SP Industries
935 Mearns Road Warminster, PA 18974 800.523.2327 Phone: 215.672.7800 Fax: 215.672.7807 www.SPindustries.com

TECH BRIEF: FLUID VERSUS DIRECT EXPANSION CONDENSERS

By: Charles D. Dern, P.E.

The Direct Expansion Condenser

The most common method of providing a cold trap to condense vapor from the freeze drying process is through the direct expansion of refrigerant into condensing plates or coils. This method, although efficient, has several drawbacks.

The first issue is lack of redundancy. Because the condensing plates are a direct part of the refrigeration piping, each plate is tied directly to one compressor. In the event of compressor failure, there will be a loss of refrigerant flow to the plates tied to that compressor. Second, direct expansion of refrigerant can, at times, cause uneven temperatures over the surface of the condenser due to the phase change and flashing of the refrigerant. Third is that a thermo-mechanical expansion valve directly controls direct expansion condensing plates. This valve meters refrigerant as determined by both the pressure and the temperature of the refrigerant exiting the condensing plates. When the plates are exposed to a sudden large load, there is a natural lag in the reaction time of the thermo-expansion valve, which in turn causes the temporary temperature increase.

This increase can be problematic when attempting to run a validated cycle. Such is the case of a phenomenon known as “hoar frost.” This condition often occurs in conjunction with loading procedures that require pre-chilled shelves. During loading, a thin film of frost develops on the shelves because of room humidity. Because the frost tends to have minimal thickness, it will have a uniform temperature. When the vapor pressure of the frost, which increases with increasing temperature, exceeds the pressure of the chamber atmosphere, the frost almost instantaneously vaporizes off the shelves and travels to the condenser plates causing a sudden but unsustained load, to which mechanical expansion valve cannot react quickly enough. Besides the inherent reaction time of the thermo-expansion valve, recovery of condenser temperature is also slowed by the ongoing condensation of water vapor that is subliming out of the product. Experience has shown that full recovery from hoar frost condensation can take up to an hour or more.

The Fluid Condenser System

The fluid condenser system solves all of these problems. The system simply replaces direct expansion of refrigerant through the condensing plates with a heat transfer fluid. The heat transfer fluid is circulated through the condenser by means of a system identical to that of the shelf heat transfer system, with the exception of the in-line heater.

First, redundancy is easily built into the system. For example, a 450-kilogram/day condenser normally would be constructed with two compressors, one each connected to one-half of the condensing plates. (A third compressor would be dedicated to shelf control.) However, with a fluid system, the fluid circuit can be run through an exchanger for each of the three compressors. Because only two compressors are required for primary drying, a third compressor is available as a back up.

Second, the redundancy allows one to switch compressors from run to run, thus leveling total run time among all compressors. Hull’s exclusive *Lyo-Link es* ® control system automatically chooses the compressor with the least run hours that is available (that is, not off-line).

Third, energy savings are possible because each compressor can act on the product shelves, the condenser or both. The secondary drying (desorption) of most products requires only a fraction of the refrigeration capacity that is required during the thermal treatment (freezing) and primary drying (sublimation) phases of the cycle. To take advantage of this reduced need, the *Lyo Link* freeze drying recipe manager allows one (with proper password clearance) to select the number of compressors that are active at any part of the cycle. For a typical Hull system, most cycles will easily run with just one compressor active during secondary drying, resulting not only in significant energy savings, but a reduction in compressor wear.

Finally, the fluid passing through the condenser plates provides an extremely even temperature distribution across the plate. The fluid also provides additional thermal mass, which in turn provides a buffer against temperature fluctuations such as those caused by hoar frost.

Additional Benefits of the Hull Fluid Condenser

The unique Hull design, besides solving the direct expansion issues raised above, also allows the capturing of the full refrigeration capacity of larger compressors while at simultaneously allowing precise control of shelf fluid temperature. The capacity of mechanical refrigeration compressors decreases by factors of 10:1 or more as evaporator temperature decreases from the maximum to the minimum of the compressor rating. However, most expansion valves, even Electronic Expansion Valves (EXV's), which have a broader operation range than mechanical Thermo-Expansion Valves (TXV's), do not have operation ranges that combine simultaneously both the breadth and precision required to maintain proper process control of the shelf fluid temperature as well as proper superheat control of refrigerant exiting the evaporator over the full capacity range of most compressors.

The Hull fluid condenser system solves this problem by employing dual heat exchangers, each with its own refrigerant control valve. This system allows both exchangers to be used to direct maximum refrigeration capacity to the shelves, and then split the compressor capacity between the shelves and the condenser with very precise control of the former.

SP has successfully installed many Hull and VirTis fluid condenser lyophilizers. The ability to build redundancy into the system enhances process validation because there is an extra degree of assurance that in the rare event of a compressor failure, another complete compressor system is available to take over seamlessly.

For more information on our products, please contact our corporate office at 800-523-2327 or visit our website (www.SPindustries.com).

Charles D. Dern is a Project Engineer with SP Industries.