

ExxonMobil DESIGN PRACTICES	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	Section	Page
		XIX-A7	1 of 24
		December, 2001	

Changes shown by ↗

CONTENTS

Section	Page
1.0 SCOPE	3
2.0 REFERENCES	3
3.0 DEFINITIONS	4
4.0 BACKGROUND AND SELECTION CRITERIA	6
4.1 BACKGROUND	6
4.2 SELECTION CRITERIA	6
5.0 GRAVITY TYPE CLARIFICATION SYSTEMS	6
5.1 DESCRIPTION	6
5.2 DESIGN CONSIDERATIONS	7
5.3 DESIGN PROCEDURE	7
Quick, Rough Sizing Basis	7
Standard Procedure - Sizing With Lab Data	8
5.4 SAMPLE DESIGN PROBLEMS	12
5.5 OPERATING STRATEGIES, TROUBLESHOOTING AND ENHANCEMENTS	18
6.0 FLOTATION TYPE CLARIFICATION SYSTEMS	18
6.1 DESCRIPTION	18
Induced Air / Gas Flotation (IAF / IGF)	18
Dissolved Air Flotation (DAF)	19
7.0 FLOCCULATION TYPE CLARIFICATION SYSTEMS	19
8.0 MEMBRANE TYPE CLARIFICATION SYSTEMS	19
9.0 FILTRATION TYPE CLARIFICATION SYSTEMS	19
10.0 CENTRIFUGE TYPE CLARIFICATION SYSTEMS	20
11.0 SLUDGE MANAGEMENT	20
12.0 NOMENCLATURE	20



Documents

Document Sharing Hub

Section XIX-A7	Page 2 of 24	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	ExxonMobil DESIGN PRACTICES
December, 2001			

CONTENTS (Cont)

Section	Page
TABLES	
Table 5.1-1 Characteristics of ExxonMobil Gravity Clarifiers	21
Table 5.3-1 Clarifier Design Parameters	21
FIGURES	
Figure 5.1-1 Typical Clarifier Configurations	22
Figure 5.3-1 Graphical Analysis of Settling Data	23
Figure 7.1-1 Flocculating Clarifiers	24

Revision Memo

12/01	Original Issue of Design Practice DP XIX-A7. Separated from DP XIX-A5. Table 5.1-1 added.
--------------	---



 DESIGN PRACTICES	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	Section	Page
		XIX-A7	3 of 24
		December, 2001	

1.0 SCOPE

This section presents sizing criteria and calculations for clarifiers associated with activated sludge units. The sizing criteria are based on overflow rate and solids loading and set the diameter of the clarifier. Other than determining the diameter, clarifiers are not designed by ExxonMobil, but would be duty specified to a qualified clarifier vendor. The vendor should have experience in designing clarifiers for biological solids. Other methods for removing biological solids from the effluent, such as flotation, filtration, membranes, and centrifuges are discussed, however, none of these are currently used by ExxonMobil facilities in place of a clarifier. Filtration and flotation have been used downstream of the clarifier for additional suspended solids removal, and flotation or centrifuging has been used to further dewater waste biological sludge.

2.0 REFERENCES

2.1 DESIGN PRACTICES

- [Section XIX-A1](#) Primary Oil / Water Separators
- [Section XIX-A2](#) Flotation Units
- [Section XIX-A3](#) Media Filtration
- [Section XIX-A4](#) Coagulation / Flocculation / Clarification Equipment
- [Section XIX-A5](#) Biological Treatment of Wastewater
- [Section XIX-A8](#) Activated Carbon Treatment
- [Section XIX-A9](#) Water / Wastewater Chemical Feed Systems

2.2 OTHER REFERENCES

1. Metcalf & Eddy Inc., *Wastewater Engineering Treatment, Disposal, and Reuse*, 2nd Edition, McGraw-Hill Inc., New York (1979)
2. Grady Jr., C. P. L., Daigger, G.T., H. C. Lim, *Biological Wastewater Treatment, Theory, and Applications*, Marcel Dekker, Inc., New York (1999)
3. Eckenfelder Jr., W. W. and P. Grau, *Activated Sludge Process Design and Control: Theory and Practice*, Water Quality Management Library Volume 1, Technomic Publishing Co, Inc., Lancaster, PA, (1992)
4. Metcalf & Eddy Inc., *Wastewater Engineering Treatment, Disposal, and Reuse*, 3rd Edition, McGraw-Hill Inc., New York (1991)
5. Water Environment Federation, *Clarifier Design - Manual of Practice FD-8*, Lancaster Press, Lancaster, PA (1985)
6. Eckenfelder Jr., W. W., *Industrial Water Pollution Control*, 2nd Edition, McGraw-Hill Inc., New York (1989)
7. Hayes, B. E. and M. C. Cancellare, *Industrial Water Pollution Control Technology Course - Eckenfelder's Method Compared to the Design Practices*, 91 ECS2 191 (December 1991)
8. Altemoeller, P. H. and R. R. Goodrich Jr., *Guidelines for Sizing Gravity Thickeners - Wastewater Treatment Sludge Applications*, EE.24E.89 (October 1989)
9. Parker, D. S., *The Case for Circular Clarifiers*, WATER / Engineering & Management, April 1991
10. Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Wastewater Facilities*, Health Education Services, Albany, NY (1990)
11. U.S. Environmental Protection Agency, *The Causes and Control of Activated Sludge Bulking and Foaming - Summary Report*, EPA/625/8-87/012, USEPA, Cincinnati, Ohio (July 1987)
12. Givens, S. W. and C. P. L. Grady et al, *Biological Process Design and Pilot Testing for a Carbon Oxidation, Nitrification, and Denitrification System*, Environmental Progress Vol. 10, No. 2 (May 1991).
13. Water Pollution Control Research Series, No. 12020, 2/70, Petrochemical Effluents Treatment Practices Detailed, U.S. Department of the Interior, Federal Water Pollution Control Administration (February 1970).
14. Water Environment Federation, *Manual of Practice No. 8 - Design of Municipal Wastewater Plants*, WEF and ASCE, Book Press, Brattleboro, VT (1992)
15. Fiessinger, F., *Water Treatment Technologies for the Challenges of the Nineties*, in Water Treatment - Proceedings of the 1st International Conference, Elsevier Science Publishers Ltd, England (1991)
16. Robertaccio, FL, *Polyelectrolyte Guide*, EE.20E.84, 1984.
17. Water Environment Federation, *Guidance Manual for Polymer Selection in Wastewater Treatment Plants*
18. Esler, John, *Optimizing Clarifier Performance*, CPE Services, Inc., New York State Department of Environmental Conservation, Albany, New York.



Section XIX-A7	Page 4 of 24	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	ExxonMobil DESIGN PRACTICES
December, 2001			

2.0 REFERENCES (Cont)

19. Clesceri, L., et al, *Standard Methods for the Examination of Wastewater*, 17th Edition, American Publish Health Association, Washington, DC, 1989.
20. Rich, L. G., *Low-Maintenance, Mechanically Simple Wastewater Treatment Systems*, McGraw-Hill, New York (1980)
21. U.S. Environmental Protection Agency, *Retrofitting POTW's - Handbook*, EPA/625/6-89/020, USEPA, Cincinnati, Ohio (July 1989)
22. Schinner, C. M., *Benicia Clarifier Improvement Study*, 96ECS2 014, (February 20, 1996)
23. Ekama, G.A., et al, *Secondary Settling Tanks: Theory, Modelling, Design and Operation*, International Water Association STP #6 (1997)

3.0 DEFINITIONS

Active Solids / Biomass - The portion of the solids in a biological system composed of microorganisms that are actively metabolizing the substrate (removing the organic or inorganic contamination). Non-biodegradable solids accumulate in the activated sludge system and reduce the percentage of active solids (biomass / organisms) in the system.

Aerobic - A system or process which is active in the presence of dissolved oxygen. In biological waste treatment, aerobic refers to a microbiological system in which microorganisms use dissolved oxygen in the metabolism of the substrate (remove contaminants).

Anaerobic - A system or process which is active in the absence of dissolved oxygen. In biological waste treatment, anaerobic refers to a microbiological system in which microorganisms metabolize the substrate in the absence of dissolved oxygen.

Anoxic - A term frequently used to describe a system or process which is active in the absence of dissolved oxygen but in the presence of nitrate. In these systems, nitrate, not dissolved oxygen, acts as the terminal electron acceptor for the metabolism of the substrate.

Autotrophs - Organisms that obtain carbon for the formation of cell tissue from dissolved carbon dioxide.

Biochemical Oxygen Demand (BOD, BOD₅, BOD_{ULT}) - A general measure of organic material in wastewater samples that can be biologically degraded. It is the quantity of oxygen consumed during the biological decomposition (oxidation) of material in water. Certain inorganic compounds that exert an immediate oxygen demand (e.g., sulfite) will be detected in the BOD test. BOD is usually measured over a specific time period; a five-day period is commonly used, with the result expressed as BOD₅. If the biological decomposition is allowed to proceed to completion, the quantity of oxygen consumed is termed the ultimate BOD, often designated BOD_{ULT} and is normally measured over 20 days. In this case, some nitrogen compounds can be oxidized, a process called nitrification. BOD is normally expressed mg/L (ppm). BOD₅ is typically 60 percent of BOD_{ULT}.

BIOX - Abbreviation for **B**iological **O**Xidation and commonly used to describe an activated sludge system but can be used in reference to other aerobic biological oxidation processes used to treat wastewater.

Bulking - An upset condition in the settling basin of a biological oxidation system during which the bio-sludge doesn't settle, or settles slowly, and leads to floc or suspended solids carryover with the effluent. Bulking is usually associated with filamentous bacterial growths.

Carbonaceous Biological Oxygen Demand (CBOD) - A general measure of organic material in wastewater samples that can be biologically degraded; similar to BOD, but a nitrification inhibitor is used to eliminate the interference of nitrifying bacteria.

Chemical Oxygen Demand (COD) - A measure of the amount of organic or reduced inorganic compounds in a sample that can be oxidized by a strong oxidizer, usually potassium dichromate and sometimes potassium permanganate. COD of a wastewater is generally greater than the BOD since the wastewater may contain oxidizable material that cannot be biologically degraded. The COD test is simpler and faster than the BOD test. Caution must be used when analyzing the COD in high salt (chloride) wastewater streams since the salts will interfere with the test results. COD is expressed as ppm or mg/L.

Dissolved Oxygen (DO) - Dissolved oxygen level, measured in mg/L (ppm), is an important monitoring parameter for biological systems and receiving water bodies. It indicates whether a biological treatment unit can sustain a healthy aerobic microbial population or whether the receiving water body can sustain microbial, aquatic fish, or plant life. A minimum DO value for healthy aerobic biological treatment systems is between 1 to 2 ppm (mg/L). The maximum concentration soluble in water under normal conditions (saturation concentration) is between 8 to 10 ppm (mg/L) and is a function of salinity and temperature. Higher DO levels are possible in high purity oxygen activated sludge systems.

Filamentous Growth - Thread-shaped microorganisms sometimes found in activated sludge plants. Excessive filamentous growth is to be avoided because they are difficult to settle. Filamentous growth can be controlled by maintaining a proper F/M ratio or SRT. Severe filamentous growth may require drastic control, i.e., chlorination or peroxide.

Floc - A flocculant mass formed by the aggregation of a number of fine suspended particles.

ExxonMobil DESIGN PRACTICES	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	Section XIX-A7	Page 5 of 24
	December, 2001		

3.0 DEFINITIONS (Cont)

F/M Ratio - Food to Mass ratio which corresponds to the amount of substrate (organic contamination) removed per day per total mass of activated bio-sludge in the aeration basin. F/M ratio is normally expressed as pounds of BOD₅ or TOC removed per day per pound of MLVSS in the aeration basin. The growth and settling characteristics of the biomass in an activated sludge plant depend upon the F/M ratio. F/M ratio varies inversely with the solid retention time (SRT).

Heterotrophs - Organisms that obtain carbon for the formation of cell tissue from dissolved organic substrates.

Hydraulic Retention Time (HRT) - The length of time the influent wastewater is retained in the aeration basin (not including the effect of sludge recycle; i.e., aeration volume divided by influent volumetric flowrate).

Inert Solids - Those solids within the aeration basin that are not active. Inert solids can include non-degradable solids which enter with the feed, activated carbon, cell debris from dead organisms, and extra-cellular by-products produced by living organisms.

Mean Cell Residence Time (MCRT) - See Solids Retention Time (SRT).

Mixed Liquor - The contents of the aeration basin, consisting of the wastewater and cell biomass.

Mixed Liquor Suspended Solids (MLSS) - The concentration of total suspended solids in the aerated section of a biological treatment unit or lagoon. MLSS is normally expressed in units of ppm or mg/L.

Mixed Liquor Volatile Suspended Solids (MLVSS) - The portion of the MLSS which volatilizes at 1022°F (550°C). Biological solids (microorganisms) are the main contributor to MLVSS. For systems which add powdered activated carbon, a separate acid digestion step can be done to distinguish between MLVSS due to carbon and MLVSS due to biomass. MLVSS is normally expressed in units of ppm or mg/L.

Nitrification - Nitrification is a biological process where ammonia is converted / oxidized to nitrate. The process involves one microorganism species (Nitrosomonas) converting ammonia to nitrite and then a different microorganism species (Nitrobacter) converting the nitrite to nitrate. This term should not be confused with "denitrification," which refers to the biological process of converting nitrates to nitrogen gas.

pH - A measurement of the acidic or basic character of a solution at a given temperature. It is defined as the negative logarithm (to the base 10) of the hydrogen ion concentration (-log[H⁺]). Pure water is slightly ionized with a pH of 7, and at equilibrium the ion product, K_w, is [H⁺][OH⁻] = 1.01 x 10⁻¹⁴ at 25°C. Generally, biological treatment systems operate best at pH ranges between 6.5 to 8.5. Wastewater outside the 5.5 to 9.5 pH range (before being commingled in the mixing zone of the wastewater effluent and the receiving water body) can potentially cause harm to the receiving water aquatic life as well as the biological treatment microorganisms.

Recycle - The portion of solids which is taken from the clarifier underflow and routed back to the aeration basin to control the mixed liquor microbe population in the bioreactor, sometimes referred to as RAS, Recycle Activated Sludge.

Sludge Blanket - The level of sludge in the settling basin (clarifier), usually expressed in ft (m).

Sludge Volume Index (SVI) - A measure of compaction of sludge after gravity settling. SVI is the volume in milliliters occupied by one liter of activated sludge after 30 minutes of settling divided by the MLSS concentration.

$$SVI = [(ml \text{ of settled sludge} / \text{litre of initial suspension}) / (mg/L \text{ of MLSS})] \times 1000$$

Normally, the SVI of the sludge varies with the F/M ratio and the SRT in the aeration basin. Values below 100 are generally indicative of good settling and compaction. Care must be taken in use of the SVI in systems with high MLSS levels, e.g., high purity oxygen systems or very high sludge ages.

Solids Residence Time (SRT) - The average length of time the solids are held in the system expressed in days, sometimes referred to mean cell residence time (MCRT).

$$SRT = (\text{Total mass of solids in the aeration basin and clarifier}) / (\text{mass of solids lost both intentionally and unintentionally per day})$$

Total Dissolved Solids (TDS) - A measure of all dissolved material in a solution, including inorganic salts (e.g., NaCl, MgCl, etc.) that typically make up the bulk of the TDS measured in the standard lab test. TDS is used to determine the salt levels of wastewater. Measurement for TDS consists of passing a sample through a standard glass fiber filter, and the filtrate is evaporated to dryness in a weighed dish and dried to a constant weight at 356°F (180°C). The material remaining on the filter paper is the total dissolved solids and is reported in units of ppm or mg/L. Conductivity can be used for a quick substitute measurement for TDS (reported in units of micromhos or microsiemens). As a rule-of-thumb, for wastewater streams at pH 7, the TDS of that stream in ppm (mg/L) can be approximated by multiplying the conductivity in units of micromhos or microsiemens by 0.7.

Total Suspended Solids (TSS) - The amount of suspended matter removed by a 0.45 micron filter when a wastewater sample is dried at 217°F (103°C) and is reported in units of ppm or mg/L. Inorganic particles such as clay or grit as well as organic particles (biological solids including algae) contribute to the suspended solids concentration.



Section XIX-A7	Page 6 of 24	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	ExxonMobil DESIGN PRACTICES
December, 2001			

3.0 DEFINITIONS (Cont)

Volatile Suspended Solids (VSS) - Volatile suspended solids is the portion of the TSS (or MLSS) which volatilizes at 1022°F (550°C). Biological solids (microorganisms) are the main contributor to VSS. VSS is normally expressed in units of ppm or mg/L.

Waste Bio-Sludge - The portion of excess biomass that is intentionally discharged from the activated sludge system. Normally bio-sludge is intentionally wasted by purging a portion of the return activated sludge from the clarifier underflow or recycle line.

4.0 BACKGROUND AND SELECTION CRITERIA

4.1 BACKGROUND

Clarifiers are used to settle and recycle biological solids back to the activated sludge unit. They are an essential part of the activated sludge process which depends on solids residence time (SRT) being longer than hydraulic residence time (HRT) to achieve high levels of biological degradation. Solids concentrations are increased in the clarifier, resulting in recycle solids being 2 - 3 times more concentrated than aeration basin solids. Effluent suspended solids levels less than 50 mg/L can generally be expected. Clarifiers for biological solids are sized based on two criteria: overflow rate and solids loading. Often in high SRT systems the solids loading criterion is limiting and therefore sets the diameter. It is therefore essential to have a good prediction of full scale MLSS level based on calculation or pilot data to be able to size the clarifier. If pilot plant biomass is available, settling tests should be performed.

4.2 SELECTION CRITERIA

There are many types of clarification systems: gravity, flotation, flocculation, membrane, filtration, and centrifuges. A brief description of each of these systems is given in this section, but typically, gravity clarifiers have been used in the activated sludge process. Rectangular, square and circular clarifiers have been used. The rectangular clarifiers typically have moving bridge, suction-type solids removal. Square clarifiers often have circular scrapers and are called squircles. A disadvantage of squircles is that it is difficult to remove sludge from the corners of the clarifier and it can become anaerobic in these areas. Circular clarifiers, although not the most efficient use of plot area, are the most common in newer designs. The internal details of the clarifier can have an effect on performance and vary for different applications. Baffling, such as the Stamford Baffle and flocculating center wells have been used to upgrade existing gravity clarifiers. In fact, in more recent years, flocculating center wells have become a common design practice for new systems. There are, however, special cases where the other types mentioned can be applied as discussed in the description section of that type.

5.0 GRAVITY TYPE CLARIFICATION SYSTEMS

5.1 DESCRIPTION

Accurate clarifier design is critical to the overall performance of the biological treatment system. In many cases, it is the final unit process before discharge and therefore directly affects the quality of the effluent being produced by the plant. In an activated sludge system, the clarifier's purpose is to separate the clarified effluent and biological solids usually by gravity so that the majority of the solids can be returned to the aeration basin and some portion wasted. The clarifier must be designed to handle both the hydraulic and solids loadings. Flow surges that can upset the settling process must be minimized. Clarifiers following an activated sludge process are sometimes referred to as secondary clarifiers or clarifiers with hindered settling or zone settling. As the blanket is formed, a layer of processed effluent with little solids content is produced. The bottom of the blanket tends to be more concentrated in solids than the top part of the blanket which interfaces with the effluent. The thickened underflow is returned to the activated sludge aeration basin, while a portion of it is wasted. Many factors influence the performance of the clarifier: flowrate, temperature, clarifier dimensions (surface area, depth, weir type, etc.), sludge settling properties (rate, compaction), nitrification and the biological process which has a direct impact on the settling characteristics of the sludge. Since all of these parameters have a direct effect on the clarified effluent and each system varies, the need for collecting settling data can not be overstated. (*Reference 7*)

Clarifiers vary in size, shape, depth as well as many other features like feed wells, inlet baffling, outlet weir type, sludge removal/return mechanisms and scum removal devices. Typical configurations are shown in **Figure 5.1-1**. For reference purposes only, a table including the characteristics of ExxonMobil gravity clarifiers is provided in **Table 5.1-1**.

 DESIGN PRACTICES	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	Section	Page
		XIX-A7	7 of 24
		December, 2001	

5.0 GRAVITY TYPE CLARIFICATION SYSTEMS (Cont)

5.2 DESIGN CONSIDERATIONS

As the design MLSS concentration increases, the size and cost of the aeration basin decreases, but increases for the clarifier. Key design considerations include: size and shape, inlet flow distribution and centerwell configuration, sludge return mechanisms, overflow weirs, and variations in hydraulic and solids loadings due to rain, high MLSS, and recycle rate.

Size and Shape

Shape and size will depend on the available plot space. Although rectangular/square clarifiers can be upgraded more cost-effectively and may take up less plot space, it is difficult to scrape the corners for biosludge return and waste.

Inlet Flow Distribution and Centerwell Configuration

The internal details of the clarifier will have an effect on the performance. The inlet flow should be balanced in order to avoid short circuiting. Flocculating center wells can increase performance. The flow should be distributed horizontally. In circular clarifiers without baffles, it has been found that spiral flow (peripheral feed) with central launders or flocculating centerwell with radial or inboard launders works best. Inlets for rectangular clarifiers seem to work best with baffled inlet pipes.

Sludge Return Mechanisms and Scum Collection

If circular sludge withdrawal tubes are used for sludge return, then it is recommended that the tubes are stacked horizontally. Hydraulic Sludge withdrawal arms (e.g., Tow-Bro) and plow-type sludge scrapers can also be used. If circular wells are used, then problems with scum can occur. For scum collection in circular clarifiers, dual skimmers are recommended. For rectangular sludge withdrawal mechanisms a mechanism for scum removal should be provided. The location of the biomass recycle hopper in rectangular clarifiers is typically at the inlet end (*Reference 18*). Recycle pumps should be specified such that they do not shear the floc (e.g., open impeller centrifugal pumps).

Effluent Weir

Effluent weir location is important. In rectangular clarifiers without baffles it has been found that the best conditions occur when the weir is covering at least 30 percent of the surface, there is the capability to measure the effluent flow, the weirs are adjustable and no deeper than necessary and parallel to the flow.

5.3 DESIGN PROCEDURE

Quick, Rough Sizing Basis

In the quick, rough sizing basis, the recycle ratio is assumed to equal 1. This is determined by first using a suspended solids mass balance around the aeration reactor, neglecting the suspended solids in the influent as shown in the following equation. Caution should be used when using this equation because it suggests that X can be controlled with Q_r , but in an underloaded clarifier, Q_r will not impact X .

$$X \cdot (Q + Q_r) = X_r \cdot (Q_r) \quad \text{Eq. (5.3-1)}$$

where: Q = Design influent flowrate (Mgal/d or m³/d)
 Q_r = Recycle flowrate (Mgal/d or m³/d)
 X = Aeration solids concentration, mg/L
 X_r = Underflow solids concentration = recycle solids concentration, mg/L

Rearranging **Eq. 5.3-1**:

$$\frac{Q_r}{Q} = \frac{X}{X_r - X} = R, \text{ the recycle ratio.} \quad \text{Eq. (5.3-2)}$$

In the absence of any pilot data, X_r can be assumed to be three times the concentration of X . In such cases, therefore, $R = 1 / (3 - 1) = 0.5$. A safety factor of two is typically used to account for system variations during actual operation by choosing a minimum R of 1.

To determine the necessary clarifier area, determine the acceptable hydraulic (including recycle) and solids loading rates. Typical design parameters are given in **Table 5.3-1**.

The clarifier area should be calculated based on the design flowrate using both **Eq. 5.3-3** (hydraulics) and **Eq. 5.3-4** (solids loading). The larger of the two areas (either $A_{\text{hydraulics}}$ or $A_{\text{solids loadings}}$) is usually selected as the clarifier design area and a contingency factor of 1.3 is commonly used.

Section XIX-A7	Page 8 of 24	WATER POLLUTION CONTROL CLARIFICATION SYSTEMS FOR BIOLOGICAL TREATMENT OF WASTEWATER	ExxonMobil DESIGN PRACTICES
December, 2001			

5.0 GRAVITY TYPE CLARIFICATION SYSTEMS (Cont)

$$A_{\text{hydraulics}}, \text{ ft}^2 = \frac{(Q) (10^6) \frac{\text{gal}}{\text{d}}}{\text{design overflow rate}, \frac{\text{gal}}{\text{ft}^2\text{-d}}} \quad \text{Eq. (5.3-3)}$$

$$A_{\text{hydraulics}}, \text{ m}^2 = \frac{(Q) \frac{\text{m}^3}{\text{d}}}{\text{design overflow rate}, \frac{\text{m}^3}{\text{m}^2\text{-d}}} \quad \text{Eq. (5.3-3)M}$$

$$A_{\text{solids loading}}, \text{ ft}^2 = \frac{(Q + Q_r) (X) (8.34) \frac{\text{lb}}{\text{d}}}{\text{design solids loading}, \frac{\text{lb}}{\text{ft}^2\text{-d}}} \quad \text{Eq. (5.3-4)}$$

$$A_{\text{solids loading}}, \text{ m}^2 = \frac{(Q + Q_r) (X) (10^{-3}) \frac{\text{kg}}{\text{d}}}{\text{design solids loading}, \frac{\text{kg}}{\text{m}^2\text{-d}}} \quad \text{Eq. (5.3-4)M}$$

Overflow rates and solids loading rates should then be calculated at hourly peak loads using the clarifier surface area determined from the design flowrate to confirm that the rates remain below the numbers given in **Table 5.3-1**. Refer to *Standard Procedure - Sizing With Lab Data*, Step 8 below. If at hourly peak loads, the values of the rates are higher than what is shown in the table, the clarifier surface area calculated by the design flowrate is not adequate to handle these peak loads; and therefore the peak loads may dictate the clarifier surface area rather than the design flowrate. Clarifier peak solids loading rates should be computed based on the design maximum day flow rate plus the design maximum return sludge rate requirement and the design MLSS under aeration.

Clarifier design depths are typically 12 - 20 ft (3.7 - 6.1 m).

Standard Procedure - Sizing With Lab Data

This procedure involves determining the total solids flux (mass of solids per clarifier surface area per time) that can be applied to a clarifier. The solids flux is greatly influenced by water conditions especially temperature and salt. The total flux consists of two components: settlement of the sludge induced by gravity, and bulk movement of sludge and water induced by recycle from the clarifier bottoms. The gravity flux component is determined by measuring the settling velocity of the sludge which is assumed equal to the sludge interface settling velocity. The bulk flux component is determined from the velocity within the tank created by the sludge recycle flow. By adding these two components, the maximum solids flux that can be applied to a clarifier producing a specified underflow concentration at a specified recycle rate can be found. In order to determine the solids flux, batch settling tests must be performed. Once the clarifier surface area is found with this method, use the quick method as a check and choose the larger area of the two methods.

Step 1: Perform batch settling tests - To be effective, these lab tests should be repeated at several SRT values.

- A. Obtain several 1L mixed liquor aeration samples from the pilot plant aeration basin.
- B. Attach a measuring tape to a graduated cylinder that is 6 in. in diameter and 4 ft high (if this is not available a typical 1L graduated cylinder can be used, but larger volumes are recommended to minimize wall effects). Attach a measuring tape to the cylinder. Pour one of the aeration samples into the cylinder. Record the level (on the measuring tape, in. or cm) of where the solids / effluent interface is located at various minute intervals (1, 2, 3, 4, 5, 10, 15, 20, 25, and 30 minutes). After 30 minutes has elapsed, re-mix, and analyze this sample for the TSS concentration.
- C. Repeat step B for several TSS (MLSS) concentrations by concentrating and diluting the aeration samples. For air activated sludge, a recommended range of solids concentrations is 1,500 to 18,000 mg/L, while for oxygen activated sludge the range should be between 3,000 and 26,000 mg/L. A minimum of five different solids concentrations is required. Use effluent water for dilution.