The upgrades to the Little Miami facility installed four blower enclosures. Each enclosure contains two blower cores, which are shown removed from the enclosure. MSDGC

Embracing variety

Cincinnati's experience with maximizing aeration system energy efficiency at three facilities

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The Metropolitan Sewer District of Greater Cincinnati (MSDGC) is upgrading the secondary aeration systems of its three largest water resource recovery facilities (WRRFs). MSDGC serves a population of 800,000 and operates seven WRRFs with a combined daily average flow of 700,000 m^3/d (184 mgd).

Aeration systems typically account for 40% to 60% of the total energy consumed at most WRRFs. So, in addition to maintenance concerns with aging equipment, the principal driver for these upgrades is energy efficiency.

All three facilities replaced their aeration blowers and one facility replaced its coarse-bubble diffusers with fine-bubble ones. All three facilities also will receive new aeration control systems to operate as efficiently as possible based on dissolved oxygen (DO) demand. MSDGC contracted with Brown and Caldwell (Walnut Creek, Calif.) for the design of upgrades to the aeration systems.

Little Miami Wastewater Treatment Plant

Design flow: 208,000 m³/d (55 mgd)
Average flow: 114,000 m³/d (30 mgd)
Status: Construction completed in 2013

The Little Miami facility serves the eastern portion of the MSDGC service area in Hamilton County. Secondary treatment process includes eight activated sludge aeration tanks. Each tank is 21 m × 46 m (68 ft × 152 ft) and flow moves across the shorter dimension. The tanks are 5.5 m (18 ft) deep with a volume of 5.3 million L (1.4 million gal). Before the upgrade, the aeration system consisted of four multistage centrifugal blowers and coarse-bubble diffusers.

Blower selection for the Little Miami facility was driven by energy efficiency and the age of the original blowers. The original blowers were installed in 1977 and had exceeded their useful life. They were less efficient compared to new blowers, and reliability and cost of repairs was an increasing concern.

MSDGC used a business case evaluation (BCE) to evaluate replacement of the blowers. The BCE showed that single-stage, direct-drive centrifugal blowers made the most sense. To replace the system with multistage, centrifugal blowers would result in a net present value of $23.2 million over 30 years; to install single-stage, direct-drive centrifugal blowers would result in a net present value of $17.8 million over 30 years – a $5.5 million savings.

New equipment

Four single-stage, direct-drive centrifugal blowers were installed at Little Miami to replace the existing four blowers. Because of the size of the blowers – 373 kW (500 hp) – the installed blowers are dual-core units. Each has two blowers, 250-hp motors, and variable-frequency drives (VFDs) in one enclosure. Little Miami is one of the first WRRFs in the country to install dual-core, single-stage, direct-drive blowers.

Each blower has two VFDs, a packaged PLC controller, and an operator touchpad. Each blower PLC communicates with a blower master PLC that coordinates the staging of the blowers and determines the speeds for pressure control. Depending on process conditions, one to three blowers operate in parallel to maintain the pressure in the combined air header.

Tube-type membrane diffusers replaced coarse-bubble diffusers to increase aeration efficiency. A comprehensive diffuser performance study compared tube-type, threaded-disc membrane diffusers, high-density disc membrane diffusers, and panel membrane diffusers. New butterfly air control valves, dissolved oxygen meters, and air flowmeters also were installed for process control.

Energy savings

During design, calculations estimated that the modifications would result in an energy savings of approximately 30%. In its first year of operation, the new aeration system yielded energy savings of approximately 55% over the prior system.

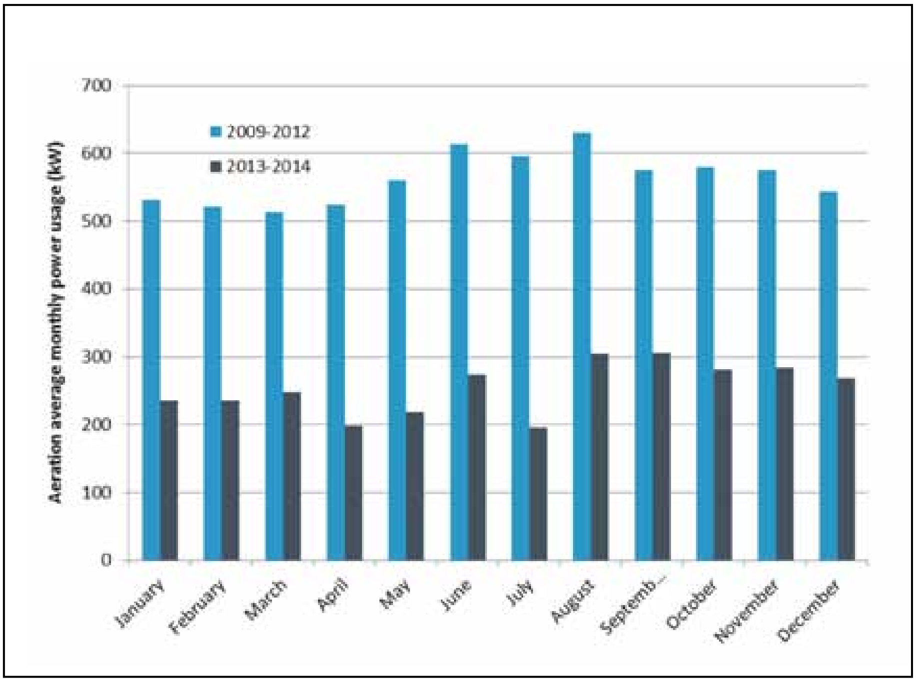
During this period, the average influent loading in pounds of carbonaceous biochemical oxygen demand and average influent flow was higher than the average for the previous 3 years compared – so energy savings are due entirely to system efficiency. Figure 1 (below) shows the change in kW usage at Little Miami before and after the new system. It is presumed that the increase in savings over what was projected was realized from the new control system because the calculated savings only took blower and diffuser efficiency into account.

Lessons learned

Design and startup of this system included several lessons:

- Dual-core, single-stage, direct-drive centrifugal blowers should include a control system that handles staging at the individual core level rather than at the blower level.
- Factory testing of blowers requires expert knowledge of draft ASME Performance Test Code 13 to ensure test conditions are properly set up and maintained.
- Tube-type membrane diffusers require periodic stretching at high airflow to maintain peak performance. These flows can be difficult to meet because they are considerably higher than design airflow.
- Aeration system control strategy energy savings can be as significant as those seen from higher efficiency blowers and diffusers.

Figure 1. Little Miami aeration power usage



Muddy Creek Wastewater Treatment Plant

Design flow: 83,000 m³/d (22 mgd)
Average flow: 57,000 m³/d (15 mgd)
Status: Construction completed in 2012

The Muddy Creek facility serves the western portion of the MSDGC service area in Hamilton County. It is a secondary treatment facility that includes two activated sludge aeration tanks. The tanks are plug flow tanks with three passes per tank. Each of the tanks are 67 × 24 m (220 × 78 ft) and 4.5 m (15 ft) deep with a volume of 7.2 million L (1.9 million gal). The original system consisted of four positive displacement blowers. Ceramic, fine-bubble diffusers were installed in 2008.

The original blowers were installed in 1972, and so the desire for energy efficiency and the need to replace equipment drove this project. The BCE again indicated that single-stage, direct-drive, high-speed centrifugal blowers were the most economic choice. Where directly replacing the positive displacement blowers would have a 30-year net present value of $7.9 million, switching to single-stage, direct-drive units cost only $6.1 million – roughly a $2 million savings.

The Muddy Creek facility's secondary aeration tanks operate in a plug-flow configuration. Flow makes three passes through the system. The arrows above show the direction of the flow through the tanks. MSDGC

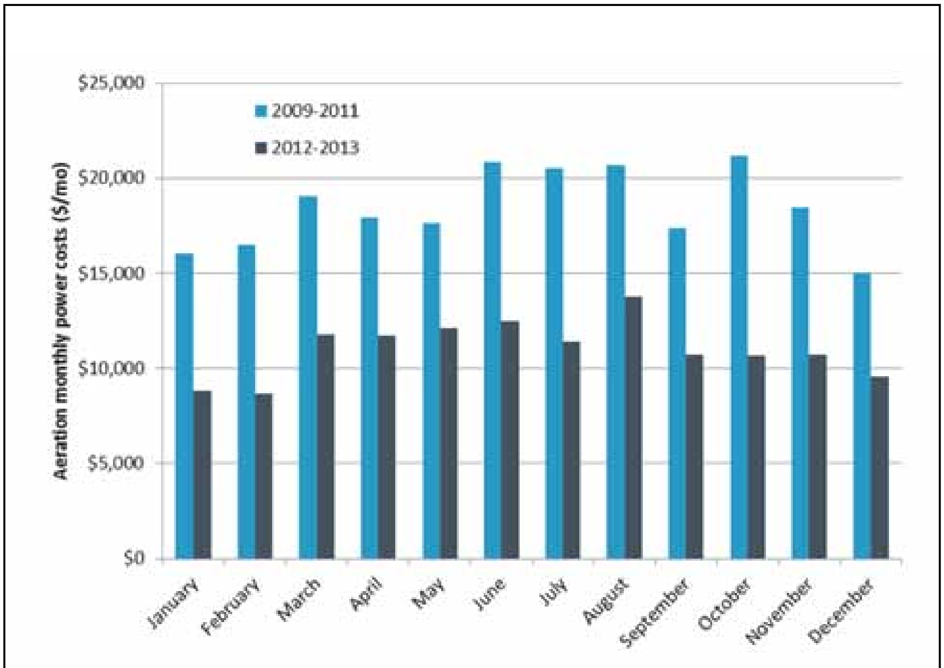
New equipment

Four new single-stage, direct-drive centrifugal blowers were installed at Muddy Creek. New butterfly air control valves, dissolved oxygen meters, and air flowmeters also were installed. The blower control system installed is similar to Little Miami's; however the header pressure setpoint is adjusted automatically to control dissolved oxygen by a most-open-valve (MOV) algorithm.

Energy savings

The projected energy savings calculated during the BCE process was approximately $36,000 per year. This represented a 20% energy savings compared to the existing blowers. In its first year of operation, the new aeration system at Muddy Creek yielded energy savings of $85,000 over the prior system. This represents approximately 40% energy savings as shown in Figure 2 (below). It is presumed that the increase in savings over projected was realized from the new control system because the calculated savings only took blower efficiency into account.

Figure 2. Muddy Creek aeration power costs



Mill Creek Wastewater Treatment Plant

Design flow: 908,000 m^3/d (240 mgd)
Average flow: 378,000 m^3/d (100 mgd)
Status: Construction scheduled for completion in 2015

The Mill Creek facility treats up to 1.6 million m^3/d (430 mgd) during wet weather through preliminary and primary treatment, and up to 908,000 m^3/d (240 mgd) through secondary treatment during wet weather.

The facility has a total of six multistage blowers currently installed. Five blowers have a capacity of 2550 m^3/min (90,000 ft^3/min) each and one blower – Blower No. 4 – has a capacity of 2067 m^3/min (73,000 ft^3/min) since it was retrofit with smaller impellers. During 3 years of data evaluated during the design phase, Blower No. 4 was used approximately 80% of the time. The blowers were installed in 1973 and require an increased amount of maintenance.

Because of the large size and variable flows at Mill Creek, the BCE evaluation to decide which blowers to install was more complicated. The BCE, completed in 2012 evaluated four alternatives:

1. Replace existing blowers with new multistage centrifugal blowers.
2. Replace existing blowers with new multistage centrifugal blowers and VFDs.
3. Replace existing blowers with new single-stage, integrally geared centrifugal blowers.
4. Rebuild the existing blowers.

Single-stage, direct-drive units were eliminated from consideration because of the large number of units that would have been needed. The BCE recommended Alternative No. 3 based on lower capital, operation and maintenance, and energy costs. This led to the decision to install five 1130-m^3/min (40,000-ft^3/min) single-stage, integrally geared units.

Mill Creek also will receive new butterfly air control valves, dissolved oxygen meters, and air flowmeters. The blower control system to be installed will be similar to the system installed at Muddy Creek with the header pressure setpoint adjusted automatically to control dissolved oxygen by an MOV algorithm.

Further evaluation, confirmation

Because of the success at Little Miami and Muddy Creek with single-stage, direct-drive units, MSDGC requested that the project team re-evaluate the potential for including direct-drive units.

The analysis showed that to meet the future demand of 4250 m^3/min (150,000 ft^3/min) would require four single-stage, integrally geared units – total capacity 4530 m^3/min (160,000 ft^3/min) with one unit in reserve – or 11 single-stage, direct-drive units – total capacity 4250 m^3/min (150,000 ft^3/min) also with one unit in reserve. The capacity of each geared unit would be 1130 m^3/min (40,000 ft^3/min) and the direct-drive units would be 385 m^3/min (13,600 ft^3/min). The team also assessed several key capital and operations and maintenance costs related to the two options.

Blower layout in existing facility. The five new integrally geared units were very well suited for replacement within the existing facility. They would use the existing inlet piping, equipment pads, and discharge piping. The proposed layout for the direct-drive units paired up two dual-core units so that two dual-core units would use the same equipment pads as an existing blower. As such, there was sufficient space but there would need to be additional modifications to the discharge piping for the direct-drive option.

The Mill Creek Wastewater Treatment Plant is scheduled to have its six multistage centrifugal blowers replaced with single-stage, integrally geared centrifugal blowers with dual vanes for inlet and outlet air control. This project is scheduled to be finished in 2015. MSDGC

Capital costs. The estimated capital costs for the two types of blowers differed only by about $500,000. The cost for 11 single-stage, direct-drive units would be $4.8 million, while the cost for four single-stage, integrally-geared units would be $4.3 million. The integrally-geared units also offered a much higher confidence because they were based on 90% design. The direct-drive units, on the other hand, were based on only a planning level estimate.

Energy savings. Blowers must be compared on equal tolerances and guaranteed power use at design conditions. Both systems were evaluated based on zero tolerance (no negative tolerance); however, more confidence was given to the integrally-geared units based on the design phase. Transformer losses of 1% were included in the direct-drive units, since these units were available only at 480V power; whereas incoming power to the existing blower building was 4160V. Based on this, the power cost to operate the direct-drive units would be the same or slightly higher than the integrally geared units.

The calculated power cost to operate the new blowers will be slightly lower than the existing blowers assuming similar air flow rates. Based on the results at the other facilities, the addition of the automatic DO control system (new butterfly air control valves, dissolved oxygen meters, and air flowmeters) to Mill Creek will reduce air flow rates and further increase energy savings.

Different situation, same goals

Choosing the right secondary aeration blower technology depends on the application. The three MSDGC facilities highlighted here all required differing technologies for the best fit.

While great energy savings can be captured from blower and diffuser efficiency, even greater results are possible by adding control systems that minimize excess aeration. A critical aspect of this savings is using dissolved oxygen monitoring with controls that automatically adjust blower speed and number of blowers in operation.

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