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Carbon Trust Networks Project:

Food & Drink Industry Refrigeration Efficiency Initiative



Guide 4

R22 Phase Out and F-Gas Regulations

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R22 Phase Out and F-Gas Regulations

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The Food & Drink Industry Refrigeration Efficiency Initiative

is a

Carbon Trust Networks Project

Supported by	The Carbon Trust
Project managed by	The Food and Drink Federation
Participating organisations	Dairy UK British Beer and Pub Association Cold Storage and Distribution Federation Institute of Refrigeration
Project Consultants	Enviros Cool Concerns Star Technical Solutions
Published.....	July 2007

R22 Phase out and F-Gas Regulations

This guide will help you comply with important EU Regulations relating to:

1. Use of ozone depleting HCFC refrigerants such as R22.
2. Use of global warming HFC refrigerants such as R134a or R404A.

1. Introduction

There are two EU Regulations that could have a significant impact on the use of refrigeration in food and drink manufacturing companies in the UK. These are:

1. EU Regulation 2037/2000 on ozone depleting substances¹.
2. EU Regulation 842/2006 on certain fluorinated greenhouse gases (F-Gases)².

The Ozone Regulation came into force in 2000 and it has already banned the use of ozone depleting HCFC refrigerants such as R22 in new systems. R22 remains a very common refrigerant in existing systems used by food and drink manufacturers. The Regulation will ban the use of R22 as a “top-up” fluid for maintenance between 2010 (for virgin fluid) and 2015 (for recycled fluid). This is of crucial importance for many companies and means that all users of R22 and other HCFC systems need to consider alternative refrigerants or the purchase of new equipment.

The F-Gas Regulation is more recent, coming into force in July 2006. It relates to the use of HFC refrigerants such as R134a and R404A. It imposes various obligations on the operators of refrigeration plant using HFC refrigerants that apply from July 2007.

This Guide provides detailed information about the impact of these two Regulations and is designed to help food and drink companies develop an appropriate action plan.

This Guide is one of a series of eight being produced under the Food & Drink Industry Refrigeration Efficiency Initiative, a project sponsored by the Carbon Trust and supported by the Food and Drink Federation, the British Beer and Pub Association, the Cold Storage and Distribution Federation, Dairy UK and the Institute of Refrigeration.

The Guide is aimed at food industry staff who are not refrigeration experts. We have tried to avoid the use of specialist terms where possible. A Glossary is included in Appendix 1 to explain acronyms and technical terms. You may find it useful to discuss the issues in this Guide with your refrigeration plant maintenance contractor – see Guide G1 relating to maintenance contractors.

¹ The full text of the Ozone Regulation can be found at <http://www.dti.gov.uk/files/file29106.pdf>

² The full text of the F-Gas Regulation can be found at <http://www.dti.gov.uk/files/file30123.pdf>

2. Refrigerant Types

Before discussing the Regulations it is useful to have a quick reminder about refrigerant types. There are many different refrigerants used for industrial refrigeration systems. These fall into the types shown in Table 1.

Table 1 Refrigerant Types and Regulatory Impact

Type	Refrigerant Examples*	EU Regulation		Comments
		Ozone	F-Gas	
CFC	R11, R12, R502	✓	✗	These are already completely phased out - it is very unlikely you have any of these on site, except in very old domestic sized refrigerators.
HCFC	Pure fluids: R22 , R123, R124, R141b, R142b	✓	✗	R22 is very common in food factories
HCFC Blends with HFCs	Blends: R401A, R401B, R401C, R402A, R402B, R403A, R403B, R408A , R411B	✓	✓	HCFC blends were introduced in mid-1990s to help with CFC phase out. Most HCFC blends <u>also contain HFCs</u> , so these refrigerants are affected by <u>both</u> Regulations.
HCFC Blends with no HFCs	R406A, R409A, R409B	✓	✗	These uncommon HCFC blends do not contain any HFC components, so are only subject to the Ozone Regulation
HFC	Pure fluids: R134a , R32, R125	✗	✓	HFCs have been used since 1995 as alternatives for CFCs and HCFCs
HFC Blends	Blends: R404A, R407C, R410A , R413A, R416A, R417A, R422D, R423A, R507, R508, FX100, RS44, RS45, RS52	✗	✓	HFC blends are used because the properties of pure HFCs do not suit all refrigeration applications.
Other	Ammonia (R717) , CO ₂ (R744), Hydrocarbons (e.g. Propane)	✗	✗	Ammonia is quite common in the food industry and is not affected by these Regulations.
Trade Names	<p>Trade names are sometimes used instead of an "R-number". The trade name is often used with the relevant R number (e.g. Harp 408A), but in some cases the trade name incorporates a completely different number (e.g. R 401A is also Suva MP39)</p> <p>Common trade names:</p> <p>Suva MP39 (R401A), MP66 (R401B), HP80 (R402A), HP81 (R402B)</p> <p>Isceon 69S (R403A), 69L (R403B)</p> <p>Dupont Isceon MO29 (R422D), 39TC (R423A), MO49 (R413A), MO59 (R417A), MO79 (R422A), MO89</p> <p>Forane FX10 (R408A), FX56 (R409A), FX57 (R409B), FX100 (R427A)</p> <p>RS RS24, RS44 (R424A), RS45, RS52 (R428A)</p> <p>Greencool, Harp, Klea</p>			

* The more commonly used refrigerants are shown in bold

3. Relevant Aspects of the Ozone Regulation

The Ozone Regulation addresses a wide range of ozone depleting chemicals used in many different end user markets. For operators of refrigeration systems in food and drink companies, there are two key clauses that are already in effect. These are:

- a) The use of CFCs for plant maintenance was banned in 2000. Effectively this meant that all industrial plant using CFCs had to be replaced by the end of 2000
- b) The use of HCFCs (including R22) in new refrigeration systems was banned between 2000 and 2004 (the exact date was dependant on the type of application – for large industrial equipment the ban started by January 2001). This means that all R22 refrigeration equipment currently in use in food factories is at least 5 years old.

Five further clauses in the Regulation affect the use of existing HCFC systems. These are:

- c) Use of virgin HCFCs for maintenance will be banned from December 31st 2009.
- d) The quantity of virgin HCFCs that can be sold in the EU is restricted. For example, in 2008 the amount available for sale will only be 25% of that available in 2001.
- e) Use of recycled HCFCs for maintenance will be banned from December 31st 2014. This date is subject to a review to be completed in 2008. This means that recycled HCFCs may be phased out earlier than the end of 2014.
- f) Operators of HCFC refrigeration systems must take “all precautionary measures practicable” to prevent leakages. Any system containing more than 3 kg of HCFC refrigerant must be checked annually for leakage, by suitably qualified personnel. Any HCFC refrigerant removed from a system during maintenance or at end of life must be properly recovered for re-use, recycling or destruction.

The phase out of virgin HCFCs at the end of 2009 could have significant implications for many food and drink manufacturers. A recent survey of 350 food and drink factories (carried out for Carbon Trust in 2005) showed that 70% of sites have at least one refrigeration system using R22. In most cases these refrigeration plants are of strategic importance as they are providing crucial process cooling or freezing.

It is important that R22 users begin to plan for the phase out of R22. There is little time available before the 2009 phase out date. It is dangerous to rely on the 2014 phase out date for recycled R22 because:

The date might be brought forward by 2 or 3 years during the review process.

There is no guarantee that sufficient supplies of recycled R22 will be available.

Recommendations to users of R22 and Other HCFCs

1. Start planning for HCFC Phase Out now. This will ensure you have time to consider the most appropriate options and will enable you to minimise the cost implications. It will also give you time to properly budget for any investments required.
2. Ensure you are complying with the leakage and recovery obligations (see (f) above). Most food industry plants contain more than 3kg, so you need to check for leaks.

Further details on these recommendations are in Section 5 of this Guide.

4. Relevant Aspects of the F-Gas Regulation

The F-Gas Regulation addresses the use of HFCs and other gases in a number of different end user markets. The Regulation came into force in July 2006. For operators of HFC refrigeration systems in food and drink companies, the key obligations come into force 12 months after the Regulation i.e. in July 2007.

Who is responsible for complying with the Regulation?

The main responsibilities are held by the “Operator” of the equipment. The Regulation defines the operator as follows:

“Operator means the natural or legal person exercising actual power over the technical functioning of the equipment and systems covered by this Regulation”.

For most food factories the operator is the owner of the factory. The phrase “*exercising actual power*” is important – it usually places responsibility with the owner, even if there is a comprehensive maintenance contract in place. The owner can transfer responsibility to a third party if a contract, with explicit clauses related to the F-Gas Regulation, is put in place.

An area of potential ambiguity is in landlord-tenant relationships e.g. in an air-conditioned office building. In these circumstances you may need to refer to the legal responsibilities set down in the lease – this would normally specify the party who is responsible for the operation and upkeep of the air-conditioning system.

A summary of the obligations in the Regulation for refrigeration plant operators is as follows:

- a) **General obligation to prevent leakage.** Using all measures which are “technically feasible and do not entail disproportionate cost” operators must: (i) prevent leakage of HFC refrigerants and (ii) as soon as possible repair any detected leakage.
- b) **Regular Leak Testing.** Plants must be checked for leakage by certified personnel on a regular basis. “Checked for leakage” means that the equipment or system is examined for leakage using direct or indirect measuring methods, focusing on those parts of the equipment or system most likely to leak. The frequency of testing depends on refrigerant charge:
 - Plants with 3 kg to 30 kg of HFC refrigerant must be checked annually.
 - Plants with 30 kg to 300 kg must be checked once every 6 months.
 - Plants with more than 300 kg must be tested once every 3 months.

Plants must be rechecked within one month after a leak has been repaired to ensure that the repair has been effective.

Plants with more than 300 kg must be fitted with an automatic leakage detection system, which is defined as: “a calibrated mechanical, electrical or electronic device for detecting leakage of refrigerants which, on detection, alerts the operator”. The detection system must be checked at least once a year to ensure proper functioning.

For any plant fitted with a leakage detection system, the frequency of leak checking can be halved, although an annual check remains the minimum frequency.

Examples of Automatic Leak Detection Systems

1. A fixed multi-point gas detector system, sampling air in a number of locations using a gas detector that will detect the relevant refrigerant.
2. An “indirect” system that monitors parameters in the refrigeration system (such as pressures, temperatures and liquid levels) and calculates whether a leak is present.

c) **Maintaining Records.** Records must be kept about each system with more than 3 kg of HFC refrigerant. The records must include:

- The quantity and type of HFC refrigerants installed in each system;
- Any quantities of refrigerant added;
- The quantity of refrigerant recovered during servicing, maintenance and final disposal;
- Other relevant information including the identification of the company or technician who performed the servicing or maintenance, as well as the dates and results of leakage checks and leakage detection system checks;
- These records shall be made available on request to the competent authority and to the Commission.

A sample record sheet is included in Appendix 3 of this Guide.

d) **Gas Recovery.** If refrigerant needs to be removed from a system (e.g. to gain access to part of a system for maintenance or during system decommissioning at the end of life) it must be properly recovered by certified personnel. After recovery the refrigerant can be reused or sent for reclamation or destruction.

e) **Use of Adequately qualified staff.** Personnel carrying out any refrigerant handling, including leak testing or gas recovery must have a suitable refrigerant handling qualification, such as City & Guilds 2078 or a CITB refrigerant handling certificate.

f) **Labelling.** Any new refrigeration system placed on the market must be fitted with a label clearly stating the type and quantity of HFC refrigerant used.

Other Important Points

Stationary HFC refrigeration systems with less than 3 kg of refrigerant do not need to comply with (b) and (c) above. However, the other obligations i.e. (a), (d), (e) and (f) apply to all types of stationary HFC refrigeration system.

Almost all HFC equipment used in food factories will contain more than 3 kg of refrigerant, hence all of the above rules will apply to most installations. The only plants that are likely to fall below the 3 kg limit are very small “integral” plants such as a small chiller cabinet in a laboratory or “domestic” equipment used in offices and canteens.

“Hermetically sealed³” systems containing between 3kg and 6kg of refrigerant are exempt from item (b) above.

The majority of obligations in the Regulation do not apply to non-stationary applications (e.g. refrigerated lorries and containers). However obligations (d), (e) and (f) do still apply to non-stationary applications.

Recommendations to users of HFC Refrigeration

1. Check whether you are using HFCs and establish the amount of refrigerant in each system – this is important as it will affect which leak testing regime applies (see (b) above).
2. Start to keep the required records about each HFC plant.
3. Define an appropriate leak testing programme for each plant and ensure that it is carried out by suitably qualified personnel.

Further details on these recommendations are in Section 6 of this Guide.

³ A hermetically sealed system is defined as: “a system in which all refrigerant containing parts are made tight by welding, brazing or a similar permanent connection which may include capped valves and capped service ports that allow proper repair or disposal and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure”.

5. Planning for Phase Out of R22 and Other HCFC Refrigerants

As discussed in Section 3, a large proportion of food and drink manufacturing plants use HCFC Refrigerants. All HCFC equipment will be affected by the phase out of virgin HCFC for plant maintenance that comes into force at the end of 2009.

The options for operators of HCFC equipment fall into 3 groups:

- a) Replace the existing system with a new plant using a non-HCFC refrigerant.
- b) Modify the existing plant so that it can operate with a non-HCFC refrigerant.
- c) Carry on using the plant for another few years after 2009, relying on the possible availability of recycled HCFC refrigerant.

Each of these options has advantages and disadvantages that will be affected by site specific circumstances such as the age of the equipment and the efficiency of the existing plant. The characteristics of each option is summarised in Table 2.

Table 2 HCFC Phase Out Options

Option	Advantages	Disadvantages
1. Replace whole plant	<p>New plant can be designed to have best energy efficiency.</p> <p>New plant can meet your current and future cooling requirements and use the latest technology.</p> <p>New plant will have 20 to 30 year life.</p> <p>You can avoid using HFCs (e.g. can use ammonia, HCs or CO₂).</p>	<p>Most expensive option in terms of first cost.</p> <p>Longest implementation time.</p>
2. Modify plant to use a new refrigerant	<p>Fairly quick implementation.</p> <p>Probably much lower capital cost than plant replacement.</p>	<p>Efficiency might get worse.</p> <p>Not applicable to all plant designs.</p> <p>Some risks of reliability problems.</p> <p>Plant life not being extended.</p>
3. Use existing plant with recycled HCFCs	<p>Easy zero capital cost option.</p> <p>Avoids being an "early mover" – you can benefit from experience gained on other conversions.</p> <p>New technology options could enter the market in next few years.</p>	<p>Efficiency not being improved.</p> <p>This Option only delays your response – Option 1 or 2 must be adopted by the end of 2014.</p> <p>The 2014 date could be changed to an earlier phase out date.</p> <p>There is no guarantee of recycled HCFCs being available at reasonable cost.</p>

The selection of the best option needs careful consideration and will be influenced by your company's circumstances. In particular, if you are a company with lots of HCFC equipment at a number of sites then you can develop a corporate strategy that creates an appropriate mixture of all 3 options. As you begin to use Option 1 or 2 you can recover the old HCFC, have it reprocessed and create your own supplies to enable some use of Option 3.

THE PLANNING PROCESS

The following steps should be used in the planning process:

Step 1: Identify all equipment with HCFCs. An important step is to identify each individual system using HCFCs. Don't forget to check air-conditioning plants as well as process refrigeration and cold stores. In most cases you will be looking for equipment that uses R22. However, be on the look out for refrigerant blends that contain HCFC components. See Table 1 for details of different refrigerant types.

Step 2: Establish relevant information about each plant. The next step is to collect relevant data about each plant. This should include:

- Quantity of refrigerant in the system.
- Historical records of amount of refrigerant used to top up the system (this gives an indication of leakage rates).
- Age of the system; estimate of original design life of the system.
- Cooling load details – e.g. size, temperature level and variability of each cooling load.
- Plant design details – e.g. compressor types and size, evaporator and condenser type, materials of construction (e.g. copper or steel pipes?), type of lubricating oil.
- Plant performance – is the plant efficient; does it meet your current and future cooling requirements?

Step 3: Evaluate Phase Out Options. Using the information collected you can begin to assess different options. Some of the influencing factors are:

Age – an old plant should be replaced, but a young plant might be suitable for modification to an alternative refrigerant. If a plant is already relatively old e.g. >15 years, then plant replacement is likely to be the best option. If the plant is less than 10 years old then it could have a lot of life left in it and a refrigerant conversion might be a good option.

Performance – if the plant is known to be inefficient, unreliable or unsuited to the current and future cooling loads then plant replacement is likely to be the best option.

Plant design – some plants are not well suited to refrigerant replacement. For example, a large R22 water chiller with a flooded shell and tube evaporator (see Glossary) is unsuited to the alternative refrigerants which are blends (e.g. R407C). If, however, the evaporator is a "DX" design (direct expansion) then a blend like R407C might be suitable.

Plant already uses an HCFC Blend – if the existing plant is using one of the HCFC blends shown in Table 1 (e.g. R403A) then it is likely that the plant has already been converted from a CFC such as R12 or R502. This is because the HCFC blends were specifically designed as CFC refrigerant replacement options – they were only occasionally used on new installations. If the plant has already been through one refrigerant replacement it is probably not practical to consider another!

Avoiding HFCs – many HCFC alternatives are based on HFC refrigerants, usually a blend. Some companies might wish to avoid making investments in HFC equipment as these come under the F-Gas Regulation and are under a long-term threat of more stringent legislation, including the possibility of a ban. If you want to avoid HFCs by using refrigerants such as ammonia, HCs or CO₂ you will need to replace the existing plant. However, it must be recognised that use of these refrigerants may require extra capital investment e.g. for ammonia and HCs to address toxicity or flammability risks.

Using an Independent Refrigeration Expert

Evaluating HCFC Phase Out Options is a complex task. You should consider using an independent expert to do this for you – this Guide will help you ensure that they are doing a thorough job!

TAKING ADVANTAGE OF A NEW PLANT DESIGN

If you are considering plant replacement, then you have a good opportunity to ensure that you are buying a plant that precisely meets your current and future requirements and that is of maximum efficiency.

Before embarking on a new plant design we strongly recommend that you do a careful evaluation of cooling loads, to ensure these are properly understood. Cooling loads should be minimised whenever possible (e.g. through use of “free cooling” or through use of variable speed drives on evaporator fans and pumps). Loads at significantly different temperature levels should be cooled by separate refrigeration plants.

After you have done a proper cooling load assessment you will be in a good position to specify a plant that gives you the best year round efficiency. Don't just concentrate on the “design point” (i.e. the peak cooling load in the hottest ambient temperature). The plant will spend much of the time at much lower load and in cooler ambient conditions – good plant design can optimise performance under a wide range of common operating conditions, not just at the design point.

Further details about buying efficient refrigeration plant can be found in another Guide written under the Food & Drink Industry Refrigeration Efficiency Initiative (G2: Procurement of New Plant). Also, look at Guide S1 on Cooling Load Reduction.

When Buying New Plant: Life Cycle Costs Should Be Assessed

Don't buy a cheap plant that will cost a lot of money to run and be a liability for the next 25 years! Ensure that you maximise the efficiency to reduce running costs.

KEEPING YOUR EXISTING PLANT – REFRIGERANT CONVERSION OPTIONS

If you are considering keeping your existing plant going by a refrigerant conversion project, you must identify the options available to you. In almost all cases you will be evaluating the replacement of R22. You cannot convert to a completely different refrigerant like ammonia – the existing plant will be incompatible with this refrigerant. Your main options will be to use one of 3 categories of HFC refrigerant, i.e.:

- A pure HFC fluid such as R134a.
- An HFC blend that is often used in new systems, such as R407C or R404A.
- An HFC “Service blend” that has been specifically designed to be retrofilled into an existing R22 plant.

A significant issue is that most R22 systems operate with mineral lubricating oil, whilst many HFC refrigerants require polyol ester oil. It is time consuming and costly to change the oil in an existing system – the service blends are designed to avoid or minimise this problem.

Another important consideration is the difference between use of a pure fluid or a blend. Your existing R22 plant uses a pure fluid as the refrigerant. This means that evaporation and condensation take place at a constant temperature. Most HFC blends exhibit a characteristic called “temperature glide” – which means that evaporation and condensation takes place across a range of temperature instead of at constant temperature. For some plant designs a high temperature glide could cause problems and it would be inadvisable to replace the R22 with a new refrigerant blend with a high glide. In general this problem occurs on flooded and pumped circulation systems – which tend to be used on large plants such as blast freezers, cold stores and large liquid chillers. There is less of a problem with DX (direct expansion) systems – these can cope much better with a refrigerant with a temperature glide.

More details about the three main refrigerant conversion options are as follows:

Conversion using a pure HFC refrigerant. This is difficult because none of the pure HFCs have properties close enough to R22. The only realistic alternative is to use HFC R134a. This will require increasing the compressor capacity by about 30%. It may also require different lubricating oil and a number of non-metallic components to be changed (e.g. O-ring seals). To use R134a the plant will require significant modification, which will represent a large financial investment.

Conversion using an HFC blend that is often used in new systems. R407C is often used in new systems in place of R22, especially in direct expansion systems. It has properties that are quite similar to R22. It can also be used to convert an existing system. The use of R407C should require far less modifications than those described above for the use of R134a. However, it will be necessary to convert to a new type of oil and it may be necessary to change some seal materials. Other fluids that fall into this category include R404A and R507.

Conversion using an HFC “Service Blend”. A number of refrigerants have been specifically developed to be easily retrofilled into existing R22 systems. As well as having similar thermodynamic properties they also are designed either to require no oil change or a single oil change. In many situations these blends can be used simply by removing the old refrigerant and refilling with the new one followed by a few simple adjustments to certain controls on the plant. In some situations some components may need replacing (e.g. seal materials). Special care must be taken with flooded systems because of the temperature glide exhibited by these blends. The main options available are Dupont Isceon MO59 (R417A), Forane FX100, RS44 and RS52.

The performance of various R22 alternatives is shown in Table 3. The table includes Service Blends, other retrofillable blends and also refrigerants that would require a new plant or major modifications.

IS IT BEST TO AVOID USE OF HFCs?

If you are replacing an R22 plant then you can choose to use an HFC refrigerant or a “natural” alternative such as ammonia or CO₂. Currently the F-Gas Regulation contains no clauses that restrict the use of HFCs for refrigeration applications, with the exception of car air-conditioning where the current refrigerant (HFC 134a) will be banned from 2011. However, the F-Gas Regulation will be reviewed by 2011 to decide whether more severe restrictions on HFC use are technically and economically feasible. This places a small threat on the long term future of HFCs, especially for larger industrial systems.

Choosing the best option depends on the size of your cooling plant and the way in which refrigerant technology develops over the next few years. If you have a large plant (e.g. a large cold store or freezing facility) then ammonia should be given careful consideration. Ammonia has been a popular refrigerant in the food and drink industry for many years, implying that it is already a cost effective option. In many situations it is possible to design a highly efficient ammonia plant. This will minimise your emissions of greenhouse gases and “future-proof” the plant from possible legislative changes. If you are replacing a relatively small plant, then ammonia can become a rather expensive option, because of the safety precautions required and HFCs would usually be more cost effective.

An interesting development in recent years has been the re-emergence of CO₂ as a refrigerant. This has been used successfully on a number of food processing and cold storage applications and is definitely worthy of consideration, especially if heat recovery to produce process hot water could be an extra benefit.

Using ammonia, CO₂ or HCs brings a number of extra practical difficulties that might add to the capital cost of a plant, especially for small systems. Table 4 summarises advantages and disadvantages of these non-HFC alternatives.

Table 3 R22 Replacements and Alternatives – Relative Performance Characteristics

Important Notes:

- 1) All performance figures are normalised to R22 = 100
- 2) The capacity and efficiency comparisons are only indicative. They are based only on use of data from thermodynamic tables – they do not take into account any variation in heat transfer properties in evaporators and condensers.
- 3) Cycle comparisons are for single stage cycle with evaporating temperature shown and a condensing temperature of 30 °C, zero suction superheat, zero liquid sub-cooling and a compressor isentropic efficiency of 75%.

Refrigerant	Cooling Capacity at		Efficiency at		Oil change needed?	Temp glide °C	Comments
	-40 °C	0 °C	-40 °C	0 °C			
R22	100	100	100	100	n/a	Zero	
Service Blends (easily retrofillable in many circumstances)							
R417A Isceon MO 59	61	78	86	93	No	3	Designed for medium / high temperature systems.
R422A Isceon MO 79	83	99	88	90	No	3	Designed for low / medium temperature systems.
R422D Isceon MO29	70	87	82	91	No	5	Designed for water chillers.
R424A RS44	54	70	84	91	No	4	Designed for medium / high temperature systems.
RS45	80	93	83	93	No	1.5	Designed for medium / high temperature systems.
R428A RS52	91	102	83	92	No	<1	Designed for low / medium temperature systems.
R427A FX100	Data unavailable				One only	7	Designed for wide applicability.
Other HFC Blends (usually more difficult to retrofit)							
R407C	75	89	90	94	Yes	7	Designed for medium / high temperature systems.
R404A	92	102	83	92	Yes	1	Designed for low / medium temperature systems.
R507	99	106	85	93	Yes	0.1	Designed for low / medium temperature systems.
The following 3 fluids need major plant modifications or a new plant							
R134a	50	63	93	101	n/a	0	Best for medium / high temperature systems.
R410A	151	149	94	97	n/a	0.5	Best for medium / high temperature systems.
R717	93	108	100	103	n/a	0	Wide applicability.

Table 4 Non-HFC Alternatives

Option	Advantages	Disadvantages	Use in food and drink processing systems
Ammonia (R717)	Widely used and understood. Good performance and reliability.	Toxic and flammable: extra safety measures required. Cannot be used with copper components.	Widely used for large systems in process and storage applications.
CO ₂ (R744)	Very high capacity so smaller compressors and pipe sizes are used. Non flammable. Excellent heat recovery opportunities.	Very high pressure, requiring new components and a new type of system design. Very few engineers familiar with CO ₂ system design, installation and service. Toxic: safety measures required.	Very few installations. But potentially could be used in most applications in specially designed systems.
HCs, e.g. propane (R290), propylene (R1270)	Good performance and reliability. Non toxic.	Highly flammable: safety measures required. Flammability limits usage - charge size limited in many applications.	Very few industrial installations. But could be used in indirect cooling plant and small charge systems.

6. Implementing the F-Gas Regulation

The main clauses of the F-Gas Regulation are designed to reduce the level of leakages from HFC refrigeration plants. Historically, refrigeration plants have tended to leak quite badly; this was not thought to be a problem as it was easy and reasonably cheap to top up a system with extra refrigerant. Now it is realised that leakage of refrigerants is very damaging to the environment – allowing leakage of HCFCs and HFCs from food industry refrigeration plants is now illegal! CFCs and HCFCs caused damage to the ozone layer and HFCs are powerful greenhouse gases, which are a contributing factor to global warming. HFCs have a global warming impact that is thousands of times stronger than CO₂ as shown in Table 5.

Table 5 Global Warming Impacts

Refrigerant	Global Warming Potential (100 year basis)
CO ₂	1
HFC 134a	1300
HFC 404A	3260
HFC 417A	1970
Ammonia	0

Providing a refrigeration plant does not leak and that refrigerant is properly recovered from a plant during maintenance and at end of life, then the fact that a plant uses a refrigerant with a high GWP does not matter. It only damages the environment if it is allowed to enter the atmosphere – hence the emphasis on refrigerant containment in the F-Gas Regulation.

To minimise HFC emissions from refrigeration equipment it is necessary to do three things:

- 1) **Design the plant for minimum leakage, using components that do not leak.**
Historically this was not considered important and plants were built with leaky

mechanical connections (e.g. flared joints), poorly sealed valves, poor compressor shaft seals and poor piping layout (that often resulted in damage and leakage). Leak rates can be drastically reduced at little extra cost if a plant is designed properly!

- 2) **Maintain the plant adequately, checking for leaks and repairing them as soon as possible.** Historically small leaks have been allowed to continue – it was considered cheaper to top up the plant than to repair the leak. Under the F-Gas Regulation this will no longer be legal.
- 3) **Properly recover refrigerant whenever it is removed from a plant.** Historically it was a common practice to vent refrigerant to atmosphere when servicing a plant or at the end of plant life – this is now illegal.

The F-Gas Regulation is designed to overcome these historical bad practices. In addition to the legal requirements there are two financial drivers that should encourage you to minimise leakage anyway:

- HFCs are quite expensive refrigerants. They cost about the same per kilogram as a decent bottle of whiskey – not something to be wasted through leakage!
- A system that leaks is likely to be inefficient, which wastes costly energy, and be unreliable, which could cause lost production.

The steps involved in complying with the F-Gas Regulation are now described. The “set-up stages” (Steps 1 to 6) must be completed by July 2007 when the on-going testing regime and record keeping becomes mandatory.

Step 1: Identify all equipment with HFCs. Ensure you have a list of every item of HFC equipment in your company. Refer to Table 1 to help identify the HFC refrigerants.

Step 2: Establish how much refrigerant is in each system. This is a crucial step as it influences the way the F-Gas Regulation will affect you. Many systems have a name plate that states the amount of refrigerant. Alternatively the plant operating manual or commissioning records should have an item specifying the amount of refrigerant in the plant. If you do not have records of this type you need to estimate the amount of refrigerant in the system. The DTI have produced a Guide on this issue and have written a spreadsheet tool to help – we strongly recommend you make use of this Guide⁴. Alternatively, ask your maintenance contractor for advice.

Step 3: For all plants > 3kg define a leak checking regime. You should establish how leak checking should be carried out and who is qualified to do it. You may need to get expert advice about this. The periodic leak checks (see Section 4(b) for leak test frequency) need to be based on the use of portable test equipment (e.g. hand-held electronic HFC “sniffer”) and should check all locations where a leak is possible. The periodic tests should also include more general checks of system performance and should review whether any refrigerant has been added to the plant since the last test.

Step 4: For all plants > 300 kg fit leak detection equipment. The Regulation requires a leakage detection system, which is defined as: “a calibrated mechanical, electrical or electronic device for detecting leakage of refrigerants which, on detection, alerts the operator”.

Step 5: For all plants > 3 kg establish a record keeping system. This is a very important aspect of the Regulation that is designed to ensure that the whole process of leakage prevention is being properly managed. The required records are described in Section 4(c) and a record keeping template is shown in Appendix 3.

Step 6: Identify competent personnel to carry out leak checks and refrigerant handling. The Regulation specifies that personnel carrying out leak checks and doing work that involves

⁴ The DTI Guide and spreadsheet tool can be obtained at www.dti.etc.etc/refrigerants

handling refrigerants (e.g. removing refrigerant, topping up a system etc.) must have a suitable qualification. The exact nature of this qualification has not yet been defined by the EC or the UK Government. The City & Guilds Refrigerant Handling Scheme 2078 is an example of a qualification that is likely to be specified by Government for refrigerant handling. It is not yet clear whether someone performing a leak test but not actually handling refrigerants will need this qualification. For the latest guidance see Defra Guidance "EC Regulation No 842/2006 on certain fluorinated greenhouse gases" available from <http://www.defra.gov.uk/environment/climatechange/uk/fgas/index.htm>

Step 7: Implement the leak testing regime. From July 2007 onwards, ensure that you are carrying out leak tests at the appropriate intervals (see Section 4(b) for leak test frequency). If leaks are found these must be noted in the plant record and repaired as soon as possible. The plant must be rechecked for leaks within a month of repair. This is actually good practice for all systems now – leaking systems cost more to run.

Step 8: Ensure plant records are maintained and used to help reduce leakage. From July 2007 onwards, ensure that you are keeping appropriate records for each HFC system. The data can be used to identify any refrigerant plants that have regular leakage problems. These should be investigated to see if any design modifications can prevent leakage.

Step 9: Ensure refrigerant recovery is carried out during plant maintenance. From July 2007 onwards, ensure that if refrigerant is removed from a system (e.g. for maintenance or at the end of plant life) that it is recovered using appropriate equipment and is then re-used or sent for recycling or destruction. For most refrigerants this requires a special recovery machine that sucks the refrigerant out of the plant and condenses it into a storage cylinder. After recovery, refrigerant must not be vented to atmosphere. It can be treated in one of four ways:

- It can be re-used in the same system. This is a common procedure during maintenance. Some refrigerant is recovered to enable a part of the refrigeration circuit to be accessed. On completion the same refrigerant is refilled into the system.
- It can be recycled and used in another plant. Recycling is a crude cleaning process that removes contaminants such as lubricating oil and moisture. This can provide a sufficiently clean refrigerant for re-use in another plant, but it does not guarantee an exact composition. Recycling can be carried out in small scale equipment that is part of a recovery machine. Some refrigeration contractors have equipment to do this.
- It can be reclaimed. This is a more sophisticated process than recycling that ensures the refrigerant is returned to a specification the same as new refrigerant. Reclaim can only be carried out at a dedicated facility that can reprocess the refrigerant to remove all contaminants and reconstitute it to the original specification. This requires sophisticated plant. There are only a few facilities in the UK that can carry out refrigerant reclaim.
- It can be destroyed. This involves incinerating the refrigerant at a sufficiently high temperature to break it down into other chemicals that are not greenhouse gases. Refrigerant destruction is only carried out at a very small number of specialist incineration plants.

Appendix 1: GLOSSARY

Automatic leakage detection system	A permanently installed system that can detect a refrigeration leak and automatically alert the plant operator.
Blast freezers	A system used to freeze products using a blast of fast moving cold air.
CITB refrigerant handling certificate.	Construction Industry Training Board training qualification for refrigerant handlers.
City & Guilds 2078	City and Guilds training qualification for refrigerant handlers.
Compressor isentropic efficiency	A measure of the energy efficiency of a refrigeration compressor. It is the ratio of “ideal” energy consumption to actual energy consumption.
Cooling load	The total amount of cooling carried out by a refrigeration plant – usually made up of several individual heat loads.
Design point	The peak operating conditions for which a refrigeration plant is designed – usually at peak cooling load and maximum summer time ambient temperature.
F-Gas	Fluorinated gases which are global warming gases covered by the Kyoto Protocol. F-Gases include HFCs, PFCs and SF ₆ (ibid.)
F-Gas Regulation	A new EU Regulation that is aimed at preventing emissions of F-Gases.
Flooded shell and tube evaporator	A type of heat exchanger with refrigerant evaporating in a cylindrical shell and a substance being cooled being passed through tubes that run through the shell.
Free cooling	Using a “free” stream such as ambient air or water from a cooling tower or other source (e.g. a river or borehole) to cool a product without needing a refrigeration plant.
Gas Recovery	Recovery of refrigerant from a refrigeration system into a storage cylinder.
Hand-held electronic HFC “sniffer”	A device that can detect the presence of a refrigerant in the air near a refrigeration plant.
HCFC	Hydrochlorofluorocarbon. HCFCs are ozone depleting substances, being phased out under the Montreal Protocol and the EU Ozone Regulation. This is <u>not</u> a gas covered by the EU F-Gas Regulation.
Hermetically sealed system	A hermetically sealed system is defined as: “a system in which all refrigerant containing parts are made tight by welding, brazing or a similar permanent connection which may include capped valves and capped service ports that allow proper repair or disposal and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure”.

HFC	Hydrofluorocarbon, one of the types of F-Gas covered by the Kyoto Protocol.
Liquid chiller	A refrigeration plant designed to cool a liquid e.g. water or glycol.
Ozone Depleting Substance	A chemical that, if it is allowed into the atmosphere, causes damage to the Earth's stratospheric ozone layer.
PFC	Perfluorocarbon, one of the types of F-Gas covered by the Kyoto Protocol.
R134a	A commonly used HFC refrigerant, which is affected by the new EU F-Gas Regulation .
R22	A commonly used HCFC refrigerant, which is being phased out under the the EU Ozone Regulation.
R404A	A commonly used HFC refrigerant, which is affected by the new EU F-Gas Regulation .
Recycled Refrigerant	Old refrigerant recovered from an existing refrigeration plant and cleaned for re-use in another system.
Refrigerant blend	A refrigerant based on more than one component. Various refrigerant blends have been introduced to replicate the properties of pure refrigerants such as R22.
Service blend	A type of refrigerant blend that has been designed for easy retrofit into an existing refrigeration plant (e.g. to replace R22).
SF ₆	Sulphur hexafluoride, one of the types of F-Gas covered by the Kyoto Protocol.
Suction superheat	The temperature difference between the saturated evaporating temperature and the actual temperature of the refrigerant vapour entering the compressor.
Temperature glide	A characteristic of a refrigerant blend. Unlike a pure fluid, a blend does not evaporate at a constant temperature. It starts evaporating at one temperature (the "bubble point" and finishes evaporating at a slightly higher temperature (the "dew point"). The difference between these dew point and bubble point is the temperature glide.
Thermodynamic tables	Data tables available from refrigerant manufacturers defining various properties such as pressure/temperature relationships, densities, enthalpies etc.
Virgin Refrigerant	New refrigerant that has not been used previously.

Appendix 2: SOURCES OF FURTHER INFORMATION

Food and Drink Federation	Trade association for food and drink manufacturers.	www.fdf.org.uk
Institute of Refrigeration	Professional body for refrigeration and air conditioning engineers.	www.ior.org.uk
British Beer and Pub Association	Trade association for brewing and pub sector.	www.beerandpub.com
Dairy UK	Trade association for dairy sector.	www.dairyuk.org
Cold Storage and Distribution Federation	Trade association for the temperature controlled supply chain.	www.csdf.org.uk
British Refrigeration Association	Trade organisation for companies in the refrigeration and air conditioning industry.	www.feta.co.uk
Carbon Trust	Information and support regarding climate change issues.	www.carbontrust.co.uk
Guide 1	Appointing and managing refrigeration contractors.	www.ior.org.uk
Guide 2	Procurement of new plant.	www.ior.org.uk
Guide 3	Checklist for operational improvements.	www.ior.org.uk
Guide 4	HCFC phase out and F gas regulations.	www.ior.org.uk
Guide 5	Reducing heat loads.	www.ior.org.uk
Guide 6	Avoiding high head pressures.	www.ior.org.uk
Guide 7	Improving part load performance.	www.ior.org.uk
Guide 8	Reducing auxiliary fan and pump power.	www.ior.org.uk
EN378	Refrigerating systems and heat pumps. Safety and environmental requirements.	www.bsi-global.com
Refrigeration and Air Conditioning	Comprehensive text book covering all aspect of refrigeration and air conditioning.	ISBN 0-13-323775-3
GPG 278	Purchasing efficient refrigeration – the value for money option.	www.carbontrust.co.uk www.ior.org.uk
GPG 279	Running refrigeration plant efficiently – a cost saving guide for owners.	www.carbontrust.co.uk www.ior.org.uk
GPG 280	Energy efficient refrigeration technology – the fundamentals	www.carbontrust.co.uk www.ior.org.uk
GPG 347	Installing and commissioning of refrigeration systems.	www.carbontrust.co.uk www.ior.org.uk
GPG 364	Service and maintenance technicians guide.	www.carbontrust.co.uk www.ior.org.uk
RAC	Monthly subscription trade journal and year book.	www.emap.com
Bitzer	Refrigerants report.	www.bitzer.de/news

Appendix 3: F-GAS RECORD SHEET

The table below shows an example record sheet for compliance with the F-Gas Regulation. Records of this type must be kept for all refrigerant plants that contain more than 3 kg of HFC refrigerant.

General Information			
Plant Name		Reference No.	
Location of plant			
Cooling loads served			
Refrigerant Type		Refrigerant Quantity (kg)	
Plant manufacturer		Year of installation	
Refrigerant Additions			
Date	Engineer	Amount Added, kg	Reason for addition
Refrigerant Removals			
Date	Engineer	Amount Removed, kg	Reason for removal. What was done with recovered refrigerant
Leak Tests			
Date	Engineer	Test Result	Follow up actions required
Follow-up Actions			
Date	Engineer	Related to test on	Actions Taken
Testing of Automatic Leak Detection System (if fitted)			
Date	Engineer	Test Result	Comments