Oil, just for lubrication! (part 2)

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Introduction

Apart from the occasional special application, oil is used to lubricate all refrigeration compressors. An annoying side effect of this is that oil residues enter the plant with the compressed gas, in vapour and liquid form. This oil will contaminate the heat exchanger present, with a negative impact on performance and operation. This two-part article presents a few ideas on how simple installation and/or adjustment of components can significantly reduce the oil concentration and therefore increase the operation and performance of the refrigeration plant.

Part 1 of this article also focused on lubrication oil; we ended there with an oil separator design for piston compressors with a performance of 95% obtained over the liquid portion. So little oil is transmitted in liquid form that only the amount of oil vapour is of any importance to the oil consumption, given the relatively high compressed gas temperatures. Placing a simple compressed gas cooler before the oil separator for instance, will reduce the oil consumption by at least 50%, so that the performance of the plant will increase by at least 10%!

If water or a heat exchanger is chosen, the compressed gas heat can be put to good use. Due to the high temperatures, demineralized water must be used to prevent calcium precipitation. To prevent the compressed gas from condensing and liquid refrigerant from getting into the oil separator, a temperature monitor (control) must be placed at the exit of the compressed gas that controls the heat dissipation. (See figure 6.)
Another possibility is cooling with evaporating condensate (see figure 7). Cooling with evaporating condensate is a safe concept by nature because the boiling pressure is around the outlet pressure minus the pipe pressure loss.

Figure 6

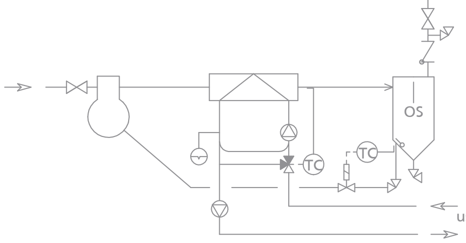


Figure 7

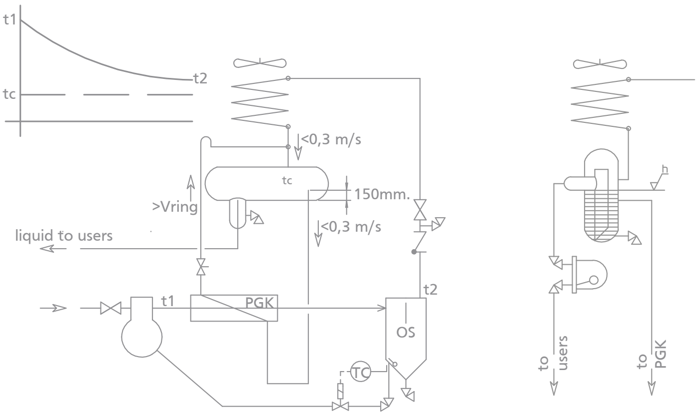
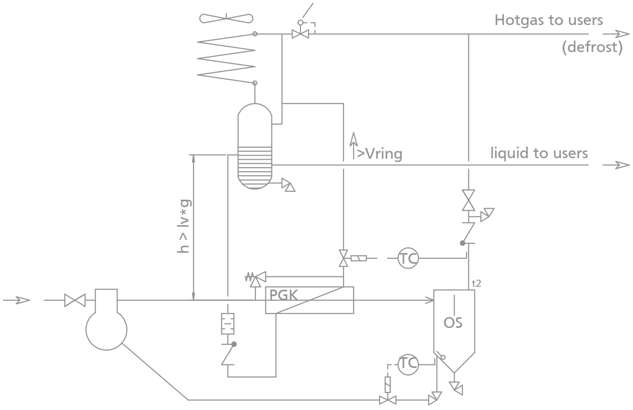


Figure 8



If the pipe pressure loss from the compressor to the entry to the condenser remains limited <1K, the surface temperature at the compressed gas side will be greater than the condensation temperature and condensation is excluded.
If the pressure loss becomes greater, for instance through the use of an entry pressure regulator (maintaining pressure with compressed gas thawing), extra components are needed to prevent refrigerant from condensing and to control the temperature. (See figure 8.)

Another option for removing oil from the refrigerant is using the liquid receiver that has been set up to allow the oil to settle. This concept is common in the oil industry and on ships for getting water to sink out of the oil. The performance of this kind of settling tank depends on the size of the entering oil drop, the time it stays, and stillness. The most classic tank is the API tank (American Petroleum Institute). In principle a settling tank can be calculated the same as a horizontal gravitational separator. Because drops of oil are now ‘falling’ into an ammonia bath, the vertical flow is laminar and the fall velocity

$$v_{settling} := \frac{g \cdot \left(d_{droplet}\right)^2 \cdot \left(\rho_{oil} - \rho_{NH_3}\right)}{18 \cdot \mu_{NH_3}}$$

can be calculated with Stokes:
If we know the fall velocity and the fall height, we know the time it takes a drop to settle. If we divide the horizontal flow length by the settling time we get the maximum flow rate. In practice, this does not always work with the horizontal pump separators and drops get swept along anyway. The reason for this is that a gas stream, after entering, is not divided immediately over the entire tank passage. A stream needs a certain length to distribute itself evenly over the whole passage.

If we keep the entry speed low for the condensate contaminated with oil, and after that we place a perforated plate with small holes and low perforation, the swirling in the liquid caused by the inlet connection will be deadened. The minimum level in the liquid tank can be calculated with the maximum flow rate (<<0.3 m/s), but may not be less than 150 mm. The flow length must be at least 20x the minimum level (so >3m).

There are now various ways to return the collected oil. We strongly advise against returning it directly with a magnetic valve without the intervention of a choke (expansion) valve and heat exchanger. As it concerns extremely small volume flows, even the smallest magnetic valve (about 0.1 gr/s per kW) available on the market is much too big for the available pressure difference. A small leak will already result in refrigerant getting through with all the ensuing devastating consequences. The sketches (see figures 9.0 to 9.3) show a number of possible solutions. If the oil is returned to 1 compressor, as with the Grasso intermediate cooler, and the system has several compressors, this compressor will have to be monitored for overfilling.

Figure 9.0

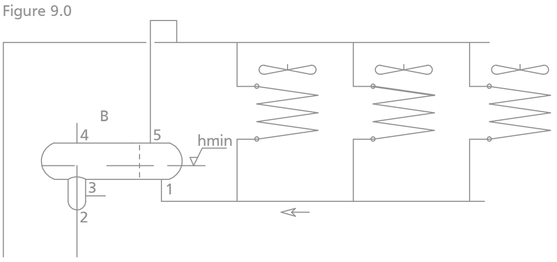


Figure 9.1

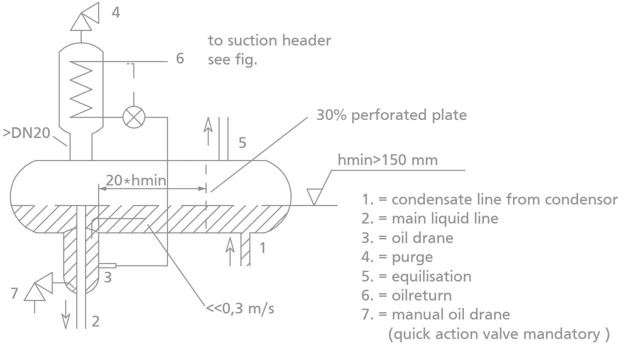


Figure 9.2

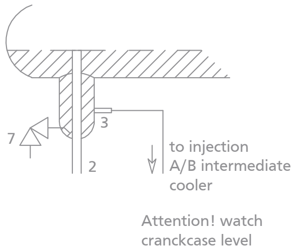
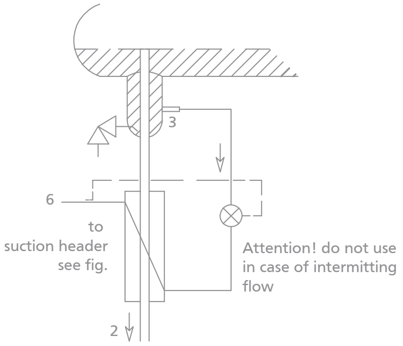
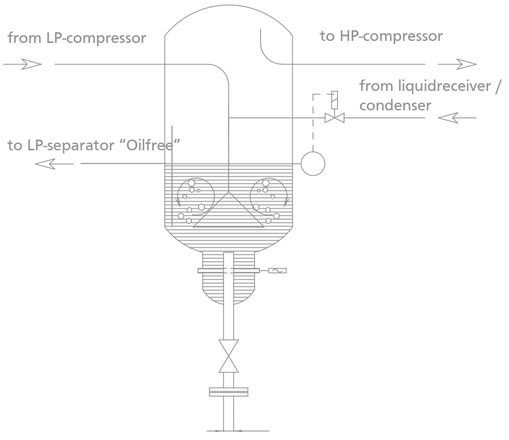


Figure 9.3



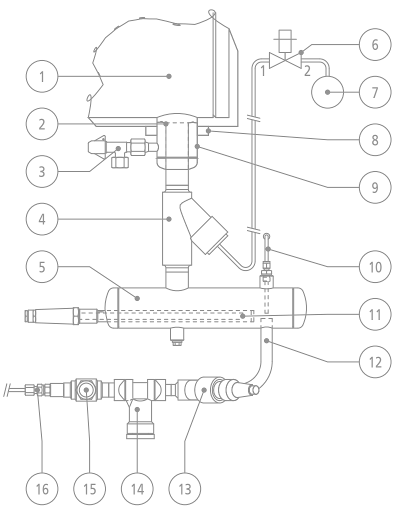
The same concept of settling can also be used in open intermediate coolers. (See figure 10.) The choking in the injection valve will turn the condensation and the oil into an emulsion; this makes separation much more difficult. If the open intermediate cooler has been designed in accordance with the proposals in the article in volume 99, no. 5 May, 2006, in practice it will turn out that the refrigerant can be sent to the low pressure separator practically free of oil.

Figure 10



Grasso has developed a fail-safe oil return system for its GCW ammonia chillers that guarantees oil return free of refrigerant in all circumstances (see figure 11).

Figure 11



The most important item, a compressed gas-powered shut-off valve, can be ordered under the name GPV from Revalco. The other components are freely available on the market or can be made. The components are constructed to be simple, sturdy and impervious to contamination. A simple control mechanism determines whether the liquid present in the drain system is oil, a mixture of oil and ammonia or pure ammonia, and if necessary, blocks the return. The system works as follows:

A mixture of oil/NH_3 flows from the evaporator or separator (1) into the oil dome and fills the space between dome and overflow pipe (2), then flows via the open gas-powered valve (4) into the collector/evaporation tank (5). The tank, with a capacity of about 0.5 litres, has a self-regulating thermostatic heating element (11) of about 400 W. The NH_3 evaporates here. Depending on the oil consumption of the compressor, the magnetic valve (6) is opened at an interval i of about 2 minutes, whereby:

$$i = \frac{\text{capacity of tank (cc)}}{\text{oil stroke}_{\text{compressor(s)}}\ (\text{cc} \cdot \text{h}^{-1})} \times 1/2^{*}\ (\text{h})$$

* the required interval is halved to catch deviations

The magnetic valve (6) mounted close to the pressure pipe (7) (to avoid condensation) now applies compressed gas to the gas-powered valve (4); the valve closes against the spring force and blocks the passage from evaporator/separator (2) to collector tank (5). With the gas-powered valve (GPV) in this setting, compressed gas pressure is applied to the level of liquid in the collector tank, causing the oil present to flow in turn via the discharge pipe (12), service shut-off valve (13), filter (14), sight-glass (15) and spring-loaded non-return valve (16) to the sump or the evaporation tank. The spring load of the non-return valve must be 1 bar to prevent liquid from flowing spontaneously.

The self-regulating heating element (8), together with the stationary oil between dome and overflow, prevents a thermal bridge. The magnetic valve is activated by temperature. If the temperature gauge (10) in the collector/evaporation tank in the immediate vicinity of the exit (12) measures a temperature higher than the evaporation temperature plus 20K, then oil may be returned; if this decreases more than 10K during pumping out for the evaporating residue of NH_3, or if the pumping out time of 2 minutes expires, the magnetic valve closes and

opens the gas-powered valve. Measuring the level in the sump (piston) or oil separator (screw) means as-need control is possible.
No spring-loaded security is needed on the evaporation tank. If both the GPV and one of the exit magnetic valves are closed at the same time, the pressure can exceed the outlet pressure. A hole in the control piston allows the overpressure to be released to the outlet side.

With soluble oils in pump and bath evaporative systems, the pulse pump section can also be used, but a larger pump tank must be used in that case. The sketches (see figures 12.0 and 12.1) show two applications.

Figure 12.0

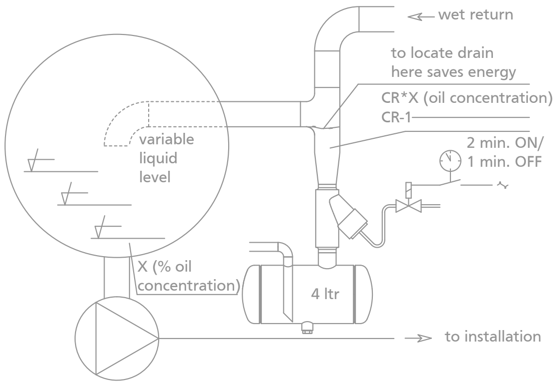
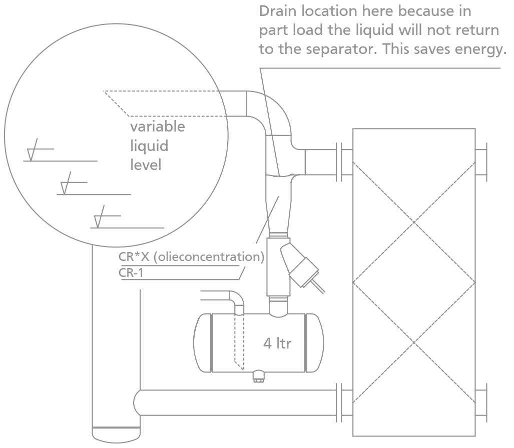


Figure 12.1



The energy needed for evaporation depends to a great extent on the allowable oil concentration in the refrigerant tank.

If the tank concentration remains the same, by connecting the oil return system to the evaporator exit (if circulation rate > 1) a higher concentration can be used. The mixture in the tank must now be pumped out at intervals that can be calculated. The mixture must then be pumped through an evaporative heat exchanger to the oil return buffer tank.

If you would like to react to this article or one of the previous articles, or have questions, you can contact:

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