
Compressed air

Opportunities for businesses



Contents

Compressed air in industry	03
Air compressors – technology overview	05
Opportunities for energy saving	09
Glossary	28
Appendix	30
Go online to get more	31

Compressed air in industry

Compressed air is very versatile and almost all industrial businesses use it - in fact, over 10% of electricity supplied to industry is used to compress air.

MENU

The proportion of energy used to produce compressed air varies between business sectors. In some cases it can be as much as 30% of the total site electricity usage. Compressed air can be used for instrumentation, control, hand tools and to drive processes. The business sectors that use the most compressed air in the UK include:

- Aircraft manufacturing.
- Cement.
- Ceramics.
- Chemicals, including pharmaceuticals.
- Electronics.
- Engineering.
- Food, drink and tobacco.
- Foundries.
- Glass.
- Insulation materials.
- Minerals.
- Motor car manufacturing and aftermarket.
- Paper and board.
- Power generation.
- Rubber and plastics.
- Steel.
- Textiles.
- Water treatment.

The process of compressing air can be wasteful. Of the total energy supplied to a compressor, as little as 8-10% is converted into usable energy at the point of use. This makes it a very expensive method of transferring energy.

Despite the high cost of production, many systems waste around 30% of the compressed air through leaks, poor maintenance, misapplication and poor control.

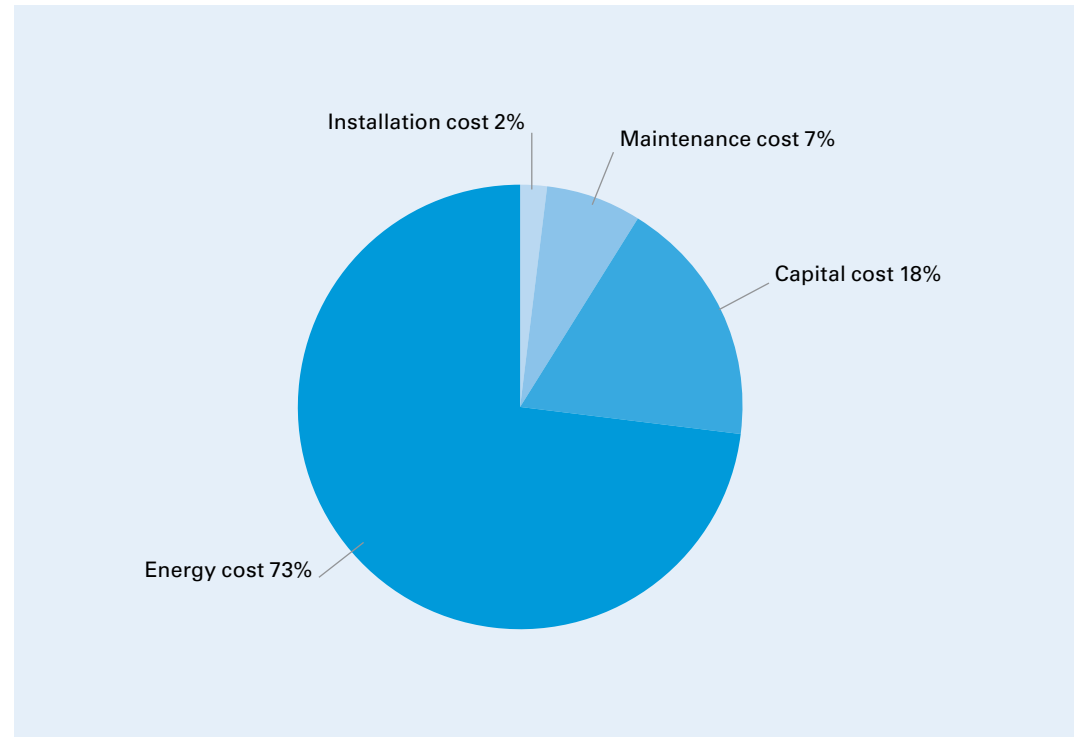
[Figure 1](#) (on page 4) shows that, over a ten-year life of a compressor, the cost of energy to run the system far outweighs the capital investment. It also shows that maintenance accounts for 7% of the total costs, yet this is a crucial activity for maximising the energy efficiency of any compressor.

This overview guide of compressed air demonstrates how action can be taken to reduce waste and save energy and money.

Fact:

Annually, UK industry uses over 10TWh of electricity to compress air – equivalent to the output of almost 1.5 power stations and over 5 million tonnes of CO₂ emitted to the atmosphere.

Figure 1 Compressor costs over a ten-year life

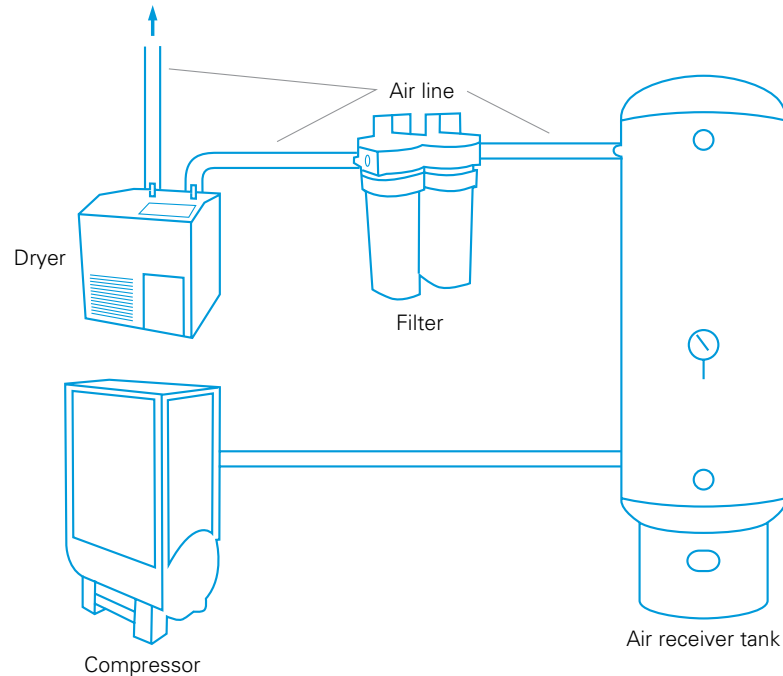


Air compressors – technology overview

Before attempting to improve the efficiency – and therefore the cost of compressing air, it is important to gain a basic understanding of the compressed air system.

A compressed air system will usually have the components shown in Figure 2 and described right.

Figure 2 A packaged compressor



Note: in most cases will incorporate an integral oil cooler and aftercooler.

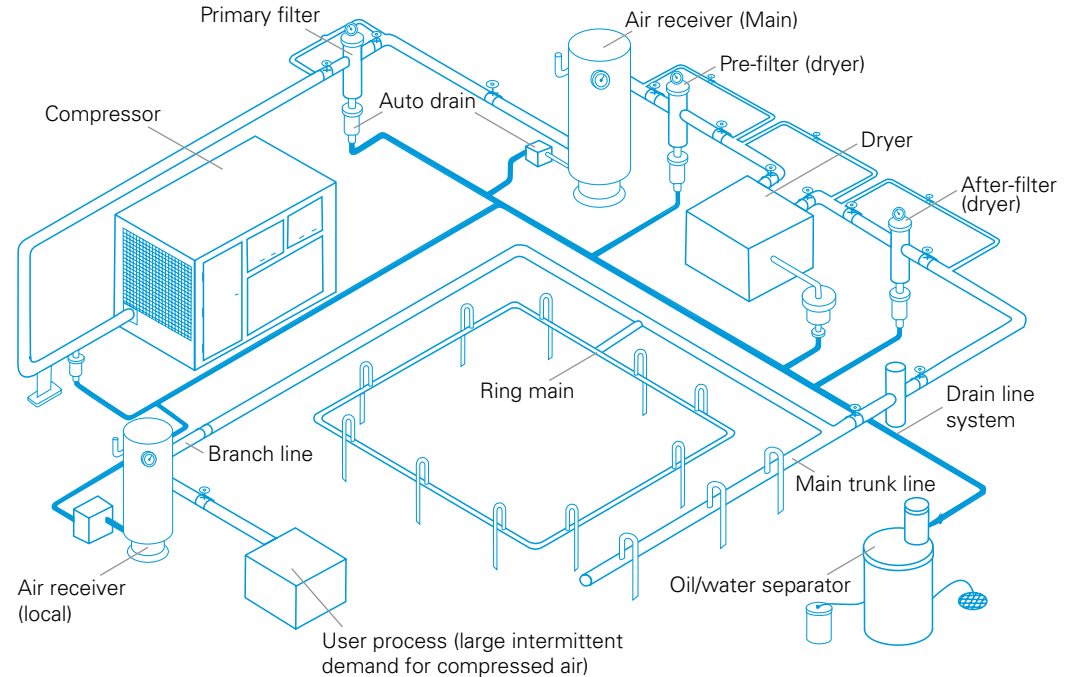
The **compressor** takes in air and compresses it to the required pressure – good control and maintenance are key to saving energy here. The **air receiver** acts as a reservoir to store and cool the compressed air and helps to ensure that the system can cope with variations in demand. **Filters** and **dryers** treat the air to remove impurities such as water, dirt and oil that are present in the ambient air being drawn into the compressor and those added by the compressor. The impurities are filtered out, with liquids removed from the system by condensate **traps**.

Most industrial users will have a compressed air system installed. These systems will normally consist of the above components feeding a distribution system running throughout the factory to the end-use equipment such as pneumatic drills supplied through a flexible hose.

Figure 3 shows how the components could be set up in a system.

Some businesses will have portable units, which have all the main components of a compressed air system. They are usually used for small-scale applications or when a mobile source is needed.

Figure 3 A typical air compressor system



Types of air compressor

Typically, industrial systems operate at pressures of 600-1,000kPa(g) (6-10bar(g)) using a packaged rotary air compressor (such as a rotary screw or rotary sliding vane), or a reciprocating/piston compressor. However, for applications with high flow requirements at these pressures, centrifugal type compressors are often used.

The **packaged rotary air compressor** is the most commonly used type, as it has the lowest capital cost with relatively low noise levels, simple installation and low maintenance costs. The most widely used of these throughout industry is the **rotary screw air compressor** as it has proved to be reliable and generally only requires a routine maintenance schedule. It also provides the widest range of products to choose from. These machines are available in lubricated and oil-free versions.

Typically, the power rating of single-stage rotary screw compressors range from 2.2kW to over 400kW, with the more energy efficient two-stage rotary screw compressors ranging from 75kW to 900kW.

Rotary sliding vane compressor models range from 1.1kW to 75kW. These machines are very quiet and easy to install in decentralised systems and laboratories.

There are still many heavy duty industrial double acting, two stage, water cooled **reciprocating piston compressors**, in service, with sizes up to and over 450kW. While these often provide equal, or better, specific energy consumption to that of rotary compressors, they can suffer from reduced performance levels as parts begin to wear therefore, extensive maintenance and overhaul are needed to overcome this potential reduction in performance. As a result, reciprocating compressors can be costly to maintain by comparison to packaged units. They are also expensive and noisy with foundations often required to site medium to large-sized units, which can add significantly to installation costs. However, reciprocating compressors are still the main machine used for high pressures applications from 30 to 400 bar and for special gases.

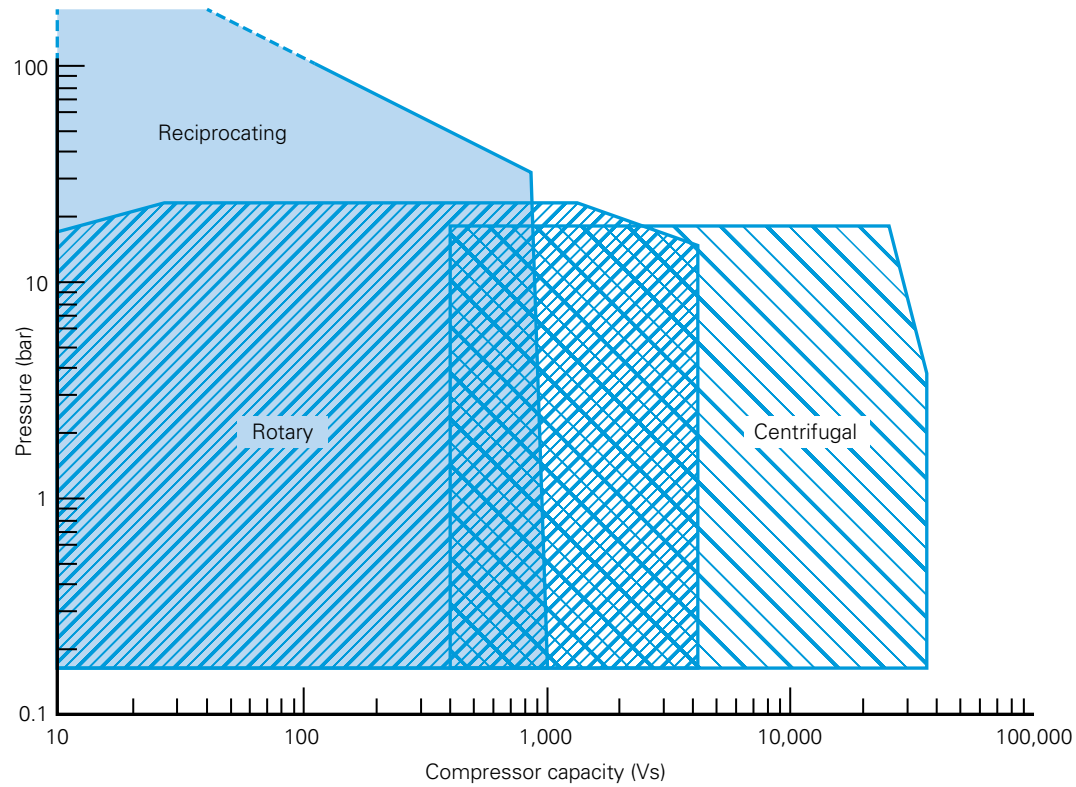
Air-cooled, receiver-mounted reciprocating compressors are popular, being simple and low cost. They are often used for small light duty industrial or DIY applications, with models ranging from 0.5kW to 5kW.

In applications requiring a high volume of air, **centrifugal compressors** are often used. Although available with a flow rate from around 200 litres/s, this type of compressor is no more efficient than the rotary screw unit until flow rates of around 1,000 litres/s are needed. In this case the centrifugal compressor begins to dominate the market because of unrivalled energy efficiency and inherent oil free design.

Remember that where the various compressor sizes overlap, one technology may prove more energy efficient and controllable than the other on a particular duty, and maintenance costs between the different technologies can vary considerably. Therefore, when selecting an air compressor, it is important to look at the total cost across the system, over the life cycle of the equipment.

The different types of compressors and size ranges are summarised in [Figure 4](#) on page 8.

Figure 4 Compressor capacity and pressure limitations



Opportunities for energy saving

Usage and housekeeping

Ensuring that compressed air is used appropriately can produce significant savings for little or no capital outlay.

Because compressed air is so convenient and easy to use, it is frequently misused in many businesses. People perceive air as being a free commodity and are not aware that the cost of compressed air is many times that of other energy transfer methods. As a result, it is commonly used for applications that could be achieved by cheaper methods. For example, people may be using compressed air to blow swarf, dust or shavings from machinery, particularly in the engineering, woodworking and textiles sectors. This is usually done because it is seen to be a low-cost solution to a problem, when in fact the reverse is true.

As many of these following measures may affect company policy and/or production, it is important that whoever is responsible for implementation has the authority to make or recommend this level of action.

Write a usage policy

In a usage policy, detail the acceptable uses for compressed air and suggest safe and easy alternatives. Ensure that equipment or tools are provided for the alternative methods suggested. A compressed air usage policy should:

- Appoint a senior manager with responsibility to ensure overall coordination of the management of the system.
- Set objectives with regard to:
 - Each department's requirements for air pressure and quality.

- Raising awareness of all those who use compressed air.
- Establishing compressed air costs.
- Setting targets for reducing avoidable waste.
- Implementing a maintenance programme.
- Defining servicing and installation guidelines using trained personnel.
- Defining a purchasing policy.

This overall management approach to compressed air systems has the same principles as general energy management. This approach is essential for the system to reach the maximum reduction in energy consumption.

The compressed air manager should also be responsible for control of changes to the system.

On many occasions what was originally an efficient system becomes inefficient as users are added with no central coordination. This can affect pressure levels, operating hours, reliability and consequently running cost.

Train staff

Make sure staff members are aware of the costs associated with compressed air. Undertake a training programme to show how staff can contribute to saving energy by discussing the above issues/policy with them. When doing so, it is important to involve staff and give them the opportunity to provide feedback – failure to do this could result in them reverting to their previous way of working. Companies that make the biggest savings have trained staff to understand the cost of producing compressed air, the interdependency of the components of a compressed air system and the importance of saving energy. It is of most importance to ensure all shop floor workers are aware of the cost of air leaks and misuse and that these are reported to the compressed air manager as soon as possible.

Fact:

Even when idling, compressors can consume between 20-70% of their full load power.

Safety first!

Check that the person carrying out changes to a compressed air system has the relevant skills and always ask for expert help if in any doubt.

Switch off

Watch what happens to air-consuming equipment when there is no production, for example, during a tea break or job change. Is equipment left working when not required?

Instigate switch-off routines and include them in the compressed air usage policy. Consider whether it is appropriate to do this for each process and plan when they will be implemented. This process could even be automated using time-operated solenoid valves or interlocks, which allow a compressed air line to operate only if another piece of equipment is already running. Another, more complex, option would be to use an interlock, with infrared or laser sensors to detect when there is process or product flow to control solenoid valves to isolate and apply the air as and when required. These systems are easy to install and, usually, more than pay for their cost in energy savings.

Does compressed air need to be used at all?

Look at all of the air-consuming equipment and ask whether there are alternatives that will do the job. For example, compressed air is often used for pick-and-place applications, where the air is used to generate a vacuum to lift a product or component from one location and take it to another. A modern, basic, vacuum generator will consume, for example, 4 litres/s of compressed air at 700kPa (7bar) working pressure (1.5kW of motor power). A vacuum pump uses only 0.44kW to generate the same volume of vacuum. Even where it is not worth installing a central vacuum system, multi-stage compressed air-driven vacuum ejectors can save 60% of the air used by a single stage ejector. Some hand tools will be best run using compressed air, but many will not. For example, using an electrically powered angle grinder would typically use in the region of 540-900W. Using a compressed air-powered equivalent the consumption will be nearer 3.5 kW. Typical energy consumption is equal to 300W/litre of compressed air used (700l/minute divided by 60*300W = 3.5 kW). In this example, compressed air is wasteful.

In all cases the overall operation and the pros and cons of each tool type should be evaluated as well as the running costs. For example, air tools can be operated to stalling point whereas doing so with an electrical tool will burn out the motor. In addition, air tools are much lighter than the equivalent electric tool, can provide very accurate torque control and reduce the risk of repetitive strain injury for operators.

Battery operated tools are becoming popular replacements for air tools on some production lines.

How is the compressed air delivered?

Ask if the system is delivering compressed air via the most efficient and effective method. Inspect air-consuming equipment and ask if the same job could be done using an alternative, more efficient method. For example, many blow guns are simple open-ended pipes and, while these are effective, they are certainly not efficient and may contravene H&SE regulations that state that the outlet pressure should not exceed 2.2 barg. Fitting a venturi-type nozzle can

deliver the same performance, but can consume up to 60% less compressed air and have the added benefit of being much quieter and safer.

Measure the air pressure

Regulating the air pressure to that required by the end-use devices can also result in excellent savings. Look at the manufacturer's stated requirements and compare these with the actual pressure at which the devices are operating on the site. If the requirement is less, fit a pressure regulator local to the device, ensuring that the air pressure to the device is maintained at the required level. Operating at too high a pressure not only wastes compressed air but can also increase wear, leading to leaks or equipment failure and increasing maintenance costs.

Another example of misuse is in spraying applications. To achieve an even finish and avoid drips, some operators use a higher pressure than necessary rather than selecting the correct nozzle for the application. The consistency and desired quantity of paint to be applied determines the operating pressure and the

nozzle diameter of the spray gun. These two values influence the compressed air requirement considerably, and the selection of spray gun is crucial in getting the right finish while being as efficient as possible. This example illustrates the principle – find the inefficient habits, seek specialist advice regarding the best practice then train operators in using the optimum nozzle.

Air is free – but compressed air is not. Use alternatives where possible.

Top tip:

Waste and misuse of compressed air are common in industry. Minimising these usually offers the greatest potential for no-cost and low-cost savings in a typical system.

Leak reduction

All compressed air systems have leaks, even new ones. Reducing air leaks is the single most important energy saving action for most sites.

It is impossible to calculate an average leakage rate but a target for a well-maintained system should be around 5 - 10% of air generated lost to leakage. The leak rate on an unmanaged compressed air system can be as much as 40-50% of the generated output and in certain applications even higher figures have been measured. It is worth mentioning here that the amount of compressed air lost to leakage is reduced at a lower system pressure (see section on Generation and control on [page 13](#) and 'Artificial demand' in the glossary). When they occur upstream of pressure regulators, leaks are effectively unregulated air demands and increasing system pressure causes every such leak in the system to pass more air.

The sources of leakage are numerous, but the most frequent causes are:

- Leaking hoses and couplings.
 - Use of jubilee clips that develop leaks.
 - Leaking pipes, flanges and pipe joints.
 - Strained flexible hoses.
 - Leaking pressure regulators.
 - Air-using equipment left in operation when not needed.
- Compressed air leaks represent a safety problem due to factors such as blowing air and noise. Furthermore, they have the potential to interrupt production through equipment failure and lead to additional costs through:
- Fluctuating system pressure. This can cause air tools and other air-operated equipment to function less efficiently potentially affecting or stalling production. It can also bring about quality issues. For example, a torque wrench used in production may have been calibrated at a 600kPa(g) (6bar(g)) working pressure. If high leakage losses cause pressure reductions in the area, the torque wrench will not tighten correctly.
 - Reduced service life and increased maintenance due to unnecessary compressor cycling and running time.
 - Excess compressor capacity required on line.

When the cost of all leaks and wastage due to inadequate maintenance is calculated, the outlay for purchase of suitable detection equipment and replacement parts is almost always justified.

Have an ongoing test and repair programme for leaks. Note that leaks reappear and a 3mm hole could cost over £1,000/year in wasted energy.

There are three main ways to check for leaks:

- 1. Listen** – run the compressor without using any air tools or equipment. Make sure that there is as little background noise as possible and then walk slowly around the system listening for hissing or rasping sounds. Check all joints, flanges and valves carefully.
- 2. Look** – make up a simple solution of soapy water. Run the system without using air tools or equipment. Apply the solution to all pipework (especially joints) and then look to see where it bubbles up, indicating air leakage.
- 3. Detect** – hire or purchase ultrasonic leak detection equipment from the compressed air system supplier.

Using ultrasonic equipment is the most convenient way to check for leaks.

Tag the leaks or mark them on a plan of the system.

Before attempting any repair work, make sure that the system is depressurised. If there is any doubt about how to proceed, then a supplier should be contacted.

Where possible, avoid using compressed air for drying applications. In the food canning industry, for example, air knives are sometimes used to blow excess water off cans at great expense in terms of the energy required to compress the air in the first place. Alternative solutions such as blowers, heaters or even using the rejected heat from the plant compressor should be considered.

¹ Based on a tariff of 8p/kWh

Fact:

Have an ongoing test and repair programme for leaks. Leaks reappear and a 3mm hole could cost over £1,000/year in wasted energy, enough to cover the cost of buying an ultrasonic leak detector.

Improving intake air quality, generation and control

Even before air is compressed, there is an opportunity to make savings.

Effective generation and control of a compressed air system will improve system efficiency, reduce wastage and improve the performance of the end-use equipment. Try to achieve a system where equipment is set up to deliver air by the most efficient and effective means according to demand requirements.

Improving the quality of intake air

Check the location of the intake

Ducting compressor intake air from a suitable place outside of the building can reduce costs. This location should be clear of any warm air exhaust ducts, protected from the elements and free from possible obstructions that may restrict airflow. Measure the temperature at the air intake and compare it with the external temperature. Intake air to the compressor should be kept as close to the outside ambient air temperature as possible. Warm air is less dense than cold air so the fixed volume compressor will develop less mass flow at higher inlet temperatures. For every 10°C the

inlet air temperature can be reduced the compressor efficiency will be improved by 2.5%.

Check the condition of the air intake filters

Dirty, blocked or obstructed filters reduce the flow to the compressor or increase the pressure drop of the compressed air system at the output of the compressor. This can cause increased energy use by up to 4%. Make sure the maintenance of inlet filters is included in any maintenance schedules.

Generation and control

Fact:

You can save 1% of energy use by reducing the air intake temperature by 4°C.

All compressed air systems have a minimum operating pressure that is necessary for the using equipment installed in the system to function correctly. In most systems this is usually around 600kPa (6bar). However, when a higher pressure than strictly necessary is applied, the system will consume more

compressed air and, therefore, more energy. Typically, 150kPa (1.5bar) more pressure will force the unregulated uses in the system to consume 20% more air. The same analogy applies to unregulated system leaks – the more pressure that is applied to a leak, the more air that leak will consume. Increasing the pressure by this amount (that is, 150kPa) will also increase the full load power consumption of the compressors by around 9%.

Match control methods to demand requirements

Some types of control are more efficient than others, depending on the compressor type and its operating conditions. For example, some compressors are more efficient when demand is running 70-100% of compressor capacity using a modulating inlet throttle. This type of throttle restricts the flow of intake air and thus controls the output over a close pressure range.

However, when demand is less than 70% of capacity it will be more efficient to use an on-load/off-load control. On-load/off-load control is where the compressor is either running at full-load with the inlet valve completely open, or off-load, where the inlet valve is completely closed.

This typically operates over a pressure range between 0.2 and 0.5bar.

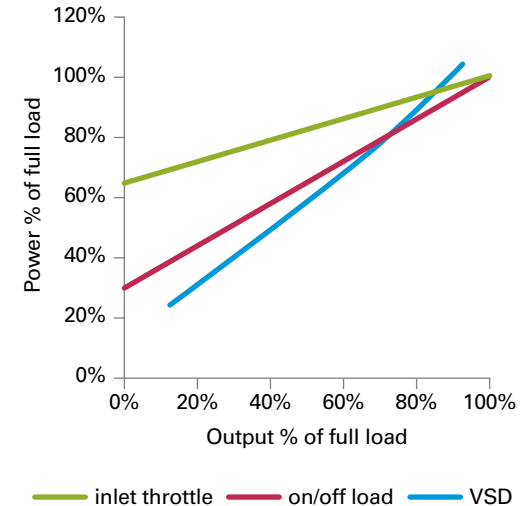
Most configurations of compressor are also now available with variable speed drive which provides more efficient running at lower demands and with close pressure control than either of the above two options. However, at loads over 75% it is also more costly to operate a VSD than an on-load/off-load compressor.

Control of centrifugal compressors is also very different to screw or piston compressors. These have a very efficient operating range between around 70 and 100% of capacity, depending on the compressor, but can be very inefficient outside this range. This is an area where much development work is taking place, with the latest types now being offered with variable speed drives.

It is important to analyse the system demand and then identify the most efficient method of control for the conditions. Ask at what capacity does the system usually run. Then decide which is the most efficient type of control to suit this capacity.

Figure 5 shows the typical control characteristics for rotary compressors.

Figure 5 Rotary screw control characteristics



Automatic shutdown control

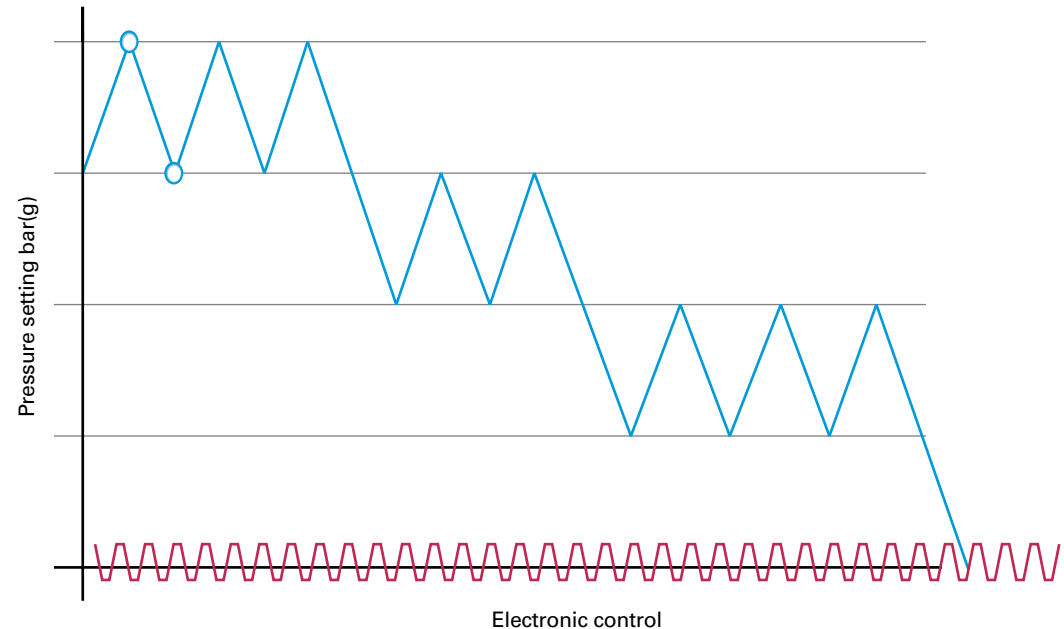
In some cases, an automatic shutdown control may be introduced, switching the compressor to stand-by mode if there has been no end-use demand for a predetermined length of time. This takes into account the maximum number of 'starts' that the compressor motor is allowed to avoid the motor overheating – check with the manufacturer for further information.

Controlling multiple compressors

In situations where the system is supplied by multiple compressors, cascade pressure control has traditionally been used to determine the sequence in which the compressors operate. Cascade pressure control maintains air pressure by automatically bringing in more compressors when the pressure drops to preset points. However, it is not the most efficient method as it only runs the system at minimum pressure at the periods of highest demand. Cascade can also create a large pressure differential, usually 50kPa (0.5bar) per installed compressor.

A more efficient method of controlling multiple compressors is via an electronic sequential controller, which can control multiple compressors around a single set pressure. These systems also make compressors available to match demand as closely as possible. An example of this is instead of using a 100kW compressor at 60% utilisation, the system will select two 30kW compressors at 100% utilisation. As well as operating up to 12 separate air compressors in a pressure window of only 0.2bar, this type of system can also predict when to start/stop or load/unload the next compressor in sequence by monitoring the decay/rise in system pressure. So rather than leaving

Figure 6 Cascade versus electronic control



potentially redundant compressors idling, the system shuts them down after a predetermined period. They can also be set to vary the pressure according to production requirements, for example, lower pressure at weekends.

Figure 6 shows the pressure difference between traditional cascade and modern electronic control systems.

Control the whole system

In addition to improving control of the individual compressors, better control can be applied to the compressed air system as a whole. System control can consist of using simple isolated controls, such as:

- Time-operated valves that control different 'zones' of the compressed air circuit.
- Interlocks that allow the compressed air circuit to open only when a particular air-using machine is running.
- Sensors that detect when a product is present and then open the compressed air circuit.

These controls could be integrated within a building management system or a plant/process control system. These systems can be used to monitor system performance as well as being used to control the compressed air plant. An additional feature normally found in this type of facility is the ability to set alarms that indicate plant faults or when threshold limits have been reached. This allows corrective action to be taken very quickly. Such systems are not expensive compared with the savings they can often produce.

Air Treatment

During the process of compressing and distributing the air impurities are added that find their way into the system. These reduce air quality and can significantly affect the system efficiency, including the performance and life of the end-use equipment. Therefore, in most compressed air systems, the air will require some form of treatment to ensure that it is of a suitable quality. Air treatment is energy intensive and air should only be treated to meet the minimum levels required. Energy is often wasted due to poor installation and maintenance of treatment equipment, and because the system has not been adjusted following a change in demand. Treatment systems and components are normally specified in accordance with ISO 8573 which provides classification in terms of oil, particulate and moisture in the system.

Check air quality and pressure dew point –

If only some processes need the air to be treated to a specified level, consider treating the bulk of the air to the minimum acceptable level, and then treating a smaller portion to the higher specification using a separate, point of-use treatment system. A typical air-treatment system will comprise of the following components:

Aftercooler – when generated, compressed air is hot (typically 80-170°C). The aftercooler, which is normally inside the compressor package, cools the air as it leaves the compressor either via a water jacket that surrounds the air outlet or an air to air heat exchanger if the compressor is air cooled. As the air is cooled, the moisture within the air forms a condensate, which is generally removed using a water separator and drain trap. The temperature of air exiting the aftercooler is typically around 35°C.

Water separator – this filter removes water or condensate before air enters the air receiver.

Air receiver – the air receiver is a temporary storage tank that provides a 'buffer' of air to ensure a consistent supply across the system. Due to the size of these vessels and, where possible, cool locations, a lot of moisture will condense here when they are located before the dryer, and so these should always have drain traps fitted to remove condensate.

Pre-filter – situated before the dryer, the pre-filter removes particulates from the air (typically down to 3 microns) as well as condensate. When the compressor is of the lubricated type the prefilter also removes oil.

Dryer – this equipment allows the air to be dried to a temperature at which water will condense in the air network known as the pressure dewpoint (PDP). Depending on the air quality required dryers vary greatly in design, ranging from desiccant dryers that are used to achieve a very low PDP of between -20 and -70°C, to refrigerated dryers that deliver a PDP of around +3°C. Adjustable dew points should be considered where the air does not need to be dried to such a high quality. The high level of treatment provided by desiccant dryers means that they tend to use more energy. They should always be equipped with dewpoint sensing controls to avoid excessive regeneration and wasted energy. [Table 1](#) on the following page, shows the relative running cost of different types of dryers.

After-filters – these filters can provide further removal of particulates for critical applications as well as oil and oil odours if required. They are typically of the finest retention capability.

Condensate drains – these are used to remove condensate from the system at points where water collects (typically, receivers, dryers, filters, pipe drain points) and can be another source of significant energy wastage.

Commonly, condensate is removed using a timed solenoid drain that uses compressed air to exhaust the condensate to a condensate management system at a predetermined interval for a set period of time. Typically, the valve opens for 10 seconds every 15-30 minutes. However, to operate correctly, these drains require adjustment to take account of changing ambient conditions and/or system load. When set incorrectly, they discharge significant amounts of air or fail to remove all of the condensate resulting in downstream contamination. They can also be prone to sticking in either the open or closed position should the vent orifice become damaged or contaminated. This can lead to corrosion in the system, causing air leaks as well as delivering poor quality air at the point of use.

A more energy efficient option is the no-loss type electronic condensate drains that use full bore to discharge rather than a small orifice. These do not waste compressed air, as this type of drain usually works by sensing an upper and lower liquid level. When the upper level is reached the valve opens and uses compressed air to force out the condensate. When the liquid reaches the lower sensor the air supply is shut off thus preventing compressed air from escaping and being wasted.

Table 1 Summary of dryer types

Pressure dewpoint, C	Dryer type	Filtration	Additional cost	Comments
+3	Refrigerant	General purpose	3%	The most common type of dryer available for almost any demand.
-20	Sorption	None	<3%	Drum type dryer specific to oil free screw compressors, very low running cost.
-40 to -70	Desiccant	Pre & After	10-20%	Most common for lower dewpoints. Use heat or air to regenerate. Consider other heat sources e.g. steam to minimise running costs.
+5 to -40	Membrane	None	10-25%	Small sizes only, purge losses very high at low dewpoints.

The running costs given above are typical but if they are incorrectly sized or not properly controlled these costs can be much higher.

Maintenance of the air-treatment system

Below are a number of maintenance and housekeeping actions that could be undertaken to ensure that the air-treatment system is operating efficiently.

During energy efficiency surveys, treatment systems can often be overlooked as they are frequently perceived to be necessary and not changeable. The pressure drop across a treatment system with the compressors on full load should not exceed 0.5 bar. A system with a 100kPa (1bar) pressure differential across a dryer/filter can be wasting as much as 3% of the total air-generation costs.

General energy saving advice

- Measure pressure drop across the treatment package. If this is in excess of 0.5 bar check the individual components and clean or replace the necessary filters.

Fact:

For a typical screw compressor operating at 700kPa(g) (7bar(g)), for every 50kPa (0.5bar) drop in pressure, a compressor will require 3-4% less energy.

- Replace manual condensate drain valves with zero-loss electronic condensate traps. Measure the dryer inlet temperature. This should not be more than 35°C with the compressors on full load. If it is, try to improve compressor cooling airflow, reduce the compressor inlet air temperature and ensure that the oil and aftercooler heat exchangers are clean. Increased inlet temperature will dramatically affect a dryer's performance, for example, at 40°C the capacity is reduced by almost 20%.
- Make sure controls are working. Check the condensate collection system is working correctly and is not constantly bleeding air. If it is repair or replace drain traps.
- Use an oil/water separator to separate condensate to waste oil and water. The bulk of condensate is separated into water that can be disposed of via normal foul drains. The oil/sludge forms only a very small fraction of this volume, so disposal costs are dramatically reduced. Installation of these devices can pay for themselves very quickly. Remember it is illegal to knowingly discharge condensate to surface or ordinary foul drains.

Specific energy saving actions for refrigerated-type dryers

- Change filter elements if the pressure drop across them is excessive. Use a pressure gauge to measure the pressure at the inlet and at the outlet of each of the filters. If the difference is more than 40kPa (0.4 bar), clean or replace filters as per manufacturer's instructions.
- Check refrigerant gas levels – a loss of just 15% of the refrigerant can lead to energy consumption doubling.
- Check the glass sight level indicator. If this is less than the minimum, top up the refrigerant; if this is not possible, contact the manufacturer for further advice.
- Ensure heat exchangers are clean internally and externally. Visually examine the heat exchangers.
- If there is any dirt, take the dryer off-line and clean them with a stiff brush, taking care not to damage them.
- Check controls, for example, by varying the adjustable dew point, to see if they are working correctly.
- Ensure that there is adequate ventilation.

Ensure that the dryer has adequate space around it and the room has sufficient air movement. Rejected heat from the condenser must be able to be removed – ensure that the grilles are free from blockages and dirt by cleaning them with a stiff brush.

Specific energy saving actions for desiccant-type dryers

- When checking controls, ensure the resulting actions of the dryer meet expectations, such as checking the drain trap works as expected.
- Ensure all valves are working. Test valves to make sure none are sticking open or closed nor are they passing air when they should not.
- Change filters if the pressure drop is excessive.
- Check purge rates and cycle times. Fitting a dewpoint sensing controller can optimise this activity, resulting in less purge energy being used.

Air receivers and distribution systems

Minimising pressure fluctuations

The majority of installations have air receivers sized with only the compressor in mind. It is important that there is sufficient stored volume in the system so that short periods of high demand can be met without the air compressor having to continually load/unload. This is known as 'useful storage' and is particularly important if there is highly fluctuating air demand. In combination with an appropriate pressure control system, a correctly-sized air receiver can reduce or eliminate pressure fluctuations and minimise off load power consumption at the compressor. Because variable speed drive and centrifugal compressors produce air at constant pressure separation of the supply and demand sides should not be necessary.

Variations in pressure influence repeatability and performance of production equipment. Therefore, by eliminating these fluctuations in air pressure, not only is less energy consumed, but also productivity and performance can also be enhanced. It is therefore important to consider receiver capacity at the end user level to meet local intermittent demands as well as at the compressor.

Distribution systems should be sized to the demand and designed to allow adequate airflow. The pressure drop from the treatment system discharge to the heaviest user at the far end of the piping network should not exceed 0.2bar. Use ring mains to minimise pressure losses and ensure the air is distributed evenly. Where this is not practical the system should be sized to prevent pressure drops down long pipe runs. The British Compressed Air Society recommends a maximum velocity of 6m/s in main distribution pipework with up to 15m/s in short drops to using areas. Some materials minimise pressure drop and are light and easy to install, such as smooth bore aluminium.

Design the distribution system to allow zone isolation so areas can be shut down when not in production. In many older systems the pressure is higher than required due to bad distribution systems. Linking lines to provide a ring or upgrading short sections of pipework can make a big difference; a bottleneck in just one area can mean the whole system needs to be increased in pressure to compensate.

Waste heat recovery

The compression process generates tremendous amounts of heat. Typically, the temperature of the air exiting the compression stage is 80-170°C. This air must be cooled before it can be passed through the distribution system. Normally, this is achieved by air or water cooling. The heat removal process can itself provide useful energy savings. The extracted heat from these removal processes is often wasted with heat being allowed to dissipate to atmosphere.

It is possible to recover most of this heat and use it for other means. In most cases, 25-80% of the electrical energy supplied to a compressor can be recovered and used for:

- Space heating for an adjacent building.
- Domestic hot water heating.
- Preheating boiler inlet air or feedwater.
- Process heating or preheating.
- Producing warm air to keep product and packing materials dry.
- Providing heat to regenerate desiccant dryers.

This guide highlights areas to consider with heat recovery but for more detailed advice see [The Heat Recovery section of the Carbon Trust site](#).

Reuse the heat produced

Think about the logistics of transporting the waste heat to where it is needed. The heat can be transported either by ducting the warm air, or by using heat exchangers to heat air or pumped water.

Seek technical advice to implement any opportunities that have been identified for waste heat recovery. This may be available in-house or may involve use of an external consultant or the compressor supplier.

Get as much advice as possible as a poorly designed system can compromise the efficiency and reliability of the compressor. In particular, if air is to be ducted away from a compressor package into a factory for space heating, additional fans may be required to ensure adequate cooling of the compressor is maintained.

Before implementation, carry out an evaluation of the potential heat-recovery savings from the compressor system. As the heat available can vary according to factors such as ambient conditions and load on the compressor, replacement of the entire existing heating system is not recommended. Instead, waste heat recovery should be used to make up any shortfall in demand that may occur, with suitable controls on the heating system used to ensure an area does not get over heated.

Before any heat-recovery system is designed, other energy efficiency measures should be carried out. Any change in compressed air load due to more efficient operations will have an impact on the heat available and will, therefore, change the payback time for the project. In calculating the feasibility of heat recovery, it is important to remember that heat may be required for the colder seasons only. Any ducting design would need to allow for heat to be rejected when not required during the summer.

Another potential use for the waste heat is to regenerate desiccant or sorption dryers. With this option some or all of the air from the compressors is delivered to the dryer without aftercooling. Heat exchangers on the dryer remove the heat for regeneration and cool the air sufficiently to pass through the duty desiccant bed. These dryers run at very low cost but need careful engineering specific to each installation.

Did you know?

Up to 80% of the energy used in compressing air can be used, for example in low-grade space heating, conversion into hot water or preheating boiler water.

Maintenance

There are two different approaches to maintenance: planned preventive maintenance (PPM) and breakdown maintenance.

PPM – is carried out regardless of whether a machine has broken down. This is essential for all critical compressed air systems to achieve long-term reliability as well as energy efficient operation.

Breakdown maintenance – is reactive and should be regarded only as a temporary ‘quick-fix’ solution. PPM should always be the preferred method of looking after compressed air assets.

Schedule maintenance

Check equipment maintenance requirements against the actual maintenance carried out. An appropriate maintenance schedule should be devised in accordance with the manufacturer’s requirements. Alternatively, use a reputable maintenance contractor – manufacturers should be able to advise on this.

Insist that only genuine original equipment manufactured spare part are used. Copy parts may be cheaper but may not give the same performance resulting in a waste of energy.

Carry out checks

Maintenance checks should be carried out in accordance with the manufacturer’s instructions. All schedules should include actions such as:

- Conducting checks based on the ‘listen, look and detect’- system to identify leaks and damage (as described on [page 12](#)). Every compressed air system in regular use should have an air-leak survey programme with checks being carried out at least every three months.
- Carrying out a lubrication regime including greasing, oil top-up and oil replacement.
- Checking and replacing filters.
- Carrying out regular system checks including indicator readings, operation of moving parts and set points.
- Checking the tension and condition of drive belts.

- Checking the operation of valves.
- Checking that oil and inter and aftercoolers are working correctly.
- Checking condensate traps and ensuring that manually operated ones have not been left open.

Predictive maintenance can pay off for larger systems particularly. Special equipment can be used to anticipate when problems start to occur. For example, use:

- Vibration analysis, where rotational equipment is analysed for noise and vibration.
- Oil analysis, which can identify friction issues or contamination issues.
- Thermographic surveys, which can identify overheating issues as well as electrical faults. Further details can be found in the Carbon Trust’s publication [Identifying energy savings with thermal imaging \(CTG003\)](#).

A compressed air supplier will be able to advise on all of the above predictive maintenance techniques.

All of these methods can help to identify problems before they become failures and point to areas of increased energy consumption.

Note that compressors cannot be run for ever on just basic servicing, oil/filter changes and so forth, and the maintenance schedule should include major overhauls such as the replacement of screw elements in accordance with the manufacturer's recommendations. For an oil-injected rotary screw compressor this is likely to be around 25,000 hours. The compressor will continue to operate after this but efficiency and performance will deteriorate without ongoing maintenance.

Fact:

Tests carried out on over 300 typical compressors showed that energy savings of 10% can be achieved through low-cost maintenance activities. So, in addition to improving reliability, maintenance can also save energy and money.

Monitoring

Without a method for monitoring consumption, you will not know how much energy your air compressors are wasting and therefore minimising costs will be harder to achieve.

A good monitoring system will help identify how much energy a system uses and where it is being used. It will also provide you with the necessary data to set energy reduction targets and to identify where improvements can be made. Higher than expected levels of energy consumption can point to:

- Poor maintenance.
- Faulty equipment.
- Increased leakage.
- Misuse of compressed air.
- System pressure that is too high.
- Compressors not being turned off.

Once energy saving measures have been implemented, then monitoring will also demonstrate the savings directly attributable to the energy saving actions.

Monitor compressed air energy use

Installing the following equipment will help in obtaining accurate measurements.

- A pressure gauge on the air receiver.
- Temperature gauges in the cooling system – these will detect problems in the cooling system.
- Air temperature gauges at the outlet of the compressor – these can help to detect fouling of the aftercooler heat exchanger.
- Pressure gauges at various intervals along the distribution network. These help to obtain a pressure profile of the system, and indicate areas where pressure is being dropped (especially across filters).
- Hours-run meters that can differentiate between time spent running on-load and off-load. This can be very useful for identifying consumption trends on compressors. Modern packaged compressors commonly have an hours-run meter built in.

- Data loggers that record when the compressor is supplying a load and when it is idling. By comparing this information against a profile of demand it can be determined whether the compressor is running at times of no demand – this can point to leakage problems or poor control. This is also a useful technique for calculating the consumption of compressors that have no energy meter and for estimating the airflow output for compressors of a known delivered volume on systems with no airflow meter.
- Electricity meters should ideally be fitted on each compressor to record energy consumption. If showing kW this will differentiate between productive and non-productive operation of the compressor and the kWh will monitor the total energy consumed.
- Airflow meters on the distribution system (on larger systems) will give a true usage demand profile as well as being very useful when combined with power meter readings for analysing the efficiency of a compressor system.

Record compressed air energy use against production levels

Compressed air use versus production should stay constant in a system with minimal leaks, good control and with stable compressed air usage patterns. Recording this data will enable a target usage pattern to be identified. When energy saving measures are implemented, you will be able to compare actual energy usage against the target enabling savings to be quantified.

A leakage-rate test can also be carried out using a simple timer to determine the time on-load and the time off-load when there are no production or process requirements.

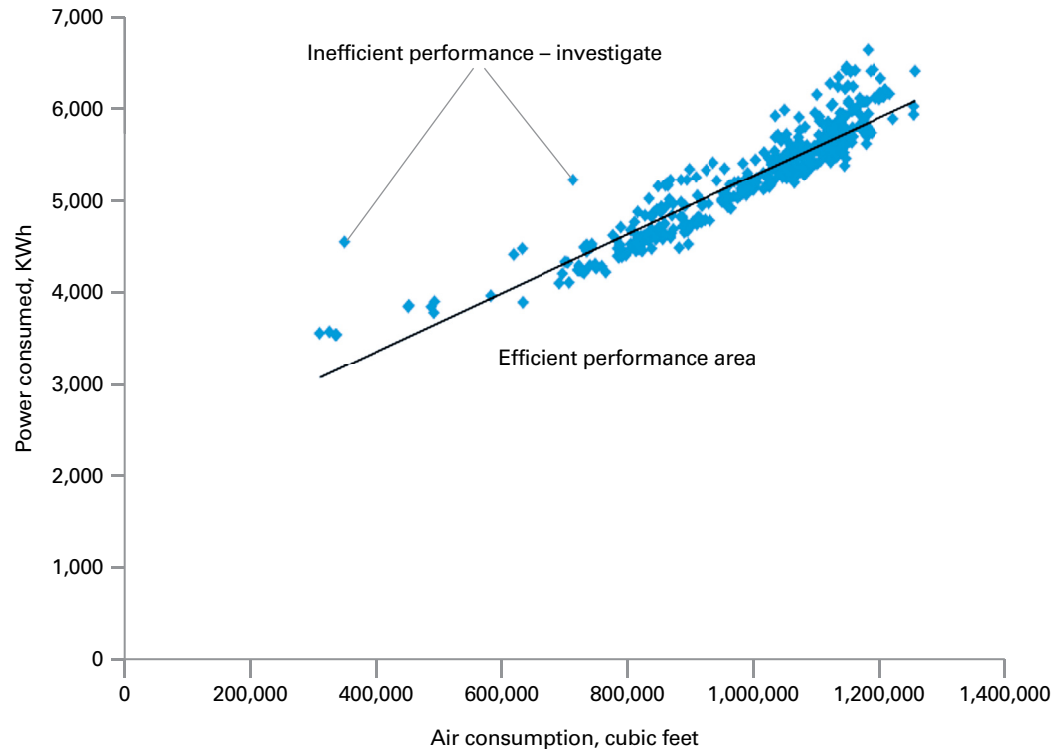
For details on how to carry out this test see the [Appendix](#).

Plot the air volume produced against energy consumed

If there is a regular variance in energy usage from week to week, then energy use should be measured against production. If there is airflow and energy information for each compressor, the energy consumed by each unit should be plotted on a chart on a weekly basis. The average trend is the average efficiency line (note: this line is unlikely to be straight). A target line can then be inserted just below this line to show where achievable performance is – the aim being to match future performance to this line. Any subsequent plots above the line will be running less efficiently and should be investigated. Equally, any improvements to the efficiency of the system are then immediately apparent and a new, improved efficiency target can be set.

In [Figure 7](#), on page 25, some inefficiencies stand out, above the trend line. These should be investigated and further instances minimised. Aim to have a trend which better matches the points labelled 'efficient'.

Figure 7 Performance monitoring of compressor system



Specification and design

Always analyse the system beforehand and then purchase the most efficient equipment possible.

At some point, compressed air equipment will require replacement due to changing business requirements or plant failure. During its lifetime, the running costs of a compressor far outweigh its purchase cost. Such decisions are, however, too frequently based on purchase price alone and the policy of lowest price is often detrimental to energy efficiency. A better method is to calculate the life-cycle cost of the equipment and buy the system that is both the most effective and the most energy efficient over time.

Depending on the size of the investment and the amount that the business relies on compressed air, the following actions may be worth considering:

- Monitor compressed air demand.
- Consider the cost of ownership and operation.
- Specify appropriately.

These are discussed in this section.

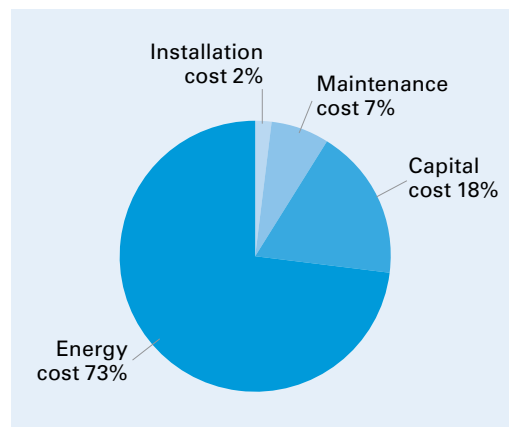
Monitor demand before investing

When new equipment is being considered, it is important to plan for the air demand. Before this work is undertaken, minimise demand by making the system as efficient as possible. At the very least, fix all major leaks and wastage. This will result in a system that is designed for the demand alone and not the demand plus waste. However, it is also important to ensure that the investment is suitable for the long-term requirements of the plant including future increases in demand due to production changes and the inevitable increases in leakage. Cutting back on capacity may give some initial savings but these can be negated if additional plant has to be installed soon afterwards.

Ideally, monitor compressed air demand constantly via some form of management information system which records the performance of compressors. Get accurate data by carrying out an independent air audit including compressor efficiency, air delivered to the system, power consumed and the system operating pressure.

The information provided by monitoring the system will give a profile of the site air demand, enabling equipment to be purchased that matches the demand profile as closely as possible, reducing the need for compressors to idle. If demand is variable, consider installing smaller compressors with a sequential controller as opposed to one large one – this will allow demand to be matched using only the compressors needed. In this context, also consider using a variable speed drive.

Figure 8 Compressor costs over a ten-year life



Consider the cost of ownership and operation

When replacing or upgrading compressors and associated equipment, consider the overall cost of ownership. Routine maintenance, repairs and energy consumption all contribute to the cost of running a compressor.

Manufacturers or agents are now able to routinely offer service contracts that run for one, three or five years. Some will even offer 10-year contracts. These contracts can either be routine basic maintenance or all-inclusive packages which cover all parts and labour costs as well as any breakdown/repair costs.

Similarly they should also be able to provide information on energy consumption at both full and no-load to allow a calculation of running costs at the plant's demand level. Make sure that this information is for the total package power into the compressor, not just shaft power.

Do not just concentrate on the compressors, treatment can add significantly to running costs and also needs to be properly specified and assessed. Similarly the overall installation including ventilation and the distribution system will all prevent a new compressor from performing efficiently. Guidance on these issues is provided in other areas of this guide and the Carbon Trust also publish several guides dedicated to particular aspects of a compressed air system.

Key considerations for specification

Because every installation is unique in its design and purpose, there is no definitive compressor solution.

Hence, the importance of carrying out an air audit prior to any investment decision. The decision on which compressor is most suitable for a particular application will be based on a number of factors, but it will be primarily driven by:

- The level of air quality required by the application/process (for example, is oil-free compressed air required?).
- The flow rate and pressure required
- The capital available and subsequent running costs.

When considering a purchase, key questions such as the following should be asked of a vendor:

- What type of compressor is proposed and why?
- Is the compressor water-cooled or air-cooled? If watercooled, what is the volume and pressure of the cooling water required and what is the water quality specification? If air-cooled, what is the cooling air volume, pressure capacity and power requirement of the compressor cooling fan?

- At the stated compressor delivery pressure, what is the free air delivered (fad) and total input power of the compressor package measured to International Standard ISO1217?
- What is the off-loaded total power input to the compressor?
- Is there a specific energy consumption (SEC) figure available (kW/m³)?

This will allow comparison between various equipment options proposed by vendors.

Legislative requirements

There are a number of legal requirements to consider when dealing with compressed air. The main requirements are outlined in [Pressure Systems Safety Regulations 2000](#). Here are just a few considerations:

- A 'written scheme of examination' must be prepared and be certified by a 'competent person', which identifies how the system shall, in future, be examined.
- There should be a regular examination of the system by a 'competent examiner'

to ensure that it continues to comply with the regulations.

- Comprehensive operating instructions including start-up and shutdown procedures should be supplied to all operators.
- Pressure vessels and, in particular, air receivers should be clearly marked.

Other regulations relate to environmental legislation and cover areas such as condensate disposal. Oil-laden condensate must be treated as a hazardous waste and cannot be discharged to normal surface or foul drains.

Advice on all applicable regulations is available from the British Compressed Air Society (BCAS). Visit their website at www.bcas.org.uk for more details.

Glossary

Absolute pressure

The pressure measured from a baseline of a perfect vacuum. Denoted by (a) after the unit of pressure.

Absolute pressure = Gauge pressure + Atmospheric pressure.

Aftercooler

A heat exchanger that reduces the temperature of the air after compression before it enters the system.

Artificial demand

The difference between the airflow of the system at its optimum operating pressure and the flow being consumed at the actual pressure applied to the system.

Bar/bar(g)

A unit of pressure commonly used in industry, which is approximately equal to atmospheric pressure. However, the SI unit for pressure is the Pascal (Pa). 1 bar is equal to 100,000 Pascals (100kPa). When referring to the pressure indicated by a system gauge (that is gauge pressure), it will often be written as bar(g). See 'gauge pressure' below.

Condensate

Water formed in a compressed air system from water vapour due to a decrease in air temperature and/or an increase in pressure.

Dew point

The temperature at which air, at a given pressure, is fully saturated. Water vapour will condense if there is a further drop in temperature or increase in pressure.

Dryer cycle time

In a dual tower drying system, the time a dryer takes to cycle between regenerating its wet desiccant bed and drying the compressed air.

Dryer purge air

A portion of dry, full line pressure, compressed air taken from the drying side tower of a dual tower desiccant dryer system. Expanded to a very low pressure and passed across the wet desiccant to strip the moisture in the desiccant.

Free air delivered

The actual flow delivered by a compressor at the stated intake (fad) temperature and pressure.

Fad is expressed in litres per second, cubic metres per minute or hour or cubic feet per minute.

Gauge pressure

The pressure measured from a baseline of atmospheric pressure. Denoted by (g) after the unit of pressure. Gauge pressure = Absolute pressure – Atmospheric pressure.

kPa

Equal to 1,000Pa (see Pascal).

Off-load

The compressor is running and consuming power but is not delivering air.

Oil-injected

An air compressor into which oil is injected to lubricate and remove heat.

On-load

The compressor is producing air, either at part load or full load.

Packaged air systems

Self-contained unit consisting of a compressor, a prime mover and various accessories (for example, filters and coolers).

Pascal (Pa)

The SI unit for pressure. When referring to the pressure indicated by a system gauge (that is gauge pressure), it will often be written as kPa(g). See 'gauge pressure' on [page 30](#).

Pressure drop

The drop in pressure between any two specified points in a system.

Pressure regulator

A device that reduces the incoming pressure to a lower level and maintains it irrespective of changes in inlet pressure and outlet flow rate.

Prime mover

A machine used to drive a compressor. For example, an electric motor or engine.

Run-on timer

A control that switches off the prime mover when the compressor has been off-load for a specified period of time.

Useful storage

Term referring to the capability of a system to store a buffer volume of air. Effective useful storage is that which is sufficient to smooth out variations in pressure and provide a reserve to meet high demands.

Appendix

Leakage measurement test

With both the following methods, it is assumed that the compressed air system is operating after normal plant operating hours, that the air being delivered is supplying only leaks and that there are no normal production or process requirements.

Different sections of the distribution network can be tested if well-sealing valves can be used to isolate different branches.

Method 1 – Cycle timing

The compressor capacity must be known for this method.

1. Use a timer to measure the time (T) that the compressor is actually delivering air (on-load). Repeat this for the duration of time (t) that the compressor is off-load. Repeat these measurements through at least four cycles to

obtain accurate average values. If the air compressor actually switches off and on, then the exercise is straightforward. If the machine keeps running but uses an off-loading mechanism, then it is necessary to listen to the tone of the compressor as it cycles between the two states.

2. Note: the delivery capacity of the air compressor (Q) from the nameplate or literature.

3. Use the following formula to determine the leak rate, Q_{leak} which will have the same units as Q (for example, litres/s or m³/min):

$$Q_{leak} = Q \times T/(T+t).$$

4. Note: an alternative method is to ensure that the timer is started and stopped at maximum and minimum pressures using an accurate pressure gauge.

Method 2 – Pressure decay

This method is used when the compressor capacity is not known or the compressor control method prevents the use of method 1.

1. Calculate the volume of the delivery network (V) in litres. This should include the volume of all receivers and the main distribution pipework.
2. Ensure an accurate pressure gauge is fitted.
3. Once the delivery network is fully pressurised, switch off the compressor and close the delivery valve between the compressor and the receiver.
4. Measure and record the time (t) in seconds for the pressure to decay by exactly 1 bar (100kPa).
5. Use the following formula to calculate the leakage rate (free air): $Q_{leak} = V/t$ (litres/s).
6. Note: this method will return less accurate results at lower system pressures.

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🔗 www.carbontrust.co.uk/carboncalculator

Publications – For more information and guidance on compressed air.

- 🔗 [How to recover heat from a compressed air system \(CTL166\)](#)
- 🔗 [How to apply variable speed drives to air compressors \(CTL167\)](#)
- 🔗 [How to implement leak detection techniques in compressed air \(CTL168\)](#)
- 🔗 [Maintenance checklist – Compressed air \(CTL169\)](#)
- 🔗 [Guide on purchasing new compressed air equipment \(CTL170\)](#)

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