Reducing Energy Consumption from Compressed Air Usage

Produced by the British Compressed Air Society.

Foreword

Energy Managers often focus on heating, cooling and lighting; however one of the really big energy wins in savings is compressed air.

The EMA trained a large number of ESOS (Energy Saving Opportunities Scheme) Lead Assessors and highlighted how maintaining and stopping wasted energy through spotting compressed air leaks should be cited in any ESOS report as one of the most cost effective energy saving measures.

Sometimes the savings can be based solely on changing employee's behaviour. Behaviour change is always hard but making staff aware of the costs of leaks that they could help to identify is important. The EMA has a ratio for energy efficiency; 40% is efficient kit, 20% is control systems and 40% is behaviour change.

This report ticks all these boxes, and will be a great tool for Energy Managers who are commissioning systems, maintaining the kit and training staff to use it properly.

Compressed air, in all its uses, is essential for British businesses, but it is also energy hungry and whilst it is only one amongst many systems Energy Managers are responsible for, it is certainly a major saving getting compressed air systems to run at peak efficiency.
This report will be an excellent tool to achieve this aim.

Lord Redesdale
CEO Energy Managers Association

About this white paper

Compressed air is often referred to as the fourth utility. It is essential to many sectors as a safe, reliable and versatile source of power.

It does however take a considerable amount of energy, generally in the form of electricity, to produce the clean, dry, pressurised air that is needed for so many processes and applications.

This whitepaper provides an overview of how to save energy in a typical compressed air system. It is not intended as a detailed guide, but rather aims to highlight areas where waste occurs, how to minimise it and then detail where you can go for further information.

Who is this whitepaper for?
If you are the person responsible for the performance of an existing compressed air system and want to make it more reliable, productive and energy efficient without the need for capital investment; then this whitepaper is a useful starting point.

Where to go for more detail
After making an initial plan to improve your compressed air system's efficiency, there are a number of other information sources that you can refer to for more detail.

The BCAS Installation Guide provides useful advice on equipment sizing and detailed pressure drop calculations.

For reputable, knowledgeable suppliers who can help you make improvements to your system visit **www.bcas.org.uk**. For independent reviews about suppliers and case studies, visit the AirRated review site at **www.referenceline.com/bcas**

And finally...
If you are planning to purchase equipment to save energy, ensure you compare alternatives based on a whole life cost and not just the initial outlay. If you buy less efficient equipment at the outset to save money, you will be locked into higher running costs for the long term. Proper design and installation are also essential for minimising energy costs.

See **Appendix A** of this whitepaper for more about the tax breaks available for energy efficient equipment through the Enhanced Capital Allowance (ECA) scheme.

Contents

A whole system approach to saving energy

Compressed air typically accounts for 10% of an industrial company's electricity bill and for some sectors it can equate to far more. It therefore makes sense to take targeted action and make your system more efficient.

Reducing compressed air waste will:

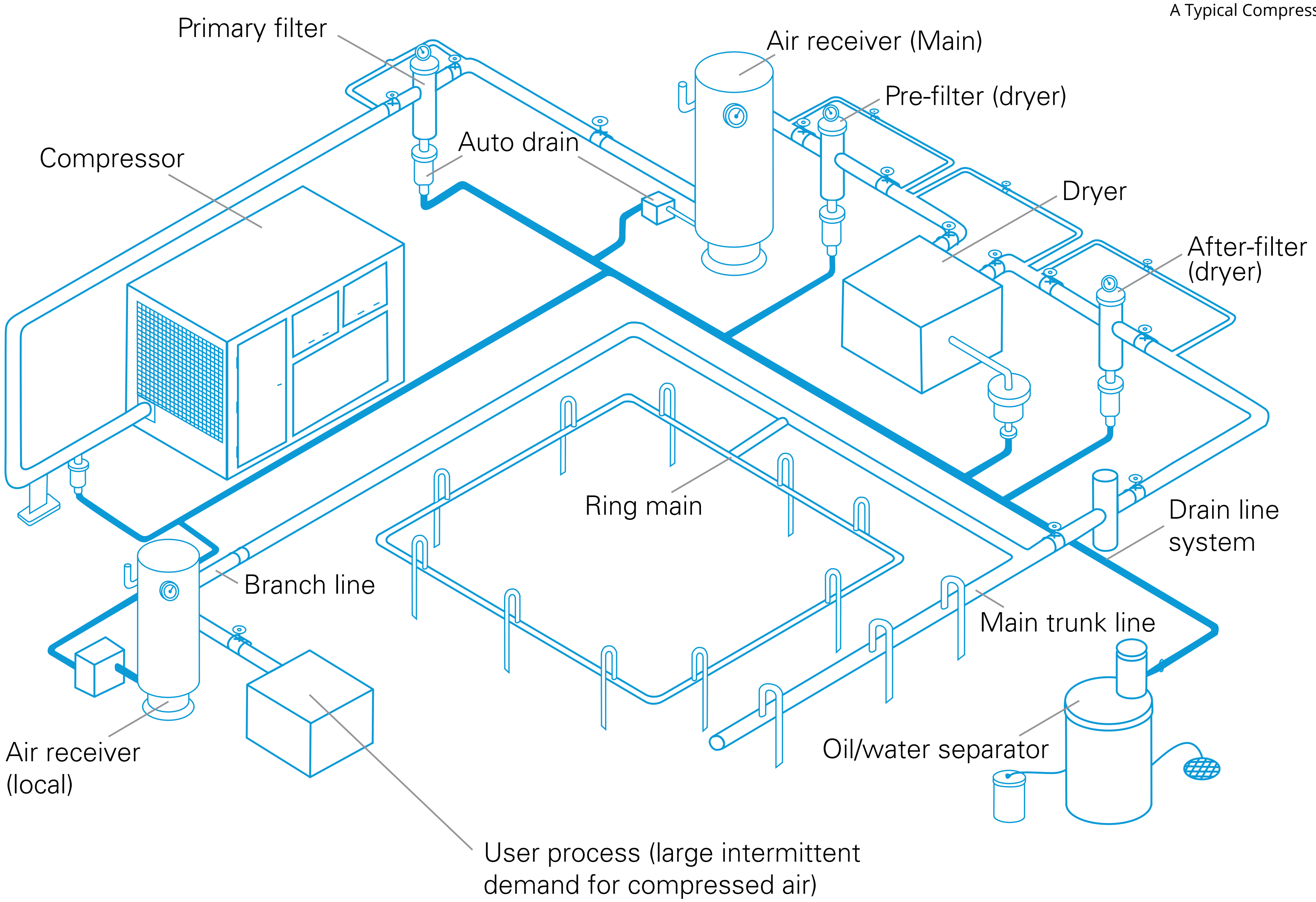
- Save energy and costs
- Improve reliability and productivity

From diagram 1, you can see that a compressed air system is just that; a system, and every element of it impacts upon its energy consumption. It is therefore a mistake to just concentrate on one aspect of the system to the exclusion of others. This will only result in missed opportunities to save energy.

If for example you were to buy the most efficient compressor on the market but connected it to a system that has a 40% leak rate, then all you are achieving is to produce waste more efficiently!

While the largest energy consuming component in the system is the air compressor(s); it is the demand by users, the overall design and how well the system is maintained that determines the demand placed on the compressor to supply the system and therefore its energy consumption.

Diagram 1:
A Typical Compressed Air System



Calculating the system's annual costs

Note that all references to pressure in this publication are expressed as bar, taken to mean gauge pressure. This can also be expressed as bar(g).

Option 1
The actual electrical consumption of the compressor(s) in kilowatt hours (kWh) can be obtained by sub-metering the compressor house.

Option 2
A quicker temporary solution is to install a data logging system over a period of at least seven days. This will determine:

- The pattern of demand (demand profile)
- The off load running time when there is no demand for air

In addition to add further information to help build a usage picture, you could also incorporate flow monitoring into the system.

Option 3
If no metering is in place, then you can estimate the energy consumption of each compressor as illustrated in the worked example below:

A 75kW compressor operates at 7 bar. It is on load for 65% of the production time, which is 2,000 hours per year. The motor is assumed to be 90% efficient.

Energy consumption of the compressor whilst on load =

(75 ÷ 0.9) x 0.65 x 2,000 = **108,333 kWh/year**

There is also energy consumption from the offload running, assuming for a screw compressor that a part-loaded running draws 25% of the full load power:

(75 ÷ 0.9) x 0.35 x 0.25 x 2,000 = **14,583 kWh / year**

Total energy consumption of the compressor = **122,916 kWh**

For unit electricity of £0.12/kWh, the annual energy cost is **£14,750**.

If production time is 6,000 hours per year, this increases to **£44,250/year**.

For older or less efficient compressors where the offload electrical draw can be nearer 70% of on load power (not 25% as in the example), then the annual energy cost for 2,000 hour operation increases from **£14,750** to **£17,900** per year.

Another method for estimating energy consumption of compressors is to use the maximum rated package power, a figure available from the manufacturer.

Note: This is only the cost of the compressor, not the system. However, it is a starting point and helps you understand the scale of expenditure that your organisation faces.

Summary

Examine the entire compressed air system to maximise energy savings.

Find and fix the leaks

All compressed air systems have leaks. Leaks are often ignored since they are not an immediate health and safety hazard, but reducing air leaks is the single most important energy saving measure you can take.

A high leak rate causes fluctuations in pressure, resulting in hidden costs such as slower running or the stalling of production lines and also creates a noisy environment for staff.

Common leakage sources are:

- Air-using equipment left running when not needed
- Manual condensate drain valves left open
- Leaking hoses and couplings
- Leaking pipes and pipe joints

To estimate your leak rate as a percentage of total demand, carry out the load /no load cycle test (see Appendix B). This is easily done with a stopwatch to find the percentage of time the compressor is on-load when there is no demand for air.

Identifying and Measuring leaks

Initially conduct an out of hours survey and walk the site listening for leaks.

Confirm the location by using any of the following methods: ultrasonic leak detector, a soap solution brushed onto pipe fittings, or a leak detection spray.

Handheld ultrasonic leak detectors are the best way to detect leaks whilst production is running. (Be aware that some dryer types have purge cycles which lose air as part of their function).

Once you have identified where there are leaks, implement a leak management programme as follows:

- Tag the leaks and record on a site plan
- Grade the priorities - it could be as simple as 1,2,3
- Fix the largest leaks first
- Encourage users to report leaks
- Repair all leaks as soon as practicable

Leaks need to be monitored constantly. Carry out a leak survey at least twice a year to keep the problem under control. If you have insufficient in-house resources, your compressed air distributor may offer a leak management service.

And finally...

Once you have repaired the leaks, check the pressure drop from the compressor to points of use as you may be able to reduce the generation pressure at the compressor. Otherwise fixing leaks could increase the pressure and the predicted savings will not be realised. Also the increased pressure could create more new leaks.

In order to monitor the leakage rate, consider installing permanent flow metering. This is also an effective way of identifying any changes in consumption which need further investigation.

Top Tip

Have an ongoing leak test and repair programme. Leaks reappear and a 3mm hole could cost over £600/year in wasted energy.

Good housekeeping and staff involvement

Many users are unaware that the compressed air generated is not free and therefore ignore leaks and use air indiscriminately.

You should involve your staff in identifying where compressed air is wasted and how they can help by reporting the problem and making suggestions.

The main areas of wasted usage to target are:

- Leaks
- Leaving air consuming equipment running during breaks
- Using compressed air lines for cleaning down benches and equipment

Safety Note

Blow gun (simple on/off type) operating pressures should be less than 2 bar. See BCAS Factsheet 102-1 for more details on blow gun safety.

Draw up a Usage Policy

Appoint someone with overall responsibility to ensure coordination and implement an action plan to:

- Raise awareness of all those who use compressed air
- Establish compressed air costs
- Set targets for reducing avoidable waste

Switch off the Compressor When There is No Demand

Do not leave compressors on overnight if there is no demand for air because electricity will be consumed to feed leaks. Even when off-load, compressors can consume up to 70% of their full load power. Fewer running hours will also reduce maintenance costs.

- Check that compressors are switched off when not needed and are not switched on earlier than necessary
- Check time switch settings regularly

Note: Ensure that when automatically shutting down the compressor, that other plant areas are not affected.

Maintain the whole system

Effective maintenance is essential to energy efficiency. Cutting back on maintenance is a false economy, because doing so increases the energy consumed, decreases service life and reduces equipment reliability. See more detail for compressor maintenance on page 10.

In addition, the law requires all systems operating at greater than 0.5 bar with an air receiver installed, to comply with the Pressure Systems Safety Regulations 2000 (PSSR). And Regulation 12 of the PSSR requires that compressed air equipment be properly maintained to minimise health and safety risks associated with a pressurised system.

Summary

- **Encourage your staff to identify and report compressed air wastage**
- **Effective maintenance reduces costs and ensures a reliable and safe air supply**

Use compressed air more efficiently

Compressed air is used for a number of applications because of its safety, flexibility and convenience. But sometimes compressed air is used just because it is there, not because it is necessarily the best solution on the site.

In the table below are some examples of where compressed air is used for low grade duty and could be replaced by a better alternative.

Note: Where there is a risk of explosion, electrical interference or extreme temperatures, then compressed air remains the best option.

Low Grade Application Using Compressed Air	Low Energy Alternative
Ventilation	Fans, blowers*
Liquid Agitation	Mechanical stirrer or blower
Transporting Powder at Low Pressure	Blower

*Blower is the commonly used term for a low pressure compressor

Safety Note

Compressed air must NOT be used for cleaning down workbenches, floors and personnel. Brushes or a vacuum cleaner are much safer, as well as more energy efficient methods.

You can also make sure that when you do need to use compressed air for certain applications that you fit air entraining nozzles or use blow guns instead of having open ended pipes.

Don't generate at a higher pressure than necessary

A pressure drop in the system means that the generating pressure is set much higher than it needs to be and is often kept high to ensure continuity of production - the "better safe than sorry" approach.

It is better to identify why there is a pressure drop and take action. It may be due to:

- Leaks
- System component constrictions (e.g. valves, bends)
- Undersized or poorly designed piping

Ideally the pressure drop should be less than 10% of the compressor's discharge pressure, as measured from the compressor outlet to the point of use. Thus, at a pressure of 7 bar, the pressure drop should be less than 0.7 bar.

If for example a compressor is delivering air at a pressure of 8 bar, but the pressure at the point of use only 6.5 bar, then this pressure drop of 1.5 bar is wasted energy and money.

Note

By reducing wastage, e.g. by repairing leaks, the generation pressure can be reduced incrementally without affecting operations or production processes.

If one section of the plant requires a much lower pressure e.g. 4 bar, instead of the typical 7 bar, then it may be better to run a dedicated low pressure compressor for that line. Seek professional advice about your best option from a BCAS member.

Top Tip

Measure the pressure drop across the system. Every 1 bar of pressure drop (i.e. over-pressurisation) represents a 7% increase in compressor energy costs.*

*This linear relationship holds for 6-12 bar, the range of many industrial compressed air applications

Pipework

Not all parts of the network operate the same hours or to the same pressure, so save energy by zoning the compressed air system.

- Split the system into zones and pressurise each only as required
- Remove or isolate redundant piping so that it does not leak out of hours

Valves

Valves are widely used for isolating parts of the distribution network.

Best option	Ball valves cause almost zero pressure drop when fully open
Not so good	Gate valve design causes pressure drop and leaks when left partially open for convenience
Avoid	Diaphragm and globe valves cause the largest pressure drop

Good design

Design all compressed air distribution pipelines to minimise pressure drop and allow for possible future expansion of the compressed air system:

- Select large radius bends instead of elbows
- Support piping to minimise movement and sagging to reduce leaks and build-up of fluids

Pipe size and energy losses

Installing a smaller pipe to save on the initial capital cost is a false economy. Smaller piping causes greater pressure drop across the system, resulting in higher energy consumption and this increased energy cost soon exceeds the price of larger diameter piping.

As a general rule, pipe diameters should be calculated based on having a maximum air velocity of 6m/s, in the main supply line. In branch lines with a total length less than 15m, velocities up to 15m/s are acceptable.

Pipe systems

The two basic distribution systems for compressed air are single main and ring main. For larger systems with numerous take-off points then a ring main is recommended. Isolation valves can be fitted to isolate specific sections of the system for maintenance purposes.

When selecting pipe material consider the alternatives to traditional galvanised steel, which eventually corrodes and has a much rougher internal surface.

Smooth bore aluminium pipe (both tube and box types), stainless steel and specialised plastics offer much lower friction and flow resistance to the air. This reduces pressure drop and saves energy, plus these materials do not corrode and potentially contaminate the air.

For more information on installation consult the BCAS Installation Guide

Top Tip

Check that any unused compressed air lines are isolated and not leaking air.

Control & Maintenance of Compressors

Compressors are at their most efficient when operating at full load. Even when off-load, the power consumed can be 20-70% of the on-load power.

To match supply and demand, a variable speed control can save a large amount of energy, but only if the air demand fluctuates. A compressor that runs at full load will consume more energy if a variable speed drive is fitted.

If retrofitting to existing machines, consult the manufacturer first.

The small additional price premium for higher efficiency motors usually pays for itself in less than two years. For compressors that are likely to operate long hours, specify best in class efficiency motors (at least IE3). Many compressors now have higher efficiency motors installed.

When two or more compressors are installed together, investigate electronic sequencing systems. These predict and select the best combination of compressors to meet the demand, such as using a combination of fixed speed and variable speed machines. They also maintain the pressure to a much narrower range - to within 0.2 bar.

For further information on the selection of compressors, consult a BCAS supplier.

Compressor location and maintenance

- Locate compressors in a dry, clean, cool and well ventilated area. Install extra ventilation to keep the compressor room as near to ambient temperature as possible. It takes more energy to compress warm air, yet some compressor plant rooms can run at temperatures of 30°C and above. This can cause more frequent breakdowns as well as wasting energy.
- Site the air inlet to the compressor house on a north-facing wall if possible, or at least in a shaded area, with a grille to prevent debris entering.
- Check inlet filters and replace before the pressure drop across them becomes significant.
- Compressor output will deteriorate by more than 10% without proper maintenance. Maintenance should only be carried out by trained personnel
- Use OEM recommended lubricants and genuine spare parts as well as OEM recommended service regimes to ensure the energy efficiency of the compressed air system.

Cool Fact

A 4°C reduction in inlet air temperature leads to drier air at a higher density, which improves compressor efficiency by about 1%.

Heat recovery

Only 10% of the electrical energy input to an air compressor is converted into compressed air energy. The remaining 90% is normally wasted as heat.

While some of this heat can be recovered and used elsewhere, beware of claims that this 90% is all recoverable, useful heat. The heat output is highly dependent on the load cycle of the compressor being able to generate sufficient heat at the right times. Heat recovery is best considered once other energy saving measures have been implemented. Professional advice must be sought.

Size and locate the air receiver correctly

The air receiver size has a direct impact on reliability and energy efficiency. The role of the air receiver (pressure vessel) is to:

- Act as a reservoir that can provide bursts of air to meet intermittent demands
- Create a more stable pressure in the system

It also acts as the first stage of water removal, so it should be located in a cool place, outside the building – it should never be lagged!

Note

The air receiver should be sized (in litres) to be at least 6-10 times the compressor free air output (in litres/s).

An undersized receiver causes the compressor to cycle frequently in response to small changes in pressure. Intelligent flow controllers are eligible for tax breaks under the enhanced capital allowances scheme. **www.gov.uk/guidance/energy-technology-list**

Fit efficient condensate drain traps

Condensate is the water vapour that condenses from the compressed air and is often contaminated with oil and dirt. Condensate is collected by installing drain traps (also known as drain valves) to components where water will condense, for example: aftercoolers, air receivers, dryers, filters.

Inefficient condensate drains are a major cause of leaks and wasted energy. Manual and timed drains are cheap to buy, but they have high energy and maintenance costs. They require frequent checking and emptying, so for convenience they are often left partially open and therefore also discharge valuable system air.

Electronic level sensing drains (also known as electronic condensate drain traps) are by far the most energy efficient. They are also reliable and require very little maintenance.

Fast Payback

An electronic level sensing condensate trap will pay for itself in less than a month compared to a half open manual drain which could be leaking thousands of pounds a year.

It will also be more economical than a timed drain after one years' use, taking the energy and maintenance costs into account. Timed drains require frequent checking and re-setting.

Note:

It is illegal to pour contaminated condensate down foul sewers unless the oil content is reduced to a very low level. Install an oil/water separator to reduce the oil concentration in the collected condensate to the level allowed by the local water authority.

In this way up to 99.9% of the total condensate volume can be disposed of safely to foul sewers. The small remaining amount of concentrated oil can be collected in drums for disposal by a specialist waste contractor.

Don’t over-treat the compressed air

Dirt, water and oil are present in all compressed air systems and need removing. The level of purity (quality) required depends on the application – for example cleaner and drier air is needed for pharmaceutical and food manufacture than for general assembly.

To save the energy and cost incurred by cleaning and drying compressed air, treat all the compressed air to the minimum acceptable level, and then improve the quality at the points of use to the required level.

Blocked filters can cause reliability problems and will increase energy consumption. Regularly check filter elements as part of a maintenance regime. Many filters have an indicator fitted to their housing, which shows when the filter is due for replacement.

Removing water

Water must be removed from the compressed air system to avoid damage to components of the compressed air system, production equipment and manufactured product.

Liquid water is removed with a water separator, aerosols by a coalescing filter and finally water vapour (which left untreated can cool and condense in air receivers and piping to create large volumes of condensate) by dryers. Different types of dryers achieve different levels of dryness.

For many general manufacturing applications with internal air receivers and piping (where ambient is never below the dryer dew point) refrigerant dryers providing pressure dew points in the range of +3 to +15 °C are adequate. Energy efficiency controls for refrigerant dryers are listed on the ETL Energy Technology List **www.gov.uk/guidance/energy-technology-list**

For compressed air systems with external air receivers or piping, more critical applications such as instrumentation, direct or indirect contact food / beverage / pharmaceutical applications or where the growth of micro-organisms needs a degree of control, lower dew point adsorption dryers should be used.

Typically offering pressure dew points between -20°C & -70°C, most applications use -40°C pressure dew point as this not only prevents corrosion, it will also inhibit the growth of micro-organisms.

Many adsorption (desiccant) drying technologies are available (differing by their regeneration method), with heatless being the most common. Standard heatless models can add 15-20% to overall compressed air running costs. However, many are now available with energy saving controls which significantly reduce operating costs. Other regeneration methods are available that can offer energy efficient drying and advanced condition monitoring controls.

When selecting an adsorption dryer technology it is important to consider purchase cost, maintenance and operating costs. For example, heatless desiccant dryers can be cheaper to purchase, and in standard option will cost more to run in terms of energy.

In these instances a lower energy consumption alternative may be selected. However, whilst the operational cost maybe lower, the purchase price and maintenance costs (often maintenance periods are more frequent) are typically higher therefore whole life cost should be calculated.

At a glance

Treat all the compressed air to the minimum acceptable level, and then improve the quality at the points of use to the required level.

Next steps and further information

Getting started on an energy saving programme for a compressed air system can seem daunting for those who are new to energy management and/or compressed air technology.

However, compressed air systems offer many straightforward energy saving opportunities through minimising avoidable waste. There is plenty of information available to help users

Carrying out a review and implementing improvements to a compressed air system will not only save energy, it will also result in a safer, more reliable and effective source of power.

Further information

www.bcas.org.uk - For professional help and advice from a BCAS member. The knowledge base section contains guides and factsheets to improve the energy efficiency and safety of your system - and to comply with legislation.

www.referenceline.com/bcas - for independent reviews of compressed air suppliers and maintenance providers, and case studies

https://www.gov.uk/guidance/energy-technology-list - for energy efficient products and systems eligible for enhanced capital allowances

http://e-learning.bcas.org.uk - for online training courses detailing efficient and safe use of compressed air

http://www.cagi.org
Compressed Air and Gas Institute

https://www.compressedairchallenge.org
The US programme for increasing efficiency of compressed air systems

http://www.hse.gov.uk/pubns/indg261.pdf
HSE’s brief guide to pressure systems safety

Appendices

Appendix A
The Energy Technology Product List

The ETL (or Energy Technology Product List, ETPL) is a government-managed list of energy-efficient plant and machinery. It is part of the Enhanced Capital Allowance (ECA) tax scheme for businesses.
https://www.gov.uk/guidance/energy-technology-list

The scheme is intended to encourage the uptake of new energy saving technologies.

ETL is a dynamic list where products are added and removed. For example, intelligent level sensing drain traps, condition monitoring desiccant dryer controls and hand held ultrasonic leak detectors, were all listed on the ETL prior to 2014.

However, as they became more established in the marketplace they were removed from the ETL. Their removal does not mean that they are no longer considered energy saving, only that the UK government had deemed the market uptake sufficient, and that tax incentives were no longer necessary.

Appendix B
Estimating a Compressed Air System's Leak Rate Using the Load /No Load Cycle Test.

1. Use a timer e.g. stopwatch to measure the time (T) that the compressor is actually delivering air (on-load).

2. Repeat this for the duration of time (t) that the compressor is off-load.

3. Repeat these measurements through at least four cycles to obtain accurate average values.

Note: If the air compressor actually switches off and on, then this is straightforward. If the machine keeps running but uses an off-loading mechanism, then listen to the tone of the compressor as it cycles between the two states.

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

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

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

About BCAS

BCAS is the only dedicated UK trade association that represents its members in the manufacture, distribution, export, disposal and usage of compressors, compressed air, compressed air treatment, gas, vacuum, blowers, pneumatic tools and allied products.

We provide an expert and impartial united voice in the face of an ever-changing industry and legislation. As an unbiased authority on technical, educational and legislation, the society provides a reference point for best practice and actively represents the interests of the compressed air industry to the UK government and many European and other overseas institutions.

BCAS and our members have the following aims:

- To promote the safe, efficient maintenance and use of equipment and services
- To cooperate with diverse groups such as governmental departments, regulatory authorities, research organisations, retailer and consumer groups and agencies in matters affecting the industry
- To bring industry specific training and the experience of the members to bear on the conduct of business for common good
- To develop and publish, standards, engineering data and statistical information
- To engage in cooperative educational research and activity providing development for the next generation of compressed air and vacuum engineers
- To promote cooperation amongst its members for improved production, proper use and distribution
- To provide a best practice forum where members can develop their professional competence

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