SERIES 15

CPD fundamentals

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MARK THROWER MANAGING EDITOR

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SERIES **15** | MODULE **03** | **COMPRESSED AIR**

Make More Efficient Use of Compressed Air

By John Pooley, managing director, John Pooley Consultancy Ltd

Compressed air is a vital resource for many industrial applications representing about 10 per cent of industrial electricity use in the UK. The uses of compressed air range from process and instrumentation through to hand tools. A common use of compressed air is for tyre inflation. A more unusual application is the launching of fireworks to avoid the use of black powder. Compressed air is also being researched as an energy storage medium. The benefits of compressed air include its safety in explosive environments and its non-overload characteristic for certain processes.

Compressed air is one of the most expensive utilities used. Given that typically 90 per cent of the energy input to an air compressor is 'lost' it can be argued that compressed air is ten times more expensive than electricity. Additionally, many compressed air systems have high levels of leakage or wastage - sometimes more than 35 per cent.

With an understanding of the technology and using a systems approach it is possible to maximise the efficiency of a compressed air system and reduce its energy use and operating costs.

The common units used are bar (gauge) for pressure and either litres/sec (l/s) or cubic metres per hour (m3/h) for flow. Pressures are gauge pressure unless otherwise noted. Some people still use Imperial units when talking about compressed air – psi (for pressure) and cfm (for flow rate).

A typical industrial compressor might be rated for 330 l/s at 7 bar or 700 cfm at 100 psi.

While most industrial compressed air systems operate at around 7 bar, specialist systems, such as those for PET bottle blowing operate at pressures as high as 40 bar. If the required working pressure is less than 1.5 bar a blower can be a more energy efficient option.

The energy professional is normally involved with existing compressed air systems. These systems have often grown over time with additional pipework, additional uses and additional compressors. These on-going additions often introduce inefficiency when they have not been correctly engineered.

Start with the end use

Traditionally, a review of a compressed air system starts with the air compressor. However, there is benefit in starting with the end uses of the air. There are two reasons for this. The first is that there may be compressed air uses that can be replaced with other more efficient methods. The second is for essential usage it is important to establish exactly what the requirements are in terms of flow, pressure and air quality, which in turn impact on system operation and economics.

It is important to 'challenge' all uses of compressed air. There may be good reasons to use compressed air – but if there are not, look at the alternatives.

Examples of processes for which compressed air is typically the right solution include: blow moulding, breathing air, spray painting (although it is possible to have airless spraying), microelectronics manufacture, tyre inflation and air bearings.

Some uses of compressed air that could be replaced include: generating a vacuum (use a vacuum pump), product assembly tools (use electric tools), air knives (use a blower instead), liquid agitation (use a mechanical stirrer or blower).

Three key parameters need to be established for all compressed air applications:

- pressure;
- flow rate; and
- air quality.

Increases in any of these boost the cost of compressed air, so ideally

Produced in Association with energy institute all should be a 'low' as possible. For example, you should not use breathing quality air for inflating tyres, or PET pressure air for pneumatic cylinders.

Pipework and fittings

The next element to consider is the distribution system – the pipework and fittings.

Pipe sizing: Often compressed air pipework has not been correctly sized. A pipe could be one pipe size too small and this might not notice in use. But, what it will do is increase the pressure drop and the cost of delivering the air. Reference to guides such as the British Compressed Air Society (BCAS) Installation Guide (5th Edition) or Carbon Trust GPG 385 can provide guidance on pipe sizing There are also several on-line calculators. As general guidance the velocity in main lines should not exceed 6 m/s.

The impact of under sizing a compressed air main is illustrated in this example taken from the BCAS Installation Guide: (Based on a 7 bar system with 100 kW compressor)

In general, oversizing pipework (by one pipe size – which might typically double the capacity) will not introduce a life cost penalty as the additional piping cost will be offset by lower operating costs.

Where possible, ring mains should be used for main distribution – this reduces the overall pressure drop as each point is served from two directions.

Pipe materials: Historically systems used steel piping – often galvanised with screwed pipe joints on pipes 65 mm diameter and below. Corrosion in black steel pipework occurs where there is moisture or condensate. However, today specialist plastic and aluminium piping systems are the preferred options. These systems have lower pressure loss, are less likely to leak and do not corrode. One benefit of the lower pressure loss is that it may be possible to use a smaller pipe size and save on material costs.

Fittings: As with other piping systems each fitting adds an equivalent length of pipe (and hence pressure drop) to the system. In a 100mm diameter pipe line a fully open ball valve might add 0.3m; a gate valve 1.3m; a diaphragm valve 6m, whereas a globe valve would add 30m. The gate valve, if it were half closed, would add 20m. It should be noted that some valves – for example gate vales, might be more likely to leak in service.

Other pipeline components, such as filters, will add to the pressure drop. For most systems the total pressure drop, from compressor to furthest point of use, should be limited to 10 per cent of the generation pressure. This means a maximum of a 0.7 bar drop for the typical 7 bar system.

Table 1. The impact of undersizing a compressed air main (based on a 7 bar system with 100kW compressor)

Pipe nominal bore (mm)	Pressure drop per 100m(bar)	Equivalent power (kW)
100	0.02	0.1
80	0.04	0.2
65	0.22	1.2
50	0.65	3.4

Drainage: Because atmospheric air contains moisture there will be water, or condensate, in the air when compressed. Whilst his can be removed by a variety of means, accumulated water in the distribution pipework may be a potential issue and needs to be addressed. This is achieved by installing the pipework so that it drains to collection points as required. These should be fitted with automatic drain traps to remove the condensate. Manual drain traps are not recommended as these can be left cracked open leading to significant air loss. The condensate, as it may contain oil, needs to be disposed of correctly.

Various research studies have found that leakage from compressed air systems represents the most common waste of energy. A study from the Energy Best Practice programme identified wastage in the region of 38 per cent in some systems. The BCAS guide states that for an installation with regular inspection and maintenance the leakage should not exceed 5 per cent. (This applies to normal, circa 7 bar, systems.) Very high pressure systems tend to have minimal leakage because of the engineering and the danger of high pressure air leakage.

Leakage can be quantified in several ways – typically by 'no-load' running. With this the estimate is based on how much compressor runs to maintain the operating pressure with no air use taking place – this means that the system is just supplying the leaks. Individual leaks are best detected using an ultrasonic leak detector.

The energy impact of leakage: Good practice is to have an on-going leakage detection and repair programme.

After management of leakage one of the most cost-effective energy-saving measures is to reduce the system operating pressure. Reducing the operating pressure by 1 bar can reduce the power requirement by around 6 per cent. (This depends on the actual operating pressure and the type of compressor.) Working pressures should always be challenged and line losses minimized so the system can work at as low a pressure as possible.

For health and safety reasons the air supply to blow guns should be restricted to 2 bar unless the gun is a safety type. High-pressure blow guns waste energy, so using a reduced pressure has a double benefit.

Zoning & multiple pressures: Consideration should be given to installing zone valves to isolate areas that are not needed when others are in operation. It may also be worth looking at having different pressure systems for different uses. For example, if there is one small high-pressure demand consider using a small dedicated high-pressure machine for that use. Another example might be having a separate 2 bar distribution network for blow guns.

Air quality is a complex subject and expert guidance should be sought. In simple terms, there are three measures of air quality – oil, water, and dirt (solid particulates).

Oil is picked up from the compressors.

Water becomes an issue because as you compress air you do not compress its water content. As a result, the relative humidity increases beyond the carrying capacity of the air.

Solid particulates come from the compressor intake air and the system.

ISO 8573-1:2010 is the key standard for air quality. This classifies each of the three contaminants with Class 0 being the highest quality and Class 9 the lowest. When specifying compressed air quality it is normal to specify the class for each of the three contaminants. A specification for general purpose oil free air might be ISO 8573-1:2010 Class 1.4.2.

Particulate matter is removed using filtration art first with intake filters and then additional filters as required. Water is initially removed through cooling and refrigeration with higher quality classes being achieved through further treatment. Air may be oil free if it is from an 'oil-free air compressor' although in many applications additional filtration will be used to meet the required quality level.

Table 2. The impact on energy of a compressed air leakage

Equivalent hole diameter(mm)	Leakage at 7 bar (l/s)	Required compressor power (kW)
0.5	0.2	0.06
1.0	0.8	0.24
1.5	1.8	0.54

Removal of moisture

The first stage of moisture removal is when the air is passed to the air receiver. As the air enters the vessel its velocity drops and any entrained water will fall to the bottom of the vessel where it can be drained away. Although this is a useful function of the receiver, its prime purpose is to provide air storage to reduce fluctuations in pressure and meet spikes in air demand.

The next level is using a refrigerated air dryer. Most general-purpose air systems will have refrigerated air dryers. It is only small, simple systems, such as tyre inflation systems, that will not use refrigerated dryers. A typical refrigerated dryer will deliver air with a pressure dew point (PDP) of around +3oC. (This means that water will not condense from the air until the temperature falls below 3oC.) For specialist applications, a PDP as low as -70oC may be required. This level of moisture removal can be achieved using additional techniques such as a membrane dryer (-40oC to -100oC) or the more efficient desiccant dryer. All these dryers add to the energy use of the system and care should be taken to only treat the air that needs to be at the required level.

Desiccant dryers can be heated or heatless. Heated dryers use external heat to regenerate the desiccant. Heatless dryers use the compressed air to purge and regenerate the dryer. There are also 'zero purge' heatless dryers that use vacuum or blower

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For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 28** technology to purge the desiccant. Earlier models of desiccant dryers used fixed timing to control regeneration – regardless of flow rate or moisture content. This can be wasteful, so the more efficient alternative is to use automatic dew point control. With this the dryer is only regenerated when needed – thus saving energy. Dew point control can be retro-fitted but the practicality and payback will depend on the model.

A desiccant dryer can add around 15-20 per cent to the overall running costs.

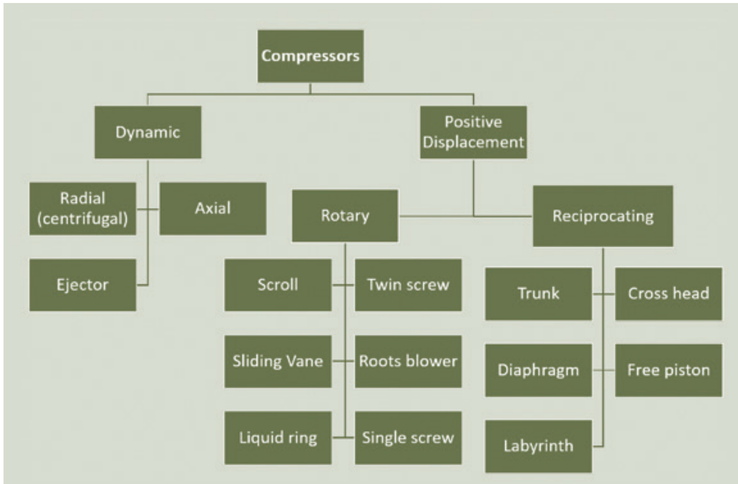
Families of air compressor

There are two main families of air compressor – dynamic and positive displacement – see diagram.

Although there is a wide range of compressors, probably the most common industrial compressor is the packaged, air cooled, lubricated, rotary screw machine.

The specific type of compressor used will depend on the duty required and the nature of the air to be delivered. For example, very high pressures will need reciprocating compressors whereas very large volumes might require a centrifugal machine. Another aspect to be considered may be having an oil-free air compressor. For example, a centrifugal machine will be oil free, while a sliding vane machine will be lubricated. The specific type of machine will dictate certain installation requirements. For example, a large reciprocating compressor will need engineered foundations, but a package screw machine can be stood on the factory floor.

There are two types of compressor - dynamic and positive displacement



Different types of machine have different energy efficiencies. This is normally measured as specific power consumption at full load – e.g. joules/litre. When making comparisons it is important to establish that the power data includes the ancillaries in the compressor, additionally, part load characteristics should be compared.

Compressors are normally rated by free air delivered (FAD) and operating pressure. Free air delivered is the air volume at the compressor discharge referred back to the inlet (atmospheric) conditions.

Traditionally compressors have been installed in central plant rooms. The advent of the packaged screw compressor has led to more decentralised systems with machines located around a factory. There are advantages and disadvantages to both approaches so it is not uncommon to have a hybrid approach with both central and distributed plant.

When evaluating compressors, it should be noted that typically over a 10-year life the capital cost of the compressor accounts for around 18 per cent plus 2 per cent for installation, maintenance at 7 per cent and energy cost at 73 per cent.

VSDs to match loadings

A major development in air compressors is the use of variable speed machines to match loading. This can be achieved by a range of technologies. Variable speed drives (VSDs) can be retrofitted but it is more common to replace an aging fixed-speed machine with a new variable-speed machine. As well as saving energy, a variable speed machine provides closer pressure control.

A key aspect is to ensure that the machine has a free flow of intake air at as low a temperature as possible. Typically, reducing the inlet temperature by 4oC will increase efficiency by 1 per cent.

Compressing air generates heat. This is simply demonstrated with a bicycle pump. This heat is then rejected using either air cooling or water cooling. Water cooling systems are more expensive to install and may have added aspects such as Legionella control to consider. However, water cooling systems can be used for heat recovery. The simplest form of compressed air heat recovery is ducting the air from an air-cooled machine into a space requiring heating. Ideally heat recovery from a compressor is related to a year-round requirement for heat – such as hot water, rather than space heating. As around 90 per cent of the input energy to the compressor is rejected as heat, making use of it should be considered.

Where there is a single compressor supplying a variable air demand the best option is to have a variable speed compressor. Added to this should be time control to ensure the machine is only working when required. Ideally this should be automatic, but circumstances may dictate that it needs to be manual.

Where there are multiple compressors it is normal to stage them. Where a VSD machine is being used this should be the lead machine at all times – matching the load. When the air demand is greater than the lead machine, a fixed speed compressor would be switched in. The fixed speed machine working at full load is typically more efficient than the variable speed machine working at full load.

Some types of compressed air equipment qualify for Enhanced Capital Allowances (ECAs) – check the ETL web site.

Maintenance is also a critical issue. It is estimated that poor maintenance can add as much as 20 per cent to energy use.

Reference material

- GPG 241 Energy savings in the selection, control and maintenance of air compressors
- GPG 385 Energy efficient compressed air systems
- British Compressed Air Society - Installation Guide 5th Edition

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SERIES **15** | MODULE **03** | JULY/AUGUST **2017**

CPD ENTRY FORM

COMPRESSED AIR

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.

QUESTIONS

1. How much of the energy input to a compressor can be lost?

- ☐ 50 per cent
- ☐ 70 per cent
- ☐ 80 per cent
- ☐ 90 per cent

2. Reducing system pressure by 1 bar reduces energy use by how much?

- ☐ 3 per cent
- ☐ 5 per cent
- ☐ 6 per cent
- ☐ 8 per cent

3. Which of the following is not a good use of compressed air?

- ☐ Blow moulding
- ☐ Tyre inflation
- ☐ Generating a vacuum
- ☐ Breathing air

4. What is the recommended maximum pressure for a blow gun?

- ☐ 1 bar
- ☐ 2 bar
- ☐ 4 bar
- ☐ 7 bar

5. What is the recommend maximum air velocity in main distribution lines?

- ☐ 3 m/s
- ☐ 4 m/s
- ☐ 5 m/s
- ☐ 6 m/s

6. What equivalent pipe length does a fully open globe valve add in a 100mm main?

- ☐ 10m
- ☐ 20m
- ☐ 30m
- ☐ 40m

7. How much compressor power is required for a 1.0 mm hole in a 7 bar system?

- ☐ 0.06kW
- ☐ 0.24kW
- ☐ 0.54kW
- ☐ 0.85kW

8. Which standard relates to air quality?

- ☐ ISO 8900
- ☐ ISO 50015
- ☐ ISO 8573
- ☐ ISO 8000

9. What pressure dew point (PDP) can be expected with a refrigerant dryer?

- ☐ Minus 3°C
- ☐ 0°C
- ☐ 3°C
- ☐ 10°C

10. Around what proportion of the 10-year life cycle cost of a compressor is accounted for by the capital cost of the compressor?

- ☐ 12 per cent
- ☐ 15 per cent
- ☐ 18 per cent
- ☐ 20 per cent

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

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Completed answers should be mailed to:

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

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This is the third module in the fifteenth series and focuses on **Compressed Air**. It is accompanied by a set of multiple-choice questions.

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SERIES 14

MAY 2016 - APR 2017

1 Biomass
2 Behaviour Change
3 Energy Management Standards
4 Air Conditioning
5 Internet of Things
6 Training for Energy Management
7 Data Centre Management
8 Metering & Monitoring
9 Battery Storage
10 Demand Side Response

SERIES 15

MAY 2017 - APR 2018

1 Lighting Technology
2 Boilers & Burners
3 Compressed Air
4 Water Management*
5 Combined Heat and Power*
6 Drives & Motors*
7 Underfloor Heating*
8 Energy Purchasing*
9 Photovoltaics*
10 Heat Pumps*

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