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Installation and Maintenance Manual

Air Cooled Condensing Units, Remote Air or Water Cooled Systems, and Multi-Compressor Systems

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General Safety Rules, Engineers Qualifications and Production Standards

Installation & Maintenance Engineers Qualifications:

- All work on the compressors and any component or refrigerant control incorporated into this system must only be carried out by refrigeration engineers who hold the current level of refrigerant handling qualification (City & Guilds 2079 or CITB J11-14) at the required level for the task being performed.

Operating Temperatures and Pressures:

- During normal operation surface temperatures exceeding 80^{o}C and below -20^{o}C can be reached therefore extreme caution must be taken as serious burns and frostbite are possible.
- Operating pressures in excess of 25 barg and below 0.5 barg can be reached therefore great care must be taken when working on this plant.
- The appropriate personal protective clothing must be worn at all times when working on this equipment.

Refrigerant type and Operating range:

- The system data/quotation will specify the type of refrigerant and the operating range which this equipment has been designed to operate with and no other refrigerant or operating range must be employed without the consent in writing of Robert C. Scutt Ltd.

Production Standards

- All Refrigeration equipment manufactured by Robert C. Scutt Ltd is in accordance with the following design standard and specifications :-

  The Pressure Equipment Directive 97/23/EC
  BS EN 378-1:2008
  BS1306
  Machinery Directive BS EN 2006/42/EC
  Institute of Refrigeration Safety Code of Practice for Refrigeration Systems utilising groups A1 and A2 refrigerants.

General Safety Considerations

- To avoid potential injury, use care when working around heat exchanger coil surfaces (fins) or the sharp edges of metal cabinets. All piping and electrical wiring must be installed in accordance with applicable codes of practice, ordinances and local by-laws.

Inspection of Equipment prior to Installation

All equipment must be visually inspected before it is unpacked for signs of damage or loss. Check the delivery note against the material received to ensure the shipment is complete.

Important: Remember, you are the consignee and it is your responsibility to report any shipping damage or missing parts as soon as delivery is accepted or at least within 12 hours. This will prevent any disputes and unnecessary problems that may occur at a later date. If damage or loss during transport is evident a claim on the carrier must be made immediately as it will be their responsibility rather than the manufacturer.
Should the packaging be damaged, but damage to the equipment is not obvious, a claim should be filed with the carrier for “concealed damage” and the product signed for as “unexamined”.

Important Electrical Inspection: Check the electrical ratings on the equipment *(voltage, phase and frequency) to make sure they correspond to those ordered and to the electrical power available at the installation site.

Shipping documents: All shipping papers, tags and instruction sheets must be retained and kept in a safe place for reference by the installer and/or the owner of the equipment.

General Warranty Policy

General Policy:

Subject to the terms and conditions set out in this General Warranty Policy, during the first 12 months after installation of this equipment we will supply under warranty any component part(s) of our product found to be defective in materials or workmanship. Replacement parts will be supplied and invoiced under our normal terms of payment pending the return of the suspect component. If the component is proved to be defective and is accepted under warranty by our supplier, a credit will be issued for our replacement part invoice. If warranty is not accepted by our supplier our replacement part(s) invoice will become due for payment.

Any replacement parts supplied under warranty will inherit the unexpired warranty life of the original component e.g. if a component fails after 3 months and is accepted under warranty the replacement will inherit 9 months of unexpired warranty of the original component. In the event that warranty is rejected the replacement part will (once paid for) carry 12 months warranty from the date of our replacement invoice.

It is a condition of this warranty that the part(s) to be replaced must be made available in exchange for the replacement parts and proof of the original installation date of the parent product must be provided together with the R C Scutt Serial number e.g. C12136 in order to establish the effective warranty date. In order to remove any uncertainty if the installation date is not supplied the effective date will be based on the manufactured date plus 30 days which will be calculated using the unit serial number.

Any labour, material, refrigerant, transportation, freight of other charges incurred in connection with the performance of this warranty will be the responsibility of the owner of the equipment.

It is an express condition of this warranty that regular maintenance and servicing is carried our by qualified personnel in accordance with the qualifications set out in the Installation & Maintenance Engineers Qualifications section above.

This warranty may be transferred to a subsequent owner of the product.

Warranty Exclusions:

Damages and Expenses caused by :-

a) Accident, abuse, negligence, misuse, riot, fire or flood.
b) Operation of the equipment in a corrosive atmosphere
c) Any unauthorized alteration or repair to the system affecting the equipment's reliability of performance.
d) Improper matching or application of the equipment to other system components not in our control.
e) Failing to provide routine and proper maintenance or service to the equipment.
f) Parts use in connection with routine service and maintenance such as filters, oil, refrigerant etc.
g) The equipment being moved and re-installed at a location other than the original site.
h) Equipment installed and operated other than in accordance with the printed instructions.
i) Equipment that is lost or stolen.

Handling, Positioning and Installation Location

When selecting a location for the condensing unit, the following constraints and design issues must be considered:-

a) Loading capacity of the floor or roof. Check building codes for weight distribution requirements.
b) A flat and level site.
c) Distance to suitable electrical supply.
d) Distance to the evaporator(s) and the remote condenser if applicable.
e) Adequate water supply and water temperature for water cooled equipment.
f) Adequate air circulation and ventilation.
g) Adequate electricity supply
h) Accessibility for maintenance and service.
i) Local building regulations and/or codes.
j) Adjacent buildings relative to noise levels.
k) Wishes of the end user/owner.

When all of the above points have been considered and a specific location chosen, it is advisable to obtain written approval of this location from the building and/or condensing unit owner. This may be a means of avoiding disagreement and expense at a later date.

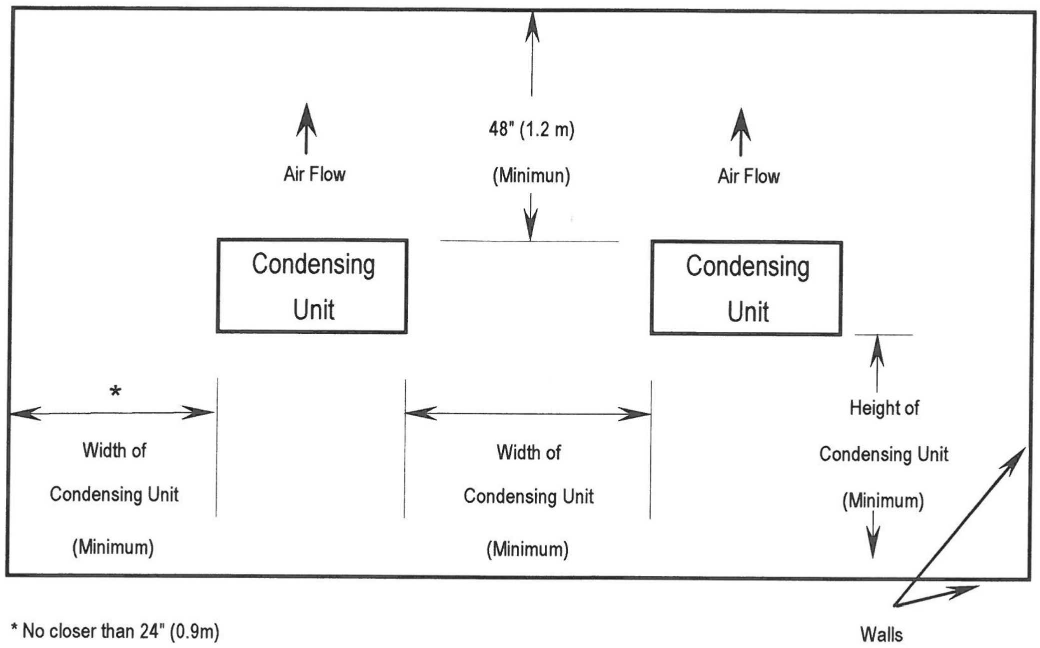
Positioning the Equipment:

- A fully qualified and properly equipped crew with the necessary lifting tackle and rigging should be engaged to locate the equipment into position. When lifting the unit, spreader bars and chafing gear should be used to prevent damage.
- The unit should be placed on a base, which is level and even. Place unit where it will not be subject to damage by traffic or flooding.
- On critical installations where noise is liable to be transmitted through the floor structure, vibration isolators should be installed.
- Isolators should be installed under mounting base and may be rubber or cork or equal.

- **DO NOT USE THE SHIPPING SKID AS A PERMANENT BASE.**

- The equipment should be positioned to allow adequate space for performing service work.

Indoor and outdoor air-cooled condensing units with horizontal air flow should be positioned using the guidelines shown in the diagram below.

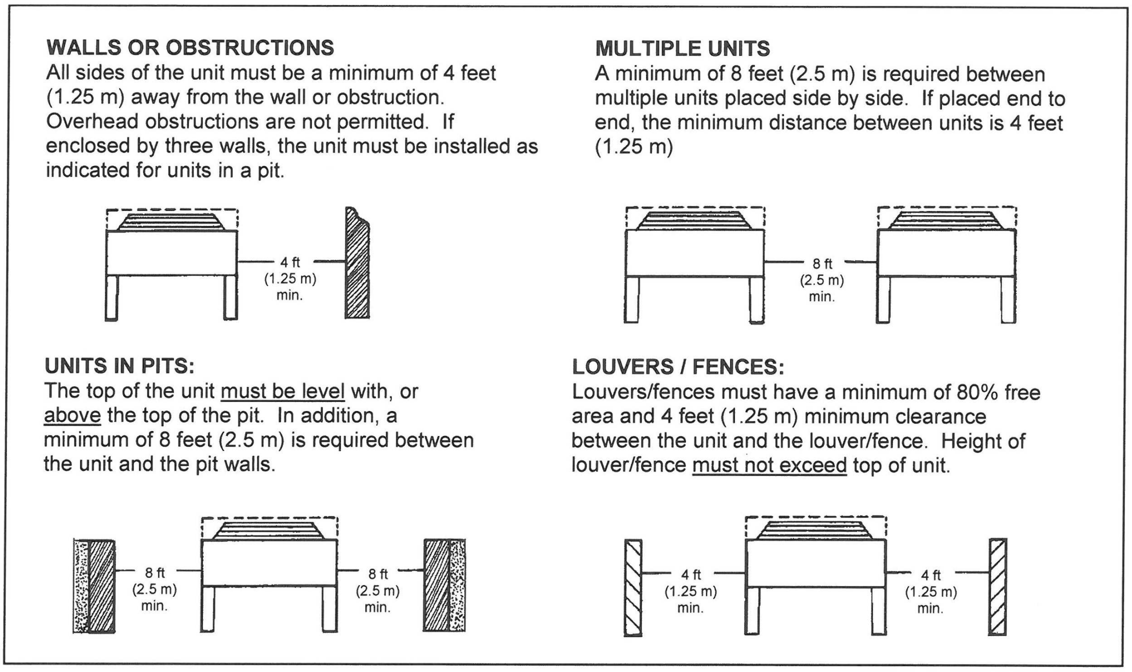


Special note for large air cooled condensing units:

The RC Scutt range of equipment incorporates a number of large condensing units which may be housed or un-housed. Great care must be taken with these large and heavy pieces of equipment as there is a risk of damage and/or personal injury if they are not handled correctly. A fully qualified and properly equipped crew with the necessary tackle and rigging should be engaged to locate these condensing units into position. Dependant on the design the unit can be lifted by means of lifting holes that may be located in the base frame of the unit. Spreader bars should be used to prevent damage to the sides of housed units. Do not sling directly around the base of unit. The unit should be placed on a base which is level and even.

The range incorporates a range of remote mount air cooled condensers and condensing units designed for vertical air flow and the chart below shows the guidelines that should be taken into account when positioning this type of equipment.

Air Cooled Condensing Unit Minimum Clearance (For Vertical Air Flow Units)



Compressor Mounts:

Single compressor condensing units are generally equipped with compressors that are mounted on soft resilient mountings. These mounts will be 'locked down' for transit and must be released prior to operating the unit to avoid unnecessary vibration transmission. Simply loosen the retaining nuts to allow a 3mm gap above the mounting foot so that the compressor is 'floating' on the mount.

Multi-compressor packs are generally fitted with compressors that are mounted on rigid 'hard' mounts. These mounts must be checked prior to setting the plant into operation to ensure that they have not become loose in transit as pipe work fractures and refrigerant loss may result if this design of mount is not fully tight.

Plant Room Ventilation

If the compressors or condensing units are to be located in a plant room, adequate ventilation must be provided in order to avoid excessive system refrigerant pressures and temperatures and to ensure the correct operation of the plant. Air requirements may vary dependant on ambient air temperature, the refrigerant type and the refrigeration application and loading, however as a 'rule of thumb' the following values can be used to assess the approximate ventilation requirements:-

Equipment Type	Air Quantity
Air cooled condensing units (horizontal air flow units)	1700 m^3/hr (1000 cfm) per Hp
Air cooled compressors (with remote condensers)	425 m^3/hr (250 cfm) per Hp
Suction cooled or water cooled compressors (with remote air cooled or water cooled condensers)	340 m^3/hr (200 cfm) per Hp

Refrigerant Pipe Sizing and Design Standards

Important: Appropriate line sizing practices must be used throughout the installation of the refrigeration system. Special consideration must be given to systems where the compressors are installed above the evaporator to ensure that good oil return to the compressor is achieved due to the correct suction vapour velocity.

Refrigeration quality copper tube must be used for all refrigeration piping systems and the following standards must be taken into account :-

- EN378:2008 Design and Construction of Refrigeration Systems
- BS1306:1975 Specification for copper and copper alloy pressure piping systems.
- Institute of Refrigeration Safety Codes of Practice.

Brazing pipe work: An inert gas such as dry nitrogen should be passed through the pipe during brazing operations. This will eliminate the possibility of oxidisation on the internal surfaces of the tube and will enhance the life of the plant.

Brazing valves: When brazing service valves and control valves or any other components that may be damaged by heat manufacturer's installation instructions must be adhered to. Wrapping components with wet cloth will help to prevent damage from heat.

Pipe Sizing:- Recognised pipe sizing charts specific to the system refrigerant type must be followed to ensure minimum pressure drop around the system and optimum vapour velocity to ensure correct oil circulation.

Suction Lines: These lines should be sized on the basis of a maximum total pressure drop equivalent to 1.1°C change in saturation temperature. At 5°C suction temperature for R4004A this equates to approximately 0.2bar (3psig) pressure drop and at -30°C to 0.15bar (2 psig). These values will vary dependant on evaporating temperature and refrigerant type.

Suction Line Insulation: All suction lines that are outside the refrigerated space must be insulated to prevent unnecessary temperature gain (superheat) and unwanted condensation forming on the outside of the pipe.

Liquid Lines: Horizontal liquid lines should be sized on the basis of a maximum pressure drop equivalent to 1.1°C drop in saturation temperature (1.1°C sub-cooling). If the liquid line travels vertically up-wards then adequate sub-cooling must be provided to overcome the vertical liquid head pressure. A head of 2.2 metres of liquid refrigerant is approximately equivalent to 0.07bar pressure drop. Liquid line velocities should not exceed 1.52 metres/sec (300 fpm). This will prevent possible liquid hammer when the solenoid valve closes or the expansion valve modulates.
The chart below shows the effect of vertical liquid line pressure drop.

Pressure Loss of Liquid Refrigerant in Liquid Line Risers (metres)

(Expressed in pressure drop barg and subcooling loss °C)

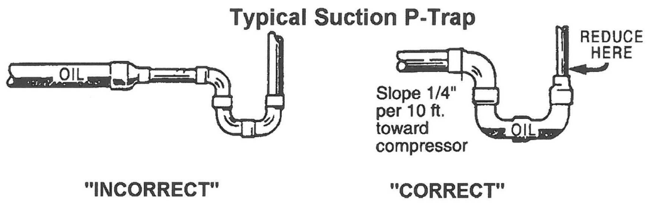
	3 m		4.5 m		6 m		7.5 m		9 m	
	bar	°C	bar	°C	bar	°C	bar	°C	bar	°C
R134a	0.34	1.1	0.51	1.6	0.68	2.7	0.85	2.9	1.01	3.5
R404A, R507	0.28	0.6	0.42	0.9	0.57	1.2	0.70	1.5	0.84	1.8

	12 m		15 m		23 m		30 m	
	bar	°C	bar	°C	bar	°C	bar	°C
R134a	1.36	4.9	1.70	6.1	2.54	9.4	3.39	13.2
R404A, R507	1.12	7.8	1.41	3.1	2.11	4.6	2.81	6.6

At the temperatures encountered in the condenser, receiver and the liquid line a certain amount of oil is always being circulated with the refrigerant through the system by the compressor however, at the evaporator where the temperature is cold, and where the refrigerant is in a vapour condition the oil and the refrigerant separate. This oil can only be returned to the compressor by gravity or by entrainment in the suction gas. Roof top installations leave no alternative but to design for oil entrainment, so suction gas velocity and correct line sizing to maintain this velocity are imperative. Care must be taken not to oversize the suction line in the desire to design for maximum performance/minimum pressure drop/optimum velocity.

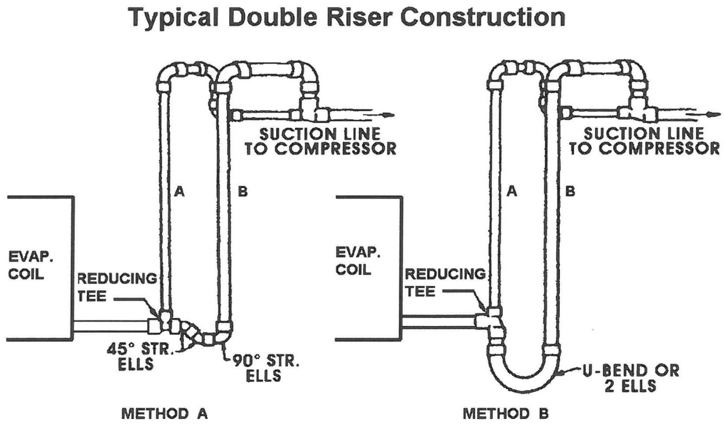
Refrigerant gas velocity in vertical suction lines must not be less than 5 metres/sec (1000fpm) as minimum value and preferably 6 to 8 metres/sec (1250 to 1500fpm) to ensure oil entrainment.

It is important to install a suction trap at the base of all suction risers which are more than 1.5 metres (5 feet) high in order to trap the oil and allow entrainment in the suction gas.



Refrigeration Systems with Capacity Control

If the system is capacity controlled either by compressor cylinder unloading or by inverter control on the compressor speed, provisions must be made for oil return at minimum compressor capacity by sizing suction risers to maintain adequate gas velocities at reduced refrigerant flow. Double suction risers are employed to achieve this as shown below.



During the lower capacity running mode (compressor capacity control energised) oil will collect in the elbow or at the U-bend below pipe 'B'. This will divert the gas and oil so that it flows up pipe 'A' at a higher velocity.

Copper Tube Selection.

Great care must be taken in respect of the selection of the wall thickness and grade of copper tube used in refrigeration systems due to the design pressures that are encountered around the system.
All copper tube used must comply with BS EN12735-1:2001 and the operating pressures around the system can be assessed using BS EN 378:2008 for specific system refrigerant and design ambient temperature.

Once the system operating pressures have been established the copper tube wall thickness can be assessed and copper tube with the correct pressure bearing capability can be selected using the calculation method shown in BS1306: 1975.

In order to assist in this selection process the chart below shows design pressures for various refrigerants in common use together with the pressure bearing capability of various gauges (swg) of all sizes of copper commonly used copper tube.

Refrigeration Quality Copper Tube - Safe Working Pressures (barg)

Refrigeration Quality Copper Tube - Soft Coils (R220)

Tube Size OD	Wall Thickness swg	(Suction Lines) Up to 50°C Straight	Formed	(Discharge Lines) (Liquid Lines) Up to 100°C Straight	Formed	Up to 150°C Straight	Formed
1/4"	22	91	73	89	71	76	61
3/8"	21	68	54	66	53	56	45
1/2"	20	53	43	52	42	44	35
5/8"	20	42	34	41	33	35	28
3/4"	19	39	31	38	30	32	26
7/8"	19	33	26	32	26	27	22

Refrigerant	High side	Low side
R134a	13.09bar	7.20bar
R404A	24.80bar	14.09bar
R407C	23.70bar	13.30bar
R410A	33.50bar	18.99bar

In line with BS EN378-2008, the minimum value for the system allowable pressure for various refrigerants used in refrigeration systems at a design ambient of 32°C

Straight = Straight un-bent lengths

Formed = Bent lengths where the bend radius is > the 3 times greater than its outside diameter.

Refrigeration Quality Copper Tube - Half Hard (R250) Straight Lengths

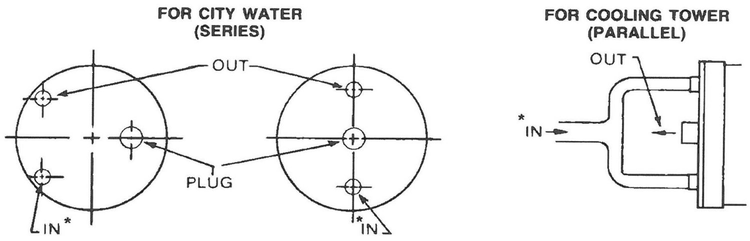
Tube Size OD	Wall Thickness swg	(Suction Lines) Up to 50°C Straight	Formed	(Discharge Lines) (Liquid Lines) Up to 100°C Straight	Formed	Up to 150°C Straight	Formed
3/8"	20	77	62	75	60	64	51
1/2"	20	57	45	55	44	47	38
5/8"	20	45	36	44	35	37	30
3/4"	18	47	38	46	37	39	31
7/8"	18	40	32	39	31	33	27
1.1/8"	18	31	25	30	24	26	20
1.1/8"	16	42	33	41	32	35	28
1.3/8"	18	25	20	24	20	21	17
1.3/8"	16	34	27	33	26	28	22
1.5/8"	18	21	17	21	16	17	14
1.5/8"	16	28	23	28	22	24	19
2.1/8"	18	16	13	16	12	13	11
2.1/8"	16	22	17	21	17	18	14
2.1/8"	14	27	22	26	21	22	18

Refrigeration Quality Copper Tube - Hard (R290) Straight Lengths

Tube Size OD	Wall Thickness swg	(Suction Lines) Up to 50°C Straight	Formed	(Discharge Lines) (Liquid Lines) Up to 100°C Straight	Formed	Up to 150°C Straight	Formed
2.5/8"	18	13	10	12	10	11	9
2.5/8"	16	17	14	17	13	14	11
2.5/8"	14	22	17	21	17	18	14
2.5/8"	12	29	23	28	22	24	19
3.1/8"	16	14	12	14	11	12	9
3.1/8"	14	18	14	18	14	15	12
3.1/8"	12	24	19	23	18	20	16
3.5/8"	16	12	10	12	10	10	8
3.5/8"	14	16	12	15	12	13	10
3.5/8"	12	20	16	20	16	17	14
4.1/8"	16	11	9	11	9	9	7
4.1/8"	14	14	11	13	11	11	9
4.1/8"	12	18	14	17	14	15	12

Water Cooled Condensers, Pipe and Flow Rates

Important: All water and drain connections to the unit must be made in accordance with national and local plumbing codes of practice and by-laws.



* From compressor cooling coil (if equipped) and water regulating valve

Condenser Circuitry

Cooling water circuits in some shell and tube water cooled condensers may be either series or parallel as required by the particular application. The ‘series’ flow is usually for city water where lower entering water temperatures exist and higher pressure drops can be tolerated. The ‘parallel’ circuit flows are usually required when the water temperatures enter at 30°C (86oF) or higher requiring lower water pressure drops, such as closed loop cooling tower supplies.

On some condensers, the water circuiting may be entirely internal with only an inlet and outlet fitting. The water inlet is always at the bottom connection.

Water Regulating Valves

All water cooled condensers require a water regulating valve.

- 2-way valves must be installed on the outlet of the condenser so that the vessel remains fully flooded.
- 3-way (bypass) valves must be installed on the water inlet side of the condenser.

The water regulating valve is adjustable and is set to provide the desired condensing pressure. As the condensing pressure rises, the valve will open and allow more water to flow. As the condensing pressure falls the valve will start to close to reduce the amount of water flow into the condenser or if a 3-way valve is installed water will bypass around the condenser and be fed into the condenser outlet pipe.

Water Pressure Reducing Valve

If the water supply pressure is excessive, a pressure reducing valve must be used since the allowable working pressure of water valves and condensers is normally 10bar (150psig)

Condensing Temperature

Typical condensing temperatures normally range from 32°C to 43°C (90°F to 110°F). The actual water inlet temperature and water supply flow capacity available at the site determines the suitable condensing temperature. Lower inlet temperatures below 21°C (70°F) allow the condensing unit to run at a lower condensing temperature without resulting in a high water flow rate. Higher water inlet temperatures above 30°C (86°F) require the condensing temperature to be higher to avoid excessive water flow rates. Refer to the water flow rate chart to estimate the flow rate at given water temperatures and loads. The TD (temperature difference) is the difference between the condensing temperature and the water inlet temperature.

Water Pressure Drop

Knowing the water flow rate you can estimate the pressure drop through the condenser in order to be able to size water pumps. Refer to the Typical Pressure Drop tables and use the appropriate flow to estimate the resulting pressure drop. If using a condenser that has one water circuit (two connections) use the ‘parallel’ column on the flow rate chart.

Care should be exercised in locating the condensing unit so that the condenser will never be exposed to temperatures below freezing.

Excessive water velocities or cavitations on the waterside of the condenser tubes may damage a water cooled condenser. In order to prevent operating difficulties care should be taken to follow the guidelines set out below.

a) Water velocities through the condenser should not exceed 2.13 metres/sec (7fps). Higher velocities can result in “impingement corrosion”. In order to maintain water velocities at an acceptable level, parallel circuiting of the condenser may be necessary when high water flow is required.
b) If a water pump is used it should be installed so that the condenser is fed from the discharge side of the pump.
c) If the condenser is installed more than 1.5 metres (5ft) higher than the outlet drain point of the condenser a vacuum breaker or open vent line should be provided to prevent the outlet line from creating a partial vacuum condition.

WATER FLOW REQUIREMENTS

(L/sec Flow rate per 1 Kw Evaporator Load)

High Water Flow Rates

11°CTD (Condensing temp - Entering Water temp

Evap Temp °C	Series connection			Parallel connection		
	Condensing Temp °C					
	30	35	40	30	35	40
+5	0.058	0.060	0.061	0.072	0.062	0.075
0	0.060	0.061	0.063	0.075	0.076	0.078
-5	0.062	0.063	0.065	0.078	0.079	0.081
-10	0.064	0.066	0.067	0.080	0.083	0.083
-20	0.069	0.070	0.072	0.086	0.087	0.090
-30	0.074	0.077	0.079	0.093	0.096	0.099

Cond temp	Water Temp On	Water Temp Off
30°C	19°C	24°C
35°C	24°C	29°C
40°C	29°C	34°C

WATER FLOW REQUIREMENTS

(L/sec Flow rate per 1 Kw Evaporator Load)

Low Water Flow Rates

16°CTD (Condensing temp - Entering Water temp

Evap Temp °C	Series connection			Parallel connection		
	Condensing Temp °C					
	30	35	40	30	35	40
+5	0.036	0.037	0.038	0.045	0.038	0.047
0	0.038	0.038	0.039	0.047	0.048	0.048
-5	0.039	0.040	0.040	0.049	0.050	0.050
-10	0.040	0.041	0.042	0.050	0.051	0.052
-20	0.043	0.044	0.045	0.053	0.055	0.056
-30	0.046	0.048	0.049	0.058	0.060	0.061

Cond temp	Water Temp On	Water Temp Off
30°C	14°C	22°C
35°C	19°C	27°C
40°C	24°C	32°C

The flow rate charts above are for guidance only and are intended to provide generic water flow rates based on evaporator duty and constant condensing temperature minus entering water temperature values.

Method: Multiply the l/sec from the chart above by the kW evap duty as shown below :-

Selection Example: Evaporator Duty = 8.6kW

Cond Temp = 35°C

Evap Temp = 0°C

	11°CTD Series	11°CTD Parallel	16°CTD Series	16°CTD Parallel
High Flow Rates (l/sec) :	0.525	0.656	-	-
Low Flow Rates (l/sec) :	-	-	0.327	0.409

Typical Pressure Consenser Drops (barg)

Model (HP)	Flow l/sec	Pressure Drop (barg) Series	Pressure Drop (barg) Parallel	Water Valve
1, 1.1/2, 2	0.06	-	0.04	1/2"
	0.13	-	0.14	
	0.19	-	0.29	
3, 4	0.13	0.17	0.03	3/4"
	0.25	0.6	0.08	
	0.38	1.28	0.17	

Model (HP)	Flow l/sec	Pressure Drop (barg) Series	Pressure Drop (barg) Parallel	Water Valve
5, 6	0.13	0.19	0.03	1"
	0.25	0.68	0.1	
	0.38	1.45	0.2	
7.1/2	0.19	0.19	0.027	1"
	0.32	0.5	0.07	
	0.57	1.45	0.2	
10	0.32	0.18	0.02	1.1/4"
	0.63	0.62	0.09	
	0.95	1.24	0.19	

Model (HP)	Flow l/sec	Pressure Drop (barg) Series	Pressure Drop (barg) Parallel	Water Valve
15	0.63	-	0.05	1.1/4"
	0.95	-	0.1	
	1.58	-	0.23	
20, 25	0.63	-	0.03	1.1/2"
	1.26	-	0.09	
	2.52	-	0.31	

System Components

Protection Devices:

All equipment manufactured by Robert C. Scutt Ltd incorporate a built-in range of safety devices to protect the equipment against malfunction. The safety devises that are applied to equipment will be automatically selected by Robert C. Scutt, unless specifically requested by the customer, dependent on the size and type of equipment and the application. The range of devises that are applied are as follows:-

- Thermister Sensor: The compressors fitted to this equipment contain an electronic thermistor sensor fitted into the compressor terminal box to protect against compressor motor overheating. This is an auto-reset device and if tripped will automatically restart the compressor once the motor winds have cooled down to a safe operating level.

- Discharge Gas Temperature: Discharge Gas Temperature Sensors are available as on option and may be fitted to individual compressors to protect against excessive discharge superheat values as an additional safety device if required.

- Crankcase Oil Level Control: On multi-compressor systems and inverter controlled single compressor systems each compressor is fitted with an electronic oil level controller which feeds and monitors each individual crankcase oil level. If this level falls too low for safe operation of the compressor the control will automatically stop the compressor. This is an auto-reset control and if tripped will automatically restart the compressor once the optimum oil level has been restored.

- Oil Separators: The compressor crankcase oil level control valves are fed directly from an oil separator mounted in the common discharge line.
  There are two types of oil separator design applied to Robert C Scutt equipment dependant on the type of application.
  - Impingement type: This design is applied to smaller single compressor condensing units and compressor/receiver units. Oil return from this design of oil separator is fed directly into the compressor crankcase.
  - Coalescent type: This design is applied to larger single compressor applications and multi compressor systems, particularly where compressors are inverter speed controlled. Oil return from this design is generally fed to the compressor crankcase via an electronic oil level control. Due to the high filtration efficiency of these oil separators they may be fitted with a monitoring device which displays the pressure drop through the separator vessel.

- High and Low Pressure Controls: Dependant on the application and system design equipment may be fitted with a range of electro-mechanical or transducer high and low pressure controls as follows:-

  - Auto/Manual Dual pressure safety controls to safeguard against to high discharge pressure or to low a suction pressure.
  - Back-up controls that take over the control of the equipment in the event of main controller failure. (Multi compressor packs only)
  - Back-up controls that take over control of the condenser fans in the event of main controller failure. (Multi compressor packs only)

Protective Devices ………. cont.

- Pressure Relief Valves: In order to protect the equipment from excessive internal pressure equipment will be fitted with pressure relief valve(s) The design, pressure setting and number of valves will be in accordance with EN378-2008 and the discharge rate and valve size has been applied in accordance with EN13136. The application of these valves is also governed by the rules set out in the Pressure Equipment Directive 97/23/EC. Typical valve settings for various refrigerants for operation up to an ambient temperature of 32^{o}C are as follows:-
  - R404A: HP = 24.8bar LP = 14.09bar
  - R407C: HP = 23.7bar LP = 13.3bar
  - R134a: HP = 13.09bar LP = 7.20bar

Pressure relief valves for HP protection are generally fitted directly onto the liquid receiver whereas LP valves are mounted directly onto the suction line or header in multi compressor applications. Larger systems will be fitted with dual valves and a manual change over control to allow for valve servicing and replacement. These dual valve assemblies are fitted with bursting discs and pressure sensing gauges to record the fact that a valve may have opened. All pressure relief valves vent to atmosphere.

- Crankcase Heaters: Crankcase heaters are fitted to each individual compressor to protect the compressor against refrigerant being dissolved into to oil and the subsequent oil foaming at start-up which can damage the compressor crank shaft, bearings and pistons. These heaters are automatically energised during compressor standstill, periods.

- Discharge Pressure Optimisation (optional): This control enhances the operational efficiency of the equipment by automatically maintaining a constant refrigerant discharge pressure. This is achieved by varying the speed of the condenser fans for air cooled plant or alternatively by-passing the water flow around the condenser on water cooled equipment. Dependant on application and size of equipment the controls are as follows:-
  - Small single compressor air cooled condensing units are fitted with an electro-mechanical fan speed controller which controls all fans at the same time. This form of control can be applied to single or three phase fans dependant on total absorbed power.
  - Larger air cooled condensing units and multi fan remote air cooled condensers are controlled by an inverter system driven by pressure transducers.
  - Optional EC fans can also be applied to larger remote air cooled condensers together with transducer pressure sensors.
  - Water cooled systems are fitted with either electronic or mechanical by-pass valves dependant on customer requirements.

  These controls are highly recommended for the optimum operation of the plant but are optional controls which will be incorporated into our equipment at the customer's request.

- Suction Line Filters & Liquid Line Driers & Sight Glasses: In order to protect the compressor motion work from foreign bodies and moisture the equipment may be fitted with a suction line filter and a liquid line filter/drier.
  - Suction Line Filter: Normally only applied to larger condensing units and multi compressor systems these filters have replaceable cores that can be replaced on site. Various types of cores are available e.g. Standard filtration quality, High filtration quality, Moisture/Acid absorption and Felt filters.
  - Liquid Line Filter Drier: These filter driers are installed in the liquid line and are selected against the system capacity. The function of this filter is to dehydrate the refrigerant as it passes through the desiccant contained in the shell and to protect any downstream components from foreign matter.

- Liquid Line Sight Glass (moisture indicating): Mounted directly after the liquid line drier it will change colour if there is moisture present in the refrigerant. It allows the contractor to detect the presence of flash gas or a shortage of refrigerant in the liquid line. Bubbles are not normally visible in the sight glass of a properly charged system; however it is normal to see bubbles appear in the sight glass for a few minutes after the compressor starts**. Caution: Bubbles in a sight glass installed on the condensing unit or multi compressor unit must never be used as a final indicator for shortage of refrigerant in the system.**

- Liquid Line Solenoid Valve: Fitted in the liquid line immediately after the liquid line sight glass this valve allows the refrigerant to be pumped out of the low side of the system when the thermostat has been satisfied. This 'pump-down' operation is especially useful as part of an electric defrost system as it will remove the refrigerant from the evaporator during the defrost cycle reducing the risk of liquid flood back at defrost termination and shortening the defrost cycle.

- Suction Line Accumulator: Fitted in the suction line immediately before the compressor suction valve and is used to prevent liquid refrigerant reaching the compressor. Liquid flood back can occur for a number of reasons such as malfunctioning expansion valve, system over charged with refrigerant, evaporator fan failure etc. An accumulator is always used in a hot gas defrost application or on systems with extremely short suction and liquid lines. Some accumulators are equipped with a built in suction to liquid heat exchanger; this design is generally used on low temperature applications as a way of ensuring the superheated vapour enters the compressor and sub-cooled liquid enters the expansion valve.

- Discharge Line Muffler: If deemed necessary Robert C. Scutt will automatically fit a muffler as a method of reducing compressor discharge gas pulsations and the resultant noise and vibration. This item will be applied based on piping configuration, pattern of gas flow, line sizes, operating pressures and/or compressor mounting. Any combination of these phenomena can set up a resonant frequency which may amplify the sound and vibration to an undesirable level. Gas pulsations from the compressor may also be amplified in a similar manner.

Test Data:
All equipment manufactured by Robert C. Scutt Ltd is tested for leaks under pressure in accordance with the Pressure Equipment Directive 97/23/EC and a pressure test certificate and a Declaration of Conformity are available on request. All equipment is CE marked in accordance with the directive.

Electrical Ratings:
The equipment serial plate will show the electrical characteristics of the equipment e.g. voltage, frequency and phase together with amperage at FLA and LRA values.
Smaller Hermetic or Semi-Hermetic equipment or equipment fitted with Scroll compressors will be designed for direct-on-line operation, whereas semi hermetic equipment over 15hp is generally fitted with compressors designed for Part Wind Starting (PWS) and dependant on the model the winding partition is 50%/50%.
There is no compressor unloading device fitted on PWS compressors as it is not necessary with this starting system. Compressors and safety controls are prewired to an electrical connection box or control panel housing the correct switchgear, overloads, fuses, circuit breakers and/or electronic controller as relevant for the equipment design.

Maintenance Schedule

There are a number of items that require regular maintenance checks and although not exhaustive, the following list high lights the major components that require regular attention.

Pressure Relief Valves & Rupture Discs

- The relief valve/rupture disc assemblies are fitted with a pressure gauge that indicates whether the rupture disc has burst and this must be checked at each visit to the plant.
- The manufacturer recommends that in the event of a PRV has discharged it should be replaced as the set pressure can no longer be guaranteed.
- In any event all pressure relief valves should be replaced every 5 years.
- If the operating pressure of the system has exceeded 90% of the rated burst pressure of the rupture disc, the disc should be replaced as it is most likely that fatigue will have occurred and the disc may be susceptible to premature rupture.

Coalescent Oil Separator

- Coalescent oil separators contain a filter element for extreme efficiency. The filter will "clean up" a new system and it may therefore be necessary to replace the filter shortly after commissioning. In order to maintain optimum operation the vessel may be fitted with a visual pressure difference gauge and if this gauge shows a pressure difference in excess of 13psig/0.9bar the filter should be changed.
- This filter must always be changed after the replacement of a compressor.

Refrigerant Charge. (F-Gas Directive)

- During the commissioning process a label must be attached to the plant showing the actual total operating system refrigerant charge and type which must be also recorded on the F-Gas record sheet for the plant. Any additions or subtractions to the charge must be recorded as part of the maintenance regime for the plant.
- Regular leak detection must be carried out, the frequency of which is dependant on the total system operating charge.
  Systems containing more than 30kg – every 6 months
  Systems containing more than 300kg – every 3 months and must also be fitted with a fixed leak detector which must also be checked for operation every 12 months.
- Once a leak has been identified and repaired a further leak test must be carried out within one month to ensure that the repair has been successful.

Compressor Oil Charge

- Regular checks must be carried out to verify the compressor oil charge ¼ to ¾ sight glass. It is not normally necessary to change the oil for factory assembled plant but for "field assembled" installations an oil change is recommended after 100 hours operation. This includes cleaning the magnetic oil plug which is fitted to larger compressors.
- In any event the oil should be completely replaced every 3 years or 10,000 hrs to12,000 hrs operation.

Liquid Line Filter Driers and Suction Filters

- Multi-compressor pack systems with integral liquid receivers are fitted with replaceable core liquid line driers, which gives the maintenance engineer the opportunity to check for excess pleasure drop through this vessel. If a pressure drop in excess of 2psig/0.14bar is observed through this vessel it is recommended that the replaceable core is changed.
- Smaller single compressor condensing units are fitted with sealed filter driers which should be replaced every time the system is broken into.
- Multi-compressor systems may be fitted with replaceable core suction filters as an option, dependant on the system design. If a pressure drop in excess of 2psig/0.14bar is observed through this vessel it is recommended that the replaceable core is changed.

Leak Testing before Commissioning

All system piping, including the condensing unit and accessories should be thoroughly tested for leaks prior to start up and charging. The system should be initially pressurized to the maximum allowable pressure relative to the refrigerant and design ambient temperature as set out on EN378-2008 e.g. R404A in an ambient of 32^{o}C = HP 24.8 bar, LP = 14.09 bar. with dry nitrogen to ensure that the system is free of major leaks. With the system free of major leaks, a more detailed leak check should be performed using a proprietary bubble up leak detector spray.
As a further check it is recommended that the test pressure is held for a minimum of 12 hours and then rechecked before releasing the dry nitrogen to atmosphere.
The system must be leak free for satisfactory operation.

Caution: HFC-134a has been shown to be combustible at pressures as low as 5.5 psig (0.37 bar) at a temperature of 177^{o}C when mixed with air at concentrations of more than 60% air by volume. At lower temperature, higher pressures are required to support combustion. Therefore, air should never be mixed with HFC-134a for leak detection.

Evacuation and Dehydration

When the system is completely free of refrigerant leaks, an evacuation of the entire system should be completed by using a “high vacuum” pump. This evacuation, if completed correctly, will ensure long life for the system as well as elimination of moisture and non-condensable gas problems. Moisture problems causing compressor failure will void warranty. Follow the recommended procedure carefully.

Caution: Do not use the refrigeration compressor to evacuate the system. Never start the compressor or perform a megger insulation test while the system is in a vacuum.

Dehydration Procedure

Use only a “high vacuum” pump capable of drawing a vacuum of 100 microns. Change the vacuum pump oil frequently. Gauges or vacuum measuring instruments should be suitable to measure conditions at any stage of the process in order to give the refrigeration engineer indications of progress.

For specific recommendations, refer to the vacuum pump supplier for these instruments.

Flexible lines should be used to interconnect both high and low-pressure sides of the system. These lines should be at least 3/8” O.D. in order to handle the light density vapor at high vacuum obtained at completion of operation. Lines smaller than 3/8” O.D. (1/4” service gauge manifold lines) will slow down the process considerably as well as making final system vacuum questionable. The entire system temperature should be over 15^{o}C for evacuation to be effective. If the temperature is less than 16^{o}C the final vacuum should be 50 microns.

Double evacuation with a “sweeping “of dry nitrogen is recommended. First evacuation should be to at least 750-micron depth. When this point is reached, break the vacuum with dry nitrogen to melt any moisture, which may have frozen inside the refrigeration pipe work during the first vacuum stage.

Line Insulation

After the final system leak test is complete, it is important that all refrigerant lines exposed to high ambient conditions must be insulated to reduce the heat pick-up and prevent excessively superheated suction vapour entering the compressor. In some circumstances (ambient temperatures above 35^{o}C) it may be necessary to insulate the liquid line to prevent the formation of flash gas prior to the expansion valve.

The most common pipe insulation in general use is nitrile foam insulation such as “Isoline” or “Armaflex” or equal which is available in 2m lengths. Insulation suppliers will advise the most suitable wall thickness for any given system however a rule of thumb the minimum would be to use :-

- -30^{o}C Evaporating temperature = ¾” wall applied to the suction line
- -10^{o}C Evaporating temperature = ½” wall applied to the suction line
- Liquid lines exposed to ambient above 35^{o}C = ½” wall

To prevent rupture due to condensate re-freezing, all suction vibration eliminators on low temperature systems must be completely insulated.

Any insulation that is to be located in an outdoor environment should be protected from UV exposure to prevent deterioration of the insulating value. Special quality pre-painted insulation is available for this purpose or alternatively specially formulated paint is available as a retro-fit option.

Direction of Refrigerant Flow

All refrigeration pipe work must be labeled in accordance with BS1710, each label must state, type of refrigerant in the pipe, direction of flow, and rated pressure.

Refrigerant Charging

Refrigeration equipment must only be charged with the refrigerant for which it has been designed. The type of refrigerant to be used is specified on the name plate of the unit.

Installing a liquid line drier between the service gauge and the liquid service port when charging a unit will ensure the refrigerant supplied to the system is clean and dry. This is especially important when charging a low temperature system using a blended refrigerant such as R404A.

Blended 400 Series refrigerants such as R404A, R410A, R407C etc. must not be vapor charged unless the cylinder is completely emptied into the system. These refrigerants only retain their correct formulation in the liquid phase therefore they must always be charged in liquid form to ensure the correct blend is in the system. This may mean inverting the refrigerant cylinder if it only has a single (vapour) outlet valve. Larger cylinders with a double outlet valve will have an internal liquid dip tube and therefore inverting these cylinders is not necessary.

Weigh the refrigerant cylinder before and after charging in order to keep an accurate record of the weight of refrigerant put into the system in accordance with the ‘F’ Gas Regulations. The total system charge must then be recorded in the plant record log that must be left on site as a permanent record of refrigerant usage in the system.

<u>Refrigerant Charging…… cont</u>

Overcharging a system can result in poor system performance, personal injury and / or compressor damage.

- **DO NOT** charge strictly by the holding capacity of the receiver.
- **DO NOT** assume that bubbles in a sight glass, when located at the condensing unit, indicates the system is undercharged.

Charging Notes: *To estimate the total system requirement, refer to the manufacturer's evaporator and condensing unit specifications on typical operating charges and include the amount for the liquid lines (see tables below).*
Allow an extra 10% to 15% safety factor.
Ensure the receiver can handle the required charge during the pump down mode. (Refer to the condensing unit brochure pump down specifications).

1. Break the vacuum by charging liquid refrigerant into the receiver side only (charge through the receiver outlet valve gauge port with the valve in the open position).
2. Close the valve and then continue to charge through the gauge port feeding the liquid line and evaporator.
3. Start the compressor and continue to charge.
4. Refrigerant may be added at the compressor through the compressor suction service valve **in vapour form only**. When liquid charging is used, a liquid charging valve must be installed.
5. While charging the system, special attention should be paid to the oil level in the compressor.
6. If charging to the "bubble" method (observing liquid line sight glass), always use a sight glass located directly before the TXV (thermostatic expansion valve) for the final indicator.

Typical Air Cooled Condensing Unit
Refrigerant operating charges (kgs)
(Less Evaporator and Liquid Line)

Unit HP	R404A	Unit HP	R404A
1/2 H & M	0.8	6 L	4.5
1/2 L	0.8	7.1/2 M	7.7
3/4 H & M	0.95	7.1/2 L	6.4
3/4 L	0.9	9 L	7.8
1 H, M & L	1.3	10 M & L	9.3
1.1/2 H & L	1.7	15 M & L	12.9
1.1/2 M	2	20 M	17.1
2 H, M & L	2	20 L	15.3
3 H, M & L	2.6	25 M & L	17.4
4 H & M	3.1	30 M & L	18.1
4 L	3.4	40 M & L	19.6
5 H	3.1	50 M & L	21.3
5 M	5.3	60 M & L	28.9
		70 M	32.1

These tables are an indication ONLY and must not be used as a difinitive system charge. The actual charge must always be assessed on a case by case basis.

Refrigerant Charge (kgs)
Liquid Lines (per 3m)

Line Size OD	R404A
3/8"	0.15
1/2"	0.29
5/8"	0.47
7/8"	0.96
1.1/8"	1.65
1.3/8"	2.5
1.5/8"	3.55

H = High Temperature
M = Medium Temperature
L = Low Temperature

Compressor Oils

Hermetic Compressors:
Welded hermetic compressors normally do not have sight glasses or means of determining their oil level. This type of compressor is usually installed in packaged systems or in close proximity to the Coldroom evaporator or display cabinet.
All welded hermetic compressors are factory charged with enough oil to compensate for any pipe runs of approximately 10 metres in a remote location.

In the event of excessive pipe runs add approximately 32 ml of oil per meter of pipe run for any remote location over 10 metres.
If in doubt about an actual oil level, the only positive check is to remove the compressor and drain the oil (through the suction connection) and recharge with the correct factory charge (refer to unit specifications).

- DO NOT re-use drained oil that has been exposed to the atmosphere.
- DO NOT re-fill, at any one time more than a total of 110 % of the compressor's factory specified charge. Allow time for some of the oil to circulate into the system.

Scroll Compressors:
The ZB (medium/high temperature) and ZF (low temperature) Scroll compressors used in equipment manufactured by Robert C. Scutt are fitted with oil level sight glasses. Check to see that the oil level is 1/8 to 1/3 up on the compressor sight glass on compressors so equipped before starting the compressor and after 15 to 20 minutes of operation.
CAUTION: Oil levels should not be allowed to go above the centre or 1/2 of the sight glass.

Semi-Hermetic Compressors:
Bock and Frascold semi-hermetic compressors are applied to equipment manufactured by Robert C. Scutt. Check to see that the oil level is 1/8 to 1/3 up on the compressor sight glass on compressors so equipped before starting the compressor and after 15 to 20 minutes of operation.
CAUTION: Oil levels should not be allowed to go above the centre or 1/2 of the sight glass.

Excessive oil levels in any refrigeration compressor can result in excessive compressor noise, higher power consumption or internal compressor damage.

Various oils have been tested and approved by the compressor manufactures. The table below shows approved oils that are in common use.

Approved Refrigeration Oils (Polyolester)

Compressor Manufacturer	HFC's R134a, R404A R507, R407C, R410A
Tecumseh	Emkarate RL32A
Copland Scroll	Mobil EAL ARCTIC 22CC
Copeland Semi-Hermetic	Mobil EAL ARCTIC 22CC
Frascold Semi-Hermetic	Emkarate RL32S
Bock Semi-Hermetic	Fuchs Reniso SE55

System Start-up Check List

Important Note: All work on the compressors and any component or refrigerant control incorporated into this equipment must only be carried out by refrigeration engineers who hold the current level of refrigerant handling qualification (City & Guilds 2079 or CITB J11-14) at the required level for the task being performed.

Before any refrigeration system is started, the following items should be checked:

1. Check that all electrical and refrigeration connections are tight.
2. Check compressor crankcase oil level (if equipped with sight glass). It should be from 1/8 to 1/2 full in the sight glass.
3. Insure that compressor shipping spacers (spring mounted compressors) or hold down nut on solid mounted compressors are properly in place.
4. Check that the compressor discharge and suction shut-off valves are open.
5. Ensure that the high and low pressure controls pressure regulating valves, oil pressure safety controls and any other safety controls are adjusted properly.
6. Check that the room thermostat is set for normal operation and adjust if required.
7. Check all motors, fans and pump bearings in the condenser and evaporator. If they are the type that requires oil or grease, make sure that this is attended to in accordance with the tag, which will be attached.
8. Fan blades and pumps should be checked for correct rotation, tightness and alignment.
9. Air should draw air through the condenser (air cooled condensing unit models).
10. Electric and hot gas evaporator fan motors should be temporarily wired for continuous operation until the room temperature has stabilized.
11. Observe the system pressures during the charging and initial operation process.
12. **DO NOT** add oil while the system is low on refrigerant charge unless the oil level is dangerously low.
13. Continue to charge the system until it has enough charge for proper operation. **DO NOT OVERCHARGE THE SYSTEM.** Note that bubbles in the sight glass may not necessarily mean a shortage of refrigerant. It could be caused by a restriction.
14. **DO NOT** leave the system unattended until the system has reached its normal operating condition and the oil charge has properly adjusted itself to maintain the proper level in the sight glass.
15. Compressor performance, and that of all of the moving components, should be watched carefully throughout the first operating cycle and then checked periodically during the first day of operation. **Careful attention to details at this time will pay dividends in trouble-free performance of the entire system.**
    Check that the wiring diagrams, instructions bulletins etc. are read and attached to the unit for future reference.

Caution: Extreme care must be used when starting a compressor for the first time after the system has been charged. During this time liquid refrigerant may have migrated to the compressor crankcase, creating a condition that could cause the compressor damage due to slugging. Energizing a crankcase heater (if so equipped) 24 hours prior to start-up is recommended.

Scroll Compressors: Three phase scroll compressors must be checked for correct rotation. During the initial start up, observe the suction and discharge gauges to ensure the suction pressure drops and the discharge pressure rises.

High Pressure Safety Controls

The high pressure safety control (HP Switch) setting is a crucial part of the commissioning process and great care must be taken in selecting the correct pressure at which the control will stop the plant.

These controls must be set in accordance with the values shown in EN378-2:2008 dependant on the design ambient temperature. The table below shows the temperature corresponding to the saturated refrigerant pressure at which the HP switch and the pressure relief valve should be set. This pressure is different depending on whether or not a pressure relief valve is fitted. The example shown is for R404A

Basis for calculating the system Design Pressure (Maximum allowable pressure)

Design Ambient R404A Systems	< 32°C	< 38°C	< 43°C	< 55°C
HP Side with Air Cooled Condenser	55°C	59°C	63°C	67°C
Max Allowable Press :	24.8barg	27.1bar	29.6barg	32.4barg
Pressure Relief Valve setting :	24.8barg	27.1bar	29.6barg	32.4barg
HP Switch setting :	22.3barg	24.4barg	26.7barg	29.2barg

Design Ambient R134a Systems	< 32°C	< 38°C	< 43°C	< 55°C
HP Side with Air Cooled Condenser	55°C	59°C	63°C	67°C
Max Allowable Press :	13.9barg	15.4barg	17.1barg	18.8barg
Pressure Relief Valve setting :	13.9barg	15.4barg	17.1barg	18.8barg
HP Switch setting :	12.5barg	13.9barg	15.4barg	19.9barg

Note: Systems with no PRV should have an HP setting of Max Allowable Pressure.

Low Temperature Room Pull-Down

It can take up to two weeks to properly start-up and pull-down a large freezer. Large freezers should be pulled down to temperature in stages. Too fast a pull-down can cause structural problems in pre-fabricated rooms and will damage (crack) concrete floors.

Reduce room temperature by 6°C to 8°C per day.

Hold this temperature for 24 to 48 hours at 2°C and again at -4°C. Monitor the amount of defrost water during this pull down stage.

Once the room is pulled down to temperature, expect frost on the compressor end bell and any exposed suction line. A lack of frost in these areas probably indicates too high of suction superheat. Reduce defrost frequency to 30 minutes every 6 hours if possible. Adjust the defrost termination (and time clock) so that the coil and drain pan are COMPLETELY free of frost at termination.

Too short of a defrost cycle will allow residual ice to grow.
Too long a defrost cycle will allow the coil(s) to steam at the end of the cycle. The steam will condense and freeze fans, fan guards and create frosting on the ceiling of the room. The evaporator fan delay must allow any condensate left on the coil surface to refreeze before the fans start.

Checking Superheat

To obtain maximum system capacity and insure trouble free operation it is necessary to check both the compressor and evaporator superheat.

Compressor Superheat:
Compressor suction superheat must be checked. To check the superheat at the compressor the following steps should be followed:

1. Measure the suction pressure at the suction service valve of the compressor. Determine the saturated temperature corresponding to this pressure from a "Pressure- Temperature" chart.
2. Measure the suction temperature of the suction line about 6 inches (15 cm) back from the compressor suction valve using an accurate thermometer.
3. Subtract the saturated temperature (from step 1) from the actual suction line temperature (from step 2). This difference is the actual superheat at the compressor.

System capacity decreases as the suction superheat increases. For maximum system capacity, the suction superheat should be kept as low as is practical. The superheat at the compressor should range within 11^{o}C to 25^{o}C Superheat.

- Too low of a suction superheat can result in liquid being returned to the compressor. This can cause dilution of the oil and eventually cause failure of the bearings and rings through wash out as well as liquid slugging.
- Too high of a suction superheat will cause excessive discharge temperatures which cause a break down of the oil and will result in piston ring wear, piston and cylinder wall damage.

If adjustment to the suction superheat is required, it should be done either by adjusting the thermostatic expansion valve at the evaporator, the use of liquid to suction heat exchanger or suitable use of suction line insulation.

Evaporator Superheat:
Once the refrigerated space is at its design temperature or close to design temperature, the evaporator superheat must be checked. To check the suction superheat at the evaporator the following steps should be followed:

1. Measure the suction pressure in the suction line at the bulb location by either,
   - A gauge in the external equalizer line will indicate the pressure directly and accurately.
   - A gauge directly in the suction line near the evaporator or directly in the suction header will suffice
2. Measure the temperature of the suction line at the point where the thermostatic expansion valve bulb is clamped to the suction line.
3. Convert the pressure obtained in step 1 above to a saturated evaporator temperature from a "Pressure-Temperature" chart.
4. Subtract the saturated temperature (from step 1) from the actual suction line temperature (from step 2). This difference is the actual superheat at the evaporator.

The superheat at the evaporator should be a minimum of 3^{o}C to 6^{o}C for systems with a 6^{o}C design TD (temperature difference) to a maximum of 7^{o}C to 8^{o}C for systems with a higher operating TD.
Low temperature applications (freezers) should be set at superheats of 2^{o}C to 3.5^{o}C.

TD = Cold room air temperature – Evaporating temperature.

System Operational Check List

When the system has been running trouble free for an extended time (two weeks or more) and design conditions are satisfied, the following check list should be followed:

1. Check that compressor discharge and suction pressures are operating within the allowable design limits for the compressor. If not, take the necessary corrective action.

2. Check the liquid line sight glass and expansion valve operation. If there is an indication that the system is low on refrigerant, thoroughly check the system for leaks before adding refrigerant.

3. Check the level of the oil in the compressor sight glass (if so equipped). Add oil as necessary.

4. The thermostatic expansion valve must be checked for proper superheat settings. The sensing bulb must have positive contact with the suction line and should be insulated. Valves operating at a high superheat setting results in low refrigeration capacity. Low superheat settings can cause liquid slugging and compressor bearing washout. (Refer to the section on compressor and evaporator superheats)

5. Check the voltage and amperage readings at the compressor terminals. Voltage reading must be within the recommended guidelines. Normal operating amperages can be much lower than the compressor nameplate values.

6. To check the high pressure control setting it is necessary to build up the head pressure to the cut-out point of the control. This can be done by stopping the condenser fan(s) (air cooled condensing units) or pump and watching the pressure rise on a high pressure gauge to make sure the high pressure control is operating at the setting

7. Check the low pressure settings by throttling the compressor shut-off valve and allowing the compressor to pump down. This operation must be done with extreme caution to avoid too sudden a reduction in crankcase pressure, which will cause oil slugging and possible damage to the compressor valves. Close the valve a turn at a time while watching the compound gauge for change and allowing time for the crankcase pressure to equalize with the pressure control bellows pressure. The slower the pressure is reduced, the more accurate will be the check on the pressure control setting.

8. Recheck all safety and operating controls for proper operation and adjust as necessary.

9. Check defrost controls for initiation and termination settings, and the length of defrost period. Set the fail safe on the time clock at the length of defrost plus 25 %.

10. If the system is equipped with winter head pressure controls (fan cycling or flooded valves), check for operation.

11. Fill in the Service Log in the back of this Installation Manual

System Trouble Shooting Guide.

The following System Trouble Shooting Guide lists the most common types of malfunctions encountered with refrigeration systems. These simple trouble shooting techniques can save time and money minimizing unnecessary down time and enhancing customer satisfaction.

Condensing Unit Problem	Possible Causes
Compressor will not run. Does not try to start.	a) Main power switch turned off b) Fuse blown or tripped circuit breaker. c) Thermal overload tripped. d) Compressor Thermister unit tripped. e) Faulty contactor coil f) System shut down on safety devices (HP/LP, Oil Diff, Thermister module) g) Open thermostat or control. No cooling required. h) Liquid line solenoid closed and will not open. i) Loose wiring.
Compressor Hums, but will not start.	a) Improperly wired b) Low line voltage. c) Loose wiring. d) Defective start or run capacitor. (1ph only) e) Defective start relay (1ph only) f) Motor windings damaged. g) Internal compressor mechanical damage.
Compressor starts but trips on overload protector.	a) Improperly wired. b) Low line voltage c) Loose wiring d) Defective start or run capacitor. (1ph only) e) Defective start relay (1ph only) f) Excessive suction or discharge pressure. g) Tight bearings or mechanical damage to the compressor. h) Defective overload protector. i) Motor windings damaged. j) Overcharged system. k) Shortage of refrigerant. l) Suction or discharge pressure too high. m) Inadequate ventilation n) Operating system outside design conditions.
Compressor Short Cycles	a) Low pressure control differential set too low. b) Shortage of refrigerant c) Low air flow at evaporator(s). d) Discharge pressure too high. e) Compressor internal discharge valves leaking. f) Valve plate damaged. g) Incorrect unit selection (oversized compressor)
Start Relay burns out.	a) Improperly wired b) Low or high voltage. c) Compressor short cycling. d) Faulty anti recycle timer. (too many starts per hour) e) Improper mounting of the relay. (wrong orientation) f) Incorrect start or run capacitor. g) Incorrect relay.
Contact welded stuck on start relay.	a) Short cycling b) No bleed resistor on start relay c) Faulty start relay.

Condensing Unit Problem	Possible Causes
Start Capacitor Burns out.	a) Improperly wired. b) Compressor short cycling c) Low line voltage. d) Relay contacts sticking or welded shut. e) Incorrect capacitor. f) Start winding remaining in circuit too long.
Compressor noisy or vibrating.	a) Flood back of refrigerant. b) Inadequate pipe support on the suction or discharge line. c) Broken or worn internal compressor motion work. d) Incorrect oil level (too high or too low) e) Scroll compressor rotating in reverse (three phase) f) Loose compressor mountings. g) Inadequate compressor vibration isolation.
Discharge Pressure too high.	a) Non-condensable (air) in the system. b) System overcharged with refrigerant. c) Discharge service valve partially closed. d) Condenser fan(s) not running. e) Dirty condenser coil (air cooled condenser) f) Dirty tubes (water cooled condenser) g) Defective or improperly set water regulating valve. h) Defective or improperly set head pressure control.
Discharge pressure too low.	a) Low suction pressure. b) Cold ambient temperature. c) Suction service valve partially closed. d) Shortage of refrigerant. e) Defective or improperly set water regulating valve. f) Defective or improperly set head pressure control.
Suction Pressure too high.	a) Excessive cooling load on the evaporator. b) Compressor valve plate damaged. c) Incorrect condensing unit/compressor selection (undersized) d) Incorrect thermostatic expansion valve bulb charge.
Suction Pressure too low.	a) Shortage of refrigerant. b) Evaporator dirty or iced up. c) Clogged liquid line drier. d) Clogged suction line filter, or compressor suction strainer. e) Expansion valve malfunction. f) Condensing temperature too low. g) Incorrect expansion valve selection (undersized) h) Evaporator distributor feed problems.
Low or no oil pressure.	a) Low oil level (trapped oil in the evaporator) b) Clogged suction oil strainer. c) Excessive liquid refrigerant in the crankcase. d) Worn oil pump. e) Oil pump revering gear sticking in the wrong position. f) Worn compressor bearings. g) Faulty oil separator/oil control system.
Compressor Loosing oil	a) Refrigerant leak b) Short cycling c) Worn compressor piston rings. d) Refrigerant flood back (intermittent) e) Incorrect or inadequate suction line traps. f) Suction velocity too low, oil trapped in the evaporator. g) Suction velocity too low (compressor capacity control)
Compressor runs continuously.	a) Excessive evaporator load. b) System thermostat setting to low or defective. c) Shortage of refrigerant. e) Compressor valve plate damaged. f) Incorrect condensing unit selection (undersized) g) Liquid line solenoid faulty.

Coldroom Problem	Possible Causes
Cold room temperature too high.	a) Faulty room thermostat or incorrect differential setting. b) Liquid line solenoid malfunction. c) Insufficient evaporator air flow (coil iced up) d) Product blocking the evaporator air flow. e) Fan motor/blade problem. f) Expansion valve superheat setting incorrect. g) Shortage of refrigerant. h) Equipment selection not balanced to the load (undersized) i) Coldroom door openings to frequent and/or too long.
Room temperature too low.	a) Faulty room thermostat or incorrect differential setting. b) Liquid line solenoid malfunction.
Ice accumulating on the ceiling.	a) Defrost cycle too long. (steam rising off the evaporator) b) Faulty defrost termination control. c) Too many defrost cycles per day. d) Fan delay system after defrost malfunctioning e) Coldroom door left open too long. f) Coldroom insulation broken down.
Evaporator coil not clear of ice after defrost.	a) Defrost cycle too short. b) Faulty defrost termination control c) Electric defrost heaters defective/mis-wired/low voltage. d) Insufficient defrosts per day. e) Air defrost evaporator operating in to low a cold room temperature (required an electric defrost system) f) Faulty or mis-wired interlock at compressor contactor. g) Faulty defrost contactor coil.
Ice build up in evaporator drain pan	a) Evaporator not level (incorrect slope in drain pan) b) Blocked drain line. c) Drain line heater faulty/Drain line not insulated. d) Faulty drain pan heater e) Insufficient defrosts per day. f) No ‘P’ trap installed in the drain line.
Evaporator Fans will not operate.	a) Main power switched off. b) Fuse blown or circuit breaker tripped. c) Defective contactor coil. d) Room temperature too high (fan delay stat open) e) Fan delay stat not set properly. f) Faulty fan motor. g) Faulty defrost time clock

Important Trouble Shooting Note: **Before any components are changed on the refrigeration system the cause of the failure must be identified. Further problems will occur unless the true cause of the problem is identified are corrected.**