

Fishing Midst the Morning Dew: Applying the Psychrometric Chart

by

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Christian and Tatiana are about to enjoy a summer day with a picnic by the lake. As they arrive at the shoreline in the early morn, they notice a phenomenon related to moisture in the air that puzzles Christian, but Tatiana, who has recently taken a food engineering course, is excited to explain it to her brother.

Christian: Nice weather for fishing. I'm sure we'll catch something, and then maybe dad can grill it for us.

Tatiana: Yes, it's perfect weather for a picnic. This was a great idea, Christian. I packed tuna salad, crackers, and lemonade, your favorites. This will be great.

Christian: Where should we sit? This grass looks all wet. Funny, since we're far away from the lake. I don't think water can splash all the way over here.

Tatiana: I think this is actually dew. It's still pretty early in the morning, it will dry up soon.

Christian: Dew? Oh, yeah, I guess it is. Why does it matter that it's early in the morning?

Tatiana: Well, dew is the condensation that occurs because of cooler temperatures at night. The water holding capacity of air is reduced when the air is cooled. If the air is saturated with water as it cools it will discharge water, causing precipitation. That point is called the *dew point*, the temperature at which precipitation starts to occur. There's a whole science to this called *psychrometry*.

Christian: Psychrometry? That's kind of cool. Is the dew point always at the same temperature?

Tatiana: Well, the dew point temperature depends on the relative humidity and temperature of the air. Let me see if I have pen and paper and I'll draw you something to explain it better. Look at this chart; it's called a psychrometric chart, and it relates different properties of air-water mixtures at a certain pressure. Actually, it can relate seven different properties! You see, air is actually a mixture of air and water. The amount of water in the air depends on the temperature and enthalpy of the air; the higher the temperature and the higher the enthalpy, the higher the amount of water in the air. Do you know what enthalpy is?

Christian: Yes! I actually just learned about this in science class: enthalpy is the amount of energy a certain amount of mass has.

Tatiana: Exactly! Look here (Figure 1); the horizontal lines are for showing the amount of water the air has. The amount of water, in units of pounds of water per pound of dry air (lb water / lb of dry air), increases from bottom to top. The vertical

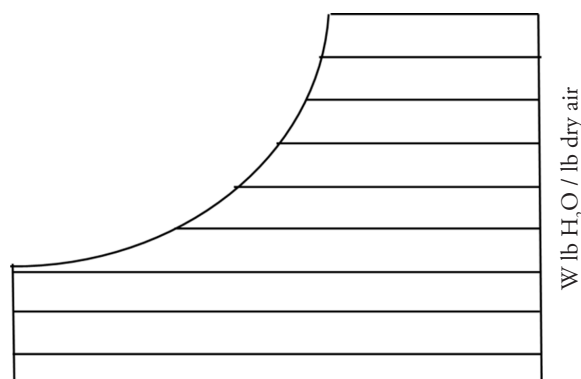


Figure 1. Horizontal lines in the psychrometric chart indicate water content.

lines (Figure 2) are the dry bulb temperature (DBT) of the air, which is the normal temperature we measure in the air. This chart uses Fahrenheit and increases from left to right.

Christian: But why do we call it dry bulb? That sounds weird; it reminds me of a dead flower, dry *bulb*.

Tatiana: The dry bulb temperature is just the temperature of the air registered by a thermometer not affected by the amount of moisture present in the air.

Christian: On our way over here we saw a bank that had one of those signs that display temperature; it read 87 °F. Would that be the dry bulb temperature?

Tatiana: Exactly! Did it have any other information?

Christian: Yeah, it had the relative humidity, 65%. What does that mean?

Tatiana: Relative humidity (RH) relates the amount of water in the air to the maximum amount of water it can hold. This is a mathematical relation between the partial pressure of water vapor and the pressure of the air. In the psychrometric chart (Figure 3) these curved lines represent the RH, see? What was the number you said you saw on the display?

Christian: 65%.

Tatiana: Well, we can actually find this air-water mixture in our chart. The point where the 65% RH curve and the DBT line of 87 °F meet is exactly our air-water mixture, so our air-water mixture contains 0.018 lb H₂O/lb dry air and its dew point is 73.6 °F (Figure 4).

Christian: So let me see if I understand this correctly. Air is actually a mixture of dry air and water. The amount of water in the air depends on its temperature. The higher the temperature, the higher the amount of water it can retain. The relation between the amount of water it retains in relation to the capacity of water retention is called relative humidity. When the air cools at night it might reach a temperature where it can no longer retain the same amount of water, causing water to condense. Since we saw dew this morning we can say the air must have cooled below 73.6 °F last night.

Tatiana: Exactly! Air retains water depending on the enthalpy it possesses. The specific enthalpy of air can also be

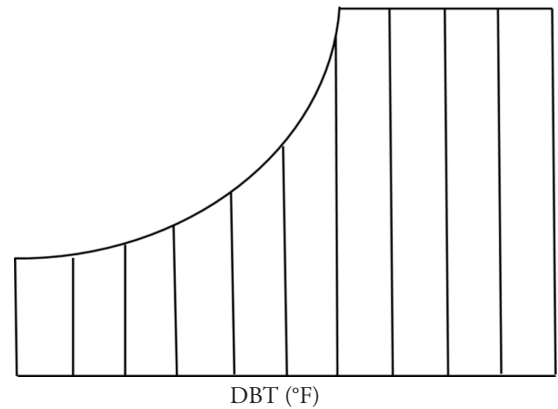


Figure 2. Vertical lines indicate dry-bulb temperature.

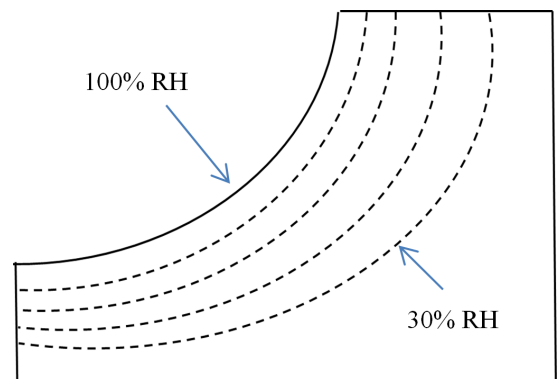


Figure 3. Curved lines in the psychrometric chart represent relative humidity.

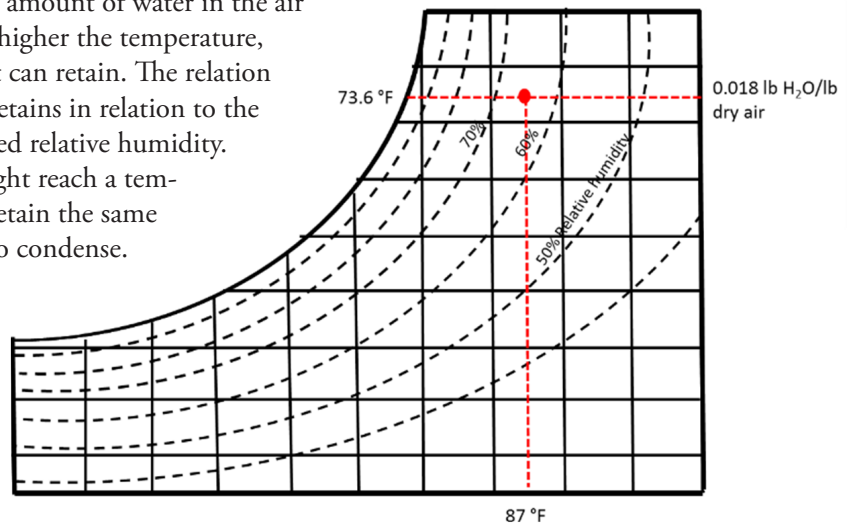


Figure 4. Example of a point in the psychrometric chart representing an air-water mixture.

read from the psychrometric chart. Look here; these diagonal lines represent the constant enthalpy that the air-water mixture contains (Figure 5).

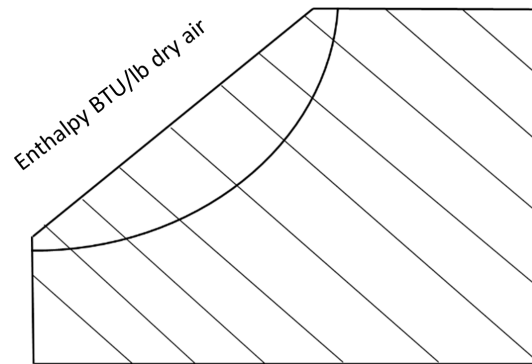


Figure 5. Diagonal lines in the psychrometric chart represent specific enthalpy.

Tatiana: In our example the air has approximately 40.8 BTU/lb dry air. So look here again (Figure 6).

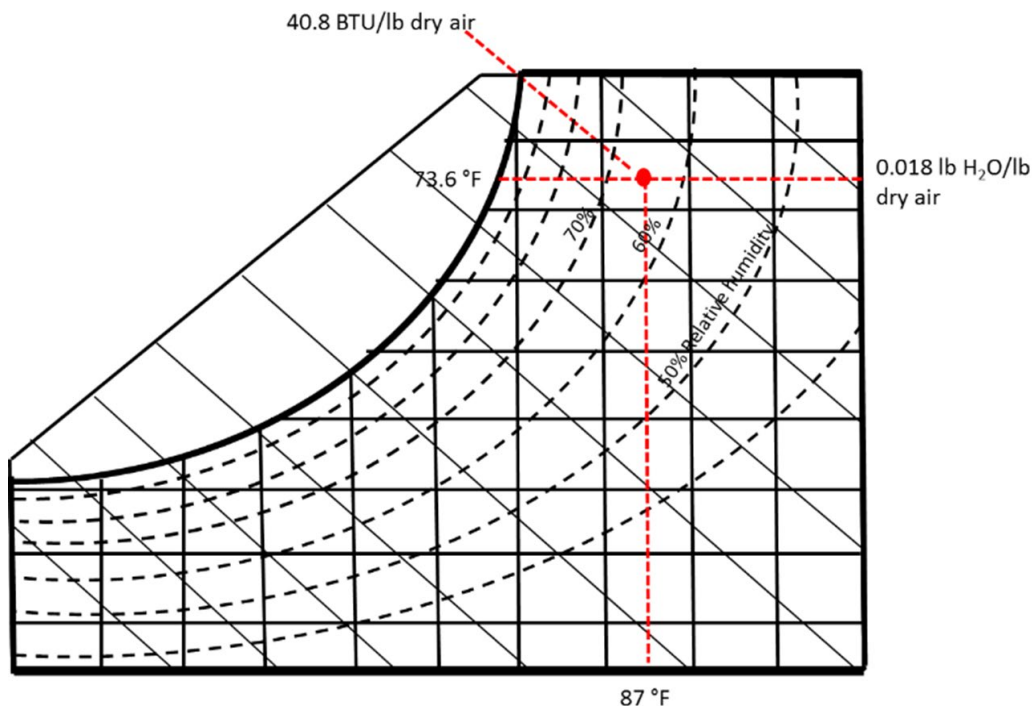


Figure 6. Enthalpy in air-water mixture studied.

Christian: Yes, but you mentioned *seven* properties. Up until now you’ve explained just five: DBT, humidity content, relative humidity, enthalpy and dew point temperature. What are the other two?

Tatiana: I see you’ve been paying attention! There are two other properties that are shown in the psychrometric chart. The first is the specific volume, the space a pound of dry air would take up (in units of ft^3/lb dry air). These lines are diagonal in the chart (Figure 7, next page). The second property is the *wet bulb temperature* (WBT), which is the temperature at which the water evaporates in the air, the cooling effect of evaporation. WBT is represented with diagonal lines in the chart, the same lines as for enthalpy, but with a different scale (units of $^{\circ}\text{F}$). This temperature is usually lower than the DBT; this difference is called the *depression*. For example, reading the chart we can see our air has a WBT of 77.2°C , which means that

the water that evaporates at that temperature and the depression would be $87 - 77.2 = 9.8$ °F. When the air is saturated, the RH is 100% and the DBT is the same as the WBT, making the depression 0.

Christian: Wow! I never thought that the air and the humidity it contains behaved in such an exact way. Well, I need a break; all this water talk has made me thirsty. Did we bring something to drink?

Tatiana: Would you like some lemonade? It's packed with ice; it must be really cold.

Christian: Yes, please. Thanks! Hey look, Tatiana, my glass is all wet. I guess my lemonade is at a lower temperature than the dew point temperature, so the water in the air must be condensing when it touches the glass.

Tatiana: Hey, you're a fast learner, just like your big sister. Now, how about we start fishing?

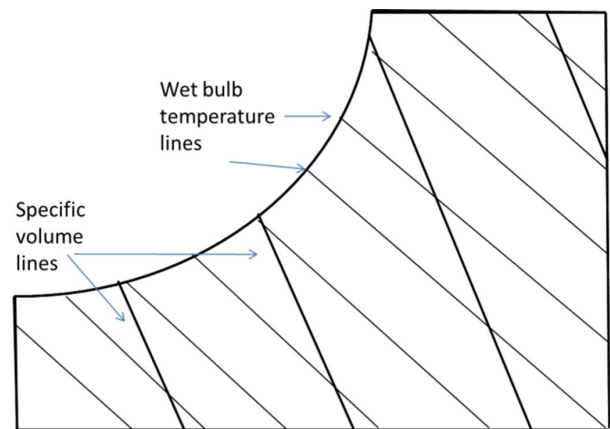


Figure 7. Specific volume and wet bulb temperature lines.



Questions

- Define the following terms.
 - Dew point:*
 - Depression:*
 - Humidity:*
 - Specific volume:*
 - Specific enthalpy:*
- How much water can air hold as water vapor?
- Compare dry bulb temperature with wet bulb temperature.
- Relate dew point with other condensation phenomena you might have experienced.
- Using the psychrometric chart, find the % relative humidity and the dew point of a volume of air that has a DBT of 100 °F and has a WBT of 65 °F.
- Using the psychrometric chart, find the DBT and specific volume of a volume of air that has 20% RH and 22 °C WBT.
- Using the psychrometric chart, what is the DBT, WBT, % relative humidity and dew point of humid air that has a specific volume of 0.85 m³/kg dry air and a moisture content of 5 g/kg dry air?
- Construct a concept map presenting the relationship between psychrometry and different unit operations used in your field of study.

Psychrometric Chart

SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975

Credit: ArthurOgawa, cc BY-SA 3.0
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File:PsychrometricChart.SeaLevel.SI.svg](https://commons.wikimedia.org/wiki/File:PsychrometricChart.SeaLevel.SI.svg)>

