

A/C Cooling Load calculation and measurement

When we talk about sizing an air conditioning appliance (tons of cooling, BTU/h or KW), we are specifying the cooling capacity (power) that needs to be moved by the appliance (air conditioner) from the indoor space to outdoors. The actual electrical power used to operate the appliance is considerably less than the cooling power it needs to move.

Fundamentals:

Air is mostly nitrogen (78%) and oxygen (21%), the amount of water moisture in the air is expressed as a relative humidity with typical values of comfort for people between 20% and 65%. When air is cooled or heated, the *heating or cooling of the air is called sensible* heating, and *heating or cooling of water vapor in the air is called latent* heating. The cooling process takes place at the evaporator (cooling coil), which is inside the air handler, as warm moist air moves across the coil the water vapor condenses and is removed from the air, this is commonly seen as water dripping from an air conditioning system.

A large amount of energy is required to heat or cool the water in the air. It is therefore important that we know both temperature and relative humidity of the air to calculate how much heating or cooling is taking place. This is especially important to get a more accurate system efficiency calculation. The amount of heat (sensible and latent) in air is referred to as *enthalpy*.

Calculating Enthalpy:

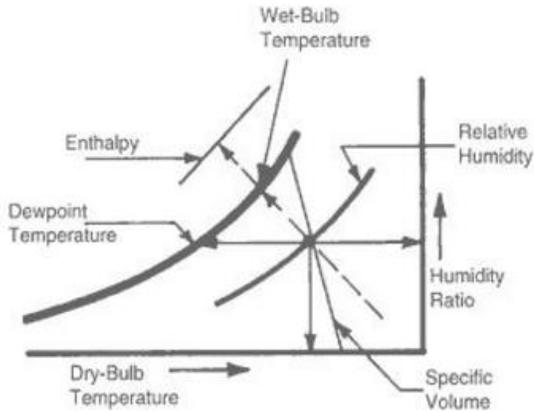
In the US, the enthalpy of air (in AC/R systems) is measured in BTUs per pound of air. Elsewhere it is measured in kilo-Joule per kilogram (kJ/kg) of air. Enthalpy is a close approximation directly related to the wet bulb temperature, you can see the relationship on a psychrometric chart. A baseline graph valid at sea level to 1,000-meter altitude and 50% relative humidity can be used as a close approximation, other elevations and RH would need to be entered.

Example Showing How to Use Psychrometric Chart

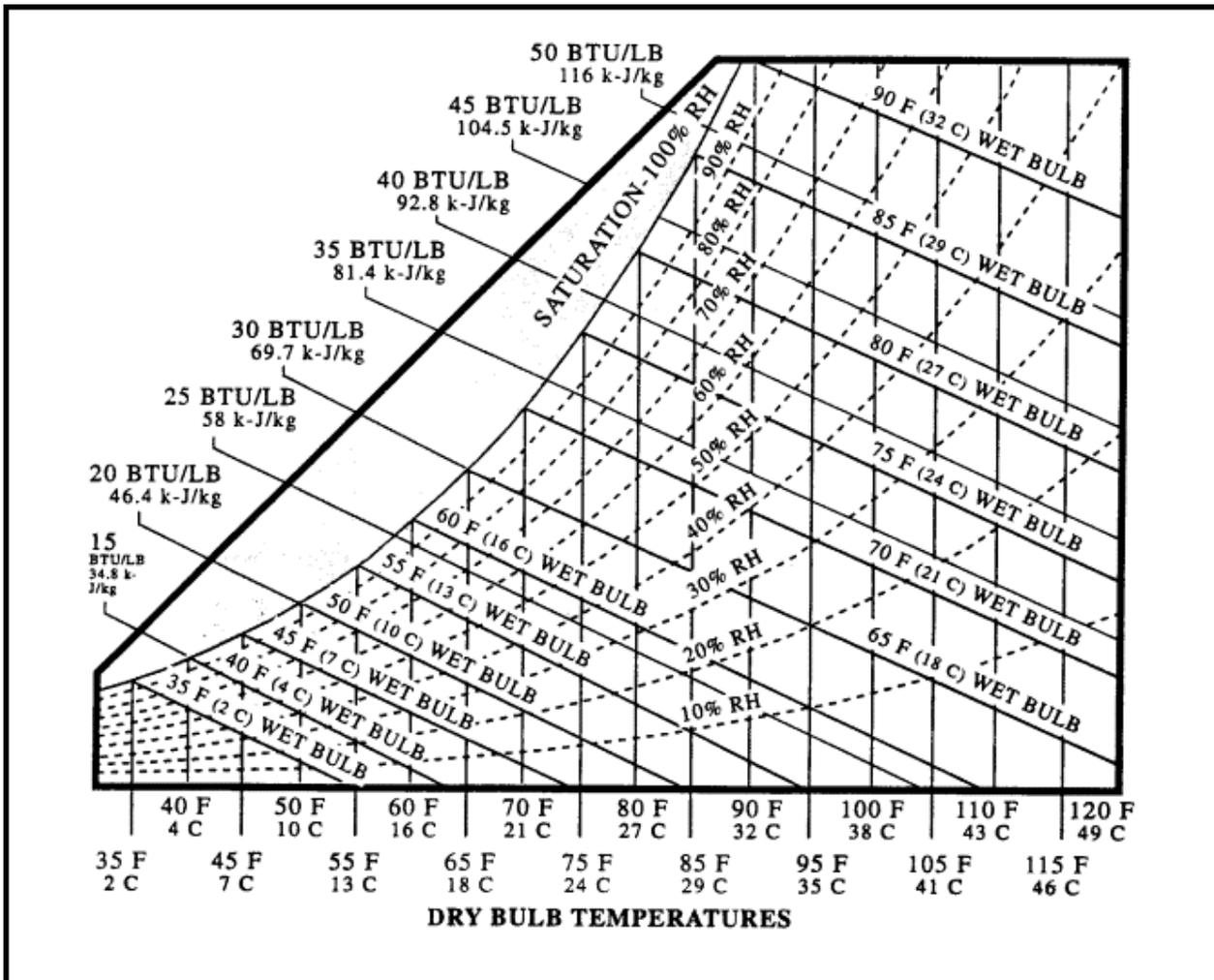
Consider an example of air where the given values of DB and WB temperature are 78 degrees F and 65 degrees F respectively. We will find out various values from these given values of DB and WB temperatures.

- 1) On the psychrometric chart locate value 78°F on the DB temperature scale located at the bottom of the chart.
- 2) Locate WB temperature of 65°F on the saturation curve scale.
- 3) Extend the vertical line (constant DB temperature line) from 78° and the diagonal line (constant WB temperature line) from 65°F and get the point of intersection of the two lines, which indicates the condition of the given air.
- 4) Find out the values of various parameters at this point. The relative humidity line passing through this point indicates RH of 50%. The horizontal line passing through this

point and meeting the saturation curve indicates DP temperature of 58°F. The specific volume of this air is 13.7 ft³/lbs. and the enthalpy of air is 30 Btu/lb.



If any of the two values from DB, WP DP temperature and the related humidity are known, all other values can be easily found from the psychrometric chart below, without having to carry out any calculations.



To see more examples, click on the link below

<http://machineryequipmentonline.com/electric-equipment/psychrometric-chart-fundamentalsthe-abridged-psychrometric-chart/>

If we measure the wet bulb temperature before and after the evaporator in the air handler, we can estimate the heat (BTU) in the AC/R system. The difference (delta) is the heat that is removed by the evaporator and therefore the heat that is removed by the air conditioning system.

The enthalpy value gives us the amount of heat in a pound of air. To know the total heat removed by the evaporator, we need to know the volume (CFM) of air that passes the evaporator and circulates through the system. Typically, volume flow (CFM) is measured or calculated based on duct area size. This measurement of heat removal by the air conditioning system is independent of the ambient temperature outside the building and independent of the actual temperatures of the room itself.

Rough calculation for *sizing an A/C system*:

((House square footage *times* 25, *divided* by 12,000 BTU) – 0.5) = required tons.

So, as an example, a 1,500-square foot home would look something like this:

1. $1,500 \text{ ft}^2 \times 25 = 37,500 \text{ ft}^2$
2. $37,500 \text{ ft}^2 / 12,000 \text{ BTU} = 3.1 \text{ tons}$
3. $3.1 - 0.5 = 2.6 \text{ tons}$, so you'd need between a 2.5 to 3.0 ton sized central air conditioning unit

A very simple approximation using measurement values:

$4.5 \times \text{the measured CFM} \times \text{Delta enthalpy} = \text{BTU output.}$

Example: $(4.5 \times 800 \times 8.6) = 30,960 \text{ BTU}$

$30,960 / 12,000 = 2.58\text{-ton system}$

A more precise *calculation of the actual heat absorption, without knowing the total sq. footage, can be done using the testo smart probes 405i (hotwire anemometer) and two 605i (thermal hygrometers):*

To find the exact amount of heat transfer, we need to measure the air flow rate (CFM) using the testo **405i**, and the Wet Bulb, Dry Bulb, (enthalpy) temperatures using two testo **605i's**.

As an **example**, measurements inside the main ducts of the air handler:

Before the evaporator (return): WB: 65° F, DB: 78° F (*using equation from the chart above or the Testo Smart Probes app's heating/cooling power routine*) Enthalpy = 30 BTU/lb.

After evaporator (supply): WB: 52° F, DB: 65° F, Enthalpy = 21.4 BTU/lb.

System Enthalpy: $30 - 21.4 = 8.6 \text{ BTU/lb.}$

Assuming we have the correct air density value, in this case at sea level, with dry bulb temp of 77° F and 50% RH, air density is 13.75 ft³/lb. (cubic feet per pound). We measure the flow rate at 800 CFM.

Total air per minute = $(800 \text{ ft}^3/\text{min}) / (13.75 \text{ ft}^3/\text{lb.})$
= 58.2 lb./min

Total air per min x 60 = 3,490 lb./hr.

With the heat absorption (system enthalpy) of 8.6 BTU/lb. of air, the system thermal (load) capacity is:

Cooling Load Capacity = 3,490 lb./hr. x 8.6 BTU/lb. = 30,014 BTU/hr.

30,014 BTU/hr. / 12,000 BTU/hr. = 2.50 tons

A **refrigeration ton** is approximately equivalent to **12,000 BTU/h or 3.5 kW/h**. Air-conditioning and refrigeration equipment capacity in the U.S is often specified in "tons" (of refrigeration). Or may be specified as BTU/h.

This means that this system's measured capacity is 2.5-tons

Note: Industry basics, operating conditions:

350 cfm per ton of cooling for *high latent heat* applications (more latent cooling, more dehumidification)

400 cfm per ton of cooling is needed for **normal** (good dehumidification) applications

500 cfm per ton of cooling with *increased sensible* heat applications (less dehumanization)

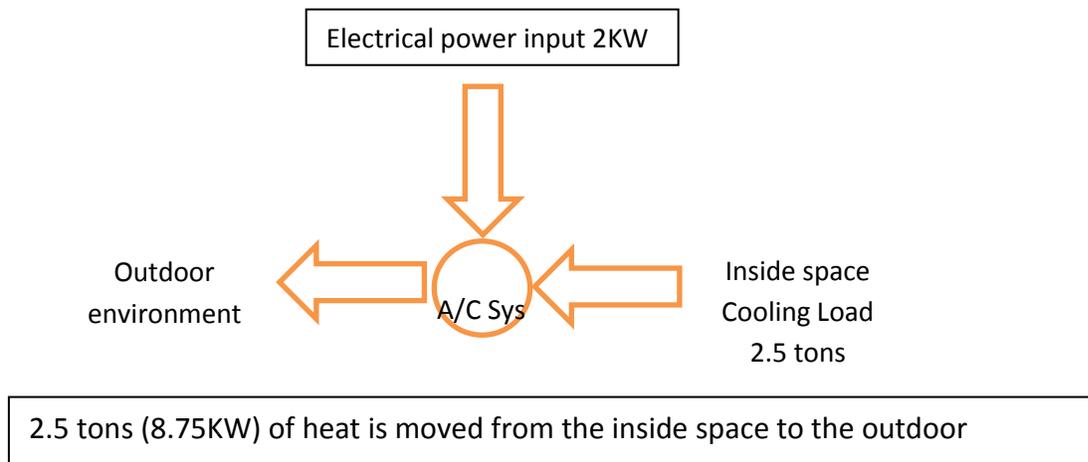
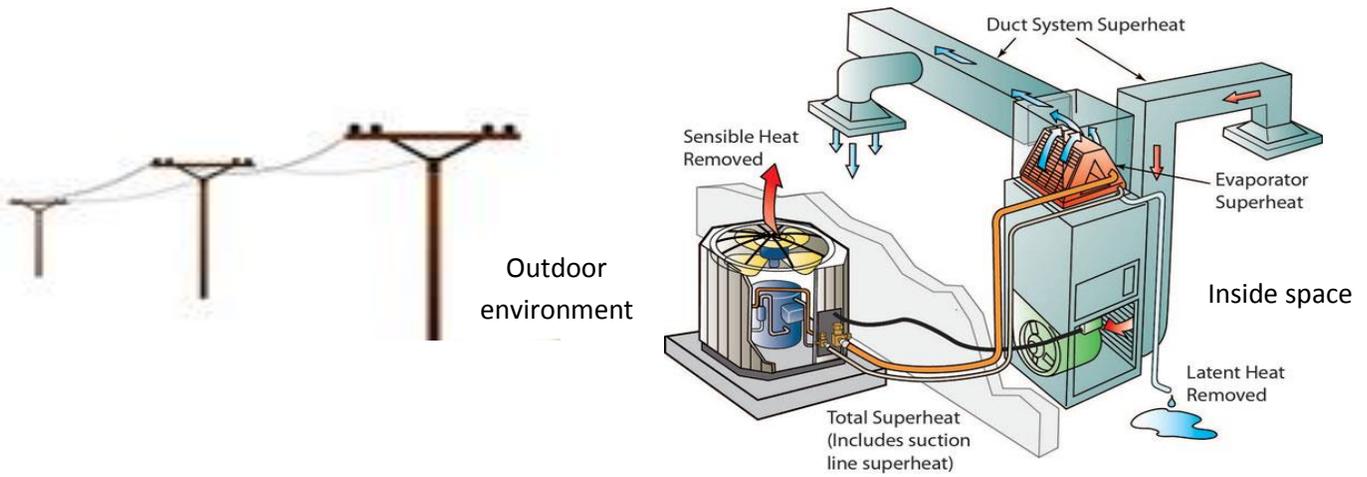
EER

Each air conditioner has an energy efficiency rating that lists **how many BTU's per hour are handled (moved from the inside of the house and transfer it to the outside) for each Watt of power the system draws**. For room air conditioners, this EER rating is calculated under a single set of conditions. Typically, the condition for calculating EER is at an outdoor temperature of 95°F and inside temperature of 80°F with 50% humidity.

SEER

For central air conditioners, SEER (Seasonal Energy Efficiency Ratio) is used. Rather than measuring the energy efficiency of an air conditioner at one operating temperature, **SEER is the calculation of how energy efficient the air conditioner is during the entire cooling season at varying temperatures between 65 to 104°F.**

For this exercise, we will consider a system in the US southeast and use the EER rating. An air conditioner uses electrical power to move (heat) thermal energy from the inside space to the outdoor environment. More thermal energy (heat) is removed from the indoor space than the electricity used to move it.



Consider the figure above and example, the cooling load is calculated to be approx. 2.5 tons. The A/C system selected to cool this space is specified as a 2.5-ton system with 230VAC input and R.L. (Running Load) of 9 amps. Most manufactures size residential A/C systems in 0.5 ton increments so this works out very well at 2.5 tons.

This system's electrical power rating is: $230V \times 9A = 2,070W \sim 2KW$
 Therefore, to move 2.5 tons (8.75KW) of thermal energy (heat) from the inside space to the outdoor environment requires 2KW of electrical power. Since the compressor and fan are outdoor the electrical heat generated by these components is not included in the above cooling load calculation.

Calculating EER, the ratio of the heat (thermal energy) removal to the electrical energy required to move it by the compressor, condenser and evaporator fans.

Using our system calculations above:

$$1 \text{ refrigeration ton} = 12,000\text{BTU} = 3.5\text{KW}$$

$$P = \text{Electrical power rating of the A/C system} = \sim 2\text{KW}$$

$$C = \text{System capacity} = 2.5 \text{ tons} \times 3.5 = 8.57\text{KW}$$

$$EER = C / P \quad 8.75 / 2 = 4.375$$

The electrical power consumed by air conditioning systems vary with environmental changes and load conditions. If the outdoor ambient temperature and/or humidity increases (where the condenser coil is located), the air conditioning unit will work harder to move the heat, this is also true if more appliances are running or more people are occupying the conditioned space. This results in the compressor running for longer periods of time to reach the set temperature. Conversely, a reduction in outdoor ambient temperature and indoor heat loads results in less power usage. We will have more on EER in subsequent papers.

The higher the rating is, the more efficient the air conditioning unit is. Today's A/C systems have EER/SEER ratings from 14 to 18.

The link below sends you to a site with a good explanation and example for calculating A/C electricity cost in your region of the country.

<https://asm-air.com/airconditioning/much-cost-run-air-conditioner/>

R. Mavrides 7/29/17