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Measuring Enthalpy to Calculate Efficiency

Application Note 96-02000-08

1 Summary

This application note describes in detail how you can calculate the gain in efficiency of a direct exchange air conditioning system before and after treatment with SRA. The physics underlying the method are explained.

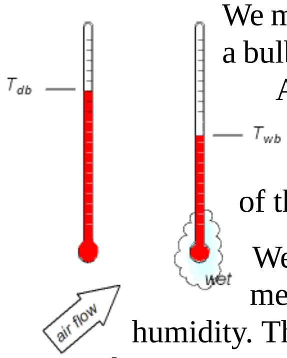
2 Introduction

Air comprises gasses and water moisture. The gasses are 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 we heat or cool air, we are heating or cooling the gasses (which is called sensible heat) and we are heating or cooling the water vapor (which is called latent heat). The cooling process often removes water vapor from the air. This is commonly seen as water running 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 to calculate how much heating or cooling is taking place. It is especially important if we want to show a change or improvement to a heating or cooling system.

3 What to Measure



We measure the temperature of the air with a thermometer. Traditional thermometers have a bulb that contains a liquid that expands, and a tube indicating the temperature on a scale. As the liquid expands, it rises up the scale. In the HVAC business, we use a thermocouple and electronic meter because these are faster and more rugged. Whichever method is used, this measurement is called the dry bulb temperature because the end of the thermometer that is making the measurement has no moisture on it.

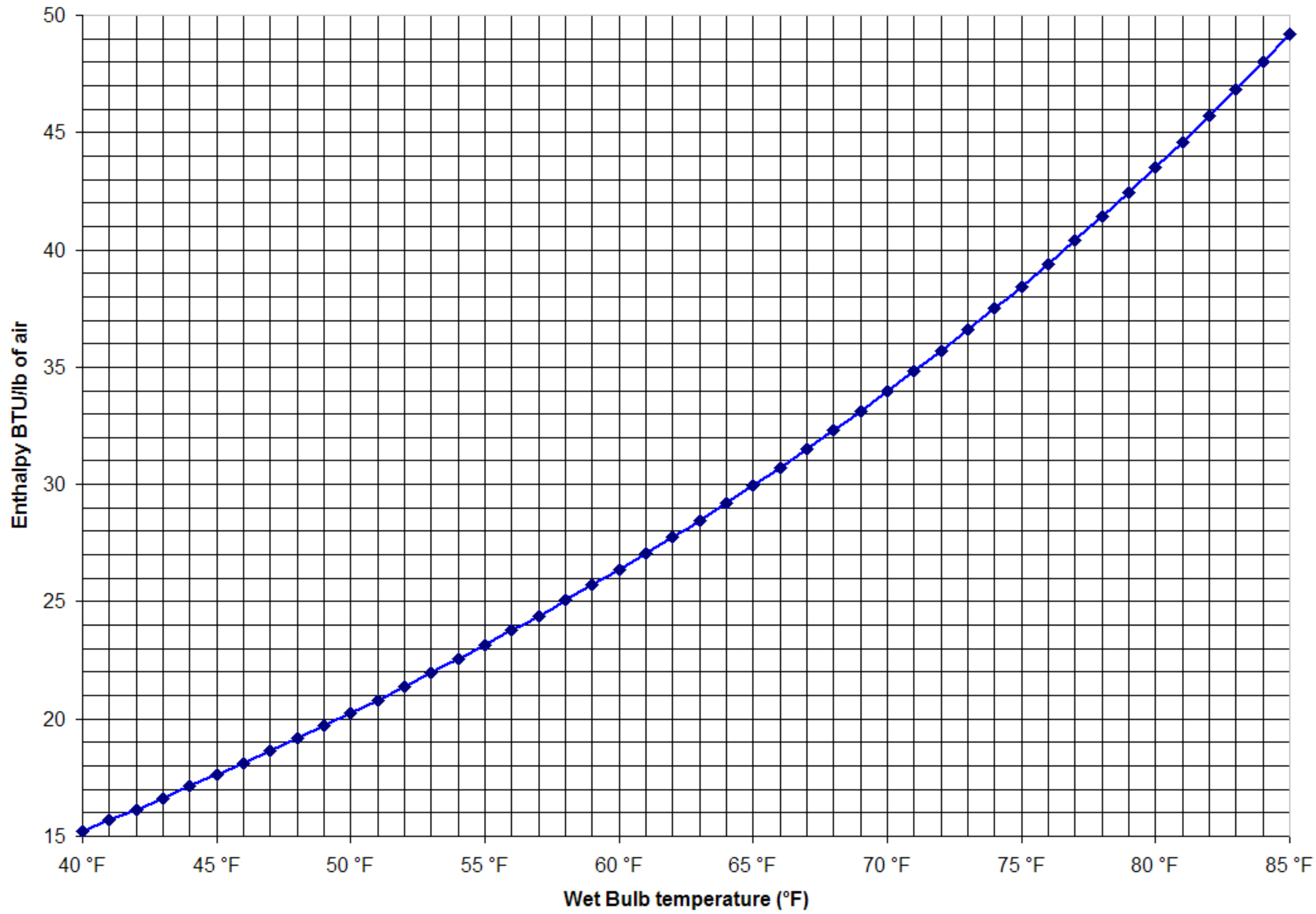
We can measure the relative humidity in a variety of ways, but the simplest way is to measure the wet bulb temperature and use a chart or calculator to find the relative humidity. The wet bulb temperature is measured by having the bulb of the thermometer moist. The moisture evaporates, lowering the temperature recorded by the thermometer. Less moisture in the air will result in a faster rate of evaporation and therefore a colder reading.

Electronic methods of measuring the relative humidity are faster but less accurate. Typically these devices have ±3% accuracy. They calculate the wet bulb temperature after measuring the dry bulb temperature and relative humidity.

4 Calculating Enthalpy

The amount of heat in air is referred to as enthalpy.[1] In the US, the enthalpy of air (in the HVAC business) is measured in BTUs per pound of air. Elsewhere it is measured in kilo-Joule per kilogram (kJ/kg) of air.

The enthalpy is to a close approximation directly related to the wet bulb temperature. You can see the relationship on a psychrometric chart.[2] Alternatively, you can use the graph below. This graph is valid at sea level and 50% relative humidity and is a close approximation at other altitudes and other levels of relative humidity.



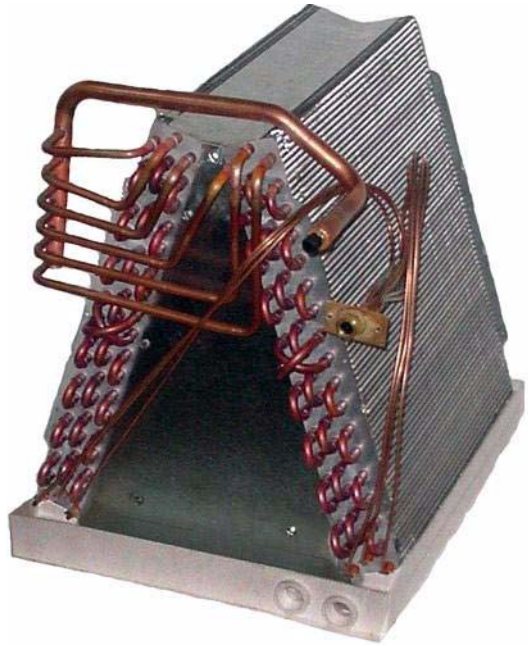
If we measure the wet bulb temperature before and after the evaporator of an air conditioning system, we can estimate the heat in the air before and after the evaporator. The difference is the heat that is removed by the evaporator and therefore the heat that is removed by the air conditioning system.

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 rate of flow of air that passes the evaporator. However, for our purposes,

1. Although this is not a strict definition of enthalpy, it is commonly used in the HVAC industry.
2. For an introduction to the psychrometric chart, see Power Knot's application note on this topic.

this actual number is not required. This is addressed in section 7.

This measurement of heat removal by the air conditioning system is independent of the ambient temperature outside the building and also independent of the actual temperatures of the room itself.



Typical A-frame evaporator. We would measure the wet bulb temperatures either side of the evaporator (in the supply and return air ducts).

5 Calculating Gains in Efficiency

If we calculate the heat removed by the air conditioning system prior to treatment with SRA and then we perform the same calculation after treatment with SRA, we can quantify the change of the system's efficiency. As noted above, this calculation can be made even if the ambient conditions are different when the first measurement is made and the second measurement is made.

Also, as stated above, we do not measure the actual rate of flow of the air. We assume that when we make the first set of measurements (before treatment with SRA) and then we make the second set of measurements (after treatment with SRA), that the rate of flow of air (cfm) is unchanged. This is a valid assumption under most circumstances. However, if the humidity of the air has altered significantly, the flow rate will be higher when the air has more water. Therefore, the two measurements should be made when the relative humidity is similar.

6 Example

Suppose we measure the wet bulb temperatures before and after the evaporator, before and after treatment with SRA. The numbers are listed in the table:[1]

	Before treatment with SRA	After treatment with SRA
Wet bulb temperature before evaporator	65°F	64°F
Wet bulb temperature after evaporator	52°F	48°F

1. The calculation of enthalpy should be made using spot readings and not an average of many readings. The enthalpy can be calculated at a specific time based on the wet (and dry) bulb temperatures. It is possible to average those temperatures separately over a period of time to make a calculation, but greater accuracy comes from a spot reading. If required, then for each set of temperature points, it is possible to calculate the enthalpy many times. Those calculations can then be averaged.

Looking at the psychrometric chart or the enthalpy graph above, we have the following complete data:

	Before treatment with SRA			After treatment with SRA		
	Wet bulb	**Dry bulb**	**Enthalpy**	**Wet bulb**	**Dry bulb**	**Enthalpy**
Before evaporator	65°F	78°F	30.0 BTU/lb	64°F	77°F	29.2 BTU/lb
After evaporator	52°F	65°F	21.4 BTU/lb	48°F	60°F	19.2 BTU/lb
			8.6 BTU/lb			**10.0 BTU/lb**

By treating this air conditioning system with SRA, we have improved the heat absorption before treatment (h_B)from 8.6 BTU/lb of air to 10.0 BTU/lb of air after treatment (h_A). If the flow of air remains constant before and after treatment (and that is a very reasonable assumption), the gain in efficiency is calculated as:

$$\text{gain in efficiency} = \frac{h_A - h_B}{h_B} = \frac{10.0 - 8.6}{8.6} = 16\% \tag{EQ 1}$$

7 Calculation of Actual Heat Absorption

If we wanted to know the exact amount of heat change, we would need to measure the rate of flow of the air. This would provide accurate values for the heat, calculated as follows. If we do not want to measure the flow rate, we can estimate that for a standard air conditioning system, the system is designed to move 400 cfm (cubic feet per minute) per ton of air conditioning over the evaporator.

We would again refer to the psychrometric chart to identify the density of the air. In the example above, for a dry bulb temperature of 77°F and 50% relative humidity, air has a volume of 13.75 cubic foot per pound of air. If we estimate or measure the flow rate to be 800 cfm, then:

$$\text{total air per minute} = \frac{800 \text{ cubic foot/minute}}{13.75 \text{ cubic foot/lb}} = 58.2 \text{ lb of air/minute} \tag{EQ 2}$$

$$58.2 \text{ lb of air/minute} = 3490 \text{ lb of air/hour} \tag{EQ 3}$$

If the heat absorption is 8.6 BTU/lb of air, then the heat capacity of the system before treatment with SRA is:

$$\text{heat absorbtion} = 3490 \text{ lb/h} \times 8.6 \text{ BTU/lb} = 30014 \text{ BTU/h} \tag{EQ 4}$$

This means that the system is approximately a 2½ ton system.[1] If we substitute equation 4 with the enthalpy value after treatment of 10.0 BTU/lb then the heat absorption is 34,900 BTU/h or approximately a 3 ton system. As stated above the actual flow rate, if constant, is immaterial to calculating the gain in efficiency.

1. For the meaning of a ton of air conditioning, please refer to Power Knot's article on this topic.

8 Comparison with Dry Bulb Measurements

If we measured the difference in dry bulb temperatures before and after treatment with SRA, we cannot easily deduce the gain in efficiency. In the example above, the delta-T before was 78°F–65°F=13°F. The delta-T after was 77°F–60°F=17°F. The delta-delta-T is 4°F.

Some have advocated that for each change in delta-T (delta-delta-T) of 1°F, there is a change in efficiency of 7%. If that was the case, we would conclude that the gain in efficiency is 28% and not the 16% that actually happened in our example in section 6.

9 Accounting for Power Consumption

The power consumed by an air conditioning unit changes with the work being done by the air conditioning unit. If the outdoor ambient temperature increases (where the condenser coil is located), the air conditioning unit has to work harder to expel the heat. This results in greater power used by the compressor. Conversely, a reduction in ambient temperature results in less power being used.

If the heat inside the space changes, the air conditioning system has to remove more or less heat from the space. If there is greater heat internally (because of the increase in people, or the use of cookers, computers, or copying machines), then the air conditioning system will work harder.

Measuring the power consumption when there is a change of ambient or load conditions will lead to results that are not easy to predict. For this reason, we recommend that when using the method in this application note to measure a gain in efficiency, that you make the measurements before and after treatment with SRA under similar ambient and load conditions. In this case, it is not usually necessary to measure the power consumption of the compressor. However, it is likely that power consumption will decrease (because the compressor is working less) and therefore, if possible, you should record power consumption.

Whether you measure power or not, ensure that the ambient temperature before and after are similar (within ±3°F), and that the load conditions inside the building are similar. If there is much variation, we suggest you return another day when the conditions are comparable to make the second set of readings.

10 Conclusion

This application note has shown that by measuring wet bulb temperatures before and after the evaporator we can deduce the heat absorption in the evaporator. If we make these measurements before and after treatment with SRA we can deduce the gain in efficiency. This is a reliable method that is valid regardless of changes to the outside ambient conditions and holds true over a range of humidity values. The measurement of wet bulb is simple and accurate.

This is an example of the benefits of the Synthetic Refrigerant Additive (SRA) supplied and supported by Power Knot. For more information on the SRA, please contact your local sales representative or send an e-mail to Power Knot at powerknot@powerknot.com.

Power Knot provides safe and economically sound solutions for businesses seeking to reduce energy costs and their carbon footprint through maximizing the efficiency of their cooling systems. Power Knot works with commercial, industrial, and military customers globally to reduce cooling system energy usage, improve energy efficiency, provide colder air, reduce maintenance expenses, and increase the lifetime of the systems. Their technologies are proven and available today, have been in reliable use for many years, and offer a payback period typically of less than two years. For more information, access www.powerknot.com. Copyright © 2010, 2011, Power Knot LLC. All rights reserved.

11 Appendix: Step by Step Procedure

Follow these steps to perform the analysis described in the preceding pages. Put the readings of temperature and calculation of enthalpy into the table on the next page.

11.1 Equipment

11.1.1 Ensure you have the required equipment:

- digital thermocouple thermometer with two inputs
- paper towel, paper tissue, or cotton ball
- rubber bands
- clean water (ideally distilled, but use drinking water if unavailable)
- psychrometric chart or enthalpy chart

11.2 Measure the temperatures

11.2.1 Measure the outdoor ambient temperature (as a dry bulb measurement).

11.2.2 Wrap a small amount of the tissue on each end of the thermocouples and hold it in place with a rubber band. Wet the tissue so that it is moist but not dripping.

11.2.3 Place the thermocouples before and after the evaporator. If you cannot access the unit itself, place them at a supply vent and a return vent of the space being cooled.

11.2.4 With the a/c unit operating, measure and record the wet bulb temperatures.

11.2.5 For greater accuracy measure the dry bulb temperatures at the same spot by removing the wet tissue and drying the thermocouples.

11.3 Determine the enthalpy

11.3.1 From the psychrometric chart or the enthalpy chart, determine the enthalpy that corresponds with the temperatures.

11.3.2 Subtract the two values to obtain the heat absorption by the a/c system.

11.4 Treat the system

11.4.1 Treat the a/c system with SRA using Power Knot's procedure.

11.4.2 Keep the a/c system running and wait approximately 30 minutes for each ton of air conditioning. For example, for a three ton system, wait 1½ hours.

11.5 Determine the enthalpy after treatment

11.5.1 Repeat the steps in section 11.2 and section 11.3 to calculate the heat absorption by the a/c system after treatment.

11.5.2 Calculate the gain in efficiency as outlined in equation 1.

12 Appendix: Chart to Record and Calculate Efficiency

12.1 Where and how

Customer name	
Location	
Instrument used	

12.2 Measurements before treatment with SRA

Date and time of measurements		Ambient temperature	

	Wet bulb temperature	Optional		Enthalpy from chart
		Dry bulb temperature	Relative humidity	
Before evaporator (return air)				
After evaporator (supply air)				
			h_B =	

12.3 Measurements after treatment with SRA

Date and time of measurements		Ambient temperature	

	Wet bulb temperature	Optional		Enthalpy from chart
		Dry bulb temperature	Relative humidity	
Before evaporator (return air)				
After evaporator (supply air)				
			h_A =	

12.4 Calculation of gain in efficiency

Gain in efficiency = $\frac{h_A - h_B}{h_B} = \frac{\quad - \quad}{\qquad} =$