What is Enthalpy?

Heat is energy; the total amount of heat energy contained in a volume of air is referred to as enthalpy. The combination of parts that make enthalpy are sensible heat and latent heat. Sensible heat is energy that is transferred to change the temperature of a material. Latent heat is the energy that is transferred to change the state of a material.

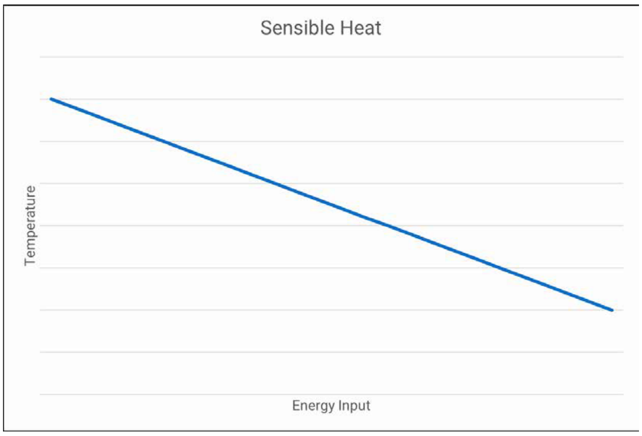
Sensible heat is easily understood and easily observed in the field, as energy into the refrigeration cooling cycle can be witnessed as a supply air dry bulb temperature drop.

The word latent comes from the Latin word 'latens', meaning hidden, latent heat literally translates to hidden energy. This is the energy that is transferred when changing a materials state, such as the condensation of water vapour in the air during a cooling cycle. Latent heat does not change the dry bulb temperature of the supply air, hence the name 'hidden energy'. Although hidden, its effects on the capacity requirements, comfort of occupants and performance related issues are very real.

Understanding the impacts of both of types of heat energy that make up enthalpy will aid and assist design, commissioning, and fault diagnosis of an air conditioning system.

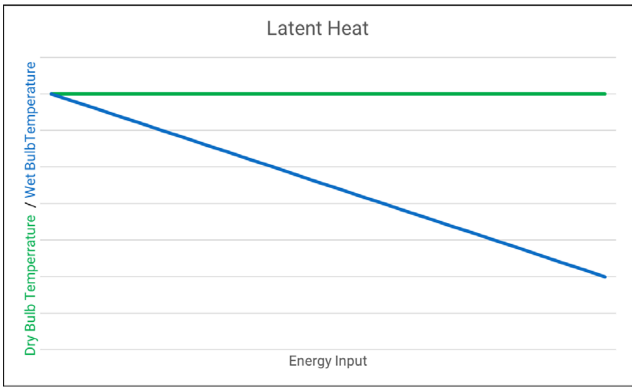
Sensible Heat – is the energy absorbed to change a material's temperature.

The energy input to the refrigeration system in cooling mode has a direct impact on the change of air temperature. As the energy input is increased, supply air temperature will decrease (until dewpoint is reached).

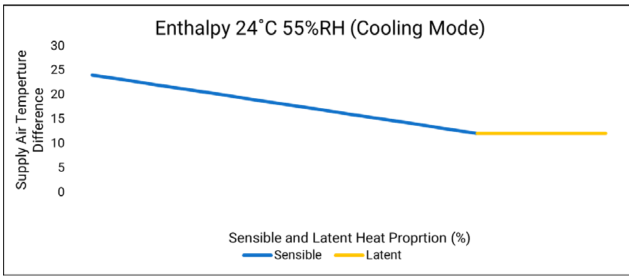


Latent Heat – is the energy absorbed to change a material's state.

The energy input to the refrigeration cooling system has no effect on the change of air temperature in the latent heat removal process. However, as the moisture in the air changes state (condenses from vapour to liquid) the moisture content within the air is reduced, decreasing the wet bulb temperature and dewpoint temperature.



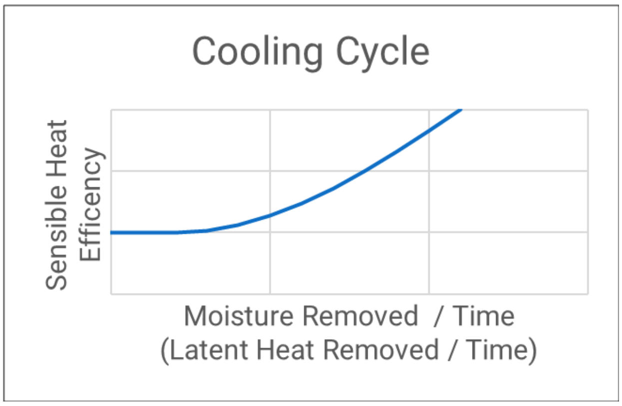
In a typical cooling cycle of a correctly performing air conditioner with room temperature of 24˚C and 55% relative humidity will have the enthalpy profile of the chart below. 75.8% of the energy input is directed to the efficient removal of sensible heat. In other words, 75.8% of the duty is used to lower supply air dry bulb temperature. 24.2% of the energy input is directed to latent heat removal. In other words, 24.2% of duty is used to remove moisture from the air without affecting the supply air temperature.



Practical Enthalpy

During a full cooling cycle, the amount of moisture in the air decreases. As this happens the amount of energy required for the latent heat process is reduced. This energy then becomes available for absorption in the sensible cooling process.

As the cooling cycle progresses over time, moisture (or latent heat) is removed from the air. As the air requires less latent heat absorption for moisture removal the availability of capacity for sensible heat absorption increases. As the sensible heat absorption increases, supply air temperature decreases, room conditions improve and energy efficiency increases (see chart to the right).



A real-world scenario that highlights thermodynamic energy distribution is to investigate the latent and sensible heat requirements of an air conditioner at the start of a cooling cycle compared to the end of a cooling cycle.

Model - OPA 970

Capacity - 16kW -

102kW Air flow -

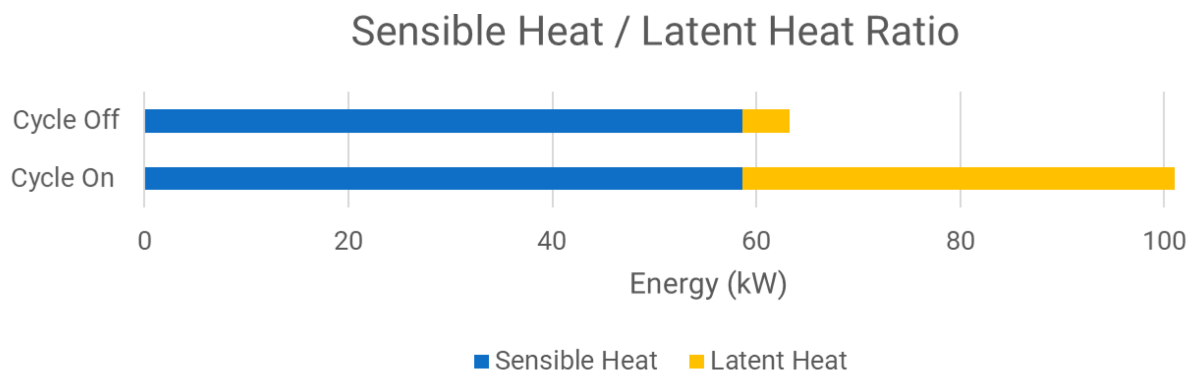
4700L/s

Cycle on - 25°C

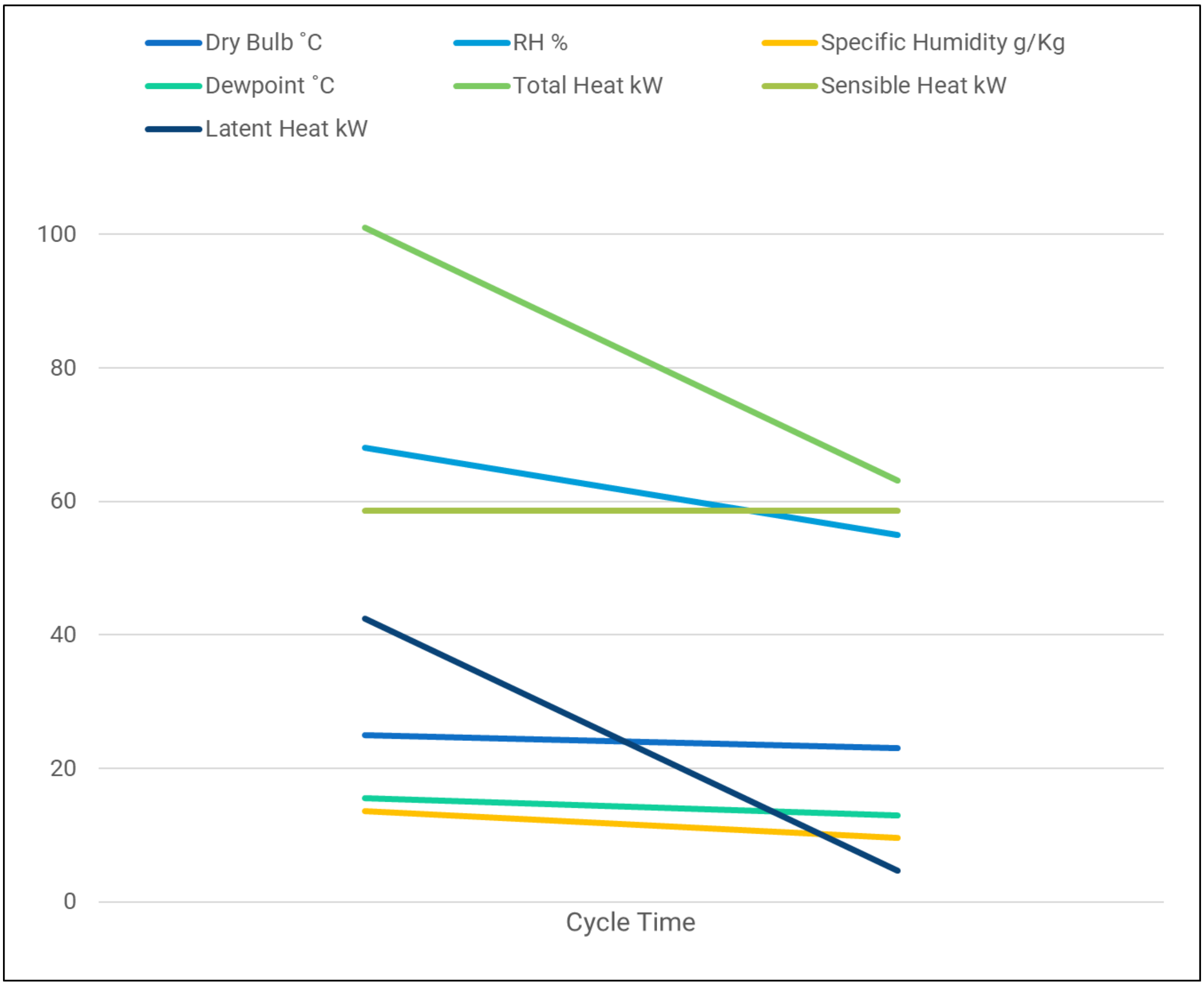
Cycle off - 23°C

Space Conditions		
Measurement	**Cycle On**	**Cycle Off**
Dry Bulb	25 ˚C	23 ˚C
Relative Humidity	68 %	55 %
Specific Humidity	13.6 g/Kg	9.6 g/Kg
Dewpoint	15.6 ˚C	13.0 ˚C
Target Supply Air Temperature	15.6˚C	13˚C
Target Supply Air Humidity	100%	100%
Total Heat	101 kW	63.2 kW

Sensible Heat	58.6 kW	58.6 kW
Latent Heat	42.4 kW	4.7 kW



The latent heat load of the air decreases as moisture content is removed. This lowers the total heat capacity of the air being conditioned. The result is compressor inverters can lower unit output decreasing the electrical input and increasing efficiency.



What are the repercussions of selecting an air conditioner that is undersized for the enthalpy (total energy) of the air within the space?

If the same cycle on conditions were present but the heat load estimation determined that air-flow requirements of the building increased from 4700 L/s to 7500 L/s, yet the same OPA970 was selected the capacity deficit would look like this.

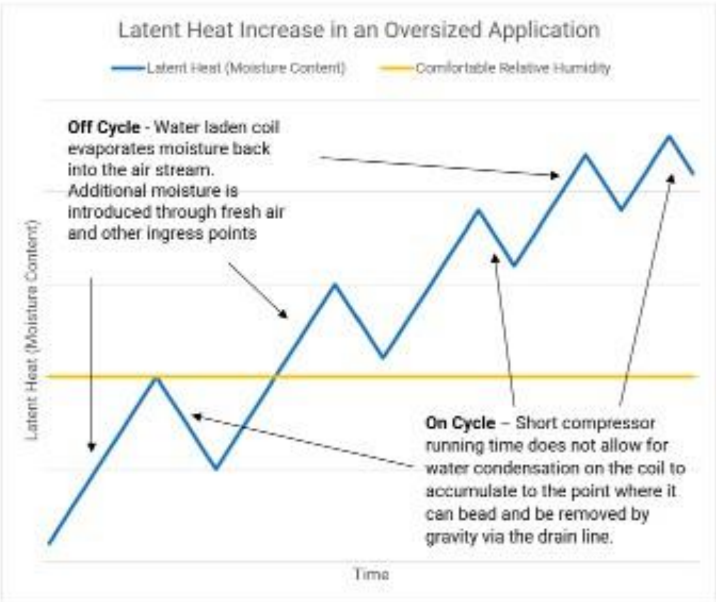
Cycle On Conditions - 25˚C, 68 % Relative Humidity	
Sensible Heat	93.5 kW
Latent Heat	67.6 kW
Total Heat	161.1 kW
OPA970 Maximum Capacity	102 kW
Capacity Deficit	59.1 kW

Due to the deficiency in capacity the OPA970 will struggle to maintain or lower space temperature as well as an inability to effectively reduce the moisture within the air.

What are the effects on latent heat when a system is oversized?

An oversized system will cycle onto cooling mode and the indoor coil will become damp with condensed moisture. The unit will then reach set point temperature and cycle off before the water condensed on the coil has had adequate time to accumulate in droplets and run off the coil and released out of the drain line. In the proceeding off cycle this moisture is evaporated back into the supply air stream along with additional moisture added from the fresh air intake and other fresh air ingress points.

In each off cycle the latent heat (and moisture content) of the conditioned space increases incrementally. Although dry bulb temperature within the space remains within the set point tolerance, the space begins to feel stuffy, and discomfort increases with every off cycle. The latent heat increase is typical of the chart to the right.



Oversizing of an air conditioner can easily be misunderstood as a necessary security measure to deal with a margin of error when designing an installation. In doing so the design risks the increase in discomfort during low load scenarios that will increase the unmanaged latent heat of the space that is to be conditioned. In fact, oversizing an air conditioner may actually lead to the space becoming de-conditioned.

What are the risks of not utilising enthalpy control when enabling economy cycle?

Economy cycle that uses dry bulb temperature control, will open the air stream to induce outside air to perform the task of cooling the space when the outside air-dry bulb temperature is lower than the inside space dry bulb temperature. This is often referred to as free cooling as the space can cooled without operating the compressors. What happens if the dry bulb temperature outside is lower than inside, but the wet bulb temperature is higher? This is not an uncommon situation that can be achieved during conditions of rain, fog and heavily overcast days at particular times of year. If economy is used in this scenario the attempted efficiency of free cooling is actually an inefficient burden of latent heat.

Energy Contained in Outside Air Compared to Inside Air at 4700 L/s		
Measurement	**Inside Air**	**Outside Air**
Dry Bulb	23˚C	19˚C
Wet Bulb	16.2˚C	17.9˚C
Relative Humidity	50%	90%
Specific Humidity	8.8 g/kg	12.4 g/kg
Enthalpy	45.5 kJ/kg	50.6 kJ/kg
Sensible Heat	-23.5 kW	
Latent Heat	53.2 kW	
Total Heat Gain	29.7 kW	

Although the outside cooler air lowers sensible heat requirements, the increased in enthalpy means the introduction of latent heat (53.2kW) outweighs the benefits of the sensible heat (-23.5kW).

The conditioned space is increasing in thermal energy rather than decreasing the need for mechanical operation of the compressors to condition the space. The added increase in latent heat will increase human discomfort due to the increase in moisture content of the air.

It is for the above reasons that economy cycle should not be used if the wet bulb temperature of outside is higher than inside as it will directly increase the amount of heat energy in the room rather than decrease.