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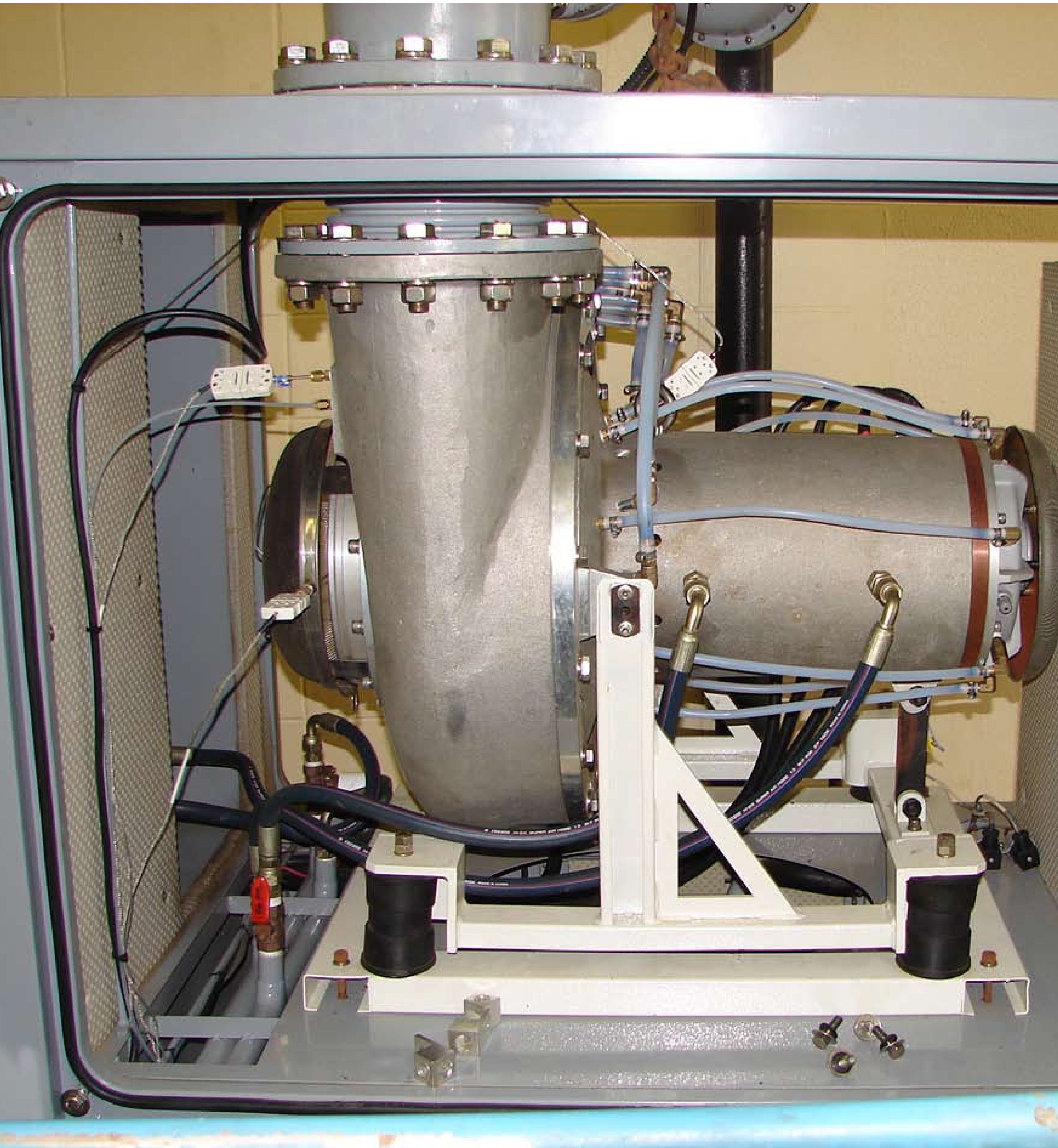

LESS

Turbo blowers can cut energy costs by more than 35%

Katherine Bell, Jason Sciandra, and Kevin Wagner

Fort Meyers, Fla., staff pilot-tested a turbo blower in the aerobic digestion system of its Central Advanced Wastewater Treatment plant. This photo shows the compressor of the turbo blower demonstration unit.

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There are many reasons why water and wastewater treatment facilities aim to become more operationally and energy-efficient; they include volatile energy prices, a desire to be more sustainable, recently proposed legislation, and energy-efficiency project funding. Most of the electricity used at wastewater treatment facilities powers aeration systems that deliver air to biological treatment processes and mix wastewaters to suspend solids in process tanks. Aeration processes can account for 60% or more of a facility's overall power consumption, so making them more energy-efficient would greatly reduce energy consumption and costs. Blowers, in particular, are often high priorities when improving energy efficiency.

Rising energy costs and an interest in sustainability prompted Fort Myers, Fla., to investigate ways to reduce its energy consumption. The city has two advanced wastewater treatment plants designed to produce effluent containing less than 5 mg/L of biochemical oxygen demand, 5 mg/L of total suspended solids, 3 mg/L of total nitrogen, and 1 mg/L of total phosphorus. The Central Advanced Wastewater Treatment Plant is designed for an annual average capacity of 41,700 m^3/d (11 mgd); the South Advanced Wastewater Treatment Plant is designed for an average annual capacity of 45,500 m^3/d (12 mgd). Both use aerobic digestion to stabilize solids.

The Central plant's aerobic digestion system includes two circular and four rectangular solids-holding tanks with a maximum side water depth of 5.18 m (17 ft). Coarse-bubble diffusers are mounted 0.3 m (1 ft) off the tank floor. The system is aerated with one of three multistage centrifugal blowers, which were installed in 1994. Each blower has a 186-kW (250-hp) motor, rated for 3575 rpm. Blowers are controlled by adjusting an intake valve to maintain set operating airflows. The tanks are aerated continuously with a single blower, except on Sunday, when facility staff turn off the blower and decant the system for 6 hours. During decant, the tank level drops by about 1.2 m (4 ft). The blower and tank configuration results in a maximum pressure drop of 49.6 kPa (7.2

The demonstration turbo blower (left) was installed next to the plant's existing multistage centrifugal blower.

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lb/in.^{2}), including losses due to diffusers, drop legs, friction losses, and submergence.

New Option: Turbo Blowers

Blowers traditionally have been selected to provide a narrow range of airflows over relatively narrow pressure ranges, so they only met a particular set of operating conditions efficiently. Wastewater utilities that wanted energy-efficient blowers had to choose either positive-displacement units running on variable-frequency drives or integrally geared, single-stage centrifugal units with inlet and outlet vanes. Beginning in the early 1980s, they had a third choice: single-stage centrifugal units. Then, in 2003, single-stage, oil-free, direct-drive turbo blowers with air-foil bearings were introduced. To date, more than 1500 of these units have been installed worldwide. Fewer than 200 of these currently are installed in U.S. wastewater utilities, although approximately that many more are on order.

According to manufacturers, direct-drive, high-speed turbo blowers use less energy and have higher surge margins than conventional blowers. They also are quieter, more durable, and more reliable. The key to these blowers is the air-foil bearing, which was developed in the 1960s for airplane ventilation systems and since has been adapted for blowers. Turbo blowers operate at high speeds (from 20,000 to more than 40,000 rpm), which improves efficiency, because a compressor's dynamic efficiency increases as speed increases.

Turbo blower packages typically include a controller, a variable-speed drive, a motor, and a blower. They are compact, with footprints that are at least 25% smaller than those of conventional blowers. Turbo blowers operate over a range of pressures and flow rates, and their only moving parts are the impeller shaft with motor

Table 1. Blower Comparison

	Existing blower	Turbo Blower A	Turbo Blower B
Type	Multistage centrifugal	Direct-drive turbo	Direct-drive turbo
Size (hp)	250	200	200
Design flow (ft^3/min)	4000	1400 to 4300	2200 to 5400
Maximum discharge pressure (lb/in.^{2})	9.5	10.2	10.2
Year installed	1994	N/A	N/A

rotor, cooling fan (for units that have these systems), and air-foil bearings. Air-foil bearings have lower discharge temperatures, resulting in higher air-transfer efficiencies than those provided by centrifugal or positive-displacement blowers. Maintenance is limited to periodically cleaning or replacing the inlet air filter, which is provided as part of the blower package. There are no lubrication requirements.

Several direct-drive turbo blower manufacturers have emerged in the U.S. market, and even more are expected to join in coming years. This emerging technology has prompted a number of demonstration projects comparing turbo blowers to similarly sized positive-displacement and centrifugal blowers. Results to date have shown that turbo blowers can cut energy costs more than 35%.

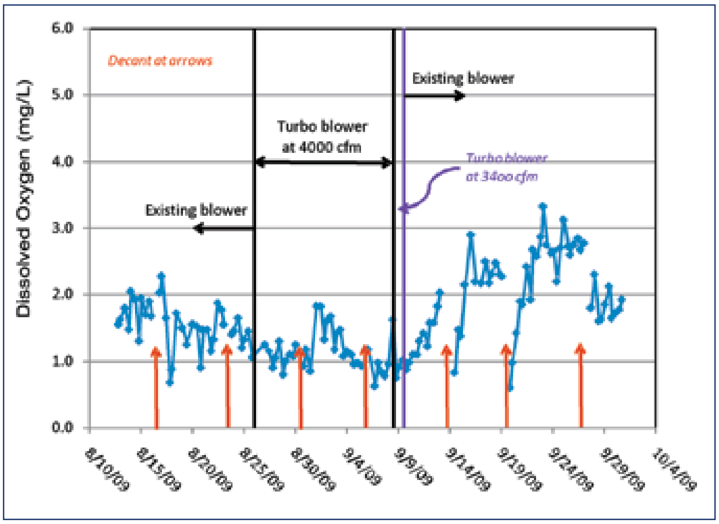
Excellent Pilot-Test Results

Fort Myers staff decided that aerobic digestion would be ideal for testing whether turbo blowers save as much energy as estimated. Working with a turbo blower manufacturer, engineers identified the optimum blower for the Central plant, and initial calculations indicated that it would cut energy needs by about 40%. Unfortunately, Turbo Blower A was not available, so the manufacturer offered a similar unit, Turbo Blower B, which had slightly different impeller trim (see Table 1, p. 42). While Turbo Blower B was adequate to meet process requirements, this blower was not optimized for maximum energy efficiency. So, engineers would not get a precise cost-savings estimate, but they would get an approximation, and plant staff would get hands-on experience with a turbo blower.

Turbo Blower B arrived at the Central plant in late August 2009 and was installed in about 3 days. The project team wanted it installed quickly so it would be running during a statewide operator tour of the plant, as well as ready to return in time for the manufacturer's customer-delivery date.

The project team operated the blower from Aug. 26 to Sept. 21, 2009. During this test, they ran Turbo Blower B at an actual airflow of 113 m^3/min (4000 ft^3/min) so it would be consistent with the existing blower's airflow. Ambient temperatures ranged from 22°C to 34°C (72°F to 94°F), and relative humidity ranged from 58% to 84%. Three times a day, team members collected dissolved oxygen (DO) readings from four digester basins (see Figure 1, above). They used a power-logging meter to collect energy data. The project team also collected power data for the

Figure 1. Average Dissolved Oxygen Concentrations Before, During, and After Turbo Blower Pilot Study



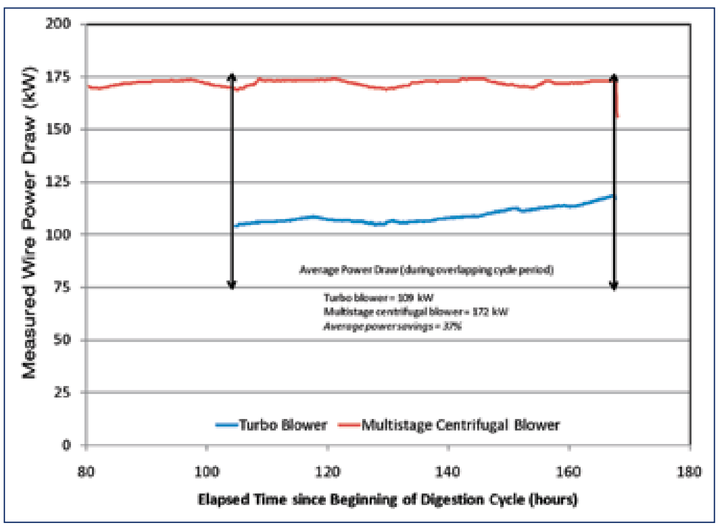
multistage centrifugal blower for 3.5 days under normal operations, so they could compare the power draw from both blowers under similar operating conditions (see Figure 2, below).

The turbo blower comes with a variable-frequency drive, so its speed can be adjusted. To determine how little aeration was needed to keep the digesters' DO concentrations at appropriate levels, researchers lowered the blower speed on Sept. 8 to provide 96 m^3/min (3400 ft^3/min) at varying head and then collected power-draw and DO data for the next 24 hours.

Automatic Control Would Further Improve Results

The Central plant currently controls its aeration system manually. In manually controlled systems, the controls typically are set to meet the maximum demand in a particular period, and staff adjust the equipment either daily or weekly.

Figure 2. Power Consumption Comparison



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However, load fluctuations cause oxygen demands to change constantly. Besides wasting energy, the excess aeration may hamper treatment by shearing flocculated particles too much.

To maximize energy efficiency, the control system should be automated. Such control systems typically use DO probes and analyzers to measure DO in aeration systems and adjust airflow accordingly in real time.

Well Worth Considering

Overall results show that simply replacing the existing blower with a turbo blower could reduce power draw by more than a third (see Table 2, p. 45). This finding is consistent with other demonstration studies involving turbo and positive-displacement blowers. Also, while Turbo Blower B's results were good, engineers expect that Turbo Blower A would reduce energy consumption by another 17%, because it would be optimized for the process. Automatic DO control could further reduce power consumption.

Turbo blowers might even meet aeration requirements at lower airflows (and energy) than

Table 2. Comparison of Power Consumption

Condition	Average power draw (kW)	Power draw reduction (%)	Average annual power consumption[1] (kWh/yr)	Estimated annual power cost[2] (@ $0.10/kWh)
Centrifugal blower @ 4000 ft^3/min	172	0%	1.5 million	$150,000
Turbo blower @ 4000 ft^3/min	109	37%	920,000	$92,000
Turbo blower @ 3400 ft^3/min	89	48%	780,000	$78,000

[1]Average annual power consumption is estimated based on average power consumption and does not account for seasonal fluctuations in aeration demands or for blower optimization.

[2]Estimated annual cost is based on average power consumption during the test period and an assumed energy cost of $0.10/kWh, which is in line with Fort Myers, Fla.'s current energy costs.

the existing blowers, although more data are necessary to confirm this. Other benefits include fewer operation and maintenance requirements, less noise and vibration, and better process control (via programmable logic controllers).

Before the pilot test, city staff had been considering replacing two 186-kW (250-hp) blowers at each plant and leaving one existing centrifugal blower as backup. Afterward, it was evident that one 149-kW (200-hp) turbo blower would be sufficient, and the plants could keep one or two existing blowers to meet process redundancy needs. This option would both minimize capital expenditures and reduce energy costs. The remaining blowers could be replaced in the future, if necessary.

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For More Information

Agrawal, G.L. (1997). *Foil Air/Gas Bearing Technology — An Overview.* New York: American Society of Mechanical Engineers.

Carlson, S.W., and A. Walburger (2007). *Energy Index Development for Benchmarking Water and Wastewater Utilities.* Denver: AWWA Research Foundation.

Della Corte, C., and M.J. Valco (2000). “Load Capacity Estimation of Foil Air Journal Bearings for Oil-Free Turbomachinery Application,” International Joint Tribology Conference. Society of Tribologists and Lubrication Engineers, Seattle (October).

Edwards, D. (2007). *Factory Test/Trip Report — NX300 Turbo Blower*. Englewood, Colo.: CH2M Hill.

Firmin, A.C., W. McConnell, and K. Noyes (2009). “Demonstration of a Direct Drive High-Speed Turbo Blower,” *Proceedings* of the 82nd Annual Water Environment Federation Technical Exhibition and Conference, Orlando, Fla. (October), pp. 7181–7197.

Valco, M.J., and C. Della Corte (2002). “Emerging Oil-Free Turbomachinery Technology for Military Propulsion and Power Applications, Transformational Science and Technology for the Army … a Race for Speed and Precision,” *Proceedings* of 23rd Army Science Conference, Orlando, Fla. (December).

Water Environment Federation (2009). *Energy Conservation in Wastewater Treatment Facilities* (Manual of Practice 32). Alexandria, Va.: Water Environment Federation.