

# *White paper* *Compressed air drying*

*Atlas Copco*





***White paper : Compressed air drying***

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## ***Introduction***

Many tools and equipment, driven by compressed air, cannot withstand water or moisture. Many processes, using compressed air, are processing products which cannot withstand water or moisture. Inherent to the compression cycle, free water is often formed in the compressed air circuit.

Free water in a compressed air system often causes corrosion which leads to rust forming in the compressed air system. Those rust particles will be released and transported through the compressed air system. This can result in damage or failure of the compressed air tools and can cause contamination of the processed products.

Free water or moisture in a compressed air system can sustain bacteria growth or the moisture can be adsorbed by the processed product leading to quality deviations and product spoilage.

## ***Where does the water come from?***

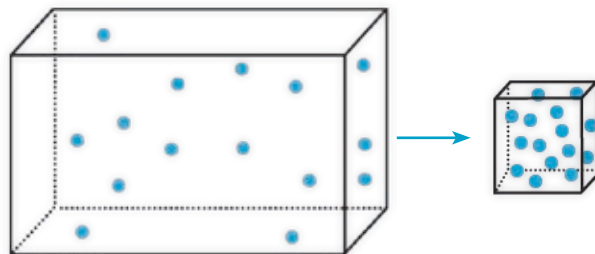
Atmospheric air always contains water, most of the times as vaporized moisture, sometimes as free water (when it rains). The water vaporized in the atmosphere is most of the times not visible or notable.

Air at a temperature of 35°C can contain a maximum of 39 grams water per m<sup>3</sup> of air in the form of vapor, with 39 g/m<sup>3</sup> the air has a relative humidity of 100%. If there is more water present in the air, excess of water condenses into droplets and not into vapor. When the temperature of the air decreases, the amount of water which can be contained as vapor is decreasing as well e.g. air at a temperature of 20°C can contain max. 17 grams of water per m<sup>3</sup> of air as vapor. This means if we take 1m<sup>3</sup> of air at 35°C with 100% relative humidity and we cool this down to 20°C, there will be 22 grams of free water formed.

The dew point is a parameter which is often used to measure the dryness of the air, air at 35°C containing 39g of water vapor per m<sup>3</sup>, which is 100% relative humidity, has a dew point of 35°C. Air at 35°C containing 22g of water vapor per m<sup>3</sup> of air has a relative humidity of 56% and a dew point of 20°C. When these values are measured at atmospheric pressure, we talk about the atmospheric dew point. When these values are measured under pressure we talk about pressure dew point. When atmospheric air is compressed, the concentration of water vapor increases with the pressure ratio.

At a normal ambient condition 35°C and a relative humidity of 60% there is approx. 23 grams of water per m<sup>3</sup> of air as vapor. When compressing the ambient air from atmospheric pressure up to 7 bar (g), the concentration of water vapor increases 8 times. So per m<sup>3</sup> of compressed air there is 184 grams of water. This means per m<sup>3</sup> of compressed air leaving the compressor at 35°C 145 grams of free water is entering the compressed air system.

A 90kW compressor, working 8 hrs. per day, delivers up to 970m<sup>3</sup> compressed air during those 8 hrs., resulting in 140 liters of water every day



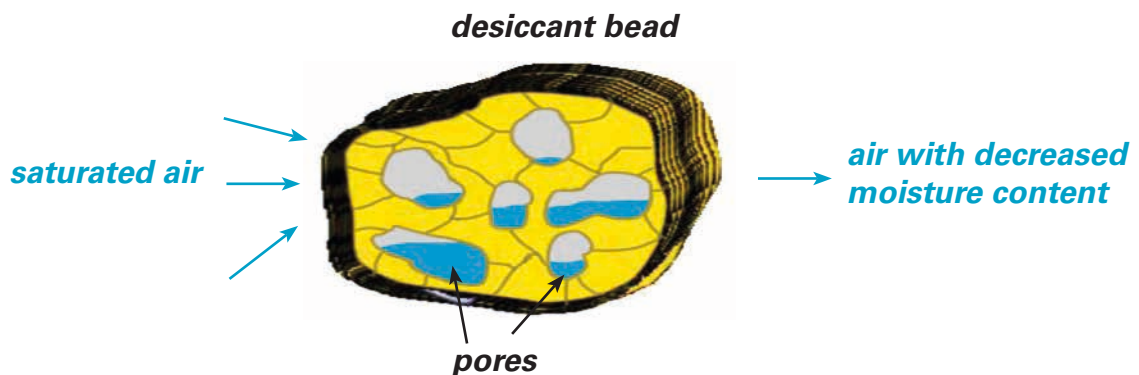
entering the compressed air system!  
Besides the free water, also water vapor is entering the compressed air system, 39 grams per m<sup>3</sup>, this results in more than 37 liters of water as vapor entering the compressed air system every day.

## ***How to remove the water?***

There are several ways to remove water and moisture from compressed air.

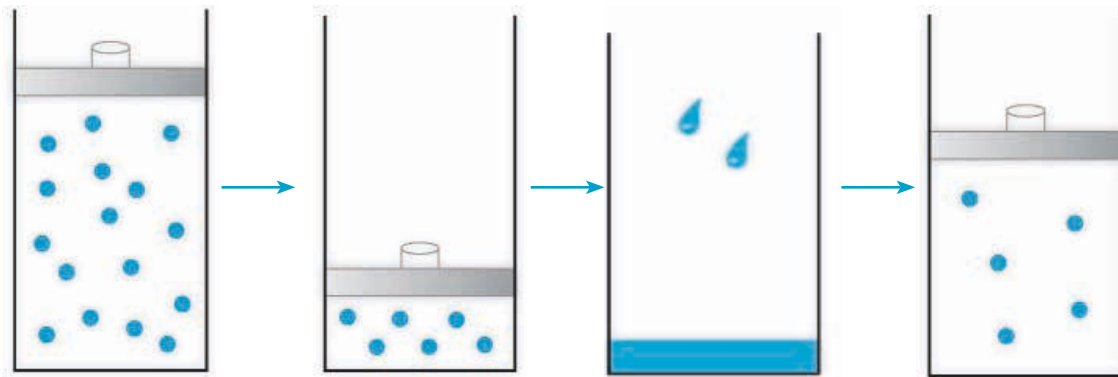
- The first method is overcompression, the pressure is increased to a level above the required compressed air pressure and at this higher pressure the free water droplets are removed. In the next step, the pressure is decreased to the required compressed air pressure. From this stage, only water vapor is present in the compressed air, the relative humidity dropped below 100%.
- A second method is cooling, the compressed air is cooled down to a lower temperature. At this lower temperature, the relative humidity exceeds 100% and free water droplets are formed. Those free water droplets are collected and removed. In the next step the temperature of the compressed air is increased again. From this stage, only water vapor is present in the compressed air, the relative humidity dropped below 100%.
- As third method chemical drying is often used, the moisture is removed by absorption or adsorption in a certain substance. With absorption, the moisture is captured in a hygroscopic liquid or powder. The moisture is attached to this material and needs to be removed and replaced by new material for further operation.

With adsorption, the moisture is captured in hygroscopic beads. The moisture molecules are transported into the pores through diffusion and are accumulated through physical binding and capillary condensation. In this case, when the beads are saturated, they have to be regenerated before they can start adsorbing again. The regeneration can be done by heating the beads or by sending extreme dry air over the beads. In both cases the water retaining forces are broken and the water molecules are removed.



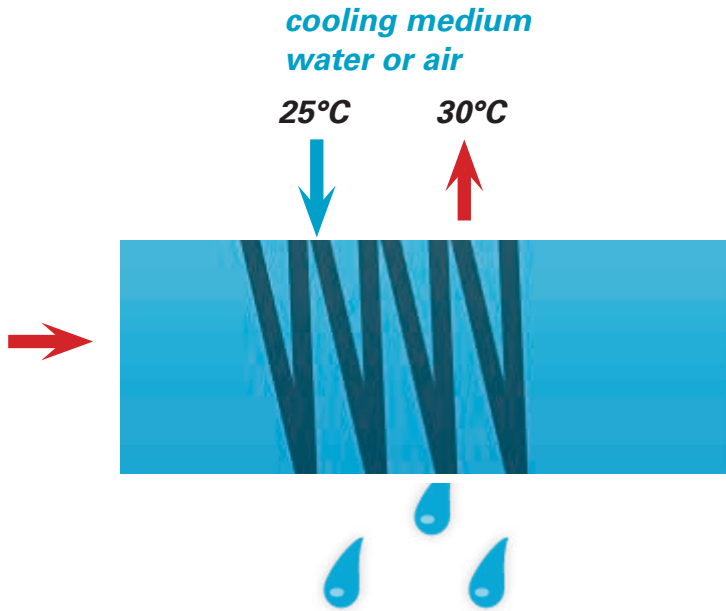
### Drying methods

Overcompression is a very expensive method of drying compressed air and the amount of water which can be removed is limited. This is not used as drying method.



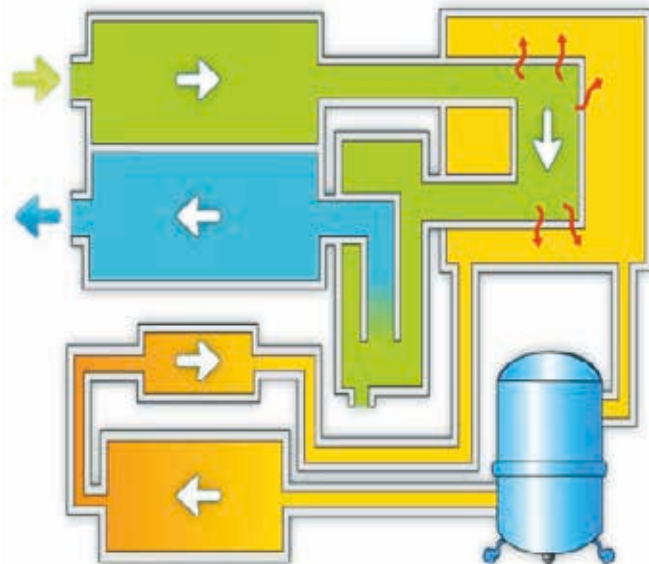
Absorption is an expensive method and the effluent of the dryer is a very aggressive liquid which needs to be treated as chemical waste. The absorption material needs to be continuously replaced with new material, this makes this system very expensive. The potential dew point suppression which can be achieved with this type of dryers is limited to 15°C.





Cooling as drying method is very often used. Sometimes a heat exchanger with chilled cooling water is used to cool down the compressed air. At this low temperature, moisture is condensed into droplets of free water, which are collected and removed. This system is limited to the cooling water temperature and requires a water chiller to reduce the cooling water temperature.

A more commonly used way of drying by cooling can be done by refrigerant dryers. In refrigerant dryers, a Freon circuit cools the compressed air. The limitation of a refrigerated dryer is the freezing point of water. If the temperature in those dryers gets lower than 0°C, the free water droplets will freeze and will block the compressed air stream.



Adsorption dryers are mainly used when the required pressure dew point needs to be below 0°C. Most of those applications require dew points down to -40°C or even -70°C.

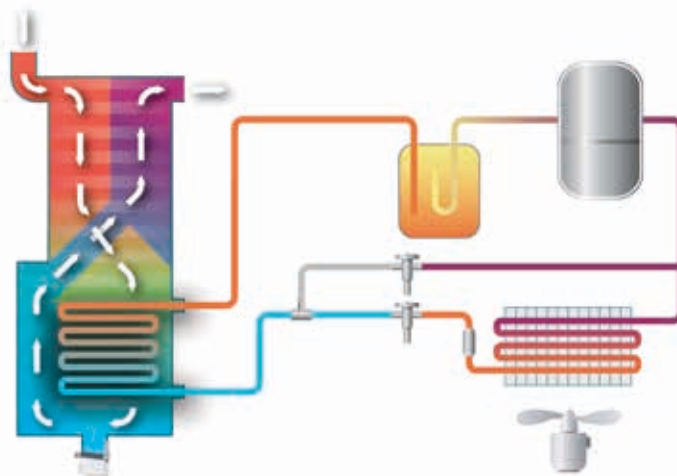


## Refrigerant dryers

Refrigerant dryers are the most common used type of compressed air dryers. They consist of an air-to-air heat exchanger and an air-to-Freon heat exchanger.

- The compressed air from the compressor first passes the air-to-air heat exchanger. In this phase the incoming air is pre-cooled by the outgoing air and the outgoing air is heated.
- In the second phase the compressed air is passing the air- to-Freon heat exchanger, in this phase the compressed air is cooled further down to a temperature of around 3°C. At this temperature the moisture is condensed, the free water droplets are collected and removed, at this point the relative humidity of the compressed air still is at 100%.
- In the next step the compressed air is heated with the incoming air, the increase in temperature assures that the relative humidity of the outgoing air is dropping below 50%.

Refrigerant dryers are used in compressed air systems to avoid free water and corrosion in the system, a relative humidity of below 50% is enough to achieve this. Refrigerant dryers are available in a water cooled and an air cooled variant.





## Adsorption dryers

Adsorption dryers are used when the compressed air application requires a pressure dew point below 0°C. In most cases, the dryers consist of two pressure vessels next to each other. Both vessels are filled with hygroscopic beads, desiccant. The compressed air is passing through one vessel while 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 point, 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.

There are two major techniques to regenerate the desiccant beads.



### 1. 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 expansion of the dried compressed air to atmospheric pressure makes the air much dryer. The moisture goes from the desiccant into the dried air and is transported to the atmosphere. The limited regeneration energy causes very short cycle times, typically 2 à 3 minutes.

The cold regeneration requires a minimum of electricity, only for the controls. Even variants with pneumatic timers are available which makes it possible to run those dryers without electrical power supply. The regeneration consumes up to 18% of the compressed air, this means 18% of your compressor power is used for the regeneration. This makes the cold regenerated compressed air dryers the most expensive in use, the design is simple and reliable and the purchase price is low.

## 2. Heating up the saturated desiccant beads

By heating the beads, the Van Der Waals 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.

### Heated purge desiccant dryers

In these 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 – 180°C. This hot air is sent through the vessel with saturated desiccant. The moisture is released and sent with the air to the atmosphere.



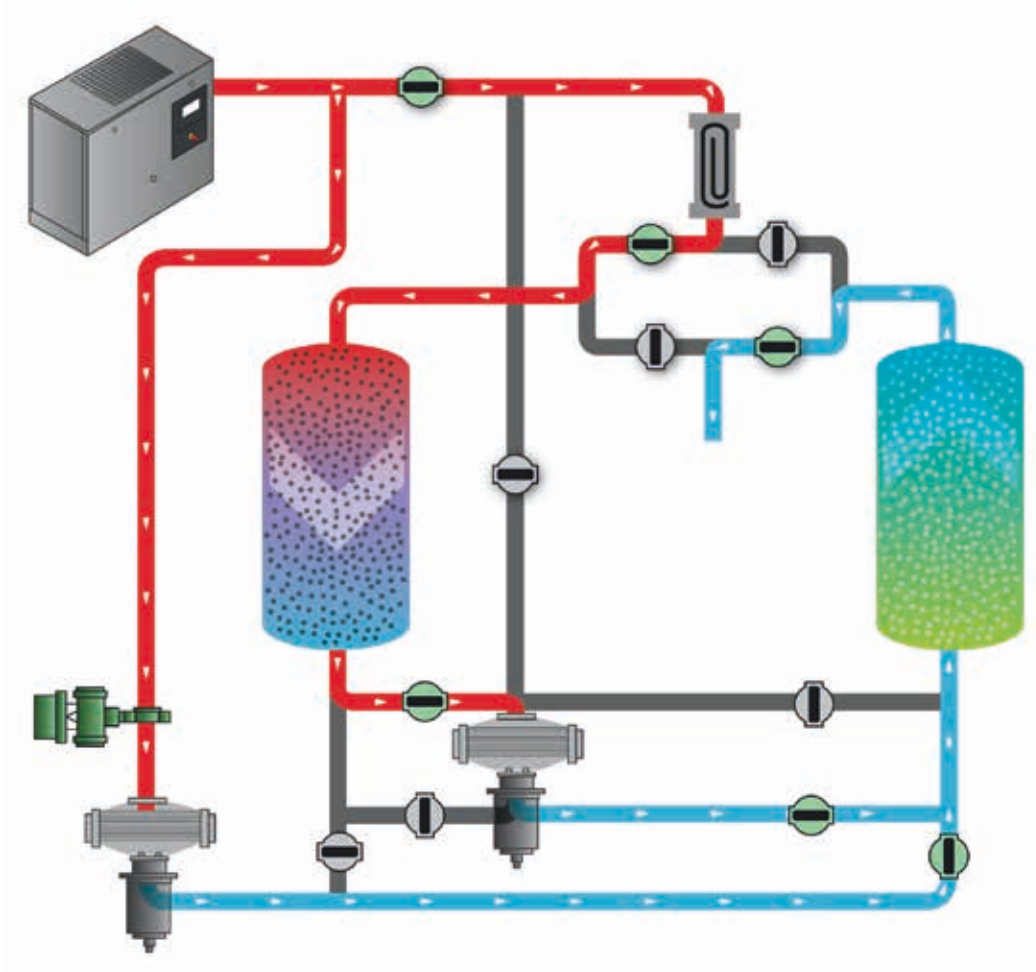
### Heated blower purge desiccant dryers

In those dryers a blower is installed, that takes ambient air and send it over a heater, the air is heated to a temperature of 150-180°C and send through the vessel with saturated desiccant. The moisture is released and send with the air to the atmosphere.



### The heat of compression desiccant dryer

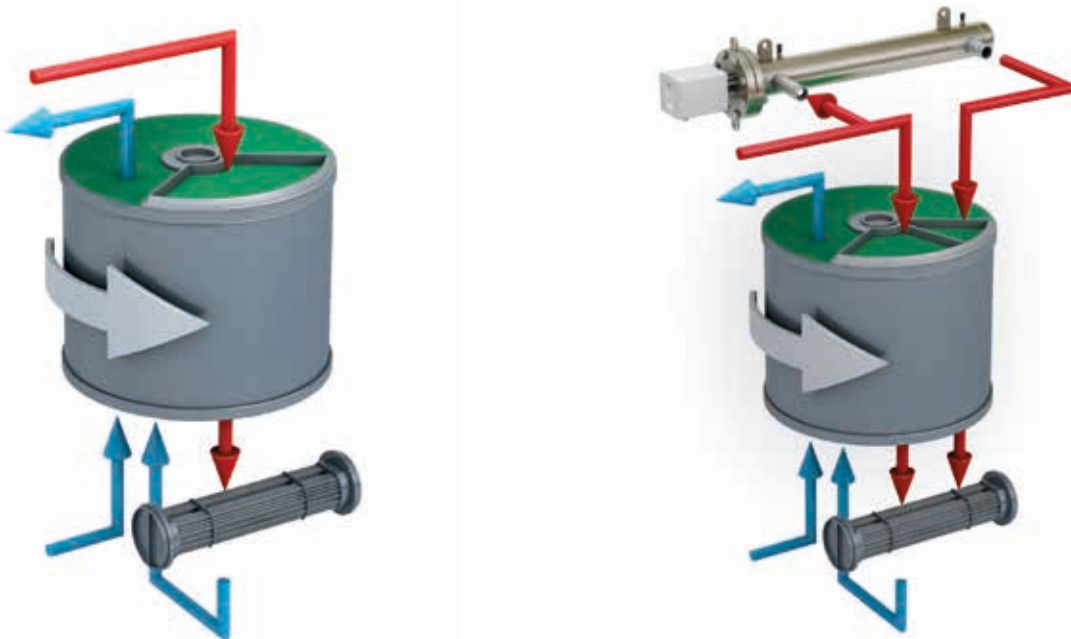
This type of dryer uses the heat generated during the compression process to heat the desiccant beads and to remove the moisture. Most of the times hot compressed air from the compressor is sent through the saturated vessel, the moisture is released and transported with the compressed air to a cooler. In this cooler the compressed air is cooled, the moisture is condensed and removed. After the cooler, the compressed air goes to the vessel with dry desiccant. In this vessel, the rest of the moisture is removed from the compressed air and dry compressed air is entering the compressed air system.



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 his pros and cons.

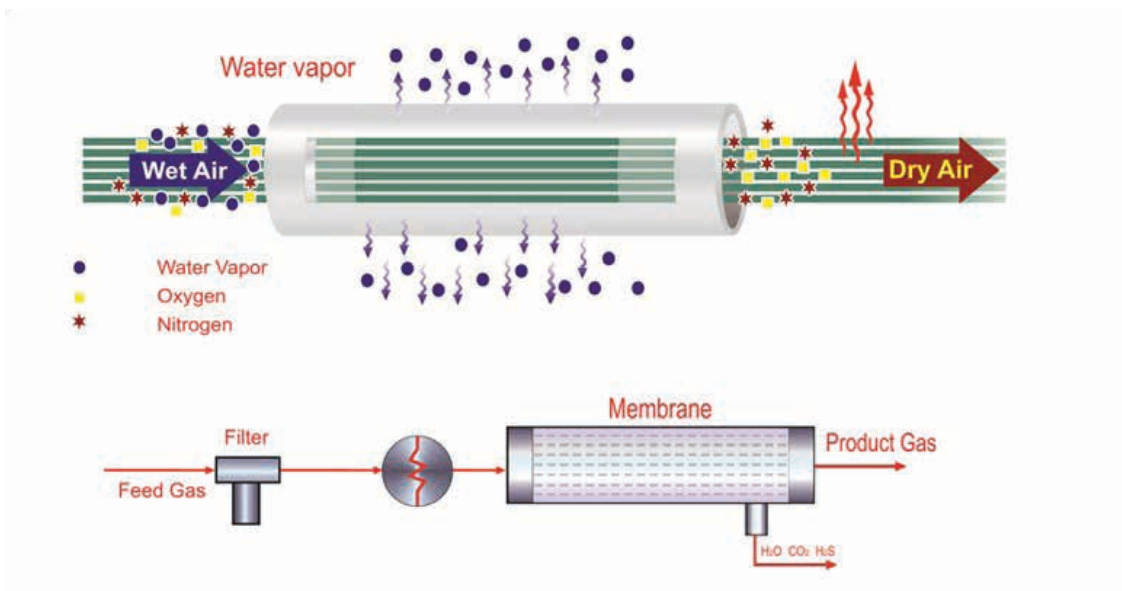
## Rotary drum dryers

A variant on the twin tower heat of compression adsorption dryer is the rotary drum adsorption dryer. The rotary drum adsorption dryers are existing out 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, 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 they don't 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. The rotary drum dryers doesn't need a separate cooling cycle. All these points results in a very low pressure drop over the dryer and a very low energy consumption of the dryer.



## Membrane dryers

Membrane dryers consist of polymeric tubes with selective permeability. This means the moisture is going through the tube shell while the compressed air stays at the inside of the tubes. A portion of the dried compressed air is sent over the outside of those tubes to remove the moisture to the atmosphere. The performance of the membrane dryers is defined by the temperature and humidity of the inlet air. They don't deliver a fixed dew point at the outlet but a dew point suppression. The construction is very simple and reliable, there are no moving components so the maintenance is nihil. The backdraft is the use of the dried compressed air, which goes up to 25% of the compressed air, meaning 25% of the compressor power is used for the regeneration.





## **Conclusion**

For standard compressed air applications where it is enough to avoid free water and corrosion in the compressed air network, a refrigerant dryer is the most energy efficient and reliable solution.

For more demanding installations where a certain negative dew point is required adsorption dryers are the only valuable solution. If it is possible to use a heat of compression dryer than this is the most economical solution, the purchase price is substantial but the cost of running is low and often a payback of less than 1 year is achieved compared to other regeneration technologies. If a heat of compression dryer is not possible, than the heated blower purge with zero purge cooling is the most economical alternative.

The heatless desiccant dryer is cheap to buy but the running costs are extremely high, this type of dryer can best be used in applications with a low amount of running hours or as back-up unit to take over in case of issues with the main dryer. Since this type of dryer can run without electrical power supply, it might be an alternative in remote installations.

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