



Compressed Air System Design, Operating and Maintenance Tips

An Online Continuing Education Course for Engineers

Course Number: M-2043

Credit: 2 Hours / 2 PDH / 2 CPD

Compressed Air System Design, Operation and Maintenance

Determine the Cost of Compressed Air for Your Plant

Most industrial facilities need some form of compressed air, whether for running a simple air tool or for more complicated tasks such as the operation of pneumatic controls. A recent survey by the U.S. Department of Energy showed that for a typical industrial facility, approximately 10% of the electricity consumed is for generating compressed air. For some facilities, compressed air generation may account for 30% or more of the electricity consumed. Compressed air is an on-site generated utility. Very often, the cost of generation is not known; however, some companies use a value of 18-30 cents per 1,000 cubic feet of air.

Compressed air is one of the most expensive sources of energy in a plant. The overall efficiency of a typical compressed air system can be as low as 10%-15%. For example, to operate a 1-horsepower (hp) air motor at 100 pounds per square inch gauge (psig), approximately 7-8 hp of electrical power is supplied to the air compressor. To calculate the cost of compressed air in your facility, use the formula shown below:

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

Where:

- bhp —Motor full-load horsepower (frequently higher than the motor nameplate horsepower—check equipment specification)
- 0.746 —conversion between hp and kW
- 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

Example

A typical manufacturing facility has a 200-hp compressor (which requires 215 bhp) that operates for 6800 hours annually. It is fully loaded 85% of the time (motor efficiency = .95) and unloaded the rest of the time (25% full-load bhp and motor efficiency = .90). The aggregate electric rate is \$0.05/kWh.

Cost when fully loaded =

$$\frac{(215 \text{ bhp}) \times (0.746) \times (6800 \text{ hrs}) \times (\$0.05/\text{kWh}) \times (0.85) \times (1.0)}{.95} = \$48,792$$

Cost when unloaded =

$$\frac{(215 \text{ bhp}) \times (0.746) \times (6800 \text{ hrs}) \times (\$0.05/\text{kWh}) \times (0.15) \times (0.25)}{.90} = \$2,272$$

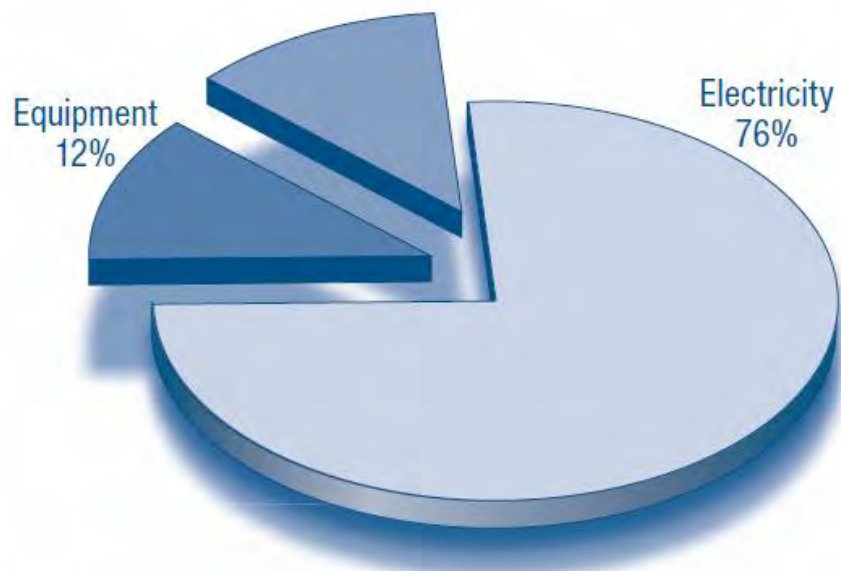
Annual energy cost = \$48,792 + \$2,272 = \$51,064

Suggested Actions

- Determine the cost of compressed air for your plant by periodically monitoring the compressor operating hours and load duty cycle.
- Use a systems approach while operating and maintaining a compressed air system.
- Adopt a plant-wide compressed air management policy to cut costs and reduce waste by eliminating inappropriate uses, fixing leaks, and matching system supply with demand.

Typical Lifetime Compressed Air Costs in Perspective—Costs Over 10 Years

Assumptions in this example include a 75-hp compressor operated two shifts a day, 5 days a week at an aggregate electric rate of \$0.05/kWh over 10 years of equipment life.



Eliminate Inappropriate Uses of Compressed Air

Compressed air generation is one of the most expensive utilities in an industrial facility. When used wisely, compressed air can provide a safe and reliable source of power to key industrial processes. Users should always consider other cost-effective forms of power to accomplish the required tasks and eliminate unproductive demands. Inappropriate uses of compressed air include any application that can be done more effectively or more efficiently by a method other than compressed air.

The table below provides some uses of compressed air that may be inappropriate and suggests alternative ways to perform these tasks.

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

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

Example

The table below shows inappropriate uses of compressed air in an automobile assembly plant. The plant took several action steps identified in the table to eliminate or reduce these inappropriate uses. Peak flow is identified in cubic feet per minute (cfm).

Operation	Original Peak Flow (cfm)	Number of Hours	Action Taken	Revised Peak Flow (cfm)	Peak Flow Reduction (cfm)
Open hand-held blow guns	200	6,500	Installed nozzles	50	150
Vacuum generator	1,000	5,000	Motor-driven vacuum pump	0	1,000
Personnel cooling	800	3,500	Used fans	0	800
Pneumatic actuators	750	3,500	Replaced with electric actuators	0	750
Total CFM reduction:					2,700

The plant audit showed that the energy used to generate the compressed air averages 18 kW/100 cfm. The aggregate electric rate at the plant is \$0.05 per kWh.

$$\begin{aligned}
 \text{Annual savings} &= [\text{kW per cfm}] \times [\text{cfm savings}] \times [\# \text{ of hours}] \times [\$ \text{ per kWh}] \\
 &= 18/100 \times [(150 \times 6,500) + (1,000 \times 5,000) + (800 \times 3,500) \\
 &\quad + (750 \times 3,500)] \times \$0.05 \\
 &= \$102,600
 \end{aligned}$$

Net savings:

Calculate electric energy costs for the motor-driven vacuum pump, fans, and actuators, and subtract these costs from the annual savings calculated to determine the net savings. Note that there will be a one-time cost of installation for the added equipment.

Suggested Actions

- Walk through your plant and identify all compressed air uses and, if possible, the flow and pressure requirements of each use.
- Take steps to eliminate any inappropriate uses. Consult with a compressed air systems specialist to see if other equipment (blowers, mechanical or hydraulic devices) will be more cost-effective for those applications.

Minimize Compressed Air Leaks

Leaks are a significant source of wasted energy in a compressed air system, often wasting as much as 20%-30% of the compressor's output. Compressed air leaks can also contribute to problems with system operations, including:

- Fluctuating system pressure, which can cause air tools and other air-operated equipment to function less efficiently, possibly affecting production
- Excess compressor capacity, resulting in higher than necessary costs
- Decreased service life and increased maintenance of supply equipment (including the compressor package) due to unnecessary cycling and increased run time.

Although leaks can occur in any part of the system, the most common problem areas are couplings, hoses, tubes, fittings, pipe joints, quick disconnects, FRLs (filter, regulator, and lubricator), condensate traps, valves, flanges, packings, thread sealants, and point-of-use devices. Leakage rates are a function of the supply pressure in an uncontrolled system and increase with higher system pressures. Leakage rates identified in cubic feet per minute (cfm) are also proportional to the square of the orifice diameter.

Leakage rates ^a (cfm)		Equivalent orifice sizes	
Pressure (psig)	1/64"	1/4"	3/8"
70	0.29	74.4	167.8
80	0.32	83.1	187.2
90	0.36	92	206.6
100	0.40	100.9	227
125	0.48	122.2	275.5

^a For well-rounded orifices, multiply by 0.61 for sharp ones.

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Leak Detection

The best way to detect leaks is with an acoustic detector, which can recognize high frequency hissing sounds associated with air leaks. These portable units are very easy to use. Costs and sensitivities vary, so test before you buy. A simpler method is to apply soapy water with a paintbrush to suspect areas. Although reliable, this method can be time consuming and messy.

Example

A chemical plant undertook a leak-prevention program following a compressed air audit at their facility. Leaks, approximately equivalent to different orifice sizes, were found as follows: 100 leaks of 1/32" at 90 pounds per square inch gauge (psig), 50 leaks of 1/16" at 90 psig, and 10 leaks of 1/4" at 100 psig. Calculate the annual cost savings if these leaks were eliminated. Assume 7,000 annual operating hours, an aggregate electric rate of \$0.05 kilowatt-hour (kWh), and compressed air generation requirement of approximately 18 kilowatts (kW)/100 cfm.