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A practical guide to using refrigerants with a temperature glide

This document is the second in a series of bulletins produced by the BRA following the publication of the PURR report (Putting into use Replacement Refrigerants). It is intended to provide advice for Service Engineers considering retrofitting high GWP systems. Some of the information will also be useful in the case of new installations. The guide is intended to cover single condensing unit and evaporator applications.

R404A is the most commonly used high GWP refrigerant, and hence the replacement refrigerants identified in the PURR document have been used to illustrate the issues with retrofitting. These are supported with information from Component and Equipment manufacturers. Any comments with regard to R404A are equally applicable to R507.

Potential Replacement Refrigerants for R404A

	R404A	R407A	R407F	R448A	R449A	R452A
GWP (AR4)	3922	2107	1825	1387	1397	2140
Glide K	0.8	6.4	6.4	6.1	6.1	6.4
Pressure @-10 °C (barg) Vapour (dew point)	3.4	2.2	2.6	2.4	2.6	3.0
Pressure @-25 °C (barg) Vapour (dew point)	1.5	0.9	0.9	0.9	1.0	1.2
Pressure @ 40° C (barg) Liquid (bubble)	17.2	17.5	18.3	17.6	17.5	18.1
Pressure @ 55°C (barg) Liquid (bubble)	24.8	25.2	26.2	25.2	25.3	25.9

The above table compares the replacement refrigerants currently available to replace R404A.

They all have broadly similar characteristics when compared to R404A:

- Wider Temperature Glide
- Higher compressor discharge temperatures
- Lower Mass flows
- Generally slightly lower suction pressures and slightly higher discharge pressures
- All classified as non-flammable and not subject to any flammability restrictions

Although it will usually be possible to retrofit R404A with one of the replacements, they should not be considered as a "Drop In", as some system adjustments will be necessary to ensure that the replacement refrigerant will operate efficiently.

What is Glide?

Refrigerant blends classified in the R400 series are mixtures containing a number of component refrigerants (between two and five depending on their intended performance). The scientific term for such a product is a **zeotropic blend**. Because the individual component refrigerants have different boiling points, the blend does not evaporate (or condense) at one temperature (at a given pressure), but over a temperature range – this is referred to as the **Temperature Glide.**

The Temperature Glide is defined as the difference between the Dew Point (when the refrigerant is 100% vapour) and the Bubble Point (when the refrigerant is 100% liquid) at a given pressure.
Refrigerant slide rules and mobile phone apps will give both temperatures for any R400 series refrigerant, and hence the glide can be calculated. The glide will vary depending on the blend components; hence R404A has a glide of less than 1K, whilst R407A and F have a glide of more than 6K.

As R404A has a very low glide, it has been possible to ignore this when setting up systems. However, **ALL** R404A alternatives (HFC and HFC/HFO blends) have a glide. Therefore, in setting up a system with one of these blends (whether retrofit or new build), the temperature glide must be taken into account to ensure that the system operates safely as intended, and so that its optimum performance can be obtained, whilst also ensuring the expected life time of the equipment.

A characteristic of zeotropic refrigerants is that the composition of the vapour is different from that of the liquid. This is why it is recommended that ALL refrigerant blends should be charged in the liquid phase to ensure the correct composition is maintained.

A question often raised is what effect does this characteristic have in the event of a leak?? Much work has been done over the years to understand this issue by refrigerant manufacturers. The conclusions are basically that in the event of a slight leak, a system can be topped up with the virgin refrigerant with no detrimental effect on system performance. **HOWEVER**, in the case of a severe leak (>50% of the charge lost), it is always safer to remove what refrigerant remains, identify and repair the leak, and re-charge the system completely with virgin product.

Retrofitting Systems

In general high temperature systems e.g. chill food can be retrofitted to a lower GWP refrigerant, such as those listed, with minimal system modifications or changes being required.

However for low temperature systems, the increased discharge temperatures may result in additional compressor cooling being necessary for systems such as frozen food. Information should be sought regarding individual compressor types or models. A number of hermetic compressor manufacturers have approved the use of R452A due to it having a lower discharge temperature than the other alternatives, although this is at the expense of a higher GWP.

Published information is now available for Condensing Units with alternative refrigerants.

In general for chill applications the condensing unit duty will be similar to R404A.

The situation for frozen food applications is:

For a typical freezer application with an evaporating temperature of around -25°C, condensing unit duties are likely to be similar to that when used on R404A

For frozen food cabinets where the evaporating temperature is more typically around -35 °C, there is likely to be a decrease in duty which will vary according to the refrigerant and the type of compressor. It is recommended that the performance and application range of condensing units fitted to frozen food cabinets should be checked prior to carrying out a retrofit.

Due to the lower mass flow and different superheat characteristics of the replacement refrigerants, it will be necessary to consider whether to replace the expansion valve or use the existing one. Information on the use of existing expansion valves is available, but in general it is recommended to use a valve optimised for the refrigerant being used. For larger systems the use of an electronic expansion valve should be considered as this will enable easier setting up of the superheat.

The pressure rating of the Pressure Relief Valve should also be checked as R407A/F, R448A and R449A have slightly higher discharge pressures than R404A. Pressure switches should be adjusted to cater for the different refrigerant pressures.

The Retrofit Process

A number of refrigerant manufacturers have published guidelines on carrying out retrofits and these should be followed.

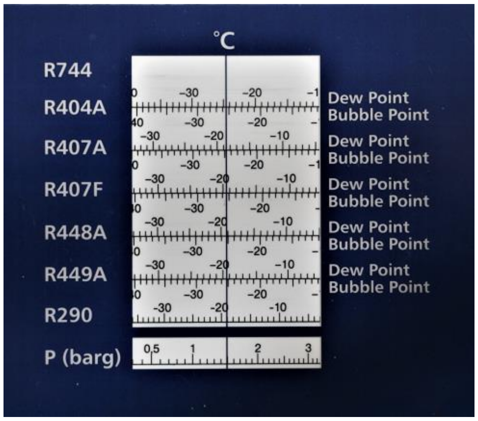
It is essential that the system is re-commissioned and adequate time allocated to this. In particular that the expansion valve superheat must be adjusted to ensure that the refrigerant is 100% vapour when leaving the evaporator. This means that the superheat, when correctly measured between evaporator inlet and outlet, must at minimum exceed the value of the glide for that particular refrigerant. The measured superheat should be the sum of the glide and any superheat created by the expansion valve.

If we assume that the superheat on a typical healthy R404A system is 6K, then on an equivalent system with one of the replacement refrigerants it will need to be 12K to ensure that no liquid refrigerant is allowed to leave the cooler and ensure the continued safe operation of the compressor.

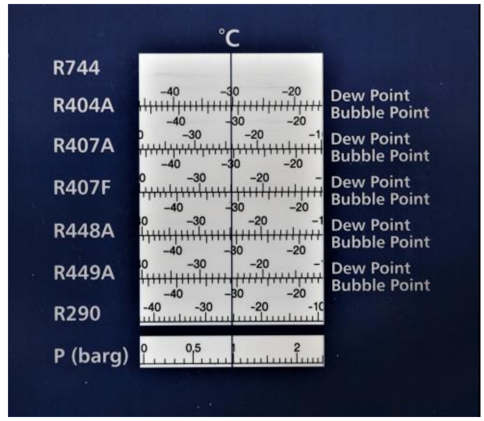
The following table shows the effect of temperature glide, when comparing R404A and R407F, operating on a freezer coldstore with a room temperature of -18°C and a design evaporating temperature of -25°C. As the temperature glide of R404A is less than 1K this has been ignored. It is assumed that the TEV superheat has been set correctly.

Cold Store Temperature -18 C		
Refrigerant	**R404A**	**R407F**
Design Evaporating Temperature C	**-25**	**-25**
Low Side Pressure (barg)	**1.5**	**1.0**
Temperature at TEV outlet (bubble point C)	**-25**	**-31**
Equivalent dew point temperature C	**-25**	**-25**
Glide K	**0**	**6**
Temperature at TEV bulb (Dew point C)	**-19**	**-19**
Temperature Difference between TEV outlet and bulb K	**6**	**12**
Superheat K (Temperature difference less glide)	**6**	**6**

Insufficient superheat will lead to lower duty from the evaporator and possibly liquid refrigerant entering the compressor.
Below the two illustrations illustrate a refrigerant comparator showing comparison of Bubble Points and Dew Points for the above example.



R404A evaporating temperature -25 C



R407F evaporating temperature -25 C

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Useful References:

Institute of Refrigeration Service Engineers Section Fundamentals and Theory series "Measuring Superheat" June 2010

Institute of Refrigeration Service Engineers Section Technical Bulletin No.2 "Thermostatic Expansion Valves"

Institute of Refrigeration Service Engineers Section Technical Bulletin No.37 "Zeotropic Refrigerant Blends" October 2012

Institute of Refrigeration Guidance Note 27 "Refrigerant Glide" March 2016

BRA PURR Report September 2015 available at
http://www.feta.co.uk/associations/bra/publications