Advanced Heat Exchanger Design Improves Compressed Air Dryer Systems

John Bergh, vice president / engineering, ZEKS Compressed Air Solutions

Moisture, oils, vapors, and other contaminants in industrial compressed air systems have long been a costly problem that negatively affect the efficiency of pneumatically operated appliances, controls, instruments, machinery, and tools, and reduces the service life of motors, air tools and cylinders. If not corrected, wet, contaminated compressed air causes equipment problems that increase maintenance costs and downtime. In many applications, liquid water in compressed air directly impacts the quality of finished products, resulting in rejects and reduced productivity.

Temperature and pressure are the variables that affect the water-carrying capacity of saturated air. Air at lower temperature and higher pressure carries less moisture. Compressed air at the inlet to a dryer is saturated, at a temperature higher than ambient. Any drop in temperature throughout the compressed air lines will cause the unwanted moisture to condense into water droplets.

Refrigerated industrial air dryers use this principle to remove water from compressed air before it is fed through the compressed air lines to the systems that use it. This removal is accomplished by cooling the air with a refrigeration unit to a low temperature at which moisture in the air is condensed and separated from the air stream. The temperature (typically between 35°F and 39°F) becomes the pressure dew point of the air. The condensate is then separated from the air and drained. After reheating (typically), the air is discharged to the compressed-air system. No further moisture will condense in the air lines assuming the temperature is kept above the pressure dew point temperature.

Of course, there is a price to pay for the operation of the compressed air dryer. Energy costs consumed by the dryer are proportional to the dryer's refrigeration system efficiency and the effectiveness of its transfer of heat away from the compressed air passing through the dryer. In a True-Cycling dryer design from Zeks

Compressed Air Solutions, West Chester, PA, a heat sink reservoir is used as an intermediary between the refrigeration and the air flow systems. This intermediary enables the refrigeration system to cycle, or turn off, when it is not needed, reducing energy consumption and saving costs. True-Cycling operation also reduces the wear-and-tear on the dryer's refrigeration system under most operating conditions, decreasing operating costs, improving compressed air quality, boosting productivity, and increasing plant equipment life. Cycling operation creates the added benefit of allowing the dryer to make use of the greater refrigeration system capacity and efficiency at lower ambient temperatures.

Better heat-exchanger efficiency

The effectiveness of heat exchangers, and their pressure drop, are large elements of dryer operating efficiency. Dryers typically have a pre-cooler/reheater (air-to-air exchanger) followed by a chiller section. The pre-cooler/reheater functions as an economizer, recovering the chiller energy to pre-cool the incoming air and reheat the outgoing air to increase volume and prevent pipe "sweating" downstream. The more effective the pre-cooler/reheater, the lower the temperature at the inlet of the chiller, resulting in lowered energy consumption by the dryer.

At the same time, pressure drop dramatically impacts total operating cost for the compressed-air system. It is costly to make pressure, then waste it in frictional resistance within the equipment, such as wasting pressure within the heat exchangers of dryers. Reducing the pressure drop associated with dryer heat exchangers is a key element in increasing the operating efficiency of the entire compressed-air system.

In the past, pre-cooler/reheaters have been implemented with shell-and-tube exchangers, which are less effective, cause high pressure drop, and are inherently bulky. Another option that has been commonly used is copper tube-in-tube coil exchangers, which also result in high-pressure drop and are incredibly bulky. The only way to solve these problems, particularly pressure drop, and increase effectiveness is to create a system that is very expensive.

Prior art in refrigeration exchangers for cycling dryers has been parallel coils of copper tubing, one containing refrigerant and the other containing compressed air. The coolant and the airflow loops are physically adjacent, which allows heat energy to flow from one loop (air) to the other (refrigerant) through the thermal storage medium, typically propylene glycol and water. Again, to increase the efficiency of heat transfer in air dryer systems and prevent excessive pressure drop, the number of parallel copper coils must be increased, thereby increasing cost.

An additional consideration is that copper also has limitations in dealing with industrial atmospheric corrosive agents, which are concentrated by the air compressor and then converted into aqueous solutions in the condensate within the dryers.

Stainless steel, in coil and plate form, is an ideal material for air dryer heat exchangers. In the proper design, with all-welded construction, it can be made into a heat exchanger that is very effective, has a low pressure drop, and tolerates common atmospheric corrosives. A corrugated, folded heat exchanger (the CFX) from ZEKS Compressed Air Solutions, takes a new approach to dryer heat exchanger technology. It's designed to be more efficient and contains no copper. The CFX exchanger utilizes a unique multi-path air-flow pattern that allows more air to pass through the dryer with less pressure drop. The new approach results in prolonged life and operational cost savings every year, with pressure drop as low as 1.48 psi across the entire dryer.

A corrugated stainless steel core within a cylindrical pressure vessel with high-flow integral ports, generates airflow eddies for self-cleaning and prevents oil, dirt particles, water and dust from accumulating. There are no "fins" that might trap dirt, cause fouling, and increase pressure drop. The unique cylindrical shape of the exchanger allows it to withstand high operating pressures. CFX provides exceptional service in all three dryer exchanger applications:

- Gas to gas (the most challenging)
- Refrigerant to gas
- Refrigerant to liquid

Better thermal performance

ZEKS True-Cycling HeatSink dryers apply active heat exchange with a pump that circulates the heatsink medium to control dew point and improve performance (not affected by seasonal conditions, varying loads, or ambient temperature changes). True-Cycling dryers use stored energy and active heat exchange to match dryer energy consumption with compressed air demand, allowing them to continually and efficiently deliver high-quality air at the required dew point. Additionally, these dryers provide greater energy savings than non-cycling (direct expansion) dryers as ambient air temperature drops because they make use of the increased power and efficiency of the refrigeration system in low ambient temperature conditions: The refrigeration unit just turns off sooner. Under these same circumstances, non-cycling dryers must continue to run their refrigeration system at full load using a hot gas bypass valve to provide a false load, consuming energy at a much higher rate.

No other component of an industrial compressed air dryer is more closely linked to the performance and efficiency of the compressed air system than the heat exchanger. Durable CFX technology allows for operational and cost savings, and has been designed specifically for use in industrial compressed air dryers.