fundamental series 10

The Continuing Professional Development Programme, produced in association with energy INSTITUTE

Current thinking on...

Compressed Air Systems

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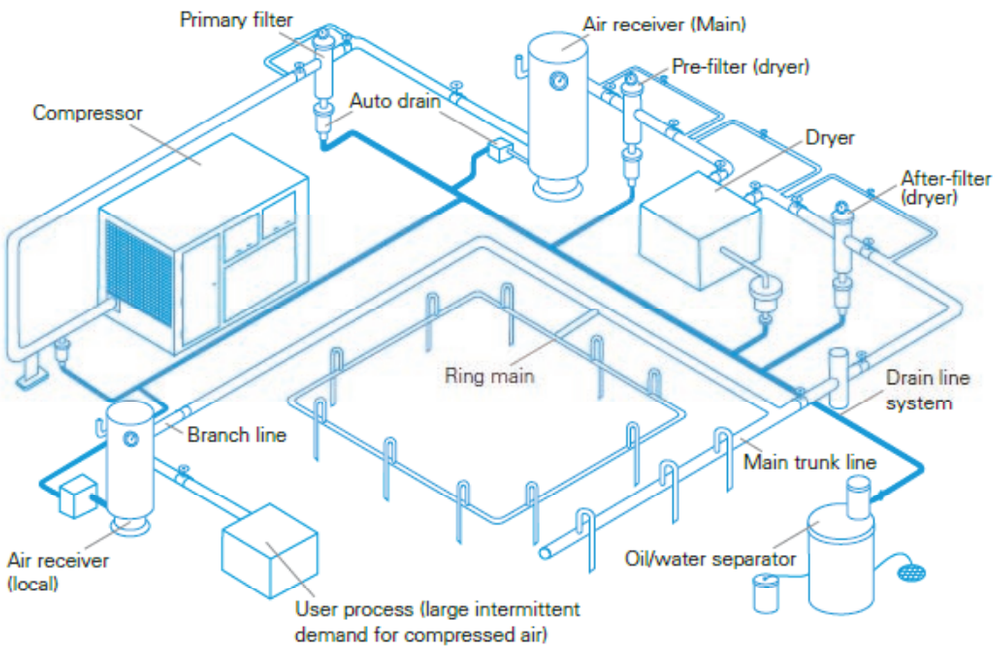
This CPD module focuses on energy efficiency issues for existing compressed air systems operating with pressures up to 10bar(g) and with compressors with a power input between 10kW and 400kW.

Compressed air systems are widely used within industry for many different applications – in fact according to Carbon Trust figures around 10 per cent of all electricity consumed in the industrial sector is for air compression.

Although compressed air is recognised as a reliable and versatile utility its high cost is often overlooked. Of the total energy used by a compressor as little as 8 to 10 per cent may be converted into useful compressed air energy at the point of use. In other words, assuming a typical electricity price of 8p/kWh, the true cost of compressed air is around 80p/kWh.

Despite its high cost a significant proportion of the air produced by the compressor is often wasted through system leaks with further energy wasted because of inadequate compressor controls and system maintenance.

Figure 1 Typical compressed air installation



(COURTESY CARBON TRUST REFERENCE 1)

Total ownership cost

According to figures from the Carbon Trust, the cost of energy consumed by the compressor and ancillary equipment represents 73 per cent of the total cost to own and operate a compressed air installation over a ten-year period. Capital and installation costs represent 20 per cent and maintenance costs the remaining 7 per cent.

Increasing the energy efficiency of a compressed air system saves money and reduces environmental impact through lower energy consumption and carbon emissions.

Compressed air is used for a variety of applications including pneumatic control and instrumentation, hand tools such as pneumatic drills and motive power using actuators or motors.

Packaged oil-injected rotary compressors are the most popular machine for the production of standard quality air for industrial applications because of their simplicity, proven reliability and low maintenance requirements. These are normally electric motor driven.

The most popular type of rotary compressor up to around 400kW drive power is the rotary screw compressor. A typical specific energy consumption for this type of compressor would be 300W per litre/second or air delivery, although performance varies from machine to machine and the manufacturer's specification should be checked. Oil free variants are available where high quality air is required such as in medical or clean room applications. The second type of rotary compressor is the vane compressor which is more popular for smaller duties.

Although water cooled reciprocating (piston) compressors can be more efficient than packaged rotary compressors they do have a higher installed installation cost. Maintenance costs are also usually higher and their operational efficiency drops off rapidly if maintenance is neglected. However, this type of compressor is the normal choice for high pressure applications (>14bar). Small reciprocating compressors packaged with an integral air receiver are popular for small duty

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requirements (less than 5kW).

Centrifugal compressors dominate the market for large duties above 2,000 l/s because of their higher efficiency and because the design is inherently oil-free means they can deliver high quality air.

A compressed air system comprises a number of components in addition to the compressor. Typically an air receiver or pressure vessel to provide a buffer to store compressed air to help even out varying air demands, an air dryer to remove water vapour from the compressed air, filters and condensate traps to remove water, oil vapour and solid contaminants, a fixed pipe work system and possibly local flexible hoses at the point of use.

Full consideration of cost

Compressed air as an energy source is convenient which means it is often used for applications without full consideration of its true cost. The first step is to consider whether compressed air is really the most effective power source for each application or whether lower cost alternatives such as a direct electricity drive could be used.

Increasing compressed air efficiency is about implementing actions across the complete air installation not just the compressor itself.

One of the basic steps to improve the efficiency of any compressed air installation is to determine the extent of air leakage from the installation and reduce if necessary. In fact the Carbon Trust notes that the leak rate on a poorly maintained system can be as high as 40 per cent of the air generated by the compressor. The sources of leakage are numerous but common examples are condensate traps, fittings and pipework, pressure regulators, filters, flexible hoses and air-using equipment left in operation when not required.

The air leakage from a single 1.5mm diameter hole is around 1.8l/s at 7bar(g) pressure. Assuming a typical compressor energy performance this equates to a constant energy waste of 0.54kW. With electricity at 8p/kWh a single air leak of this magnitude would cost almost £108/annum assuming the system is pressurised for 48 hours a week.

While every effort should be made to keep a compressed air system leak-tight, all systems will have some leakage. There are, however, ways of reducing the potential for leaks: for example do not run the system at a higher pressure than necessary (the higher the pressure, the more air will escape through a given-size hole) and isolate parts of the system that require air at different times using isolation valves. Isolation valves can be operated manually or automatically using simple control devices like time switches or interlocks.

There are a number of ways of detecting leaks. Handheld ultrasonic detectors can be hired or purchased and are the most effective method of detecting leaks without having to stop production. Another method is to inspect the system, under no load conditions, to listen for leaks and visually examine the sources of leakage for air tightness.

Occasionally a compressed air system will have a flow meter which can be used to measure the volume of air generated when all air-consuming equipment is switched off to give a good indication of leakage rate. Alternative methods are to measure compressor cycling times or system pressure decay – see Reference 1 Appendix for detailed guidance on these methods.

Extent of air leakage

Having established the extent of the air leakage the next steps are to:

- set a realistic target for leakage rate – typically 5 to 15 per cent of the maximum air demand;
- establish an on-going maintenance programme to identify, report and repair leaks;
- make operators aware of the cost of compressed air and set up a procedure for them to report leaks and make sure they are repaired.



The compressor outlet pressure should be regulated to match that required by the end-use equipment and to meet the system pressure drop. At a typical system pressure every 1 bar of over pressure represents at least 6 per cent increase in compressor energy consumption. Increased system pressure also increases the rate of air leakage further increasing energy losses. If reducing system pressure is implemented, this should be carried out in incremental steps to make sure that all air consuming equipment or processes still have sufficient volume and pressure to operate.

Pressure drop in a compressed air system is caused by airflow resistance due to pipe friction and the various components within the system. In a well designed and installed system the pressure drop should be less than 10 per cent of the compressor outlet pressure. The need to generate substantially higher pressure than that required by the end use equipment is usually an indication of poor pipework design or poor maintenance of filters and other ancillary equipment.

Compressors are often found left running when there is no demand for air (e.g. overnight). This wastes energy because power is being used to satisfy system leaks or non-productive machines.

A fixed speed compressor even when in an off-loaded condition can still consume between 20 per cent and up to 70 per cent of its full power loading depending upon its design and type. It is important when deciding to shut down air compressors that other plant and safety protection equipment is not adversely affected.

Air inlets to compressors should be located to ensure the intake air is as cool, dry and clean as possible. A 4oC drop in intake air temperature will improve compressor efficiency by about 1 per cent. Ideally ambient air should be ducted directly from outside to the compressor or forced ventilation used to dissipate the build-up of heat in the compressor room.

Compressors should be serviced by trained personnel in accordance with the manufacturer's requirements to achieve long-term reliability and efficient operation. The Carbon Trust state that tests on over 300 compressors showed that energy savings of 10 per cent can be achieved through low-cost maintenance activities. Reference 2 provides a list of items that should be checked on the compressor, air treatment system and compressed air system.

Figure 2 shows the control characteristics of the commonly found rotary screw compressor. This demonstrates that some compressors run more efficiently above 70 per cent using a modulating inlet valve to throttle flow. However, when demand is less that 70 per cent it becomes more efficient to use on-load/off-load control where the compressor is either running at full-load with the inlet valve open or off-load where the inlet valve is closed.

Varying air output

A variable speed drive varies the air output by varying the speed of the electric motor driving the compressor and provides significant potential to reduce energy consumption where the air demand varies widely and particularly at low air volume outputs. This form of drive also offers a closer control of air pressure than either of the above control options because the compressor supplies only the volume required to meet the demand.

However, at loads above around 75 per cent compressors with this type of drive consume more energy, on a like for like basis, than fixed speed on-load/off-load units because of the electronic control losses. This type of drive is available for most new compressors and can be retrofitted to existing fixed speed machine but this is not recommended without consulting the manufacturer because of potential operational issues.

Modern rotary compressors have automatic 'stop start' control such that the machine will stop after a period of no load operation and automatically restart when a demand for air exists. The off-load running

period helps to protect the drive motor from an excessive number of start-ups.

Where the installation has more than one compressor cascade pressure control has traditionally been used to control the number of compressors required to meet the air demand.

This control method automatically increases the number of compressors running as the system pressure drops below predetermined set points. However, the disadvantage is that it only runs the system at the required system pressure at times when all compressors are running to meet the highest demand. A more efficient method to control multiple compressors is to use a sequential controller which controls the compressors based on a single set point pressure.

The compression process concentrates the atmospheric contaminants and water vapour contained in the outdoor air drawn into the compressor. This raises the dew point of the compressed air and could lead to condensation as the compressed air cools downstream of the compressor. Excessive water in compressed air, in either the vapour or liquid phase, can cause operational problems.

Water removal

The first stage of water removal occurs in the after cooler, which is usually within the compressor package and the air receiver. Most end-use applications require further treatment including an air dryer to remove water vapour from the compressed air and further treatment using filters and drain traps to remove condensate which can be contaminated with oil and solid particles.

The level of air purity required and therefore the type of air treatment method depends upon the air application. The energy consumption for drying is often overlooked. The higher the degree of air treatment required the greater the energy consumption. This is dependent upon the pressure drop across the filters, and the dryer plus the energy used by the dryer itself. Ineffective or faulty condensate drains can be a cause of air leaks and hence wasted energy and should be checked under any maintenance programme.

There are two common types of dryers, although other types exist. Refrigerant type dryers are adequate for many standard applications (they can achieve a pressure dew point of 3ºC). Desiccant dryers can produce virtually moisture-free compressed air with pressure dew points down to –70ºC. They are designed such that, while one desiccant column is in use to dry the air, the other is being regenerated (i.e. dried out for re-use). Desiccant dryers can have a high energy demand, and can add up to 20 per cent to the overall compressed air energy consumption. Controls can be retrofitted to both types of dryer to match the operation of the dryer with drying load to provide energy savings.

An often overlooked energy saving opportunity is the ability to make use of the waste heat generated by the compressor, provided a feasible heating application can be identified.

As already noted above, only approximately 10 per cent of the electrical energy driving an air compressor is converted into compressed air energy. Almost all of the remaining 90 per cent is heat and this represents a significant energy waste since it is normally dissipated within the compressor house. New compressors can be purchased with heat recovery fitted or existing compressors can be retrofitted for heat recovery. A properly designed heat recovery unit can recover up to 80 per cent of this as low-grade heat.

Where the compressor is packaged in an acoustic enclosure heat can be recovered in the form of warm air and ducted into a factory or warehouse space to offset other forms of heating. The ducting should allow the warm air to be dumped during warmer periods when it is not required for space heating. The recovered heat can also be used to pre-heat combustion air for certain burners used for steam or hot water boilers. The waste heat can also be recovered in the form of hot water from the compressor for process heating or pre-heating boiler feed water.

Identifying viable heat recovery options depends upon the building's requirement for heat and the type of compressor cooling available. Potential savings should be evaluated carefully as they are dependent on the actual load cycle of the compressor being able to generate sufficient heat at the right times.

Some form of monitoring is required to effectively manage the energy consumption of the compressed air installation. A good monitoring system will help determine how much energy is being used and where savings can be made. Higher than expected energy consumption can pin point issues such as increased air leakage and poor compressor maintenance or control.

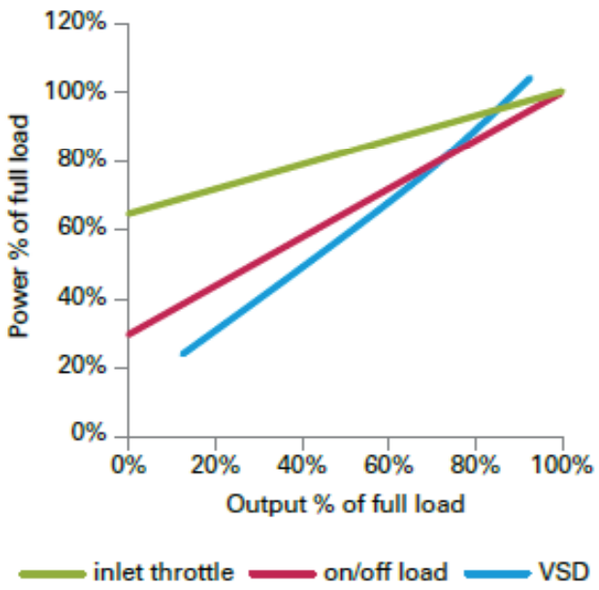
This CPD module provides an overview of a typical compressed air installation and a number of energy issues. In summary an energy efficient compressed air system will be one that is:

- well maintained with all equipment serviced regularly;
- properly designed to minimise pressure drop with respect to all fittings, air treatment and pipe work monitored continuously or on a regular basis; and
- used by staff who are aware of the cost of compressed air and properly trained in the effective use of equipment using the compressed air subject to an on-going programme to repair leaks.

If any part of the compressed air system is not working efficiently, the system's overall performance suffers and operating costs rise. Each component in the system interacts with others and should not be considered in isolation. For example, upgrading to a new, energy efficient compressor will have only a limited impact if the leakage rate is too high or if the flow is restricted by an inadequately sized delivery pipe network.

• Any work on a compressed air system should only be carried out by a competent person and all health and safety risks evaluated.

Figure 2 Rotary screw control characteristics



(COURTESY CARBON TRUST REFERENCE 1)

References

Publications noted below are available at the Carbon Trust website www.carbontrust.co.uk.

CTV050 Compressed air – opportunities for business

CTL169 Compressor maintenance checklist

CTL166 How to recover heat from a compressed air system

Information is also available from the British Compressed Air Society Ltd at www.bcas.org.uk

Compressed Air Systems

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ENERGY IN BUILDINGS & INDUSTRY

How to obtain CPD accreditation



Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative.

This is the ninth module in the tenth series and focuses on compressed air. It is accompanied by a set of multiple-choice questions. To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to ***Energy in Buildings and Industry*** for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, for a fee of £15 (for members) or £25 (for non-members).

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject.

The final modules in the tenth series will focus on: training for energy management. The first eight modules examined small-scale wind power, water management, fuel cells, solar thermal power, smart metering systems, sustainable refurbishment, LED lighting, and photovoltaics.

All previous modules from this series as well as the 90 modules from the first nine series are available free of charge on CD. Send your request to **mark.thrower@btinternet.com**

MARK THROWER, MANAGING EDITOR

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Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry, P. O. Box 825, GUILDFORD, GU4 8WQ

SERIES 10 MODULE 9: QUESTIONS

Compressed Air Systems

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

1. What percentage of the electricity input to an air compressor is converted into useful energy at the point of use?

☐ 90 per cent ☐ 50 per cent ☐ 30 per cent ☐ 10 per cent

2. What percentage of the total cost of operating an air compressor would energy typically represent over a 10-year period.

☐ 5 per cent ☐ 18 per cent ☐ 50 per cent ☐ 73 per cent

3. Where does the majority of energy go in the air compression process?

☐ Compressed air
☐ Noise
☐ Heat
☐ Condensate

4. Which is not one of the main sources of waste in a compressed air system?

☐ Cooling the compressed air
☐ Air leakage
☐ System pressure drop
☐ Running the compressor when there is no demand

5. What leakage rate could be found in a poorly managed compressed air system?

☐ 80 per cent ☐ 40 per cent ☐ 20 per cent ☐ 5 per cent

6. How much energy could be saved by reducing system pressure by 1 bar

☐ 20 per cent ☐ 12 per cent ☐ 6 per cent ☐ 2 per cent

7. Where should air be ducted from as the best source for an compressor?

☐ Factory
☐ Ambient air
☐ Compressor house
☐ Compressor exhaust

8. The consequences of specifying higher quality air are:

☐ Lower energy consumption
☐ Best practice
☐ Increased energy consumption
☐ Increased system pressure

9. A variable speed drive will save energy when?

☐ There is a need for low pressure air
☐ The air demand is constant and at the maximum compressor output
☐ The air demand varies across a wide range
☐ There is a need for high quality air

10 Which one of the following factors would reduce leakage from a compressed air system?

☐ Increasing system pressure
☐ Reducing system pressure
☐ Compressor design
☐ Ducting fresh air to the compressor inlet