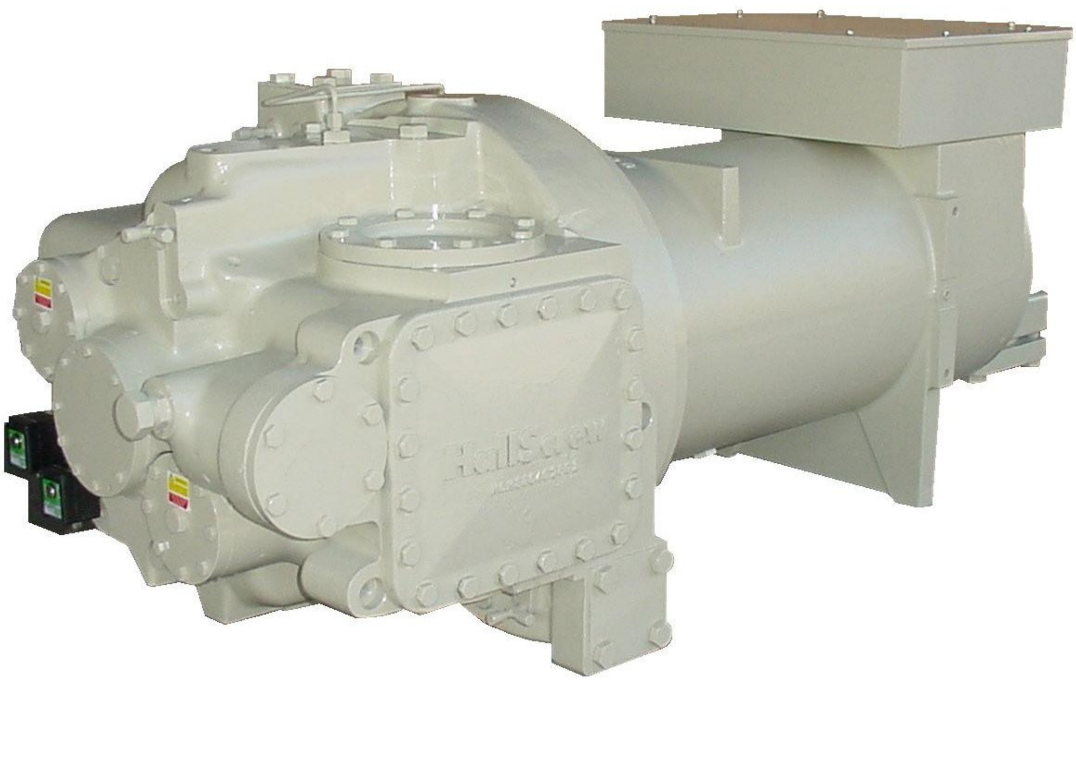
HallScrew HS L/M 4200 Series

Semi-hermetic Single Screw Compressors

HS L/M 4221, HS L/M 4222, HS L/M 4223 and HS L/M 4224

Installation, Operation and Maintenance Manual



Safety

In common with most other forms of mechanical and electrical equipment, there are a number of potential hazards associated with operating and servicing refrigeration plant.

In writing this instruction manual every emphasis has been given to safe methods of working. These safety instructions are intended to draw attention to the potential hazards that could be encountered during installing, operating and maintaining the plant. At the same time, it should be emphasised that these notes are not exhaustive, and are principally intended to draw attention to the most important points; where necessary, reference is made to other parts of the manual.

Please note that the installer is responsible for the correct installation of equipment, and on completion, the owner and/or user are responsible for safe operation and maintenance.

Personnel Permitted to Install, Commission and Maintain the Plant

It is essential that only authorised and competent personnel are allowed to install, commission and maintain the plant. A permit to work system should be introduced before commissioning begins, and should be rigorously enforced thereafter.

Any person rendering assistance or under training must be supervised by the authorised competent person who has responsibility for safety.

Personnel must be familiar with the plant's construction, operation and the hazards involved. **All** personnel should make a thorough study of these instructions before undertaking installation, commissioning, maintenance or repair procedures.

Mechanical

Refrigeration compressors manufactured and/or supplied by J & E Hall International must be operated within their design parameters, and should never be used as vacuum pumps or for compressing air.

Personnel must not start the plant until they have taken steps to verify the following:

- Guards on couplings, belt drives and fans are in place, and other personnel are not in positions that might be hazardous when the plant is in operation.
- The compressor discharge stop valve is fully open.

Parts of the plant, specifically the compressor, drive motor and discharge line, are liable to be at temperatures high enough to cause a burn. A 'cold' burn can result from accidentally touching any part of the plant containing oil at low temperature, or subcooled liquid refrigerant.

Personnel who stop the plant must be aware of the potential hazard if pipeline stop valves are closed in such a manner as to trap cold liquid refrigerant between valves. If this should accidentally occur, rising ambient temperature will cause the liquid to expand and eventually fracture the pipe or valves, etc.

Stop valves should be opened slowly to begin with and by a small amount, say half a turn, before the valve is fully opened. This procedure allows system temperatures and pressures to equalise gradually, so reducing the risk of physical and/or thermal shock which might cause damage.

⚠ WARNING

As described under 4.1. Slide Valve Actuation, the capacity control mechanism contains a heavy duty spring under compression. Any attempt to remove the spring without using the correct tools could result in serious injury to the operator.

Examination of Pressure Systems

Within the United Kingdom, statutory regulations require the user to prepare a 'written scheme of examination' to cover all parts of the plant subject to pressure. It is a requirement that the scheme be introduced before the plant is put into operation for the first time. If the plant is modified, the written scheme of examination must be reviewed and updated to incorporate these modifications.

Noise Hazard

The majority of noise emanating from refrigeration plant is produced by the compressor(s), pump(s) and fan(s) and the motors which drive them. While short term exposure to the typical average noise level which might be encountered is unlikely to be detrimental to health, ear defenders should be worn by those personnel who have to work near major sources of noise. The type of ear defenders worn must not compromise the wearing of other essential safety clothing, for example, goggles or a respirator.

Electrical

Electrical wiring must be sized and installed to such a standard as to meet the requirements of the national or local codes pertaining to the area in which the installation is taking place.

The electrical power used in this equipment is at a voltage high enough to endanger life. Before undertaking maintenance or repair procedures on electrical equipment, personnel must isolate equipment from the electrical supply and test to verify that isolation is complete. Precautions must be taken to prevent circuits being inadvertently energised, for example, withdraw the mains fuses, or, if this is not practicable, disconnect the equipment from the supply before work commences.

If the supply cannot be disconnected or must remain connected to permit functional testing, fault diagnosis and repair should only be undertaken by persons who are aware of the hazard and who have taken adequate precautions to avoid direct contact with dangerous voltages.

If electrical equipment overheats or a fault occurs, it must be disconnected from the supply and allowed to cool. Overheating may damage the insulation system, cables, mouldings, gaskets and seals. The materials used in these components may contain complex organic compounds which, when degraded by heat or electrical action, produce chemical compounds in gaseous, liquid or solid forms. Many of these gaseous and liquid product compounds are highly flammable and toxic.

If it is necessary to extinguish a fire in electrical equipment, follow the advice given in the Fire Precautions Act 1971, 'Guide to Fire Precautions in Existing Places of Work that require a Fire Certificate' available from HMSO. Do not approach the equipment until the fire has been extinguished and the equipment is cool.

Lubricating Oils

Refrigeration oils are unlikely to present any significant health and safety hazard provided they are used properly, and good standards of industrial and personal hygiene are maintained. The following general precautions are recommended:

- Avoid unnecessary handling of oily components. Use of a barrier cream is recommended.
- Oils are potentially flammable and should be stored and handled with this in mind. Rags or disposable 'wipes' used for cleaning purposes should be kept well away from naked flames and disposed of properly.
- Oil contained in the compressor lubrication system, oil separator, oil filter etc, will remain hot enough to cause burns for some time after the system has been shut down. If it is necessary to open the system soon after the compressor has stopped, to change the oil filter for example, always allow long enough for the oil to cool down so that the oil which is likely to escape is cool enough not to be a danger (less than 35 °C is recommended).

Hydrochlorofluorocarbon and Hydrofluorocarbon Refrigerants

Refrigeration systems contain liquid and vapour under pressure; personnel should be aware of this fact at all times. Suitable precautions must be taken to guard against the pressure hazard when opening any part of the system.

Opening up part of the primary refrigeration circuit will necessitate the loss of a certain amount of refrigerant to atmosphere. It is essential to restrict the amount which escapes to a minimum by pumping over and isolating the charge in another part of the system.

Where lubricating oil may be present, when changing the oil filter element for example, caution must be exercised as the oil will contain a certain amount of refrigerant which will be released when subjected to atmospheric conditions.

Refrigerant and lubricating oil, especially liquid refrigerant at low temperature, can cause freezing injuries similar to a burn if allowed to come into contact with the eyes or skin. Suitable protective clothing, gloves, goggles etc. must be worn when opening pipes or vessels which may contain liquid.

Although not considered toxic, being heavier than air, hydrofluorocarbon refrigerant vapour can endanger life by displacing air from cellars, ships engine rooms, etc. If refrigerant is released accidentally, fan assisted ventilation must be used to remove the vapour. Exposure levels in the workplace should be kept to a practicable minimum and certainly within the recognised threshold limit value of 1,000 parts per million (ppm) based on an 8 hour day, 40 hour week.

While hydrofluorocarbon refrigerants are not flammable, naked flames, for example, smoking, must be prohibited in the presence of vapour as temperatures above 300 °C will cause it to decompose and form phosgene, hydrogen fluoride, hydrogen chloride and other toxic compounds. If ingested, these compounds can have very dangerous physiological effects.

Refrigerant which is not required for immediate use must be stored in approved containers, and the quantity held in the plant room limited. Cylinders and drums of refrigerant must be treated with care.

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1. About this Publication

These instructions have been prepared according to the following standards:

BS 4884 : Technical Manuals:

Part 1 : 1992 Specification for Presentation of Essential Information.
Part 2 : 1993 Guide to Content.
Part 3 : 1993 Guide to Presentation.

BS 4899 : User's Requirements for Technical Manuals:

Part 1 : 1991 Content.
Part 2 : 1992 Presentation.

BS 4899 is based on the principles of BS 4884.

BS 5378 : Part 2 : 1982 Safety Signs.

1.1. Safety Warnings and Symbols

The system of safety warnings and symbols is based on BS 5378 : Part 2 : 1982 Safety Signs and BS 4884 : Technical Manuals : Part 1 : 1992 Specification for Presentation of Essential Information.

⚠ WARNING

This denotes an immediate hazard with a high likelihood of personal injury or death if instructions, including recommended precautions, are not followed. There is also a potential risk of damage to the product, process or its surroundings.

⚠ CAUTION

This draws attention to instructions which must be complied with to avoid damage to the product, process or its surroundings.

NOTE: draws attention to important additional information.

1.2. Units of Measurement

Quantities are expressed in SI units or SI derived units.

1.3. Terminology

Terminology, abbreviations and acronyms are those currently in use throughout the refrigeration and air conditioning industry.

1.4. Publications and Support

Publications, contact details and other useful information can be downloaded from our website at www.jehall.co.uk.

2. Misuses that Invalidate Guarantee

Please note that the installer is responsible for the correct installation and commissioning of equipment and, on completion, the owner and/or user is responsible for its safe operation and maintenance.

Failure to comply with the following provisions will invalidate the guarantee as set out in J & E Hall International standard conditions of sale.

2.1. Application

The following is specifically prohibited:

(a) Operation outside the limits detailed in Appendix 1 Compressor Data.

(b) Use of any anti-freeze, trace chemical or other additive in the primary refrigerant system.

(c) Use of any refrigerant other than R404a, R407c, R507a, R134a or R22 without prior agreement with J & E Hall International.

Installing the compressor into a system previously charged with R717 (ammonia).

(d) Use of lubricating oils other than those specified by J & E Hall International; refer to publication 2-59 Lubricating Oils.

2.2. System Provisions

Refer to Appendix 2 Oil Support System Schematic Flow Diagrams. Items specifically required and which are considered mandatory are as follows:

(a) Fit an adequately sized refrigerant filter/drier, preferably of the type using renewable cores. Fit a sight-glass/moisture indicator.

(b) Fit an oil filter. The filter must be adequately sized and to the specification described in Table 1.

(c) If the system is fitted with an economiser, fit an adequately sized strainer in the economiser suction line. The strainer must have a mesh aperture of 250µ or better.

(d) To prevent excessive reverse rotation of the compressor at shutdown it is necessary to fit a non-return valve immediately after the oil separator discharge outlet.

NOTE: the discharge non-return valve must be sized according to the operating conditions.

(e) Adequate precautions must be taken to prevent oil or liquid refrigerant accumulating in the compressor when it is stopped. This includes the mandatory use of an oil drain line to return oil an/or liquid to the oil separator, which must be positioned to permit free-drainage; refer to 6.2. Oil Drain.

Under certain operating conditions, the compressor will need cooling; refer to 6.9. Compressor Cooling.

(f) HS L/M 4200 series semi-hermetic compressors are normally cooled by direct injection of liquid refrigerant.

If liquid injection cooling or thermosyphon oil cooling is used, a preferential supply of liquid refrigerant must be provided for cooling purposes. The priority supply must be arranged so that the cooling requirement is satisfied before liquid can flow to the evaporator(s); refer to publication 2-122 Compressor Cooling.Fit, and maintain in an operational condition, the cut-outs and other safety devices described in Appendix 1 Compressor Data, illustrated in Appendix 2 Oil Support System Schematic Flow Diagrams.

Under no circumstances should the compressor be operated with cut-outs or other safety devices short-circuited or rendered inoperative by mechanical or electrical means.

(g) The plant controller is required to supply load/unload pulses to the capacity control solenoid valves, minimum pulse length 0.1 to 0.5 seconds, depending upon the accuracy of control required.

The control system must be interlocked to prevent the compressor starting unless the slide valves are at minimum load.

2.3. Prolonged Storage

If, for any reason, the compressor cannot be installed immediately and must be placed in prolonged storage, refer to 8. Prolonged Storage.

2.4. Commissioning Provisions

General commissioning procedures are described in 10. Commissioning and Operation.

The following provisions are considered mandatory:

(a) The system into which the compressor is installed must be dehydrated by evacuation to a pressure of no more than 2.0 mm Hg before charging and commissioning take place. Under no circumstances must the HallScrew compressor be used to evacuate or pump out the system.

The evacuation procedure is described in publication Part E : Evacuation and Dehydration, available from J & E Hall International.

NOTE: remember that evacuating the system does not remove moisture dissolved in synthetic ester lubricant; refer to (c).

(b) When a mineral oil is specified for compressor lubrication, maintain the acid number of the oil <0.05 by checking on a regular basis using a proprietary acid test kit.

(c) With HFC refrigerants, for example, R134a or R404a, it is necessary to use polyolester synthetic lubricants. Maintain the acid number of the compressor lubricating oil <0.15 by checking the oil on a regular basis using a proprietary acid test kit available from the oil supplier.

Additives in the oil mean that acid numbers are generally higher than those for traditional mineral oils. It is essential to maintain a record of the oil acid number and change the oil when the acid number rises by 0.05, even if this is below the 0.15 maximum.

When using polyolester synthetic oils, care must be taken to ensure that contact between air and the lubricant is minimised. Spare oil must be adequately protected against contamination; refer to 10.7. Adding Oil to the System.

NOTE: compressor failure due to internal corrosion, copper plating, sludged oil or etching of internal components due to high acidity will be taken as evidence that the above provisions have not been complied with.

(d) Discharge high temperature and stator winding high temperature thermistors are fitted as standard and must be wired as illustrated in Fig 10.

(e) Connect the compressor stator/rotor phase rotation in accordance with phase rotation wiring diagram illustrated in Fig 10.

Check the direction of rotation; refer to 10.3. Checking Compressor Rotation.

(f) Do not attempt to run the compressor with an electrical supply voltage, frequency or phase rotation other than as designated on the motor electrical data plate.

(g) Do not exceed the maximum of 8 starts per hour.

3. General Description

The J & E Hall International HS L/M 4200 series of semi-hermetic compressors are the latest addition to the HallScrew family of oil injected, positive displacement, single screw compressors. Reflecting the very latest innovations in screw compressor technology, they are designed for refrigeration systems using R404a, R407c, R507a, R134a or R22 and used in conjunction with a high efficiency oil separator (not supplied with compressor) fitted in the discharge line.

HS L/M 4200 series compressors are capable of operating without cooling over a limited range, but when indicated, cooling by liquid injection can be employed.

3.1. Main Features

- For use with R404a, R407c, R507a, R134a and R22.
- Designed and tested to international standards.
- Robust construction.
- Improved machine clearance control for maximum efficiency.
- Oil injected for maximum reliability.
- Balanced loading on main bearings for maximum bearing life.
- Enhanced slide valve geometry for capacity modulation with minimum loss of efficiency. Infinite adjustment between maximum (100 %) and minimum load (nominal 25 %).
- Simple, built-in capacity control using two solenoid valves.
- Single connection for oil injection/lubrication/capacity control.
- Economiser facility provided to improve operating efficiency, especially at high compression ratios.

  For further information refer to publication 2-129 Economiser Facility For HallScrew Compressors.
- Internal suction/discharge safety relief valve (not UL approved).
- High efficiency built in 3 phase, 2 pole motor unit for reliable operation. Two different motor power options. Available for 50 Hz or 60 Hz operation.
- Motor designed for star/delta or soft-start.
- Thermistor high temperature protection to motor.
- Thermistor discharge gas high temperature protection.
- Built-in oil filter.

3.2. Construction

The compressor is driven by a specially designed motor mounted on one end of the compressor main shaft.

The compressor consists of two cast-iron castings which are bolted together. The first casting, the main casing, encloses the motion work comprising the main rotor and star rotors. The second casting, the motor housing, encloses the 3 phase, 2 pole motor. Returning suction vapour flows around the stator/rotor unit, cooling the windings in the process, before entering the main rotor flutes.

Thermistor probes, buried deep in each phase of the stator windings, provide protection against high temperatures. Phase wiring and thermistor terminations are made to a terminal plate inside an enclosure mounted on the top of the motor housing.

The motion work, i.e. that part of the machine which performs the compression function, consists of three rotating parts; there are no eccentric or reciprocating motions. These fundamental components comprise the cylindrical main rotor in which are formed six-start, helically grooved screw threads with a spherical (hourglass) root form. The main rotor meshes with two identical toothed wheels each having eleven teeth. These wheels (or 'star rotors' as they are called owing to their shape), are made from a special synthetic material. They are located in a single plane diametrically opposite each other on either side of the main rotor, with their axes at right angles to the main rotor axis. As the main rotor turns, it imparts a freely rotating motion to the star rotors.

The star rotors are supported by metal backings which are cast in one-piece with the star rotor shafts. Although they are located in place on their backings, the stars are allowed to 'float' a small amount in a rotational sense. This floating action, combined with the low inertia and negligible power transmission between the main rotor and star rotors, ensures compliance of the star/main rotor combination. The star rotor shafts are supported at each end by taper roller bearings.

The main rotor is supported on a shaft the other end of which carries the motor rotor. The shaft is supported by an arrangement of rolling element bearings at three positions. This entire assembly is dynamically balanced.

The main rotor and star rotors are housed inside the main casing. The inside of this main casing has a somewhat complex shape, but essentially consists of a specially shaped cylindrical annulus, which encloses the main rotor leaving a small clearance. Part of the annulus is cutaway at the suction end to allow the suction gas to enter the rotor. In addition there are two slots, one each side, to allow the star teeth to mesh with the main rotor flutes. The discharge ports (one for each star), are positioned at the other end of the annulus. These ports convey the compressed gas out of the compressor via the two discharge outlets. Except for the discharge ports and oil management system, suction pressure prevails throughout the main casing.

Side covers are provided to allow easy access to the star rotors, star rotor shafts and bearings, without disturbing working tolerances.

The compressor is fitted with an integral suction strainer, built into the suction end cover, designed to trap any dirt circulating with the refrigerant which might otherwise enter and damage the compressor.

To prevent reverse rotation of the compressor at shutdown it is necessary to fit a non-return valve immediately after the oil separator discharge outlet; refer to 6.4.2. Discharge Non-return Valve.

3.2.1. Internal Relief Valve

The compressor is fitted with an internal suction/discharge relief valve to protect against overpressure, for example, in the event of operation with a closed delivery valve in the system. Adequate system relief valves designed to match the plant design pressure must be retained.

3.3. The Compression Process

With single screw compressors the suction, compression and discharge process occurs in one continuous flow at each star wheel. In this process the suction gas fills the profile between the rotor, star tooth and casing. The volume is steadily reduced and the refrigerant gas thereby compressed. The high-pressure gas is discharged through a port, the size and geometry of which is determined by the internal volume ratio (ratio of the volume of gas at the start and finish of compression). This volume ratio must have a defined relationship to the mass flow and the working pressure ratio, to avoid losses in efficiency due to over and under compression.

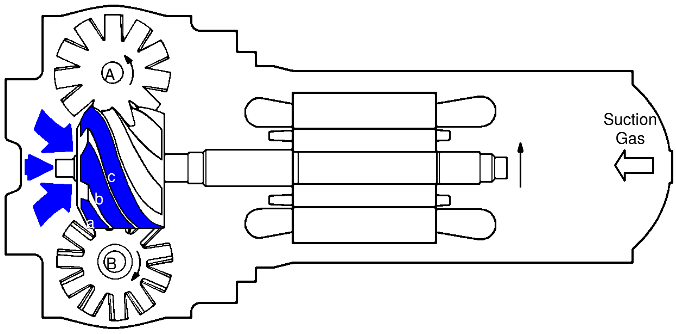
As the HallScrew is a positive displacement compressor, there are three separate stages in the compression cycle: suction, compression and discharge. These are illustrated in Fig 1.

1. and 2. Suction

Main rotor flutes 'a', 'b' and 'c' are in communication at one end with the suction chamber via the bevelled rotor end face, and are sealed at the other end by the teeth of star rotor A. As the main rotor turns, the effective length of the flutes increases with a corresponding increase in the volume open to the suction chamber: Diagram 1 clearly shows this process. As flute 'a' assumes the position of flutes 'b' and 'c' its volume increases, inducing suction vapour to enter the flute.

Upon further rotation of the main rotor , the flutes which have been open to the suction chamber engage with the teeth of the other star rotor. This coincides with each flute being progressively sealed by the main rotor. Once the flute volume is closed off from the suction chamber, the suction stage of the compression cycle is complete.

1.



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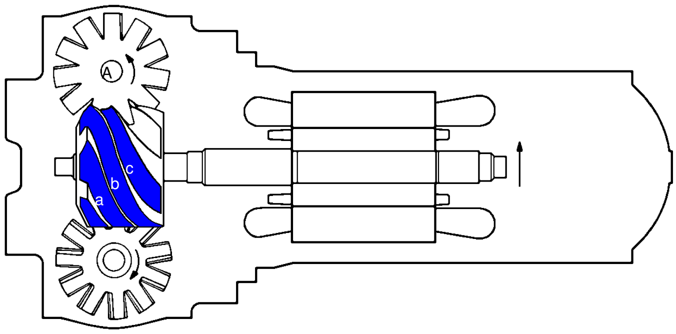
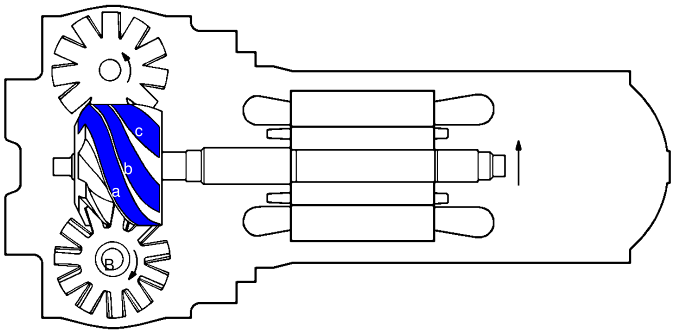


3. Compression

As the main rotor turns, the volume of gas trapped within the flute is reduced as the length of the flute shortens and compression occurs.

3.



4. Discharge

As the star rotor tooth approaches the end of a flute, the pressure of the trapped vapour reaches a maximum value occurring when the leading edge of the flute begins to overlap the triangular shaped discharge port. Compression immediately ceases as the gas is delivered into the discharge manifold. The star rotor tooth continues to scavenge the flute until the flute volume is reduced to zero. This compression process is repeated for each flute/star tooth in turn.

While the compression process described above is occurring in the upper half of the compressor, there is an identical process taking place simultaneously in the lower half using star B, thus each main rotor flute is used twice per rotor revolution (one by one tooth in each star). The compression process may be likened to an assembly of six double-acting cylinders (the main rotor flutes) in which the star rotor teeth move as pistons (always in the same direction).

4.

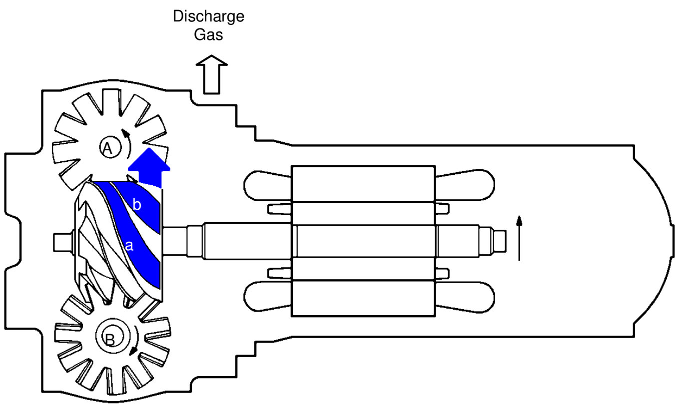


Fig 1 Compression Process

4. Capacity Control and Volume Ratio

HallScrew HS L/M 4200 series compressors are provided with infinitely variable capacity control as standard.

Since the HallScrew compressor utilises fixed intake and discharge ports instead of valves, the overall compression ratio is determined by the configuration of these ports. The degree of compression is governed by the ratio between the flute volume when it is sealed off by the star tooth at the beginning of the compression process, to that immediately before the discharge port is uncovered. This is known as the built-in volume ratio (V_R) and is an important characteristic of all fixed-port compressors.

In order to achieve maximum efficiency, the pressure within the flute volume at the end of the compression process should equal the pressure in the discharge line at the instant the flute volume opens to discharge. Should these conditions not prevail, either overcompression or undercompression will occur, both of which result in internal losses. Although in no way detrimental to the compressor, inefficient compression will increase power consumption.

The compressor is fitted with a pair of sliding valves, one for each half of the symmetrical compression process. These valves reduce pumping capacity by delaying the sealing of the flute volume together with the opening of the discharge port, altering the effective length of the main rotor flutes. The valves permit stepless capacity control down to approximately 25 % of full load (actual minimum value varies with operating conditions).

Each slide valve is housed in a semicircular slot in the wall of the annular ring which encloses the main rotor. As the slide valve travels axially from the full load position it uncovers a port, which vents part of the gas trapped in the main rotor flute back to suction, before compression can begin. When the flute has passed beyond the port, compression commences with a reduced volume of gas. However, a simple bypass arrangement without any further refinement would produce an undesirable fall in the effective volume ratio which in turn causes under compression and inefficient part load operation. To overcome this problem, the slide valve is shaped so that it delays the opening of the discharge port at the same time as the bypass slot is created.

4.1. Slide Valve Actuation

The method of operation is illustrated in Fig 3.

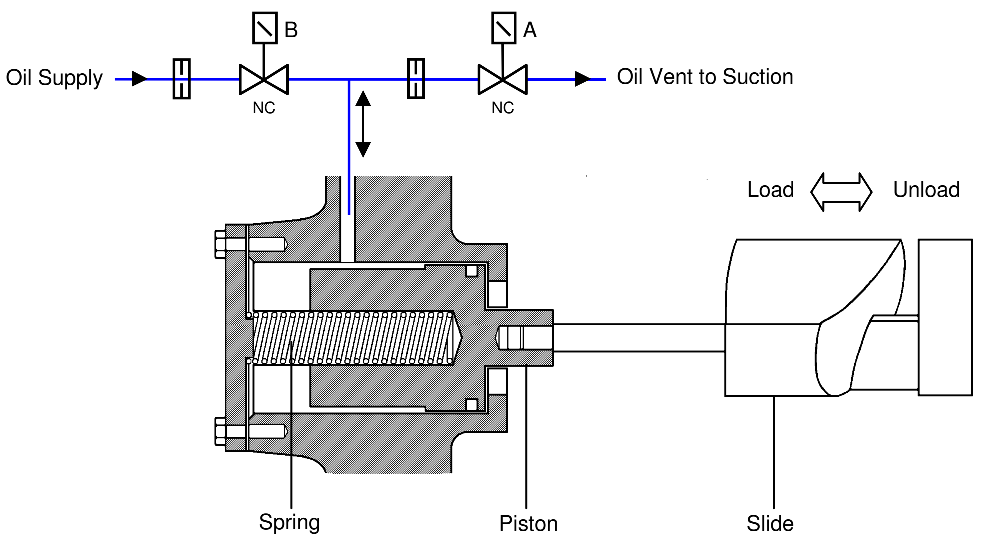


Fig 2 Capacity Control Mechanism

Variation in compressor pumping capacity is achieved by altering the forces acting on the slide valve/piston assemblies.

Internal drillings communicate pressurised oil to the capacity control cylinders and vent the oil from the cylinders. The flow of oil is controlled by two separate solenoid valves, A and B; the solenoids are normally closed (NC), energise to open.

Each piston cylinder incorporates a spring. When the compressor is running, a pressure difference is created across each slide valve: discharge pressure acts on one end of the slide, suction pressure at the other end. This differential pressure creates a force on the slides tending to drive them towards the maximum load position. Oil pressure assisted by the spring force acting on the pistons, creates an opposing force tending to move the slides towards the minimum load position.

When the compressor is required to stop, or if the compressor is stopped before minimum load is attained, for example, a fault condition or operating emergency, the pressures within the compressor equalise. Under these conditions the springs move the slide valves to the minimum load position, thereby ensuring that the compressor always starts at minimum load.

4.1.1. Minimum Load Interlock

Starting at minimum load minimises motor starting current and starting torque. This in turn minimises stresses on the motor and mechanical parts, and also reduces the load on the power supply network.

The control system must be interlocked to prevent the compressor starting unless the linear variable displacement transducer (LVDT) provides an 'at minimum load' permit start signal.

4.2. Continuously Variable Capacity Control

The plant controller energises and de-energises the solenoids to control the rate of loading/unloading. These signals must be provided by a suitable pulse timer with a minimum pulse length of 0.1 to 0.5 seconds, depending upon the accuracy of control required.

Solenoid A is energised to load the compressor, solenoid B is energised to unload.

4.2.1. Controlled Stop

When the compressor is required to stop from a loaded condition, solenoid valve B is energised (open). High pressure oil is admitted to the capacity control cylinders. Oil pressure supplements the force of the spring acting on the unload side of each piston. The combined force is sufficient to overcome the action of the suction/discharge differential pressure and move the slide valves towards the minimum load position.

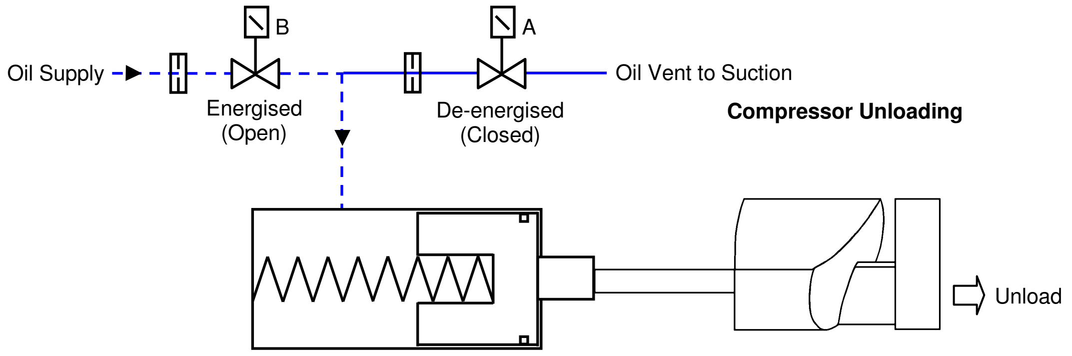
4.2.2. Uncontrolled Stop

When an uncontrolled stop occurs: safety control operating, emergency stop or power failure, the unloading springs automatically return the slide valves to minimum load.

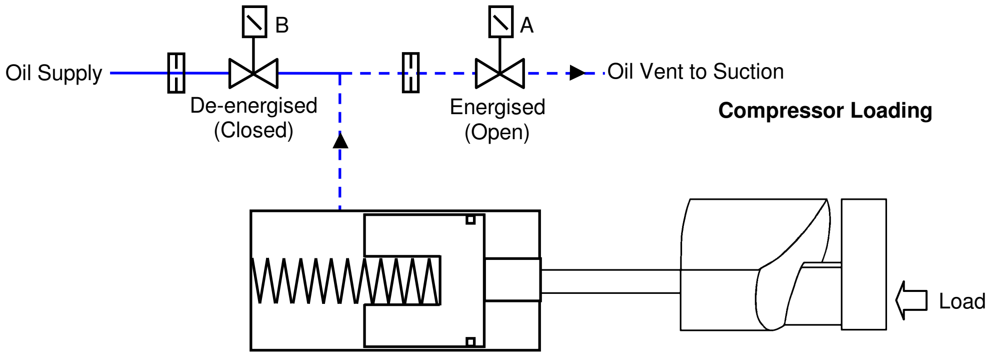
Unlike a controlled stop, unless the compressor was at minimum load before the uncontrolled stop occurred, the capacity control cylinders may contain some refrigerant vapour instead of being completely filled with oil. In this event a hydraulic lock will not be present and uncontrolled loading may occur on restarting.

This undesirable behaviour can be minimised by arranging for solenoid valve B to energise (open):

- If a compressor trip, emergency stop or power failure occurs.
- 60 seconds before (but not during) compressor start-up. Energised until the compressor is required to load; ref Fig 3.



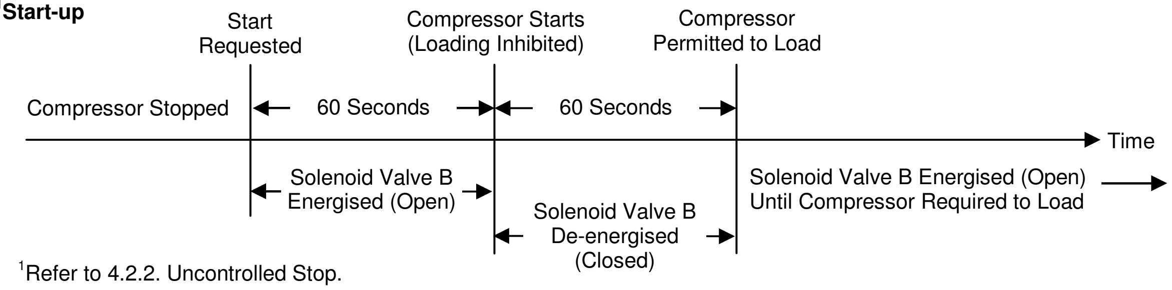
Oil Pressure + Spring Force > Suction/Discharge Differential Pressure = Slide and Piston Move Towards Unload



Suction/Discharge Differential Pressure > Spring Force = Slide and Piston Move Towards Load

CAPACITY CONTROL ACTION	SOLENOID VALVE A	[1]SOLENOID VALVE B
Load compressor Oil is vented from the capacity control cylinder. The action of the suction/ discharge differential pressure on the slide/piston assembly overcomes the force of the unloading spring and moves the slide valve towards the maximum load position.	Energise (open)	De-energise (close)
Unload compressor High pressure oil is admitted to the capacity control cylinder. Oil pressure supplements the force of the spring acting on the unload side of the piston. The combined force is sufficient to overcome the action of the suction/discharge differential pressure and move the slide valve towards the minimum load position.	De-energise (close)	Energise (open)
Hold slide valve position The slide valve is hydraulically locked at the desired load position.	De-energise (close)	

[1]Start-up



[1]Refer to 4.2.2. Uncontrolled Stop.

Fig 3 Continuously Variable Capacity Control

4.3. Capacity Control by Inverter Drive

Instead of using the slide valve, compressor capacity can be controlled using a frequency inverter (also know as Variable Speed Drive or Variable Frequency Drive). If an inverter is used, the load/unload solenoid valves need to be controlled to allow the compressor to start at minimum load but load to full load when the compressor is running. There are three methods of achieving this;

- Energise the load solenoid continuously irrespective of whether the compressor is running or not.
- Energise the load solenoid continuously when the compressor is running and the unload solenoid continuously when the compressor is stopped.
- Remove the plunger from the load solenoid valve (only) and do not fit the coils.

When using an inverter, it is of utmost importance that it is both sized and set up correctly.

4.3.1. Inverter Size

The inverter must be sized to deliver the maximum current taken by the compressor motor at the maximum power conditions – in most cases this is during pull down.

NOTE: the current capacity of an inverter drive is not reduced by running at less than synchronous speed.

During pull down, the current can be limited by either using the slide valve to run the compressor unloaded, or by throttling the suction. If it is required to use the slide valve during pull down, then normal manual slide valve control can be used; refer to 4.2. Continuously Variable Capacity Control.

4.3.2. Inverter Set-up

The inverter drive used must have the following facilities as a minimum;

- Load type: constant torque.
- Control method: PID (automatic) with facility for manual frequency control.

Particular attention has to paid to setting up the inverter with the correct minimum frequency, maximum frequency and acceleration time.

NOTE: minimum frequency and maximum frequency must be set according to the operating conditions; refer to J & E Hall International.

4.4. Linear Variable Displacement Transducer (LVDT)

The LVDT provides a continuous 4 to 20 mA slide valve position signal between minimum load (25 %) and maximum load (100 %). The LVDT operates on the principle of using a coil (inductance element) to produce an electrical output proportional to the displacement of a separate movable indicator rod. The indicator rod is spring-loaded and rests against the end of the capacity control piston. The complete assembly screws into a boss in the end of the compressor.

The LVDT electronics module is outside the pressure envelope of the compressor, eliminating any possibility of refrigerant leakage and allowing the module to be easily renewed in the event of failure.

⚠ CAUTION

The LVDT contains electronic components which are susceptible to the interference from mobile phones, portable radios or other devices which emit electromagnetic radiation. Such items must not be operated adjacent to the LVDT assembly.

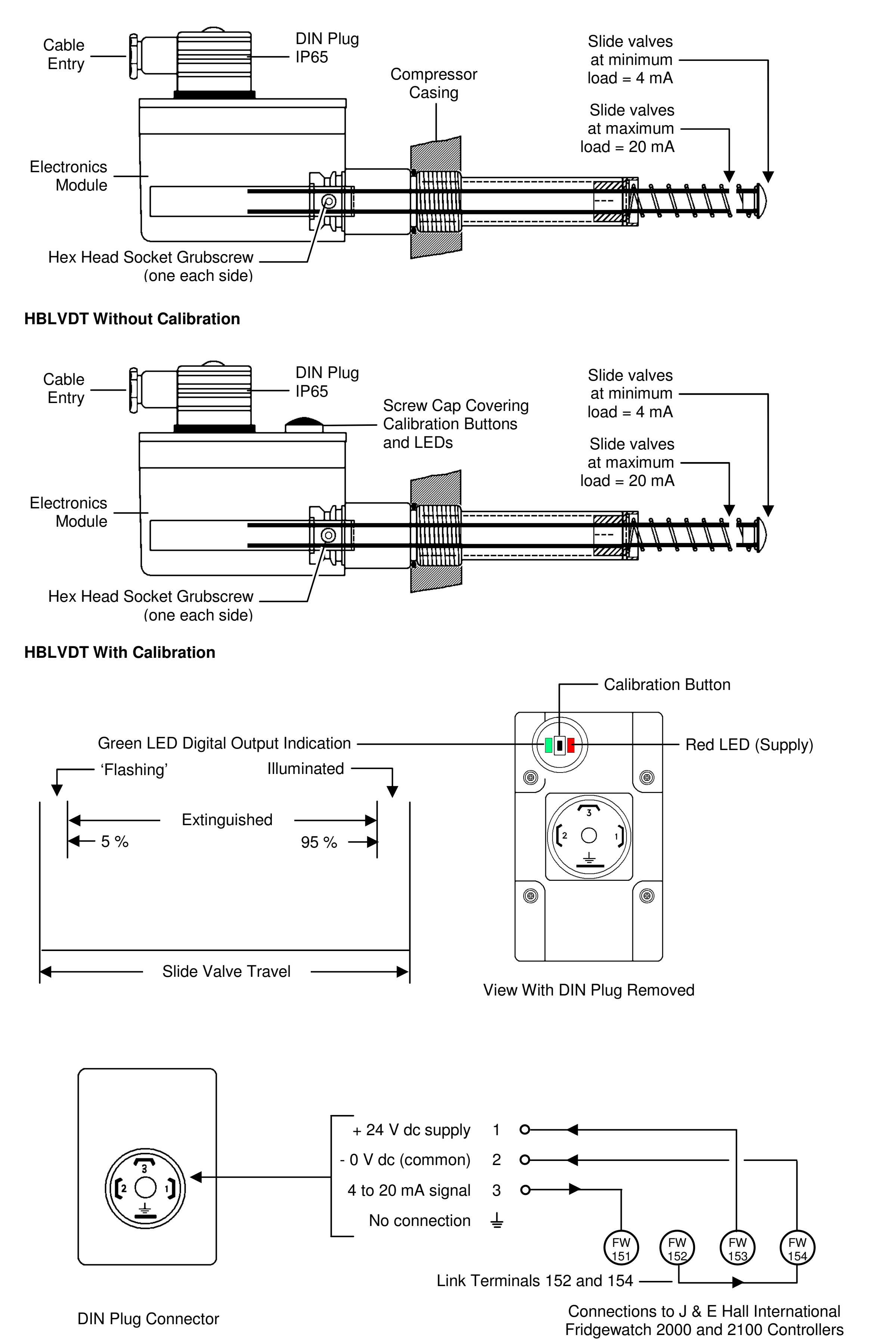


Fig 4 HBLVDT Arrangements and Wiring Connections

Two designs of LVDT are fitted to HS 4200 series compressors:

- Until February 2008: HBLVDT, refer to 4.5.
- After February 2008: MSI LVDT (direct replacement), refer to 4.8.

4.5. HB Linear Variable Displacement Transducer (HBLVDT)

External wiring connections are illustrated in Fig 4.

There are two versions of the HBLVDT depending on the method of calibrating the 4 to 20 mA signal for maximum and minimum load.

- Calibration via suitable software within the plant controller.
- Calibration at the HBLVDT.

4.6. 4 to 20 mA Calibration – Calibration Not Fitted to the HBLVDT

If the HBLVDT is not fitted with calibration, the 4 to 20 mA signal must be calibrated for maximum and minimum load via suitable software within the plant controller.

4.7. 4 to 20 mA Calibration – Calibration Fitted to the HBLVDT

To use this procedure, sufficient heat load must be available to permit the compressor to run at maximum load long enough for the procedure to be completed.

The HBLVDT should be wired as shown in Fig 4, check this point.

(a) Start the compressor if it was not already running. If the compressor will not start, refer to the notes at the end of this procedure.

(b) Supply power to the HBLVDT at least 5 minutes before calibration begins.

(c) Unscrew and remove the cap covering the calibration button and LEDs.

(d) Select ‘hand capacity control’. Move the capacity control slides to the minimum load position. The slides must remain at minimum load for the duration of step (e).

(e) Press the calibration button once. The red LED will illuminate for 30 seconds, then ‘flash’ to indicate that the HBLVDT is ready for maximum load calibration.

(f) Check ‘hand capacity control’ is selected. Move the capacity control slides to the maximum load position. The slides must remain at maximum load for the duration of step (g).

(g) Press the calibration button once. The red LED will illuminate for 30 seconds then extinguish to indicate that calibration is complete.

(h) If the compressor was not already running and at operating temperature, wait until steady operating temperature is achieved before repeating the calibration procedure from (d) to (g).

(i) Refit the screw cap over the calibration button and LEDs.

To calibrate the HBLVDT it is necessary to run the compressor. If the compressor does not start the calibration may be so far out that the plant controller will flag an analogue input error on the HBLVDT channel, or the signal may be so far away from 4 mA that the controller does not consider that the compressor is at minimum load. The compressor is interlocked to prevent starting unless the slide valves are at minimum load, refer to 4.1.1, therefore, either of the above conditions will result in the controller refusing to allow the compressor to start.

To enable the compressor to start under these circumstances and to allow the compressor to continue running during the HBLVDT calibration procedure, the plant controller must provide a way to temporarily disable the ‘minimum load interlock’ and the ‘HBLVDT analogue out-of-range error trip’.

⚠ CAUTION

It is essential for safe compressor operation that the minimum load interlock and the HBLVDT analogue out-of-range error trip are both re-enabled as soon as the calibration of the HBLVDT is completed.

4.7.1. Fitting a New HBLVDT Electronics Module

In the event of malfunction, the HBLVDT electronics module can be replaced without disturbing the compressor pressure envelope.

NOTE: the electronics inside the module can be damaged by static discharges so take all relevant precautions, including earthing yourself before touching the module. Also, it is important that the 24 V dc power supply to the HBLVDT is turned off before removing the old module or fitting the new one.

(a) Switch off the 24 V dc power supply to the HBLVDT. Disconnect the DIN plug.

(b) Loosen the 2 hex head socket grubscrews which secure the module to the stainless steel pressure containment body. Carefully withdraw the module.

(c) Fitting the new module is the reverse of the dismantling sequence. Tighten the 2 grubscrews evenly and alternately.

(d) Reconnect the DIN plug and switch on the 24 V dc power supply to the HBLVDT. Check the calibration as described in 4.6. or 4.7.

4.8. MSI Linear Variable Displacement Transducer (MSI LVDT)

From the February 2008, all HS 4200 series compressors are supplied with the MSI LVDT which replaces the HBLVDT previously fitted.

- The MSI LVDT is a drop-in replacement for the HBLVDT. Adaptors, spacers etc., are not required. HBLVDT part number 7876-112 replaced by MSI LVDT part number 7876-142.
- The MSI LVDT is only available without calibration, this must be done on the controller. However, a signal conditioning module is available, part number 2848-601, for applications where this is not possible. The module is suitable for DIN rail mounting; refer to Fig 6.
- The method of 4 to 20 mA signal calibration using the signal conditioning module is described in Appendix 6 Pepperl & Fuchs Signal Conditioning Module KFU8-USC-1.D Set-up.

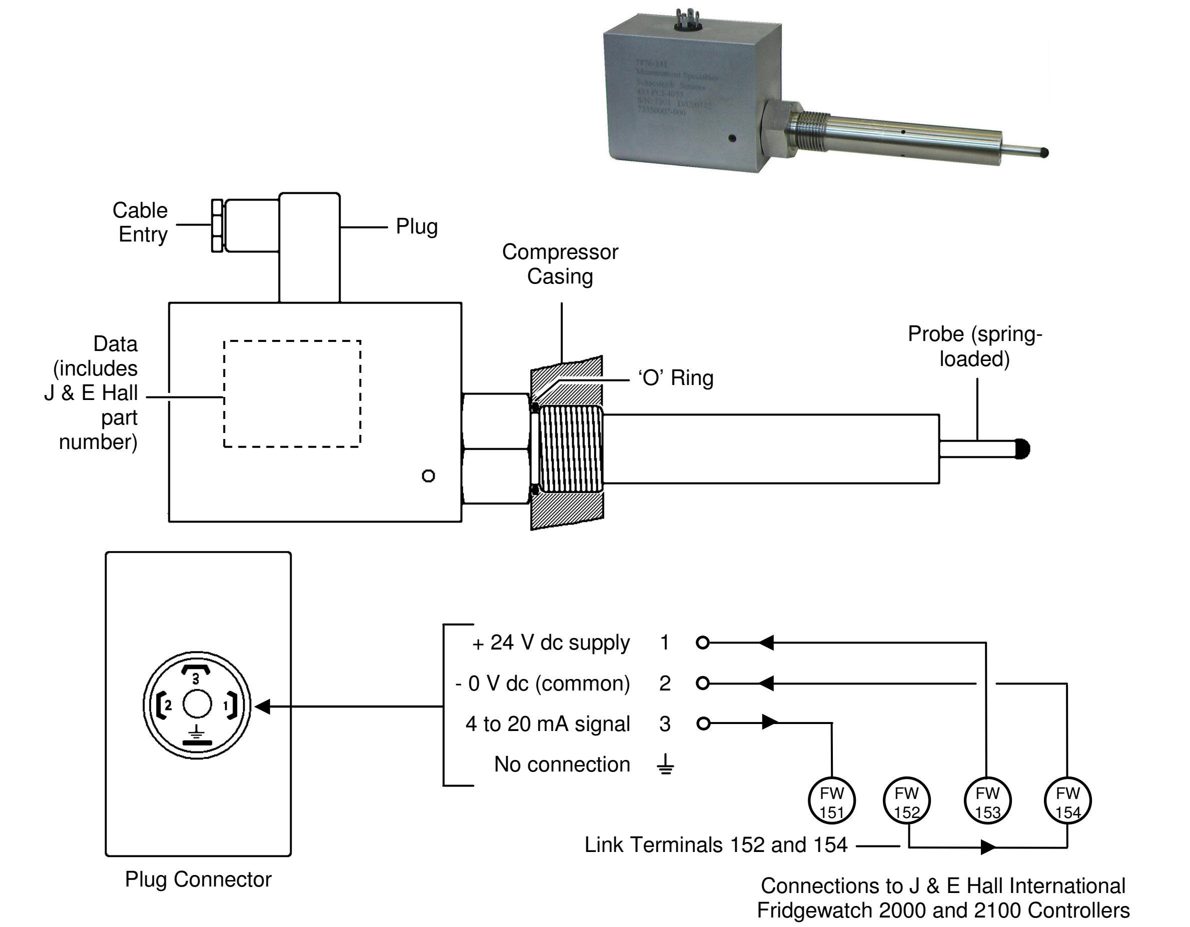
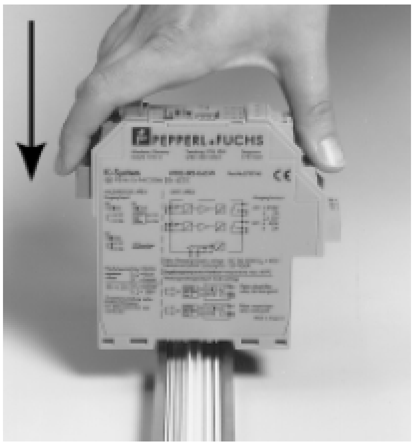
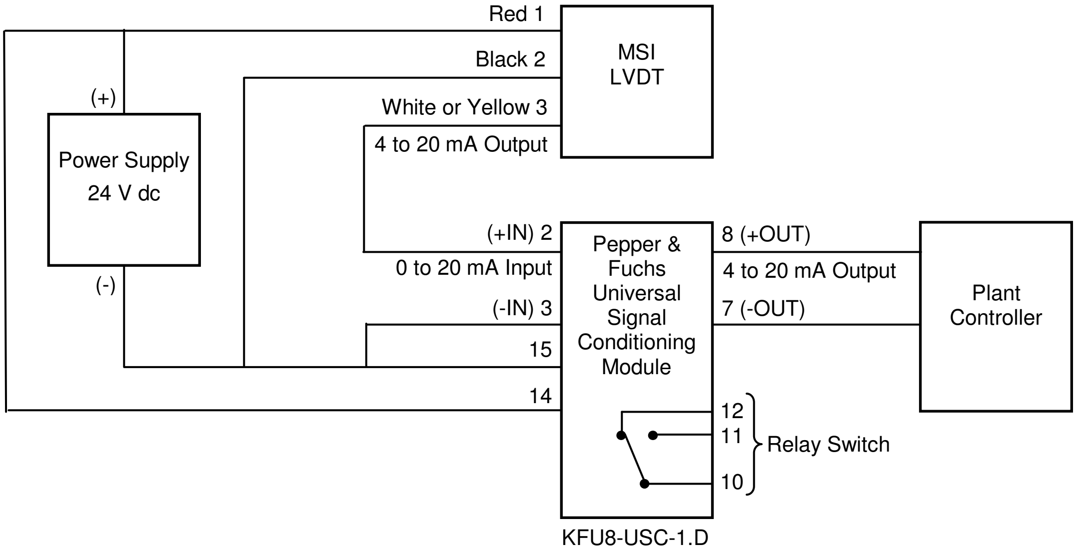


Fig 5 MSI LVDT Arrangement and Wiring Connections

Pepperl & Fuchs Module KFU8-USC-1.D
Part Number 2848-601



Suitable for DIN Rail Mounting



Wiring for MSI LVDT and Pepperl & Fuchs Universal Signal Conditioning Module

Fig 6 Signal Conditioning Module

5. Compressor Lubrication, Sealing and Cooling

In common with other types of oil injected screw compressor, HS L/M 4200 series compressors do not possess a built-in oil reservoir (sump) or oil circulation pump. Instead, oil is supplied by a separate external oil support system.

NOTE: it is essential to supply the compressor with an adequate supply of clean (filtered) oil at the correct temperature; refer to 6. Oil Support System.

The oil performs three basic functions:

5.1. Capacity Control Actuation

Oil pressure is used to actuate the compressor capacity control mechanism; refer to 4.1. Slide Valve Actuation.

5.2. Bearing Lubrication

The rolling element bearings used in the construction of the HallScrew compressor require a steady but relatively small supply of oil for satisfactory operation and long life. Oil is supplied either directly via separate oil drillings or indirectly from the injection supply to the bearings.

5.3. Oil Injection for Sealing and Cooling

The third oil supply, which is the predominant oil usage, provides oil for injection to seal the compression process. In the design of the compressor the star rotor teeth must form an effective seal with the flute profiles in the main rotor, while at the same time maintaining a satisfactory operating clearance. The main rotor flute/star tooth profile enables hydrodynamic and hydrostatic actions to combine to provide a wedge of oil at this point. Between the main rotor and the casing, and in several other positions where a pressure differential is separated by two surfaces moving relative to each other, the oil injected provides a sealing film enabling effective compression to take place. The oil also has a silencing effect.

Oil is injected via fixed ports in the casing around the rotor. This provides a variable injection period within the compression process as the compressor unloads. This variation of injection period is so designed as to allow the compressor to operate at lower system pressure differentials at minimum load compared to operation at full load. This provides an element of additional safety during start up at reduced load before full system differentials may be achieved. This arrangement is different to previous HallScrew compressors, in which the compressor was required to load as quickly as possible so that the system pressure difference was built up as quickly as possible. This rapid loading is no longer required. Once normal system pressures have been achieved, oil is injected over a period in the compression process when the pressure of the gas trapped in the flutes is considerably lower than discharge pressure. This means that in the majority of instances the system pressure difference can be used to provide the required oil flow without the need for an oil pump running continuously, while the plant is in operation.

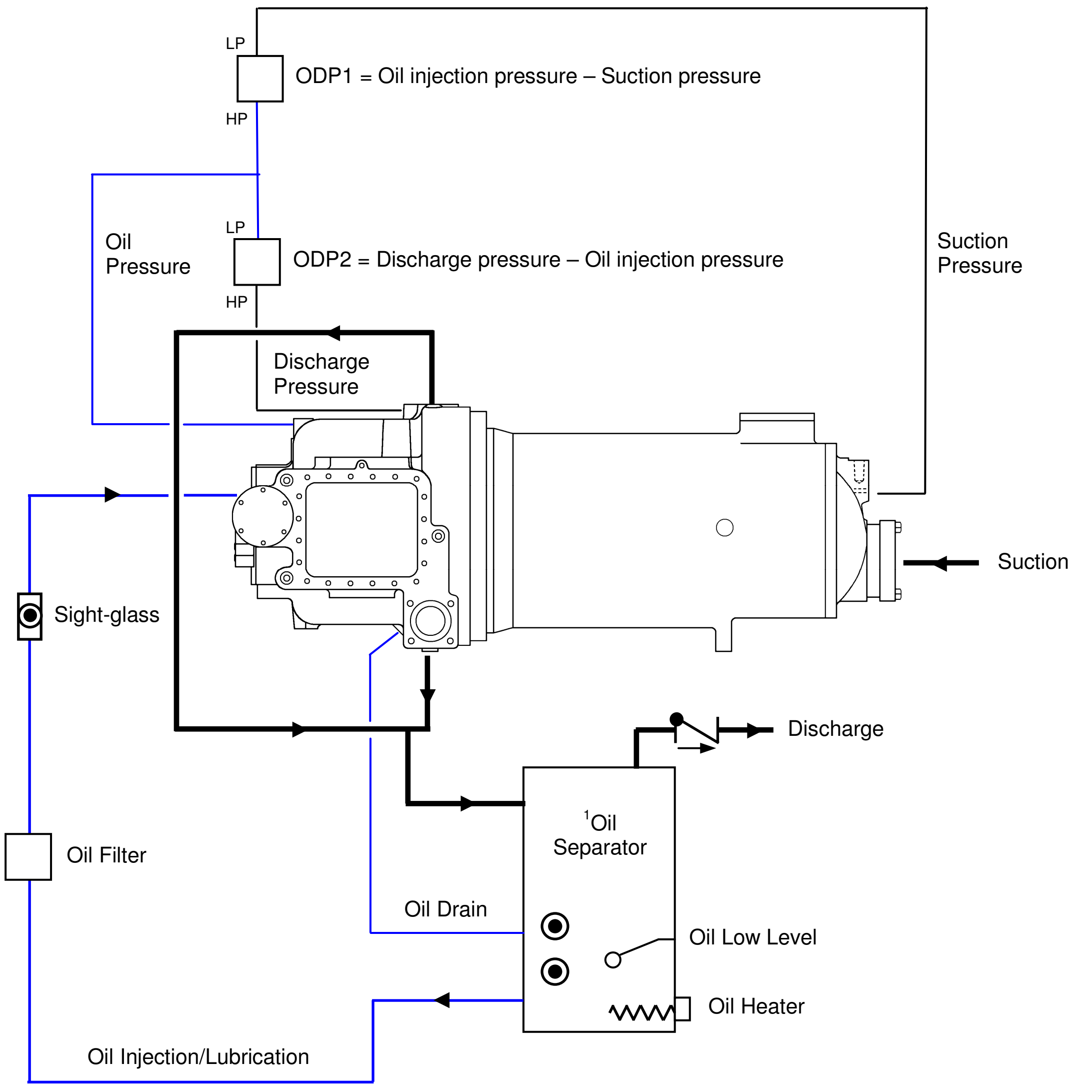
Compressor cooling can be accomplished by the direct injection of liquid refrigerant into the compression process. When liquid injection is not used, the oil injected for sealing absorbs a large proportion of the heat of compression, thus reducing the maximum discharge temperature, and is cooled externally via an oil cooler; refer to 6.9. Compressor Cooling.

6. Oil Support System

HS L/M 4200 series compressors require an external oil separator and oil support system; refer to Fig 7.

NOTE: the system into which the compressor is to be installed must fully comply with the recommendations in 6.1. to 6.8. Failure to do so could result in deterioration of the compressor, both mechanically and functionally.

Typical oil support system schematic flow diagrams for different applications can be found in Appendix 2 Oil Support System Schematic Flow Diagrams.



The oil support system must conform with the provisions described in 6.1. to 6.8.

[1]The maximum oil level in the oil separator with the compressor stopped (under any circumstances including initial filling) must be below the bottom of the compressor casing (bottom of side cover).

Fig 7 Oil Support System

6.1. Oil Injection/Lubrication

A single line provides oil for injection, lubrication and capacity control actuation. The connection size at the compressor can be found in Appendix 1 Compressor Data.

If it is required to fit service valves in this line, these should be full-flow ball valves to minimise pressure drop.

6.2. Oil Drain

Oil which collects inside the compressor casing must be allowed to drain back to the oil separator when the compressor stops. The oil drain connection is fitted with an internal non-return valve.

To ensure the oil drain line functions correctly:

- The oil separator must be sized and positioned to provided adequate oil return.
- An external drain line must be fitted from the oil drain connection to the oil separator or oil line. If a service valve is fitted in the line, this should impose minimum pressure drop. The drain line must slope down all the way to the oil separator without any traps or rises.
- The maximum oil level in the oil separator with the compressor stopped (under any circumstances including initial filling) must be below the bottom of the compressor casing (bottom of side cover).

Multiple compressors operating with a single oil separator (also refer to 6.4.1):

- An external drain line must be fitted from each compressor and piped to a common suction header or collector located below the level of the compressors and vented to suction pressure. If a service valve is fitted in the line, this should impose minimum pressure drop. Each drain line must slope down all the way to the header or collector without any traps or rises.
- The suction header or collector must be designed such that oil draining from stopped compressors can be returned from running compressors in a controlled way. Oil hold up in the suction header, leading to the potential for slugging, must be prevented.
- The maximum oil level in the oil separator with the compressors stopped (under any circumstances including initial filling) must be below the bottom of the compressor casing (bottom of side cover).

6.3. Oil Separation

All the oil injected into the compressor for lubrication, sealing and capacity control actuation, ultimately ends up in the discharge gas stream. During its passage through the compressor the oil is thoroughly mixed with the refrigerant, eventually ending up in the discharge gas stream as a fine mist of oil droplets. Before the oil can be recirculated it must be separated from the discharge gas, filtered, cooled (if compressor cooling is required and internal cooling by liquid injection is not used), and then returned to the compressor. An oil separator is therefore required in the discharge line. This vessel effectively removes the majority of the oil constituent from the oil/gas mixture, the oil draining into a reservoir which usually forms the lower portion of the separator vessel.

6.3.1. Oil Separator Design

The method of oil separation utilised by the oil separator is not important in itself in that velocity, impingement coalescent or other types or combination of types may be used. However it is important that the separator operates at sufficient efficiency over the actual operating range, with the compressor at all load conditions.

Deciding the required level of efficiency is important and is dependant not only on the compressor but also on the system design. No separator is 100 % efficient and some oil will always be carried over into the system. On a small direct expansion system this oil will be rapidly recirculated back to the compressor travelling with the refrigerant through the system and returning via the suction line. In this case the separator can be sized such that allowing for the extremes of operation, sufficient oil is maintained in the oil separator to ensure an adequate head of oil to match the specified oil flow rate from the separator into the compressor.

Additionally, as the separator efficiency changes with load and operating conditions, then the amount of oil carried into the system through the separator will also vary. Therefore the oil remaining in the separator will vary by an equal amount. Thus either sufficient oil capacity must be provided in the separator to allow for this change in oil quantity or a more consistent separator performance must be attained.

As high quantities of oil in the evaporator are detrimental to system performance it is normal to design the separator with as high an efficiency as is economically achievable. Even in this case the separator must provide sufficient oil volume above the normal operating volume to cater for the variation in efficiency. In addition the separator must have sufficient oil volume to provide an adequate dwell time to allow oil and refrigerant to reach their equilibrium condition.

In systems such as those incorporating flooded evaporators where oil carried over from the separator is not so readily or quickly returned then greater care is required in oil separator design. The separator must be of sufficient efficiency that oil carried over into the system can be returned by the oil rectification system. For miscible oil/refrigerant combinations a sample of refrigerant is taken from the evaporator the refrigerant boiled off and the oil returned to the compressor. If this refrigerant is not boiled off in a useful fashion then this is a direct loss on the system performance. If conditions change rapidly then it can take considerable time for equilibrium to be achieved. Under these conditions oil will build up in the evaporator and be lost from the separator. Thus the separator must be of a high efficiency type perhaps including coalescent elements and at the same time must have sufficient oil volume above the minimum requirement to cope with these variations in operating conditions.

6.4. Oil Separator Provisions

In addition to the considerations discussed in 6.3.1, the oil separator should comply with the following recommendations:

6.4.1. Multiple Compressors

If two or more compressors are used on the same oil separator the following provisions must be made.

- For each compressor, a solenoid valve must be provided in the oil injection line. The solenoid valve must be electrically interlocked to energise (open) when the delta contactor of the compressor starter is energised, and de-energised (closed) when the compressor stops. For inverter drive starting, the oil injection solenoid must be energised with a timed delay after the start signal. The delay time should be approximately 3 to 5 seconds, by which time the compressor speed must be at least 1500 rpm.

- For each compressor, a non-return valve must be provided in the discharge line before the inlet to the oil separator. This dispenses with the need for a suction non-return valve.
- The suction to each compressor must be taken from a separate suction header located below the level of the compressor. The header should be insulated with the suction line in the normal way.
- If there is any possibility of liquid refrigerant collecting in the header during the off cycle, the header should be fitted with heater(s) or wound with heater tape underneath the insulation. The heater(s) must be electrically interlocked to de-energise when the first compressor starts and energise when the last compressor stops.
- The oil drain line from each compressor must be taken to the suction header.

A typical arrangement is shown in Fig 14 in Appendix 2 Oil Support System Schematic Flow Diagrams.

6.4.2. Discharge Non-return Valve

For a single compressor/oil separator, a discharge non-return valve must be fitted after the oil separator.

For multiple compressors with a single oil separator, a discharge non-return valve must be fitted between the compressor discharge and the oil separator inlet.

6.4.3. Oil Separator Heaters

The oil separator is fitted with heaters to maintain an oil temperature minimum 20 °C above the ambient temperature, thereby preventing refrigerant migration into the oil and the resultant loss of viscosity and potential foaming. The oil heaters must be electrically interlocked to energise when the compressor stops.

If the plant is sited in a cold environment, the oil separator and oil lines must be suitably lagged and heater tape applied if necessary.

6.4.4. Compressor Casing Heater

The compressor is supplied with a casing heater which should be fitted and used if the compressor is located outside, or in an area which could be at a lower temperature than outside or at a lower temperature than the evaporator or condenser saturation temperatures. The casing heater must be electrically interlocked to energise when the compressor stops.

6.4.5. Oil Low Level

A level switch or opto-electronic liquid sensor must be fitted to the oil separator at a point corresponding to a dangerously low oil level. The switch or sensor must be electrically interlocked to prevent the compressor starting unless there is sufficient oil in the reservoir, and stop the compressor should the oil level fall below the danger level.

6.4.6. Dual Compressor Circuits

Refer to J & E Hall International.

6.5. Oil Differential Pressure Monitoring

As already described in 5. Compressor Lubrication, Sealing and Cooling, HS L/M 4200 series compressors require an adequate supply of oil for injection, bearing lubrication and capacity control actuation.

Under normal operating conditions this oil is supplied via the difference in pressure between discharge and suction pressures. On starting the suction/discharge pressure differential across the compressor builds rapidly. However, this pressure difference must be monitored to ensure it achieves the correct value within a specified time. Oil differential pressure monitoring must continue all the while the compressor is running in case operating conditions cause the differential to fall to an unacceptable level. Under these conditions operation of the compressor must be prevented or alternative oil injection arrangements made.

The oil system must be protected by monitoring two oil differential pressures: ODP1 and ODP2. Two different methods are available:

- Electro-mechanical oil differential pressure switches.
- Transducers sensing the required pressures, connected to the plant controller with the differential pressure calculation performed by the software programme.

6.5.1. ODP1

This is the differential between oil injection pressure/suction pressure and determines if there is sufficient pressure difference for adequate oil injection to occur.

ODP1 = Oil injection pressure – Suction pressure

Because oil injection takes place into a sealed flute during the compression process an estimate of the pressure in this flute must be made. This pressure is a ratio of the suction pressure and for maximum safety should be taken as twice absolute suction pressure. If ODP1 is sensed by transducers then the pressure ratio from suction to oil should be set to 2. If an oil differential pressure switch is used, this should be set to trip when oil pressure is below twice the maximum operating suction pressure (absolute).

Example:

Maximum suction pressure 3.0 bar abs (2 bar g)

Minimum oil pressure 2 x 3.0 bar abs = 6.0 bar abs

Oil differential switch setting (oil pressure – suction pressure)
= 6.0 – 3.0 = 3.0 bar

On start up there is no system pressure differential, therefore, ODP1 must be timed out. The standard time out period is 30 seconds. If ODP1 is not achieved after this period alternative arrangements must be made. Refer to J & E Hall International for advice on the appropriate action.

6.5.2. ODP2

This is the differential across the oil injection line and should initially be set to 2.0 bar in order to prevent operation in the event of a blocked oil filter or similar obstruction in the oil injection line.

ODP2 = Discharge pressure - Oil injection pressure

If it is found that the normal operating ODP2 differential is above 2 bar with a clean filter, then the cut-out differential can be increased accordingly. ODP2 does not need to be timed out.

6.6. Maintaining Discharge Pressure at Start up

Because oil pressure is generated by suction/discharge pressure differential, there is a minimum discharge pressure value which must be maintained in order to ensure adequate and reliable oil flow.

In circumstances where the minimum discharge pressure is difficult to achieve, even with the help of condenser head pressure control devices, a differential pressure regulator must be fitted in the discharge line immediately after the oil separator. Fig 8 shows a typical arrangement using a Danfoss PM 1 main valve and CVPP pilot valve.

Discharge pressure, inlet pressure to the main valve, is applied to the space below the pilot valve diaphragm. Suction pressure is applied via a pilot line to the space above the diaphragm. The main valve, therefore, controls on the differential between suction and discharge pressure.

The differential pressure regulator allows discharge pressure to build up quickly on starting to achieve the necessary oil differential pressure before the start delay time expires (usually 30 seconds). If the suction/discharge pressure differential falls below the minimum requirement to maintain adequate oil flow, the pilot valve throttles the main valve to maintain the differential pressure, thereby ensuring adequate oil flow to the compressor. During normal operation the main valve will usually be fully open with little detrimental effect on compressor performance.

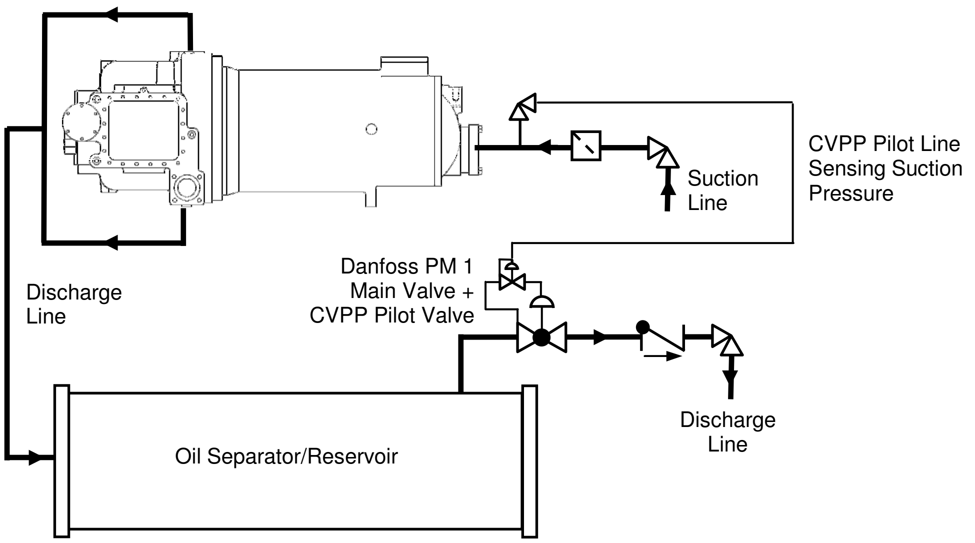


Fig 8 Maintaining Discharge Pressure at Start up

6.7. External Oil Filter

HS L/M 4200 series compressors are fitted with a built-in oil filter. This filter is adequate for complete package unit applications where standards of system cleanliness can be guaranteed. However, for part packaged site erected systems or when the compressor is applied to an existing installation, the high levels of dirt likely to be encountered mean that the built-in filter will need to be changed at frequent intervals. For these applications it is recommended to fit an external oil filter to the minimum specification shown in Table 1. A bypass must **NOT** be included in the filter assembly.

When it is necessary to use an external oil filter, the integral oil filter must be removed together with the internal oil filter locating spigot piece.

PARAMETER		VALUE
Filter minimum particle size		Down to 5 micron (Beta 5 value >1)
Filter absolute rating		25 micron (Beta 25 value >75)
Minimum filter area	Synthetics: felts/glass fibre with in-depth filtration	2500 cm^2
	Paper or cellulose	10400 cm^2
Minimum dirt holding capacity		>22.5 gm
Minimum filter element collapse pressure		20.0 bar
Complete filter assembly maximum clean pressure drop		0.7 bar with oil flow of 83.0 lt/min

NOTE: All filter components must be suitable for use with POE oils and R134a refrigerant.

Table 1 External Oil Filter Minimum Specification

6.8. Lubricating Oils

The choice of lubricant depends on the refrigerant, the type of system and the operating conditions.

For applications using R134a, R407c or other HFC refrigerants, ester lubricants **must** be used. The compressor is supplied already charged with oil, either Emkarate RL68H or ExxonMobil EAL Arctic 68.

For applications using R22, the compressor is supplied already charged with Mobil Arctic 300 mineral oil.

6.9. Compressor Cooling

The heat of compression must be removed either by the evaporation of liquid refrigerant injected directly into the compression process (liquid injection), or by using an external heat exchanger to cool the oil injected to seal the compression process. In some circumstances no cooling is required.

For further details refer to publication 2-122 Compressor Cooling.

7. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type. For HS L/M 4200 series compressors, the system must contain an oil separator of sufficient capacity. The system must be designed to return any oil carried over into the system from the separator, back to the compressor.

The suction return to the compressor must be dry gas in order to achieve full performance. Liquid return will be detrimental to performance although unlike reciprocating compressor is not harmful to the compressor in small quantities. However large quantities of liquid or oil returned to the compressor via the suction line can form an incompressible fluid in the rotor flutes with resultant damage to the compressor. Thus the system must be designed to prevent such occurrences.

7.1. Oil System

The recommendations in 6. Oil Support System should be adhered to.

7.2. Suction Line

The suction line should be designed to allow any build up of liquid to drain back to the evaporator. Refrigerant gas velocities should be sufficient to ensure recirculating oil is returned to the compressor.

7.2.1. Liquid Separation in the Suction Line

If liquid is present in the suction line due to excessive carry over from the evaporator and velocities are low, separation of the liquid can occur. If U-bends are present in the suction line liquid can collect in these traps. If the flow rate is suddenly increased (due to sudden increase in compressor load) then this liquid can be carried through to the compressor as a slug. It is these large erratic slugs of liquid that are detrimental to the compressor rather than constant small amounts of liquid return.

7.3. Discharge Line

The discharge line must slope downwards or be so sized to ensure that oil is carried through with the discharge gas to the oil separator.

7.3.1. Discharge Superheat

Adequate discharge superheat is essential in order to prevent excessive liquid refrigerant dilution of the oil in the separator. If excessive refrigerant is present then oil viscosity will be reduced to an unacceptable level. The main problem however, is that for a small change in discharge pressure oil foaming and loss of oil from the separator can occur. Thus a safe minimum discharge superheat should be taken as 13.0 K for R134a, 15.0 K for R404a and R507a, and 20.0 K for R407c and R22.

7.4. Liquid Injection Lines

Different arrangements are used depending on the refrigerant, these are summarised below. For further details refer to publication 2-122 Compressor Cooling.

7.4.1. R134a Only

A single liquid injection line is required, connected to the special top liquid injection plug fitted. The bottom liquid injection/economiser port is fitted with a blanking plug which should **not** be removed.

7.4.2. All Refrigerants Other Than R134a

Liquid injection lines are piped to the top and bottom liquid injection/economiser connections.

> **NOTE: both the top special R134a liquid injection plug and the bottom blanking plug must be removed. Use the connectors supplied in the liquid injection kit.**

Liquid injection lines must be of equal diameter and length so that liquid is distributed uniformly to both connections.

7.5. Economiser Connections

If an economiser subcooler is fitted, the economiser line must be split into two equal branches near the compressor and connected to the top and bottom liquid injection/economiser connections.

NOTE: both the top special R134a liquid injection plug and the bottom blanking plug must be removed. Use the connectors supplied in the liquid injection kit.

7.6. Safety Requirements for Compressor Protection

There are a number of system pressures and temperatures which must be monitored to protect the compressor and obtain an overall view of performance; refer to Appendix 1 Compressor Data.

8. Prolonged Storage

In certain cases, it may be necessary to keep the compressor in store for several months before installation and commissioning takes place. In this event, the following precautions should be taken.

8.1. Placing the Compressor into Store

(a) The store area must be weatherproof, well ventilated, warm and dry.

It is not recommended to transport or store the compressor where vibration from adjacent machinery may be present as this can be a contributory factor in the 'Brinelling' (fretting corrosion) of the bearing tracks and rolling elements. The method of packing the compressor for storage is of great importance, using any method that may help to reduce play between the bearing elements. Rubber blocks or pads introduced under the compressor mounting feet are very helpful in dampening out external vibrations and should be fitted whenever possible.

(b) External fittings should be protected from damage.

(c) Leak test the compressor at frequent intervals to ensure that it retains the holding charge of nitrogen. If pressure gauges are fitted these can be checked for a decrease.

8.2. Taking the Compressor out of Storage

At the end of the period in store, install the compressor as described under 9. Installing the Compressor.

NOTE: the holding charge of nitrogen must be removed before the compressor is run.

Commission and run-in the compressor as described in 10. Commissioning and Operation and 11. Running-In the Compressor.

9. Installing the Compressor

The following instructions apply to 'bare' compressors; adapt as necessary if the compressor forms part of a package unit.

If the compressor has been in prolonged storage, carry out the instructions described under 8.2. Taking the Compressor out of Storage, before installation takes place.

9.1. Lifting the Compressor

Attach lifting tackle to 2 x M20 eyebolts (full thread) screwed into the top of the compressor casing as shown in Fig 9. A crane or block and tackle will be required to lift the compressor. Check that the lifting equipment is stout enough to take the weight by referring to Appendix 1 Compressor Data.

⚠ WARNING

ALL the eyebolt positions MUST be used when lifting the compressor.

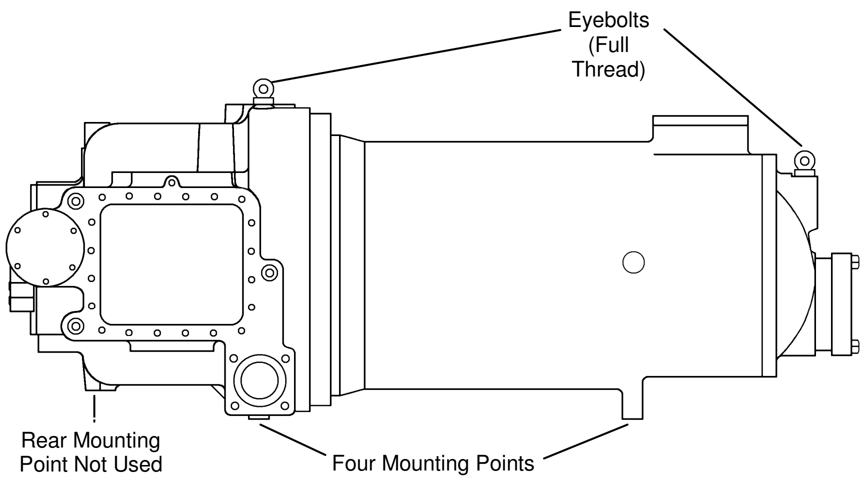


Fig 9 Lifting the Compressor

Check that the compressor mounting points on the baseframe are completely free from rust, dirt or burrs. Lift the compressor and make the same check at the compressor's four mounting points; check the tapped holes are undamaged and the threads are completely free of dirt.

⚠ CAUTION

To prevent the compressor holding-down bolts working loose during operation, it is essential to secure them with shakeproof washers or Loctite thread sealer.

As the compressor is being positioned, insert the holding-down bolts through the baseframe and screw them into the tapped holes. When all four bolts are in position, set the compressor down on the baseframe and remove the lifting gear. Finish tightening the bolts.

9.1.1. Making Connections

Pipeline connection sizes are detailed in Appendix 1 Compressor Data.

(a) Carefully purge the holding charge of nitrogen from the compressor.

NOTE: the holding charge of nitrogen must be removed before the compressor is run.

(b) HS 4200 series semi-hermetic compressors use the same connection for liquid injection and the economiser facility. If the liquid injection/economiser facility is to be used, remove the blanking plugs from the connections. Connect the liquid injection and/or economiser lines to the ports; refer to 7.4. Liquid Injection Lines and 7.5. Economiser Connections.

(c) Before running the compressor, the moving parts must receive some initial lubrication.

Remove the blank plug from the oil injection connection. Inject oil to lubricate the mainshaft bearings, main rotor flutes, star rotors and star rotor bearings.

It is important to be fairly generous with this initial lubrication, using in all about 2 litres of oil. Use the same type and ISO grade of oil as that used in the rest of the system.

(d) Connect the suction, discharge and oil injection lines.

NOTE: It is important to fit break flanges on the oil injection line to allow compressor removal.

(e) Connect the suction, discharge and oil pressure gauge lines.

(f) Connect the oil drain line between the underside of the compressor casing and the return connection, usually located on the oil separator. The line must be fitted with a non-return valve, designed to open with zero head; refer to Fig 7. The latest compressors are fitted with an integral drain line non-return valve.

(g) Make electrical connections as described in 9.2.

(h) Leak test and evacuate the system as described in 9.2.1.

9.2. Electrical Wiring Connections and Interlocks

Make the following wiring connections and interlocks:

- Mains electrical supply to the compressor stator/rotor from the motor starter; refer to 9.2.1. Motor Wiring Connections.
- Compressor motor and discharge high temperature thermistors. These are fitted as standard and should be wired as illustrated in Fig 10.
- Electrical supply to the oil separator reservoir heaters: refer to 6.4.3 Oil Separator Heaters.
- Electrical supply to the compressor casing heater (if used): refer to 6.4.4. Compressor Casing Heater.
- Electrical supply to the oil separator low level sensor or switch: refer to 6.4.5 Oil Low Level.
- Electrical supply to the capacity control solenoid valves, these are marked ‘Load’ and ‘Unload’; refer to Appendix 1 Compressor Data.
- Electrical supply to the capacity control slide valve position transducer; refer to 4.8. MSI Linear Variable Displacement Transducer (MSI LVDT).
- Power must be supplied to the solenoids via a suitable pulse timer capable of supplying a minimum pulse length of 0.1 to 0.5 seconds, depending upon the accuracy of control required.
- Electrical interlock to prevent the compressor starting unless the slide valves are at minimum load; refer to 4.1.1. Minimum Load Interlock.

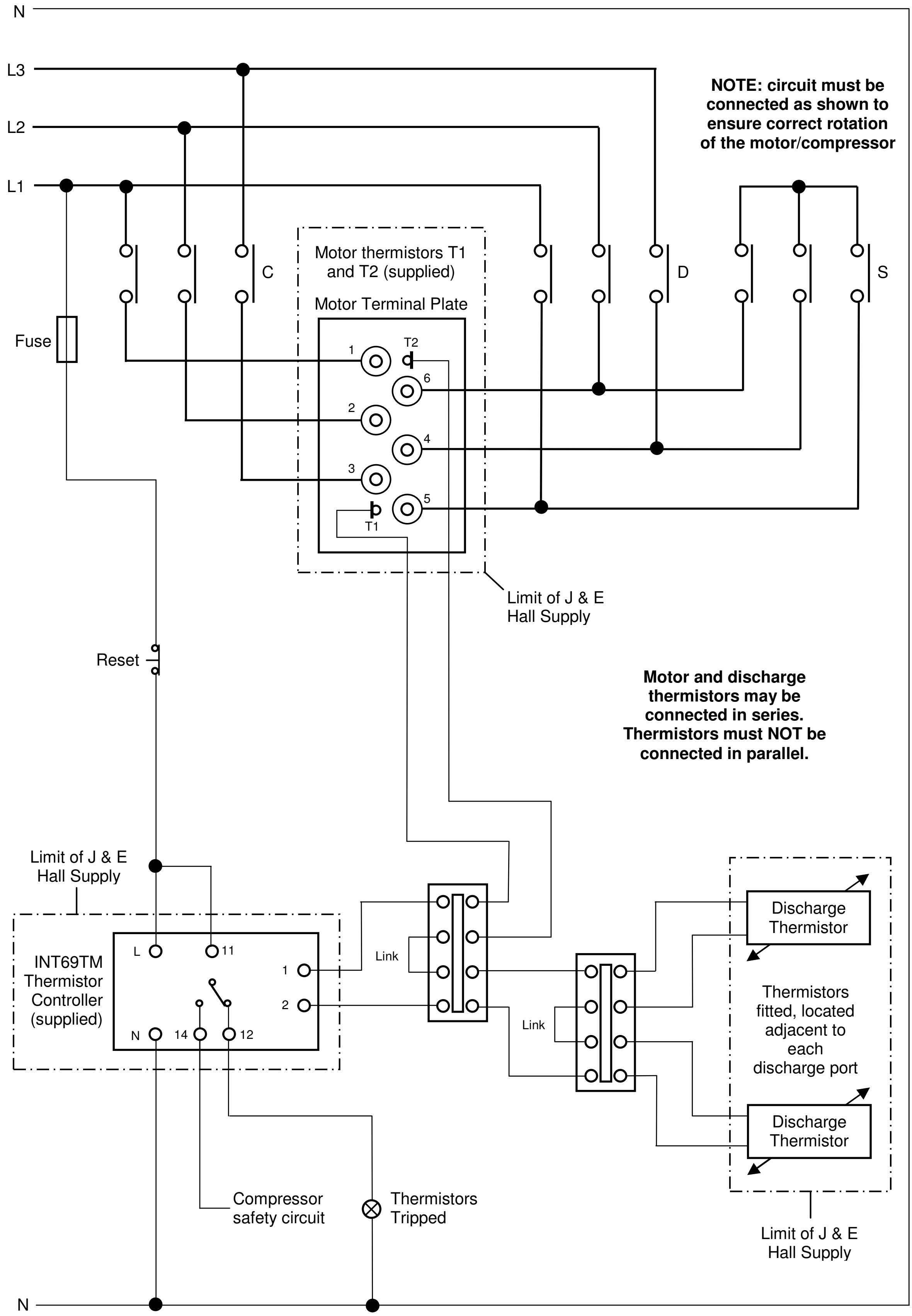


Fig 10 Motor Terminal Box Wiring: Star/Delta

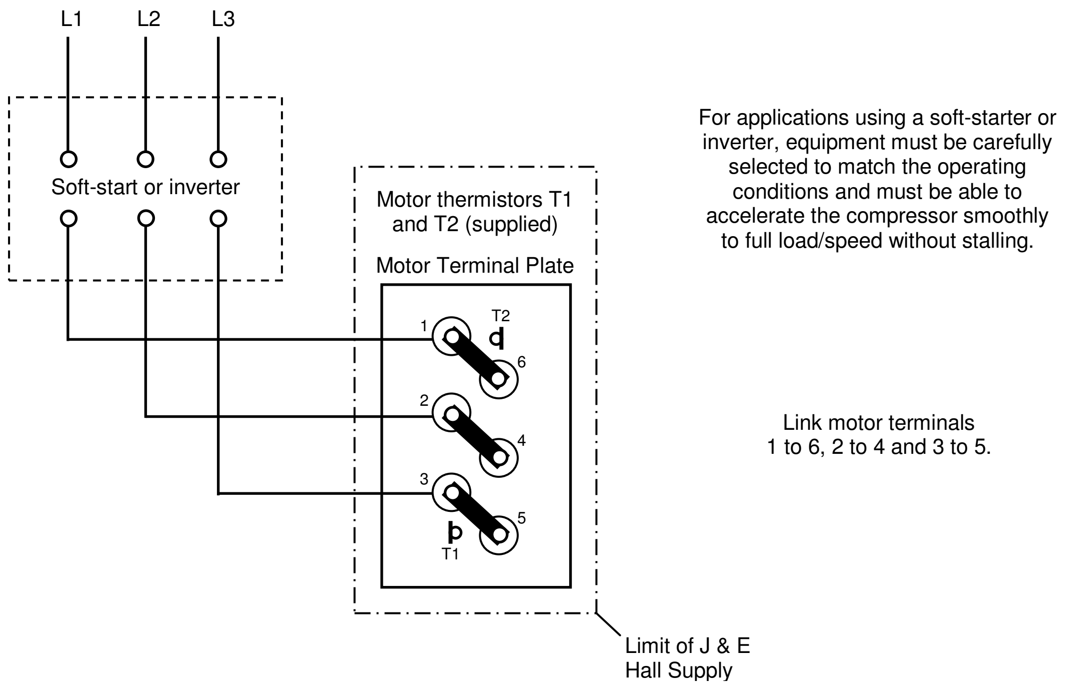


Fig 11 Motor Terminal Box Wiring: Soft-start and Inverter Drive

9.2.1. Motor Wiring Connections

The HS L/M 4200 series compressor motor is wired for star/delta starting. Soft-start or inverter drive starting methods can be accommodated using terminal links available from J & E Hall International.

NOTE: these links could be used for DOL starting, but this method of starting is not recommended by J & E Hall International.

Terminal box wiring is illustrated in Fig 10 and Fig 11. Refer to Appendix 1 Compressor Data for motor data. The standard terminal box rating is IP54, IP65 available to special order.

9.3. Leak Testing, Evacuation and Charging

Leak testing and evacuation are described in the following publications available from J & E Hall International:

- Part D : Strength and Tightness Testing.
- Part E : Evacuation and Dehydration.

(a) Before the compressor/system evacuation process commences, energise (open) capacity control solenoid valve A. Check that the compressor oil injection line is open to the system.

(b) After the required vacuum has been achieved, de-energise (close) solenoid valve A.

(c) Use the vacuum to draw the required quantity of oil into the oil separator/reservoir.

(d) Energise solenoid valve B. System pressure is utilised to drive oil into the evacuated unloading cylinders.

(e) Charge the system with refrigerant.

(f) Start the compressor for the first time; refer to 10. Commissioning and Operation. Carefully run in the compressor; refer to 11. Running-In the Compressor.

10. Commissioning and Operation

If the compressor is supplied as part of a package unit supplied by J & E Hall International, refer to Section 1 of the plant instruction manual for detailed installation and commissioning instructions.

The instructions included in this part of the manual cover bare-shaft compressors supplied for incorporation into package units or site erected systems.

NOTE: these procedures cover the most important points for consideration and do not in any way supersede instructions for the operation of specific plant.

10.1. Checks Prior to the First Start

Before the first start, or when recommissioning after a maintenance period, there are a number of important checks to be undertaken in addition to the normal pre-start routine when the compressor is in commission.

10.2. General Checks

(a) Check that the compressor package unit is firmly installed on its foundations and all piping and wiring connections have been made.

(b) Check incoming main supply cables and fuses are correctly sized; refer to the wiring diagrams supplied.

(c) Check that the compressor package unit is correctly earthed. Depending on circumstances, this may require the installation of a separate earthing system.

(d) Check electrical connections for tightness. All interlock and external wiring should be in accordance with the wiring diagrams supplied.

(e) Check wiring for continuity and earth leakage. Ensure wiring is restored correctly after testing.

⚠ CAUTION

DO NOT, under any circumstances, carry out a high voltage test (Megger test) on:

- The discharge high temperature thermistor and compressor drive motor winding high temperature thermistor protection circuits, otherwise the thermistors will be damaged. A thermistor for high temperature protection may also be fitted in the oil injection/lubrication line.
- The HS L/M 4200 series semi-hermetic compressor while it is under a vacuum; under these conditions the motor insulation may be seriously damaged.
- Any part of the control system containing semi-conductor devices.

(f) Check the electrical operation of all pressure controls, temperature controls and solenoid valves, using a multi-meter or test-lamp.

Pressure and temperature controls are set at approximately the required setting before leaving the factory.

(g) Check that the compressor discharge high temperature thermistors and compressor drive motor winding high temperature thermistors each has a resistance of approximately 100 Ω and is neither open circuit or a short circuit.

Repeat this check for the thermistor that may be fitted in the oil injection/lubrication line.

(h) Check that stop valves isolating pressure gauges, cut-outs or other pressure controls are fully open. These valves should be locked-open using circlips or equivalent locking devices.

10.3. Checking Compressor Rotation

(a) The HS L/M 4200 series semi-hermetic compressor is a positive displacement machine designed to rotate in one direction only, this is **clockwise** when looking on the motor end.

NOTE: HS 4200 series semi-hermetic compressor direction of rotation is the reverse of all other HallScrew compressors.

To prevent incorrect compressor rotation, it is **ESSENTIAL** to check wiring connections to the stator/rotor terminal box have been made correctly in accordance with Fig 10.

Use a phase tester to make a final check for correct rotation. If a phase tester is not available, it is possible to check the direction of rotation by running the compressor for a few seconds and observing the suction and discharge pressure gauges; refer to 10.5. step (g).

(b) Check the supply voltage and frequency comply with the motor manufacturer's data (usually stated on the motor data plate), and any difference in voltage does not exceed 3 % between any two lines. Since an imbalance produces a dramatic rise in the temperature of the motor windings, it is important that any imbalance is kept to a minimum.

Check and record the control supply voltage, this should be within 5 % of the design voltage.

NOTE: never attempt to run the compressor drive motor with an electrical supply voltage, frequency or phase rotation other than as designated on the motor electrical data plate.

10.4. Lubrication System

(a) Check that the oil separator/reservoir is filled to the correct level. This precaution will prevent any delay in oil reaching the compressor on starting.

If the compressor is fitted with a remote water-cooled or air cooled oil cooler, check the cooler is filled with oil.

(b) The oil separator/reservoir heaters must be energised at least 24 hours before the initial start to ensure that the oil is warm.

An oil temperature of approximately 45 °C is about right.

If the heaters are thermostatically controlled, the thermostat should be set to maintain the desired oil temperature.

NOTE: the oil heaters must NOT be energised without first of all checking that the oil reservoir has been charged with oil as described in step (a). Failure to take this precaution may result in the heaters burning-out.

The oil heaters must be electrically interlocked to energise during the off-cycle (compressor stopped).

(c) Check that the stop valves in the oil circulating system are fully open except, of course, drain and purge valves which open to atmosphere.

10.5. First Start

(a) Check that the oil in the reservoir is warm enough (the heaters should have been energised 24 hours before the first start to ensure this). An oil temperature of approximately 45 °C is about right.

If an oil heater thermostat is fitted, the thermostat should maintain the oil at the correct temperature.

(b) Open the suction and discharge stop valves.

⚠ WARNING

The compressor must NEVER be started with the discharge stop valve closed or partially closed, nor must the discharge stop valve be throttled when the compressor is running.

(c) If liquid injection oil cooling is fitted, check that stop valves are open in the line supplying refrigerant to the liquid injection valve. With the solenoid valve in the line energised (open), the sight-glass in the line should be full of refrigerant.

Check that the stop valves in the the rest of the refrigeration system are in their correct running positions.

(d) If the plant is fitted with a water cooled oil cooler, start the water circulation pump and check for adequate flow through the cooler.

(e) Check the following:

- Safety devices and interlocks are in a ‘safe’ condition.
- Auxiliaries which are required to run before the compressor starts, for example, the condenser water pump and/or evaporator cooled medium pump, are providing interlock ‘running’ signals to the control system.

(f) For safety reasons, select hand compressor start/stop - hand capacity control operating mode for starting the compressor for the first time and for the initial period of operation.

(g) If a phase tester was not available to check the compressor drive motor’s direction of rotation, carry out the following check for correct rotation.

Close the suction stop valve, then press the ‘start’ button to run the compressor for 1 or 2 seconds (or turn control switch to ‘on’), followed **immediately** by the ‘stop’ button (or turn control switch to ‘off’).

During this short period of operation, if compressor rotation is correct, the suction pressure should fall and the discharge pressure rise as indicated on the suction and discharge pressure gauges respectively.

In the case of incorrect rotation, disconnect the mains supply to the compressor control panel and compressor drive motor, open the motor terminal box and check the incoming wiring against the wiring diagrams. Rotation can be reversed by exchanging any two of the supply phases.

⚠ WARNING

The electrical supply must be switched 'off' and isolated before removing the terminal box cover. Check this point.

Reinstate the mains electrical supply and reopen the suction stop valve.

(h) Start the compressor.

After the compressor has started and been in operation for a short time, allowing sufficient time for the system oil injection pressure/suction pressure differential to become established, ODP1 is brought into circuit. ODP1 will stop the compressor motor if the system pressure differential falls to the trip setting.

(i) Monitor the compressor discharge temperature. Either use a 'touch' thermometer on the discharge line or, for a more accurate reading, use a wire temperature probe taped to the line; the probe can be left in-situ. Continue to monitor the discharge temperature during the commissioning period.

If the compressor is fitted with cooling by liquid injection, with the compressor in operation the solenoid valve in the liquid injection line energises (opens) allowing refrigerant to enter the injection line. Check the sight-glass positioned in the line to the injection valve is full of liquid refrigerant. Observe the liquid injection valve opens when the discharge temperature rises to approximately 75 °C. Adjust the injection valve if required, however, final adjustment must wait until after charging has been completed and the compressor is running at design conditions.

If the compressor is fitted with a water-cooled oil cooler, adjust the water valve at the cooling water outlet to give an oil temperature of 40 °C. If automatic flow regulation is not fitted, a manual valve must be throttled to achieve the correct temperature.

If the compressor is fitted with a remote air cooled oil cooler, adjust the device controlling the air flow (fan speed control, dampers etc.,) to give an oil temperature of 40 °C.

(j) Check that the oil separator/reservoir heaters de-energise when the compressor motor starts.

(k) Calibrate the LVDT 4 to 20 mA slide valve position signal for maximum and minimum load; refer to 4.8. MSI Linear Variable Displacement Transducer (MSI LVDT).

(l) Check that safety devices, the HP and LP cut-outs for example, and all external safety interlocks trip and stop the compressor.

(m) Run-in the compressor; refer to 11. Running-In the Compressor.

10.6. Normal Starting and Running

(a) Check the oil level in the oil reservoir. The sight-glass should show an oil level equal to the standing level when the plant is not operating.

Check the oil in the reservoir is warm enough (the heaters should have been energised 24 hours before the first start to ensure this). An oil temperature of approximately 45 °C is about right.

If an oil heater thermostat is fitted, the thermostat should maintain the oil at the correct temperature.

(b) Check all pressure gauge valves and transducer or cut-out isolating valves are open.

(c) Stop valves throughout the system must be in their correct positions for running, this is particularly important regarding the compressor suction and discharge stop valves.

⚠ WARNING

The compressor must NEVER be started with the discharge stop valve closed or partially closed, nor must the discharge stop valve be throttled when the compressor is running.

Check that the stop valves in the rest of the refrigeration system are in their correct running positions.

(d) If the plant is fitted with a water-cooled oil cooler, start the water circulation pump and check for adequate flow through the cooler.

(e) Begin the compressor start sequence.

(f) After the plant has started and operating conditions have stabilised, check and record temperatures, pressures and flow rates throughout the system.

(g) When shutting down the plant for any length of time, it is advisable to close the suction and/or discharge stop valves, together with the stop valve(s) in the oil feed lines. Make sure that stop valves are opened as required before restarting.

NOTE: in the case of prolonged shutdown periods, the procedures described under 13.5.9. Prolonged Shutdown should be followed.

10.7. Adding Oil to the System

If the compressor is fitted to a package unit supplied by J & E Hall International, the method of adding oil to the system is described in the plant instruction manual; refer to Section 1 Part H : Operation.

Oil added to the system must be fresh, clean oil of the same type and ISO grade as that already used in the system.

Acid test all oil before adding it to the system; even new oil has been known to fail this test. Refer to 13.7. Oil Acid Content Record.

Spare oil for use in the plant should always be kept in properly closed containers. Exposure to atmosphere for extended periods may result in the oil becoming contaminated with dirt and/or moisture which can cause harmful reactions in the system. For similar reasons, oil reclaimed from the system should not be reused.

NOTE: these precautions are particularly important with polyolester synthetic lubricants which are very hygroscopic.

11. Running-In the Compressor

These procedures are carried out during the plant's first 200 hours of operation. Depending on circumstances, this time period may need to be extended.

11.1. Filters and Strainers

Refrigerant tends to have a scouring effect on the internal surfaces of the system. Despite the utmost care taken during manufacture, dirt, scale, grit and other extraneous material are released, especially during the early life of a new plant. It is essential not to add to the dirt burden, which is why attention to cleanliness is so important during installation and erection.

Apart from the compressor suction strainer (see next heading), change filters and clean strainers at the end of 200 operating hours.

11.1.1. Suction Strainer

It is important to remove and clean the strainer basket during the plant's initial period of operation; suggested intervals are after 12 compressors operating hours and again at the end of 200 hours. If the strainer is partially choked with dirt when first cleaned, indicating that the system is particularly dirty, an additional cleaning after 100 hours may be necessary.

11.1.2. Oil Filter

HS L/M 4200 series semi-hermetic compressors are fitted with an external oil filter; refer to Table 1.

Renew the oil filter element at the end of 200 compressor operating hours. If the system is very large or particularly dirty, it may be necessary to fit a new filter element before 200 operating hours are completed.

The pressure drop across the oil filter is a good indicator as to the condition of the filter element. If the oil filter pressure drop exceeds the clean filter pressure drop plus 1.4 bar, change the element.

11.1.3. Refrigerant Filter/Drier

Renew the filter/drier cores at the end of 200 plant operating hours. If available, cores having high acid retention properties should be used.

11.2. Monitoring for Moisture

During the running-in period, the system must be monitored for moisture. Moisture in the system, usually the result of inadequate evacuation procedures, is a major cause of motor winding insulation failure and can result in a motor burnout.

It must be emphasised that provided the system has been installed, evacuated and commissioned according to the principles laid down in this manual, the possibility of a motor burnout is remote.

Check the refrigerant sight-glass/moisture indicator on a regular basis during the first 12 plant operating hours, and occasionally over the next 100 hours. If there is evidence of moisture, immediate steps must be taken to remove the moisture by changing the filter/drier cores. In any case, fit new cores at the end of the first 200 operating hours.

11.3. Lubricating Oil

Check the oil level in the oil separator/reservoir on a regular basis, preferably once every day.

During the running-in period, as oil is distributed throughout the system, it may be necessary to add extra oil from time to time until the overall oil content has stabilised. Afterwards, it should only be necessary to replace the small quantity of oil lost during maintenance exercises, for example, changing the oil filter element.

11.3.1. Oil Acid Level

Checking the acid content of the lubricating oil is the primary method of determining its condition. Since the acid content directly affects the condition of the motor windings, it is recommended to closely monitor the oil's acidity during the running-in period. Remember that a relatively small increase in acid content significantly increases the probability of a motor burn-out.

When a mineral oil has been specified for compressor lubrication, maintain the acid number of the oil <0.05 by checking on a regular basis using a proprietary acid test kit.

For polyolester synthetic lubricants, used with HFC refrigerants, maintain the acid number of the compressor lubricating oil <0.15 by checking the oil on a regular basis using a proprietary acid test kit available from the oil supplier.

Additives in the oil mean that acid numbers are generally higher than those for traditional mineral oils. It is essential to maintain a record of the oil acid number and change the oil when the acid number rises by 0.05, even if this is below the 0.15 maximum.

> **NOTE: failure to maintain the oil's acid number invalidates the guarantee; refer to 2. Misuses that Invalidate Guarantee.**

Drain off a sample of oil after the first 12 compressor operating hours. Use an acid test kit, available from the manufacturer of the lubricating oil, to check the acid number remains within the normal range for the oil. Continue to monitor the condition of the oil according to the manufacturer's instructions and specifications.

Each time the oil's acid content is checked, the acid number should be entered in the Oil Acid Number Record in Part J : Maintenance.

11.4. Checking for Leaks

Check the plant daily during the first week or two of operation for leakage of refrigerant or oil; thereafter check for leaks weekly.

11.5. Compressor Holding-down Bolts

After approximately the first 200 compressor operating hours, check the tightness of the nuts securing the compressor holding-down bolts.

12. Pumping Down and Opening Up the Compressor

⚠ WARNING

Before opening up any part of the system, all personnel concerned must be aware of the potential hazards involved. Because safety is such an important topic, personnel should be thoroughly acquainted with the principles laid down in Safety.

On various occasions it will be necessary to open up part of the system for routine maintenance and inspection. It may also be necessary to dismantle the compressor for overhaul, in the event of mechanical failure.

If a mechanical failure is suspected within the compressor, proceed to 12.3. Isolating the Electrical Supply, omitting the pumping down procedure.

NOTE: do not attempt to run the compressor if a mechanical failure is suspected.

12.1. Preparing for Pump Down

As there is no stop valve fitted between the compressor and the discharge outlet from the oil separator, pumping down the compressor includes the oil separator as well.

Differences in plant layout, with particular reference to the position of pipe line stop valves, means that it is impossible to give precise instructions for every installation. However, the following method of pumping down the compressor and recovering the remaining refrigerant charge is generally applicable where suction and discharge stop valves are provided.

Close the discharge gauge valve and disconnect the gauge line. Connect a suitably sized refrigerant recovery unit to the gauge valve connection.

12.2. Pumping Down the Compressor

NOTE: ensure that the cooled medium flow through the evaporator and the evaporating temperature are both adequate to prevent freezing in the evaporator during pump down.

Start and run the compressor.

It is desirable to reduce the capacity of the compressor as much as possible when pumping down. Turn the capacity control switch to the minimum load position and, using the load and unload push-buttons, move the capacity control slide valves to minimum load.

Slowly close the suction stop valve until the LP cut-out trips and stops the compressor. Fully close the suction stop valve as the compressor stops. Close the discharge stop valve after the compressor has stopped, together with the stop valves in all other pipe line connections to the compressor (for example liquid injection, oil injection, capacity control).

NOTE: do not bypass the LP cut-out to achieve a lower suction pressure. This practice may ultimately result in marginal compressor lubrication conditions if excessive amounts of oil are pumped over.

12.3. Isolating the Electrical Supply

After pumping down the compressor, isolate the electrical supply to the control panel(s) and drive motor.

⚠ WARNING

Withdraw the fuses from the motor starter and keep them on your person so that they cannot be accidentally refitted, place a warning notice on the panel next to the main isolator. Disconnect the electrical supply to the compressor drive motor.

12.4. Removing the Residual Refrigerant Gas

Using the refrigerant recovery unit, transfer the remaining gas into approved storage containers. Each vessel to receive the refrigerant should be mounted on a suitable weighing device to ensure that the rated capacity of the vessel is not exceeded, taking into account the lower density of the oil/refrigerant mixture compared with pure refrigerant.

NOTE: do not mix different grades of refrigerant in the same recovery vessel. Each vessel should be used for only one grade of refrigerant.

When the suction pressure has fallen to approximately 0.75 bar abs, stop the recovery unit to allow the dissolved refrigerant to separate out from the oil. It may be necessary to run the recovery unit two or three times before it is possible to pump down to approximately 0.3 bar abs.

When as much gas as possible has been recovered from the compressor, close the discharge gauge valve connection and stop the refrigerant recovery unit.

Isolate and disconnect the refrigerant recovery unit and allow air to enter the compressor via the gauge valve.

12.5. Opening up the Compressor

Before opening up, drain off any oil left behind in the compressor.

⚠ WARNING

For protection against escaping refrigerant the operator should wear protective clothing, goggles and a suitable respirator.

Remove the side covers to reveal the stars, main rotor and capacity control slide valves. Carry out the necessary maintenance and/or inspection as required.

NOTE: when working on the compressor, great care must be taken to keep all components clean and prevent dirt from entering. Rags used for cleaning must be lint-free. If the compressor has to be left open for any length of time, covers should be refitted and any other openings blanked off to prevent the ingress of moisture, dirt or other foreign matter.

Reassemble the compressor using the original or replacement components. New gaskets, 'O' rings, lockwashers and a new oil filter element must be used; refer to Table 1.

12.6. Re-instating the Compressor

Reunite the compressor with the rest of the system by cracking open the discharge stop valve, before opening the suction stop valve.

Open the stop valves in all other pipe line connections to the compressor (for example liquid injection, oil injection).

Check all joints for tightness, then check for leaks on the compressor and any other items disturbed during the maintenance operation.

Once the leak test has proved satisfactory, evacuate and dehydrate the compressor and all other parts of the system open to atmosphere. Adopt the procedures described in publication Part E : Evacuation and Dehydration, available from J & E Hall International.

Reconnect the electrical supply to the compressor motor. Make sure all wiring is restored in accordance with the original arrangement as shown on the plant wiring diagrams.

Replace the mains fuses and reinstate the power supply.

Recommission the compressor; refer to 10. Commissioning and Operation.

13. Maintenance

Routine maintenance is essential for the optimum availability and performance of all mechanical equipment, however, in this respect, refrigeration plant is in a somewhat different category since it is particularly susceptible to the presence of air and moisture inside the system, especially when the installation is fitted with a semi-hermetic compressor. Consequently, it is undesirable to open up any part of the system on more occasions than is necessary to ensure efficient working.

13.1. Spare Parts

New parts must be suitable for use in the refrigeration environment. 'O' rings and gaskets, for example, must be compatible with the system refrigerant and lubricating oil.

Depending on the application, components may require the following certification:

- Material certification. The component is suitable for use with the system refrigerant, lubricating oil and secondary refrigerant (if used).
- Pressure test certification. The component is capable of withstanding the pressures likely to be encountered within the system.
- Pressure relief devices require certification that they open at the set pressure and discharge at the required rate.

To ensure that the correct parts are supplied, manufactured from compatible materials and accompanied by all necessary certification, it is important to use spares obtained from J & E Hall International.

Obtain spare parts from the address below:

J & E Hall International
Hansard Gate,
West Meadows,
Derby,
DE21 6JN
England

Telephone: +44 (0) 1332-253400
Fax: +44 (0) 1332-371061
E mail: jehall.derby@dial.pipex.com
Website: www.jehall.co.uk

Always provide the J & E Hall International contract number and compressor serial number(s) when ordering spares; refer to Part A : Specification.

Refer to Appendix 4 HS 4200 Series Compressor Replacement Parts.

13.2. Filters and Strainers

If a strainer is fitted in the suction line before the compressor, clean the strainer at the end of the first 12 hours operation.

Change the oil filter element and clean strainers at the end of the first 200 hours operation, then at the intervals specified in 13.4. Maintenance Schedule. Experience of running the plant may suggest that strainers require cleaning at shorter intervals.

Filter and strainer locations for the compressor and oil support system are detailed in Table 2. Refer to the plant instruction manual for the location of filters and strainers in the refrigerant and cooled medium lines.

Compressor suction end cover (strainer forms integral part of compressor).
Compressor liquid injection line - *liquid injection cooling fitted.* Economiser (subcooler) line before the solenoid valve and thermostatic expansion valve - *if economiser fitted.*
Oil filter in the oil injection line after the oil separator.

Table 2 Filter and Strainer Locations

13.3. Running-in

At the end of the commissioning period, the running-in procedures, described under 11. Running-In the Compressor, must been carried out during the first 200 hours of operation.

After running-in has been completed, maintain the plant according to the schedule following.

13.4. Maintenance Schedule

According to Lloyds survey requirements, unless a specific problem arises, the HallScrew compressor should not need opening up until the first inspection after six years or 25,000 operating hours run have elapsed, whichever is the sooner. Maintenance during the guarantee period should be carried out by J & E Hall International, or our appointed service representative, unless specifically agreed to the contrary by written agreement with J & E Hall International.

This maintenance schedule refers to the compressor, the package unit with which it is associated, and generally to the rest of the plant. Reference is made to instruction publications which can be found in the J & E Hall International instruction manual for the plant.

13.5. Maintenance Intervals

Planned maintenance exercises are initiated at intervals of calendar months *or* compressor operating hours, whichever time period expires first.

For multi-compressor installation using a common oil separator, maintenance intervals every 5,000 and 15,000 operating hours refer to the *total* number of hours run by all the compressors on the plant.

Examples are included to make this point clear.

Example 1:

In the 12 months from the last planned maintenance interval, compressor 1 has run for 1,200 hours and compressor 2 has run for 2,700 hours. Total compressor running hours are 1,200 + 2,700 = 3,900 hours, however, the plant has been running for 12 months so it is time to carry out the 12 month/5,000 hour plant maintenance exercise.

Example 2:

In the 8 months from the last planned maintenance interval, compressor 1 has run for 3,500 hours and compressor 2 has run for 1,500 hours. Total compressor running hours are 3,500 + 1,500 = 5,000 hours, so it is time to carry out the 12 month/5,000 hour plant maintenance exercise.

13.5.1. Daily

(a) Check the level in the compressor package unit oil separator/reservoir.

It should not be necessary to add large quantities of oil to the system, other than that necessary to replace the small amount lost during maintenance exercises.

(b) Check and record system temperatures, pressures and flow rates.

The specimen log sheet illustrated in Appendix 5 Plant Performance Record shows the minimum number of readings which should be taken to enable an accurate assessment of the plant's performance to be made. In the case of a very large plant, many more readings need to be logged to complete the overall picture.

Particular attention should be paid to the following readings:

- Oil temperature measured at the oil cooler outlet (if an oil cooler is fitted instead of liquid injection).

- Oil pressure at the compressor oil injection connection.
- The net oil pressure drop across the oil filter.
- Suction and discharge pressures and temperatures.

  Gauge and temperature readings should be checked regularly, in addition to routine logging, and any variations from normal promptly investigated.

13.5.2. Weekly

(a) Check the plant for refrigerant and oil leaks; refer to Leak Detection in the publication for the refrigerant in Section 5.

(b) Check that capped valves have their caps firmly in position to prevent tampering, loss of refrigerant or the entry of air and moisture.

(c) Check the sight-glass/moisture indicator. If there is evidence of an increase in the moisture content of the system, corrective action must be taken immediately by changing the refrigerant filter/drier cores, and tracing and rectifying the cause of moisture ingress.

(d) On multi-compressor applications, changeover the role of lead, lag and/or standby compressor.

13.5.3. Monthly

(a) Check the operation of the compressor capacity control system; refer to 4.8. MSI Linear Variable Displacement Transducer (MSI LVDT).

13.5.4. Every Year, or at Intervals of 5,000 Operating Hours

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 12. Pumping Down and Opening Up the Compressor.

(b) Take a sample of oil from the oil separator/reservoir. Preferably, send the sample to the oil supplier for laboratory analysis and report; the analysis must include checking the oil's acid content and moisture content. Alternatively, use an acid test kit, available from the manufacturer of the lubricating oil, to check that the acid content remains within the normal range for the oil.

Record the acid content in Table 4.

If it is necessary to change the oil, drain off the oil charge from the oil separator/reservoir. Decant the old oil into empty drums and return it to the oil supplier/manufacturer for recycling. Do not forget to mark each drum with its contents.

Evacuate the oil separator/reservoir as described in Part E : Evacuation and Dehydration. Refill the reservoir with the correct quantity of fresh, clean oil of the same type and ISO grade as that already used in the system, using the vacuum in the reservoir to draw the oil into the vessel through the connection provided; refer to the plant schematic flow diagram.

(c) Renew the oil filter element.

It may be necessary to fit a new element before this interval/hours-run time expires if the oil filter pressure drop exceeds the clean filter pressure drop plus 1.4 bar.

(d) Clean strainers throughout the system; refer to Table 2.

Examine each strainer basket. If the mesh is damaged, torn etc., fit a new basket.

Experience of running the plant may suggest that more frequent cleaning is necessary.

(e) Renew the refrigerant filter/drier cores. Drier cores should be changed at earlier intervals if the cores become choked, or the amount of moisture in the system reaches a dangerous level. The sight-glass/moisture indicator will show evidence of contamination.

(f) Check that pressure and temperature controls operate correctly at the appropriate setting value.

(g) Check the tightness of the fastenings securing the compressor mountings.

(h) Check the condenser gauge temperature against the liquid refrigerant outlet temperature. If the presence of air or other non-condensable gas is suspected, carry out a full test and purge as required.

Check more frequently if operating conditions are such that the pressure in the suction line is below atmospheric.

13.5.5. Every 3 Years, or at Intervals of 15,000 Operating Hours

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 12. Pumping Down and Opening Up the Compressor.

(b) Drain off the oil charge from the oil separator/reservoir. Decant the old oil into empty drums and return it to the oil supplier/manufacturer for recycling. Do not forget to mark each drum with its contents.

(c) Evacuate the oil separator/reservoir as described in Part E : Evacuation and Dehydration. Refill the reservoir with the correct quantity of fresh, clean oil of the same type and ISO grade as that already used in the system, using the vacuum in the reservoir to draw the oil into the vessel through the oil drain line.

13.5.6. Every 6 Years, or at Intervals of 25,000 Operating Hours

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 12. Pumping Down and Opening Up the Compressor.

(b) Open the compressor for inspection in the presence of J & E Hall International or our appointed representative. Remove the side covers to reveal the stars, main rotor and capacity control slide valves.

13.5.7. Every 12 Years, or at Intervals of 50,000 Operating Hours

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 12. Pumping Down and Opening Up the Compressor.

(b) Open up the compressor for inspection in the presence of J & E Hall International or our appointed representative.

Remove the side covers and examine the star shaft bearings and main bearings with a view to replacement. Renew if in any doubt.

Examine the stars. Renew if damaged or worn.

(c) Check the operation of the capacity control mechanism for ‘drifting’ from the required slide valve position. If ‘drifting’ is occurring and the capacity control solenoid valve(s) are in good condition and appear to be working correctly, renew the glide ring/’O’ ring seal on the capacity control hydraulic piston.

13.5.8. Every 24 Years, or at Intervals of 100,000 Operating Hours

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 12. Pumping Down and Opening Up the Compressor.

(b) Dismantle the compressor and check parts for damage or wear. Renew the main bearings.

13.5.9. Prolonged Shutdown

(a) If the plant is shutdown for an extended period, it is advisable to close the compressor suction and discharge stop valves. Make sure that stop valves are opened as required before restarting.

⚠ WARNING

The compressor must NEVER be started with the discharge stop valve closed or partially closed.

(b) It is important to run the plant for at least one hour each week. This short period of operation helps maintain components by ensuring that bearing surfaces are well lubricated, especially mechanical gland seals which might otherwise leak, and promotes trouble-free running when full-time operation resumes.

With sufficient oil pressure available, use the load/unload push-buttons to operate the compressor capacity control mechanism over the full length of its travel.

(c) The electrical system is arranged to ensure that heaters de-energise when the compressor starts and re-energise when the compressor stops.

If the plant has been electrically isolated long enough for the lubricating oil to cool down, the isolator(s) must be turned to the 'on' position and the oil separator/reservoir heaters energised to warm the oil before restarting. Wait until the oil temperature risen to approximately 45 °C, this ensures that any refrigerant absorbed by the oil is evaporated.

(d) If it is not possible to run the plant periodically during the prolonged shutdown period, contact J & E Hall International for recommendations on safe storage and long term preservation of the plant.

13.6. Maintenance Check List

Table 3 illustrates the maintenance schedule as a 'Check List'.

PARA	DAILY	✓
13.5.1.	Check the oil separator/reservoir oil level.	
	Check and record system temperatures, pressures and flow rates.	
PARA	**WEEKLY**	✓
13.5.2.	Check for leakage of refrigerant and oil. Inspect the exterior of the plant for damage or corrosion.	
	Check valve caps are in place.	
	Check the sight-glass/moisture indicator for the presence of moisture.	
	On multi-compressor applications, changeover the role of lead, lag and/or standby compressor	
PARA	**MONTHLY**	✓
13.5.3.	Check the compressor capacity control system operates correctly	
	Check the pressure drop across the secondary oil separator - *separate secondary oil separator fitted in the discharge line*	
PARA	**EVERY YEAR, OR AT INTERVALS OF 5,000 OPERATING HOURS**	✓
13.5.4.	Check the condition of the system oil charge, renew if necessary	
	Renew the oil filter element	
	Clean strainers throughout the system	
	Renew the refrigerant filter/drier cores	
	Check pressure and temperature safety controls operate correctly	
	Check the condition of the coupling membrane/spacer assembly	
	Check the tightness of the fastenings securing the compressor and motor mountings	
	Check for air in the system. Check more frequently if operating conditions are such that the pressure in the suction line is below atmospheric.	
PARA	**EVERY 3 YEARS, OR AT INTERVALS OF 15,000 OPERATING HOURS**	✓
13.5.5.	Renew the system oil charge	
PARA	**EVERY 6 YEARS, OR AT INTERVALS OF 25,000 OPERATING HOURS**	✓
13.5.6.	Remove side covers, inspect the compressor	
PARA	**EVERY 12 YEARS, OR AT INTERVALS OF 50,000 OPERATING HOURS**	✓
13.5.7.	Examine the star bearings and main bearings. Renew if in doubt.	
	Examine the stars. Renew if damaged or worn.	
	Check the capacity control mechanism for 'drifting'	
PARA	**EVERY 24 YEARS, OR AT INTERVALS OF 100,000 OPERATING HOURS**	✓
13.5.8.	Dismantle the compressor and check parts for damage or wear. Renew the main bearings.	

Table 3 Maintenance Check List

13.7. Oil Acid Content Record

Each time the oil's acid content is checked, record the value in Table 4.

Acid Content	Signature	Printed Name	Date

Table 4 Oil Acid Content Record

Appendix 1 Compressor Data

- HS L/M 4200 Series: Compressor Model Nomenclature.
- HS L/M 4200 Series: Physical Data.
- HS L/M 4200 Series: Motor Data.
- HS L/M 4200 Series: Limits of Operation.
- Safety Requirements for Compressor Protection.
- HS L/M 4200 Series: Physical Dimensions and Connections.

HS L/M 4200 Series: Compressor Model Nomenclature

HallScrew	Application	Compressor			Capacity Control Slide V_R	Lubricant	Motor Power (Nominal)	Motor Voltage	Refrigerant	Voltage (Auxiliary)	Capacity Indicator	Stop Valves and Flanges	Economiser Kit	Discharge Thermistor	Oil Level Detector	DOL Kit
HS	X	4	2	X	X	X	X	X	X	X	X	X	X	1	X	X

Application	L	Semi-hermetic compressor for low temperature application
	M	Semi-hermetic compressor for medium temperature application
Compressor	42X	Series 4200 Twin Star 21, 22, 23 or 24
Capacity Control Slide V_R	3	3.0 V_R
	5	4.9 V_R
Lubricant	E	Ester oil
	L	Polyvinyl ether oil
	M	Mineral oil
Motor Power (Nominal)	D	145/174 kW @ 50/60 Hz
Motor Voltage	Q	400/460 V 3 ph 50/60 Hz
	U	380 V 3 ph 60 Hz
	B	208 V 3 ph 60 Hz
	D	500/575 V 3 ph 50/60 Hz
	V	230 V 3 ph 60 Hz
	X	Special voltage
Refrigerant	A	R134a
	B	R22
	C	R407c
	E	R507a
	F	R404a
	X	Other
Voltage (Auxiliary)	1	115 V 1 ph 50/60 Hz
	2	230 V 1 ph 50/60 Hz
	3	24 V dc
	4	24 V ac
	X	Asco solenoid valves less coils (ATEX coils for Zone 2 application, free issue)
Capacity Indicator	0	No capacity indicator (standard)
	D	Capacity indicator (not self-setting)
	E	Capacity indicator (not self-setting + signal conditioning module)

Stop Valves and Flanges	A	Suction and discharge flanges
	B	Suction flange and discharge stop valve (standard)
	C	Suction flange and 3N1 3 in 1 discharge valve
	D	Suction and discharge stop valves
	E	Suction stop valve and discharge flange
	F	Suction stop valve and 3N1 3 in 1 discharge valve
Economiser Kit	0	No economiser kit
	1	Economiser kit
Discharge Thermistor	1	Discharge thermistors (max temp 100 °C) and Kriwan INT 69 TM controller
Oil Level Detector	0	No oil level detector
	1	Oil level detector
DOL Kit	0	No DOL kit
	1	DOL kit
Example: HSM 4222/3/M/D/D/B/2/D/B/1/1/0/0 This describes a HallScrew 4222 twin star semi-hermetic compressor for medium temperature application fitted with 3.0 V_R capacity control slide valves, lubricant is mineral oil. Fitted with a 145 kW motor suitable for 500/575 V 3 ph 50/60 Hz supply. Compressor for operation with R22. Solenoid voltage 230 V 1 ph 50/60 Hz. Fitted with capacity indicator (not self-setting), suction flange and discharge stop valve, economiser kit and discharge thermistors. Oil level detector and DOL kit not fitted.		

HS L/M 4200 Series: Physical Data

Compressor Type	Single screw, semi-hermetic.
Compressor Rotation	Clockwise looking on the motor end. Under no circumstances should the compressor run in the reverse direction.
Method of Drive	Suction gas cooled 3-phase, 2-pole stator/rotor arranged for start/delta, soft-start or inverter drive. Maximum of 6 starts per hour. Refer to Motor Data for kW ratings.
Speed Range	Depends on the supply frequency, 50 Hz or 60 Hz; refer to Motor Data.
Physical Dimensions	Refer to Physical Dimensions and Connections.
Weight	730 kg (approx, all models).
Capacity and Power	Refer to selection data.
Capacity Control	Compressor capacity infinitely variable from 100 % to approximately 25 % of full load (depends on the operating conditions). Slide valve position indication by 4 to 20 mA Linear Variable Displacement Transducer (LVDT). DIN plug terminal box rating IP65.
Capacity Control Solenoids	115 V or 240 V ac (other voltages available on request). Terminal box rating IP65.
Suction Strainer	Integral. 60 mesh x 37 SWG.
Motor Terminal Box Rating	IP54 (standard), IP65 (available to special order).

Swept Volume

Swept Volume (m^3/hr)	HS L/M 4221	HS L/M 4222	HS L/M 4223	HS L/M 4224
Compressor running @ 50 Hz (2 pole speed)	504	611	716	828
Compressor running @ 60 Hz (2 pole speed)	605	733	859	994

[1]Sound Pressure Levels @ 2980 rpm (50 Hz)

Compressor	Total dB 'A'	Centre Frequency – Hz						
		125	250	500	1 k	2 k	4 k	8 k
HS L/M 4221	81	62	73	73	77	75	69	62
HS L/M 4222	82	62	74	74	79	76	70	63
HS L/M 4223	83	61	75	75	80	77	71	64
HS L/M 4224	83	61	75	75	80	77	71	64

[1]Sound pressure level data refers to free-field conditions at a distance of 1 metre from the compressor periphery. It is important to remember that on a specific installation the actual sound pressure level is considerably affected by the size and type of room, material of construction and plant design. Adjoining pipework, including suction, can have a very substantial effect on the noise level.

Sound pressure levels given in dB refer to 2×10^{-5} N/m^2 RMS.

HS L/M 4200 Series: Motor Data – 50 Hz Operation

COMPRESSOR RUNNING @ 50 HZ (2980 RPM)	HS L/M 4221	HS L/M 4222	HS L/M 4223	HS L/M 4224
Motor nominal output (kW)	145			
Motor maximum output (kW)	162	192	220	207
Maximum running current (A) @ 400 V	259	304	341	325
Starting current (locked rotor) in Y (A) @ 400 V	464			
Starting current (locked rotor) in Δ (A) @ 400 V	1517			
Standard voltage range (V)	400 ± 10 %			

HS L/M 4200 Series: Motor Data – 60 Hz Operation

COMPRESSOR RUNNING @ 60 HZ (3575 RPM)	HS L/M 4221	HS L/M 4222	HS L/M 4223	HS L/M 4224
Motor nominal output (kW)	174			
Motor maximum output (kW)	194	230	264	248
Maximum running current (A) @ 460 V	264	311	358	335
Starting current (locked rotor) in Y (A) @ 460 V	457			
Starting current (locked rotor) in Δ (A) @ 460 V	1458			
Standard voltage range (V)	460 ± 10 %			

HS L/M 4200 Series: Limits of Operation

Pressure Limits

The pressure limits detailed below **MUST NOT** be exceeded during installation, commissioning or operation of the plant. Refer to Appendix 3 Limits of Operation Envelopes for further details.

			R134a	R407c
Maximum Design Pressures	[1]High side/low side test pressure		23.6 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	3.0 V_R	3.5 bar g	5.4 bar g
		4.9 V_R	3.5 bar g	4.0 bar g
	Maximum pressure ratio	3.0 V_R	10	10
	Minimum pressure ratio	4.9 V_R	5	5
	Maximum compressor operating discharge pressure (HS L/M 4221, HS L/M 4222 and HS L/M 4223)		19.4 bar g	29.6 bar g
	Maximum compressor operating discharge pressure (HS L/M 4224)		17.9 bar g	16.1 bar g
	Maximum compressor operating pressure differential (discharge – suction) (HS L/M 4221, HS L/M 4222 and HS L/M 4223)		17.5 bar	23.0 bar
	Maximum compressor operating pressure differential (discharge – suction) (HS L/M 4224)		17.5 bar	17.5 bar
	Minimum compressor operating pressure differential at minimum load		2.0 bar	3.0 bar

			R22	R404a	R507a
Maximum Design Pressures	[1]High side/low side test pressure		32.9 bar g	32.9 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	3.0 V_R	5.8 bar g	5.7 bar g	6.0 bar g
		4.9 V_R	4.0 bar g	4.0 bar g	4.0 bar g
	Maximum pressure ratio	3.0 V_R	10	10	10
	Minimum pressure ratio	4.9 V_R	5	5	5
	Maximum compressor operating discharge pressure (HSL/M 4221, HS L/M 4222 and HS L/M 4223)		27.9 bar g	24.4 bar g	27.6 bar g
	Maximum compressor operating discharge pressure (HS L/M 4224)		15.9 bar g	N/A	N/A
	Maximum compressor operating pressure differential (discharge – suction) (HS L/M 4221, HS L/M 4222 and HS L/M 4223)		20.0 bar	23.0 bar g	23.0 bar g
	Maximum compressor operating pressure differential (discharge – suction) (HS L/M 4224)		17.5 bar	N/A	N/A
	Minimum compressor operating pressure differential at minimum load		3.0 bar	3.6 bar	3.6 bar

Temperature Limits

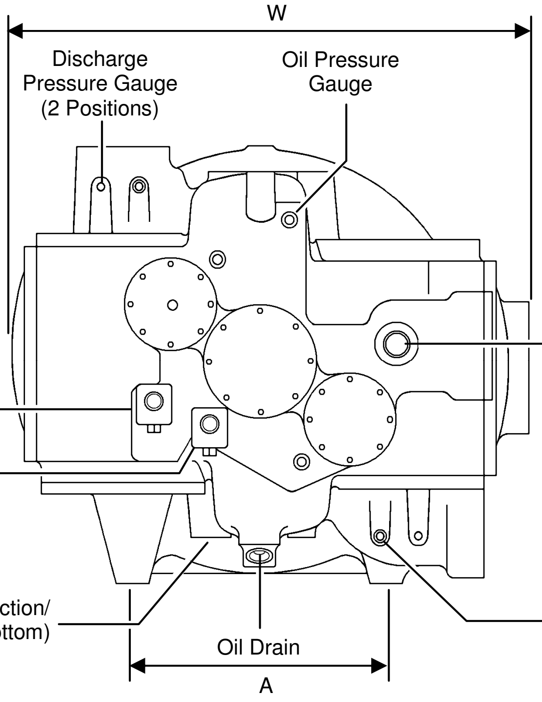
Temperature Limits	Discharge temperature	100 °C (standard) 120 °C (special)
	Discharge minimum superheat	R134a = 13.0 K R404a and R507a = 15.0 K R22 and R407c = 20.0 K

[1]Compressors must **NOT** be subjected to pressures higher than those indicated. **This may require isolation of the compressor during system strength pressure testing**.
[2]Oil separator pressure limits may be less than those applicable to the compressor.

Safety Requirements for Compressor Protection

Parameter	Trip	Device	Setting	Remarks
Discharge pressure	High	HP cut-out	According to the operating conditions	Connected to compressor discharge.
Discharge pressure	Low	Pressure control or pressure transducer and programmable controller with suitable analogue inputs	According to the operating conditions	-
Discharge temperature	High	Thermistor (fitted as standard, located adjacent to each discharge port)	100 °C (standard) 120 °C (special)	For 120 °C (special) refer to J & E Hall International. The discharge thermistors can be wired in series with the motor thermistor; refer to Fig 10.
Suction pressure	Low	LP cut-out or pressure transducer and programmable controller with suitable analogue inputs	According to the operating conditions	Prevents operation at low suction gauge pressures
Oil differential pressure 1 Oil injection pressure - suction pressure	Low	Preferred method: Pressure transducers and programmable controller with suitable analogue inputs	Pressure ratio 2	Oil pressure should be twice suction pressure (absolute) 30 second delay required on starting only
		Alternative method: Differential pressure switch; refer to Fig 7.	Value of the differential to be equal to the value of the highest operational suction pressure (absolute)	30 second delay required on starting only
Oil differential pressure 2 Discharge pressure - oil injection pressure	High	Differential pressure switch (refer to Fig 7) or pressure transducers and programmable controller with suitable analogue inputs	2 bar (standard) 3 bar (maximum)	Should be approximately 1 bar above difference when filter is new. ODP2 is not mandatory but is recommended to detect when the oil filter is becoming blocked and it is time to renew the filter element.
Oil separator oil level	Low	Level switch or sensor	Trip on low level	Time delay (5 secs max) required during operation to prevent spurious trips
Compressor motor high temperature	High	Thermistor (fitted as standard)	-	The motor thermistor can be wired in series with the discharge thermistors; refer to Fig 10.
Compressor motor current	High	Current limiter, or current transformer and programmable controller with suitable analogue inputs	Set according to the compressor motor size	Prevents operation above the maximum rated motor power

HS L/M 4200 Series: Physical Dimensions and Connections

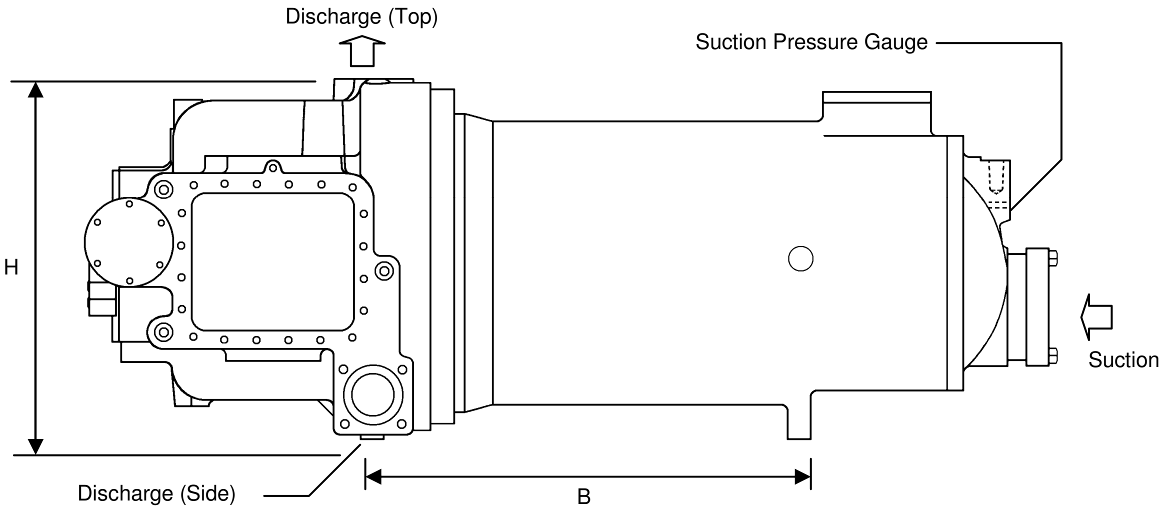


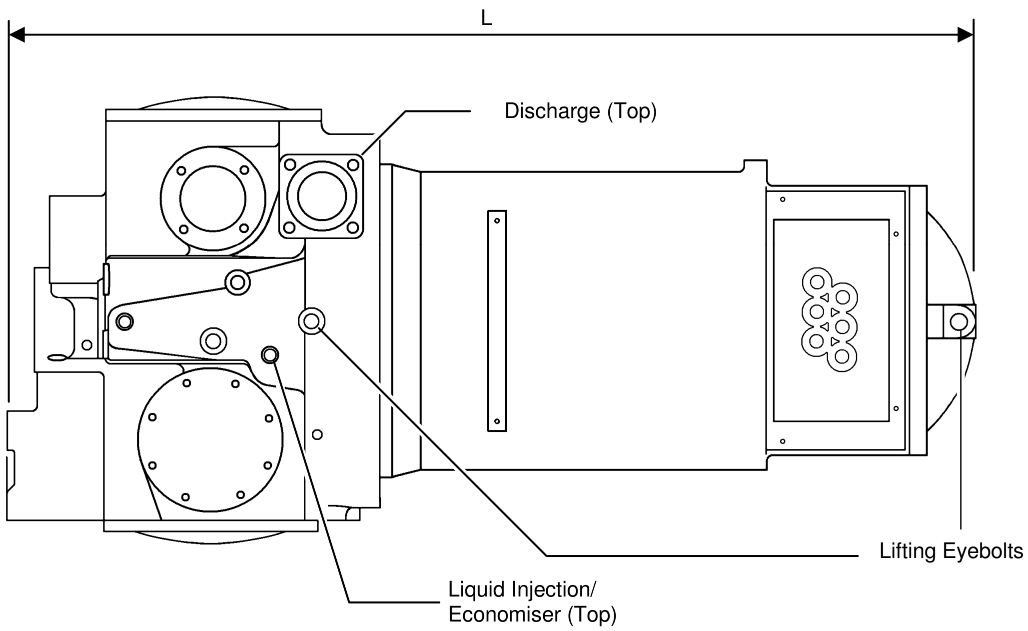
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall International certified drawing

	Description			Size
Dimensions	Overall	Length – Normal Motor	L	1432 mm
		Length – Large Motor	L	1451 mm
		Height	H	546.5 mm
		Width	W	629 mm
	Holding-down bolt centres		A	320 mm
			B	652 mm
	Holding-down bolt		-	4 off M12 x 50 mm
	Lifting eyebolts (2 off)		-	2 x M20 full thread

	Description	No Off	Size
Connections	Suction	1	4” NB (4 1/8” OD)
	Discharge (top and side)	2	2 1/2” NB (2 5/8” OD)
	Suction pressure gauge	1	1/8” NPT
	Discharge pressure gauge (2 positions)	2	1/8” NPT
	Oil pressure gauge	1	1/8” NPT
	Liquid injection/economiser (top and bottom)	2	1 1/16” (12 UNF)
	Oil injection/lubrication	1	1 1/16” (12 UNF)
	Oil drain	1	1 1/16” (12 UNF)

[1]Both discharge high temperature thermistors must be used, wired in series; refer to Fig 10.


Discharge (Top)
Suction Pressure Gauge
H
Suction
Discharge (Side)
B


L
Discharge (Top)
Lifting Eyebolts
Liquid Injection/
Economiser (Top)

Appendix 2 Oil Support System Schematic Flow Diagrams

Normally Open	Locked Open	Normally Closed	Normally Closed and Capped	
				Valve, straight through
				Valve, right angle

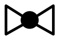
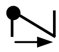
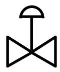
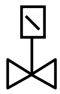
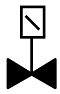
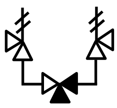
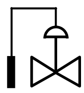
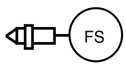
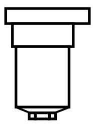
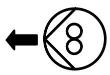
	Ball valve		Non-return valve
	Quick-acting drain valve, normally closed and capped		Control valve
	Relief valve		Solenoid valve (normally open)
	Relief valve (to atmosphere)		Solenoid valve (normally closed)
	Dual relief valve (to atmosphere)		Thermostatic expansion valve
	Sight-glass (on vessel)		Liquid drainer
	Sight-glass (in line)		Heater
	Strainer		Opto sensor in drain line
	Oil filter		Oil pump
PI	Pressure Indication (pressure gauge or transducer)	DPS	Differential Pressure Switch
PSH	Pressure Switch High (discharge high pressure cut-out or transducer)	LSL	Level Switch (opto sensor or level switch)
PSL	Pressure Switch Low (suction low pressure cut-out or transducer)	TE	Thermistor or high temperature cut-out

Fig 12 Key to Schematic Flow Diagrams

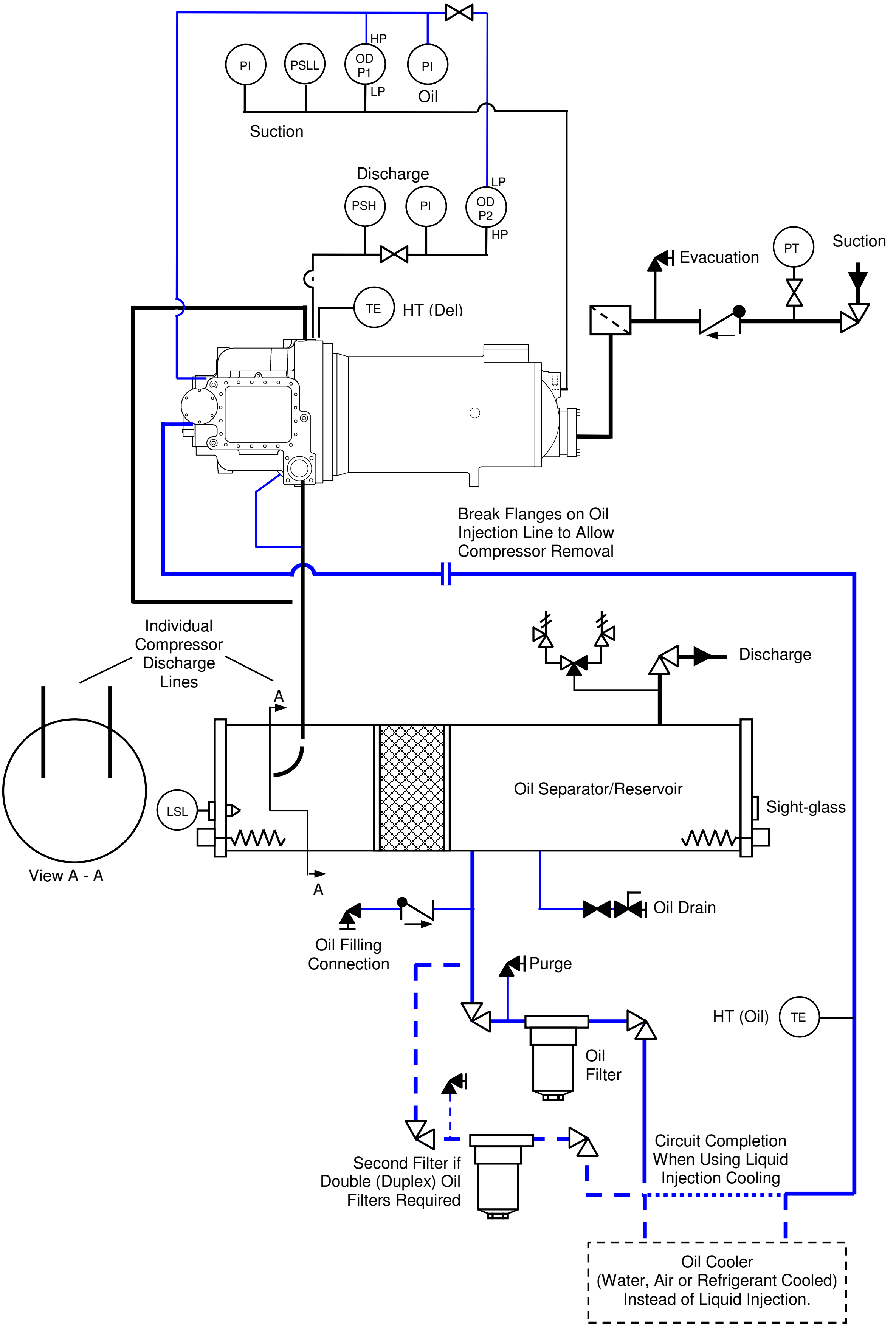


Fig 13 Oil Support System For Single Compressor

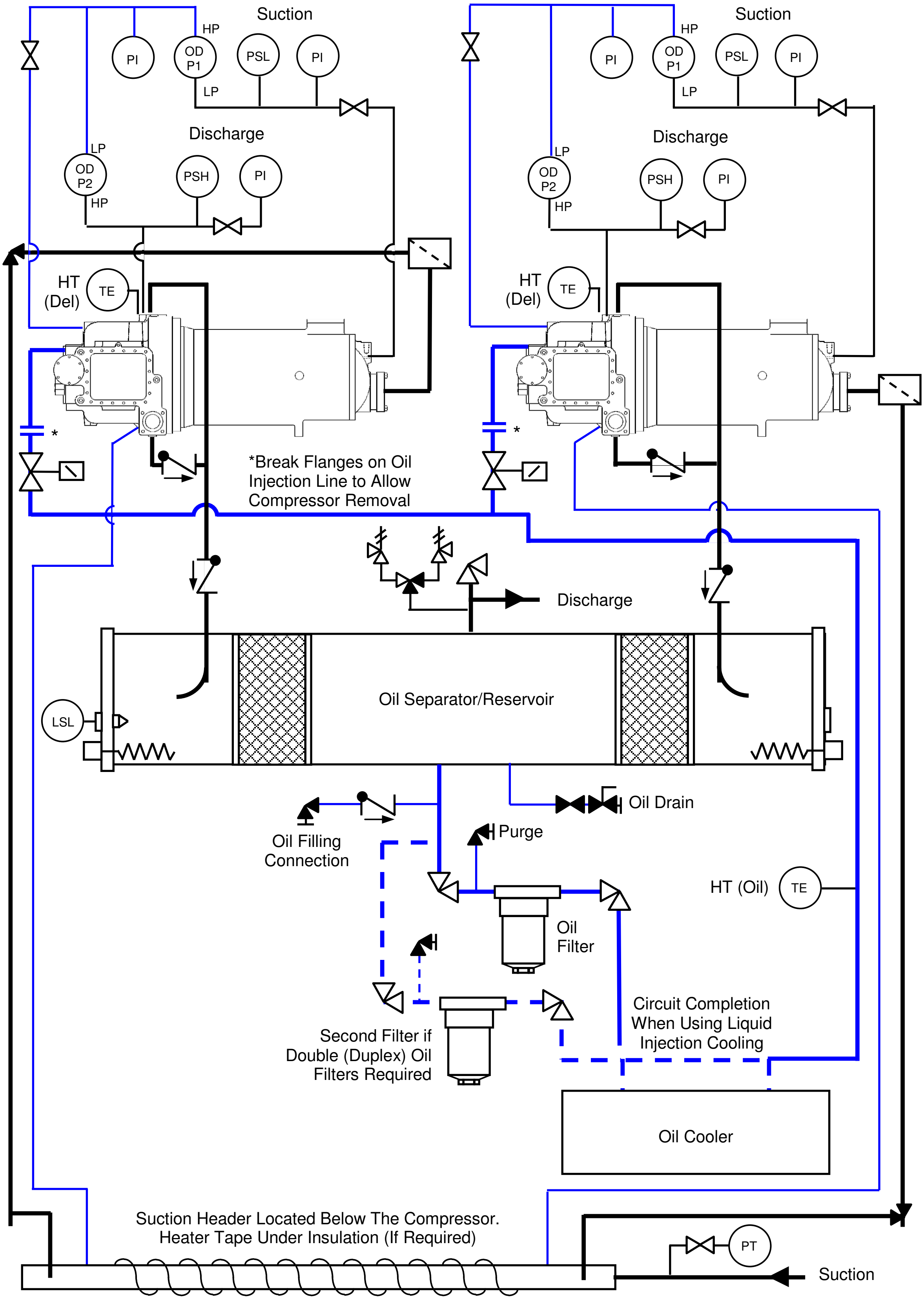
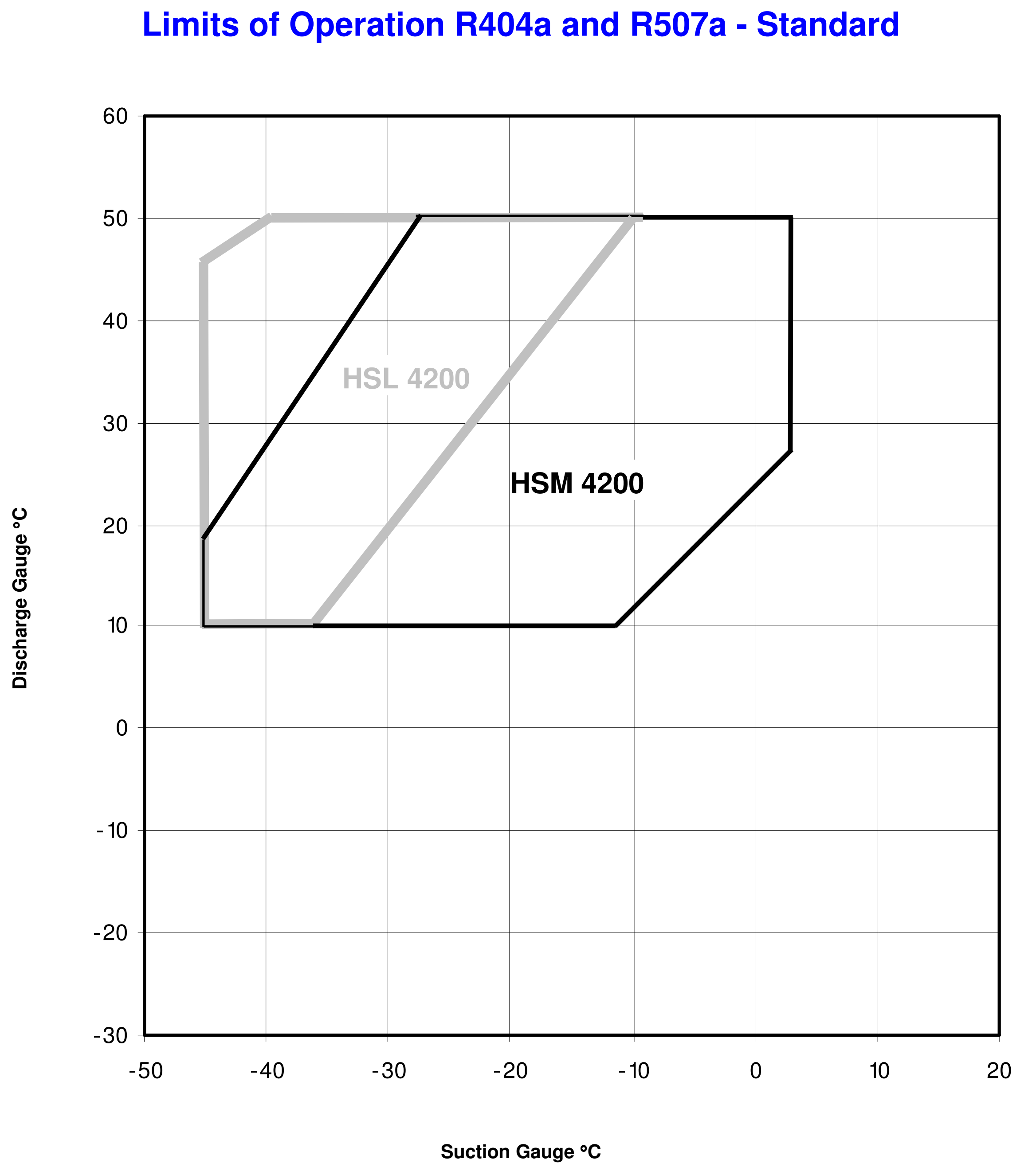


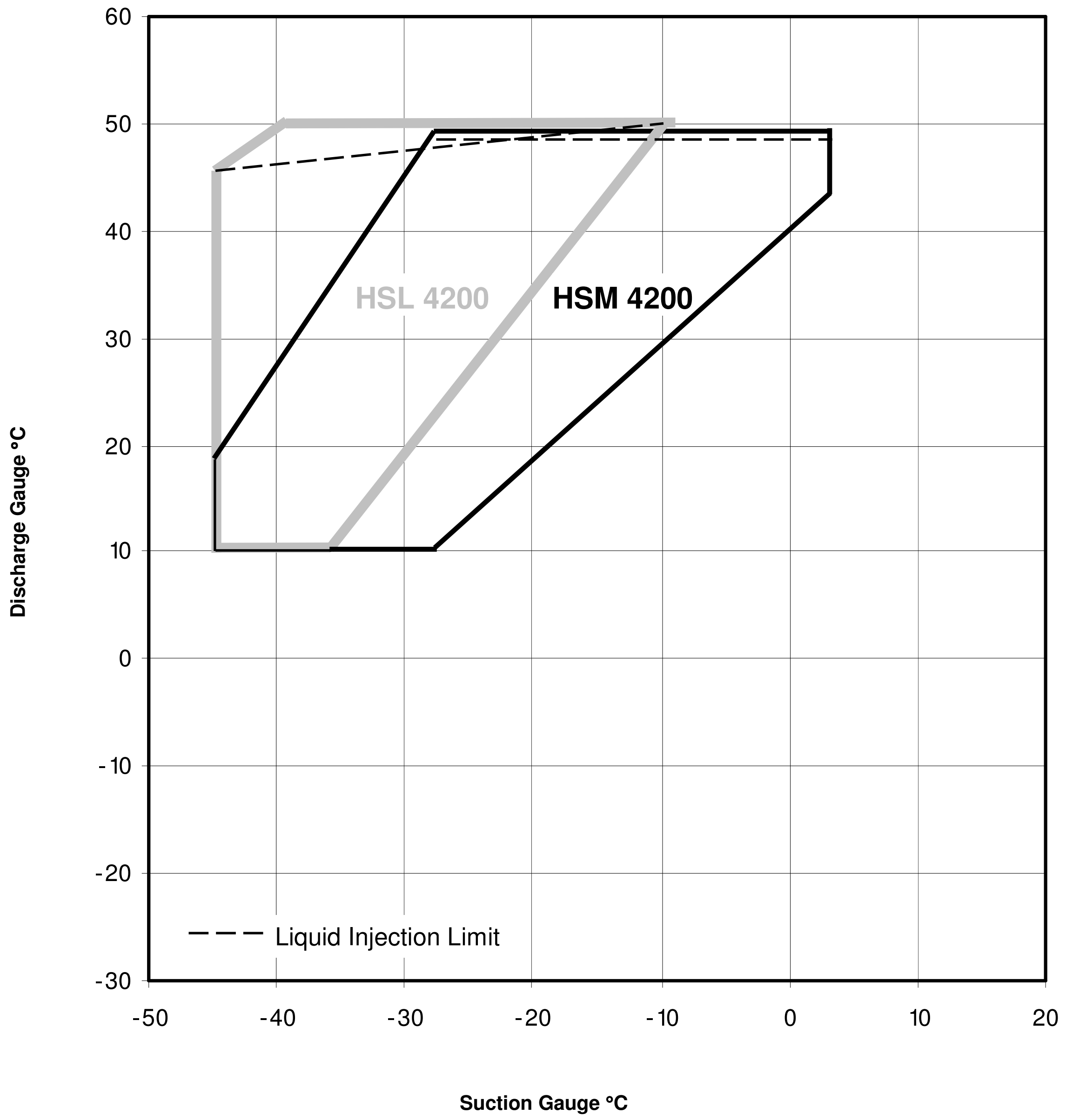
Fig 14 Oil Support System For Multiple Compressors

Appendix 3 Limits of Operation Envelopes



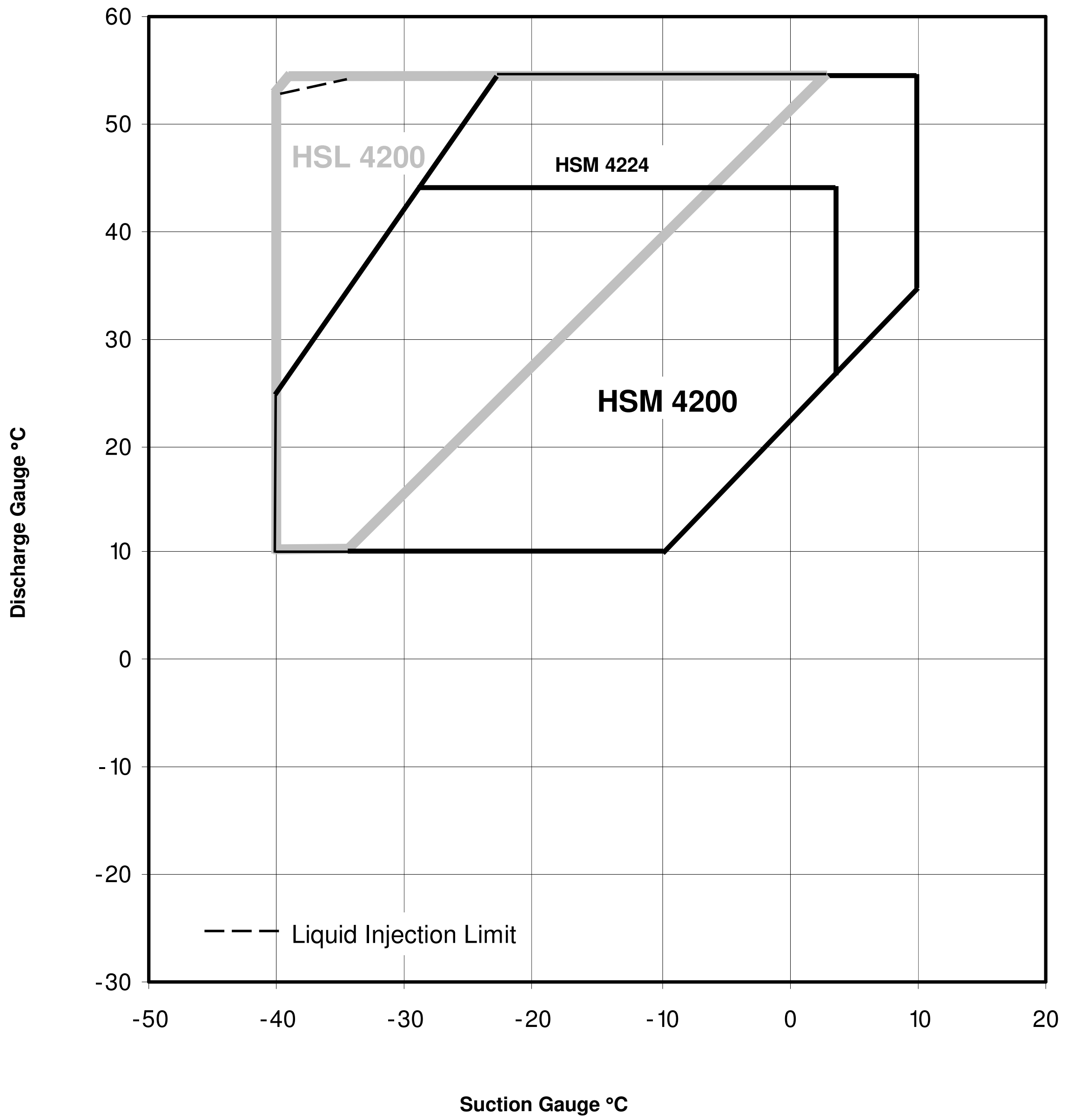
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R404a and R507a - Economised



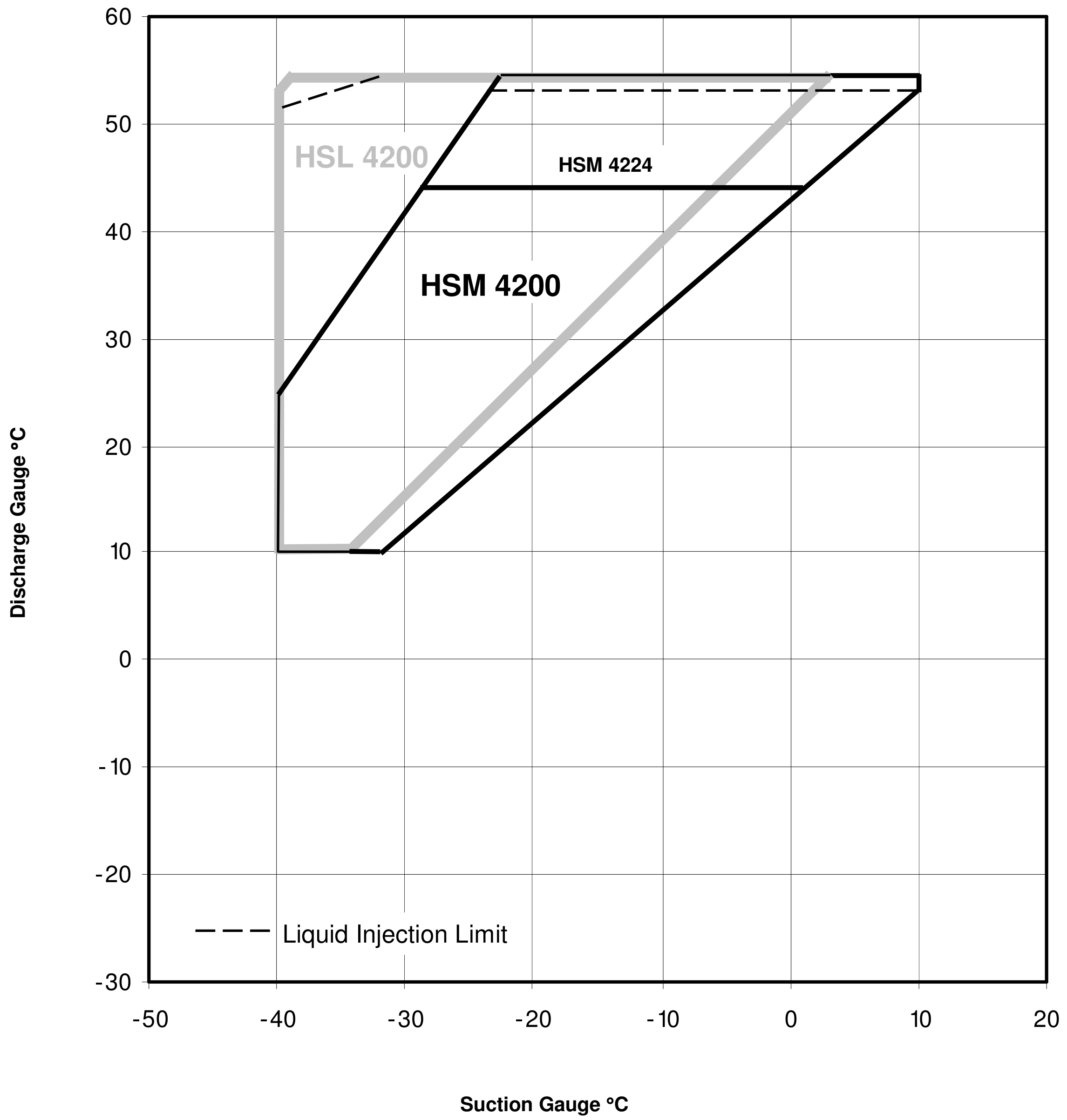
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 and R407c - Standard



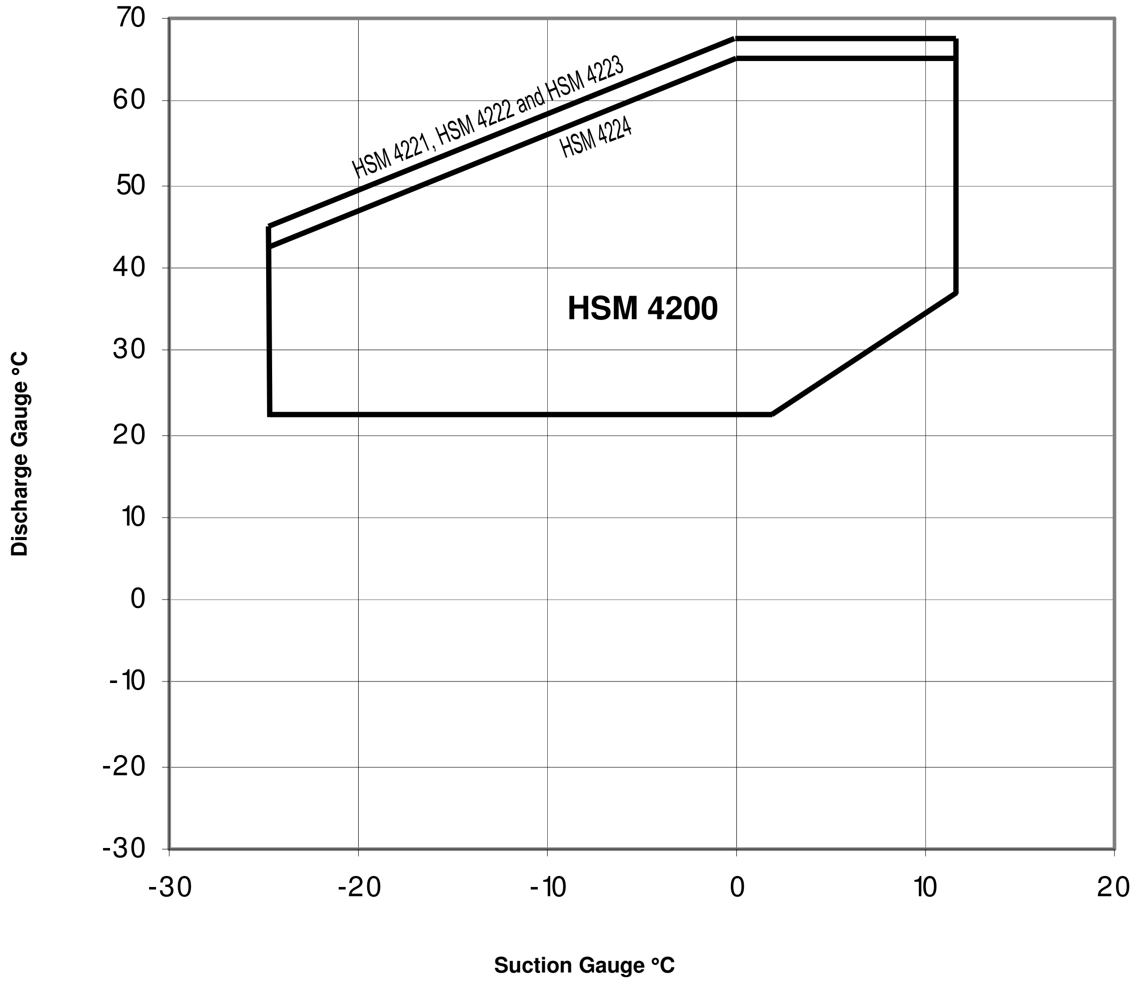
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 and R407c - Economised



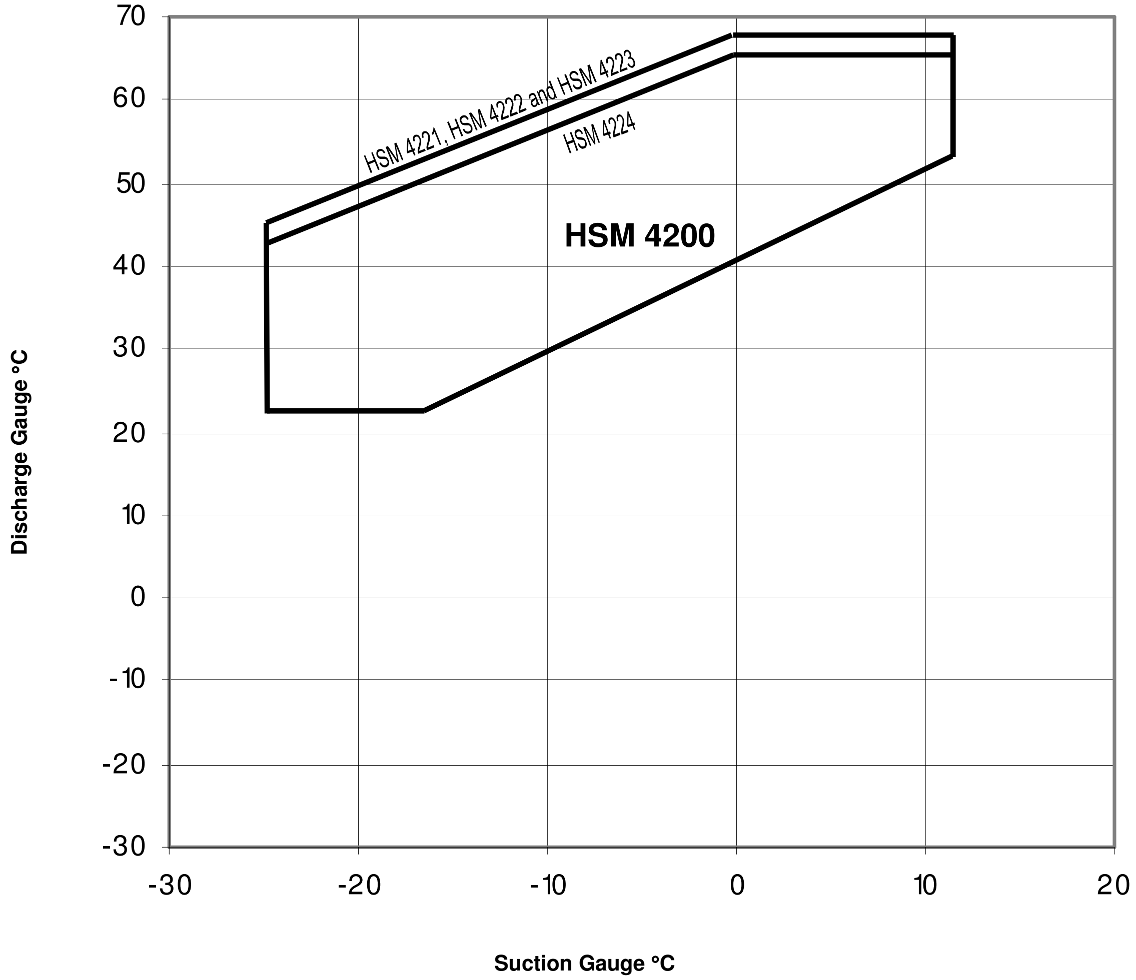
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R134a - Standard



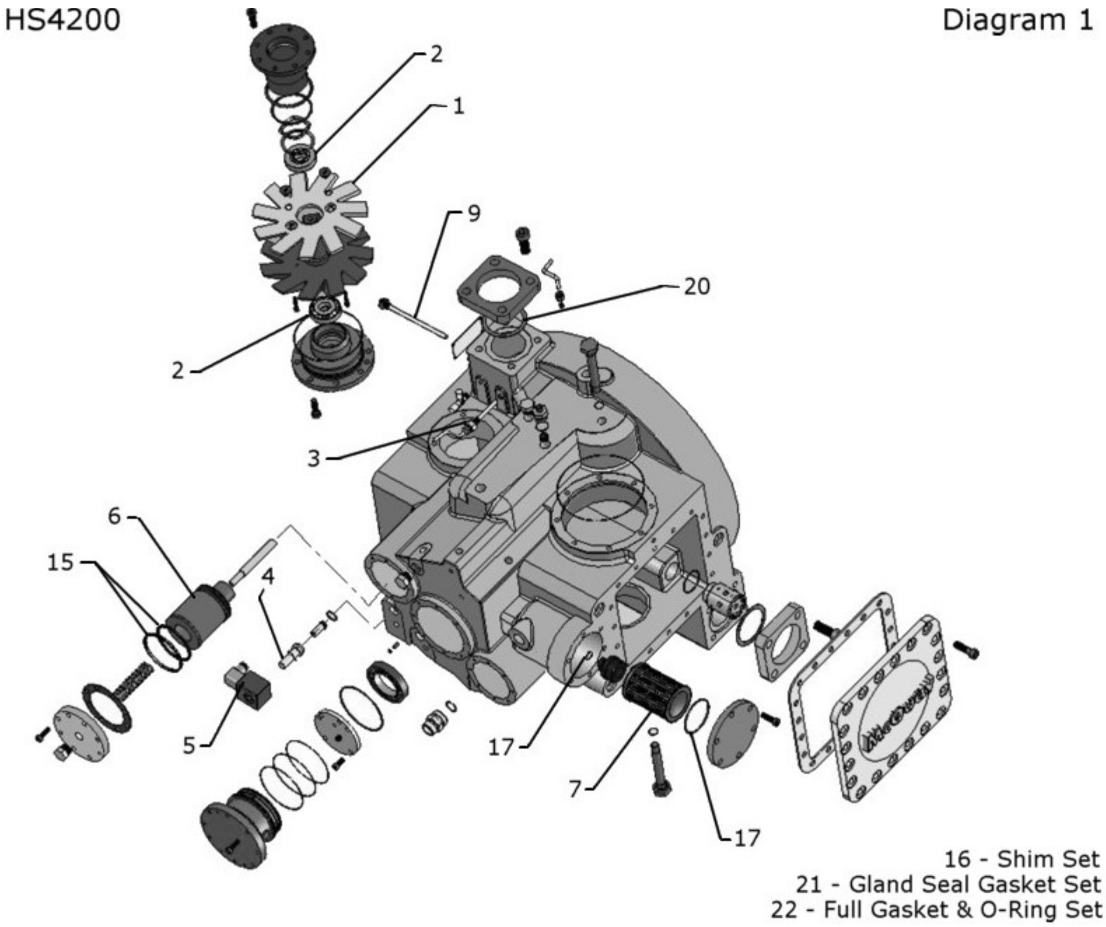
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

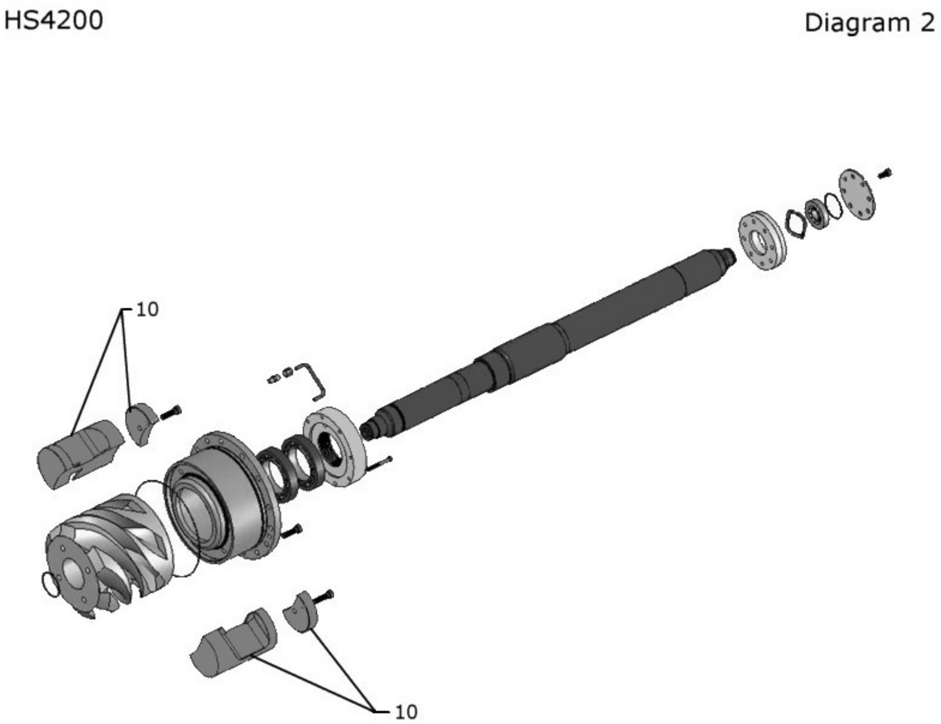
Limits of Operation R134a - Economised

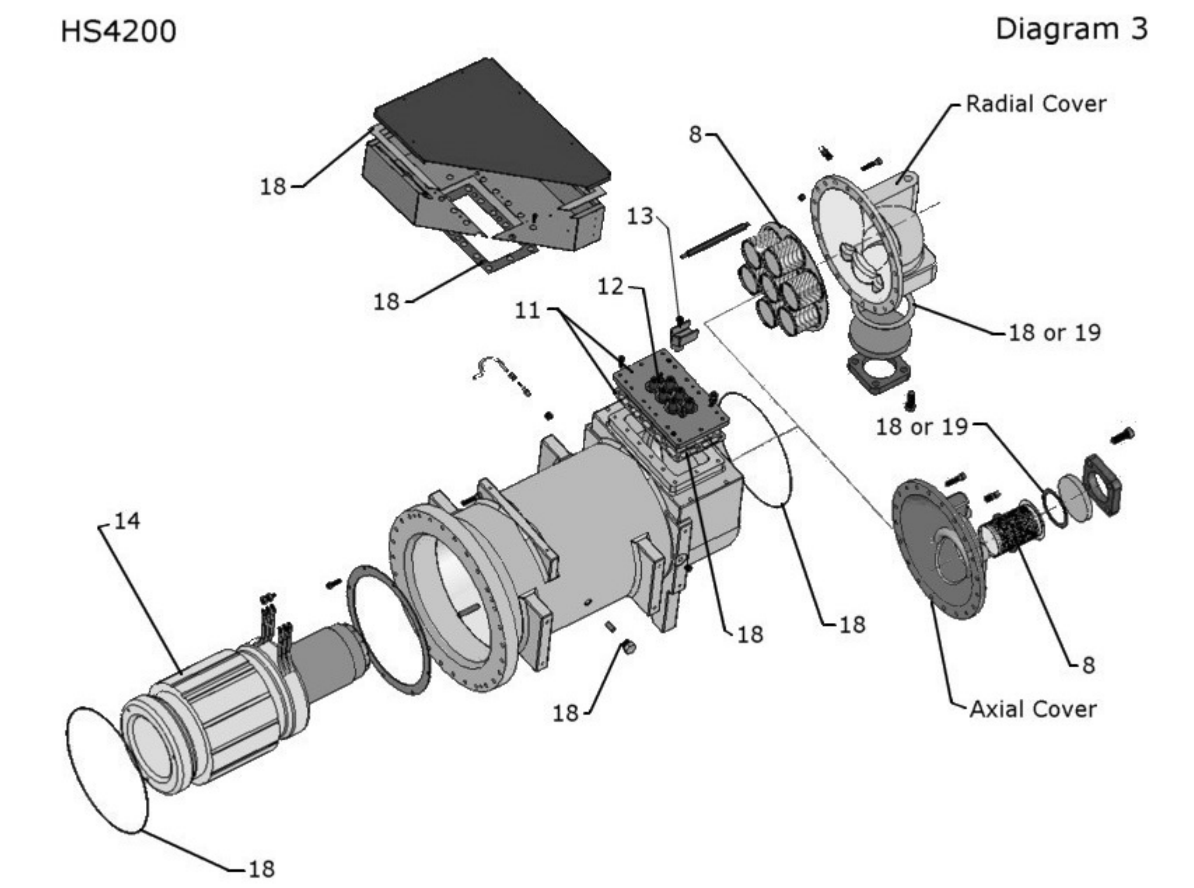


This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Appendix 4 HS 4200 Series Compressor Replacement Parts







Item	Diagram	Description	Part Number	Old Part Number	4221	4222	4223	
		Stars						
1	1	Hallplas Star Kit (also requires items 16 and 22)	N02280007	95813-401	1			
1	1	Hallplas Star Kit (also requires items 16 and 22)	N02280008	95814-401		1		
1	1	Hallplas Star Kit (also requires items 16 and 22)	N02280009	95815-401			1	
		Bearings						
2	1	Star Bearing Kit (also requires items 16 and 22)	N02050049	95813-404	1	1	1	
		Thermistors						
3	1	Discharge Thermistor 100 °C	N05060031	95814-502	2	2	2	
		Solenoid Valves						
4 & 5	1	Capacity Control Solenoid Valve Kit 115 V 50/60 Hz (Asco) (kit includes 2 valves and 2 coils)	N30010038	95823-415	1	1	1	
4 & 5	1	Capacity Control Solenoid Valve Kit 115 V 50/60 Hz (Sporlan) (kit includes 2 valves and 2 coils)	N30010041	95823-417	1	1	1	
5	1	Capacity Control Solenoid Valve Coil 115 V 50/60 Hz (Asco)	N30020034	131066074	2	2	2	
5	1	Capacity Control Solenoid Valve Coil 115 V 50/60 Hz (Sporlan)	N30020039	131066072	2	2	2	
4 & 5	1	Capacity Control Solenoid Valve Kit 230 V 50/60 Hz (Asco) (kit includes 2 valves and 2 coils)	N30010039	95823-416	1	1	1	
4 & 5	1	Capacity Control Solenoid Valve Kit 230 V 50/60 Hz (Sporlan) (kit includes 2 valves and 2 coils)	N30010042	95823-418	1	1	1	
5	1	Capacity Control Solenoid Valve Coil 230 V 50/60 Hz (Asco)	N30020047	131066073	2	2	2	
5	1	Capacity Control Solenoid Valve Coil 230 V 50/60 Hz (Sporlan)	N30020045	131066071	2	2	2	
		Capacity Control Piston						
6	1	Capacity Control Piston and Piston Ring Kit (also requires item 15)	N02630006	95814-407	1	1	1	

Item	Diagram	Description	Part Number	Old Part Number	3216	3218	3220	
		Filters						
7	1	Oil Filter (also requires item 17 or 22)	N02370008	95816-401	1	1	1	
8	3	Suction Filter (axial suction) (also requires item 18 or 22)	N12010011	87211-301	1	1	1	
8	3	Suction Filter (radial suction) (also requires item 18 or 22)	N02490009	132004007	1	1	1	
		Oil Heaters						
9	1	Compressor Oil Heater 110 V 400 W (direct immersion)	N19030041	2858-642	1	1	1	
9	1	Compressor Oil Heater 220 V 400 W (direct immersion)	N19030042	2858-643	1	1	1	
N/S	N/S	Oil Separator Heater 110 V 150 W	N19030016	132012025	1	1	1	
N/S	N/S	Oil Separator Heater 220 V 150 W	N19030015	132012001	1	1	1	
		Oil Heater Pocket						
N/S	N/S	Oil Separator Heater Pocket	N13390001	131506010	1	1	1	
		Capacity Control Slides						
10	2	Capacity Control Slide Kit 2.2 V_R (also requires items 16 and 22)	N02860008	95823-403	1			
10	2	Capacity Control Slide Kit 2.6 V_R (also requires items 16 and 22)	N02860009	95823-404	1			
10	2	Capacity Control Slide Kit 3.5 V_R (also requires items 16 and 22)	N02860010	95823-405	1			
10	2	Capacity Control Slide Kit 4.9 V_R (also requires items 16 and 22)	N02860011	95823-406	1			
10	2	Capacity Control Slide Kit 2.2 V_R (also requires items 16 and 22)	N02860012	95823-407		1	1	
10	2	Capacity Control Slide Kit 2.6 V_R (also requires items 16 and 22)	N02860013	95823-408		1	1	
10	2	Capacity Control Slide Kit 3.5 V_R (also requires items 16 and 22)	N02860014	95823-409		1		
10	2	Capacity Control Slide Kit 4.9 V_R (also requires items 16 and 22)	N02860015	95823-410		1		
10	2	Capacity Control Slide Kit 3.5 V_R (also requires items 16 and 22)	N02860016	95823-411			1	
10	2	Capacity Control Slide Kit 4.9 V_R (also requires items 16 and 22)	N02860017	95823-412			1	
		Motor Terminals						
11	3	Terminal Plate Kit (Europe and China) (also requires item 18 or 22)	N02470010	95812-423	1	1	1	
12	3	Motor Terminal (USA only) (also requires item 18 or 22)	N02480006	95812-424	6	6	6	
		Stators						
14	3	Stator 400 V 50 Hz 145 kW/460 V 60 Hz 174 kW (also requires item 18 or 22)	N02330008	95813-410	1	1	1	
14	3	Stator 400 V 50 Hz 232 kW/460 V 60 Hz 280 kW (also requires item 18 or 22)	N02330033	95813-416	1	1	1	
14	3	Stator 500 V 50 Hz 145 kW/575 V 60 Hz 174 kW (also requires item 18 or 22)	N02330009	95813-411	1	1	1	
14	3	Stator 230 V 60 Hz 174 kW (also requires item 18 or 22)	N02330010	95813-412	1	1	1	
14	3	Stator 208 V 60 Hz 174 kW (also requires item 18 or 22)	N02330011	95813-413	1	1	1	
14	3	Stator 380 V 60 Hz 174 kW (also requires item 18 or 22)	N02330012	95813-414	1	1	1	
		Capacity Indicators						
N/S	N/S	Capacity Indicator (HBLVDT) (calibration via suitable software within the plant controller)	N05390002	95822-413	1	1	1	
N/S	N/S	Capacity Indicator (HBLVDT) (calibration at the HBLVDT)	N05390006	95822-415	1	1	1	
N/S	N/S	Capacity Indicator (HBLVDT) Protective Cover	N02080030	119403516	1	1	1	
		Tube Kits						
N/S	N/S	Bearing Oil Supply Tube Kit (also requires item 24)	N02210015	95822-411	1	1	1	
		Capacity Control Piston Ring						
15	1	Piston Ring (Glyd Ring) and Gasket Set	N02630005	95814-205	1	1	1	
		Shims						
16	1	Shim Set	N02260012	92848-405	1	1	1	

Item	Diagram	Description	Part Number	Old Part Number	3216	3218	3220	
		Gasket Sets						
17	1	Oil Filter Replacement Gasket and 'O' Ring Set	N33010027	128810988	1	1	1	
18	3	Motor Replacement Gasket and 'O' Ring Set	N33010037	128810983	1	1	1	
19	3	Suction Connection Gasket (axial suction)	N33070011	M350233902	1	1	1	
19	3	Suction Connection Gasket (radial suction)	N33100006	130609266	1	1	1	
20	1	Discharge Connection Gasket	N33070010	M350233901	1	1	1	
22	1	Full Gasket and 'O' Ring Set	N33010040	128810989	1	1	1	
		Oils						
N/S	N/S	J & E Hall Ester Oil	TBA	TBA	19 lit	19 lit	19 lit	
N/S	N/S	J & E Hall Mineral Oil	TBA	TBA	19 lit	19 lit	19 lit	

Obtain replacement parts from the address below:

J & E Hall International
Hansard Gate,
West Meadows,
Derby,
DE21 6JN
England

Telephone: +44 (0) 1332-253400
Fax: +44 (0) 1332-371061
E mail: jehall.derby@dial.pipex.com
Website: www.jehall.co.uk

The compressor design and construction is subject to change without prior notice.

Appendix 5 Plant Performance Record

It cannot be too strongly emphasised that the regular and accurate logging of plant performance data makes an important contribution to safety, efficiency and reliability, by ensuring that the plant operates within the design conditions. This important point is highlighted in BS EN 378-2 : 2000. If variations from normal are noted without delay, steps can then be taken immediately to discover and, if necessary, rectify the cause.

When consulting J & E Hall International about the operation of the plant, send a copy of the performance record.

Methods of Recording Data

There are a number of different methods of recording and storing this information. A popular method for small plants is the traditional, hand-written log sheet. For large plants a better method would be a computer database, or a plant monitoring system with a data-logging facility.

When designing a log sheet for the plant, either on paper or as an electronic form held in a computer database, there are certain pressures, temperatures and flow rates which are common to nearly every plant; these are shown on the typical log sheet. Other variables, equally important, are peculiar to different plants; these must be observed and logged to obtain a complete picture of performance.

Log Book

Completed log sheets should be collated to form a log book. Basic information about the plant should be recorded at the front of the log book.

- Title.
- Plant location.
- Date plant was commissioned.
- Compressor model and serial number(s).
- Refrigerant and quantity of charge.
- Type and method of refrigerant regulation.
- Condenser type and cooling medium.
- Evaporator type and cooled medium. For aqueous solutions, for example alcohols, brines or glycols, record the % concentration and specific gravity.

It is also recommended to record the following information:

- Details of all maintenance and repair work.
- The quantity of refrigerant charged or removed from the system.
- The quantity and grade of oil added or drained from the system.
- Changes and replacement of components.
- The results of all tests.
- Trip events and their cause.

DATE										
TIME										
LOG TAKEN BY										
COMPRESSOR										
Hours Run............										
% Capacity............										
Net Oil Pressure at Compressor............										
Oil Temperature (°C)............										
COMPRESSOR MOTOR										
Speed (rpm)............										
Volt										
Amp										
[1]**GAUGE TEMPERATURES**										
Evaporator (°C)										
Suction (°C)										
Intermediate (°C)............										
Discharge (°C)										
Economiser (°C)............										
Refrigerant Temperatures										
At Evaporator (°C)............										
LP Suction (°C)										
LP Discharge (°C)										
HP Discharge (°C)										
Economiser (°C)............										
[2]**OIL COOLER COOLING MEDIUM**										
Inlet Temperature (°C)										
Outlet Temperature (°C)............										
Rate of Flow (m^3/h)										
CONDENSER COOLING MEDIUM										
Inlet Temperature (°C)										
Outlet Temperature (°C)............										
Rate of Flow (m^3/h)										
[3]Ambient Dry Bulb Temperature (°C).........										
[3]Ambient Wet Bulb Temperature (°C)........										
EVAPORATOR COOLED MEDIUM										
Inlet Temperature (°C)										
Outlet Temperature (°C)............										
Rate of Flow (m^3/h)										
LIQUID REFRIGERANT TEMPERATURES										
At the Condenser Outlet (°C)										
Before the Regulator (°C)............										

[1]It is also desirable to give the gauge temperature readings approximately 15 minutes after the plant has stopped.
[2]Required for refrigerant or water cooled oil cooling.
[3]Required for air cooled or force draught evaporative condensers.

Appendix 6 Pepperl & Fuchs Signal Conditioning Module KFU8-USC-1.D Set-up

Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

Refer to Table 5.

The KFU8-USC-1.D module can be used simply to calibrate the output from the MSI LVDT to provide 4 mA and 20 mA signals, at the compressor minimum and maximum slide valve positions respectively, by following the instructions in Table 5. Setting the 'Start Value' (at minimum load) and setting the 'End Value' (at maximum load) are independent processes. The End Value setting can be made at any time after the Start Value setting. The values can be reset at any time. If necessary, the unit can be reset to the factory settings by following the instructions in the Pepperl & Fuchs manual included with the unit.

Setting the Display to Read 0 at Minimum Load and 100 at Maximum Load

Refer to Table 6.

This procedure is optional and not necessary for the basic calibration of the signal from the MSI LVDT, however it is useful for setting a slide valve position for the relay switch. It also provides a visual display of the slide position as if it were a percentage value.

> **NOTE: although '%' is a unit option in the module, this cannot be used as the units for this application because it has a pre-programmed function which does not allow the required 'Factor' to be set up (also 'mA' cannot be used as a unit because this is the same as the input units). It is therefore recommended that 'l' is used for the units; this allows the 'Zero' and 'Factor' to be set to give the 0 to 100 numerical values required even though the actual unit is not meaningful.**

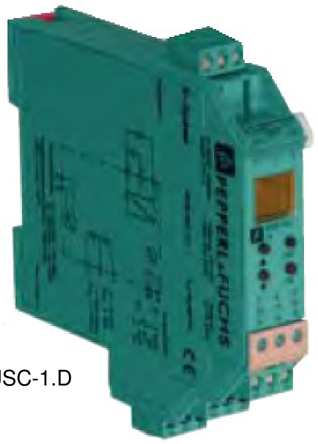
Unless the 'units' are reconfigured, the value displayed on the module is always the actual **input value** in mA from the LVDT. This is not particularly meaningful for the user.

To set the relay switch trip point, the value must be in the units displayed, so if not reconfigured, this would need to be calculated from the input mA for a given slide valve position. It is therefore easier to set the trip point if the display reads 0 at minimum load and 100 at maximum load, then the switch point trip value can be set as if it were a percentage slide valve position.

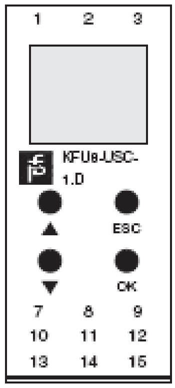
Setting the Relay Switch Value

Refer to Table 7.

Once the display units have been reconfigured to 'l' and the display values at minimum and maximum load slide positions are 0 and 100 respectively, the switch (Trip) point can be set as a value as if it were a percentage. The 'Hysteresis' value can also be set as equivalent to a percentage. Depending on how it is required for the switch hysteresis to operate with rising and falling values, the module can be configured accordingly; refer to the note at the bottom of Table 7. This is also demonstrated fully in the Pepperl & Fuchs manual included with the unit).



KFU8-USC-1.D



Display

Slide Valve Position	Action	Input		Output	
		Display	Comment	Value	Comment
Minimum load	Record value displayed on unit	6.235 mA	For example	6.235 mA	Start
	Press buttons on Display:				
	ESC + OK (together)	Unit			
	▼	Input			
	▼	Output			
	OK	Relay			
	▼	Analogue Out			
	OK	Characteristic			
	OK	0 to 20 mA	'Flashing'		
	▼	4 to 20 mA NE4	'Flashing'	6.235 mA	
	OK	4 to 20 mA NE4	Set (saved)	9.0 mA	Temporary value
	ESC	Characteristic			
	▼	Start Value			
	OK	Numeric			
	▼	Teach In			
	OK	6.235 mA	'Flashing'	9.0 mA	
	OK	6.235 mA	Start value saved	4 mA	Minimum load set
	ESC	Teach In			
	ESC	Start Value			
	ESC	Analogue Out			
	ESC	Output			
Minimum load	ESC	6.235 mA	Default screen	4 mA	

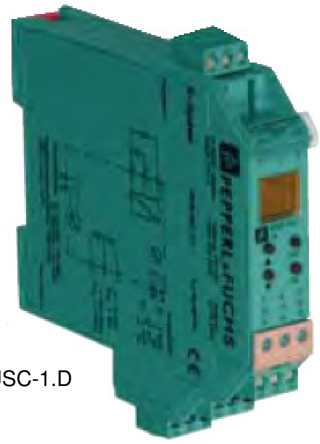
Table 5 Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

Slide Valve Position	Action	Input		Output	
		Display	Comment	Value	Comment
Maximum load	Record value displayed on unit	15.76 mA	For example	15.1mA	Temporary value
↓	Press buttons on Display			↓	
	ESC + OK (together)	Unit			
	▼	Input			
	▼	Output			
	OK	Relay			
	▼	Analogue Out			
	OK	Characteristic			
	▼	Start Value			
	▼	End Vlaue			
	OK	Numeric			
	▼	Teach In			
	OK	15.76 mA	'Flashing'	15.1 mA	
	OK	15.76 mA	End value saved	20 mA	Maximum load set
	ESC	Teach In		↓	
	ESC	End Value			
	ESC	Analogue Out			
	ESC	Output			
Maximum load	ESC	15.76 mA	Default screen	20 mA	Finish
Minimum load		6.235 mA		4 mA	

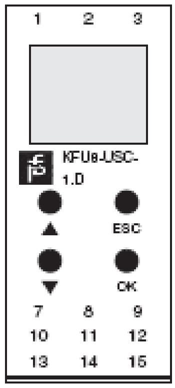
NOTE: Setting the 'Start Value' (at minimum load) and setting the 'End Value' (at maximum load) are independent processes. The End Value setting can be made at any time after the Start value setting.

Table 5 (continued) Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

This procedure is optional but recommended for easy set up of the relay switch point (if used); refer to Table 7



KFU8-USC-1.D



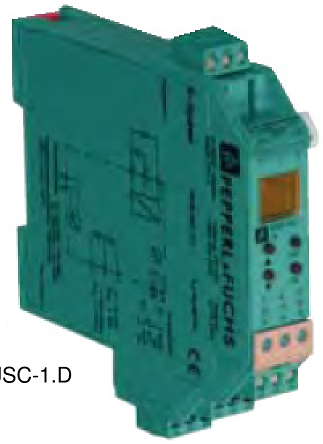
Display

Slide Valve Position	Action	Input		Output Value
		Display	Comment	
[1]Min load		6.235 mA	For example	4 mA
↓	Press the following buttons			↓
	ESC+OK (together)	Unit		
	OK	mA	'Flashing'	
	▼	[2]%	'Flashing'	
	▼	[2]l	'Flashing'	
	OK	[2]l	Unit set	
	ESC	Unit		
	▼	Input		
	OK	Type		
	▼	Zero		
	OK	4.000	'Flashing'	
	▲ ▼	6.23 mA	Set value = min load input value	
	OK	6.23 mA	Zero set	
	ESC	Zero		
	▼	Factor		
	OK	1.000	'Flashing'	
	▲ ▼	10.49	Set value = 100/(15.765 - 6.235)	
	OK	10.49	Multiplying factor set	
	ESC	Factor		
	ESC	Input		
Min load	ESC	0.000	% slide valve setting	4 mA
Max load		100.0	% slide valve setting	20 mA

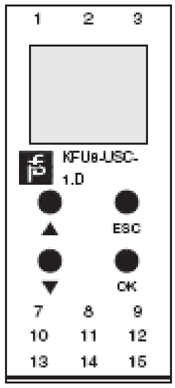
[1]Operation can be done with the slide valve in any position.
[2]The unit of % cannot be chosen for this application because of the special functionality given to it inbuilt in the unit (for example, if % is chosen as the unit then the required Factor cannot be set). Therefore it is suggested that 'l' is chosen as the unit for simplicity although it must be recognised that for this application the unit does not any real meaning, i.e. the value is dimensionless or can be interpreted as a percentage value.

Table 6 Setting the Display to Read 0 at Minimum Load and 100 at Maximum Load

Set the display to read 0 at minimum load and 100 at maximum load before setting the relay switch value



KFU8-USC-1.D



Display

Slide Valve Position	Action	Input		Output Value
		Display	Comment	
[1]Min load		0.000	For example	4 mA
	Press the following buttons			
	ESC + OK (together)	Unit		
	▼	Input		
	▼	Output		
	OK	Relay		
	OK	[2]MIN/MAX	Default set to MIN	
	▼	Trip		
	OK	102.4	For example 'Flashing'	
	▲ ▼	70.00	Set value (for example) 'Flashing'	
	OK	70.00	Trip value set	
	ESC	Trip		
	▼	Hysteresis		
	OK	20.98	For example 'Flashing'	
	▲ ▼	2.000	Set value (for example) 'Flashing'	
	OK	2.000	Hysteresis value set	
	ESC	Hysteresis		
	ESC	Relay		
	ESC	Output		
Min load	ESC	0.000		4 mA

[1]Operation can be done with the slide valve in any position.
[2]MIN setting will make/break switch at Trip value when value is falling. When value is rising, the switch will break/make at the Trip value + Hysteresis value. MAX setting will make/break switch at Trip value when value is rising. When value is falling, the switch will break/make at the Trip value – Hysteresis value; refer to pages 18 and 19 of the Pepperl & Fuchs manual included with the unit.

Table 7 Setting the Relay Switch Value

Questor House, 191 Hawley Road, Dartford, Kent DA1 1PU England
Telephone: +44 (0) 1322 223 456 Facsimile: +44 (0) 1322 291 458
www.jehall.co.uk