coolconcerns
Training | Consultancy | Technical Support

R400 Series Refrigerants and Temperature Glide
Implications for Design Engineers

July 2016

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.

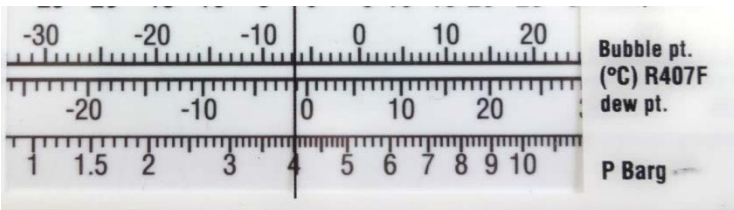
The box, right, includes definitions of these and other useful terms.

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^{O}C ;
- The saturated liquid temperature (bubble point) is -7^{O}C.

So the temperature glide is 6K.

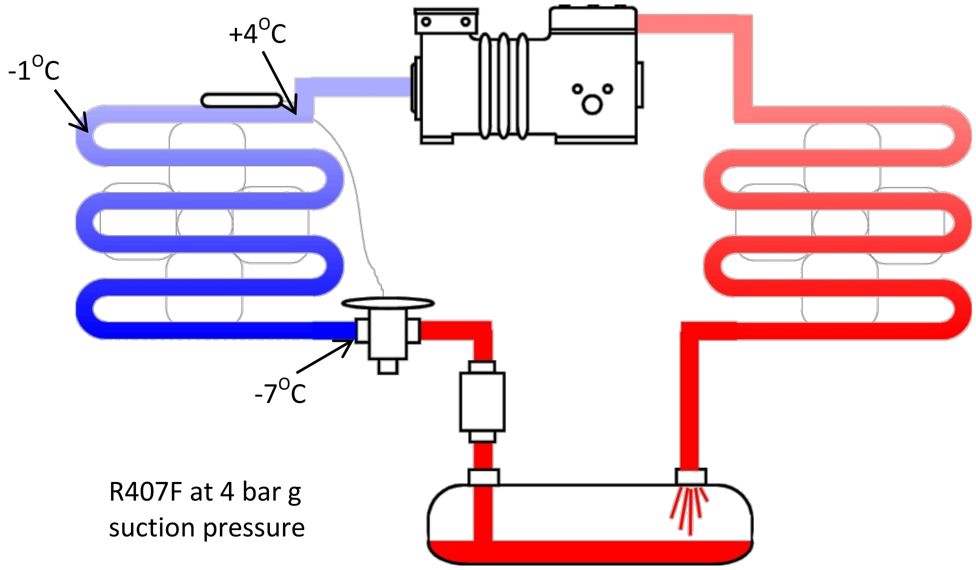


What this tells us is that, at a suction pressure of 4 bar g, R407F would start evaporating at -7^{O}C, and have totally evaporated into a saturated gas at -1^{O}C.

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

Cool Stuff from Cool Concerns

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



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.

Selection of Components

The capacity of components such as compressors, evaporators and condensers varies dependent on whether they are rated at the dew temperature or the mid point temperature. It is essential that you use the correct temperature. For high glide blends the difference between dew and midpoint (about 3K) is enough to have a significant effect on capacity of the wrong value is used.

Mid point temperature
The **simple** mid point temperature is the average of the dew and bubble temperatures. In the previous example this is -4°C (-1°C dew and -7°C bubble).
In reality, in the evaporator the **actual** mid point temperature is the average of the evaporator inlet temperature and the dew temperature. The evaporator inlet temperature is higher than the bubble temperature because of a proportion of the liquid flashes off through the expansion device. The proportion of flash gas depends on the degree of liquid sub cooling and the compression ratio.

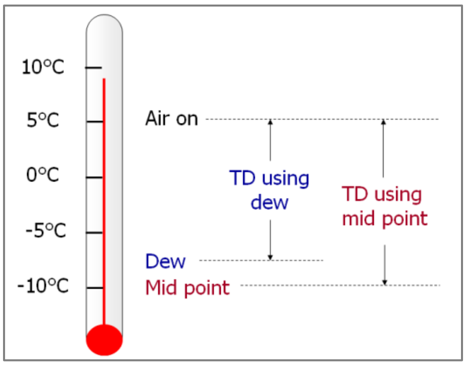
Compressors

Compressors are also rated at the dew temperature (evaporating and condensing), but most selection software will also provide data using the mid point. If you input the correct mid point temperatures the capacity stated will be the same as at the dew point. For simplicity it is recommended to use the dew point for compressor selection because it is obtained simply from refrigerant data, it does not have to be calculated (as explained in the text box about mid point temperature).

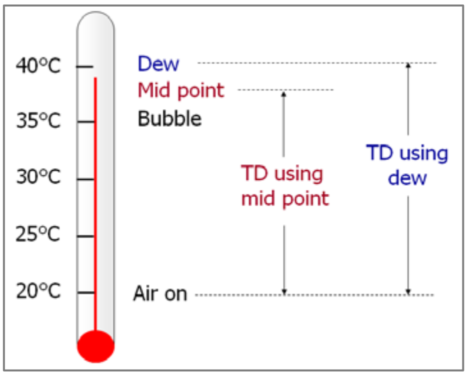
Evaporators and condensers

Evaporators and condensers are typically rated at the dew point. Capacities stated at the midpoint will differ because the capacity is proportional to the temperature difference:

- Evaporator capacity stated at the midpoint will be higher than at the dew point;



- Condenser capacity stated at the midpoint will be lower than at the dew point.



For evaporators and condensers it is recommended to use the simple midpoint temperatures for selection.

Application of High Glide Blends

Blends with a high temperature glide are not suitable for use in systems with flooded evaporators.

Overview of Service Issues

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

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.

To maintain the correct composition when charging blends, they are charged as a liquid. If gas is removed, the blend charged into the system is not the correct composition.

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.

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.

Disclaimer

Every effort has been made to ensure the accuracy of the information in this document, but the content is subject to change and Cool Concerns Ltd cannot guarantee its accuracy or currency. No legal responsibility is accepted for any errors, omissions or misleading statements.