4/1/11

Chesterton, IN WWTF Blower Power Consumption Analysis

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Introduction

Universal Blower Pac has been asked to explore the benefit of upgrading the Chesterton, IN Fritz C. Dietrich Environmental Control Facility with high efficiency blower systems. The intent is to reduce power consumption and the corresponding cost to operate the equipment. The current blower system, power consumption, and ongoing operating cost has been evaluated and compared with three different proposed blower systems.

Current Equipment

The Utility currently owns three 200 HP Roots blower systems. The bare blowers are Roots model 826 RCS-J. This is a traditional straight lobe positive displacement blower. The Roots blowers are configured to deliver 3350 CFM / each at 7.5 psig with an RPM of 1780. This is the design point. Each blower is connected to a 200 HP Reliance motor, model P44G4408A, with a v-belt drive of sheave ratio of 1:1. This is a traditional squirrel cage induction motor. Each motor is powered with a 200 HP Allan Bradley variable frequency drive, model 1136. The power supply to the variable frequency drive is 460V 3P. Each system is equipped with inlet filters, inlet silencers, discharge silencers, pressure relief valves, check valves, flex joints, and instrumentation.

The three existing blowers are connected to the aeration tanks via a common discharge header. Tank fluid level is constant. Under normal operation, one blower operating at the design point is more than adequate to meet the process oxygen demand. During the summer months, demand increases, but one blower operating at the design point is still adequate to meet the oxygen demand. Dissolved oxygen readings are currently taken by hand. Operating frequency, and the consequent blower airflow, is not typically modulated with the variable frequency drives.

Proposed Equipment

Universal Blower Pac has proposed three different blower system configurations for replacement of the existing equipment. Since the process oxygen demand is always met by a single blower, the scope of system upgrade has been constrained to replacement of one or two of the existing blowers. In this manner, the third blower can remain as a full standby. All proposed blower systems are equipped with inlet filters, inlet silencers, discharge silencers, pressure relief valves, check valves, flex joints, instrumentation, and acoustical enclosures.

The first proposed blower system is a single EE-PAC model 3112. The EE-PAC 3112 utilizes an axially twisted positive displacement lobe blower directly coupled to a 175 HP switched-reluctance DC motor. The motor is equipped with an encoder and variable speed controller. The blower control is accessed via an onboard touch screen HMI. The system requires 460V 3P service from a local disconnect. The system has an operating range of 600 – 3100 CFM. This system is a standard product. See the following figure.

Figure 1: EE-PAC 3112

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The second proposed blower system consists of two EE-PACs, model 2320. This model is smaller than the 3112 and is capable of less flow, therefore two units would be used together to meet the process oxygen demand. The model 2320 utilizes an axially twisted positive displacement screw blower, with internal compression, directly coupled to a 125 HP switched-reluctance DC motor. As before, the motor is equipped with an encoder and variable speed controller all interfaced through the onboard touch screen HMI and powered by 460V 3P service. These systems individually have an operating range of 500 – 2300 CFM or a combined capability of 500 – 4600 CFM. These blowers are a standard product as shown in the following figure.

Figure 2: EE-PAC 2320

The third proposed blower system would consist of two custom blowers, working model Custom Attenu-PAC. The model would utilize an axially twisted positive displacement lobe blower directly coupled to a Baldor 150 HP RPM AC motor, model P32L0228. This is a special design squirrel cage induction motor. This system would utilize the existing variable frequency drive and 460V 3P service. Each system has an operating range of 600 - 3100 CFM or a combined capability of 600 – 6200 CFM. A drawing from a similar project is shown in the following figure.

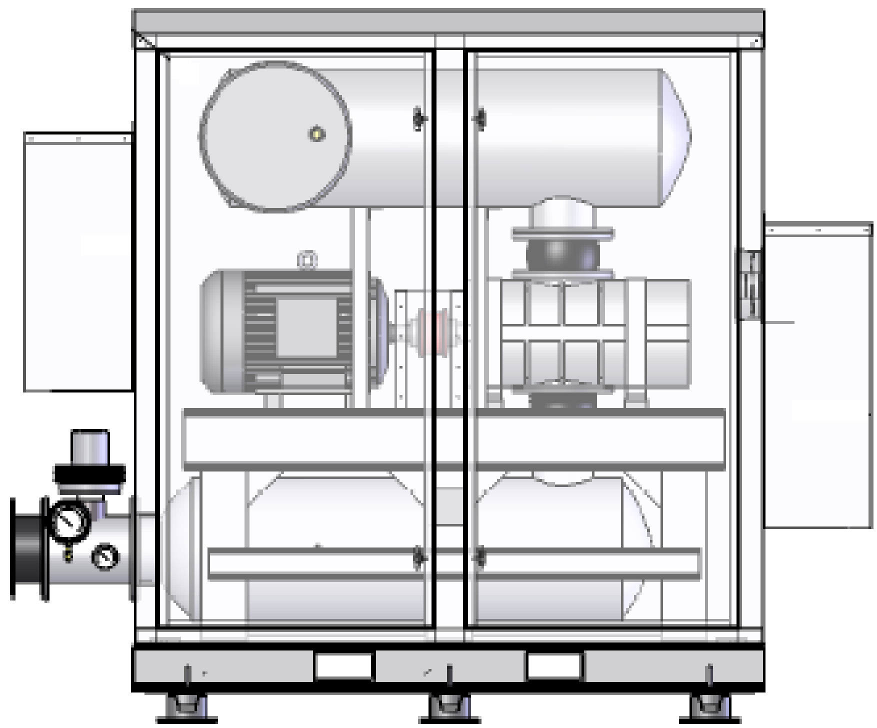

Figure 3: Custom Attenu-PAC

Methods of Analysis

Comparisons of the different blower systems are made using volume flow, ICFM, and total differential pressure, ΔP. Therefore, ICFM = ACFM. All system pressure drops due to filtration, silencers, flex joints, valves, and instrumentation are assumed to be equal for the different systems and included in the total differential pressure.

The existing equipment power consumption is estimated through use of Roots blower standard model power draw curves, Baldor/Reliance motor manufacturer efficiency data at partial loads, and belt drive efficiency data[1]. Actual belt drive efficiency is a function of speed and load, however η_{belt} is assumed to be constant for the comparison.

To estimate the variable frequency drive efficiency, a VFD efficiency factor[2] must be utilized. This factor estimates the VFD efficiency at partial load and speed along with the affect it has on reduced motor efficiency at the corresponding speed and load. The total estimated power consumption is calculated in the following equation.

$$P_{total} = \frac{P_{blower}}{\eta_{belt} * \eta_{motor} * \eta_{VFD}} * 0.7457 \frac{kW}{hp}$$

Equation 1

Where:

Total Estimated Power Draw, (kW): P_{total}
Blower Power Draw, (bhp): P_{blower}
Motor Efficiency: η_{motor}
VFD Efficiency Factor: η_{VFD}
Belt Drive Efficiency: η_{belt} *(0.965 assumed)*

The Attenu-PAC 3112 custom blower system power consumption is similarly estimated from standard blower model power draw curves, Baldor/Reliance motor manufacturer efficiency data at partial load, and a VFD efficiency factor[2]. However, the system is coupling driven, so there are no belt losses, $\eta_{belt} = 1$.

The proposed EE-PAC blower systems power consumption estimates are based upon power and efficiency curves from actual performance testing on the standard blower systems. The power consumption is for the complete system and includes all ventilation and control system power.

Monthly operating cost for each configuration is calculated across the entire range of operation for a plant power cost of 0.08 $ / kWhr.

$$Monthly\ Operating\ Cost = P_{total} * \frac{\$0.08}{kW\ hr} * \frac{720\ hr}{1\ month}$$

Equation 2

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Results & Analysis

The first proposed replacement system, EE-PAC 3112, estimated power consumption is plotted in the following figure versus airflow. It is overlaid onto the existing system's estimated power consumption to allow for a direct comparison.

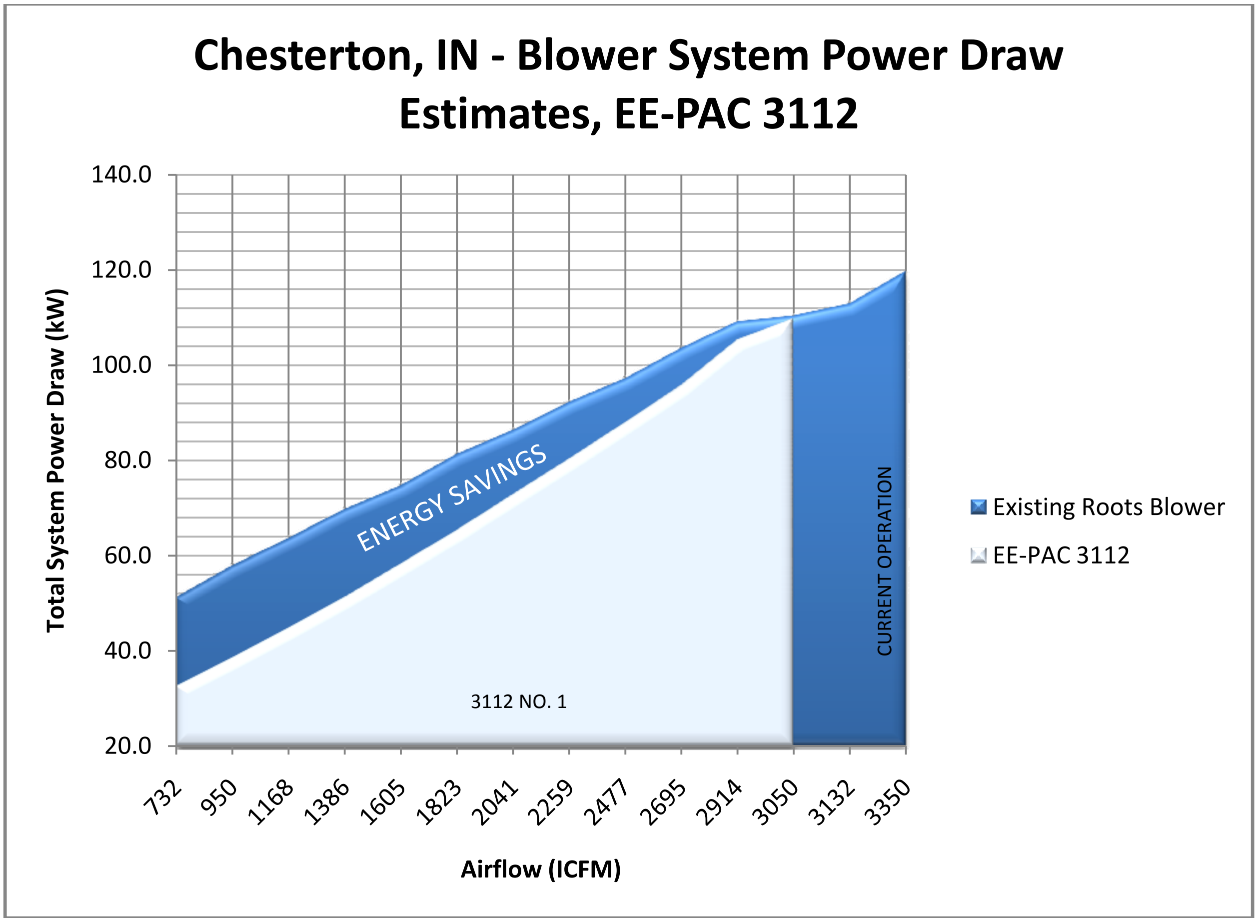

Figure 4

The EE-PAC 3112 has a maximum capability of 3100 CFM, 250 CFM less than that of the existing system. It shows the highest power savings at the lower operational capability, but significant savings over the majority of operation. Estimated power draw is less than that of the current system for a multitude of reasons:

1) The bare blower in the EE-PAC 3112 is a higher efficiency machine drawing less power per unit flow.
2) The bare blower is operating at a higher percentage capability for the process, which is its most efficient application.
3) The motor to blower connection is direct, negating the power transfer losses of a belt drive.

4) The motor is switched reluctance and DC versus induction and AC. This provides better efficiency and lower power draws off of the base operating frequency, which is in part why the difference in power draws increases as the airflow decreases.

The second proposed replacement system, two EE-PAC 2320, estimated power consumption is evaluated in the following figure. It is also overlaid onto the existing system's estimated power consumption to allow for an easy comparison.

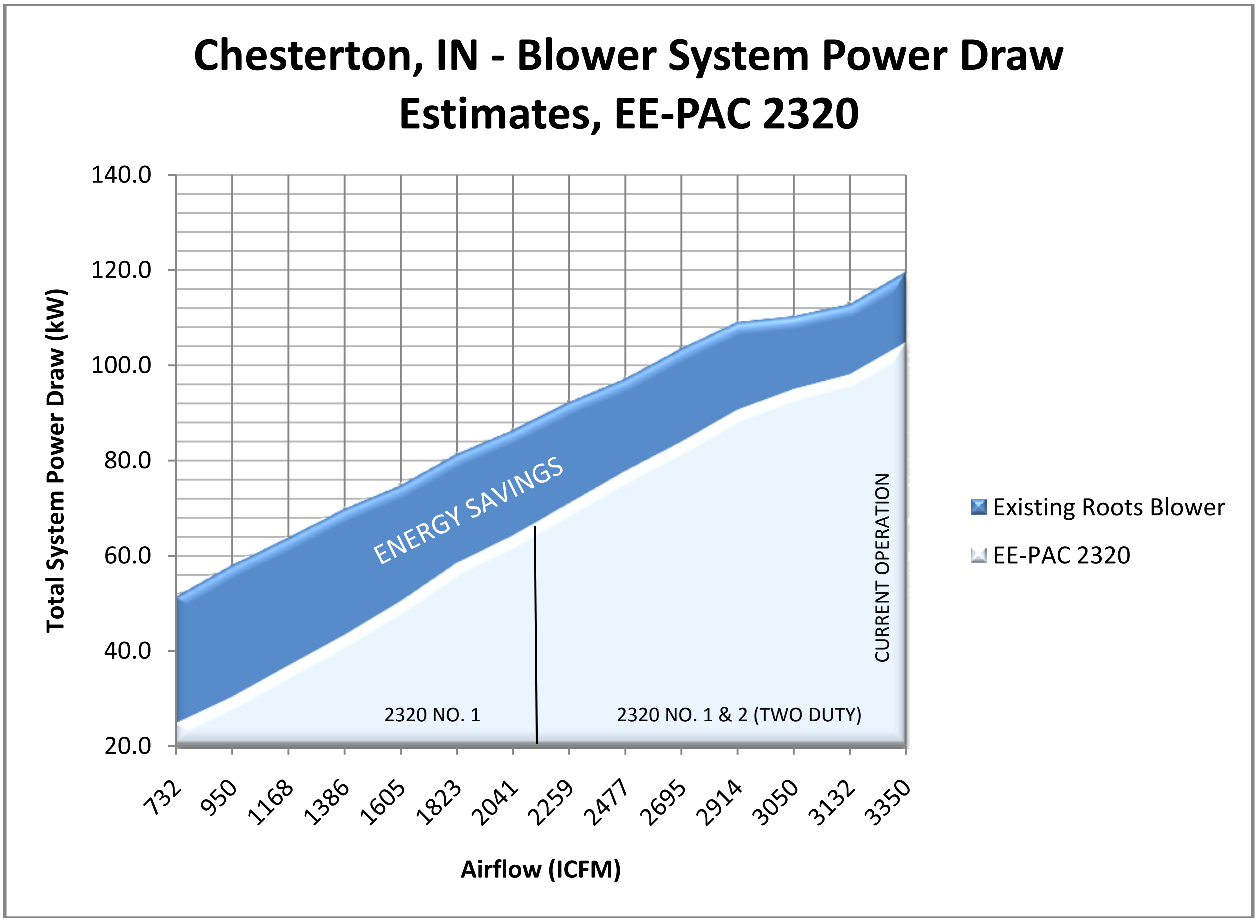

Figure 5

Again, the proposed system shows an energy savings. This time the savings is significant over the entire range of operation. The proposed system consumes less power for the same reasons as the EE-PAC 3112 with the addition of:

5) The bare blower is an axially twisted screw blower with internal compression. This machine has higher efficiencies than a traditional straight lobe blower or axially twisted lobe blower.

The third proposed replacement system, two Attenu-PAC custom blowers, estimated power consumption is evaluated in the following figure versus the existing system power consumption. The system offers significant savings over the majority of operation.

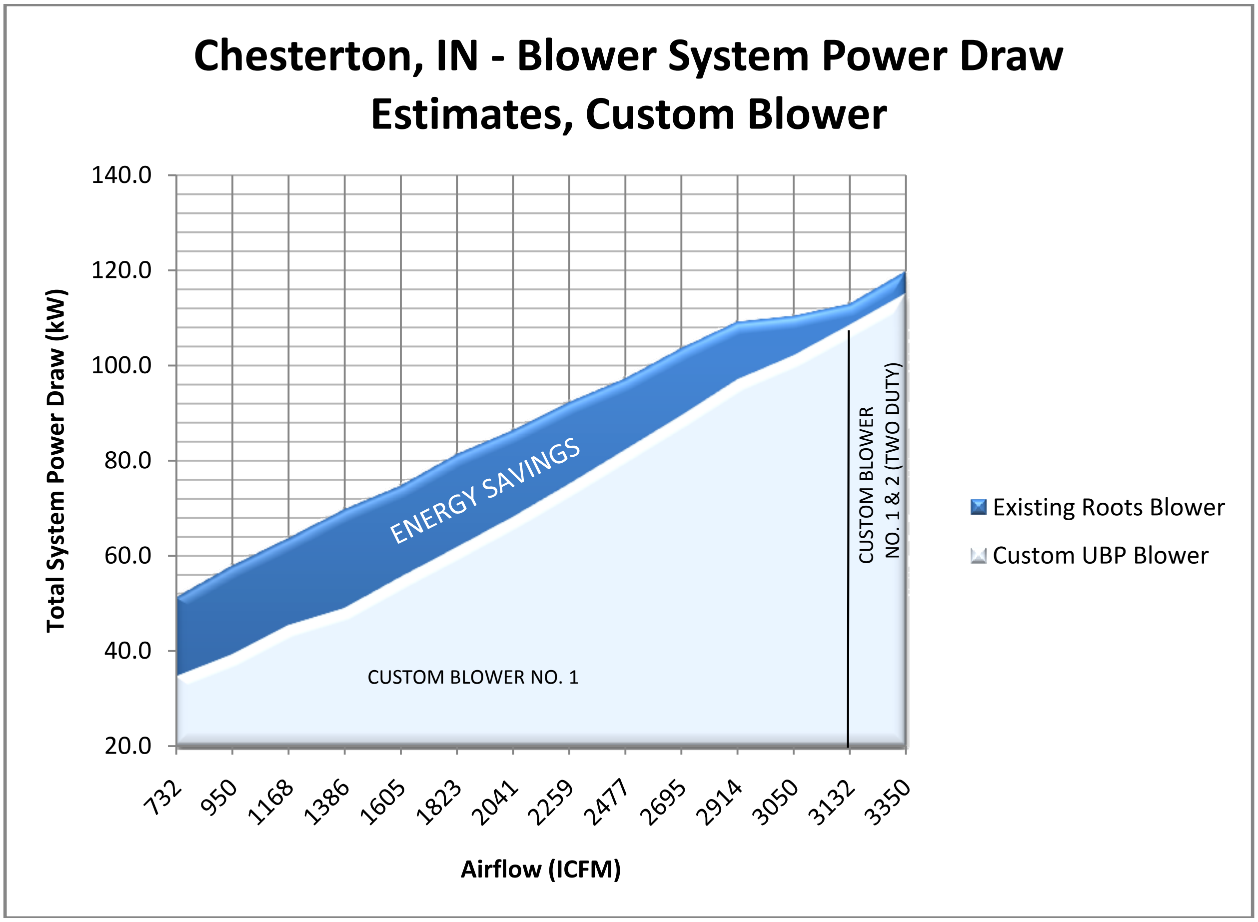

Figure 6

This system uses an axially twisted blower, direct connection between the blower and motor, and specialty design AC motor. Alternative to the EE-PAC models, this is more traditional equipment; however it has been optimized for the specific application.

All proposed replacements will provide power consumption savings. The estimated monthly savings versus the existing blowers are quantified in the following figure.

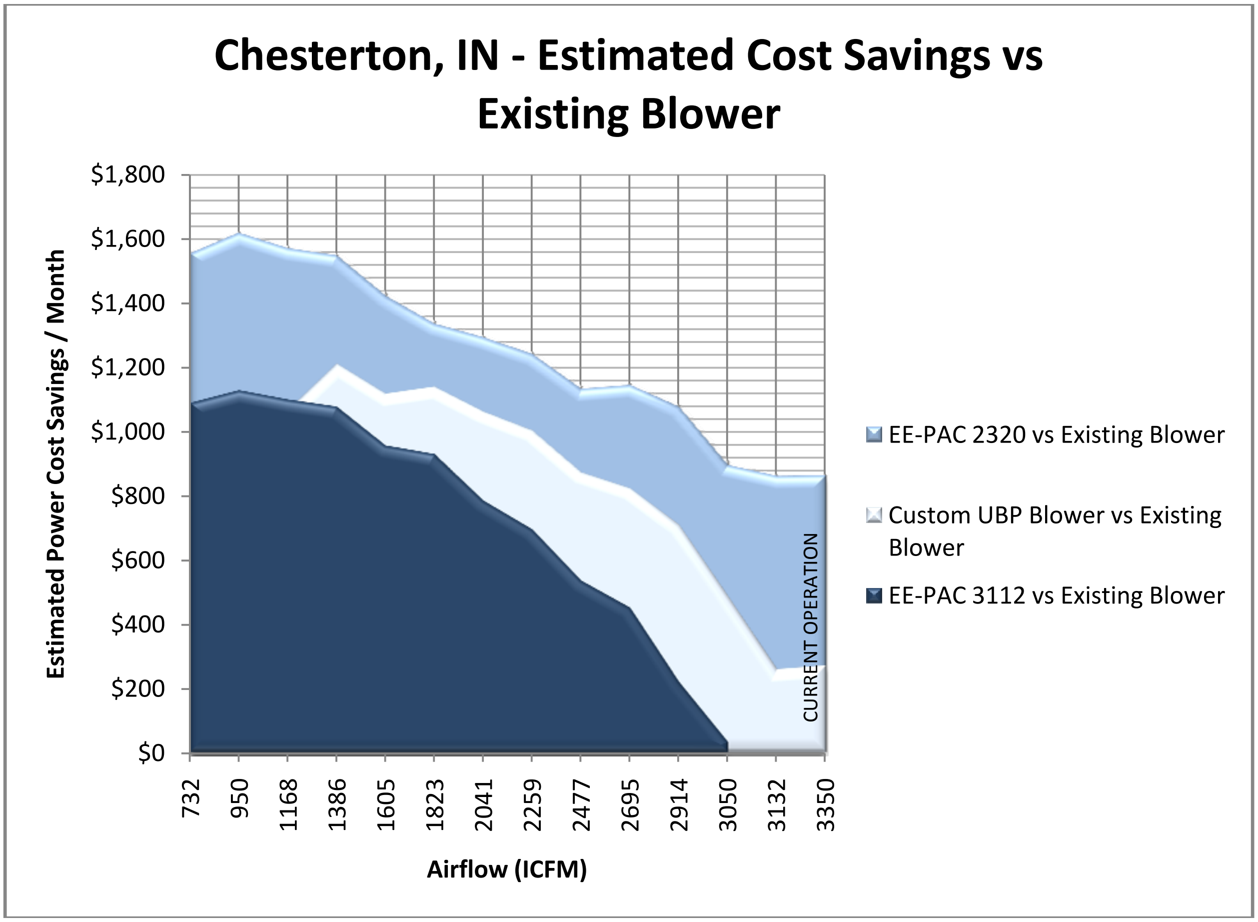

Figure 7

An airflow of 3350 CFM is the current operating point. At this point, the Custom Attenu-PAC blower system will offer estimated power cost savings of $270. / month and the EE-PAC 2320 system will offer estimated power cost savings of $863. / month. The single EE-PAC 3112 does not have capability at this point.

The savings increase steadily for all systems as the airflow is reduced. At 50% turndown of current capability the systems will have the following estimated cost savings versus a 50% turndown for the current system.

1)	EE-PAC 3112	$ 940. / month
2)	EE-PAC 2320	$1,400. / month
3)	Custom Attenu-PAC	$1,120. / month

The savings is the operating cost difference assuming an equal turndown in airflow of the equipment with reduced process oxygen demand. Currently, the equipment is not being modulated with the variable frequency drive to match process oxygen demand. This will require frequent readings of the process and hand control of the speed *or* a dissolved oxygen probe and control system to automatically adjust the system flow and meet demand. The power savings for implementation of this control for any of the evaluated systems can be estimated by taking the difference in power consumption between 119.6 kW (current system power draw at design) and any other power consumption at a desired airflow from the existing or proposed system on figures 4-6. Monthly cost savings can be estimated from Equation 2.

Additional Considerations

If a dissolved oxygen probe and control system is deemed appropriate for the application Universal Blower Pac can assist with the supply and programming a multiple blower control system (EE-PAC 2320 & Custom Attenu-PAC) to achieve an optimum operating scheme. A single EE-PAC (2320 & 3112) is equipped with a pre-programmed onboard control system that allows for direct connection to a dissolved oxygen probe and control of airflow to match a desired process demand. Multiple operating variables and maintenance functions are available in a graphical interface on the touch screen HMI.

The Custom Attenu-PAC proposed replacement system would utilize the existing variable frequency drives and would require a separate PLC or DO probe with programmability for automatic operation. Hand operation would be the same as is currently available with the existing equipment.

Maintenance should also be a consideration in equipment selection, as it is an ongoing operating expense. Each of the proposed replacement systems has a similar preventative maintenance process as the existing equipment with the exception of the belt drive. The proposed replacement systems are coupling driven and will not require belt tensioning or replacement. Furthermore, this drastically increases the expected lifespan of the equipment versus a belt driven arrangement, as it eliminates lateral loading on the blower and motor shafts. The EE-PAC systems are equipped with programmable maintenance indication, alarms, and scheduling to assist personnel.

Noise level from the current blower system is estimated at 93 dBA at 1m in a free field environment, this exceeds OSHA permissible exposure limits for an eight hour time period.[3] Each of the proposed replacement systems is equipped with a full acoustical enclosure specifically designed to attenuate noise from the equipment. The anticipated noise level from each of the proposed replacement systems is less than 85 dBA at 1m free field for any point of operation. This would significantly reduce noise pollution from the blower system and allow for continuous exposure by plant personnel.

Conclusion

It's likely that of the three evaluated replacement systems one or more would be a logical choice for an upgrade. Universal Blower Pac's recommendation will depend upon the Utility's desired return on investment, the projected future operating scheme, and available capital for investment. The existing system is costly to operate and can be improved upon with properly engineered equipment and a more functional control scheme.

References

1) Avallone, E., & Baumeister III, T. (1987). *Mark's Standard Handbook for Mechanical Engineers, Ninth Edition*. New York, NY: McGraw-Hill. 3-30 p.

2) Wallbom-Carlson, A. (1998). "Energy comparison. VFD vs. On-Off Controlled Pumping Stations." *Scientific impeller*, ITT Flygt AB, Sweden, 29-32.

3) Occupation Safety & Health Administration, U.S. Department of Labor. (1974). *1910.95, Occupational Noise Exposure*. Retrieved from: http://www.osha.gov/dts/osta/otm/noise/standards_more.html .