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Revision Memo

12/01	Original Issue of Design Practice XIX-A6. This Design Practice was formerly Section 6 of DP XIX-A5. Expanded Section 6.3. Corrections made to Table 6.3-1. Added Section 9.0 on Deep Tank Aeration and Section 10.0 on Aeration System Performance Testing.
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1.0 SCOPE

This section covers selection of aeration equipment for activated sludge aeration basins and lagoons, and design procedures for calculating actual oxygen demand and for estimating standard airflow rate and horsepower requirements. Aeration equipment discussed includes mechanical surface aerators, fine and coarse bubble diffused aerators, aspirating aerators and jet aerators. Aeration equipment is duty specified to a qualified aeration vendor. The vendor calculates the standard air flow rates and horsepower requirements based on their equipment. Calculations in this section can be used to verify the vendor's calculations.

2.0 REFERENCES

2.1 DESIGN PRACTICE

DP XIX-A5 Biological Treatment of Wastewater

2.2 EMRE WATER AND WASTEWATER DESIGN GUIDE (TMEE 080)

DG 11-9-1 Aeration Systems

2.3 OTHER REFERENCES

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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.

Aerated Lagoon - An oxidation pond with aeration devices. Mixing energy supplied to an aerated lagoon is usually insufficient to completely mix 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).

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3.0 DEFINITIONS (Cont)

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 (oxidize) 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.

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 biological oxidation processes used to treat wastewater.

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 microbial population or whether the receiving water body can sustain microbial, aquatic fish, or plant life. A minimum DO value for healthy 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.

Endogenous Respiration - The energy required for cell maintenance. Other factors such as cell death and predation are usually combined with endogenous respiration in a term called endogenous decay.

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).

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 contributors 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.

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 × 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.

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.

Theoretical Oxygen Demand (ThOD) - The oxygen required to oxidize all organic or reduced inorganic compounds to CO₂, SO₄, NO₃, etc. In practice, the TOD and COD measure by analytical procedures will approach the calculated ThOD. ThOD is normally expressed as ppm or mg/L.

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3.0 DEFINITIONS (Cont)

Total Organic Carbon (TOC) - The quantity of organically bound carbon in a sample. TOC is commonly used as a replacement for BOD since the test for TOC is significantly faster than the 5-day test for BOD, and the BOD test can sometimes give erroneous results. TOC is normally expressed as ppm or mg/L.

Total Oxygen Demand (TOD) - The amount of oxygen required to oxidize all oxidizable substances in a sample, including the biodegradable organic matter. It is measured using a special analytical instrument. TOD is normally expressed as ppm or mg/L.

4.0 BACKGROUND AND SELECTION CRITERIA

4.1 BACKGROUND

Aeration provides dissolved oxygen in the wastewater and necessary mixing for sludge suspension in the suspended growth or combination systems, intimate sludge-waste contact, and dispersion. There are two basic methods to supply oxygen and mixing to the biological treatment system: agitate the wastewater mechanically so the wastewater contacts the air from the atmosphere, or introduce air or pure oxygen into the wastewater with submerged diffusers or devices. (11)

4.2 SELECTION CRITERIA

The selection criteria are based mainly on the amount of oxygen transfer needed and the volume (particularly depth) of the aeration basin. **Figure 4.2-1** contains a decision tree for rough guidelines used to choose which type of aeration system is recommended for a particular application. Since temperature / heat loss from mechanical aerators is higher than diffused, in the case of cold climates, diffused aeration should be considered. In terms of minimum depth, it is difficult to select either type (mechanical or diffused) for tanks / basins less than 6 ft (2 m). Aeration systems used at various ExxonMobil facilities are listed in **Table 4.2-1**.

5.0 MECHANICAL AERATION SYSTEMS

5.1 DESCRIPTION

Mechanical aeration systems agitate the wastewater to serve two functions: supply oxygen to the wastewater by contacting it with the air from the atmosphere and provide the necessary mixing for sludge suspension. There are two groups of mechanical aerators: aerators with vertical axis and aerators with horizontal axis. Within these two groups aerators are classified as surface or submerged. **Figure 5.1-1** contains examples of various types of mechanical aerators that are available.

Mechanical Aerators-Vertical Axis

Surface aerators with vertical axis are designed to induce either updraft or downdraft flows below the aerator. Impellers are either totally or partially submerged and are attached to the motors. The aerators can be mounted on floats (pontoon-mounted) or fixed (mounted on a bridge or on columns). Updraft impeller types and speed vary including centrifugal (high-speed), radial-axial (medium speed) and axial (low speed). Low speed aerators are driven through a reduction gear by an electric motor while high-speed aerator impellers are coupled directly to the electric motor rotating shaft. Low speed aerators are usually mounted on fixed supports because they tend to be heavier and require more maintenance than high speed. The updraft aerators usually are positioned at, or slightly below, the surface, where they pump large amounts of water and propel it into the air. Down draft impeller types also vary including open-turbine, closed turbine, and forced air-propeller aerators. The down draft aerators force liquid from the top through a vertical tube to the basin bottom while entraining air. The aerated water is expelled from the bottom of the tube. Down draft aerators are usually less efficient than updraft aerators but are used when turbulence and splashing by updraft aerators would throw water out of the basin.

Submerged surface aerators with vertical axis are classified into three groups: turbine, impeller (suction), and porous-rotating discs. Turbine aerators either have mechanical means for drafting air in the liquid or use spargers that are fed air by blowers. Impeller aerators are operated with impeller created suction or air from a blower. Porous rotating discs using forced air have a cored impeller with a porous top plate secured to a hollow shaft. Air is blown through the hollow shaft in the impeller core and is passed through the porous plate.

Mechanical Aerators-Horizontal Axis

Mechanical aerators with horizontal axis are either surface aerators or submerged aerators. The surface aerators have a horizontal cylinder rotor with bristles / angle steel / plastic bars submerged in the bulk liquid of the aeration basin / tank. As the cylinder rotor rotates, the bars drive air into the water and throw water jets and droplets into the air while the liquid is propelled forward to provide mixing.

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5.0 MECHANICAL AERATION SYSTEMS (Cont)

An example of a submerged aerator with horizontal axis is a disc aerator. Thin discs are mounted on a horizontal shaft that rotates within the wastewater. As the shaft rotates, recesses and nodules on the disc face propel and transfer oxygen into the wastewater.

Performance

Mechanical aerators are rated in terms of their oxygen-transfer rate under standard conditions, expressed in pounds of oxygen per horsepower-hour (kilograms of oxygen per kilowatt-hour). Standard conditions include temperature at 20°C, dissolved oxygen of 0.0 mg/L, and clean tap water. Standard transfer rates for mechanical aerators range from 1.5 to 5 lb O₂/hp hr.

5.2 DESIGN CONSIDERATIONS

In the design of a surface aeration system, considerations must be given to selecting which type of surface aerator will provide sufficient amount of oxygen and mixing and still be most economical for the aeration basin volume and depth. Once the type of surface aerator has been identified, aerator layout is critical. Another important consideration to keep in mind if surface aerators are chosen is that the temperature / heat loss for mechanical surface is higher than diffused. Like all other rotating equipment, mechanical surface aerators require maintenance and therefore consideration should be made to their accessibility. Also, certain surface aerators have better control techniques to vary the oxygen concentration in the basin / tank. For example, surface high speed aerators usually have two options: on or off, while surface low speed aerators can be controlled by submergence, speed, and the option of being on or off. **Table 5.2-1** shows a sample duty specification sheet that is normally supplied to the aeration vendor.

5.3 DESIGN PROCEDURE FOR MECHANICAL SURFACE AERATORS

Before the surface aerators can be designed, the aeration basin / depth must be assumed, since many of the parameters used to size the surface aerators are depth dependent. The aeration basin / tank volume is set to provide sufficient hydraulic retention time for degradation and the basin water depth is set to provide effective and economical aeration and mixing. Depth selection is governed by aerator size, impeller speed and design, civil engineering considerations, construction costs, the available plot area, and the water table. Once the basin water depth is decided, 2 to 3 ft of freeboard above the water level is added to obtain the total basin depth. When using mechanical surface aerators the basin / tank depth normally ranges from 6 - 12 ft. Surface aerators used in depths greater than 15 ft require draft tubes or double impellers.

Once the total basin depth is assumed, two equations are used to determine the Total BHP requirement. One equation calculates the BHP necessary to fulfill the oxygen requirement while the other determines the BHP necessary to keep the solids in suspension. The greater of the two requirements is used for the design purposes. Once the total BHP has been determined, the total number of aerators and layout configuration of these aerators can be estimated.

A. Calculation of BHP needed for O₂ requirement

Quick, Rough Sizing Basis

Use 2 lb O₂/bhp hr as the actual oxygen transfer rate, N, of the surface aerators under operating conditions when temperature is around 25°C and TDS levels are 0 - 1000 mg/L to determine the total surface aerator HP required for the oxygen requirements using **Eq. 5.3-1**. If the operating conditions are not 25°C and 0 to 1000 mg/L TDS, use the standard procedures:

$$\text{Total BHP for O}_2 \text{ requirement} = \frac{\text{AOR (lb O}_2\text{/d)}}{24 \cdot (2 \text{ (lb O}_2\text{/bhp} \cdot \text{hr)})} \quad \text{Eq. (5.3-1)}$$

where: AOR= Actual Oxygen Required, calculated from Step 10 and 11 in **Section 6.3** of **DP XIX-A5**

Note: 1W = 1.341 x 10⁻³hp
1kg = 2.20462 lb

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5.0 MECHANICAL AERATION SYSTEMS (Cont)

Standard Procedures

Step 1. Determine the actual oxygen transfer rate of the surface aerators under operating conditions, N (lb O_2 /bhp hr) using the following equation:

$$N = N_0 \cdot \frac{(C_{sw} - C_L)}{9.17} \cdot (1.024^{(T - 20)}) \cdot \alpha \quad \text{Eq. (5.3-2)}$$

$$C_{sw} = C_{ss} f_p \beta \quad \text{Eq. (5.3-3)}$$

$$f_p = \frac{(\pi - p)}{(760 - p)} \quad \text{Eq. (5.3-4)}$$

where: N = Actual oxygen transfer rate of the surface aerators under operating conditions, lb O_2 /bhp hr
 N_0 = Standard oxygen transfer rate of the surface aerators under standard conditions, clean water, 20°C, zero dissolved oxygen and 1 atm pressure, usually supplied by the aeration vendor, estimated to be at 3.4 lb O_2 /bhp hr for large horsepower surface aerators (100 hp). The standard oxygen transfer rate decreases with horsepower size.
 C_{sw} = Saturation oxygen solubility in the mixed liquor at operating temperature and design altitude, mg/L
 C_{ss} = Oxygen saturation value in pure water at the temperature of the mixed liquor, mg/L (see **Figure 5.3-1**)
 f_p = Pressure factor for oxygen solubility, dimensionless
 π = Total pressure, mm Hg
 p = Saturation water vapor pressure at the temperature of the mixed liquor, mm Hg

$$\beta = \frac{\text{Saturation concentration of oxygen in the mixed liquor}}{\text{Saturation concentration of oxygen in clean water at same temperature}}, \text{ dimensionless} \quad \text{Eq. (5.3-5)}$$

The Beta factor usually ranges from approximately 0.8 to 1.0. It is difficult to measure the saturation concentration of the oxygen in the mixed liquor accurately with a dissolved oxygen membrane probe because many wastewaters contain substances that interfere with the dissolved oxygen determination. The value of beta, therefore is usually based on the dissolved solids content of the process water and should be calculated as the ratio of the dissolved surface saturation concentration in water, with dissolved solids equal to that of the process water, to the dissolved oxygen surface saturation concentration in clean water. Therefore, to determine the value of Beta, obtain a TDS value of the mixed liquor, assume that all the TDS is NaCl and estimate the total Chloride (g/kg of solution) $\approx$ Chlorinity content in the mixed liquor. Using **Table 5.3-1** at the mixed liquor temperature and Chlorinity, determine the oxygen solubility (saturation concentration of oxygen in the mixed liquor). The saturation concentration of oxygen in clean water at the same temperature can be determined from this same chart assuming the Chlorinity = 0. The ratio of these two oxygen solubilities = the Beta factor. (Many factors influence the Beta factor including temperature, pressure, and wastewater characteristics.)

$$\beta = \frac{\text{Oxygen solubility at the mixed liquor Temp. and Chlorinity}}{\text{Oxygen solubility of clean water at mixed liquor Temp. and 0 Chlorinity}}, \text{ dimensionless} \quad \text{Eq. (5.3-6)}$$

where: C_L = Concentration of dissolved oxygen to be maintained in the aeration basin, mg/L, usually = 2 mg/L,
9.17 = Saturation oxygen concentration in clean water at 20°C and 1 atm pressure, mg/L,
 T = Mixed liquor temperature in aeration basin, °C,

$$\alpha = \text{Alpha Factor, } \frac{\text{Rate of transfer of oxygen } (K_L a) \text{ of the mixed liquor at } 20^\circ\text{C}}{\text{Rate of transfer of oxygen } (K_L a) \text{ of clean water at } 20^\circ\text{C}}, \text{ dimensionless} \quad \text{Eq. (5.3-7)}$$

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5.0 MECHANICAL AERATION SYSTEMS (Cont)

The alpha factor ranges from approximately 0.2 to greater than 1.0. For surface aerators in refinery wastewater, 0.8 is traditionally used. *(Many factors influence the alpha value including process conditions such as surfactants, turbulence, power input per unit of volume, tank geometry, geometric scales between aeration tank and aeration device, bubble size, degree of treatment and wastewater characteristics. Vendors often supply alpha factors for their equipment. Use of the vendor-supplied values is only recommended if the vendor can supply data to support their use in the similar-type wastewater.)*

Step 2. Determine the total BHP required to fulfill the oxygen requirements:

$$\text{Total BHP for O}_2 \text{ requirement} = \frac{\text{AOR (lb O}_2\text{/d)}}{24 \cdot (N \text{ (lb O}_2\text{/bhp} \cdot \text{hr))}} \quad \text{Eq. (5.3-8)}$$

B. Calculation of BHP needed for solids suspension in an activated sludge unit

Step 1. Estimate the brake horsepower per thousand gallons:

$$\frac{\text{BHP}}{1000 \text{ gal}} = \frac{\text{BHP for O}_2 \text{ requirement}}{\left[V \text{ (gal)} \left(\frac{1 \text{ kgal}}{1000 \text{ gal}} \right) \right]} \quad \text{Eq. (5.3-9)}$$

Step 2. If BHP/1000 gal is greater than or equal to 0.14, then the total brake horsepower needed for the oxygen requirement is also sufficient to keep the solids suspended in an activated sludge unit. (Aerated lagoons have different requirements discussed in [DP XIX-A5, Section 8.0](#).)

If BHP/1000 gal is less than 0.14 for an activated sludge unit, then the total brake horsepower needed for both the oxygen requirement and solids suspension is calculated by:

$$\text{Total BHP required for O}_2 \text{ and solids suspension} = (1.4 \times 10^{-4}) V \text{ (gal)} \quad \text{Eq. (5.3-10)}$$

If BHP/1000 gal is greater than 0.35, the total brake horsepower may be too high for mechanical aeration (check with vendor); consider diffused aeration.

Note: Aerated lagoons have different requirements, refer to [DP XIX-A5, Section 8.0](#).

C. Determine the aerator horsepower size and number of surface aerators needed to supply the total BHP.

Step 1. The aerator horsepower size is determined by taking into account the horsepower sizes which are offered by the aeration vendors, the representative circles of influences (diameters for complete mixing, D_{CM} , and impingement pattern diameters, D_{IP}) and the depth of the aeration basin. The aeration basin depth is usually the limiting parameter, as large horsepower sized surface aerators can not be used in shallow aeration basin depths because the aerator hydraulic energy tends to scour the bottom of the basin. The table below describes the common horsepower sizes available and their circles of influence and minimum basin water depth recommended.



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5.0 MECHANICAL AERATION SYSTEMS (Cont)

AERATOR HORSEPOWER SIZE, BHP	CIRCLE OF INFLUENCE FOR COMPLETE MIXING, D_{CM} , ft	CIRCLE OF INFLUENCE FOR IMPINGEMENT PATTERN DIAMETERS, D_{IP} , ft	MINIMUM BASIN WATER DEPTH RECOMMENDED FOR THIS AERATOR SIZE, ft*
1	18	6.5	6
2	23	7	6
3	42	14	6
5	45	15	6
7.5	50	18	8
10	51	18	10
15	62	20	10
20	72	20	10
25	80	24	10
30	88	24	10
40	102	26	10
50	105	26	12
60	115	27	12
75	130	30	12
100	150	38	12
125	165	40	12
150	185	40	12

* Basin with a depth greater than 15 ft that use surface aerators require draft tubes on the aerators, or double impellers for oxygen transfer and mixing.

Step 2. Using the aeration basin depth as the deciding parameter, choose an aerator horsepower size and estimate the number of surface aerators that would be required to supply the Total BHP required for O_2 and solids suspension, rounding up to the next higher whole number:

$$\# \text{ of aerators} = \frac{\text{Total BHP required for } O_2 \text{ and solids suspension, BHP}}{\text{Aerator Horsepower Size, BHP}} \quad \text{Eq. (5.3-11)}$$

Step 3. After determining the number of aerators necessary for the Total BHP requirement, lay out the aerators within the basin area using the following guidelines:

- The aerators should be laid out such that the circles of influence are within the minimum-maximum range and are as far apart as possible, in other words the complete mixing zones are just about touching. If placement requires that the mixing zones partially overlap, the aerators should be laid out such that the impingement pattern diameters do not overlap.
- It is important to maintain complete aeration coverage throughout the aeration basin without creating any dead zones.
- Ensure that each aerator has an equal area of influence, and the interaction of the aerators does not cause a vibration problem.

Step 4. Repeat steps 2 and 3 until the optimum number of aerators and aerator horsepower size is established to supply sufficient oxygen at a minimum cost.

Step 5. If layout considerations permit, and if adjustment of basin geometry will permit a more economical use of aerators, adjust basin geometry (length, width, and depth) and repeat steps as necessary to determine the most economical unit.



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5.0 MECHANICAL AERATION SYSTEMS (Cont)

5.4 SAMPLE DESIGN PROBLEMS

From the data given in the sample design problem of the activated sludge section:

$V = 5.8 \text{ Mgal (21,800 m}^3\text{)}$
 $\text{AOR, O}_2 = 27,800 \text{ lb/d (12,700 kg/d)}$
 $\text{Min. temperature} = 60^\circ\text{F (15}^\circ\text{C)}$
 $T = 68^\circ\text{F (20}^\circ\text{C)}$
 $\text{Max. dissolved solids} = 3000 \text{ mg/L}$
 $\text{Total pressure} = 760 \text{ mm Hg}$

Note: The following is an example for an aeration system in an activated sludge process. Aerated lagoons have different criteria which are covered in [DP XIX-A5](#), Section 5.1.3.

A. Calculation of BHP needed for O₂ requirement

Step 1: Determine the actual oxygen transfer rate of the surface aerators under operating conditions, N (lb O₂/bhp hr) using [Eq. 5.3-2](#).

a. **Assumptions:**

Assume $N_0 = 3.4 \text{ lb O}_2/\text{bhp hr}$ (this value is normally supplied by the aeration vendor)
 Assume $\alpha = 0.8$ because this is surface aerators and refinery wastewater
 Assume $C_L = 2 \text{ mg/L}$ recommended concentration of dissolved oxygen maintained in the aeration basin / tank

- b. Use [Figure 5.3-1](#) to determine C_{ss} at $68^\circ\text{F (20}^\circ\text{C)}$, $C_{ss} = 9.4 \text{ mg/L}$
- c. From Steam Tables determine, p , the saturation water vapor pressure at 20°C , $p = 17.55 \text{ mm Hg}$
- d. Determine the value of f_p from [Eq. 5.3-4](#).

$$f_p = \frac{(760 - 17.55)}{(760 - 17.55)} = 1$$

- e. Determine the value of β by assuming the maximum dissolved solids is all NaCl and determining the chlorine content. Use [Table 5.3-1](#) to determine the saturation concentration of oxygen in the mixed liquor at 20°C with this chlorinity and in clean water at 20°C

$$3000 \frac{\text{mg}}{\text{L}} \text{ NaCl} \cdot \frac{1 \text{ mmole NaCl}}{58.5 \text{ mg NaCl}} \cdot \frac{1 \text{ mmole Cl}}{1 \text{ mmole NaCl}} \cdot \frac{35.5 \text{ mg Cl}}{1 \text{ mmole Cl}} = 1821 \frac{\text{mg}}{\text{L}} \text{ Cl} = 1.8 \frac{\text{g}}{\text{kg solution}} \approx 1.8 \text{ chlorinity}$$

From [Table 5.3-1](#), at 20°C and 1.8 Chlorinity (interpolation), the saturation concentration in the mixed liquor = 8.92 mg/L

From [Table 5.3-1](#), at 20°C and 0.0 Chlorinity the saturation concentration in pure water = 9.09 mg/L

Therefore from [Eq. 5.3-6](#):

$$\beta = \frac{\text{saturation concentration of oxygen in the mixed liquor at } 20^\circ\text{C}}{\text{saturation concentration of oxygen in clean water at } 20^\circ\text{C}} = \frac{8.92}{9.09} = 0.98$$

- f. Calculate C_{sw} from [Eq. 5.3-3](#):

$$C_{sw} = C_{ss} f_p \beta = 9.4 \cdot 1 \cdot 0.98 = 9.212$$

- g. Calculate N from [Eq. 5.3-2](#):

$$N = N_0 \cdot \frac{(C_{sw} - C_L)}{9.17} \cdot (1.024^{(T-20)}) \cdot \alpha = 3.4 \cdot \frac{(9.212 - 2)}{9.17} \cdot (1.024^{(20-20)}) \cdot 0.8 = 2.14 \frac{\text{lb O}_2}{\text{bhp} \cdot \text{hr}}$$

Step 2. Determine the total BHP required to fulfill the actual oxygen requirements:

Use [Eq. 5.3-8](#) to calculate the total BHP required for oxygen:

$$\text{Total BHP for O}_2 \text{ requirement} = \frac{\text{AOTR (lb O}_2/\text{d)}}{24 \cdot [N(\text{lb O}_2/\text{BHP} \cdot \text{hr})]} - \frac{27,800}{24 \cdot 2.14} = 541 \text{ BHP}$$

