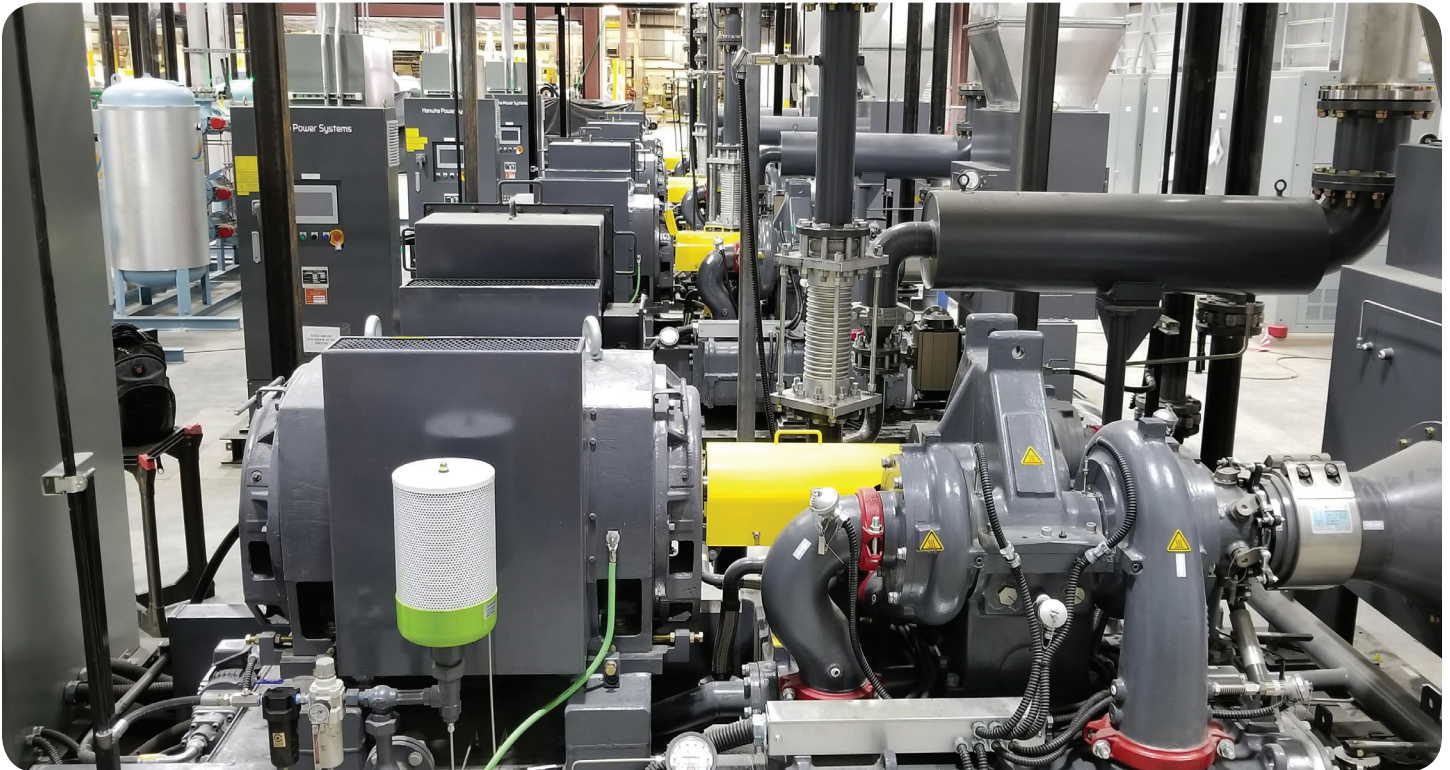


HOW TO REDUCE ENERGY COSTS IN COMPRESSED AIR SYSTEMS

By Ed Borkey, P.E., General Manager, Fluid Flow Products and N₂O₂

Compressed air is a widely used – but often inefficient – utility. This guide explains how operators can improve efficiency to realize significant savings.



DID YOU KNOW?

Up to 30% of the electricity consumed by industrial facilities is used to generate compressed air. The good news?

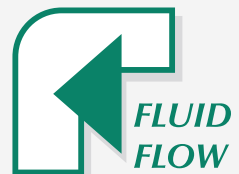
By implementing a few corrective strategies, operators can reduce energy costs associated with compressed air systems by 20% to 40%.

HIGHLIGHTS OF THIS REPORT:

- Summarizes Key Operating Costs Associated with Compressed Air Systems
- Reveals Common Mistakes Operators Make in Attempts to Address Compressed Air Performance Issues
- Outlines How Optimization of Compressed Air Systems Can Provide Significant Energy Efficiency Improvements

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How to Reduce Energy Costs in Compressed Air Systems



Compressed air is an essential utility requirement of many processes in industrial manufacturing plants. In fact, more than 75% of all industrial applications require compressed air at some point of their operating cycle. It is used as a power source for tools and equipment, and it is used for pressurizing, atomizing, agitating and mixing applications in a myriad of industries including, but not limited to:

- | | |
|---------------------------|------------------------|
| • Automotive | • Oil & Gas |
| • Chemicals | • Petroleum |
| • Electronics | • Pharmaceutical |
| • Food & Beverage | • Plastics |
| • Manufacturing | • Power & Energy |
| • Medical | • Printing |
| • Metal, Steel & Aluminum | • Pulp and Paper Mills |
| • Mining | |

Compressed air systems account for \$1.5 billion per year in energy costs in the United States. Unfortunately, compressed air systems are usually the most inefficient utility in any plant. Electricity costs by far account for the largest expense of owning and operating a compressed air system. As such, energy costs related to compressed air usage should be a major concern for plant managers, as well as maintenance, production, project and planning engineers.

To help operators prepare their compressed air systems for improved efficiency and annual cost savings, this report will:

- Review the energy expenditures related to compressed air equipment.
- Outline how optimization of compressed air systems can provide energy efficiency improvements of 20-40%.

How to Reduce Energy Costs in Compressed Air Systems

THE CHALLENGE:

COMPRESSED AIR ENERGY COSTS INCREASE OPERATING COSTS

A survey by the U.S. Department of Energy revealed that approximately 10% of the electricity consumed by a typical industrial facility is used to generate compressed air. For other facilities, energy required to generate compressed air may account for up to 30% of all electricity consumed.¹

Further, when analyzing the 5-year life cycle cost of new compressed air systems, 80% of costs are energy-related. Only about 9% involve the purchase of capital equipment. However, operators are often only concerned with initial equipment costs and many are unaware of how much their compressed air systems cost on an annual basis.

COMPRESSED AIR SYSTEMS 5-Year Life Cycle Costs



Source: <http://www.n202.com/index.html>

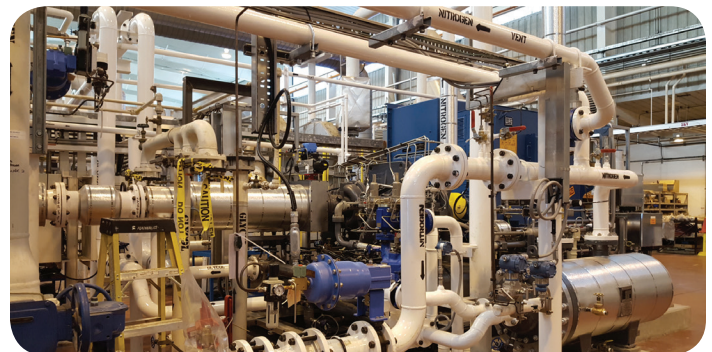
ONE-TIME COST
OF A 100-HP COMPRESSOR:
\$30,000-\$50,000²

ANNUAL ELECTRICITY CHARGES
FOR A 100-HP COMPRESSOR:
UP TO \$50,000

Signs of Inefficient Compressed Air System Operation

It is not uncommon for the overall efficiency of a typical compressed air system to be as low as 10% to 15%.¹

- Compressors operating in conflict with one another
- Short-cycling
- Blowing off



Addressing Compressed Air Equipment Emergencies in Industrial Operations

Operators who are unfamiliar with their compressed air system's energy costs may obtain auditing services from electric utilities, equipment distributors and manufacturers,

energy service companies and engineering firms. They also may use the following formula to estimate annual energy costs for fully loaded and unloaded operations:

ANNUAL ENERGY COST¹ = FULLY LOADED + UNLOADED ENERGY COSTS

$$\text{COST} = \frac{(\text{bhp}) \times (0.746) \times (\# \text{ of annual operating hours}) \times (\$/\text{kWh}) \times (\% \text{ time}) \times (\% \text{ full-load bhp})}{\text{Motor Efficiency}}$$

Bhp = Motor full-load horsepower (frequently higher than the motor nameplate horsepower; check equipment specification)

Percent time = percentage of time running at this operating level

Percent full-load bhp = bhp as percentage of full-load bhp at this operating level

Motor efficiency = motor efficiency at this operating level

0.746 = conversion between hp and kW

EXAMPLE CALCULATION

A 200-hp compressor requires 215 bhp and it operates for 6800 hours per year. It is fully loaded 85% of the time (with a motor efficiency of .95). It operates unloaded 15% of the time and has a 25% full-load bhp with a motor efficiency of .90.

$$\text{Fully Loaded Cost}^3: \frac{(215 \text{ bhp}) \times (0.746) \times (6800 \text{ hours}) \times (.069/\text{kWh}) \times (.85) \times (1)}{.95} = \$67,333$$

$$\text{Unloaded Cost: } \frac{(215 \text{ bhp}) \times (0.746) \times (6800 \text{ hours}) \times (.069/\text{kWh}) \times (.15) \times (.25)}{.90} = \$3,136$$

Annual compressed energy costs = \$70,469

Electric utilities utilize a more complicated rate structure that incorporates demand charges into the billing. Seasonal demand charges, which account for peak usage for a period of time, can significantly affect electricity costs. As such, the actual marginal cost of electricity should be considered when evaluating the economic impact of compressed air energy costs.



How to Reduce Energy Costs in Compressed Air Systems

THE SOLUTION:

AUDIT AND MODIFY AIR SYSTEMS TO INCREASE EFFICIENCY

Although electricity for compressed air applications may account for one-third of energy costs for industrial operations, there are several steps plant managers can take to improve efficiency of their compressed air systems – potentially by as much as 20% to 40%. These savings may exceed a combined total of \$400 million per year nationwide. Overcoming a couple of common misconceptions about compressor performance as it relates to the entire system is an important first step to improving compressed air efficiency:

Misconception 1: Many operators incorrectly assume that an energy-efficient motor or compressor design are the primary contributing factors to an efficient system. The reality is that *overall system efficiency* of the entire compressed air system is necessary to obtain maximum savings.

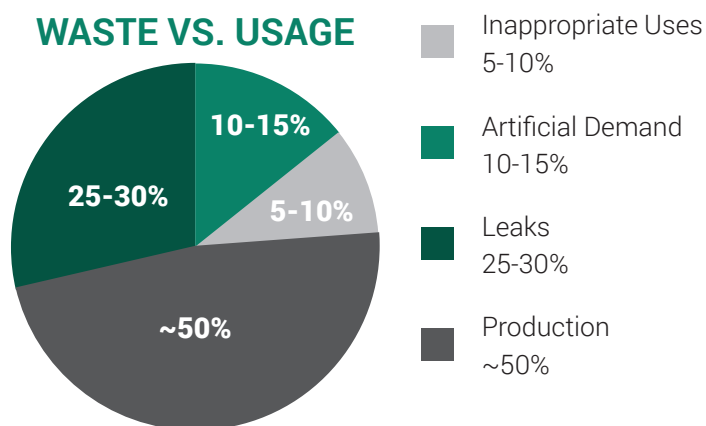
Misconception 2: Increased pressure is not the solution to all problems. The physics and dynamics of a compressible fluid are technically challenging, particularly in production areas. This makes analyzing the relationships between rate, flow, pressure and pressure drop difficult. Unfortunately, the default solution for many operators is to increase pressure to address all problems. This misstep leads to exponential increases in energy costs, which are difficult to identify and report.



Improving the performance of compressed air systems requires an approach that ultimately optimizes them to operate efficiently during both peak demand and during partial loads.

Operators who collaborate with a trained compressed air specialist to audit and modify their compressed air systems can position their systems to reduce energy costs. Follow these five recommended actions to begin saving today:

WASTE VS. USAGE



1. Analyze the supply and demand sides of the system to evaluate how they interact, particularly during peak demand.

Compressors that run at part-load are less efficient than when they operate at full-load. By identifying potential waste and understanding the system's authentic demand requirements, operators can deploy strategies to improve efficiency. Energy costs will be reduced when the system is adjusted to manage changes in demand over time. A compressed air specialist can conduct an audit of the system and provide a report of notable findings.

WASTE - Only 50% of the compressed air produced is appropriately utilized.

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2. Be sure to include end-use performances in the audit.

Steady pressure level at the end-use application is a key to efficient, reliable compressed air outcomes. However, many pressure fluctuations can be traced to the applications that use compressed air. Therefore, an audit of end-use performances can yield many opportunities for improvement. Unfortunately, operators often incorrectly recognize low air pressure fluctuations as a need for additional compressor capacity. Operators should revisit the pressure level requirement (this is different than maximum allowable pressure) of each end-use application. There is often a significant difference in air consumption and pressure level requirements for similar tools that are available from different manufacturers. Therefore, requesting exact pressure requirements from each manufacturer for each application is recommended. The end-use application pressure level requirements will determine the system pressure level. Additionally, operators should evaluate if the end-use application can be reconfigured to operate more efficiently. A compressed air specialist can assist with this task.

5 Additional End-Use Evaluation Steps⁴

- Check the air pressure at the inlet to the tool (poorly fitted hoses, fittings and quick disconnects can lead to pressure drops).
- Avoid operation of air tools at “free speed” with no load. Lubricate air tools according to the manufacturer’s specifications and make sure air going to all end uses is free of condensate. Avoid using tools that have exceeded their service life because they often require higher pressure, which can affect other nearby operations.
- Group end uses with similar air requirements (pressure and quality) in close proximity to minimize distribution of piping, air treatment and controls.
- If possible, reduce the highest point-of-use pressure requirements and adjust the system pressure accordingly.
- Replace inefficient end uses with efficient end uses (such as installing a vortex nozzle on an open hand-held blow gun).



- 3. Eliminate inappropriate uses of compressed air.** In many instances, other cost-effective forms of power can be used in place of compressed air:

Potentially Inappropriate Uses	Suggested Alternatives/ Actions
Clean-up, drying, process cooling	Low-pressure blowers, electric fans, brooms, nozzles
Sparging	Low-pressure blowers and mixers
Aspirating, atomizing	Low-pressure blowers
Padding	Low to medium-pressure blowers
Vacuum generator	Dedicated vacuum pump or central vacuum system
Personnel cooling	Electric fans
Open-tube, compressed air-operated vortex coolers without thermostats	Air-to-air heat exchanger or air conditioner, add thermostats to vortex cooler
Air motor-driven mixer	Electric motor-driven mixer
Air-operated diaphragm pumps	Proper regulator and speed control; electric pump
Idle equipment*	Put an air-stop valve at the compressed air inlet
Abandoned equipment**	Disconnect air supply to equipment

Source: U.S. Department of Energy, Compressed Air Tip Sheet #2, August 2004

*Equipment that is temporarily not in use during the production cycle.

**Equipment that is no longer in use either due to a process change or malfunction.

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4. Partner with a compressed air specialist to identify and correct compressed air leaks, which can waste 20%-30% of a compressor's output⁵.

An ultrasonic acoustic detector or soapy water can be used to identify leaks in a compressed air system. Prioritize the leaks and repair the largest leaks first. The most common sources of leaks are:

- Couplings
- Hoses
- Tubes
- Fittings
- Pipe joints
- Quick disconnects
- FRLs (filter, regulator and lubricator)
- Condensate traps
- Valves
- Flanges
- Packings
- Thread sealants
- Point-of-use devices

5. Cultivate a new compressed air control and storage strategy, or make modifications to existing controls, to match the system's actual needs.

Operators who leverage compressed air storage in their systems enable them to meet peak demand requirements without starting additional compressors. By utilizing controls to reduce lost air volume and to optimize compressed air usage, operators will not only benefit from power savings, but will also increase the service

life of the compressor and reduce maintenance costs (the less a compressor runs, the longer it can be expected to reliably operate).

There are three primary methods for controlling compressed air systems:

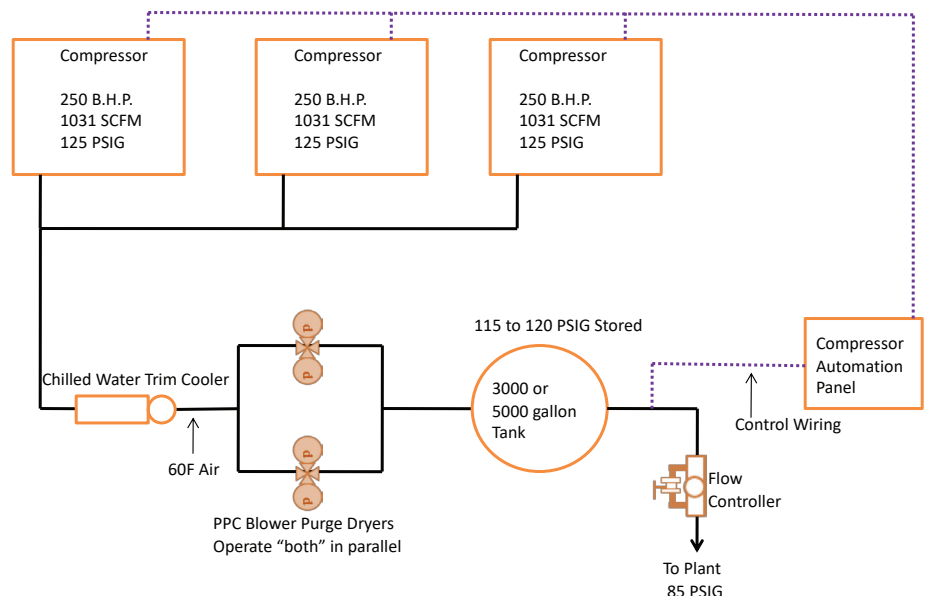
Individual compressor controls: Start/stop, load/unload, modulating inlet, multi-step and variable speed controls enable the compressor to adjust to changing demands in various ways.

Multiple compressor controls: Systems with multiple compressors require network controls that use the integrated compressor controls' microprocessors to form a chain of communication for stopping/starting, loading/unloading, modulating, and varying displacement and speed. Master controls coordinate all the steps needed to optimize the compressed air system as a unified utility. These sophisticated controls can monitor trending data to improve performance and reduce operating costs.

Pressure Flow/Controllers (P/FCs): A P/FC separates the supply from the demand through controlling the storage of compressed air. This device helps to efficiently manage intermittent loads and maintain system pressure.

Controls Create Savings:

Distributed Air Pressure Reduction	=	Energy Savings
10 psi	=	7%
20 psi	=	14%
30 psi	=	21%
40 psi	=	28%
50 psi	=	35%
60 psi	=	42%
70 psi	=	49%



Sample Configuration of Compressed Air System with Automation, Storage and Pressure Control

How to Reduce Energy Costs in Compressed Air Systems

CONCLUSION



A systematic, evaluative approach to compressed air operation will produce an air system that is most likely to yield cost-savings. Obtaining a consultation from a compressed air system specialist can be a point of differentiation between a system that is operating inefficiently and one that is fully optimized. Reputable compressed air consultants collaborate with plant managers, as well as maintenance, production, project and planning engineers to provide the following benefits:

- Extensive operational experience and technical expertise.
- A truly consultative, data-driven approach that provides a full evaluation, not simply a quotation for equipment that satisfies a perceived need.
- Long-term, tailored solutions that respond to the unique needs of each application.
- A comprehensive approach to system optimization to ensure that individual components operate together effectively.
- System optimization through a collaborative partnership that yields solutions with maximum return on investment (in some cases this involves working with a plant's existing vendor).

By working with a compressed air consultant to audit their air systems and implement strategic energy-

saving initiatives, industrial operations can position their application for cost-savings as well as improved productivity and reliability.

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