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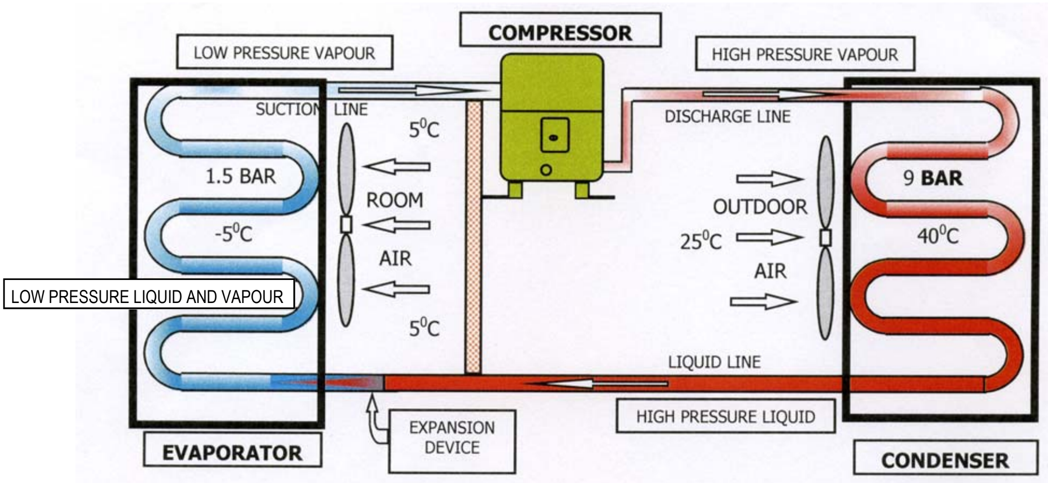
The Vapour Compression Cycle



This is the first in a series of RACHP Engineering Technicians Section guides to refrigeration and air conditioning fundamentals. Many experienced and fully trained engineers will know much of this basic theory already — but the guides can be used for training of colleagues, apprentices or helping customers understand their equipment. Other Fundamental guides cover pressure enthalpy diagrams, pressure temperature relationships, sub cooling and superheat, key components.

The basic vapour compression or mechanical refrigeration cycle involves the circulation of refrigerant, which in the process of boiling (evaporating) absorbs large amounts of heat and gives up heat when condensing. This heat which must be gained or lost during the change of state is called latent heat of vaporisation. It is in general more than the specific heat, that is the heat lost or gained during a one degree change in temperature.

There are in principal, only two pressures within the refrigeration system, which are relative to the required evaporating and condensing temperatures but vary depending on the refrigerant used, the temperature of the space to be cooled and the type of application.

An example of a basic vapour compression circuit for an air conditioning application operating on R134a is shown above.

1. The refrigeration cycle starts with high pressure liquid (e.g 9 BAR) in the liquid line passing through a restrictor device, which typically could be a capillary line or an expansion valve. Here it is allowed to expand and its flow is regulated.
2. Next it passes into the evaporator where with its pressure greatly reduced e.g 1.5 BAR, it will be boiling at –5°. But in order for it to boil it must absorb heat, which it gets from the metal of the coils which in turn absorb heat from the room space which, in this example is 5°C.
3. Once the refrigerant has been vaporised it moves from the evaporator into the suction line and on to the compressor. The compressor compresses the vapour into a smaller volume and in doing so raises its pressure (e.g 9 BAR) and its condensing temperature (40°C).

4. The high pressure refrigerant vapour now passes into the condenser (also a matrix of finned pipes), where it is condensed back into a liquid state, by use of a fan drawing ambient air over it. The warmer refrigerant rejects heat to cooler ambient air.
5. The high pressure refrigerant now moves to the bottom of the condenser coil and sometimes into a vessel called a liquid receiver, where the cycle begins again!

The zone temperature can be controlled by simply cycling the compressor on and off according to the set point of a thermostat or controller, where it is monitored by a bulb or sensor usually found in the return air to the evaporator or a suitable place in the cooled space.

Note: the refrigeration cycle does not create "cold" it merely transfers heat from one place to another. A heat pump is a refrigeration system which absorbs heat from outdoor air and transfers it to where it is required.

SI units and useful definitions

Some of the useful definitions related to the basic refrigeration cycle are shown below:

Saturation temperature
The temperature at which a change of state occurs, vapour to liquid or liquid to vapour.

Saturated vapour
A vapour at its saturation temperature.

Sensible heat
Sensible heat is where a body or substance has become hotter or colder, i.e there is a change of temperature. Sub cooling of a liquid refrigerant is the result of a reduction of sensible heat.

Latent heat
Latent heat is the heat that has been absorbed by or given up from a substance where there is no change in temperature but there is a change of state. For example when water freezes it gives up heat but the thermometer stops at 0°C and when it boils the thermometer stops at 100°C (at atmospheric pressure). Latent heat is absorbed in the evaporator and dissipated in the condenser with no difference in temperature throughout the majority of either.

Evaporating temperature
The temperature at which liquid turns into a vapour at a given pressure.

Condensing temperature
Is the temperature at which vapour turns into a liquid at a given pressure.

Boiling point
Is the temperature at which a liquid turns into a vapour at atmospheric pressure.

Enthalpy
Enthalpy is a measurement of the amount of energy, measured in joules (J) or kilojoules (kJ) contained in 1kg of a substance, and is determined by the temperature and pressure of that substance, calculated from a base reference temperature of 0°C for water and –40°C for refrigerants.

Pressure-enthalpy diagram
There is a pressure-enthalpy diagram for each refrigerant. This diagram shows the amount of heat contained in one unit of weight of the refrigerant in its saturated liquid state and also its vapour state at different pressures, their corresponding temperatures, in a scale called enthalpy. Pressure-enthalpy diagrams are covered in bulletins F2, F3, F4, F8 and F9.

The accepted units of measurement in the refrigeration and air conditioning industries throughout Europe are those that have been harmonised by the International Organisation of Standardisation (ISO). ISO 1000 recommends that the International System of Units (SI) is used.

Temperature
The Kelvin scale (k) is an SI base unit and is the absolute scale of temperature.

Pressure
Pascal (Pa)
100kPa = 1 bar

Mass
Kilogram (kg) – base unit

Length
Metre (m) – base unit

Time
Second (s) – base unit

Volume
Cubic metres (m^3)
Litre (l) is a 1/1000th of a cubic metre of water or 1 cubic decimeter (dm^3) which is $1cm^3$

Speed/velocity
Metres per second (m/s)

Mass flow rate
Cubic metres per second (m^3/s)

Density
Density is the ratio of the mass (weight) of a substance compared with its volume

$$= \frac{\text{mass}}{\text{Volume}} \qquad = \frac{\text{kg } (\text{kg}/\text{m}^3)}{\text{m}^3}$$

Energy
Joule (J)

Power
Watt (w) is the equivalent of 1 joule per second 1kW = 1000w = 1000J/s.

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