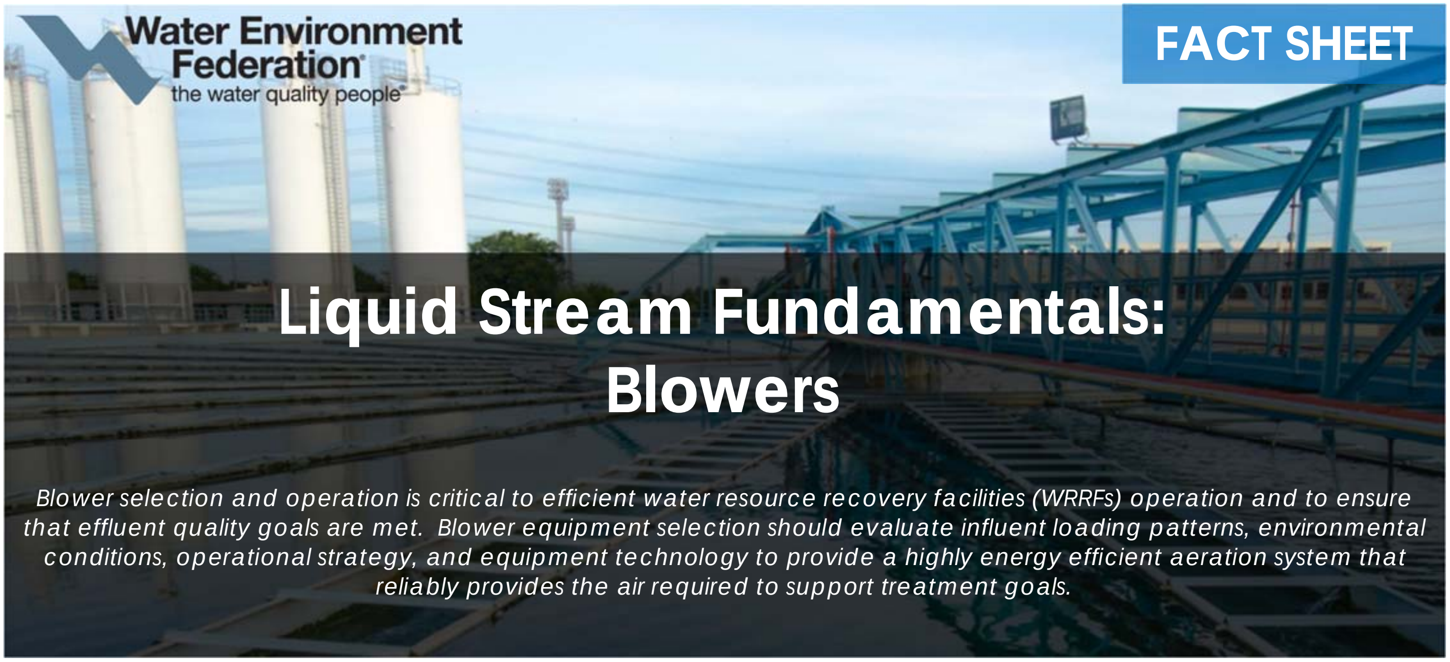

FACT SHEET

Liquid Stream Fundamentals: Blowers

Blower selection and operation is critical to efficient water resource recovery facilities (WRRFs) operation and to ensure that effluent quality goals are met. Blower equipment selection should evaluate influent loading patterns, environmental conditions, operational strategy, and equipment technology to provide a highly energy efficient aeration system that reliably provides the air required to support treatment goals.

Introduction

Blowers are an integral component of an overall aeration system (refer to Aeration Design factsheet for an overview on aeration) and are the key component for transferring air to the biological treatment process through air piping and diffusers (refer to Diffuser factsheet for more information on diffusers). Aeration is a significant portion of a WRRF's operating cost and can range from 45 to 75 percent of the facility's overall electricity demand (Rosso and Stenstrom, 2006). As the industry progresses towards more efficient controls and technologies to reduce energy consumption, it is critical to understand the factors that impact selection and operation of aeration blowers.

An aeration system is comprised of the blower and associated appurtenances (e.g. inlet filter), diffusers, piping, and aeration controls. Aeration blower equipment technology can generally be divided into two major categories: centrifugal and positive displacement. Centrifugal blower volumetric output is dependent on the required pressure across the blower. Output of positive displacement blowers is based on blower speed.

Figure 1— Different Blower Types – (A) Positive Displacement (Rotary Lobe), (B) Multistage Centrifugal, (C) Single-Stage Integrally Geared, (D) High Speed Direct Drive (Turbo)

Aeration blower equipment technologies include:

Positive Displacement

Rotary lobe blowers have either two or three lobes to compress a given volume of air per revolution. This technology is common at smaller facilities and for applications with variable discharge pressures due to varying side water depths. Rotary lobe blowers are often supplied as pre-packaged systems within a single acoustical enclosure.

Hybrid rotary lobe-screw blowers are newer, have a twisted lobe similar to screw compressors, and promise greater efficiency compared to traditional rotary lobe blowers.

Centrifugal

Multistage centrifugal blowers typically have between two and eight stages with individual impellers per stage. As air passes through each stage, the pressure is increased until the discharge pressure is achieved by the last stage. This technology is well established in the wastewater industry.

Single-stage centrifugal blowers have a single impeller for air compression, but operate at greater speeds to meet discharge pressure requirements. The main differentiators among single-stage equipment are how the speed to the blower is increased and bearing type.

- *Integral-gear driven blowers* use a gear box to increase the impeller speed above that of the motor. They use standard bearings to support the drive shafts through the gear box into the blower. These blowers use inlet guide vanes and outlet diffuser vanes to vary the output volume.
- The impeller of a *direct-drive blower (turbo blower)* is directly attached to the motor drive shaft, hence the name “direct-drive”. Blower output is varied by the use of a variable frequency drive. Turbo blowers utilize both air and magnetic bearings and have become more prevalent in the industry over the past ten years. These bearings do not require lubrication because the blower shaft is either levitated by an air film or positioning magnets to prevent the blower shaft from touching the bearing during high speed operation.

Design

Historically, blowers were often sized based on maximum, minimum and average flow and load conditions at worst case site conditions for conservatism. Blower design has traditionally focused on oxidation of biochemical oxygen demand (BOD) and possibly ammonia removal, but not on nutrients (e.g. TN and TP). Typically, actual facility operational conditions are far below these design conditions, resulting in various inefficiencies (e.g. inability to turndown, blow-off of air, performance gap). Sustainable aeration blower design must have a holistic approach and consider the entire envelope of environmental conditions and operational considerations, which are further discussed below.

Environmental Conditions

Blower equipment performance varies significantly based upon environmental conditions and location of the wastewater treatment facility. A wide range of environmental conditions should be evaluated during aeration blower selection. These environmental conditions include:

1. **Site elevation** impacts the relative mass of oxygen per volume of atmospheric air. Higher altitudes (“thinner” air) have a lower oxygen mass in atmospheric air than at mean sea level. Therefore, a greater volume of air must be produced by the equipment to transfer the same mass of oxygen at higher elevations.
2. **Ambient temperature** also impacts the mass of oxygen delivered as warmer air is less dense and provides less oxygen per given volume. This requires more volume for a given mass of oxygen at warmer temperatures. Hourly, daily and seasonal variations in ambient temperatures should be considered when evaluating blower performance.
3. **Relative humidity** is a measurement of water vapor in atmospheric air, which has some impact on the mass of air requiring compression. Typically, higher relative humidity occurs during the morning and decreases throughout the day for lower afternoon relative humidity conditions.
4. **Varying flows and loads** throughout the day require the blowers to match output to demand.
5. **Side water depth** of the aeration tanks is also important as it will impact blower discharge pressure.

Operational Considerations

Each WRRF has different blower operational strategies, based on the requirements of the individual facility. Typically, blowers should have the ability to modulate air capacity to meet all varying aeration demands for aerobic biological treatment. Types of diffusers (e.g. coarse bubble or fine bubble diffusers) can also impact operations (refer to the Aeration Diffuser Fundamentals factsheet for more information). Blower operational considerations include:

1. **Equipment turndown** is typically controlled either by inlet throttling valves for multistage centrifugal blowers, a reduction in blower speed for positive displacement and direct-drive (turbo) blowers, or modulation of inlet guide vanes and outlet diffuser vanes for integral-gear driven blowers. The ability to turndown centrifugal blowers is limited by “surge” conditions. “Surge” is defined as the point where the centrifugal blower cannot generate sufficient discharge pressure to meet the required operating pressure, which causes a reversal of air backwards across the impeller. Surge is a serious issue which can destroy a blower if allowed to continue. Positive displacement blowers are not impacted by surge, but “slip” can occur at lower speeds, resulting in increased discharge temperature and reduced efficiency. Typical turndown ratios and efficiency ranges are provided for each blower type in Table 1 below.

Blower Type	**Typical Turndown Range (from maximum capacity)**	**Typical Blower Efficiency**
Multistage Centrifugal	20% to 40%	55% to 70%
Single-Stage Integrally Geared	50 to 60%	70% to 78% (dual guide vanes)
High Speed Direct Drive (Turbo)	35 to 55%	65% to 75%
Positive Displacement (Rotary Lobe)	40 to 60%	45% to 65%

Table 1: Typical Blower Turndown Range for Various Blower Types

2. **Operating envelope** is the capacity range of a blower that the equipment can safely operate in. As wastewater flows and especially loads fluctuate, there is a corresponding fluctuation in the amount of oxygen required to provide treatment over the course of the day. A sustainable blower system should be capable of providing the entire range of required airflow and pressures with no gaps in coverage. Current diurnal loads, as well as future diurnal loads, depending on the facility’s load projections, must be considered. Identifying the surge point and specifying a pressure rise to surge is important in identifying the turndown range of a blower. Aeration blower selection needs to consider eliminating operating envelope “gaps” between blowers as they come in and out of service (one blower has inadequate capacity, two blowers have too much capacity).

3. **Discharge pressure** is a critical design criterion to ensure air is conveyed to the diffusers. Discharge pressure for aeration systems in some processes can be variable (e.g. sequencing batch reactors), which impacts blower technology selection.

Other Considerations

1. **Avoid over-aerating under minimum mixing conditions by providing adequate blower turndown** - A minimum level of aeration needs to be maintained to ensure adequate mixing in fine bubble aeration systems. For a full-floor grid, 0.05 to 0.09 scfm/sf of basin floor area is a typical value for providing adequate mixing (WEF MOP 8).

2. **Avoid oversizing the system by setting realistic design criteria -** Blower systems may be required to adhere to Class I Reliability as outlined by EPA (EPA-430-99-74-01). They are also often sized to meet maximum day aeration requirements with the largest unit out-of-service. Blowers historically have been sized based on the worst case short-term temperature and humidity conditions, which can also contribute to oversizing of blowers when coupled with the maximum day requirements. There should be consideration to sizing blowers for maximum day aeration demands with all units in service to reduce capital costs and the need for extraneous blower capacity. Dynamic simulation with wastewater process models can also be utilized to predict diurnal airflow requirements for varying conditions to support proper sizing of blowers. The blower system should still be sized to satisfy maximum month diurnal air requirements with the largest one unit out of service.

   Many treatment facilities are now required to treat nutrients such as nitrogen and phosphorus. Historically, DO was used as the control variable, and maintaining a DO of 2 mg/L, provided confidence that the effluent BOD and TSS (and ammonia if necessary) would meet permit requirements. As nutrient removal processes have been implemented globally, DO typically continues to be the monitoring parameter. However, as many plants are required to denitrify as well as nitrify and remove phosphorus, control of DO becomes much more critical to ensure over aeration does not occur. This has led to the implementation of advanced control strategies such as ammonia-based aeration control (ABAC), which are fast gaining acceptance in the industry. Under the use of ABAC, where the controlled variable is now being used to control the system instead of a surrogate (DO), measured DO in the aeration basins can reach as low as 0.2 mg/L in the aeration basins.

3. **Defer installation of equipment** - Blower systems are often designed for a design flow that will not occur until 20 years in the future or beyond. This can result in a blower system with operating gaps and multiple idle blowers, incurring unnecessary capital, operation and maintenance costs. Sometimes it is necessary to provide adequate blower capacity to meet the permitted design conditions of the plant, even if this results in idle equipment. If permit conditions allow, it is good practice to provide enough blower capacity to meet intermediate flow and loading rates, while leaving room in the blower facility for installation of future blowers.

Aeration Control Strategies

Aeration system controls are typically divided into three inter-related strategies to provide optimum treatment performance while limiting the costs of operation. The three inter-related strategies are parameter, airflow, and equipment controls. Each can be evaluated separately, but must work together effectively to maximize energy efficiency. Figure 2 provides a typical arrangement of aeration system controls.

Parameter Control (within Bioreactor)

Parameter control strategies consist of operational philosophies for the biological treatment environment. The intent is to monitor the biological environment to ensure adequate oxygen is available for aerobic treatment (or no oxygen for anoxic and anaerobic treatment). Potential options for parameter controls include:

1. **Dissolved oxygen (DO) control** is a well-established approach for aeration system control throughout the wastewater treatment industry. Typically, a DO set point is selected and maintained. Additionally, the DO set point controls airflow distribution in the aerobic zone via modulating air control valves. It should be noted that proper taper of aeration diffusers is important for proper airflow distribution (refer to Aeration Diffuser Fundamentals factsheet for more information). When using DO to control airflow for nitrification, it is important to note that DO is a surrogate, not the controlled parameter.
2. **Oxidation- reduction potential (ORP) control** monitors the aeration tank to determine whether the biological activity is either aerobic, anoxic (nitrogen removal), or anaerobic (phosphorus removal). For nitrification, a typical ORP value found in aerobic conditions is greater than +100 millivolts (mV). When using ORP to control airflow for nitrification, it is important to note that ORP is a surrogate, not the controlled parameter.
3. **Ammonia (NH_4-N) based control** monitors and maintains an NH_4-N concentration to determine oxygen required for nitrification. This approach allows the DO concentration to fluctuate based on process demands. There are many ways to use on-line NH_4-N measurement to control airflow. Two typical control strategies include direct control where NH_4-N is used to control airflow based on an NH_4-N setpoint using DO to control the maximum airflow rate, or cascaded control where on-line measured NH_4-N concentrations are used to calculate the required DO concentrations, required airflow rates and airflow control valve settings.
4. **Simultaneous nitrification/denitrification (SND) control** is an enhanced nitrogen removal process where either a low DO concentration is maintained or intermittent aeration is executed to provide environmental conditions for both nitrification and denitrification within the same volume. Typically, DO, NH_4-N and NO_x-N measurements are implemented.
5. **Ammonia vs. NOx-N (AvN™) control** is a patented control process to apply selective pressure to different microbial populations (ammonia oxidizing bacteria and nitrite oxidizing bacteria) to achieve more efficient nitrogen removal through the nitrite shunt and/or partial nitritation/deammonification pathways. Please refer to the *WEF/WERF*

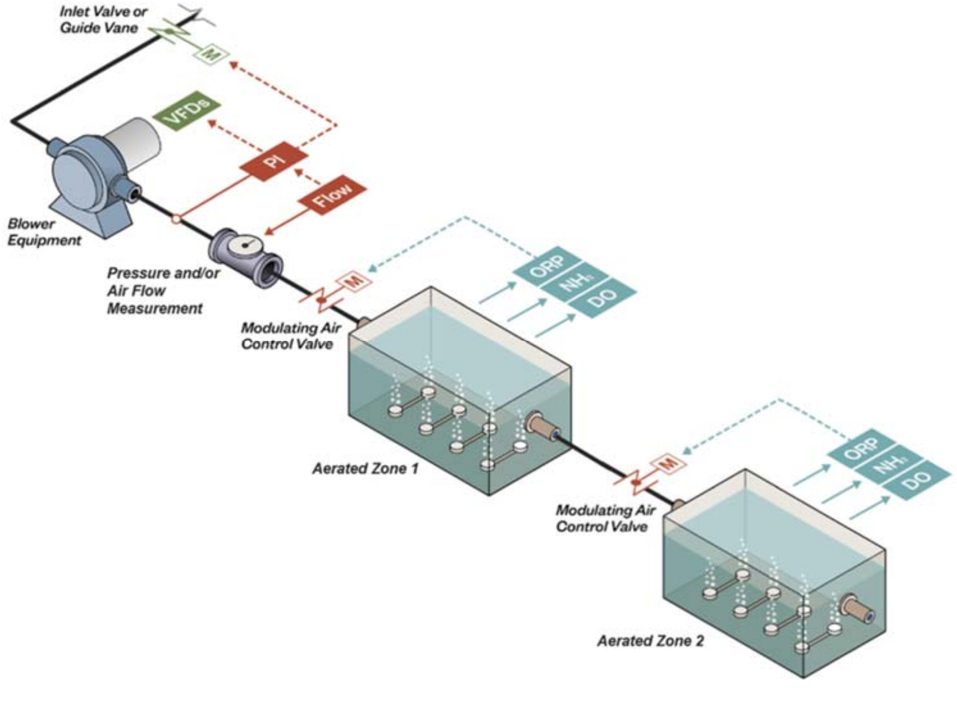

Figure 2— Typical Arrangement of Aeration System Controls for Parameter Controls (Blue), Conveyance Controls (Red), and Equipment Controls (Green)

publication Shortcut Nitrogen Removal – Nitrite Shunt and Deammonification (2015) for more details on the nitrogen removal pathways.

Blower Airflow Control

Airflow control strategies provide parameters to indicate whether more or less air is required for biological treatment. The intent is to provide a methodology for the air production equipment (blowers) to increase or decrease air output to the aeration system. Potential options for system controls include:

1. **Constant system pressure** operation provides a set discharge pressure that the blower equipment is required to maintain. As the parameter control system (i.e. DO, NH_4-N, ORP, etc.) fluctuates, the system pressure will increase or decrease depending on the air distribution valve closing or opening, respectively. For example, the system pressure increases as the air distribution valves close, which indicates less air is required from the blower equipment.
2. **Variable system pressure** operation is similar to the constant system pressure strategy. However, a variable system pressure strategy does not have a defined pressure set point to maintain. The system pressure is controlled by the most open air distribution valve (MOV). The intent of this strategy is operating at the lowest possible pressure to minimize electrical costs.
3. **Flow control** is an alternative strategy that implements control algorithms (typically proportional-integral-derivative [PID] control loops) to estimate the air demand. A programmable logic controller (PLC) monitors DO or NH_4-N probes located in the biological treatment system and determines the required increase or decrease in airflow to the process.

Blower Control

Blower control strategies provide modulation of the airflow to the aeration system. Capacity control of blower equipment is typically controlled by changes to the inlet air pressure, blower operating speed, or through discharge vane modulation. Potential approaches for blower control include:

1. **Inlet valve throttling** is used for multistage centrifugal blowers for capacity control. The inlet valve will partially close to decrease blower output. Similarly, the inlet valve will modulate open to increase the blower output.
2. **Variable frequency drives (VFD**) are often implemented to control the blower speed, which controls the blower output capacity. VFD controls are typically applied to single-stage direct-drive centrifugal blowers and positive displacement blowers. VFD controls have also been applied to multistage centrifugal blowers.
3. **Guide vane controls** are used on integrally-geared single-stage centrifugal blowers to control capacity. Inlet guide vanes control discharge pressure (head) and discharge guide vanes control blower capacity (airflow) while maximizing efficiency.

WEF Resources

1. Water Environment Federation. Design of Municipal Wastewater Treatment Plants: WEF Manual of Practice 8
2. WEF/WERF publication Shortcut Nitrogen Removal – Nitrite Shunt and Deammonification (2015) for more details on the nitrogen removal pathways.

Other References

1. Mueller, J.A. 2002. Aeration: Principles and Practice. Boca Raton: CRC Press
2. Rosso, D. and Stenstrom, M.K. 2006. Economic Implications of Fine-Pore Diffuser Aging. Water Environment Research, Volume 78, No. 8 (August): 810-815.

Acknowledgments

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