BestPractices

BestPractices
Technical Case Study

June 2001

OFFICE OF INDUSTRIAL TECHNOLOGIES
ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Benefits
- Saves $226,000 annually
- Reduces energy use
- 40% reduction in compressed air energy costs per unit of production
- Increases reliability
- Reduces CO_2 emissions

Applications
Compressed air systems are found throughout industry and consume a significant portion of the electricity used at manufacturing plants. Specifying correct pressure levels for end-use equipment and making the appropriate changes to the supply system can improve the performance of almost any compressed air system.

Compressed Air System Redesign Results in Increased Production at a Fuel System Plant

Summary

In 1999, Caterpillar Fuel Systems performed a compressed air system improvement project at its fuel injector plant in Pontiac, Illinois. The project's implementation greatly improved the compressed air system's reliability and efficiency. As a result, the plant achieved important energy savings through reduced energy consumption, was able to increase production by 18% without purchasing additional compressors, and solved an air supply problem to a critical production area. Had the plant not increased its production, it would have been able to take some of its compressors offline. The plant's compressed air energy savings total $226,000 (5,280,000 kWh) per year and represent over 6% of annual energy costs. Since the project's cost was approximately $1,000,000, the simple payback is 4.4 years. In addition, the project resulted in a 40% reduction in compressed air energy costs per unit of production.

Caterpillar's Pontiac Plant

Plant Overview

The fuel injector manufacturing plant is a large facility, employing 1,000 people, and is part of Caterpillar's Fuel Systems Division. The plant specializes in production of fuel injectors and fuel system machinery for motor vehicles. The plant has many assembly lines and machining operations, such as lathes, drills, and grinders, that use compressed air to manufacture the fuel injector components. The majority of the plant's applications will work reliably at 90 psig. However, the plant does have two applications, the Hydraulic Injector Product (HIP) assembly area and a new automated assembly line, that need compressed air at a minimum of 105 psig for their robotics to operate dependably.

Prior to the project, the plant was served by eight 350-hp centrifugal compressors that produced between 6,800-8,000 scfm at discharge pressures of 116-122 psig. Six of the compressors were located in a central building within the plant, while the other two were remotely located in the building that housed the HIP assembly area. In the summer months, a diesel-powered 350-hp, lubricant-free rotary screw compressor that produced an additional 1,500 scfm was hooked up to the HIP assembly area.

Project Overview

Despite operating all eight of its centrifugal compressors and renting an additional one for the summer months, the plant was unable to consistently supply its HIP area with air at the pressure level it needed. Because of this, Caterpillar commissioned a comprehensive assessment of the plant's compressed air system by an independent team of experts. The assessment was performed in two phases and led to a system-level strategy to improve the plant's compressed air system so that manufacturing would be more reliable. The first phase of the evaluation focused on addressing the specific problems associated with supplying the HIP assembly area. The assessment's second phase dealt with improving the system's overall efficiency and solving the issues uncovered during Phase 1.

<u>Phase 1</u>—The first phase of the evaluation discovered several issues that contributed to the plant's inability to adequately supply the HIP assembly area. The first problem was the high pressure drop in the air treatment and distribution systems. The pressure drop was due to undersized and poorly functioning filters, dryers, and aftercoolers and ranged from 7 to 18 psig. This led to a fluctuating pressure in the main header of 96 to 108 psig. Pressure loss/drop is a function of a compressed air system's dynamics—the interaction of airflow rate with the inherent resistance of the pipeline and air system components. The pressure drop was exacerbated by the configuration of the distribution system. The evaluators determined that the dimensions of the main header (6 inches) were undersized for the system's airflow. This led to a high degree of resistance to airflow within the piping that exceeded the optimal design parameters. In addition, three 4-inch pipelines that were served by the main header were found unconnected to the piping loop, causing an unbalanced airflow across the system. Together, these factors combined to create a dynamic system pressure profile that made it impossible for the compressors to maintain a pressure level of 105 psig consistently.

In an effort to keep the pressure level for the HIP area adequate, plant personnel tightened the compressor control band to 6 psig. This created an insufficient pressure differential for a workable compressor control band and caused the compressors to enter into each other's throttling band and work against each other. As a result, the plant had to keep more compressors online than necessary.

Phase 2—In addition to the problems identified in Phase 1, the second phase of the evaluation exposed several other issues that prevented the compressed air system from operating efficiently. This phase showed that the plant was wasting energy because of a high estimated air leakage rate and artificial demand. An estimated leakage rate of about 3,200 scfm at 102 psig, representing 40% of the total flow, was due to leaks in the distribution piping network and improperly functioning condensate drains. In addition, some of the plant's compressed air applications, such as venturi vacuum systems and some partial drying, could have been accomplished with less energy-intensive equipment.

Compressor Controls and Storage

Artificial demand is the excess air required by a compressed air system's unregulated uses because the system is being operated at a pressure level in excess of actual production requirements. At the Caterpillar plant, artificial demand resulted because the plant's pressure level was dictated by the needs of the HIP assembly area, which required 400 scfm (only 5% of total flow) at 105 psig. Because the plant's entire pressure level was kept higher than necessary for the majority of the plant's compressed air applications, the system consumed 1,300 scfm unnecessarily through artificial demand.

Next, the evaluation team reported problems with the compressor control configuration that prevented them from operating effectively. Since the compressor control band was unrealistically tight, the compressor operators could not establish a workable sequencing strategy, which led compressors to blow off compressed air into the atmosphere and operate at reduced efficiency. The ineffective control of the compressors was compounded by the fact that at least 25% of the plant's compressor capacity was located in a remote area. In addition, the evaluators found that the pressure signals that the compressors were responding to were coming from a location that did not allow them to reflect the system's true air demand. This resulted in unnecessary compressor run time.

Finally, the team found that the 350-hp compressor that was rented during the summer months only delivered 300 scfm of air to the HIP area. This compressor was connected to the system via a 2-inch hose and was found to short cycle very rapidly between unloading because the pressure signals that controlled this compressor were coming from the compressor load cycles instead of the system's air demand. The short cycling prevented this compressor from responding to the system air demand properly and from delivering the volume of air that was expected.

Project Implementation

The evaluation team devised a system-level strategy that became the basis for the plant's compressed air system optimization project. To meet the compressed air needs of the HIP assembly area, the evaluation team recommended that it be sectioned off from the rest of the plant. This would allow the HIP area to receive compressed air at the required pressure level of 105 psig, while the rest of the plant's applications would operate at their optimal pressure level of 90 psig. However, before the HIP area could be partitioned, the issues that caused the pressure drop and inadequate airflow had to be addressed. The team determined that to allow for the maximum rate of airflow the size of the main header needed to be increased from 6 inches to 16 inches. In addition, the 4-inch pipes in the building that were dead-ended needed to be extended to form a complete loop and allow for balanced airflow. The next step was to repair and upgrade the plant's air treatment equipment to reduce the pressure drop across those components. In addition to new aftercoolers, separators, and filters, the team recommended that a new dryer be installed. The evaluation team also recommended a new control strategy to sequence the compressors more efficiently. The team determined that a sophisticated control strategy was required since the compressors were not all centrally located. Finally, the team recommended that a leak identification and repair program be implemented to reduce compressed air waste and the resulting artificial demand.

The compressed air improvement project at Caterpillar Fuel Systems' plant included five main action items.

- Correct the flow/piping issues—The plant extended the 4-inch pipelines in the northeast corridor so they can be linked up with the rest of the network. Next, the plant added a 16-inch header to go along with the existing 6-inch header.
- Provide HIP area with consistent high pressure—The plant sectioned off the HIP assembly area from the main header and dedicated the two compressors in that section of the plant to supply it exclusively. This was accomplished by installing a pressure/flow controller that released air into the HIP area at 105 psig.
- Eliminate excessive pressure drop across air treatment equipment and stabilize plant pressure—The plant installed a new 6,000 scfm dryer with pre- and after-filters. In addition, new aftercoolers with separators were installed upstream of each dryer to reduce pressure drop in air treatment equipment. Then, the plant installed a pressure/flow controller with 8,000 gallons of storage capacity that released air into the main header at 95 psig.
- Improve the compressor control strategy—The plant installed a Programmable Logic Control (PLC) system to regulate the compressors more efficiently. In addition, the new controls were configured to interface with the plant's data acquisition equipment to achieve trending and alarming capabilities.
- Eliminate wasteful practices—After installing the new header and the components called for in the evaluation, the plant was able to lower the system pressure. The plant measured its leakage rate, which was found to be substantially less than at the time of the evaluation. They then located and repaired the largest of the remaining leaks in the system.

Results

The compressed air optimization project at Caterpillar Fuel Systems increased the compressed air system's efficiency, resulting in important energy savings and improved manufacturing capacity.

The measures taken to reduce the piping restrictions improved the plant-wide airflow and reduced system pressure drop. This has allowed the plant to operate at a lower system pressure. Sectioning off the HIP area with dedicated compressors has allowed it to receive air consistently at its minimum needed pressure, while reducing the plant's demands on its compressors. The new dryer and air treatment equipment has reduced the pressure drop from between 10 and 18 psig to 3 psig and provides consistently dry air. With the previous configuration, each compressor had to be manually set with its own independent control pressure band. The new control strategy has centralized the control of all of the compressors in a single pressure band that maintains adequate pressure differential between the compressor pressure settings. This allows the controls to respond more effectively to system demand and sequence the compressors efficiently. Currently, the plant alternates the two compressors serving the HIP area and baseloads five out of the six compressors that serve the rest of the plant. The sixth compressor is brought online for peak needs.

Due to the project's implementation, the Caterpillar plant achieves annual compressed air energy savings of $171,000 and 3,420,000 kWh. This has been made possible through lower system pressure, more efficient compressor sequencing and reductions in artificial demand and leakage. The plant also saves $42,000 per year because they no longer lease the 350-hp diesel-powered compressor. They also save $13,000 in diesel fuel costs for total annual savings of $226,000. By not using the diesel-powered compressor, the plant was also able to reduce its annual CO_2 emissions by 400,000 pounds. Since the project cost was $1,000,000, the simple payback is 4.4 years. In addition, compressed air costs per unit of production have declined by 40% and manufacturing has increased by 18% without the need for additional compressors. Had the plant not increased production, it could have taken one other compressor completely offline.

Lessons Learned

An improperly configured industrial compressed air system leads to unreliability in product quality, energy waste, lower productivity, higher than necessary operating costs, and poor system performance. At the Caterpillar Fuel Systems plant, an incomplete and undersized piping distribution network led to excessive pressure gradient, exacerbating the system's already severe pressure drop. The operational solution for satisfying the HIP assembly area's pressure requirement was to boost the air pressure throughout the system, which led to compressed air waste through artificial demand. Once the piping network was completed and resized to allow maximum rate of flow, the system was able to operate more effectively.

High-pressure air should be used only when necessary. Once the HIP area was determined to be a valid high-pressure compressed air application, it was separated from the rest of the plant so that it alone would receive the required high-pressure air. This allowed the plant to provide air to the rest of the applications at a lower pressure level that was more consistent with their true requirements. Changing the system to this more optimal configuration resulted in substantial energy savings and improved productivity.

BestPractices is part of the Office of Industrial Technologies' (OIT's) Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together the best-available and emerging technologies and practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

PROJECT PARTNERS

Caterpillar Fuel Systems
Pontiac, IL

ConservAIR Technologies
Kenosha, WI

Kroeschell Operations
Chicago, IL

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

OIT Clearinghouse
Phone: (800) 862-2086
Fax: (360) 586-8303
clearinghouse@ee.doe.gov

Visit our home page at
www.oit.doe.gov

Please send any comments, questions, or suggestions to
webmaster.oit@ee.doe.gov

Office of Industrial Technologies
Energy Efficiency
and Renewable Energy, EE-20
U.S. Department of Energy
Washington, DC 20585-0121

DOE/GO-102001-1322
June 2001