Selecting a Compressed Air Dryer

By William J. Ulrich, adapted from Machine Design magazine

Like gas, electricity, and water, compressed air is a common utility in most industrial and process plants. Typically, pneumatics consumes 10 to 15% of a plant's electrical energy, according to most experts. The big difference is that while the other utilities are purchased, compressed air must be generated in-house. This puts the burden on the user to ensure that the compressed air quality is suitable for plant operations.

Compressors produce high pressure air that is hot, wet, and dirty. In this state, it cannot be used. Just as untreated water is not potable and unregulated natural gas is a safety hazard, compressed air must be properly treated to make it fit for pneumatic equipment and processes.

Water problems

In most cases, liquid water is an unavoidable by-product of compressed air. Compressing ambient room air to 100 psig, for example, increases the vapor content or humidity by a factor of roughly eight. Thus, if ambient humidity is greater than about 12.5%, the air becomes saturated at line pressure (12.5% x 8 = 100%), and any subsequent cooling forms liquid water. So in practice there are few systems that do not saturate and condense. It is not unusual for a typical plant compressor to send several gallons of water downstream every day.

If not removed, liquid water in an air system leads to a lot of different problems.

- Water rusts and corrodes piping and other metal components.
- Air tools often run on lubricated air. Water leaches out additives in the lubricant and accelerates tool wear.
- Water can destroy positive-displacement, rotary-vane air tools because they are not designed to operate with incompressible fluids.
- Air lines that run outdoors can freeze, shutting down an operation or even an entire plant.
- In paint booths, water in air lines causes blisters, bubbles, poor adhesion, and corrosion. Electrostatic painting processes are sensitive to moisture as well.
- Wet air can affect the quality of moisture sensitive chemicals and processes, from manufacturing pharmaceuticals to transporting powdered concrete.

With increasing emphasis on producing high-quality products while lowering production costs—in which minimizing downtime and maintenance requirements play a big part—most compressed air users understand that dryers are essential in any air system.

Today, the question is not so much whether or not an air dryer is needed, but which is the best, most cost-effective solution for a particular application.

Air dryer operation

Fortunately, designers have a number of options when selecting a dryer. There are three general dryer categories: deliquescent, refrigerated, and regenerative desiccant. These designs vary in terms of dew point performance, initial cost, energy consumption, and maintenance requirements. Generally, the lower the dew point the more a dryer costs to purchase and operate. To help select a dryer and size it to an application, look at each dryer's capabilities.

Single tower deliquescent dryers are filled with an absorbent deliquescent desiccant. This material attracts moisture and gradually dissolves as compressed air passes through the desiccant bed. Single tower dryers are simple, durable devices that have no moving parts, consume no power, and require no special control systems. One benefit of single tower deliquescent dryers is that operating costs are directly proportional to air use. If there is no air demand, no desiccant is consumed. The dryers are simple to maintain as well. Draining the dryer vessel daily and periodically re-filling it with desiccant are the only requirements. For these reasons, single tower dryers are generally the most economical in terms of both initial cost and operating expense.

Single tower deliquescent dryers produce a compensating dew point that is directly related to the inlet-air temperature. In other words, they reduce the dew point by a fixed amount below the inlet temperature. Outlet dew point, therefore, varies as inlet temperature changes. The desiccants are mixtures of hygroscopic salts, compressed into tablets. Standard materials reduce the dew point by 20ºF; more aggressive desiccants reduce the dew point more than 55ºF below the inlet temperature, but they are also more expensive.

One concern with single tower dryers is the possibility of desiccant salts carrying downstream. Used properly, this will not occur. Flow velocity through the dryer vessel is only 15 fpm, too low to transport the material downstream. Further, the tablets slowly dissolve as they absorb water and generate no dust. Only if the dryer vessel is never drained and floods could the desiccant carry to other system components.

Single tower deliquescent dryers appear simple, but they encompass considerable technology, from ensuring optimum air flow through the vessel to the science of producing high quality desiccant tablets. Single tower dryers have certain advantages over other types of dryers, but they have the smallest market share. Furthermore they are arguably underused in many applications, such as abrasive blasting and steel manufacturing. One reason for this is that the delineation between single tower deliquescent dryers and refrigerated dryers is rather fuzzy: the two types offer similar dew points in many cases. Often, the choice is simply a matter of user preference, not the advantages of one over the other. However, single tower deliquescent dryers are suitable for some applications where refrigerated dryers will not work, particularly in harsh environments that quickly foul the air-cooled or water-cooled condensers on a refrigerated unit. Also, because no power is required, deliquescent units are well-suited for mobile applications and in hazardous areas with electrical restrictions. Single tower deliquescent dryers can be used outdoors, as well as with air-cooled after-coolers. Refrigerated dryers are stationary devices strictly for indoor use.

Refrigerated dryers operate much like a household refrigerator. They cool the compressed air sufficiently to condense the entrained moisture and separate it from the air supply. An advantage refrigerated dryers hold over single-tower deliquescent dryers is that they produce a constant dew point regardless of fluctuations in inlet temperature. The dryers typically deliver a dew point of either 38ºF or 50ºF depending on the design. For the best performance when operating in high ambient temperatures or in dirty environments, a water-cooled condenser is recommended.

Most refrigerated dryers run continuously; others cycle on and off. Continuous operation eliminates start/stop current in-rush and extends compressor life. It also permits instantaneous response to airflow demands to produce the required dew point. Cycling-type refrigerated dryers do not respond as quickly. On the plus side, however, they may use less electrical power during extended periods of low air consumption. While both types are dependable, servicing generally requires a qualified technician with refrigeration recovery/recycling equipment.

The major limitation with refrigerated dryers is their dew points. Because they operate by condensing water in a heat exchanger, the lowest practical dew point reached is about 35ºF. Any lower and there is the danger of water freezing and plugging or cracking the heat exchanger. While this limits them to indoor applications, refrigerated units are the most commonly used dryers.

Regenerative desiccant dryers adsorb moisture on solid desiccants, such as activated alumina, silica gel, or molecular sieves. Two desiccant-packed towers operate alternately; compressed air flows through the desiccant in one tower while the desiccant in the other tower is dried, or regenerated.

Regenerative desiccant dryers supply the lowest dew point, usually -40°F but as low as -100°F. They are also the most expensive, so specify a regenerative desiccant dryer only when the application calls for maximum dew point performance. Regenerative dryers are often used to protect instrumentation and control systems, laboratory equipment, and moisture-sensitive processes and materials. They also protect outdoor lines from freezing in severe weather conditions.

There are three different methods to regenerate the saturated desiccant bed: by a purge of dry air from the operating tower, by internal heaters, or by an external heat source. Here are the pluses and minuses of each:

- Heatless dryers use a purge of compressed air from the active tower, expanded to atmospheric pressure to dry the desiccant. It is a simple process, with the purge air vented to atmosphere. The units require little maintenance and, because they do not deal with the high voltages or high temperature, are quite safe. Heatless dryers are also the least expensive regenerative dryers, so they are a good choice for smaller systems with sufficient excess air capacity. Unfortunately, the purge requires 15 to 18% of air capacity, which means high operating costs in larger systems. Often the expense associated with lost compressor horsepower restricts heatless dryers to systems smaller than approximately 2,000 scfm. This is increasingly the case as energy costs rise and companies strive to minimize power consumption.
- Heated regenerative desiccant dryers use electrical resistance or steam heat to dry the desiccant bed, so only about 4.5% purge air is needed to drive off the water. These units initially cost more

than heatless dryers because they have additional components and more complex controls. Skilled personnel are also required for maintenance. Heated dryers are predominantly used in the 500 - 3,000 scfm range. However, the specific application always dictates the best choice.

- Blower-purge compressed air dryers use an external blower to force heated atmospheric air through the regenerating tower. This dries the bed without requiring compressed air. However, blower units require the highest initial investment among regenerative dryers. For two reasons, they are used almost exclusively in large systems above 3,000 scfm. One, the cost of purge air is proportional to the size of the system, making the expense of purging prohibitive in large installations. Two, conducting heat evenly though a large desiccant bed is a technical challenge that requires many embedded heaters; to regenerate a large desiccant bed it is much simpler to evenly heat the bed with a blower.

The desiccant in heatless dryers lasts three to five years with an oil-free compressor and two to three years with a lubricated compressor and a good pre-filter. Operating a regenerative desiccant dryer without a coalescing pre-filter is ill-advised. Oil contamination destroys the sensitive desiccant in about two to three weeks. Heated dryers tend to accelerate the aging process of adsorbent desiccant. Typically, new desiccant material is needed every one to two years.

A concern associated with all regenerative desiccant dryers is preventing desiccant fines from carrying into downstream components. Certain adsorbent desiccants have abrasive properties and can damage pneumatics and other air system equipment. Unlike single tower deliquescent dryers that operate in wet conditions, regenerative desiccants are dry and inherently dusty. Further, regenerative dryers operate at relatively high flow velocities, up to 75 feet per minute. These velocities entrain desiccant particles in the compressed air stream. A particulate after-filter is required on all regenerative desiccant installations.

The pressure differential across pre- and after-filters should be closely monitored. At 10 PSID filter elements should be replaced.

Selection Factors

To select a dryer, first determine dew point requirements for the application, then determine which dryer type will produce that dew point. Finally, examine the economics of the dryer types that suit the application.

Generally there are no standard recommended dew points for specific types of applications. For most instruments, actuators, tools, and the like, the only requirement is that the compressed air contains no liquid water. Water vapor passes harmlessly through a system. As long as the water does not condense or freeze, it is generally tolerated in most applications.

Thus, the compressed air dew point must be lower than the lowest temperature to which the lines or equipment are exposed. Otherwise, the water will likely condense. When looking for the lowest ambient temperatures, consider:

- Equipment and line location. If indoors, look for the lowest ambient temperature in the plant. If outdoors, determine minimum temperatures to which the lines are exposed.
- Piping that runs through air-conditioned areas that are cooling the surrounding rooms.
- Lines that are below ground where, particularly in the summer, temperature is lower than ambient.
- Piping located in unheated areas, such as basements.
- Piping that runs in front of open doors, windows, or cooling fans.

Another way to determine requirements is with Instrument Society of America specification ISA S7.3. It defines "instrument air" as having a dew point 18°F below the lowest ambient operating temperature, or no higher than 35°F, whichever is worse. The safety factor protects against unexpected temperature changes. Thus, ISA recommends air that does not contain liquid water.

This guideline does not hold true in many refineries, petrochemical plants, pharmaceutical facilities, and process industries. In these arenas, applications for compressed air typically have a very low tolerance for moisture and the required dew points call for regenerative desiccant dryers.