Environment Protection Engineering

Vol. 2 1976 No. 2

J. DENNIS CROCKER*

DESIGNING A MECHANICAL AERATION SYSTEM

The method presented for preliminary sizing of surface mechanical aerators has been based on the quantity and concentration of incoming wastewater, and on assumed aeration time. Typical nomograms have been used for estimation of power requirements (solely) for the oxygen dispersion and maintenance of aerobic conditions, separately as well as both for oxygenation and suspension of mixed liquor suspended solids. The outline of tank design and recommendations for installation of draft tubes and anti-erosion assemblies are given.

1. INTRODUCTION

Traditional waste treatment systems, relying on surface aeration, are becoming increasingly outmoded. Purification standards are demanding longer retention times. In urban areas with a high concentration of industry producing organically polluted water, there is often not enough land available for surface aeration ponds. Some form of mechanically induced aeration, therefore, is going to be mandatory in most wastewater treatment processes.

Mechanical surface aeration is an efficient and inexpensive method. As with all aeration systems, its purpose is to increase the water surface area available for oxygen transfer. It has a second equally important purpose — that of mixing the basin contents thoroughly. Mixing keeps the sludge in close contanct with the waste material and keeps the oxygen thoroughly dispersed throughout the basin.

In the basic system, clarified wastewater is aerated. Sludge flocculates and settles in a secondary clarifier. The effluent is clear and low in organics. In the step aeration system, settled wastewater is distributed to different portions of the basin to spread oxygen demand. Aerated wastewater passes to a secondary clarifier to allow flocculation and settling. Sludge is returned to the head of the basin. This system can be combined with one of the other three. In the contact stabilization process, raw wastes are mixed with aerated sludge and then treated by aeration. This is perhaps the most efficient method employing

* Vice-President, Aqua-Aerobic Systems, Inc. Rockford, Illinois.

mechanical aeration in terms of space requirements. The extended aeration system handles raw wastes without primary settling at a cost in space requirements. In this system, physical mixing is very important because it evens out variations in load and dilutes concentrations of impurities. Detention time in the aeration tank is usually about 24 hours.

2. SYSTEM DESIGN

In all systems, there must be a balance between basin design and aerator performance. New systems wherein basin geometry and aerator selection are matched are most efficient. Older systems can be converted, however, by sizing and placing aerators properly. While it may not match a new system in efficiency, a converted system can be economically feasible. Aerator selection is perhaps the most important step in arriving at a new system design.

Table 1

Aerator size and performance data

Hp	*RPM*	N_c (kg/Hp·hr)	N_{ce} (kg/kwh	Z_{cm} (m)	*D* (m)	*ZOD* (m)	*Q* (gpm) (m^3/ /min)	Shaft Dia. (mm)	Mooring Cable Dia. (mm)
1	1800	1.54	1.86	6	1.8	19.5	5.5	20.7	5
2	1800	1.77	2.13	8.4	1.8	27.0	6.6	20.7	5
3	1800	1.62	2.08	12.0	1.8	43.5	10.4	31.75	5
5	1800	1.62	2.08	13.5	1.8	45.0	12.8	31.75	5
7.5	1800	1.63	1.97	15.5	1.8	48.0	14.3	31.75	5
10	1800	1.54	1.86	15.3	3.0	51.6	19.1	44.45	5
15	1800	1.59	1.92	18.6	3.0	60.0	23.2	44.45	5
20	1800	1.44	1.75	21.6	3.0	69.0	31.4	53.97	5
25	1800	1.54	1.86	24.0	3.0	76.5	37.2	53.97	5
30	1200	1.60	1.92	26.4	3.0	84.0	47.5	53.97	5
40	1200	1.63	2.08	30.6	3.0	97.5	53.9	63.5	6.35
50	1200	1.59	1.92	31.5	3.6	99.0	70.2	63.5	6.35
60	1200	1.59	1.92	34.5	3.6	105.0	77.7	63.5	6.35
75	1200	1.36	1.64	39	3.6	114.0	85.2	74.6	6.35
100	1200	1.41	1.70	45	4.5	132.0	155.0	85.7	9.5
125	1200	1.50	1.81	49.5	4.5	147.0	180.0	85.7	9.5

Notation:
N_c = transfer rate — kg of oxygen per brake hp per hour at standard conditions,
N_{ce} = transfer rate — kg of oxygen per kilowat hour per hour (wire to water) at standard conditions,
D = depth (m),
Z_{cm} = zone of complete mix — (m),
ZOD = zone of complete oxygen dispersion (m),
Q = pumping rate through unit (m^3/min),

Sizes commercially available are shown in Table 1, along with important performance data. When selecting aerators, the following steps in the design process should be considered:

1. Determine the described retention time in the system (hrs).
2. Determine the flow rate for the system (m^3/d).
3. Calculate the volume in cubic meters required in the aeration basin.
4. Referring to Fig. 1, determine the horsepower required for mixing in the system under consideration. If oxygen mixing alone is required (aerated lagoon system only), use the left-hand band; if solids must be suspended, use the right-hand band.
5. Referring to Fig. 2, determine the horsepower required for the necessary oxygen transfer This chart will select the total amount of horsepower required to treat a given waste if the BOD_5 and the daily flow is known. To use, select the appropriate daily waste

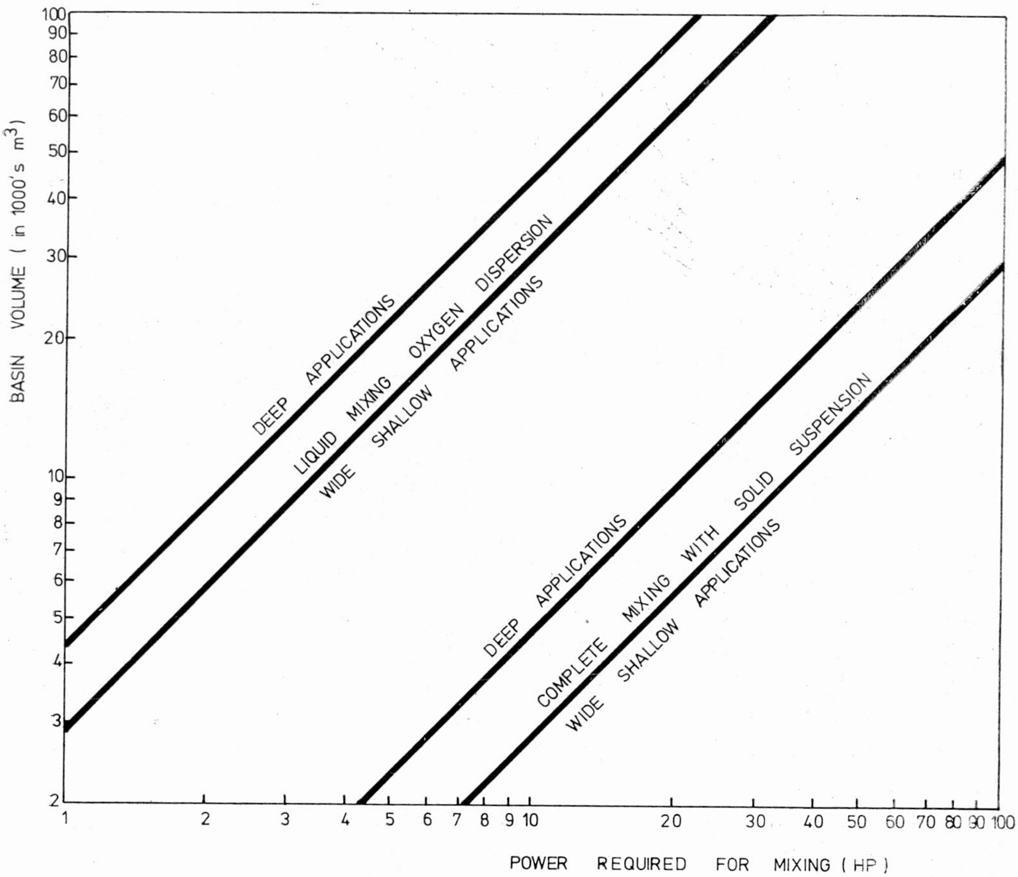

Fig. 1. Power required for mixing a given volume of wastewater

Rys. 1. Moc potrzebna do mieszania

flow on the left-hand side of the chart. Extend a horizontal line to the right until you intersect the appropriate BOD curve. Drop a line vertically and read the horsepower required for aeration. Accuracy is usually within 10%.

6. From Table 1 select the number and size of aerators required. Use the higher Hp figure obtained from steps 4 and 5 above in selecting the aerator pattern. Consider also the mixing dispersion zones for the aerators selected.

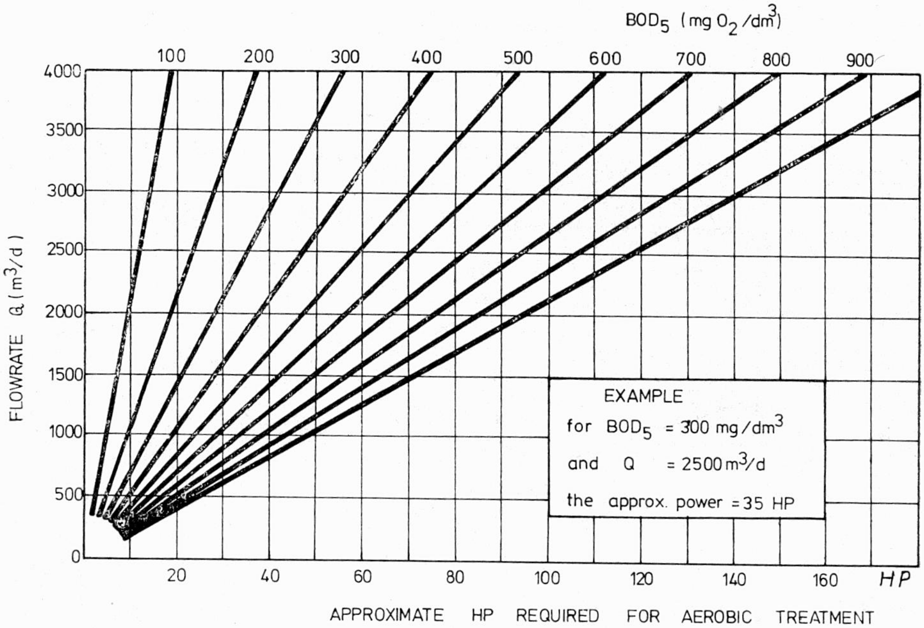

Fig. 2. Aerator horsepower required for oxygen transfer

Rys. 2. Moc potrzebna do przenoszenia powietrza

If it is important to avoid solid suspension, as in the aerated lagoon, and if oxygen transfer requires higher power input ($>$3.9 kW/1000 m^3), the basin size should be increased. Work backward through Fig. 1 to determine the size of basin needed. The increased size will add to the retention time within the basin and will probably result in a slightly greater BOD_5 removal.

It is wise to investigate several patterns using various sizes of aerator to arrive at a suitable basin depth.

If the system is subject to cyclic loading, smaller dual-speed aerators should be considered. This will allow mixing to be maintained while governing the power consumption of the system. Control of speed can be automatic via Dissolved Oxygen probe signal inputs, timeclock, or maintained manually. Power consumption can be made to range from full load to approximately 60 percent of the full load.

7. Settle on a placement pattern for the aerators. The optimum pattern for a single unit is circular; however, construction economics usually rule out circular tanks in larger sizes. The next best compromise is a square. A rectangular basin is best handled by dividing the overall basin into squares, or rectangles that approach a square configuration.

8. Determine the approximate size of the basin by balancing aerator patters against depth. Fig. 3 provides proper operating depths for each aerator size. The basin depth should be such that neither draft tube or anti-erosion assembly is needed. If the actual water depth exceeds 50% of the normal operating depth the manufacturer of the aerator should be consulted for design recommendations.

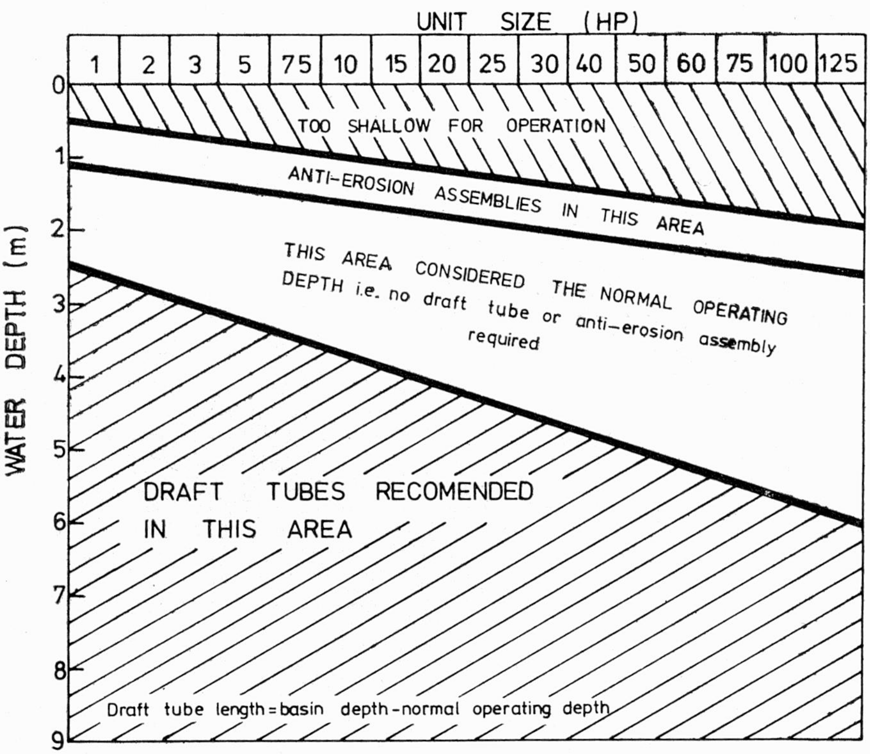

Fig. 3. Aerator operating depth

Rys. 3. Głębokość robocza aeratora

Choose a pattern that washes slightly the sides of the basin approximated. The above calculations provide "ballpark" dimensions to arrive at a ratio R between length and width. Because the basin is normally constructed with sloping sides, the final surface dimensions arrived at below will be larger than those approximated.

9. Select an appropriate side slope S (2/1, 3/1, etc.).

10. Determine the exact length of the basin by solving the following formula:

$$L = \frac{\sqrt{4R(A)-6R(SD)^2+2(SD)^2}+SD(1+R)}{2R},$$

where:

L = basin length (m),

$$R = \frac{\text{approx. width of basin}}{\text{approx. length of basin}},$$

$$A = \frac{V(\text{m}^3)}{D(\text{m})} = \text{average surface area},$$

S = side slope,

D = basin depth (m).

11. Determine the basin width by solving the following formula:

$$W = RL,$$

where W = basin width.

12. Obtain bottom dimensions by subtracting $2SD$ from both L and W.

At this point in the design, several details remain to be settled. Piping and liquid transfer provisions should follow industry standards. Aerator mooring must be considered. Aerators can remain stationary or be allowed to rise and fall with the level of the aeration basin. Cables for floating aerators must take into account variations in level. Recommended cable sizes are provided in the Table. (These sizes are for direct-drive aerators only.)

Electrical power cable must also be selected. Its insulation must be suitable for underwater use and impervious to the impurities encountered in the waste being treated. It should be a simple continuous piece with no splices. Its size is dependent on the power requirements of the motor, the length of the run, and the available voltage.

3. CONVERTING EXISTING SYSTEMS

When converting existing systems, basin size is seldom a serious problem. Basins tend to be larger than required, rather than too small. Basin configuration may be a problem, however, being too deep or too shallow, or long and narrow or irregularly shaped. Shape problems can be alleviated in part by introducing the waste effluent at several different points to help even out loading. These points should be close to aerators within the basin.

Aerators are selected in the same fashion as for new systems. Two conditions, however, may modify the selection process. First, the configuration of the basin may require several smaller units, rather than one larger one, to assure uniform mixing. Second, in earthen basin applications, aerators must be placed so that high turbulence does not impinge on the earthen walls.

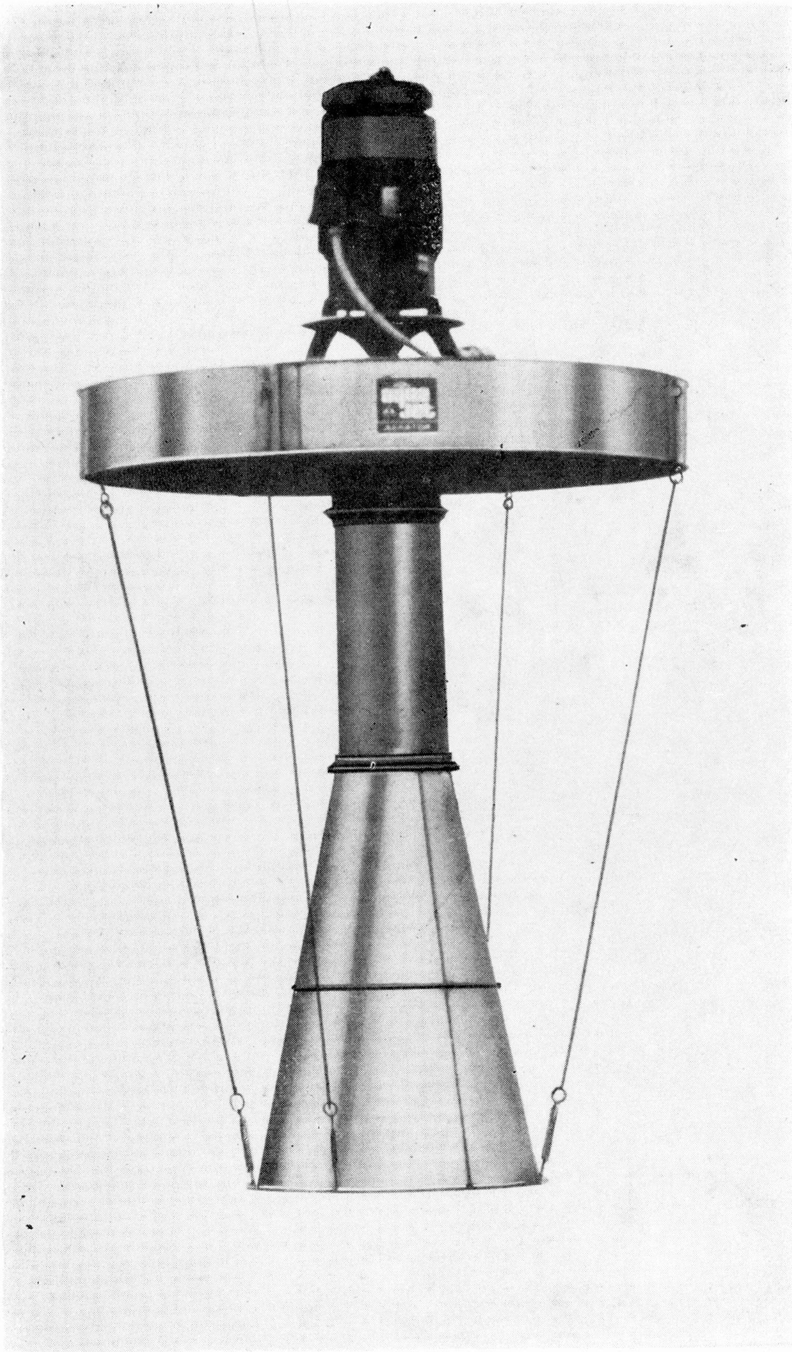

Fig. 4. Aerator

Depth problems are solved by adding the proper accessory. If the basin is too shallow, the aerator must be equipped with an anti-erosion assembly to prevent bottom scour. This device consists of a large disc mounted below the intake cone. If the basin is too deep, a draft tube solves the problem. A draft tube is a simple extension which provides for a deeper intake.

PROJEKTOWANIE MECHANICZNEGO SYSTEMU NAPOWIETRZANIA

W artykule omówiono sposób doboru mechanicznych aeratorów powierzchniowych na podstawie znajomości ilości i stężenia dopływających ścieków oraz czasu napowietrzania. Przedstawiono typowe nomogramy stosowane do obliczania mocy niezbędnej jedynie do dyspersji tlenu i utrzymania warunków aerobowych w komorze oraz mocy potrzebnej do natleniania i utrzymania w stanie zawieszenia kłaczków osadu czynnego. Zostały podane zasady wymiarowania komór i zasady stosowania urządzeń wspomagających mieszanie i przeciwdziałających erozji dna.

ENTWURFSGRUNDLAGEN ZUR OBERFLÄCHENBELÜFTUNG

Im vorgelegten Beitrag wird das Prinzip eines Berechnungsverfahrens von Oberflächenbelüftern beschrieben. Grundlagen zur Berechnung bilden: Menge und Konzentration der zufliessenden Abwässer sowie Belüftungszeit. Die beigefügten Nomogramme ermöglichen die Berechnung der installierten Leistung. Die Leistung der Kreisel dient zum Sauserstoffeintrag, zur Erhaltung der aeroben Verhältnisse im Belüftungsbecken und zur Verhinderung von Schlammablagerungen am Beckenboden. Weiterhin sind die Bemessungsmethoden und Hilfseinrichtungen sowie die Gestaltung des Beckenbodens, die einer Erosion entgegenwirkt, besprochen.

ПРОЕКТИРОВАНИЕ МЕХАНИЧЕСКОЙ СИСТЕМЫ АЭРАЦИИ

В работе приведён ориентировочный способ подбора механических поверхностных аэраторов на основе знания количества и концентрации поступающих сточных вод, а также времени аэрации. Приведены типичные монограммы, применяемые для расчёта мощности, необходимой только для дисперсии кислорода и сохранения аэробных условий в камере, а также мощности, необходимой для насыщения кислородом и сохранения во взвешенном состоянии клочков активного ила. Описаны принципы определения размеров камер и принципов применения установок, способствующих перемешиванию и противодействующих эрозии дна.