Understanding Refrigerant Blend Performance

PART ONE

Knowing how and why blends differ from single-component refrigerants can help you better identify or avoid problems when installing or servicing equipment. Part one of a three-part series covers fractionation

By Jim Lavelle

Since the phaseout of CFCs more than 10 years ago, refrigerant blends have become commonplace in the refrigeration market for both retrofit and new installations. Equipment that traditionally used R-12 or R-502 is now running on one of approximately 13 commercially available blends.

When you consider the pending phasout of R-22, another three or four blends get thrown into the mix. In addition, contractors and service technicians must know the pitfalls of refrigerant blends. Fortunately, we have learned much about blend performance during the last 15 years.

Each refrigerant blend has its own unique properties that are somewhat different from the original product they are intended to replace. By understanding how blends differ from single-component refrigerants, contractors and technicians can better identify or avoid blend-related problems when installing or servicing equipment.

Fractionation and temperature glide will affect system operation, control settings and service/troubleshooting practices. Different blends will show different amounts of fractionation or temperature-glide effects, though the impact on a system will be similar for all blends.

What are blends?

Blends are made up of two or more single-component refrigerants. Each single-component refrigerant has its own pressure-temperature relationship and unique physical properties, such as density, heat of vaporization and heat-transfer coefficient. To match the properties of a single refrigerant with a blend, the individual components must be mixed in the right proportions.

Azeotropes are a special case in which the refrigerants combine in a unique way. There is some attraction/interaction between the different types of molecules, which causes unique properties within the blend. Since azeotropes, such as R-500, R-502, R-503, R-507 and R-508B, do not allow components to separate, they will not be included in this discussion.

Zeotropes have a pressure-temperature relationship that is a natural combination of the components' properties. There is no interaction between
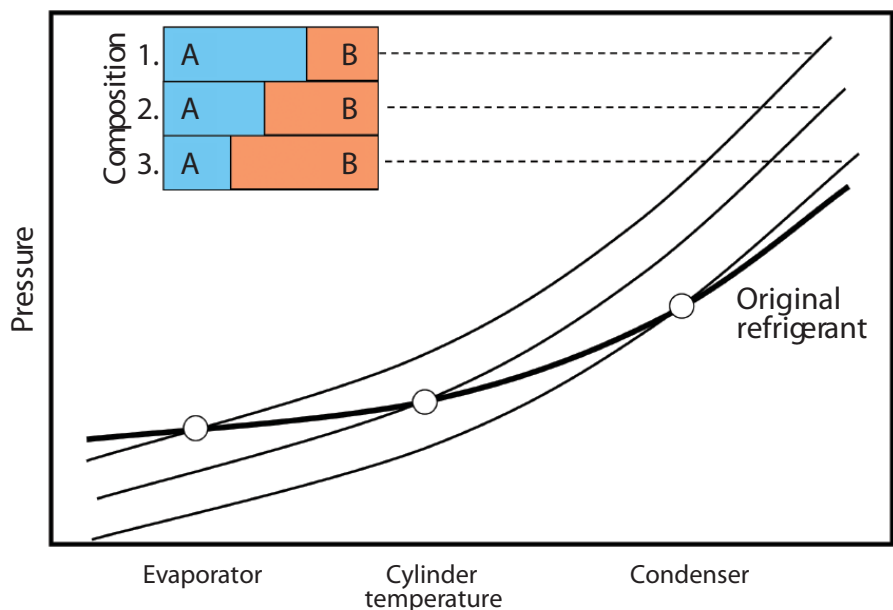
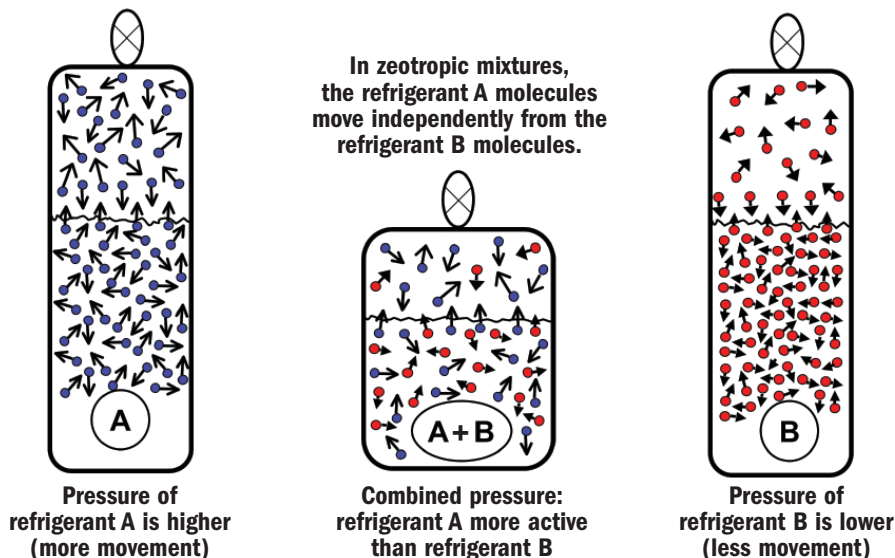### Figure 1: New variable — composition

Figure 2: Behavior of individual refrigerant molecules

In zeotropic mixtures, the refrigerant A molecules move independently from the refrigerant B molecules.

Pressure of refrigerant A is higher (more movement)

Combined pressure: refrigerant A more active than refrigerant B

Pressure of refrigerant B is lower (less movement)

the different types of molecules. The pressure for the blend falls between the pressures of its components. But as we will see later, the vapor composition will become a problem.

If we mix a blend of refrigerant A and refrigerant B, we usually talk about the higher-pressure component first, in this case A. In general, if a greater amount of A is mixed with B, then the blend will have a pressure closer to A. If a greater amount of B is in the mix, then the blend will have a pressure closer to B. If you mix equal amounts, the blend will fall in between the pressures of A and B.

Zeotropic blend compositions have been adjusted so the resulting blend properties fall exactly where the manufacturers intended. The problem, however, is that not all of the properties can match the original refrigerant under all conditions.

Composition is a concern
Once a blend is mixed at a given composition, the pressure-temperature relationships follow the same general rules as for pure components. For example, the pressure goes up when the temperature goes up.

For three blends containing different amounts of refrigerants A and B, the pressure curve is similarly shaped (see Figure 1). But the resulting pressure will be higher for the blend that contains more of the A (higher pressure) component.

Refrigerant blends that are intended to match some other product (R-12, for example) will rarely match the pressure at all points in the desired temperature range. What is more common is the blend will match in one region and the pressures will differ elsewhere.

The blend with composition 1 matches the pure refrigerant at cold evaporator temperatures, but the pressures run higher at condenser conditions. The blend with composition 2 matches closer to room temperature and might show the same pressure in a cylinder being stored, for example. The operation pressures at evaporator and condenser temperatures, however, will be somewhat different.

Finally, the blend at composition 3 will generate the same pressures at hot condenser conditions, but the evaporator must run at lower pressures to get the same temperature. We will see later that the choice of where the blend matches the pressure relationship can solve (or cause) certain retrofit-related problems.

The graph also illustrates that if a blend loses some of the higher-pressure component, the remaining blend will have to achieve a lower operating pressure in order to achieve the same temperature. Turning this around, a system operating at the same pressure actually will boil refrigerant at a higher temperature.

Why blends fractionate
Figure 2 illustrates two basic behaviors of refrigerant molecules that will help explain why fractionation occurs. A pure refrigerant, A or B, exerts pressure on the cylinder (or a system) because the molecules are in motion.

At higher temperatures the molecules move faster, which increases pressure. At lower temperatures there is less movement and lower pressure. Different refrigerants have different energies at the same temperature, and, therefore, generate higher or lower pressures at the same temperature.

Molecules of refrigerant are constantly moving from liquid to vapor and vapor to liquid at the surface of the liquid. Vapor and liquid at equilibrium transfer the same number of molecules back and forth.

Boiling liquid transfers more from liquid to vapor and condensing refrigerants transfer more from vapor to liquid. Different refrigerants transfer back and forth to the vapor at different rates and ultimately have different numbers of molecules in the vapor at the same temperature.

When refrigerants A and B are mixed together and they don't form an azeotrope, the individual refrigerant molecules behave as if the other type is not there. The refrigerant A molecules bounce harder than the refrigerant B molecules, contributing more pressure to the blend. The composition can be adjusted so that the combined pressure from the two types of molecules matches the desired pressure.

More importantly, as the two refrigerants move in the cylinder, the A's transfer back and forth to vapor faster than the B's. This means there will be a higher concentration of A's building up in the vapor compared to the B's. When liquid and vapor are together at equilibrium, it is always the vapor that goes to the wrong composition.

How blends fractionate
Looking at the containers in Figure 3, you can see that when vapor is removed from a cylinder or system containing a zeotropic blend, two things will happen:

1. The vapor being removed is at the wrong composition. The vapor will have more of the higher pressure/higher capacity refrigerant component compared to the liquid composition.

2. The liquid that is left behind boils more of the higher-pressure component out of the liquid to replace the vapor. Eventually, the liquid composition changes because more of the A component leaves the container compared to the bulk liquid composition.

Fractionation is the change in composition of a blend because one (or more) of the components is lost or removed faster than the other(s). A larger difference between the pressures of the starting components will cause a greater difference in the vapor composition compared to liquid.

This will worsen the effect of fractionation on that blend. The high fractionation potential blend shown in Figure 3 will produce a vapor composition of 80 percent refrigerant A and 20 percent refrigerant B above the liquid composition of 50/50. The closer the individual component pressures become, the more similar the transfer of molecules to vapor. The low-fractionation-potential blend in Figure 3 will not have that different a vapor composition compared to the liquid. In this case it will take a long time to noticeably change the liquid composition away from 50/50. Temperature glide, which I will discuss in part two in the February issue, will be higher for high-fractionation blends and lower for low-fractionation blends.

In order to avoid charging the wrong composition and fractionating the remaining blend, zeotropic blends must be removed from the cylinder as a liquid. You can do this by turning the cylinder over so the valve is on the bottom. You should open larger cylinders with vapor and liquid valves using the liquid valve. This will force the liquid product through a dip tube to the valve. (All of the major manufacturers removed dip tubes from their 30-pound packages as of 1999. There
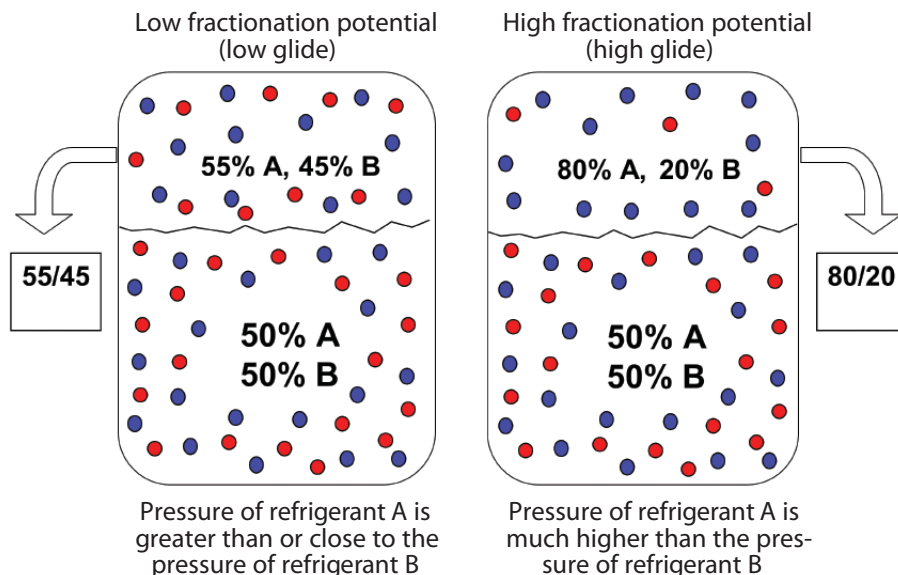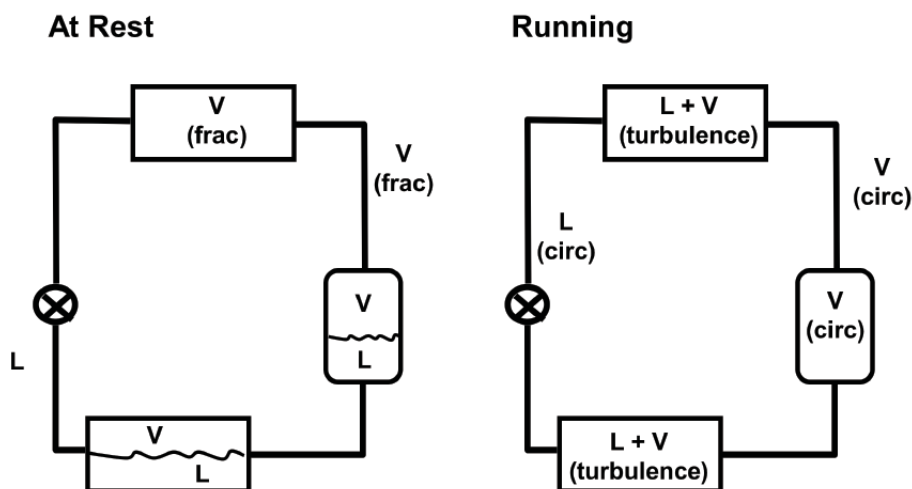
Figure 3: Fractionation of blends

Low fractionation potential
(low glide)

55% A, 45% B

55/45

50% A
50% B

Pressure of refrigerant A is greater than or close to the pressure of refrigerant B

High fractionation potential
(high glide)

80% A, 20% B

80/20

50% A
50% B

Pressure of refrigerant A is much higher than the pressure of refrigerant B

Figure 4: Fractionation effects on system charge

At Rest

V (frac)

V (frac)

V L

L

V L

Running

L + V (turbulence)

V (circ)

L (circ)

V (circ)

L + V (turbulence)

may be some older cylinders or products from third-party packaging companies that still contain dip tubes. Check the box or cylinder labels for instructions on which side should be up for liquid removal.)

Liquid charging does not mean that liquid refrigerant should be pushed into the suction line of the system and allowed to slug the compressor. After the initial charge into the high side of a system, you can start the compressor and complete the charging by flashing the refrigerant from liquid to vapor in the charging hose or across specially designed valves.

Any method that allows the refrigerant to become vapor before it hits the compressor should work. In gen-

eral, it's best to add refrigerant slowly at this point.

Effects of fractionation

A system at rest will allow the refrigerant to pool and the vapor to reach an equilibrium concentration above the liquid. Leaks that occur in vapor areas of the equipment will allow fractionation of the blend. The worst case will occur when about half of the refrigerant charge has leaked.

(Small amounts of refrigerant leaked from a system will not change the remaining blend by much. Large leaks will shift the composition, but the majority of the pounds after recharge will be from fresh product at the right composition.)

Recharging the system after repair will result in a blend with slightly reduced capacity and operating pressures. Looking again at Figure 1, you will see that blends that have fractionated — the composition changes from composition 1 to composition 2 — will lose some of the higher-capacity/higher-pressure component.

In general, the pressures will run lower in order to satisfy the thermostat and the system may run longer during the on-cycles. It is possible to check for a fractionated refrigerant charge. I will cover that topic in part three on system operation and troubleshooting in the March issue.

In smaller systems where charge size is critical, it is best to pull any remaining refrigerant and charge with fresh blend. In larger systems, you will need to make a decision whether the remaining charge should be pulled or not. For low-fractionation-potential blends, you will not see much shift in composition anyway. Therefore, the charge can be topped off after repair without loss of properties.

In running systems it has been found that the circulating composition is the bulk blend composition. In liquid and suction lines there is no second phase and in the heat exchangers there is much turbulence.

Leaks anywhere in a running system will lose both vapor and liquid.

Testing has shown that leaks from a running system do not cause fractionation, and a normal cycling system will not fractionate much during the off cycle. In most cases, servicing systems with blends does not require full recovery of the charge.

After repair, most systems can be topped off with the blend. Only systems that are off for long periods of time, such as air-conditioning units over the winter, will need charge replacement after leakage of a blend.

There are two system components that can be directly affected by fractionation effects: flooded evaporators and suction accumulators. Flooded evaporators are designed to keep a pool of boiling liquid refrigerant surrounding a bundle of tubes. When using blends the vapor that boils off this pool of refrigerant will be at the fractionated composition.

If the properties at this composition differ significantly from what the compressor expects, then the system could develop high head pressures, high amperage draw at the compressor and reduced cooling effectiveness (capacity) in the evaporator. Normally, it is not recommended to use blends in this type of system.

Suction accumulators are placed in the suction line before the compressor to keep liquid from flowing into the compressor The liquid slug is trapped in the accumulator where it can boil off to vapor, combining with other suction gas. Zeotropic blends will fractionate in the accumulator, giving a short-lived spike of higher-pressure vapor back to the compressor.

Generally, this dissipates quickly as the refrigerant boils out of the accumulator. Systems with suction accumulators should not be overcharged with the expectation that the accumulator will protect the compressor. (This may lead to frequent pressure spikes.) In addition, this type of system should never be charged by dumping liquid refrigerant into the suction line and allowing it to vaporize in the accumulator.

Part two in next month's issue will focus on how temperature glide occurs with blends and the effect glide has on system operation and control settings. Part three in March will cover system operation and troubleshooting systems with blends. ◆

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