K_La Systems Technology Guide

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K_La Systems – Jet Aeration Technology

K_La Technology

K_La jet aerators transfer oxygen by simultaneously introducing large volumes of high kinetic energy liquid and air through a series of jet nozzles (Figure 1). The high velocity liquid exits the inner, primary jet and rapidly mixes with the in-coming air in the outer jet. The intense mixing and high degree of turbulence rapidly dissolves the air into a fine dispersion of gas and liquid. This high velocity, oxygen rich cloud is discharged from the outer nozzle where the plume mixes with and entrains the surrounding liquid. Each individual jet plume travels horizontally along the basin floor prior to the vertical rise of the gas bubble column to the surface.

In biological treatment processes, the motive liquid to the jet is furnished by recirculating the mixed liquor using centrifugal pumps. Low-pressure air is supplied to the process via compressors or blowers.

K_La Jet Aerator

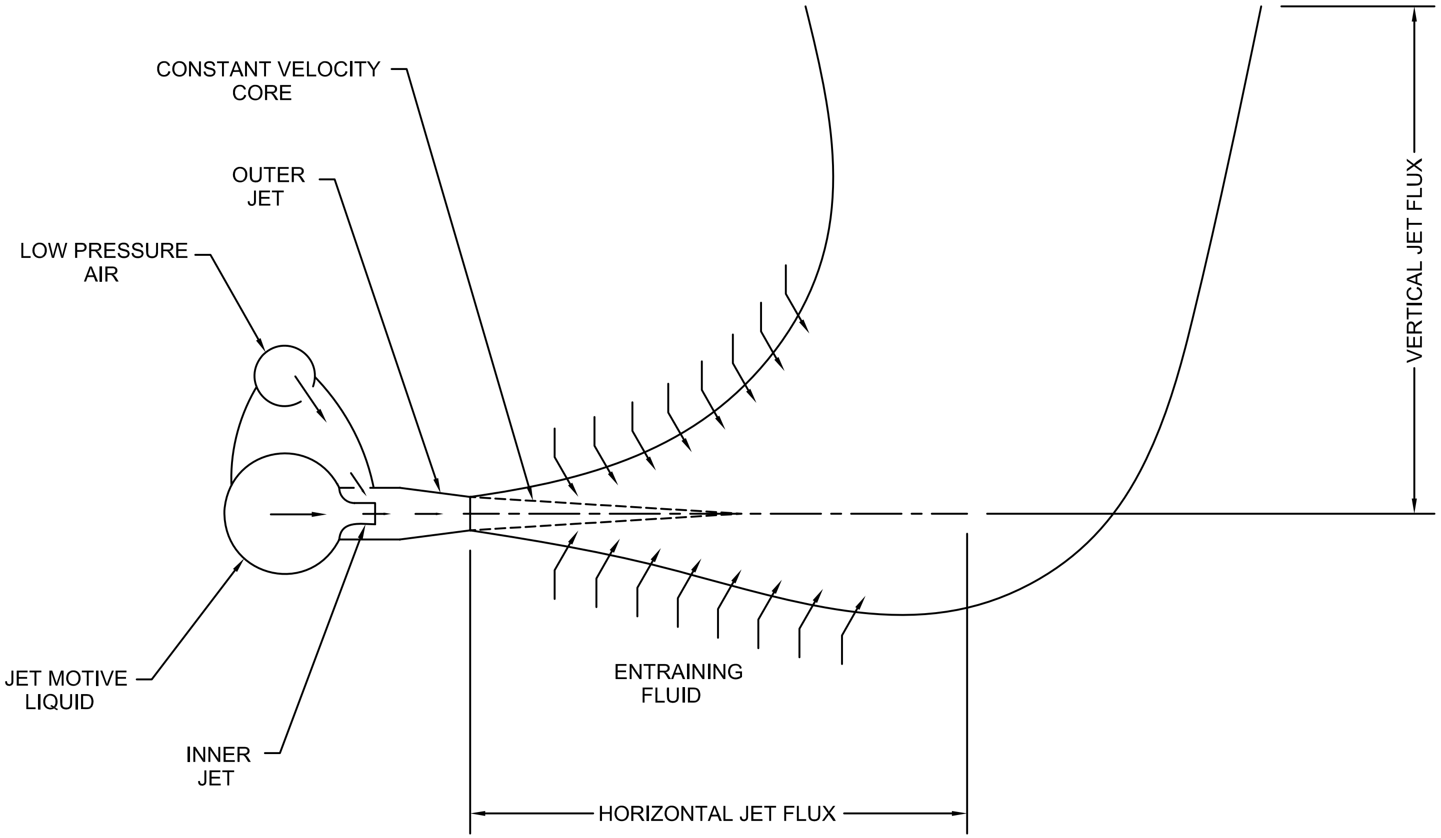
K_La jet aerators consist of two general configurations of jet nozzles mounted on specific distribution systems. Both jet aerator designs are supplied as fabricated, monolithic units. Manifold type jet aerators locate jet aeration nozzles (jets) on either one or both sides of a liquid distribution pipe. The jet nozzles are attached to an air distribution pipe by individual air ducts that serve as both an air source for the jets and support the air distribution pipe. They are typically supplied in lengths of up to 45-ft. (13.7 m.) with the jet nozzles, air ducts, liquid distribution manifold and air distribution manifold supplied as a single unit. For export containers, the maximum length is just under 40-ft. (12 m.)

Radial jet aerators distribute jets uniformly around the circumference of a central, pressurized, tank type chamber. As a rule, the jet manifold is used in larger scale applications, and the radial aerators are limited to smaller scale biological processes utilizing circular tanks. The two types of jet aerators are shown in Figure 2 and 3.

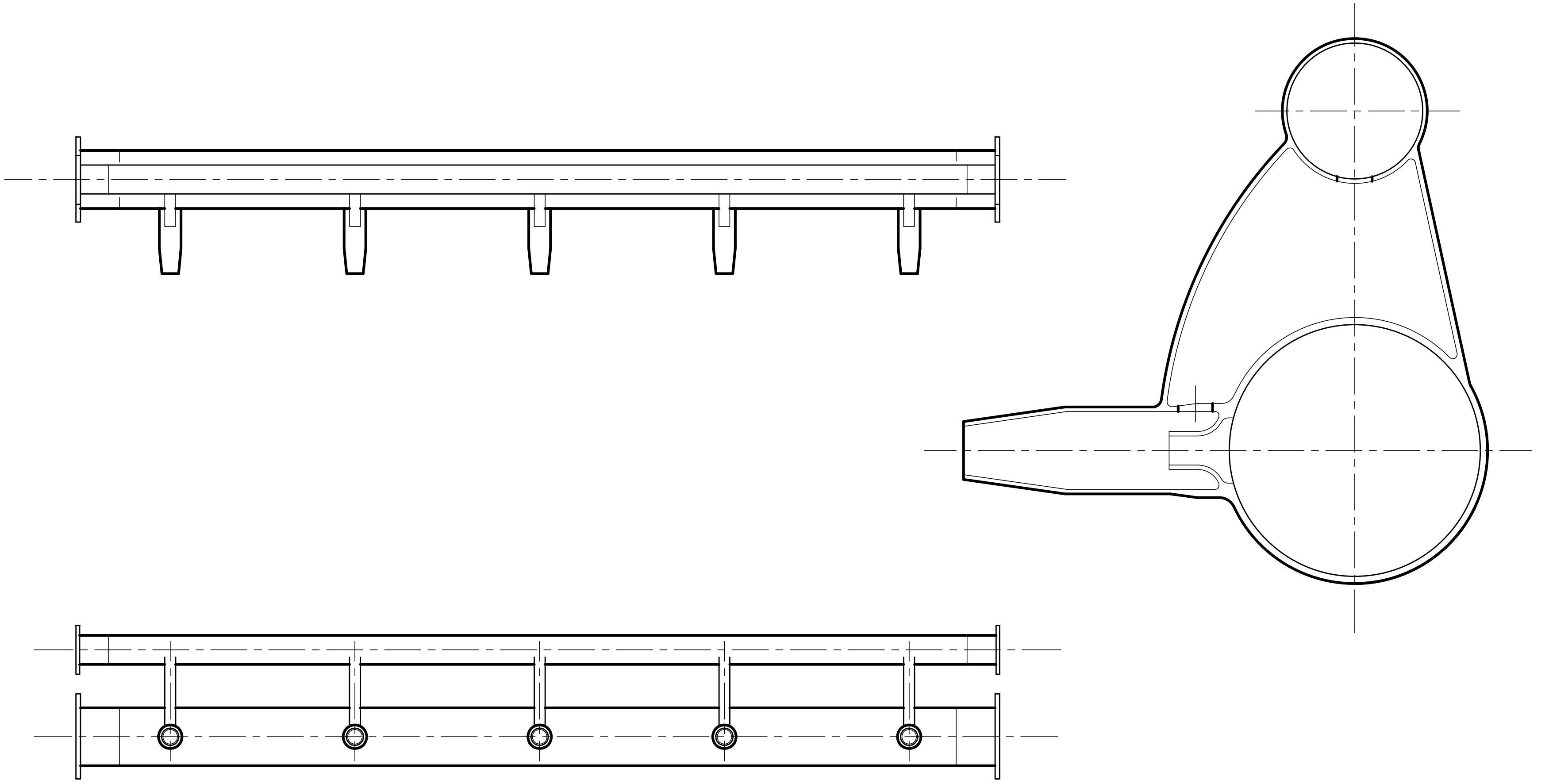
The aerator configuration, number of jet nozzles and nozzle spacing is designed to maximize oxygen transfer and mixing. Effective spacing of the nozzles and aerators will insure uniform oxygen transfer throughout the basin as well as optimizing the overall mixing process.

Fiberglass reinforced plastic (FRP) is the material of construction of the jet aerator. FRP is not only an economical material, but also it is durable, lightweight, highly corrosion resistant, and easily assembled in the field. Typically, the piping for the aerators or air/liquid distribution system is machine filament wound. The jet nozzles, radial chambers and air ducts are fabricated by custom contact molding processes. The assembly process for the connection of the jets and air ducts to the aerator piping or radial chambers is via hand lay-up manufacturing methods. The selection of the various grades of FRP resins, piping thickness and design pressure ratings as well as different abrasion liners are dictated by the specific application. The K_La Systems standard jet aerator specifications are included in this catalog. Structural support systems are fabricated from various grades of 300 series stainless steel and occasionally epoxy coated steel. Jet aeration and mixing systems fabricated entirely of stainless steel are available, although more costly then FRP systems.

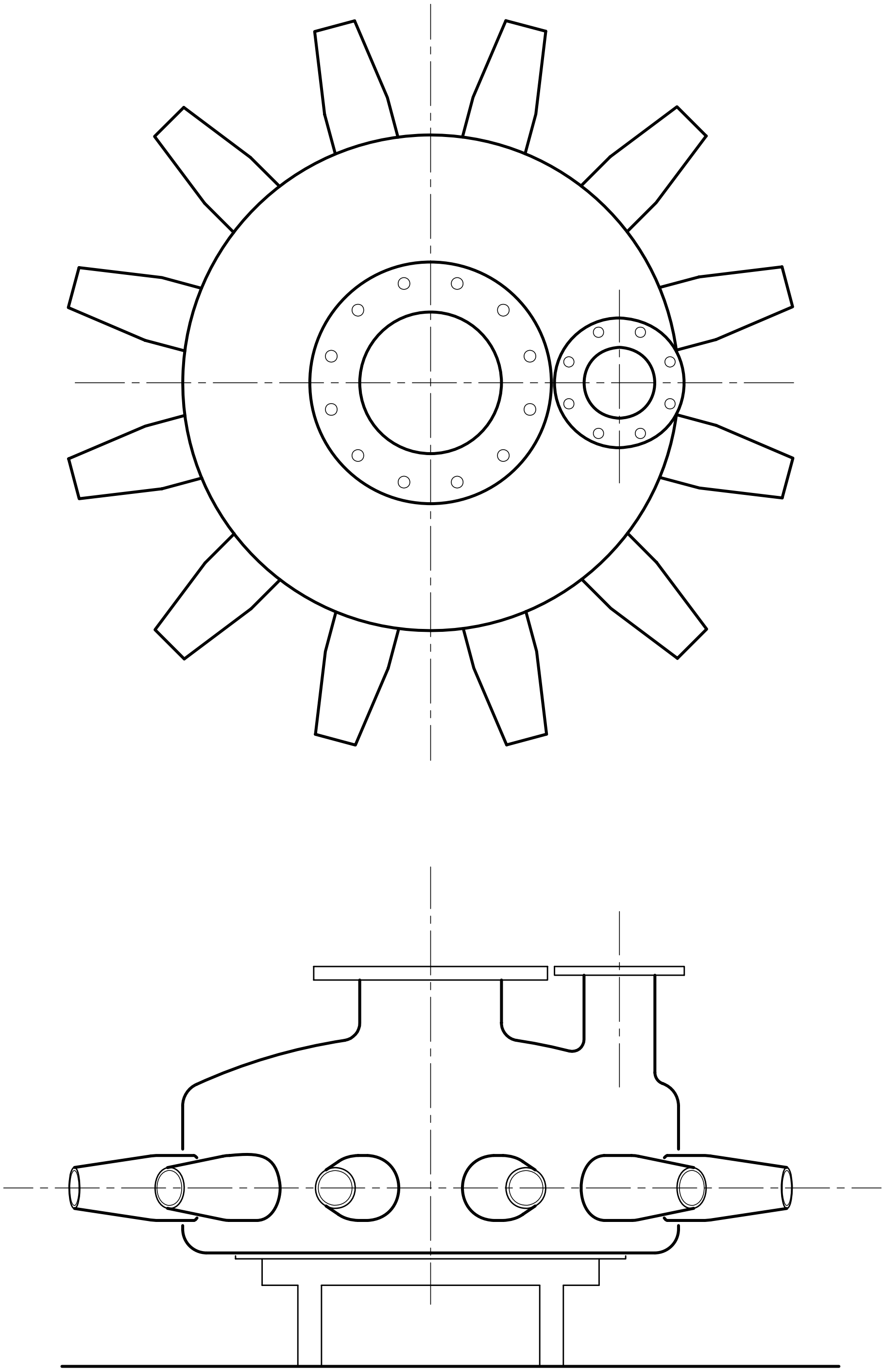
KLA JET NOZZLE



KLA JET NOZZLE
FIGURE 1



JET AERATION HEADER
FIGURE 2



RADIAL JET AERATOR
FIGURE 3

K_La Jet Aeration System

The K_La Jet aeration system includes the individual jet aerators and in-basin piping system, often along with the supply of air blowers and liquid recirculation pumps. Other jet system components include: back-flush system, out-of-basin air and liquid piping systems, isolation valves, expansion joints, pressure gauges, air flow measurement devices and instrumentation, supports, fittings, dissolved oxygen control system, motor control center, and acoustical enclosures. A typical jet aeration system is shown in Figure 4.

For the supply of air, rotary positive displacement blowers, multi-stage centrifugal blowers, and single-stage turbine type compressors and accessories are typically supplied. End suction centrifugal pumps, vertical submersible pumps or vertical propeller pumps are usually furnished for the supply of jet motive liquid. The pumping systems are configured as a recirculation loop where the mixed liquor is directly withdrawn from the basin and pumped back into the process via the liquid distribution pipe or manifold. The proper design of the liquid recirculation system is critical to insuring that the there is a 33 ft./sec. (10 m/s) liquid velocity continuously pumped through the inner jet nozzle.

Key Performance Factors

The high velocity stream, in combination with the introduction of air, is the key feature that makes the technology unique, and the resultant hydrodynamic conditions contribute to the superior oxygen transfer and mixing performance as follows:

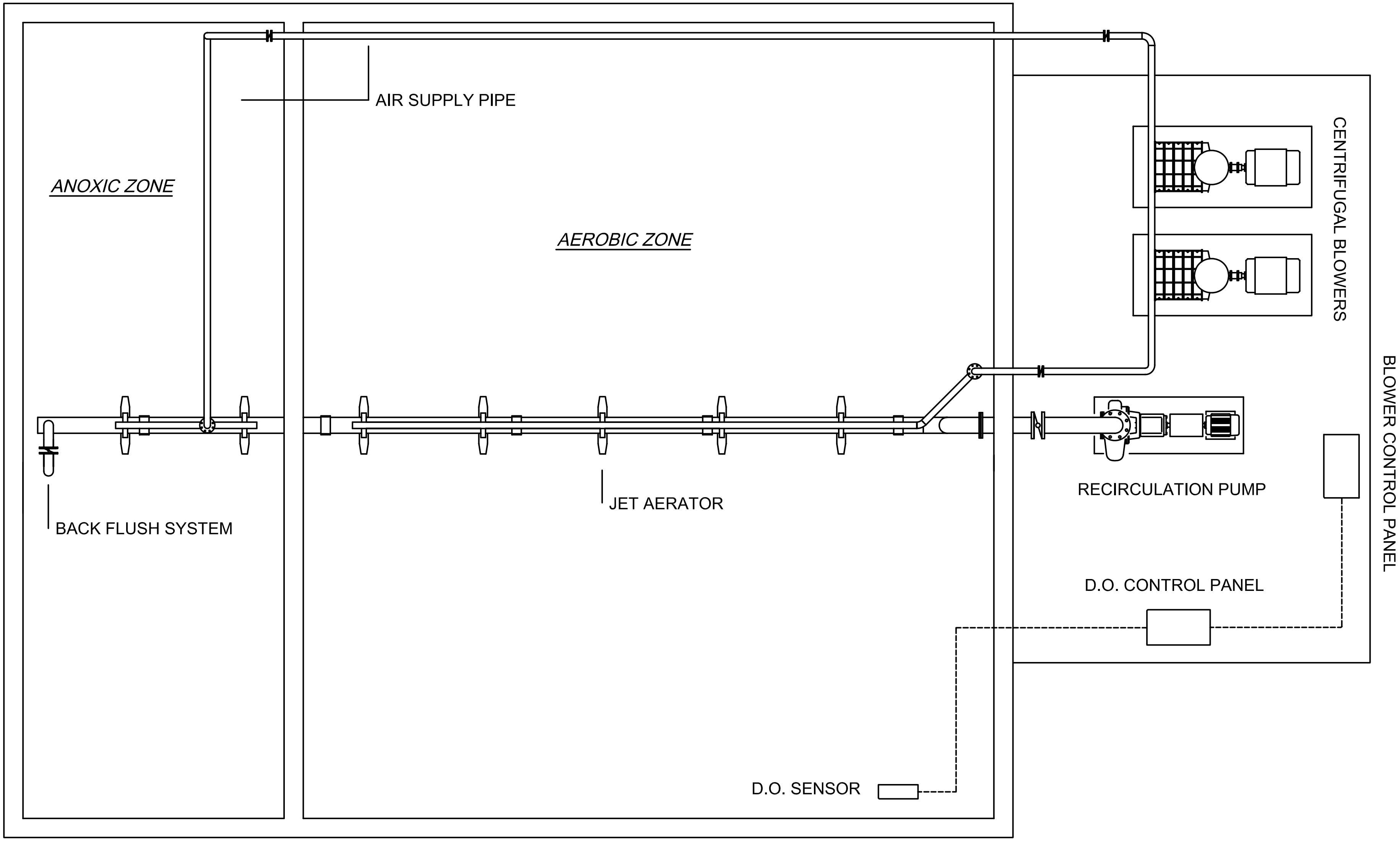
1. The highly turbulent, fine bubble cloud creates an enormous gas/liquid interface inside the jet and along the horizontal plume, resulting in high mass transfer coefficients (K_La).

2. The transfer of horizontal momentum from the jet to the surrounding liquid, combined with rising bubble columns, provides superior process mixing.

Process Benefits

These two factors translate into many of the process benefits of the jet aeration systems, including:

1. **High aeration efficiency**
2. **Higher percentage of oxygen utilization**
3. **Superior mixing and process control**
4. **Independent control of mixing and oxygen transfer**



JET AERATION SYSTEM
FIGURE 4

Project Life Cycle Benefits

These process benefits, along with the physical features of the jet aeration system, result in significant improvements to the aeration system life cycle such as:

1. **Reduced capital costs**
2. **Lower energy costs**
3. **Lower Maintenance Costs**
4. **Small plant footprint**
5. **Reduced aerosols**
6. **Reduced volumes of off-gas**

K_La Systems-Oxygen Transfer Performance

An important aspect of jet aeration is that the device has two components of mass flow that give it unique oxygen transfer performance characteristics. The jets use continuous mixed liquor recirculation as the motive fluid for dissolving the gas stream and transferring momentum to the bulk liquid. The secondary fluid (air) is introduced over a range of flow rates depending upon the oxygen transfer and mixing requirements of the process.

The percentage of standard oxygen utilization (a.k.a. standard oxygen absorption efficiency or standard oxygen transfer efficiency) is affected by the jet air/liquid flow ratio and liquid depth. This is illustrated in Figure 5, with two very important characteristics of the series of curves:

- The percentage of oxygen utilization increases with reactor depth. This phenomenon is related to Henry's law of partial pressures, but is more pronounced with jet aerators (when compared with other diffusers) due to the ability of the high velocity liquid stream to dissolve more of the compressed gas into solution at greater liquid depths.

- As air/liquid ratio is increased, the percentage of oxygen utilization decreases. Conversely, as ratio is decreased, the percentage of oxygen utilization increases. This characteristic is based on the fact that one component of mass flow (liquid side) is held constant while airflow is varied. At a constant liquid velocity, the formation and size of the gas bubbles (which is directly related to the percent standard oxygen utilization) is primarily controlled by the amount of airflow. Finer (smaller) bubbles are formed at low airflows, and medium to coarse bubbles are formed as airflow increases towards the maximum air/liquid ratio.

Varying the air/liquid ratio to a jet system is accomplished in the field by throttling the airflow. This results in visible changes in the jet plume length. At lower airflows the motive fluid carries the plume further along the horizontal plane, resulting in a larger mixing zone. At higher airflows, the lower density and greater buoyancy of the gas/liquid cloud results in a shorter horizontal component of the jet plume.

Figure 6 shows the relationship between Standard Aeration Efficiency and Jet Air/Liquid Flow Ratio as a function of reactor depth. These curves are widely published, with their characteristic "hump" at the optimum air/liquid ratio. K_La jet aeration systems are designed near or at the optimum air/liquid ratio based on meeting the average oxygen requirement of the process. Increasing or decreasing the ratio by throttling the airflow allows the flexibility to meet minimum and maximum oxygen requirements. This feature is unique to jet aerators, is easily automated with dissolved oxygen sensors, and improves the ability of a plant operator to maintain process control.

The series of curves reveals the improvement in energy efficiency with increased reactor depth. As the depth increases, the percentage of oxygen utilization increases resulting in a decrease in the amount of jet nozzles required to meet the standard oxygen requirement. A reduction in the number of jets decreases the liquid recirculation and airflow requirements, with the effect being a reduction in overall energy usage (and capital cost of the aeration system).

Another characteristic of the jet aerator is a shifting to the right of the optimum air/liquid ratio as reactor depth increases. This is due to the high velocity liquid stream more efficiently dissolving larger volumes of compressed gas at increased depths.

An important feature of the jet aeration system as it relates to Standard Aeration Efficiency is shown in Figure 7. This curve shows the relationship between Standard Aeration Efficiency and Jet Air/liquid Flow Ratio at 20-ft. (6 m.) and 40-ft. (12 m.) depths. The primary point of the graph is to depict that, in the "real world," these performance curves are not thin lines, but broad ranges due the wide variation in the efficiency of the prime movers. The selection of liquid recirculation pumps and air blowers are extremely important in optimizing the aeration efficiency. Pump hydraulic efficiency typically ranges from 65-85%, while blower adiabatic efficiency ranges from 60-80%.

It should be pointed out that selecting the prime mover based solely on efficiency has an impact on the capital cost of the system. For example, substituting a low efficiency positive displacement blower with a high efficiency turbo compressor can result in a increase in the aeration system capital cost by 50%. The affect of proper selection of pumping systems is more complex in terms of proportioning hydraulic efficiency to capital cost, but equally important.

The K_La jet system design will always take into consideration project life cycle analyses, and carefully balance the energy and capital costs in order to determine the optimum solution for each project.

K_La Systems -Aeration System Design

Aeration equipment suppliers rate the performance of their equipment by its oxygen transfer capacity in clean water (SOTR) at 0 mg/l dissolved oxygen, one atmosphere pressure, and 20^0 C. In aeration system design, the goal is to convert the engineer's actual (a.k.a. field or process) oxygen requirement (AOR) to a Standard Oxygen Requirement (SOR) using the following formula:

Standard Oxygen Utilization vs. Jet Air/Liquid Flow Ratio
(10 to 50 ft. SWD)

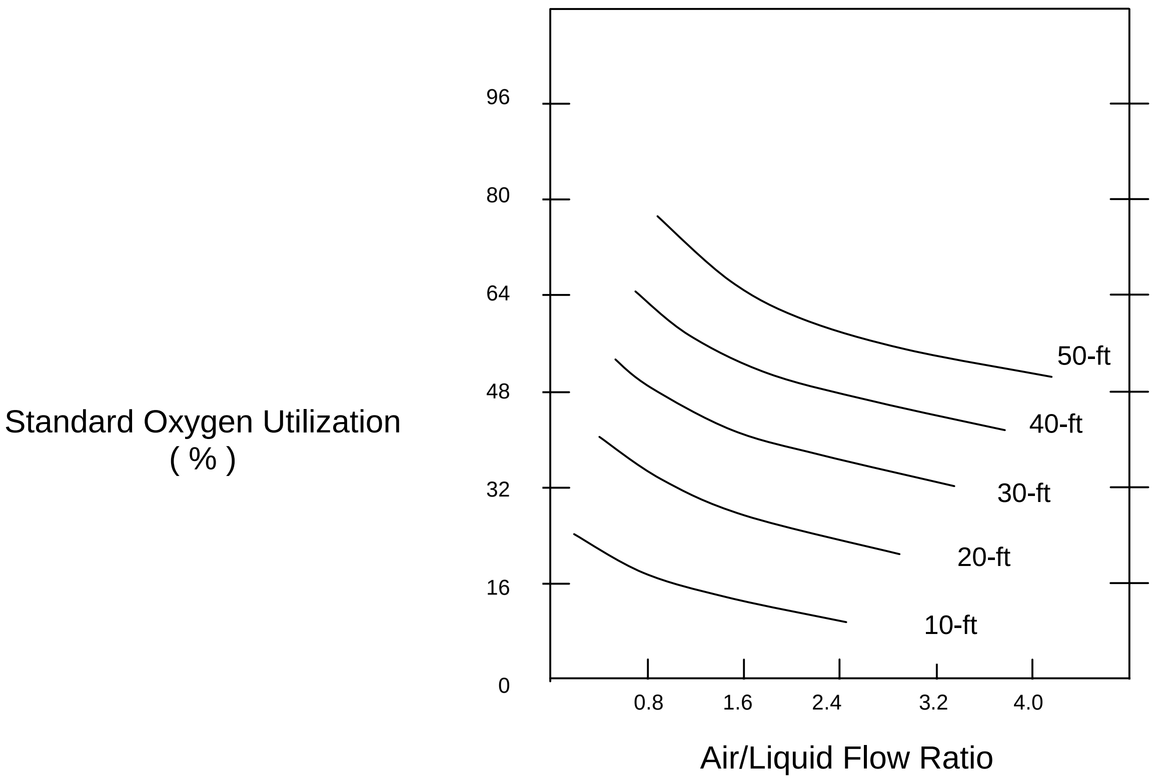
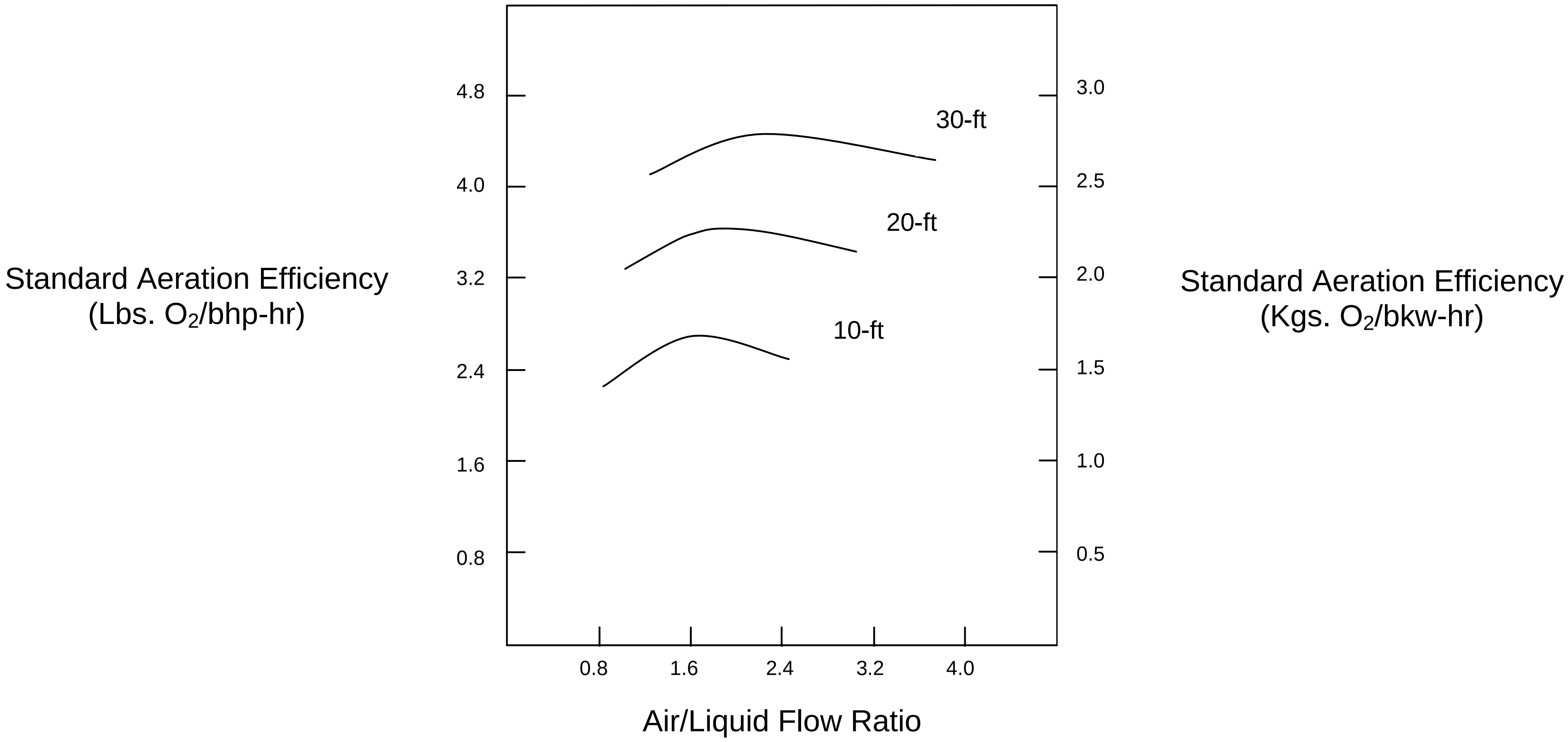


Figure 5

Aeration Efficiency vs. Jet Air/Liquid Flow Ratio
(10, 20 & 30 ft. SWD)



Note: For Liquid depths in Excess of 30-ft,
Contact K_La Systems

Figure 6

Aeration Efficiency vs. Jet Air/Liquid Flow Ratio
(Performance Range)

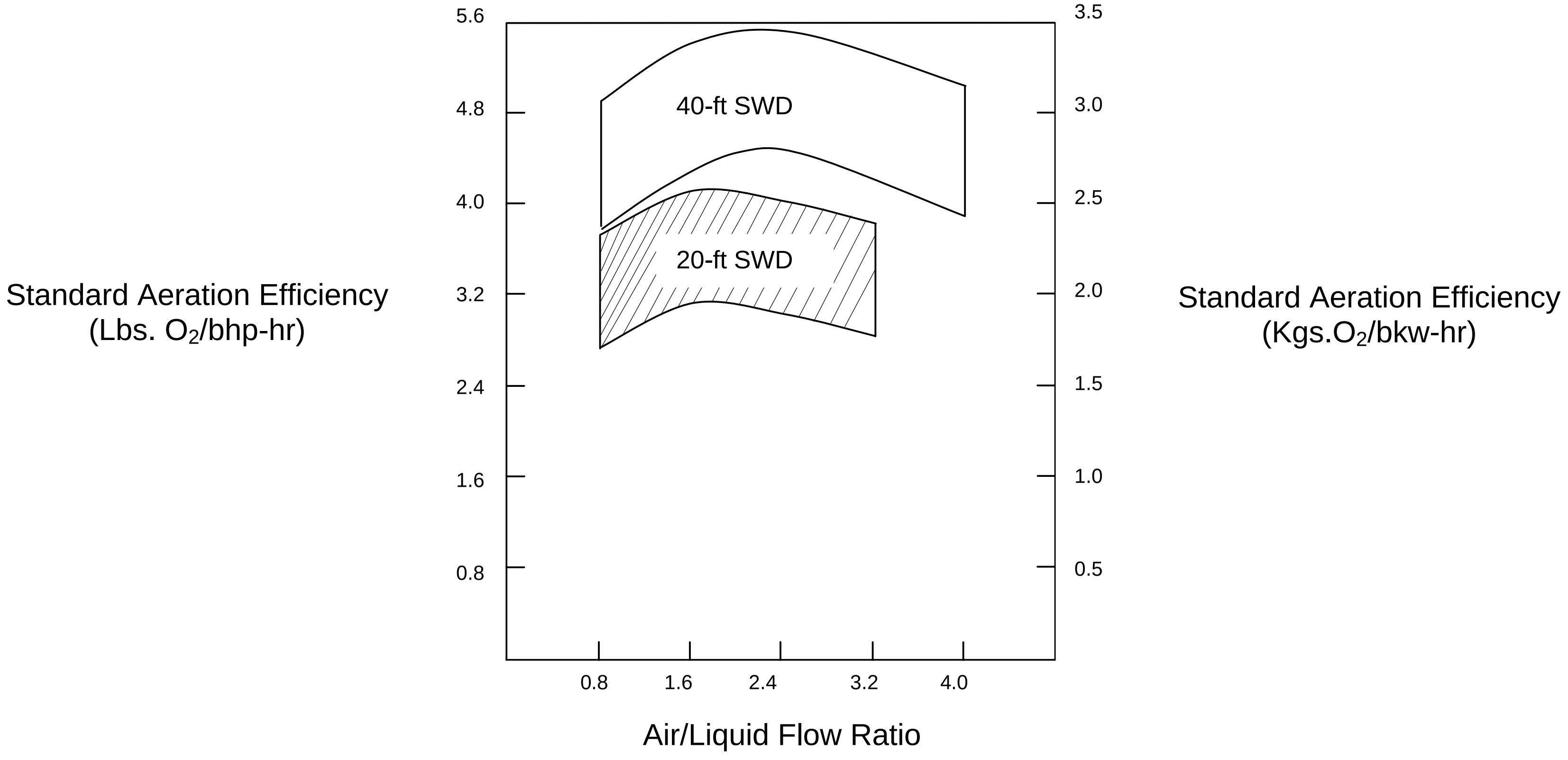


Figure 7

STANDARD OXYGEN REQUIREMENT (SOR)

$$SOR = \frac{AOR}{\alpha \left\{ \dfrac{((\beta \ x \ C_{WALT} \ x \ D_C) - C_L)}{(C^*_{20} \ x \ D_C)} \right\} \theta^{(T_W - 20)}}$$

SOR = Standard Oxygen Requirement, (lb or kg/hr)

AOR = Actual (Process) Oxygen Requirement, (lb or kg/hr),
Also known as OTR_F per ASCE

α = Alpha factor, ratio of oxygen transfer coefficient (K_La)
of the wastewater to that of tap water

β = Beta factor, ratio of oxygen saturation of the wastewater
to that of tap water

C_{WALT} = Surface saturation dissolved oxygen
concentration in clean water at the
wastewater temperature (T_W) and basin elevation, mg/l

D_C = Depth Correction Factor, $D_C = \frac{\text{Water Depth, ft.}}{100} + 1$

C_L = Residual Dissolved Oxygen concentration,
Typically is 2 mg/l

C^*_{20} = Surface saturation dissolved oxygen
concentration in clean water at 20°C and
one atmosphere

= 9.09 mg/l (per ASCE)

θ = Theta Factor, Temperature correction coefficient = 1.024

T_W = Wastewater Temperature (°C)

Once the SOR is determined, clean water performance data (i.e. standard conditions) is applied in order to develop the system design. It is the role of the aeration system supplier to make sure that the recommended design delivers an SOTR that meets or exceeds the SOR.

In review of the above equation, it can be seen that alpha factor is directly proportional to the SOR calculated for each design. It is the only parameter that is device specific, and has a major impact on both the size of the aeration system, and the power required to operate it. Aeration systems consume approximately 70% of the power to run a wastewater treatment plant, and the selection of the design alpha factor, as well as understanding its relationship to the actual operating conditions, is one of the most important considerations with respect to the system design.

In comparison to other diffused aeration technologies, jet aeration systems yield a higher alpha value. This is especially true in the biological treatment of production plant effluent from various pulp/paper, pharmaceutical, chemical and food processing plants. This characteristic of the jet aerator is due to the hydrodynamic conditions produced by the high velocity, turbulent jet plume in combination with some wastewater constituents common to these industries. A detailed description of the mechanism for enhancing or depressing the alpha factor can be found at the end of this section.

In aeration system design, a higher alpha factor results in a lower design Standard Oxygen Requirement (SOR). The following table shows commonly accepted values of alpha for various aeration devices treating wastewater from industry, along with the affect on the design SOR, and power required.

Type of Aerator	Alpha	Relative SOR (%)	Relative Power (%)
Jet	0.90	100	100
Coarse Bubble	0.70	129	157
Fine Pore	0.40	225	142
Surface	0.90	100	130

Note that the SOR is directly proportional to alpha, but the power required is not.
This is due to the differences in the standard oxygen utilization (a.k.a. SOTE) between the devices. For example, in 20-ft. (6 m.) deep aeration basins, a fine pore diffuser will have a standard oxygen utilization efficiency of 31% versus 26% and 16% for jets and coarse bubble diffusers respectively. These differences, combined with the affect of the alpha value contribute to the overall energy requirement of the aeration system.

In the design of aeration systems for sewage treatment plants, the differences in alpha between jets and fine pore diffusers are not as great. In many instances the total power usage for fine pore technology will be less then jet aerators, and this has contributed greatly to the success that fine pore diffusers have had in the municipal market.

For municipal applications, particularly where nutrient removal is a design consideration, the jet aerator's ability to mix the basin contents with the airflow turned off should be emphasized. This feature allows for superior process control, and is a key advantage in applying the technology to SBR, Oxidation Ditch and other nutrient removal processes. Another important feature of jet aerators in municipal applications is the frequency of cleaning the in-basin components and the design life of the system. Jet systems are self-cleaning (see Back-Flush system, pg. 7) and have a proven 20-year design life, which is not the case with submerged diffuser technology.

K_La Systems – Technology Applications

The following list shows the main applications of the K_La Systems jet aeration technology. This list can be generally broken down into three categories (activated sludge processes, aerobic biosolids treatment processes and equalization/holding). For industrial bioprocesses, the complete mix activated sludge process, equalization and sludge holding are the most popular applications typically with reactor depths in the 20-30-ft. (6-9 m.) range. For municipal applications, oxidation ditches, SBR and other nutrient removal processes are the most popular applications. Reactor depths here are typically in the 12-20-ft. (3.5-6.0 m.) range. The ASB process is generally found in the pulp/paper industry, where land is plentiful and inexpensive. In northern climates, jet aeration systems are applied to these massive basins due to their ability to provide superior mixing without severe loss of reactor temperature or the need for full floor coverage. The aerobic treatment of biosolids is regaining popularity, with conventional (mesophillic) aerobic digestion taking a backseat to auto thermal thermophillic aerobic digestion (ATAD). This is an excellent application of the technology, with special emphasis on both superior oxygen transfer and mixing under very high ($\geq$ 3.0 %) solids concentrations and reactor temperature ($\geq$ 55 degrees C).

Jet Aeration Applications

- **Complete Mix Activated Sludge**
- **Plug Flow Activated Sludge**
- **Oxidation Ditches (CLR)**
- **Sequencing Batch Reactors**
- **Pure Oxygen**
- **ASB**
- **ATAD**
- **Aerobic digestion**
- **Equalization**
- **Sludge Holding**

K_La Jet Aeration System-Maintenance Considerations

There are three main components to the jet aeration system: in-basin aerators with piping system and supports, liquid recirculation pumps with accessories, and air blowers with accessories.

Blowers: The routine maintenance required for the air blowers are minor, and will generally be per the manufacturers O&M manual. However, due to the large openings of the jet aerator, the inlet filters will require less maintenance or replacement as compared to blowers furnished for fine pore diffused aeration systems.

Pumps: When applying pumps for jet service, the primary maintenance concern is with leakage of the pumped liquid. For dry pit applications, the K_La pumping system is designed to include a mechanical seal. Single seals with hard faces and clean water flushing are recommended over double seal arrangements due to the need for positive flushing of biosolids off the seal faces, which also serves to cool the seal under continuous pumping service. In many industrial activated sludge applications, the jet pumps are furnished with dynamic seals with excellent results. Dynamic seals consist of an expeller that continuously repels pumped fluid from around the seal area while the pump is running, and a flexible, static seal which prevents leakage during times when the pump is not running (i.e. routine maintenance). Single seals with clean water flush systems typically promote a seal life of 2 to 4 years. Dynamic seals have been in jet service for over 7 years without replacement.

When submersible pumps are furnished for liquid recirculation, seals and an operator friendly retrieval system are the primary maintenance considerations. These pumps are equipped with tandem mechanical seals, which typically run, trouble-free, for 12 –24 months under continuous duty service with recommended replacement every 18 months.

Back-Flush System: One of the biggest drawbacks of most submerged aeration systems is the requirement to drain the basin for routine cleaning of the diffusers.
This is not the case with jet aerators. The K_La jet system is available with an optional Back-Flush System that allows for cleaning the jets without the need for basin drainage or to have an operator enter the basin. Back-flushing the jets is conducted essentially with an airlift pump that reverses the flow through the inner jet nozzle. The driving force for the reverse flow through jets is the pressure differential created by the lower density of the Back-flush stream compared to the surrounding liquid. This powerful flushing action removes any debris that may plug the inner jet nozzle.

The Back-Flush operation consists of:

1. Stop the airflow to the aerator.
2. Turn off the recirculation pump to the aerator.
3. Slowly open the Back-Flush valve.
4. Slowly start the airflow back to the aerator, until there is a smooth flow of air and liquid exiting the Back-flush valve.
5. Continue flushing for 5 minutes.
6. Stop the airflow again.
7. Restart the jet pumps.
8. Restart airflow to the aerator, regulate to the original setting.

The Back-Flush is typically included in aeration system designs for municipalities and pulp mills where heavy solids can occasionally enter the aeration basin. In many of the treatment plants built over the past 5 years, the application of fine screens (less then 6 mm openings) for pretreatment, has resulted in jet aeration systems that never experience plugged jet nozzles.

A typical Back-Flush operation takes only a few minutes, and is easily automated. The K_La Back-Flush system consists of a riser pipe connected to the liquid header or distribution pipe, supports, and a valve with operator. For deep aeration tank applications, the Back-Flush System requires special design considerations to protect the piping system from excess stresses.

K_La and Alpha

In order to understand alpha, it is important to review the basis for the oxygen transfer rate equation (which is the basis for the SOR equation). Among the theories describing oxygen transfer, the most widely accepted theory is the existence of two films (a thin film on each side of the gas/liquid interface), and the resistance to transfer of solutes across the gas and liquid films.

The oxygen transfer rate can be expressed as:

$$\mathbf{N = K_La\ (C_S - C_L)}$$

N = Mass of oxygen transferred per unit time
K_La = Overall mass transfer coefficient, comprising K_L and a
K_L = Liquid film mass transfer coefficient
a = Interfacial area per unit volume (A/V)
C_S = Saturation concentration of oxygen at the gas/liquid interface
C_L = Concentration of oxygen in the bulk liquid

The above equation is commonly viewed as:

Oxygen Transfer Rate = K_La x Driving Force

In aeration system design and testing, the combined coefficient, K_La, is used due to the logistical challenges in measuring 'K_L' and 'a' separately, as well as the fact that K_La can be determined via non-steady state oxygenation tests using a non-linear regression data reduction technique.

Mass Transfer Coefficient (K_L)

Many of the early studies of oxygen transfer theorized that liquid film resistance to molecular diffusion of oxygen into bulk solution was the controlling parameter in oxygen transfer.

The principal limitation to the theory is the assumption of a "steady-state" transfer across the gas/liquid interface. Dankwertz introduced the surface renewal theory that defines the liquid film coefficient by the following equation:

$$\mathbf{K_L = (D_L\ r)^{1/2}}$$

K_L = Liquid film mass transfer coefficient
D_L = Molecular diffusion coefficient
r = Surface renewal rate (average frequency that the liquid film is replaced by liquid from the bulk solution)

The key hypothesis is the assumption of “non-steady state” mass transfer. For turbulent conditions, eddies from the bulk liquid move to the gas/liquid interface and undergo short non-steady molecular diffusion, and are then displaced from the interface by subsequent bulk liquid. While under laminar conditions, no bulk liquid displacement takes place.

The molecular diffusion coefficient ‘D_L’ is greatly affected by the presence of chemical compounds (surfactants and other organic and inorganic chemicals) and the surface tension at the gas/liquid interface. The surface renewal rate ‘r’ is affected by the hydrodynamic conditions created by the type of aeration device used and the energy input (mixing intensity) to the process. Under laminar (low turbulence) conditions ‘K_L’ is controlled by molecular diffusion ‘D_L’. Under turbulent conditions, ‘K_L’ is controlled by surface renewal ‘r’.

Interfacial Area per Unit Volume (a):

The effects of bubble size, interfacial area per unit volume and oxygen transfer have been studied for the past forty years. Aeration devices are typically rated as either coarse, medium and fine bubble systems. As bubble size decreases, the interfacial area per unit volume ‘a’ increases resulting in greater oxygen transfer rates.

In biological processes, surface-active agents and dissolved salts greatly affect gas bubble size and the corresponding surface area available for mass transfer. Surface active agents lower the surface tension of the liquid resulting in a significant reduction in bubble diameter thus increasing the value of ‘a’ for the overall mass transfer coefficient K_La. Dissolved salts inhibit the coalescing affect of the bubble plumes or clouds allowing the fine bubble formation to maintain its small size, resulting in optimum mass transfer conditions throughout the entrainment process and vertical bubble rise. Some other organic compounds such as phenols, alcohols and carboxylic acids have the same affect as dissolved salts.

Overall Mass Transfer Coefficient (K_La):

It is important to consider that several of the above factors that affect the liquid film mass transfer coefficient ‘K_L’ also impact the surface area to volume ratio ‘a’. In particular, wastewater characteristics (dissolved salts, surfactants and other organic compounds), the type of aeration device, and the degree of turbulence and mixing intensity will play a major role in the oxygen transfer process.

It has been shown that the presence of certain organic chemicals (surfactants for instance) will have the following affect on the overall mass transfer coefficient, K_La.

1. Increased resistance at the gas/liquid interface, which impedes molecular diffusion, D_L, and thus reduces the liquid film coefficient ‘K_L’ and overall mass transfer coefficient, K_La.

2. Increased interfacial area per unit volume ‘a’ which increases the overall mass transfer coefficient, K_La.

The hydrodynamic conditions created by the aeration device and the mixing intensity to the process determine whether or not the K_La value is depressed or enhanced in the presence of surfactants as follows:

1. Under laminar (low turbulence) conditions, molecular diffusion controls the liquid film coefficient 'K_L'. In the presence of surfactants the increase in interfacial area, a, is negated by the resistance to molecular diffusion (due to the accumulation of organic molecules at the surface of the film). This leads to the subsequent reduction in the values of 'D_L' and'K_L', and a depressed value of K_La.

2. Under turbulent conditions the liquid film is continually disrupted (or renewed) so that the surfactant molecules do not become diffusion barriers. The surface renewal rate 'r', controls the value of the liquid film coefficient 'K_L', and the increase in interfacial area 'a' is not negated by the resistance to molecular diffusion, resulting in an enhanced value of K_La.

In the presence of high dissolved salt concentrations (0.5-3.0 %), there are often enhanced values of K_La and alpha due to the maintenance of very small gas bubbles from initial formation through the buoyant rise.

Design Alpha-Enhancement and Depression

Since Alpha is defined as:

$$\frac{K_La\ (\text{wastewater})}{K_La\ (\text{clean water})}$$

The determination as to whether the value of alpha is enhanced or depressed by the wastewater constituents or the type of aeration device (and the hydrodynamic conditions it produces) is a function of comparing the K_La values in wastewater to those in clean water. In certain industries, it is not uncommon for the alpha factor to be in excess of unity, and there are many jet aeration installations around the world producing these results continuously. This phenomenon is a result of the wastewater characteristics common to many production facilities containing a combination of high dissolved salts and/or surfactants. The result is ideal conditions for high "dirty water" K_La values (i.e. extremely fine bubbles and no diffusion barrier). Fine pore diffusers typically will have depressed alpha factors under the same conditions. This is because the production of very fine bubbles under laminar transfer conditions can not over come the diffusion barrier. However, in wastewater with low organic content and the high TDS levels, fine pore diffusers have produced enhanced alpha values. Surface aerators have produced elevated alpha values under similar wastewater conditions where jet aerators tend to perform above expectation.

Jet systems applied to long sludge age processes with high bacterial cell concentrations (membrane bioreactors and ATAD for example) often produce high alpha factors. This has been attributed to the release of extra-cellular enzymes and their surfactant-like characteristics.

Without extensive pilot testing, K_La Systems does not recommend selecting a design alpha factor above 0.90. In these cases, K_La will incorporate a flexible, air blower and pumping system design to insure that the system can be efficiently "turned down" should the apparent alpha factor greatly exceed the design value.

For large-scale aeration projects, pilot testing (under actual or simulated bioreactor concentrations) is recommended to determine an appropriate design alpha factor. Alpha test units in the 500-1000 gallon range have been shown to furnish good scale-up data for jet aeration system design.

Foam

An interesting challenge that has developed from jet aeration applications where high alpha factors have been documented has been the characteristic of foam formation during the aeration process. This is typically attributed to: the low surface tension of the mixed liquor, the very stable fine bubbles that exist under high TDS levels, the degree of turbulence generated by the jet, and the mixing intensity of the process. Under these conditions, nuisance foaming events are not uncommon, nor are the use of anti-foams or de-foamers by plant operators to combat these occurrences.

Note that there are other types of foams that form due to the nature or mode of operation of the biological process (nutrient removal processes and ATAD for example). These "biological" foams are often reduced or minimized by modifications to the process operating strategy rather then the use of chemicals.

The chemical additives used to combat foam are also surfactants and are classified as anionic, cationic and non-ionic. De-foamers and anti-foams are used differently. De-foamers are typically added during and after a foaming event, destroying the existing foam and preventing further foam production for a period of time. Anti-foams inhibit foam production by preventing the formation of fine bubbles and accelerating the coalescence of the bubbles as they exit the jet aerator and enter the entrainment process and vertical bubble column. A secondary affect of these coalescence-enhancing chemicals, even at concentrations as low as 3 mg/l, is the depression of oxygen transfer (K_La). Full-scale plants have experienced up to a 50 % reduction in the system oxygen transfer capacity. Non-ionic de-foamers and anti-foams appear to be the biggest oxygen transfer depressors.

Anti-foams are rarely ever recommended to combat nuisance foaming events. If chemical de-foamer is required, there are products available that perform well without depressing oxygen transfer. K_La Systems will work with our customers to find suitable products that mitigate foaming, while not adversely affecting the oxygen transfer capacity of the jet aeration system.

JET AERATION SYSTEM
TECHNICAL SPECIFICATIONS

GENERAL

The Jet Aeration System shall consist of ______ jet headers(s), each provided with in-basin liquid and air piping, back-flush system, and supports and hardware. Liquid recirculation shall be provided by _____ submersible pump(s) **OR** ________ external centrifugal pump(s). Airflow shall be provided by _____ positive displacement blower(s) **OR** ____ muti-stage centrifugal compressor(s).

PERFORMANCE

The aeration system shall be designed to transfer sufficient oxygen to meet a standard oxygen requirement (SOR) of _____ lbs/hr as well as provide complete mixing of the basin contents.

MANUFACTURER

The Jet Aeration System shall be Model K ___ ___ JA-________ as manufactured by K_La Systems Inc., Assonet, MA.

JET AERATOR

Each aerator shall be a monolithic unit, comprised of integrally fabricated air and liquid headers equipped with ___ air/liquid jet nozzles. The jets shall be either Directional (mounted on one side of the liquid header) **OR** Bi-directional (mounted “back-to back” on both sides of the liquid header). Jet nozzles shall be equally spaced along the length of the header. Jet motive liquid shall enter the liquid header through a _____-inch flanged connection and compressed air shall enter the air header through a _______-inch flanged connection. The jet aerator shall provide uniform distribution of the liquid and air to each jet nozzle. The jet motive liquid and compressed air shall combine in the outer jet nozzle, discharging as a high energy, fine bubble cloud in the lower regions of the basin. The jet aerator shall be shipped in integral section(s), each approximately ____ feet in length.

Liquid header shall be a cylindrical member, internally smooth and free from protrusions, which might create additional headloss or collect stringy material. The jet nozzles shall be aligned on a common horizontal plane. The air header shall also be a cylindrical member located above and parallel to the liquid header. The air header shall be attached to and supported above the liquid header by an air duct at each jet location. Individual air ducts shall ensure uniform air distribution to each jet. Additional supports shall be provided as necessary.

JET NOZZLES

Each jet aeration nozzle (K_La Model K4) shall consist of an inner liquid jet nozzle and outer air/liquid jet nozzle and an air duct. The jet nozzles and air ducts shall be fabricated from contact-molded reinforced thermosetting laminates in accordance with ASTM C 582-95 and NBS PS 15-69 using vinylester resin (or equal) formulated for ultra-violet protection The resin shall be natural in color (No Pigment Allowed). A combined 20 mil "C" veil, nexus and silicon carbide liner will be applied to the inside of all inner and outer jet nozzles for corrosion and abrasion resistance.

The jets shall be molded and assembled to be concentric with the inner liquid and outer air/liquid discharge nozzle in axial alignment. The outer jet nozzles shall be of constantly decreasing cross-sectional area so as to increase the velocity of the air/liquid mixture originating from the inner jet nozzle and the air duct. The inner and outer jet nozzles shall be circular and shall be capable of passing a 2.2-inch diameter solid and be smooth and free from all protrusions, which may increase headloss or collect stringy material. The outer jet nozzle shall have a circular orifice outlet having a diameter approximately 2.0 times the inner jet nozzle.

LIQUID AND AIR PIPING

All air and liquid header piping for fabricating the jet aerators and connection piping within the basin (including back-flush system piping) shall be provided as part of the jet system. Air down-comer and air header pipe shall be ____- inch diameter and connect to the contractor-supplied out-of-basin pipe located one foot above the maximum liquid level. Liquid suction, discharge and header pipe shall be ____- inch diameter and connect to the contractor-supplied out-of-basin pipe located at the tank wall penetration pipe. Back-flush pipe shall be ____-inch diameter. A(n) ______-inch diameter, 150-lb. drilling flange(s) shall be furnished for supplier/contractor interface.

The fiberglass reinforced polyester (FRP) pipe used for K_La Systems' jet aeration systems will be fabricated from premium grade vinyl ester resin. The pipe will incorporate a resin-rich liner on both the inside and outside that consists of a "C" glass veil and resin, to a 10-20 mil nominal thickness, with a minimum amount of wax in the surface resin to allow the pipe to cure. The total pipe wall thickness will be per the following table with a structural wall of continuous glass fibers wound at a 54.75^o helical angle in a matrix of vinyl ester resin. Pipe will be fabricated in conformance with ASTM D-2996-00, type 1, grade 2, class E. The resin shall be formulated for ultra-violet protection. The resin shall remain natural in color (No Pigment Allowed). A 10 to 20 mil "C" veil liner shall be applied to the inside and outside of all piping. Unless otherwise noted the wall thickness of the piping is to be as follows:

K_La Systems-Piping Table

Pipe Size	Wall Thickness (inches)
2"	0.15
4"	0.15
6"	0.15
8"	0.15
10"	0.15
12"	0.21
14"	0.21
16"	0.21
18"	0.24
20"	0.26
24"	0.31

Pipe, fittings, and air feeds shall be fabricated utilizing a vinylester resin Gaskets and Type Stainless Steel connection hardware shall be supplied for all flanged connections except supplier/contractor interface. All distribution piping and manifold sections shall be field connected by 150-lb. flange-by-flange sets **OR** FRP field wrap joints. Field wraps kits shall be furnished with all necessary materials and instructions. FRP flanges shall be fabricated in accordance with NBS PS 15-69.

FABRICATION

The jet nozzles, air ducts, flanges, elbows and other fittings shall be attached to the air and liquid headers and connection piping (as required) using hand lay up fabrication methods in accordance with NBS PS 15-69 and ASTM C 582-95. All sharp edges, cuts and burrs are to be sanded and resin coated to seal exposed edges. All flange connections are to straddle the vertical and horizontal centerlines of the equipment in the installed position. Whenever possible flange and fitting to pipe joints are to be hand-layed-up and resin coated internally so there are no internal seams. All external areas of the fiberglass equipment are to be resin coated after completion of all assembly and hand-lay-up procedures.

SUPPORTS

All necessary supports for the aeration manifold, air and liquid piping, and back-flush system(s) shall be provided. Supports shall be spaced on approximately ten (10) foot centers. All liquid manifold supports shall consist of a contoured saddle and ______-inch diameter, Schedule 40 leg assembly welded to a supporting base. Air down-comer and back-flush supports shall consist of a contoured saddle and a _____-inch diameter, Schedule 40 leg assembly welded to a supporting base. The support base shall be welded to the tank bottom or anchored with four (4) anchor bolts and grouted in place as necessary. A contoured clamp shall hold the piping to the saddle using four (4) full thread cap screws with lock washers. The saddle and clamp shall be provided with rubber pads to prevent abrasion. Supports and clamps shall be Type _____ stainless steel, connection hardware shall be Type ____ Stainless Steel, and anchor bolts shall be Type _____ stainless steel.

BACK-FLUSH SYSTEM

Each jet manifold shall be equipped with a back-flush system, which can clear any fouling debris without requiring maintenance personnel to enter the basin. The system shall be an air-lift type, activated by turning off the recirculation pump(s) while keeping the blower operating and opening the back-flush valve. The air-lift shall draw air and liquid in a reverse direction through the inner liquid nozzle, into the manifold piping, and then exiting the system up the riser pipe, and discharging back into the basin.

The system shall include back-flush riser, eccentric plug valve, and supports. Unless otherwise specified, the back-flush pipe, flanges, and valves shall be sized to be one standard pipe size larger than the largest air down-comer pipe. The vertical back-flush pipe shall connect to the liquid pipe with a flanged connection. The plug valve shall be horizontal and flanged between two 90° piping elbows as shown on the drawings and connect to the liquid pipe with a flanged connection.

RECIRCULATION PUMPS

END SUCTION CENTRIFUGAL OPTION

Liquid recirculation shall be provided to each aerator by ______ @ ______ HP horizontal, end suction centrifugal pump(s). Each pump shall be sized to deliver ____ GPM @ ____ ft. TDH, and furnished with the following accessories:

- ________(Cast Iron, Type 316 SS or Duplex SS) volute
- ________ (Cast Iron, Type 316 SS or Duplex SS) impeller
- Fabricated steel base with overhead, slide base motor mount, **OR**
- Fabricated steel base with direct drive mounting
- ____ HP ____ rpm TEFC motor (____ V, ___ ph, ____ Hz)
- Single mechanical seal with close clearance throat bushing and flush gland, requiring clean water flush **OR** dynamic seal
- V-belt drive assembly and guard **OR** Flexible coupling drive and guard

Pumps utilizing the single mechanical seal arrangement shall require hook-up to a customer furnished seal water flush system.

AIR BLOWERS

POSITIVE DISPLACEMENT OPTION

Airflow shall be delivered to the aeration system by ___ *(* ___ OPERATING, 1 STANDBY) ____ HP positive displacement blower(s). Each blower is sized to deliver ______ scfm at a discharge pressure of _____ psig. Each blower package will be supplied in a completely assembled package with the blower, motor, and accessories mounted on a structural steel frame complete and ready for installation, with the following accessories:

- ____ HP ____ rpm TEFC/ODP motor (____ V, ___ ph, ____ Hz)
- Fabricated steel table-top style base for blower, motor, and accessories, fully assembled and painted

- V-belt drive assembly and guard
- Discharge check valve
- Discharge isolation valve
- Inlet filter
- Inlet silencer
- Discharge silencer
- Flexible inlet and discharge connectors
- Pressure relief valve (spring type/weighted)
- Pressure gauges
- Motor slide base
- Acoustical Enclosure

Blowers are sized for inlet conditions of ____° F, ____ feet MSL elevation.

MULTI-STAGE CENTRIFUGAL OPTION

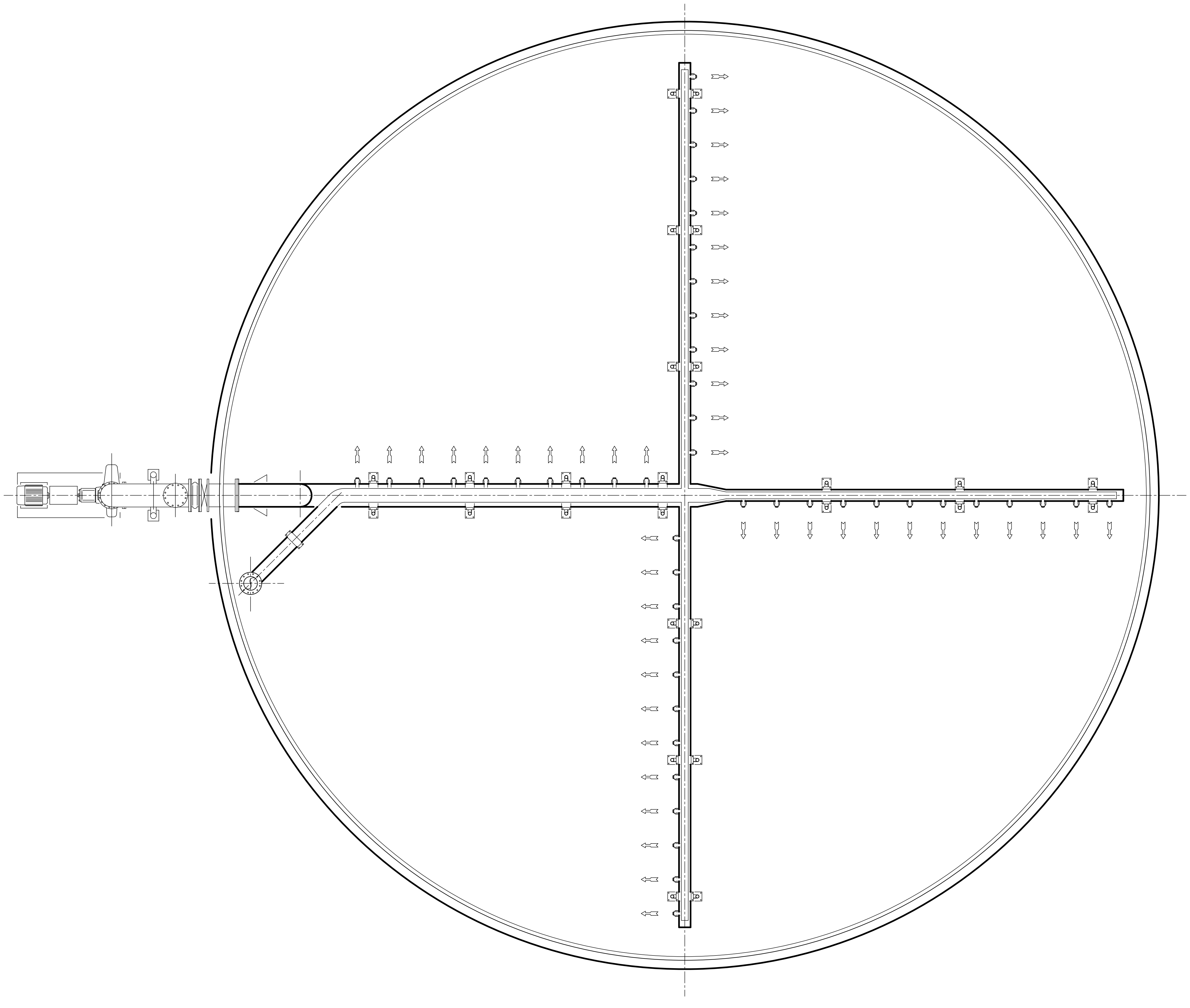
Airflow shall be delivered to the jet aeration system by ____ (___ operating, 1 standby) _____HP multi-stage centrifugal compressor(s). Each compressor is sized for _____ scfm at a discharge pressure of ______ psig, with a minimum ______ psig pressure rise to surge. Each compressor will be supplied with the following accessories:

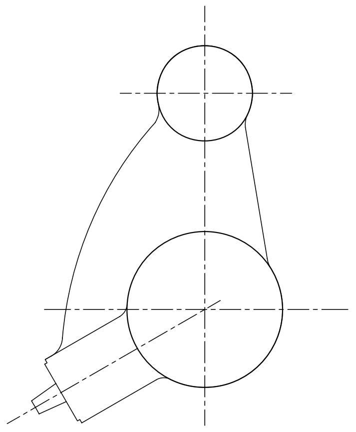
- ____ H.P., ____ rpm TEFC/ODP motor (____ V, ___ ph, ____ Hz)
- Fabricated steel base for compressor and motor
- Flexible coupling drive and guard
- Inlet butterfly valve with _____ operator
- Discharge check valve
- Discharge butterfly valve with _____ operator
- Inlet filter-silencer with restriction gauge
- Flanged inlet and discharge expansion joints
- Surge/overload panel

Compressors are sized for inlet conditions of ___° F, ____ feet MSL elevation.

SERVICES:

- Jet Aeration System Supplier shall furnish a complete Submittal Package (bound in a 3-Ring Notebook) including: Process Design Information, Jet Aerator and Piping System Manufacturing and Material Specifications, Pump Data, Plan and Elevation Drawings and Equipment Scope.
- Jet Aeration System Supplier shall furnish a complete I,O&M Package (bound in a 3-Ring Notebook) including: User Instructions, Process Design Information, Shipping, Off loading and Equipment Handling Information, Installation Information, Operation/Maintenance Information, and all Project Drawings.
- Jet Aeration System Supplier shall furnish a factory trained service engineer for ___ trips and ____ days at the jobsite for installation inspection, start-up and operator training.





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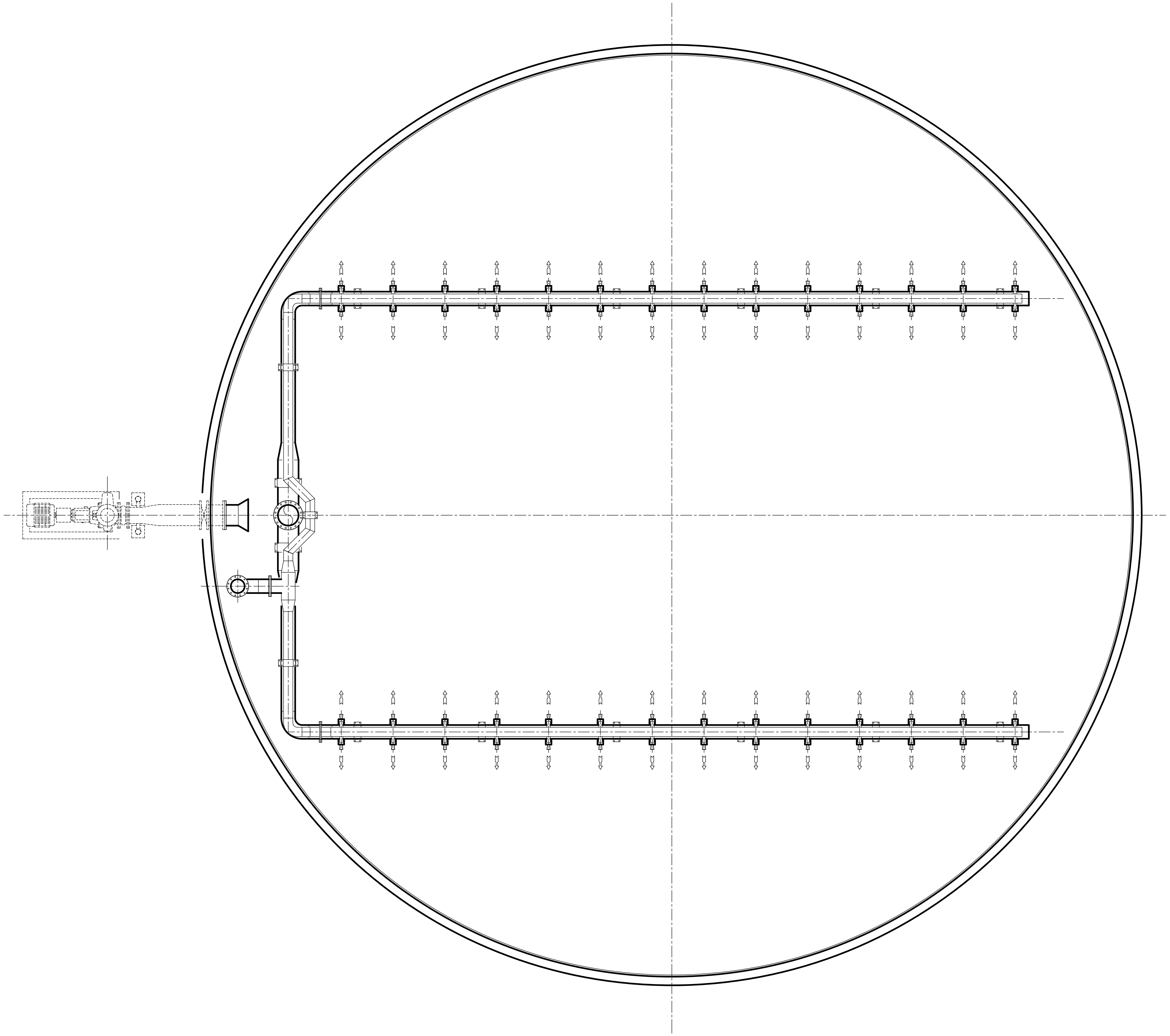
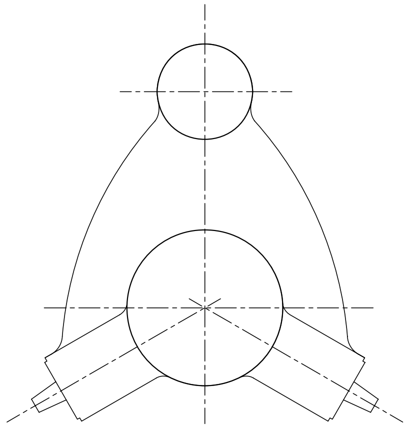
DIRECTIONAL SLOT INJECTOR HEADER
CIRCULAR TANK





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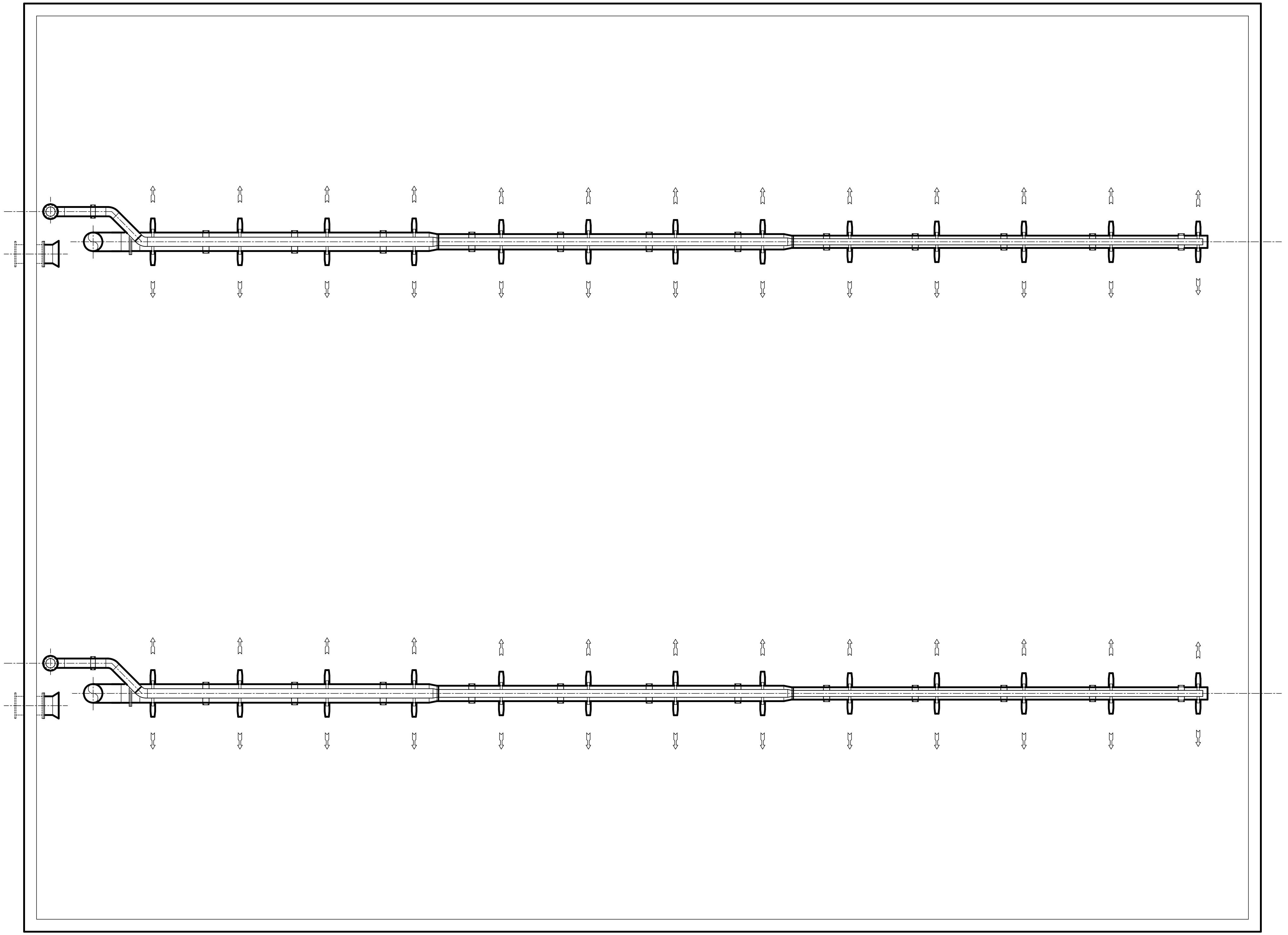
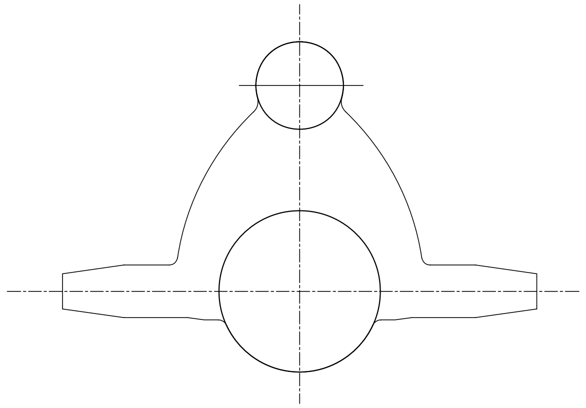
BI–DIRECTIONAL SLOT INJECTOR HEADER
CIRCULAR TANK





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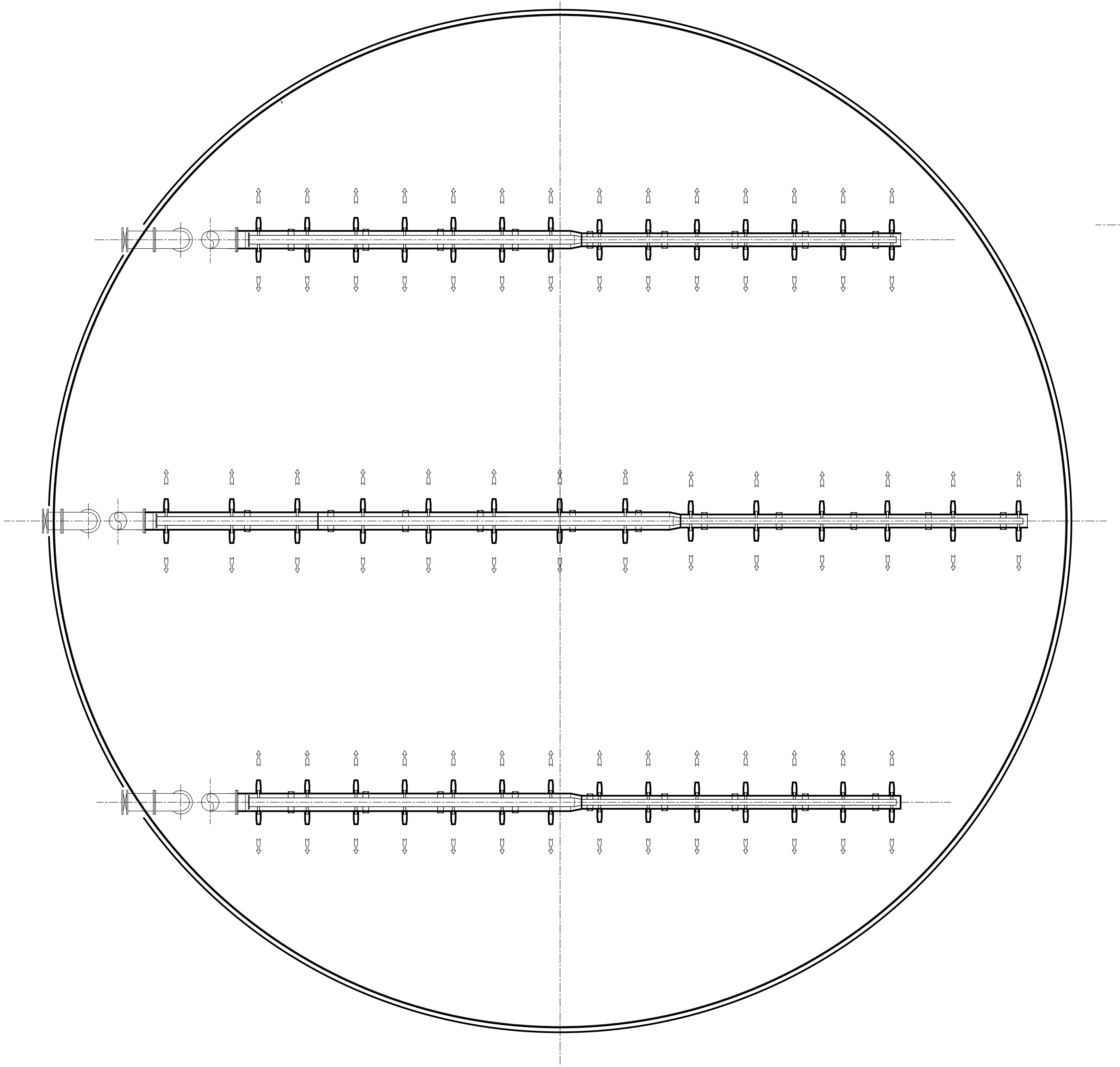
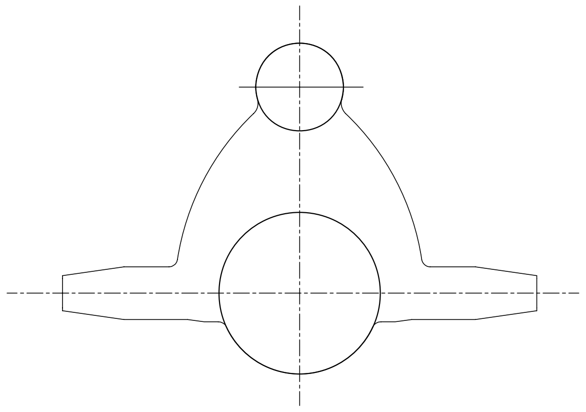
BI–DIRECTIONAL AERATION HEADER
AERATION TANK





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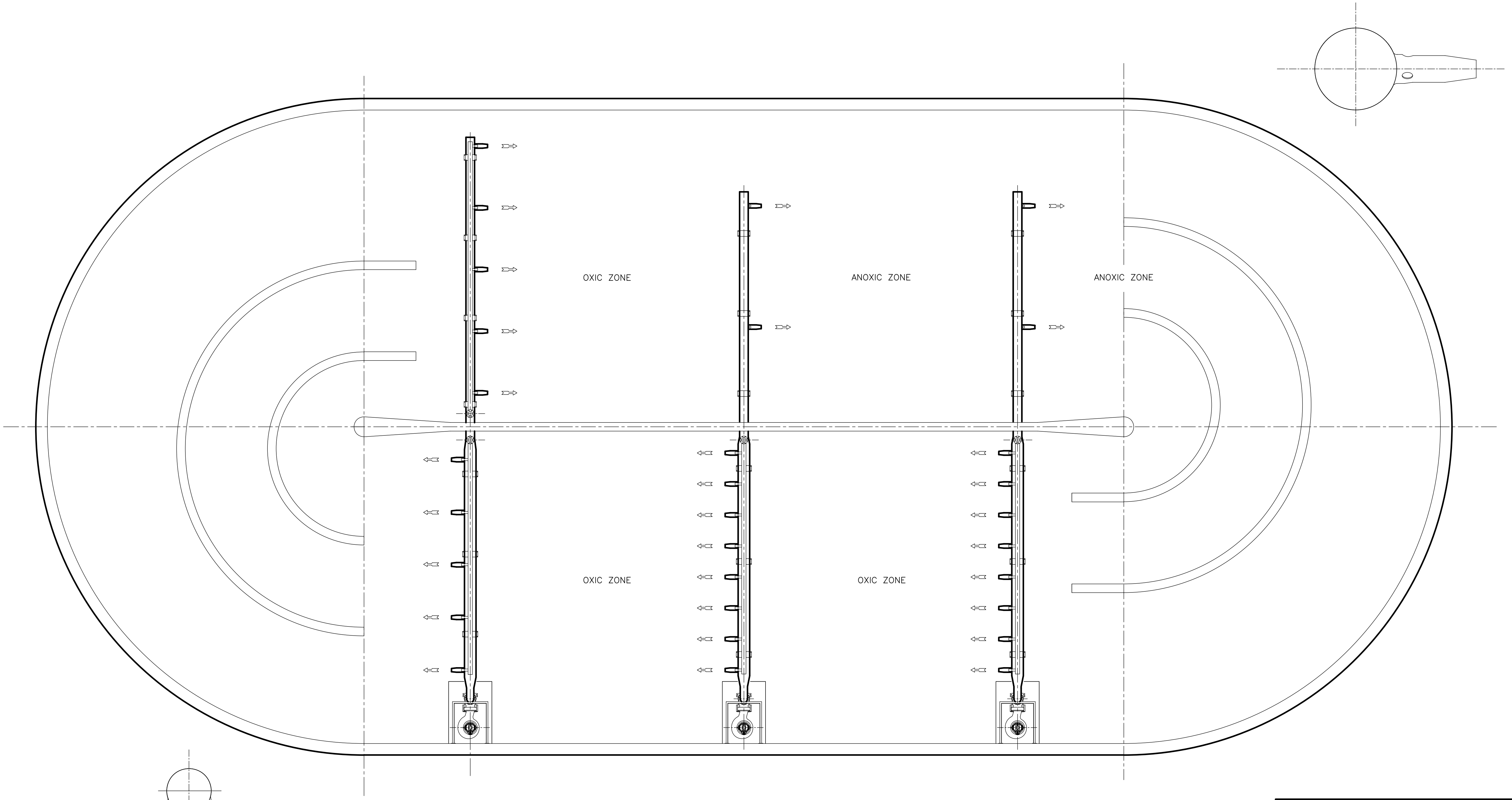
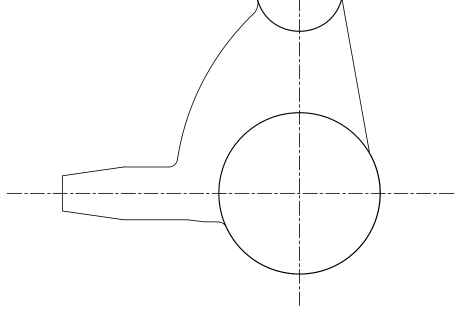
BI–DIRECTIONAL AERATION HEADER
CIRCULAR AERATION TANK





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DIRECTIONAL AERATION HEADER
OXYDATION DITCH