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Compressed Air Dryer Guide

> What to consider & compare

Do you have moisture in your air system?

Is it affecting your process?

If you look online for options, there is an endless supply of information on compressed air dryers. Trying to decipher it all can quickly eat up time and put you in information overload. But it's critical to making the right choice for your application. The type you chose affects not only your process but operation and maintenance costs. Don’t forget your bottom line too.

Sauer Compressors USA has developed the following Compressed Air Dryers Guide to help you decipher sort through all the information. The document covers key considerations, advantages, disadvantages of refrigerated, desiccant, and membrane compressed air dryers.

Establish the Basics

Let's begin by reviewing some basics to create a background for those unfamiliar and refresh others' minds. Compressed air dryers use air that has been compressed. Compression occurs when the molecules are forced to move faster and closer together into a smaller space. The act increases the temperature in the air.

All compressed air contains naturally occurring moisture from the air used in compression. The hot air from compression can hold this moisture. If the gas cools at any point in the system, the moisture will condense into the air stream. That moisture can be a problem, and even more so if your application needs moisture-free air. Compressed air dryers separate water vapor or moisture from process air by cooling the air, absorbing the moisture, or permeation.

As compressed air cools, water vapor condenses, steam is collected, and moisture is removed. How this happens depends upon the type of compressed air dryer. By removing the moisture, you reduce the chances of problems like rust, scaling, or freezing in pipes, along with malfunctions, excessive wear, or poor performance by the equipment. You also avoid the slow or inconsistent operation of valves and cylinder control instruments. Removing condensed liquids from the gas will, in turn, remove oil liquids, which are present with oil-lubricated compressor systems, as well.

Overall Compressed Air Dryers Considerations

There are several overall areas to consider when comparing compressed air dryers. They include dew point, compressor size, operating pressure, operating costs, etc. Performance is measured by flow rate in Standard Cubic Feet per Minute (SCFM), and dew point expressed as a temperature (Pressure Dew Point), read at operating pressure of the compressor equipment.

Use the following for first level comparisons.

1. **Know your Dew Point**
   A top reason dryers fail is because they have not been sized correctly for the processes operating pressure. Determine the right size by looking at the air flow rate and pressure moving through the dryer. Find the balance between your dryer being able to handle larger CFM amounts without losing performance.
2. **Look at Compressor Size**
   Determine the best compressor size by looking at your dryer needs. Using a larger compressor than needed will lead to higher energy costs. You must ensure that the dryer selected is compatible with your compressor flow and operating pressure.
3. **Consider your Operating Pressure**
   A top reason dryers fail is because they have not been sized correctly for the processes operating pressure. Determine the right size by looking at the flow rate and pressure of the air moving through the dryer. Find the balance between your dryer being able to handle larger CFM amounts without losing performance.
4. **Match up the Specific Application and Dryness Level**
   Over specifying to bring all compressed air to its lowest possible dew point is expensive. It can eat into your bottom line and is usually not essential for lowering operating costs. Underspecifying can bring the dew point too high and damage the system, which is expensive. Find a happy medium.
5. **Leverage Pressure Reduction's Drying Effects**
   Gain the most out of drying effects from pressure reduction by installing filters or filter

regulators that will tolerate some water vapor in applications using air at lower pressures.

6. **Consider Up-front Operation and Maintenance Costs**
   Dryer sizing can be smaller at higher pressure (gas is moving slower) but rated for higher pressure. It may allow for a smaller footprint and greater pressure capabilities downstream. Dryer power consumption should be limited, controls confirmed, and maintenance regimes detailed.
7. **Create the Proper Environment for Success**
   Dryers typically require being paired with other ancillary equipment to ensure proper operation. Inlet gas and ambient conditions can affect a dryer's capabilities.

Comparison by Type - Refrigerated, Desiccant, & Membrane

Next, let's look at the advantages and disadvantages of the main types of compressed air dryers. The following chart covers refrigerated, desiccant, and membrane compressed air dryers. Use the information to compare further which type is best for your application and process. In general, you will find that all three are comparable for initial installation but separate when you start looking at operating costs.

Refrigerated Compressed Air Dryers

Refrigerated compressed air dryers are a commonly used and been the standard choice for manufacturing processes that do not have special requirements. One reason is that once installed correctly, you can almost forget them.

Refrigerated air dryers work much like a refrigerator in your home. They cool down the air to a pressure dew point of between 35°F – 50°F. As the temperature drops, water in the air becomes a vapor that condenses into water droplets. The droplets are separated from the compressed air

stream, collected, and discharged. The air, now called conditioned air, continues downstream for use further down in the process.

For this process to work, temperatures must not drop lower than 32°F. If it occurs, water in the pipes will freeze, causing damage and interrupting or stopping the process. Therefore, refrigerated dryers are not feasible for every process, especially water-sensitive applications that need extremely dry air. Initial costs for refrigerated dryers are affordable, and operating costs are reasonable if dew points are kept within the specified range.

Costs for maintenance are minimal, with no need for replacement parts or repairs caused by the process. The only operating cost is electricity. Unlike the other dryers discussed here, refrigerated dryers have no purge losses to dry the air, but they are limited in the achievable pressure dew point.

Two Kinds of Refrigerated Dryers

There are two kinds of refrigerated compressed air dryers called cycling and non-cycling. The difference between the two relates to how the refrigerant is cycled.

Type #1 - Cycling Dryers

Cycling dryers, also sometimes called thermal mass dryers, do what their name says. They cycle the refrigeration on and off, like your refrigerator at home, depending on demand to manage the pressure dew point within specifications (35°F – 50°F) at a varying flow rate. Heat is exchanged between the thermal mass and air entering the dryer. Air is cooled, and heat is transferred to a thermal storage media. They are used most often for manufacturing, especially in applications with fluctuating air demands.

The initial cost of the cycling dryer is a little higher than a non-cycling. However, over time they are more cost-effective. Manufacturers often select them because cycling adds the capability to increase or decrease cooling capacity according to air use. Plus, they reduced energy costs whereby lowering life-cycle costs. Maintenance time and costs are somewhat higher because cycling dryers use additional equipment such as thermal mass or frequency controllers.

Type #2 - Non-cycling Dryers

Non-cycling dryers are designed to run the refrigeration compressor continuously. It makes it possible to respond faster when changes occur in moisture densities within the incoming air. Refrigerant is managed by a hot gas by-pass valve that regulates the flow to accommodate changes. A heat exchanger condenses the refrigerant.

Non-cycling dryers are used regularly in manufacturing environments where steam engines remove moisture similarly to low-moisture environments. They cost less than cycling dryers and need virtually no maintenance. However, keep in mind that repair costs can change quickly with low compressor usage, leading to freezing pipes that can cause a shutdown.

Refrigerated Dryer-Specific Considerations

There are several key areas to consider when deciding whether to purchase cycling or non-cycling refrigerated compressed air dryers.

1. **What is the dryer's maximum pressure?**
   Check the maximum pressure when considering non-cycling or cycling dryers. The dryer's specifications must be the same or higher than the compressor for safe and efficient operation. The dryer is most efficient when used at the highest operating pressure allowable by the dryer and the compressed air system.
2. **What is the maximum flow?**
   Look at air flow rates. The highest flow rate for air moving through the dryer must be higher than the compressor can distribute.
3. **What is the maximum room temperature (outside the dryer)?**
   Dryers are prone to overheat if placed in a hot room. Check the specifications of the compressor and make sure it can handle the room's temperature. Be sure to consult any correction factors for the capabilities of the dryer.
4. **What is the maximum inlet temperature?**
   If the parts within the dryer exceed specified inlet temperatures, damage can occur. Plus, the dryer will be unable to reach the desired dew points. Check the inlet temperature specifications for cycling or non-cycling dryers under consideration. Make sure you do not exceed its capabilities. Depending on the temperature of the gas from the compressor, additional cooling may be required.

5. **What to do with condensate?**
   Refrigerated dryers produce condensate (water and oil) from cooling the air. It is collected within the dryer and must be disposed of per local regulations. Drainage methods are typically utilizing automatic no loss drains for medium pressure and below, and timer solenoid drains for higher pressure applications.
6. **Protect your equipment.**
   Consult the dryer manufacturer's installation instruction as pre-filtration is typically required. Getting particulate into the dryer piping can bring costly damage expenses.

Refrigerated dryers like the one below is in use by manufacturing facilities around the world. These products provide dry air for pneumatic equipment, bottle blowing machines, and even missile support systems.

Figure 1: Sauer USA refrigerated dryer capable of operation up to 6000psi.

Refrigerated Dryers Advantages & Disadvantages

Beyond matching the specifications with your application's needs and process, look at the advantages and disadvantages. These can be indicators for initial, operation, and maintenance costs. Below is a comparison chart with the advantages and disadvantages of cycling and non-cycling options. Overall, if you are looking at purchase and installation costs, non-cycling is the more affordable option. For operating costs, cycling is the better option.

Refrigerated Compressed Air Dryer Comparison			
Cycling		**Non-cycling**	
Advantages	Disadvantages	Advantages	Disadvantages
Lower Operating Costs - Lower energy cost - Lower lifecycle costs	**Higher Initial Costs** - Purchased and installation cost slightly higher than non-cycling dryers.	**Lower Initial Costs** - Initial costs lower compared to non-cycling dryers	**Higher Operating Costs** - No cycling capability to lower energy costs.
More Benefits - Known for performance and reliability. - Easy to install - Low noise - Smaller footprint	**Higher Operating & Maintenance Costs** - Additional costs due to additional parts.	**Comparable Operating Costs** - Maintains a consistent dew point. - Capable of continuous operation.	**Potential for Higher Maintenance Costs** - Low usage can cause pipes to freeze resulting in potential failure and a need for maintenance.

Desiccant Compressed Air Dryers

Desiccant compressed air dryers remove moisture by absorbing it from the air with porous desiccant beads. The most common media used for the beads is Silica Gel. It is like the bead packs often used in product packaging.

The desiccant beads are in two towers. The first towers dry's the air, and the second does the regeneration. Towers are alternated to create a continuous steady stream of dry air. Overall pressure dew point ratings range from -40 to -100 degrees F**.**

Desiccant dryers are required when a plant needs instrument-quality compressed air. Examples of these critical applications are the Pharmaceutical, Food, and Breathing Air industries where very dry air is needed. Desiccant dryers are also often used in the Construction industry and High-Speed Wind Tunnel test facilities. A common application is media blasting and metal surface prep work by painting contractors.

Desiccant dryers are a bit more expensive to purchase than a refrigerated dryer, but the electrical load is negligible. Operating costs are considered reasonable but keep in mind that desiccant beads will need to be replaced periodically, per manufacturer's instructions. Plus, desiccant dryers require regular maintenance to ensure no loss in performance or even a shutdown from dislodged desiccant beads. Regenerative dryers use purge air, while there are also non-regenerative, cartridge-style options, which do not use purge air. However, the cartridges are limited in the amount of air it may process before the elements require replacing. These are not ideal for continuous operation applications.

Three Kinds of Regenerative Desiccant Dryers

Energy costs vary by type of desiccant compressed air dryers. The three types used most often are heatless, heated, and blower purged. The amount of energy used is tied to the manner of regeneration used for the desiccant material. For heated and blower purged types, they can become more cost-effective by using thermal energy.

Type #1 - Heatless Desiccant Dryers

Heatless desiccant dryers, sometimes called pressure swing absorbers, rely on the retention of heat for reducing moisture. Desiccant beads or beds absorb water during the drying process. Some of the flow from the dry side of the processing tower is recirculated at reduced pressure to the regenerating tower, providing purge flow from top to bottom. This dry purge air pulls the moisture from the desiccant, forcing it to exit from a purge silencer. Regeneration and purge cycle times can be controlled via dew point monitoring to further reduce purge losses in the system (typically 15-20%).

Type #2 - Heated Desiccant Dryers

Heated **desiccant dryers** have a heater in the dryer regeneration circuit and require little or no process air. In the first tower, ambient air passes through the heater and becomes hot regeneration air. As it moves through the second tower, moisture is absorbed by the desiccant adsorption beads. Because of the simple design, desiccant dryers are the preferred choice for extreme environments. Plus, due to the higher electrical load from a heating element, heatless dryers are more affordable to operate than heated desiccant dryers.

Type #3 - Blower Purged Desiccant Dryers

Blower purged desiccant dryers eliminate the need for compressed air purge. By adding a blower, they use ambient air from the outside (room) environment and augment it with heat. The hot, dry air removes moisture in the first tower, which is absorbed by the desiccant beads in the second. Operating costs go down from the elimination of the need for compressed air. However, energy costs go up from the need for electricity to power the blower's electric motor.

Once again, with costs in mind, look at the advantages and disadvantages of each. Keep in mind purged air is expensive to produce.

Desiccant Compressed Air Dryer Comparison					
Heatless		Heated		Blower Purged	
Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadva
Low Dew Points - Low dewpoints can be reached without potential freezing.	**Desiccant Replacement Costs** - Desiccant beds/beads must be replaced on average every 3-5 years. - Desiccant beds/beads are more difficult to change.	**Low Dew Points** - Low dewpoints can be reached without potential freezing.	**Desiccant Replacement Costs** - Desiccant beds/beads must be replaced on average every 3-5 years. - Desiccant beds/beads are more difficult to change.	**Low Dew Points** - Low dewpoints can be reached without potential freezing.	**Desicca Rep**
Lower Initial Cost - Initial capital costs are lower as compared to other regenerative types.	**Purged Air Cost** - Purged air is required, expensive, and will increase operating costs.	**Less Purged Air** - Less purged air is required as compared to other desiccant dryers.	**Prefiltering Co** - Desiccant prefilteri not		
Remote/Mobile Operation - Heatless dryers ca be designed to function pneumatically for remote and mobile locations.					

Desiccant Dryer-Specific Considerations

When considering purchasing a desiccant compressed air dryer, keep in mind the hidden costs beyond the purchase price. Also, that the purge is typically 15 to 20 percent of the dryers rated flow.

1. **Keep an eye on the pressure**
   The dryer could create an extra pressure drop, which may draw more energy and increase your production cost. To keep down the cost, align the compressor size with the dryer.
2. **Weigh in energy costs**
   Compare the costs of unheated, heated, and blower purged desiccant dryers concerning energy costs. Unheated dryers need negligible energy. However, they have high purge consumption rates, and waste 15-20% of compressed air. Heated dyers use energy for the heater and have medium purge consumption rates at approximately 7.5% of capacity less than of heatless. Purged blower dryers use energy for the blower and have lower purge consumption rates. Non-regenerative dryers use no energy but are limited in their processing capabilities.

3. Protect the equipment

Many desiccant dryers require the use of wet tanks to protect the dryer from incoming pulsations. Cooling systems may be necessary to reduce the supply air temperatures as desiccant become useless at inlet temperatures above 130°F. Filtration is also required to avoid any slugs of liquid or condensing oil from reaching the desiccant. Oil will hinder or prevent the adsorbing process.

The dryer in Figure 2 is used to dry high-pressure air up to 7250psig. Prefiltration is fitted to accept air from a high-pressure compressor while ensuring any bulk liquid is coalesced prior to reaching the desiccant. This product also comes with dew point demand capabilities to reduce the purge and regeneration cycle times, which reduces your purge losses.

Figure 2.

Desiccant Dryer Advantages & Disadvantages

Looking at the desiccant compressed air dryer advantages and disadvantages, you will find all three deliver low dew points. But they lose a few points when you look at operation and maintenance costs.

Desiccant Compressed Air Dryer Comparison					
Heatless		Heated		Blower Purged	
Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadva
Low Dew Points - Low dewpoints can be reached without potential freezing.	**Desiccant Replacement Costs** - Desiccant beds/beads must be replaced on average every 3-5 years. - Desiccant beds/beads are more difficult to change.	**Low Dew Points** - Low dewpoints can be reached without potential freezing.	**Desiccant Replacement Costs** - Desiccant beds/beads must be replaced on average every 3-5 years. - Desiccant beds/beads are more difficult to change.	**Low Dew Points** - Low dewpoints can be eached without potential freezing.	**Desicca Rep**
Lower Initial Cost - Initial capital costs are lower as compared to other regenerative types.	**Purged Air Cost** - Purged air is required, expensive, and will increase operating costs.	**Less Purged Air** - Less purged air is required as compared to other desiccant dryers.	**Prefiltering Co** - Desiccant prefilteri not		
Remote/Mobile Operation - Heatless dryers ca be designed to function pneumatically for remote and mobile locations.					

Membrane Compressed Air Dryers

Membrane are the newest type of compressed air dryer. They were designed for processes using pneumatic equipment that is more sensitive to contaminants like oil. Membrane dryers rely upon selective gas component permeation during migration. The compressed air passes over a selectively permeable membrane. The membrane is structured so that gases such as oxygen pass through faster than others like nitrogen. Moisture builds upon the membrane and is discharged.

Controlling the lowering of dew points can be tricky. If the dew point of air entering the dryer is lower than the targeted range, the outlet dew point will become lower than specified. Pressure can complicate things too. If the pressure is higher than intended, the outlet dew point will be lowered because of the extra time spent in the membrane. Membrane dryers are limited to low capacity systems and experience high purge air losses as high as 15-20%.

But there are also advantages, including being reliable, quiet, and requiring no electricity. Membrane dryers are designed to run continuously 24 hours a day, seven days a week, and produce low dew points. Common compressed air moisture removal applications are laboratories and medical facilities. Membrane dryers are also used in food packaging where the

separated nitrogen is stored and used later in the process. They are also used in plastics manufacturing.

As for costs, they have lower start-up costs with being easy to install and requiring no extra parts. Operating and maintenance costs are affordable other than the need for special coalescing type prefilters and related maintenance. Before air enters the dryer, the prefilter is required to avoid the membrane becoming fouled by lubricants and other contaminants.

Types of Membrane Dryers

Dew points in membrane dryers can vary from day-to-day, week-to-week, month-to-month, etc. Fiber material in the tube form to allow certain molecules through, while preventing others from moving out. They are used in gas processing (i.e. nitrogen generation). In this case to remove water droplets. Droplets move through while air does not. Limitations are ~1300psig.

Membrane Dryer-Specific Considerations

Membrane dryers have no moving parts, so they require very little maintenance. However, costs for filtration and maintenance should be considered.

1. **Look at filter costs**
   Avoiding and managing contaminants is imperative to gaining and maintaining high performance. That means having quality prefilters and replacing them regularly.
2. **Consider piping costs**
   When piping ages, it is often contaminated with water and oil downstream. The contamination travels to the end of the system long after the dryer is installed. It brings new costs to your calculations for replacing and cleaning pipes.
3. **Understand the temperature specifications**
   Membrane systems require that the incoming air not exceed 135°F.

One Last Thing

One other item to keep in mind is reference points for determining dryer performance. Changes in temperature or supply pressure can hinder performance. Typical, expected ambient conditions are 80-100°F and inlet air temperature of 100°F. It has always best to follow the manufacturer's recommendations to ensure proper design and sizing to meet your desired specifications.