Basic Thermodynamics For Refrigeration and Air Conditioning - Part 2

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This simple system shows the application of the Second Law. The compressor Ⓐ adds energy to the refrigerant, and it becomes hot, just the way a hand operated tire pump does. Since the compressed refrigerant is hotter than the air blowing across the condenser Ⓑ, the heat will flow to the cooler air. This is a transfer of heat energy out of the refrigerant.

The refrigerant vapor is cooled to the point of condensation to a liquid because its pressure remains high Ⓒ but its temperature is reduced. The liquid refrigerant is expanded into the evaporator Ⓓ at a low pressure which allows it to boil at a low temperature. The temperature of the evaporator is designed to be lower than the air it is cooling, so heat from the air will flow into the cold refrigerant. The cold vapor returns to the compressor to start the cycle over. Note that in all cases, the heat flow is from the hotter to the cooler, just as the Second Law requires. For further discussion, please refer to KE2 Therm W.9.3 Basic Superheat and Saturation.

Sensible vs. Latent Heat

It is obvious that adding heat to a substance will raise its temperature and subtracting heat will lower its temperature. Less obvious is that the amount of heat needed to do so is relatively small. For water, it is one BTU per pound for each degree F change in the water temperature. Copper, a good conductor, only requires one twelfth of the heat to change one degree, in other words, the same amount of heat will change the temperature of a pound* of copper by 12°F. Since the copper or water, in these examples, did not change state, the heat required to change the temperature is called sensible heat.

*For the purposes of this discussion, and to simplify the text, temperature will be expressed in degrees Fahrenheit (°F), and weight as pounds (lbs). For a true measure of heat quantities, mass is used for calculation rather than weight.

Part 1 explained that the phase change of a substance meant that it changed state, for example, from solid to a liquid, or liquid to a vapor. Of course, this process is reversible, steam can condense into water and water can freeze into ice. The key to phase change is heat. And it always requires a much greater amount of heat to cause a phase change. The heat required is called latent heat.

Figure 1 Basic System

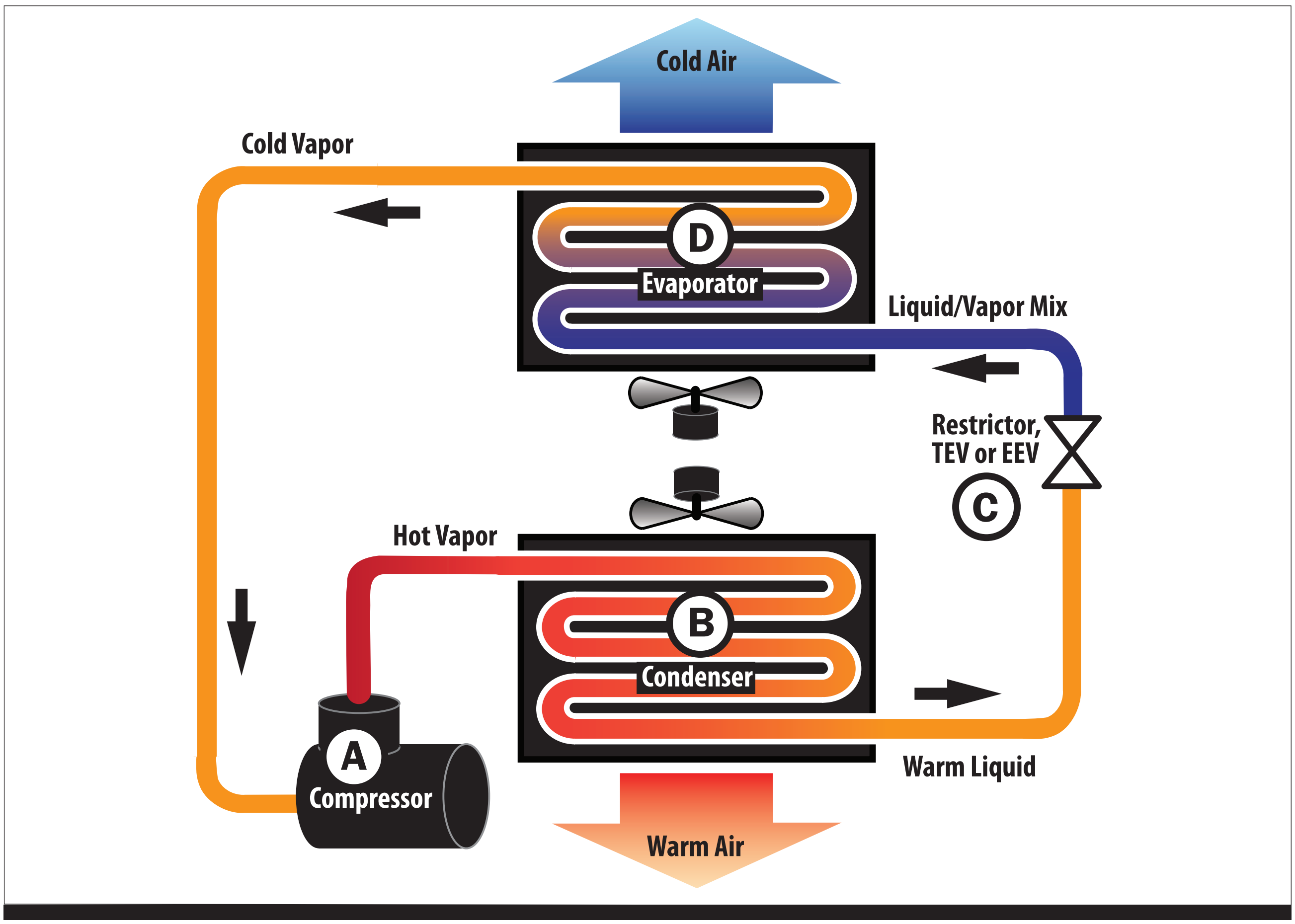

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Table 1 shows the comparison between water and copper.

Table 1 - Latent Heat Comparison - Water vs. Copper

	Water		Copper	
	BTU/pound	kJ/kg	BTU/pound	kJ/kg
Sensible heat	1 /°F (liquid)	4.19/K	.09/°F (solid)	.39/K
Latent heat of melting, fusion	144	334	57	134
Latent heat of vaporization/condensation	971	2260	2179	5069
Melting/freezing temperature	32°F	0°C	1981°F	1083°C
Boiling/condensing temperature	212°F	100°C	4703°F	2595°C

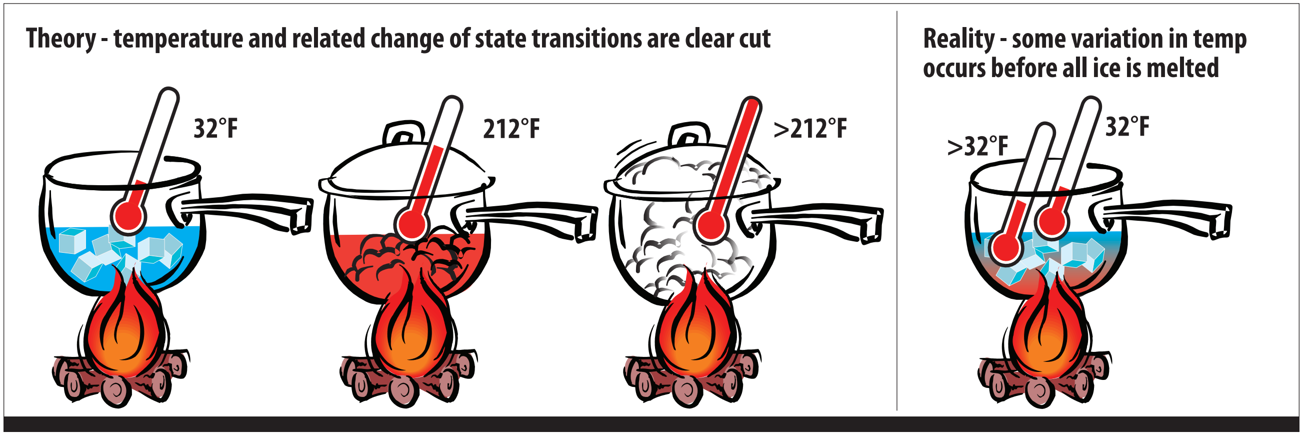
Note that the amount of heat to melt copper is less than that needed to melt ice, but the temperature is very different.

In theory, ice will melt into water with added heat, but the temperature of the water will not rise above 32˚F until all the ice is melted. Once the ice has melted, continuing to add heat will raise the temperature of the water to boiling, 212˚F. At which point the water begins turning to steam. Once all the water has turned to steam, adding more heat will continue raising the temperature of the steam.

In the real world, the transitions are never so clear cut.

The water in the glass can begin to warm even when ice is still present, but the amount of heat needed to melt the ice is still 144 btu/lb.

Figure 2 - Change of State - Theory vs. Reality



Questions

1) **What is the First Law of Thermodynamics?**
2) **Define BTU.**
3) **What are the three common states of matter?**
4) **What is the difference between Sensible and Latent heat?**
5) **What does SI refer to, and what temperature scales are used in it?**
6) **If a cold object and a hot object are in contact with each other, can the cold object transfer even more of its heat to the hot object making it hotter?**

Going Further

This presentation is meant as an easy to understand overview. It is accurate for basic understanding but leaves out the math and equations.

The slides concerning the stack of blocks is accurate in common experience but not at the sub-atomic or quantum level. In the realm of the very small entropy and energy can flow the "wrong" way.

Sources

Modern Refrigeration and Air Conditioning
Althouse, Turnquist and Bracciano - Goodheart Wilcox Publishing, Tinley Park, IL
Provides easy to use formulas and illustrations of thermodynamics and HVACR systems. Available from Amazon.com and other technical booksellers.

ASHRAE Fundamentals Handbook
American Society of Heating, Refrigeration and Air Conditioning Engineers, 1791 Tullie Circle, N.E, Atlanta GA 30329 http://www.ashrae.org
Provides in depth engineering data, with complete formulas, for HVACR applications.

Web searches for "thermodynamics" and "entropy" will yield thousands of sources for more information, although few are focused on HVAC applications.

Answer to the puzzle in Part 1 - "What is the temperature of outer space?" A trick question because answers can vary with frames of reference. Outer space is a near vacuum and therefore has no temperature at all, however, there are energetic sub-atomic particles that have "temperatures" in the millions of degrees. The temperature of the background radiation is about 3 degrees above absolute zero. Remember that heat always moves from a higher temperature to a colder temperature and can move by radiation. Surfaces facing the sun on Mercury can reach 800˚F while the surface away from the sun radiates almost all its energy away and can reach temperatures of -334˚F.

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