PSA Versus VSA

Total Cost of Ownership and Energy Efficiency

By David Schneider, Bob Wimmer, and Bill Goshay — PCI

Drinking water requires the precise application of the oxygen molecule in several parts of a water treatment process train. On-site oxygen generators can be used for odor control applications and to generate ozone for disinfection or remediation. Oxygen also plays a role in wastewater treatment for aerobic digestion and in aquaculture where the demand for dissolved oxygen in a body of water rises as the number of aquatic species in the water increases. In this article, we look at on-site systems used to provide oxygen for odor control.

Pacific Consolidated Industries (PCI) (*www.pcigases.com*), a California-based manufacturer of oxygen generators used in water and wastewater applications, conducted an energy study on behalf of a Southern California municipality. This study compared life cycle costs of two technologies—Vacuum Swing Adsorption (VSA) and Pressure Swing Adsorption (PSA)—used to generate on-site oxygen supply for two separate lift station odor control projects. Each lift station was supplied oxygen by the competing oxygen supply technologies.

Project Background

The City of Laguna Beach, CA had odor problems at several manholes near the discharge of a three-mile-long force main (a force main is a pressurized main pipe, which can carry water, sewage, and other materials). Hydrogen sulfide (H_2S) levels peaked at concentrations of 800 ppm whereas the odor threshold from H_2S is less than 1 ppm. Additionally, the city was conscious of the potential corrosion issues associated with high concentrations of H_2S and decided to employ a novel, pure oxygen injection system from ECO_2 Oxygen Technologies. The solution system dissolves oxygen provided by on-site oxygen generation into a sidestream, which is then blended back into the force main flow. The high dissolved oxygen (DO) levels create aerobic conditions preventing the formation of H_2S, eliminating odor complaints and significantly improving the longevity of the lift station infrastructure.

Process Flow Diagram Comparing PSA and VSA Technology

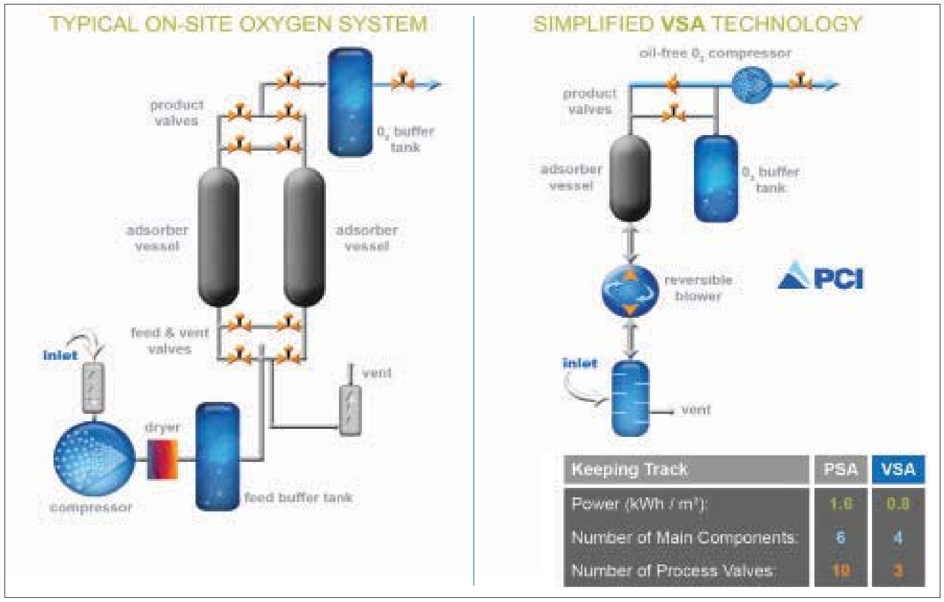

Figure 1 Source: PCI

While this first odor control project was supplied with pure oxygen from a PSA system, in early 2009 the city installed a second ECO_2 solution where a VSA system was used to supply the oxygen. While the municipal staff was aware of the power savings associated with the VSA, they commissioned PCI to perform a power monitoring study to compare the two oxygen supply systems.

Oxygen Technology Comparison

While PSA and VSA are both capable of delivering oxygen at concentrations ranging from 90–95 percent and use a zeolite molecular sieve (adsorption) process, there are significant differences in the main operating components and the pressures at which the units operate. Figure 1 highlights the key differences between PSA and VSA process technologies.

Central to the operation of both technologies is the ability of the molecular sieve to separate oxygen from nitrogen in the feed air stream. The feed air system of this VSA uses a reversible blower that operates at a pressure of an order of magnitude lower than the air compressor found in PSAs. This results in significant energy savings when using VSA, because higher pressures are directly proportional to higher energy consumption. PSAs also require a dryer unit to remove condensed water vapor that would otherwise foul the adsorbent material. Because VSAs operate at lower pressures, water vapor does not condense on the adsorbent material and a dryer unit is not required.

One common cause of high cost maintenance repairs is oil contamination of the adsorbent material. Many PSA compressors utilize oil-flooded screw compressors, which lead to oil vapor mixed with the compressed air. This VSA design uses an oil-free blower to eliminate this fouling problem. Another benefit of the lower pressure operating regime of VSA technology relates to the longevity of the adsorbent material. The higher pressure swings associated with PSA systems lead to attrition of the adsorbent material. This limits their useful life and requires maintenance personnel or contractors to have to repack the bed at regular intervals. This VSA design, with its lower operating pressures, is designed so that the adsorbent material will last for the entire lifetime of the equipment.

The adsorber vessel(s) allows the oxygen to pass through and produce 93 percent (+/- 3%) purity oxygen gas. In this VSA design a reversible blower is utilized for both generation and regeneration of a single adsorber vessel. PSAs, on the other hand, use complex valve systems to isolate two adsorber vessels for this generation and regeneration sequence. These valves are often one of the highest maintenance items associated with on-site generation and detrimentally affect the reliability of the oxygen system.

While the PSA does deliver higher operating pressures for the product oxygen gas, the VSA can deliver higher pressures with an oil-free oxygen compressor on the outlet gas from the adsorber. The advantage of this design is that the oxygen compressor on a

VSA is only compressing pure oxygen. This represents about one-fifth of the gas compressed on a PSA where the compression is done prior to gas separation.

The benefits of a VSA are summarized in Figure 1 *(see "Keeping Track" inset)*. A VSA will save approximately 50 percent of the energy consumption over a PSA of equivalent size and delivered pressure. A VSA also eliminates 33 percent of the main components and 70 percent of the process valves, which increases its reliability and significantly reduces its maintenance costs.

Energy Measurements and Analysis

As part of PCI's energy study for Laguna Beach, a power meter was attached to the power supply for the compressor on the PSA system located at one of the city's lift stations. Figure 2 shows the power consumption data recorded and indicates the average power demand of 19.2 kW. Another 1.1 kW of demand that was not measured on this power line can be attributed to the dryer and controls circuit, for a total average power demand for this PSA of 20.3 kW. Conversely, the competing VSA system installed at the second lift station has a total average power demand of 9 kW for a delivered pressure of 55 psig. This indicates an average power savings of 11.1 kW for the VSA for an equivalent system in oxygen flow, purity, and pressure. The raw data for energy consumption and demand was collected by Fluke Power Log 2.8.2 and post-processed to show the average power consumption. Assuming 90 percent utilization, the VSA reduces annual energy consumption by nearly 90,000 kWh or 55 percent of the PSA energy consumption. Since a VSA reduces energy consumption, there is often energy efficiency grant funding available that can offset the purchase price.

In addition to energy consumption savings associated with the VSA, the data also indicates that there is a demand charge savings. The PSA peak demand occurs at approximately 26 kW and the VSA at 11.6 kW, resulting in a demand reduction of nearly 55 percent.

Lifecycle Cost Analysis

Utilizing the recorded power data for the Laguna Beach systems, an analysis was performed on total life cycle cost for both. In addition to the power cost savings, the simplified design of the VSA system significantly reduces the maintenance cost, which further improves the life cycle costs when compared to a PSA. Using information on actual maintenance costs and power costs, a discounted cash flow (DCF) model was performed comparing the VSA against the PSA. The 10-year DCF model assumptions were: a discount rate of 12 percent; no tax shield (municipal customer); maintenance escalation of two percent/year; and energy costs escalation of five percent/year.

Figure 3 shows the results of the DCF model for the cumulative cash flow for each supply system. It indicates that replacing the current four-year-old PSA system with a new VSA will result in a payback in 22 months. The VSA will save the city approximately $265,000 over the next 10 years and will reduce the total cost of ownership by 65 percent.

Summary

The power study conducted at Laguna Beach's two lift stations utilizing competing on-site oxygen generation technologies clearly indicates that there is a significant cost savings associated with VSA technology. Paybacks of less than two years can lead to significant cost savings over the lifetime of the system and save a substantial amount of energy that is directly related to greenhouse gas emissions. Over 10 years, the VSA will save the city: 870,000 kWhs of energy consumption; avoid emitting approximately 3,500 metric tons of greenhouse gases emissions; and save $260,000 in costs or 65 percent of the costs associated with a PSA.

Based on the above analysis, the City of Laguna Beach decided to replace their existing PSA with a new VSA. The new 200 liter-per-minute system was installed in November 2010 and had the added benefit of a smaller footprint, which allowed the City to add additional equipment to improve the reliability of their main pump station.

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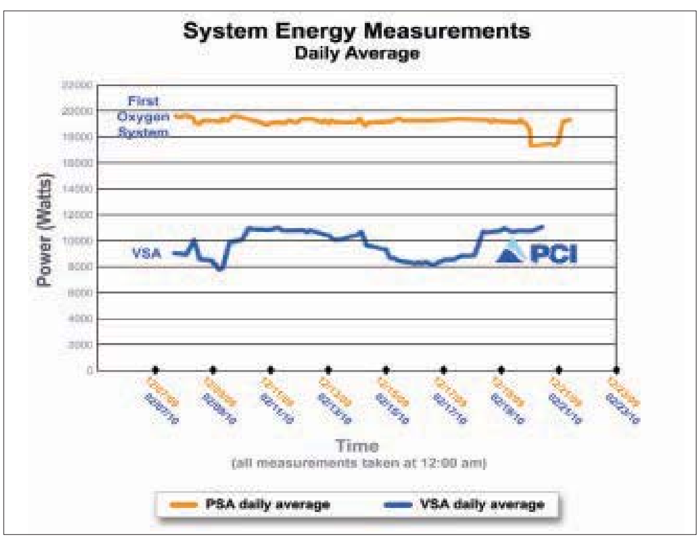
PSA and VSA System Energy Measurements*



*Fluke Power Meter data recorded for both the PSA and VSA systems

Figure 2 Source: PCI

Total Cost of Ownership: PSA vs. VSA

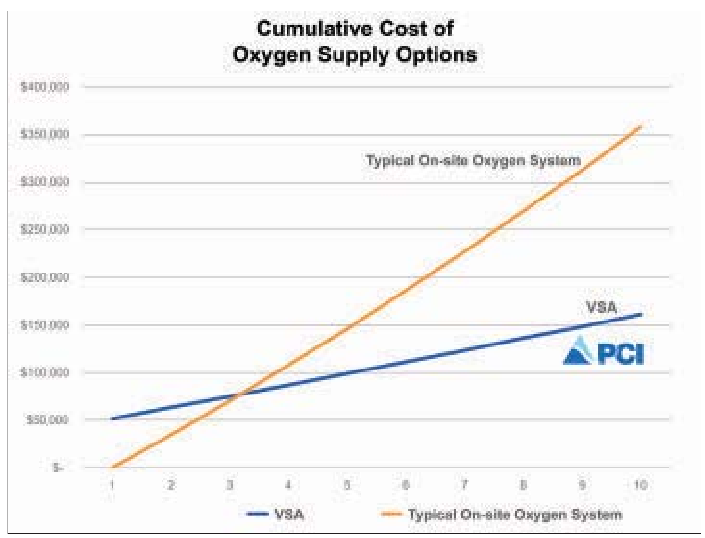


Figure 3 Source: PCI