Low pressure air drying

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Introduction

For the drying of compressed air several technologies are available on the market. Compressed air often has a pressure of 5 bar(g) – 7 bar(g). However, many applications run at pressures between 0.5 bar(g) and 4 bar(g). For those applications drying is often required.

Points of attention

Drying of compressed air requires specific precautions. When the air is under pressure, the dryer needs to be constructed to avoid burst or explosion of the pressure bearing parts. On the other hand the volume taken by compressed air is much smaller than the volume taken by air at atmospheric pressure. This makes it possible to use smaller components. This also means the lower the pressure, the bigger the volume, the bigger the components or dryers. In general a compressed air dryer sized for a certain compressed air flow at 7 bar(g) is half the size of a compressed air dryer for the same flow at 3 bar(g).

Another important point of attention is the pressure drop over the dryer. A pressure drop of 0.3 bar at a working pressure of 7 bar(g) is high and causes an increased energy consumption of 2% of the compressor power.
The lower the working pressure, the bigger the impact of the pressure drop.

Refrigerant dryers and adsorption dryers which are equipped with electronic water drains require a check of the minimum working pressure of those drains. Some models do not function below a certain minimum pressure and will need to be replaced with another variant or model.

Solutions

Depending on the application requirements, different drying techniques can be used. When the application requires a pressure dew point of only 3°C, a refrigerant dryer will be sufficient. When the application requires pressure dew points of -20°C to -40°C or even down to -70°C a desiccant dryer is required.

For both technologies a rule of thumb can be applied to do a preliminary sizing. Starting with the dryer size for the flow at 7 bar(g) apply a correction factor based on the pressure ratio between the 7 bar(g) and the real working pressure e.g. 3 bar(g). To calculate the pressure ratio, the absolute pressure needs to be taken. For this example (7+1) / (3+1) = 2 so a derating factor of 2 is applicable in this case. The dryer needs to be twice the size for the same flow at 3 bar(g) iso at 7 bar(g).

This principle is valid for all types of compressed air dryers.

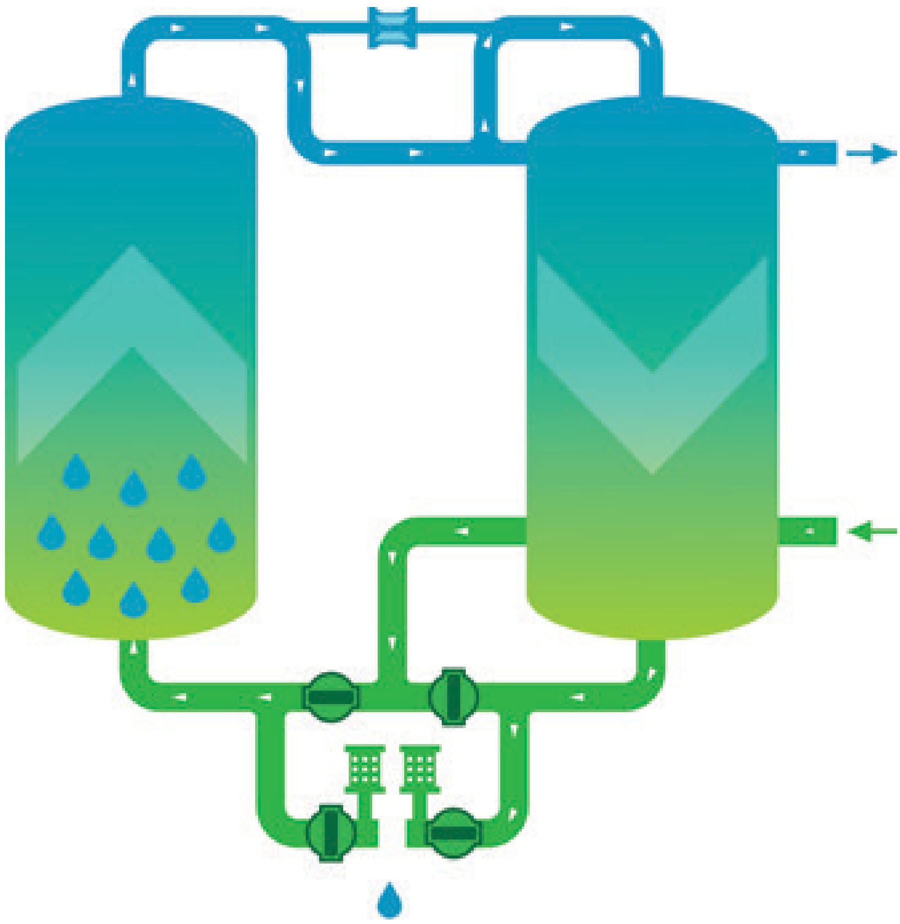
For applications working at very low pressures below 0.5 bar(g), an atmospheric air dryer can be installed at the inlet of the blower. The air is dried and then compressed to the required pressure. The benefit of this is the use of standard available ambient air dryers, the backdraft is there is no knowledge or control on the humidity of the compressed air. Furthermore, at atmospheric pressure the dryer needs to be bigger than at 0.5 bar(g).

Adsorption dryers

Adsorption dryers are used when the compressed air application requires a pressure dew point which is below 0°C. In most cases those dryers exist of two pressure vessels next to each other, both vessels are filled with hygroscopic beads, desiccant. The compressed air is passing through one vessel and the moisture from the air is adsorbed by the beads. After a certain amount of moisture has been captured, the beads are saturated, at this moment the air is guided to the second vessel. While the compressed air is passing through the second vessel, the first vessel is regenerated, when the second vessel is saturated, the air is guided again through the first vessel and the regeneration of the second vessels starts.

Cold regenerated dryers

There are two major manners to regenerate the desiccant beads. The first one is the cold regeneration. With this type of dryer a small portion of the dried compressed air is expanded to atmospheric pressure and sent over the saturated vessel of desiccant. The cold regeneration requires a minimum of electricity, only for the controls. At a working pressure of 7 bar(g) this type of dryer consumes up to 18% of the compressed air for the regeneration, at a working pressure of 3 bar(g) it consumes up to 40% of the compressed air to fulfill the regeneration. For low pressures, the heatless desiccant dryers are not an economic solution.



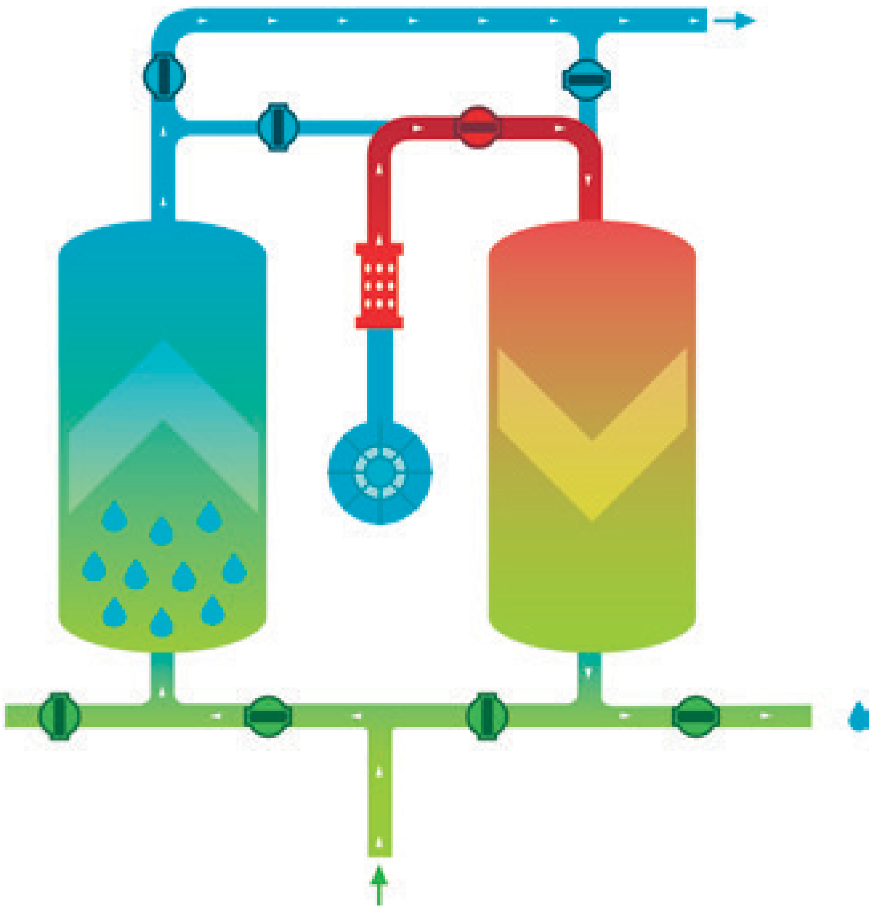
Heat regenerated dryers

The second regeneration principle is heating up the saturated desiccant beads. By heating them the water retaining forces are broken and the moisture is released from the beads, an air flow transports the moisture away from the saturated vessel. The heat regenerated adsorption dryers are available in several executions.

In heated purge desiccant dryers a portion of the dried compressed air is expanded to atmospheric pressure and sent over a heater to increase the temperature up to 150°C – 180°C. This hot air is sent through the vessel with saturated desiccant. The low working pressure has a big impact on the running cost during the regeneration cycle of this type of dryers.

For the heated blower purge desiccant dryers, a blower is installed. This blower takes ambient air and sends it over a heater. The air is heated to a temperature of 150°C - 180°C and sent through the vessel with saturated desiccant. The low working pressure has a limited impact on the running cost during the regeneration cycle of this type of dryers.

The heat of compression desiccant dryer uses the heat generated during the compression process to heat the desiccant bed and to remove the moisture. If there is not enough heat available from the compression process, extra heat augmentation might be needed to achieve the required pressure dew point.



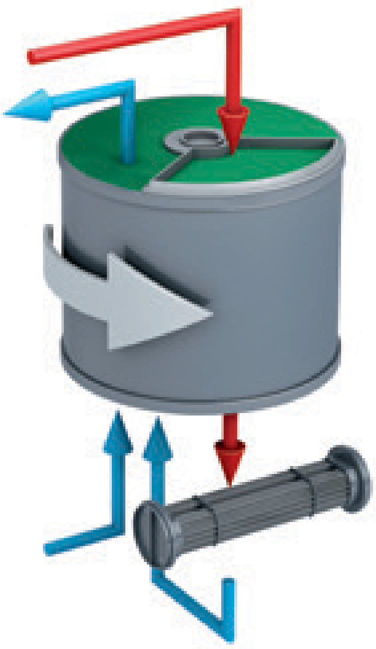
After heating, the desiccant beads need to cool down before they can start adsorbing again. The cooling can be done with dry compressed air, with cold ambient air or with cold compressed air. Each cooling method has its benefits and backdrafts.

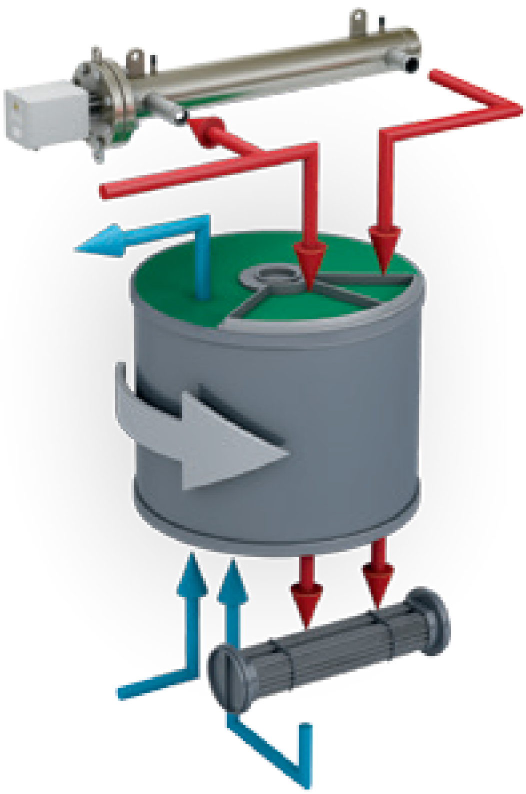
For the desiccant dryers which are consuming purge air to cool down the desiccant bed, the working pressure has a big impact on the energy consumption to execute the cooling of the desiccant bed.

Rotary drum dryers

A variant on the twin tower heat of compression adsorption dryer is the rotary drum adsorption dryer. The rotary drum adsorption dryers are made of one vessel. In this vessel there are no desiccant beads but a drum. This drum is a honeycomb structure on which the adsorption material is impregnated. The drum is rotating at a very low speed and makes a few rounds per hour. A part (3/4th) of the drum is used to dry the compressed air, the other part (1/4th) is regenerating.

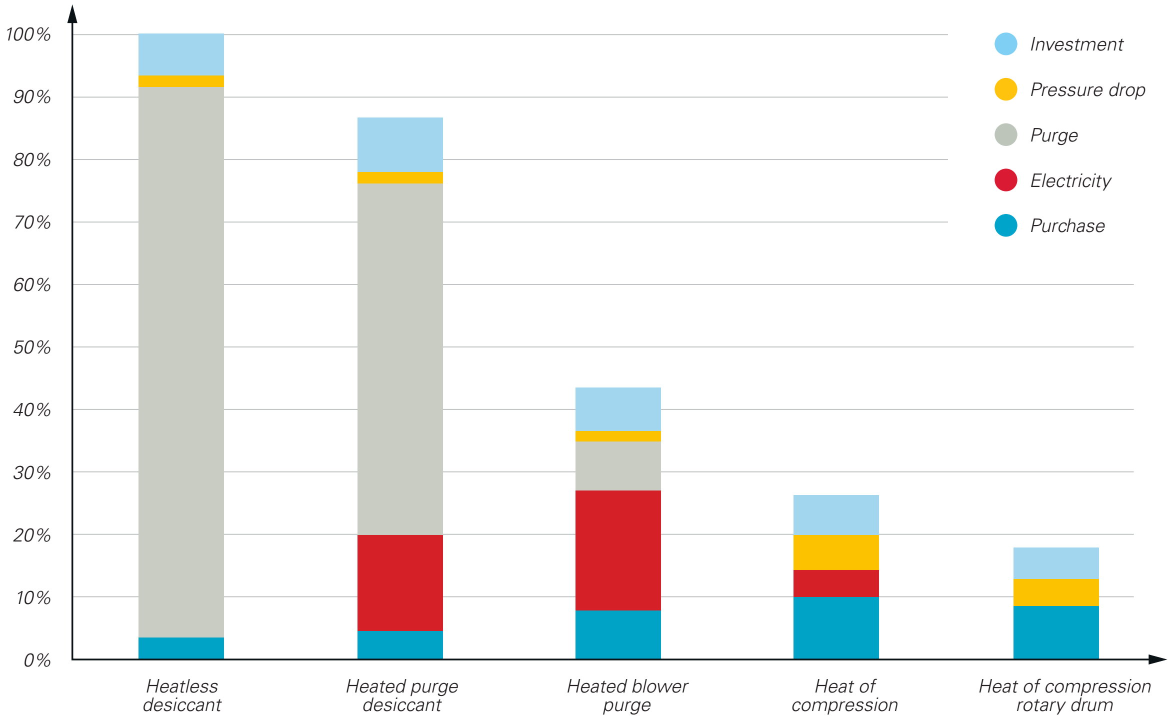
The regeneration is done with hot compressed air. If there is not enough heat available from the compression process, extra heat augmentation might be needed to achieve the required pressure dew point. The benefit of the rotary drum dryers is that they do not have switching valves, there is only the electrical motor and the rotating drum, no more moving components. There is no need for filtration of the compressed air before the dryer and due to the fact that the active material is bounded to the drum, there is no need for outlet filtration. Rotary drum dryers do not need a separate cooling cycle. All these points result in a very low pressure drop over the dryer and a very low energy consumption of the dryer.





Life Cycle Cost comparison

When we compare the total life cycle cost of the different drying technologies for a 10 year period, we can see that the rotary drum dryer has a life cycle cost less than 1/5th of the total life cycle cost of a heatless desiccant dryer. This calculation is executed for a working pressure of 3 bar(g). When the working pressure is lower, the difference is even bigger.



Refrigerant dryers

For applications which do not require dew points lower than 0°C a refrigerant dryer is the best solution. To do the sizing, the rule of thumb of the pressure ratio explained before is valid for refrigerant dryers.

Aftercoolers

Often low pressure compressors or blowers are not equipped with a built-in aftercooler. Depending on the working pressure and the inlet temperature, the outlet temperatures can go up above 60°C to over 250°C. Often those temperatures are harmful for the process, the processed goods or are dangerous for the people using the equipment. When the installation is modified by adding a dryer when the air needs to be dried, or when the air needs to be cooled down and has to pass through an aftercooler before entering the dryer, standalone coolers can be a solution. Water cooled coolers give the best performance for the space consumption compared to air cooled coolers.

By cooling down the air, the moisture can condensate, to avoid free water entering the system. A proper water separation and drain needs to be part of the cooler set-up. One of the key performance indicators for the coolers is the pressure drop, especially for applications at low pressure, each mbar pressure drop results in an increased energy consumption of the compressor or blower. Important is also the material from which the cooler core is made. Often copper is used, which has a very good heat transfer capacity, the backdraft is the sensitivity to the quality and the components of the cooling water. They might cause corrosion of the copper core which has a negative impact on the heat transfer capacity and the life time of the cooler. Therefore it is better to use stainless steel, which requires a bigger cooler but the lifetime is much longer and the maintenance costs are much lower.

Conclusion

Depending on the requirements for the application, standard refrigerant or standard adsorption dryers can be used.

For the adsorption dryers it is best to use the variants which do not consume any purge for the regeneration or the cooling. From life cycle cost point of view, the rotary drum heat of compression dryers are the best solution, if heat of compression dryers are not possible, the heated blower purge desiccant dryers with zero purge cooling are the best alternative.

For all dryer types, the pressure ratio between 7 bar(g) and the real working pressure gives an indication of the derating factor to be applied and can help to do a preliminary sizing of the dryer.

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