Energy saving in compressed air systems — how Norgren is helping to improve energy efficiency

Compressed air is often wrongly assumed to be cheap or even a ‘free’ source of power. A typical 1000 scfm installation will consume $32,000 of electricity a year. During its lifetime, energy costs represent 75% of the total cost of buying and running a compressor.

Consider then an inefficient system and the costs involved begin to rise rapidly. Numerous independent studies confirm that industry wastes around 30% of the compressed air it generates, equivalent to wasting $9,600 in a typical 1000 scfm installation.

Fuelled by the need for pollution control and increasing difficulty in extracting raw materials, energy saving and the efficient use of energy is one of the most important issues facing industry worldwide.

Norgren, world leader in pneumatic components and automation systems, has taken the initiative to help compressed air users to increase energy efficiency. By systematic self-examination and with the help of safety and energy saving techniques and products, there is the potential for large and small users to make substantial annual cost savings which directly increase overall profits, as well as making a valuable contribution to the wider issues.

Compressed air installation

A typical industrial compressed air installation consists of three main categories: the compressed air production plant, the distribution system and application equipment.

A compressor is powered by an electrical drive. Atmospheric air is drawn through a dust filter and compressed by a factor of up to ten times. Freshly compressed air is hot and contains moisture concentrated from the natural humidity of the atmosphere. Processing takes place through an after-cooler and water-separator before the air passes to an air receiver for storage.

Main and branched lines distribute compressed air throughout an industrial site. Basic conditioning is carried out in this system by the use of filters. Take off points will be terminated with an isolating valve, filter, pressure regulator and optional lubricator. The many applications attached to the distribution system can vary from a connection to a single tool.
to sophisticated and extensive special purpose machines and systems.

The main causes of wasted energy are leaks, pressure drops, over pressurization, misuse of jets and poor compressor management.

An example factory has an installed compressor capacity of 1,500 cfm, and average demand of 1000 cfm. It operates 24 hours per day, 7 days per week, for 50 weeks a year. Electricity costs 0.068 $/kWh (national US average 99). The compressor duty cycle is 75%. To evaluate the power needed: 4.5 cfm compressor capacity require 1 compressor horsepower. The total running cost is then $107,000 per year.

If the compressed air system has many of the commonly found problems, it is likely that around 30% of the air produced is wasted. Curing the problems will yield a fast payback and substantial savings of $ 32,100 in the first year.

**Leakage**

Because compressed air leaks do not make a mess like oil leaks, it is easy to ignore them. The continuous hiss of leaks is usually dismissed as part of the general background and is often drowned by the higher noise levels from machinery. Generation capacity is frequently increased needlessly, when simply fixing the leaks would have restored system efficiency.

At a considerable high price it is well worth establishing a planned maintenance routine that is intolerant of leaks. Leakage is the major source of energy loss in compressed air systems. A typical plant may lose up to 30% of its compressed air through poorly maintained pipe joints, fittings, couplings and equipment.

**Where to find leaks**

- **Aging pipework** particularly at corroded joints and take off points.
- **Flange connectors** where gaskets and pipe dope need replacing.
- **Fittings** that have worked loose or have had excessive strain placed on them.
- **Manifolds** with closely spaced connections. These can be easy to ignore when a leaking fitting is difficult to access.
- **Flexible hoses** with cuts and splits caused by strain and abrasion.
- **Couplings** with damaged seals. Grit may have been picked up during the break and make process.
- **Drain valves** found on air receivers, drip leg drains, filters and other equipment can become stuck open due to pipe scale and sludge or even intentionally left partially open to avoid the maintenance routine.
- **Pneumatic components** including tools, valves and actuators are all subject to worn and damaged seals resulting in leaks.
Isolate systems when not in use

Where a subsystem has unavoidable leaks or a natural idle consumption, it can be isolated from the air supply until it is required in service again. Simple shut-off valves (figure 2), or electrically operated soft start dump valves (figure 3) offer cost effective ways to isolate leaky systems that are used intermittently.

Estimating the leakage

For a particular installation get a feel for the percentage of air lost to leaks. Tests need to be conducted at night or other time when manufacturing is closed. Allow the compressor to fill the system to normal working pressure, then record the timing of the load/off-load cycle of the compressor as it does nothing more than sustain the leaks.

Compare this with the normal daily compressor cycle to estimate the losses. The actual losses are likely to be more. Devices and components used in machinery may well have dynamic leakage occurring during their normal cycle of use but no leak when not running.

Identify leaks by listening for a characteristic hiss. Examine suspect areas and if necessary spray on a leak detection liquid and watch for bubbles. Static leak rates to individual machines and local sections can be measured using a plug in flow meter.

Please note: audio leak detection equipment is available for plant-wide audits of large leaks even while production is operating.
Orifice flow data can be used to approximate the flow to atmosphere through holes of different sizes. The graph (figure 5) shows the relation between flow and hole diameter.

**Figure 5: Leakage rate for different hole diameters**

The basis for calculating the costs of flow losses is the waste formula:

\[ \text{Total cost} = 0.19 \times \text{operating hours per year} \times \text{flow scfm} \times \text{energy cost per kWh}. \]  

\( (0.19 \text{ is a factor relating kW to scfm for typical compressors}) \)

The cost of a single continuous leak from a 0.08 in (2mm) diameter orifice with 8 scfm is:

\[ 0.19 \times 8400 \times 8 \times 0.068 = $868 / \text{year} \]

The average leak will take around half a man-hour to fix and offer quick payback.

**Misuse of jets**

A major waste of compressed air is lack of consideration for the detailed specification and application of equipment. Frequently within a machine cycle, jets of air from nozzles are used to carry out processes such as dusting, cooling, separating and other tasks.

Sometimes due to the normal high throughput of a machine these jets are left permanently running. With most machines there will be times when the production process is intermittent or even at a halt. Jets that continue to run in these circumstances are incurring unnecessary costs. With a suitable valve and sensor, these can be controlled automatically so they are only on when required.

When applying jets ensure that the distance between the exit nozzle and the product is as short as possible, this will allow the supply pressure to be reduced. Air saver nozzles are designed to entrain and accelerate air, these produce the desired outputs with reduced supply pressures (typically 30 psig). Savings of up to twenty times can result.
Safety issues of hand held blowguns are of extreme importance. Selecting pressure regulation and blowgun types of the air saver and safety design, good practice can be adopted to reduce the risk of injury as well as saving costs (figure 6).

Figure 6: Safety blow gun with air saver nozzle

Over pressurisation

Many systems run at full line pressure with the only control being the compressor cut off switch. Pneumatic systems and individual components have an optimum operating pressure and flow for their particular application. Both under and over pressurisation will slow down production rates and over pressurisation additionally increases the amount of air consumed and wear in components.

The absence of pressure regulators in a system may indicate that equipment is being used at excessive pressures. Savings can be realised in many areas, including air tools, control valves and on the return stroke of large double acting cylinders. Check for correct lubrication, high friction will demand higher set pressures.

For a device or system that is over pressurised, the cost can be calculated by using a simple calculation. For example, a system is designed to run at 45 psig and consume air at 17 cfm. If it is supplied at 100 psig, the waste of air in scfm can be found using the following approach:

\[
\begin{align*}
CR_1 &= \frac{14.7 + P_1}{14.7} = \frac{14.7+45}{14.7} = 4.06 \\
CR_2 &= \frac{14.7 + P_2}{14.7} = \frac{14.7+100}{14.7} = 7.8 \\

To convert cfm into scfm:
Air usage at normal pressure &= CR_1 \times \text{air consumption} = 4.06 \times 17 = 69 \text{ scfm} \\
Air usage at high pressure &= CR_2 \times \text{air consumption} = 7.8 \times 17 = 132.6 \text{ scfm}
\end{align*}
\]

This represents a wastage of compressed air of 63.6 scfm. Using the formula from the previous page and the same operation time this wastage represents $ 6900 / year.
Double acting cylinders are usually applied to give a power stroke in one direction but simply return the piston rod in the other direction. If the control valve is connected to a single supply pressure, the return stroke will be at the same pressure as the power stroke thereby wasting energy.

Where large bore, long stroke or multiple cylinder systems exist, considerable savings can be made. Use a pressure regulator to reduce the return stroke pressure. Where several cylinders are involved, a single pressure regulator could feed a common low pressure supply to the changeover valves. Use control valves that can be reverse connected to provide dual supply porting (figure 7). Average air consumption saving can be measured using the formula:

\[
\frac{\pi (D^2 - d^2)}{4} \times L \times (CR_1 - CR_2) \times N = \text{saving in scfm,}
\]

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Where:

- \(D\) = cylinder diameter (in)
- \(d\) = piston rod diameter (in)
- \(L\) = stroke length (in)
- \(CR_x\) = compression ratio = \((P_x + 14.7)/14.7\)
- \(P_1\) = applied pressure (psig) - outstroke
- \(P_2\) = applied pressure (psig) - return stroke
- \(N\) = cycles per minute

Pressure drop

Pressure drops in a system are caused by resistance to flow by localized restriction and general friction in pipes and components. A distribution system constructed from large bore pipe keeps the velocities low therefore the friction low.

Working velocities should be under 20 ft/s in main line. Increasing the source pressure to compensate for undersized systems increases compressed air production costs. Every 14.5 psig of unnecessary pressure drop leads to an increase of 7% in generating costs.

Pipe routing should have gentle sweeping bends where possible. An elbow fitting has resistance equivalent to 5.2 ft of straight pipe. Use ball valves at isolation points. These have an equivalent resistance of just 1.3 ft of straight pipe, less than half the resistance of a gate valve. When selecting primary components such as filters, it is important to have units large enough to realise no more than 1.5 psig pressure drop (with a new element) at the desired working flow rate.

Figure 7: Reverse connected valve with dual supply pressures
Never match a filter’s maximum flow rate to the desired flow rate. Fitting a smaller filter is false economy. Due to the smaller surface area of the element (figure 8) it will give a higher initial pressure drop and contaminate more quickly.

**Filtration**

Filtration in various parts of a system is essential for the removal of water and solid particles. This ensures long life and trouble free operation of components in compressed air systems. The micrometer size of the filter elements determines the air quality.

The standard size for the vast majority of applications is 40 µm. Finer sizes of 5 µm and 0.01 µm are available for special applications but size for size will be more restrictive (figure 9). Fine grade filters should be installed based on their specific applications. Do not filter the whole of a sub-system to a fine grade if the majority of connections to it need only standard grade.
Filters can be specified with pressure drop indicators, also known as $\Delta p$ indicators or service life indicators, which can be pneumatic or electrical, as standard (figure 10). These give a visual or remote indication of when a filter element is becoming too restrictive and needs replacing. Changing the elements at this point means significant energy saving (figure 11).

**Compressor management**

Large compressor installations are likely to be fitted with sophisticated power and load management systems as part of the package. Simpler compressor installations with intermittent use could also benefit from automatic compressor management systems. These use figures of expected consumption rate, storage volume and pressure to tell the compressor how long to run in an off load condition before shutting down during times of low or no demand.

**A safety conscious system helps to save energy**

Much of the legislation, standards and codes of practice necessary to ensure safe systems deal with correct selection, installation and maintenance of equipment and systems. This includes safety details such as the use of air fuses and replacement of old polycarbonate bowls with new ones or with metal bowls.

Compliance with safety requirements and advice inherently addresses many of the issues appropriate to energy efficient systems. Add specific energy saving awareness and a few fast pay back techniques and pneumatic systems of all sizes can realize significantly reduced operational costs and increased reliability for years to come.

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