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Fault Diagnosis Using a P-H Chart

Building on the first two Fundamentals which introduced the Pressure Enthalpy Diagram we look this time at how these charts can be put to everyday use to diagnose faults and help improve the efficiency of installed refrigeration and air conditioning systems.

Reading and interpreting a pressure-enthalpy chart (also referred to as p-h chart or diagram and as a Mollier diagram) is a key skill for diagnosing problems and maximising efficiency.

Efficiency is not just about saving the customer running costs — if a system is not working efficiently then it may not achieve its required output, it will use more power and is likely to fail prematurely.

1 Standard cycle

The chart in Figure 1 shows a vapour compression cycle working correctly. The coefficient of performance for cooling (theoretical) can be obtained by dividing the length of the evaporation process by the horizontal length of the compression process. For heating the length of the condensing process is divided by the horizontal length of the compression process. As sketched this gives a C.O.P. of about 2.3 for cooling and about 3.3 for heating.

2 Increased sub-cooling

Next, we have a diagram in Figure 2 that shows an increase in the amount of sub cooling at the expansion valve entry. This improves the refrigeration effect without any increase in compressor work. The sub cooling is often delivered by a suction/liquid line heat exchanger or a sub cooling circuit expanding some liquid from the liquid line to cool the remaining liquid heading for the main expansion valve. This cooling may not therefore be “free” but as drawn it increases the C.O.P.s to 2.7 and 3.7 for cooling and heating. The same evaporator is achieving more cooling because each kg of refrigerant is doing more work.

3 Diagnosing a condenser problem

In Figure 3 we see the effect of a dirty condenser. Increased condensing and discharge temperatures, increased compressor work, reduced cooling and slightly reduced heating output. C.O.P.s are reduced to 2.0 and 3.0.

An increase in condensing temperature results an efficiency reduction. As a rule of thumb assume that for every 1K rise in condensing temperature you will lose 3% of cooling capacity and use 3% more energy. You can see the effect of reduced evaporating temperature in Figure 4. Again the rule of thumb is that for every 1K drop in evaporating temperature you will lose 3% of cooling output and pay for 3% more energy. This makes your filter cleaner a key efficiency tool.

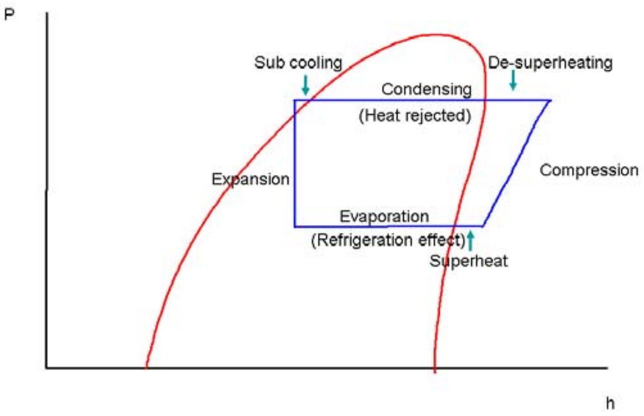

Figure 1: Standard cycle

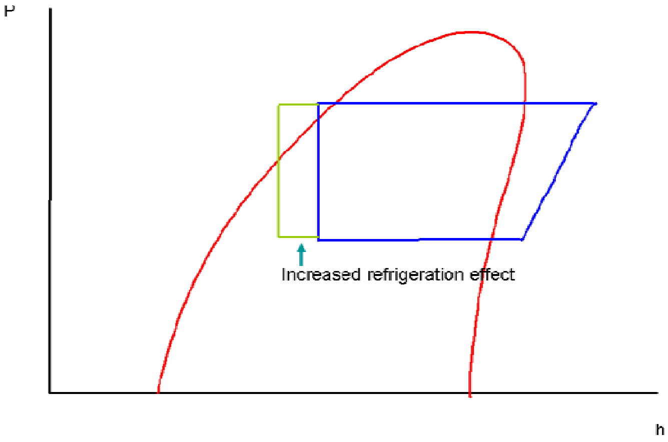

Figure 2: Increased sub-cooling

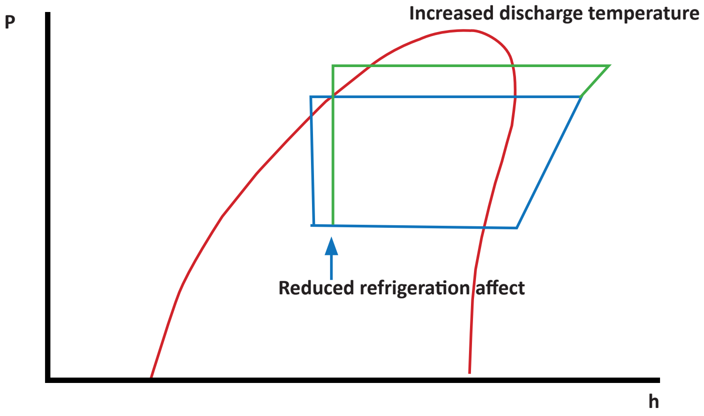

Figure 3: Diagnosing a compressor problem

4 Diagnosing a filter or evaporator problem

Finally we now see the effect of dirty filters or evaporators in Figure 4. The evaporating temperature is reduced and the C.O.P. is slightly reduced but the most significant effect is the increase in specific volume of the refrigerant at the compressor inlet. This also applies to Figure 5 where we have an excessively long, undersized or bendy suction line. A compressor can be considered as a constant volume pump. Due to the increased specific volume the compressor will pump a reduced mass flowrate. This reduces the cooling and heating outputs, makes the compressor run longer and hotter as suction gas cooling reduces with mass flowrate.

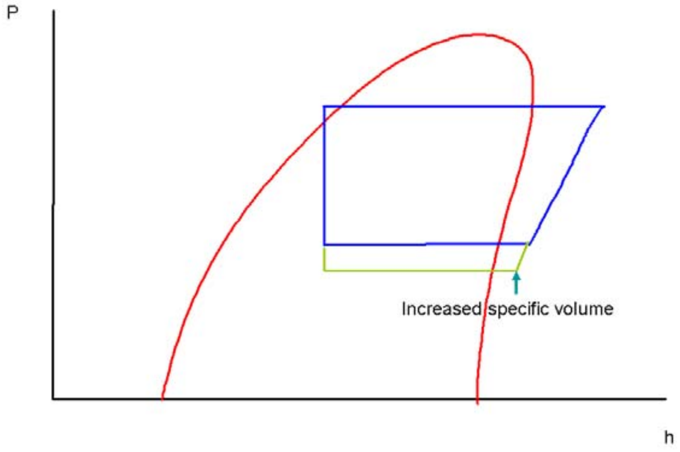

Figure 4: Effect of reducing evaporating temperature

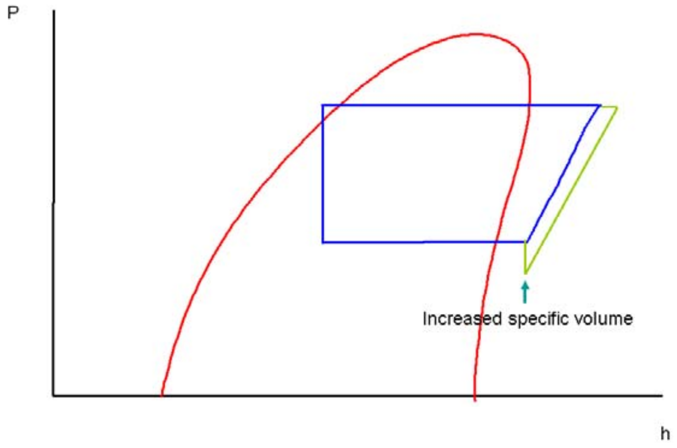

Figure 5: Diagnosing a filter or evaporator problem

Glossary – Subcooling

Subcooling is the condition where the liquid refrigerant is colder than the minimum temperature (saturation temperature) required to keep it from boiling and, hence, change from the liquid to a gas phase. The amount of subcooling, at a given condition, is the difference between its saturation temperature and the actual liquid refrigerant temperature.

Effect of subcooling:

It increases the efficiency of the system since the amount of heat being removed per pound of refrigerant circulated is greater. In other words, you pump less refrigerant through the system to maintain the refrigerated temperature you want. This reduces the amount of time that the compressor must run to maintain the temperature. The amount of capacity boost which you get with each degree of subcooling varies with the refrigerant being used.

It is beneficial because it prevents the liquid refrigerant from changing to a gas before it gets to the evaporator. Pressure drops in the liquid piping and vertical risers can reduce the refrigerant pressure to the point where it will boil or “flash” in the liquid line. This change of phase causes the refrigerant to absorb heat before it reaches the evaporator. Inadequate subcooling prevents the expansion valve from properly metering liquid refrigerant into the evaporator, resulting in poor system performance.

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