COMMONLY USED BUT NOT PROPERLY UNDERSTOOD TERMINOLOGIES BY AIR CONDITIONING & REFRIGERATION PROFESSIONALS

1. Air Conditioning and Refrigeration are two different Technologies:

Refrigeration is a process of cooling by moving or pumping out heat from a place where it is not wanted to a place where it is less objectionable.

So to achieve any temperature below ambient temperature we require energy. Refrigeration covers entire spectrum from ambient temperature to absolute zero temperature of minus 273.15^0C

Air conditioning therefore is a part of refrigeration covering a narrow band in the range of 19^0C to 26^0C where temperature is lowered to suit human comfort. It is therefore not different science but very much the part of refrigeration Technology.

The other major areas of refrigeration technology, depending on specific requirements are

1. Process air conditioning
2. Commercial Refrigeration
3. Industrial & Low temperature refrigeration
4. Cryogenics

2. Enthalpy means sum of sensible and latent heat:

In reality Enthalpy is the sum of both, internal energy (u) and the product of pressure and volume(pv) or flow energy

H= u+ pv

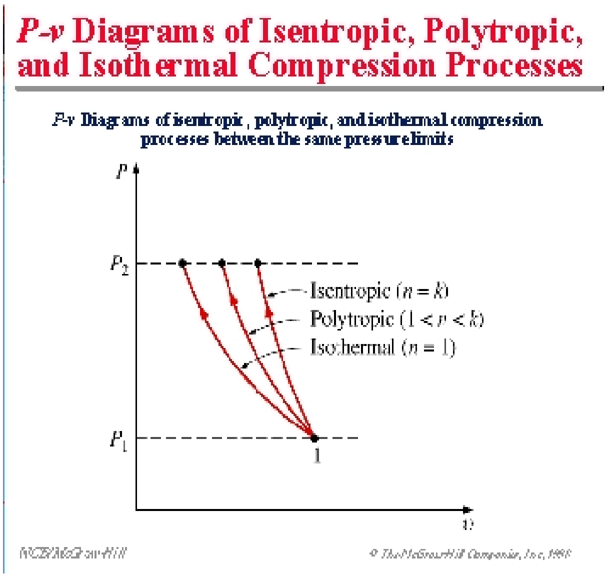
Vapour compression refrigeration & air conditioning systems are all in the category of flow processes, and therefore only flow energy is considered with any datum level.

Hence in refrigeration systems we call the total heat as enthalpy, which is the sum of sensible and latent heat. It is measured in **BTU's or kcal/hr or Watt.**

Technically anything above -460°F/-273.15^0C contents heat but we view it relatively. We should therefore address as how much heat energy substance contains rather than how hot or cold it is.

3. ENTROPY:

We use this terminology when we talk of isentropic compression of refrigerant in the compressor, to determine discharge pressure/temperature conditions at the end of compression process. However, the meaning of this terminology is not understood by majority of practicing professionals.



Entropy measures the molecular disorder of a system. The more mixed the system, the greater is the entropy, and conversely an orderly or unmixed configuration is one of low entropy.

The term entropy means transformation. It is thermodynamic property of a working substance, which increases with addition of heat, and decreases with its removal. It is comparatively easy to define change of entropy of a working substance. In a reversible process, over a small range of temperature, the increase or decrease of entropy, when multiplied by absolute temperature, gives the heat absorbed or rejected by the working substance. The heat absorbed (ΔQ) by the working substance is equal to:

$\Delta Q = T \times \Delta S$ or $\Delta S = \Delta Q/T$ or where T is absolute temperature and ΔS is increase/decrease in entropy

IS standard 3615 defines entropy as ratio of the heat added to a substance to the absolute temperature at which it has been added.

Since in universe some activity is constantly taking place in all the processes such as mechanical work, electrical work or chemical work including lights and solar energy, and all these forms are finally converted into or generate heat which is the lowest form of energy, the law of thermodynamics states that entropy of universe is constantly increasing.

A simple understandable statement for entropy is- a measure of energy unavailable for useful work or wasteful energy. A certain portion of energy added to a system at high temperature is later lost from the system to the surroundings at a lower temperature & this energy is unavailable for doing any useful work between the two temperatures involved- Entropy is expressed as kJ/kg.K. (Definition given in Automotive Design and Development-in Annexure under definitions)

4. **Thermal conductivity:**

Many professionals use either FPS system or SI system. When looking at the units of thermal conductivity, there is confusion with many users since the units in FPS are per inch thickness basis whereas in SI system they are per meter thickness, hence there is a difference as given below

In FPS units, It is the rate of heat transfer in Btu per hour per square foot of area per degree Fahrenheit temperature difference **per inch** thickness.

In order to convert Thermal conductivity '**K**' value in **Btu.in/h.ft^2.°F, we need to multiply FPS value by 0.1442 to get 'K' value in SI system (W/m.K) as given in conversion tables.**

How this has been worked out is given hereunder

Thermal conductivity, (K): 1Btu /h.$\frac{ft2}{in.}$.°F (x 0.1442) = 1W/$\frac{m2}{m.}$.K

$$K = \frac{\mathbf{1x1055.056\ J(J = W.s)}}{\mathbf{inchx3600s\ x(3.2808\ ftx12)x}\frac{1}{\mathbf{3.2808}ft}\mathbf{x}\frac{1}{\mathbf{3.2808}ft}x\frac{1}{\mathbf{1.8}F}}$$

$$\left[\frac{\mathbf{1055.056\ J(W.s)\ x\ 3.2808\ ft\ x\ 3.2808ft\ x\ 1.8F}}{\mathbf{3600\ x\ 3.2808ft\ x\ 12in}}\right] = \mathbf{0.1442}$$

Hence, when we multiply thermal conductivity in FPS unit by **0.1442** we get Thermal conductivity in SI unit as **W/m.K**

Please note the major difference between FPS and SI system. In FPS 'K' value is for per inch thickness where as in SI system it is per meter thickness, hence 'K' value in SI is not **W/m^2.K, but W/m^2/m.K= or W/m.K**

Many engineers argue that the units indicated in SI units are incorrect and hence this clarification.

5. **The difference between saturation temperature and boiling point.**

Saturation temperature is another word for boiling point. Every substance has only one boiling point which is at atmospheric pressure whereas it has many saturation temperatures depending upon pressure. Saturation temperature goes up when pressure increases and saturation temperature reduces when pressure reduces. If we refer to refrigerant tables we notice a small letter 'b' near the temperature and the pressure against the same is always 101.325 kPa. Which is the boiling point of the refrigerant.

6. **Heat flow and heat content:**

Heat flow depends on temperature of the substance and not the heat contained in the substance. If a 100kg metal ball at 99^{0}C is kept on contact with 1kg of metal ball at 100^{0}C, the heat will flow from smaller metal ball to larger metal ball although the heat content of bigger ball is much more.

If we relocate the refrigeration plant from lower climate temperature region to warmer areas, say from Bangalore to Delhi, the same refrigeration plant would operate at higher saturated discharge temperatures (SCT) as the compressor has to raise the energy level beyond ambient conditions so that heat will flow from condenser to atmosphere. Heat content is measured by the formula $Q=m.\ c_p \times \Delta T$ where m is the mass of substance, Cp is the specific heat and ΔT is the temperature difference.

7. Difference between Air compressor and refrigeration compressor and some other misconceptions.

In air compressors, the compressor sucks ambient air and compresses it to desired pressure as warranted by the applications. Mostly the discharge pressure is either 7bar or 10 bar. In other wards the suction pressure is generally same as surrounding ambient conditions where the compressor is installed & working and the discharge pressure varies as per requirement.

In refrigeration compressor operation, it is just the opposite. The discharge pressure is dependent on ambient temperature conditions, if it is air cooled application and depends on wet bulb temperature if it is water cooled application. The suction pressure is selected by the design engineer, depending upon the application for which he intends to design the system.

In case of air conditioning applications or chilled water applications suction pressure is high and thus compressor ratio is low. As we reduce the temperatures, the suction pressure starts falling. For cold rooms, it would be lower than air conditioning application, for -20^0C cold rooms it would be still lower and for blast freezer applications of -40^0C it would be very low. But in all these cases the Saturation discharge pressure remains same so long as we use the same refrigerant for all applications and same condenser cooling methodology i.e. either air or water cooled.

The compressor functions like water pump which raises water from lower level to a higher level. The compressor similarly raises the temperature level from saturated evaporating temperature to saturated condensing pressure so that refrigerant is able to reject heat to a medium which could be either air or water. In other words, compressor raises the energy level of the refrigerant.

All that a refrigeration compressor does is to pump a volume of gas. Once the suction and discharge conditions at the compressor are selected, then the mass flow of refrigerant in lbs/hr. or kg/hr. can be worked out. The system designer should ask for the accurate volume/mass flow rates at specified conditions from the compressor manufacturer. The designer should realize that a refrigeration compressor pumps a required volume of gas, and not refrigeration capacity.

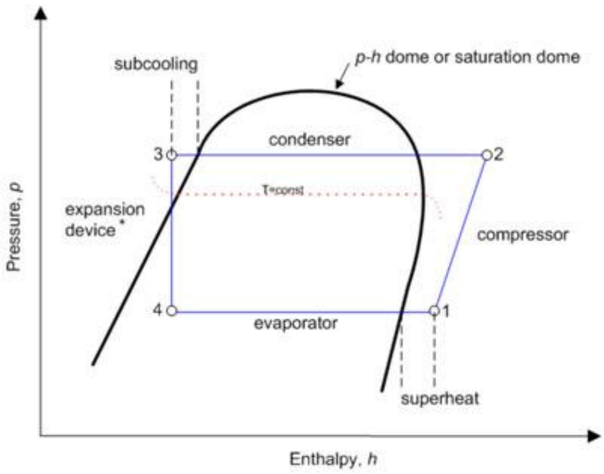
Another important fact to be remembered is refrigeration compressor is not designed to increase the discharge pressure. The discharge pressure is totally dependent on condenser cooling medium and condensing temperature. I have observed that most of the engineers, while conducting training programs, indicate that function of refrigeration compressor is to raise the pressure. This statement is incorrect. The compressor increases the temperature of refrigerant so that it is able to reject heat to cooling medium. The corresponding pressure to this condensing temperature is the property of refrigerant used in the system. There is nothing build into the compressor whereby one can increase pressure. Once the condensing temperature is decided, the refrigerant discharge pressure will be based on which refrigerant has been used. For example, at 40^0C condensing temperature the same compressor, when used with Ammonia refrigerant will have discharge pressure as 14.55bar whereas it would have, the discharge pressure for R134a refrigerant as10.11 bar and with 404A18.5 bar approx. and with 410A 24.5bar approx.

Thus it can be seen that compressor manufacturer does not provide any feature which enables these different pressures to be obtained. The same compressor is used with different refrigerants. It is the property of refrigerant which decides compressor discharge pressure.

8. **Sub cooling & superheating**:

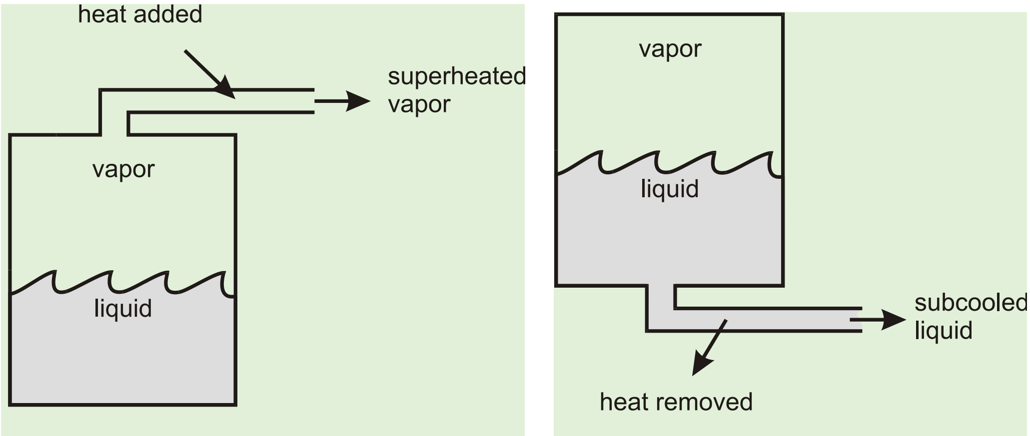
Many professional do not clearly understand the meaning and use of these terminologies.

In order to understand these, knowledge of P-H diagram is essential.



Sub-cooling the refrigerant before it enters the expansion device increases the system capacity without increasing compressor power and this is possible to certain extend by providing additional sub cooler or building extra area in water cooled condenser where the liquid gets trapped and then it can be cooled by separate water circuit.

Majority of compressor manufacturers indicate in their published catalogues, compressor capacity with 10^0F or 15^0F sub cooling. This makes the power consumption per Ton of refrigeration looks very attractive and many engineers come to me stating that so and so compressor consumes lower power compared to that of other manufacturer who has published ratings at Saturated conditions without sub-cooling. I ask the engineer to go to compressor manufacturer and find out how the compressor achieves sub-cooling as per published rating. The answer always is it is not the compressor which achieves sub-cooling but system designer must build the sub cooling circuit in his plant design or provide additional suction liquid line heat exchanger. One has to therefore be careful while comparing two manufacturers ratings to ensure both are on common basis of saturated conditions and not with sub cooling.



(a) superheated vapor (b) subcooled liquid

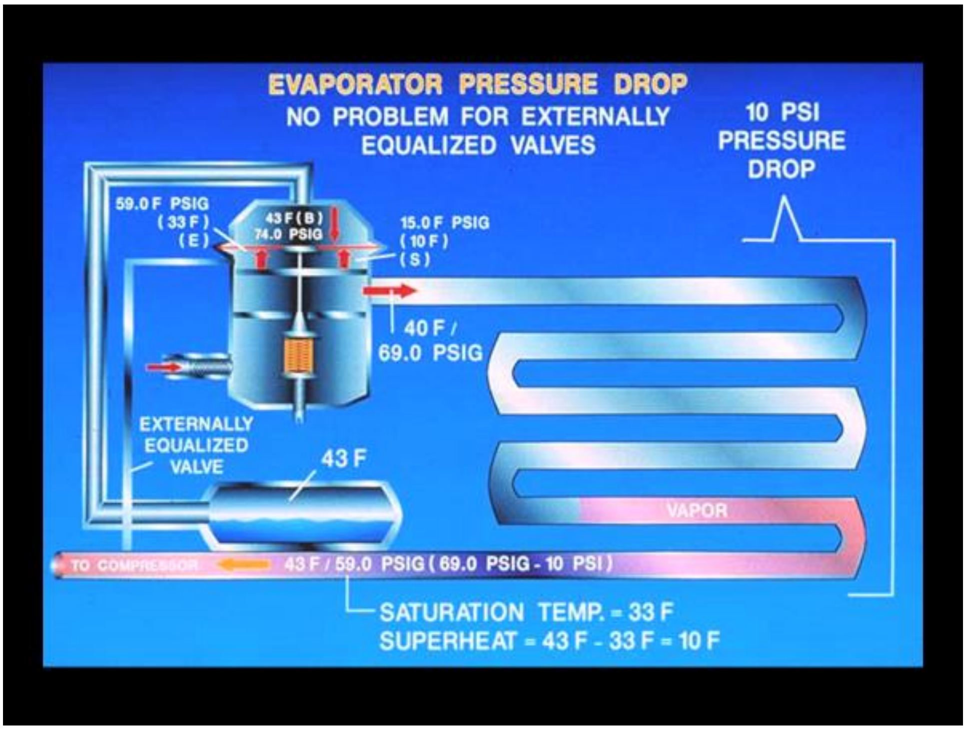
It can be seen from the P-H diagram that that only liquid can be sub cooled and only gas can be superheated. A mixture of refrigerant cannot be superheated or subcooled.

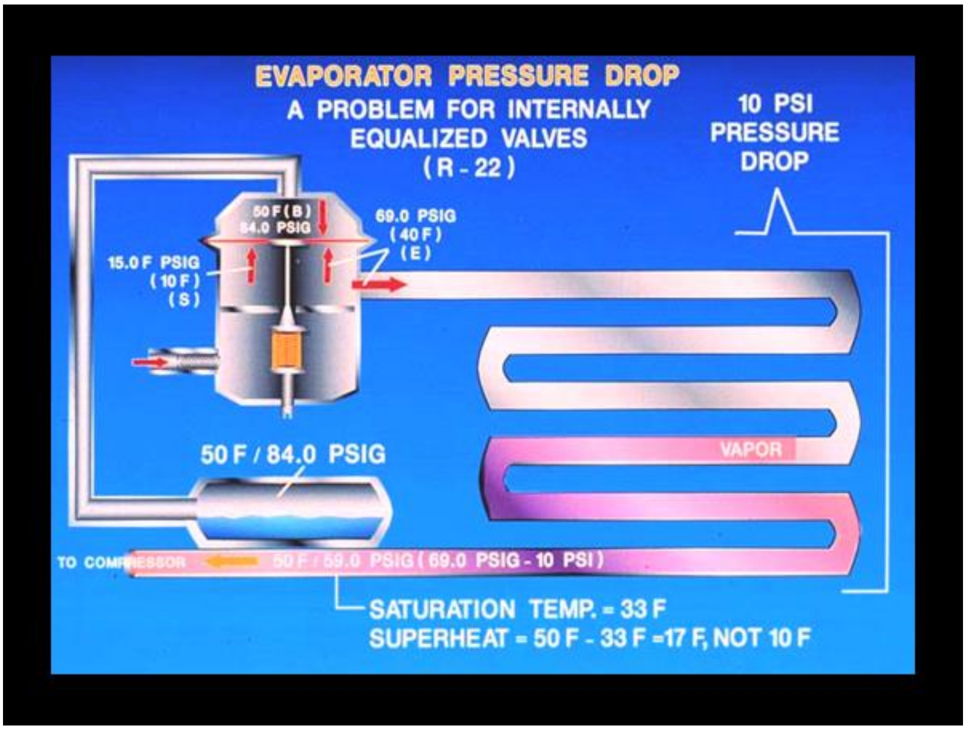
If we want to sub-cool the liquid, then it should be 100% liquid and no vapours. If vapours are present, the cooling provided would be first used in condensing the vapours and not sub cooling the liquid. Some manufacturers build separate liquid trap in condenser where only liquid accumulates and then it can be sub-cooled by providing independent water circuit. Similarly, if we wish to superheat the vapours it has to be 100% vapour. If some liquid is present, the heat would first be used in evaporating liquid and not superheating the vapours. The superheating and sub-cooling has to be at constant pressure as shown in the P-H diagram. If the pressure changes the saturation properties of refrigerant change.

9. Useful superheat:

There is nothing like useful super heat. It may be useful from compressor point of view as providing superheat minimizes risk of liquid coming to compressor.

The superheat in the suction line from outlet of the evaporator to inlet of compressor should be kept bare minimum as it reduces compressor capacity. The myth is regarding useful super heat. If one studies in detail the thermodynamic cycle, super heat is never useful as it increases the specific volume at the entry of compressor thereby reducing the mass flow rate and thus the cooling capacity. It is useful in the sense that it only helps in protecting the compressor by reducing the chances of getting liquid at the suction of the compressor. Similarly, if super heat is produced in the evaporator, vapour zone area becomes larger thereby making evaporator less efficient as expensive heat transfer area is used for super heating rather than for latent heat transfer by way of evaporation, which is the main function of evaporator. The most efficient system is without any super heating of suction gas which is possible with all flooded coolers predominantly used in Ammonia systems.
Centrifugal machines or screw chillers working with R134a, 404A also use flooded evaporators as these are more efficient than Direct Expansion evaporators.





The above diagrams show that when superheat in the evaporator increases the more area of evaporator is wasted

SUPERHEAT REDUCES CAPACITY

KC3 COMPRESSOR + 40^0 C / +5^0 C = AMMONIA

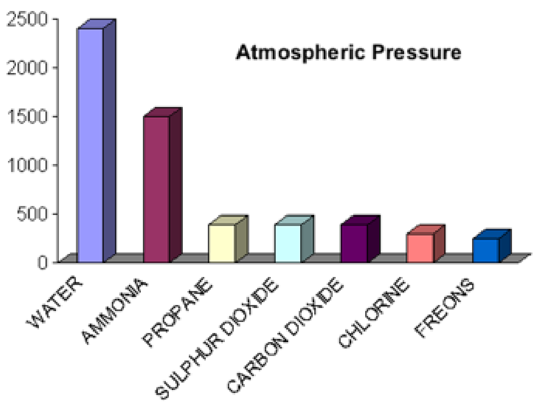
SUPERHEAT	CAPACITY Kcal/hr
0 K	359400
5 K	350700
10 K	342600

10.Latent heat makes refrigeration systems work efficiently:

It is very important to keep in mind that it is only the latent heat which makes refrigeration systems work efficiently. Sensible heat has hardly ant contribution. Hence, the refrigerant which has maximum latent heat is most efficient refrigerant.

Ammonia refrigerant is therefore more efficient than currently used any other refrigerants. Ammonia has highest latent heat compared to other refrigerants as can be seen for the diagram given below

LATENT HEAT



Ammonia refrigerant being natural refrigerant having best thermodynamic efficiency, and having no global warming effects is now increasingly being used in air conditioning installations where the machine room is away from the human occupied areas. Few major once are indicated below:

1.Oslo Air Port -Norway
2. Heathrow Terminal -5
3. Singapore Air Port
4. Dusseldorf Airport
5. Zurich Airport
6. New Zealand Christchurch Airport
7. Stuttgart Airport Terminal 3-2300kW Grasso
8. Telephone Exchange- Copenhagen
9. Thermal storage systems for Malls, Cinema Halls
10. KWN Greenpeace Headquarters-Vienna
11. Sabb-Linkoping-Sweeden-4 ammonia chiller of 2 megawatts
12.Berlin Ostbanhof train station-Grasso system for three storey building complex
13. Roche Headquarters in London -930 kW- Star Refrigeration
14. Mulligan Letter sorting center-Switzerland-Johnson Controls
15. Ozeaneum in Stralsund-Johnson controls-500kW A

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