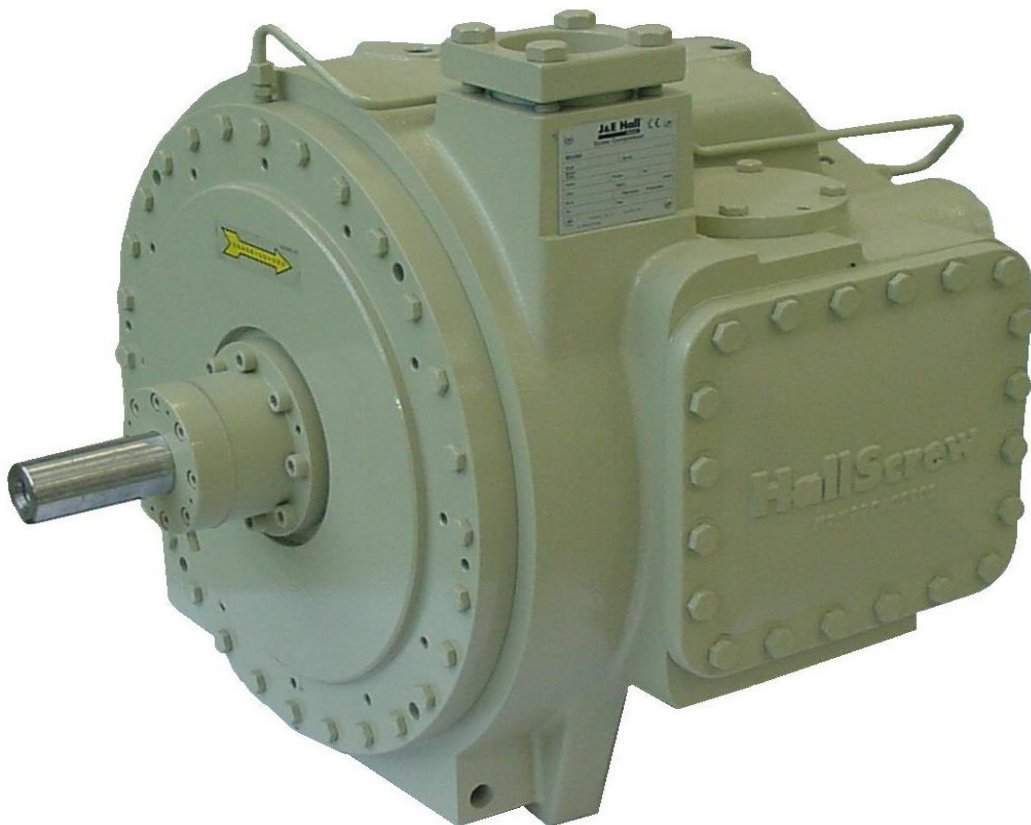


HallScrew HSO 4200 Series
Open Drive Single Screw Compressors

HSO 4221, HSO 4222 and HSO 4223

Installation, Operation and
Maintenance Manual



J & E Hall International® 2009

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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.

WARNING

A minimum of two personnel should always be present when working on ammonia refrigeration plant.

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).

Ammonia Refrigerant 717

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.

Ammonia, refrigerant R717, is a colourless gas with a very powerful characteristic smell which is so pungent that it is unpleasant at concentrations too low to be considered dangerous.

Ammonia has inherent material and physiological hazards. A limited range of ammonia/air mixtures (16 % to 27 % ammonia by volume) can be ignited by a naked flame and an explosion may result. While ammonia is not a cumulative poison, exposure will cause chemical burns and can destroy body tissue. Because of ammonia's high affinity with water, moist areas of the skin, breathing passages and the eyes, are areas particularly susceptible to damage.

Maintenance procedures must not be carried out unless adequate fan assisted ventilation has been provided to avoid any risk of explosion or physiological harm. Naked flame must not be permitted in the area. Personnel carrying out maintenance procedures must have a respirator of the correct type ready to wear at all times.

Exits and gangways from areas where ammonia is used or stored must be kept clear and free from obstructions to permit rapid evacuation if there is a serious escape of ammonia. Locations from which evacuation can only be carried out with difficulty must be designated 'gas mask areas'. All persons entering such areas must be thoroughly trained in the use of respirators and carry one at the ready.

When purging ammonia or draining oil from the plant, it is essential to use a purge apparatus as a precaution against ammonia escaping into the plant room.

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. Ordering Extra Copies

Obtain extra copies of these instructions from the address below:

J & E Hall International	Telephone: +44 (0) 1634-731-400
Engineering & Projects,	Fax: +44 (0) 1634-731-401
Invicta House,	Email: helpline@jehall.co.uk
Sir Thomas Longley Road,	Website: www.jehall.co.uk
Medway City Estate,	
Rochester,	
Kent ME2 4DP	
England	

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 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) On all systems other than those using R717 (ammonia), fit an adequately sized refrigerant filter/drier, preferably of the type using renewable cores. Fit a sight-glass/moisture indicator.
- (b) If it is necessary to fit an external oil filter (refer to 6.8. Oil Filter), the filter must be adequately sized and to the specification described in Table 1.
- (c) Fit an adequately sized suction strainer having a mesh aperture of 250 μ or better.
- (d) 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 250 μ or better.
- (e) 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.

- (f) 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.
- (g) Under certain operating conditions, the compressor will need cooling; refer to the HSO 4200 Series Compressor Application Manual and publication 2-122 Compressor Cooling, available from J & E Hall International.

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.

- (h) 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 HallScrew compressor be operated with cut-outs or other safety devices short-circuited or rendered inoperative by mechanical or electrical means.

- (i) The plant controller is required to supply load/unload pulses to the capacity control solenoid valves; refer to 4.2. Continuously Variable Capacity Control.

The control system must be interlocked to prevent the compressor starting unless the slide valves are at minimum load; refer to 4.1.1.

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.

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 10.8. 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) Connect and use the discharge high temperature thermistors, fitted as standard and should be wired as illustrated in Fig 11.
- (e) Connect the compressor drive motor such that the compressor rotates clockwise when looking on the compressor shaft end (driven end); refer to 10.4. Checking Compressor Rotation.

3. General Description

The J & E Hall International HSO 4200 series of open drive 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 have been specially developed for refrigeration, air conditioning and heat pump applications, and can be applied to single stage and multi-stage systems using all normal refrigerants as well as many other process gases.

3.1. Main Features

- For use with R717 (ammonia), R22, R404a, R507a, R134a, R407c, R410a and R23.
- 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, choice of suction connections.
- 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.

- Thermistor discharge gas high temperature protection.
- Built-in oil filter.
- Clockwise rotation looking on the motor (driven) end for gas engine drive without intermediate gearbox.

3.2. Construction

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/main shaft assembly is supported by an arrangement of rolling element bearings. This entire assembly is dynamically balanced. Where the shaft emerges from the casing, leakage of oil or refrigerant is effectively prevented by a specially designed mechanical seal.

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 ports. 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 suction connection, mounted on one side cover, can be taken from either side of the compressor.

It is necessary to fit a suction strainer immediately before the compressor suction inlet. The strainer is 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

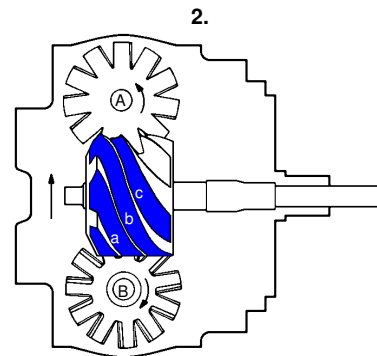
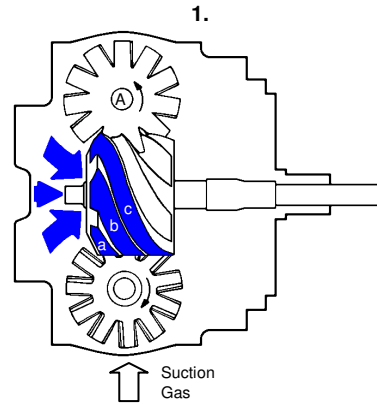
With single screw compressors the suction, compression and discharge process occurs in one continuous flow at each star wheel. In this process the suction gas fills the profile between rotor, star tooth and casing. The volume is steadily reduced and the refrigerant gas thereby compressed. The high-pressure 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

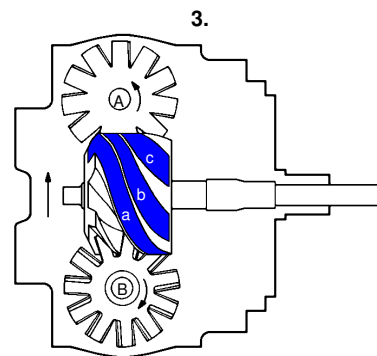
Main rotor flutes 'a', 'b' and 'c' are in communication at one end with the suction chamber via the bevelled rotor end face, and are sealed at the other end by the teeth of star rotor A. As the main rotor turns, the effective length of the flutes increases with a corresponding increase in the volume 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.



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.



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).

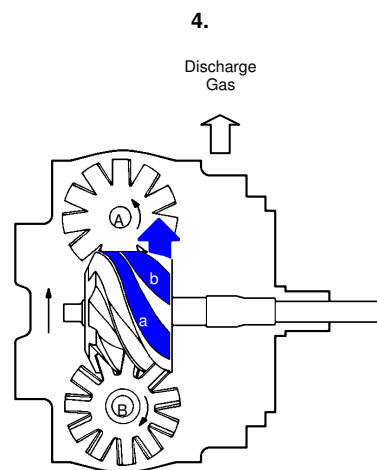


Fig 1 Compression Process

4. Capacity Control and Volume Ratio

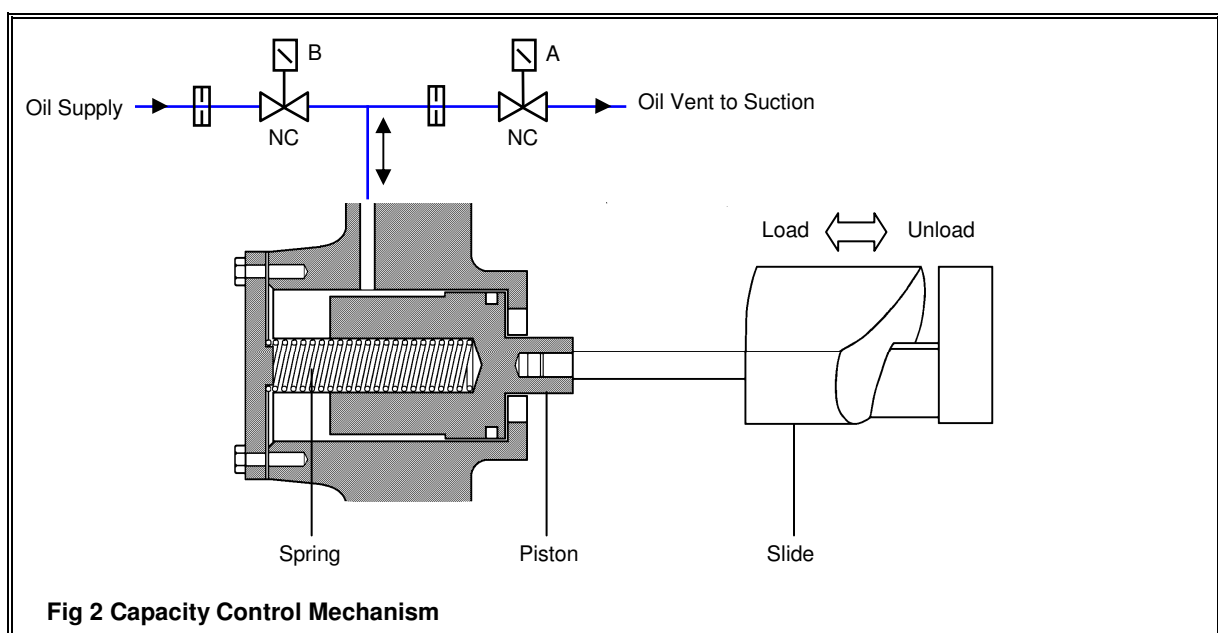
HallScrew 4200 series compressors are provided with infinitely variable capacity control as standard.

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.

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.

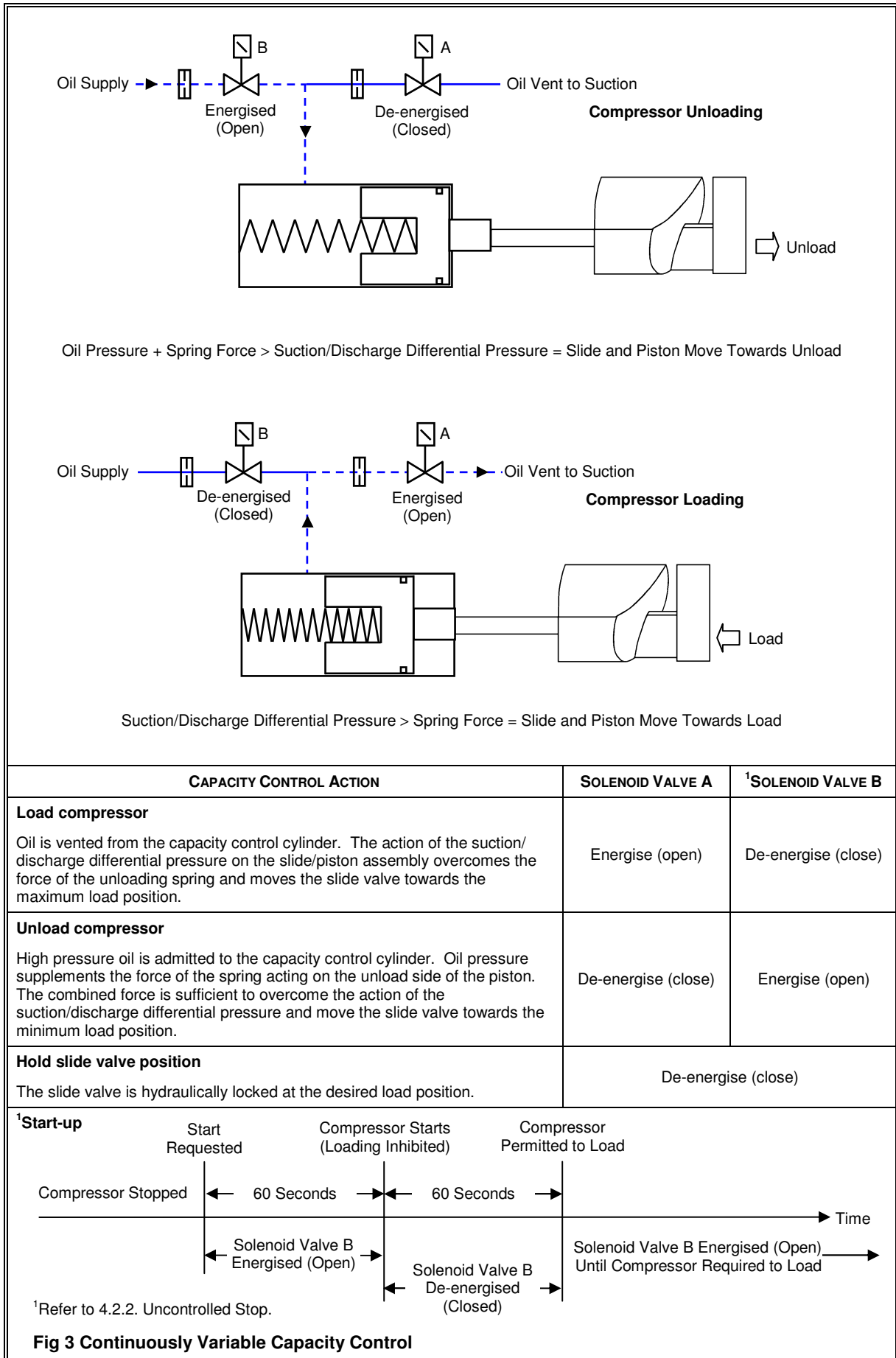
4.2.1. Controlled Stop

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; refer to Fig 3.

4.3. Capacity Control by Inverter Drive

Instead of using the slide valve, compressor capacity can be controlled using a frequency inverter (also known 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 be 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.

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 4.6.

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.

4.5.1. 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.

4.5.2. 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).

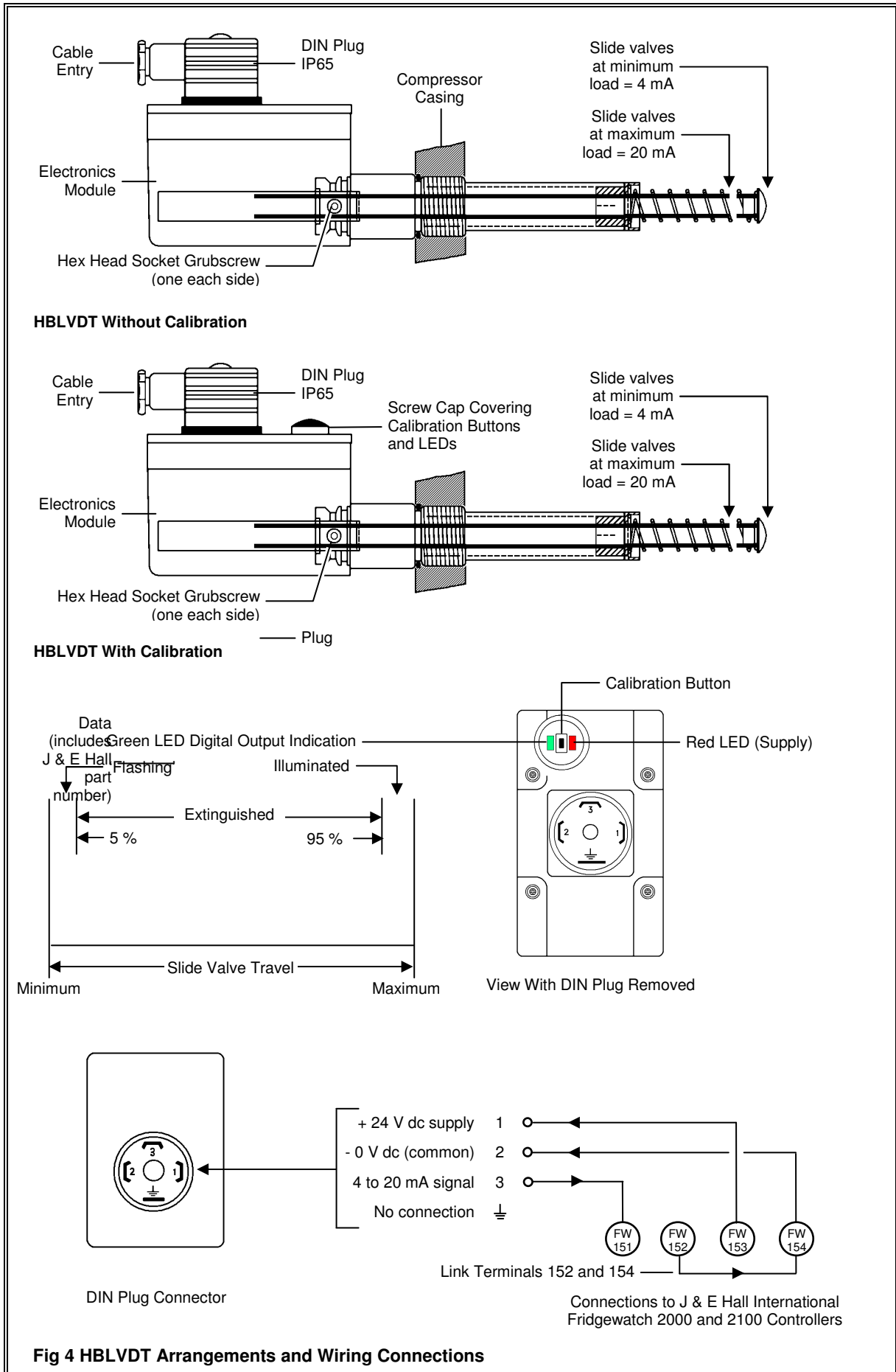


Fig 4 HBLVDT Arrangements and Wiring Connections

- (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.

4.5.3. 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 4.5.1. or 4.5.2.

4.6. 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.

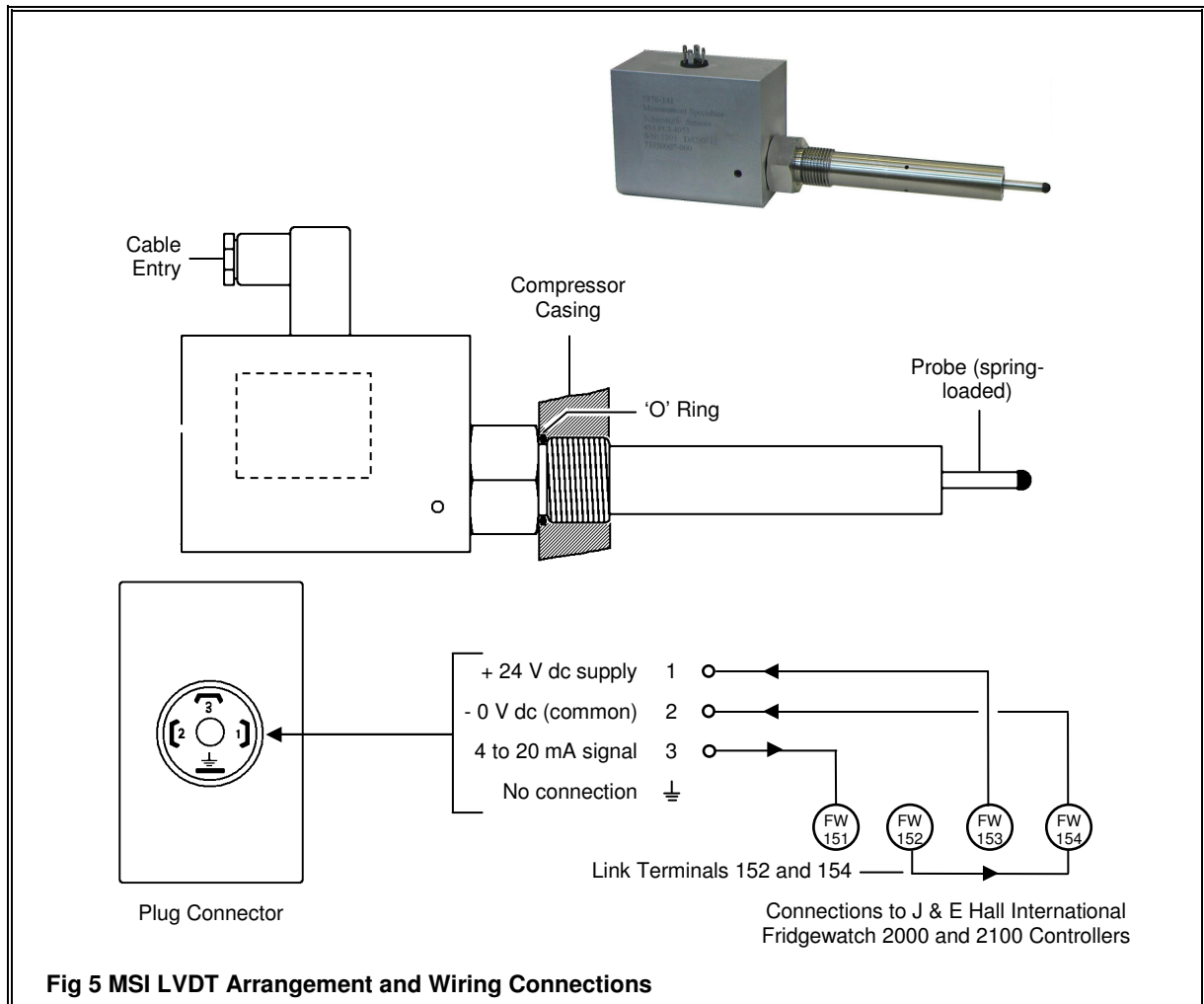
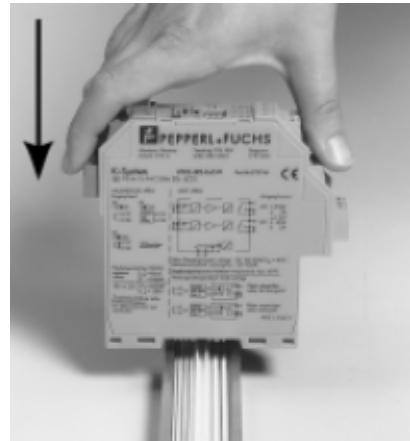


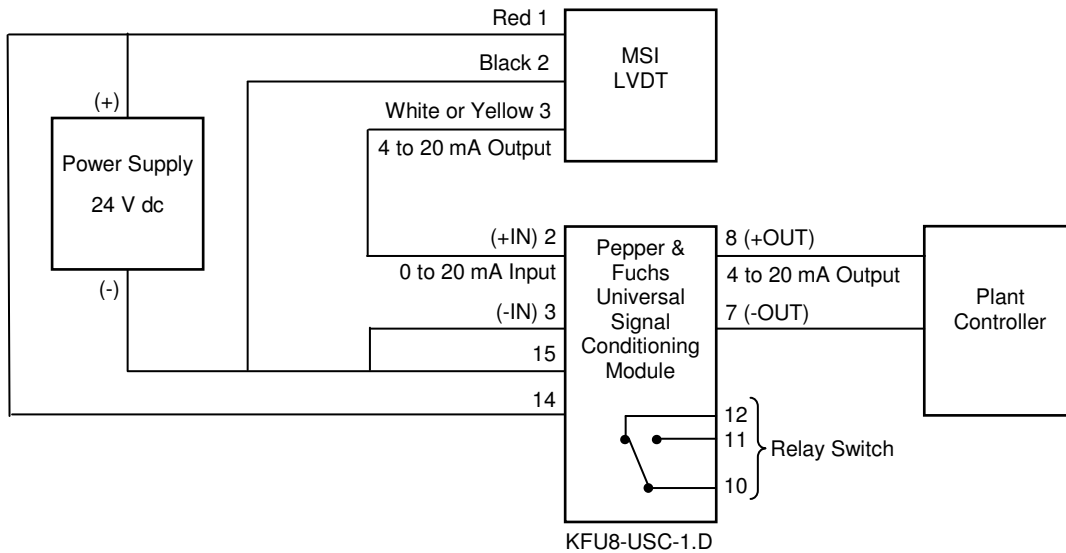
Fig 5 MSI LVDT Arrangement and Wiring Connections



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

HSO 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.

CAUTION

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 four 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. Shaft Seal Lubrication, Sealing and Cooling

The main shaft gland seal is a balanced mechanical type comprising a rotating, spring-loaded sealing face element fixed to the shaft and a stationary sealing face element located in the cover plate attached to the shaft seal housing. Each sealing face has a highly polished optically flat surface separated by a thin oil film which provides an effective seal to minimise oil/refrigerant leakage.

The seal assembly is supplied with oil via an external pipe from a connection on the non-driven end of the compressor. The oil both lubricates the moving surfaces and carries away the heat generated at the gland seal faces. After flowing through the gland, the oil drains into the main casing.

5.4. Oil Injection for Sealing and Cooling

The fourth 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 6.10. Compressor Cooling.

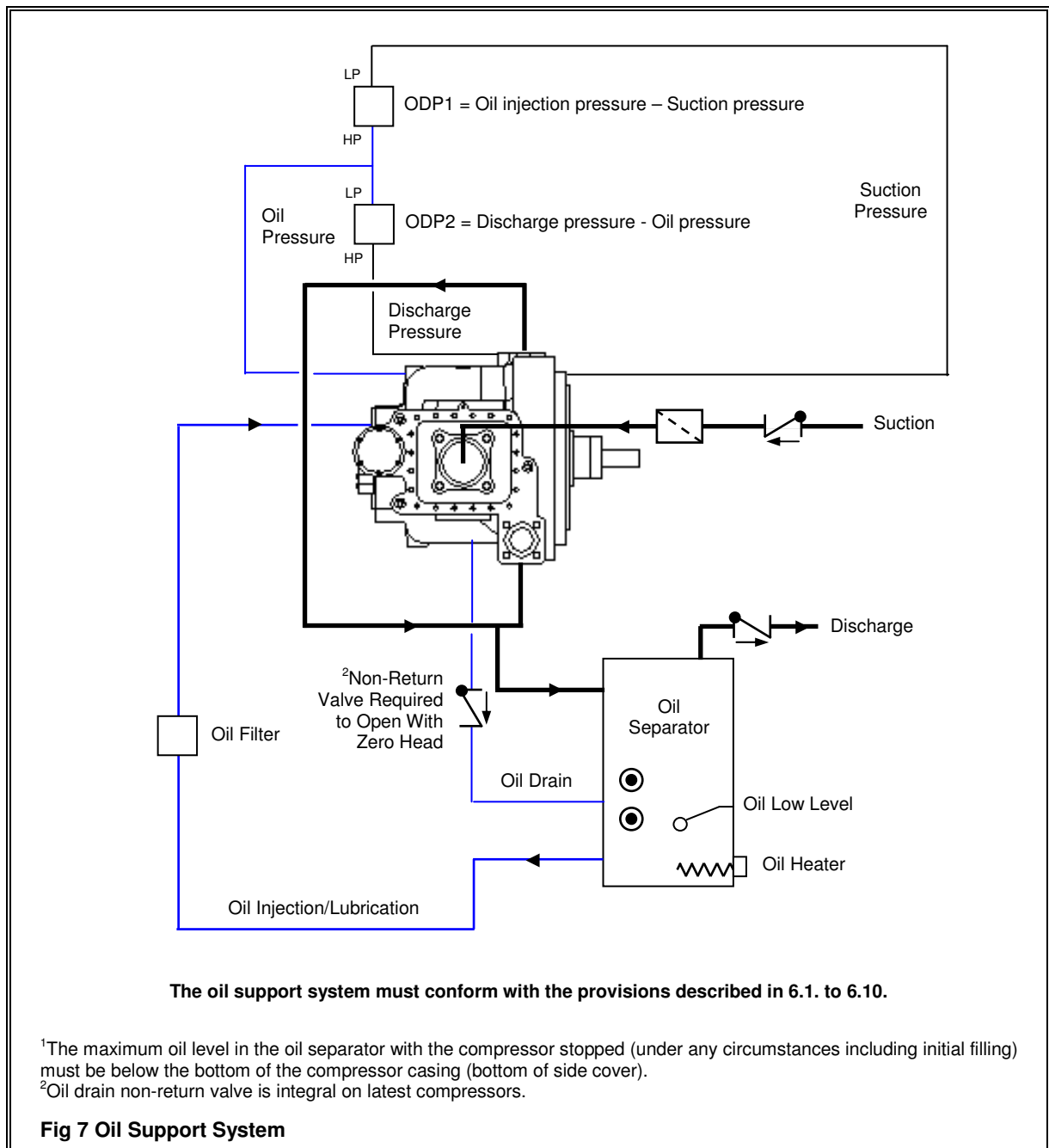
6. Oil Support System

HSO 4200 series compressors require an external oil separator and oil support system; refer to Fig 7.

CAUTION

The system into which the compressor is to be installed must fully comply with the recommendations in 6.1. to 6.10. 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.



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. On the latest compressors the oil drain connection is fitted with an internal non-return valve. On older compressors the non-return valve is fitted in the drain line.

To ensure the oil drain line functions correctly:

- The oil separator must be sized and positioned to provide 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 6.3.1):

- 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 two solenoid valves must be provided in the oil injection line in parallel – one corresponding to the normal line size and a smaller one with flow coefficient $K_v < 1.0$. The smaller solenoid valve must be energised on compressor start and the main solenoid valve electrically interlocked to energise (open) when the delta contactor of the compressor starter is energised. The smaller solenoid valve can remain energised. Both solenoid valves must be de-energised (closed) when the compressor stops. For inverter drives, the main oil injection solenoid valve 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 Diagram

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 Heater

The separator must be fitted with an oil heater of sufficient capacity to maintain an oil temperature 20 °C above the ambient temperature, thereby preventing refrigerant migration into the oil and the resultant loss of viscosity and potential foaming. The oil heater 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. 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.

6.4.5. Dual Compressors Circuits

Refer to J & E Hall International.

6.5. Booster, Low Stage or Low Pressure Difference Applications

HSO 4200 series compressors may not be suitable for low pressure difference applications. Ask J & E Hall International.

6.6. Oil Differential Pressure Monitoring

As already described in 5. Compressor Lubrication, Sealing and Cooling, HSO 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.

6.6.1. 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.

$$\text{ODP1} = \text{Oil injection pressure} - \text{Suction pressure}$$

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 2×3.0 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.

6.6.2. 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.

$$\text{ODP2} = \text{Discharge pressure} - \text{Oil injection pressure}$$

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.

6.7. Maintaining Discharge Pressure at Start up

Because oil pressure is generated by discharge pressure, a minimum discharge pressure must be maintained, this minimum pressure increases as suction pressure increases in order to maintain the required pressure differential.

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.

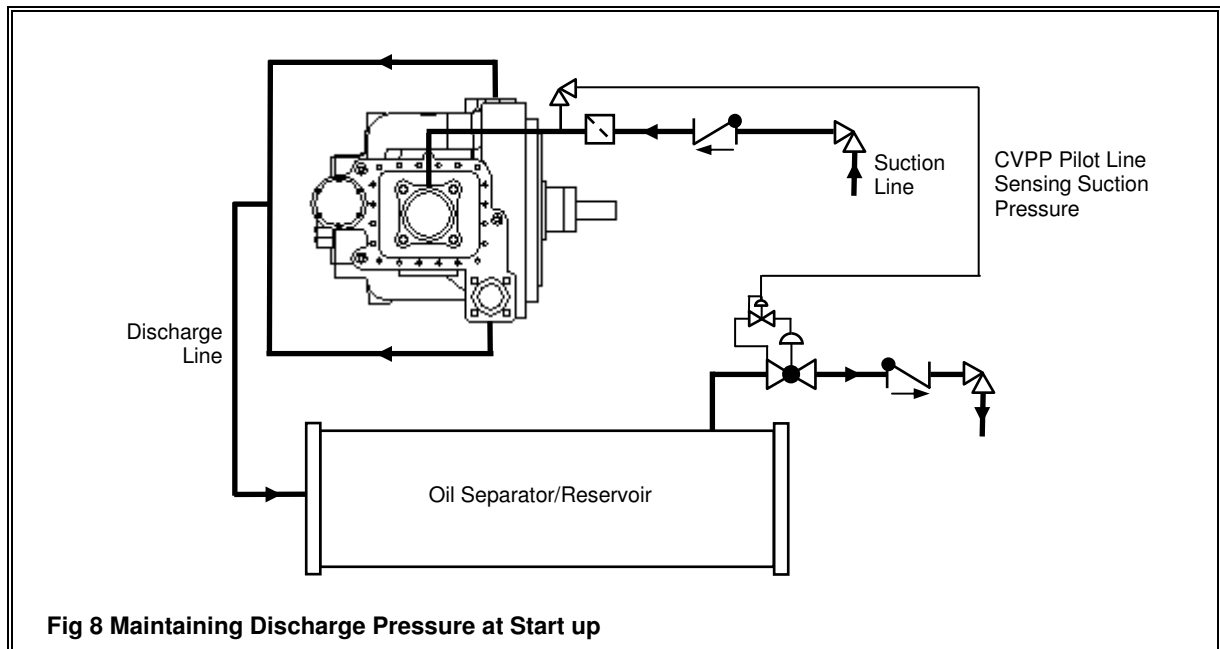


Fig 8 Maintaining Discharge Pressure at Start up

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.

6.8. Oil Filter

HSO 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 the system oil and refrigerant. As refrigerant R717 (ammonia) attacks copper, nickel, tin, zinc and cadmium, filter components containing these metals or their alloys are prohibited from ammonia refrigeration systems.		
Table 1 Oil Filter Minimum Specification		

6.9. Lubricating Oils

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

As choosing the correct lubricant is essential for compressor reliability and optimum system performance, this issue is discussed in detail in publication 2-59 Lubricating Oils.

6.10. 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.

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

7. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type and 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 recommendation 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.

7.2.2. Suction Strainer

HSO 4200 compressors are not fitted with a suction strainer. An adequately sized suction strainer must therefore be fitted in the suction line. 250 micron mesh size is recommended.

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

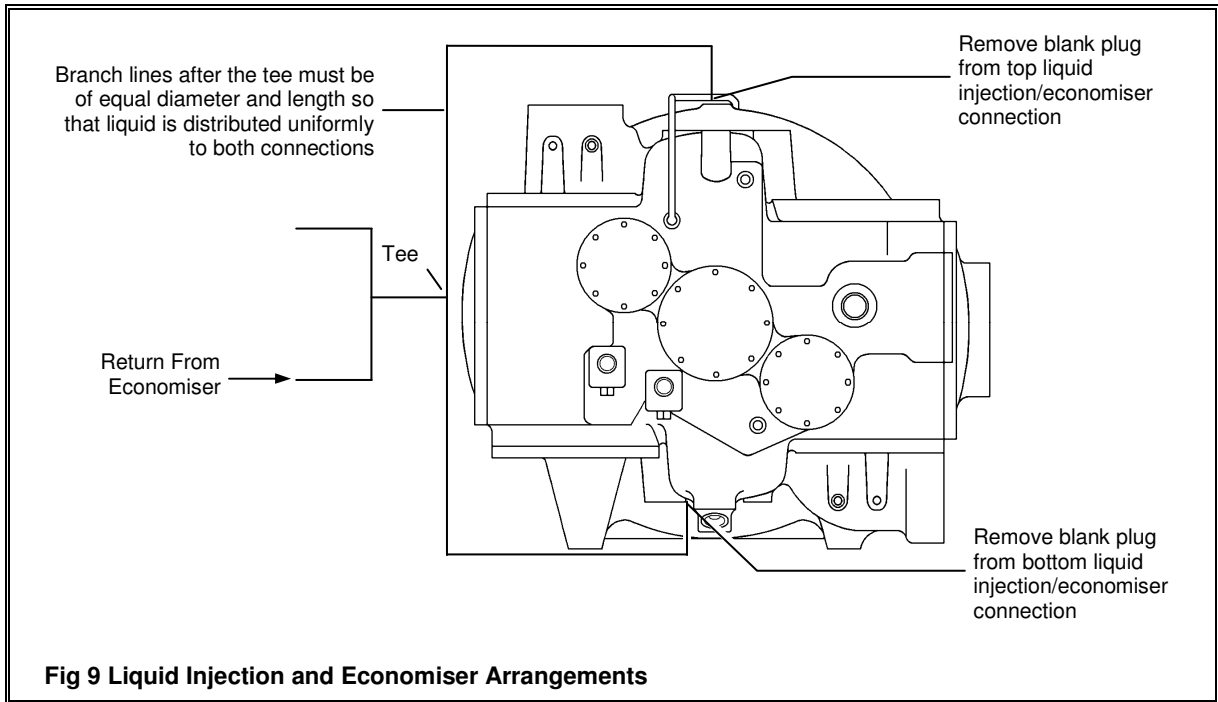
Adequate discharge superheat is essential in order to prevent excessive liquid refrigerant dilution of the oil in the separator. If excessive refrigerant is present then oil viscosity will be reduced to an unacceptable level. The main problem however, is that for a small change in discharge pressure 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 and Economiser Connections

For liquid injection cooling a thermostatic or electronic liquid injection valve can be used. If liquid injection and economiser are required, refer to Fig 9.

7.5. 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.

NOTE: the above precautions are equally applicable to other items of equipment fitted with rolling element bearings, for example, drive motors and pumps.

During the time in store, it is very important that the compressor mainshaft is not rotated as this will tend to remove the film of grease protecting the gland seal faces, described in step (b), below.

- (b) To prevent damage to the gland seal faces, these surfaces should be lightly greased before the compressor is placed in store.

If the compressor drive half coupling is already fitted, this must be removed from the mainshaft. Purge the holding charge of nitrogen from the compressor.

Dismantle the gland assembly and lightly grease the seal faces. The correct grade of grease to use is Aviation Grease No 14DID5609, Specification: Aviation Grease No 14 DEF STAN 91/81-1 (available from J & E Hall International – part number 6764-102).

NOTE: grease is applied to the gland seal faces to keep the two surfaces apart during storage as prolonged stationary contact may cause molecular bonding between the carbon faces, resulting in damage to the seal when the compressor is started.

Reassembly the gland. Re-evacuate the compressor to a pressure of 2 mm Hg absolute, or lower, and charge with dry nitrogen to a pressure above atmospheric (0.7 bar g to 1 bar g); this will prevent ingress of air and moisture which can result in oxidation. Check for leaks.

NOTE: the film of grease between the two gland seal faces will not necessarily produce a perfect seal and a pressure higher than that recommended may force the grease from between the faces. Even at this low pressure a leak may occur but provided that this is not excessive the inert atmosphere within the compressor will be maintained.

At the end of the period in store, the protective grease must be removed and the sealing faces inspected for damage prior to installing and running the compressor; refer to 8.2. Taking the Compressor out of Storage.

- (c) Suitably protect the compressor mainshaft extension from moisture and external damage by coating the shaft with Shell Enis Fluid MD or a thin film of grease, then covering with a plastic or rubber sleeve. External fittings, if any, should also be protected from damage.
- (d) Leak test the compressor at frequent intervals to ensure that it retains the holding charge of nitrogen; refer to the **NOTE** in step (b). If pressure gauges are fitted these can be checked for a decrease.
- (e) Carry out any special instructions for the long term storage of the compressor drive motor (if supplied); refer to the manufacturer's instructions.

8.2. Taking the Compressor out of Storage

At the end of the period in store, the following procedure should be adopted before the initial start in order to minimise the possibility of damage.

NOTE: specially negotiated guarantee terms to cover 'stored compressors' will not be honoured unless these procedures are followed.

- (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) Remove the protective sleeve from the compressor mainshaft extension. Clean off the grease or, if Shell Enis Fluid MD was used, use white spirit or similar solvent to remove the protective film.
- (c) Dismantle the gland assembly. Carefully clean the protective grease from the seal faces. If the faces are in a satisfactory condition they should be lightly oiled and the gland reassembled; if they are damaged, a new seal must be fitted.
- (d) If necessary, refit the compressor drive half coupling. If the drive coupling is supplied by J & E Hall International, refer to publication 2-79.
- (e) Finish installing the compressor as described under 9. Installing the Compressor.

Protecting the gland seal faces with grease can result in the gland needing rebedding-in, and might therefore, leak a small amount during the running-in period.

9. Installing the Compressor

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

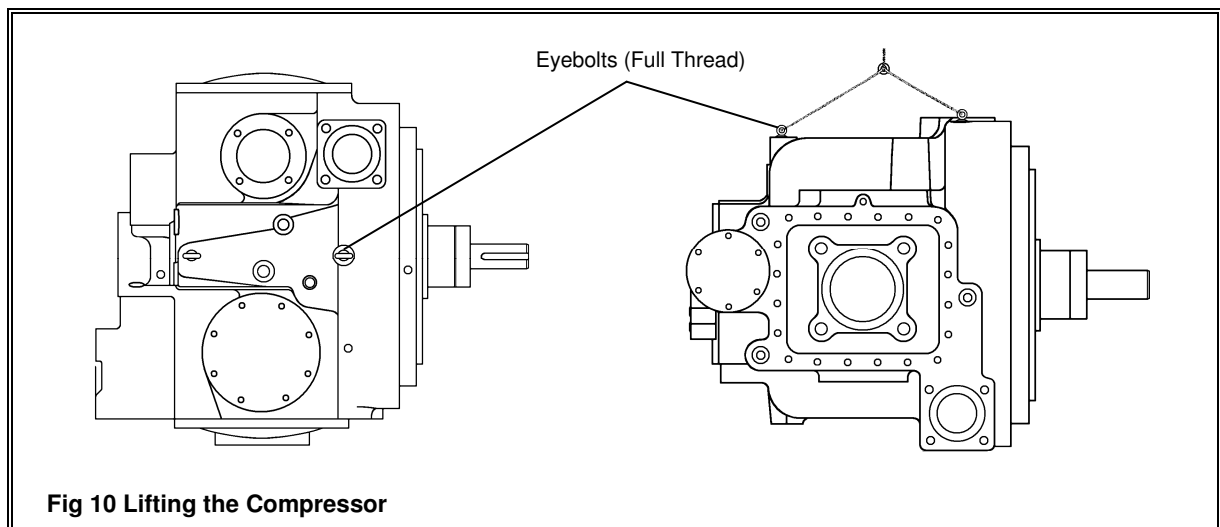
If the compressor has been in prolonged storage, carry out the instructions described under 8.2. Taking the Compressor out of Storage, before installation takes place.

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 10. 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.



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 three 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 three bolts are in position, set the compressor down on the baseframe and remove the lifting gear. Finish tightening the bolts.

9.2. 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) HSO 4200 series compressors use the same connection for liquid injection and the economiser facility. If the liquid injection/economiser facility is to be used, refer to 7.4. Liquid Injection and Economiser Connections.
- (c) Connect the suction and discharge lines, and suction, discharge and oil pressure gauge lines.

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

- (d) 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.

- (e) Connect the oil injection line.

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

- (f) Connect the suction and discharge pressure gauge lines.
- (g) 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.
- (h) Rotate the mainshaft by hand to ensure that the motion-work turns smoothly and evenly.

If the compressor proves very stiff to turn, turns unevenly, or rotation is accompanied by any unusual noise, contact J & E Hall International.

- (i) Connect the drive between the compressor and the prime mover. If the drive coupling is supplied by J & E Hall International, refer to publication 2-79 for drive installation and alignment details.

WARNING

The drive coupling MUST be protected by a suitable FIXED coupling guard.

- (j) Make electrical wiring connections as described in 9.4.
- (k) Leak test and evacuate the system as described in 9.5.

9.3. Internal Oil Filter

HallScrew HSO 4200 series compressors are fitted with an integral oil filter, and may also be fitted with a separate external oil filter; refer to 6.8. Oil Filter

NOTE: if an external oil filter is used, the integral oil filter and filter locating spigot piece must be removed before commissioning begins.

9.4. Electrical Wiring Connections and Interlocks

Make the following wiring connections and interlocks:

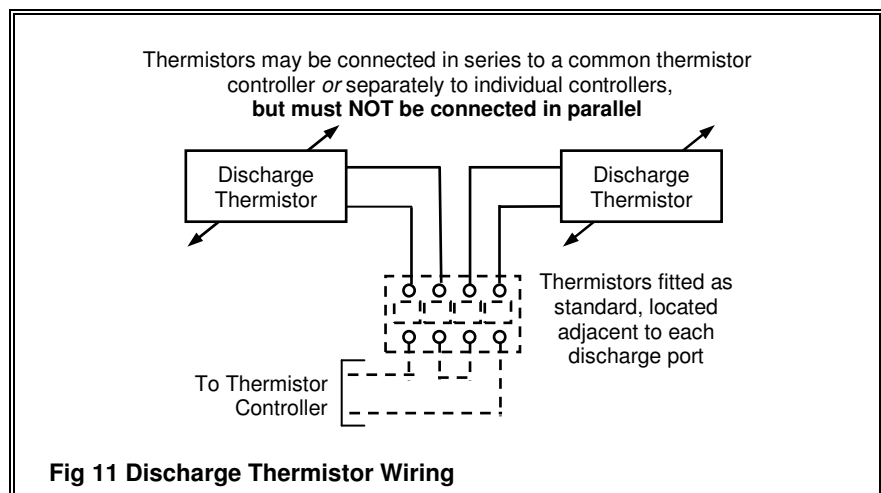
- Mains electrical supply to the compressor drive motor and motor starter. Refer to the motor and starter manufacturer’s instructions.
- Electrical supply to the discharge high temperature thermistors; refer to 9.4.1. Thermistors.
- Electrical supply to the capacity control solenoid valves, these are marked ‘load’ and ‘unload’; refer to Appendix 1 Compressor Data
- Electrical supply to the capacity control slide valve position transducer; refer to 4.6. MSI Linear Variable Displacement Transducer (MSI LVDT).

Power must be supplied to the solenoids via a suitable pulse timer with 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.

9.4.1. Thermistors

Discharge high temperature thermistors are fitted as standard and should be wired as illustrated Fig 11.



9.5. 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 Leak Testing.
 - Part E : Evacuation and Dehydration.
- (a) Before the compressor/system evacuation process commences, energise (open) capacity control solenoid valve A; refer to Fig 2. 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 protection circuit, otherwise the thermistor will be damaged (these thermistors are supplied with the compressor). Thermistors for high temperature protection may also be fitted in the compressor drive motor windings and/or oil injection/lubrication line.
 - 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 each compressor discharge high temperature thermistor has a resistance of approximately 100 Ω and is neither open circuit or a short circuit.

Repeat this check for thermistors that may be fitted in the compressor drive motor windings and/or 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. Compressor Drive Motor

The following general checks are applicable. Also refer to the motor manufacturer's instructions.

- (a) 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.

- (b) The compressor drive motor must **NOT** be started unless it is completely dry. If a moisture indicator is fitted this can be checked to ensure the motor is dry.

If the motor is fitted with anti-condensation heater(s), these must be energised at least 24 hours before running the motor for the first time.

If there is any doubt whether the motor has been affected by moisture, the value of the motor insulation resistance must be checked. The motor should not be run if the insulation resistance is not up to the minimum specified by the motor manufacturer, refer to the manufacturer's instructions.

NOTE: the practice of running a motor having low insulation resistance on full voltage is not recommended. Insulation breakdown may occur before the windings dry out.

- (c) Check that the motor cooling air intakes are not obstructed, permitting free air flow with no recirculation. This is particularly important if the motor is of the closed circuit, air-cooled type.

10.4. Checking Compressor Rotation

- (a) The HSO 4200 series compressor is a positive displacement machine designed to rotate in one direction only, this is **clockwise** when looking on the drive end of the compressor main shaft.

NOTE: HSO 4200 compressor direction of rotation is the reverse of all other HallScrew compressors.

- (b) To prevent incorrect compressor rotation, it is ESSENTIAL to check the rotation of the compressor drive motor with the coupling disconnected.

The various safety controls can also be tested while the motor is running.

- (c) Isolate the electrical supply to prevent the compressor accidentally starting.

Remove the coupling guard. Disconnect the drive coupling by removing the membrane/spacer unit.

Refit the coupling guard so that the rotation of the motor can be safely observed.

- (d) Switch on the drive motor and check the direction of rotation. When looking on the end of the motor drive shaft the shaft should turn in an anti-clockwise direction.
- (e) With the motor running, check that all safety controls operate at their correct settings and stop the drive motor.
- (f) Stop the motor and isolate the electrical supply to prevent it accidentally restarting.

Remove the coupling guard. Rotate the compressor mainshaft several times, by hand, to check that the motion-work turns smoothly and evenly.

- (g) Check the drive alignment, adopting the method described in publication 2-79 in Section 2. If the alignment is out, check the baseframe is level and not distorted, or the compressor package unit is not under excessive strain from the various pipe connections.

Refit the membrane/spacer assembly and coupling guard.

10.5. 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.

10.6. 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) 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.

- (h) 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.

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

- (j) Calibrate the LVDT 4 to 20 mA slide valve position signal for maximum and minimum load; refer to 4.6. MSI Linear Variable Displacement Transducer (MSI LVDT).
- (k) Check that safety devices, the HP and LP cut-outs for example, and all external safety interlocks trip and stop the compressor.
- (l) Run-in the compressor; refer to 11. Running-In the Compressor.

10.7. 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 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) 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.

10.8. 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. Compressor Suction Strainer

To prevent an excessive accumulation of dirt in the suction strainer, which would reduce the compressor's pumping efficiency, it is important to remove and clean the strainer basket during the plant's initial period of operation; suggested intervals are after 12 compressor 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.

If the suction strainer has provision to fit a felt filter or separate suction filter, it is recommended to use this additional cleaning aid for the first 100 compressor operating hours.

After the commissioning period, clean the suction strainer annually, or at intervals of 5,000 operating hours, whichever is the sooner.

11.1.2. Oil Filter

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(s).

11.1.3. Changing the Compressor Integral Oil Filter

The internal oil filter and locating spigot are removed if an external oil filter is fitted.

WARNING

The oil filter is in direct contact with the system environment. DO NOT attempt to change the filter element until the compressor has been pumped down and isolated. Suitable clothing must be worn; this should include goggles, gloves etc.

- (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.

⚠ WARNING

After the compressor has been pumped down and isolated, the oil contained inside the filter housing will remain hot enough to cause burns for some time afterwards. Always allow sufficient time for the oil to cool down so that it is cool enough not to be a danger when drained off (less than 35 °C is recommended).

- (b) Position a suitable container underneath the filter housing to catch the escaping oil.
- (c) Unscrew and remove the capscrews securing the filter cover. Lift away the cover and joint.
- (d) Remove and discard the dirty filter element.
Use a wad of lint free rag to remove any dirt, sediment etc., from inside the filter housing.
- (e) Locate the new filter element over the spigot piece.
- (f) Position a new joint onto the joint face on the filter housing.
Locate the filter cover. Insert the capscrews, tightening them evenly and alternately so that the cover is retained by even tension.
- (g) Reinstale the electrical supply to the control panel and compressor drive motor.
- (h) Restart the compressor. Check the filter cover for leaks.

11.1.4. Refrigerant Filter/Drier

Not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.

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

Not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.

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

At the end of the first 200 compressor operating hours, drain off a sample of oil for analysis. Unless there is evidence of excessive contamination, there is no need to change the oil at this time.

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

*Next paragraph **not** applicable to plants charged with ammonia (R717), applicable to all other refrigerants.*

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.

Next paragraph applicable to plants charged with ammonia (R717), not applicable to other refrigerants.

Unless the system is fitted with an oil still which automatically returns oil to the separator/reservoir, it is usually necessary to manually drain oil from vessels in the LP side of the system (suction separator, flooded evaporator or plate heat exchanger). If there is very little oil to drain, this period can be extended.

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 Drive Motor Coupling

After the first 12 hours of compressor operation, stop the plant and remove the guard from the drive coupling. Remove the coupling membrane/spacer assembly.

Check the tightness of the ®Taper Lock bush grub screws securing the compressor half-coupling, check the half-couplings have not slackened-off their shafts.

Check and record the distance between shaft ends (DBSE) and the drive alignment. The half-couplings should be aligned within 0.125 mm when using dial test indicators on each face and around the circumference. Refit the membrane/spacer assembly and the coupling guard.

Recheck and record the DBSE and drive alignment after approximately the first 200 operating hours.

11.6. Compressor and Drive Motor Holding-Down Bolts

After approximately the first 200 compressor operating hours, check the tightness of the fastenings securing the compressor and motor mountings.

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. If the system uses ammonia refrigerant, the recovery unit must be compatible for operation with this primary refrigerant.

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, lubrication, 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

If the system uses R717 (ammonia) refrigerant, oil drained from the compressor may contain traces of ammonia. The compressor will certainly contain some residual ammonia which the recovery unit could not remove.

For protection against escaping ammonia 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 and a new oil filter element must be used; refer to 6.8. Oil Filter.

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. 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.

As ammonia attacks copper, nickel, tin, zinc and cadmium, components containing these metals or their alloys are prohibited from ammonia refrigeration systems.

WARNING

The use of incompatible materials in an ammonia refrigeration plant can cause component failure and result in the release of large quantities of ammonia refrigerant.

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.
- For plants located within the European Economic Area (EEC), components subject to pressure must, where necessary, be certified that they comply with the Pressure Equipment Directive (PED).
- 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

Clean the compressor suction strainer at the end of the first 12 hours operation.

Change the compressor 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.

13.3. Running-in

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

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

Compressor suction line.
Compressor liquid injection line - <i>liquid injection cooling fitted.</i>
Economiser (subcooler) line before the solenoid valve and thermostatic expansion valve - <i>if economiser fitted.</i>
Compressor discharge line - if separate secondary oil separator fitted.
Oil filter in the oil injection line after the oil separator.
Integral oil filter. If an external oil filter is fitted, the integral oil filter and filter locating spigot piece must be removed before commissioning begins.
Table 2 Filter and Strainer Locations

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.

13.5.1. Daily

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

Not applicable to plants charged with ammonia (R717), applicable to all other refrigerants.

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.

Applicable to plants charged with ammonia (R717), not applicable to other refrigerants.

If it is necessary to manually drain oil from vessels in the LP side of the system (suction separator, flooded evaporator or plate heat exchanger), it will be necessary to top up the level in the separator/reservoir to account for the oil drained off.

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

The specimen log sheet illustrated in Appendix 7 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.

While checking for leaks, inspect the exterior of the plant for damage or corrosion.

- (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) *Not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.*

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) *Applicable to plants charged with ammonia (R717), not applicable to other refrigerants.*

Unless the system is fitted with an oil still which automatically returns oil to the separator/reservoir, it is usually necessary to manually drain oil from vessels in the LP side of the system (suction separator, flooded evaporator or plate heat exchanger). If there is very little oil to drain, this period can be extended.

Turbulent conditions inside these vessels when the plant is operating tend to distribute the oil in droplet form throughout the body of liquid ammonia. It is necessary to stop the plant and wait for the oil to collect in the bottom of the vessel before draining off.

WARNING

The greatest care must be taken when using external drain valves. Protective clothing, gloves, goggles and a respirator must be worn.

- (e) 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 4.6. MSI Linear Variable Displacement Transducer (MSI LVDT).
- (b) If a secondary oil separator is fitted in the discharge line, check the pressure drop across the secondary oil separator. If the pressure drop exceeds 0.7 bar, change the filter elements.

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.

For all plants *other* than those charged with ammonia (R717), 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(s).
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) *Not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.*
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) Remove the membrane/spacer assembly from the compressor drive coupling. Examine the membrane spigots closely for signs of cracking, fretting or other wear. If any damage is evident a new membrane/spacer assembly should be fitted.

Check and record the distance between shaft ends (DBSE) and the drive alignment before reconnecting the coupling.

- For details of the spacer drive coupling, including the method of checking the coupling alignment, refer to publication 2-79 in Section 2.

- (h) After approximately the first 200 compressor operating hours, check the tightness of the fastenings securing the compressor and motor mountings.

- (i) 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.

Oil separator with single stage oil separation.

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.

Oil separator fitted with coalescing elements for two stage oil separation.

The oil separator/reservoir is fitted with coalescing elements. Remove the inspection cover situated at one end of the separator shell to gain access to the coalescing elements; these should be inspected for obvious signs of damage and renewed if necessary.

⚠ WARNING

The greatest care must be exercised when opening up the separator. Protective clothing, gloves, goggles and a respirator must be worn; refer to Safety Equipment in the publication for the refrigerant in Section 5.

If new coalescing elements are to be fitted, after removing the old elements, this opportunity should be taken to clean out the inside of the vessel; pay particular attention to the area around the outlet stub pipe. Refit the inspection cover using a new gasket if required.

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.

- (c) Renew the compressor drive coupling membrane/spacer assembly.
 - For details of the spacer drive coupling, including the method of checking the coupling alignment, refer to publication 2-79 in Section 2.

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. - <i>not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.</i>	
	Drain off any oil which has collected in the LP side of the system - <i>applicable to plants charged with ammonia (R717), not applicable to other refrigerants.</i>	
	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 - <i>separate secondary oil separator fitted in the discharge line</i>	
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(s)	
	Clean strainers throughout the system	
	Renew the refrigerant filter/drier cores - <i>not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.</i>	
	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	
	Check the condition of the coalescing elements in the oil separator - <i>oil separator fitted with coalescing elements for two stage oil separation</i>	
	Renew the compressor drive coupling membrane/spacer assembly	
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.	
REFERENCE TO OTHER MAINTENANCE SCHEDULES		
Grease compressor drive motor bearings according to the motor manufacturer's instructions.		
Table 3 Maintenance Check List		

Appendix 1 Compressor Data

- HSO 4200 Series: Compressor Model Nomenclature.
- HSO 4200 Series: Physical Data.
- HSO 4200 Series: Starting Torque Characteristics.
- HSO 4200 Series: Limits of Operation.
- Safety Requirements for Compressor Protection.
- HSO 4200 Series: Physical Dimensions and Connections.

HSO 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 Thermistors	
HS	O	4	2	X	X	X	X	X	X	X	X	X	X	X	
Application		O	Open drive												
Compressor		42X	Series 4200 Twin Star 21, 22, 23 or 24												
Capacity Control Slide V_R		2	2.2 V _R												
		3	3.0 V _R												
		5	4.9 V _R												
Lubricant		E	Ester oil												
		M	Mineral oil												
Motor Power (Nominal)		0	Without motor												
Motor Voltage		0	No voltage (without motor)												
Refrigerant		A	R134a	F	R404a										
		B	R22	G	R717										
		C	R407c	H	R23										
		D	R410a	X	Other										
		E	R507a												
Voltage (Auxiliary)		1	115 V 1 ph 50/60 Hz							3	24 V dc				
		2	230 V 1 ph 50/60 Hz							4	24 V ac				
		5	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) plus signal conditioning module												
Stop Valves and Flanges		A	Suction flange and discharge flanges (standard)												
		B	Suction flange and discharge stop valve												
		D	Suction and discharge stop valves												
		E	Suction stop valve and discharge flange												
Economiser Kit		0	No economiser kit (standard)												
		1	Economiser kit												
Discharge Thermistors		B	Discharge thermistors (standard)												

Example: HSO 4222/2/M/B/2

This describes a HallScrew 4222 twin star open drive compressor fitted with 2.2 V_R capacity control slide valves, supplied with mineral oil. Compressor for operation with R22. Solenoid voltage 230 V 1 ph 50/60 Hz.

HSO 4200 Series: Physical Data

Compressor Type	Single screw, open drive.								
Compressor Rotation	Clockwise looking on the motor (driven) end. Under no circumstances should the compressor run in the reverse direction.								
Method of Drive	Direct coupled to foot mounted drive motor.								
Speed Range	1500 to 4000 rpm.								
Physical Dimensions	Refer to Physical Dimensions and Connections								
Weight	460 kg (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.								
Swept Volume	SWEPT VOLUME (M³/HR)		HSO 4221	HSO 4222	HSO 4223	HSO 4224			
	Compressor running @ 50 Hz (2 pole speed)		504	611	716	828			
	Compressor running @ 60 Hz (2 pole speed)		605	733	859	994			
¹Sound Pressure Levels @ 2980 rpm (50 Hz)	COMPRESSOR	TOTAL DB 'A'	CENTRE FREQUENCY – Hz						
			125	250	500	1 K	2 K	4 K	8 K
	HSO 4221	81	62	73	73	77	75	69	62
	HSO 4222	82	62	74	74	79	76	70	63
	HSO 4223	83	61	75	75	80	77	71	64
HSO 4224	83	61	75	75	80	77	71	64	
<p>¹Sound pressure level data applies to the compressor only. The sound pressure level for a standard air-cooled compressor drive motor is usually higher.</p> <p>The 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.</p> <p>Sound pressure levels given in dB refer to 2×10^{-5} N/m² RMS.</p>									

HSO 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	R717		
Maximum Design Pressures	¹ High side/low side test pressures	32.9 bar g	32.9 bar g	32.9 bar g		
² Operational Pressures ³ 4.9 V _R not applicable to HSO 4224	Maximum compressor operating suction pressure	2.2 or 3.0 V _R	6.0 bar g	6.0 bar g	6.0 bar g	
		³ 4.9 V _R	4.0 bar g	4.0 bar g	4.0 bar g	
	Maximum pressure ratio	2.2 V _R	7	7	7	
		3.0 V _R	10	10	10	
		³ 4.9 V _R	20	20	20	
	Minimum pressure ratio	³ 4.9 V _R	5	5	5	
	Maximum compressor operating discharge pressure (HSO 4221, HSO 4222 and HSO 4223)		24.0 bar g	26.2 bar g	23.6 bar g	
	Maximum compressor operating discharge pressure (HSO 4224)		17.9 bar g	16.1 bar g	16.4 bar g	
	Maximum compressor operating pressure differential (discharge – suction) (HSO 4221, HSO 4222 and HSO 4223)		20.0 bar	23.0 bar	20.0 bar	
	Maximum compressor operating pressure differential (discharge – suction) (HSO 4224)		16.0 bar	15.6 bar	15.5 bar	
Minimum compressor operating pressure differential at minimum load		2.0 bar	3.0 bar	3.0 bar		
		R22	R404A	R507A		
Maximum Design Pressures	¹ High side/low side test pressures	32.9 bar g	32.9 bar g	32.9 bar g		
² Operational Pressures ³ 4.9 V _R not applicable to HSO 4224	Maximum compressor operating suction pressure	2.2 or 3.0 V _R	6.0 bar g	6.0 bar g	6.0 bar g	
		³ 4.9 V _R	4.0 bar g	4.0 bar g	4.0 bar g	
	Maximum pressure ratio	2.2 V _R	7	7	7	
		3.0 V _R	10	10	10	
		³ 4.9 V _R	20	20	20	
	Minimum pressure ratio	³ 4.9 V _R	5	5	5	
	Maximum compressor operating discharge pressure (HSO 4221, HSO 4222 and HSO 4223)		25.9 bar g	24.6 bar g	24.6 bar g	
	Maximum compressor operating discharge pressure (HSO 4224)		16.6 bar g	n/a	n/a	
	Maximum compressor operating pressure differential (discharge – suction) (HSO 4221, HSO 4222 and HSO 4223)		23.0 bar	23.0 bar	23.0 bar	
	Maximum compressor operating pressure differential (discharge – suction) (HSO 4224)		15.2 bar	n/a	n/a	
Minimum compressor operating pressure differential at minimum load		3.0 bar	3.6 bar	3.6 bar		
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. ³ 4.9 V _R not applicable to HSO 4224.						

HSO 4200 Series: Limits of Operation (continued)

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 R717 = 25.0 K

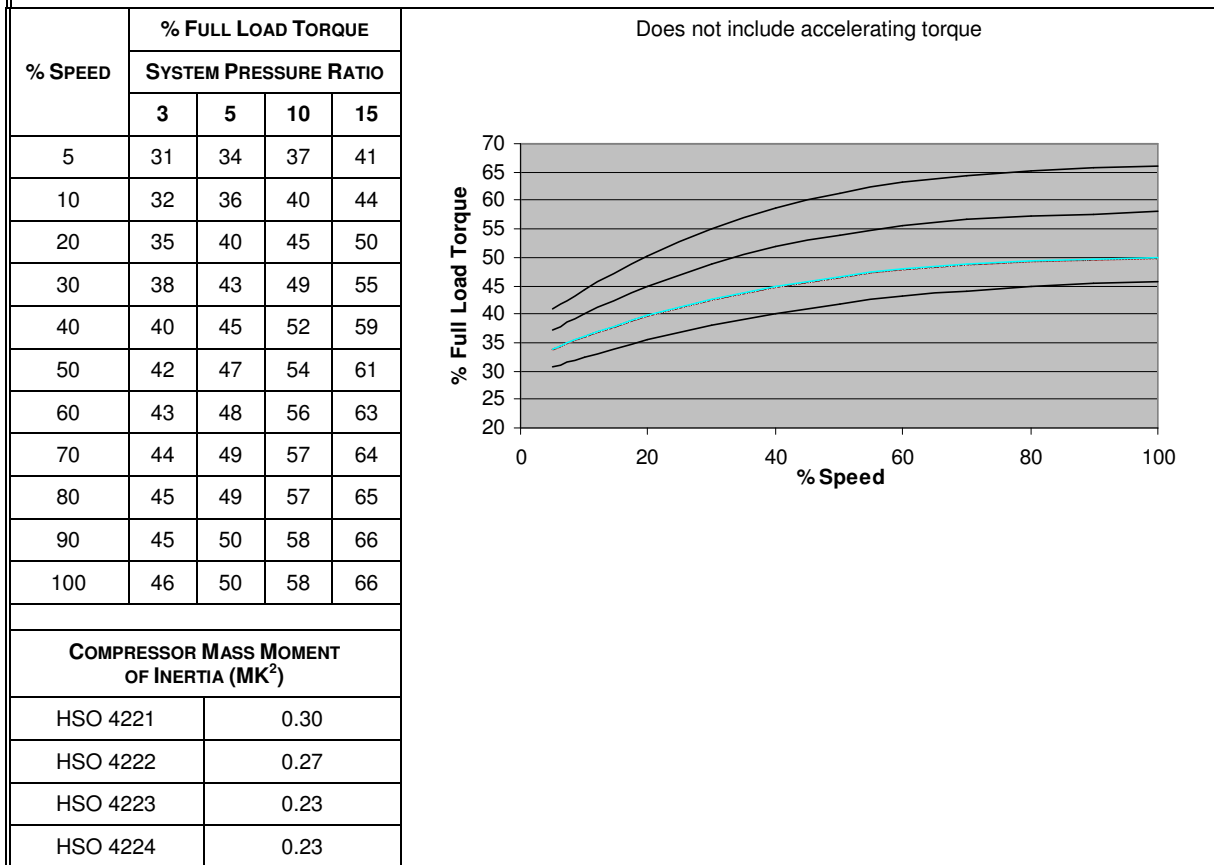
¹Compressors must **NOT** be subjected to pressures higher than those indicated. **This may require isolation of the compressor during system strength pressure testing.**

²Oil separator pressure limits may be less than those applicable to the compressor.

34.9 VR not applicable to HSO 4224.

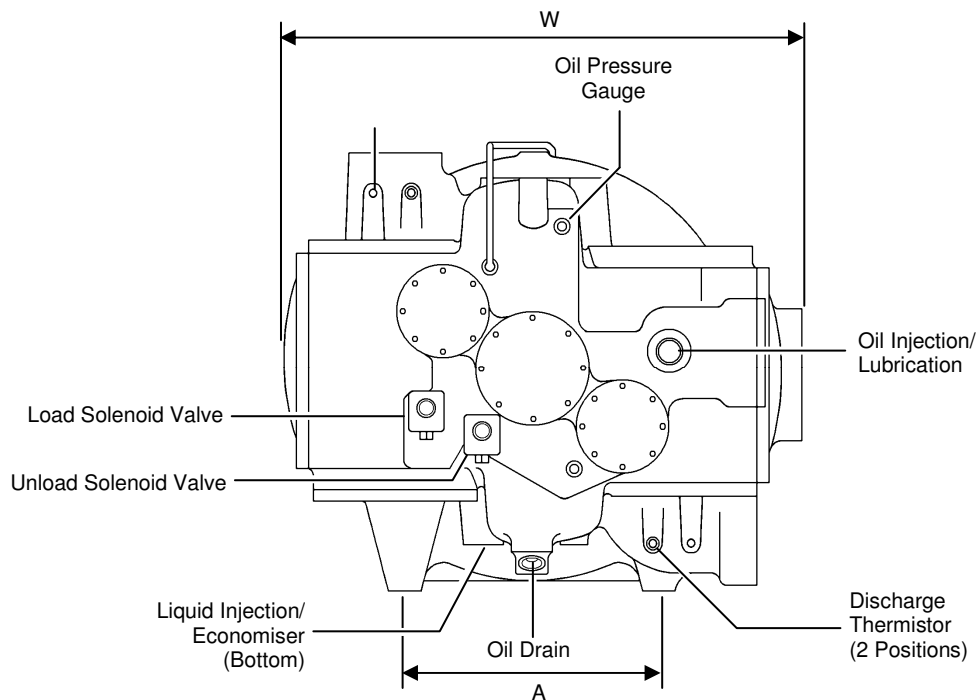
HSO 4200 Series: Starting Torque Characteristics

Starting torque characteristics are shown for different system pressure ratios, in tabular form and as a graph.



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	Thermistors (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
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
Oil temperature	High	Thermistor or HT cut-out	80 °C	Mandatory requirement if compressor fitted with external oil cooling

HSO 4200 Series: Physical Dimensions and Connections



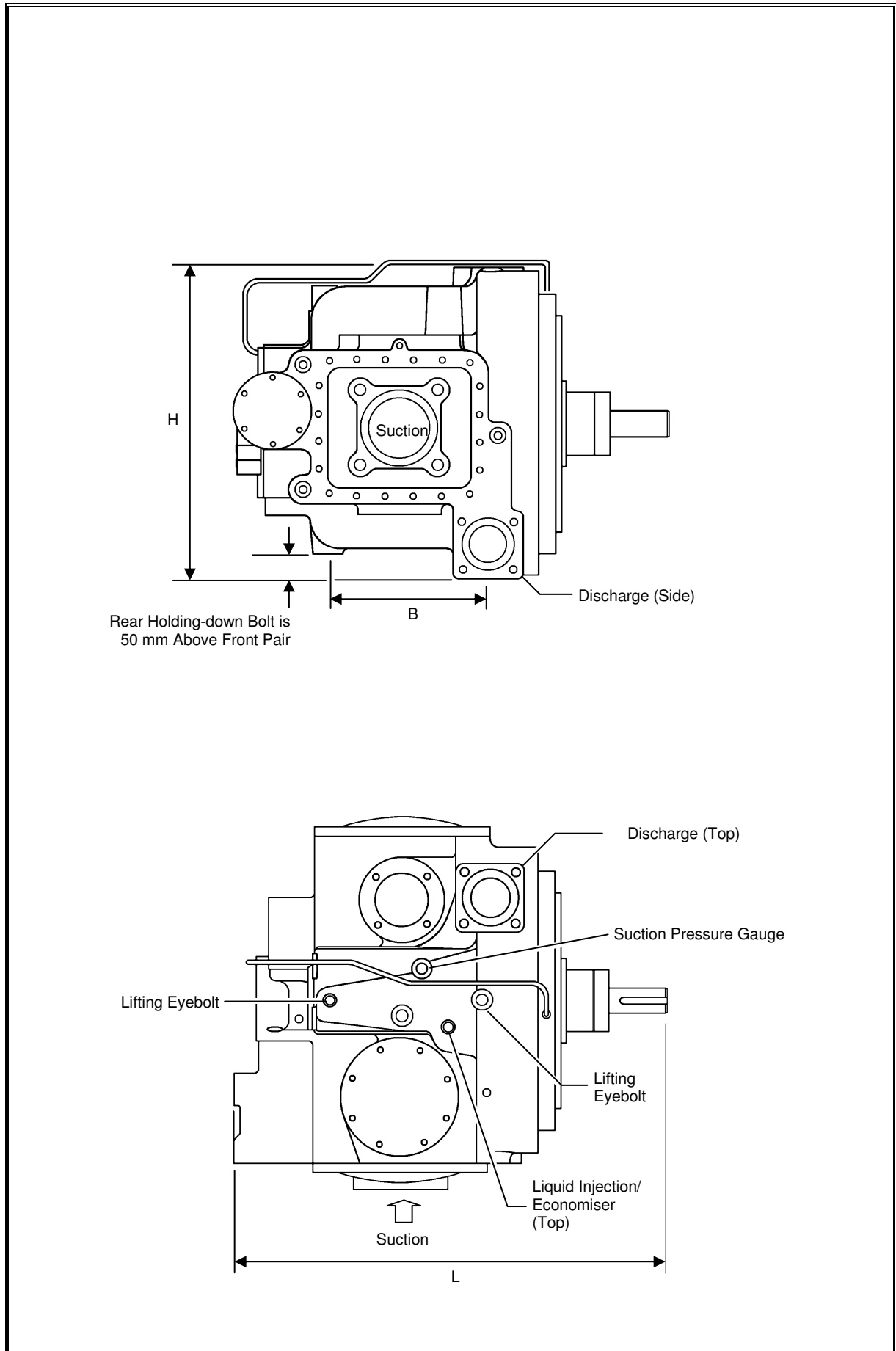
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall International certified drawing

Dimensions	DESCRIPTION		SIZE
	Overall	Length	L
Height		H	546.5 mm
Width		W	655 mm
Holding-down bolt centres	A		320 mm
	B		652 mm
Holding-down bolt	-		3 off M12 x 50 mm
Lifting eyebolts	-		2 x M20

Connections	DESCRIPTION	No OFF	SIZE
	² Suction		1
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)

¹Both discharge high temperature thermistors must be used, wired in series; refer to Fig 11.

²Suction can be taken from either side of the compressor.



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
	Pressure Indication (pressure gauge or transducer)			Differential Pressure Switch
	Pressure Switch High (discharge high pressure cut-out or transducer)			Level Switch (opto sensor or level switch)
	Pressure Switch Low (suction low pressure cut-out or transducer)			Thermistor or high temperature cut-out
Fig 12 Key to Schematic Flow Diagrams				

¹Break flanges required to allow side cover removal

²Break flanges required to allow compressor removal

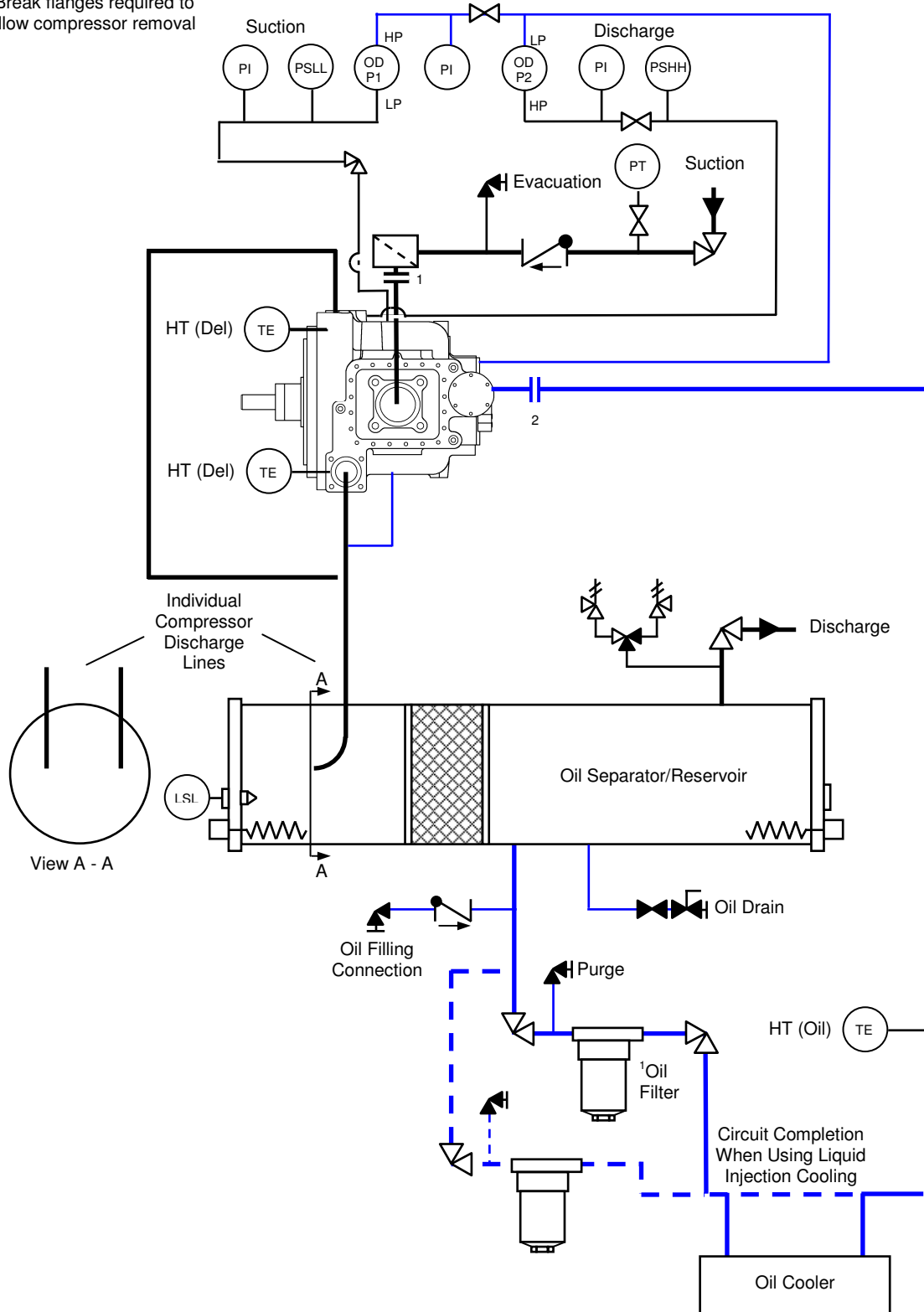


Fig 13 Oil Support System For Single Compressor

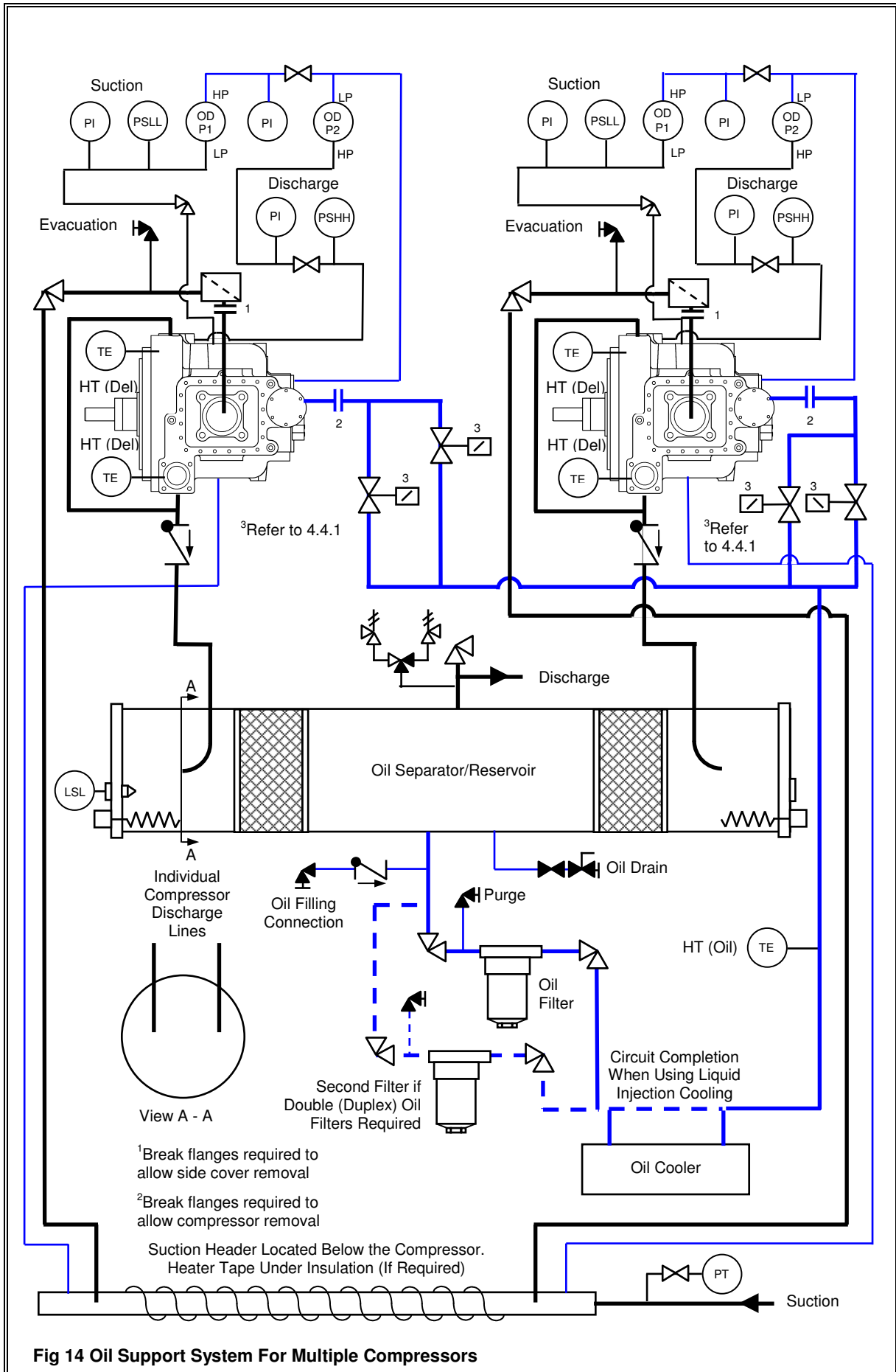
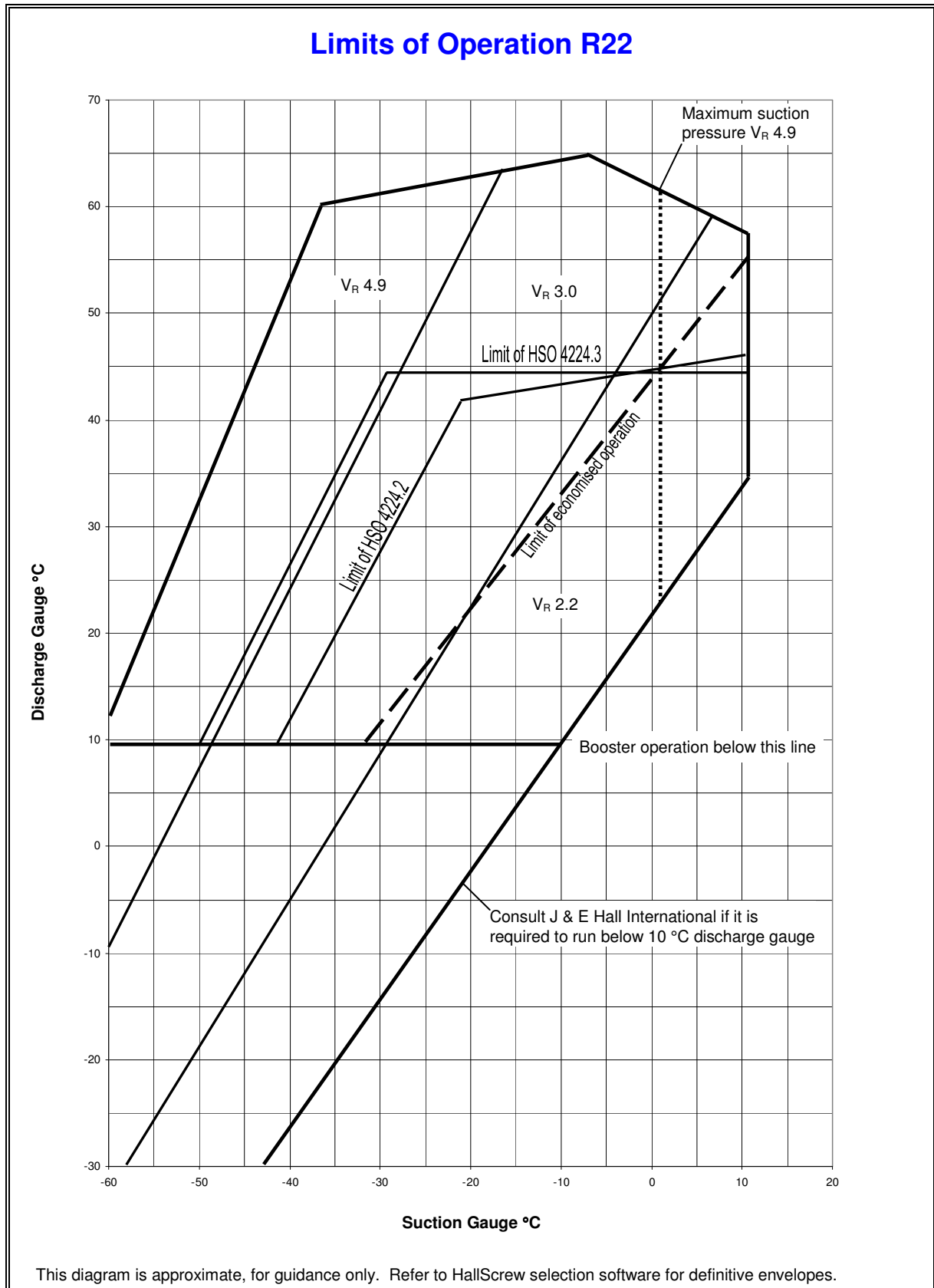
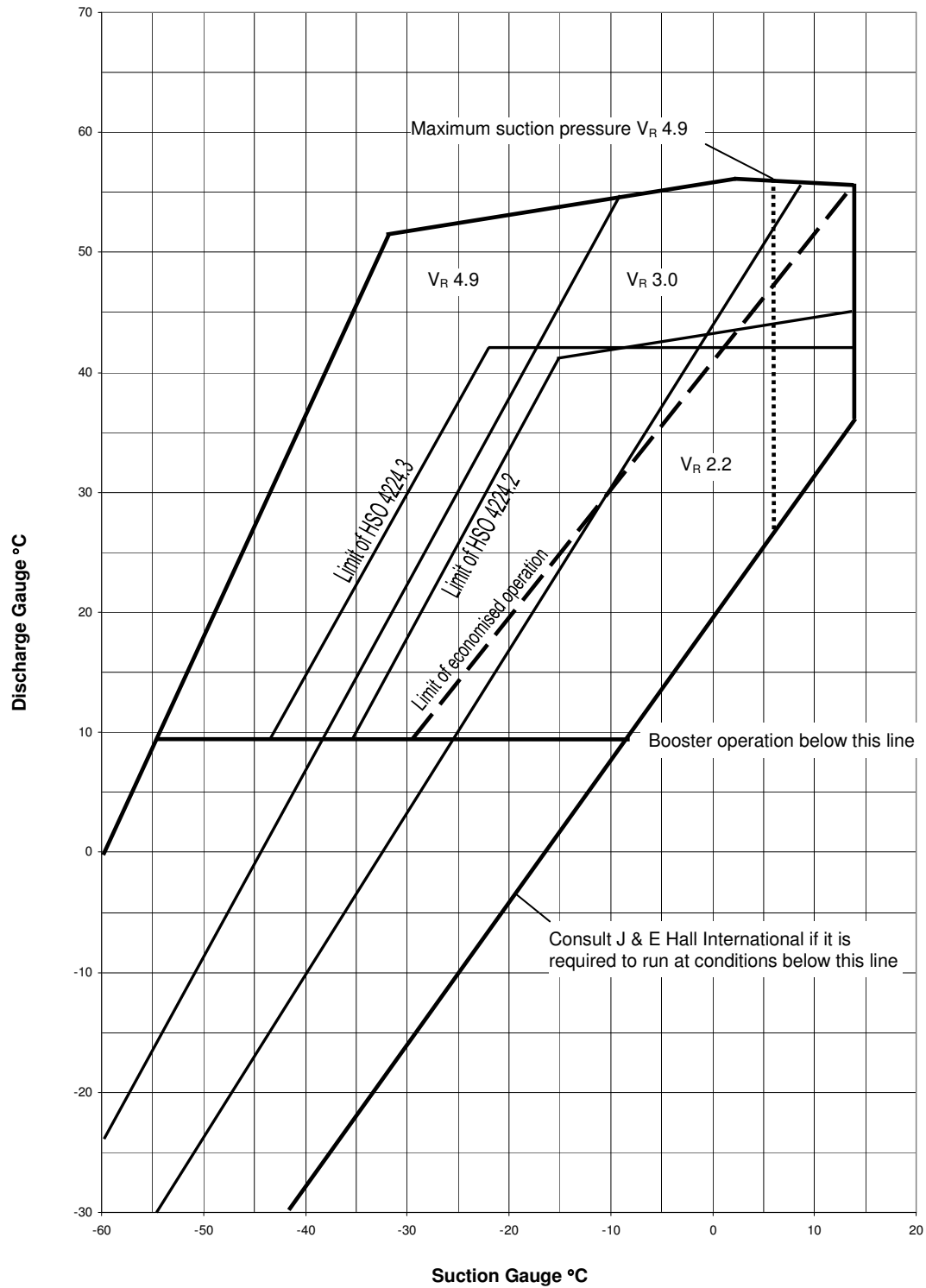


Fig 14 Oil Support System For Multiple Compressors

Appendix 3 Limits of Operation Envelopes

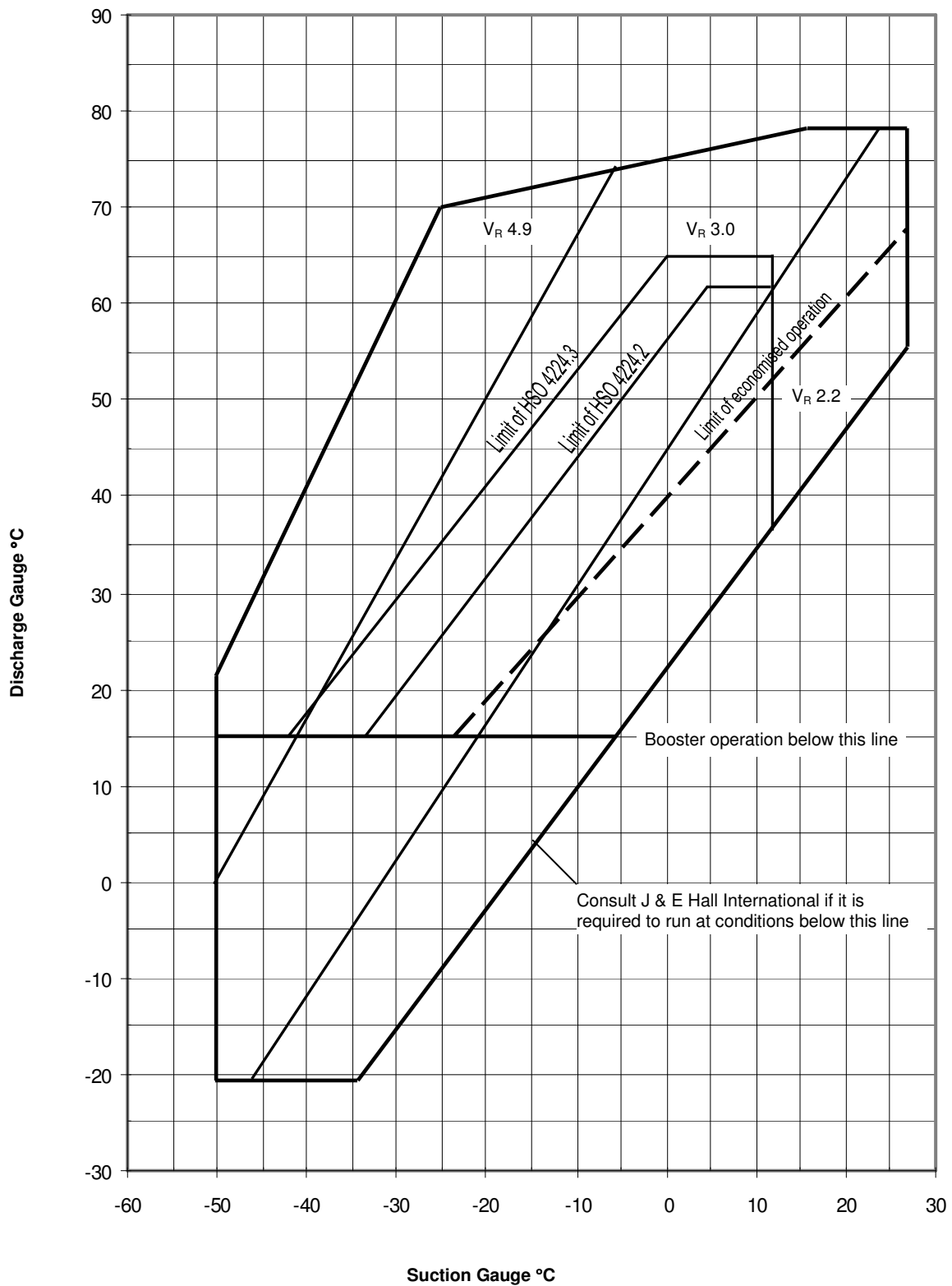


Limits of Operation R717 (Ammonia)



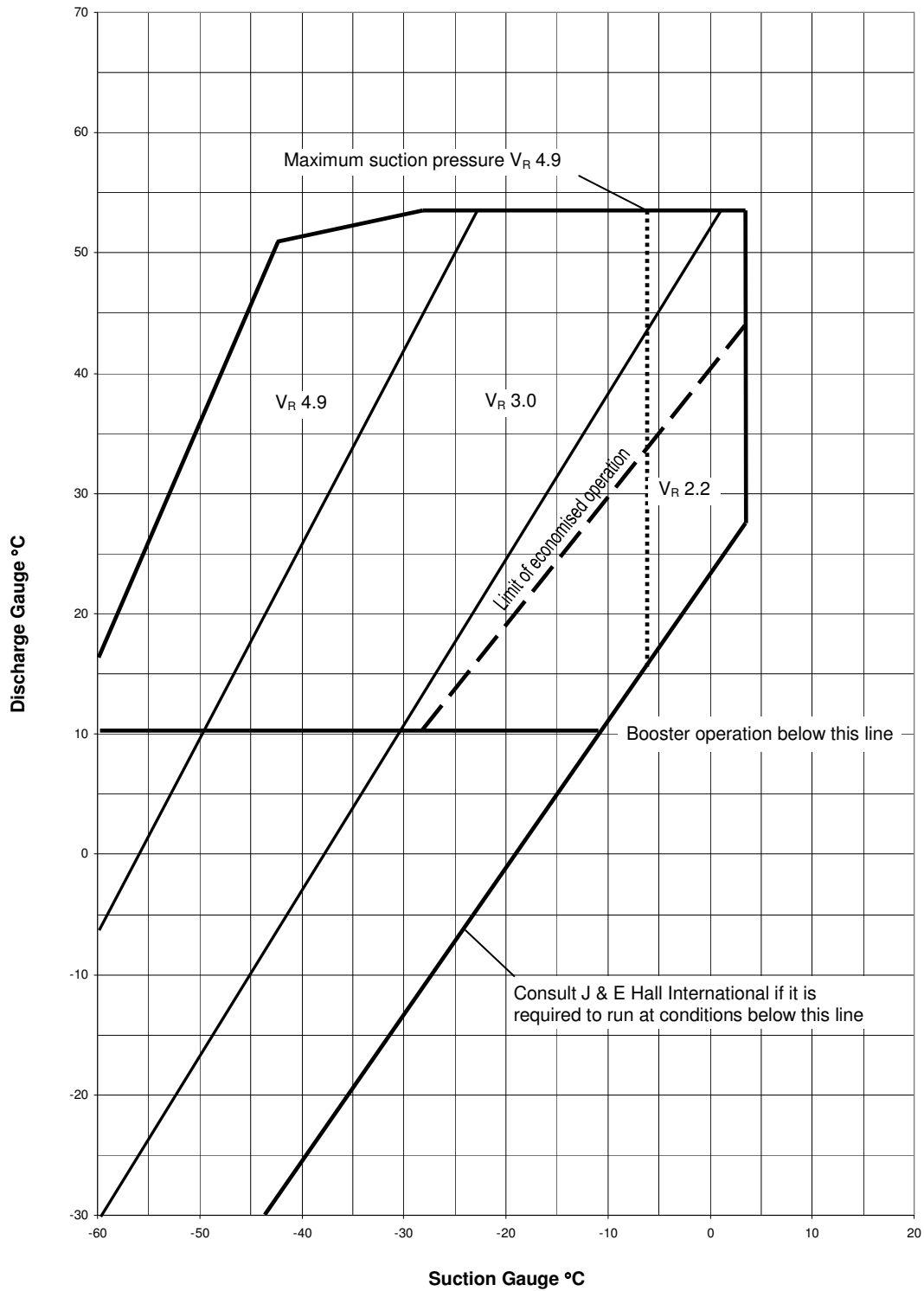
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R134a



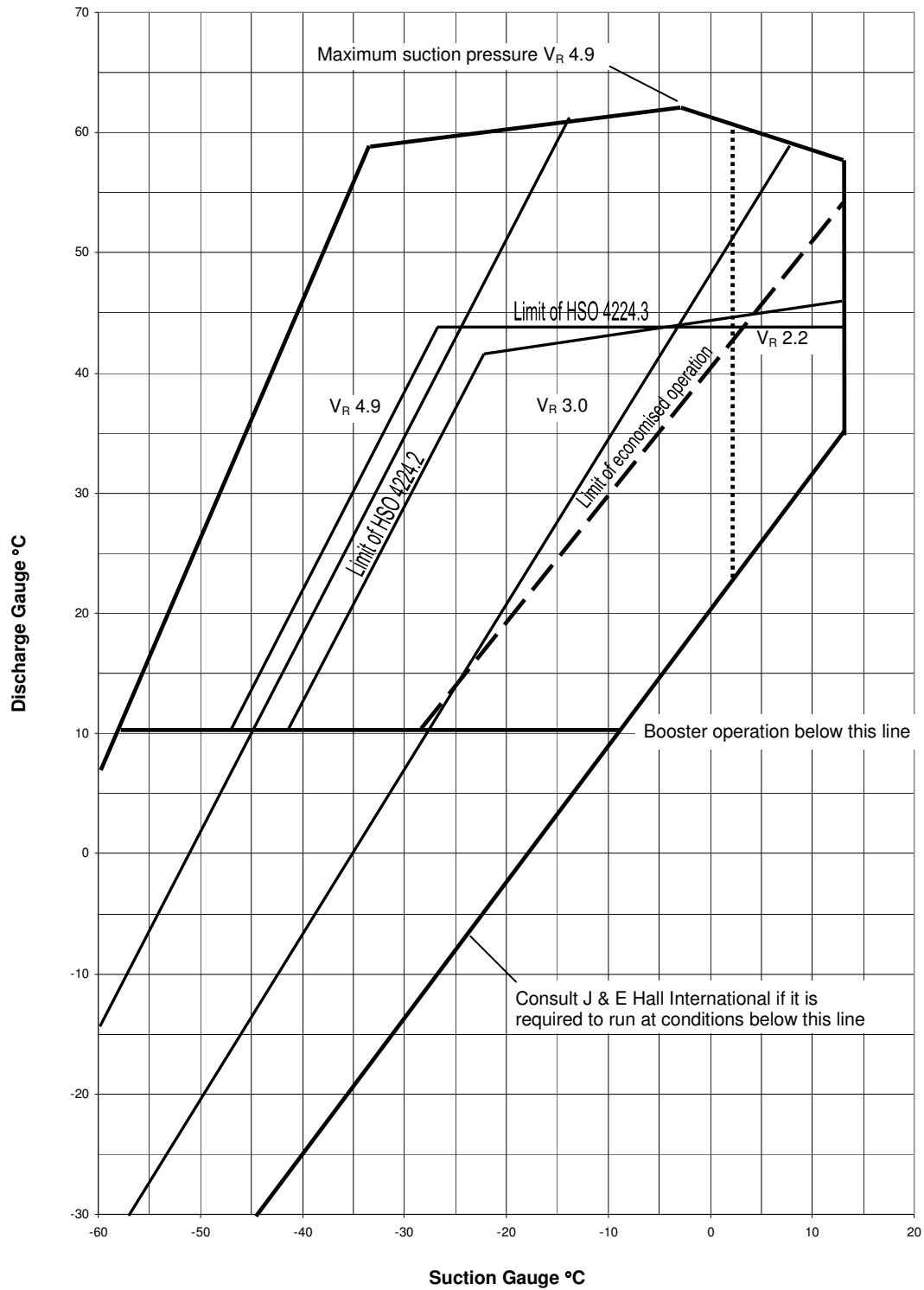
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R404a and R507a



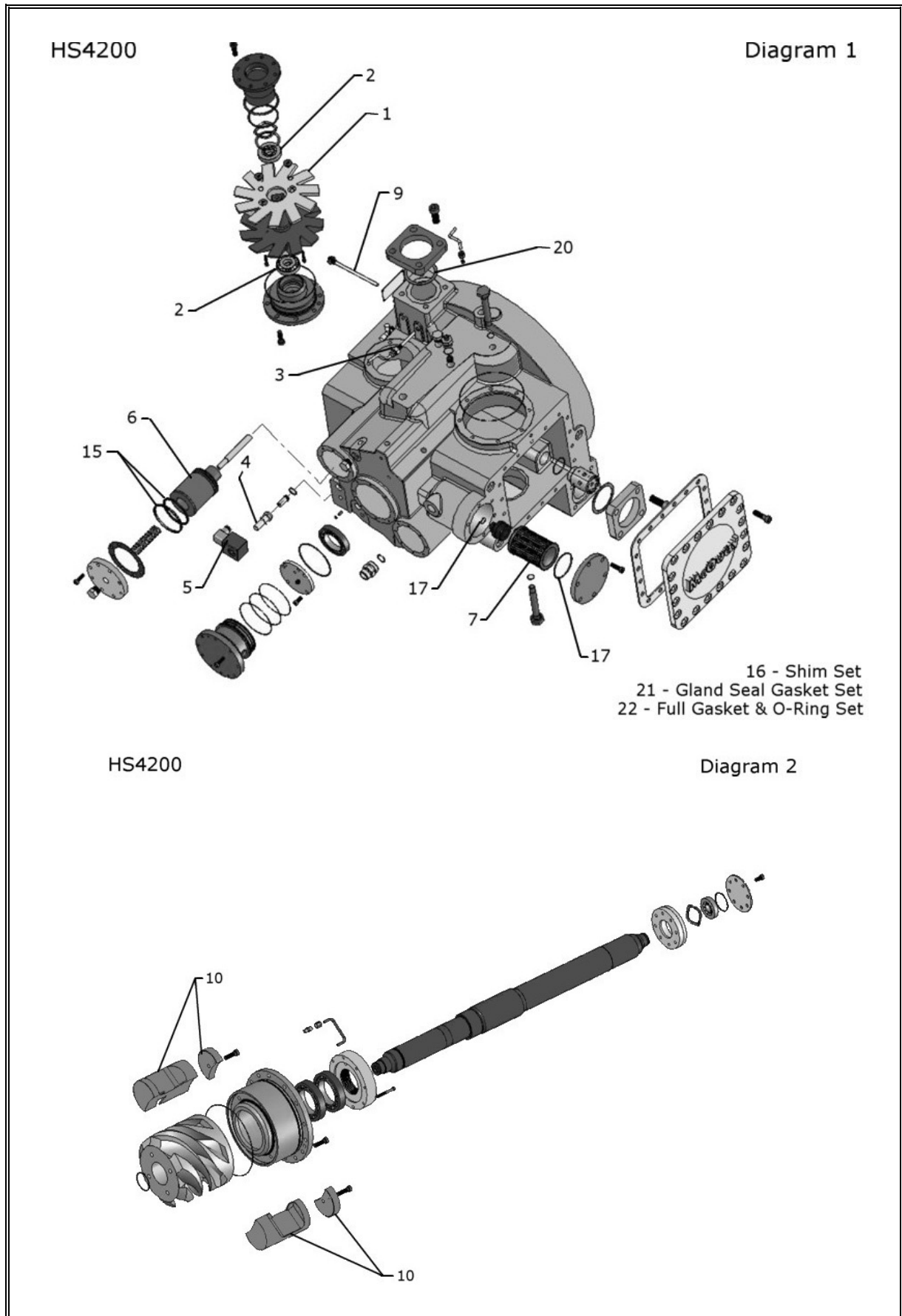
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R407c



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
Filters							
7	1	Oil Filter (also requires item 17 or 22)	N02370008	95816-401	1	1	1
Oil Heaters							
9	1	Compressor Oil Heater 110 V 400 W (direct immersion)	N19030041	2858-642			
9	1	Compressor Oil Heater 220 V 400 W (direct immersion)	N19030042	2858-643			
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
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

Item	Diagram	Description	Part Number	Old Part Number	3216	3218	3220	
Tube Kits								
N/S	N/S	Bearing Oil Supply Tube Kit (also requires item 24)	N02210016	95822-412	1	1	1	
Gland Seal								
N/S	N/S	Gland Seal (also requires item 21 or 22)	N02020041	95813-402	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	
Gasket Sets								
17	1	Oil Filter Replacement Gasket and 'O' Ring Set	N33010027	128810988	1	1	1	
20	1	Discharge Connection Gasket	N33070010	M350233901	1	1	1	
21	1	Gland Seal Replacement Gasket and 'O' Ring Set	N33010039	128810987	1	1	1	
22	1	Full Gasket and 'O' Ring Set	N33010038	128810984	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										

¹GAUGE 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).....										

²OIL 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).....										

¹It is also desirable to give the gauge temperature readings approximately 15 minutes after the plant has stopped.

²Required for refrigerant or water cooled oil cooling.

³Required 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.


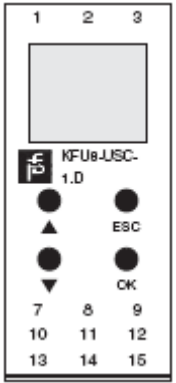
Unless the 'units' are reconfigured, the value displayed on the module is always the actual **input value** in mA from the LVDT. This is not particularly meaningful for the user.

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).

←

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	

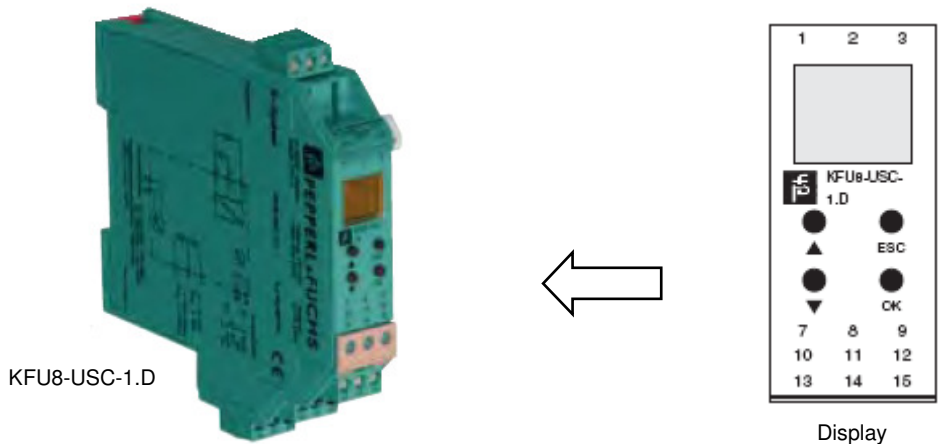
Table 5 Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

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

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



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

¹Operation can be done with the slide valve in any position.

²MIN 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

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