Temperatures, Pressures, & Refrigerants

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This column is the second in a series exploring refrigeration and heat pump concepts without using jargon.

Most stuff we come across on a daily basis has a boiling point and a freezing point. For example, water at sea level will boil at 212°F (100°C) and freeze at 32°F (0°C). The subtle disclaimer "at sea level" is important because the boiling temperature for all stuff is dependent on pressure, so it varies at different conditions.

This is how pressure cookers are able to cook food much faster than in an open saucepan. The water inside the

Edmund Hillary wonders if he will ever have a good cup of tea again.

pressure cooker is boiling at a higher temperature and so less time is required for cooking. Conversely, it also explains why it is difficult to make a decent cup of tea up a high mountain; the water boils, but it is not at a high enough temperature to properly infuse the tea leaves. To put some numbers against this, if the pressure in the cooker is double the normal atmospheric pressure then the water will boil at about 250°F (121°C). At the top of Mount Everest (29,029 ft [8848 m]), water boils at about 160°F (71°C). This is definitely not hot enough to make tea.

The substances that are used as working fluids inside refrigerators and heat pumps all have a fixed relationship between their pressure and their boiling point. Some of them, such as R-11 operate at very low pressures and others, for example, carbon dioxide, run at much higher pressures, for the same boiling point. For most other substances used as refrigerants, the pressure at a given temperature is somewhere between these two extremes.

In last month's column, the temperature lift for the refrigerator circuit was described. The way in which work can be done on the heat taken out of the stuff in

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a fridge is by pressurizing the working fluid so that its boiling point rises. In this way, the same working fluid can be boiled at low pressure (when it is colder than the stuff in the fridge) and reliquefied at high pressure (when it is warmer than the outside of the refrigerator). While the working fluid is boiling or reliquefying it does not change temperature or pressure but the amount of liquid in the total fluid content changes. If liquid is at its boiling point, for example just at the beginning of the boiling process or just at the end of the liquefying process, then this is called saturated liquid. At the opposite end of these processes, when the liquid is all turned to gas, or the gas is just on the point of liquefying, this is called saturated vapor. Calling it vapor instead of gas is just another example of refrigeration people wanting to sound smarter than they are. Maybe they don't like the thought of admitting that they have saturated gas.

For most situations within the refrigeration system, to know the condition of the working fluid, it is sufficient to know the temperature and the pressure. If these are known, then everything else about the fluid can be calculated, or looked up in tables, or most likely these days read off a computer screen or an app. However, when the working fluid is boiling or liquefying, the boiling point and pressure are locked together by their fixed relationship. Knowing the temperature and pressure of the fluid is not enough to determine the other properties. This is a bit like when you drive your car into a tunnel and the satnav system loses contact with the satellite. You know the car is in the tunnel but until it emerges from the other end and can be seen again it is not possible for the satellite to tell exactly where in the tunnel it is.

Unfortunately, for the interested operator who wants to know what's happening all around the refrigeration circuit the two "tunnels" in the system are where most of the heat transfer action takes place. In the evaporator the working fluid is boiled from liquid to gas, and in the condenser it is reliquefied. Most of the refrigerant in the circuit will be in one or the other of these places, and its other properties are hidden from view by the tunnel effect. The normal way of describing the condition of the fluid is as a percentage quality. If the fluid has a vapor quality of 10%, then 90% of it is liquid, and 10% is gas. If it has a vapor quality of 80%, then only 20% of it is liquid. The vapor quality is the percentage of the weight of working fluid in the vapor state. However, because the density of liquid is much higher than gas, the liquid only takes up a very small amount of the space.

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