

R400 Series Refrigerants and Temperature Glide Implications for Service Engineers

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Many of the refrigerants we use and for new systems and to replace R404A in existing systems are zeotropic blends, most of which have a high temperature glide. They are mixtures of two or more substances ("components") and they don't behave like a single substance in the refrigeration system.

Zeotropic blends are identified by the 4 as the first number in the refrigerant designation (R4xxx, e.g. R407F).

Temperature Glide

With single substances such as R134a the saturated liquid (bubble) temperature and the saturated gas (dew) temperature are the same. This means the temperature at which the refrigerant evaporates or condenses remains constant. Zeotropic blends have a higher saturated gas temperature than saturated liquid temperature because the individual components have very different saturation temperatures at a given pressure. This is the temperature glide.

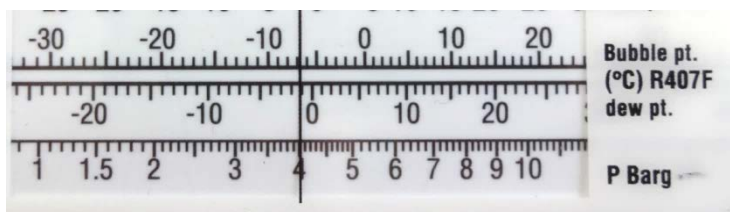
The box, right, includes definitions of these and other useful terms.

Example of temperature glide

R407F at 4 bar g suction pressure, it can be seen from the comparator below that:

- The saturated gas temperature (dew point) is -1°C ;
- The saturated liquid temperature (bubble point) is -7°C .

So the temperature glide is 6K.



What this tells us is that, at a suction pressure of 4 bar g, R407F would start evaporating at -7°C , and have totally evaporated into a saturated gas at -1°C .

Saturated

A mix of liquid and gas, e.g. in an evaporator or condenser

Saturation temperature

Temperature at which a refrigerant changes state, e.g. from a liquid to a gas or a gas to a liquid. The saturation temperature rises as the pressure rises (and vice versa)

Sub cooled

A liquid which is at a temperature below the saturation temperature

Superheated

A gas which is at a temperature above its saturation temperature

Saturated liquid

A liquid at the saturation temperature (bubble temperature)

Saturated gas (vapour)

A gas at the saturation temperature (dew temperature)

Temperature glide

The difference between the saturated gas (dew) temperature and the saturated liquid (bubble) temperature

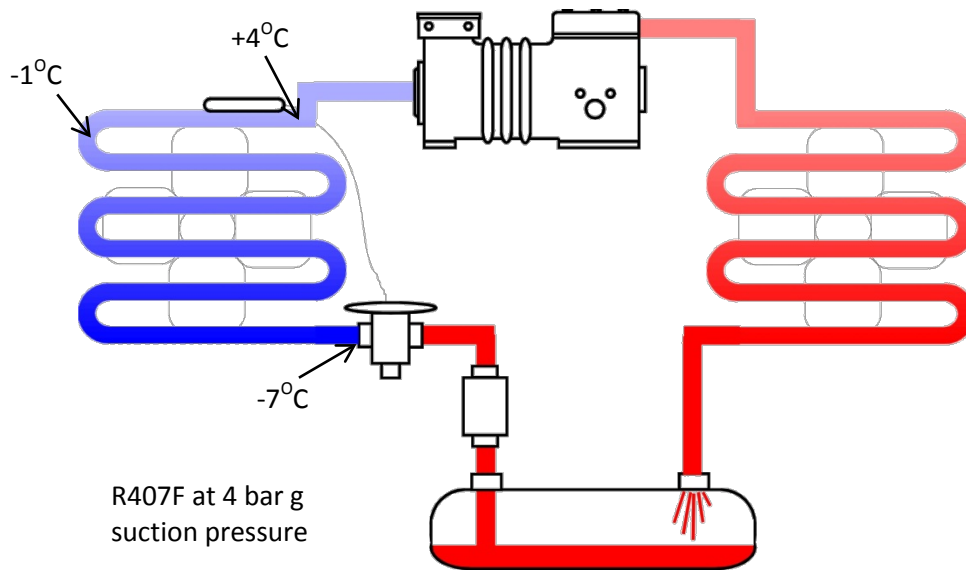
Zeotropic

A mixture of chemicals is zeotropic if the composition of the vapor and the liquid phase at the vapor-liquid equilibrium state is never the same. These mixtures have temperature glide

Azeotropic

A mixture of chemicals is azeotropic if the composition is the same in the vapor and liquid phases. These mixtures have zero temperature glide

In most RAC systems it would then typically superheat by 5K, so the temperature of the R407C leaving the evaporator would be +4°C (as shown in the diagram below).



The refrigerant temperature entering the evaporator will actually be warmer than -7°C as it is not pure saturated liquid at this point because some of the liquid flashes off (evaporates) as the pressure drops through the expansion device.

Saturation temperatures for refrigerants can be found on comparators as shown in the example, on smart phone apps and on electronic gauges. The electronic gauges default to showing the dew temperature corresponding to the low side pressure and the bubble temperature corresponding to the high side pressure.



Setting superheat

The superheat of a zeotropic blend is the difference between the temperature of the superheated refrigerant leaving the evaporator and the dew (saturated gas) temperature corresponding to the evaporating pressure:

Superheat = evaporator exit temperature – saturated gas (dew) temperature

If the saturated liquid temperature (bubble point) is used instead of the saturated gas temperature to set an expansion valve this can lead to a very low or zero superheat, with a consequent risk of compressor failure due to liquid flood back.

Cool Stuff number 5 provides more information about setting superheat.

Measuring sub cooling

The degree of sub cooling is the difference between the condensing temperature and the temperature of the sub cooled liquid refrigerant entering the expansion device. With a zeotropic blend the saturated liquid (or bubble) temperature is used:

Sub cooling = saturated liquid (bubble) temperature – expansion device inlet temperature.

Charging

To maintain the correct composition when charging zeotropic blends you should always connect to the liquid off-take valve of the cylinder so the refrigerant is removed as a liquid. If gas is removed, the blend charged into the system is not the correct composition. It will operate at a higher pressure than the correct blend would and could cause compressor overload. The refrigerant remaining in the cylinder will be richer in the lower pressure component(s) and will have a lower operating pressure and a lower refrigerating capacity.

Care must be taken when charging into the low pressure side of the system – the liquid must be evaporated (“flashed off”) before it enters the compressor. When charging through a gauge manifold set, this can be achieved by throttling the manifold’s low pressure valve.

Differential leakage (composition shift)

If a zeotropic blend with a wide temperature glide leaks from the system the blend components can leak at different rates. The refrigerant which remains in the system will be richer in the lower pressure components and will have a lower cooling capacity. If the system is topped up rather than the charge replaced, it is possible the cooling capacity will not meet the load. This is more acute with refrigerants with a high temperature glide such as R407C and R407F.

With such refrigerants, if there has been a significant leak it is recommended that the remaining charge is recovered and the system re charged with new refrigerant.

Refrigerant can be analysed by a refrigerant supplier to determine if the composition has changed, for example due to differential leakage.

Examples of Zeotropic Blends

The table below lists common zeotropic blends with key information.

Refrigerant	Approx. glide in the evaporator, K	Application
R404A	< 1	Wide range of existing refrigeration systems
R407A	6	New refrigeration systems and to replace R404A
R407C	6	Older air conditioning systems
R407F	6	New refrigeration systems and to replace R404A
R410A	< 1	New and existing air conditioning systems
R448A	6	Replacement for R404A in existing systems
R449A	6	Replacement for R404A in existing systems

This list is not exhaustive but includes the most common blends. The glide in the condenser is less than in the evaporator.

Azeotropic blends

There is a group of refrigerants which are mixtures of different components which have zero temperature glide. These are called azeotropic blends. An azeotropic blend has a 5 as the first number in the designation (R5xxx, e.g. R507).

An azeotropic blend:

- has the same saturated gas and saturated liquid temperatures (zero temperature glide);
- can be charged as a gas or a liquid;
- does not exhibit composition shift in the event of a leak (differential leakage), so can be topped up rather than the whole charge replaced.

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