Report of British Refrigeration Association Action Group

On

Putting into Use Replacement Refrigerants (PURR)

Executive Summary

This report has been produced by an Action Group made up of members of the British Refrigeration Association (BRA). The purpose of the report is to help people address the task of meeting some of the key implications and requirements of the EU F-Gas regulation which came into force on 1st January 2015.

The document is aimed at all stakeholders involved in the commercial refrigeration market – designers, manufacturers, installers, commissioners and end users – and is designed to highlight the challenges the sector faces in the next few years, and offer guidance and suggestions as to how these issues can be dealt with.

The ban on new installations and servicing with refrigerants with a Global Warming Potential of 2500 or more, together with the cap and phase down of HFC refrigerants, presents the sector with a major challenge. With a very tight timescale in which these factors must be actioned, the need for advice and information will be vital in the decision making process.

Sections 1 to 3 outline the challenge to be faced in more detail, and propose some of the actions that will need to be taken. Sections 4 and 5 contain detailed comments on replacement refrigerant candidates and the components that are relevant to their use. In Section 6, there is a summary of strategic matters that need addressing.

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Contents

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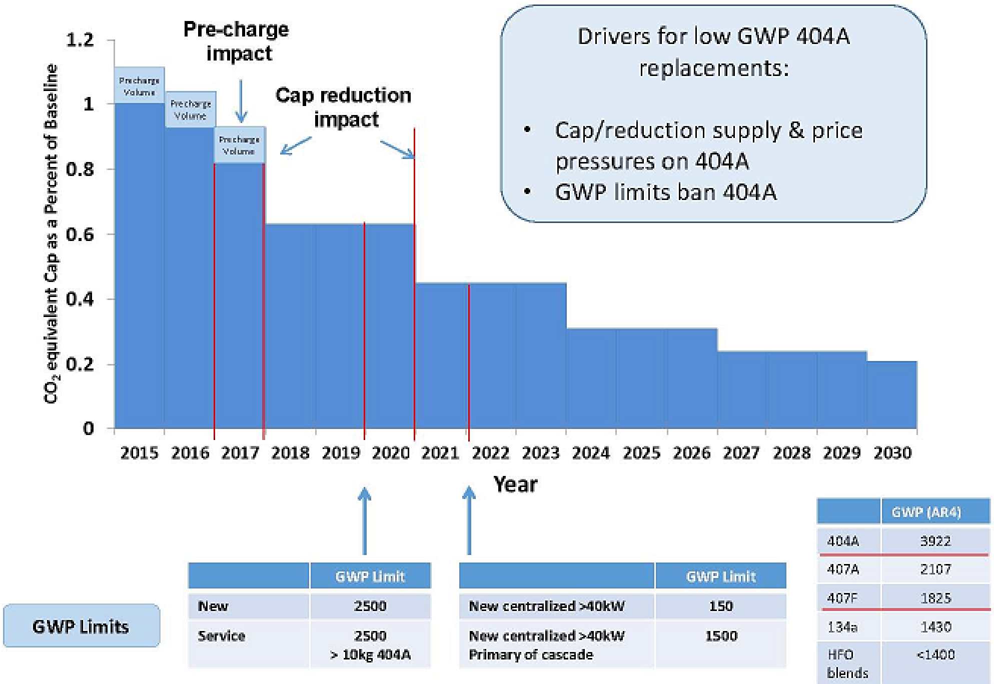
1. Introduction

The EU has legislated that there is a ban on new equipment using refrigerants with a global warming potential (GWP) of 2500 or more from 2020 being installed; and a ban on using virgin such refrigerants for servicing from 2020.
There is also a phase down limiting the quantity of carbon dioxide equivalents of F-Gas that can be placed on the market from the beginning of 2015.
[The GWP of a refrigerant is equivalent to the quantity of carbon dioxide that would be needed to have the same warming impact on the environment.]

The phase down is defined in terms of Equivalent Carbon Dioxide Release Potential of the basket of gases put on the market in the EU each year. The amounts (related to average consumption in 2009-2012) are shown below:-



Values taken from Intergovernmental Panel for Climate Change (IPCC) Assessment Report 4 (AR4)

The phase down applies to Europe as a whole – i.e. it is not applied separately in each country.

There is clear commercial logic in producing lower GWP refrigerants rather than higher ones. As is obvious from the next section, even before it is banned, R404A is going to be a target. It is generally accepted in the industry that its availability is likely to reduce substantially well before the ban date.

A Note on Refrigeration System Configurations

There are two basic configurations of the commercial refrigeration systems considered in this document. These are single compressor systems (condensing units), which are used predominantly for smaller loads having a single evaporator; and multi-compressor packs, which are used for larger loads with multiple evaporators in supermarkets.

The control of these two types of system varies. The single compressor systems have a thermostat in the load space. When the temperature exceeds the thermostat set point, this causes a valve to open allowing liquid refrigerant to enter the evaporator. The pressure in the evaporator rises. There is a pressure stat on the pipe from the exit of the evaporator to the compressor suction port. The higher pressure read by this causes the compressor to start and the load begins to cool.

When the temperature reaches the thermostat set-point, the feed valve to the evaporator closes; the compressor continues to run, "pumping down" the suction pipework between it and the evaporator. When the pressure reaches the low set-point of the pressure stat, the compressor is turned off.

The second configuration is the multi-compressor pack. In this the suction pressure is held, in a band, by altering the number of compressors running. The discharge pressure is held by the number of fans running on the condenser. Each load (display cabinet or similar) operates autonomously taking refrigerant as needed to hold the correct temperature.

For the most part, the contents of this report are valid for both single and multiple compressor implementations. When differences occur, these are noted in the text.

2. Facing Facts

There are 12,000 to 20,000 R404A systems in Britain roughly half being large supermarket systems driven by multi-compressor packs and the other half systems driven by single compressor units. These loads are such things as cold storage, convenience stores and process cooling etc.

Before 2020 some systems will be replaced completely and others will need their R404A retrofitted with another refrigerant.

So, for a considerable number of systems, the R404A will have to be removed and a different refrigerant put in. The chart in Section 4 of the full report, giving the properties of selected gases is intended to help initial selection.

It is crucial that the R404A taken out is kept for servicing the systems that remain in use. From a self interest point of view, it may be sensible for owners of "donor" systems, having R404A removed, to enter into contractual agreements that mean that a similar quantity of recycled (or reclaimed) refrigerant to be returned to them (probably at another site.) The legal considerations are as follows:-

F-Gas legislation gives the following definitions;
Recycling means the reuse of a recovered fluorinated greenhouse gas following a basic cleaning process.
Reclamation means the reprocessing of a recovered fluorinated greenhouse gas in order to match the equivalent performance of a virgin substance, taking into account its intended use.
Reclaimed and recycled HFCs are likely to play an important part in the F-Gas phase-down process as they are 'quota free' however; there is a very big difference between reclaimed and recycled product and how and where it can be used.

Recycled product can only be used on the same site or another site owned by the same company, whilst the contractor removing the product is allowed to use the product elsewhere, however they are not allowed to resell it. Any movement of recycled product to another site must be made using hazardous waste consignment notes and all cylinders must be labelled as containing recycled product. The basic cleaning process is very unlikely to bring the product back to virgin specification and composition of blends will be unknown, with no guarantee of quality. Anyone thinking of using recycled product should evaluate the risk of using product of unknown quality compared to that of reclaimed product where the quality is guaranteed by the reclamation facility.

For reclaimed product it is generally recognised in the UK that it should meet the AHRI 700 specification, which is the same as the requirement for virgin product.
The reclamation process is carried out off site by the UK fillers and packers of refrigerant who are able to offer this service.

It should be noted that all reclaimed or recycled F-Gases needs to be labelled as such, with information on the batch number and the name and address of the reclamation or recycling facility. Anyone using reclaimed or recycled product needs to keep a record of how much they use and where the product was reclaimed or recycled in their respective log books.

It is also crucial the leaks are minimized so that the demand for refrigerant, especially R404A, is kept as low as possible.

For small R404A systems (typically condensing units) which are retrofitted, there may be a loss of capacity, and this needs to be considered when selecting the replacement refrigerant. The alternative to retrofit would be to install a new system charged with a low GWP refrigerant.

Integral units will not be amenable to retrofit, and the only alternative is to replace the whole system.

3 Responding to the Changed Environment

It is clear that:-

- Virgin R404A is not going to be available much longer.
- New systems should use a refrigerant for which the future availability appears reasonably secure for the life of the new system.
- Existing R404A systems are either going to have be retired or to have a change of refrigerant. Nevertheless, there are so many R404A systems in use that many of them will remain in service beyond 2020. These will have to be serviced with reclaimed or recycled refrigerant.
- Servicing with recycled or reclaimed R404A refrigerant is outside the phase-down quota. There will be a market in reclaimed R404A. The product is likely to be called R404A-R.
- R404A from existing systems that are being retired or being charged with a replacement refrigerant should be reclaimed or recycled and kept to be used as service material for the remaining R404A systems.
- It is important for owners to ensure that they keep title to the amount of refrigerant that has been reclaimed or recycled from their system. This is a contractual matter between the servicer and the owner of the refrigerant prior to its removal. Owners should act appropriately.
- Clearly demand for refrigerant for service needs to be minimized – i.e. leakage must be held to the minimum possible.

Further detail:-

- Analysis of information from the BRA Annual Statistics and collection and further discussions with the information providers for the survey and end users gives an estimate in excess of 11 000 tonnes of R404A deployed throughout the food chain in the UK. More details on this can be provided on application to BRA/FETA.
- There are 8 000 to 12 000 multi evaporator refrigeration systems in retail premises in the UK. In addition, there are a similar number of single compressor systems in commercial and/or retail premises. The majority of these use R404A as the working fluid.
- Migration away from R404A can be done with a new system using a low GWP gas, or by replacing the gas in an existing system.
- For example, to change 10% of the present number of R404A systems each year is the fastest it is reasonable to consider that the switch-out can be done. A working hypothesis would be that half of these are replaced by new systems using a low GWP refrigerant, and the other half by retrofitting to one of the refrigerants covered in this report. If this were to be achieved, migration away from R404A systems would not be completed until 2025.
- To keep the remaining R404A systems going, it will be necessary to use the R404A taken from retiring systems for servicing the remaining R404A population. The period of maximum stress will be when new (virgin) R404A becomes short and there are still a large number of R404A systems in the population. This is likely to be around 2019 to 2021 and may be as early as 2018.

4. Refrigerant Gases and Their Attributes

General notes on the following tables

- Where cells are empty, the necessary information is not to hand at the time of writing.
- Glide is calculated as the temperature difference between bubble and dew points at 1 atmosphere pressure.
- It should be noted that, whilst this report focuses on R404A, all comments concerning R404A are equally applicable to other high GWP refrigerants, such as R507.

4.1 Attributes of the Refrigerant Gases under consideration for replacing R404A

				Potential R404A Replacements		
	Gas	**R404A**	**R507**	**R452A**	**R407A**	**R442A**
GWP		3922	3885	2140	2107	1888
Toxicity Classification		A	A	A	A	A
Flammability Classification		1	1	1	1	1
Actual/Anticipated Main Use		Frozen and Chill	Frozen and Chill	Frozen and Chill	Frozen and Chill	Frozen and Chill
Glide K		0.8	None	3.8	6.4	6.6
Comment on Capacity Change as Result of using RX in place of R404A		Benchmark	Essentially Same as Benchmark	Capacity needs to be checked using Compressor Manufacturer's Published data for the intended operating conditions		
Comments				Suggested Use is replacement for R404A in transport refrigeration	Higher discharge gas temperature and may require additional cooling liquid injection at low temperature)	
Pressures compared with R404A/R134a		Benchmark	Marginal Increase over R404A	Slightly higher than R404A	Marginal Increase over R404A	Slight Increase over R 404A
Pressure corresponding to 32 deg C in Barg		14	14.3	14.7	14	c. 15.9
Pressure corresponding to 55 deg C in Barg		24.8	25.4	25.9	25.2	c. 27.2
Material Compatibility with parts used with R404A		Benchmark	OK	OK	OK	OK
Oil		POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	POE/PVE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used

4.1 Attributes of the Refrigerant Gases under consideration for replacing R404A (continued)

	Potential R404A Replacement			
	Gas	**R407F**	**R449A**	**R448A**
GWP		1825	1397	1387
Toxicity Classification		A	A	A
Flammability Classification		1	1	1
Actual/Anticipated Main Use		Frozen and chill		
Glide K		6.4	6.1	6.1
Comment on Capacity Change as Result of using RX in place of R404		Capacity needs to be checked using Compressor Manufacturer's Published data for the intended operating conditions.		
Comments		Higher discharge gas temperature and may require additional cooling liquid injection at low temperature		
Pressures compared with R404A		Marginal Increase over R404A	Marginally Lower Than R404A	Marginally Lower Than R404A
Pressure corresponding to 32 deg C in Barg		14.7	14.3	14.4
Pressure corresponding to 55 deg C in Barg		26.2	25.3	25.2
Material Compatibility with parts used with R404A		OK	OK	OK
Oil		POE/PVE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used

4.2 Attributes of the Refrigerant Gases under consideration for replacing R134a

		Reference	Potential R134a Replacement			
	Gas	R134a	R513A	R450A	R1234ze	R1234yf
GWP		1430	631	605	6	4
Toxicity Classification		A	A	A	A	A
Flammability Classification		1	1	1	2>2L	2>2L
Actual/Anticipated Main Use		Established Refrigerant	Chill Applications	Chill Applications	Chillers	Car AC
Glide K		None	None	0.4	None	None
Comment on Capacity Change as Result of using RX in place of R134a		Benchmark	Capacity needs to be checked using Compressor Manufacturer's Published data for the intended operating conditions.			
Comments		Refrigerant much less dense than R404A so larger cylinder volume in compressors (or equiv) required for same capacity	More suitable as a R134A replacement than as replacement for R404A Chill not frozen		Mildly flammable (A2L) presently A2. See section 6	
Pressures compared with R134a		Benchmark	Slightly higher than R134a	Lower than R134a	Lower than R134a	Similar to R134a
Pressure corresponding to 32 deg C in Barg		7.2	7.6	6.3	5.1	7.3
Pressure corresponding to 55 deg C in Barg		14.0	14.5	12.3	10.3	13.7
Material Compatibility with parts used with R134a		Benchmark	OK	OK	OK	OK
Oil		POE/PVE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	Modified Special Purpose Oil. Ensure Acceptable Additives Used	Modified Special Purpose Oil. Ensure Acceptable Additives Used

4.2 Attributes of the Refrigerant Gases under consideration for replacing R134a (continued)

		Potential R134a Replacement		
	Gas	**R600a**	**R290**	**R1270**
GWP		3	3	2
Toxicity Classification		A	A	A
Flammability Classification		3	3	3
Actual/Anticipated Main Use		Iso-butane Small Domestic Fridges	Propane Small Commercial Freezers	Propylene Small commercial fridges and freezers
Glide K		None	None	None
Comment on Capacity Change as Result of using RX in place of/R134a		Capacity needs to be checked using Compressor Manufacturer's published data for the intended operating conditions		
Comments		Flammable – A3. Quantity limits in one machine.		
Pressures compared with R134a		Lower than R134a	Higher than R134a	Higher than R134a
Pressure corresponding to 32 deg C in Barg		3.3	10.3	12.7
Pressure corresponding to 55 deg C in Barg		6.7	18.0	21.8
Material Compatibility with parts used with R404A/ R134a		OK	OK	OK
Oil		MO/AB/POE but possibly higher viscosity. Ensure Acceptable Additives used	MO/AB/POE but possibly higher viscosity. Ensure Acceptable Additives used	MO/AB/POE but higher viscosity likely. Ensure Acceptable Additives Used.

4.3 Attributes of the Refrigerant Gases of potential interest for new commercial systems

		Other Potentially Relevant Gases			
	Gas	**R410A**	**R32**	**R744**	**R717**
GWP		2088	675	1	0
Toxicity Classification		A	A	A	B
Flammability Classification		1	2>2L	1	2>2L
Actual/Anticipated Main Use		Air Conditioning and Chill	Air Conditioning	Carbon Dioxide	Ammonia needs new machinery
Glide K		None	None	None	None
Comment on Capacity		Capacity needs to be checked using Compressor Manufacturer's Published data for the intended operating conditions		N/A	N/A
Comments		High discharge gas temperature. Not suitable for low temperature application. Different compressor construction required because of high pressures.	Mildly flammable (A2L) (see section 6)	Carbon Dioxide refrigeration design is similar to conventional HFC design for the lower part of a cascade system (i.e. from chill to frozen.) The upper part is different as it has to cope with both sub-critical and supercritical operation.	Ammonia systems need to be engineered as such Ammonia is a B2 refrigerant – i.e. toxic and inflammable. It is incompatible with copper so motor windings and pipes have to be made of aluminium and steel respectively.
Pressures compared with R404A		Significantly higher than R404A			Lower than R404A
Pressure corresponding to 32 deg C in Barg		18.8	19.3	30 degs 71.1 on verge of supercritical	11.4
Pressure corresponding to 55 deg C in Barg		33.3	34.2	Supercritical	22.1
Material Compatibility with parts used with R404A/ R134a		OK	OK	OK	Copper is an issue
Oil		POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	POE Ensure Acceptable Additives Used	MO/PAO/HCMO. Ensure Acceptable Additives used.

4.4 Commentary on Tables 4.1 - 4.3 above – system aspects relevant to refrigerants

4.4.1 Global Warming Potential (GWP)

The GWP of a refrigerant is a calculated value of the potential of 1kg of that refrigerant to contribute to global warming if released into the atmosphere, compared to the global warming effect of 1kg of carbon dioxide, over a given time period. This is the number on which bans and phase-downs are based. The values are taken from the IPCC AR4 report.

4.4.2 Toxicity and Flammability

Gases are categorized A, B or C according to their toxicity. They are categorized 1, 2 or 3 according to their flammability.
In both cases the lower category (A or 1) refers to the safest.

All refrigerants need care. There are limits on the amount of flammable refrigerant that can be used in one system. At present the degree of flammability is indicated by a number - 1, 2 or 3. Refrigerants rated 1 have no flame propagation; those rated 2 are flammable and those rated 3 are highly flammable. In the US there is now a rating of 2L to cover the mildly flammable family of HFO refrigerants. It is expected that the 2L rating will be adopted in Europe within the next two years. The addition of the 2L rating may allow lesser restraints on systems that use such refrigerants than are presently applicable to all category 2 refrigerants. The designation 2>2L is used in the tables to show that a gas is expected to be put into the 2L category once the 2L category is available.

It is possible to use small quantities of highly flammable refrigerants in small integral applications such as integral refrigerators and freezers as used in domestic situations. This is done to a considerable extent already.

4.4.3 Glide

When a refrigerant is a blend of substances whose boiling points at any given pressure vary, there may be a temperature range at which boiling occurs. The difference between the temperature at which boiling starts and that at which complete dryness (i.e. the refrigerant is totally in the vapour phase) occurs is referred to as glide.

At a given pressure, the temperature at which boiling starts is referred to as the Bubble Point; the point at which dryness is reached is called the Dew Point. The temperature glide is the difference between these two temperatures.

It is important that refrigerant leaving an evaporator is completely in the vapour phase. This means that the superheat setting of the expansion valve needs to be set to give the amount of superheat that is required above the Dew Point of the refrigerant. Similarly, in a condenser, it is important that the refrigerant is completely in the liquid phase at exit.

It is important to understand the implications of glide in the evaporator. Whereas with a near azeotrope, like HFC 404A, the refrigerant boils at a nearly constant temperature in the evaporator, with the refrigerants being discussed the evaporating temperature continuously increases through the evaporator. Thus in order that the evaporator absorbs the same amount of heat as when used with HFC 404A, it is necessary that the average evaporating temperature be the same as the HFC 404A evaporating temperature. On multi-compressor pack systems this can be achieved by adjusting the evaporating pressure of the system.

This will be discussed in a Refrigerant Glide Fact Finder available from the BRA.

4.4.4 Capacity Effects

Retrofitting may alter the capacity of a system either up or down. This occurs in three ways:–

- The effect of glide on the evaporators
- The thermodynamic properties of the gases
- Differences in pressure changes in the pipework.

The effect of glide has been described in 4.4.3 above.

The thermodynamic effects of the gas in conjunction with the compressor can be seen from compressor manufacturers' published data. The pressure drops as refrigerant flows through pipes, particularly suction pipes, is a critical factor in refrigeration systems. If the flow is too slow, oil can get left behind in the pipe and not be returned to the pack. This happens if the diameter of the pipe is too large.

If the pipe is too small, there is excessive pressure drop. This means the suction pressure at the pack will be lower than is optimal in order that the pressure at the cabinets is at the level required by the cabinet design. With the gases referred to earlier in this report, pressure drops are not expected to be sufficiently different from those using R404A to cause problems.

When considering capacity, it is important to realize that systems spend very little of their time operating at full capacity. In a multi-compressor pack system, it is rare to see all the compressors working at the same time. With a single compressor system, it is rare to see a situation where the compressor is running continuously and not cycling off for a significant proportion of the time. If full capacity is required, it is rarely needed for long. The thermal inertia of food product can be expected to restrict the amount by which the temperature of the load increases and the cooling deficit will be recovered once the high load period has passed.

All the refrigerant manufacturers publish guides as to how refrigerant replacement should be performed. They should be followed assiduously. Since the operation is likely to take some time and there will be no refrigeration from the system during this time, appropriate provision must be made for the product normally held in the cabinets, etc. forming part of the system.

4.4.5 Pressure comparison

For refrigerant substitution, it is essential that the system can withstand the operating/design pressures of the replacement refrigerant. Obviously, this is only a potential problem if the pressures with the new refrigerant are greater than they were with the previous one.
[This is particularly relevant with Carbon Dioxide, where the pressures are very much larger than with other refrigerants considered in this document. It must be noted that Carbon Dioxide cannot be regarded as a replacement refrigerant in existing R404A systems.]

4.4.6 Material Compatibility

No issues have been raised about compatibility between the materials conventionally used in R404A or R134a systems and the listed refrigerants, except for Ammonia (R717) which is incompatible with copper leading to a large number of changes. This means that it can only be used in a complete system replacement.

4.4.7 Performance Data Availability

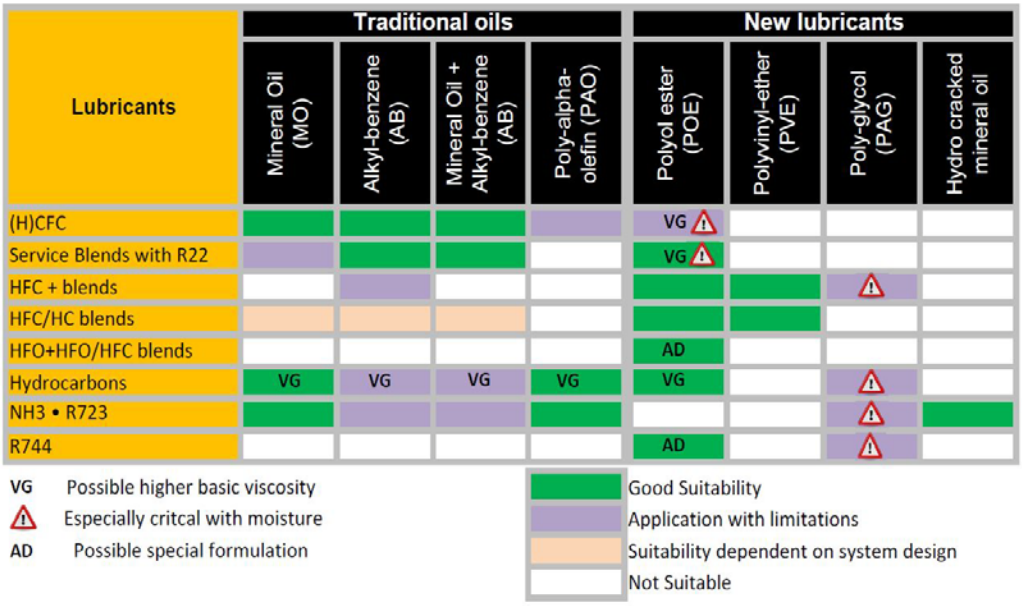
For the replacement refrigerants referred to in this report, compressor manufacturers have completed testing of their current products and have included performance data in their software. Other component manufacturers are gradually adding data for their range of compressors.

4.4.8 Oil

The appropriate basic types of lubricants for each gas are shown in the chart below. These include Polyolester (POE), Polyvinyl Ether (PVE), Mineral Oil (MO), Poly-alpha-olefin (PAO), Hydro Cracked Mineral Oil (HCMO).

However, all the lubricant companies put their own mix of additives into their products. It is imperative that advice is taken from the lubricant supplier and the compressor supplier about the detail of the oil to be used. Lubrication failure is the most prevalent cause of compressor breakdown so choice of oil is a crucial component in defining any strategy to deal with gas change to enable the continuance of systems.

The compatibility of oils with the different refrigerant types is outlined by a compressor manufacturer in the diagram below.



Above information equates to a generic approval however for specific grades/formulation advice from equipment manufacturers must be sought

4.4.9 "O" Rings

"O" rings throughout a system may develop leaks at the time of a refrigerant change, or for reasons of age, but only become apparent at refrigerant change time. (This is particularly true with changes from R22, which are not the main subject of this document, but for completeness are mentioned. It should be noted that if a change is from R22 [which contains chlorine atoms and is hence now unacceptable], to a non-chlorine containing compound such as R407 series or R448A or R449A, an oil change is also required.)

5. Consequences of Changing Refrigerant – System Aspects Relevant to Components

NOTE: The comments made in Section 5 refer to Fluorocarbon refrigerants ONLY

5.1 Compressors

In general compressors will work with different refrigerants. The current R404A alternatives may result in higher discharge temperatures which are likely to have an effect on the operating envelope. This has a greater impact on LT (frozen) applications.

There is, however, a problem with hermetic compressor applications currently running on R404A. Some approvals have been given to hermetic compressors operating with R407F at high temperature (evaporating down to -10°C). There is currently little published data for using alternative refrigerants at LT applications due to the potential of high discharge temperatures. A number of products are under development for this application, including some listed in this report.
The option of flammable refrigerants requires compliance with EN378 and will only be possible in specific applications.

Understandably, compressor manufacturers are very reluctant to use their testing capacity to generate characteristic tables for compressors that are no longer their current production. It should be possible to use the compressor manufacturer's software for comparing new refrigerants to old, as a guide to performance.

5.2 Heat Exchangers - Evaporators

It is important that the operating temperature of an evaporator is correctly defined. Temperature glide of the new refrigerant, the suction pressure set point at the pack and expansion valve setting all affect this.

The expansion valve needs to be set in such a way that the desired amount of superheat above the **dew point** of the refrigerant in use is obtained. To obtain the desired evaporator temperature, the suction pressure set-point of the system has to be set so as to give the **average of the temperature through the evaporator** at the required level

When retrofitting R404A systems, the effect of changes in temperature glide may require adjustment to the defrost control regime and/or the defrost thermostat.

In the case of capillary fed system, it may be that the system will work with a new gas, but the set up may not be optimum. Careful checks are recommended.

It is suggested that the manufacturer is consulted when selecting equipment for use with new refrigerants.

5.3 Heat Exchangers – Condensers

The pressure rating of the condenser must be checked to ensure that it is adequate for the pressures of the new refrigerant.

For pack installations, the pressure set point setting for condensers must be changed to match the characteristics of the new refrigerant. It is important that the output of the condenser is in the liquid phase. This means the pressure set point needs to be lower than the pressure that equates to the bubble point of the refrigerant at design condensing temperature.

For single compressor installations, the condensing temperature is dependent on the ambient temperature of the air around the condenser. This, along with the load on the unit, will determine the balance point pressures for the system.

It is suggested that the manufacturer is consulted when selecting equipment for use with new refrigerants

5.4 Expansion Valves

Major manufacturers of expansion valves have confirmed that they have expansion valves suitable for R407A and R407F. Valves are currently not available for refrigerants such R448A and R449A, but it is likely that manufacturers will release valves for these refrigerants in the near future.

In retrofit situations the current R404A expansion valves are likely to operate with some degree of superheat adjustment. Manufacturers' advice should be obtained where necessary. It is recommended that new systems are fitted with the correct valve for the new refrigerant.

Electronic Expansion Valves are likely to need their controllers reprogramming. In order to work correctly such devices do need a reading of suction pressure. Because of the temperature glide through the evaporator coil, it is not possible to take the temperature at a point in the coil and translate that to a pressure. So Electronic Expansion Valves using a pressure input should work with a small amount of reprogramming; any that use a temperature input from a point on the evaporator are not suitable for use on a system using a refrigerant with considerable glide.
In all cases, the superheat setting has to be the desired number of degrees above the dew point temperature.

5.5 Suction Pressure Settings at Compressor Pack

For pack systems, the Suction Pressure set-point for at the Pack needs to take into account the pressure drops along the suction lines. So, for example, if the required cabinet temperature is -20 degrees C and the Evaporator Temperature to achieve this is -24 degrees C and the glide of the refrigerant is 7 K and the pressure drop through the Suction Line is the equivalent of 2.5 K, the suction pressure set point at the pack needs to be the equivalent pressure to -30 degrees C **dew point**. This is made up of -24 less 3.5 (half the glide) less 2.5 (pressure drop along suction line).

For single compressor systems, there is only a pressure setting for the suction line below which the compressor is switched off. With a different refrigerant, the “off” set point needs to be checked to ensure that it corresponds to a pressure that is well below the intended evaporation temperature.

5.6 Other Valves – Ball Valves, Check Valves, Sight Glasses, Driers and Oil Systems.

A number of component manufacturers have confirmed in general that their valves are suitable for R407A and R407F. The situation with other refrigerants such as R448A and R449A is not yet defined, but it is expected they will release products for these valves in the near future.

5.7 Pressure Relief Valves

The table below provides information for pressure relief valve selection for use with new installations and retrofitting existing R134a and R404A systems. The pressures are based on minimum design pressures from EN378 in 32°C ambient conditions and the last two columns detail potential suitability of the valve under retrofit conditions.

As the valve selection criteria is based on the pressure setting and valve discharge capacity both sets of data have been provided. For retrofit applications, where the valve capacity is less than the R404A / R134a capacity it needs to be checked as a larger capacity valve may be required.

For new systems the appropriate valve should be obtained.

Refrigerant		Low Pressure side corresponding to 32 °C		High Pressure side corresponding to 55°C		Existing relief valve suitable (Yes or No)	
		Min Design Pressure bar-g	Capacity	Min Design Pressure bar-g	Capacity	Low Pressure side	High Pressure side
R404A		14.0	100%	24.8	100%	N/A	N/A
R404A Alternatives	R407A	14.0	93.5%	25.2	90.3%	Check capacity	No
	R407F	14.7	89.5%	26.2	85.8%	No	No
	R448A	14.4	100.0%	25.2	98.0%	No	No
	R449A	14.3	92.4%	25.3	89.3%	No	No
R134a		7.2 10.3*	100% 100%	14.0	100%	N/A	N/A
R134a Alternatives	R450A	6.3	91.4%	12.3	91.2%	Check capacity	Check capacity
	R513A	7.6**	103.2%	14.5	103.5%	Yes	No

Red Minimum design Pressure (as per EN 378) above that of R404A or R134a / capacity reduced, therefore potentially undersized

Green OK

* Relief valve minimum set pressure

** Assumes 10.3 bar is fitted

5.8 Pressure Switches and Fan Speed Controllers

All pressure switches and fan speed controllers should be checked and adjusted as necessary.

5.9 Pipe sizing and specification

Pipe sizing information is available from Refrigerant Manufacturers for the R404A alternatives. Initial comparisons suggest that the pipe size selection for the other gases considered is similar to R404A.

As the pressures for the alternative refrigerants (as per table 4.1 – 4.2) are very similar to R404A it is likely that the wall thickness will be the same. For further information on pipe wall thickness selection please refer to BRA Fact finder no 7.

5.10 Oil Separators

Oil and equipment come together in the lubrication issue. Advice is needed from the suppliers of all the components and lubricant suppliers in order to come to a conclusion on this matter. It is suggested that a preferred combination of refrigerant and oil is found with the help of the oil and compressor suppliers and then this is discussed with the oil separator supplier with a view to gaining advice on the best separator for the chosen oil/refrigerant combination.

5.11 Service Equipment – Recovery Units and Gauges, Charging Scales, Leak Detectors, Vacuum Pumps

Recovery Units suitable for R404A will be suitable for R407A and R407F. They are likely to be suitable for R448A and R449A.

Charging Scales will be suitable for any of the refrigerants.

Leak Detectors suitable for R404A will be suitable for R407A and R407F. The position with R448A, R449A and any other refrigerant containing HFOs needs to be checked with the Leak Detector Manufacturer.

Current vacuum pumps are suitable for R407A and R407F. It is expected that they will be suitable for R448A, R449A and other HFO blends as well, but manufacturers should be contacted for confirmation.

6 Overall Comment on Systems and Alternative Refrigerants

There are two considerations that influence decisions that have to be made.

- The first is what refrigerants should be put into systems that are being totally replaced, or installed for the first time.
- The second is what refrigerant should be put into systems which are going to be kept operating, but on a different refrigerant.

Although HFC refrigerants other than R404A will be permitted for servicing systems, the phase-down is likely to make higher GWP refrigerants progressively less available and more expensive**.**

For changing refrigerants in an existing system, the lower the GWP of the replacement refrigerant, the more secure the continuity of availability of servicing quantities of virgin refrigerant will be.

Care has to be taken with HFOs – R1234ze and R1234yf - because they fall into the A2 classification. – i.e. they are mildly flammable. This classification is expected to be relaxed when the A2L classification becomes available in EN378. There are likely to still be charge size restrictions. The pressure regimes for these gases are similar to those for R134a. Consequently, if used in frozen applications, there is a danger, as there is with R134a, that the suction side will be sub-atmospheric. This needs to be addressed in the system design.

The hydrocarbons (R600a, R290 and R1270) have to be used in special ways because of the limitation of the amount that can be used in one system. This is because of their high flammability. This is not likely to change – the flammability level 3 restrictions will continue to apply to their use – i.e. special consideration and precautions have to be taken.

Other very low GWP refrigerants for use in new systems are Ammonia (R717) and Carbon Dioxide (R744). Ammonia is a B2 refrigerant. It is incompatible with copper; and there remains a reluctance to use ammonia in populated areas because of its toxicity, and, in certain concentrations, flammability (which may, in due course be rated 2L rather than, as at present, 2) and smell. Carbon Dioxide operates at comparatively high pressures and, at ambient temperatures above about 26^{o}C, is liable to operate transcritically.

For both Ammonia and Carbon Dioxide, the system designs are substantially different from those that have been used with traditional CFC, HCFC and HFC refrigerants. System designers have to take this into account when generating designs.

Appendix 1

Members of the Action Group

Mike Lawrence	Chairman and Editor Chairman of FETA and President of BRA	JTL Systems Ltd
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This report is aimed at helping those involved in managing the changes in refrigerants required by the EU F-Gas legislation. Readers are advised that they need to check with suppliers of any potentially chosen gases, lubricants and physical components before making any definite decisions.