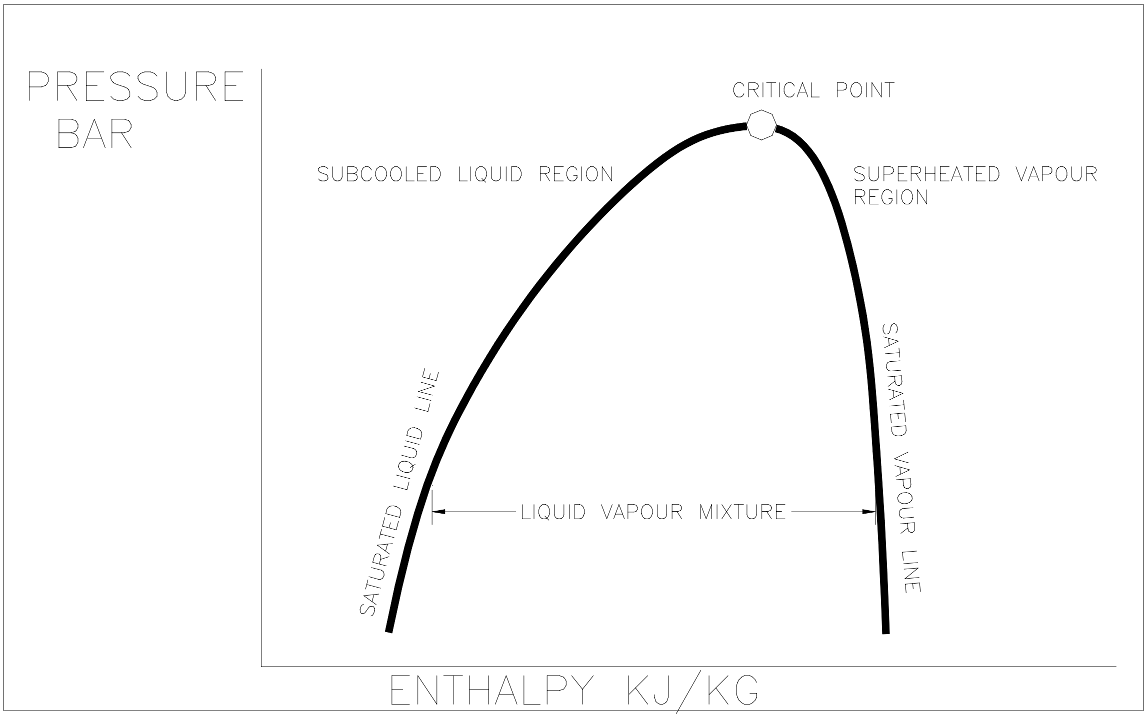
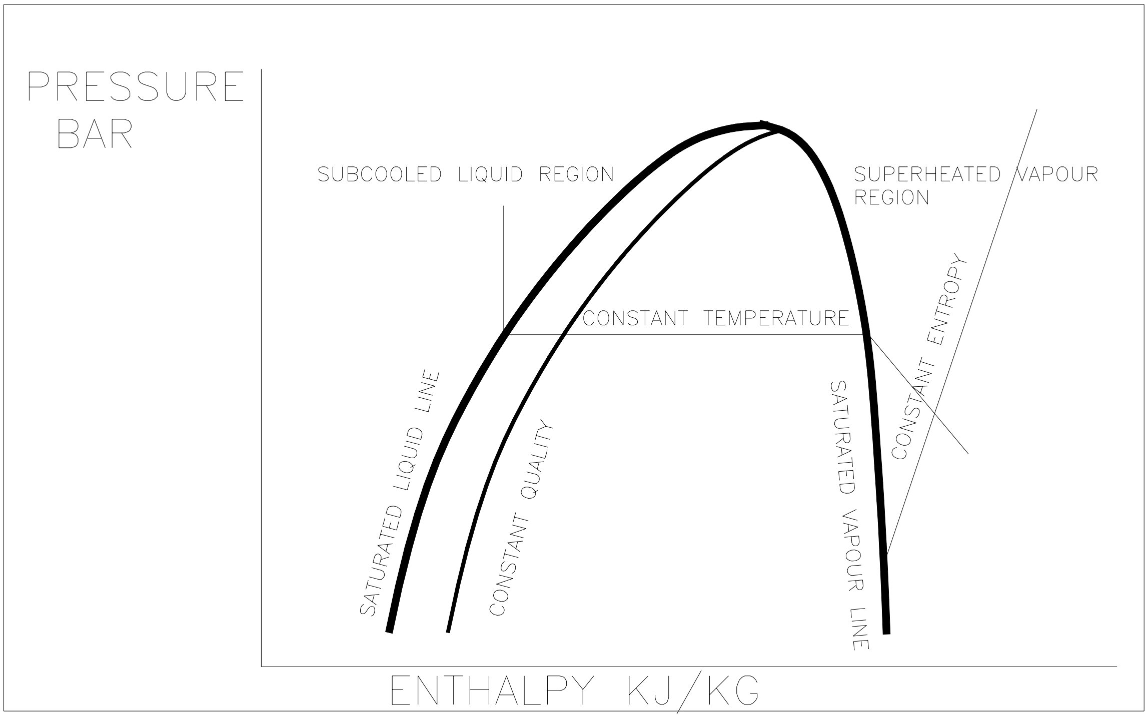
Refrigerants
PH Chart

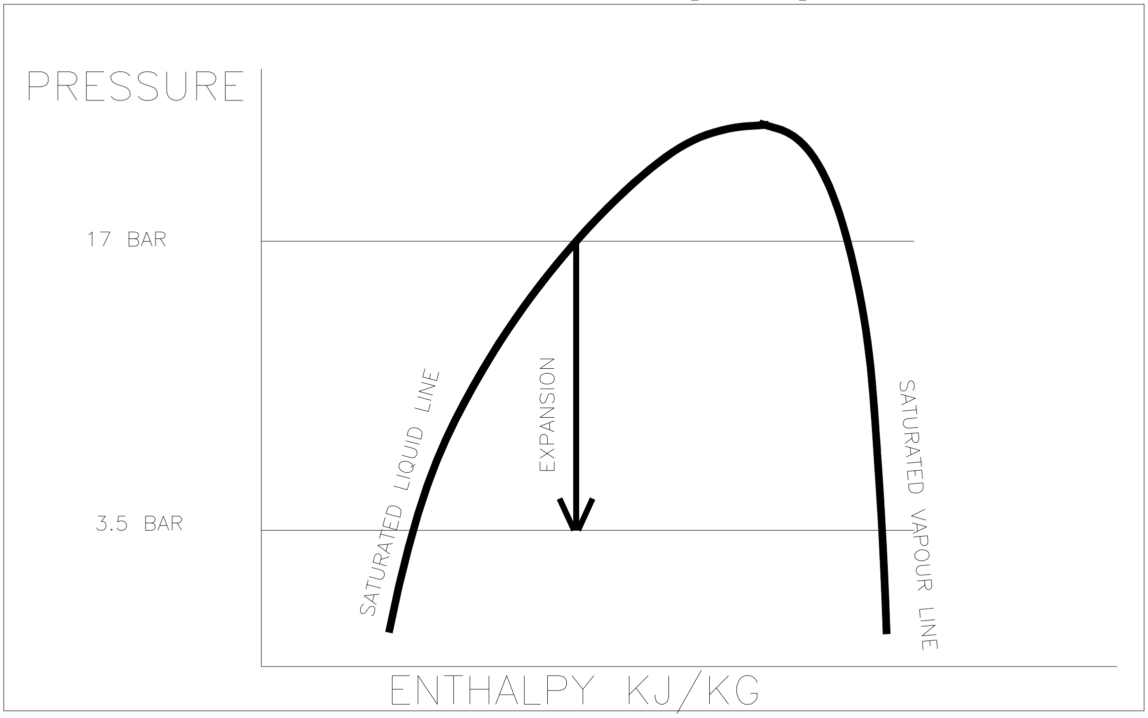


This diagram shows a simplified pressure/ enthalpy chart for a non specified refrigerant. The area contained within the envelope is for a liquid vapour mixture. The region to the left of the envelope represents liquid in a subcooled condition. The region to the right of the envelope represents vapour in a superheated condition.

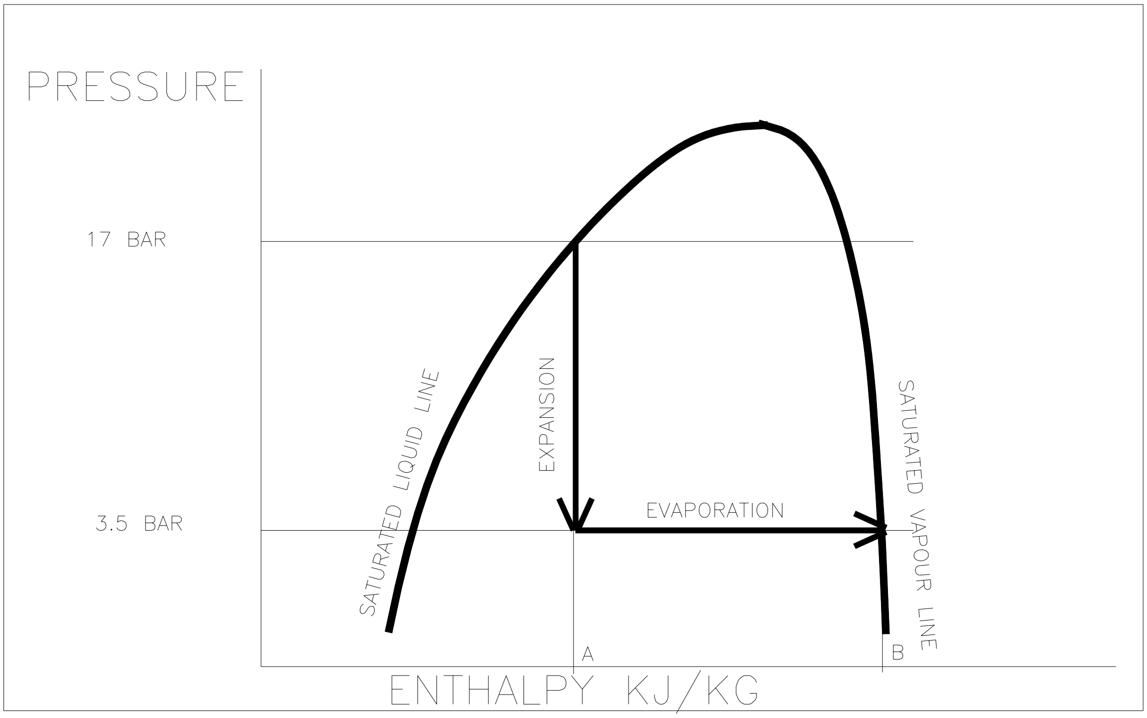


Here we see a similar chart to the original but containing further information. It represents a single component refrigerant such as R22 and it can be seen that lines of constant temperature correspond with lines of constant pressure. That means that there is only one saturation temperature for a given pressure irrespective of the state of the fluid.

What can this chart tell us? Here is a chart with the expansion process drawn on it.

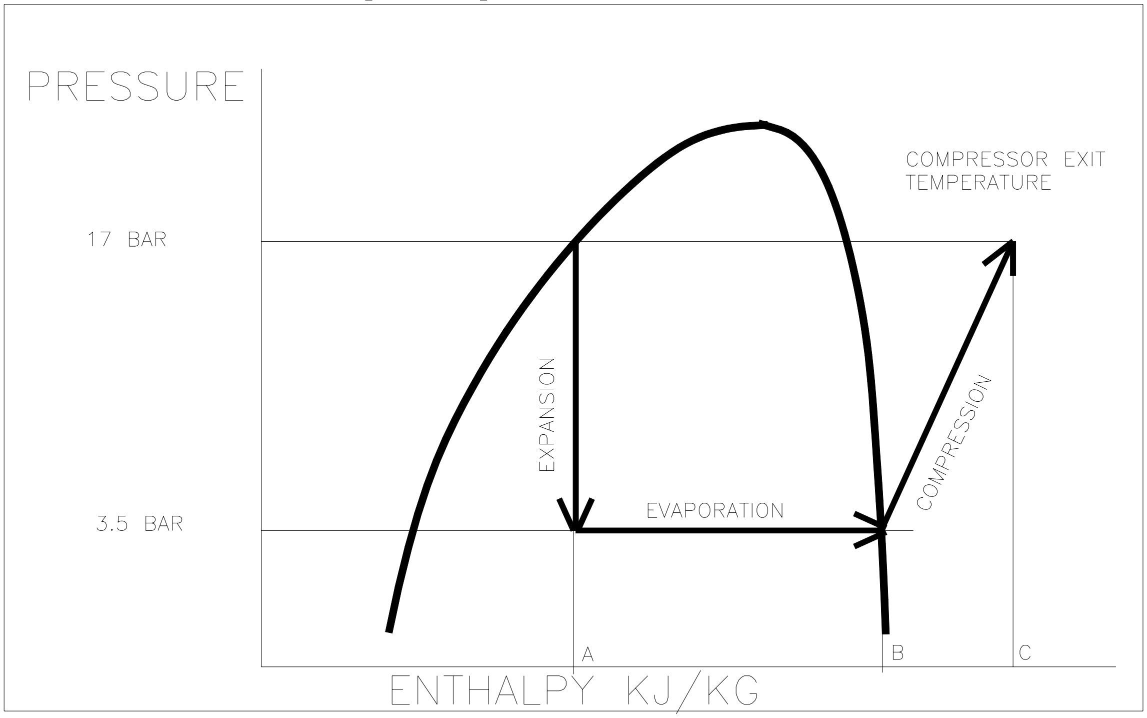


The expansion process is represented by a vertical line which drops from the condensing condition to the evaporating condition. The enthalpy (which is the energy that the fluid possesses) does not change .The pressure of the fluid does drop from 17 bar to 3.5 bar. The line will intersect with a line of constant quality at the lower pressure which will be the ratio of vapour that the refrigerant contains. The reduction in pressure can be provided by an expansion valve or a capillary tube or a hand operated expansion valve.

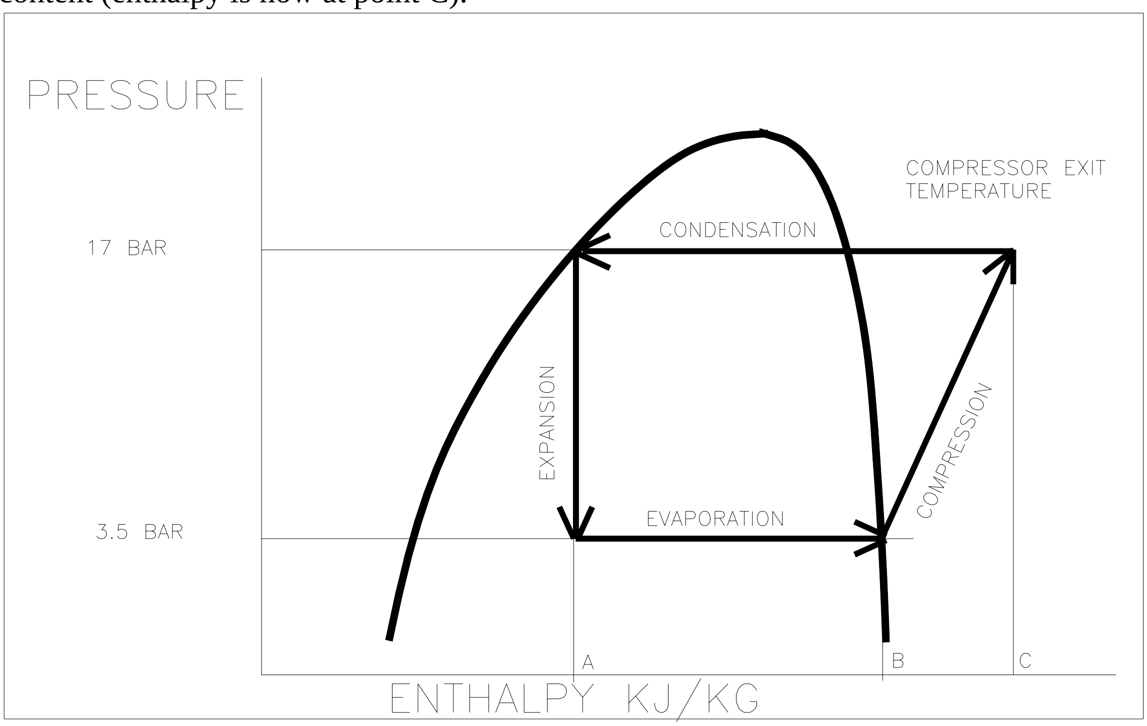


On this chart we have added the expansion process. The line moves horizontally to the right until it reaches the saturated vapour line. The enthalpy has increased from A to B. This means that energy has been absorbed by the refrigerant and this energy has been removed from the air stream.

Now we can look at the compression process.



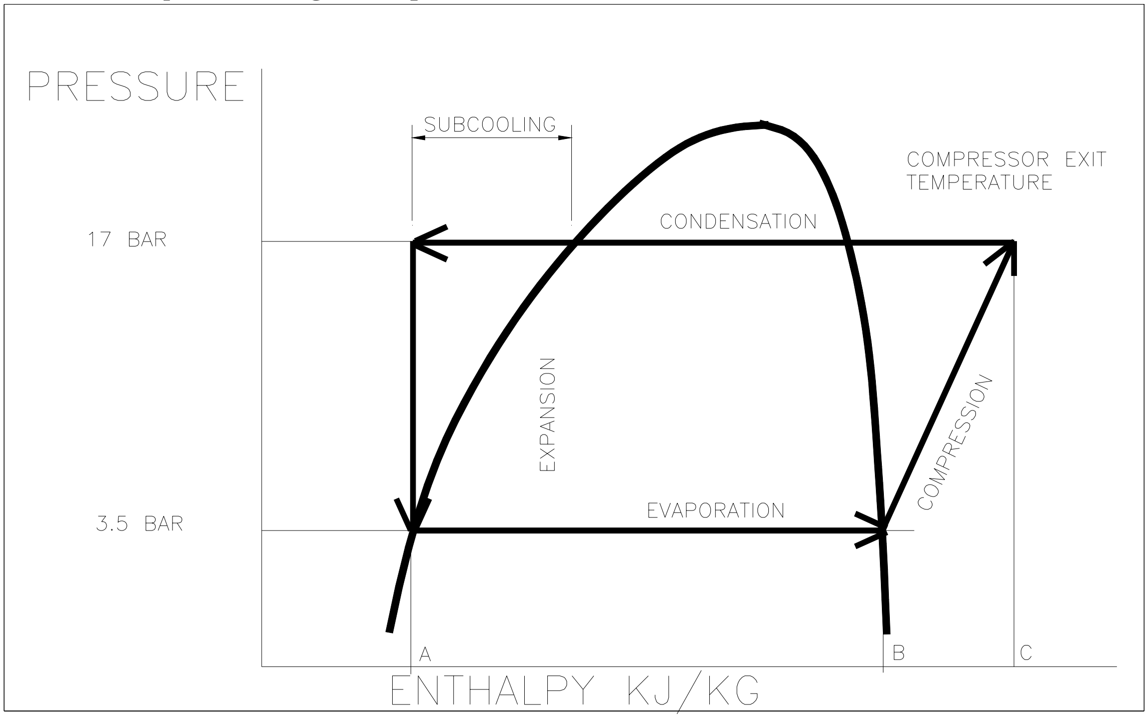
The act of compression requires energy to be added in the form of mechanical work. This is transformed into heat and the compression process follows the line of constant entropy. The point where it reaches the condensing pressure defines its temperature and its energy content (enthalpy is now at point C).



This chart shows the final part of the cycle. Heat is removed from the refrigerant until the enthalpy is reduced to the level at A where the cycle begins again.

Subcooling

I have previously stated that subcooling of liquid refrigerant has a beneficial effect on the cooling obtained from a refrigeration system . This diagram shows a system with subcooled liquid entering the expansion device.

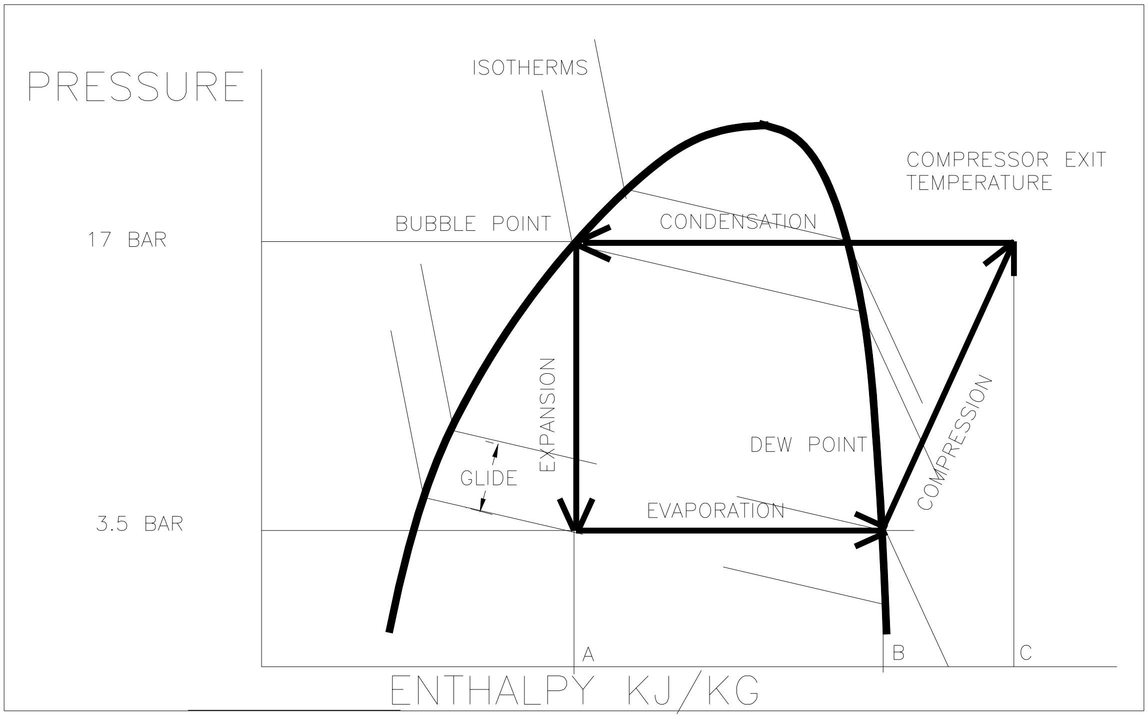


You will note that the expansion phase has moved to the left of the saturation line and the entering liquid enthalpy has reduced.

This means that the difference in energy between the entering liquid and leaving gas has increased. It follows that a fixed mass of refrigerant flowing around the system will now be able to absorb more heat in the evaporation part of the cycle.

The other main use of subcooling is to overcome pressure losses created by liquid lifting. If the condenser is positioned below the level of the evaporator it will be subjected to the weight of the column of liquid refrigerant which is acting against the direction of the flow. This will reduce the pressure seen at the expansion device and would cause some of the refrigerant to boil off because the liquid is no longer saturated. The expansion valve will only pass sufficient refrigerant if there is not an excessive quantity of gas within it.

By supplying the correct amount of subcooling to overcome this pressure loss it can be guaranteed that the valve will only see liquid at its inlet.



This final chart shows a non azeotrope. That is a mixture of refrigerants which do not operate as a single component. You can see the isotherms (which are lines of constant temperature) do not line up with the lines of constant pressure. The effect of this is to have a liquid saturation pressure and a separate vapour saturation pressure for any given temperature. The difference between the two temperatures for a given pressure is known as the glide. Glide is important for the following reasons. Expansion valves have historically been controlled by superheat. This is on the basis that if the refrigerant is superheated there can be no liquid present. Now look at this situation where the pressure remains constant at 3.5 bar on R 407C this equates to a liquid saturation temperature of -15°C, a vapour saturation temperature of –8°C and a temperature at the point where it enters the evaporator of –13°C. Now ,if we measure the temperature of the fluid leaving the evaporator the minimum temperature that we can safely say that all the refrigerant has boiled off is –8°C. We also need a quantity of superheat to drive the valve . This is always greater than 3°C. So we are saying that the minimum temperature that the refrigerant should be leaving the coil is –5°C.

It has always been standard practice to specify pressures in the form of their saturation temperature. This was always acceptable because we had a fixed relationship between temperatures and pressures. With non azeotropes this is not the case. There are a range of temperatures associated with every pressure. A refrigeration system is only capable of providing a quantity of refrigerant at a single **pressure** in to the evaporator. The decision now needs to be made as to which point is going to be taken as the evaporating temperature.

If we take the liquid saturation point as the evaporating temperature this gives us a temperature of -15°C. If we take the vapour saturation temperature this gives an evaporating temperature of -8°C. Some manufacturers adopt the mid point as the representative temperature which would be -11.5°C.The operating point of the equipment has not changed. All of these points relate to R407C evaporating at 3.5 bara. So what is the evaporating temperature at these conditions? The answer is that they are all valid providing that we explain which one we are using.

We also need to look at the effect of a non azeotrope on the condenser. Once again for any given pressure there will be a range of temperatures. At 17 bara the vapour saturation temperature is 43°C,however, the liquid saturation temperature is 37.5°C. To guarantee that all the refrigerant has turned to liquid at 17 bara the fluid must be at a lower temperature than 37.5°C. It is very important that we appreciate that this is the case and use the liquid saturation line temperature as the condensing pressure. It is also important that we inform our customer what we have done so that he can compare quotations on a fair basis.

Coefficient of performance COP

This is a representation of the efficiency of the system. It is the ratio of the refrigeration effect to the power input. So in our diagram the COP will be B-A/C-B.

Importance of pressure drop

We have now established that there will be changes in temperature as a result of the pressures within any system. Let us now consider the effect of the dynamic pressure losses around the system caused by friction in pipework and components.

Our compressor is running and sucking a fixed volume of refrigerant at a pressure determined by the system and discharging this refrigerant at high pressure into the discharge line. There will be a difference in pressure at this point which will be the driving force for the system. All flow requires a difference in pressure. If there is no pressure difference across components there will be no flow. One point in the system that requires high pressure drops to work correctly is the expansion process. There is a dramatic change in the entering and leaving pressures through the expansion device in order to produce the required effect in the evaporator. The evaporator and the tubing connecting it to the suction of the compressor should be as small as possible ,whilst still maintaining the necessary velocities for oil entrainment. If the pressure drop through the evaporator and suction piping is too high the compressor will be operating at a lower pressure than the evaporator and the system efficiency will be reduced.

The discharge pipework should be sized for minimum pressure drop whilst maintaining gas velocities sufficiently high to entrain the oil. The reason for this is the same as that for the evaporator in that the discharge pressure at the compressor will be higher than that at the entry to the condenser which will reduce the system efficiency..

Generally tubing and major components are sized with a maximum pressure drop that is equivalent to 1°C change. E.g. The compressor will have a pressure equal to 45°C.
The pressure at the inlet to the condenser will be equal to 44°C. The evaporating pressure in the coil will be equal to 5°C and the suction pressure at the compressor will be equivalent to 4°C. The duty obtained from the compressor will be that applicable at 45°C SDT and 4°C SST. The duty available at the condenser will be that applicable when condensing at 44°C and the duty at the evaporator will be that obtainable when evaporating at 5°C.