ENVE 302
Environmental Engineering Unit Processes

CHAPTER: 7

Aeration Systems

Air Requirement Calculations

Assist. Prof. Bilge Alpaslan Kocamemi
Marmara University
Department of Environmental Engineering
Istanbul, Turkey

AERATION SYSTEMS

Because of low solubility of oxygen , low rate of oxygen transfer;

sufficient oxygen to meet the requirement of aerobic waste treatment does not enter water through normal air-water interface.

To transfer the large quantites of oxygen ;

additional interfaces must be formed

air or oxygen can be introduced into liquid

the liquid in the form of droplets can be exposed to the atmosphere

Factors Affecting Oxygen Transfer

The rate of gas transfer is generally proportional to the difference between the existing concentration and the equilibrium concentration of the gas in solution

$$r_c = \frac{dc}{dt} = \underbrace{K_g . \frac{A}{V}}_{K_{La}} (C_s - C)$$

$$\boxed{\frac{C_s - C_t}{C_s - C_0} = e^{-(K_L a t)}}$$

- The overall mass transfer coefficient (K_{La}) is determined in test or full-scale facilities.

- If pilot-scale facilities are used → Scale up must be considered to determine K_{La}

Determination of K_{La} in clean water (ASCE, 1992)

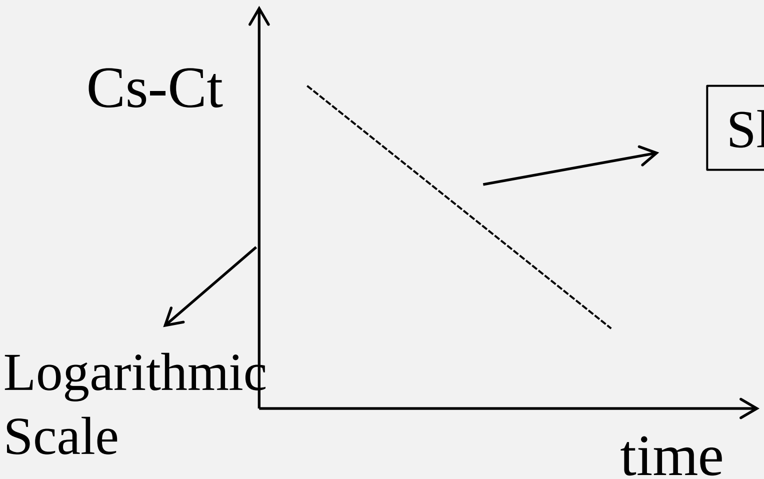
- Dissolved oxygen (DO) is removed from a known volume of water by the addition of sodium sulfite
- Then the water is reoxygenated to mean the saturation level. During reoxygenation (reaeration) period, DO concentrations are measured

Experimental Data:

Time, min	*DO Concentration, mg/L*
…..	….
…..	…

$$\frac{C_s - C_t}{C_s - C_0} = e^{-(K_L a t)} \Rightarrow \log(C_s - C_t) = \log(C_s - C_0) - \frac{K_L a}{2.303}$$

Using experimental data, Cs-Ct versus t is plotted



Slope = K_{La} / 2.303 = K_{La} = (slope) (2.303)

Determination of K_{La} in wastewater

Uptake of oxygen by microorganisms must be considered.

Typically, oxygen is maintained at a level of 1 to 3 mg/L and the microorganisms use the oxygen as rapidly as it is supplied.

$$\boxed{\frac{dc}{dt} = K_La(C_s - C) - r_m}$$

$\longrightarrow$ Rate of oxygen used by microorgnisms can be determined in lab by using respirometer

If the oxygen level is maintaned at a constant level, dc/dt = 0 and ;

$$\boxed{r_m = K_La(C_s - C) \rightarrow \quad K_La = \frac{r_m}{(C_s - C)}}$$

The mass transfer coefficient K_{Lu} is a function of:

- Temperature
- Intensity of mixing (type of aeration device & geometry of mixing basin)
- Constituents in water

Effect of Temperature on Oxygen Transfer

$$K_{La(T)} = K_{La(20^\circ C)} \theta^{(T-20)}$$

$\theta = 1.015 - 1.040$

1.024 is a typical for both diffused and mechanical aeration devices.

Effects of mixing intensity & tank geometry

$$\alpha = \frac{K_La(\text{wastewater})}{K_La(\text{tap water})}$$

α varies with;

- Type of aeration device
- The basin geometry
- The degree of mixing
- The ww characteristics

α = 0.3 – 1.2
For diffused aeration equip. = 0.4 – 0.8
For mechanical equipment = 0.6 – 1.2

Pöpel Equation ⟶

$$\alpha = 1 - 0.16\left(\frac{MLSS}{1000}\right)^{2/3}$$

Effects of wastewater characteristics

β → is used to correct the test system oxygen transfer rate for differences in oxygen solubility due to constituents in the water such as salts, particulates, and surface-active substances

$$\beta = \frac{C_s(wastewater)}{Cs(tap\ water)}$$

β = 0.7 – 0.8
(0.95 is commonly used for ww)

CALCULATION OF ACTUAL AMOUNT OF OXYGEN REQUIRED UNDER FIELD CONDITIONS

$$AOTR = SOTR\left(\frac{\beta C_{\overline{S},T,H} - C_L}{C_{s,20}}\right)(1.024^{T-20})(\alpha)(F)$$

AOTR = actual oxygen transfer rate under field conditions, kg O_2 / hr

SOTR = standard oxygen transfer rate in tap water at 20 C, and zero dissolved oxygen, kg O_2 / hr

β = salinity-surface tension correction factor = C_s (ww) /C_s(tapwater)

$C_{s,T,H}$ = average dissolved oxygen saturation concentration in clean water in aeration tank at temperature T and altitude H, mg/L

C_L = operating oxygen concentration, mg/L

$C_{S,20}$ = DO saturation concentration in clean water at 20 C and 1 atm, mg/L

T = operating temperature, C

α = oxygen transfer correction factor for waste

F = fouling factor (typically 0.65 – 0.9) is used to account for both internal & external fouling of air diffusers.

Diffuser Fouling

internal

caused by impurities in the compressed air

external

caused by the formation of biological slimes

and inorganic precipitants

$$\bar{C}_{S,T,H} = C_{S,T,H}\frac{1}{2}\left(\frac{P_d}{P_{atm,H}} + \frac{O_t}{21}\right)$$

For surface aerators:
$\bar{C}_{S,T,H} = C_{S,T,H}$

$C_{S,T,H}$ = oxygen saturation concentration in clean water at temperature T and altitude H), mg/L *(see Metcalf & Eddy, 2004, Appendix D)*

P_d = pressure at the depth of air release, k_{Pa}
($P_{atm,H} + P_{w,effective\ depth}$)

$P_{atm,H}$ = atmospheric pressure at altitude H, k_{Pa} *(see Metcalf & Eddy, 2004, Appendix D)*

O_T = % oxygen leaving tank (usually 18 – 20 %)

$$C_{\overline{S},T,H} = C_{S,T,H}\frac{1}{2}\left(\frac{P_d}{P_{atm,H}} + \frac{O_t}{21}\right)$$

The term in the brackets when multiplied by one-half represents the average pressure at mid depth and accounts for the loss of oxygen to biological uptake.

If biological uptake is not considered,

$$C_{\overline{S},T,H} = C_{S,T,H}\left(\frac{P_{atm,H} + P_{w,middepth}}{P_{atm,H}}\right)$$

$P_{w,mid\ depth}$ = pressure at mid depth, above point or air release due to water column.

Specific Oxygen Transfer Efficiency (SOTE) of Diffusers

(% OTE / m water depth)

$$SpOTE(\%/m) = 9 - 8.63.10^{-4} MLSS + 2.56.10^{-8} MLSS^{2}$$

Oxygen Transfer Efficiency (OTE) of Diffusers

$$OTE(\%) = SpOTE \text{ x } m \text{ water depth}$$

Typical clean water transfer efficiencies (SOTE) for various diffused air devices → M&E, 4th Edition Table 5.27, pg. 437

Table 5–27
Typical information on the clean water oxygen transfer efficiency of various air diffuser systems[a]

Diffuser type and placement	Air flowrate/diffuser ft³/min	Air flowrate/diffuser m³/min	SOTE (%) at 4.5 m (15 ft) submergence[b]
Ceramic disks—grid	0.4–3.4	0.01–0.1	25–35
Ceramic domes—grid	0.5–2.5	0.015–0.07	27–37
Ceramic plates—grid	2.0–5.0[c]	0.6–1.5[d]	26–33
Rigid porous plastic tubes			
Grid	2.4–4.0	0.07–0.11	28–32
Dual spiral roll	3.0–11.0	0.08–0.3	17–28
Single spiral roll	2.0–12.0		13–25
Nonrigid porous plastic tubes			
Grid	1.0–7.0	0.03–0.2	26–36
Single spiral roll	2.0–7.0	0.06–0.2	19–37
Perforated membrane tubes			
Grid	1.0–4.0	0.03–0.11	22–29
Quarter points	2.0–6.0	0.6–0.17	19–24
Single spiral roll	2.0–6.0	0.6–0.17	15–19
Perforated membrane panels	N/A	N/A	38–43[e]
Jet aeration			
Side header	54–300	1.5–8.5	15–24
Nonporous diffusers			
Dual spiral roll	3.3–10	0.1–0.28	12–13
Midwidth	4.2–45	0.12–1.25	10–13
Single spiral roll	10–35	0.28–1.0	9–12

[a] Adapted in part from WPCF (1988) and U.S. EPA (1989).
[b] SOTE = standard oxygen transfer efficiency. Standard conditions: tap water 20°C (68°F); at 101.3 kN/m² (14.7 lb_f/in^2); and initial dissolved oxygen = 0 mg/L.
[c] Units are ft³/ft² of diffuser·min.
[d] Units are m³/m² of diffuser·min.
[e] Personal communication, Parkson Corporation.
N/A = not applicable.

Example: Calculate the required total blower capacity necessary to supply oxygen requirement of 2892.7 kg/d for the plant having following characteristics.

- Fine bubble aeration system
- DO in aeration basin = 2 g/m^3
- Site elevation = 500 m (pressure 95.6 K$_{Lu)}$)
- α = 0.5, β = 0.95, F = 0.9
- Liquid depth for aeration basin = 4.9 m
- The point of air release for the aerobic diffuser is 0.5 m above the tank bottom

Solubility of Dissolved Oxygen in Water as a Function of Salinity and Barometric Pressure

Ref: Metcalf & Eddy

Table D–1
Dissolved-oxygen concentration in water as a function of temperature and salinity (barometric pressure = 760 mm Hg[a]

Temp. °C	Dissolved-oxygen concentration, mg/L									
	Salinity, parts per thousand									
	0	5	10	15	20	25	30	35	40	45
0	14.60	14.11	13.64	13.18	12.74	12.31	11.90	11.50	11.11	10.74
1	14.20	13.73	13.27	12.83	12.40	11.98	11.58	11.20	10.83	10.46
2	13.81	13.36	12.91	12.49	12.07	11.67	11.29	10.91	10.55	10.20
3	13.45	13.00	12.58	12.16	11.76	11.38	11.00	10.64	10.29	9.95
4	13.09	12.67	12.25	11.85	11.47	11.09	10.73	10.38	10.04	9.71
5	12.76	12.34	11.94	11.56	11.18	10.82	10.47	10.13	9.80	9.48
6	12.44	12.04	11.65	11.27	10.91	10.56	10.22	9.89	9.57	9.27
7	12.13	11.74	11.37	11.00	1065	10.31	9.98	9.66	9.35	9.06
8	11.83	11.46	11.09	10.74	10.40	10.07	9.75	9.44	9.14	8.06
9	11.55	11.19	10.83	10.49	10.16	9.84	9.53	9.23	8.94	8.66
10	11.28	10.92	10.58	10.25	9.93	9.62	9.32	9.03	8.75	8.47
11	11.02	10.67	10.34	10.02	9.71	9.41	9.12	8.33	8.56	8.30
12	10.77	10.43	10.11	9.80	9.50	9.21	8.92	8.65	8.38	8.12
13	10.53	10.20	9.89	9.59	9.30	9.01	8.74	8.47	8.21	7.96
14	10.29	9.98	9.68	9.38	9.10	8.82	8.55	8.30	8.04	7.80
15	10.07	9.77	9.47	9.19	8.91	8.64	8.38	8.13	7.88	7.65
16	9.86	9.56	9.28	9.00	8.73	8.47	8.21	7.97	7.73	7.50
17	9.65	9.36	9.09	8.82	8.55	8.30	8.05	7.81	7.58	7.36
18	9.45	9.17	8.90	8.64	8.39	8.14	7.90	7.66	7.44	7.22
19	9.26	8.99	8.73	8.47	8.22	7.98	7.75	7.52	7.30	7.09
20	9.08	8.81	8.56	8.31	8.07	7.83	7.60	7.38	7.17	6.96
21	8.90	8.64	8.39	8.15	7.91	7.69	7.46	7.25	7.04	6.84
22	8.73	8.48	8.23	8.00	7.77	7.54	7.33	1.12	6.91	6.72
23	8.56	8.32	8.08	7.85	7.63	7.41	7.20	6.99	6.79	6.60
24	8.40	8.16	7.93	7.71	7.49	7.28	7.07	6.87	6.68	6.49
25	8.24	8.01	7.79	7.57	7.36	7.15	6.95	6.75	6.56	6.38

Ref: Metcalf & Eddy

B–2 CHANGE IN ATMOSPHERIC PRESSURE WITH ELEVATION

In SI units

The following relationship can be used to compute the change in atmospheric pressure with elevation:

$$\frac{P_b}{P_a} = \exp\left[-\frac{gM(z_b - z_a)}{RT}\right]$$

where P = pressure, 1.01325×10^5 N/m^2

g = 9.81 m/s^2

M = mole of air (see Table B-1) = 28.97 kg/kg-mole

z = elevation, m

Ref: Metcalf & Eddy

R = universal gas constant = 8314 N·m/kg-mole·K
= 8314 kg·m^2/s^2·kg-mole·K

T = temperature, K (Kelvin) = (273.15 + °C)

In U.S. customary units

The following relationship can be used to compute the change in atmospheric pressure with elevation.

$$\frac{P_b}{P_a} = \exp\left[-\frac{gM(z_b - z_a)}{g_c RT}\right]$$

where P = pressure, lb/in^2

g = 32.2 ft/s^2

g_c = 32.2 ft·lb$_m$/lb·s^2

M = mole of air (see Table B–1) = 28.97 lb/lb-mole

z = elevation, ft

R = universal gas constant = 53.3 ft·lb/lb-air·°R

T = temperature, °R = (459.67 + °F)

Ref: Metcalf & Eddy

Table B-1

Molecular weight, specific weight, and density of gases found in wastewater at standard conditions (0 C and 1 atm)

Gas	Formula	Molecular weight	Specific weight, lb/ft^3	Density g/L
Air	—	28.97	0.0808	1.2928
Ammonia	NH_3	17.03	0.0482	0.7708
Carbon dioxide	CO_2	44.00	0.1235	1.9768
Carbon monoxide	CO	28.00	0.0781	1.2501
Hydrogen	H_2	2.016	0.0056	0.0898
Hydrogen sulfide	H_2S	34.08	0.0961	1.5392
Methane	CH_4	16.03	0.0448	0.7167
Nitrogen	N_2	28.02	0.0782	1.2507
Oxygen	O_2	32.00	0.0892	1.4289

[a] Adapted from Perry, R. H., D. W. Green, and J. O. Maloney (eds.) (1984) *Chemical Engineers' Handbook*, 6th ed., McGraw-Hill, New York.

Ref: Metcalf & Eddy

Table B-2

Composition of dry air at 0^{o} C and 1.0 atmosphere

Gas	Formula	Percent by volume[b,c]	Percent by weight
Nitrogen	N_2	78.03	75.47
Oxygen	O_2	20.99	23.18
Argon	Ar	0.94	1.30
Carbon dioxide	CO_2	0.03	0.05
Other[d]	—	0.01	—

[a] Values reported in the literature vary depending on the standard conditions.

[b] Adapted from North American Combustion Handbook, 2d ed., North American Mfg. Co., Cleveland, OH.

[c] For ordinary purposes air is assumed to be composed of 79 percent N_2 and 21 percent O_2 by volume.

[d] Hydrogen, neon, helium, krypton, xenon.

Note: $(0.7803 \times 28.02) + (0.2099 \times 32.00) + (0.0094 \times 39.95) + (0.0003 \times 44.00) = 28.97$ (see Table B–1).

Ref: Metcalf & Eddy

B–1 DENSITY OF AIR AT OTHER TEMPERATURES

In SI units

The following relationship can be used to compute the density of air ρ_a.

$$\rho_a = \frac{PM}{RT}$$

where P = atmospheric pressure = $1.01325 \cdot 10^5$ N/m^2
M = mole of air (see Table B–1) = 28.97 kg/kg-mole
R = universal gas constant = 8314 N·m/kg-mole·K
T = temperature, K (Kelvin) = (273.15 + °C)

For example, at 20°C, the density of air is

$$\rho_{a,20^\circ\mathrm{C}} = \frac{(1.01325 \times 10^5\ \mathrm{N/m^2})(28.97\ \mathrm{kg/kg\text{-}mole})}{(8314\ \mathrm{N{\cdot}m/kg\text{-}mole{\cdot}K})[(273.15 + 20)\mathrm{K}]} = 1.204\ \mathrm{kg/m^3}$$

Ref: Metcalf & Eddy

In U.S. customary units

The following relationship can be used to compute the specific weight of air γ_a at other temperatures at atmospheric pressure.

$$\gamma_a = \frac{P\,(144\ \text{in}^2/\text{ft}^2)}{RT}$$

where P = atmospheric pressure = 14.7 lb/in^2

R = universal gas constant = 53.3 ft·lb/lb-air·°R

T = temperature, °R (Rankine) = (459.67 + °F)

For example, at 68°F, the specific weight of air is

$$\gamma_{a,68°\text{F}} = \frac{(14.7\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)}{(53.3\ \text{ft·lb/lb-air·°R})[(459.67 + 68)\text{°R}]} = 0.0753\ \text{lb/ft}^3$$

Aeration Systems Used for WW Treatment

Diffused Air Systems

- Blower , air mains, header pipes through which air passes
- Diffusers that are submerged in ww

•Porous diffusers
•Non-porous diffusers
•Other diffusion devices

Mechanical Aeration Systems

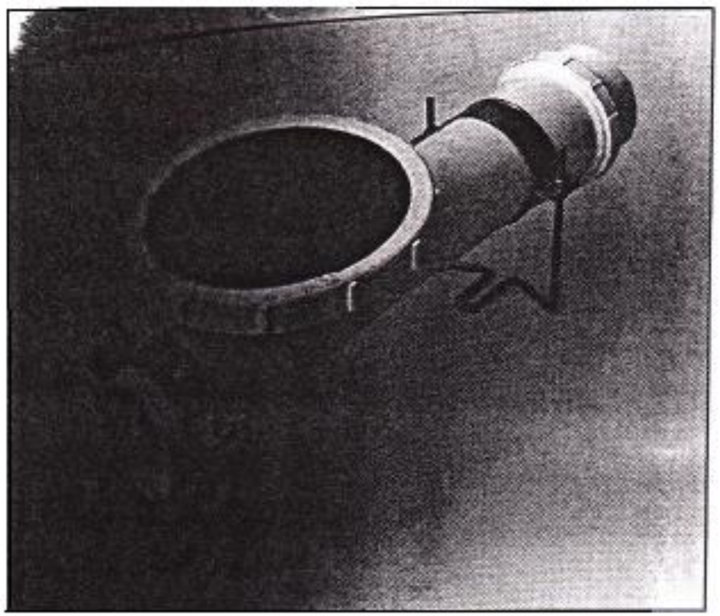
- Aerations w/ vertical axis
  →surface aerator
  →submerged aerator
- Aeration w/ horizontal axis
  →surface aerator
  →submerged aerator

High Purity Oxygen Systems

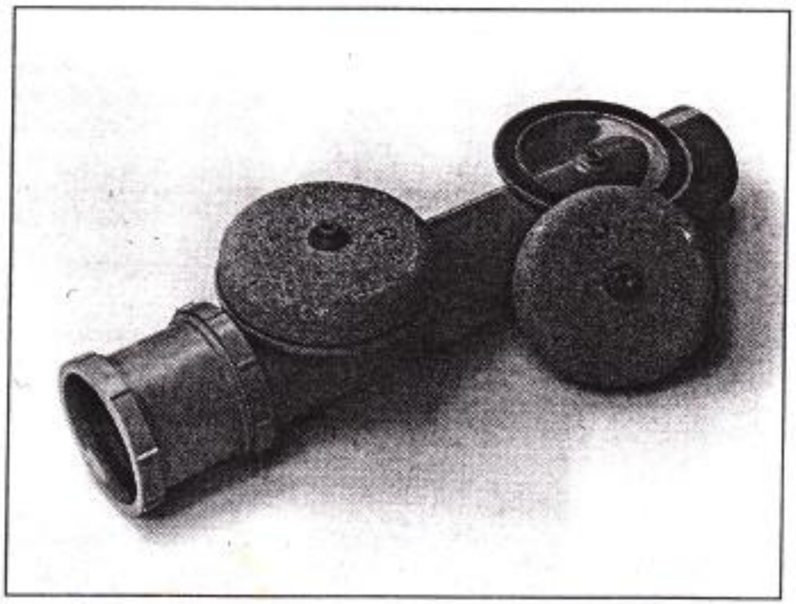
- Downflow bubble contactor
- U tube contacter

Typical Porous Air Diffusers

- Domestic disks membranes
- Tubes
- Plutes

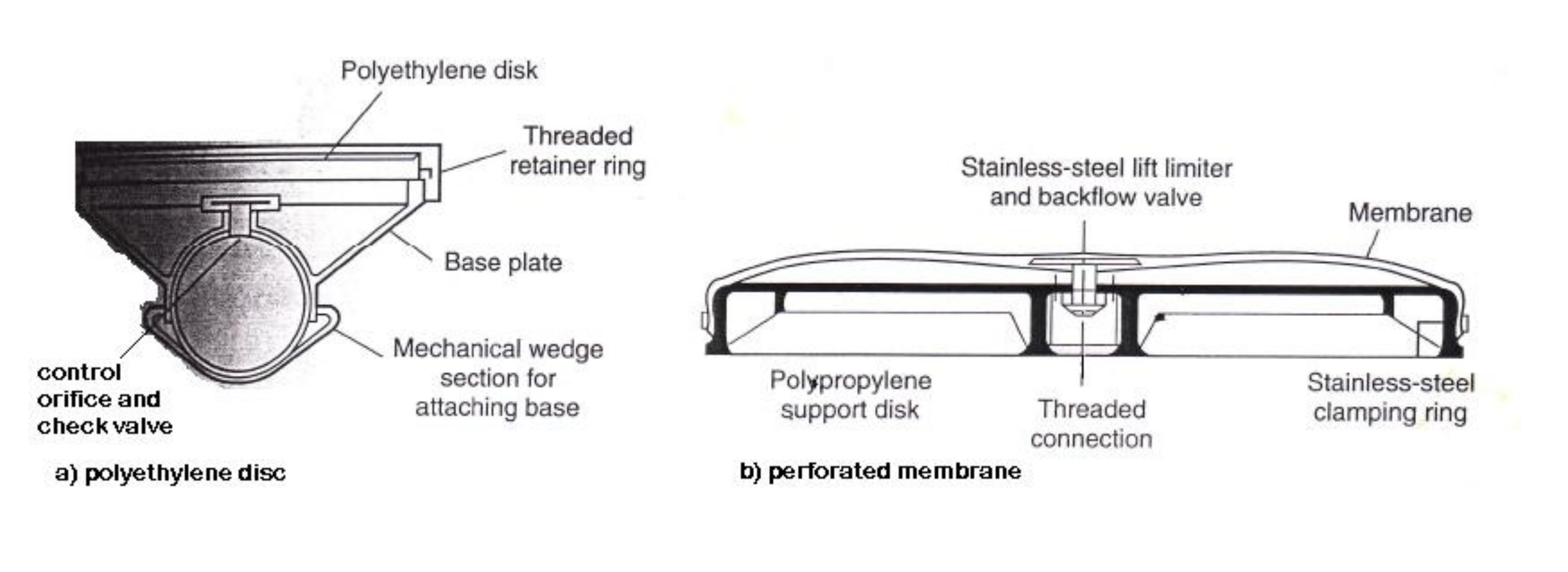


a) Aluminum Oxide Disc



b) Ceramic Dome

Typical Porous Air Diffusers (continue)



Diffused – Air Aeration Systems

air is introduced into liquid being aerated in the form of bubbles which typically rise through the liquid

common device for ;

transferring oxygen in aerobic biological treatment

systems stripping of volatile organics

Ref: http://www.brightwaterfli.com/diffused_aeration_systems.htm

FINE BUBBLE

- the size of bubbles varies from coarse to fine
  - fine-bubble diffusers
  - coarse bubble diffusers

Ref:http://www.hellotrade.com/diffused-gas-technologies-incorporated/ss-series-plenum-coarse-bubble-diffusers.html

COARSE BUBBLE

Diffused – Air Aeration Systems (continue)

gas transfer rate $\propto$ size of bubbles

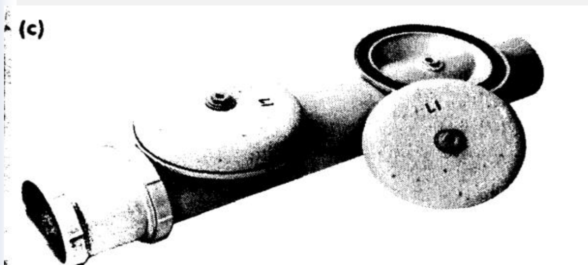
$\rightarrow$ smaller bubbles $\rightarrow$ greater A/$\forall$ $\rightarrow$ more efficient than larger sized bubbles for mass transfer

- Porous diffusers (e.g., plate, dome, disc, tubular diffusers)
- Nonporous diffusers (e.g., fixed orifice, valved orifice)
- Other diffusers (e.g., jet aeration)

Diffused – Air Aeration Systems (continue)

Typical Porous Diffusers

DOME DIFFUSER



Ref: Metcalf & Eddy, 1991, McGraw Hill

DOME DIFFUSER

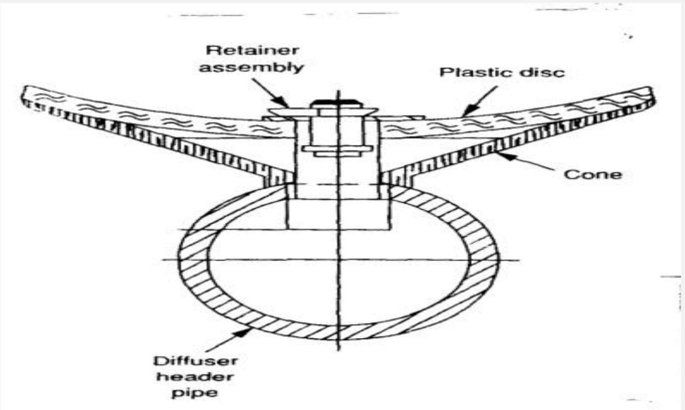
DISC DIFFUSER

Dome, disc diffusers → are mounted on or screwed into air manifolds

Diffused – Air Aeration Systems (continue)

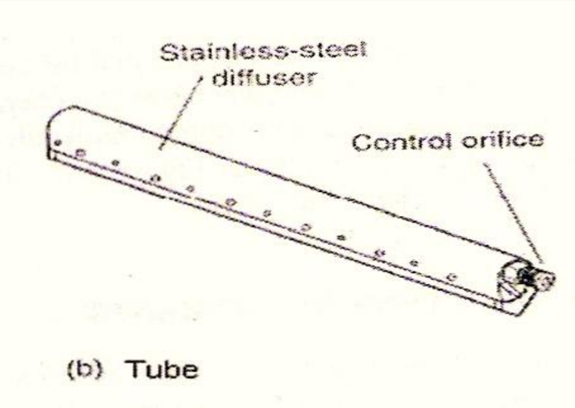
Typical Non Porous Diffusers

Valved orifice diffuser



Ref: Metcalf & Eddy, 1991, McGraw Hill

Perforated tube diffuser



Ref: Metcalf & Eddy, 1991, McGraw Hill

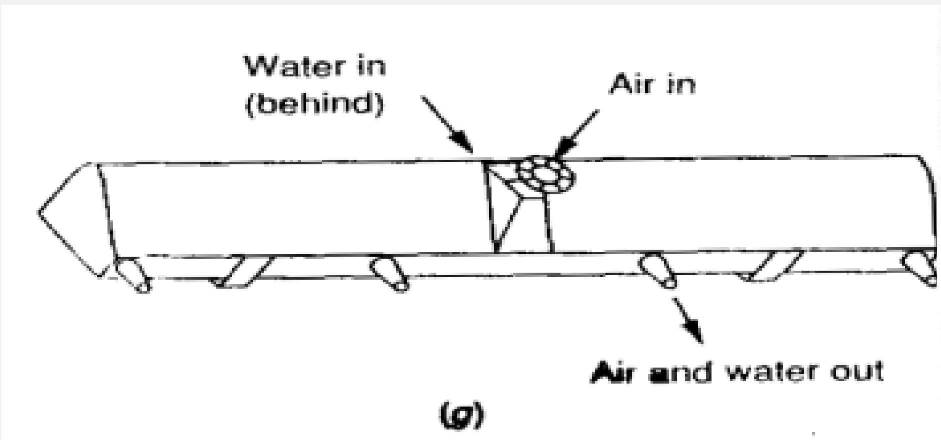
VALVED ORIFICE DIFFUSER
(non porpous diffuser)
Device that contains a check value to prevent backflow when air is shut off. Mounts on air distribution piping.

- Produce larger bubbles than porous diffusers
- Lower aeration efficiency
- Lower cost, less maintanance

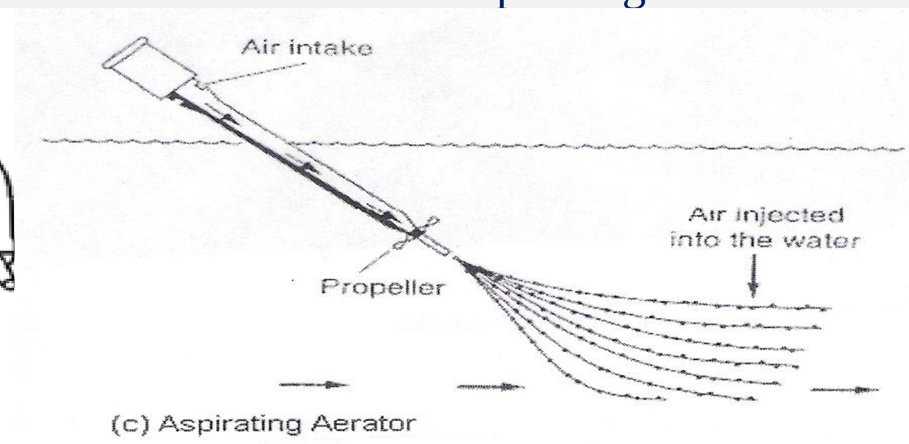
Diffused – Air Aeration Systems (continue)

Typical Other Diffusion Devices

Jet aerator

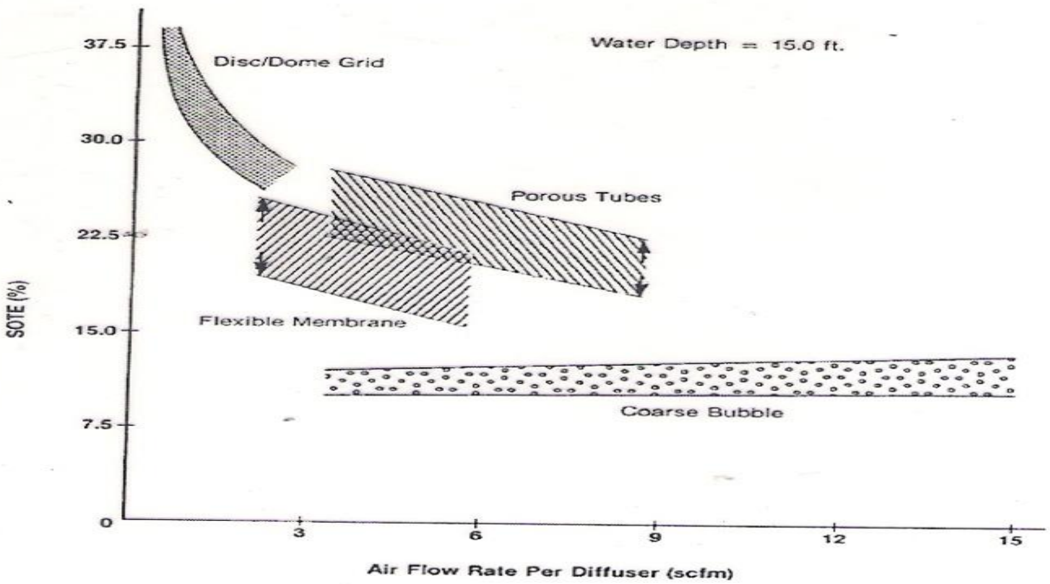


Aspirating aerators



Jet aerator

discharges a mixture of pumped liquid and compressed air through a nozzle.



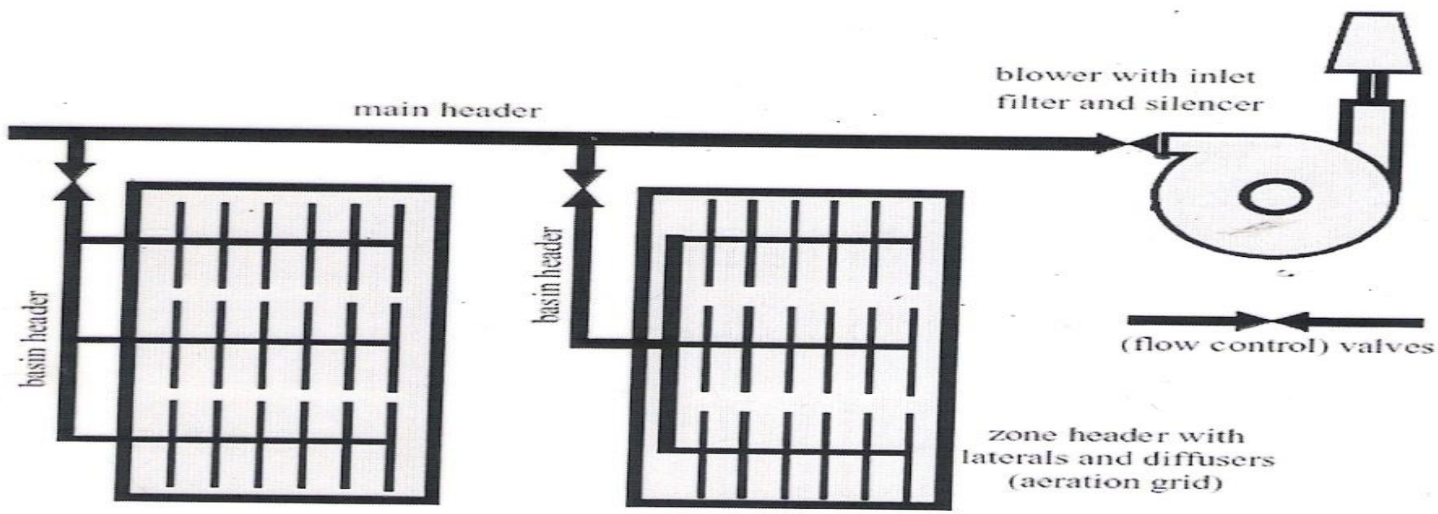
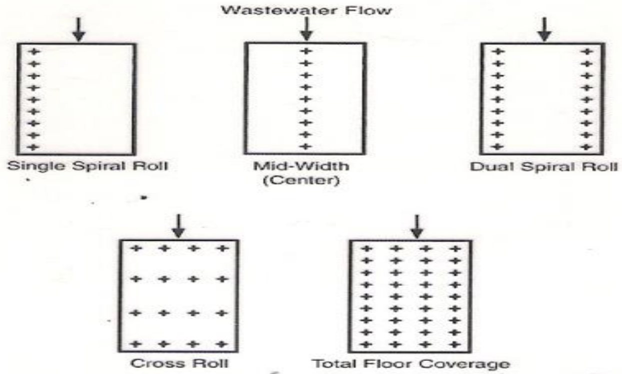
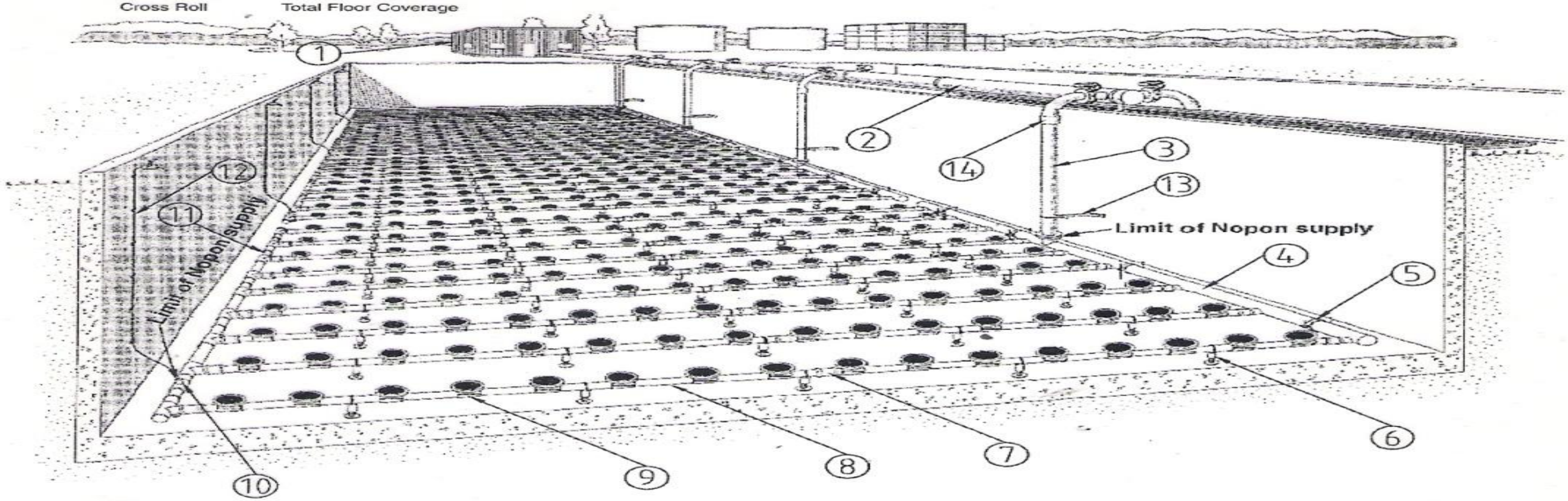
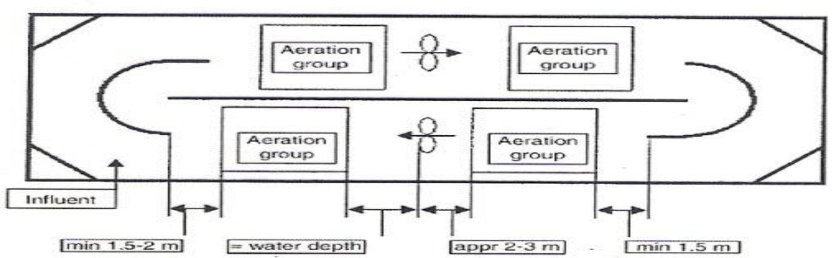


FIGURE 4.13 Schematic of the air supply system.





1. Blower station
2. Air supply header
3. Dropleg
4. Zone header
5. Bottom mountting bracket TPK 150
6. bottom mountting bracket HPK 210
7. Connection sleeve HSY 90-90
8. Diffuser element
9. Diffuser (here membrane diffuser KKI 215)
10. Drainage coupling VPL 90
11. Water collection pipe
12. Purge hose/pipe
13. Pipe supporting
14. Expansion joint



Placing of diffusers in an oxidation ditch (race track) equipped with flow generators

TABLE 10-6
Description of air diffusion devices[a]

Type of diffuser or device	Transfer efficiency	Description	See Figure
Porous			
Plate	High	Square ceramic plates installed in fixed holders on tank floor.	
Dome	High	Dome-shaped ceramic diffusers mounted on air distribution pipes near tank floor.	10-10*a*
Disc	High	Rigid ceramic discs or flexible porous membrane mounted on air distribution pipes near tank floor.	10-10*b*
Tube	Moderate to high	Tubular-shaped diffuser that uses rigid ceramic media or flexible plastic or synthetic rubber sheath mounted on air distribution pipes.	10-10*c*
Nonporous			
Fixed orifice			
Perforated piping	Low	Air distribution piping with small holes drilled along the length.	
Spargers	Low	Devices usually constructed of molded plastic and mounted on air distribution pipes.	10-10*d*
Slotted tube	Low	Stainless steel tubing containing perforations and slots to provide a wide band of diffused air.	
Valved orifice	Low	Device that contains a check valve to prevent backflow when air is shut off. Mounts on air distribution piping.	10-10*e*
Static tubes	Low	Stationary vertical tube mounted on basin bottom that functions like an air lift pump.	10-10*f*
Perforated hose	Low	Perforated hose that runs lengthwise along basin and is anchored to the floor.	
Other devices			
Jet aeration	Moderate to high	Device that discharges a mixture of pumped liquid and compressed air through a nozzle assembly located near the tank bottom.	10-10*g*
Aspirating	Low	Inclined propeller pump assembly mounted at basin surface that draws in air and discharges air/water mixture below water surface.	10-10*h*
U-tube	High	Compressed air is discharged into the down leg of a deep vertical shaft.	10-10*i*

[a] Adapted from Ref. 63.

DIFFUSER PERFORMANCE

The efficiency of oxygen transfer depends on many factors;

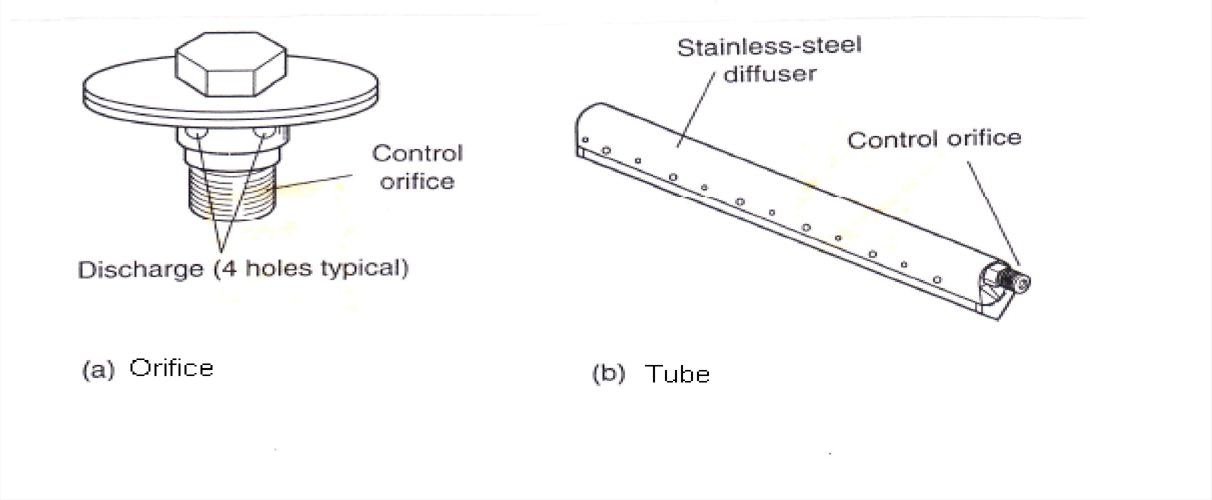
- Type, size, and shape of diffuser
- The air flowrate
- The depth of submersion
- Tank geometry including the header and diffuser location
- ww characteristics

Aeration devices → evaluated in clean water (SOTE, standard oxyen transfer efficiency)

→ the results are adjusted to process operating conditions

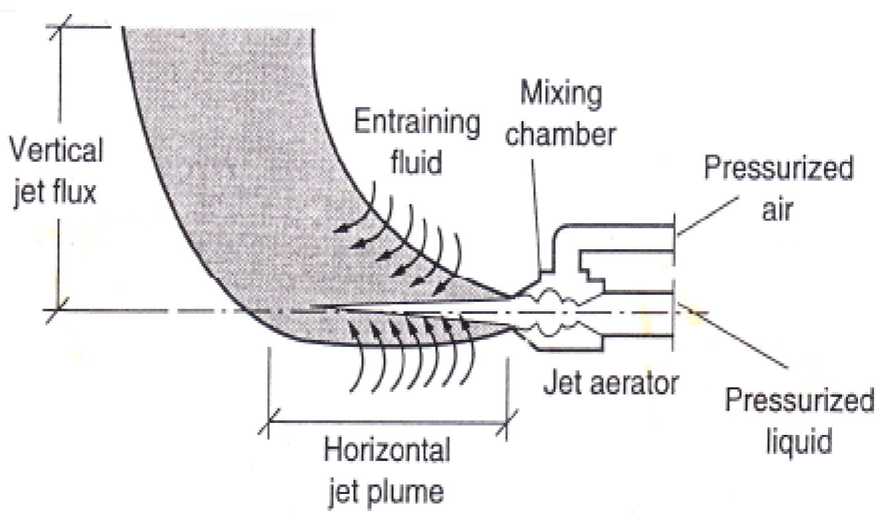
Typical Nonporous Air Diffusers (continue)

- Non-porous Diffusers; (produce more bubble than porous diffusers)
  - Orifice
  - tube



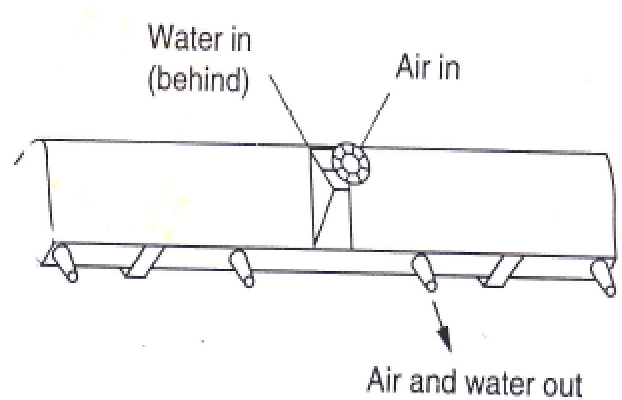
Other Diffusion Devices

- Other Diffusion Devices
  - Jet aerator
  - Aspirating aerator
  - U-tube



(a) Jet Aerator

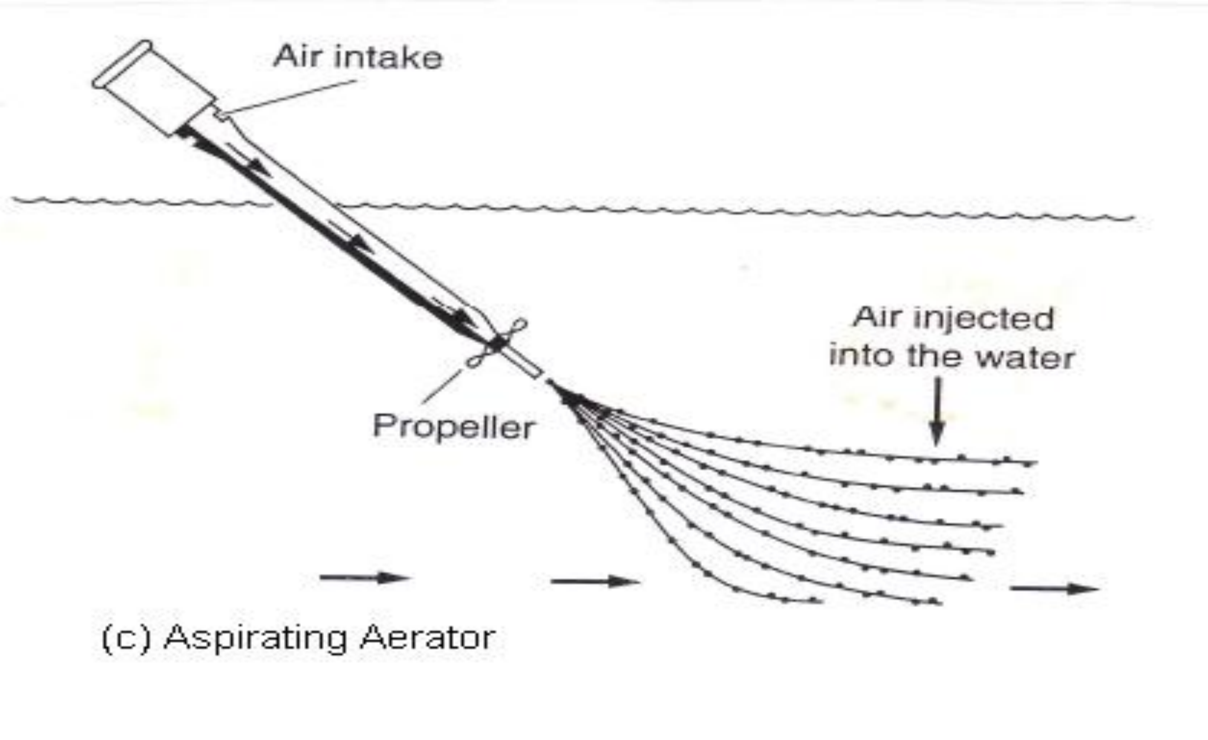
particularly suited for deep (>8m) tanks



(b) Jet Aerator in a manifold arrangement

pressurized air and liquid are combined in a mixing chamber

Other Diffusion Devices (continue)



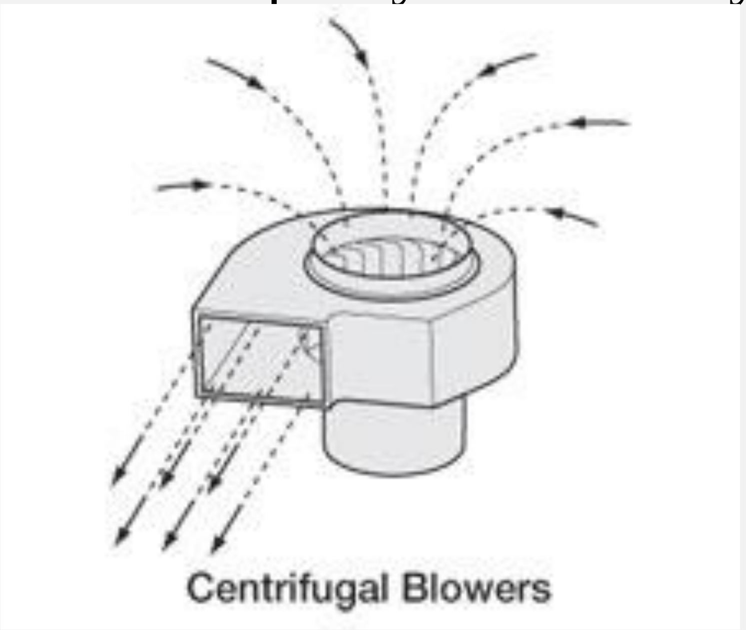
Blowers;

3 types of blower are commonly used for aeration;

- Centrifugal
- Rotary lobe positive displacement
- Inlet guide vane-variable diffuser

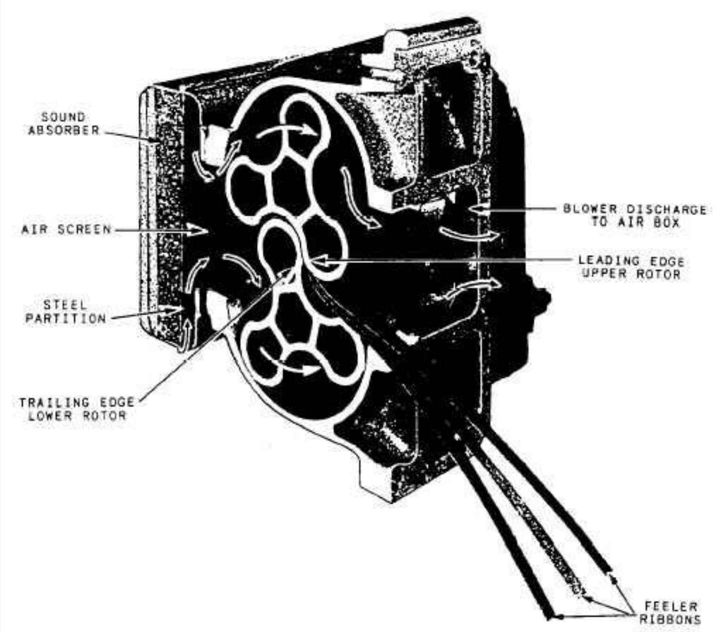
Centrifugal blowers (capacity > 425 m^3/min

- discharge pressure ranges 48-62 kN/m^2
- similar to low-specific-speed centrifugal pumps
- the operating point is determined by the intersection of the head-capacity curve and system curve

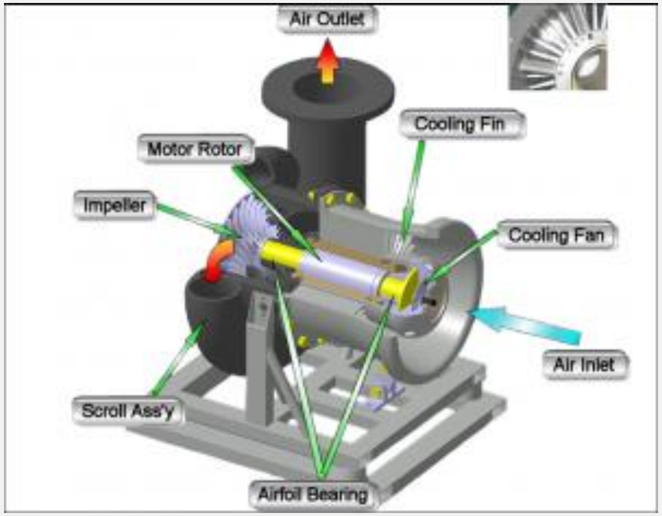


Rotary lobe positive displacement (capacity < 425 m^3/min)

- for higher discharge pressure applications > 55 kN/m^2
- is a machine of constant capacity w/ variable pressure
- the units can not be throttled but capacity control can be obtained by the use of multiple units or a variable speed drive



Inlet guide vane-variable diffuser (capacity 85 – 1700 m^3/min)



- a relatively new blower design
- a single stage centrifugal operation that incorporates activaters to position the inlet guide vane and variable diffuser to vary blower flowrate.
- well suited to applications with medium to high fluctuations in inlet temperature, discharge pressure and flowrate
- blower capacity 85 – 1700 m^3/min at pressures up to 170 kN/m^2
- turndown rate (Qmin/Qmax) : 40% is possible w/o significant reduction in operating efficiencies
- high initial cost , sophisticated computer control system

In WWTP, blowers must supply a wide range of airflows under varied environmental conditions. Provisions have to be included in the blower system design to regulate or turndown the blowers

Methods to achieve regulation or turndown;

- Flow blow-off or by passing → effective method of controlling surging of a centrifugal blower

- Inlet throttling
- discharge diffuser

are applicable only to adjustable centrifugal blowers

- variable speed driver → more commonly used on positive displacement blowers

- parallel operation or multiple units

MECHANICAL AERATORS

- By producing a large air-water interface the transfer of oxygen from atmosphere is enhanced

- Can be VERTICAL SHAFT or HORIZONTAL SHAFT

Ref: http://en.wikipedia.org/wiki/File:Surface_Aerator.jpg

Ref: http://www.waterandwastewater.com/www_services/newsletter/april_18_2011.htm

MECHANICAL AERATOR PERFORMANCE

- are rated in terms of kg O_2 / kw – hr at standard conditions, 20 C, DO = 0, test liquid is tap water.

- commercial size surface aerators range in efficiency from 1.2 – 2.4 kg O_2 / kwhr

For design purposes, the standard performance data must be adjusted to reflect field conditions by using the following equation;

$$N = N_0\left(\frac{\beta C_{walt} - C_L)}{9.17}\right)1.024^{T-20}\alpha$$

N = kg O_2/ kw.hr transferred under field conditions

N_o = kg O_2/kw.hr transferred in water at 20 C, and 0 DO.

β = salinity-surface tension correction factor (usually 1)

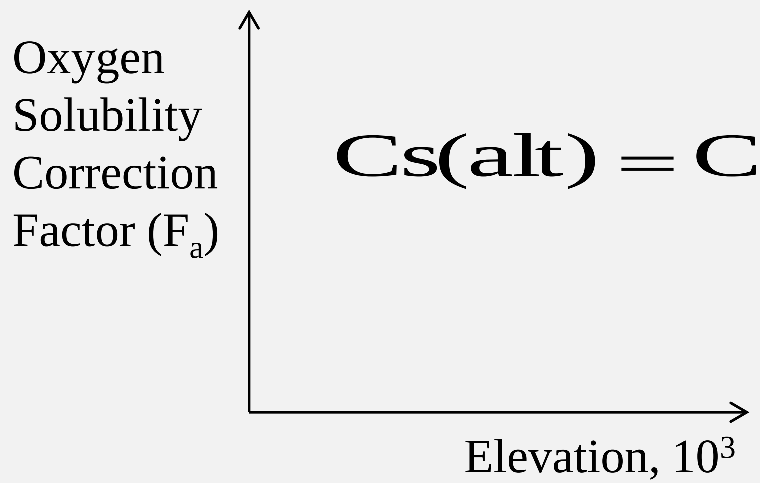
C_{walt}= oxygen saturation concentration for tap water at given temperature and altitude (Appendix D) (Figure 5.68)

C_L = operating oxygen concentration, mg/L

T = temperature, C

α = oxygen transfer correction factor for waste (Table 5.32, pg.447)

Figure 5.68 (Metcalf & Eddy, 2004



$$Cs(alt) = Cs(at\ sea\ level) x Fa$$

Oxygen transfer data for various types or mechanical aerators → Table 5.31, pg. 446 (Metcalf & Eddy, 4th Edition)

Table 5-31
Typical ranges of oxygen transfer capabilities for various types of mechanical aerators[a]

Aeration system	Transfer rate, lb O_2/hp·h		Transfer rate, kg O_2/kW·h	
	Standard[b]	Field[c]	Standard	Field
Surface low-speed	2.5–3.5	1.2–2.4	1.5–2.1	0.7–1.5
Surface low-speed with draft tube	2.0–4.6	1.2–2.1	1.2–2.8	0.7–1.3
Surface high-speed	1.8–2.3	1.2–2.0	1.1–1.4	0.7–1.2
Submerged turbine with draft tube	2.0–3.3	1.2–1.8[d]	1.2–2.0	0.6–1.1
Submerged turbine	1.8–3.5		1.1–2.1	
Submerged turbine with sparger	2.0–3.3	1.2–1.8[d]	1.2–2.0	0.7–1.0
Horizontal rotor	1.5–3.6	0.8–1.8	1.5–2.1	0.5–1.1

[a] Derived in part from WPCF (1988) and WEF (1998b).
[b] Standard conditions: tap water 20°C (68°F); at 100 kN/m² (14.7 lb$_f$/in²); and initial dissolved oxygen = 0 mg/L
[c] Field conditions: wastewater, 15°C (59°F); altitude 150 m (500 ft), α = 0.85, β = 0.9; operating dissolved oxygen = 2 mg/L
[d] Based on research results, it appears that α values may be lower than 0.85; reported ranges vary from 0.3 to 1.1, WEF (1998b).