Hydrocarbons in Commercial Refrigeration

Introduction

Hydrocarbons are environmentally friendly efficient refrigerants for use in commercial refrigeration. Hydrocarbons are not new and were developed as refrigerants in the early 19^{th} century. However, hydrocarbons were quickly abandoned in favour of CFC refrigerants (R11, R12, R502) as they were easier to use having none of the flammability issues.

The emergence of concerns over damage to the ozone layer due to the chlorine content of refrigerants led to the banning of CFC's (R12, R502) and phase out of HCFC's (R22) through the Montréal protocol (superseded by the Kyoto agreement). This led to the adoption primarily of R134a and R404a refrigerants having the same ease of use as CFC's.

Recent attention has turned to the Global Warming Impact which focuses on the Fluorine content of refrigerants. The transition away from HFC's is not as straightforward and has led to industry looking a various technologies and chemical fluids to sustain the refrigeration process.

The reality is that where there were single solutions for all but specialist refrigeration needs, it is necessary to consider a more strategic view of refrigeration and refrigerants in the context of the application and environment. There is no single solution that will form the basis for all food service and storage applications.

In the opinion of Foster Refrigerator and validated by demands of large food service organisations is the emergence of a combined solution of hydrocarbon refrigerants for small unitary systems, the use of HFC for intermediate sized equipment and process applications and the possibility of CO_2 for large scale systems where economies of scale can justify the investment.

There has been considerable scaremongering in the commercial food service industry from organisations that do not offer hydrocarbon refrigerant solutions. These organisations are usually characterised as industry followers not industry innovators. To really tackle global issues around climate change and global warming and of course the escalating energy costs both manufacturers and end users must be prepared to innovate and embrace technology.

Foster Refrigerator has been instrumental in the introduction of Hydrocarbon refrigerants into commercial food service cabinets with the introduction of the first production model in 1996. Foster Refrigerator takes safety extremely seriously both in product manufacture and in use and since introduction Foster Refrigerator have maintained an unblemished safety record.

To address some of the concerns raised by other organisations please carefully read the following analysis. It must be stressed that although the analysis is focussed on Hydrocarbons most recommendations or guidelines represent good practice for the manufacture, service and maintenance of all types of refrigerants.

Scope of Analysis

This analysis is for hydrocarbon refrigeration systems produced by Foster Refrigerator and represent typical systems used in unitary food storage cabinets. These systems have a refrigerant charge weight of up to 200g. It does not cover larger systems using in excess of 1.0 kg which would need a separate analysis covering leak detection systems and a detailed location assessment.

Analysis of HC Application for H&S purposes

The purpose of this analysis is to assess the safety implications arising from the use of hydrocarbons in unitary commercial food service refrigeration equipment.

System Type

The DX system manufactured by Foster Refrigerator is classified as a direct system with the evaporator in direct contact with the air being cooled.

System Features and Components for Hydrocarbons

Propane is an A2 refrigerant based on flammability, toxicity and charge weight (ACRIB). Table 1 contains a review of key components and identifies the action taken to minimise both likelihood and severity of risk from using hydrocarbon on Foster product (ACRIB).

Component/Feature	Action
System design	Hermetic – fully sealed and tested within the manufacturing facility. Testing includes helium detection and evacuation test
Compressor	Dedicated hydrocarbon compressor and/or sealed thermal cut-out switch
Controller	Insulated terminals and/or located above leakage positions. Encapsulated relay switching
Ventilation	Ventilation allowing refrigerant to disperse in the event of a leak Air movement exceeding EN378 ventilation criteria
Fan motors	Brushless motor design No capacitor start motors used
Door switch	Encapsulated reed switch (where fitted)
Exposed electrical heaters	Prohibited
Lighting	Prohibited
Joints	Brazed joints used where possible with the exception of service ports
Internal component protection	All refrigerant containing components are protected by metal panels of 0.7mm thickness or fan grills
Identification	Labelling on the compressor, condenser and serial plate

Table 1 – System Review for Hydrocarbon Refrigerants

Compressors used for hydrocarbons are either dedicated hydrocarbon models or are R404a compressors where Foster has obtained dispensation from the manufacturer for their use with Hydrocarbons. Foster primarily use R290 refrigerant. R290 compressors are in fact R404a compressors with improved electrical safety and in some cases have different lubricants. Pre 2000 most hydrocarbons did indeed use R404a compressors due to the lag of the compressor industry however, **increase in volume and market forces have resulted in all major compressor manufacturers offering dedicated R290 compressors which are fully warranted and supported by the manufacturers to Foster.**

Location for Use

Systems will be located in an A category location i.e. un-restricted access to people who are not personally aquatinted with necessary safety procedures. This application is also referred to as domestic / public access.

Systems containing a refrigerant charge of 150 g or less can be located in any size of room in any location. Systems with a refrigerant charge of greater than 150 g but less than 1.5 kg are subject to a room size analysis to avoid high concentrations of hydrocarbons in the event of a leak.

Refrigerant Charge / Room Volume analysis

This analysis is based on a major release of hydrocarbon refrigerant with a short exposure time from a Foster R290 charged cabinet. It is made using information from EN378-1:2000 and ACRIB. It is based on a typical charge weight of 180g.

The reality of a sudden leak within a hermetic critically charged refrigeration system is highly unlikely however in the event that it could happen, the following analysis ensures that an explosive situation will not occur. Sudden release of refrigerant would require a rupture in the system. Testing has shown that the rupture pressure of a hermetic system is typically 90 barg.

The criterion is such that with a sudden loss of refrigerant the concentration of R290 in the surrounding space does not exceed 20% of the lower flammability limit.

Using the calculation: $m_r = 0.2 \times LFL \times V_{room}$

Where

m_r = maximum allowable refrigerant charge per separate circuit (kg) or actual charge weight (180 g)

LFL = Lower Flammability limit (for R290 [propane] = 0.038 kg/m^3)

V_{room} = Volume of the room in which the appliance is located (with no additional ventilation or airflow)

Rearranging,

$V_{room} = 0.18 / (0.2 \times 0.038) = 24\ m^3$ minimum room size

Based on a typical room height of 2.4m the minimum floor area is 9.9 m^2 (approx. 3.1m x 3.1m) assuming the room is sealed and the complete charge is released rapidly.

To avoid stratification in the event of a catastrophic leak, the condenser fan of the appliance or surrounding ventilation from air conditioning is required to disperse the refrigerant. The calculation shows that the condenser fan fitted to the appliance satisfies this criterion as follows:

$V_{air} = = C \times m_r / LFL$

Where

V_{air} = minimum required air flow rate from the ventilation device

C = constant (17 for the condenser fan & 20 for an air conditioning ventilation system)

$V_{air} = 17 \times 0.16 / 0.038 = 72\ m^3/hr$

Minimum condenser airflow for this appliance type = 250 m^3/hr (condenser fan data). **It must be noted that although additional ventilation has not been included in the calculation, in a room of this size, satisfactory system operation would not be possible without external ventilation due to the build up of heat from the refrigeration system.**

This analysis is per appliance. As a sudden release would not occur on multiple systems at the same time multiple appliances can be located together in the same room. The impact of a fire in one affecting the other is highly unlikely.

However this is considered in the following analysis. Table 2 shows the effect of an increase in the external temperature on the internal pressure within the system (for example; in the event of a fire). This shows that at a temperature of 90°C (well above occupancy tolerance) the system internal pressure is approximately 42 Bar. Therefore, the system pressure of 42 Barg is within the system rupture pressure.

R290 Refrigerant	
Temperature (^{o}C)	Pressure (BarA)
20	8.3
30	10.7
40	13.7
50	17.1
60	21.2
70	25.9
80	37.7
90	42.4

Table 2 – Effect of Temperature on System Pressure (Dept of Mech Eng – Univ. of Denmark)

Video footage from testing conducted by BOC shows that in the event of a fire, the support of fire by hydrocarbon refrigerants (with Approx. 50% of the charge weight of a HFC system) is equalled by the effect of a conventional refrigerant propelling the ferocity of fire from the increased charge weight.

Servicing

The products supplied by Foster Refrigerator are clearly labelled with the original refrigerant type. Similar to all refrigerants, it is the responsibility of the consumer to ensure that appropriately qualified service agents are employed to carry out any remedial work. A good starting point is to mandate the qualification of all engineers employed to maintain all refrigeration equipment including Hydrocarbons is C&G 2078. The repair of hydrocarbon refrigerants can be performed similarly to traditional HFC refrigerants as engineers do have a duty of care and to conduct a risk assessment of the surrounding environment relative to the service activity being performed although in many establishments' health & safety procedures prescribe the removal of all products where hot works operations are required.

There are no mandatory inspection periods. This equipment is too small to be covered by the F-Gas directive. However, the general recommendation for the service and maintenance of refrigeration equipment applies to ensure the systems are clean and are operating efficiently. The hydrocarbon is installed in a hermetic system so no intrusive maintenance is required.

Emissions

Hydrocarbons are fuels and are classified as Volatile Organic Compounds (VOC's). The release of VOC's is undesirable and can have adverse health effects. Also included in the list of VOC's are household products including paints, paint strippers, and other solvents; wood preservatives; aerosol sprays;

cleansers and disinfectants; moth repellents and air fresheners; automotive products; hobby supplies; dry-cleaned clothing.

In the context of refrigeration systems, hydrocarbons are used in hermetically sealed that are pre tested with helium during manufacturing. This compares favorably with household goods that are freely emitted into the environment in the pursuit of DIY and hygiene in both domestic and commercial premises. There is typically 100 - 200g of hydrocarbons which is less than will be found in a typical cleaning fluid bottle.

References

EN378-1:2000 - Refrigerating systems and Heat Pumps – Safety and Environmental Requirements

ACRIB - Guidelines for the use of Hydrocarbon Refrigerants in Static Refrigeration and Air conditioning

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For more detailed information …

BS EN 378:2000 - Refrigerating systems and heat pumps - Safety and environmental requirements, Institute of Refrigeration's (loR) Safety Code for Compression Refrigerating Systems.

- Institute of Refrigeration's Safety Code for Refrigerating Systems Utilizing Group A1 and A3 Refrigerants.

- Pressure equipment Regulations.
- British Refrigeration Association's Risk and Task Assessments.
- Material Data Safety Sheets for refrigerants, oils, oxygen, acetylene, nitrogen, brazing materials.
- Institute of Refrigeration Service Engineers Section.