EFFICIENT COMPRESSED AIR SYSTEMS

COMPRESSED AIR ASSOCIATION of Australasia
The smarter energy source

HOW TO SAVE ENERGY, REDUCE COSTS AND HELP THE ENVIRONMENT

3 COMPRESSED AIR TREATMENT

All compressed air needs some form of treatment to achieve the desired air quality. This guide investigates the various technologies available to treat compressed air and how to operate them efficiently to assist you to save energy and money.

SEPARATOR AND CONDENSATE DRAINAGE

The accumulation of condensed water in the system can lead to pressure drop. In lubricated compressors the oil vapour can condense with the water and form an emulsion. Additionally, wear particles and pipescale can amplify the problem by becoming trapped in valves and diaphragms. Water condensation can occur throughout a compressed air system and it is good practice to remove as much of this water as possible.

AFTERCOOLERS

Nowadays, most compressors have an after-cooler as a standard fitting to perform the function of removing water, and some oil vapour. However, after coolers are also available as free standing units, in air blast or water cooled versions, for compressors not fitted with them. The after-cooler, through condensing, usually reduces the water content of the air by around 68% and uses approximately 2% of the total package power.

When air mains travel outside the compressor room, temperatures are typically lower and lead to condensation. As such, the air mains should slope to drain legs located at strategic intervals. Drain points should be constructed with a fall of not less than 1 meter in 100 meters of ring main pipe-work. The recommended distance between drain points is approximately 30 meters. If there is a need for branch lines, these should be installed at the top of the main to prevent water running into it from the main pipe. Branch line pipes should also be drained. In order to remove the water drain traps need to be fitted to the drain points.

DRAIN TRAPS

There are a variety of drain traps available with large differences in efficiency. Manual traps are often left open and are known to be responsible for significant compressed air leakage. Reliable automatic condensate traps are available that ensure water is regularly drained away and provide good energy efficiency. The most common type of drain trap is the ball float, which opens only if water is present and closes immediately the water has cleared. If large quantities of water are likely to enter the trap, a balance pipe must be fitted allowing displaced air to be forced back into the main system. Alternatively, electronic condensate drain traps are also available in a range of sizes from very small units attached to the bottom of filters to larger units for air receivers. The advantages of this type of trap are no air loss during discharge, low maintenance and high reliability.

In order to ensure drain traps perform efficiently, it is strongly recommended that simple wire type strainers be fitted prior to the drain trap to prevent particulate contamination of the trap. Occasional maintenance is also required. Oil or emulsion build-up needs to be removed regularly and if the build-up is heavy, drain trays, which have a blast action discharge, should be considered. Making wise drainage decisions can save up to 10% of the costs of compressed air.

Condensate from lubricated compressed air systems must be disposed of in a responsible manner, in accordance with local regulations and by laws. The costs associated with this disposal can be minimised by the use of adequate condensate management systems, commonly know as 'oil-water separators'.

DRYERS

Water in compressed air: There are 3 phases of water in compressed air being liquid water, aerosol (mist) and vapour (gas). The most noticeable and easily removable are water and aerosol which can be removed by high efficiency filtration together with refrigeration dryers. Water vapour is more difficult to remove and requires the use of a desiccant dryer together with high efficiency filtration.

Removing water and aerosol can be satisfactory for general industry where corrosion damage is not an issue. If there are concerns about corrosion damage inside the compressed pipe work, together with ensuing rust and debris which may damage and contaminate downstream equipment and products, then desiccant quality air should be considered.

The general measurement of air dryness is dewpoint, which can cause confusion when choosing the required dryer for the system, particularly in generally warm countries such as Australia. It should be noted that to stop corrosion (and rust, etc.,) air dryness should be 2% RH (Relative Humidity) or better. A dryness of 2% RH is equivalent to −30˚C Pressure Dewpoint. Table 1 provides a comparison guideline for air dryness. It is also relatively easy to calculate how much more water (litres) can be removed from a compressed air pipe work by alterative dryers.

Table 1. Pressure Dewpoint and Relative Humidity

Pressure Dewpoint	Relative Humidity
+10ºC	54%
+3ºC	34%
-20ºC	5%
-30ºC	2% (Limit of Corrosion)
-40ºC	0.7%
-70ºC	0.016%

Typically atmospheric air passing through a compressor is one eighth its previous volume, yet still contains the same amount of contaminants (water and particulate). Increasing pressure would normally cause moisture to condense out of the air, however, due to frictional heat the temperature of the air rises during the compression process and increases the compressed airs ability to hold water vapour. The water content of compressed air can be decreased using dryers. Dewpoint is the temperature below which water vapour will condense to liquid water at given conditions. Lowering the dew point effectively means the system can endure much lower temperatures before water droplets begin to condense. Essentially for every 11°C drop in compressed air temperature, the moisture holding capacity of air is reduced by 50%. Therefore, drying prevents liquid water forming downstream where it can contaminate or damage the system causing operating problems, costly maintenance, and repair expenses.

When selecting a dryer you need to determine the most cost-effective system suitable for your application as compressed air dryers vary in relation to their dew point, initial cost, and ongoing maintenance requirements. The factors to be considered include:

- Calculating the required dew point temperature, which needs to be below the lowest ambient temperature your compressed air system will be exposed too. Take into account the location of air lines i.e. Located in front of open doors or windows, throughout air conditioned or unheated areas, running underground or between buildings
- Determining which type of dryers will produce the required dew point
- Consider initial and operating costs. The lower the dew point, the more expensive the dryer is to purchase and operate

After selecting the type of drying system required, determine the actual conditions under which the dryer will be operating. This allows you to determine the correct size of the dryer.

- Max flow capacity (l/sec)
- Max acceptable pressure dew point (°C)
- Minimum inlet air pressure (kPa)
- Maximum and minimum inlet air temperature (°C)
- Maximum ambient or cooling water temperature (°C)
- Maximum allowable pressure drop (kPa)

There are five main types of dryers suitable for compressed air systems and each will perform differently and will be suited to different applications. Table 2 summarises the performance and approximate energy costs for the different types of dryers. More detailed descriptions of each dryer type follow.

Table 2. Typical additional costs for drying compressed air

Pressure Dewpoint	Dryer type	Added Energy Cost
+10°C	Deliquescent	1%
+3°C	Refrigeration	5%
-20°C	Membrane	28%
-20°C	Sorption	3-5%
-40°C	Desiccant Heatless	10-15%
-40°C	Desiccant heated	8-12%
-70°C	Desiccant Heatless	21%

Source: UK Department of Environment Transport and Regions 1998 Good practice Guide 216

REFRIGERATION DRYERS (15°C TO 2°C DEWPOINT)

The refrigeration dryer cools the incoming air condensing moisture out. The dried air is then re-heated by the incoming air in the air-to-air exchanger. This method of drying is very popular as it produces dew points, which are adequate for most duties in an energy efficient and reliable manner. The extra cost will typically be 5% over delivering standard after-cooled air, which will deliver pressure dewpoints of +3°C and remove an additional 28% of the initial water content. The use of a pre-filter prior to the dryer can not only protect the dryer from internal contamination (especially oil carryover) but also reduce the amount of liquid water (and particulate which can block drains) the dryers have to deal with and, therefore, increasing the dryers efficiency. Therefore, both oil lubricated and non-oil lubricated compressors require high efficiency filtration. In some climates winter ambient temperatures fall below the dryer dew point so air taken outside the buildings will cause water to condense. It is recommended that a condensate trap be fitted to the system where it enters the next building to prevent problems. Refrigeration dryers use well proven technologies that encounter few problems if properly installed and maintained. The types of problems that can affect the performance, and hence energy consumption include:

- internal contamination effects dewpoint - pre-filtration is recommended
- high compressor delivery temperatures
- high ambient temperatures
- poor installation/ventilation
- faulty drain traps allowing liquids downstream of the dryer
- loss of refrigerant.

DESICCANT DRYERS (-20°C TO -70°C DEWPOINT)

Desiccant dryers work by feeding compressed air through an alternating duty section while a non-duty section is used for regeneration. These units are designed to remove vapour phase moisture. There are several types of desiccant systems, the main two types being: heated and heatless dryers. 'No Purge' low energy use desiccant dryers have recently been introduced to the market, these dryers work on similar principles to standard desiccant dryers, however, regeneration is carried out by the use of heated ambient air being drawn over the non-duty section under vacuum. All types usually require oil removal filters, water removal filters and dust removal filters (and an activated carbon absorber unit may also be used for oil vapour and hydrocarbon odour removal). Desiccant dryers are reliable, well-proven machines, however, it is important that they are correctly sized, controlled and maintained, otherwise they have the potential to be high energy users, costing your business greatly. It is important not to oversize desiccant dryers, particularly the heatless models as the dryer has a fixed purge loss/purge cycle time. This means much energy is wasted if the demand is considerably less than the dryer design flow.

However, most dryers are now supplied with energy management control systems, such as dewpoint dependant switching. This makes desiccant dryers more efficient and by using an energy management control system such as dewpoint switching, can lead to savings of up to 90%, depending on installation and usage. These models have built-in dewpoint switching or in-bed sensing devices that alter the level of regeneration according to the load level. Running costs will also rise significantly without proper operation and maintenance. Efficient operation of a desiccant dryer can also be hampered by:

- poor cooling of inlet air
- poor pre-filtration causing liquid phase water and oil carry over
- high peak loads causing desiccant bed fluidisation (twin tower type only)
- faulty change-over valves causing continuous purge
- faulty controls causing poor or no regeneration of individual towers
- desiccant contamination by oil.

DELIQUESCENT DRYERS (10°C TO 11°C DEWPOINT)

This is a simple form of chemical dryer in which the compressed air is passed over soluble material such as a bed of salt. The soluble material dissolves as it absorbs moisture. These dryers are not regenerative. Deliquescent dryers do not lose any air volume (unless fitted with an automatic draining system - generally a timed drain) and have virtually no energy loss. The only extra energy consumption is required to overcome the pressure drop that occurs within the dryer. Deliquescent dryers generally require oil/water removal filters and dust removal filters. While they are the least expensive dryer and are very energy efficient, deliquescent dryers can only produce dew points about 6°C below the inlet temperature. Deliquescent dryer efficiency is hampered by the following factors:

- The deliquescent material needs to be regularly replaced incurring higher labour and material costs
- If the dissolved deliquescent material is not correctly drained it can cause pressure drop and blockage of the post-filter
- Corrosion and Health and Safety issues also need to be considered when using this method

MEMBRANE DRYERS (+4°C TO -40°C DEWPOINT)

These dryers diffuse the moisture from the compressed air to the atmosphere using hollow-fibre membranes. Membrane dryers are mostly used when low dewpoints are required in localised areas of a system. These dryers can prove very costly, particularly if operated at a light load. The membranes are also highly susceptible to oil and dirt, which causes the membranes to break down quickly. As the structure is microscopic, it cannot be cleaned and has to be replaced. In an oil free environment the membrane dryer should last for many years. Membrane dryers cost as much to run as a heatless desiccant dryer without the advantage of a low pressure dewpoint. Certain types of membrane can reduce the oxygen content of the compressed air and, therefore, should not be used in breathing air applications.

SORPTION DRYERS (-15°C TO -40°C DEWPOINT)

Sorption dryers can only be used with an oil-free compressor. Compressed air travels via a sealed segment of a drum, which contains the drying medium. A very small motor slowly rotates the drum, drying the air. In the part of the drum not being used the drying medium is regenerated by hot air taken from a previous process, i.e. by the compressor's waste heat. The cost to provide air by this method is typically around 3% more than delivering after-cooled air. Limitations of sorption dryers are as follows:

- Units must be accurately matched to an individual compressor and can not be shared by multiple compressors
- The dewpoint output is directly related to the temperature of the cooling medium used
- Sorption Drum replacement expensive

DEWPOINT ISSUES

No matter which configuration of dryers is chosen there are some common problems that impact on their efficiency and energy costs. Often dryers have difficulty performing at expected efficiency due to poor ventilation and/or incorrect installation. Furthermore, inlet temperatures are frequently elevated above those allowed for in the system design causing poor dewpoints. A common cause of poor dewpoint is when different dryers are arranged in parallel – different makes of dryer, or dryers of different capacities – creates unbalanced flow between dryers. The correct manifolding, piping and utilising either sonic nozzles or orifices can overcome this.

AIRLINE FILTERS

Air compressor systems need filters to create the different air quality levels required by different machines. Air filters can be located throughout the system and the number and type of filters will vary according to the quality of air required.

Compressed air has 3 contaminants: water, particulate and oil (if lubricated compressor) which all mix together to form an unwanted abrasive sludge. The same amount of water and dirt is generated whether a lubricated or non-lubricated compressor is used, therefore, both types of compressor need the same level of filtration. It also corroded piping systems which contributes to additional particulate (rust) contamination to downstream equipment and products. This all leads to decreased efficiency and increased energy consumption. It is, therefore, imperative that high efficiency filtration is selected which will maintain a low operation pressure differential whilst providing complete protection.

Air-filters can be divided into two categories: Pre-filters, which operate prior to compression and/or drying and After-filters which are put in place after the air is dried.

PRE–FILTERS

INLET FILTERS are provided to protect the compressor from incoming dirt. These filters use power to overcome pressure drop, however, this is taken into account in the compressor package performance figures. These filters will affect efficiency when they become dirty and can typically cause an increase in power consumption of 3%. Therefore, it is important to change the filters as recommended by the compressor service manual.

GENERAL PURPOSE FILTERS are usually installed between the after-cooler and drying process. Filters remove the contaminants from compressed air (water, particulate and oil) and are, therefore, required by non- lubricated and lubricated compressors.

HIGH EFFICIENCY OIL REMOVAL FILTERS provide air quality (technically oil-free) similar to that supplied by an 'oil-free' machine. It is able to remove almost all water and oil aerosol.

AFTER-FILTERS

DUST REMOVAL FILTERS are most commonly used with a desiccant dryer to remove the desiccant fines that are collected and carried downstream as the air encounters the drying process.

ACTIVATED CARBON FILTERS are required if the air is required for breathing; mixing with food, pharmaceutical products or other such duties. While other filters will remove water, liquid oil, oil aerosols, and dirt, only carbon filters will eliminate oil vapours and oil (and other hydrocarbon) odours.

HOPKALITE FILTERS are required if the air is required for breathing and there is a risk of Carbon Monoxide being present in the system. These filters are used in conjunction with desiccant dryers, which with the use of the correct desiccant can reduce Carbon Dioxide levels and are required to keep the Hopkalite active.

STERILE FILTERS eliminate micro-organisms from compressed air and are used in processes which require the highest air quality. Sterilised filters are designed to be resterilised in place using steam.

POINT OF USE FILTERS are used to remove particles that have accumulated during distribution of compressed air. This contamination often occurs in piping, particularly in ageing large systems where rust and pipescale can collect. Activated Carbon filters are also used as point of use filters for the application as stated above.

Filters cause pressure drop and are often responsible for compressors generating at a pressure well above that required for the process. This occurs if filters are undersized, the wrong filters are being used for the job, too many filters are being used or filters are poorly maintained. When designing new or reviewing older systems it is recommended that the following points be considered:

- Peak air demand
- Piping - size and the type of material it is made from
- Contamination levels in the pipe including any effects from treatment changes
- The required air quality at each usage points and the demand for each quality
- Compressor configuration
- Compressed air and ambient temperature at filtration points
- Air dryer configuration
- Isolation valves in the system.

This information will assist in the calculation of the minimum number of filters required for the duty. Energy costs can be avoided by minimising your filtration requirement. Ensuring filters are adequately sized is also an important step in lowering running costs. Many systems have screwed or flanged connections to housing, which are often found to be much smaller than the pipe work diameter upstream and downstream of the filter. These filter connections that are considerably smaller than the pipe work will cause pressure drops. Paying more for filters with correctly sized flanges avoids energy wastage and saves dollars in the long term. When selecting filters the flowing capacity should be rated using peak potential flows. The capacity of filters to efficiently capture contaminants is also greatly reduced if the inlet air temperature is greater than the manufacturer's recommendations. Pressure differential gauges show when filters need to be replaced and should be fitted to all filters. Maintenance of filters is very important and will lower compressed air costs. Studies have shown that the economic offset between cost of element replacement and cost of energy to overcome pressure drop as 35 kPa. It is, therefore, paramount that a high efficiency filter is used that will remove all contamination with the lowest possible pressure drop.

RECEIVER

Air receivers can be added to compressed air systems allowing the compressor capacity to be temporarily exceeded so that short-term demand spikes can be met. Receivers also create more stable pressure conditions, working to dampen compressor pulsation, separate out particles and liquids, and make the compressed air system easier to control. Additionally, receivers act as a secondary cooling device. Installing a larger receiver tank to meet occasional peak demands can even allow a smaller compressor to be connected.

In most systems, the receiver will be located just before the dryer, as the receiver gives further cooling of the air prior to the dryer, and so reduces the amount of condensate the dryer has to deal with, increasing efficiency or the dryer. Alternatively, you may use multiple receivers, one prior to the dryer and others closer to the points of intermittent/high demand. Storage can be used to control peak demand periods in the system, to protect critical pressure applications from other events in the system or to control the rate of pressure drop in demand while supporting the speed of transmission response from supply. Often systems run a secondary compressor to cater for intermittent demand, compressor failure or short energy outages. The installation of air receivers may enable this compressor to be turned off.

On most installations, the receiver is fed from the after-cooler and further cooling will take place in the receiver. On installations where an after-cooler is not fitted, the receiver is where most condensed liquid is found. Therefore, the receiver needs to be fitted with drain traps, (preferably automatic) to remove the condensate and any carry-over solids such as dust, scale, carbon etc. The receiver should, wherever possible, be placed outside in a cool location, further reducing the temperature of the compressed air and increasing the amount of water and oil condensation. Additionally, some moisture can pass through the after-cooler condensate removal separator at high velocity. A receiver can help to trap this by creating a quiet zone where the turbulence is considerably reduced.

REGULATOR

Regulators allow a compressed air system to supply air at different pressure while minimising wastage. If an application requires air at a pressure lower than the main supply and it is not practicable to install a separate pressure system a regulator should be fitted. An example of this might be when using compressed air for control and instrumentation. By not over supplying air pressure and decreasing pressure at the point of use efficiency gains and dollar savings can be achieved. Regulators can also help to maintain pressure to the minimum acceptable level. The air consumption of most air-using devices, such as air tools, spray guns and air knives, increases in proportion to the operating pressure ratio. Minimising this level reduces operating costs.

CHECK LIST	
Separator and Condensate Drainage	
	Ensure drain points are located correctly
	Consider installing automatic drain traps
	Design and implement a maintenance plan for drainage system
Dryers	
	Determine required dewpoint
	Select an appropriate dryer considering dewpoint and size requirements
	Check adequate ventilation and inlet temperature
	Review the layout of multiple dryers within the system
Air Line Filters	
	Decide type of filters required to achieve desired air quality
	Minimise the number of filters in the system, without sacrificing the desired air quality
	Ensure filter size is matched to piping system
	Check inlet temperature is not too high
	Clean and replace filters elements in a timely fashion as per manufacturers instructions
Receiver	
	Investigate the possible uses for receiver
	Consider placing receivers in cool outdoor locations
	Assess the removal/downsizing of compressors as a result of receivers
Regulator	
	Investigate installing regulators

If you would like more information contact:

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For up-to-date telephone details please check the AMEI website

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