Understanding Pressure and Vacuum

Vital to understanding refrigeration is the science of vacuum and the theoretical and practical principles involved.

Ultimate Pressure (Vacuum)

The first concept has to do with the Ultimate Pressure (vacuum level) inside the refrigeration circuit. One may ask why the circuit has to be evacuated and "dried" before being charged with refrigerant. The reason is that any air or more importantly moisture must be removed from the system. Air or other "non-condensable" gases diminish the high heat transfer coefficient typical of condensing vapors; the non-condensables would remain in the upper area of the circuit and raise the delivery pressure in the system.

Water, besides being unable to be vaporized in the evaporator, freezes at the colder part of the circuit and could block the expansion capillary tube or throttling valve. Moisture is picked up by the refrigerant and transported though the refrigerant line in a fine mist with ice crystals forming at the point of expansion. All it takes is a few milligrams of moisture in a critical part of the system to cause the system to not operate correctly. This is made even more intense by its combination with refrigerant oil, which has a natural attraction for moisture and absorbs it rapidly. Acids are formed with the water which combines with the refrigerant creating "sludge" that greatly reduces the lubrication quality of the oil.

Both air and water absorb a portion of the compressor power without producing any cooling, or refrigeration effect. Furthermore, oxygen in air considerably increases corrosion in the circuit, especially at the compressor valve faces.

Residual Balanced Pressure and Water vapor

The Residual Balanced Pressure (RBP) inside the refrigeration circuit is the stable pressure that exists in an evacuated circuit after reaching the pressure equilibrium.

If you use the formula of perfect gases, assuming that the RBP is caused by the residual humidity only, the amount of water vapor can be calculated:

$$PV = \frac{M}{\mu} RT$$

Where:	P	=	pressure (mbar)
	V	=	volume (liters)
	M	=	mass (grams) – mass of water vapor is our unknown value
	μ	=	molecular weight
	R	=	universal constant of perfect gases (mbar.l.mol^{-1}, K^{-1})
	T	=	temperature (°K)

<u>Example:</u> Take a refrigeration circuit having an internal volume of 4 liters, with RBP of 1 mbar. Using the formula above, you can determine the water vapor quantity is:

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$$1x4 = \frac{M}{18}x83.15x300$$

$$M = 2.9mg\,H_2O$$

In theory this quantity is sufficient to block the capillary by forming ice. In practice, however, a good filter drier placed in the circuit can gradually absorb this quantity of water, therefore a RBP of 1mbar is considered acceptable. Filter dryers have a rating of X “drops” at X temperature of X PPM of refrigerant.

Optimum value of ultimate vacuum: How low should I go?

Considering the above, a refrigeration system will not work correctly with excess moisture in the system. The RBP should be no higher than 1 mbar in order to maintain a tolerable amount of water in the circuit. Data suggests that such a RBP value is achieved only if the pumping system is able to achieve vacuum levels in the range of 10^{-2} mbar (.75 Torr/.1 kPa) or lower.

A vacuum pump removes unwanted moisture by lowering the pressure inside the system, vaporizing it and then exhausting it along with the air. In the next section we’ll look at vacuum pumps and how science as well as practical experience comes into play when sizing a pump or pumps for production.

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