R407C

The Engineers Guide

ZERO OZONE DEPLETING REFRIGERANT FOR AIR CONDITIONING AND HEAT PUMP SYSTEMS

MITSUBISHI
HEAVY INDUSTRIES, LTD.
air conditioning

INTRODUCTION

This Engineer's Guide has been compiled to provide essential information for consulting engineers and contractors involved in the application and design of split system air conditioning and VRF (variable refrigerant flow) multi systems.

There has been a great deal of publicity in the refrigeration and air conditioning industry about the phasing out of ozone depleting refrigerants, but very little information on the implications and safeguards of using HFC alternatives.

Manufacturers have been carrying out extensive research and testing, making engineering changes to air conditioning systems, to ensure optimum performance and reliability using the new refrigerants currently available from the major refrigerant producers.

Many people in the air conditioning industry are not aware of the characteristics and potential problems associated with the new refrigerants and the new refrigerant oils. There is a high risk of failure if the design of equipment is inadequate, or the installation does not take account of the additional precautions required to ensure a satisfactory operation. The dangers of potential long term equipment failure will inevitably damage the clients' perception of installed equipment, and of the industry in general.

Whilst this guide is concerned mainly with the application of R407C, the reader must be aware of other alternative refrigerants entering the market, notably R417A (ISCEON 59), which was introduced in 1997 as a "drop in" for R22. This refrigerant is now in common use, and has the key advantage of being compatible with the mineral oils used in R22 systems.

Just when we thought there was a clear long term policy for overcoming the phase out of CFCs and HCFCs, the DETR has now (March 2000) issued a consultation climate change policy document. This document describes HFCs as "not sustainable technology in the long term". The refrigeration and air conditioning industry, and the food processing, transport, storage and retail industries worldwide, have invested £billions in developing and implementing new technologies based on HFCs, are now very confused. No doubt there will be very strong objections to the proposals, but for the time being, and probably for another 15 years at least, HFC's will be the only viable alternative to ozone depleting refrigerants.

Mitsubishi Heavy Industries is one of the world's largest manufacturers of air conditioning systems, specialising in split systems and VRF systems. Its long history of engineering, and its association with exceptional reliability, are evident in the quality of its manufactured products, and in the culture of the many very experienced individuals involved in the extensive research and development facilities at Nagoya, Japan.

I am indebted to Mr Brian Overall who has combined his knowledge and experience in researching and gathering information for this publication. Thanks also to Mike Creamer, Business Edge for the P/E diagrams, and to Jacqui Burke and Andrew Faulkner, both of 3D, who helped with the production.

We hope this publication will benefit those involved in designing and installing air conditioning systems, which use R407C as the refrigerant. Attention to detail at the outset will benefit everyone in the long term.

John Roe
Managing Director
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Distributors of air conditioning equipment manufactured by **MITSUBISHI HEAVY INDUSTRIES**

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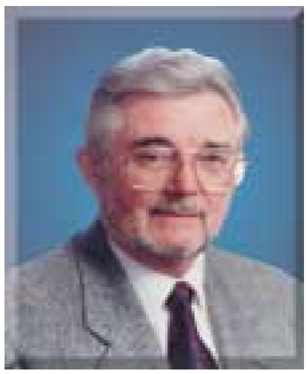

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Section 1

1.0 Overview of the Phase Out of Refrigerant 22

1.1 Refrigerants are the working fluid in any refrigeration system. They absorb heat from one source and reject it in another area usually through the evaporation and condensation processes respectively, due to phase changes. The chlorofluorocarbons – CFC's and hydro-chlorofluorocarbons HCFC's were developed as a range of non-toxic, stable, and (at normal temperatures) chemically inert refrigerants, and these refrigerants belong to a larger family of substances known as halogens. These refrigerants contained, amongst other elements, chlorine.

1.2 Refrigerants known as CFC12 (R12) and HCFC22 (R22) are stable, remain in the atmosphere for many years, and eventually diffuse into the stratosphere. In the upper atmosphere the refrigerant molecules breakdown and release chlorine, which destroys the ozone layer. In the lower atmosphere the molecules absorb infrared radiation and contribute to global warming. Each chlorine atom released can destroy up to 100,000 ozone molecules before it is removed from the stratosphere. Although the natural cycle of formation and destruction of stratosphere ozone continues, the additional rapid removal of ozone via man-made chlorine (and bromine) containing compounds accelerates the rate of destruction, thus leading to a nett depletion.

1.3 The Montreal Protocol (1987) is a landmark in environmental policy making. It was an international treaty designed on the basis of scientific evidence, to prevent rather than cure the problem.

The Montreal Protocol (1990) initially dealt with the phase out of CFC's,by the year 2000 including R12, which has an Ozone Depletion Potential index of 1.0. However, subsequent meetings and agreements within the EEC, the phase out date was brought forward to 1995.

1.4 Further meetings between the Member Parties of the Protocol and the EEC recognised the burden placed on industry as a whole by the rapid removal of CFC's, and allowed HCFC's as transitional substances. These were added to a list of controlled substances, althoughrefrigerant R22 has an Ozone Depletion Potential index of 0.055, which is 5% of that of R12.

1.5 The United Kingdom, along with other members of the European Union, has implemented the Montreal Protocol, through an EC Regulation, which is directly applicable in UK law. In general the European countries are keen to move faster than the Montreal Protocol, and EC regulations have been updated several times.

Under EC regulations CFC's were phased out a year ahead of the Montreal Protocol, and EC regulations 3093/94 proposal stated that HCFC would be regulated and controlled. However, revised proposals were put in March 1999. Table 1.1 overviews the requirements, availability and the recent proposals.

Table 1.1 EU HCFC Availability

Year	Estimated HCFC Requirement, ODP Tonnes	Amount Available in Article 4, ODP Tonnes	Revised Proposal 05/03/1999 ODP Tonnes (%)
1999	8079	8079	8079
2000	7869	8079	8079
2001	7403	6678	6678
2002	6387	6010	5676
2003	3631	2337	3005
2004	1985	2003	2003
2005	1891	2003	2003
2006	1797	2003	2003
2007	1703	2003	2003
2008	220	334	1670
2009	220	334	1670
2010	220	334	0
2011	220	334	0
2012	220	334	0
2013	220	334	0
2014	220	334	0

It can be seen that there is a mismatch between the requirements and proposed availability of HCFC's.

Recent negotiations regarding new EC regulations progressed at a meeting on the 21 December 1998, and the details of the new EC regulations are awaited.

1.6 Hydro fluorocarbons - HFC's are acknowledged by governments around the world as important replacements for CFC's and HCFC's.

HFC production will increase as HCFC's are phased out. Whilst refrigerant HFC407C (R407C) is at 03/99 some 20% more expensive than HCFC22 (R22), the price of R22 is progressively increasing.

Due to the reduced production of R22, there will no longer be the economies of scale, resulting in a high priced refrigerant, against R407C whereby the economy of scale in production will become effective.

Section 2

2.0 New Regulations - Impact on Refrigeration and Air Conditioning End Users

2.1 Under current regulations production and imports of CFC's (R12) are banned, and there are regulations regarding HCFC's in new refrigeration equipment.

Revised regulations, to be ratified by EC, are proposing that HCFC production now ceases in 2009. Production in this context includes the import of virgin material from non-European countries such as Japan, USA and Thailand etc.

2.2 The impact of the proposed regulations are detailed as follows:

1-1-2003 Cooling only air conditioning units and systems (under 100KW) HCFC R22 will be banned for all new installations.

1-1-2004 Cooling and heat pump units and systems (under 100KW) HCFC R22 will be banned for all new installations.

1-1-2008 Total ban on the production and importation of HCFC R22. The only available product for maintenance and repair will be reclaimed or recycled HCFC.

2.3 Fortunately, forward looking organisations have recognised the effects of these regulations. In the retailing, banking and property sector, CFC and HCFC refrigeration systems have already been replaced, or are programmed for replacement with HFC refrigeration systems.

2.4 The replacement programme is accelerating for AC equipment with HCFC's in older establishments, and all new establishments will have air conditioning with HFC refrigeration systems.

Section 3

3.0 Air Conditioning & Heat Pump Systems

Refrigerants, both HCFC and HFC, are commonly applied to air conditioning systems, heat pump systems, and VRF (variable refrigerant flow) multi-systems.

Single systems (one outdoor unit + one indoor unit) have a simple refrigeration cycle, with the main components, i.e. compressor, heat exchangers, expansion devices, fans, carefully designed and tested to perform at optimum efficiency in a range of climatic conditions.

Multi-Systems (non VRF), consisting of one outdoor unit + 2,3 or 4 indoor units, are designed with the same principle as above, with the indoor units operating in the same mode – either all heating or all cooling. It is necessary to balance the length of the various branch pipes, to ensure all indoor units receive the same volume of refrigerant.

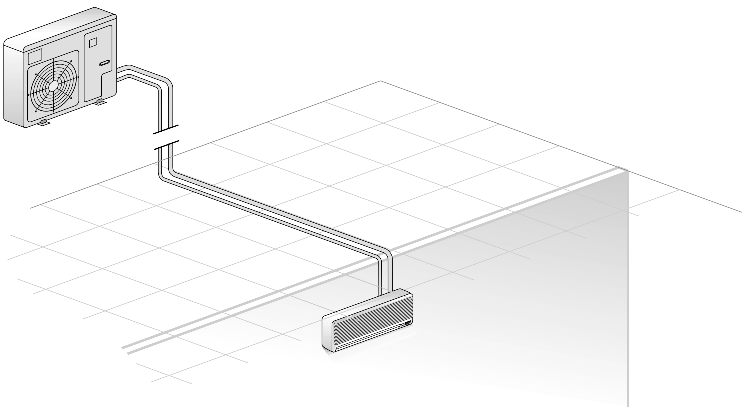
With the advancement of micro-processor technology applied to air conditioning systems, much of the control of the refrigerant, plus the protective devices, are temperature actuated through small thermistors linked to a central control board.

Single Split Systems

Single split systems range from 1.8KW cooling to 25.0KW. The SRK 'mini-split' range of cooling and heat pump systems is at the lower end of the price range, offering a simple low cost solution for small offices, shops, and for residential application.

The outdoor unit is connected by small bore copper piping, which carries the pressurised refrigerant to provide either heating or cooling at the indoor unit. Both pipes require insulation, to prevent condensation forming, and to ensure the system performs to its maximum efficiency.

The outdoor units are fully weatherproof, and are normally located on a flat roof, balcony, or wall mounted using suitable wall brackets.



Single Split Systems

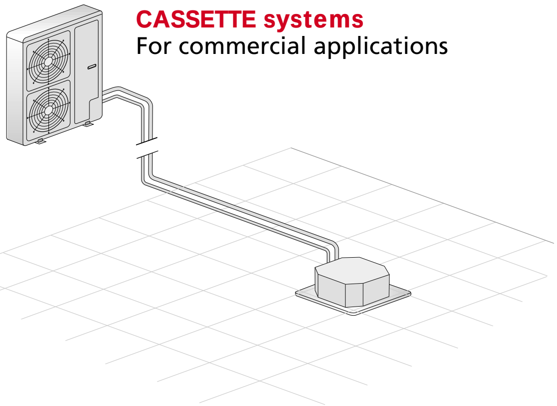
For larger applications, and where longer interconnecting pipe runs are required, a range of 'commercial specification' split systems are available (known as PAC type).

These have different indoor units, which can be selected by the designer to suit the building, and the client's requirements.

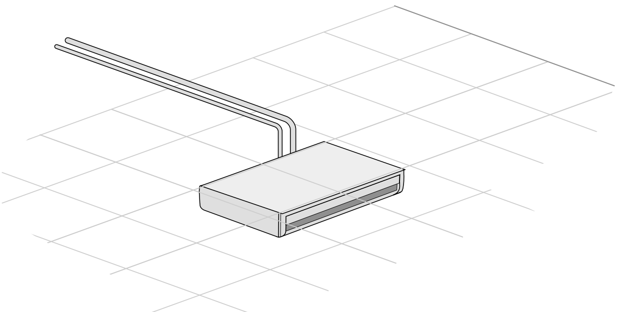
Cassette type indoor units, which are normally installed into a suspended ceiling, are very popular for shops, offices, restaurants, cafes, meeting rooms, fitness gyms, and laboratories.

A variety of other indoor units is available to suit different site requirements:

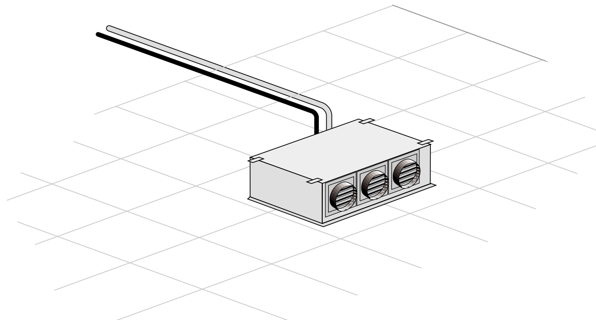
CASSETTE systems
For commercial applications



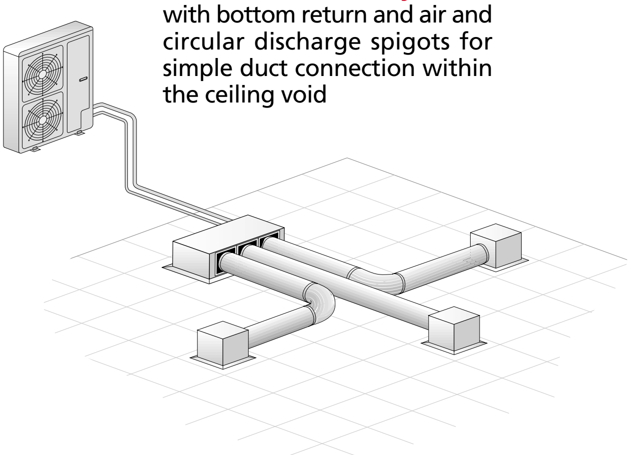
CEILING suspended units,
Where there is no ceiling void



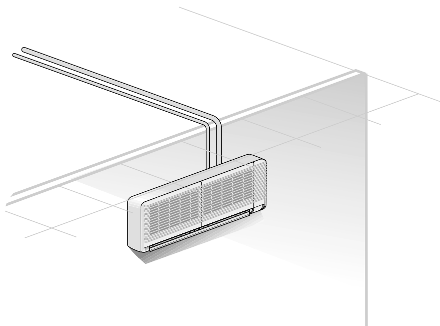
DUCTED units, with horizontal supply and return air, installed within a ceiling void



DUCTED CASSETTE systems,
with bottom return and air and circular discharge spigots for simple duct connection within the ceiling void



Wall mounted units,
installed at high level

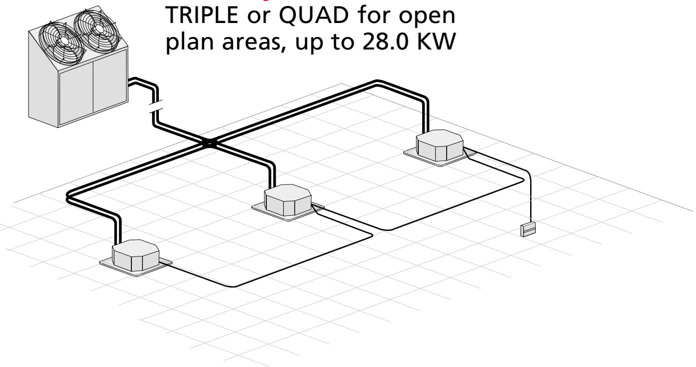


All Mitsubishi single systems for commercial application are available for cooling and heat pump operation.

Multi Split Systems

For larger open plan areas, Multi Split Systems provide a low cost solution for air conditioning and heating. Internal units (maximum four) are connected to one outdoor unit, and all units operate in the same mode together, i.e. all cooling/off or heating/off. The multi systems are designed for retail stores, convenience shops, fitness gyms, and other open plan areas, where individual control is not required. For large multiple applications, the number of outdoor units is reduced, as well as the amount of refrigerant piping entering the building, and the number of external power supplies.

Multi systems, -TWIN, TRIPLE or QUAD for open plan areas, up to 28.0 KW



VRF Multi Systems

Variable refrigerant flow multi systems are a very cost effective alternative to chiller/fan coil systems, both in terms of installed cost, and running costs.

The system originated in Japan to meet the demand for modular de-centralised systems with variable capacity for commercial buildings. Many large office buildings in Japan have in excess of 200 outdoor units, with up to 1800 indoor units. These buildings are both single tenant and multi tenant occupation, allowing simple billing methods for running costs for different zones within the building.

The vrf technology allows automatic variable capacity at each internal unit, the proportion of heating or cooling depending on the differential between the set temperature and the actual temperature in each conditioned space. The refrigerant in each internal unit is controlled by a Linear Expansion Valve, a motorised pulse-modulating valve, its opening setting determined by the microprocessor receiving information from the thermistor sensors in each unit. The internal units are linked by a two core control wire to the connected outdoor unit, which responds to the combined demand from the internal units, by varying its compressor speed to match the total cooling and/or heating requirements.

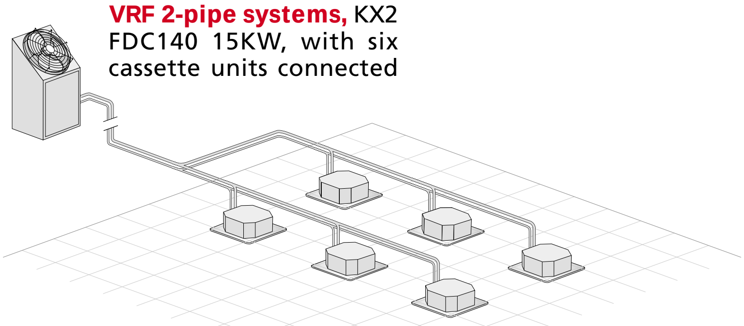
This type of control prevents large variations in room temperature compared to a simple on/off type of control. The 'fuzzy logic' control system constantly monitors the condition and temperature of the refrigerant in different parts of the system, to ensure optimum performance and efficiency.

VRF 2 Pipe Systems

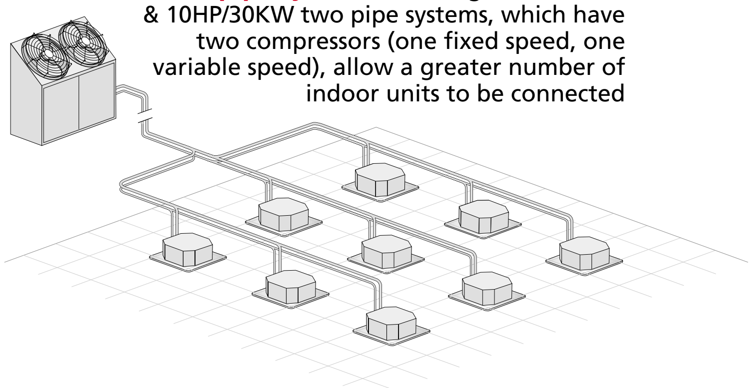
2-Pipe Systems can be applied to open plan areas, retail stores, or cellular offices, which would required cooling or heating during the same operational periods.

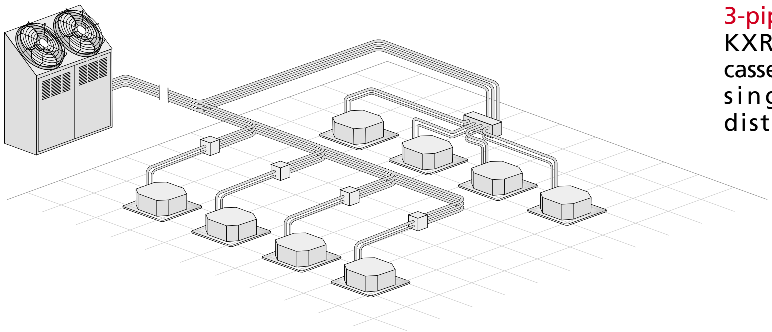
The smaller 5HP, 15KW outdoor cooling/heat pump unit can be connected to a maximum of eight indoor units, each with automatic variable capacity, and operating independently.

VRF 2-pipe systems, KX2 FDC140 15KW, with six cassette units connected



VRF 2-pipe systems, The larger 8HP/24KW & 10HP/30KW two pipe systems, which have two compressors (one fixed speed, one variable speed), allow a greater number of indoor units to be connected





3-pipe system:
KXR FDC280 with eight cassette units connected, via single and a 4-way distribution controllers

VRF 3 Pipe Systems

3-pipe Systems provide the client with a fully flexible comfort control system, where there is a mixed requirement for some areas to be cooled and others to be heated, e.g. areas on the north and south sides of a building.

Energy Recovery

The Mitsubishi KXR three pipe systems also include energy recovery, taking unwanted heat energy from warm areas, and transferring this energy to areas that require heating. This energy recovery significantly reduces running costs, whilst providing stable comfort conditions.

The three refrigerant pipes supply refrigerant from the outdoor unit in three different phases: - high pressure hot gas, and high pressure liquid. The third pipe is suction return to the compressor.

These three pipes are connected to the indoor units via PFD Distribution Controllers, which will divert either hot gas or liquid refrigerant to the indoor units, depending on its requirements for either heating or cooling.

Pipe Joints

All pipe joints are required to be brazed and thoroughly tested for leakage. There are nine brazed joints per single branch connection. There is obviously a significant advantage in using a 4-Way or 6-Way Distribution Controller, where appropriate, as this eliminates many additional joints compared to single way controllers.

Section 4

4.0 Refrigerant R407C

4.1 Whilst refrigerant R22, an HCFC, is not so environmentally aggressive as a CFC refrigerant, it is being phased-out of production, and will eventually no longer be a viable proposition as a first choice refrigerant for new installations. Indeed from January 2004 it will not be available for new installations.

4.2 The refrigerant R22 being phased-out, will be replaced by '400 series' refrigerants which have no chlorine molecules, and are known as HFC's (hydro flourocarbons).

4.3 The thermodynamic properties of R22 are not exactly matched by any one individual HFC, and refrigerant manufacturers have developed HFC blends, which overcome some of the disadvantages of individual HFC's.

4.4 Three individual 'series 400' refrigerants have been blended to produce refrigerant R407C as an alternative to R22, with the objective of designing out chlorine, which is responsible for ozone depletion.

4.5 The blending has overcome the individual HFC disadvantages, and has provided a refrigerant, the performance of which is very similar to R22.

4.6 The three HFC component parts of R407C are detailed in Table 4.1.

Table 4.1

HFC	Boiling Point oC	Flammable	Effect on Energy Efficiency	Pressure	Effect on Discharge Temperature
R32	-52	Y	Positive	High	Increase
R125	-51	N	Negative	High	Decrease
R134a	-27	N	Positive	Medium	Decrease

4.7 The actual physical characteristics of R407 with respect to R22 is given in the following Table 4.2.

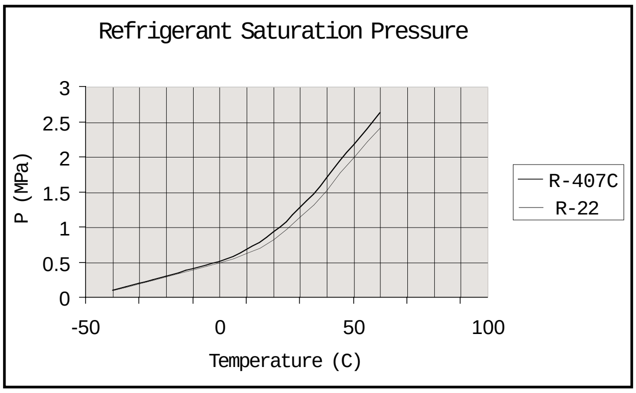
Table 4.2

Physical Characteristics	Units	Refrigerant	
Type		R407C HFC Blend	R22 HCFC
Constituents		HFC's R32, R125,R134a % by Weight 23, 25 & 52	HCFC22
Boiling Point @ 1.013 Bar.	°C	-43.6	-40.8
Molecular Weight		86.2	86.5
Flammability in Air Vol	%	Non Flammable	Non Flammable
Practical Limit (BS4434)	kg/m^3	0.31	0.3
ODP (R11=1)		0.00	0.06
GWP (CO_2=1, 100 yrs)		1600	1700
Evaporating Pressure @ 0°C	Bar	4.6	5
Condensing Pressure @ 40°C	Bar	16.5	15.4
Pressure Ratio		3.6	3.1
Critical Temperature	°C	87.3	96.1
Specific Heat Ratio CP/CV Vapour @ 5°C		1.14	1.18
Discharge Temperature	°C	59.3	63
Total Latent Heat @ 0°C	kJ/kg	212	205.4
Theoretical Coefficient of Performance		5.6	5.8
Refrigeration Capacity at 0°C / 40°C	kJ/m^3	3456	3430.8
Temperature Glide in Evaporator	°k	4.93	0

4.8 Figure 4.1 compares the saturation pressure against temperatures of R407C and R22.

The saturation pressure of R407C is at a given temperature marginally higher than that of R22.

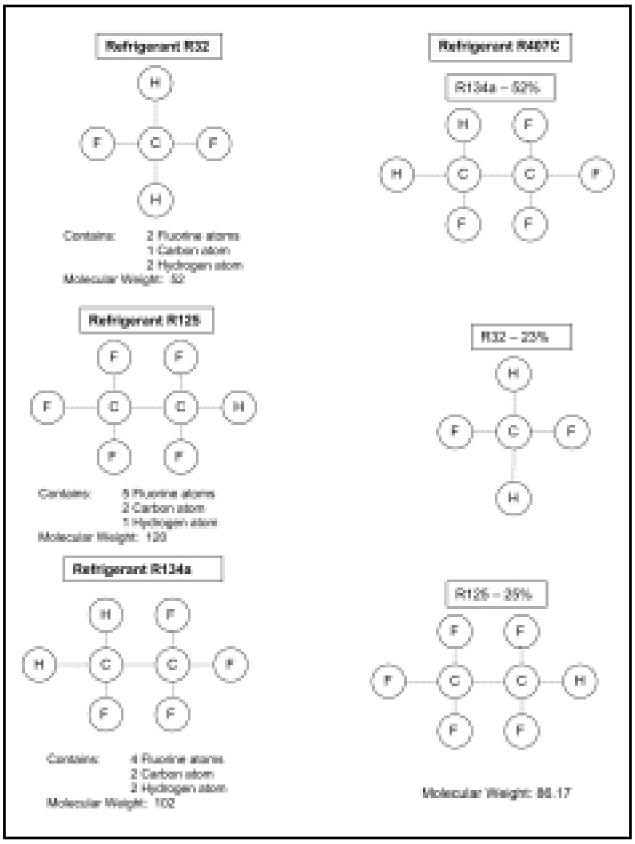
Figure 4.1
Graphical Comparison Saturation Pressure v Temperature of R407C and R22



4.9 There are no perfect refrigerants; all have advantages and disadvantages. R407C has a Zero Ozone Depleting Potential, but has the disadvantage of a Global Warming Potential of 1600. This is better than that of R22 at 1700, but substantially higher than that of refrigerant R717 Ammonia which is zero. However, Ammonia is a far more hazardous substance, being flammable in air with a volume between 15 to 28%, and the practical limit is 0.00035kg/m3 as per BS.4434. There is no perfect refrigerant.

4.10 The molecular structure of the component refrigerants of R32, R125 and R134a and the blend R407C is given in Figure 4.2.

Figure 4.2



4.11 The refrigerant R407C is a blended refrigerant, being a mixture of R32, R125 and R134A, and is known as a ZEOTROPE fluid, and at a given pressure each component part of the blend will boil at a different temperature.

4.12 The pure refrigerant fluids R32 and R125 boiling points are -52ºC and -51ºC respectively, and are more volatile than R134a - boiling point -27ºC.

4.13 Consequently R32 and R125 exert a higher vapour pressure than R134a and should there be any leaks in the system, the partial loss of one component would result in the total remaining blend being of the incorrect composition.

4.14 The magnitude of the leak is significant, but the amount of the leak usually impossible to establish. Small changes in the refrigerant quality / composition may not noticeably affect the equipment performance in the short term. However, the leakage effect is irreversible and at some point, the refrigerant has to be reclaimed and returned to the manufacturers for reblending or disposal, and the system would require evacuating and completely recharging.

4.15 R407C systems are now of a higher design standard than CFC & HCFC systems, and are continuing to improve, which makes environmental and economic sense.

Section 5

5.0 **Technical Characteristics - R407C v R22**

5.1 Measurements with positive displacement compressors have shown almost identical volumetric and isentropic efficiencies for R407C and R22.

5.2 A theoretical comparison, of refrigerant R407C and R22 in the cooling mode is given in Table 5.1 based on the calculation programme as issued by a major worldwide manufacturer of refrigerants.

Table 5.1
Cycle Performance Properties

	Units	R407C	R22
1.0 Input Conditions			
Evaporator Temperature	°c	2	2
Condenser Temperature	°c	38	38
Compressor Inlet	k	10	10
Compress Efficiency Isentropic	%	75	75
Evaporator Outlet	°c	7	7
Expansion Valve Inlet	k	10	10
Cooling Duty	kW	12.5	12.5
2.0 Output Data			
Condenser Pressure	Bar	15.645	14.6
Evaporator Pressure	Bar	5.4	5.312
C.O.P. (Exc. Superheat)		4.81	4.88
C.O.P. (Exc. Superheat)		5.04	5.09
Gross Capacity	kW	12.64	12.776
Cooling Duty	kW	12.5	12.5
Compressor Power	kW	2.507	2.562
Mass Flow Rate	kg/s	0.07024	0.07288
Volumetric Flow into Compressor	m3/hr	11.844	12.204
Discharge Temperature	°c	70.11	73.70
Suction Line Temperature	°c	14.64	12.0
Temperature Guide in Evaporator	k	5.28	0
Temperature Guide in Condenser	k	5.25	0

5.3 In the heating mode both refrigerants have similar performance properties, and therefore R407C in terms of thermodynamic performance properties is an acceptable alternative to R22.

5.4 The most important technical difference between R407C and the hydrochloroflourocarbon R22, is that R22 has chlorine as part of its chemical structure, which now makes it totally unacceptable as a refrigerant for the future.

Section 6

6.0 Refrigerant Oil

6.1 Mitsubishi Heavy Industries air conditioning systems are designed on the basis that oil carried over by the compressor is returned by the refrigerant flowing around the system.

6.2 As the traditional mineral oils (used with R22 a HCFC) are not miscible with R407C, a new lubricant based on polyolester has been developed for R407C.

During the final stage of manufacturing the outdoor units, the evacuation, refrigeration and oil charging procedures are performed with automated equipment under very controlled and monitored operations. The elimination and removal of moisture from the system is critical to the long-term performance and reliability of the system.

6.3 These same procedures, when performed on installed equipment, require the same critical attention to the elimination/removal of moisture, and the prevention of moisture in the atmosphere being absorbed by the hygroscopic refrigerant oil. MOISTURE CONTAMINATION OF THE OIL WILL RESULT IN IRREVERSIBLE DETERIORATION OF THE OIL AND WILL RESULT IN SYSTEM FAILURE.

6.4 The hygroscopic nature of the ester oils requires special care, and it is critical that the oil and the system are kept dry, the system being properly dehydrated and held at a vacuum before charging with refrigerant.

6.5 As with refrigerant leaks, oil loss is also possible; again care is required when replacing oil on site. When replacing or adding oil on site, apart from good housekeeping measures such as closing valves capping open ends, oil from small sealed containers rather than from large drums should be used, as this will keep the oil free from moisture at source.

6.6 Individual HFC's have differing miscible properties with oils and under certain conditions of temperature and pressure can cause fractionation of a HFC blend eg. R407C. Under these exceptional circumstances the fractionation can lead to a change in composition of the circulating blend and a change in system performance. However, these circumstances are unlikely to arise with equipment operating at temperatures and pressures of typical refrigeration systems used in building air conditioning systems.

6.7 The Mitsubishi Heavy Industries pipework design recommendations for single split systems will maintain the refrigerant mass flow at an optimum velocity to ensure that the oil is returned to the compressor. In the case of a VRF system, the refrigerant mass flow velocities vary due to the system requirements. If the oil remains in the refrigerant piping it may become trapped in the indoor unit heat exchangers. To ensure an adequate volume of oil in the compressor crankcase, the VRF outdoor unit is equipped with an automatic oil recovery system, which protects the long-term operation and reliability of the compressor.

Section 7

7.0 Refrigerant Cycle

To understand the mechanical vapour compression refrigerant cycle, an understanding is required of the individual processes that make up the cycle, the relationship that exists between the several processes, and the effect that changes in any one process in the cycle have on all the other processes in the cycle.

For a mechanical vapour compression refrigeration cycle to function, there has to be a pressure differential between the evaporator and the condenser.

The principal refrigerant system components are an evaporator, a vapour compressor, a condenser, a receiver and an expansion device to control the refrigerant flow - all as shown in Figure 7.1.

In the evaporator the refrigerant absorbs heat where the low pressure liquid boils, and a slightly superheated vapour returns to the compressor.

This superheated vapour is conveyed in the suction line to the suction inlet of the compressor. The compressor does work on the low pressure slightly superheated vapour raising its temperature and pressure to a point at which this high pressure vapour can be condensed to a liquid by using ambient air, as in a split system (or cooling water).

The high temperature, high pressure vapour is piped to the condenser in the hot gas line. The condenser provides a heat transfer surface through which rejected heat passes from the hot refrigerant vapour to the condenser air flow - usually provided by one or two fans.

Finally the refrigerant flow is controlled through the expansion device to supply the evaporator with the correct amount of refrigerant to satisfy the cooling load.

Figure 7.1
Basic Refrigeration Cycle

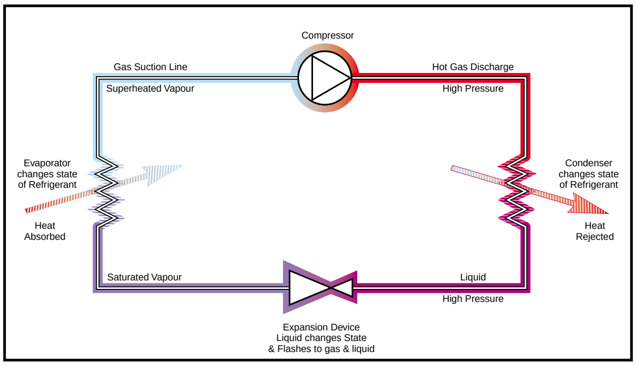


Figure 7.2

Cooling Only Split System - Typical Layout of Refrigeration Components (MHI model series SRK)

In a typical Mitsubishi Heavy Industries air conditioning cooling only split system, the evaporator is the indoor unit (room) heat exchanger, the compressor, condenser and expansion device are located in the outdoor unit as shown in Figure 7.2.

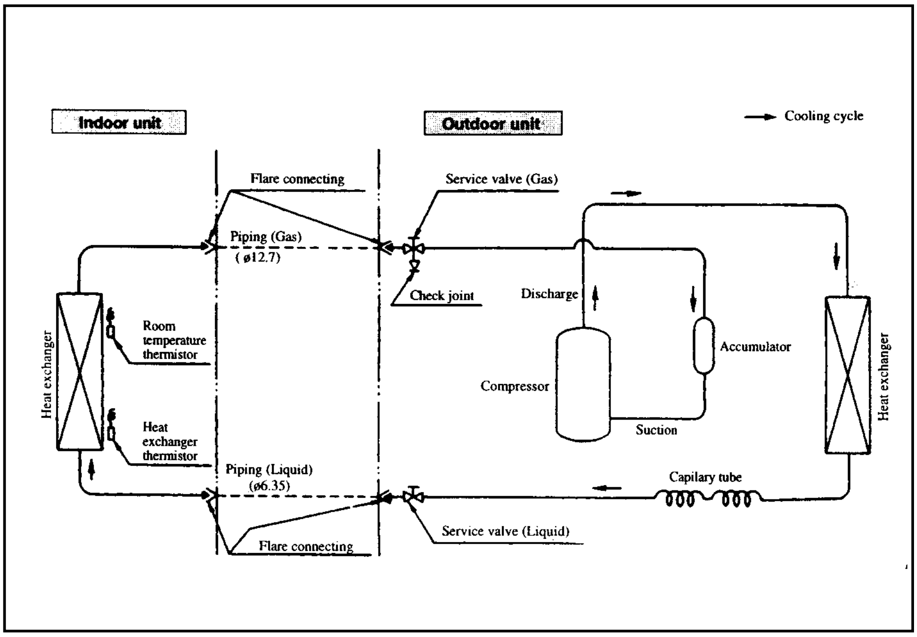
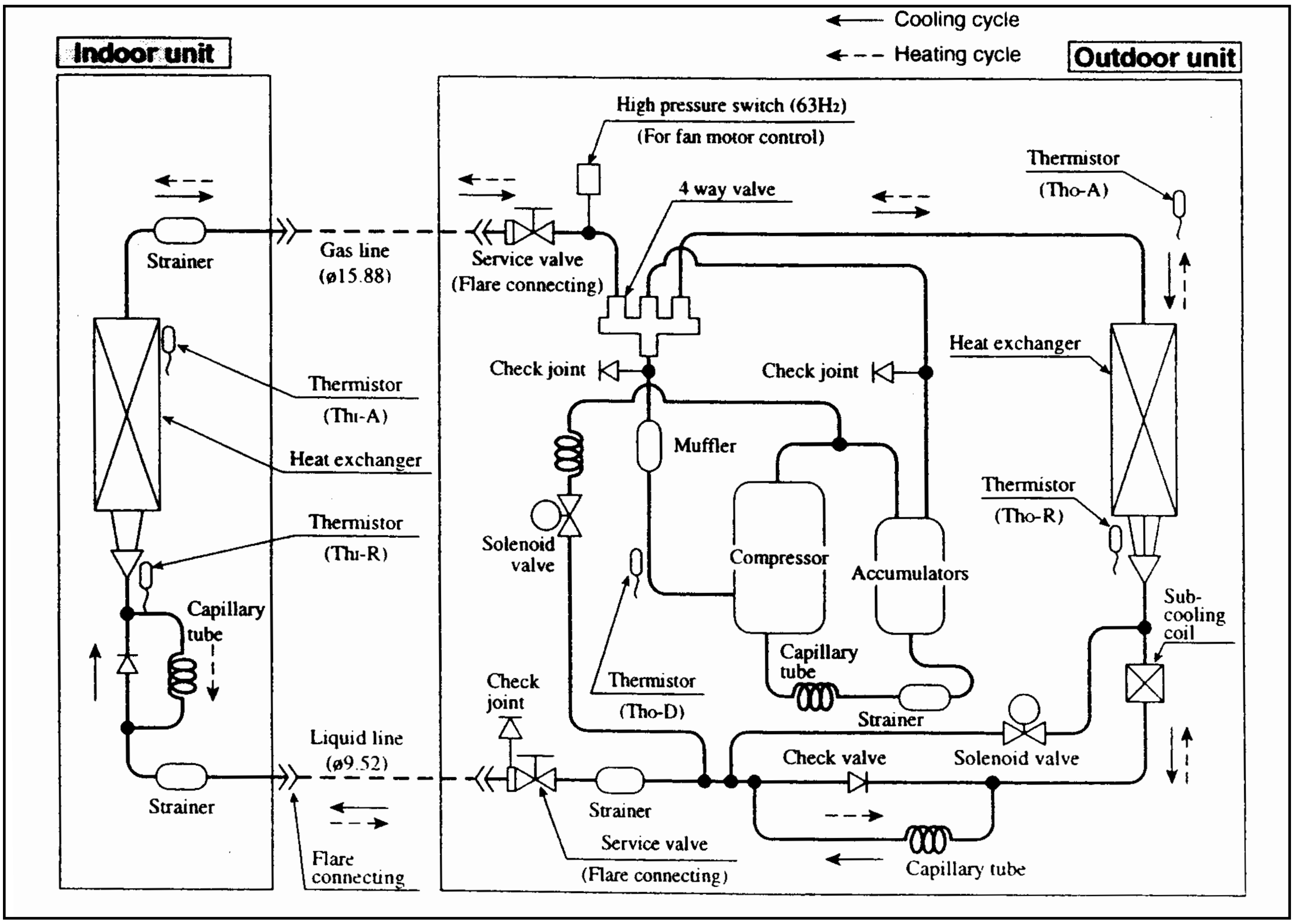


Figure 7.3

Heat Pump Split System - Typical Layout of Refrigeration Components - (MHI model FDTN208HEN)



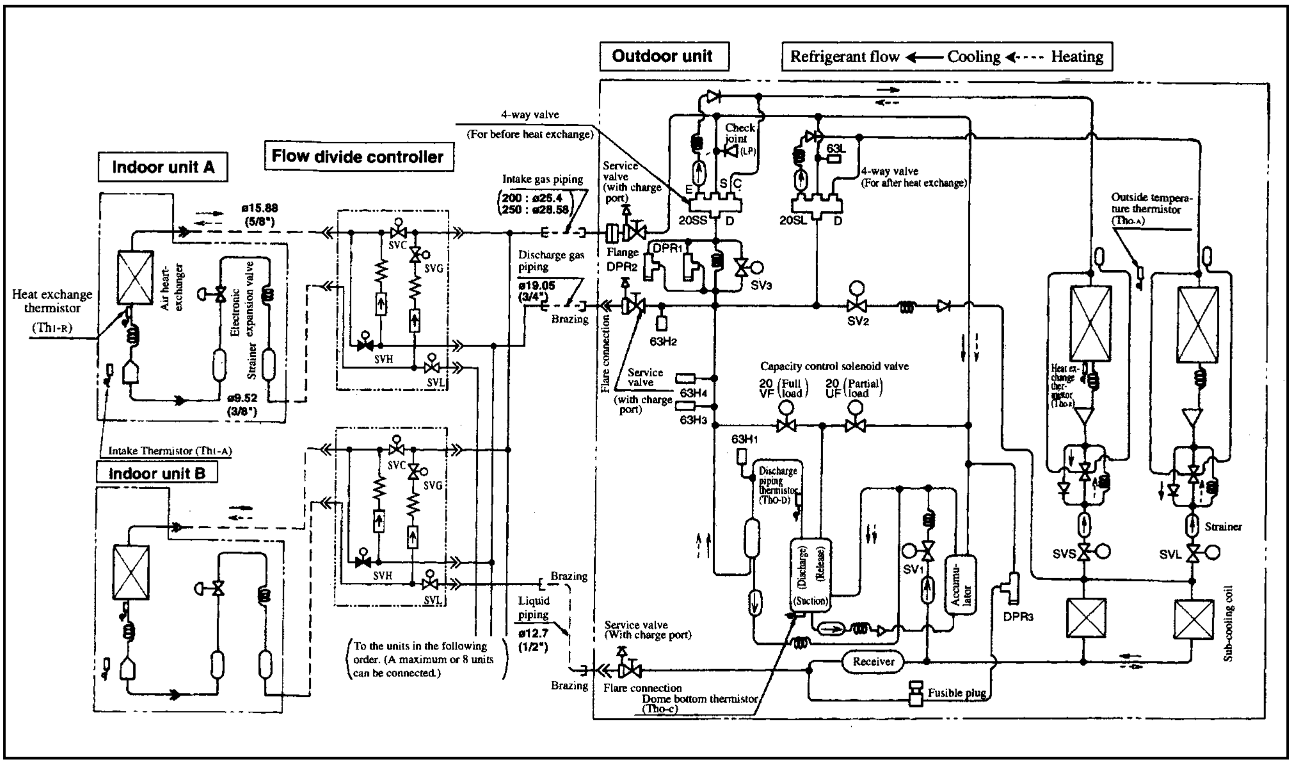
In the case of a typical air conditioning heat pump split system, the layout of the components of the engineered system is shown in Figure 7.3. The outdoor unit houses the compressor, heat exchanger, four way reversing valve, expansion devices, accumulator, thermistors, solenoid valves, safety devices, strainers and service valves. The expansion devices within the outdoor unit function to maintain the system stability in either the heating or cooling mode.

The indoor unit (room) houses a heat exchanger, non-return valve, expansion device and strainers. The heat exchanger will function as a condenser or evaporator depending on the system operational mode.

The heat pump system as shown in Figure 7.3 is a complete pre-engineered system requiring refrigerant pipework connections and the minimum of interconnection electrical wiring

Figure 7.4

VRF System - Simultaneous Heating and Cooling - Typical Layout of Refrigeration Components (MHI model FDC2001HKXR)



With a Mitsubishi Heavy Industries VRF system with simultaneous heating and cooling, the refrigeration equipment within the indoor (room) and outdoor unit is relatively complex, compared to a cooling only and heat pump split system. The arrangement is shown in Figure 7.4.

The outdoor unit houses the compressor, heat exchangers, accumulator, four-way reversing valves, and various expansion devices, plus an internal pipework system to maintain the systems stability and operation. The indoor unit(s) are complete with heat exchanger electronic variable opening expansion devices, and strainers. The system performance and refrigerant temperatures are constantly monitored and controlled by an integrated 'fuzzy logic' control system.

The arrangement of the refrigerant control, and full or partial expansion devices becomes complex, as the system requirements become more sophisticated, but fundamentally they all rely on the basic refrigeration cycle.

7.1 Refrigerant - Pressure / Enthalpy

Whilst tabulated data is available for each refrigerant and can be used for the thermodynamic calculations of the refrigerant cycle, the data is shown on charts. The complete refrigerant cycle can be shown graphically.

The graphical representation of the refrigerant cycle permits the desired simultaneous consideration of all the various changes in the condition of the refrigerant, which occur during the cycle, and the effect these changes have on the refrigerant cycle.

The most common diagram frequently used in the analysis of the refrigerant cycle is the Pressure Enthalphy diagram (also known as a Mollier diagram).

Figure 7.5 shows a skeletal Pressure - Enthalpy diagram for a typical pure refrigerant fluid (R-134a, R22,R12). Enthalphy is a property of a fluid which represents the work and heat energy contained in a fluid. It is pressure and temperature dependant, and is usually measured in units of kJ/kg.

Figure 7.5

Pressure - Enthalpy diagram for a Pure Refrigerant R22

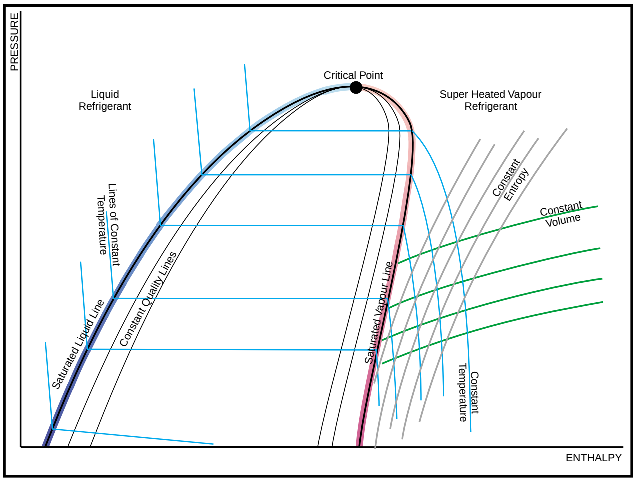
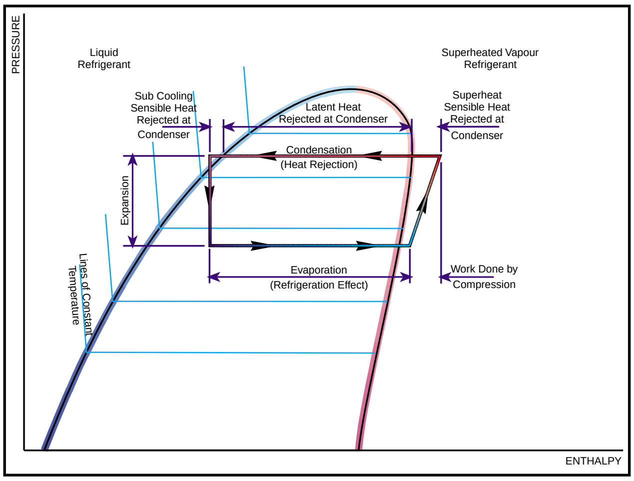


Figure 7.6 shows a typical graphical representation of a refrigeration cycle for a single fluid of R22.

Note that the evaporation of the refrigerant occurs at a constant temperature. Refrigerant R22 has a single boiling point for a given pressure, and although there is a minimal pressure drop in the system components resulting in a small temperature difference, the temperature "glide" effect can be ignored.

Figure 7.6

Typical Graphical Representation of Refrigerant Cycle for a Pure Refrigerant R22



Refrigerant R407C is a zeotrope, which is a fluid mixture, whereby the components boil over a range of temperatures, albeit temperatures which are within a reasonably close range.

The characteristics of zeotropes are:

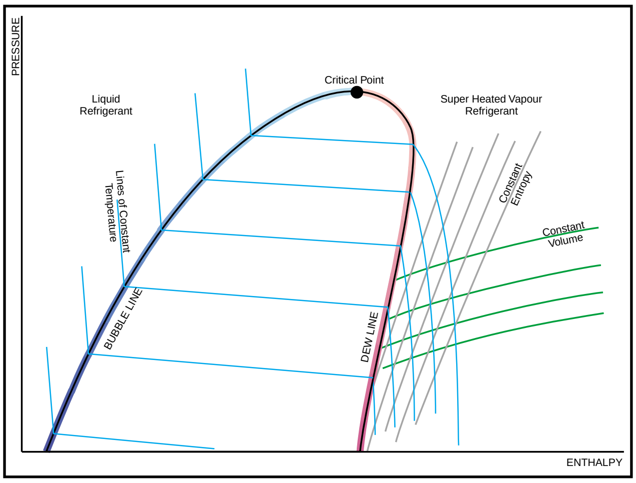
1. Different compositions for vapour and liquid
2. Boil and condense over a range of temperatures
3. Possible heat transfer reduction

Now R407C is a mixture of refrigerants R32, R125 and R134a, and as a zeotrope has the ability to fractionation, whereby refrigerants will boil at different temperatures in the vapour stage. This causes the temperature of a zeotrope to noticeably increase as it passes through the evaporator and noticeably decrease in the condenser.

A pressure enthalphy diagram for R407C has different terminology, in as much that the bubble line and dew line replace the saturated liquid line, and saturated vapour line respectively.

Figure 7.7 shows a skeletal pressure/enthalphy diagram for zeotrope - typically R407C. As the refrigerant boils at different temperatures there is a change of vapour content and composition. As the components evaporate or condense, at differing rates, lines of constant quality are not shown on the pressure/enthalphy diagram.

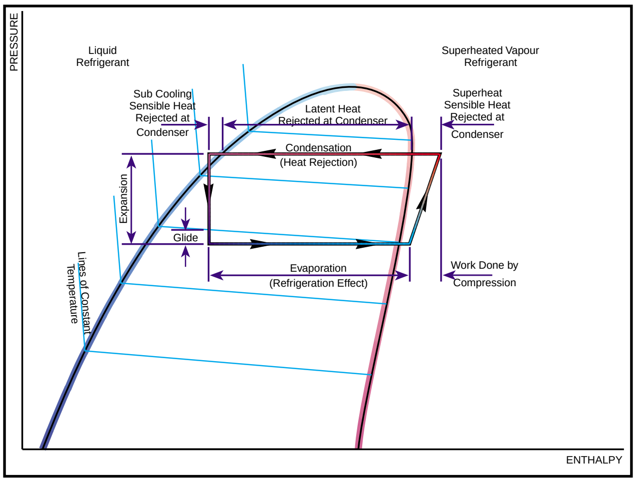
Figure 7.7
Pressure - Enthalpy diagram for a Zeotrope Refrigerant R047C



With R407C as it does not have a single boiling point, the lowest temperature at which it begins to boil is the bubble point. When condensing the temperature of the first component to reach saturation is known as the dew point.

Figure 7.8 shows a typical graphical representation of the refrigerant cycle for R407C.

Figure 7.8
Typical Graphical Representation of Refrigerant Cycle for a Zeotrope Referant R047C

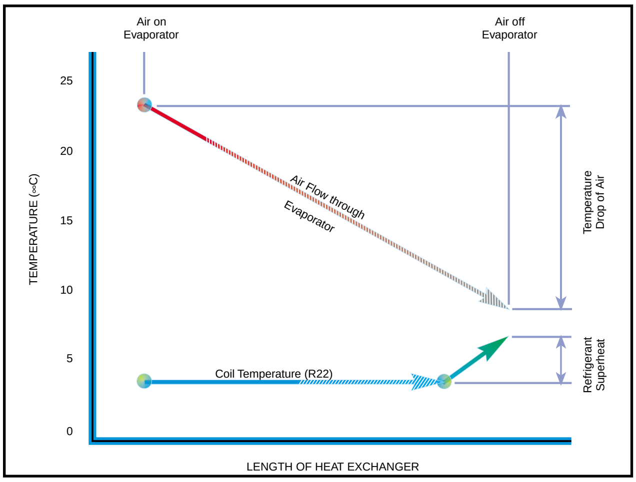


When comparing PE diagrams for pure fluid and zeotrope there are other differences. Firstly, with a pure fluid there are lines of constant quality and the isotherms are horizontal. Secondly, with a zeotrope fluid there are no lines of constant quality, and the isotherms are at an angular negative displacement. This displacement is the "glide," ie the difference in temperature between bubble point and dew point.

R407C has the typical characteristics of a zeotrope in as much as there is a possible heat transfer reduction due to poor vapour-liquid mixing.

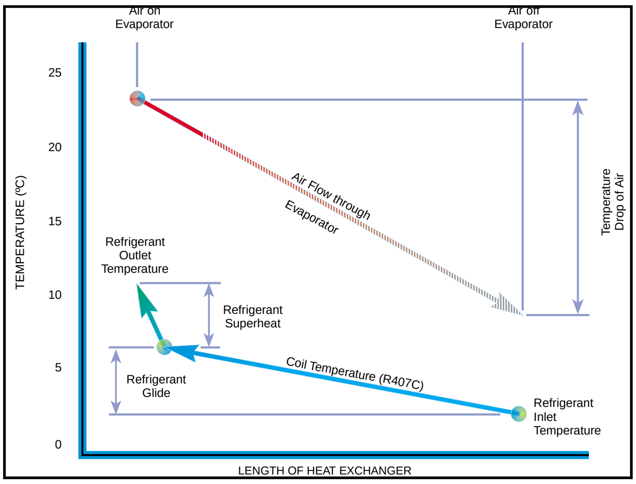
Typically a compromise of crossflow/parrallel flow design has been used for R22 heat exchangers and the process through the evaporator is shown in Figure 7.9.

Figure 7.9
Parallel Flow Through an Evaporator



To take advantage of the temperature glide through the evaporator, and to improve the log mean temperature, the heat exchangers for R407C are designed on the truly counterflow principle as indicated in Figure 7.10.

Figure 7.10
Counterflow Process Through an Evaporator



Section 8

8.0 Installation of Refrigerant Pipework

8.1 Overview

A VRF system or split system does not normally have indoor isolation valves, sight glasses or refrigerant level indicators. Therefore it is essential that the system be installed clean, dry and totally leak free, as well as being charged with refrigerant accurately to the manufacturers stated quantity.

8.2 Skill Requirements

All interconnecting pipework between the system components should be installed, pressure tested with oxygen free nitrogen, and commissioned by a specialist refrigeration contractor, who shall provide for each operative certificates of competence regarding the brazing of copper pipework and the safe handling of refrigerants.

8.3 Copper Pipework

All copper pipework and associated copper materials must conform to the requirements of BS2871. Part 2 being of suitable quality for refrigerants.

Copper pipe shall be to the following specification:

Type	Quality	Size
Coils	Soft Tempered	1/8 to 7/8
Straight Lengths	Half Hard tempered	3/8 to 2 1/8

The table 8.1 below details the Maximum Allowable Pressures for copper tube as supplies by reputable suppliers for Copper Tube. They have been calculated according to the requirements of BS4434:1995 using the stress values from BS1306. Although tube is supplied in half hard or fully hard condition, figures are given in the fully annealed condition which is representative of the tube in the area immediately surrounding brazed joints.

Table 8.1
Maximum Allowable Pressures

Outside Diameter (inch) OD	Gauge S.W.G/ Thickness mm	Max Allowable Pressure (bar g) Fully annealed conditions		
		50°C	100°C	150°C
3/8	21/0.813	67.79	66.14	56.22
1/2	20/0.914	56.58	55.2	46.92
5/8	20/0.914	44.67	43.58	37.04
3/4	19/1.016 18/1.2	41.23 49.98	40.23 48.76	34.19 41.45
7/8	19/1.016 18/1.2	35.08 49.98	34.22 48.76	29.09 41.45
1.1/8	18/1.2 16/1.6 14/2.0 12/3.0	32.67 44.14 44.14 74.23	31.87 43.07 43.07 72.42	27.09 36.61 36.61 61.56

Tests performed by manufacturers of pipe fittings have indicated the Maximum Allowable Pressure for Copper Fittings up to and including 4⅛in (105mm) is 33bar. This rating has been made using the requirements of BS4434 with a refrigerant temperature of 100°C based on a condensing temperature of 55°C. Certificates are available from reputable suppliers of refrigeration quality copper tube.

8.4 Pipework Support

Copper pipework shall either run in cable trays or run individually. Whatever method is used the pipework will be fixed or supported at the maximum centres stated in the following table.

Fixing or Support Centres -
Soft Tempered Copper Pipe

Maximum Centre Between Supports (M)	Refrigerant Pipework Size (inch O/D)					
	1/4	3/8	1/2	5/8	3/4	7/8
Horizontal	0.8	1.0	1.2	1.2	1.5	1.5
Vertical	1.0	1.2	1.5	1.5	1.5	1.8

Fixing or Support Centres -
Half Hard Copper Pipe

Maximum Centre Between Supports (M)	Refrigerant Pipework Size (inch O/D)							
	1/4	3/8	1/2	5/8	3/4	7/8	1 1/8	1 3/8
Horizontal	0.8	1.0	1.2	1.2	1.5	1.5	1.5	1.8
Vertical	1.0	1.2	1.5	1.5	1.8	1.8	1.8	2.4

The fixing and/or supports shall allow pipework movement in the expansion plane and shall not be used as indiscreet anchor points. The fixing and/or supports shall not allow any vibration to be transmitted to the structure.

8.5 Pipework Site Management

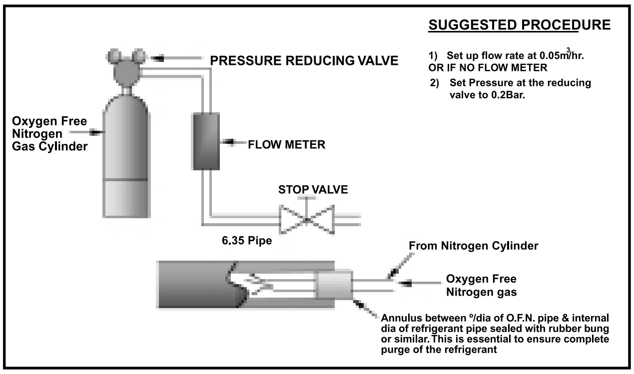
To minimise the number of joints between the system components coiled copper shall be used in preference to straight lengths of half hard copper. All joints should preferably be brazed, as flare joints are prone to leakage.

The copper pipework shall be capped at all times (with outside cover and caps), except when being worked upon.

All pipework shall be cut square with a proprietary pipecutter to give a clean cut, without copper fragmentation. Hacksaws must not be used.

When brazing, all pipework shall be purged with low-pressure oxygen-free nitrogen, above atmospheric pressure (to provide a positive pressure in the pipe) to prevent the formation of copper oxides and scale, and to prevent moisture from the surrounding air entering the system. Any annulus between the oxygen-free nitrogen feedpipe and the refrigerant pipe shall be sealed to prevent the ingress of air due to the ejector effect of the higher pressure oxygen free nitrogen, as indicated in Figure 8.1.

Fig 8.1 Method to prevent ingress of air when brazing



When all siteworks have been completed the pipework should be flushed with oxygen free, high-pressure nitrogen to ensure that any moisture and debris are removed. All fittings should be kept to a minimum to reduce the number of joints (ie potential leaks) and frictional losses. Swept bends should be formed using a bending tool with the correct dies/mandrill /spring to prevent reeking or barreling.

8.6 Pressure Testing

The indoor units are charged with nitrogen during manufacture and capped. Prior to installation the caps are removed, and an aural inspection should be done by listening as the caps are removed. If the indoor units have lost nitrogen gas, and there is no aural indication when the caps are removed, this indicates a possible leak, and prompts further investigation prior to installation in the system.

A structured test procedure shall be carried out as part of the general commissioning procedure and records kept.

The formal test will be a multiple test and include the site pipework, indoor units and control boxes. All capillary, solenoid and expansion valves shall be opened for these tests, to ensure all parts of the system are subjected to the test.

The pressures used in testing are as recommended in Table 8.2 below, but other values may be chosen, depending on the site specific requirements providing the pressures are within 90% of the maximum allowable pressure as Table 8.1.

The pressurisation agent shall be oxygen-free nitrogen.

Stage	Operation	Pressure	Time	Results
1	Flush System	3.0 Bar	2-3 mins	To indicate major leaks
2	1st Pressurisation Test	15.0 Bar	10 mins	If 1.0% deviation, check for leaks at all joints
3	2nd Pressurisation Test	28.0 Bar	24 hours	No deviation in pressure. If deviation check for joint porosity and small flare joint leaks

8.7 Vacuum Drying

After satisfactory completion of the pressure testing, the system (excluding the outdoor unit) will be put under vacuum. This will remove moisture from the system (by vaporisation) and furthermore should the system fail to hold a vacuum it will demonstrate that there is a small leak in the system.

8.8 Triple Evacuation & Charging

The pipework will be evacuated to -755mm Hg for 1 to 2 hours, and the vacuum broken with oxygen free dry nitrogen, this process is then repeated and, after the third vacuation refrigerant is used in place of the nitrogen.

8.9 Additional Refrigerant Charge

The additional refrigerant charge required shall be calculated accurately in accordance with MHI detailed instructions.

8.10 Insulation

All pipework shall be insulated with preformed armaflex or similar, Class "O" fire rated and vapour sealed.

The insulation shall be installed as each section of the pipework is completed and each section of insulation shall be glued together.

At each joint in the pipework, the insulation shall be neatly drawn back and secured to allow inspection of the joint during pressure/vacuum tests and system charging. Upon completion the insulation shall be released, jointed and vapour sealed.

When the installation is complete, identification bands/tags complete with outdoor unit, internal systems and indoor unit reference, shall be fitted at a maximum of 4 metre centres.

The insulation thickness shall be as follows:

Refrigeration Pipe Size inch O/D	Insulation Thickness **mm**
$^1/_4$"	6
$^3/_8$" and above	13

8.11 Condense Drainage

The condensate pipework material shall either be heavy duty PVC to BS3505 Class E or copper to Table Y BS2871 Part 1.

PVC pipework joints shall be made with couplers and solvent cement.

Copper pipework shall have soldered joints.

The condensate drainage pipework shall be installed with a minimum gradient of 1;100.

To prevent the pipework 'sagging', the support centres will be as follows:

Pipework Diameter	Maximum Distance Between Supports mm
Up to 20mm O/D	1.5
Up to 32mm O/D	1.5

Condensate pipework shall not terminate in foul drains.

Copper pipework shall be insulated with 6mm thick insulation.

Access fittings for pipe cleaning shall be installed at suitable positions to allow rod access in the event of a blockage.

Section 9

9.0 **Evacuation, Leak Testing, Equipment and Charging**

9.1 When the system pressure testing indicates that the system is completely free from leaks, then before charging the system with refrigerant, the systems must be free from air, moisture and non-condensable gases.

9.2 Failure to remove these contaminants will cause several problems. Air or other non-condensable gases will cause the system to operate at higher condensing pressures, which will have the effect of increasing the discharge temperature, perhaps to a level which will lead to the breakdown of the oil, and ultimately lubrication failure. The capacity of the system will be reduced, so that at periods of fullload requirements, temperatures may not be maintained. Furthermore, the running costs will increase due to increased energy consumption.

9.3 Polyolesters are also highly hygroscopic (20 times more so than mineral oils) which can lead to moisture related internal icing, or acid formation which can have a deletrious effect on the system.

9.4 R407C and polyolesters have strong searching properties, which can cause leaks, by removing "stable contaminant deposits at joints".

9.5 To achieve this complete removal of all these contaminants in the system a vacuum pump is connected to both the high and low pressure side of the system. In the case of a 3-pipe VRF system, the distribution controller valve must be opened / closed to effect a vacuum to the complete system.

9.6 It has been the practice in the past to remove contaminant and moisture by purging the system with refrigerant. This practice is no longer acceptable and is indeed, under legislation, illegal.

9.7 Refrigerant R407C is a zeotrope, and its compatible lubricant is a synthetic polyolester. The whole system is to be compatible with R407C and polyolester lubricants. All servicing equipment must be suitable for refrigerant R407C and polyolester lubricants, and only made for R407C. Refrigerant R22 is highly soluble in polyolesters and only reiterates the need for dedicated equipment for R407C.

9.8 The two methods of evacuating a system are:

Single Deep Vacuum

In this process the system is pulled down to a vacuum of 2 mm Hg and left at this condition for 4 hours. To test whether all the moisture has been removed from the system, the valves at the vacuum pump should be shut off and the system allowed to stand for five minutes for the internal pressure to equalise. If the pressure rises quickly there is a leak in the system. If the pressure rises slowly to 15 mm Hg this indicates that there is moisture in the system which is boiling off, raising the internal pressure and further evacuation is required. Should the system remain static over the period of four hours, the system is clean.

Triple Evacuation

Whilst there are no hard and fast rules when applying this method, it has proved very effective for general service work and, using the pressures stated, is in effect a combination of triple evacuation and deep vacuum methods:

Evacuate the system to 2mbar for 20 minutes and shut off valves to the vacuum pump. A quick rise in pressure indicates a leak, whereas a slow rise in pressure indicates gas in the system boiling off.

Break vacuum with dry oxygen free nitrogen to 140 - 210 mbar and hold for 15 minutes.

Evacuate to 2mbar and maintain for 20 minutes.

Break vacuum with dry oxygen free nitrogen to 140 - 210 mbar and hold for 15 minutes.

Evacuate to 1mbar and maintain for 20 minutes.

Break vacuum and charge with refrigerant.

9.9 The dedicated equipment required for evacuating and dehydrating a R407C refrigeration system.

Equipment (dedicated to R407C)	Notes
Vacuum Pump	The vacuum pump must only be used for R407C and be complete with an integral check valve. It may be necessary to have two pumps of differing capacities to match system requirements. The vacuum pump should be connected both sides of the system with large diameter short connecting lines.
Gauge Manifold and Hoses	The gauges will be suitable for R407C and be of good quality with an accurate well-defined scale. The gauges should ideally be fitted onto the systems at the furthest point away from the vacuum pump, to ensure, as far as possible, that the whole of the system has been processed. If the gauge is fitted to the pump there is no way of checking that the whole system is processed.
Charging Cylinder	Must be calibrated for R407C.
Refrigerant Cylinder	Must be marked and used for R407C.
Leak Detector	Must be dedicated for R407C.
Electronic Scales	Must be dedicated for R407C.

9.10 Charging the System

Refrigerant R407C is a zeotrope and one characteristic is that the refrigerant will boil and condense over a range of temperatures. Consequently in a closed vessel there will be a different composition for vapour and liquid. The process of separating occurs not only in the system but also in service cylinders. Typically a service cylinder is about 80% full and the space left is filled with vapour, which is rich in the more volatile R32.

Whilst the vapour composition varies, the composition of the liquid refrigerant in a refrigerant service cylinder changes slightly as liquid refrigerant is removed, but these changes are not significant until the cylinder is almost empty. Once all the liquid is removed from the cylinder the remaining vapour composition (the heel) is significantly different from the original specification.

Liquid composition remains sensibly constant when charging the systems when the ambient is less than 30°C, but if the ambient is above 30°C, then the last 10% of liquid refrigerant remaining in the cylinder may be marginally different in composition.

The best practice is to use refrigerant cylinders with dip pipe to ensure liquid refrigerant is drawn into the system.

Where cylinders are not fitted with dip pipes, the cylinder should be inverted. At least 10% liquid weight should be left in the cylinder.

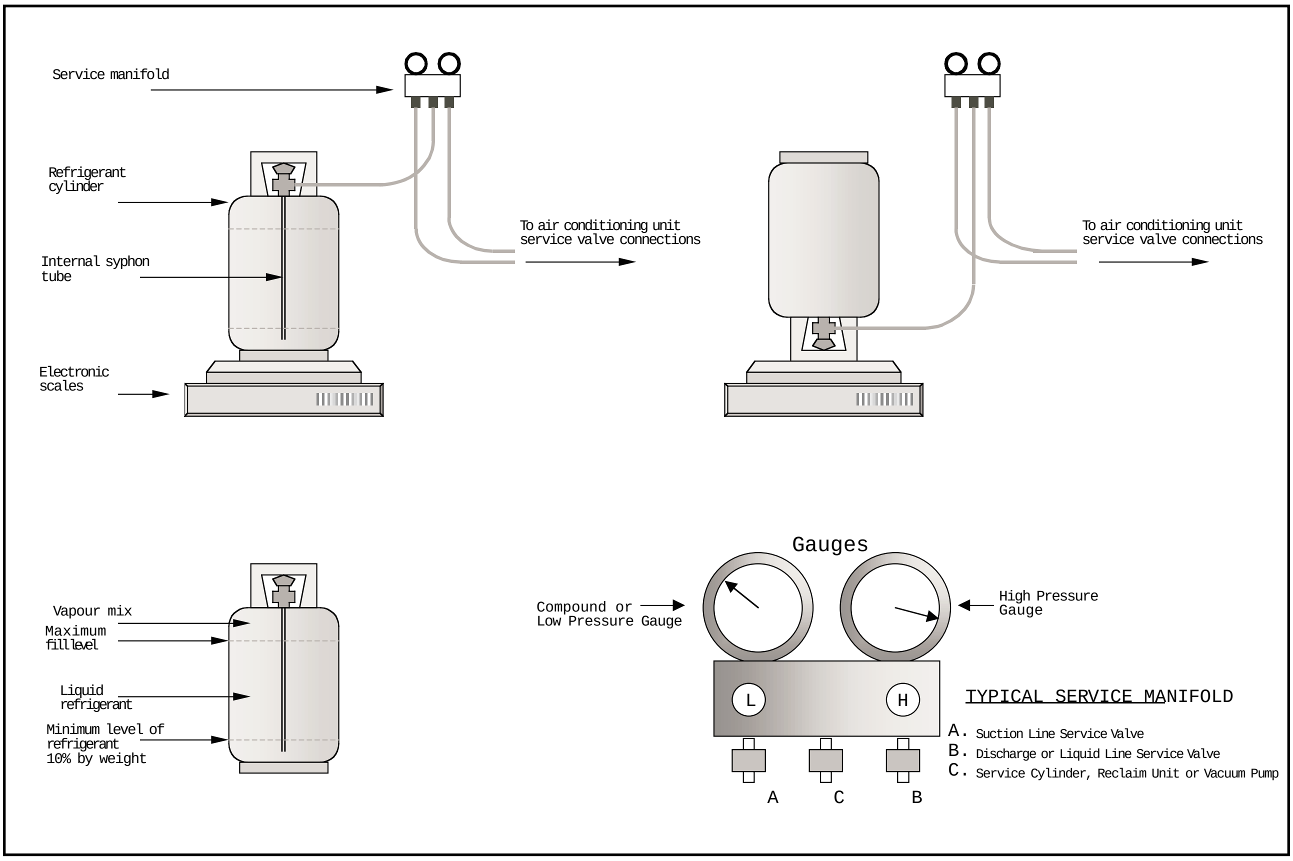
Refrigerant cylinders should only be filled in accordance with the manufacturer's recommendations, and the cylinders must be dedicated for use with that refrigerant only.

The refrigerant charge to be added to the system will depend upon the equipment - indoor and outdoor and the physical layout of the system.

The outdoor unit is precharged and will be suitable for a given length of pipework, but when the length exceeds this, an additional refrigerant charge is required which must be calculated in accordance with MHI technical data.

To add the additional refrigerant charge, the outdoor unit service valves are connected to a dedicated R407C service manifold, which is in turn connected to a R407C refrigerant service cylinder, safely located on refrigerant electronic scales. With blended HFC refrigerant liquid phase charging is necessary as in the vapour phase, the composition of the refrigerant changes. The charge must be added in the liquid state into the liquid outlet service valve, with the compressor in operation. Should, for whatever reason, a decision be made to add the refrigerant charge to the suction line, (note: this is not approved), care must be taken to ensure that refrigerant drawn from the service cylinder is in the liquid state, but, changed into a gaseous state via a specialist heat exchanger unit.

Figure 9.1 shows a typical charging arrangement.



Information regarding additional refrigerant charge will be logged as part of the commissioning procedure.

As zeotrope fluids do not have a constant saturation temperature/pressure relationship, then to evaluate their systems' pressure at various locations the pressure/temperature tables provide the saturation temperatures at the liquid bubble and vapour 'dew point'

Section 10

10.0 Safety Precautions

10.1 The constituents of R407C (HFC's: R134a, R125 & R32) have undergone extensive testing and shown to have low toxicity levels which are comparable with, or lower than the refrigerant R22.

10.2 The safety issues for R407C (and indeed any HFC) are generally similar for R22 (and any HCFC's) which it replaces.

10.3 It is fundamental that any site technician should know and understand the properties and hazards before using liquid refrigerants.

10.4 Refrigerant manufacturers issue chemical safety data sheets and they must be consulted for detailed advice regarding health and safety. However, site technicians must have a certificate of competence in the handling of refrigerants issued by a registered approved organisation, and furthermore, be able to cope with an emergency situation.

10.5 Every site technician handling refrigerants must be properly attired with safety clothing, gloves, overalls and eye protection, and have available a comprehensive first aid kit including an eye wash.

10.6 The correct handling of refrigerants and the correct attire will eliminate typical accidents, skin, eye contact and freeze burns.

10.7 Although R407C has excellent thermal and chemical stability, thermal decomposition of the refrigerant can evolve toxic and corrosive vapours will be driven by HF formations.

10.8 Thermal decomposition will occur when R407C vapour is exposed to brazing, welding, hot surfaces, naked flames and smoking, and is usually detected by a pungent odour.

10.9 Motor burnout can result in some refrigerant decomposition, again detected by a pungent odour.

10.10 In all cases where there is thermal decomposition, the areas must be evacuated and thoroughly ventilated before any work is undertaken.

10.11 As with all good refrigeration industry practice R407C should only be recovered using equipment that is dedicated to R407C recovery, as and when required. The refrigerant recovery cylinders should be used for the sole purpose of returning used or reclaimed refrigerant to an approved reclamation operator.

10.12 When R407C, for whatever reason, is badly contaminated and can not be reclaimed it must be destroyed by an approved operator. Venting R407C to atmosphere is not only bad practice but also illegal with punitive consequences.

10.13 Refrigerant vapour is heavier than air and consequently it will tend to displace air in poorly ventilated spaces. In the case of a leak from a refrigeration system the quantity of refrigerant leaking into the space may well be above acceptable levels.

Local standards give guidance regarding the maximum charge of refrigerant in enclosed spaced, these are sometimes referred to as Practical or Recommended Quantity limits.

BS4434:1995 is a standard which is intended to minimise possible hazards that may be associated with refrigeration equipment and systems, and classifies the various refrigerants by their flammability and toxicity.

The refrigerants are classified as follows:

Group	Refrigerant	Practical Quantity Limits kg/m²	Ignition °C	GWP	ODP
A1	R22	0.14	635	1700	0.055
A1	R407C	0.35	704	1610	0

The practical limit as defined in BS4434 "is less than half the concentration of refrigerant that can lead to suffocation due to oxygen displacement or which has a narcotic or cardiac sensitisation effect after a short time, whichever is most critical".

Therefore, it is assumed that the refrigerant quantity as determined by MHI recommendations regarding pipe runs is the critical charge, and it must be assumed the refrigerant quantity if the system is ruptured, will escape into the smallest occupied space.

If a continually manned refrigerant detector system is installed the practical quantity limits can be increased by a factor of 2.

In determining the space that could be contaminated by the refrigerant if the system was ruptured, that the total space is considered i.e. corridors, interconnecting areas not sealed off.

Section 11

11.0 Electrical Installation

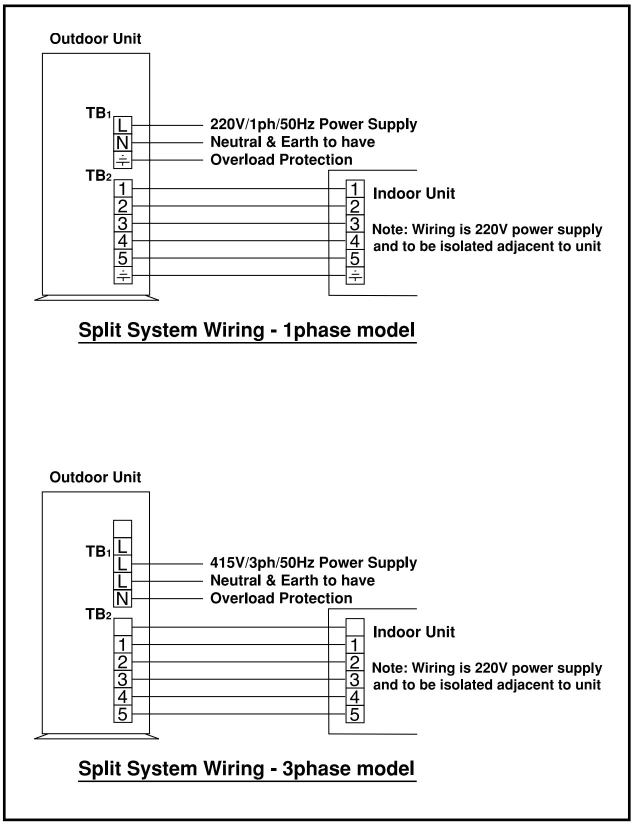
11.1 All electrical installation work shall be in accordance with BS7671. 1992 and local codes of practice.

11.2 A dedicated single phase with neutral and earth, or if required three phase with neutral and earth power supply, will be installed for each split system, either cooling only or heat pump. This supply shall have overload protection and shall be isolated at the outdoor unit, and interconnecting wiring between the outdoor and indoor unit shall be complete with an isolator.

The wiring between the outdoor and indoor unit must be mechanically suitable for the application and will connect equivalent terminals.

Typical wiring connections are as Figure 11.1.

Figure 11.1 Typical Wiring Connections



Note:

1. The power for the indoor unit is supplied by terminals 1 & 2 within the outdoor unit.
2. On cooling only split systems terminals 4 & 5 on terminal strip TB2 are omitted.

11.3 A 2-pipe or 3-pipe Variable Refrigerant Flow System (MHI KX & KXR Multi-Systems) require a dedicated 415v, 3ph, 50Hz power supply with neutral and earth for each outdoor unit.

This power supply must have overload protection and be isolated at the outdoor unit.

The indoor units and distribution controllers require a separate 220v, 1ph, 50Hz power supply with neutral and earth, and each indoor unit is ideally supplied with power via a 5amp, switched fused outlet.

The control wires are 2 core screened installed from the outdoor unit to the indoor units, and the remote controller is connected to the indoor unit with a 3 core cable (low voltage 12v DC).

A typical schematic wiring layout is shown in Figure 11.2.

Note:

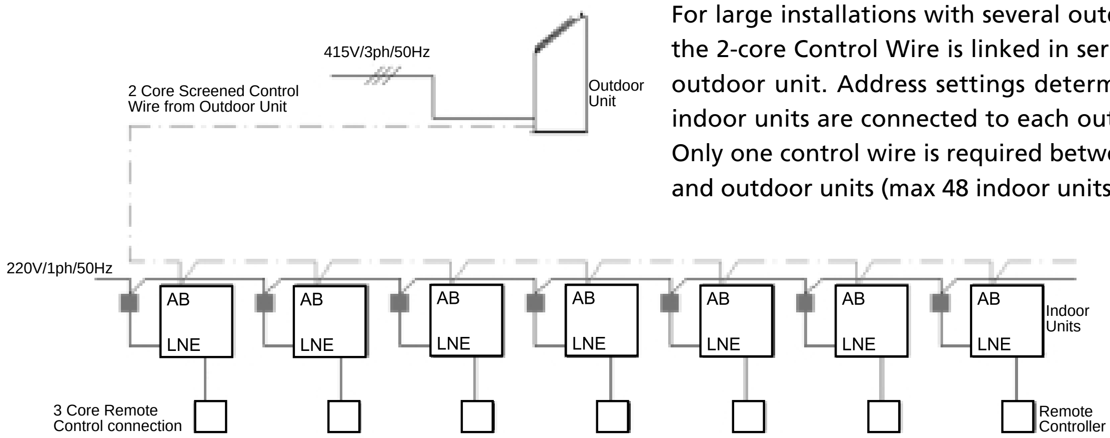
1) The distribution controllers are provided with a relay kit and a 2 metre wiring looms and connection plugs.

2) If the location of the distribution controller is greater than 2 metres from the indoor unit, the wiring between the relay kit and, distribution controller can be extended using 3 core cable with the same colour coded wires.

3) Distribution controllers and relay kits have metal enclosures, and must be earthed.

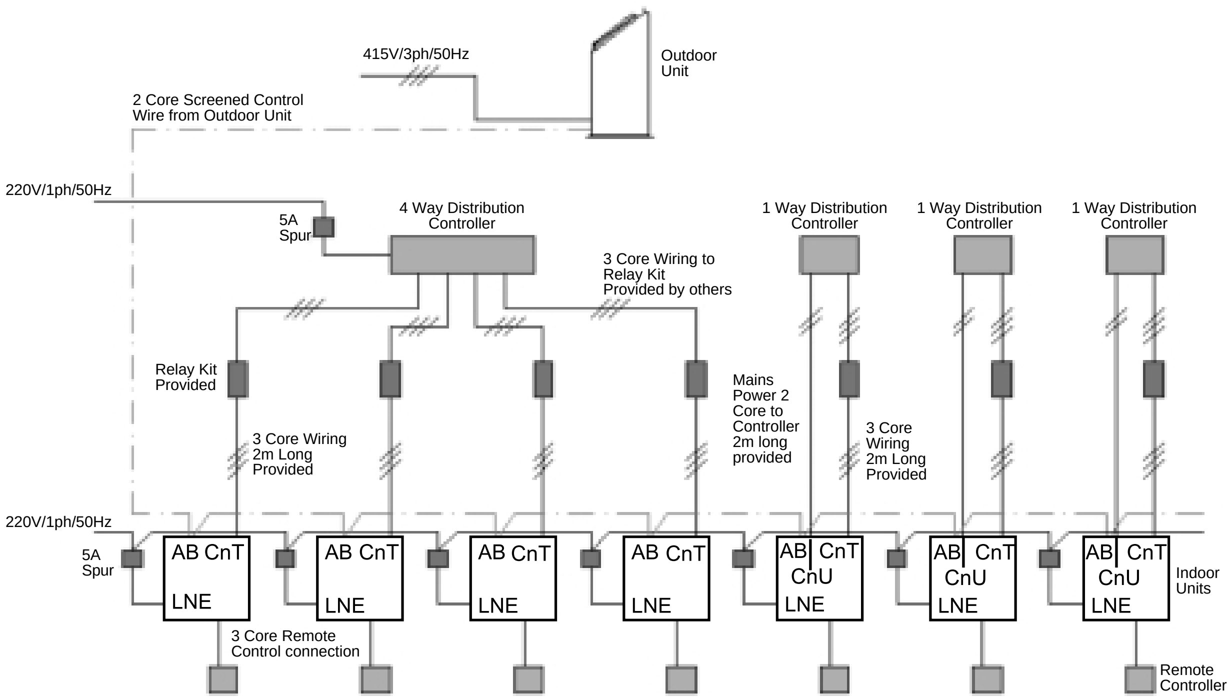
4) 1 way distributor controllers can be supplied with 240v, 1ph, 50Hz power from the indoor unit

Figure 11.2 Wiring for 2-pipe VRF Systems



For large installations with several outdoor units, the 2-core Control Wire is linked in series to each outdoor unit. Address settings determine which indoor units are connected to each outdoor unit. Only one control wire is required between indoor and outdoor units (max 48 indoor units)

Figure 11.3 Wiring for 3-pipe VRF Systems



The distribution controllers are supplied with the wiring loom connections to the indoor units. The 2-core Control Wire is linked as the 2-pipe system in the above diagram.

Section 12

GLOSSARY OF TERMS

AZEOTROPIC MIXTURE This is a mixture of fluids that has thermodynamic characteristics that mimic those of a pure fluid. In particular, an azeotropic mixture boils at a constant temperature.

BUBBLE POINT The temperature at which a liquid forms bubbles (usually the lower or lowest boiling point of one of the constituents of a blend). The liquid temperature without sub-cooling.

CFC Chlorofluorocarbon. Saturated hydrocarbons in which all of the hydrogen atoms in the molecule have been replaced by chlorine and fluorine atoms. CFCs are identified by a 2 or 3 digit number with each digit representing the number of particular atoms in the compound.

Reading from left to right:

1st digit = number of carbon atoms (C) - 1 (omitted if equal to zero)
2nd digit = number of hydrogen atoms (H) + 1
3rd digit = number of fluorine atoms (F)
All the remaining atoms are chlorine (C1)

CONDENSER A heat exchanger on the 'hot side' of a refrigeration system in which refrigerant condenses while rejecting heat to a cooling stream (eg. ambient air).

CONDENSING TEMPERATURE The temperature at which refrigerant is condensed from a vapour to a liquid.

COP Coefficient of Performance. A measure of the efficiency of a refrigeration system. The COP is defined as the ratio of the cooling duty to the power consumption. For example, if a system has a cooling duty of 100kW and it requires 50kW of power to operate it, the COP is 2.

COP is generally related to the temperature level at which refrigeration is required. At -3°C a COP of 2 is typical whereas for air conditioning applications at +15°C a COP of 4 is achievable.

There can be a great deal of confusion over the definition of COP. In particular, there is often a big difference between cycle COP and system COP. Cycle COP only accounts for compressor power, and is usually quoted at full load. System COP also accounts for power consuming auxiliaries such as pumps and fans and can also take into account part load inefficiencies.

CRITICAL PRESSURE The saturation pressure equivalent to the Critical Temperature.

CRITICAL TEMPERATURE The temperature above which gas cannot be liquefied, irrespective of pressure. Conventional refrigeration cycles can only operate efficiently using fluids well below critical temperature.

DEW POINT The temperature at which a vapour will condense or, where associated with glide, the higher or highest boiling point of the mixture. The vapour temperature without superheat.

EVAPORATOR A heat exchanger on the 'cold side' of a refrigeration system in which refrigerant evaporates whilst a substance is being cooled.

EVAPORATING TEMPERATURE The temperature at which refrigerant boils from a liquid to a vapour.

EXPANSION DEVICE A valve, orifice, or capillary tube connecting the condenser and evaporator, designed to create a pressure drop between these two heat exchangers.

FLARE FITTING A compression fitting used to join ductile (usually copper) pipes to other pipes or to equipment such as valves, heat exchangers etc.

FRACTIONISATION The separation of the components of a refrigerant blend in the vapour phase in zeotrope fluids.

GWP Global Warming Potential. Associated with the 'greenhouse effect', the Global Warming Potential is the calculated ability of a chemical to affect global climate through the absorption and emission of infrared radiation. It is expressed in relation to CO_2 the main greenhouse gas. CO_2 is defined as having a GWP of 1. GWPs have different values dependent on the 'time horizon' chosen for their calculation; 20 year, 100 year and 500 year figures are commonly quoted. All figures used in this report are 100 year values based on IPCC (95).

GWP TONNAGE This is the mass of an individual fluid multiplied by its GWP, representing the relative contribution to global warming.

HALON Brominated Hydrocarbon. Halons contain bromine, chlorine, fluorine and carbon; they have very high ODPs. They are used as fire protection gases. Production and import (for the EU) was phased out at the beginning of 1994.

HALOGENATED HYDROCARBON Hydrocarbons, such as methane, in which the hydrogen atoms have been replaced by halogen atoms. Where all hydrogens have been replaced, the compound is referred to as fully halogenated. Where only some of the hydrogens have been replaced, the compound is referred to as partially halogenated.

HC Hydrocarbon (see below).

HCFC Hydrochlorofluorocarbons. CFCs which have not been fully halogenated, so that one or more hydrogen atoms remain the molecule. These materials are more readily decomposed in the troposphere and as such their ODPs are less than for CFCs.

HFC Hydrofluorocarbons. Partially halogenated hydrocarbons containing only fluorine, hydrogen and carbon. These chemicals have zero ozone depleting potential.

HYDROCARBONS Organic substances which contain only hydrogen and carbon.

MONTREAL PROTOCOL International agreement related to the phase out of ozone depleting substances.

ODP Ozone Depletion Potential. The relative ability of a substance to cause damage to the earth's stratospheric ozone layer.ODP is measured relative to CFC 11 or 12 which is defined as having an ODP of 1.

ODP TONNAGE This represents the mass of an individual fluid multiplied by its ODP representing the relative contribution to ozone depletion.

STRATOSPHERE The region of the earth's atmosphere extending from the top of the troposhere (a height of about 10km) to about 50km. The stratosphere is characterised by the presence of relatively high concentrations of ozone.

TEMPERATURE GLIDE The temperature difference between the bubble point and dew point temperatures.

TEWI Total Equivalent Warming Impact. This represents the global warming impact of system. For example for refrigeration TEWI is the sum of the direct global warming caused by leakage of refrigerant and the indirect global warming caused by the use of electricity (which leads to CO_2 emissions at the power station). For insulating foam TEWI is the sum of direct blowing agent emissions and the CO_2 emitted from energy used to heat the insulated space.

TRANSITIONAL FLUIDS Fluids defined by the Montreal Protocol as ones that will be phased out within the next 20 - 30 years. This applies to HCFCs being considered as transitional replacements for CFCs.

VAPOUR COMPRESSION CYCLE This is the conventional cycle used in most refrigeration applications, making use of a volatile primary refrigerant that is evaporated at low pressure to produce cooling and condensed at high pressure to reject heat. It is driven by supplying shaft power (usually from an electric motor) to a vapour compressor.

ZEOTROPE A blend of refrigerants that boil over a temperature range, and will fractionise in the vapour stage.

List of References

CIBSE

BSI

ICI

Dupont

BSRIA

MITSUBISHI HEAVY INDUSTRIES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The purpose of this Engineers Guide, is to provide an informed technical document for those involved in specifying, designing and installing air conditioning and heat pump systems, which use HFCs as the heat transfer medium. There is much at stake if the equipment is not specified and installed correctly, and hopefully the pitfalls have all been covered in this guide.

HFCs are established as the most commonly available alternative at present, with R407C at the forefront of the manufacturers' most favoured solution. Other refrigerants are also available, including R417A, as an alternative "drop in" for R22. The same quality standards are necessary for all of these new ozone benign refrigerants.

The guide emphasises the need for training and supervision, with regard to the correct installation practices for systems using the new alternative refrigerants. The potential problems of contamination in the system are of the most concern.

3D distributes air conditioning systems manufactured by Mitsubishi Heavy Industries, one of the worlds leading companies, having a reputation for high quality products. The subjects covered in this guide are intended to ensure the same quality applies to the installation, in order to ensure long term client satisfaction.

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