FACT SHEET 1

Compressed Air System Selection and Efficient Production

How to save energy, reduce costs and help the environment

Compressed Air Association of Australasia

The smarter energy source

COMPRESSED AIR USES

Compressed air is clean, readily available, and simple to use. However, as with most forms of energy it is expensive. Therefore, the first task for any plant would be to consider if compressed air is the most cost-effective form of power for the job. For example, it might be more beneficial to use:

- air conditioning or fans for cooling,
- blowers to provide cooling, aspirating, agitating, mixing, or to inflate packaging,
- brushes, blowers or vacuum systems to clean parts or remove debris,
- lower pressure compressed air for blow guns, air lances, and agitation.

When using compressed air for any application, attempts should be made to optimise the quantity and pressure of air used, as well as the running times. Compressed air demand should be constantly monitored and re-evaluated, for example, it is not uncommon to find airflow still being supplied to unused equipment when plants reconfigure their processes.

SYSTEM DESIGN CONSIDERATIONS

A number of efficiencies can be gained by making well informed choices when selecting and installing new plant or altering and adjusting existing systems. When designing a compressed air system there are a number of factors which should be considered including:

- Type of Compressor
- Size of Compressor
- Required Pressure
- Air Quality
- Fixed or variable Load

Each of these factors are discussed in some detail in this guideline.

COMPRESSOR TYPES

There are many different types of compressors on the market, each using different technology to produce air.

RECIPROCATING COMPRESSORS

Reciprocating compressors work through the action of a piston in a cylinder. Pressure can be developed on one or both sides of the piston.

For large volumes of compressed air, they are usually the most expensive to buy and install, and require greater maintenance, however, they may be lower cost at small capacities.

Due to their size and the vibrations caused they require large foundations and may not be suitable where noise emissions are an issue. Nevertheless, they are the most energy efficient, both at full and part loads.

VANE COMPRESSORS

Vane compressors have a rotor with metallic sliding vanes inside an eccentric housing. The vanes form pockets of air that are compressed as the rotor turns until an exhaust port is exposed. This working principle is also widely used in air motors.

SCREW COMPRESSORS (OIL INJECTED)

Screw (or rotary) compressors use two meshing helical screws, rotating in opposite directions to compress air. These compressors are usually the lowest cost to install, for large volumes of compressed air.

To ensure maximum efficiency, it is important to correctly size the screw compressor and apply internal and external control systems for part load conditions. Variable output and variable speed drives are usually available from most suppliers.

SCREW COMPRESSORS (OIL FREE)

Oil free screw compressors carry the same benefits as oil injected screw compressors but compress in two stages and have no lubricant in contact with the air during its passage through the compressor. Water injected screw compressors are also available where oil free air is required.

CENTRIFUGAL COMPRESSORS

Centrifugal compressors use high speed rotating impellors to accelerate air. To reach operating pressures, several impellor stages are required. They have low installation costs, but are expensive to buy because they are precision machines. They are fairly efficient down to about 60% of their design output.

SCROLL COMPRESSORS

These compressors are suitable for oil free air compression at smaller air capacities.

ROTARY TOOTH COMPRESSORS

These compressors have the same characteristics as oil free screw compressors but are more efficient at small air capacities.

Table 1. Main features of air compressor types

Compressor Type	Key Characteristics	
Reciprocating	• Low energy consumption • Suitable for high pressures • Easily adjustable • Compact and portable for small loads	• Oscillating forces • High end temperatures • High maintenance • Noisy • Relatively expensive for larger outputs
Vane	• Simple construction • Quiet • Compact	• Limited capacity range • Oil residues in the air
Screw (oil injected)	• Quiet and simple operation • Lower end temperatures • Simple to use for heat recovery • Compact	• Oil residues in the air
Screw (oil free)	• Quiet and simple operation • Lower end temperatures • Simple to use for heat recovery • Compact	• Oil free • Reduced air treatment
Centrifugal	• Low energy user for large capacities • Quiet • Controllable capacity	• Sensitive to dirt in air • Relatively high cost • Energy efficient
Scroll	• Oil free	• Energy efficient
Rotary tooth	• Oil free	• Energy efficient at smaller capacities

SIZING

When designing an air compressor system, users should seek to correctly size the system, as oversized air compressors are extremely inefficient. This is because most systems use more energy per unit volume of air produced when operating at part load. Hence, while air compressor efficiency generally increases with size, due to lower part-load efficiency it is usually more efficient to run a smaller compressor at full load rather than a large one at low load.

In a new installation, a compressor plant is generally sized by adding all the likely individual loads allowing for simultaneous use, constant demand requirements and using diversity factors for intermittent air users. Ideally, the total capacity would be based on exact knowledge of the equipment or process requirements. If this is underestimated, the compressor plant will be too small and unable to maintain the required pressure in the system. Conversely, if the total air consumption is greatly over-estimated there may be excessive capital investment and reduced efficiency.

In existing installations, it may be possible to monitor current demand and use this to size a replacement plant. As modern compressors have high reliability, standby plant requirements should be carefully considered and not guessed. It is good practice to include a standby compressor equal in size to the largest duty machine. However, it is possible to reduce capital costs by opting for a smaller standby plant. This depends on the down-time that can be accommodated and/or any mobile units that could be hired.

To ensure optimum energy efficiency, designers should avoid adding excessive or arbitrary ‘future changes’ or ‘standby’ margins to the output of the selected compressors. However, when installing a new compressed air station, future expansion should always be taken into account by making an allowance for the purchase of an additional compressor at a later date. Increasing compressor capacity presents no problem, provided that the rest of the installation has been planned accordingly.

REQUIRED PRESSURE

When designing and operating a system it is important to correctly evaluate the amount of pressure required. Air must be delivered to the point of use at the desired pressure and in the right condition. Too low a pressure will impair tool efficiencies and affect process time. Too high a pressure may damage equipment, and will promote leaks and increase operating costs.

Many industrial plants run at unnecessarily high pressure, which wastes energy and increases running costs. For example, some systems operate at an elevated pressure of 700 kPa at full load when the machinery and tools can operate efficiently at a lower air pressure of 500–600 kPa. The extra 100-200 kPa would be responsible for approximately 8% -16% of the plant's energy costs. Many system designs include the extra pressure as a contingency factor to compensate for possible leaks and pressure drops, however, this is unnecessary for a well maintained system (see Fact Sheet 2 - Efficient Utilisation of Compressed Air). Installing pressure regulators that keep the supply pressure to the minimum required will also reduce running costs (see Fact Sheet 3 - Efficient Compressed Air Treatment).

Different air pressures are required when operating different tools and processes. Supplying an air main at high pressure just to satisfy the pressure requirements of one or two pieces of equipment should be avoided. Small, high-pressure compressors or local boosters may be more cost effective for local high pressure needs. Alternatively, the system may be able to be divided in two, with a high pressure network and a low pressure section. Table 2, shows the level of energy savings that can be achieved through a reduction in operating pressure.

Table 2. Annual energy savings resulting from reduction in air pressure

Reduction in air pressure at the compressor	50 kPa	100 kPa	150 kPa	200 kPa
Comparative Average Load (kW)	Energy Saving (kWh/y)			
4	320	640	960	1280
7.5	600	1200	1800	2400
11	875	1750	2625	3500
15	1195	2390	3583	4780
22	1755	3510	5265	7020
30	2390	4780	7170	9560
37	2945	5890	8835	11780
55	4380	8760	13140	17520
75	5975	11950	17925	23900
110	8760	17520	26280	35040
160	12750	25500	38250	51000

(Source: Sustainable Energy Authority Victoria, Energy Smart Compressed Air Systems, 2001)

AIR QUALITY

The quality of the compressed air required from a system can range from plant air to high quality breathing air. Different end-uses require different levels of air quality (see Table 3).

Dryness and contaminant level are the two key factors used to distinguish low from high quality air. The higher the quality, the more the air costs to produce. Higher quality air usually requires additional equipment, which not only increases initial capital investment, but also makes the overall system more expensive to operate in terms of energy consumption and maintenance costs. It is, therefore, important when designing the system to assess the level of air quality required.

Internationally, guidelines are available that allow the quality of air to be specified, such as ISO Standard 8573, which defines different classes, as shown in Table 4.

When selecting a compressor consideration needs to be given to the level of air quality required. If lubricant-free air is required, this can be achieved with either lubricant-free compressors, or with lubricant-injected compressors that have additional separation and filtration equipment. Lubricant-free compressors usually cost more to install and have higher maintenance costs.

Lubricant-injected compressors while cheaper to purchase have the additional capital, energy and maintenance costs of separation and filtration equipment. Careful consideration should be given to the specific end-use for the lubricant free air, including the risk and cost associated with product contamination, before selecting a lubricant-free or lubricant-injected compressor. Table 5 lists some of the characteristics of the two compressor types.

In addition to understanding your air quality requirements and compressor types, efficient methods to reduce contaminants need to be investigated. Prior to the compression cycle an air compressor inhales water vapour, dirt, and atmospheric pollution. During the process the volume of air reduces, causing the level of contamination to increase. Additionally, further contaminants such as oil vapour or wear particles can be introduced by certain types of compressors during the compression process.

This concentration of contaminants means that the compressed air can rarely be used without some form of treatment. A wide range of filtration and drying equipment is available to improve air quality. However, it needs to be remembered that careful selection, installation and maintenance of compressed air treatment equipment is required to reduce the energy costs of treating the air.

These costs can be quite high and include direct energy costs for running equipment, the extra generation cost needed to overcome additional pressure drops, or the cost of purging air. This topic is covered comprehensively in the CAAA Fact Sheet 3 - Efficient Compressed Air Treatment.

Table 3. Types of Air Quality

Air Quality	Applications
Breathing Air	Hospital air systems, refill diving tanks, respirators for cleaning and/or grit blasting and spray painting
Process Air	Food and pharmaceutical process air, electronics
Instrument Air	Laboratories, paint spraying, powder coating, climate control
Plant Air	Air tools, general plant air

Table 4. ISO 8573-1:2010 Air Quality Classifications

Particle Classes

Class	max. number of particles per m^3 of particle size d in [µm]*		
	$0,1 < d \leq 0,5$	$0,5 < d \leq 1,0$	$1,0 < d \leq 5,0$
0	As specified by the user or supplier and more stringent than class 1		
1	≤ 20.000	≤ 400	≤ 10
2	≤ 400.000	≤ 6.000	≤ 100
3	Not specified	≤ 90.000	≤ 1.000
4	Not specified	Not specified	≤ 10.000
5	Not specified	Not specified	≤ 100.000
	particle concentration Cp [mg/m^3]*		
6	$0 < Cp \leq 5$		

AIR QUALITY CONT...

Table 4. ISO 8573-1:2010 Air Quality Classifications cont...

Humidity and liquid water classes

Class	pressure dew point [°C]
0	As specified by the user or supplier and more stringent than class 1
1	≤ -70°C
2	≤ -40°C
3	≤ -20°C
4	≤ +3°C
5	≤ +7°C
6	≤ +10°C
	concentration of liquid water Cω [g/m³]*
7	Cω ≤ 0,5
8	0,5 < Cω ≤ 5
9	5 < Cω ≤ 10
X	Cω > 10

Oil classes

Class	concentration of total oil (liquid, aerosol and vapour) [mg/m³]
0	As specified by the user or supplier and more stringent than class 1
1	≤ 0,01
2	≤ 0,1
3	≤ 1,0
4	≤ 5,0
X	> 5

Designation principle: ISO 8573-1:2010 [A:B:C] with; A: solid contaminants class, B: water class, C: total oil class
*at reference conditions 20°C, 1 Bar(a), 0% rel. humidity

Table 5. Characteristics of Lubricated and Non-lubricated Compressors

Non-Lubricated Compressor
• May require fewer filters and oil changes • Longer operational life • Often preferred when manufacturing sensitive products such as food or pharmaceuticals • Higher capital costs • Routine service costs usually high • To reach high pressure need multi-stage compression • More complex compressor
Lubricated Compressor
• Considerably lower capital cost • Simple plant • Oil provides an important cooling effect • Lower speeds/temperatures • Filter maintenance and oil changes are required more often • Due to pressure drop air treatment capital and running costs are higher

MATCHING LOAD

Variable versus Steady Load
Demand patterns for compressed air can be relatively constant, stepped or widely fluctuating and will vary considerably from one application to the next. When designing the system it is important to understand not just how much air is required but when it is needed.

The first task is to determine if any processes can be altered to flatten the load. If a simple change in the timing of an activity can occur you may be able to reduce peak demand thereby reducing costs. Load will also affect compressor selection. If the load is constant for all periods then clearly a single, correctly sized compressor will efficiently do the job. However, with stepped or fluctuating loads it is often more efficient to use a combination of compressors and controls (including variable output and variable speed technology) rather than one large compressor running at part load. This is because air compressors are most efficient when operating at or near full load.

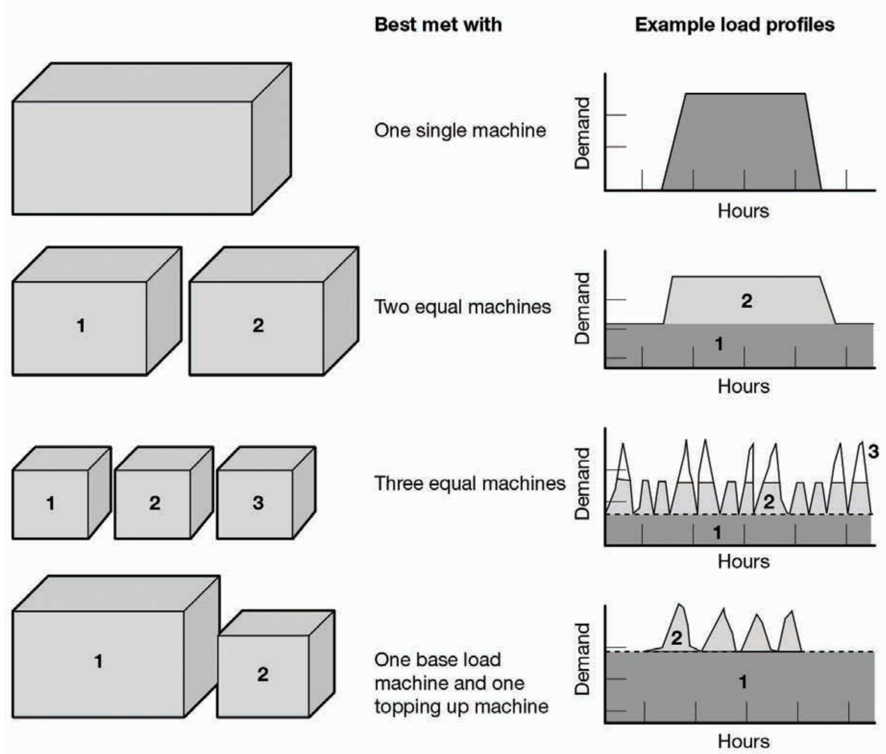
Figure 1 presents some examples of demand patterns and how they can be met efficiently with combinations of multiple compressors.

In addition, demand peaks can be smoothed and peak loads reduced by using storage receivers. A storage receiver can typically store 5% to 10% of the compressor capacity avoiding excessive cycling and part-load operation. This improves energy efficiency and reduces wear on the compressor. During periods of sudden high demand, an extra receiver near the point of use may avoid the need to provide extra capacity.

Where the user is operating multiple compressors, efficient station control may also be achieved by integrating a master controller.

Such sophisticated compressed air management systems can ensure the efficient interplay between all components in a compressed air system by precisely matching compressed air flow with demand. In this way the user can optimise the energy consumption of the equipment throughout its entire life cycle.

Figure 1. Meeting Demand Patterns Efficiently with Combinations of Compressors



Source: UK Department of Environment Transport and Regions 1998 Good practice Guide 241

CHECKLIST

Compressed Air Uses		Required Pressure	
Does the job really need compressed air or will a blower suffice?		Evaluate the pressure required by different tools	
Continually monitor compressed air requirements		Consider using multiple compressors if pressure requirement varies widely	
Compressor Types		**Air Quality**	
Different compressors suit different applications		Assess quality of air required	
Choose the compressor which best meets your needs		Consider the affect compressor type has on efficiently meeting air quality	
Matching load		Scrutinise efficient filtration and drying treatments	
Can load be flattened?		**Sizing**	
Is load constant or variable?		Can demand be reduced?	
Determine most efficient air compressor combination to meet demand		For retrofit systems measure actual demand	
Investigate the potential of storage receivers		Design system to cope with expansion or altered processes	

SUMMARY

Whether installing a new system or altering an existing plant there are many opportunities to make long term dollar savings. It is important to have a thorough understanding of your exact requirements for compressed air – how, when and where it will be used. Additional guides are available that provide more detailed information on efficient utilisation (see Fact Sheet 2 - Efficient Utilisation of Compressed Air) and treatment of compressed air (see Fact Sheet 3 - Efficient Compressed Air Treatment). Additionally, there are many professional companies that can assist you in designing a system that will efficiently meet your needs, see the CAAA website for details (www.compressedair.net.au).

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