

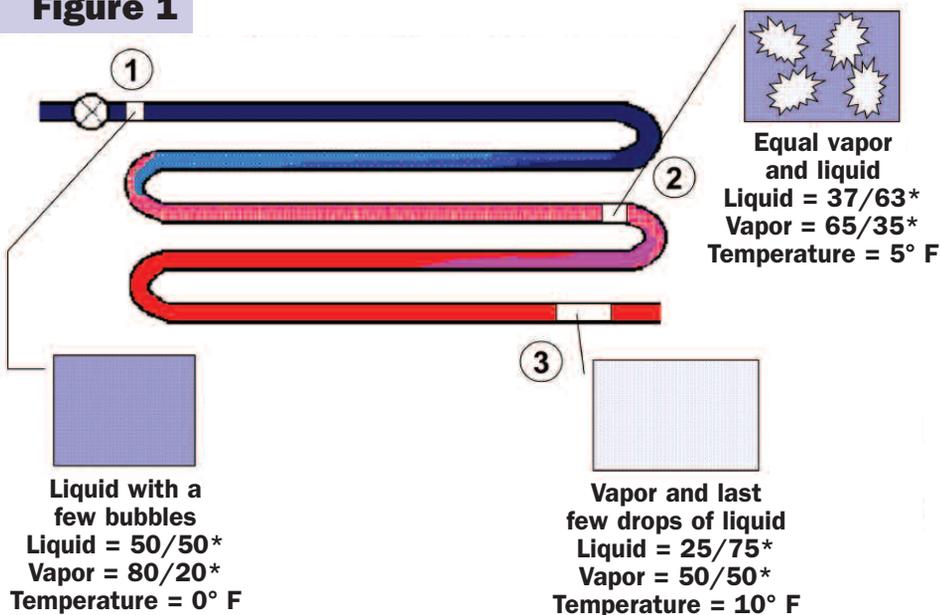
## Part 2

# Refrigerant Blends: The Impact of Temperature Glide

The second report in a three-part series on refrigerant blends addresses how temperature glide occurs in the evaporator and its effect on system operation and controls

BY JIM LAVELLE

Figure 1



The diagram shows the relationship between blend fractionation and temperature glide through an evaporator coil. \*The number left of the slash represents the percentage of refrigerant A and the number right of the slash represents the percentage of refrigerant B.

**B**ecause temperature glide results from the effects of fractionation inside the evaporator, it is useful to review a few key points from last month's article on fractionation.

► When two (or more) refrigerants are mixed and they don't form an azeotrope, the vapor and liquid compositions tend to differ. This occurs because the higher-pressure refrigerant tends to jump into the vapor faster than the other(s) and take up more space.

► When individual components have extremely different pressures, the vapor composition will be much different than the liquid composition. When the pressures are similar the vapor composition will be close to that of the liquid.

► When vapor is taken away from the liquid, more liquid will boil to replace the vapor and more of the high-pressure component boils out of the liquid. This causes the liquid composition to change, becoming more concentrated in the lower boiling component(s).

► Changing the liquid composition causes the boiling point temperature to rise.

## Fractionation and temperature glide

The key point with fractionation is that the vapor above a large pool of liquid turns into the wrong composition. When considering temperature glide in the evaporator, however, there is no longer a large pool of liquid.

Instead, there will be a small amount of liquid that we will follow as it travels down the length of the evaporator coil and eventually becomes vapor. Figure 1 shows a blend of 50 percent refrigerant A and 50 percent refrigerant B, with A being the higher-pressure refrigerant.

The refrigerant flows into the evaporator as liquid then it leaves as vapor. It is the local fractionation effect on each portion of the refrigerant that causes the shift in liquid composition along the way, which then causes a rise in the boiling temperature. In the example given in

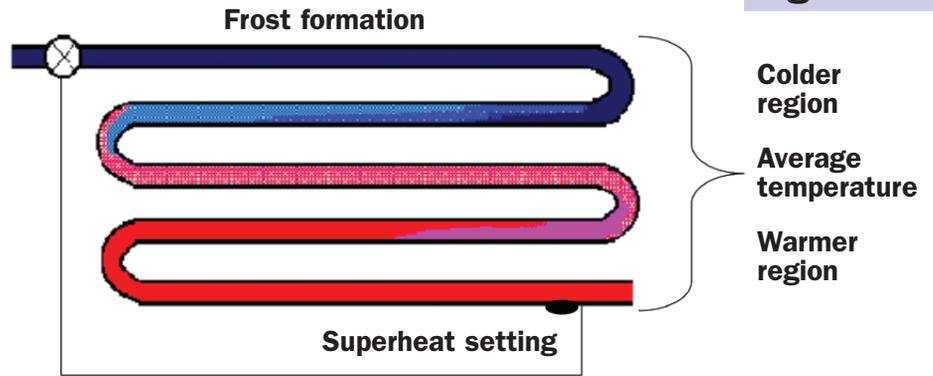
Figure 1 the blend begins boiling at 0° F and ends boiling at 10° F. That means there is a 10° F temperature glide across the coil.

At the beginning of the coil, the blend is mostly liquid with a few bubbles in it. The liquid is composed of half refrigerant A and half refrigerant B (the correct composition) and the vapor in each bubble consists of 80 percent refrigerant A and 20 percent refrigerant B.

For this example, the 50/50 liquid is boiling at 0° F. As the blend moves down the coil, more of the refrigerant A molecules will shift to the vapor and the liquid composition will begin to change (see sidebar below for an analogy).

Somewhere in the middle of the coil, the blend will become part liquid and part vapor. Both of these phases are at the wrong composition because of the uneven shift of refrigerant A molecules to the vapor. The liquid composition has changed to 37 percent refrigerant A and 63 percent refrigerant B. The corresponding boiling point has gone up to about 5° F.

At the end of the coil, most of the refrigerant is now vapor at the correct composition of half of each of the two refrigerants. The last few



**Figure 2**

**Effects of temperature glide**

- Thermostat placement in air stream.
- Ice machine: ice formation and harvest control setting.

drops of liquid are now at 25 percent refrigerant A and 75 percent refrigerant B, and boiling at 10° F.

**Impact on system operation**

Figure 2 shows the effects of temperature glide on system operation. Extending the previous example, the average evaporator temperature will be 5° F. The first part of the coil is colder and the last part of the coil is warmer.

But if you blow a fan over the entire coil, the air coming off the other side will look like it went over

a 5° F coil. There are several system operation issues that will be different with blends than they would be with single refrigerants:

► **Frost formation.** Coils operating below 32° F probably will show frost formation, and the colder a system runs the more likely there will be a defrost timer and some sort of defrost mechanism (electric coil, hot-gas bypass). Systems with a single refrigerant, like R-12 or R-22, will show an even frost pattern over the entire surface of the coil.

High-glide blends, however, will

**Refrigerant can behave like stopped traffic**

If traffic is stopped, then allowed to move suddenly, the cars will take off quickly and the trucks will take some time to rumble up to speed. Refrigerant acts quite similarly.

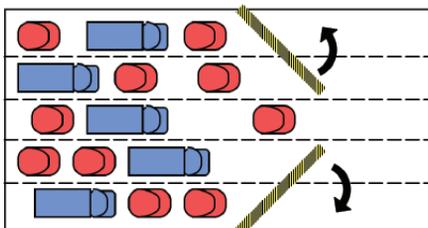
This is like the molecules in refrigerant A jumping quickly into the bubbles, while the molecules in refrigerant

B stay in the liquid. The average speed is low, just as the boiling point is lower at this point.

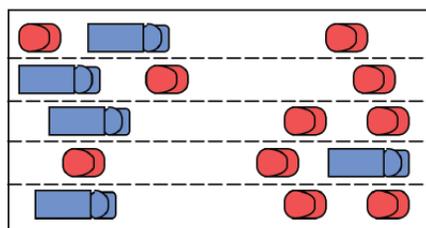
If you stand about one mile down the road, you will see a bunch of cars go by with a truck or two, then you will see a bunch of trucks with a car or two. This is like the liquid and

vapor being at different compositions. The average speed is higher, as the boiling point is getting higher.

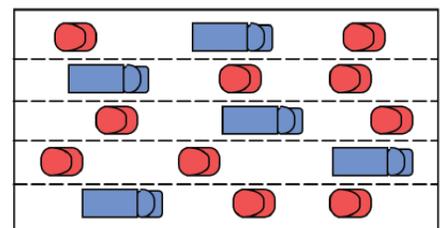
Go 10 miles down the road and the trucks have caught up to the cars. Similarly, the refrigerant A and B molecules come together as vapor. The speed is higher still, like the boiling point.◆



**1**

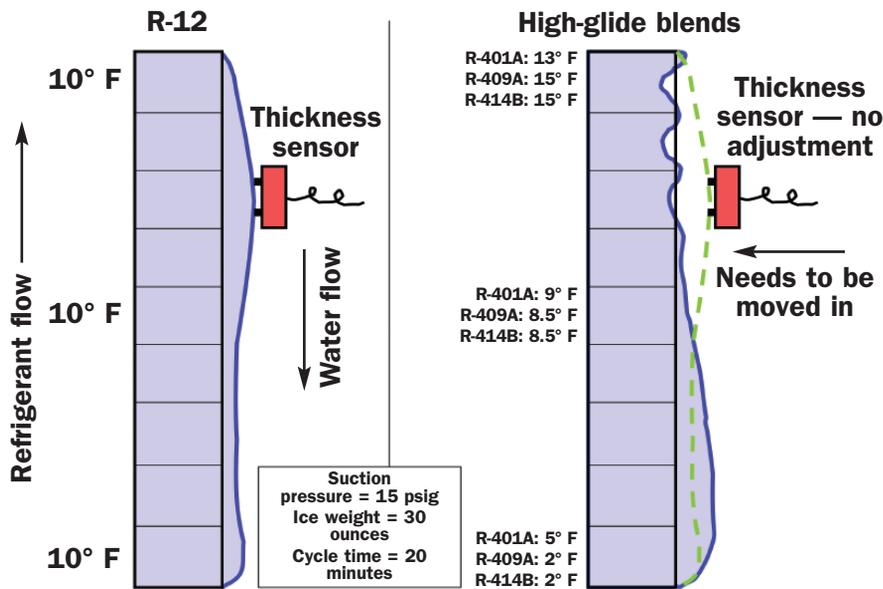


**2**



**3**

**Figure 3**



**Side view of an ice machine grid/ice profile near harvest — R-12 and high-glide blends.**

show thicker frost formation toward the valve, where the actual boiling temperatures are lower than at the end of the coil. After a retrofit to a high-glide blend, it is possible that the first part of the coil could be blocked by frost before the original timer setting calls for defrost. You may need to adjust the defrost timer to avoid this condition.

► **Temperature controls or indicators.** It is possible that thermostat bulbs or case temperature indicators could be placed close enough to the coil to be affected by temperature glide. If the bulb is located nearer the colder part of the coil, then the system may shut off early (or show a colder temperature). If the bulb is closer to a warmer part of the coil, then the system may run longer (or show a warmer temperature).

In general, temperature sensors should be located far enough from the coil that they will read the bulk air temperature in the case or box, not the air temperature coming directly off a part of the coil.

► **Thermostatic expansion valve (TXV) sensor bulbs.** These are located on the suction tubing after the outlet of the evaporator. The spring

setting on a TXV is adjusted to make sure that superheated vapor is moving up the suction line, not liquid.

Because the boiling temperature of the refrigerant gets warmer toward the end of the evaporator, and there is still liquid present, you need to check the superheat setting of the TXV and possibly adjust it higher after a retrofit to a high-glide blend. I will address superheat adjustment in part three of this series, in the March issue.

► **Ice machines.** Many ice machines have an evaporator coil running vertically behind a cube-making plate. A single refrigerant will produce a constant temperature across the entire face of the plate, whereas a high-glide blend will be colder at the bottom than at the top. Figure 3 summarizes a retrofit study for high-glide blends used in an R-12 ice machine.

Generally speaking, a high-temperature glide does not necessarily affect a system's ability to remove heat from the air or from a product. More likely, the glide will affect the response of various controls on the system and retrofitting with high-glide blends will require adjustment

of those controls.

Frost formation and hot or cold spots will need to be addressed outside of the refrigeration loop by adjusting the defrost timer and product placement, for example. Changing the thermostat setting to avoid frost or a cold spot would make the box run too warm.

### Ice machine retrofit study

A retrofit study was performed on a Manitowoc 200 ice machine using the popular R-12 retrofit blends R-401A, R-409A and R-414B.

Original baseline R-12 operation:

- **Suction pressure:** dropped to just below 15 psig before harvest.

- **Suction temperature:** around 10° F across entire coil before harvest.

- **Cycle time:** about 20 minutes per block.

- **Ice weight:** entire block weighed about 30 ounces after harvest.

After retrofit, each blend performed similarly:

- **Suction pressure:** dropped to just below 15 psig before harvest.

- **Suction temperature:** R-401A averaged 9° F. R-409A and R-414B averaged 8.5° F.

- **Cycle time:** about 20 minutes (after adjustment of thickness sensor).

- **Ice weight:** about 30 ounces after harvest.

The key difference from R-12 to the blends was in the profile of ice thickness from the top of the block to the bottom. Figure 3 shows a side view of the ice plate showing how the thickness of the ice grew away from the coil.

For R-12, with a constant temperature profile, the ice sheet grew steadily and uniformly until harvest. The third row from the top showed the most weight of ice compared to the other rows. This also happened to be where the thickness sensor was located.

With each of the high-glide blends the general result was the same: there were dimples in the first few rows of ice, and the majority of the weight of ice was in the lower five rows. The first cycle after retrofitting took over 30 minutes to harvest because the thickness sensor was not

contacting the ice after 20 minutes.

The bridge between cubes had not grown out as far on the upper part of the plate. After adjusting the sensor closer to the ice, harvest times came back closer to 20 minutes. The total ice block was about the same size (30 ounces). However, more of the ice was on the lower part of the plate where the temperature was colder.

Overall, the ice machine still produced the same amount of ice and the bin was full each morning regardless of the refrigerant used. Each sheet of ice, however, looked different than it did with R-12 because of the temperature glide. All that was needed to make this a successful retrofit was an adjustment of the control.

### **Temperature glide in the condenser**

The discussion for evaporator coils can be reversed for condenser coils. As the blend condenses, initially

forming a few drops and later becoming all liquid, the condensing temperature will drop by an amount similar to the glide seen in the evaporator.

Air-cooled condensers will operate similarly to how they did with a single

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refrigerant. Water-cooled condensers may gain or lose efficiency depending on which way the water and refrigerant flow relative to each other, but generally they will behave as they did with the original refrigerant.

Localized fractionation as refrigerant moves through the heat exchanger will create temperature glide. The glide may cause the system to behave differently than it did with a single refrigerant.

The changes, however, usually will involve adjustment of a control. Affected controls typically include the defrost timer, thermostat bulbs, ice machine thickness sensors, and superheat and pressure control settings, which I will address in part three in next month's issue of *RSES Journal*.

Part three also will cover how temperature glide affects the information given on a pressure-temperature (PT) chart. Pressure gauges and PT charts are used to check for correct or abnormal system operation, set superheat and subcool temperatures and set pressure controls. High-glide blends require special attention for these operations.◆

*Jim Lavelle is technical sales manager at National Refrigerants Inc.*