AERATION BLOWERS – THEY ARE NOT ALL EQUAL

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Abstract

Aeration of the activated sludge process in a typical suspended growth wastewater treatment facility can consume anywhere from 40 to 70 percent of the power consumed by the total plant. Because such a large fraction of the overall plant power is consumed by the aeration blowers, it is important to select the blower system on best value. So how does one identify best value? With a minimum of 16 different blower manufacturers, how does one sift through the sixteen different sets of manufacturers' information to provide a comprehensive and defensible result?

For activated sludge aeration, there are currently three different blower technologies that are economically applicable: multi-stage, gear-driven single-stage, and direct-drive single-stage centrifugals. Many recent papers have discussed various blower technologies, mainly focusing on the newer direct-drive technology, which exploded onto the marketplace approximately five years ago, with each different manufacturer telling different stories about their efficiency and applicability. Few papers have provided side-by-side comparison of the predicted power consumption of the various blower configurations.

Historically, blower performance and selection has been specified on a few theoretical performance points. A more realistic approach is required to match realistic airflow rates with realistic relative humidity and inlet air temperatures. A much larger set of data points than 4-5 is required to realistically describe the daily airflow requirements throughout the year, and hence develop a more realistic picture of power consumption throughout the year.

Aeration blower types and manufacturers are discussed. An evaluation procedure is outlines and results from the analysis of the manufacturers' proposals are discussed.

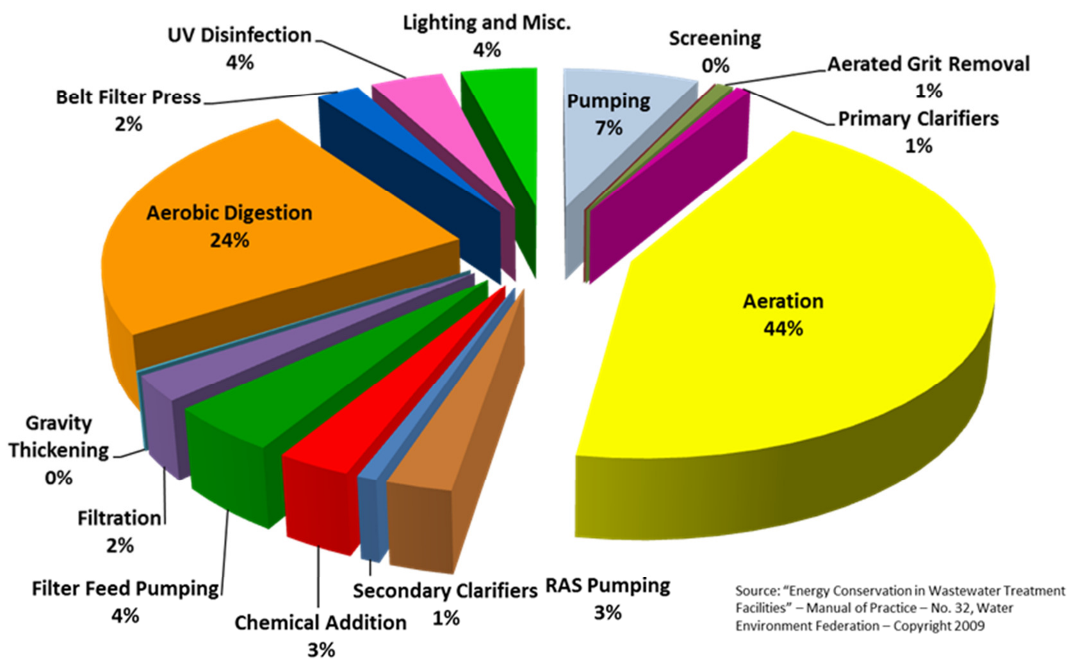
Key Words

Aeration blowers, multi-stage centrifugal, single-stage direct-drive centrifugal, single-stage gear driven centrifugal, selection procedures

1. Introduction

Aeration of the activated sludge process in a typical suspended growth wastewater treatment facility can consume anywhere from 40 to 70 percent of the power consumed by the total plant as illustrated in Figure 1. Because such a large fraction of the overall plant power is consumed by the aeration blowers, it is important to select the blower system on best value. How is best value identified? Historical selection procedures were typically based on an evaluation of three to five points. With a minimum of 15 different blower manufacturers in today's market, does an evaluation based on three to five points provide sufficient detail to identify performance differences between the manufacturers' products? How does one sift through the fifteen different sets of manufacturers' information to provide a comprehensive and defensible result?

Figure 1 Estimated Energy Usage for a 20 ML/d Nitrifying Activated Sludge Facility



2. Current Aeration Blower Technology

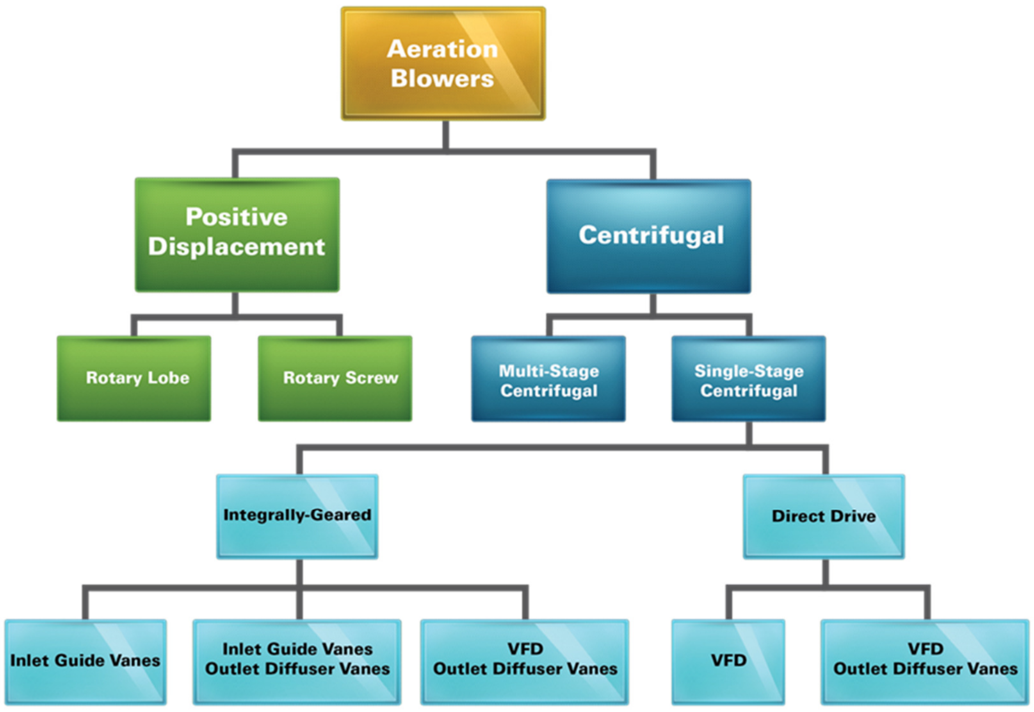
For activated sludge aeration, there are currently three different blower technologies that are economically applicable: multi-stage centrifugal, gear-driven single-stage centrifugal, and direct-drive single-stage centrifugal blowers. Many recent papers have discussed various blower technologies, mainly focusing on the newer direct-drive technology, which exploded onto the marketplace approximately five years ago, with each different manufacturer telling different stories about their efficiency and applicability. Few papers have provided side-by-side comparison of the predicted power consumption of the various blower configurations. Figure 2 shows the various types of blowers used for aeration of activated sludge processes.

Although positive displacement blowers such as the rotary lobe and rotary screw types are shown on Figure 2, their use in activated sludge aeration applications has declined in recent history because they are not as efficient as centrifugal blowers. They are mostly use in varying liquid level applications such as aerated sludge storage tanks or aerobic digesters.

Aeration of activated sludge processes is provided through the use of multi-stage, gear-driven single-stage, and direct-drive single-stage centrifugal blowers as discussed above. As power cost continues to increase, and existing aeration blowers reach their design life, many utilities are looking for the replacement systems to be more efficient. Many facilities are currently replacing old multi-stage centrifugal blowers with single-stage centrifugal blowers due to the higher efficiencies.

Reduction of power consumption of the aeration system while reducing overall operating costs also reduces the carbon footprint.

Figure 2. Activated Sludge Aeration Blower Types



These blower types and the manufacturers of these blower types are shown on Figure 3. As with all equipment for wastewater treatment facilities, mergers and acquisitions occur

Figure 3. Current Centrifugal Blower Manufacturers

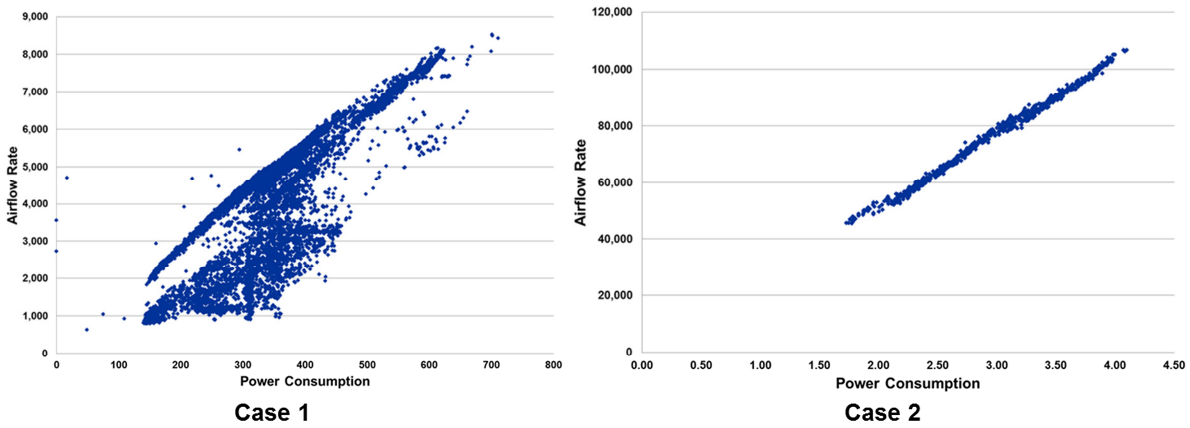
Multi-Stage Centrifugal	Direct-Drive Single-Stage Centrifugal	Gear Driven Single-Stage Centrifugal
Gardener-Denver	ABS	Atlas-Copco
Hoffman/Lamson	Aerzen (K-Turbo)	Roots (GE)
Atlas-Copco/HSI	APG-Neuros	Ingersol-Rand
Hibon	BKT	Howden
Spencer	Continental	Siemens
Continental	Gardner-Denver	
	Howden	
	Atlas-Copco/HSI	
	Piller	
	Siemens	
	Spencer	

continuously. For example, just recently, Aerzen acquired K-Turbo, and Atlas-Copco acquired HSI. It is reasonable to assume new aeration blower manufacturers will appear and mergers and acquisitions will continue to occur.

3. Evaluation of Existing Aeration Systems

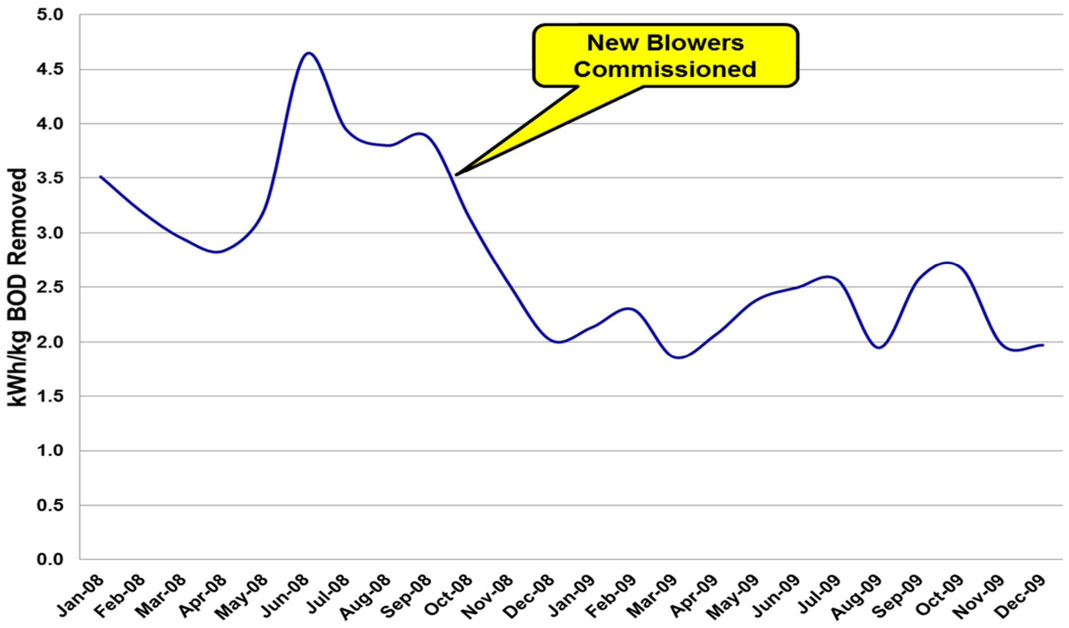
When evaluating the overall performance of an existing aeration system, a few parameters can be used as the initial gauge. The first parameter to evaluate is the airflow rate versus power consumption as shown in the examples shown in Figure 4. Case 1 shows the power consumption versus airflow rate for a poorly sized and controlled aeration system where airflow rates are not synchronized with the process demands. Case 2 shows the same analysis for properly designed system where the airflow demand and airflow production are better synchronized.

Figure 4. Examples of Airflow Rate vs Power Consumption



The second parameter to evaluate is the historic power consumption per unit of BOD removed. Although there are few if any comparative benchmarks for this parameter at this time, it is a reasonably easy parameter to develop from treatment facility to treatment facility. Comparisons can then easily be made between facilities. Figure 5 shows an example of this parameter plotted before and after the upgrade of the aeration system for a 5-stage Bardenpho treatment facility.

Figure 5. Example of Power Consumption per Unit of BOD Removed



4. Aeration Blower Evaluation

Historically, blower performance and selection has been specified on three to five theoretical performance points. These typical performance points might consist of:

- Minimum airflow
- Average day
- Maximum month
- Peak day

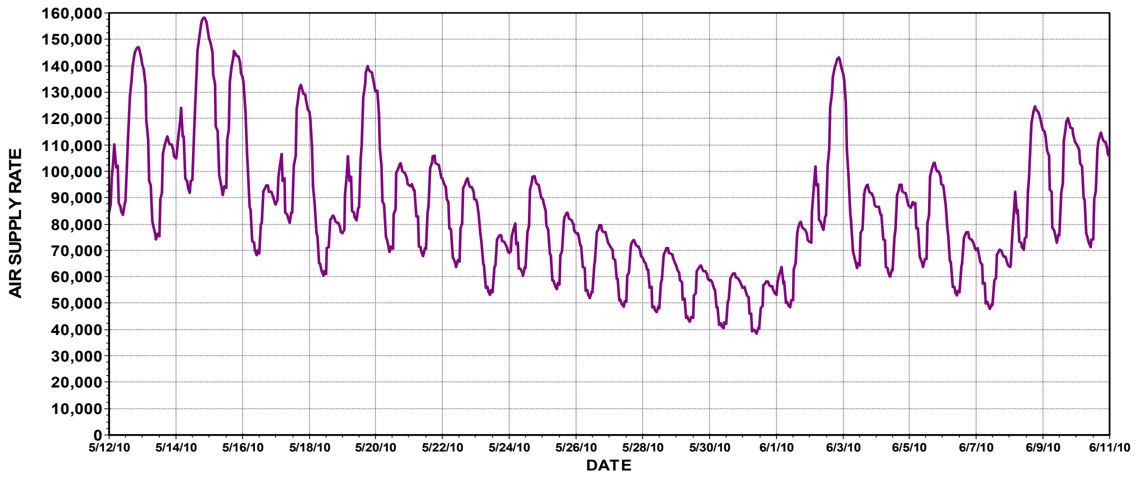
Occasionally a few additional performance points may be included. For these specific performance points, average air temperature and relative humidity values are selected. The minimum airflow, (which should be the greater of the mixing air or minimum process air requirement) and the maximum airflow, with realistic air temperature and relative humidity define the performance envelope. Any of the performance points between the minimum and maximum provide information to be used for evaluation purposes. These additional points; average day, maximum month, etc. are provided with air temperature and relative humidity values that unfortunately are not realistic. They are often average values with little chance that they will ever coincide.

A more realistic approach is required to match realistic airflow rates with realistic relative humidity and inlet air temperatures. A much larger set of data points than three to five is required to realistically describe the daily airflow requirements throughout the year, and hence develop a more realistic picture of power consumption throughout the year.

4.1. Maximum Airflow

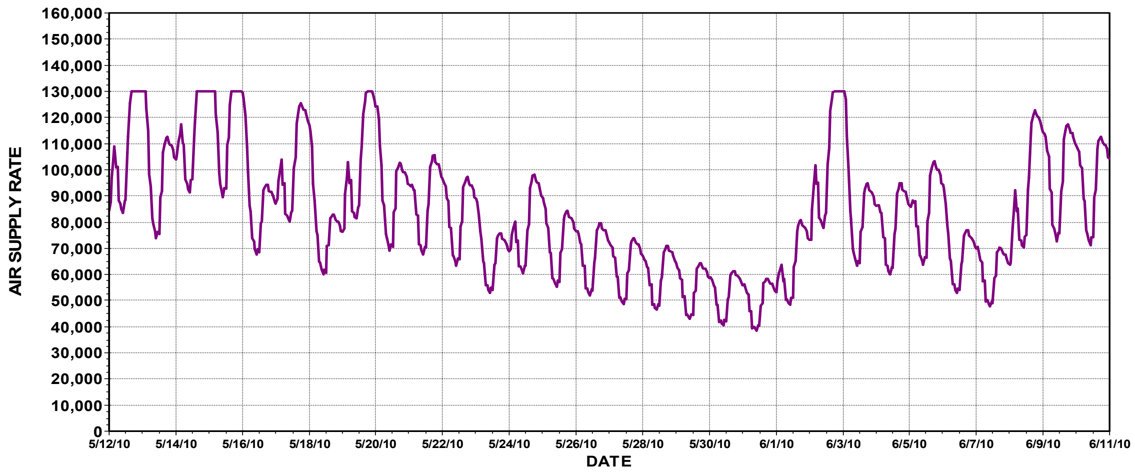
Some regulatory agencies require the maximum airflow rate provided to match the maximum day design. In this case, there is no question with regard to the maximum airflow rate. However, if the regulatory agency allows discretion in determining the maximum airflow rate, other alternative can be explored. With the use of current process models, it is relatively simple to perform a diurnal analysis of the maximum month (which would contain the maximum week and peak day) to determine the various different airflow rates. Figures 6 and 7 show a case comparison where the maximum month diurnal airflow rates as predicted by a process model with the full airflow rate shown on Figure 6 and the capped airflow rate shown on Figure 7.

Figure 6. Predicted Maximum Month Diurnal Airflow Rates



The difference in the two maximum airflow rates equates to one full blower unit, which if eliminated with no negative impact on effluent quality, significantly reduces the total project capital cost.

Figure 7. Predicted Maximum Month Diurnal Airflow Rates Under Capped Conditions

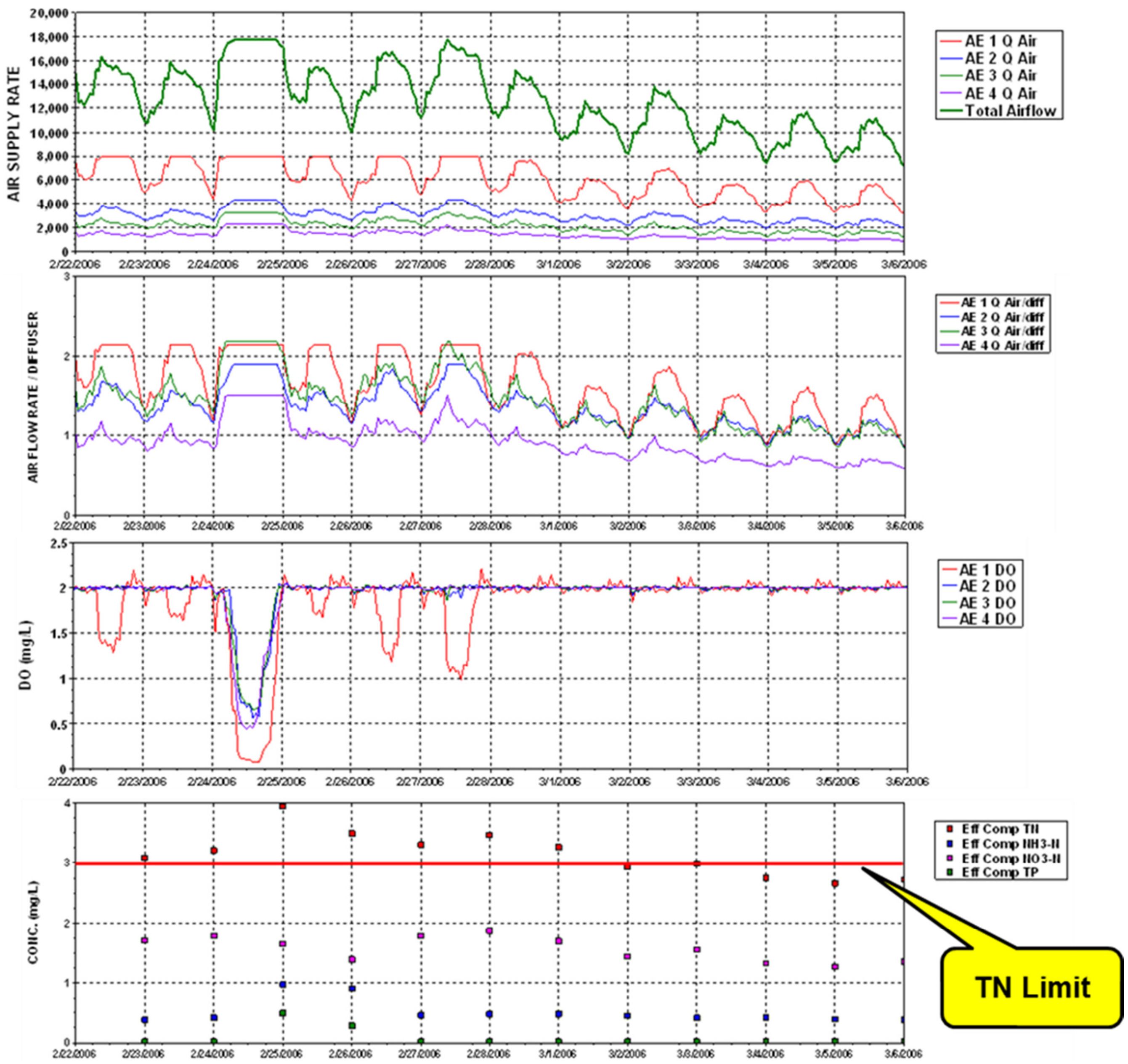


So the next step is to determine if capping the airflow rate has a negative impact on effluent quality, and where is an appropriate level to cap the airflow rate. Figure 8 shows an example of an analysis for a 3-stage activated sludge treatment facility where the airflow rate was capped at the limit of additional available on-site power consumption without incurring the significant capital cost of replacing the plant power transformer.

The aeration basins consisted of an anaerobic zone, an anoxic zone, and an aerated zone divided into four separate diffuser grids in a plug-flow configuration.

The top graph in Figure 8 shows predicted airflow rates for the individual diffuser grids plus the total predicted airflow rate under the capped condition. The second graph shows the airflow rate per diffuser, to ensure the airflow rate per diffuser is maintained within the manufacturers recommended operating range. The third graph in Figure 8 shows the dissolved oxygen concentration in each individual diffuser zone. The final graph shows the

Figure 8. Predicted Maximum Week Performance Under Capped Airflow



predicted effluent quality as 24-hour flow weighted composite samples for total phosphorus (TP), ammonia (NH3-N), nitrate (NO3-N), and total nitrogen (TN). This particular treatment facility has a 30-day average effluent limit of 3.0 mg/L TN and 1.0 mg/L TP. Under average day flow and load conditions, the effluent TN is predicted to average approximately 2.0 mg/L. For this evaluation, under maximum week conditions, seven days will exceed the 30-day average limit of 3.0 mg/L. For the full 30-day period, the average will be approximately 2.4 mg/L, which is satisfactorily below the 30-day limit.

It must be noted that each treatment facility has its own specific performance ability and specific flow and load patterns. This analysis has been performed at a number of treatment facilities. The results of these analyses indicate that providing sufficient airflow to meet the daily diurnal peak of the maximum week days is usually sufficient.

MWHs current standard is to provide a sufficient number of performance points that describe the hourly airflow requirements for a number of typical days throughout the year. Evaluations performed to date have utilized a range of 96 to 144 separate performance points.

A scope for selection must be developed. An example of the information typically included is provided below:

- Define the performance envelope
  - Realistic airflow range (minimum and maximum airflow)
  - Realistic ambient conditions (air temperature and relative humidity)
  - Discharge pressure
  - Pressure rise to surge
- Operating points
- Site Constraints
  - Site elevation
  - Limitations on power availability
- Scope of Supply
  - Materials of construction
  - Valves
  - Instruments, etc.
- Performance Testing Method
  - ISO 5389 Annex G
  - ASTM PTC 13
- Evaluation criteria
  - Reference installations
  - Any other relevant selection criteria

Each individual blower manufacturer knows their own product much better than any designer ever will. Yet many blower specifications contain specific airflow capacity and motor size information, although there is no standardization in unit sizes from manufacturer to manufacturer. Since blower manufacturers often can provide a range of options to provide a solution, the selection process should allow the manufacturers' to provide their optimum package. Therefore, in addition to the selection scope, MWHs sizing and selection procedure includes a number of "do's and don'ts" as listed in Table 1.

Table 1. Blower Selection Do's and Don'ts

Do	Don't
Allow the manufacturer to provide their best package combination	Define the number of blowers
Pre-select the blowers (allows design of appurtenant facilities around specific units)	Define the specific motor size
	Define the blower unit capacity

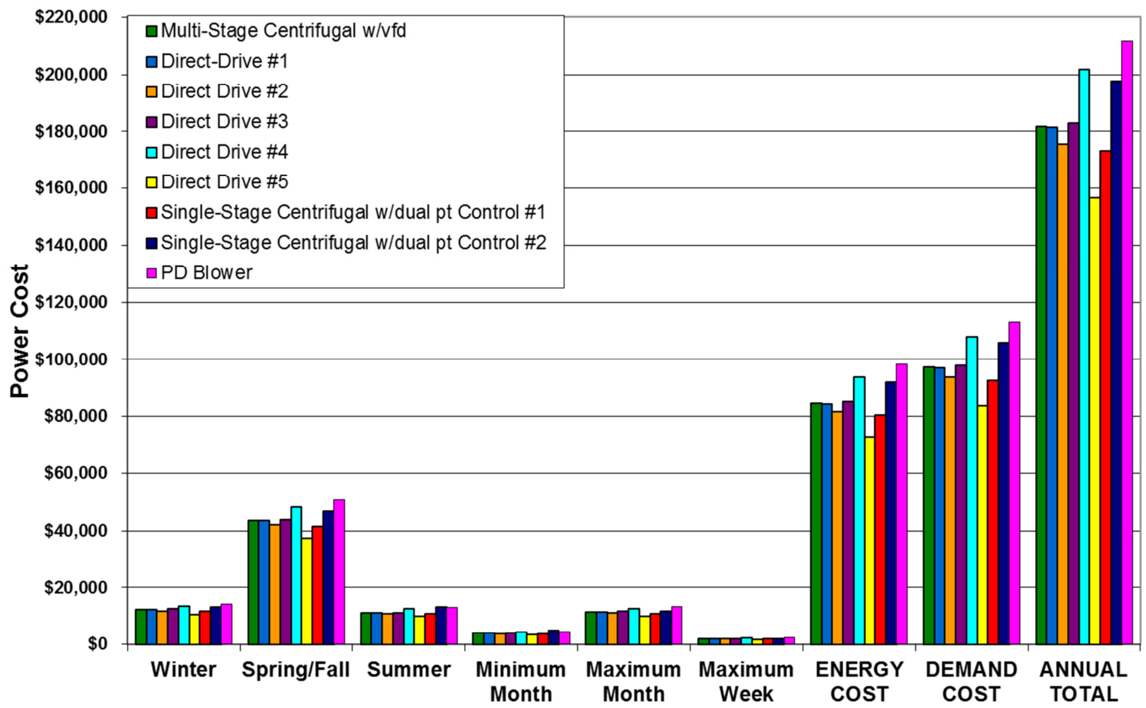
5. Evaluation of Manufacturers Proposals

In addition to the cost of the equipment, the cost of the predicted power consumption is an important part of the total proposal evaluation. For this case, six days were selected to represent the full year. Each day represented a specific number of days throughout the year:

- Winter 49 days
- Spring/Fall 181 days
- Summer 63 days
- Minimum Month 26 days
- Maximum Month 40 days
- Maximum Week 6 days

The total daily power consumption estimated by the manufacturer was multiplied by the number of days that particular day represented. An example of the estimate of the cost of power provided by each manufacturer solicited for this case is shown on Figure 9.

Figure 9. Case Study Comparison of Predicted Power Cost



Careful scrutiny of the manufacturer's proposals is required. Once the manufacturers' powers costs were plotted in Figure 9 and the capital cost and 20-year net present value results provided in Table 2 were reviewed, it appeared that the "Direct Drive #5" manufacturer provided the lowest cost package. Under further scrutiny, however, the "Direct Drive #5" manufacturer violated a number of the specifications, and the proposal was rejected.

Table 2. Case Study Comparison of Total Cost

Manufacturer	Number	Capital Cost	Power Cost	20-yr NPV
Multi-Stage Centrifugal w/vfd	3+1	$728,200	$181,740	$3,622,400
Direct Drive #1	3+1	$787,630	$172,860	$3,765,700
Direct Drive #2	3+1	$582,260	$175,475	$3,426,000
Direct Drive #3	4+1	$836,500	$183,040	$3,870,500
Direct Drive #4	2+1	NP	$201,700	NP
Direct Drive #5	4+1	$558,500	$156,760	$2,991,400
Single-stage Centrifugal w/dual point #1	2+1	$630,155	$173,210	$3,500,500
Single-stage Centrifugal w/dual point #2	1+1	$900,000	$142,610	$4,141,240
Positive Displacement	7+1	$445,390	$211,575	$3,900,000

6. Blower Selection

The results of the analysis indicated that the options "direct drive#2" and "single-stage centrifugal w/dual point #1" were very close in comparison on the 20-year net present value analysis. However, after the evaluation of the remainder of the other criteria, and the opinion of the owner, the "single-stage centrifugal w/dual point #1" was selected for installation at this particular facility. Figure 10 shows the 90 percent complete installation of the selected aeration blowers.

Figure 10. Case Study Blowers at 90 Percent Complete Installation

7. Conclusions and Recommendations

There are currently fifteen various manufacturers of aeration blowers. At this time, the most efficient aeration blower technology available for aeration of activated sludge processes consists of the direct-drive and gear driven single-stage centrifugal blowers. Each manufacturer of these type of blowers offers a range of sizes. There is no standardization of aeration blower capacities.

Because there are variations in all the manufacturers' products, it is recommended that blower specifications be prepared to allow the manufacturers to select the optimum combination of their range of products that best fits the performance envelope described. It is recommended that the specifier not identify the number, airflow capacity and motor size of the individual blowers.

A method of identifying a significant number of operating point to allow a side-by-side power consumption comparison is described.

A case study illustrating the use of the procedures described throughout the paper is provided.

8. References

WEF MOP 32 (2009). Energy conservation in wastewater treatment facilities. Manual of Practice No. 32. Water Environment Federation, Alexandria VA, USA.