

## MULTI-STAGE CENTRIFUGAL BLOWER DESIGN PRESSURE CONSIDERATIONS

### Aeration Systems

#### Technical Presentation

For air volumes above 1000 scfm (1700 Nm<sup>3</sup>/hr) multi-stage centrifugal blowers are often considered or employed for diffused aeration systems. As air volume increases centrifugal blowers become considerably more attractive and almost all treatment plants use centrifugal machines when air volumes are greater than 2000 scfm (3400 Nm<sup>3</sup>/hr).

A key element in design of the centrifugal machines is the need to operate units in a narrow range of operating pressures. Typically centrifugal machines are considered fixed pressure – variable volume machines. With the fixed pressure design conditions, proper sizing and proper pressure loss calculations for diffuser systems becomes critical.

For diffuser systems the operating pressures are generally made up of the following components.

1. Pressure losses through blower inlet filter.
2. Losses through blower and piping at blower manifold.
3. Header losses between blower building and aeration tanks or basins.
4. Water depth to centerline of diffusers (static head).
5. Losses through the drop pipe and diffuser piping in the basin.
6. Diffuser and/or membrane losses for the diffuser.
7. Safety factor.

Calculations of operating pressure must consider all 7 of the above components to confirm a proper blower size and pressure. Items number 1 through number 6 are recognized by most aeration system designers and usually completed with reasonable accuracy. Item number 7 is commonly ignored in system designs which can be a MAJOR oversight!

### Safety Factory Pressure Addition

The safety factor in centrifugal blower pressure design can be any value desired but must consider the following variables when designing fine bubble diffuser systems. Safety factor variables can be considered permanent, long-term, or routine pressure increases which affect operating pressure as follows:

1. Process changes requiring redistribution of air into a fixed size air distribution system.
2. Peak conditions when it may be desirable to operate all blowers in the system including spares, i.e., airflow increase of 20-100%!
3. Possible losses accumulating from dirty filters on the blower.
4. Membrane aging for fine bubble membrane units. Fouling for ceramic diffuser units.

While the safety factor can be any value, it is recommended a value of 0.5 to 0.75 psi be considered when the total aeration system is properly designed. EDI typically uses conservative system designs then adds 0.5 psi system safety factor for establishing blower pressure values.

Please note including the safety factor and resultant total pressure is the design pressure for the blower and motors. Actual operating pressures when the system is new should be less than the design value, i.e., psi less the 0.5 psi safety factor if calculations and operations were controlled properly. The 0.5 psi is available to accommodate the long-term or operation pressure increases **WHILE DELIVERING FULL DESIGN AIRFLOW.**

The full design airflow is the critical factor because of the centrifugal compressor air volume/pressure delivery curve. A quick look at a typical blower curve number 1 (Figure No. 1) shows this variable factor. If design airflow to meet process needs for the system is 4000 scfm (6800 Nm<sup>3</sup>/hr) this value can be established and a blower curve selected. Designs without the safety factor would select a blower to deliver air with a characteristic response curve as shown by curve number 1.

Curve number 1 shows this blower will deliver the proper air volume only at NEW system pressures, i.e., without overpressure. As system pressure increases because of aging or items number 1-4 listed above; note what happens when pressure increases! The air volume delivered by the compressor reduces so there is not sufficient air to handle the process. For 0.5 psi overpressure on curve number 1, air volume drops from 4000 scfm to 3250 scfm (5525 Nm<sup>3</sup>/hr) or loses 18.75% air volume. How do you maintain the process if air volumes reduce 18.75%?

Curve number 2 (Figure No. 1) shows proper blower design with full process design airflow available at the 0.5 psi increased pressure for safety factor. This design shows proper air delivery capability for the blowers when new at 4750 scfm (8075 Nm<sup>3</sup>/hr) or 18.75% greater than process requirements. As the system ages or if process changes and pressure increases, the system still functions at 100% process oxygen requirements. This is the correct operational and process design for the blowers.

### Overpressure Considerations

One other design pressure point is critical for optimum performance of centrifugal blowers: the blower must be capable of handling short-term operation at pressures greater than the proper design pressure, i.e., higher than pressures computed using items 1-7 of page 1 which includes the safety factor, typical at 0.5 psi. This short-term increase in pressure (OVERPRESSURE) is typically generated by start-up with piping full of water or other short-term conditions.

Overpressure design is a necessary design to prevent SURGE conditions in the blower. Blower surge will destroy the blower or shut down the blower and cause the system to fail unless proper OVERPRESSURE is designed into the blower performance curves.

It should be noted the overpressure can also be long-term if the actual operational safety factor pressure increases were overlooked exceed the 0.5 psi design allowance.

The blower curves shown in Figure number 2 demonstrate the need for OVERPRESSURE design. Curve number 3 shows a blower designed to deliver the 4000 cfm (6800 Nm<sup>3</sup>/hr) process air volume at the proper pressure. No overpressure is built into curve number 3. Result of any overpressure during operation is a dramatic reduction in air delivery. Air delivery can be reduced to the surge point on the blower with any slight overpressure condition. This blower will shut down because of the flat pressure curve and the system fails. No air will be available for the process.

Curve number 4 shows proper blower curve geometry with the design air volume of 4000 cfm. Overpressure can be routinely and properly handled with this blower design. This is a proper shape blower curve, i.e., steep curve. Short-term overpressure can be routinely handled with modest reduction in airflow and nominal impact on system operation. Long-term overpressure will also reduce air volume in the blower number 4 curve but the system stays in operation and maintains the process. If long-term overpressure develops it is

possible to maintain the process and schedule routine maintenance or upgrades to return (reduce) operating pressure to, or below the design pressure.

NOTES:

1. Air volume and blower throttling for operational or energy savings are not considered here.
2. Positive displacement blowers operate at constant volume-variable pressure capability. This discussion does not relate to positive displacement blowers.
3. Turbo blowers are special centrifugal machines with adjustable pressure and air volume relationships, i.e., multiple operating conditions with the same machine. This discussion does not relate to turbo blowers.

For additional information regarding your specific application contact Environmental Dynamics Inc. at (573) 474-9456

