	2	20.39	3.896	39.72
5.6	1.0104	4	41.62	7.791	81.06
8.4	1.0618	6	63.71	11.69	124.1
11.2	1.0837	8	86.75	15.58	168.9
13.9	1.1062	10	110.6	19.48	215.5
16.6	1.1293	12	135.5	23.37	264.0
19.2	1.1529	14	161.4	27.27	314.4
21.8	1.1770	16	188.3	31.16	366.8
24.3	1.2017	18	216.3	35.06	421.3
26.8	1.2270	20	245.4	38.96	478.1
29.3	1.2531	22	275.7	42.85	537.1
31.7	1.2803	24	307.3	46.75	598.5
34.1	1.3079	26	340.1	50.64	662.4

LINE SIZING CHART

$$Q = \frac{\pi}{4} d^2 \times V \times 3600 \times 10^{-6} \quad m^3/h$$

$$= \frac{\pi}{4} d^2 \times V \times 60 \times 10^{-3} \quad \ell/min \qquad d \cdots mm \quad V \cdots m/s$$



Pressure Drop by Piping Components

Type of valva/fitting			Equivalent length (m)
Vaves (full-open)	Ball valve	Reduced bore 40 mm and smaller	65 D
		Reduced bore 50 mm and larger	45 D
	Gate valve	Standard bore	13 D
			65 D
	Globe valve	Straight pattern	340 D
		Y pattern	160 D
		Angle pattern	145 D
	Check valve	Swing type	135 D
		Ball or piston type, 40 mm and smaller	340 D
	Plug valve	regular pattern	45 D
	Butterfly valve	150 mm and larger	20 D
	Control valves		ask instrument group
Fittings	Tee	Flow straight through	20 D
		Flow through side outlet	65 D
	Elbow	90° ,R= 1 $^1/_2$ D	20 D
		45° ,R= 1 $^1/_2$ D	16 D
	Bend	90° ,R= 4D	14 D
		90° ,R= 5D	16 D
		180° ,R= 4D	25 D
		180° ,R= 5D	28 D
Miscellaneous	Strainer	Pump suction Y-typeand bucket type	250 D
	Equipment		ask equipment manufacturer

Note: D = nominal size in meters.

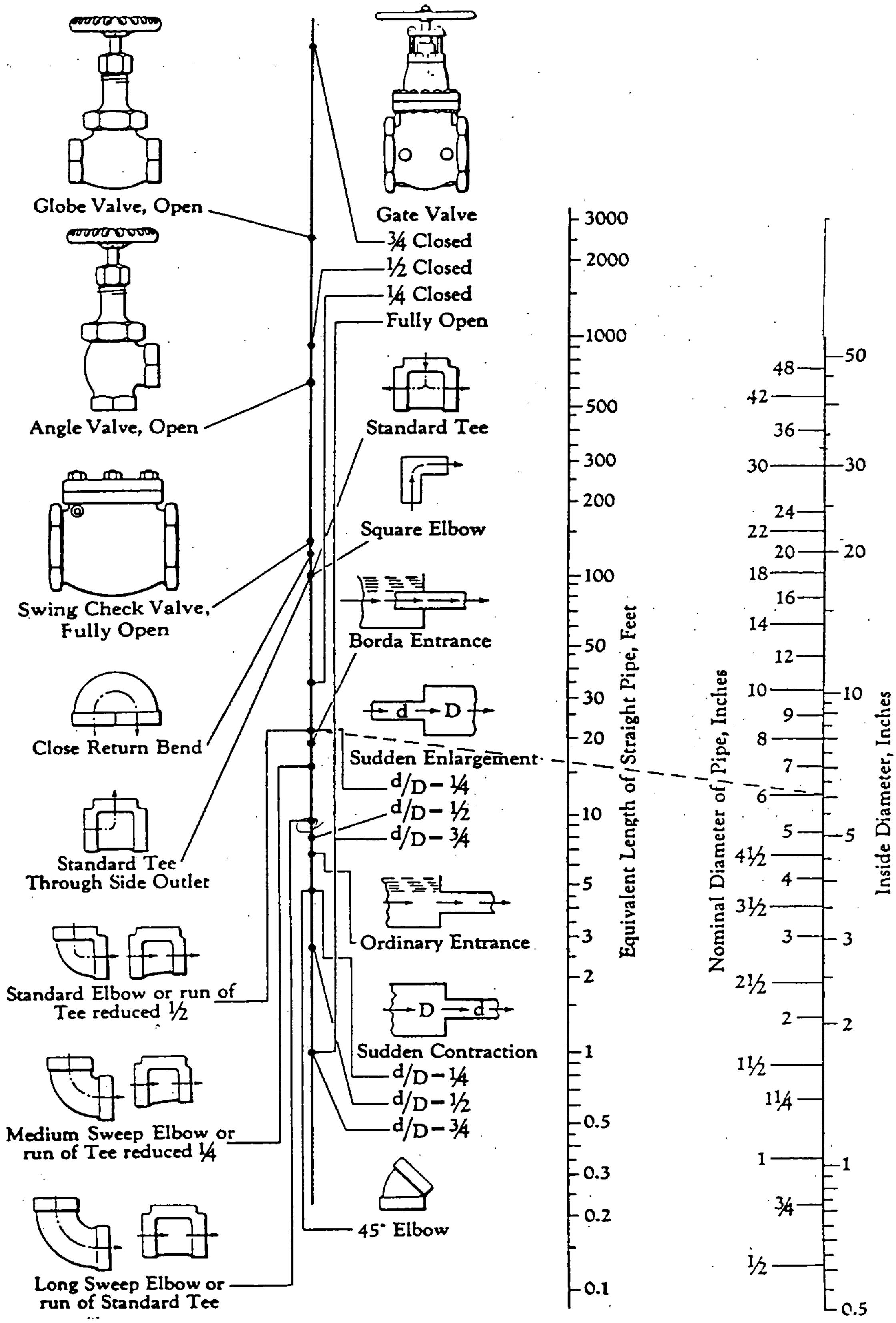


Figure 2-7. Resistance of valves and fittings to flow of fluids. (Reprinted by permission "Technical Paper #409," Crane Co., Engineering Div., 1942, Chicago.)

1 Feet = 0.305 m

Reference for Material Selection

Chemicals	Solution Strength	Pumps	Valves	Piping	Tanks	Agitators
Coagulant						
Aluminium Sulfate $Al_2(SO_4)_3 \cdot 14H_2O$	15 to 17 % as Al_2O_3	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel or Rubber/PP lined CS	316L Stainless Steel	316L Stainless Steel
Calcium Hydroxide $Ca(OH)_2$	5 % Slurry	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Ferric Chloride $FeCl_3$	32% $FeCl_3$	FRP, PVC, or PVDF	FRP, PVC, or PVDF	FRP, PVC, or PVDF	FRP, or Rubber lined CS	FRP, PVC, or PVDF
Ferrous Sulfate $FeSO_4 \cdot 7H_2O$	20 % as Fe	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel
Polyelectrolytes	0.5 to 5.0 %	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel
pH adjustment						
Calcium Carbonate $CaCO_3$	5 % Slurry	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Hydrochloric Acid HCl	30 to 40 % HCl	Hastelloy	Hastelloy or Rubber Lined CS	Rubber or PPL lined CS	Rubber or PPL lined CS	Hastelloy or Rubber Lined CS
Sodium Hydroxide NaOH	25 to 50% NaOH	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Sulfuric Acid H_2SO_4	93 to 98%	Alloy 20 or PTFE lined CS	Alloy 20 or PTFE lined CS	PP lined CS	Carbon Steel	Alloy 20
Nutrient Sources						
Ammonium Hydroxide NH_4OH	20 % NH_4OH	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Ammonium Phosphate	98% $NH_4H_2PO_4$	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel or rubber/PP line CS	304L Stainless Steel, or FRP	304L Stainless Steel
Phosphoric Acid H_3PO_4	75% as H_3PO_4	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel
Urea NH_2CONH_2	40% Urea	316L Stainless Steel	316L Stainless Steel	316L Stainless Steel	316L Stainless Steel or PVE lined CS	316L Stainless Steel
Oxidant						
Hydrogen Peroxide H_2O_2	35 to 70% H_2O_2	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel	304L Stainless Steel
Sodium Hypochlorite NaOCl	13 to 17 % NaOCl	PPL or PTFE lined CS, Hastelloy C	PVDC, PV2F line Ductile Iron, or Hastelloy C	Butyl Rubber line CS	Glass Reinforced Epoxy, or Butyl Rubber lined CS	Butyl Rubber line CS

Blower Calculation Example using spreadsheet

1 Oxygen Requirement

Oxygen Requirement for BOD Removal = [a'*(So-Se)*Q+b'*X*V]*10^-3

Q	2000	m^3/D
Reactor volume	2000	m^3
MLSS	3000	mg/l
RW_BOD	**1000**	mg/l
TW_BOD	30	mg/l
Constant_a	0.535	kg/kg
Constant_b	0.163	kg/kg/D
Oxygen Requirement	**2015.9**	kgO_2/d

2 Air requirement

Air requirement = Oxygen requirement * 22.4/32*1/oxygen efficiency *1/0.21*((temp+273)/273)

Oxygen requirement	2015.9	kgO_2/D
Temp	0	$_oC$
Oxygen efficiency	10	%
Air requirement	**55905.24**	m^3N/D
	2329.385	m^3N/h
	38.82308	m^3N/min

3 The power requirement for blower (2+1S Basis)

Pw=(w*R*T1)/(29.7*n*e)*(((p2/p1)^0.283)-1)

Air in N	27952.62	m^3N/D
	1164.692	m^3N/h
	19.41154	m^3N/min
	21.9002	m^3/min
w: weight of flow air	0.415962	kg/s
R: engineering gas constant for air	8.314	kJ/k mol $_oK$
T1: absolute inlet temp.	308	$_oK$
p1: absolute inlet press.	1	atm
p2: absolute outlet press.	1.7	atm
n: (k-1)/k=	0.283	for air
k=	1.395	for air
29.7: constant for SI uint conversion		
e: efficiency	0.4	

The required power for blower=	**51.33392**	kW
	55	kW

OIL Separator

Oil separation by gravity is applicable only to remove free state oils and hydrocarbons from wastewater.

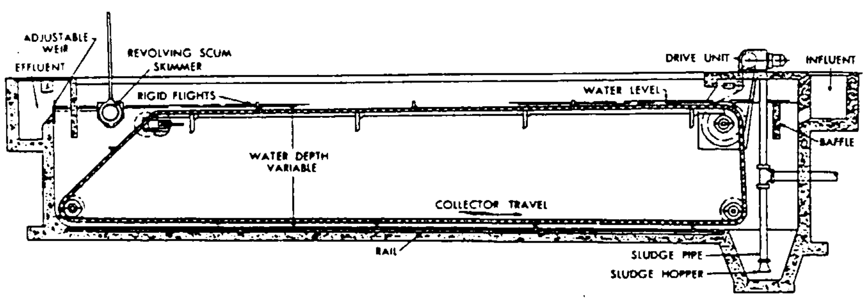
There are several types of gravity separators.

Oil concentration in the treated water is 10 to 50 mg/L in general. This value does not meet to the discharge limitation in many cases.

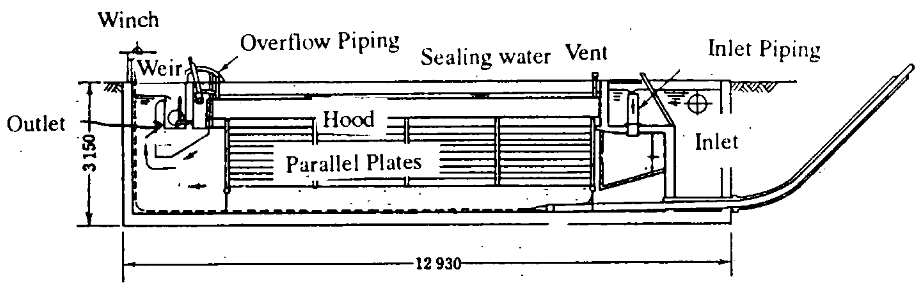
So that oil separator is generally used as preliminary treatment prior to dissolved air flotation process.

Type of Oil Separator

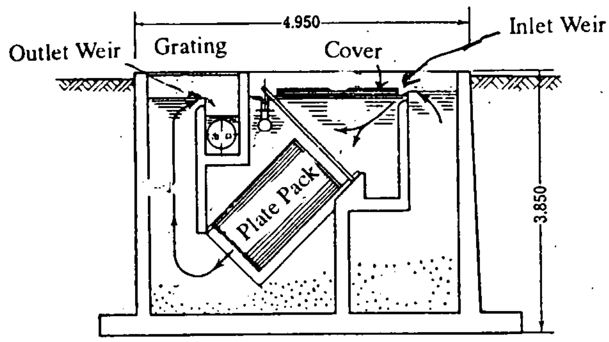
Item	API (American Petroleum Institute)	PPI (Parallel Plate Interceptor)	CPI (Corrugated Plate Interceptor)
Area required	1	0.50	0.35
Applicable oil droplet size	150μ	60μ	60μ
Oil droplet floating velocity	0.9 mm/sec	0.2 mm/sec	0.2 mm/sec
Structure	Simple	Complicated	Complicated
Maintenance	Easy	Hard	Hard
Installation Cost	Inexpensive	Expensive	Inexpensive
License fee	None	Required	Required



Schematics of API separator



Schematics of PPI separator



Schematics of CPI separator

Design and engineering of API separator should be conformed to "Management of Water Discharges: Design and Operation of Oil-Water Separators, API, 1990".

For installation and operation, following item should be paid attention.

- It is recommended not to use pump for influent feeding in order to avoid emulsifying of oil and grease.
- Furnish the retention tank with smooth surface in order to avoid turbulences.
- Floated oil layer should be skimmed adequately.
- The overflow weir and skimming pipe should be leveled horizontally.
- In order to maintain good floating performance, solid substances, chemicals, and sand should not be fed into the wastewater.