NORTHCUTT, INC

HC Refrigerant Products Training Manual

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HC REFRIGERANT PRODUCTS

HC-12a® HC-22a® HC-502a®

HC REFRIGERANT PRODUCTS
TRAINING MANUAL

ACKNOWLEDGEMENTS:

HYDROCARBON TECHNOLOGY II
GTZ Yearbook 1996
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Eschborn, 1996

All quotes in the manual are taken from:
GUIDELINES FOR THE USE OF HYDROCARBON REFRIGERANTS IN STATIC REFRIGERATION AND AIR CONDITIONING SYSTEMS
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TRAINING MANUAL * HC Refrigerant Products* Table of Contents

Section 1
REFRIGERATION ISSUES

"While the most notable aspects associated with hydrocarbon refrigerant system designs are safety matters, general refrigeration issues should also be considered. These include Thermodynamic Properties, Material Compatibility and Component Selection."

1.1 Refrigerant Selection

Standard Selection Criteria:

1. Match refrigerant vapor pressures to operating conditions.
2. Creation of good system efficiency.

Blended Refrigerants:

1. Selected when the effect of temperature glide and composition shift is not an issue

Table 1.1 provides a general guide and comparison for refrigerant selection and application ranges. For more information regarding refrigerant selection, please contact the HC Refrigerant Products Technical Support representative.

Table 1.1: Application ranges for HC Refrigerant Products

Refrigerant	Application Range	Replacement
HC-12a®	High/Medium temperature; domestic appliances; automotive	R12 R134a
HC-22a®	High/Medium temperature; commercial; reefer	R22 R407c R410a R411a
HC-502a®	Medium/low temperature; commercial; industrial; industrial process refrigeration; chillers; reefer	R502 R404a R408a R507a

Use refrigerant grade products only.
"Commercial grade hydrocarbons contain significant quantities of water and other impurities and could contribute to oil degradation and shorten the compressor life. Another problem with commercial LPG is that the composition of any specific hydrocarbon can be variable thus drastically changing the properties of the refrigerant from cylinder to cylinder."

1.2 Refrigerant Properties

The physical properties of a refrigerant determine its application. The predictions of system behavior and performance are aided by the known Thermodynamic and Transport properties of the refrigerant. Table 1.2 shows basic properties. Please consult the MSDS for more comprehensive information, or contact the HC Refrigerant Products Technical Support Representative.

Table 1.2: Physical Properties of Refrigerant (Metric and Standard)

PHYSICAL PROPERTIES OF REFRIGERANT – METRIC							
Refrigerant	**Density of Liquid @ 30°C (Mg/m3)**	**Boiling Point @ 1 Atmosphere (°C)**	**Critical Temperature (°C)**	**Critical Pressure (kPa)**	**Temperature Glide @ 25°C**	**Latent Heat of Vaporization @ Boiling Point (kJ/kg)**	**Density of Saturated Vapor @ Boiling Point (kg/m3)**
R12	1.29	-29.8	112.0	4015	0	165	6.3
R22	1.17	-40.8	96.1	4877	0	233	4.7
R502	1.19	-45.4	82.2	3974	< 1.0	172	6.2
HC-12a®	0.517	-32.6	113.0	3989	6	405	1.9
HC-22a®	0.484	-44.6	96.7	4248	0	426	2.4
HC-502a®	0.475	-49.8	93.5	4280	2	444	1.8

PHYSICAL PROPERTIES OF REFRIGERANT - STANDARD							
Refrigerant	**Density of Liquid @ 90°F (lb/ft3)**	**Boiling Point @ 1 Atmosphere (°F)**	**Critical Temperature (°F)**	**Critical Pressure (psig)**	**Temperature Glide @ 77°F**	**Latent Heat of Vaporization @ Boiling Point (Btu/lb)**	**Density of Saturated Vapor @ Boiling Point (lb/ft)**
R12	80.12	-21.6	234	582	0	71.5	0.39
R22	72.52	-41.4	205	707	0	101.0	0.29
R502	73.49	-49.7	180	576	< 1.0	74.6	0.38
HC-12a®	31.9	-24.7	235	579	6	177.0	0.12
HC-22a®	29.9	-43.8	206	616	0	186.0	0.15
HC-502a®	29.6	-56.2	200	621	2	191.0	0.12

1.3 Lubricants

"Hydrocarbon refrigerants possess full chemical compatibility with nearly all lubricants commonly used within refrigeration systems."

1. Good miscibility is maintained with most lubricants under all operating conditions.
2. Where high solubility could occur:
   a. It may be necessary to use a lubricant with lower solubility or increased viscosity to compensate for thinning.
   b. This is due to the good solubility with mineral oils.

"Lubricants containing silicone or silicate (often used as anti-foaming additives) are not compatible with hydrocarbon refrigerants and should not be used."

Table 1.3: Compatibility of Various Lubricants with HC Refrigerant Products

Lubricant Type	Compatibility
Mineral (M)	Fully soluble with HC refrigerants. Excessive solubility at high temperature conditions. Compensate by selection of higher viscosity grade oil.
Alkyl benzene (AB)	Fully soluble and typical viscosity grades applicable to all applications.
Semi-Synthetic (AB/M)	A blend of AB and M oils achieving desirable properties for use with HC refrigerants.
Polyol ester (POE)	Generally exhibit excessive solubility with HC refrigerants. May necessitate higher viscosity grade.
Polyalkylene glycol (PAG)	Soluble or partially soluble with HC refrigerants depending upon the conditions. Normal grades are generally satisfactory.
Poly-alpha-olefins (PAO)	Soluble with HC refrigerants but typically used for low temperature applications.

* HC Refrigerant Products are compatible with all lubricants generally used in the A/C system. It is recommended that the technician utilize the lubricant designed for use with the selected compressor.

1.4 Materials

"Virtually all common elastomer and plastic refrigeration materials used as 'O' rings, valve seats, seals and gaskets are compatible with hydrocarbon refrigerants."

Compatible materials
Neoprene
Viton
Nitrile rubbers
HNBR
PTFE
Nylon

Non-Compatible materials*
EPDM
Natural rubbers
Silicone rubbers

*These are rarely used with modern compressors but may be found in older systems.

1.5 General System Components

"Typically, system components used for fluorocarbon refrigerants do not differ significantly when using hydrocarbons. Component suppliers should be consulted regarding other in-line components such as pressure regulators, solenoid valves, etc."

Evaporators and condensers

"Evaporators and condensers using hydrocarbons tend to be virtually the same design and size as those used for conventional fluorocarbon refrigerants that operate at similar pressures. Heat transfer coefficients tend to be higher for most hydrocarbons but this does not significantly affect heat exchanger dimensions. All common types of heat exchangers are suitable for use with hydrocarbon-based refrigerants including:

- Air coiled
- Shell and tube (flooded and direct expansion)
- Plate heat exchangers

Suction-Liquid heat exchangers should also be considered since they contribute to improved system efficiency especially when using hydrocarbons"

Compressors

"Most compressor types are suitable for use with hydrocarbon refrigerants and compressor suppliers should be consulted for application and selection. Using a compressor with hydrocarbons without the supplier's approval may invalidate the warranty."

"In order to secure satisfactory performance, long life, and to protect the compressor against overload, certain design criteria should be observed. Compressor application notes and data should always be consulted when designing a system. Ensure compressors are clearly labeled to indicate that hydrocarbon refrigerants are being used in the system. The use of crankcase heaters should be considered to avoid excessive oil solubility."

Refrigerant Control Devices

All expansion device types are suitable for use with HC Refrigerants. "Design and selection criteria are the same as those for conventional fluorinated refrigerants. Computer programs and tables are available for determining capillary tube size and length, although trial and error is generally the preferred route. Thermostatic Expansion Valves (TEV) for other refrigerants that operate with similar pressure-temperature relationships can be used. Electronic Expansion Valves (EEV) may also be used. EEV's used in HC refrigerant systems must conform to the requirements of electrical components as detailed in Section 2.6.6."

Desiccants

"Desiccants are used within filter dryers. Most commonly used desiccants are compatible with hydrocarbon refrigerants. Acceptable types are XH-5, XH-6 or equivalent."

Pipe Size Selection

"When selecting refrigerant line sizes, specific hydrocarbon refrigerant pipe sizing literature should be used. Despite most hydrocarbon refrigerants having similar operating pressures to the 'equivalent' fluorocarbon refrigerants, thermodynamic and transport properties can differ significantly, thus data for other refrigerants will not be directly applicable. Refrigerant supplies should provide the appropriate pipe size selection data."

SECTION 2
SAFETY

2.1 General Safety Issues

"All hydrocarbon refrigerants are highly flammable but non-toxic."

This gives them an "A3" classification according to ASHRAE. Reference should be made to the specific Standards, which detail the requirements for the safe use of "A3" refrigerants in commercial and industrial applications. The most relevant and up to date Standard available is the EN 378 (European Standard 2000). Northcutt, Inc. recommends that the Standard EN 378 be consulted for the design and use of "A3" Refrigerants, within Canada and the United States the technician should refer to ASHRAE 15-2001 or where other Standards have not been legislated in your specific region. The European equivalent "A3" classification as used in the Standard EN 378 is "L3".

Regardless of the flammability of the refrigerant used, there are numerous safety requirements that should be considered. General safety standards and codes of practiced should be consulted for additional information.

2.2 Allowable Refrigerant Charge

"The Limiting factor associated with the use of hydrocarbon refrigerants is the refrigerant charge size, the occupancy category and the room size."

Systems with charge sizes of 0.15 kg (0.33 lb) or less may be installed in any size of room. Systems with charge size of more than 0.15 kg (0.33 lb) the room size should be such that a sudden loss of refrigerant shall not raise the mean concentration in the room above the practical limit 0.008 kg/m^3 (0.00049944 lb/ft^3). The charge size requirements according to the EN 378 annex C of Part 1 are summarized in Table 2.2. Consult the Standard EN 378 for the complete charge size requirements.

Table 2.2: Charge size requirements

Category	Examples	Volumes calculated from practical limits above up to:
A (Domestic/public)	Hospitals, prisons, theatres, schools, supermarkets, hotels, dwellings.	• 1.5kg (3.3lb) per sealed system provided there are no sources of ignition associated with the refrigerating system • 5kg (11lb) in special machinery rooms or in the open air
B (Commercial/private)	Business or professional offices, places for general manufacturing and where people work.	• 2.5kg (5.5lb) per system • 10kg (22lb) in special machinery rooms or in the open air
C (Industrial/restricted)	Cold stores, dairies, meatpacking, refineries, non-public areas of supermarkets, plant rooms.	• 10kg (22lb) in human occupied spaces • 25kg (55lb) if high pressure side (except air cooled condenser) is located in a special machinery room or in the open air • Not limited if all refrigerant containing parts located in a special machinery room or in the open air

2.3 Flammable Properties

"Table 2.3 provides property data relevant to HC refrigerants. These values are necessary in the design stage when determining maximum refrigerant charge, ventilation, flow rates and maximum allowable temperatures of components."

Table 2.3: Flammability properties for selected HC refrigerants

Refrigerant	Lower Flammability Limit (LFL)			Auto Ignition Temp
	By volume (%)	By mass (kg/m^{33})	(lb/ft^{3})	
HC-12a®	1.95	0.040	0.002497	891°C (1636°F)
HC-22a®	2.0	0.038	0.002372	480°C (896°F)
HC-502a®	2.2	0.038	0.002372	472°C (882°F)

The practical limit as defined in the EN 378 is 20% of the LFL.

2.4 Safety Standards and Code of Practice

"There are a number of codes and safety standards that are appropriate to the use of HC refrigerants and related equipment. The selection of appropriate documents is not always obvious and therefore the objective of this section is to provide a degree of clarity in this area."

Generally, refrigeration systems should be designed and constructed in accordance with the general safety requirements for A3/L3 refrigerants. These are detailed in various regional (Provincial, State or Municipal) codes. It is the responsibility of the Air Conditioning or Refrigeration Engineer/Contractor to know and understand the restrictions governing the use of A3/L3 refrigerants and to follow the guidelines accordingly.

The most fundamental difference between systems using flammable refrigerants and non-flammable refrigerants is
a) the volume allowances per square footage and
b) the use of suitable electrical equipment that will not pose a risk in the event of a release.

It is expected that engineers/contractors involved in the design, construction and maintenance of refrigeration systems be competent and up to date with training.

NOTE: Domestic and small hermetic type refrigeration systems often have other safety issues such as electric regulations related to them since they are considered as appliances. Please consult the safety requirements specific to small appliances when installing.

Standards are not exhaustive in their requirements and if a safe system of work can demonstrate an equal level of safety as that implied by the standard and satisfy Canadian or American legislation, then this approach is equally acceptable. Indeed Notified Bodies often set their own construction and test criteria when standards are not yet available or existing standards are not considered appropriate for use.

2.5 Design

Specific design requirements are generally applied to a system based on the refrigerant charge size and location.

The following pages contain an explanation of the rules governing equipment design.

2.5.1 Refrigerant Charge

Below are the equivalencies of hydrocarbon refrigerants versus CFC and HCFC system charges. Under no circumstances should the system be overcharged. It is important to note that because the density of HC refrigerants are much lower, during charging the volume of HC Refrigerant is basically equivalent to double the volume of the CFC or HCFC's. Therefore, overcharged systems pose dramatic differences in terms of the kPa (psig) increases and could therefore potentially damage systems or components.

Please refer to pages 8 & 9 for Table 2.5.1.a representing equivalencies to R12 and R134a and Table 2.5.1.b.

Table 2.5.1.a: Equivalencies to R12 and R134a

HC-12a® Refrigerant						
REFRIGERANT QUANTITY EQUIVALENT BY WEIGHT						
HC-12a®			**HFC R134a**		**CFC R12**	
1 oz			2.5 oz		2.8 oz	
2 oz			5.0 oz		5.7 oz	
3 oz		= 1/2 can	7.5 oz		8.5 oz	
4 oz			10 oz		11.4 oz	
5 oz			12.5 oz		14.2 oz	
6 oz		= 1 can	15 oz		17 oz	
7 oz			**1 lb.**	1 oz	**1lb.**	4 oz
8 oz				4 oz		6 oz
9 oz		= 1 ½ cans		6 oz		9 oz
10 oz				9 oz		12 oz
11 oz				11 oz		15 oz
12 oz		= 2 cans		14 oz	**2 lb.**	2 oz
13 oz			**2 lb.**			5 oz
14 oz				3 oz		8 oz
15 oz		= 2 ½ cans		5 oz		10 oz
1 lb.	(16 oz)			8 oz		13 oz
	1 oz			10 oz	**3 lb.**	
	2 oz	= 3 cans		13 oz		3 oz
	3 oz			15 oz		6 oz
	4 oz		**3 lb.**	2 oz		9 oz
	5 oz	= 3 ½ cans		3 oz		12 oz
	6 oz			7 oz		14 oz
	7 oz			9 oz	**4 lb.**	1 oz
	8 oz	= 4 cans		12 oz		4 oz
	9 oz			14 oz		7 oz
	10 oz		**4 lb.**	1 oz		10 oz
	11 oz	= 4 ½ cans		3 oz		13 oz
	12 oz			6 oz	**5 lb.**	
	13 oz			8 oz		2 oz
	14 oz	= 5 cans		11 oz		5 oz
	15 oz			13 oz		8 oz
2 lb.			**5 lb.**			11 oz
	1 oz	= 5 ½ cans		2 oz		14 oz
	2 oz			5 oz	**6 lb.**	1 oz
	3 oz			7 oz		4 oz
	4 oz	= 6 cans		10 oz		6 oz
	5 oz			12 oz		9 oz
	6 oz			14 oz		12 oz
	7 oz	= 6 ½ cans	**6 lb.**	1 oz		15 oz
	8 oz			4 oz	**7 lb.**	2 oz
	9 oz			6 oz		5 oz
	10 oz	= 7 cans		9 oz		8 oz
	11 oz			11 oz		10 oz

Table 2.5.1.b: Equivalencies to R22 and R502

HC Refrigerants						
REFRIGERANT QUANTITY EQUIVALENT BY WEIGHT						
HC-22a® HC-502a®			**HCFC R22**		**CFC R502**	
1oz			2.3 oz		2.5oz	
2oz			4.7oz		5.0oz	
3oz			7.0oz		7.5oz	
4oz			9.3oz		10.0oz	
5oz			11.6oz		12.5oz	
6oz			14.0oz		15.0oz	
7oz			**1 lb**		**1 lb**	1oz
8oz				3oz		4oz
9oz				5oz		7oz
10oz				7oz		9oz
11oz				10oz		11oz
12oz				12oz		14oz
13oz				14oz	**2 lb**	
14oz			**2 lb**	1oz		3oz
15oz				3oz		5oz
1 lb. (16oz)				5oz		8oz
	1oz			8oz		10oz
	2oz			10oz		13oz
	3oz			12oz		15oz
	4oz			15oz	**3 lb**	2oz
	5oz		**3 lb**	1oz		4oz
	6oz			3oz		7oz
	7oz			5oz		9oz
	8oz			8oz		12oz
	9oz			10oz		14oz
	10oz			12oz	**4 lb**	1oz
	11oz			15oz		3oz
	12oz		**4 lb**	1oz		6oz
	13oz			3oz		8oz
	14oz			6oz		11oz
	15oz			8oz		13oz
2 lb. (32oz)				10oz	**5 lb**	
	1oz			13oz		2oz
	2oz			15oz		5oz
	3oz		**5 lb**	1oz		7oz
	4oz			4oz		10oz
	5oz			6oz		12oz
	6oz			8oz		15oz
	7oz			11oz	**6 lb**	1oz
	8oz			13oz		4oz
	9oz			15oz		6oz

2.5.2 Categories

As defined by the EN 378, the following Occupancy categories require attention to the allowable charge and the provisions for each individual category.
Occupancy types as defined under EN 378 Standard are:

(A) – Rooms, parts of buildings or buildings where people may sleep, people are restricted in their movements or an uncontrolled number of people are present or to which any person has access without being personally acquainted with the necessary safety precautions.

(B) – Rooms, parts of buildings, buildings where only a limited number of people may be assembled, some being necessarily acquainted with the general safety precautions of the establishment.

(C) –Rooms, parts of buildings, buildings where only authorized persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing or storage of material or products take place.

Where there is the possibility of more than one category of occupancy, the more stringent requirements apply. If occupancies are isolated, e.g. by sealed partitions, floors and ceilings, in which case the requirements of the individual category of occupancy apply.

> NOTE: Attention is drawn to the safety of adjacent premises and occupants in areas adjacent to a refrigerating system. Refrigerants heavier than air can cause oxygen deficient pockets at lower levels.

2.5.3 Construction

If the charge is more than .15 kg (0.33 lb), then a sudden loss of refrigerant should not raise the mean concentration in the room above the practical limit 0.008 kg/m^3 (0.0004994 lb/ft^3). The room volume governs the total charge size. This can be determined by the equation 2.5.3.a.

$$M_r = 0.2 \cdot (LFL) \cdot V_{room} \quad \text{(Equation 2.5.3.a)}$$

Where:
M_r = maximum allowable refrigerant charge per separate refrigerant circuit (kg or lb)
V_{room} = room volume (m^3 or ft^3)
LFL = lower flammability limit of refrigerant (kg/m^3 or lb/ft^3) from table 2.3

Similarly, the minimum room volume for a specific refrigerant charge is determined by the equation 2.5.3.b.

$$V_{room} = \frac{M_r}{0.2 \cdot (LFL)} \quad \text{(Equation 2.5.3.b)}$$

In practical terms, for a 100m^3 (3531 ft^3) of room volume, the maximum allowable charge would be 760 g (27 oz) of HC-22a® per refrigerant circuit. Charges in systems below ground (i.e. cellars and basements) are restricted to a maximum of 1.0 kg (2.2 lb) even with larger room sizes. Sealed systems containing a charge of less than 150 g (5.3 oz) can be situated in any location, regardless of room volume.

<u>Note that all charge limits apply per single refrigerant circuit, on the basis of probability that two circuits will not have catastrophic failures simultaneously.</u>

Avoidance of Stratification

In the event of a “catastrophic” leak it is possible that stratification of refrigerant can occur, resulting in the formation of flammable concentrations at lower levels. In order to prevent this from occurring the fan associated with the refrigerating system should be able to provide a minimum airflow, as detailed in the equation 2.5.3.c. It is suggested that the fan operate only during the compressor on-cycle since the probability of a catastrophic leak during the off-cycle is negligible, or ensure the fan is connected to an interlock that would be activated only when the detection of a leak is evident.

$$V_{air} = C \cdot \frac{M_r}{(LFL)} \qquad \text{(Equation 2.5.3.c)}$$

Where:
V_{air} = minimum air flow rate from the fan m^3/h (ft^3/h)
The constant, C depends upon the origin of the airflow:
C = 17 when the evaporator fan on an air conditioning unit is providing the air flow into the room or,
C = 20 when the condenser fan on a refrigerating unit is providing the air flow into the room.

The different constants result from the effectiveness of fan mixing, primarily due to the velocity of the discharged air.

Maximum Refrigerant Charge
The maximum allowable refrigerant charge for specific installation types, subject to other requirements is as outlined in the Standards as defined by the location of the installation. We recommend that the European Standard EN 378 be consulted where relevant Provincial, Municipal or State Standards have not been legislated in your region.

Combustible Materials
Materials used to construct the refrigerating system should not be combustible.

2.5.4 Use of Components

Vibration Elimination
"If the equipment is solidly mounted then vibration eliminators to the suction and discharge lines should not, under normal circumstances, be required. If the compressor is mounted on rubber or spring mounts it may be advisable to install vibration eliminators to the suction and discharge line."

Pressure Relief
Depending on the type of system and charge size some systems must use some type of pressure relief device but not only a fusible plug. When required it is preferable to use an automatic pressure relief valve on the high side, vented to the low side before other pressure relief devices discharge refrigerant to the atmosphere. The European Standard EN 378 should be consulted to identify the type and size of systems that require some pressure relief where relevant Provincial, Municipal or State Standards have not been legislated in your region.

Pressure Switches
Depending on the type of system and charge size some systems must use low and high pressure switches located on the suction and discharge sections of the system. The European Standard EN 378 should be consulted to identify the type and size of systems that require pressure switches where relevant Provincial, Municipal or State Standards have not been legislated in your region.

Pipe Connections
Flanged joints are preferred to flared, screwed or compression type joints. For non-detachable joints soldering, welding or brazing shall be used.

Other System Components
Other system mechanical components such as pressure vessels, compressors, heat exchangers, piping and fittings should conform to the requirements of the relevant standards.

2.6 Installation

2.6.1 General

Minimum Room Volume
"Systems, or part of a system should not be located within a space or room where its volume is such that an entire refrigerant leak would cause a refrigerant/air mixture of a concentration higher than one-fifth (20%) of the Lower Flammability Limit (LFL) of the refrigerant. If this is not possible and the installation is in a machinery room then the use of a refrigerant leak detector and mechanical ventilation should be employed."

Floor Voids
"If equipment that could release its charge is installed in a room with a floor void, certain precautions should be taken. Where sources of ignition exist within the floor void, then it should either be sealed or the space ventilated. In particular, precautions should be made against refrigerant collecting in drains."

Maximum Charge Below Ground Level
"Refrigeration systems containing more than 1.0 kg (2.2 lb) should not be located in spaces below ground level."

Systems on Roofs
"In the case of installations on the roof of a building, precautions should be taken to ensure that in the event of a leak refrigerant would not enter the building."

2.6.2 Refrigerant Piping

Refrigerant Piping
Depending on the system charge size some systems cannot have piping passing through rooms that do not contain machinery as a part of the same refrigeration system. Where impractical this requirement can be overcome by using a sheath around the pipe work, with each end vented to the rooms containing the refrigerating machinery or the outside. The European Standard EN 378 should be consulted to identify the size of systems where relevant Provincial, Municipal or State Standards have not been legislated in your region.

Piping Duct Services
"Piping ducts must not contain any other pipe work or electrical wires or cables unless protection is provided to prevent damage due to interaction between services. Piping through ducts shall not contain any mechanical connections or other line components. Any ducts through which refrigerant piping passes must be vented to the atmosphere."

Piping Through Walls, Floors, Ceiling and Roof Spaces
"Piping passing through fire resisting walls and ceilings shall be so sealed as not to allow spreading of fire to neighboring rooms. Pipe ducts and shafts shall be shut off from other rooms in such a way as to resist the spread of fire. Piping through false ceilings is permitted provided that a false ceiling is not completely sealed."

Pipe work Routing Arrangements
"The route of the pipe work between the evaporator and the condensing unit or compressor, and remote condenser should be as direct and as short a distance as possible."

Water Circuits
"For systems using an indirect cooling circuit, there is a possibility of accidental release of refrigerant into the secondary circuit from a rupture of the evaporator or condenser wall. This should be dealt with by one of the following options:

- Incorporate an air vent/air separator within the secondary circuit, on the outlet pipe from the evaporator or condenser. Ensure that it is adequately sized such that it will release any refrigerant back into the housing, machinery room, special area or to the outside. This release can then be dealt with as any normal refrigerant release from the primary circuit.

Use a 'double-walled' heat exchanger, of the type that is laser-welded, designed such that it can only vent to atmosphere rather than the secondary circuit in the event of damage."

2.6.3 Machinery Rooms

"Machinery rooms for systems using HC refrigerants shall be designed to prevent the ignition of a refrigerant / air mixture. There should be warning notices stating that smoking, potential ignition sources or flames are prohibited. Fire extinguishers should be available and should provide clear instructions."

"Machinery rooms must not be constructed out of combustible materials. If it is possible for the concentration of refrigerant to reach the Lower Flammability Limit (LFL) then some explosion relief should be provided in the construction of the machinery room. This may be in the form of movable panels or louvers."

Protect all refrigerant containing machinery so that damage from external sources would be difficult.

"NOTE: Although a machinery room does not necessarily serve exclusively for refrigeration equipment, boilers and other open flame devices should not share the space. Air intakes for equipment should not be taken from within the machinery room, or close to the machinery room ventilation outlet."

As always, regional guidelines and standards should be consulted.

2.6.4 Ventilation

"Refrigeration machinery rooms should be vented to the outside air by means of natural or mechanical ventilation.

Free Air Movement (All)
"Ensure that free air movement can be achieved around all refrigerant containing parts of the system. Openings for outside air should be positioned such that short circuiting does not occur."

Mechanical Ventilation (All)
Where the refrigerant charge of a single refrigerating circuit exceeds the mass in Equation 2.5.3.a, a machinery room containing HC refrigerants must employ mechanical ventilation capable of providing the minimum ventilation rate. The minimum ventilation rate depends upon the type of electrical protection within the machinery room. Where the installation is protected according to Section 2.6.6 the mechanical ventilation rate should be equivalent to at least 10-room volume changes per hour.

Where the electrical installation does not conform to Section 2.6.6 the minimum ventilation rate is defined by equation 2.6.4.a.

$$V_{min} = \frac{M_r}{t_r \cdot (SF) \cdot (LFL)} \qquad \text{(Equation 2.6.4.a)}$$

Where:
V_{min} = minimum volume flow rate of extract fan, m^3 /hr (ft^3 /hr).
M_r = largest mass of refrigerant within any single circuit of any refrigerating system, kg (lb).
t_r = minimum release time of refrigerant following a catastrophic leak, typically 0.17 hr.
SF = safety factor, 0.5.
LFL = Lower Flammability Limit of refrigerant, kg/m^3 (lb/ft^3) from Table 2.3.

"In all cases a refrigerant detector should be linked into the initiation of mechanical ventilation. The location of the sampling point should be at low level (where heavier than air refrigerants are used). The ventilation must either be running continuously or use a refrigerant detector starting device set at 20% of the Lower Flammability Level (LFL). Lower ventilation rates can be initiated upon detection of lower refrigerant concentrations."

"The inlet of the extract ventilation should be located at floor level, and ducted to a safe location. Discharge points for vented air or openings for fresh air shall be positioned so as to avoid discharged air being drawn back in the building such as ventilation system inlets, opening windows and doors and sources of ignition. The rejection of flammable materials shall not present a hazard externally, such as entering a building or being in contact with sources of ignition. The mechanical ventilation system should be designed to maintain the room at a lower pressure than surrounding areas so that there will be no escape of leaked refrigerants to other areas. Fans for mechanical ventilation should use motors of non-sparking type and the fan blades and cowling should be designed so as to avoid sparking as a result of metal-to-metal contact. Mechanical ventilation equipment should be installed with independent emergency control located outside of and near to the machinery room."

NOTE:
- To obtain a reduced airflow under non-emergency conditions, multi-speed fans may be used.
- Machinery rooms can also use natural ventilation provided that it is designed adequately.
- As always, regional guidelines and standards should be consulted.

2.6.5 Refrigerant Detection

"Refrigerant vapor detectors should be provided in machinery rooms to activate an alarm and to automatically switch on ventilation fans if the concentration of refrigerant release exceeds the Practical Limit. Detectors should be used to isolate electrical equipment that does not conform to the electrical requirements detailed in Section 2.6.6, and to warn persons that a release has occurred. Sampling points should be installed at strategic points within machinery rooms. Points should be located so that they provide rapid signals in the event of a leak, and that the effect of air movement does not inhibit their effectiveness. Refrigerant leak detectors shall be calibrated for the specific refrigerant they are intended to detect. Where the refrigerant is heavier than air, sampling points shall be located at floor level. The European Standard EN 378 should be consulted to identify the type of systems, size and location for detection where relevant Provincial, Municipal or State Standards have not been legislated in your region."

2.6.6 Sources of Ignition

There should be no sources of ignition as part of the refrigerating system or equipment.

Electrical Components

Precautions should be taken to avoid the possibility of direct sources of ignition from exposed electrical contacts. Electrical items that have the potential to produce electrical sparks during normal operation should receive particular attention to eliminate them as potential sources of ignition. The following methods can be applied:

- Insulate terminals
- Locate within appropriate enclosures
- Replace with solid state type components
- Replace with explosion proof components
- Locate externally

Providing such items only comprise of solid state parts or have casings which are solid encapsulated or otherwise sealed or are located externally to casing of the refrigerant containing parts then adequate precautions as required above are normally achieved. Motors, including fans, pumps and compressors should be of brushless design so as not to cause potential sparks.

Components to consider as possible sources of ignition are:

- On/off manual switches
- Thermostats
- Pressure switches
- Oil differential switches
- Fan delay switches
- Contactors
- Isolator switches
- Liquid level switch
- Flow switches
- Start relays
- Thermal overload relays
- Potential relays
- Universal relays
- Condensate pump switch
- Fan speed controllers
- Humidity controllers
- Programmable controllers
- Defrost timers/switches
- Time switches/relays

NOTE: This list is not exhaustive.

If the refrigerant charge exceeds 2.5 kg (5.5 lb) in any one refrigerant circuit then the selection of electrical apparatus and its installation should be in accordance with the relevant Provincial, Municipal or State requirements.

In machinery rooms it is sufficient to fit leak detection equipment which isolates all plant room electrical via a contactor, upon detection of refrigerant. The detection device should also initiate ventilation with an appropriate extract system from a separate dedicated power supply.

Hot surfaces

Parts of refrigerating machines whose surfaces could become excessively hot shall be avoided. All components that could come into contact with released refrigerant shall have a maximum surface temperature not higher than 100°C (212°F) below the auto-ignition temperature of the refrigerant used. Auto-ignition temperatures for various refrigerants are provided in Table 2.3.

2.6.7 Pipe work Installation

Pipe work installation should be done in accordance with the requirements for the particular region that the installation is being completed in.

2.7 Marking and Instruction

Marking of Systems Installed on site

Safety instructions relating to the refrigerant in use shall be predominately displayed in machinery rooms. It is suggested that refrigerating systems installed on site shall be provided with a clearly visible plate giving at least the following information:

- Installer's name and address
- The year of installation
- The refrigerant type and number
- The allowable pressures for the system
- The approximate refrigerant charge

Marking the Compressors and Unit Systems

It is suggested that each unit system and compressor shall be provided with an adhesive plate giving at least the following:

- Manufacturer or vendors' name(s)
- Model or type reference
- Serial number
- System charge weight of refrigerant
- Test pressure and allowable pressure (if applicable)

Marking of Pipes

Pipes shall be marked, preferably according to a suitable code, e.g. a color code, to indicate the substance flowing through them.

'Flammable Gas' Stickers

It is suggested that all systems should have at least two 'flammable gas' stickers placed on them before commissioning. The stickers should be located on the compressor, receiver and any other part of the system to which an engineer would have access to the refrigerant.

2.8 General Considerations For Workshop/Manufacturing

Production areas within factories and workshops require additional precautions in addition to those detailed in other sections. While the scope of this publication does not allow for detailed coverage of these requirements, the following lists items that should be considered.

- **Storage and handling of HC refrigerant cylinders**

a) General requirements
b) Open air storage
c) Storage within specially designed buildings
d) Storage within parts of a building

- **Bulk storage installations**

a) Location, separation and security requirements
b) Underground and mounded vessels
c) Fittings and piping
d) Fire precautions

- **Appliance charging areas**

a) General requirements
b) Factory – bay areas
c) Factory – production line

- **Electrical requirements**
- **Safety management**

3.0 Service, Maintenance and Refrigerant Handling

"This section deals with practical aspects relating to the handling of both the refrigeration machine and the hydrocarbon refrigerant itself. It is recommended that companies who use hydrocarbon refrigerants either in equipment they manufacture or equipment for which they are responsible, put into place a general strategy to ensure that correct work practices are employed."

"Note that the requirements detailed under Section 3 are not exhaustive, but are intended as a guide only. Additional precautions may be appropriate dependent upon the particular equipment and conditions."

3.1 Practical Competence

"Any person who is involved with working on or breaking into a refrigerant circuit should hold a valid certificate from an industry accredited assessment authority, which authorizes their competence to handle refrigerants."

3.2 General Approach to HC Refrigerant Handling

"All flammable refrigerant gases when mixed with air form a flammable mixture. The effect of ignition of such a mixture can be severe. It is therefore important that the appropriate safety requirements are observed at all times when working with flammable refrigerants."

Any equipment used in the process of repair must be suitable for use with flammable refrigerants. All tools and equipment (including measuring equipment) are to be checked for suitability for working on the equipment, particular attention is to be paid to the selection of:

- Refrigerant recovery units (no external brushes)
- Refrigerant leak testers
- Electric test meters
- Refrigerant recovery cylinders
- Portable lighting

"If the installation permits, it is recommended that the equipment be removed from its existing position to a controlled workshop environment suitable for the type of repair where work can be conducted safely."

3.3 Safety Checks

3.3.1 Checks to the Area

Prior to beginning work on systems containing HC refrigerants, safety checks are necessary to ensure that the risk of ignition is minimized. Prior to conducting work on the system, the following precautions shall be complied with:

Work Procedure

Work shall be undertaken under a controlled procedure so as to minimize the risk of a flammable gas or vapor being present while the work is being preformed.

General Work Area

All maintenance staff and others working in the local area should be instructed as to the nature of work being carried out. Work in confined spaces should be avoided. The area around the workspaces is to be sectioned off. Ensure that the conditions within the area have been made safe by control of flammable materials.

Checking for Presence of Refrigerant

The area shall be checked with an appropriate refrigerant detector prior to and during work to ensure the technician is aware of potentially flammable atmospheres. Ensure that the leak detection equipment being used is suitable for use with flammable refrigerants, i.e. non-sparking, adequately sealed or intrinsically safe (see section 3.4).

Presence of a Fire Extinguisher

If any hot work is to be conducted on the refrigeration equipment or any associated parts, appropriate fire extinguishing equipment shall be available at hand. Have a dry powder or CO^2 fire extinguisher adjacent to the charging area.

No Ignition Sources

No person carrying out work in relation to a refrigeration system which involves exposing any pipe work which contains or has contained flammable refrigerant shall use any sources of ignition in such a manner that it may lead to the risk of fire or explosion. All possible ignition sources, including cigarette smoking, should be sufficiently far away from the site of installation, repairing, removing and disposal during which flammable refrigerant can possibly be released to surrounding space. Should there be a need for brazing or welding to be undertaken this should be done in an area detached from the A/C or Refrigeration system. If this is not possible, then the system should be fully evacuated using the guidelines as outlined in 3.5.1. Prior to work taking place the area around the equipment is to be surveyed to establish any flammable hazards or ignition risks. Display 'no smoking' signs.

Ventilated Area

Ensure that the area is in the open or that it is adequately ventilated before breaking into the system or conducting any work. A degree of ventilation should continue during the period that the work is carried out. The ventilation should safely disperse any released refrigerant and preferably expel it externally to the atmosphere.

3.3.2 Checks to the Refrigeration Equipment

Where electrical components are being changed, they are to be "fit for purpose" and to the correct specifications. At all times the manufacturer's maintenance and service guidelines are to be followed. If in doubt consult the manufacturer's Technical Department for assistance.

The following checks should be applied to installations using HC refrigerants:

- That the charge size is in accordance with the room size within which the refrigerant containing parts are installed, according to section 2.5.3 (note that HC refrigerants charge sizes are typically 40% to 42% of HCFC and some CFC's and 35% to 38% of HFC and other CFC charge sizes).
- That ventilation machinery and outlets are operating adequately and not obstructed, according to section 2.6.4
- Confirm operation of equipment such as refrigerant leak detectors and mechanical ventilation systems.
- If an indirect refrigerating circuit is being used, the secondary circuit should be checked for the presence of refrigerant.
- Ensure that marking to the equipment continues to be visible and legible. Marking and signs that are worn should be replaced (see section 2.7).
- Ensure refrigeration pipe or components are not installed in a position where it is likely to be exposed to any substance which may corrode refrigerant containing components, unless the components are constructed of materials which are inherently resistant to being corroded or are suitably protected against being so corroded.

3.3.3 Checks to Electrical Devices

Repair and maintenance to electrical components shall include initial safety checks and component inspection procedures. If a fault exists that could compromise safety, then no electrical supply should be connected to the circuit until it is satisfactorily dealt with. If the fault cannot be corrected immediately but it is necessary to continue operation, an adequate temporary solution shall be used, but this must be reported to the owner of the equipment so all parties are aware.

Initial safety checks should be as follows:

- Capacitors are discharged. This should be done in a safe manner to avoid the possibility of sparking.
- Do not work on "live" electrical components and wiring while charging, recovering and purging the system.
- Continuity of earth bonding.

During repairs to sealed components, all electrical supplies must be disconnected from the equipment being worked upon prior to any removal of sealed covers, etc. If it is absolutely necessary to have an electrical supply during servicing, then a permanently operating form of leak detection shall be located at the most critical point to forewarn the individual of a potentially hazardous situation.
For repairs to sealed components, particular attention should be paid to the following:

- Ensure that by working on electrical components, the casing is not altered in such a way that the level of protection is affected. This should include damage to cables, too many connections, terminals not made to original specification, damage to seals, incorrect fitting of glands, etc. This includes secure mounting of apparatus.
- Ensure seals or sealing materials have not degraded such that it is no longer serving the purpose of preventing the ingress of flammable atmospheres. Replacement parts shall be in accordance with the manufacturer's specifications.

NOTE: The use of silicone sealant may inhibit the effectiveness of some types of leak detection equipment. Intrinsically safe components do not have to be isolated prior to working on them.

Information for repair to intrinsically safe components shall be observed:

- Do not apply any permanent inductive or capacitance loads to the circuit without ensuring that this will not exceed the permissible voltage and current permitted for the equipment in use.
- Intrinsically safe components are the only types that can be worked on while live in the presence of a flammable atmosphere. However, test apparatus should also be of an appropriate rating.
- Replace only with parts specified by the manufacturer. Other parts may result in the ignition of refrigerant in the atmosphere from a leak.

Check that cabling will not be subject to wear corrosion, excessive pressure, sharp edges or any other adverse environmental effects. This should also take into account the effects of aging or continual vibration from sources such as the compressor or the fans.

Local electrical codes must be followed when installing or maintaining the system.

3.4 Detection Of Hydrocarbon Refrigerants

"Under no circumstances should potential sources of ignition be used in the searching or detection of refrigerant leaks. A halide torch (or any other detector using a naked flame) must not be used."

The following leak detection methods can be used on systems containing HC refrigerants:

- Electronic leak detectors may be used to detect HC refrigerants, but the sensitivity may not be adequate, or may need re-calibration. (Detection equipment should be calibrated in a refrigerant-free area). Ensure that the detector is not a potential source of ignition and is suitable for HC refrigerants. Leak detection equipment should be set at a percentage of the Lower Flammability Limit (LFL) of the refrigerant and should be calibrated to the refrigerant employed and the appropriate percentage of gas.
- Leak detection fluids are suitable for use with HC refrigerants but the use of detergents containing chlorine should be avoided as the chlorine may corrode the copper pipe work.
- Oil additives such as those used in fluorescent leak detection systems will operate with all HC refrigerants.
- If a leak is suspected form a HC refrigerant system all potential sources of ignition should be removed/extinguished.

"If a leakage of refrigerant is found which requires brazing, all of the refrigerant shall be recovered from the system, or isolated (by means of shut off valves) in part of the system remote from the leak. Nitrogen should then be purged through the system; vacuum the system to ensure any residual refrigerant that may be trapped in the systems oil is removed and then use nitrogen to purge the system during the brazing process."

3.5 Breaking Into A System And Charging

3.5.1 Removal and Evacuation

"When breaking into the refrigerant circuit to make repairs, or for any other purpose, conventional procedures are used. However, it is important that best practice is followed since flammability is now a consideration. The following procedure shall be adhered to:"

- remove refrigerant
- flush the circuit with inert gas
- evacuate
- flush again with inert gas
- open the circuit by cutting or brazing

The refrigerant charge should be recovered into the correct recovery cylinders, the system is then to be flushed with nitrogen to render the unit safe, this process may need to be repeated several times. Do not use compressed air or oxygen for this task.

Flushing is achieved by breaking the vacuum in the system with nitrogen and continuing to fill until the working pressure is achieved, then venting to atmosphere, and finally pulling down to a vacuum. This process is repeated until satisfied that no hydrocarbon refrigerant is in the system. When the final nitrogen charge is used, the system can be vented down to atmospheric pressure to enable work to take place. This operation is absolutely vital if brazing operations on the pipe work are to take place.

"Ensure that the outlet for the vacuum pump is not close to any ignition sources and there is ventilation available."

3.5.2 Charging

"The charging of refrigeration systems with HC refrigerants is similar to those using halocarbon refrigerants. As with all blend refrigerants, HC refrigerant blends should also be charged in the liquid phase in order to maintain the correct composition of the blend."

The following additional requirements should be adhered to:

- Ensure that contamination of different refrigerants does not occur when using charging equipment. Hoses or lines are to be as short as possible to minimize the amount of refrigerant contained in them.
- It is recommended that cylinders be kept upright and refrigerant is charged in the liquid phase.
- Ensure that the refrigeration system is grounded prior to charging the system with refrigerant.
- Label the system when charging is complete. The label should state that HC refrigerants have been charged into the system and that the refrigerant is flammable. Position the label in a preeminent position on the equipment (see section 2.7).
- Extreme care shall be taken not to overfill the refrigeration system. (Note that HC Refrigerant charges are typically 40% to 42% of HCFC and some CFC's and 35% to 38% of HFC and other CFC charge sizes).

Prior to recharging the system it should be pressure tested in accordance with all local/regional regulations.

The system must be leak tested on completion of charging but prior to commissioning. A follow up leak test should always be carried out prior to leaving the site.

3.5.3 Commissioning

A refrigeration system-containing HC refrigerants is commissioned in exactly the same manner as systems containing CFC/HCFC/HFC refrigerants.

Ensure that correct marking is applied to the system (see section 2.7).

3.5.4 Decommissioning

Before carrying out this procedure, it is essential that the engineer is completely familiar with the plant and all its detail. Prior to the task being carried out, an oil and refrigerant sample should be taken and case analysis is required prior to re-use of reclaimed refrigerant. It is essential that electrical power is available before the task is commenced.

1) Be familiar with the equipment and it's operation.
2) Isolate system electrically.
3) Before attempting the procedure ensure that:
- Mechanical handling equipment is available if required for handling refrigerant cylinders
- All personal protective equipment is available and being used correctly
- A competent person should supervise the recovery at all times
- Recovery equipment and cylinders conform to the requirements of section 3.5.5
4) Pump down refrigerant system if possible.
5) If a vacuum is not possible, make a manifold so that refrigerant can be removed from various parts of the system.
6) Make sure that the cylinder is situated on the scales before recovery takes place.
7) Start the recovery machine and operate in accordance with manufacturer instructions.
8) Do not overfill cylinders (no more than 80% volume liquid charge).
9) Do not exceed the maximum working pressure of the cylinder, even temporarily.
10) When the cylinders have been filled correctly and the process completed, make sure that the cylinders and the equipment are removed from the site promptly and all isolation valves on the equipment are closed off.
11) Recovered refrigerant should not be charged into another refrigeration system unless it has been checked.

NOTE: Label equipment stating that it has been de-commissioned and emptied of refrigerant. The label should be dated and signed. Unless the equipment has been purged, ensure that there are labels on the equipment stating the equipment last contained HC refrigerant.

3.5.5 Recovery

When removing refrigerant from a system, for servicing or decommissioning it is recommended good practice that all refrigerants are removed safely.

When transferring refrigerant into cylinders, ensure that only appropriate refrigerant recovery cylinders are employed. Ensure that the correct numbers of cylinders for holding the total system charge are available. All cylinders to be used are designated for the recovered refrigerant and labeled for that refrigerant. Cylinders should be complete with pressure relief valve and the cylinder and associated shut-off valves in good working order. Empty recovery cylinders are evacuated and if possible cooled before recovery occurs.

The recovery equipment shall be in good working order with a set of instructions and be suitable for the recovery of HC refrigerants. In addition, a set of calibrated weighing scales should be available and in good working order. Hoses are complete with leak-free disconnect couplings and are all in good condition. The main points to observe are:

- Check before using the recovery machine that it is in satisfactory working order and has been properly maintained and that any associated electrical components are sealed to prevent ignition in the event of a refrigerant release. Consult manufacturer if in doubt.
- Follow the advice given in this Code of Practice on general safety and the handling of cylinders.

The recovered refrigerant must be in the correct recovery cylinder. Do not mix HC refrigerants with other refrigerants in recovery units and especially not in cylinders.

If compressors or compressor oils are to be removed, ensure that it has been evacuated to an acceptable level to make certain that flammable refrigerant does not remain within the lubricant. The evacuation process shall be carried out prior to returning the compressor to the suppliers. Only electric heating to the compressor body shall be employed to accelerate this process. When oil is drained from a system, it shall be carried out safely.

3.6 Handling of Cylinders

HC-12a® refrigerant is available in 6 oz (170 g) containers, 30 lb (13.6 kg) equivalent, 50 lb (22.6 kg) equivalent, 1,000 lb (454 kg) equivalent cylinders as well as bulk.

HC-22a® and HC-502a® refrigerants are available in 50 lb (22.6 kg) equivalent, 1,000 lb (454 kg) equivalent cylinders as well as bulk. A pressure relief valve is fitted to the cylinders to prevent excess pressure build up. The cylinders are fitted with liquid off-take valves, ¼" Flare and ½" Acme connections.

The fitting is to be removed and the cylinder capped when not in use.

Safe cylinder handling differs little from other refrigerant cylinders and are as follows:

- Do not remove or obscure official labeling on a cylinder
- Always refit the valve cap when the cylinder is not in use
- Use and store cylinders in an upright position
- Check the condition of the thread and ensure it is clean and not damaged
- Store and use cylinders in dry, well-ventilated areas remote from fire risk
- Do not expose cylinders to direct sources of heat such as steam or electric radiators
- Do not repair or modify cylinders or cylinder valves
- Always use proper equipment for moving cylinders even for a short distance – never roll cylinders along the ground
- Take precautions to avoid oil, water and foreign matter from entering the cylinder
- If it is necessary to warm the cylinder, use only warm water or air, not naked flames or radiant heaters, the temperature of the water or air must not exceed 40°C (104°F)
- Always weigh the cylinder to check if it is empty – its pressure is not an accurate indication of the amount of refrigerant that remains in the cylinder

Use only dedicated recovery cylinders for the recovery of HC refrigerants.

3.7 Transportation Of Cylinders

Dangerous Goods Regulations apply to the transportation of cylinders containing refrigerants. These regulations also apply to the carriage of other compressed gasses such as oxygen, acetylene and halocarbon refrigerants. Failure to comply with the regulations will result in prosecution. All persons responsible for the shipping of Dangerous Goods must have taken an appropriate Training Course. Contact Transport Canada, the Department of Transportation (D.O.T.) or your local governmental agency responsible for transportation safety for information on local agencies authorized to provide such training.

For further information on transport of cylinders please contact the HC Refrigerants Technical Assistance Line.

3.8 Storage of Cylinders

Cylinders should be stored outside and never stored in residential premises. Cylinders may be (subject to the Authority having Jurisdiction) stored in commercial and industrial premises according to the following guidelines for storage:

- Quantities stored are to be in specific dedicated areas or cages.
- Access to storage areas restricted to 'authorized personnel only' and such places shall be marked with notices prohibiting smoking and the use of potential ignition sources.
- Cylinders containing refrigerants should be stored at ground level, never in cellars or basements. Cylinders should be readily accessible, and stored upright.

Static electricity build-up should be avoided.

3.9 Carriage Of Systems

Adherence to National and International Regulations is necessary if refrigeration equipment containing a refrigerant charge is to be transported. Particular requirements are generally determined by the equipment charge size. In general, the applicable Regulations require adequate packaging and marking. Transport companies should also be consulted when transporting equipment containing refrigerants. HC refrigerants have the United Nations designation number UN1075, and refrigeration systems containing flammable refrigerants have the United Nations designation number UN3358. The following summarizes various transportation Regulations for equipment containing flammable gas:

Transport by Road:
The Canadian Transportation of Dangerous Goods Act (TDG, 2002) and US D.O.T. CFR 49 Parts 100 – 185 (2002) Regulate the transportation of all Hazardous Goods including all refrigerants. Training is mandatory for those persons responsible for shipping. The various acts contain exemptions relating to quantities, retail and consumer packages and therefore should be consulted for specific information.

Transport by Sea:
The International Maritime Dangerous Goods Code (IMDG, 2001) prescribes requirements for transport of equipment by sea. Refrigerating machines containing less than 100 g (3.5 oz) of HC refrigerant are not subject to the regulations. Otherwise, packaging requires special marking. Refrigerating machines may be carried unpacked in crates or other appropriate overpacks, provided that the equipment has been pressure tested and designed so as to prevent the release of refrigerant during transport conditions.

Transport by Air:
The International Civil Aviation Organization/International Air Transport Association (IATA, 2003) prescribes the Regulations for transport by air. This forbids transport of equipment containing more than 0.1 kg (4 oz) in either passenger or cargo planes. If transport by air is necessary, the regulations do permit up to 150 kg (330 lb) of HC refrigerant to be carried by cylinder, so systems can be charged.

NOTE: In line with other requirements, the refrigerant charge is applicable per refrigerant circuit.

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4.1 Suction Line Data for HC-12a®

4.1.1 Evaporator Capacity Table for Suction Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

	Evaporating (Dew/Bubble) Temperature (°C)						
	-30/-38.7	-20/-28.6	-10/-18.4	-5/-13.3	0/-8.2	5/-3.1	10/2.0
Nominal Pipe Size (in)	Suction Line Pressure Loss (equivalent to 0.04 K/m) (Pa/m)						
	132	184	240	288	328	376	424
1/4	0.06	0.09	0.13	0.17	0.20	0.24	0.28
3/8	0.18	0.28	0.42	0.52	0.63	0.75	0.88
1/2	0.41	0.65	0.97	1.20	1.45	1.75	2.05
5/8	0.78	1.23	1.83	2.28	2.74	3.30	3.87
3/4	1.25	1.97	2.92	3.64	4.48	5.27	6.18
7/8	1.94	3.03	4.53	5.64	6.79	8.17	9.58
1 1/8	3.93	6.18	9.18	11.4	13.8	16.5	19.4
1 3/8	6.86	10.8	16.0	19.9	24.0	28.7	33.9
1 5/8	10.9	17.1	25.4	31.6	38.1	45.8	53.7
2 1/8	22.6	35.7	52.9	65.8	79.3	95.4	112
2 5/8	40.9	64.5	95.7	119	143	173	202
3 1/8	63.7	100	149	185	223	269	315
3 5/8	95.5	150	233	278	334	402	472

4.1.2 Evaporator Capacity Correction Factors, Cf_{co}' for Condenser Outlet Temperature

Condenser Outlet Temperature (°C)	1.8	12.1	22.3	32.7	43.0	53.5
Correction Factor Cf_{co}'	1.29	1.20	1.10	1.00	0.90	0.78

4.1.3 Minimum Refrigeration Capacity for Oil Entrainment up Suction Risers

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating (Dew/Bubble) Temperature (°C) -30/-38.7	-20/-28.6	-10/-18.4	-5/-13.3	0/-8.2	5/-3.1	10/2.0
1/4	0.04	0.05	0.06	0.07	0.08	0.09	0.10
3/8	0.12	0.15	0.19	0.22	0.24	0.27	0.30
1/2	0.27	0.35	0.45	0.50	0.56	0.63	0.69
5/8	0.50	0.66	0.85	0.95	1.06	1.19	1.30
3/4	0.81	1.06	1.35	1.52	1.70	1.90	2.08
7/8	1.25	1.64	2.10	2.36	2.64	2.94	3.23
1 1/8	2.53	3.32	4.25	4.77	5.34	5.97	6.55
1 3/8	4.42	5.79	7.42	8.34	9.33	10.4	11.4
1 5/8	7.01	9.19	11.8	13.2	14.8	16.5	18.1
2 1/8	14.6	19.1	24.5	27.5	30.8	34.4	37.7
2 5/8	26.4	34.6	44.3	49.8	55.7	62.2	68.2
3 1/8	41.1	53.9	69.0	77.6	86.7	96.9	106
3 5/8	61.6	80.7	103	116	130	145	159

4.2 Liquid Line Data for HC-12a®

4.2.1 Evaporator Capacity Table for Liquid Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, Condensing temperature 40.0 / 32.7 °C, 5K liquid subcooling)

Nominal Pipe Size (in)	1/4	3/8	1/2	5/8	3/4	7/8
Capacity @ 0.02 K/m (402 Pa/m)	2.10	6.54	15.2	28.6	48.7	70.9

Nominal Pipe Size (in)	1 1/8	1 3/8	1 5/8	2 1/8
Capacity @ 0.02 K/m (402 Pa/m)	144	251	398	828

4.2.2 Evaporator Capacity Correction Factors, Cf_{te} for Evaporating temperature

(10K evaporator superheat)

Evap Temp (°C)	-30	-20	-10	-5	0	5	10
Corr Factor Cf_{te}	0.91	0.96	1.01	1.03	1.06	1.08	1.11

4.3 Discharge Line Data for HC-12a®

4.3.1 Evaporator Capacity Table for Discharge Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating (Dew/Bubble) Temperature (°C)						
	-30/-38.7	-20/-28.6	-10/-18.4	-5/-13.3	0/-8.2	5/-3.1	10/2.0
1/4	0.33	0.35	0.38	0.39	0.40	0.42	0.43
3/8	1.03	1.10	1.18	1.22	1.25	1.29	1.33
1/2	2.38	2.55	2.73	2.82	2.90	2.99	3.08
5/8	4.50	4.83	5.16	5.33	5.49	5.66	5.82
3/4	7.18	7.71	8.24	8.50	8.77	9.03	9.29
7/8	11.1	12.0	12.8	13.2	13.6	14.0	14.4
1 1/8	22.6	24.2	25.9	26.7	27.5	28.4	29.2
1 3/8	39.4	42.3	45.2	46.6	48.1	49.5	51.0
1 5/8	62.4	67.0	71.6	73.9	76.2	78.5	80.8
2 1/8	130	140	149	154	159	164	168
2 5/8	235	252	270	278	284	296	304
3 1/8	366	393	420	434	447	460	474
3 5/8	548	589	629	649	669	690	710

4.3.2 Evaporator Capacity Correction Factors, Cf_{te} for Condensing Temperature

(5k subcooling)

Condensing Temperature (°C)	10	20	30	40	50	60
Pressure Loss 0.02 K/m (Pa/m)	212	266	330	402	482	574
Correction Factor, Cf_{te}	0.61	0.74	0.90	1.05	1.19	1.31

Notes

1. Pipe selection table methodology based on Chapter 2, *System Practices for Halocarbon Refrigerants of* 1994 ASHRAE Refrigeration Handbook.
2. Properties of refrigerants taken from KMKREIS version 3.22.
3. All Pipe internal diameters based on mean values from ASTM B88 Table 3.
4. Discharge line capacities assume compressor efficiency of 65%.
5. To convert table evaporator capacities for ½ the pressure loss indicated, multiply by 0.68.
6. To convert table evaporator capacities for 1 ½ pressure loss indicated, multiply by 1.25.

5 PIPE SELECTION TABLES FOR HC-22a®

5.1 Suction Line Data for HC-22a®

5.1.1 Evaporator Capacity Table for Suction Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

	Evaporating Temperature (°C)						
	-30	-20	-10	-5	0	5	10
Nominal Pipe Size (in)	**Suction Line Pressure Loss (equivalent to 0.04 K/m) (Pa/m)**						
	264	**352**	**460**	**520**	**584**	**652**	**728**
1/4	0.12	0.18	0.26	0.31	0.36	0.43	0.50
3/8	0.37	0.55	0.80	0.96	1.13	1.33	1.56
1/2	0.85	1.28	1.86	2.22	2.62	3.08	3.61
5/8	1.61	2.42	3.52	4.19	4.96	5.83	6.83
3/4	2.58	3.86	5.61	6.69	7.92	9.30	10.9
7/8	4.00	5.99	8.70	10.4	12.3	14.4	16.9
1 1/8	8.09	12.1	17.7	21.0	24.9	29.2	34.3
1 3/8	14.1	21.2	30.8	36.7	43.4	51.0	59.8
1 5/8	22.4	33.6	48.8	58.3	68.8	80.9	94.8
2 1/8	46.7	69.9	102	121	143	168	197
2 5/8	84.4	126	185	219	259	305	357
3 1/8	131	197	286	341	404	474	556
3 5/8	197	295	429	511	604	710	832

5.1.2 Evaporator Capacity Correction Factors, Cf_{co}' for Condenser Outlet Temperature

Condenser Outlet Temperature (°C)	1.8	12.1	22.3	32.7	43.0	53.5
Correction Factor Cf_{co}'	1.29	1.20	1.10	1.00	0.90	0.78

5.1.3 Minimum Refrigeration Capacity for Oil Entrainment up Suction Risers

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating Temperature (°C)						
	-30	-20	-10	-5	0	5	10
1/4	0.05	0.07	0.08	0.09	0.10	0.11	0.13
3/8	0.16	0.21	0.26	0.29	0.32	0.35	0.39
1/2	0.38	0.48	0.60	0.66	0.75	0.82	0.91
5/8	0.71	0.90	1.13	1.27	1.39	1.55	1.71
3/4	1.13	1.45	1.81	2.01	2.25	2.46	2.72
7/8	1.75	2.24	2.80	3.13	3.46	3.82	4.23
1 1/8	3.55	4.54	5.69	6.36	7.01	7.81	8.52
1 3/8	6.21	7.89	9.94	11.1	12.3	13.6	15.0
1 5/8	9.83	12.6	15.7	17.5	19.4	21.5	23.7
2 1/8	20.5	26.2	32.8	36.5	40.5	45.0	49.2
2 5/8	37.0	47.2	59.4	66.0	73.4	80.7	89.1
3 1/8	57.7	73.7	92.5	103	114	126	140
3 5/8	86.5	110	138	154	170	189	209

5.2 Liquid Line Data for HC-22a®

5.2.1 Evaporator Capacity Table for Liquid Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, Condensing temperature 40°C, 5K liquid subcooling)

Nominal Pipe Size (in)	1/4	3/8	1/2	5/8	3/4	7/8
Capacity @ 0.02 K/m (644 Pa/m)	2.62	8.15	18.9	35.7	57.1	88.4
Nominal Pipe Size (in)	1 1/8	1 3/8	1 5/8	2 1/8		
Capacity @ 0.02 K/m (644 Pa/m)	179	313	496	1033		

5.2.2 Evaporator Capacity Correction Factors, Cf_{te} for Evaporating temperature

(10K evaporator superheat)

Evap Temp (°C)	-30	-20	-10	-5	0	5	10
Corr Factor Cf_{te}	0.92	0.97	1.02	1.04	1.06	1.08	1.11

5.3 Discharge Line Data for HC-22a®

5.3.1 Evaporator Capacity Table for Discharge Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating Temperature (°C) -30	-20	-10	-5	0	5	10
1/4	0.53	0.57	0.60	0.62	0.64	0.66	0.68
3/8	1.64	1.76	1.88	1.94	2.00	2.06	2.12
1/2	3.80	4.08	4.36	4.50	4.64	4.78	4.92
5/8	7.18	7.71	8.24	8.51	8.78	9.04	9.31
3/4	11.5	12.3	13.2	13.6	14.0	14.4	14.9
7/8	17.8	19.1	20.4	21.1	21.7	22.4	23.0
1 1/8	36.0	38.7	41.3	42.7	44.0	45.3	46.7
1 3/8	62.8	67.5	72.2	74.5	76.8	79.1	81.5
1 5/8	99.6	107	114	118	122	125	129
2 1/8	208	223	238	246	254	261	269
2 5/8	375	403	431	445	459	472	486
3 1/8	584	628	671	693	714	736	758
3 5/8	875	940	1005	1037	1070	1096	1135

5.3.2 Evaporator Capacity Correction Factors, Cf_{te} for Condensing Temperature

(5k subcooling)

Condensing Temperature (°C)	10	20	30	40	50	60
Pressure Loss 0.02 K/m (Pa/m)	364	446	538	644	758	882
Correction Factor, Cf_{te}	0.70	0.82	0.95	1.06	1.16	1.21

Notes

1. Pipe selection table methodology based on Chapter 2, *System Practices for Halocarbon Refrigerants of* 1994 ASHRAE Refrigeration Handbook.
2. Properties of refrigerants taken from KMKREIS version 3.22.
3. All Pipe internal diameters based on mean values from ASTM B88 Table 3.
4. Discharge line capacities assume compressor efficiency of 65%.
5. To convert table evaporator capacities for ½ the pressure loss indicated, multiply by 0.68.
6. To convert table evaporator capacities for 1 ½ pressure loss indicated, multiply by 1.25.

6 PIPE SELECTION TABLES FOR HC-502a®

6.1 Suction Line Data for HC-502a®

6.1.1 Evaporator Capacity Table for Suction Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

	Evaporating (Dew/Bubble) Temperature (°C)						
	-30/-36.0	-20/-25.7	-10/-15.	-5/-10.2	0/-5.0	5/0.1	10/5.3
Nominal Pipe Size (in)	**Suction Line Pressure Loss (equivalent to 0.04 K/m) (Pa/m)**						
	276	**372**	**484**	**548**	**612**	**688**	**768**
1/4	0.13	0.19	0.28	0.33	0.39	0.46	0.54
3/8	0.40	0.60	0.87	1.04	1.22	1.44	1.69
1/2	0.93	1.40	2.02	2.41	2.84	3.34	3.91
5/8	1.76	2.64	3.81	4.55	5.36	6.32	7.40
3/4	2.81	4.21	6.08	7.26	8.56	10.1	11.8
7/8	4.35	6.54	9.43	11.3	13.3	15.7	19.3
1 1/8	8.81	13.2	19.1	22.8	26.9	31.7	37.1
1 3/8	15.4	23.1	33.4	39.8	46.9	55.3	64.8
1 5/8	24.4	36.7	52.9	63.2	74.4	87.7	103
2 1/8	50.8	76.3	110	132	155	183	214
2 5/8	91.9	138	199	238	280	330	387
3 1/8	143	215	310	370	437	515	602
3 5/8	214	322	464	555	660	771	902

6.1.2 Evaporator Capacity Correction Factors, Cf_{co}' for Condenser Outlet Temperature

Condenser Outlet Temperature (°C)	5.7	16.0	26.3	36.6	46.9	57.3
Correction Factor Cf_{co}'	1.34	1.23	1.12	1.00	0.88	0.74

6.1.3 Minimum Refrigeration Capacity for Oil Entrainment up Suction Risers

(Capacities in kW, $Q_e' = Q_e/Cf_{co}'$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating (Dew/Bubble) Temperature (°C) -30/-36.0	-20/-25.7	-10/-15.4	-5/-10.2	0/-5.0	5/0.1	10/5.3
1/4	0.06	0.07	0.09	0.10	0.11	0.12	0.13
3/8	0.17	0.22	0.27	0.30	0.34	0.37	0.41
1/2	0.40	0.51	0.63	0.70	0.78	0.86	0.95
5/8	0.75	0.96	1.20	1.33	1.48	1.63	1.79
3/4	1.20	1.53	1.91	2.13	2.36	2.60	2.86
7/8	1.87	2.37	2.96	3.30	3.65	4.04	4.44
1 1/8	3.78	4.80	6.00	6.68	7.40	8.17	9.00
1 3/8	6.59	8.39	10.5	11.7	12.9	14.3	15.7
1 5/8	10.5	13.3	16.6	18.5	20.5	22.6	24.9
2 1/8	21.8	27.7	34.6	38.5	42.7	47.1	51.9
2 5/8	39.4	50.1	62.6	69.6	77.1	85.2	93.8
3 1/8	61.3	78.0	97.4	108	120	133	146
3 5/8	91.8	117	146	162	180	199	219

6.2 Liquid Line Data for HC-502a®

6.2.1 Evaporator Capacity Table for Liquid Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, Condensing temperature 40.0°C, 5K liquid subcooling)

Nominal Pipe Size (in)	1/4	3/8	1/2	5/8	3/4	7/8
Capacity @ 0.02 K/m (678 Pa/m)	2.77	8.60	19.9	37.7	60.1	93.3
Nominal Pipe Size (in)	1 1/8	1 3/8	1 5/8	2 1/8		
Capacity @ 0.02 K/m (678 Pa/m)	189	330	523	1090		

6.2.2 Evaporator Capacity Correction Factors, Cf_{te} for Evaporating temperature

(10K evaporator superheat)

Evap Temp (°C)	-30	-20	-10	-5	0	5	10
Corr Factor Cf_{te}	0.93	0.97	1.02	1.04	1.06	1.08	1.10

6.3 Discharge Line Data for HC-502a®

6.3.1 Evaporator Capacity Table for Discharge Lines

(Capacities in kW, $Q_e' = Q_e/Cf_{te}$, 10K evaporator superheat, 10K suction superheat)

Nominal Pipe Size (in)	Evaporating (Dew/Bubble) Temperature (°C)						
	-30/-36.0	-20/-25.7	-10/-15.4	-5/-10.2	0/-5.0	5/0.1	10/5.3
1/4	0.57	0.62	0.66	0.68	0.70	0.72	0.74
3/8	1.78	1.91	2.04	2.11	2.17	2.24	2.30
1/2	4.13	4.43	4.74	4.89	5.04	5.19	5.33
5/8	7.81	8.38	8.96	9.24	9.53	9.80	10.1
3/4	12.5	13.4	14.3	14.8	15.2	15.7	16.1
7/8	19.3	20.8	22.2	22.9	23.6	24.3	25.0
1 1/8	39.2	42.0	44.9	46.3	47.8	49.2	50.6
1 3/8	68.4	73.4	78.4	80.9	93.4	85.8	88.3
1 5/8	108	116	124	128	132	136	140
2 1/8	226	242	259	267	275	284	292
2 5/8	408	438	468	483	498	512	527
3 1/8	636	682	729	752	775	798	821
3 5/8	952	1022	1092	1126	1161	1195	1229

6.3.2 Evaporator Capacity Correction Factors, Cf_{te} for Condensing Temperature

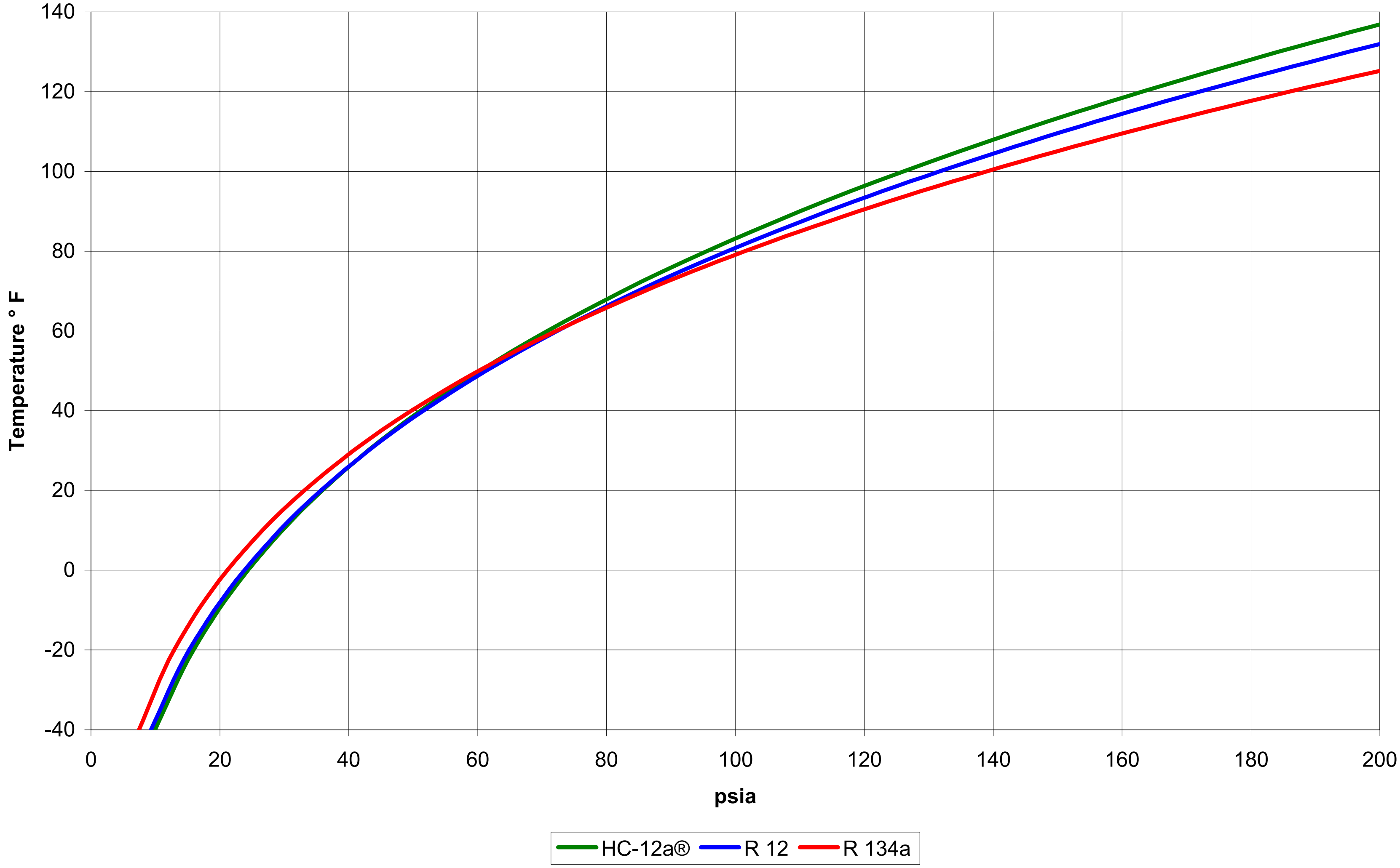
(5k subcooling)

Condensing Temperature (°C)	10	20	30	40	50	60
Pressure Loss 0.02 K/m (Pa/m)	384	472	570	678	802	938
Correction Factor, Cf_{te}	0.72	0.86	0.99	1.12	1.23	1.30

Notes

1. Pipe selection table methodology based on Chapter 2, *System Practices for Halocarbon Refrigerants of* 1994 ASHRAE Refrigeration Handbook.
2. Properties of refrigerants taken from KMKREIS version 3.22.
3. All Pipe internal diameters based on mean values from ASTM B88 Table 3.
4. Discharge line capacities assume compressor efficiency of 65%.
5. To convert table evaporator capacities for ½ the pressure loss indicated, multiply by 0.68.
6. To convert table evaporator capacities for 1 ½ pressure loss indicated, multiply by 1.25.

HC-12a® Vapor Pressure vs. Temperature

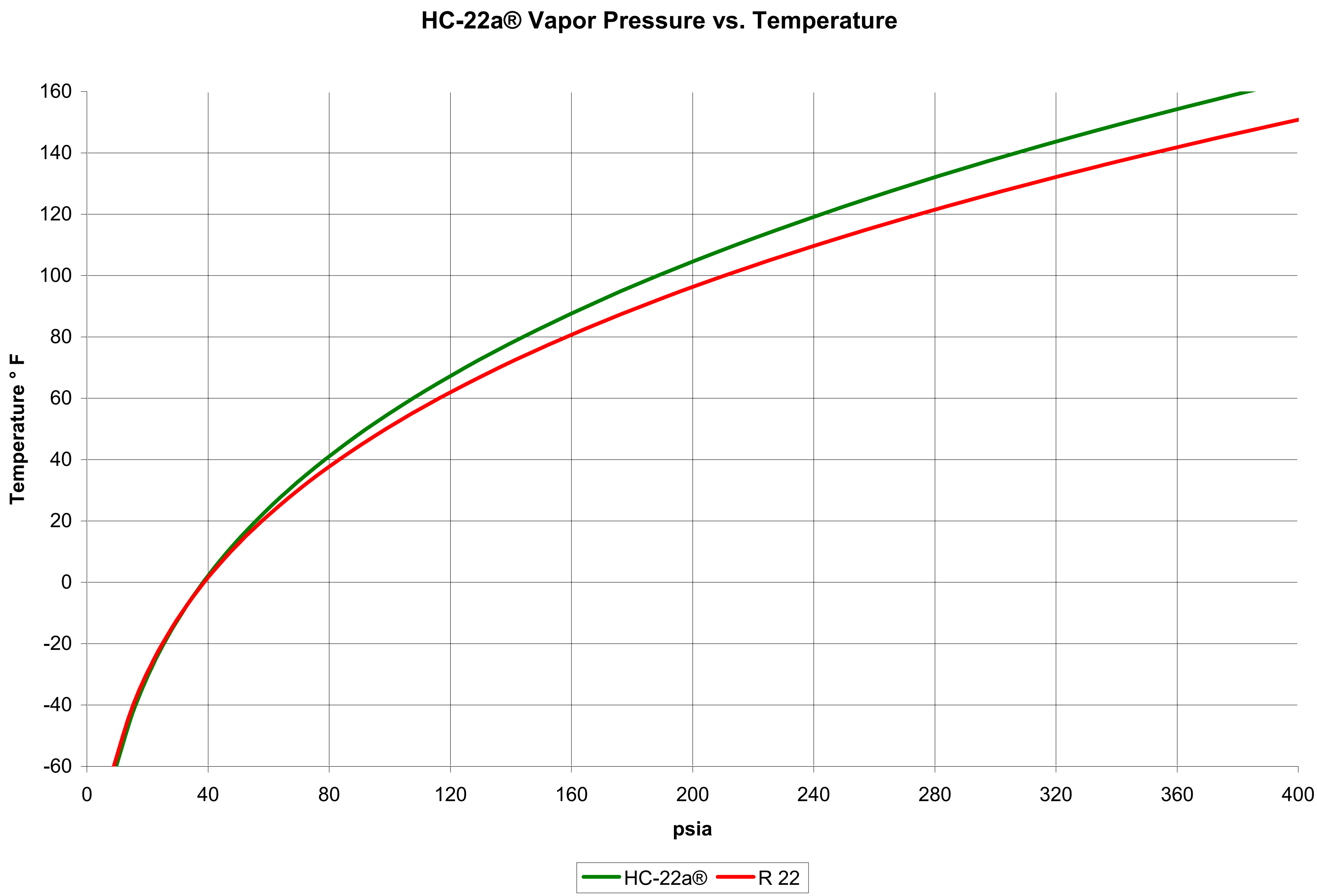


HC-12a®: Bubble Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°F)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	10.7	10.7	37.5	0.1	46.7	208.5	0.2	0.5
-35	12.0	12.0	37.3	0.1	49.3	210.1	0.2	0.5
-30	13.5	13.5	37.1	0.2	51.9	211.6	0.2	0.5
-25	15.2	15.2	36.9	0.2	54.6	213.2	0.2	0.5
-20	17.0	17.0	36.7	0.2	57.2	214.8	0.2	0.5
-15	19.0	19.0	36.5	0.2	59.9	216.3	0.2	0.5
-10	21.1	21.1	36.3	0.2	62.6	217.9	0.2	0.5
-5	23.5	23.5	36.1	0.3	65.3	219.5	0.2	0.5
0	26.0	26.0	35.9	0.3	68.1	221.0	0.2	0.5
5	28.7	28.7	35.7	0.3	70.8	222.6	0.2	0.5
10	31.7	31.7	35.5	0.3	73.6	224.2	0.2	0.5
15	34.8	34.8	35.3	0.4	76.4	225.8	0.2	0.5
20	38.2	38.2	35.1	0.4	79.2	227.3	0.2	0.5
25	41.8	41.8	34.9	0.4	82.0	228.9	0.2	0.5
30	45.7	45.7	34.7	0.5	84.9	230.5	0.2	0.5
35	49.9	49.9	34.5	0.5	87.8	232.0	0.2	0.5
40	54.3	54.3	34.3	0.6	90.7	233.6	0.2	0.5
45	59.0	59.0	34.0	0.6	93.6	235.2	0.3	0.5
50	64.0	64.0	33.8	0.7	96.5	236.7	0.3	0.5
55	69.4	69.4	33.6	0.7	99.5	238.3	0.3	0.5
60	75.0	75.0	33.4	0.8	102.5	239.8	0.3	0.5
65	81.0	81.0	33.1	0.8	105.5	241.4	0.3	0.5
70	87.3	87.3	32.9	0.9	108.5	242.9	0.3	0.5
75	94.0	94.0	32.6	1.0	111.6	244.5	0.3	0.5
80	101.0	101.0	32.4	1.0	114.7	246.0	0.3	0.5
85	108.4	108.4	32.2	1.1	117.8	247.5	0.3	0.5
90	116.2	116.2	31.9	1.2	120.9	249.0	0.3	0.5
95	124.4	124.4	31.6	1.3	124.1	250.5	0.3	0.5
100	133.0	133.0	31.4	1.3	127.3	252.0	0.3	0.5
105	142.1	142.1	31.1	1.4	130.6	253.5	0.3	0.5
110	151.5	151.5	30.8	1.5	133.8	254.9	0.3	0.5

HC-12a®: Dew Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°F)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	7.0	7.0	35.3	0.1	51.5	222.2	0.2	0.6
-35	8.0	8.0	35.2	0.1	54.2	223.7	0.2	0.6
-30	9.2	9.2	35.1	0.1	57.0	225.3	0.2	0.6
-25	10.4	10.4	34.9	0.1	59.7	226.8	0.2	0.6
-20	11.8	11.8	34.8	0.1	62.4	228.3	0.2	0.6
-15	13.3	13.3	34.6	0.1	65.2	229.8	0.2	0.6
-10	15.0	15.0	34.5	0.2	68.0	231.3	0.2	0.6
-5	16.8	16.8	34.3	0.2	70.8	232.9	0.2	0.6
0	18.8	18.8	34.2	0.2	73.6	234.4	0.2	0.6
5	21.0	21.0	34.0	0.2	76.4	235.9	0.2	0.6
10	23.4	23.4	33.9	0.2	79.2	237.4	0.2	0.6
15	25.9	25.9	33.7	0.3	82.1	239.0	0.2	0.6
20	28.7	28.7	33.5	0.3	84.9	240.5	0.2	0.6
25	31.7	31.7	33.4	0.3	87.8	242.0	0.2	0.6
30	34.9	34.9	33.2	0.4	90.7	243.5	0.3	0.6
35	38.4	38.4	33.0	0.4	93.6	245.0	0.3	0.6
40	42.2	42.2	32.9	0.4	96.5	246.5	0.3	0.6
45	46.2	46.2	32.7	0.5	99.5	248.1	0.3	0.6
50	50.5	50.5	32.5	0.5	102.4	249.6	0.3	0.6
55	55.0	55.0	32.3	0.6	105.4	251.1	0.3	0.6
60	59.9	59.9	32.1	0.6	108.4	252.5	0.3	0.6
65	65.1	65.1	31.9	0.7	111.4	254.0	0.3	0.6
70	70.7	70.7	31.7	0.7	114.5	255.5	0.3	0.6
75	76.5	76.5	31.6	0.8	117.6	257.0	0.3	0.6
80	82.8	82.8	31.3	0.8	120.6	258.4	0.3	0.6
85	89.4	89.4	31.1	0.9	123.7	259.9	0.3	0.6
90	96.4	96.4	30.9	1.0	126.9	261.3	0.3	0.6
95	103.7	103.7	30.7	1.0	130.0	262.7	0.3	0.6
100	111.5	111.5	30.5	1.1	133.2	264.1	0.3	0.6
105	119.8	119.8	30.3	1.2	136.4	265.5	0.3	0.6
110	128.4	128.4	30.1	1.3	139.7	266.9	0.3	0.6

HC-12a®: Bubble Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m^3)	(kg/m^3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	73.40	73.40	600.80	1.96	108.50	484.70	0.64	2.23
-35	91.20	91.20	595.30	2.40	119.50	491.20	0.69	2.23
-30	112.20	112.20	589.70	2.91	130.60	497.70	0.73	2.22
-25	136.70	136.70	584.00	3.49	141.80	504.30	0.78	2.22
-20	165.20	165.20	578.20	4.17	153.10	510.90	0.82	2.21
-15	198.00	198.00	572.40	4.94	164.60	517.50	0.87	2.21
-10	235.60	235.60	566.50	5.81	176.30	524.00	0.91	2.21
-5	278.20	278.20	560.40	6.79	188.10	530.60	0.96	2.21
0	326.50	326.50	554.20	7.90	200.00	537.20	1.00	2.21
5	380.80	380.80	548.00	9.14	212.10	543.70	1.04	2.21
10	441.50	441.50	541.50	10.53	224.40	550.30	1.09	2.21
15	509.20	509.20	535.00	12.08	236.80	556.80	1.13	2.22
20	584.10	584.10	528.20	13.80	249.40	563.20	1.17	2.22
25	666.90	666.90	521.30	15.71	262.30	569.70	1.22	2.22
30	758.00	758.00	514.20	17.83	275.30	576.00	1.26	2.23
35	857.80	857.80	506.80	20.18	288.50	582.30	1.30	2.23
40	966.80	966.80	499.20	22.79	302.00	588.50	1.34	2.24
45	1085.50	1085.50	491.40	25.67	315.70	594.60	1.39	2.24
50	1214.50	1214.50	483.20	28.88	329.70	600.50	1.43	2.24
55	1354.10	1354.10	474.70	32.44	343.90	606.40	1.47	2.25
60	1505.10	1505.10	465.80	36.40	358.50	612.00	1.52	2.25
65	1667.80	1667.80	456.50	40.83	373.40	617.40	1.56	2.26
70	1842.80	1842.80	446.60	45.80	388.60	622.50	1.60	2.26
75	2030.80	2030.80	436.20	51.41	404.30	627.30	1.65	2.27
80	2232.30	2232.30	425.00	57.79	420.40	631.60	1.69	2.27

HC-12a®: Dew Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m^3)	(kg/m^3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	48.30	48.30	566.00	1.28	119.80	516.50	0.68	2.43
-35	61.50	61.50	562.00	1.61	131.10	522.90	0.73	2.41
-30	77.30	77.30	557.80	1.99	142.60	529.20	0.78	2.40
-25	96.20	96.20	553.60	2.44	154.10	535.60	0.83	2.39
-20	118.50	118.50	549.20	2.96	165.80	542.00	0.87	2.39
-15	144.70	144.70	544.80	3.57	177.50	548.40	0.92	2.38
-10	175.10	175.10	540.20	4.26	189.40	554.70	0.97	2.37
-5	210.10	210.10	535.50	5.06	201.40	561.10	1.01	2.37
0	250.30	250.30	530.60	5.97	213.50	567.50	1.06	2.37
5	296.10	296.10	525.60	7.00	225.70	573.80	1.10	2.36
10	347.90	347.90	520.50	8.17	238.10	580.10	1.15	2.36
15	406.20	406.20	515.20	9.48	250.60	586.30	1.19	2.36
20	471.60	471.60	509.70	10.94	263.30	592.50	1.23	2.36
25	544.50	544.50	504.00	12.59	276.10	598.70	1.28	2.36
30	625.60	625.60	498.20	14.43	289.10	604.70	1.32	2.36
35	715.20	715.20	492.10	16.48	302.30	610.70	1.36	2.36
40	814.10	814.10	485.70	18.77	315.60	616.50	1.40	2.36
45	922.80	922.80	479.10	21.33	329.20	622.20	1.45	2.36
50	1041.90	1041.90	472.20	24.18	342.90	627.80	1.49	2.36
55	1172.00	1172.00	465.00	27.37	356.90	633.20	1.53	2.36
60	1313.90	1313.90	457.30	30.94	371.10	638.30	1.57	2.37
65	1468.30	1468.30	449.30	34.95	385.60	643.20	1.61	2.37
70	1635.90	1635.90	440.70	39.47	400.40	647.70	1.65	2.37
75	1817.70	1817.70	431.60	44.61	415.50	651.90	1.70	2.37
80	2014.60	2014.60	421.80	50.47	431.00	655.50	1.74	2.36

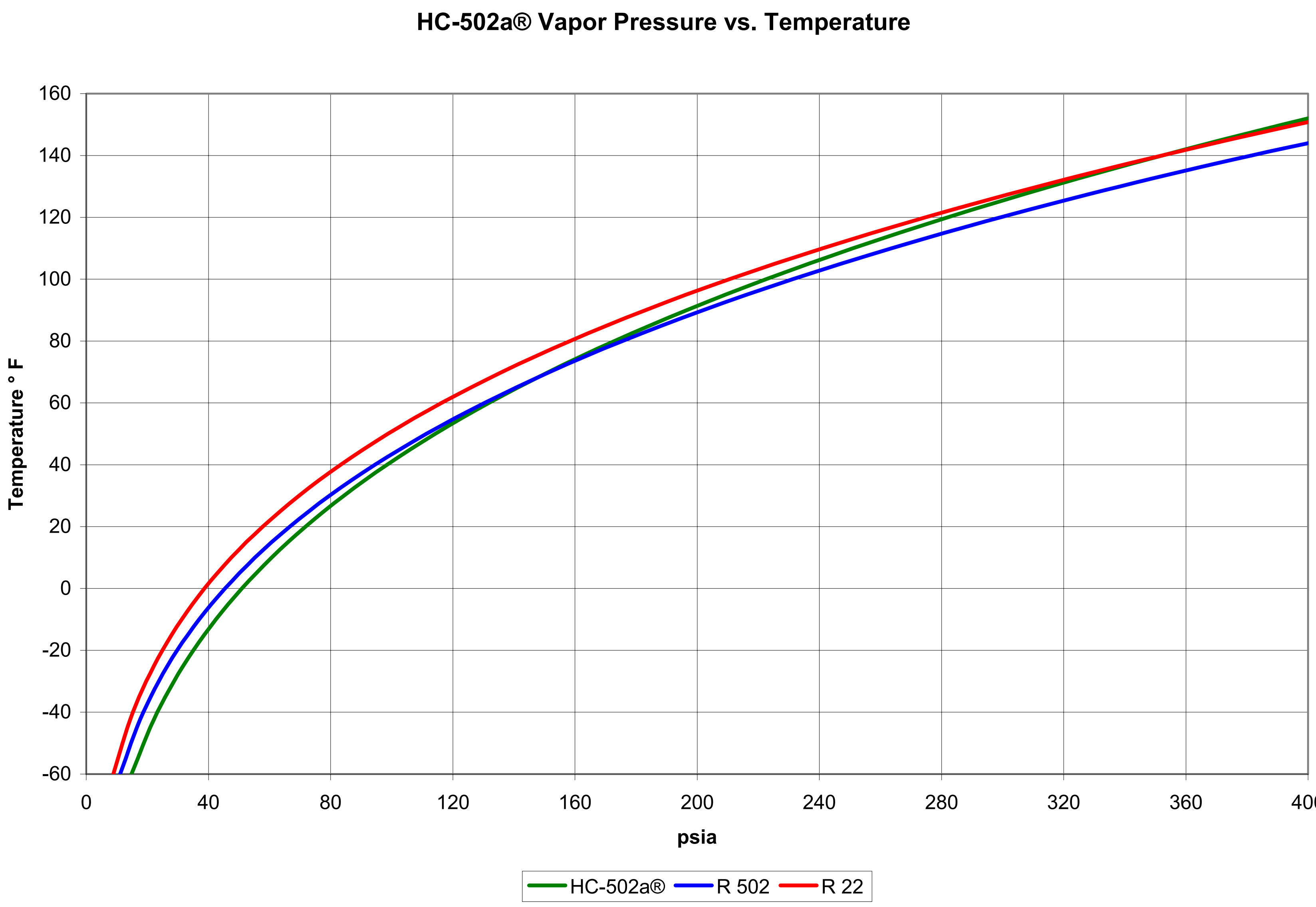

HC-22a® Vapor Pressure vs. Temperature
160
140
120
100
80
60
40
20
0
-20
-40
-60
Temperature ° F
0
40
80
120
160
200
240
280
320
360
400
psia
HC-22a®
R 22

HC-22a®: Bubble Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°F)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	18.2	18.2	36.1	0.2	45.3	220.3	0.2	0.6
-35	20.4	20.4	35.9	0.2	48.0	222.0	0.2	0.6
-30	22.8	22.8	35.7	0.2	50.7	223.6	0.2	0.6
-25	25.4	25.4	35.4	0.3	53.5	225.2	0.2	0.6
-20	28.2	28.2	35.2	0.3	56.3	226.9	0.2	0.6
-15	31.3	31.3	35.0	0.3	59.1	228.5	0.2	0.6
-10	34.6	34.6	34.8	0.3	61.9	230.0	0.2	0.6
-5	38.2	38.2	34.6	0.4	64.7	231.6	0.2	0.6
0	42.1	42.1	34.4	0.4	67.5	233.2	0.2	0.6
5	46.2	46.2	34.2	0.4	70.4	234.7	0.2	0.6
10	50.7	50.7	33.9	0.5	73.3	236.3	0.2	0.6
15	55.4	55.4	33.7	0.5	76.2	237.8	0.2	0.6
20	60.5	60.5	33.5	0.6	79.2	239.3	0.2	0.6
25	65.9	65.9	33.3	0.6	82.1	240.8	0.2	0.6
30	71.7	71.7	33.0	0.7	85.1	242.2	0.2	0.6
35	77.9	77.9	32.8	0.7	88.2	243.7	0.2	0.6
40	84.4	84.4	32.5	0.8	91.2	245.1	0.3	0.6
45	91.4	91.4	32.3	0.8	94.3	246.6	0.3	0.6
50	98.7	98.7	32.1	0.9	97.4	248.0	0.3	0.6
55	106.5	106.5	31.8	1.0	100.5	249.3	0.3	0.6
60	114.8	114.8	31.5	1.1	103.7	250.7	0.3	0.6
65	123.4	123.4	31.3	1.1	106.8	252.0	0.3	0.6
70	132.6	132.6	31.0	1.2	110.1	253.3	0.3	0.6
75	142.3	142.3	30.7	1.3	113.3	254.6	0.3	0.6
80	152.4	152.4	30.5	1.4	116.6	255.9	0.3	0.6
85	163.1	163.1	30.2	1.5	120.0	257.1	0.3	0.6
90	174.4	174.4	29.9	1.6	123.3	258.3	0.3	0.6
95	186.1	186.1	29.6	1.7	126.7	259.5	0.3	0.6
100	198.5	198.5	29.3	1.9	130.2	260.6	0.3	0.6
105	211.4	211.4	29.0	2.0	133.7	261.7	0.3	0.6
110	225.0	225.0	28.7	2.1	137.2	262.8	0.3	0.6

HC-22a®: Dew Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°F)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	16.4	16.4	35.9	0.2	45.4	227.3	0.2	0.6
-35	18.5	18.5	35.7	0.2	48.1	228.8	0.2	0.6
-30	20.7	20.7	35.5	0.2	50.9	230.2	0.2	0.6
-25	23.2	23.2	35.3	0.2	53.6	231.6	0.2	0.6
-20	25.9	25.9	35.1	0.3	56.4	233.0	0.2	0.6
-15	28.8	28.8	34.9	0.3	59.2	234.4	0.2	0.6
-10	32.0	32.0	34.7	0.3	62.0	235.8	0.2	0.6
-5	35.4	35.4	34.5	0.3	64.9	237.2	0.2	0.6
0	39.1	39.1	34.3	0.4	67.7	238.6	0.2	0.6
5	43.1	43.1	34.1	0.4	70.6	240.0	0.2	0.6
10	47.4	47.4	33.8	0.4	73.5	241.4	0.2	0.6
15	51.9	51.9	33.6	0.5	76.4	242.7	0.2	0.6
20	56.9	56.9	33.4	0.5	79.4	244.1	0.2	0.6
25	62.1	62.1	33.2	0.6	82.4	245.4	0.2	0.6
30	67.7	67.7	32.9	0.6	85.4	246.8	0.2	0.6
35	73.7	73.7	32.7	0.7	88.4	248.1	0.2	0.6
40	80.1	80.1	32.5	0.7	91.4	249.4	0.3	0.6
45	86.9	86.9	32.2	0.8	94.5	250.7	0.3	0.6
50	94.0	94.0	32.0	0.9	97.6	252.0	0.3	0.6
55	101.6	101.6	31.7	0.9	100.7	253.2	0.3	0.6
60	109.7	109.7	31.5	1.0	103.9	254.5	0.3	0.6
65	118.2	118.2	31.2	1.1	107.1	255.7	0.3	0.6
70	127.2	127.2	30.9	1.2	110.3	256.9	0.3	0.6
75	136.7	136.7	30.7	1.3	113.6	258.1	0.3	0.6
80	146.7	146.7	30.4	1.4	116.9	259.3	0.3	0.6
85	157.2	157.2	30.1	1.5	120.2	260.4	0.3	0.6
90	168.3	168.3	29.8	1.6	123.6	261.5	0.3	0.6
95	179.9	179.9	29.5	1.7	127.0	262.6	0.3	0.6
100	192.1	192.1	29.2	1.8	130.5	263.6	0.3	0.6
105	204.9	204.9	28.9	1.9	133.9	264.6	0.3	0.6
110	218.4	218.4	28.6	2.1	137.5	265.5	0.3	0.6

HC-22a®: Bubble Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m3)	(kg/m3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	126.0	125.5	578.0	3.0	105.2	512.1	0.6	2.5
-35	154.0	153.8	572.0	3.6	116.6	519.0	0.7	2.4
-30	187.0	186.7	566.0	4.3	128.2	525.8	0.7	2.4
-25	225.0	224.8	560.0	5.1	139.9	532.5	0.8	2.4
-20	269.0	268.6	553.0	6.0	151.7	539.1	0.8	2.4
-15	319.0	318.6	547.0	7.1	163.7	545.6	0.9	2.4
-10	375.0	375.3	541.0	8.3	175.8	552.0	0.9	2.4
-5	439.0	439.3	534.0	9.6	188.2	558.3	1.0	2.4
0	511.0	511.2	527.0	11.1	200.7	564.4	1.0	2.4
5	591.0	591.5	520.0	12.8	213.4	570.5	1.1	2.4
10	681.0	680.8	513.0	14.7	226.3	576.4	1.1	2.4
15	780.0	779.6	506.0	16.8	239.5	582.1	1.2	2.4
20	889.0	888.7	498.0	19.2	252.8	587.7	1.2	2.4
25	1009.0	1009.0	491.0	21.8	266.5	593.1	1.2	2.4
30	1140.0	1140.0	482.0	24.7	280.4	598.2	1.3	2.4
35	1283.0	1283.0	474.0	28.0	294.6	603.2	1.3	2.4
40	1440.0	1440.0	465.0	31.7	309.1	607.8	1.4	2.4
45	1609.0	1609.0	456.0	35.8	324.0	612.1	1.4	2.4
50	1793.0	1793.0	446.0	40.4	339.2	616.1	1.5	2.3
55	1992.0	1992.0	436.0	45.7	354.9	619.6	1.5	2.3
60	2207.0	2207.0	425.0	51.7	371.1	622.5	1.6	2.3
65	2439.0	2439.0	413.0	58.6	387.8	624.8	1.6	2.3
70	2688.0	2688.0	400.0	66.7	405.3	626.2	1.7	2.3
75	2956.0	2956.0	385.0	76.3	423.6	626.5	1.7	2.3
80	3243.0	3243.0	369.0	88.0	443.1	625.2	1.8	2.3
85	3552.0	3552.0	349.0	103.1	464.5	621.5	1.8	2.3
90	3884.0	3884.0	323.0	124.6	489.4	613.1	1.9	2.2
95	4429.0	4429.0	308.0	308.0	509.0	509.0	1.9	1.9

HC-22a®: Dew Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m3)	(kg/m3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	113.1	113.1	575.3	2.7	105.5	528.4	0.6	2.5
-35	139.7	139.7	569.5	3.2	116.9	534.4	0.7	2.5
-30	170.9	170.9	563.7	3.9	128.5	540.3	0.7	2.4
-25	207.2	207.2	557.7	4.7	140.2	546.2	0.8	2.4
-20	249.0	249.0	551.6	5.6	152.1	552.0	0.8	2.4
-15	297.0	297.0	545.4	6.6	164.1	557.8	0.9	2.4
-10	351.6	351.6	539.0	7.7	176.3	563.6	0.9	2.4
-5	413.5	413.5	532.5	9.0	188.6	569.3	1.0	2.4
0	483.2	483.2	525.9	10.5	201.2	574.8	1.0	2.4
5	561.3	561.3	519.1	12.1	213.9	580.3	1.1	2.4
10	648.4	648.4	512.1	14.0	226.9	585.7	1.1	2.4
15	745.1	745.1	504.8	16.0	240.0	591.0	1.1	2.4
20	852.0	852.0	497.4	18.3	253.4	596.1	1.2	2.4
25	969.8	969.8	489.6	20.9	267.1	601.0	1.2	2.4
30	1099.0	1099.0	481.6	23.8	281.0	605.8	1.3	2.4
35	1241.0	1241.0	473.3	27.0	295.2	610.3	1.3	2.4
40	1395.0	1395.0	464.5	30.6	309.7	614.5	1.4	2.4
45	1563.0	1563.0	455.4	34.7	324.6	618.5	1.4	2.4
50	1746.0	1746.0	445.7	39.3	339.8	622.0	1.5	2.4
55	1944.0	1944.0	435.5	44.5	355.5	625.2	1.5	2.3
60	2158.0	2158.0	424.5	50.4	371.6	627.7	1.6	2.3
65	2389.0	2389.0	412.8	57.2	388.4	629.6	1.6	2.3
70	2639.0	2639.0	399.9	65.2	405.8	630.7	1.7	2.3
75	2907.0	2907.0	385.7	74.7	424.0	630.6	1.7	2.3
80	3197.0	3197.0	369.4	86.3	443.4	628.9	1.8	2.3
85	3510.0	3510.0	349.9	101.3	464.6	624.8	1.8	2.3
90	3849.0	3849.0	324.0	122.6	489.2	616.0	1.9	2.2
95	4409.0	4409.0	306.1	306.1	509.9	509.9	1.9	1.9


HC-502a® Vapor Pressure vs. Temperature
Temperature ° F
160
140
120
100
80
60
40
20
0
-20
-40
-60
0
40
80
120
160
200
240
280
320
360
400
psia
HC-502a®
R 502
R 22

HC-502a®: Bubble Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°F)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	22.8	22.8	35.9	0.2	45.7	210.3	0.2	0.6
-35	25.4	25.4	35.7	0.3	48.4	212.1	0.2	0.6
-30	28.2	28.2	35.5	0.3	51.2	214.0	0.2	0.6
-25	31.2	31.2	35.2	0.3	53.9	215.8	0.2	0.6
-20	34.5	34.5	35.0	0.3	56.7	217.6	0.2	0.6
-15	38.0	38.0	34.8	0.4	59.5	219.4	0.2	0.6
-10	41.8	41.8	34.6	0.4	62.4	221.2	0.2	0.6
-5	45.8	45.8	34.4	0.4	65.2	223.0	0.2	0.6
0	50.2	50.2	34.2	0.5	68.1	224.7	0.2	0.6
5	54.9	54.9	33.9	0.5	71.0	226.4	0.2	0.6
10	59.9	59.9	33.7	0.6	73.9	228.1	0.2	0.6
15	65.2	65.2	33.5	0.6	76.8	229.8	0.2	0.6
20	70.9	70.9	33.3	0.7	79.8	231.5	0.2	0.6
25	76.9	76.9	33.0	0.7	82.8	233.2	0.2	0.6
30	83.3	83.3	32.8	0.8	85.8	234.8	0.2	0.6
35	90.1	90.1	32.6	0.8	88.8	236.4	0.3	0.6
40	97.3	97.3	32.3	0.9	91.9	238.0	0.3	0.6
45	104.9	104.9	32.1	1.0	95.0	239.6	0.3	0.6
50	113.0	113.0	31.8	1.0	98.1	241.1	0.3	0.6
55	121.5	121.5	31.6	1.1	101.3	242.7	0.3	0.6
60	130.4	130.4	31.3	1.2	104.4	244.2	0.3	0.6
65	139.9	139.9	31.0	1.3	107.7	245.7	0.3	0.6
70	149.8	149.8	30.8	1.4	110.9	247.1	0.3	0.6
75	160.3	160.3	30.5	1.5	114.2	248.5	0.3	0.6
80	171.2	171.2	30.2	1.6	117.5	249.9	0.3	0.6
85	182.7	182.7	29.9	1.7	120.9	251.3	0.3	0.6
90	194.8	194.8	29.6	1.8	124.3	252.6	0.3	0.6
95	207.4	207.4	29.3	1.9	127.7	253.9	0.3	0.6
100	220.6	220.6	29.0	2.1	131.2	255.2	0.3	0.6
105	234.4	234.4	28.7	2.2	134.8	256.4	0.3	0.6
110	248.9	248.9	28.3	2.4	138.4	257.5	0.3	0.6

HC-502a®: Dew Point (Standard)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(ºF)	(psia)	(psia)	(lb/ft^3)	(lb/ft^3)	(Btu/lb)	(Btu/lb)	(Btu/R-lb)	(Btu/R-lb)
-40	17.1	17.1	35.4	0.2	46.0	227.7	0.2	0.6
-35	19.3	19.3	35.2	0.2	48.8	229.1	0.2	0.6
-30	21.7	21.7	35.0	0.2	51.6	230.6	0.2	0.6
-25	24.2	24.2	34.8	0.2	54.4	232.0	0.2	0.6
-20	27.0	27.0	34.6	0.3	57.2	233.4	0.2	0.6
-15	30.1	30.1	34.4	0.3	60.0	234.8	0.2	0.6
-10	33.4	33.4	34.2	0.3	62.9	236.2	0.2	0.6
-5	36.9	36.9	34.0	0.4	65.7	237.6	0.2	0.6
0	40.8	40.8	33.8	0.4	68.6	239.0	0.2	0.6
5	44.9	44.9	33.6	0.4	71.6	240.3	0.2	0.6
10	49.4	49.4	33.4	0.5	74.5	241.7	0.2	0.6
15	54.2	54.2	33.2	0.5	77.5	243.1	0.2	0.6
20	59.3	59.3	33.0	0.6	80.4	244.4	0.2	0.6
25	64.8	64.8	32.7	0.6	83.4	245.8	0.2	0.6
30	70.7	70.7	32.5	0.7	86.5	247.1	0.2	0.6
35	76.9	76.9	32.3	0.7	89.5	248.4	0.3	0.6
40	83.5	83.5	32.0	0.8	92.6	249.7	0.3	0.6
45	90.6	90.6	31.8	0.8	95.7	251.0	0.3	0.6
50	98.1	98.1	31.6	0.9	98.9	252.2	0.3	0.6
55	106.0	106.0	31.3	1.0	102.0	253.5	0.3	0.6
60	114.4	114.4	31.1	1.0	105.2	254.7	0.3	0.6
65	123.3	123.3	30.8	1.1	108.5	255.9	0.3	0.6
70	132.7	132.7	30.6	1.2	111.7	257.1	0.3	0.6
75	142.6	142.6	30.3	1.3	115.0	258.3	0.3	0.6
80	153.0	153.0	30.0	1.4	118.4	259.4	0.3	0.6
85	164.0	164.0	29.7	1.5	121.7	260.5	0.3	0.6
90	175.6	175.6	29.5	1.6	125.1	261.6	0.3	0.6
95	187.8	187.8	29.2	1.7	128.6	262.6	0.3	0.6
100	200.5	200.5	28.9	1.9	132.1	263.6	0.3	0.6
105	213.9	213.9	28.6	2.0	135.6	264.6	0.3	0.6
110	227.9	227.9	28.2	2.1	139.2	265.5	0.3	0.6

HC-502a®: Bubble Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m3)	(kg/m3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	157.3	157.3	574.5	3.666	106.1	488.8	0.6722	2.404
-35	190.3	190.3	568.6	4.373	117.6	496.5	0.7206	2.397
-30	228.4	228.4	562.5	5.18	129.2	504.2	0.7686	2.391
-25	272.1	272.1	556.4	6.099	141	511.7	0.8161	2.385
-20	321.9	321.9	550.1	7.139	152.9	519.1	0.8633	2.38
-15	378.3	378.3	543.7	8.312	164.9	526.3	0.9101	2.376
-10	441.9	441.9	537.2	9.631	177.2	533.5	0.9566	2.372
-5	513.2	513.2	530.5	11.11	189.6	540.4	1.003	2.369
0	592.8	592.8	523.7	12.76	202.2	547.3	1.049	2.366
5	681.2	681.2	516.7	14.61	215	554	1.095	2.364
10	779	779	509.4	16.66	228	560.5	1.14	2.362
15	886.8	886.8	502	18.95	241.3	566.9	1.186	2.36
20	1005	1005	494.3	21.5	254.8	573.1	1.232	2.358
25	1135	1135	486.3	24.33	268.6	579	1.277	2.356
30	1276	1276	478	27.49	282.6	584.7	1.323	2.355
35	1430	1430	469.3	31.01	296.9	590.2	1.369	2.353
40	1597	1597	460.2	34.95	311.6	595.4	1.415	2.351
45	1778	1778	450.7	39.36	326.7	600.2	1.461	2.349
50	1973	1973	440.7	44.34	342.1	604.6	1.508	2.346
55	2183	2183	430	49.97	358	608.5	1.556	2.342
60	2410	2410	418.5	56.41	374.5	611.8	1.604	2.337
65	2653	2653	406.1	63.85	391.5	614.5	1.653	2.33
70	2914	2914	392.5	72.56	409.4	616.2	1.703	2.322
75	3194	3194	377.2	83	428.2	616.6	1.756	2.311
80	3493	3493	359.4	95.96	448.5	615.2	1.811	2.295
85	3812	3812	337.4	113.1	471.1	610.9	1.872	2.272
90	4150	4150	305.4	139.8	499.1	600	1.947	2.231

HC-502a®: Dew Point (Metric)								
Temperature	Pressure (Liquid)	Pressure (Vapor)	Density (Liquid)	Density (Vapor)	Enthalpy (Liquid)	Enthalpy (Vapor)	Entropy (Liquid)	Entropy (Vapor)
(°C)	(kPa)	(kPa)	(kg/m3)	(kg/m3)	(kJ/kg)	(kJ/kg)	(kJ/K-kg)	(kJ/K-kg)
-40	118.1	118.1	567.6	2.743	107	529.3	0.6488	2.501
-35	145.9	145.9	562	3.339	118.6	535.3	0.6983	2.488
-30	178.4	178.4	556.2	4.029	130.3	541.2	0.7473	2.475
-25	216.2	216.2	550.3	4.825	142.2	547	0.7958	2.464
-20	259.9	259.9	544.4	5.736	154.2	552.9	0.844	2.455
-15	309.9	309.9	538.3	6.775	166.3	558.7	0.8917	2.446
-10	366.9	366.9	532.1	7.953	178.7	564.4	0.9392	2.438
-5	431.4	431.4	525.7	9.287	191.2	570	0.9863	2.431
0	504.1	504.1	519.1	10.79	203.8	575.6	1.033	2.425
5	585.5	585.5	512.4	12.48	216.7	581	1.08	2.419
10	676.3	676.3	505.5	14.37	229.8	586.3	1.127	2.414
15	777.1	777.1	498.4	16.5	243.1	591.5	1.173	2.409
20	888.7	888.7	491	18.87	256.7	596.6	1.219	2.405
25	1012	1012	483.4	21.53	270.5	601.4	1.266	2.401
30	1147	1147	475.4	24.51	284.5	606.1	1.312	2.396
35	1294	1294	467.1	27.84	298.9	610.5	1.359	2.392
40	1456	1456	458.4	31.58	313.6	614.6	1.406	2.388
45	1632	1632	449.3	35.8	328.6	618.4	1.453	2.384
50	1823	1823	439.7	40.57	344	621.8	1.5	2.378
55	2030	2030	429.4	45.99	359.8	624.7	1.548	2.373
60	2255	2255	418.4	52.2	376.2	627	1.597	2.366
65	2498	2498	406.5	59.39	393.1	628.6	1.646	2.357
70	2761	2761	393.4	67.85	410.7	629.2	1.697	2.347
75	3045	3045	378.8	78	429.3	628.5	1.75	2.334
80	3352	3352	361.7	90.61	449.2	626.1	1.805	2.316
85	3686	3686	340.7	107.3	471.2	620.5	1.866	2.291
90	4052	4052	310.6	132.9	497.9	608.5	1.939	2.25