Cool Concepts

For Industrial Refrigeration Systems

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Ammonia Thermosiphons

Thermosiphon systems have been traditionally thought of as methods of oil cooling for screw compressors. The term thermosiphon was not in frequent use prior to the advent of screw compressors in industrial refrigeration.

However for many years prior to this the same principles were being used for a very common application, i.e., gravity flooded evaporators. A gravity flooded evaporator operates on the same principles as a thermosiphon oil cooling system.

The only difference is the operating temperature and the type of heat exchanger used for the respective purpose.

With a thermosiphon oil cooling system (Fig. 1) we commonly see a shell and tube heat exchanger (or brazed plate or plate and shell heat exchanger) used. The pilot receiver provides a source of liquid ammonia and also acts as a liquid/vapor separator using the principles of gravity separation.

When an air-cooling evaporator is gravity flooded, the pressure vessel does the same thing as the pilot receiver in the thermosiphon oil cooling scenario. The vessel acts as a source of liquid ammonia and also separates the liquid from the vapor. In this application, the pressure vessel is commonly called a surge drum (Fig. 2).

It is common to see the surge drum installed in a horizontal or vertical orientation. This is determined by the actual installation requirements. Depending on the vessel orientation there may be slight differences in the internal construction of the surge drum.

- *In the case of the thermosiphon oil cooling system the heat comes from the hot oil.*
- *For the gravity flooded evaporator the heat energy comes from the air/liquid being cooled.*

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In both applications (oil cooling or other lower temperature fluid cooling) the flow of refrigerant is induced by the boiling of liquid ammonia in the respective heat exchanger. Heat added to the refrigerant will cause a phase change (liquid to a vapor). This heat comes from the medium circulating through the heat exchanger (vapor or liquid, Fig. 2).

Remember, when we discuss heat energy we are describing it in a relative way. The energy does not have to be "hot", it simply needs to be at a temperature greater than the boiling temperature of the refrigerant.

This boiling temperature is referred to as the saturation temperature of the refrigerant.

The principle mechanism for fluid flow is the apparent difference in the density of the two phases, i.e., liquid and vapor.

When a saturated refrigerant is heated it begins to boil. This boiling action results in the liquid being converted to a saturated vapor. The higher density of liquid pushes down, while the less dense vapor wants to rise.

This driving force or buoyancy of the lighter gas is the principle mechanism for the circulation of refrigerant by heat.

As the liquid flashes off into a vapor, the less dense gas rises up while the higher density liquid causes the liquid to flow into the heat exchanger to replace the evaporated liquid.

The rate of circulation increases as the heat input to the refrigerant also increases.

As shown in Fig. 1, the pilot receiver is a reservoir for liquid refrigerant. The liquid falls into the oil cooler where the heat transfer from the hot oil to the liquid refrigerant creates the boiling effect.

As the lighter vapor rises out of the oil cooler a small portion (by volume) of liquid is lifted

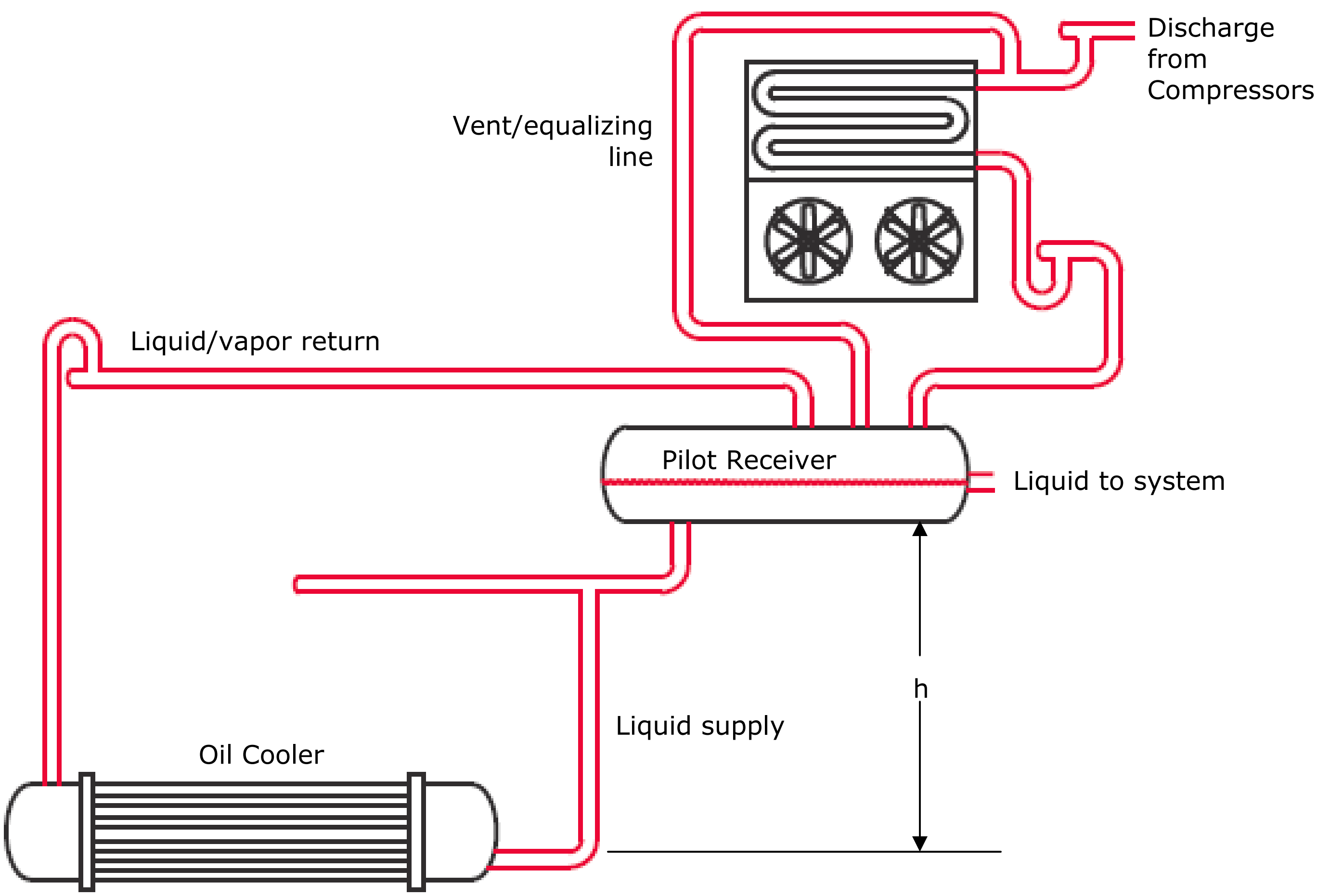

Figure 1. Example of basic thermosiphon oil cooling system

with the gas. This liquid/vapor mixture is then lifted into the return line back to the pilot receiver.

Note: For those who remember the old style coffee pots this is a similar effect. The percolation of the coffee rising up the tube in spurts of liquid offers a simple comparison to the operation of the thermosiphon riser.

The returning liquid refrigerant is separated in the pilot receiver, while the vapor is returned to the condenser inlet by the equalized line.

Any liquid refrigerant that is boiled off in the oil cooler is replenished by additional liquid flowing out of the condenser.

In a gravity thermosiphon the friction and static pressure losses (created by the piping and installation geometry) are controlled by the heat flux of the heat exchanger. In effect, this is a completely self regulating loop driven solely by heat energy.

By comparison, a gravity flooded evaporator operates with the same principle (Fig. 2 or 3). The higher density liquid flows into the heat exchanger. With the addition of heat from the circulated fluid (liquid or air), a portion of the refrigerant is flashed off into a vapor.

This vapor rises through the heat exchanger and vents back to the pressure vessel. In this instance we call the vessel a surge drum.

The liquid is separated in the vessel by gravity separation while the vapor flows back to the compressor suction valve. The liquid refrigerant that is boiled off in the evaporator is replenished by additional liquid flowing from the high pressure receiver or another liquid source.

From this comparison of similarities we find the oil cooling method and gravity flooded method both operate on the thermosiphon principle.

One of the greatest differences is due to the operating temperatures of the refrigerant in

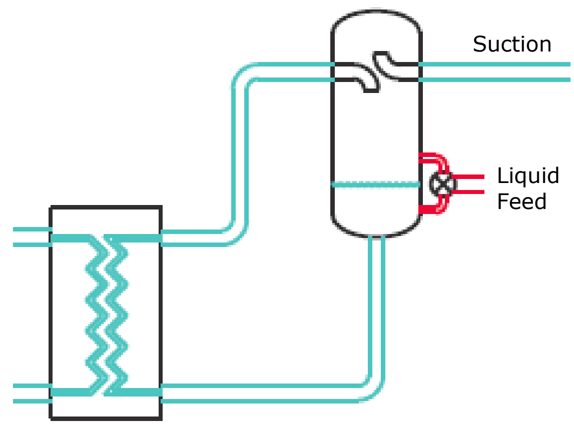

Fig. 2 Example of a flooded plate heat exchanger.

the various applications. Secondly, upon inspection we find another subtle fact.

Most installations of thermosiphon's used for oil cooling are installed with a large elevation difference between the pilot receivers and the oil coolers. This is noted as "h" in Fig. 1.

This increase in elevation is required to provide sufficient static head in the liquid column feeding the oil coolers.

It is interesting to note that the gravity flooded air units (or other heat exchanger types) are almost universally installed with the vessels close to the air units.

At this point you might be asking why are the installation requirements different if both systems operate as a thermosiphon?

The fundamental fact is due to the elevation difference. This is a function of the friction losses within the respective piping system.

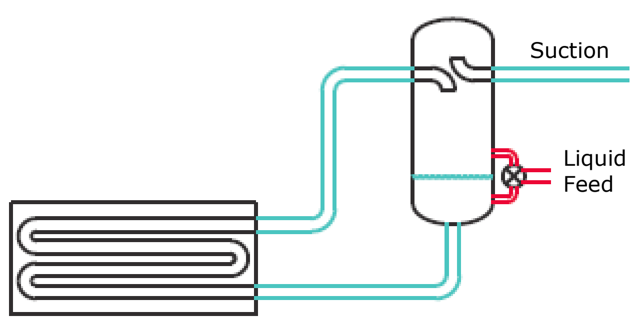

Fig. 3 Example of a flooded ceiling hung evaporator (fans not shown).

On a gravity flooded evaporator you will notice these are installed with large pipes in comparison with the cooling capacity. These larger pipes reduce the friction loss due to flow at varying heat load conditions.

By reducing the friction losses the static head required is greatly minimized.

In addition, it is common for system designers to use a single surge drum for each evaporator. This greatly reduces the complexity of the piping and the resulting problems with feeding liquid to multiple evaporators.

On the other hand, a thermosiphon system used for oil cooling may be installed over a much larger area. It is common to find multiple heat exchangers (oil coolers) installed over what may be large distances.

The increased complexity of the piping system necessitates the higher elevation to provide sufficient static head.

It is important to recognize it is possible to have too much static head on the liquid feed also. More is not necessarily better! Excess allowances for static head can increase the saturation temperature of the liquid ammonia in the oil cooler.

This reduces the operating log-mean temperature difference of the heat exchanger. This can result in a loss of oil cooling or air cooling capacity of the heat exchanger.

Upon further examination we also find a vast difference in the means of returning the vapor from the pressure vessel (surge drum or pilot receiver depending on the application).

From this comparison of similarities we find the oil cooling method and gravity flooded method both operate on the thermosiphon principle.

In a thermosiphon used for oil cooling, the pressure generated by the boiling liquid in the oil cooler is vented back to the condenser inlet. This area requires careful calculation of pipe friction losses to limit potential problems.

Conversely, the vapor generated in a gravity flooded evaporator is pulled back by the suction of the compressor. Since the compressor is providing the motive force to pull back the vapor, the friction losses of the pipe are much less critical.

When considering the design of thermosiphons it is imperative to carefully evaluate the effect of pressure gradients and changes in refrigerant properties. Any issue which affects the saturation temperature or phase change of the refrigerant can contribute to less than successful results.

Thermosiphons are typically very forgiving in operation. However, if certain design aspects or installation methods are not adequately addressed substantial costs may be required to correct piping or other installation deficiencies.

