A

HallScrew HS H/M/L 3200 Series

Semi-hermetic Single Screw Compressors

HS H/M/L 3216, HS H/M/L 3218, HS H/M/L 3220 and HS H/M/L 3221

Installation, Operation and Maintenance Manual

Safety

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

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

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

Personnel Permitted to Install, Commission and Maintain the Plant

In accordance with BS EN 13313, only authorised competent personnel are allowed to work on the refrigeration plant.

Within the UK, companies who service, maintain or install refrigeration, air conditioning and heat pump systems must be certified by one of the following organisations:

- Bureau Veritas;
- Quidos;
- Refcom.

This indicates adequate training has recently been received.

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

A permit to work system must be introduced when the plant is commissioned and rigorously enforced thereafter.

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.

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.

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

The capacity control mechanism contains a heavy duty spring under compression. Attempting to remove the spring without using the correct tools could result in serious injury; refer to 5.1. Slide Valve Actuation.

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).

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 operation, maintenance and testing of electrical systems and equipment must only be carried out by qualified and competent persons.

Electrical Isolation

The electrical power used in this equipment is at a voltage high enough to endanger life.

⚠ WARNING

Disconnect the power source before servicing or repairing electrical equipment.

Where there is no local means of isolation or where there is a risk of accidental reinstatement of the supply, the circuit or equipment to be worked on must be securely isolated by one of the following methods:

- Isolate at the main switch;
- Distribution board switch-disconnector (MCB);
- Remove cartridge fuses.

Isolation of equipment or circuits using the main switch or distribution board switch-disconnector is the preferred method. The point of isolation must be locked off using a unique key or combination retained by the person carrying out the work or the appointed person, and a 'Caution' notice attached to the point of isolation.

Where more than one operative is working on circuits supplied from an isolated distribution board, a multi-lock hasp can be used to prevent accidental operation of the main isolator until such time that all persons working on the installation have completed their work and removed their padlocks from the hasp. If lock-off facilities are not provided on the relevant switch, it is acceptable to use a locked distribution board which prevents access to the switch-disconnector provided the key or combination is unique and is retained by the person carrying out the work or the appointed person.

Functional Testing

If the supply must remain connected to permit functional testing, fault diagnosis and repair must only be undertaken by persons who are aware of the hazard and who have taken adequate precautions to avoid direct contact with dangerous voltages.

Electrical Hazard in the Event of Fire

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.

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.

While HFC refrigerants have a zero ozone depletion potential compared with chlorofluorocarbon (CFC) refrigerants, they can contribute towards global warming and are classed as fluorinated greenhouse gases covered by the Kyoto Protocol.

Under no circumstances should refrigerant be deliberately vented to atmosphere, within the European Community it is illegal to do so.

⚠ **WARNING**

Opening up the system should only be carried out by authorised competent personnel who are fully aware of the potential hazards involved.

When opening up any part of the primary refrigeration circuit, care must be taken to minimise the loss of any refrigerant to atmosphere. It is essential to prevent any escape by first recovering, decanting, or 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 could 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 EN ISO 11442: Technical product documentation. Document management;
- BS EN ISO 12100: Safety of machinery - General principles for design - Risk assessment and risk reduction;
- BS EN 62023: Structuring of technical information and documentation;
- BS EN 82079-1: Preparation of instructions for use. Structuring, content and presentation. General principles and detailed requirements.

1.1. Safety Warnings and Symbols

The system of safety warnings and symbols is based on:

- BS EN ISO 7010: Graphical symbols. Safety colours and safety signs. Registered safety signs;
- BS EN 82079-1: Preparation of instructions for use. Structuring, content and presentation. General principles and detailed requirements.

⚠ DANGER

This indicates a hazard with a high level of risk, which if not avoided, will result in death or serious injury if instructions, including recommended precautions, are not followed.

⚠ WARNING

This indicates a hazard with a medium level of risk, which if not avoided, will result in death or serious injury if instructions, including recommended precautions, are not followed. In addition, there is a high risk of damage to the component, product or process.

⚠ CAUTION

This indicates a hazard with a low level of risk, which if not avoided, will result in minor or moderate injury if instructions, including recommended precautions, are not followed. In addition, there is a potential risk of damage to the component, product or process.

NOTE: Draws attention to important additional information.

1.2. Units of Measurement

Quantities are expressed in SI units or SI derived units; refer to J & E Hall International Standard JEH-ES-02 Guide to the International System of Units (SI).

1.3. Terminology

Terminology, abbreviations and acronyms are those currently in use throughout the refrigeration and air conditioning industry; refer to J & E Hall International Standard JEH-ES-01 Definition of Terms and Acronyms Used in the Refrigeration Industry.

1.4. Additional Copies

Obtain additional copies of these instructions from J & E Hall International; go to www.jehall.com.

2. Reference Publications

Further details of certain aspects of compressor application and operation can be found in the following publications available from J & E Hall International at the address below. These publications are referenced in the text.

Number	Description
Part D	Strength and Tightness Testing (J & E Hall Standard JEH-ES-18-001)
Part E	Evacuation and Dehydration (J & E Hall Standard JEH-ES-18-002)
2-59	Lubricating Oils For HallScrew Compressors
2-121	Maintaining Discharge Pressure at Start-up
2-122	Compressor Cooling
2-129	Economiser Facility For HallScrew Compressors
2-205	MSI Linear Variable Displacement Transducer (LVDT) and Slide Valve Position Signal Conditioning Module
2-206	HB Linear Variable Displacement Transducer (LVDT)
2-250	Semi-hermetic Compressor Motor Burnout

Table 1 Reference Publications

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: sales@jehall.co.uk
Website: www.jehall.co.uk

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

3. 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 set out in J & E Hall International standard conditions of sale.

3.1. Application

The following is specifically prohibited:

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

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

(c) Use of any refrigerant other than R404A, R407C, R407F, R448A, R449A, R452A, R507A, R513A, R134a and R22 without prior agreement with J & E Hall International.

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

(d) Use of lubricating oils other than those specified by J & E Hall International; refer to 7.9 Lubricating Oils.

3.2. System Provisions

Refer to Appendix 2 Oil Support System Schematic Flow Diagrams. The following items are specifically required and are considered mandatory.

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

(b) Fit an oil filter. The filter must be adequately sized and to the specification described in Table 2.

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

(d) To prevent excessive reverse rotation of the compressor at shutdown it is necessary to fit a discharge non-return valve; refer to 7.2 Non-return Valve for single and multiple compressor applications.

(e) Adequate precautions must be taken to prevent oil or liquid refrigerant accumulating in the compressor when it is stopped. This includes the mandatory use of an oil drain line to return oil and/or liquid to the oil separator, which must be positioned to permit free-drainage; refer to 7.2. Non-return Valve.

(f) Under certain operating conditions, the compressor will need cooling; refer to 7.10. Compressor Cooling. HS L/M 3200 series semi-hermetic compressors are normally cooled by direct injection of liquid refrigerant.

If liquid injection cooling or thermosyphon oil cooling is used, a preferential supply of liquid refrigerant must be provided for cooling purposes. The priority supply must be arranged so that the cooling requirement is satisfied before liquid can flow to the evaporator(s); refer to publication 2-122 Compressor Cooling.

(g) Fit and maintain in an operational condition the cut-outs and other safety devices illustrated and described in Appendix 1 Compressor Data, Appendix 2 Oil Support System Schematic Flow Diagrams.

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

(h) The plant controller is required to supply load/unload pulses to the capacity control solenoid valves; refer to 5.2 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 5.1.1.Minimum Load Interlock.

3.3. Prolonged Storage

If, for any reason, the compressor cannot be installed immediately and must be placed in prolonged storage, refer to 9. Prolonged Storage.

3.4. Commissioning Provisions

Refer to 11. 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.

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 available from J & E Hall part number N29580002.

(c) With HFC refrigerants, for example, R134a or R407F, it is necessary to use polyol ester 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 or from J & E Hall part number N29580002.

Additives in the oil mean that acid numbers are generally higher than those for traditional mineral oils. It is essential to maintain a record of the oil acid number and change the oil when the acid number rises by 0.05, even if this is below the 0.15 maximum.
When using polyol ester 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 11.7. Adding Oil to the System.

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

(d) Discharge high temperature and stator winding high temperature thermistors are fitted as standard and must be wired as illustrated in Fig 7.

(e) Connect the compressor stator/rotor phase rotation in accordance with phase rotation wiring diagram illustrated in Fig 7.

Check the direction of rotation; refer to 11.3. Checking Compressor Rotation.

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

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

4. General Description

The J & E Hall International HS L/M 3200 series of semi-hermetic compressors are the latest addition to the HallScrew family of oil injected, positive displacement, single screw compressors. Reflecting the very latest innovations in screw compressor technology, they are designed for refrigeration systems using R404A, R407C, R407F, R448A, R449A, R452A, R507A, R513A, R134a or R22 and used in conjunction with a high efficiency oil separator (not supplied with compressor) fitted in the discharge line.

HS L/M 3200 series compressors are capable of operating without cooling over a limited range, but when indicated, a suitable cooling system is required.

4.1. Main Features

- For use with R404A, R407C, R407F, R448A, R449A, R452A, R507A, R513A, R134a and R22;
- Designed and tested to international standards;
- Robust construction;
- Improved machine clearance control for maximum efficiency;
- Oil injected for maximum reliability;
- Balanced loading on main bearings for maximum bearing life;
- Enhanced slide valve geometry for capacity modulation with minimum loss of efficiency. Infinite adjustment between maximum (100 %) and minimum load (nominal 25 %);
- Simple, built-in capacity control using two solenoid valves;
- Single connection for oil injection/lubrication/capacity control;
- Economiser facility provided to improve operating efficiency, especially at high compression ratios;

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

4.2. Construction

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

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

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

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

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

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

The main rotor and star rotors are housed inside the main casing. The inside of this main casing has a somewhat complex shape, but essentially consists of a specially shaped cylindrical annulus, which encloses the main rotor leaving a small clearance. Part of the annulus is cutaway at the suction end to allow the suction gas to enter the rotor. In addition there are two slots, one each side, to allow the star teeth to mesh with the main rotor flutes. The discharge ports (one for each star), are positioned at the other end of the annulus. These ports convey the compressed gas out of the compressor via the discharge outlet. 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 discharge end cover can be removed to inspect the capacity control mechanism.

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

To prevent excessive reverse rotation of the compressor at shutdown it is necessary to fit either a suction or discharge non-return valve; refer to 7.2. Non-return Valve.

4.2.1. 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.

4.3. The Compression Process

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

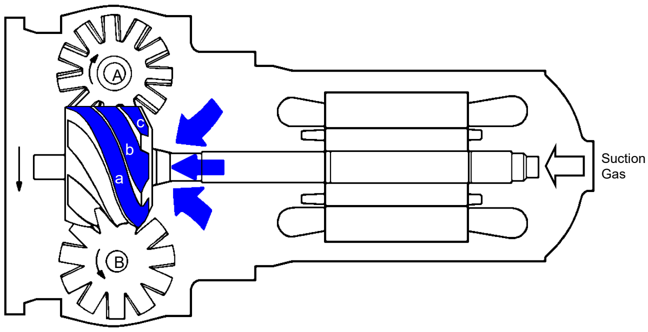
As the HallScrew is a positive displacement compressor, there are three separate stages in the compression cycle: suction, compression and discharge. These are illustrated in Fig 1.

1. and 2. Suction

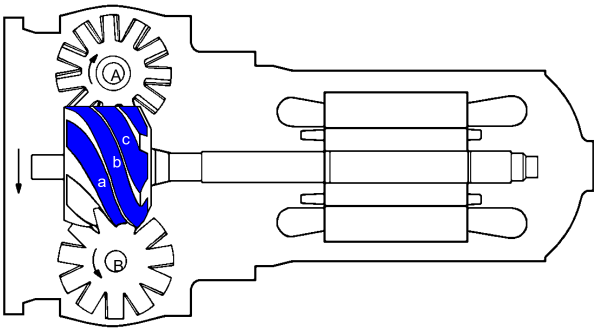
Main rotor flutes 'a', 'b' and 'c' are in communication at one end with the suction chamber via the bevelled rotor end face, and are sealed at the other end by the teeth of star rotor A. As the main rotor turns, the effective length of the flutes increases with a corresponding increase in the volume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

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

1.



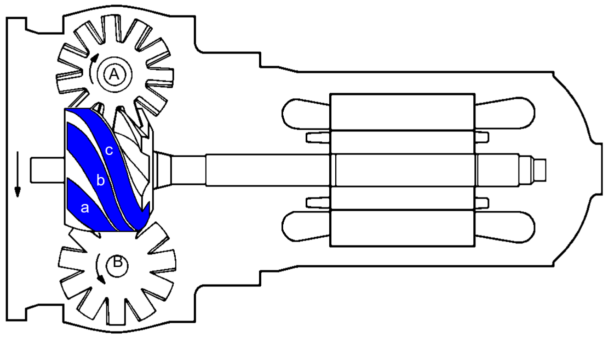
2.



3. Compression

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

3.



4. Discharge

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

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

4.

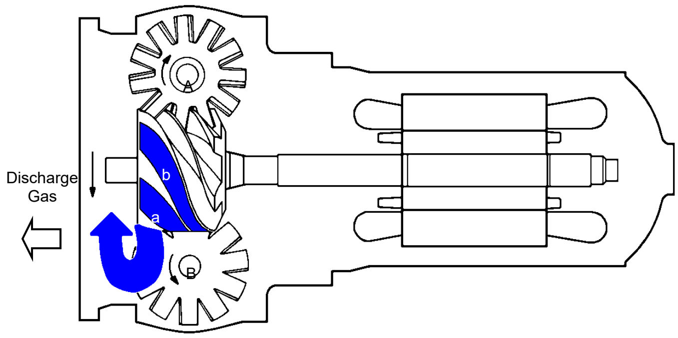


Fig 1 Compression Process

5. Capacity Control and Volume Ratio

HS L/M 3200 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 over compression or under compression 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).

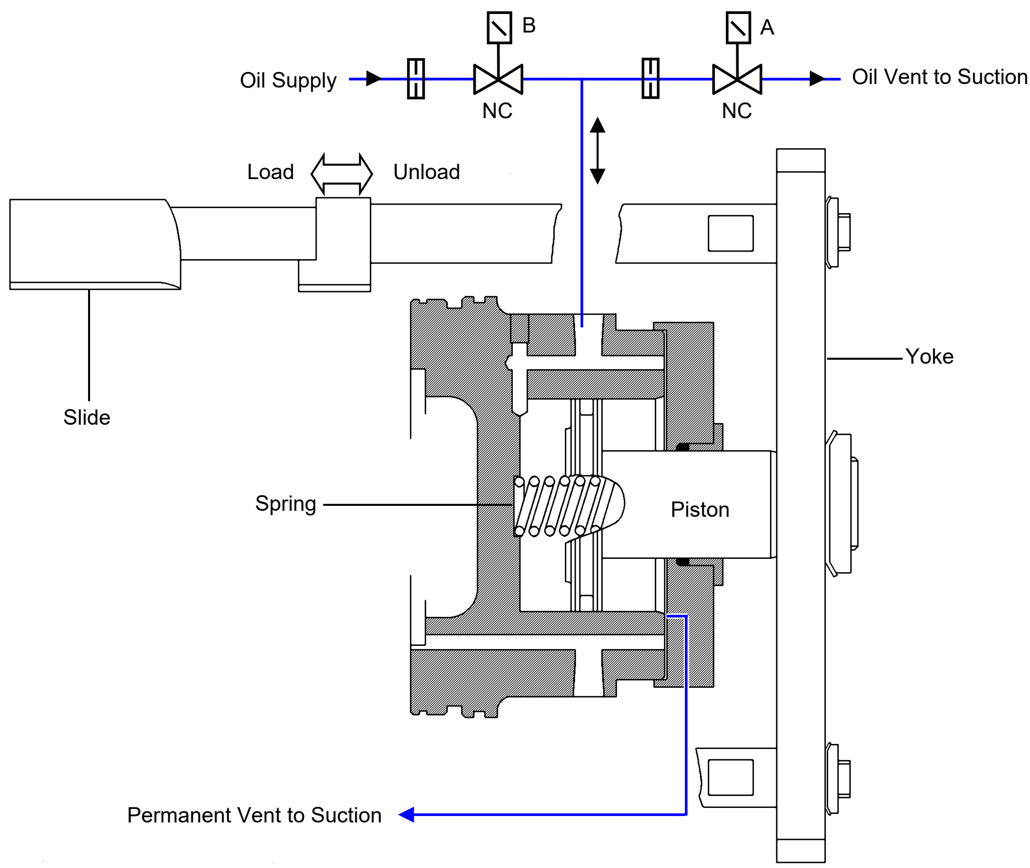


Fig 2 Capacity Control Mechanism

Each slide valve is housed in a semi-circular 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.

5.1. Slide Valve Actuation

The method of operation is illustrated in Fig 3.

The capacity control slides valves are joined together by a yoke, which is connected to a hydraulic piston, housed inside a cylinder and mounted internally at the discharge end of the compressor.

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

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

The piston cylinder incorporates a spring. When the compressor is running, a pressure difference is created across the slide valves: discharge pressure acts on one end of the slides, 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 piston, 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 spring moves the piston and slide valves to the minimum load position, thereby ensuring that the compressor always starts at minimum load.

5.1.1. 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.

5.2. 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.

Energise solenoid A to load the compressor, energise solenoid B to unload.

5.2.1. 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 cylinder. Oil pressure supplements the force of the spring acting on the unload side of the piston. The combined force is sufficient to overcome the action of the suction/discharge differential pressure and move the slide valves towards the minimum load position.

5.2.2. Uncontrolled Stop

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

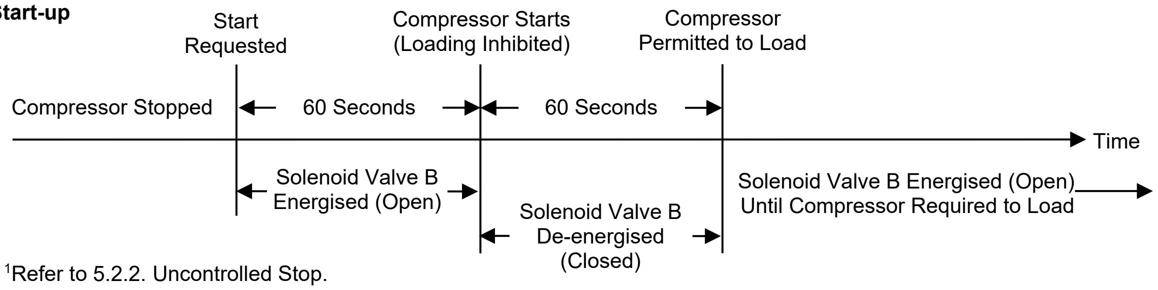
Unlike a controlled stop, unless the compressor was at minimum load before the uncontrolled stop occurred, the capacity control cylinder may contain some refrigerant vapour instead of being completely filled with oil. In this event a hydraulic lock will not be present and uncontrolled loading may occur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

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

[1]Start-up



[1]Refer to 5.2.2. Uncontrolled Stop.

Fig 3 Continuously Variable Capacity Control

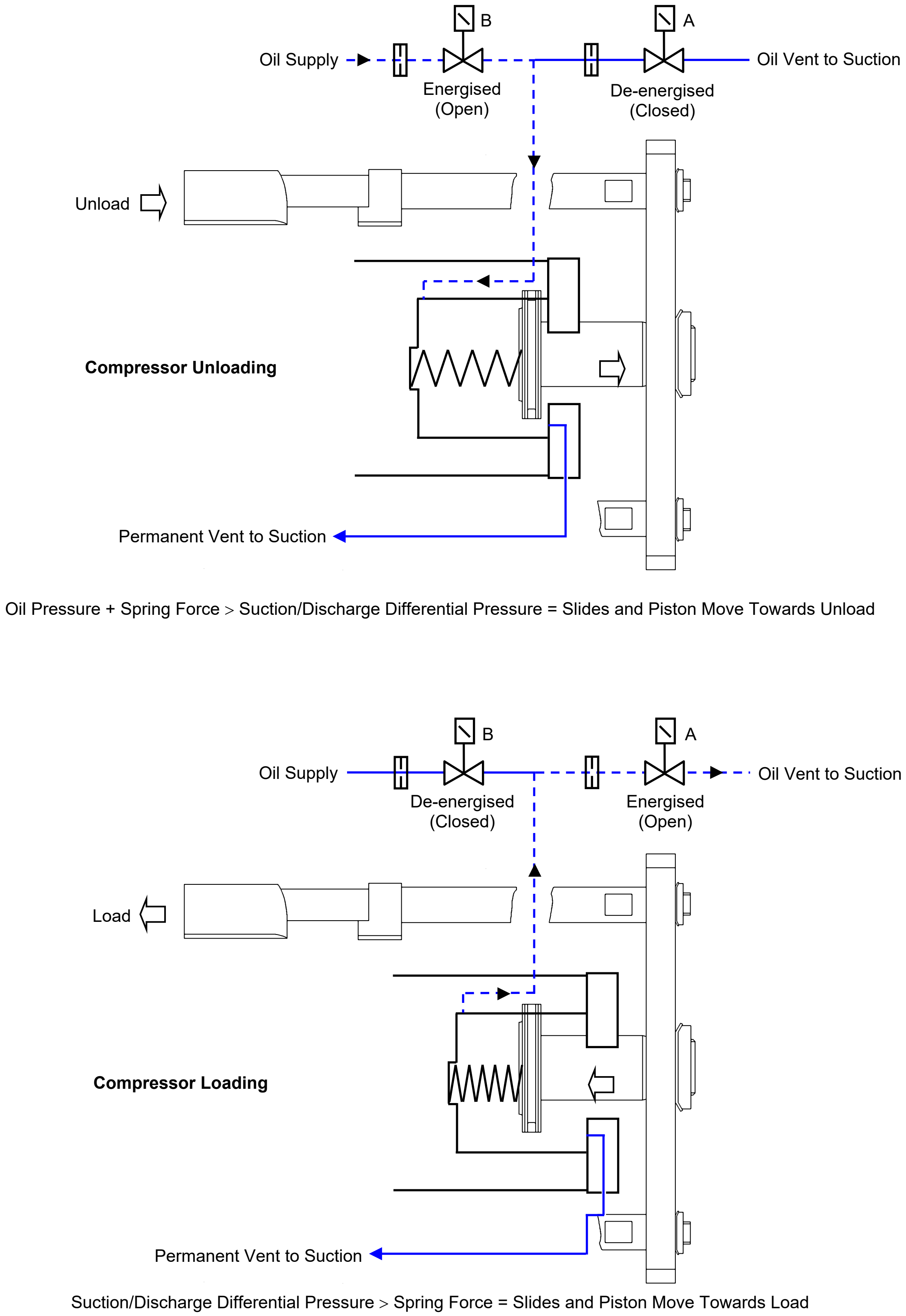


Fig 3 (continued) Continuously Variable Capacity Control

5.3. 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.

5.3.1. 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, motor current can be limited either by using the slide valves to run the compressor unloaded or by throttling the suction. If it is required to use the slide valves, normal manual slide valve control can be used; refer to 5.2. Continuously Variable Capacity Control.

5.3.2. 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.

Pay particular attention 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.

5.4. 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 which is spring-loaded. The complete LVDT assembly screws into a boss on the side of the compressor, the tip of the indicator rod rests against and travels along a ramp machined into the capacity control slide.

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.

The latest design of LVDT, the MSI LVDT, is described in publication 2-205 MSI Linear Variable Displacement Transducer (LVDT) and Slide Valve Position Signal Conditioning Module.

6. Compressor Lubrication, Sealing and Cooling

In common with other types of oil injected screw compressor, HS L/M 3200 series compressors do not possess a built-in oil reservoir (sump) or oil circulation pump. Instead, oil is supplied by a separate external oil support system.

NOTE: It is essential to supply the compressor with an adequate supply of clean (filtered) oil at the correct temperature; refer to 7. Oil Support System.

The oil performs three basic functions:

6.1. Capacity Control Actuation

Oil pressure is used to actuate the compressor capacity control mechanism; refer to 5.1. Slide Valve Actuation.

6.2. 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.

6.3. Oil Injection for Sealing and Cooling

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

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

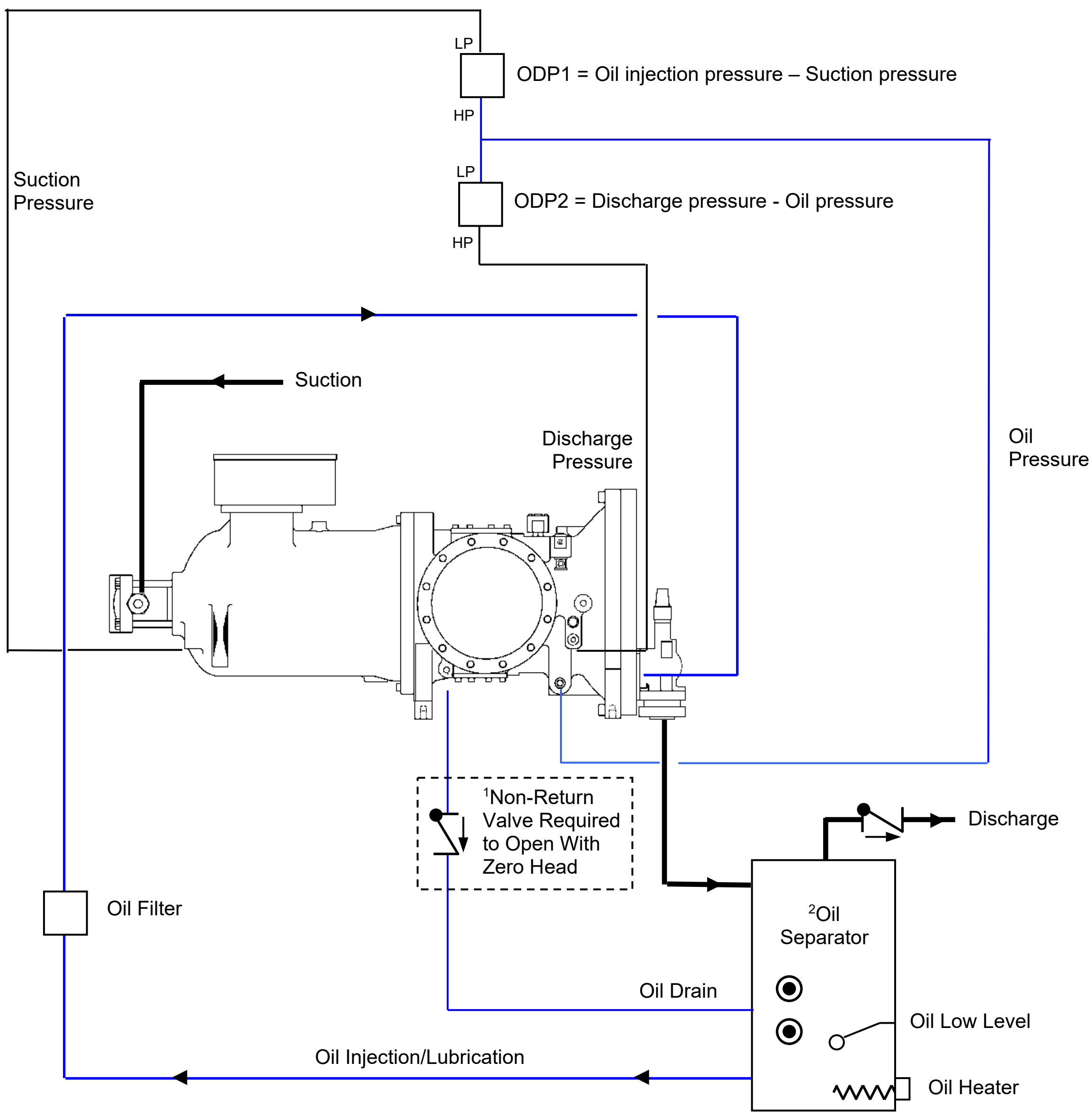
Compressor cooling can be accomplished by the direct injection of liquid refrigerant into the compression process. When liquid injection is not used, the oil injected for sealing absorbs a large proportion of the heat of compression, thus reducing the maximum discharge temperature, and is cooled externally via an oil cooler; refer to 7.10. Compressor Cooling.

7. Oil Support System

HS L/M 3200 series compressors require an external oil separator and oil support system; refer to Fig 4.

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

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



The oil support system must conform with the provisions described in 7.1. to 0.

[1]Drain line is not required if the oil separator inlet is level or below the compressor discharge port.
[2]The maximum oil level in the oil separator with the compressor stopped (under any circumstances including initial filling) must be below the bottom of the compressor casing (bottom of side cover).

Fig 4 Oil Support System

7.1. 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.

7.2. Non-return Valve

To prevent excessive reverse rotation of the compressor at shutdown it is necessary to fit a non-return valve in the system:

- Single compressor/oil separator, a suction non-return valve is normally fitted;
- Multiple compressors with a single oil separator, a discharge non-return valve must be fitted between the compressor discharge and the oil separator inlet.

  NOTE: Discharge non-return valves must be sized according to the operating conditions.

7.3. Multiple Compressors

If two or more compressors are used on the same oil separator the following provisions must be made in addition to those described in 7.2.

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

A typical arrangement is shown in Fig 12.

7.4. Oil Drain

Oil which collects inside the compressor casing must be allowed to drain back to the oil separator when the compressor stops.

Single compressor operating with a single oil separator:

- A discharge non-return valve must be fitted after the oil separator to ensure that the compressor and separator are maintained at the same relative pressures after shutdown; refer to 7.2 Non-return Valve;
- The oil separator must be sized and positioned to provide adequate oil return;
- Provided the oil separator inlet is below or level with the compressor discharge port, with no sections above this, then oil will drain down the discharge pipe into the oil separator. In this case there is no need for an external drain line;
- If the discharge pipe is arranged such that the oil cannot free drain into the oil separator, then an external drain line must be fitted. The drain line should incorporate a non-return valve which will open by gravity with only the liquid head of oil available (i.e. with the spring removed). If a service valve is fitted in the line, this should also 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 7.3 Multiple Compressors):

- 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 An adequate volume must be allowed for in the section of discharge pipe between the compressor discharge port and the discharge non-return valve to accommodate the volume of oil drained from each compressor when shutdown. Typically this volume should be 1.5 to 2.0 litres;
- 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).

7.5. 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.

7.5.1. 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.

7.5.2. Oil Separator Provisions

In addition to the considerations discussed in 7.5.1 Oil Separator Design, the oil separator should comply with the following recommendations:

7.5.2.1. Oil Separator Heater(s)

The oil separator must be fitted with an oil heater or heaters of sufficient capacity to maintain an oil temperature minimum 20 °C above the ambient temperature, thereby preventing refrigerant migration into the oil and the resultant loss of viscosity and potential foaming. The oil heater(s) 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, if necessary, heater tape applied under the insulation.

7.5.2.2. Oil Low Level Trip

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 trip and stop the compressor should the oil level fall below the danger level.

7.6. Oil Differential Pressure Monitoring

As already described in 6. Compressor Lubrication, Sealing and Cooling, HS L/M 3200 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.

7.6.1. 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.

ODP1 = Oil injection pressure – Suction pressure

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

Example:

Maximum suction pressure 3.0 bar abs (2 bar g)

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

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

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

7.6.2. 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.

ODP2 = Discharge pressure - Oil injection pressure

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

7.7. Maintaining Discharge Pressure at Start up

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

In circumstances where the minimum discharge pressure is difficult to achieve, even with the help of condenser head pressure control devices, a differential pressure regulator must be fitted in the discharge line immediately after the oil separator.

For further details refer to publication 2-121 Maintaining Discharge Pressure at Start-up.

7.8. External Oil Filter

To ensure minimum wear on moving parts and to maximise bearing life, it is essential to fit an adequately sized oil filter. The location of the filter is shown in Appendix 2 Oil Support System Schematic Flow Diagrams.

The oil filter should be of the type that uses a disposable element and must be compatible, in all respects, with the minimum specification outlined in Table 2. A bypass must **NOT** be included in the filter assembly.

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	1500 cm2
	Paper or cellulose	5000 cm2
Minimum dirt holding capacity		>13.5 gm
Minimum filter element collapse pressure		20.0 bar
Complete filter assembly maximum clean pressure drop		0.7 bar with oil flow of 50.0 lt/min

NOTE: All filter components must be suitable for use with the system oil and refrigerant.

Table 2 Oil Filter Minimum Specification

7.9. Lubricating Oils

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

For applications using R407F, R134a or other HFC refrigerants, ester lubricants **must** be used. The compressor is supplied already charged with oil, either Emkarate RL68H or ExxonMobil EAL Arctic 68.

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

7.10. 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. In some circumstances no cooling is required.

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

8. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type. For HS L/M 3200 series compressors, the system must contain an oil separator of sufficient capacity. The system must be designed to return any oil carried over into the system from the separator, back to the compressor.

The suction return to the compressor must be dry gas in order to achieve full performance. Liquid return is 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.

8.1. Oil System

The recommendation in 7. Oil Support System should be adhered to.

8.2. 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.

8.2.1. 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, liquid separation 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.

8.3. 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.

8.3.1. 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 and R513A.

15.0 K for R404A, R452A and R507A.

20.0 K for R407C, R407F, R448A, R449A and R22.

8.4. Liquid Injection Lines

The arrangement differs depending on the refrigerant, these are summarised below. For further details refer to publication 2-122 Compressor Cooling.

8.4.1. R134a and R513A Only

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

8.4.2. All Refrigerants Other Than R134a and R513A

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

NOTE: Both the top special R134a/R513A liquid injection plug and the bottom blanking plug must be removed. Use the connectors supplied in the liquid injection kit.

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

8.5. Economiser Connections

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

NOTE: Both the top special R134a/R513A liquid injection plug and the bottom blanking plug must be removed. Use the connectors supplied in the liquid injection kit.

8.6. Safety Requirements for Compressor Protection

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

9. 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.

9.1. Placing the Compressor into Store

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

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

(b) External fittings should be protected from damage.

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

9.2. Taking the Compressor out of Storage

At the end of the period in store, install the compressor as described under 10. Installing the Compressor.

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

Commission and run-in the compressor as described in 11. Commissioning and Operation and 12. Running-In the Compressor.

10. 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 9.2. Taking the Compressor out of Storage, before installation takes place.

10.1. Lifting the Compressor

Attach lifting tackle to 2 x M16 eyebolts (full thread) screwed into the top of the compressor casing as shown in Fig 5. Suitable lifting equipment will be required to lift the compressor. Lifting equipment must be stout enough to take the weight; refer 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 four mounting points; check the tapped holes are undamaged and the threads are completely free of dirt.

⚠ CAUTION

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

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

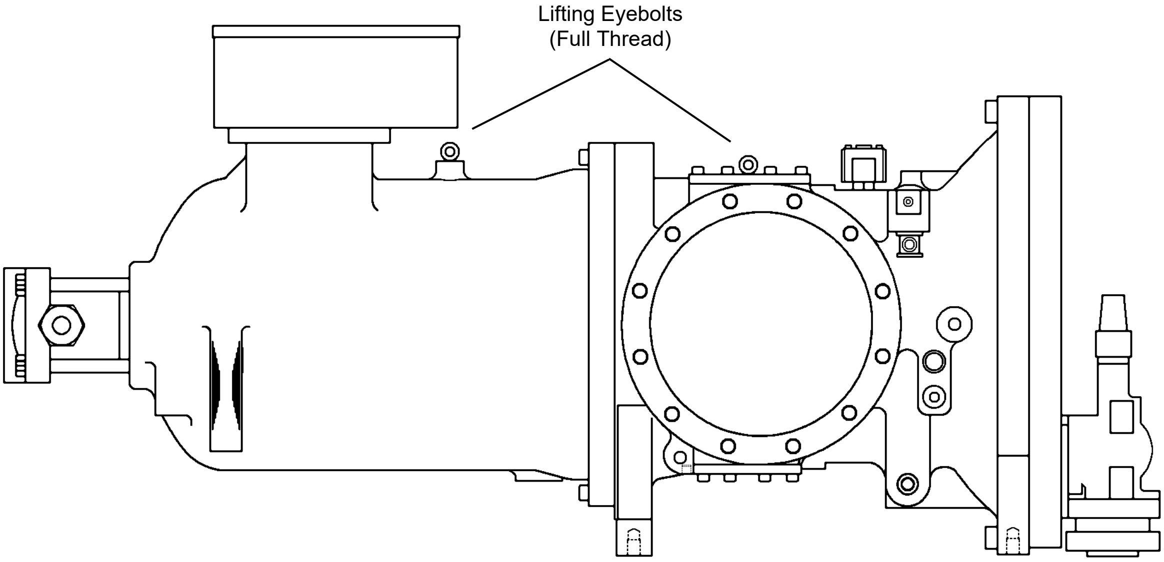


Fig 5 Lifting the Compressor

10.2. Pipeline Connections

Refer to Appendix 1 Compressor Data for connection sizes.

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

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

(b) HS 3200 series semi-hermetic compressors use the same connection for liquid injection and the economiser facility. If the liquid injection/economiser facility is to be used, remove the blanking plugs from the connections. Connect the liquid injection and/or economiser lines to the ports; refer to 8.4. Liquid Injection Lines and 8.5. Economiser Connections.

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

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

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

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

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

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

(f) Connect the oil drain line between the underside of the compressor casing and the return connection, usually located on the oil separator. The line must be fitted with a non-return valve, designed to open with zero head; refer to Fig 4.

(g) Make electrical connections as described in 10.3.

(h) Leak test and evacuate the system as described in 10.4.

10.3. Electrical Wiring Connections and Interlocks

Make the following wiring connections and interlocks:

- Mains electrical supply to the compressor stator/rotor from the motor starter; refer to 10.3.1. Motor Wiring Connections;
- Electrical supply to the following items:

  Compressor motor and discharge high temperature thermistors, fitted as standard and wired as illustrated in Fig 7.

  Oil separator reservoir heaters; refer to 7.5.2.1 Oil Separator Heater(s.

  Oil separator low level sensor or switch; refer to 7.5.2.2 Oil Low Level.

  Capacity control slide valve position transducer; refer to 5.4 Linear Variable Displacement Transducer (LVDT).
- Electrical supply to the capacity control solenoid valves, these are marked 'Load' and 'Unload'; refer to Appendix 1 Compressor Data;
- Power must be supplied to the solenoids via a suitable pulse timer capable of supplying a minimum pulse length of 0.1 to 0.5 seconds, depending upon the accuracy of control required;
- Electrical supply to the capacity control slide valve position transducer; refer to 5.4 Linear Variable Displacement Transducer (LVDT);

- Electrical interlock to prevent the compressor starting unless the slide valves are at minimum load; refer to 5.1.1. Minimum Load Interlock.

10.3.1. Motor Wiring Connections

The HS L/M 3200 series compressor motor is wired for star/delta starting. Soft-start or inverter drive starting methods can be accommodated using terminal links available from J & E Hall International.

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

Terminal box wiring is illustrated in Fig 7 and Fig 6. Refer to Appendix 1 Compressor Data for motor data. The standard terminal box rating is IP54, IP65 available to special order.

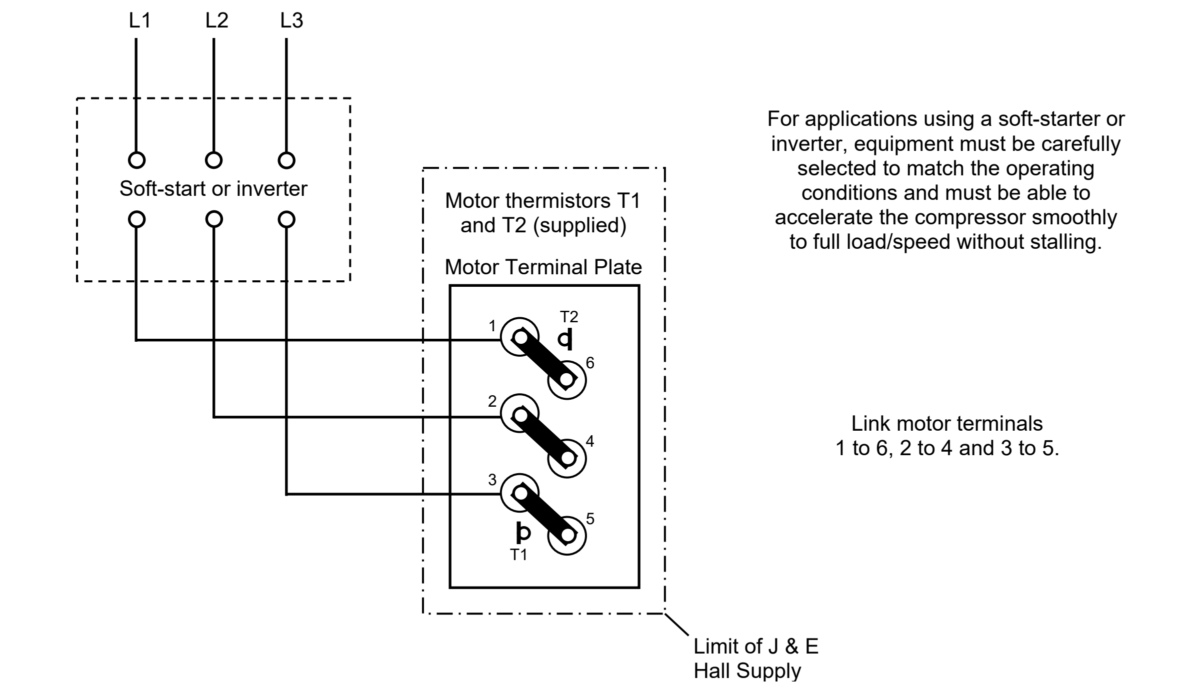


Fig 6 Motor Terminal Box Wiring: Soft-start and Inverter Drive

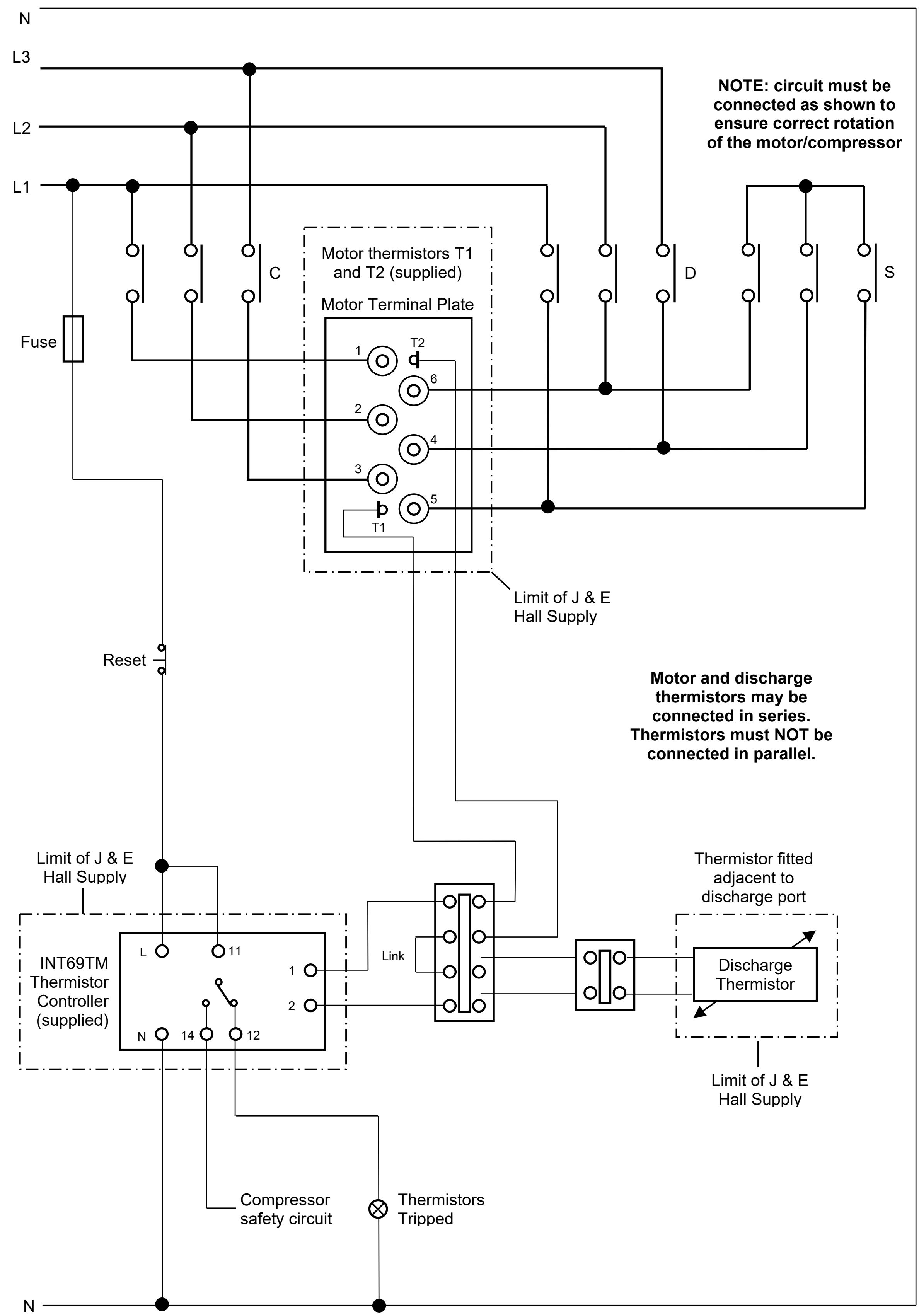


Fig 7 Motor Terminal Box Wiring: Star/Delta

10.4. Leak Testing, Evacuation and Charging

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

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

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

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

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

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

(e) Charge the system with refrigerant.

(f) Start the compressor for the first time; refer to 11. Commissioning and Operation.

(g) Carefully run in the compressor; refer to 12. Running-In the Compressor.

11. Commissioning and Operation

The instructions included in this part of the manual cover a bare-compressor supplied for incorporation into a package unit or site erected system.

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

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

11.1. 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.

11.2. General Checks

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

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

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

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

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

⚠ CAUTION

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

- The discharge high temperature thermistor and compressor drive motor winding high temperature thermistor protection circuits, otherwise the thermistors will be damaged.
  A thermistor for high temperature protection may also be fitted in the oil injection/lubrication line;
- The HS L/M 3200 series semi-hermetic compressor while it is under a vacuum; under these conditions the motor insulation may be seriously damaged;
- Any part of the control system containing semi-conductor devices.

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

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

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

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

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

11.3. Checking Compressor Rotation

(a) The HS L/M 3200 series semi-hermetic compressor is a positive displacement machine designed to rotate in one direction only, this is anti-clockwise when looking on the motor end.

To prevent incorrect compressor rotation, it is ESSENTIAL to check wiring connections to the stator/rotor terminal box have been made correctly in accordance with Fig 7.

Use a phase tester to make a final check for correct rotation. If a phase tester is not available, it is possible to check the direction of rotation by running the compressor for a few seconds and observing the suction and discharge pressure gauges; refer to 11.5. step (g).

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

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

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

11.4. Lubrication System

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

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

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

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

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

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

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

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

11.5. First Start

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

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

(b) Open the suction and discharge stop valves.

⚠ **WARNING**

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

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

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

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

(e) Check the following:

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

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

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

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

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

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

⚠ WARNING

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

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

(h) Start the compressor.

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

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

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

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

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

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

(k) Calibrate the LVDT 4 to 20 mA slide valve position signal for maximum and minimum load; refer to 5.4 Linear Variable Displacement Transducer (LVDT).

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

(m) Run-in the compressor; refer to 12. Running-In the Compressor.

11.6. Normal Starting and Running

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

Check 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 14.5.9. Prolonged Shutdown should be followed.

11.7. Adding Oil to the System

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

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

Acid test all oil before adding it to the system; even new oil has been known to fail this test. Refer to 14.7.1 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 polyol ester synthetic lubricants, which are very hygroscopic.

12. 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.

12.1. 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.

12.1.1. Suction Strainer

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

12.1.2. Oil Filter

HS L/M 3200 series semi-hermetic compressors are fitted with an external oil filter; refer to Table 2.

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.

12.1.3. Refrigerant Filter/Drier

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

12.2. Monitoring for Moisture

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

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

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

12.3. Lubricating Oil

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

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

12.3.1. Oil Acid Level

Checking the acid content of the lubricating oil is the primary method of determining its condition. Since the acid content directly affects the condition of the motor windings, it is recommended to closely monitor the oil's acidity during the running-in period. Remember that a relatively small increase in acid content significantly increases the probability of a motor burn-out. For further information on the causes and prevention of motor burn-out refer to publication 2-250 Semi-hermetic Compressor Motor Burnout.

After the first 12 hours of compressor operation, drain off 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 J & E Hall International, to check the acid content remains within the normal range for the oil; refer to 14.7 Oil Acid Content.

- When a mineral oil has been specified for compressor lubrication, maintain the acid number of the oil <0.05;
- For polyol ester synthetic lubricants, used with HFC refrigerants, maintain the acid number of the compressor lubricating oil <0.15.

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

  NOTE: Failure to maintain the oil's acid number invalidates the guarantee; refer to 3. Misuses that Invalidate Guarantee.

Each time the oil's acid content is checked, the acid number should be recorded in Table 5 Oil Acid Content Record.

12.4. 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.

12.5. Compressor Holding-down Bolts

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

13. 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 13.4. Isolating the Electrical Supply, omitting the pumping down procedure.

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

13.1. Personnel Permitted to Work on Refrigeration Plant

In accordance with BS EN 13313 : 2010, only authorised competent personnel are allowed to work on the refrigeration plant.

Within the UK, companies who service, maintain or install refrigeration, air conditioning and heat pump systems must be certified by one of the following organisations:

- Bureau Veritas;
- Quidos;
- Refcom.

This indicates adequate training has recently been received.

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

13.2. 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.

If the compressor is fitted to a plant supplied by J & E Hall International, also refer to Opening Up the System and Pumping Down, Recovering Refrigerant Charge in the publication for the refrigerant in Section 5 of the plant instruction manual.

13.3. 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, and/or if variable speed drive is fitted via an inverter, reduce drive motor speed to minimum.

With the compressor running at minimum pumping capacity, slowly close the suction stop valve. The compressor will pump down and stop on the LP trip when suction pressure falls to the control setting. 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).

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

13.4. Isolating the Electrical Supply

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

⚠ WARNING

The electrical power used in this equipment is at a voltage high enough to endanger life. The electrical supply must be switched 'off' and isolated before disconnecting the electrical supply to the compressor drive motor. Refer to Safety at the front of this manual.

13.5. Removing the Residual Refrigerant Gas

Connect a refrigerant recovery unit to a suitable valve connection on the isolated portion of the system. Use the recovery unit to 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.

13.6. Opening up the Compressor

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

⚠ WARNING

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

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

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

Reassemble the compressor using the original or replacement components. New gaskets, 'O' rings, lockwashers and a new oil filter element must be used; refer to Table 2.

13.7. 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 11. Commissioning and Operation.

14. Maintenance

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

The maintenance schedule in this manual refers to bare compressors supplied for incorporation into a package unit or site erected system. Besides maintaining the compressor oil support system, reference is also made to controlling system moisture and acid levels; all these factors contribute to compressor health.

NOTE: The schedule covers the most important points for consideration and do not in any way supersede instructions for the maintenance of specific plant.

If the compressor is supplied as part of a package unit or site erected system supplied by J & E Hall International, the maintenance schedule included in Part J : Maintenance in Section 1 of the plant instruction manual includes compressor maintenance and other maintenance procedures specific to the plant.

14.1. Spare Parts

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

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

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

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

Obtain 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: sales@jehall.co.uk
Website: www.jehall.co.uk

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

When ordering always quote the J & E Hall International contract number and the component serial number (if available).

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 L/M 3200 Series Compressor Replacement Parts.

14.2. Filters and Strainers

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

Change the oil filter element and clean strainers at the end of the first 200 hours operation, then at the intervals specified in 14.4. 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 3. Refer to the plant instruction manual for the location of filters and strainers in the refrigerant and cooled medium lines.

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

Table 3 Filter and Strainer Locations

14.3. Running-in

At the end of the commissioning period, the running-in procedures, described under 12. Running-In the Compressor, must been carried out during the first 200 hours of operation.

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

14.4. 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.

14.5. Maintenance Intervals

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

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

Examples are included to make this point clear.

Example 1:

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

Example 2:

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

14.5.1. Daily

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

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

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

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

Particular attention should be paid to the following readings:

- Oil temperature measured at the oil cooler outlet (if an oil cooler is fitted instead of liquid injection);
- Oil pressure at the compressor oil injection connection;
- The net oil pressure drop across the oil filter;
- Suction and discharge pressures and temperatures.

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

14.5.2. Weekly

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

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

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

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

14.5.3. Three Monthly, or at Intervals of 1,250 Operating Hours

(a) Check the operation of the compressor capacity control system; refer to 5. Capacity Control and Volume Ratio.

14.5.4. 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 13. 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 J & E Hall International, to check that the acid content remains within the normal range for the oil; refer to 14.7 Oil Acid Content. Record the acid content in Table 5.

(c) 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.

(d) Renew the oil filter element.

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

(e) Clean strainers throughout the system; refer to Table 3.

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.

(f) 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.

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

(h) Check the tightness of the fastenings securing the compressor 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.

14.5.5. 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 13. Pumping Down and Opening Up the Compressor.

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

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

14.5.6. 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 13. 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.

14.5.7. 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 13. 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.

14.5.8. 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 13. Pumping Down and Opening Up the Compressor.

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

14.5.9. 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 (If fitted).

(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.

14.6. Maintenance Check List

Table 4 illustrates the maintenance schedule as a 'Check List'.

Para	Daily	✓
14.5.1.	Check the oil separator/reservoir oil level.	
	Check and record system temperatures, pressures and flow rates.	
Para	**Weekly**	✓
14.5.2.	Check for leakage of refrigerant and oil. Inspect the exterior of the plant for damage or corrosion.	
	Check valve caps are in place.	
	Check the sight-glass/moisture indicator for the presence of moisture.	
	On multi-compressor applications, changeover the role of lead, lag and/or standby compressor	
Para	**Three Monthly, or at Intervals of 1,250 Operating Hours**	✓
14.5.3.	Check the compressor capacity control system operates correctly	
	Check the pressure drop across the secondary oil separator - *separate secondary oil separator fitted in the discharge line*	
Para	**Every Year, or at Intervals of 5,000 Operating Hours**	✓
14.5.4.	Check the condition of the system oil charge, renew if necessary	
	Renew the oil filter element	
	Clean strainers throughout the system	
	Renew the refrigerant filter/drier cores	
	Check pressure and temperature safety controls operate correctly	
	Check the tightness of the fastenings securing the compressor	
	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**	✓
14.5.5.	Renew the system oil charge	
Para	**Every 6 Years, or at Intervals of 25,000 Operating Hours**	✓
14.5.6.	Remove side covers, inspect the compressor	
Para	**Every 12 Years, or at Intervals of 50,000 Operating Hours**	✓
14.5.7.	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**	✓
14.5.8.	Dismantle the compressor and check parts for damage or wear. Renew the main bearings.	

Table 4 Maintenance Check List

14.7. Oil Acid Content

An acid test kit, available from J & E Hall International, is required to carry out this check. Kit part number N29580002.

Take a sample of oil from the oil separator/reservoir. Compare the result with the normal acid number for the oil (refer to the oil supplier's published data or compare with a sample of fresh oil from a previously unopened container).

14.7.1. Oil Acid Content Record

Each time the oil's acid content is checked, record the value in Table 5.

Acid Content	Signature	Printed Name	Date

Table 5 Oil Acid Content Record

Appendix 1 Compressor Data

- HS H/M/L 3200 Series: Compressor Model Nomenclature.
- HS H/M/L 3200 Series: Physical Data.
- HS H/M/L 3200 Series: Motor Data
- HS H/M/L 3200 Series: Limits of Operation.
- Safety Requirements for Compressor Protection.
- HS H/M/L 3200 Series: Physical Dimensions and Connections – 82/98 kW Motors.
- HS H/M/L 3200 Series: Physical Dimensions and Connections – 138/166 kW Motors.

HS H/M/L 3200 Series: Compressor Model Nomenclature

HallScrew	Application	Compressor			Capacity Control Slide V_R	Lubricant	Motor Power (Nominal)	Motor Voltage	Refrigerant	Voltage (Auxiliary)	Capacity Indicator	Stop Valves and Flanges	Economiser Kit	Discharge Thermistor	Oil Level Detector	DOL Kit
HS	X	3	2	X	X	X	X	X	X	X	X	X	X	1	0	X

Application	L	Semi-hermetic compressor for low temperature application		
	M	Semi-hermetic compressor for medium temperature application		
Compressor	32X	Series 3200 Twin Star 16, 18, 20 or 21		
Capacity Control Slide V_R	3	3.0 V_R		
	5	4.9 V_R		
Lubricant	E	Ester oil		
	L	Polyvinyl ether oil		
	M	Mineral oil		
Motor Power (Nominal)	A	82/98 kW @ 50/60 Hz (3216/3218/3220)	H	138/166 kW @ 50/60 Hz (3221)
Motor Voltage	Q	400/460 V 3 ph 50/60 Hz	D	500/575 V 3 ph 50/60 Hz
	U	380 V 3 ph 60 Hz	V	230 V 3 ph 60 Hz
	B	208 V 3 ph 60 Hz	X	Special voltage
Refrigerant	A	R134a	L	R407F
	B	R22	N	R448A
	C	R407C	O	R449A
	E	R507A	X	Other
	F	R404A		
Voltage (Auxiliary)	1	115 V 1 ph 50/60 Hz		
	2	230 V 1 ph 50/60 Hz		
	3	24 V dc		
	4	24 V ac		
	X	Asco solenoid valves less coils (ATEX coils for Zone 2 application, free issue)		
Capacity Indicator	0	No capacity indicator (standard)		
	D	Capacity indicator (not self-setting)		
	E	Capacity indicator (not self-setting) plus signal conditioning module		
Stop Valves and Flanges	A	Suction and discharge flanges (option)		
	B	Suction flange and discharge stop valve (standard)		
	C	Suction flange and 3N1 three function discharge valve		
	D	Suction and discharge stop valves		
	E	Suction stop valve and discharge flange		
	F	Suction stop valve and 3N1 three function discharge valve		

Economiser Kit	0	No economiser kit
	1	Economiser kit (standard)
Discharge Thermistor	1	Discharge thermistor (max temp 100 °C) and Kriwan INT 69 TM controller
Oil Level Detector	0	No oil level detector
DOL Kit	0	No DOL kit
	1	DOL kit

Example: HSM 3218/3/M/A/D/B/2/D/B/1/1/0/0

This describes a HallScrew 3218 twin star semi-hermetic compressor for medium temperature application fitted with 3.0 V_R capacity control slide valves, lubricant is mineral oil. Fitted with a 82 kW motor suitable for 500/575 V 3 ph 50/60 Hz supply. Compressor for operation with R22. Solenoid voltage 230 V 1 ph 50/60 Hz. Fitted with capacity indicator (not self-setting), suction flange and discharge stop valve, economiser kit and discharge thermistor. Oil level detector and DOL kit not fitted.

HS H/M/L 3200 Series: Physical Data

Compressor Type	Single screw, semi-hermetic
Compressor Rotation	Anti-clockwise looking on the motor end. Under no circumstances should the compressor run in the reverse direction.
Method of Drive	Suction gas cooled 3-phase, 2-pole stator/rotor arranged for start/delta, soft-start or inverter drive. Maximum of 6 starts per hour. Refer to Motor Data for kW ratings.
Speed Range	Depends on the supply frequency, 50 Hz or 60 Hz; refer to Motor Data
Physical Dimensions	Refer to Physical Dimensions and Connections.
Weight	720 kg (all models).
Capacity and Power	Refer to selection software.
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	110 V or 240 V ac (other voltages available on request). Terminal box rating IP65.
Suction Strainer	Integral. 60 mesh x 37 SWG.
Motor Terminal Box Rating	IP54 (standard), IP65 (available to special order)

Swept Volume

Swept Volume (m^3/hr)	HS H/M/L 3216	HS H/M/L 3218	HS H/M/L 3220	HS H/M/L 3221
Compressor running @ 50 Hz (2 pole speed)	286	343	415	471
Compressor running @ 60 Hz (2 pole speed)	343	411	498	565

[1]Sound Pressure Levels @ 50 Hz (2 pole speed)

Compressor	Total dB 'A'	Centre Frequency – Hz						
		125	**250**	**500**	**1 k**	**2 k**	**4 k**	**8 k**
HS H/M/L 3216	82	67	75	78	79	77	72	71
HS H/M/L 3218	83	67	75	79	80	78	72	71
HS H/M/L 3220	84	67	76	80	81	77	74	72
HS H/M/L 3221	85	68	77	81	82	78	75	73

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

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

HS H/M/L 3200 Series: Motor Data – 50 Hz Operation

Compressor Running @ 50 Hz (2980 rpm)	HS H/M/L 3216		HS H/M/L 3218	
Motor nominal output (kW)	82		82	
Refrigerant	R134a	All Other Refrigerant	R134a	All Other Refrigerant
Capacity control slide valve V_R (refer to Appendix 3 for limits of operation)	2.2/3.0 (H/M)	3.0/4.9 (M/L)	2.2/3.0 (H/M)	3.0/4.9 (M/L)
Motor maximum input (kW)	73	88	88	105
Maximum running current (A) @ 400 V	123	141	146	167
Starting current (locked rotor) in Y (A) @ 400 V	288		288	
Starting current (locked rotor) in Δ (A) @ 400 V	906		906	
Standard voltage range (V)	400 ± 10 %			
Compressor Running @ 50 Hz (2980 rpm)	**HS H/M/L 3220**		**HS H/M/L 3221**	
Motor nominal output (kW)	82		82	138
Refrigerant	R134a	All Other Refrigerant	R134a	All Other Refrigerant
Capacity control slide valve V_R (refer to Appendix 3 for limits of operation)	2.2/3.0 (H/M)	3.0/4.9 (M/L)	2.2/3.0 (H/M)	3.0/4.9 (M/L)
Motor maximum input (kW)	108	127	122	164
Maximum running current (A) @ 400 V	177	201	199	263
Starting current (locked rotor) in Y (A) @ 400 V	288		288	455
Starting current (locked rotor) in Δ (A) @ 400 V	906		906	1480
Standard voltage range (V)	400 ± 10 %			

HS H/M/L 3200 Series: Motor Data – 60 Hz Operation

Compressor Running @ 60 Hz (3575 rpm)	HS H/M/L 3216		HS H/M/L 3218	
Motor nominal output (kW)	98		98	
Refrigerant	**R134a**	**All Other Refrigerant**	**R134a**	**All Other Refrigerant**
Capacity control slide valve V_R (refer to Appendix 3 for limits of operation)	2.2/3.0 (H/M)	3.0/4.9 (M/L)	2.2/3.0 (H/M)	3.0/4.9 (M/L)
Motor maximum input (kW)	88	105	106	126
Maximum running current (A) @ 460 V	122	144	146	172
Starting current (locked rotor) in Y (A) @ 460 V	285		285	
Starting current (locked rotor) in Δ (A) @ 460 V	893		893	
Standard voltage range (V)	460 ± 10 %			
Compressor Running @ 60 Hz (3575 rpm)	**HS H/M/L 3220**		**HS H/M/L 3221**	
Motor nominal output (kW)	98		98	166
Refrigerant	**R134a**	**All Other Refrigerant**	**R134a**	**All Other Refrigerant**
Capacity control slide valve V_R (refer to Appendix 3 for limits of operation)	2.2/3.0 (H/M)	3.0/4.9 (M/L)	2.2/3.0 (H/M)	3.0/4.9 (M/L)
Motor maximum input (kW)	130	152	146	197
Maximum running current (A) @ 460 V	177	209	201	273
Starting current (locked rotor) in Y (A) @ 460 V	288		285	461
Starting current (locked rotor) in Δ (A) @ 460 V	893		893	1499
Standard voltage range (V)	460 ± 10 %			

HS H/M/L 3200 Series: Limits of Operation

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.

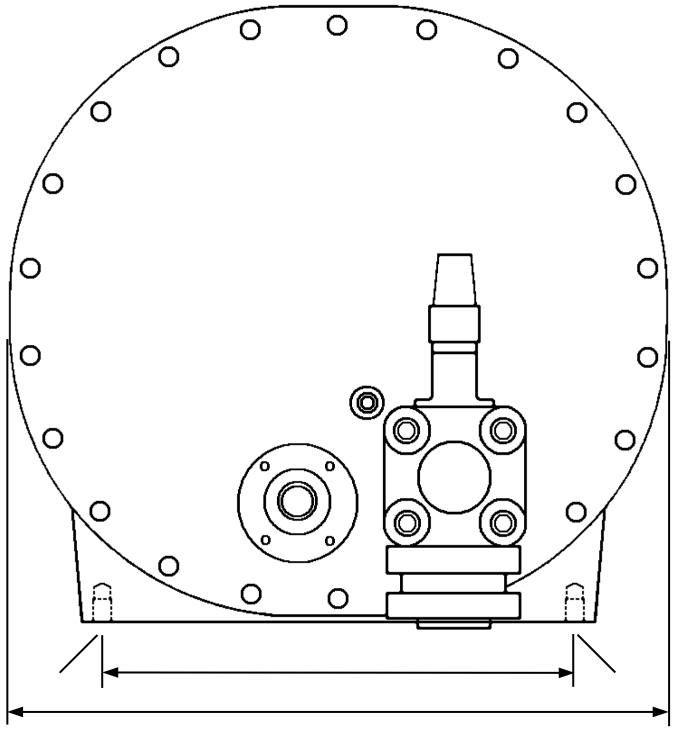
Pressure Limits			R22	R134a R513A	R404A R507A
Max Design Pressures	[1]High side/low side test pressure		32.9 bar g	23.6 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	3.0 V_R	5.8 bar g	3.5 bar g	5.8 bar g
		4.9 V_R	4.0 bar g	3.5 bar g	4.0 bar g
	Maximum pressure ratio	3.0 V_R	10	10	10
	Minimum pressure ratio	4.9 V_R	5	5	5
	Maximum compressor operating discharge pressure		27.9 bar g	19.4 bar g	25.4 bar g
	Maximum compressor operating pressure differential (discharge – suction)		20.0 bar	17.5 bar	23.0 bar g
	Minimum compressor operating pressure differential at minimum load		3.0 bar	2.0 bar	3.6 bar
Pressure Limits			**R407C**	**R407F**	**R448A R449A R452A**
Max Design Pressures	[1]High side/low side test pressure		32.9 bar g	32.9 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	3.0 V_R	5.4 bar g	5.7 bar g	6.0 bar g
		4.9 V_R	4.0 bar g	4.0 bar g	4.0 bar g
	Maximum pressure ratio	3.0 V_R	10	10	10
	Minimum pressure ratio	4.9 V_R	5	5	5
	Maximum compressor operating discharge pressure		29.6 bar g	23.9 bar g	24.2 bar g
	Maximum compressor operating pressure differential (discharge – suction)		23.0 bar	23.0 bar g	23.0 bar g
	Minimum compressor operating pressure differential at minimum load		3.0 bar	3.6 bar	3.6 bar
Temperature Limits	Discharge temperature		100 °C (standard) 120 °C (special)		
	Discharge minimum superheat		R134a and R513A = 13.0 K R404A, R452A and R507A = 15.0 K R22, R407C, R407F, R448A and R449A = 20.0 K		

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

Safety Requirements for Compressor Protection

Parameter	Trip	Device	Setting	Remarks
Discharge pressure	High	HP cut-out	According to the operating conditions	Connected to compressor discharge
Discharge pressure	Low	Pressure control or pressure transducer and programmable controller with suitable analogue inputs	According to the operating conditions	-
Discharge temperature	High	Thermistor (fitted as standard)	100 °C (standard) 120 °C (special)	For 120 °C (special) refer to J & E Hall International. The discharge thermistor can be wired in series with the motor thermistor; refer to Fig 7.
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 4.	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 4) or pressure transducers and programmable controller with suitable analogue inputs	2 bar (standard) 3 bar (maximum)	Should be approximately 1 bar above difference when filter is new. ODP2 is not mandatory but is recommended to detect when the oil filter is becoming blocked and it is time to renew the filter element.
Oil separator oil level	Low	Level switch or sensor	Trip on low level	Time delay (5 secs max) required during operation to prevent spurious trips
Compressor motor high temperature	High	Thermistor (fitted as standard)	-	The motor thermistor can be wired in series with the discharge thermistor; refer to Fig 7.
Compressor motor current	High	Current limiter, or current transformer and programmable controller with suitable analogue inputs	Set according to the compressor motor size	Prevents operation above the maximum rated motor power

HS H/M/L 3200 Series: Physical Dimensions and Connections

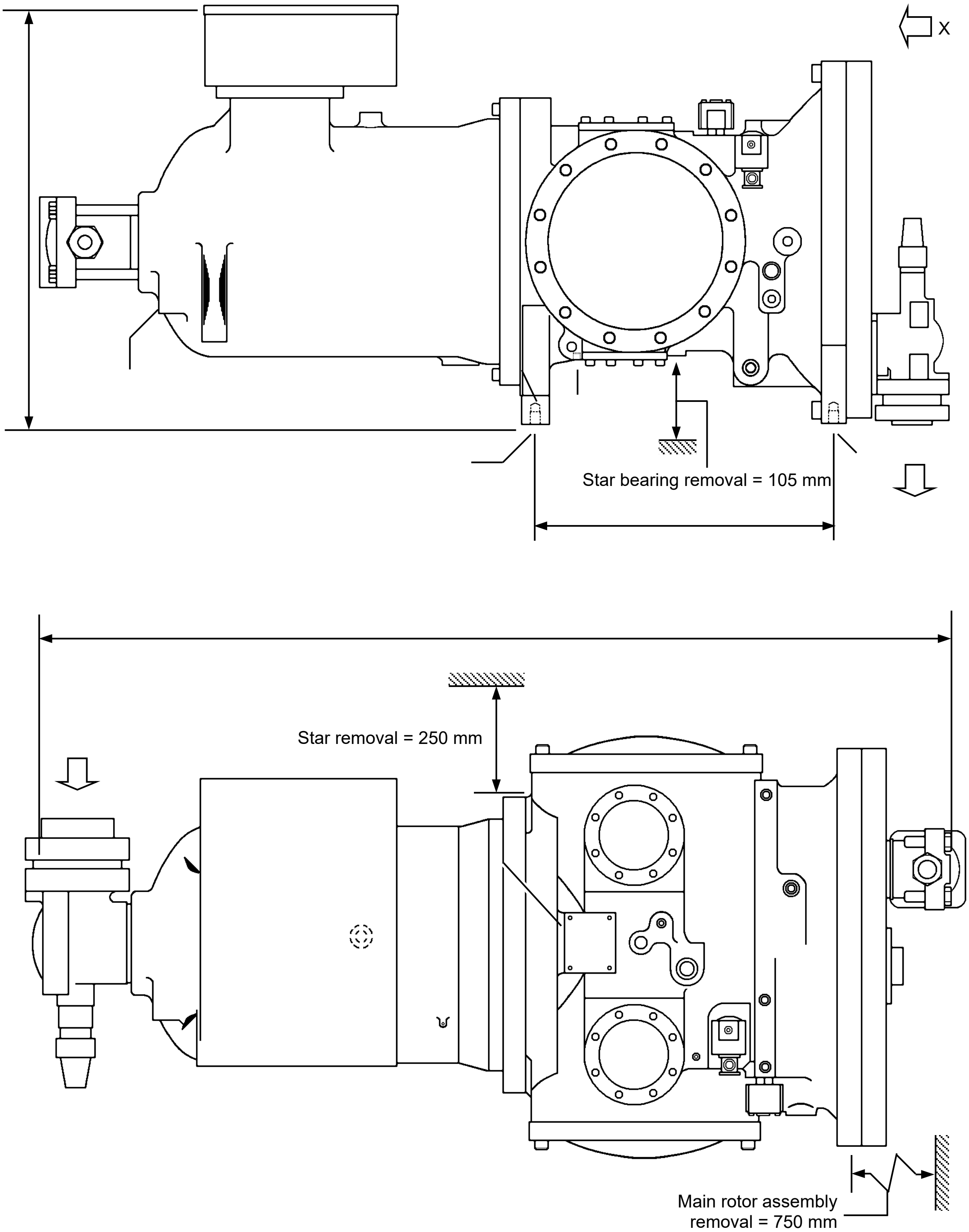


View on arrow X

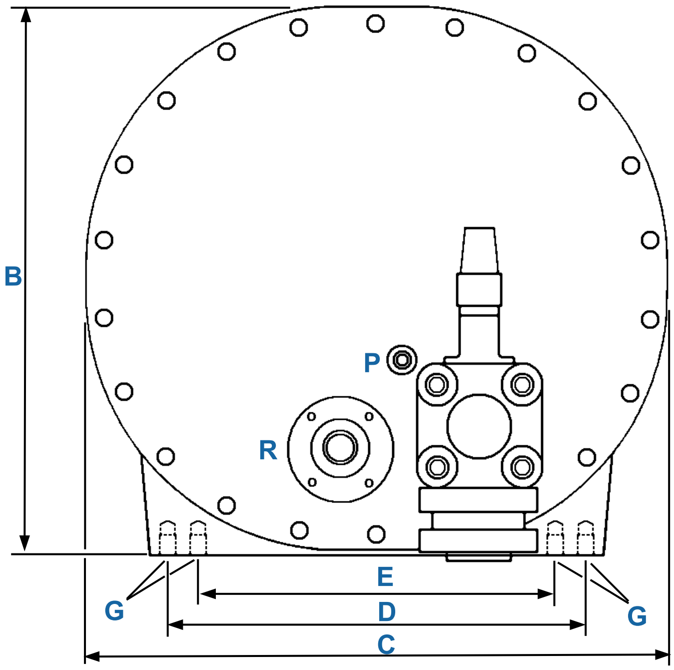
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall International certified drawing

	Description				Size
Dimensions	Overall	Length	A		1298 mm
		Height	B		584.5 mm
		Width	C		566 mm
	Holding-down bolt centres		D		380 mm
			E		420 mm
	Holding-down bolts		F	4 off	M12 x 1.75P x 21 full thread
Lifting	Lifting eyebolts		G	2 off	M16 x 2P x 27 full thread
Connections	Suction		H	1 off	3” NB (3 1/8” OD)
	Discharge		I	1 off	2” NB (2 1/8” OD)
	Suction pressure gauge		J	1 off	1/8” NPT
	Discharge pressure gauge		K	1 off	1/4” NPT
	Oil pressure gauge (two positions)		L	2 off	
	Discharge HP switch or pressure transmitter		M	1 off	1/8” NPT
	High temperature switch or thermistor		N	1 off	1/8” BSP
	Liquid injection/economiser (top and bottom)		O	2 off	1 1/16” (12 UNF)
	Oil injection/lubrication		P	1 off	
	Oil drain		Q	1 off	3/4" (16 UNF)
Electrical	Load solenoid valve		R	1 off	Not applicable
	Unload solenoid valve		S	1 off	
	LVDT		T	1 off	3/4" (16 UNF)

HS H/M/L 3200 Series Physical Dimensions and Connections: 82 kW @ 50 Hz and 98 kW @ 60 Hz Motors



HS H/M/L 3200 Series Physical Dimensions and Connections: 138 kW @ 50 Hz and 166 kW @ 60 Hz Motors

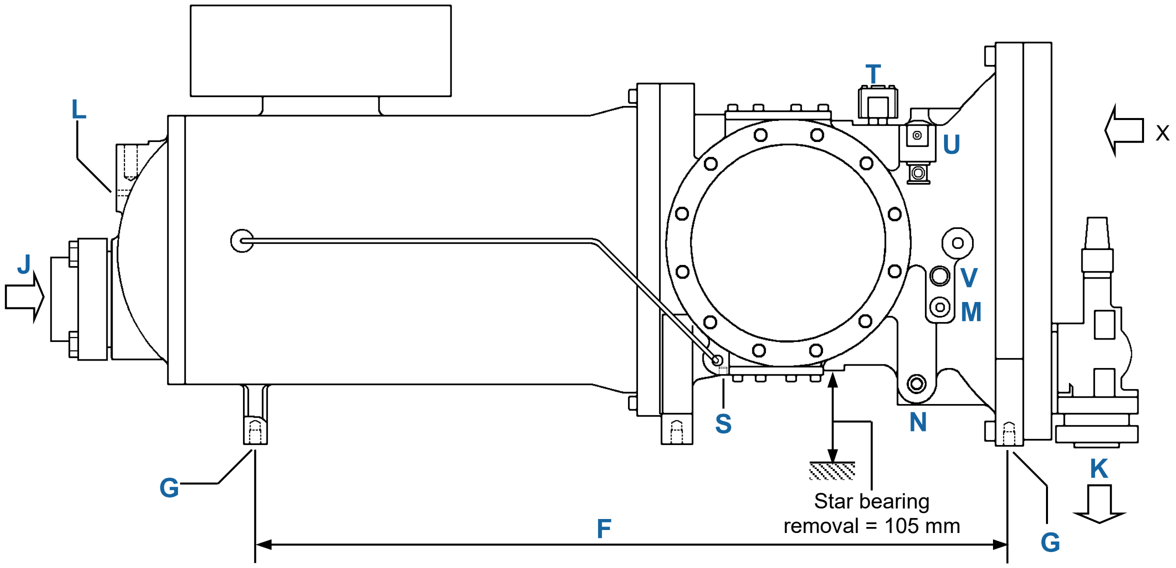


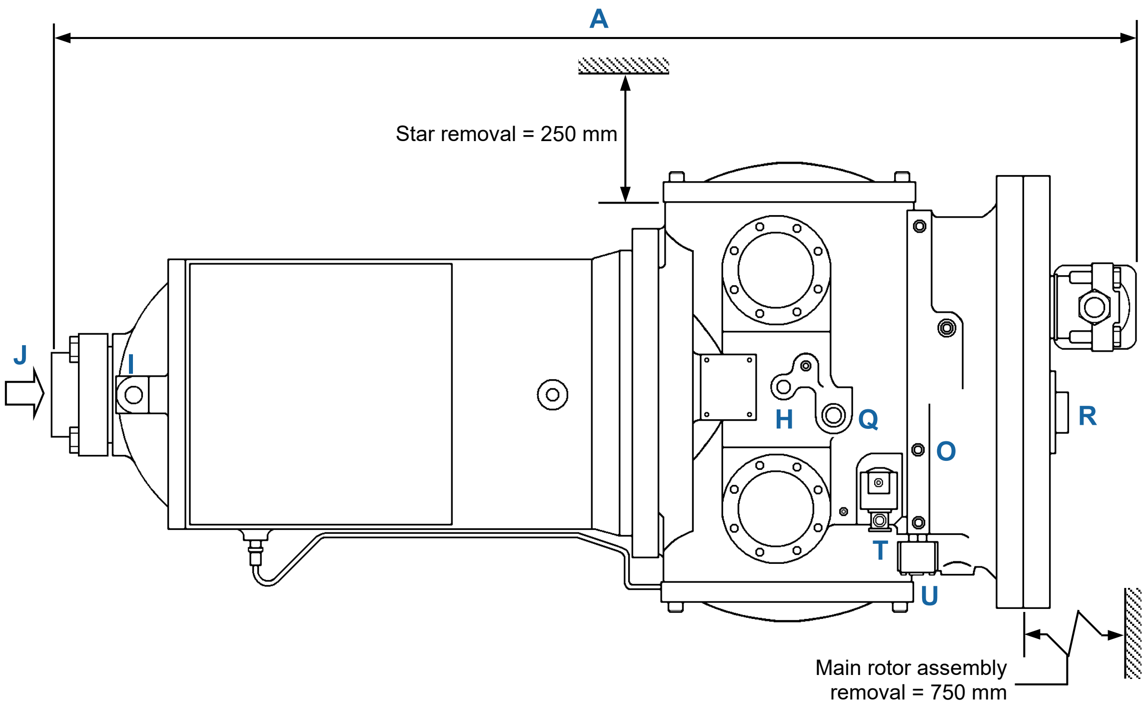
View on arrow X

Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall certified drawing D100355

	Description				Size
Dimensions	Overall (including discharge stop valve)	Length	A		1365 mm
		Height	B		590 mm
		Width	C		566 mm
	Holding-down bolt centres	Casing	D		380 mm
		Motor housing	E		320 mm
		Casing/motor housing	F		938 mm
	Holding-down bolts		G	4 off	M12 x 1.75P x 21 full thread
Lifting	Lifting eyebolts	Casing	H	1 off	M16 x 2P x 27 full thread
		Motor housing	I	1 off	M20 x 2.5P x 35 full thread
Connections	Suction		J	1 off	4” NB (4 1/8” OD)
	Discharge		K	1 off	2 1/2” NB (2 5/8” OD)
	Suction pressure gauge		L	1 off	1/8” NPT
	Discharge pressure gauge		M	1 off	1/4” NPT
	Oil pressure gauge		N	1 off	
	Discharge HP switch or pressure transmitter		O	1 off	1/8” NPT
	High temperature switch or thermistor		P	1 off	1/8” BSP
	Liquid injection/economiser (top and bottom)		Q	2 off	1 1/16” (12 UNF)
	Oil injection/lubrication		R	1 off	
	Oil drain		S	1 off	3/4" (16 UNF)
Electrical	Load solenoid valve		T	1 off	Not applicable
	Unload solenoid valve		U	1 off	
	LVDT		V	1 off	3/4" (16 UNF)

HS H/M/L 3200 Series Physical Dimensions and Connections: 138 kW @ 50 Hz and 166 kW @ 60 Hz Motors





Appendix 2 Oil Support System Schematic Flow Diagrams

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

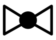
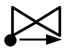
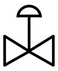
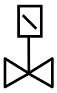
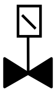
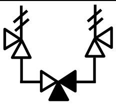
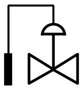
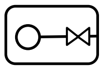
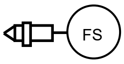
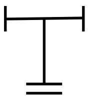
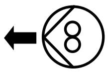
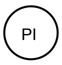
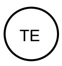
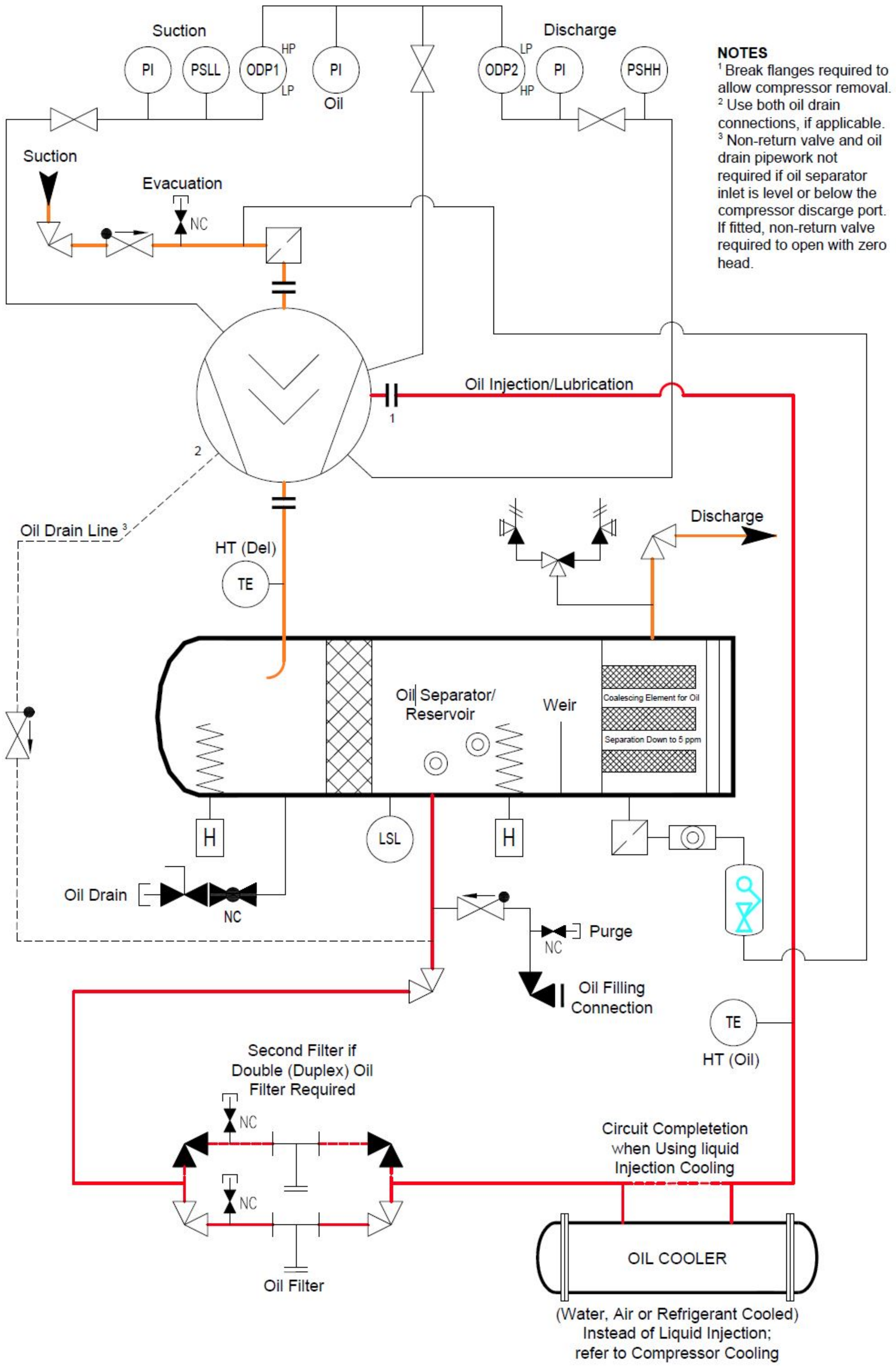
	Ball valve		Non-return valve
	Quick-acting drain valve, normally closed and capped		Control valve
	Relief valve		Solenoid valve (normally open)
	Relief valve (to atmosphere)		Solenoid valve (normally closed)
	Dual relief valve (to atmosphere)		Expansion valve (thermostatic type shown)
	Sight-glass (on vessel)		Liquid drainer
	Sight-glass (in line)		Heater
	Strainer		Opto sensor in drain line
	Oil filter		Oil pump
	Pressure gauge or transducer		Oil differential pressure switch
	Discharge high pressure switch or transducer		Opto liquid level sensor or level switch
	Suction low pressure switch or transducer		High temperature thermistor or switch

Fig 8 Key to Schematic Flow Diagrams



NOTES

[1] Break flanges required to allow compressor removal.

[2] Use both oil drain connections, if applicable.

[3] Non-return valve and oil drain pipework not required if oil separator inlet is level or below the compressor discarge port. If fitted, non-return valve required to open with zero head.

Fig 9 No Oil Pump, Oil Support System for Single Compressor

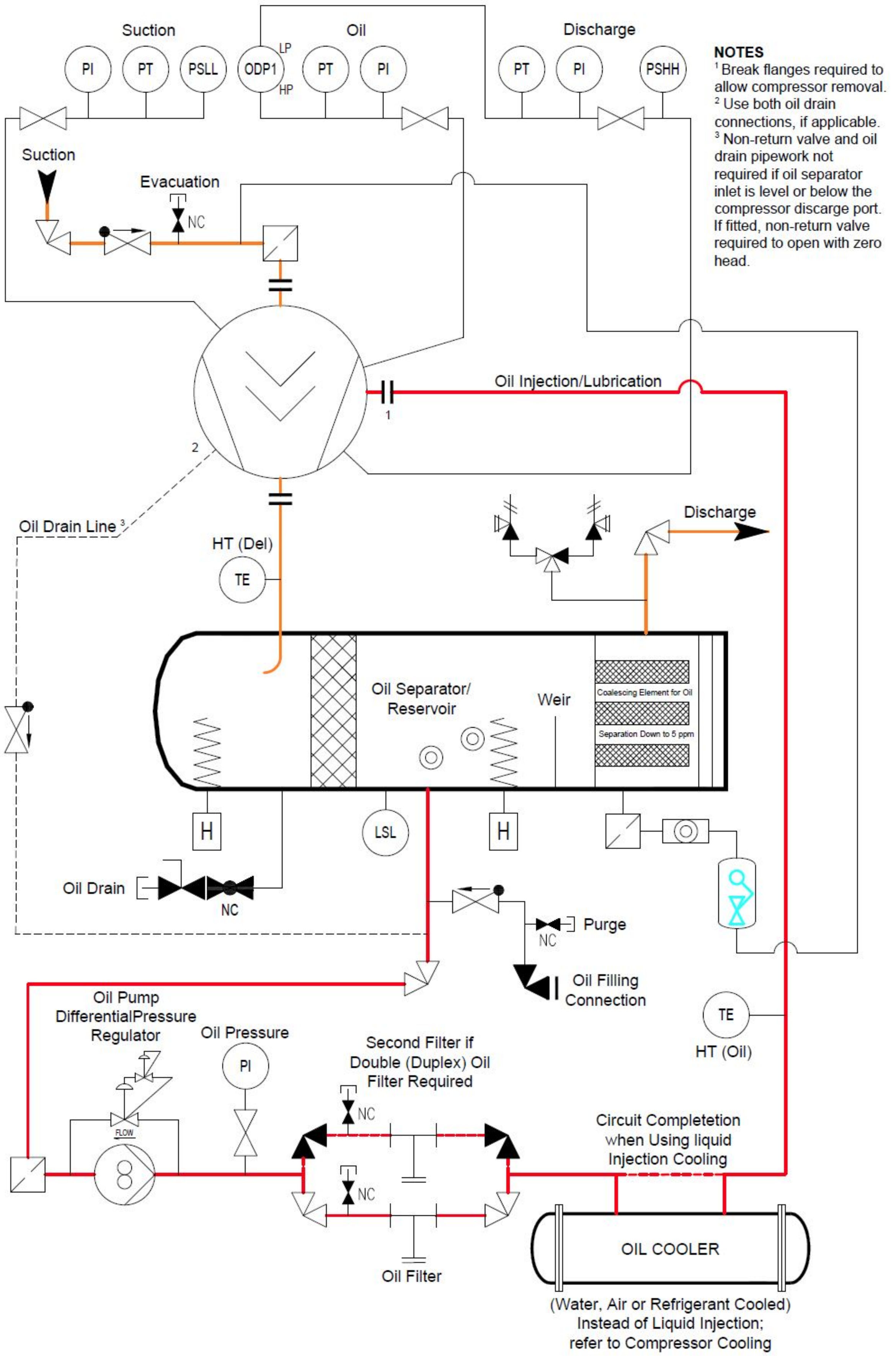


Fig 10 Continuous Running Oil Pump, Oil Support System for Single Compressor

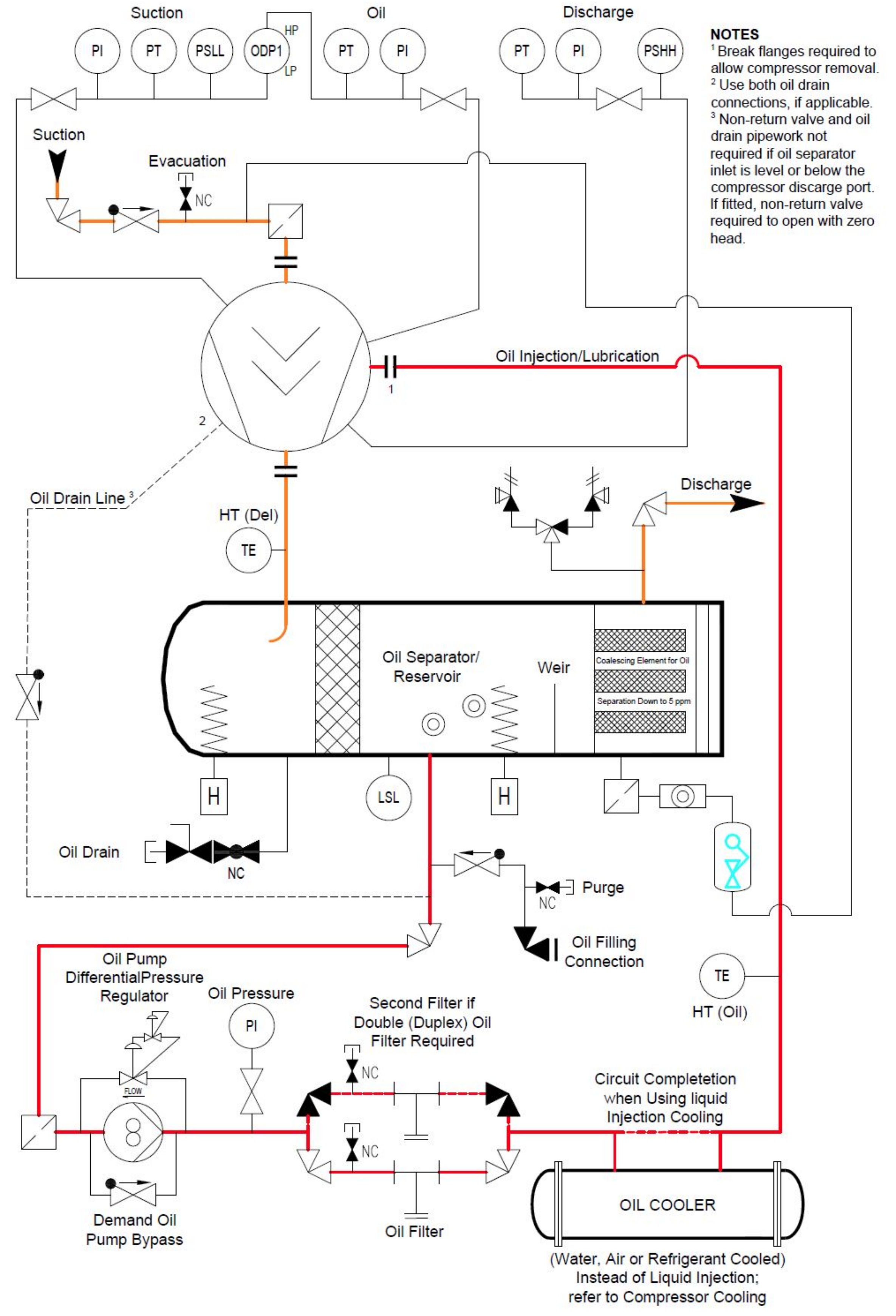


Fig 11 Demand Oil Pump, Oil Support System for Single Compressor

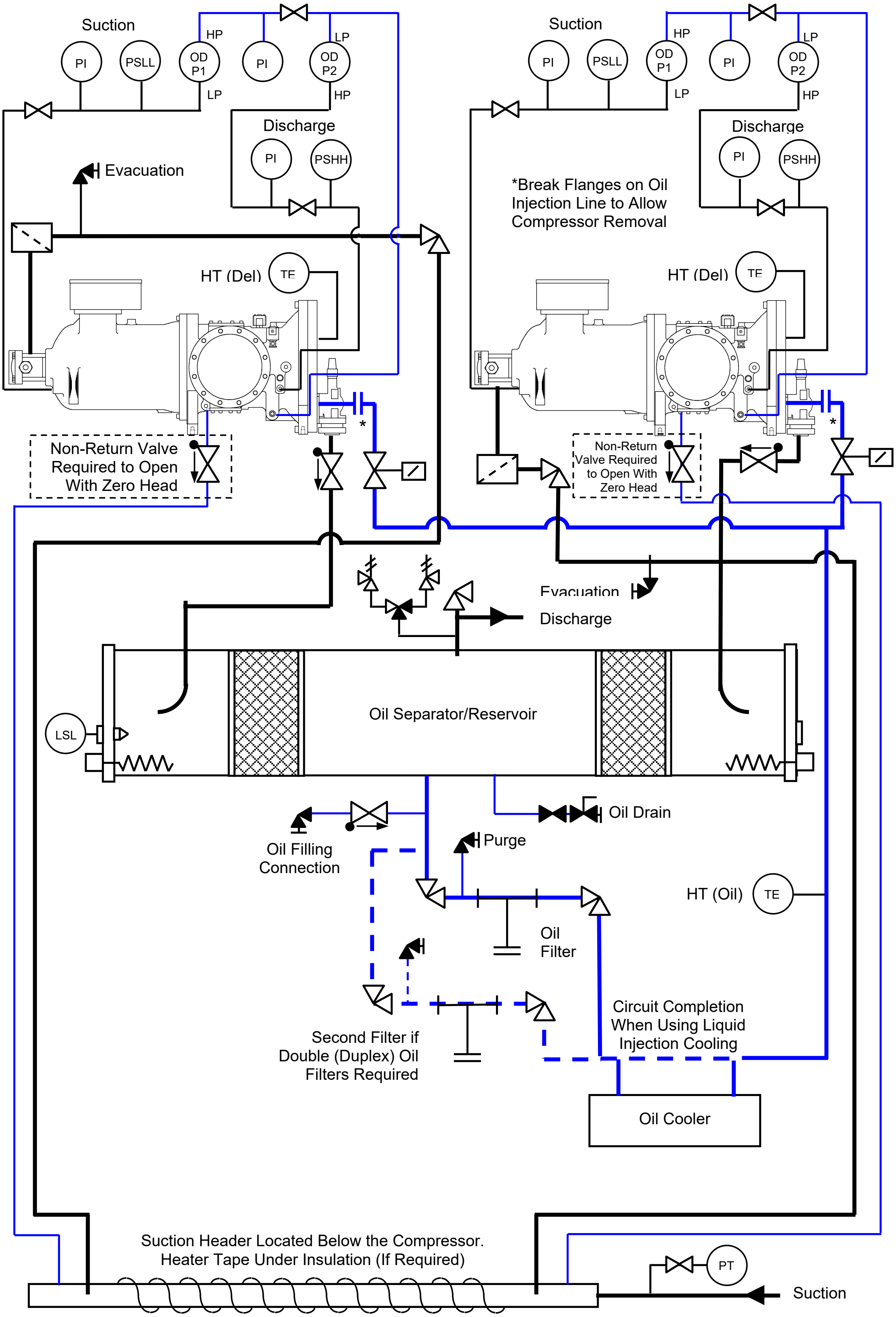
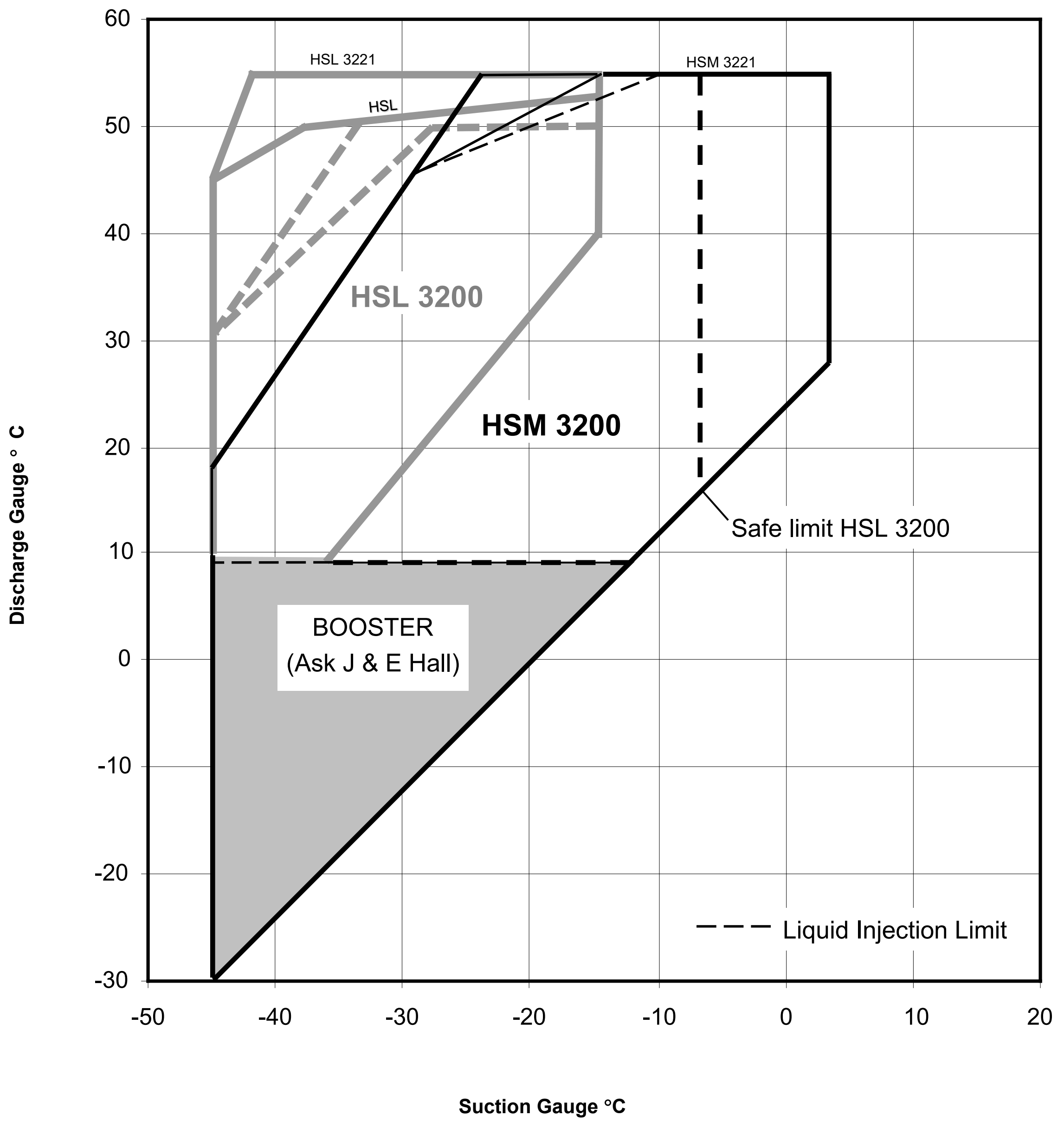


Fig 12 No Oil Pump, Oil Support System Dual Compressor

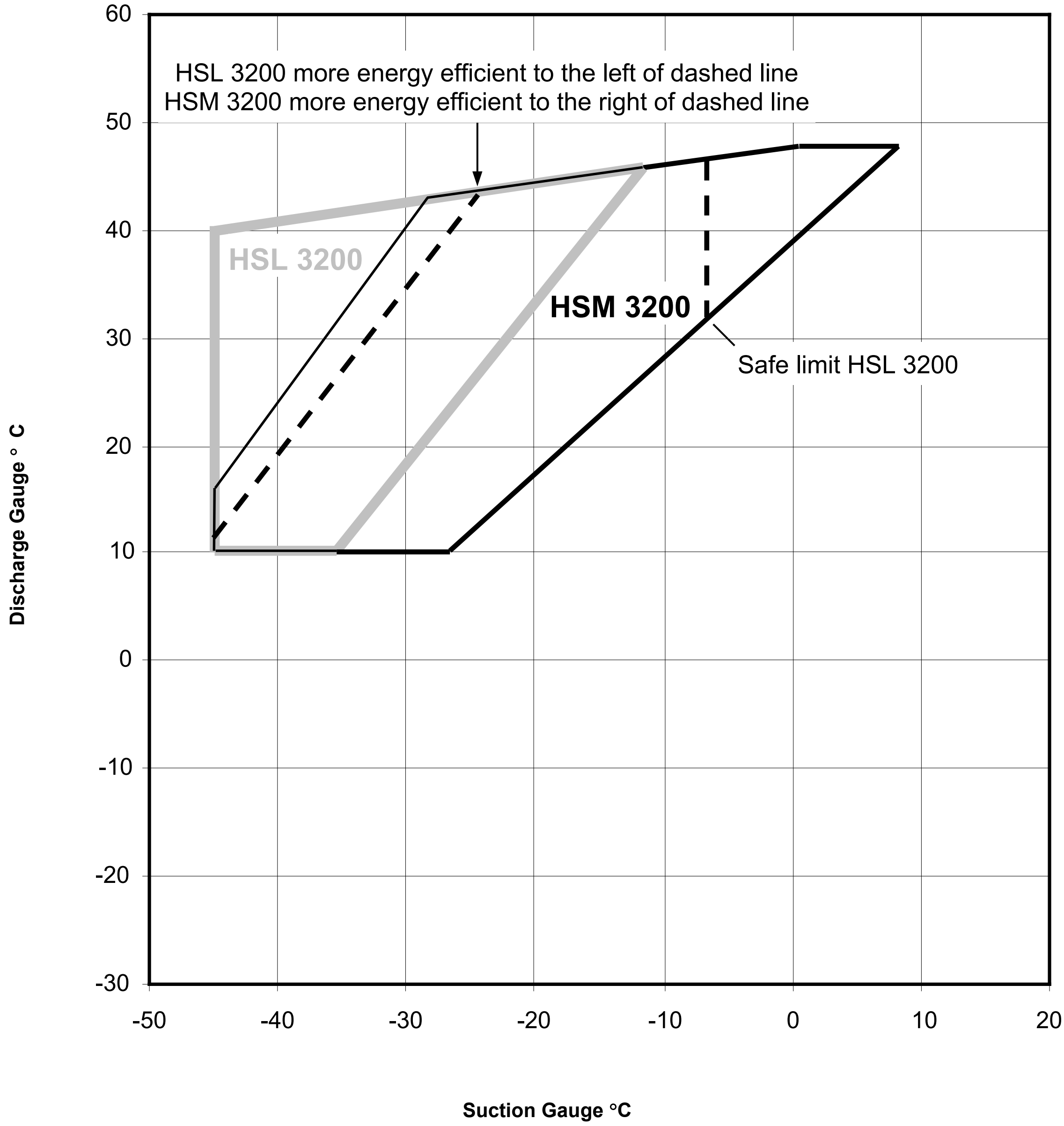
Appendix 3 Limits of Operation Envelopes

Limits of Operation R404A and R507A – Standard



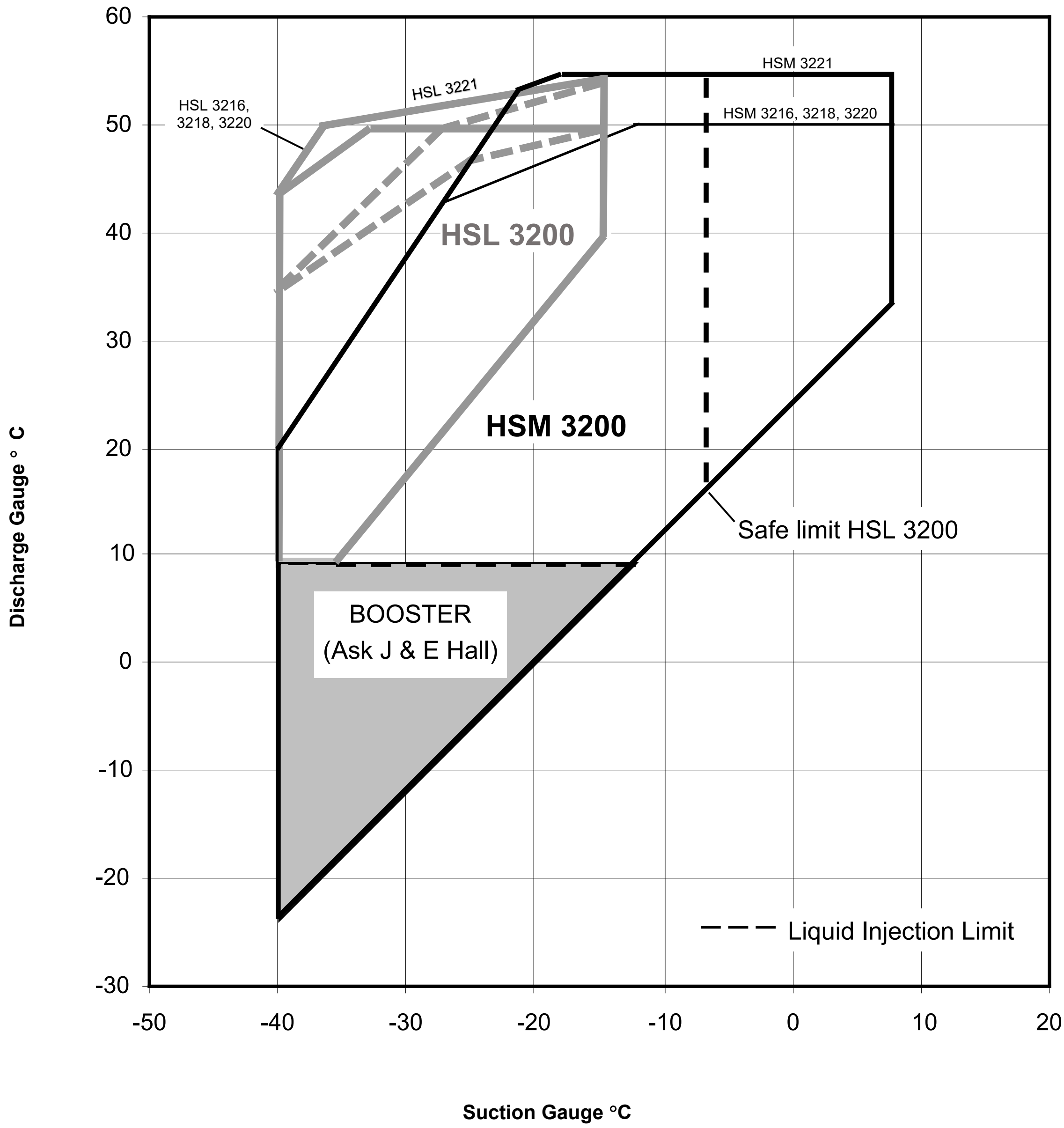
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R404A and R507A - Economised



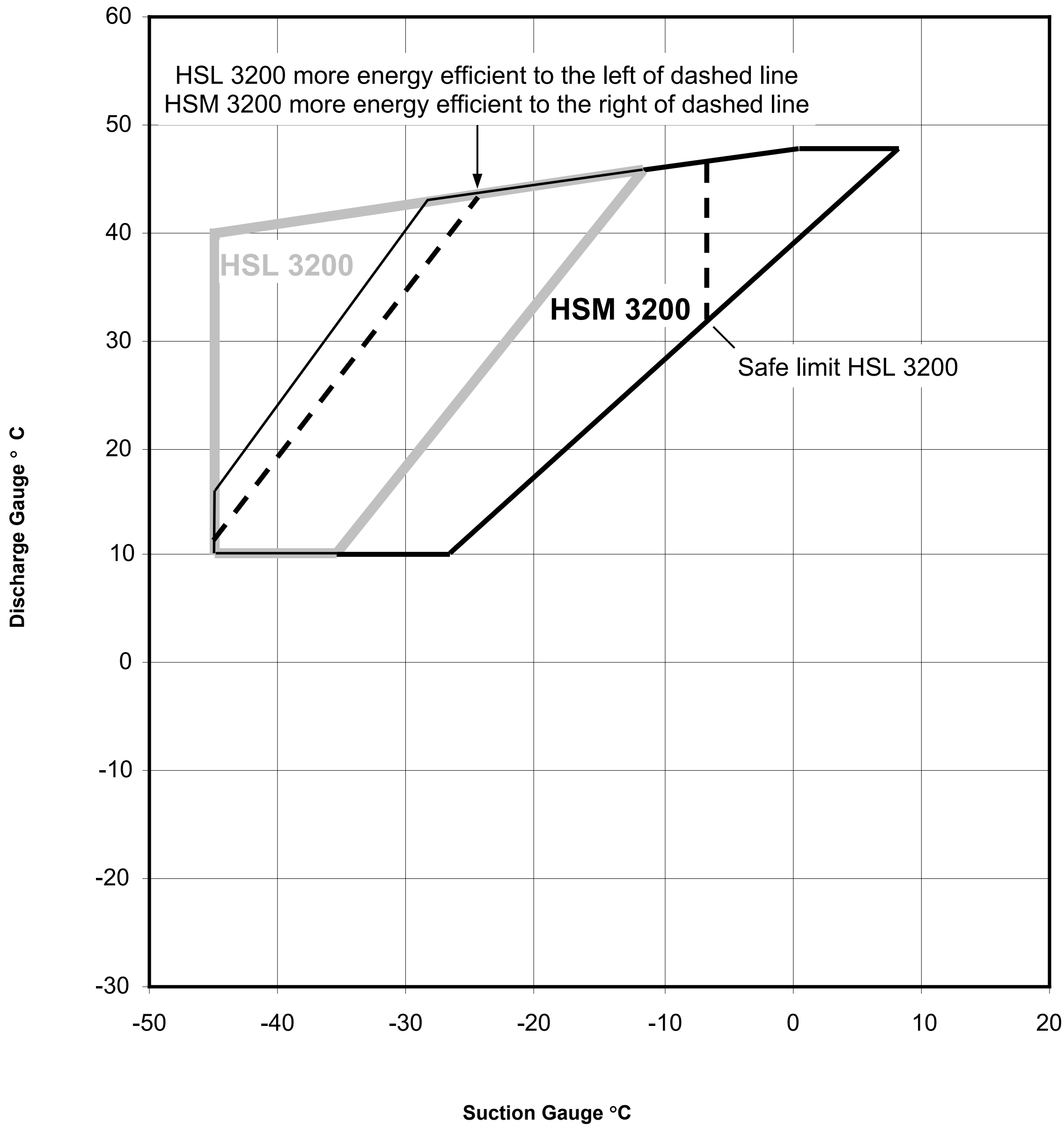
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R407F, R448A and R449A - Standard



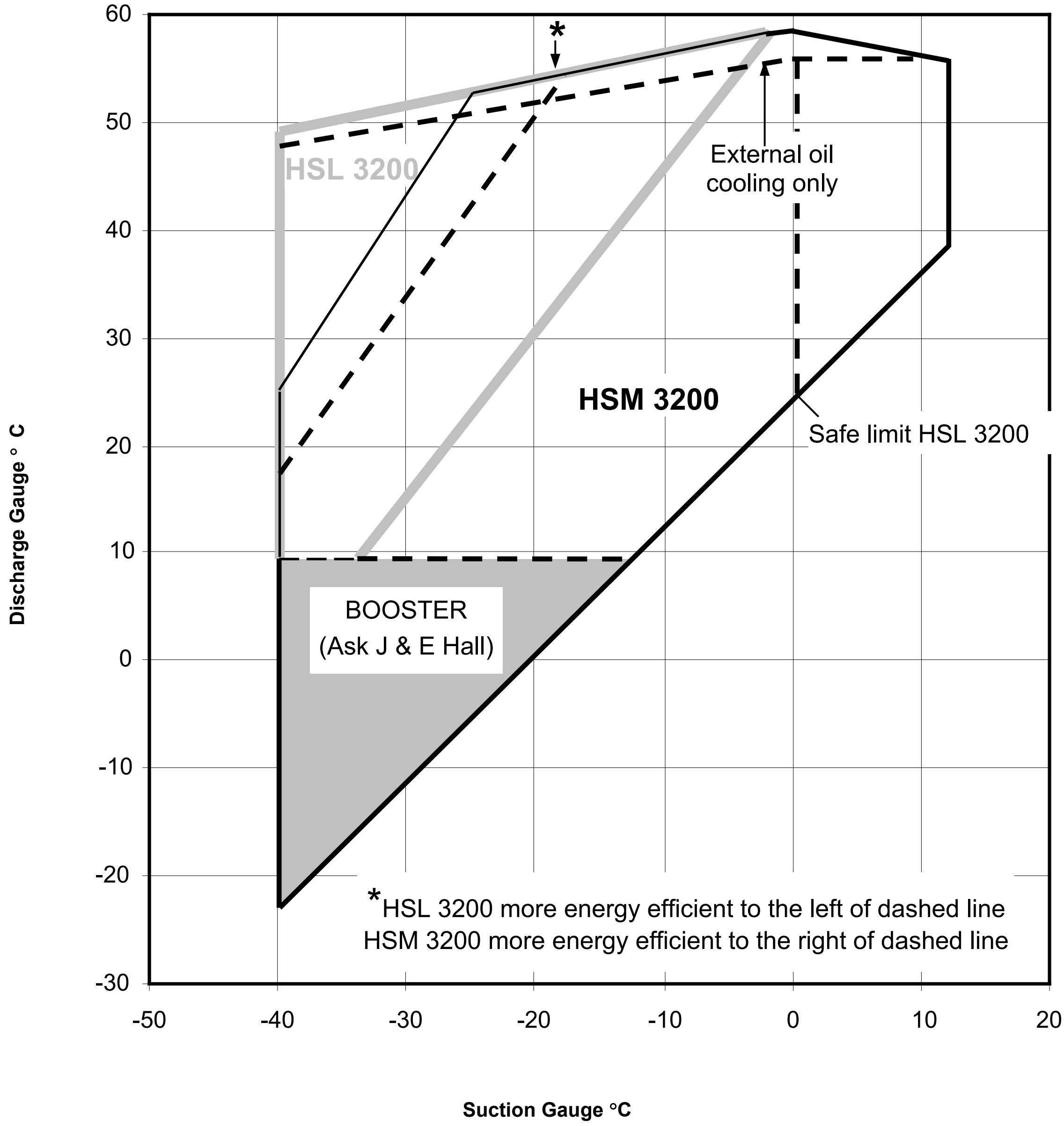
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R407F, R448A and R449A - Economised



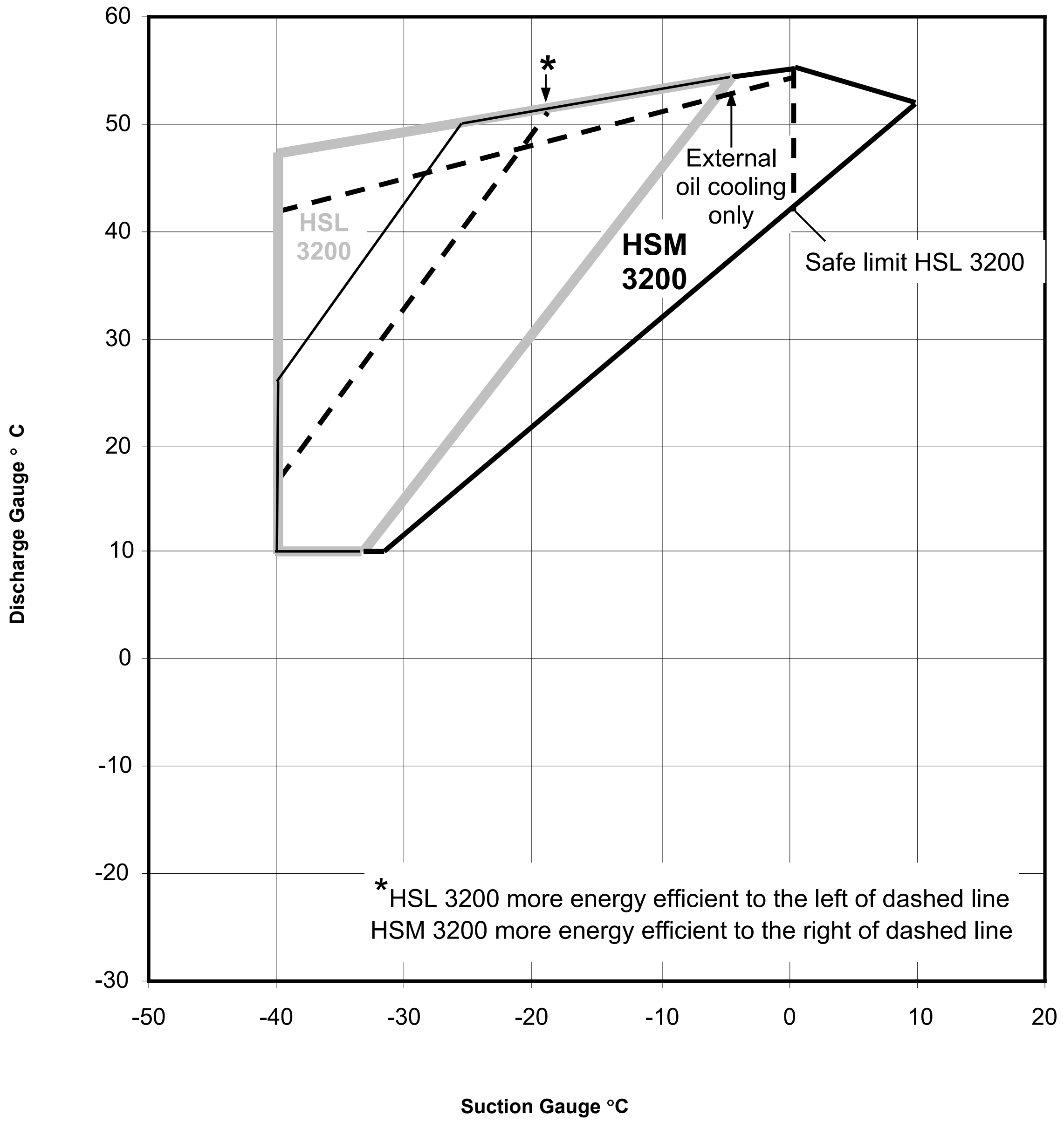
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 - Standard



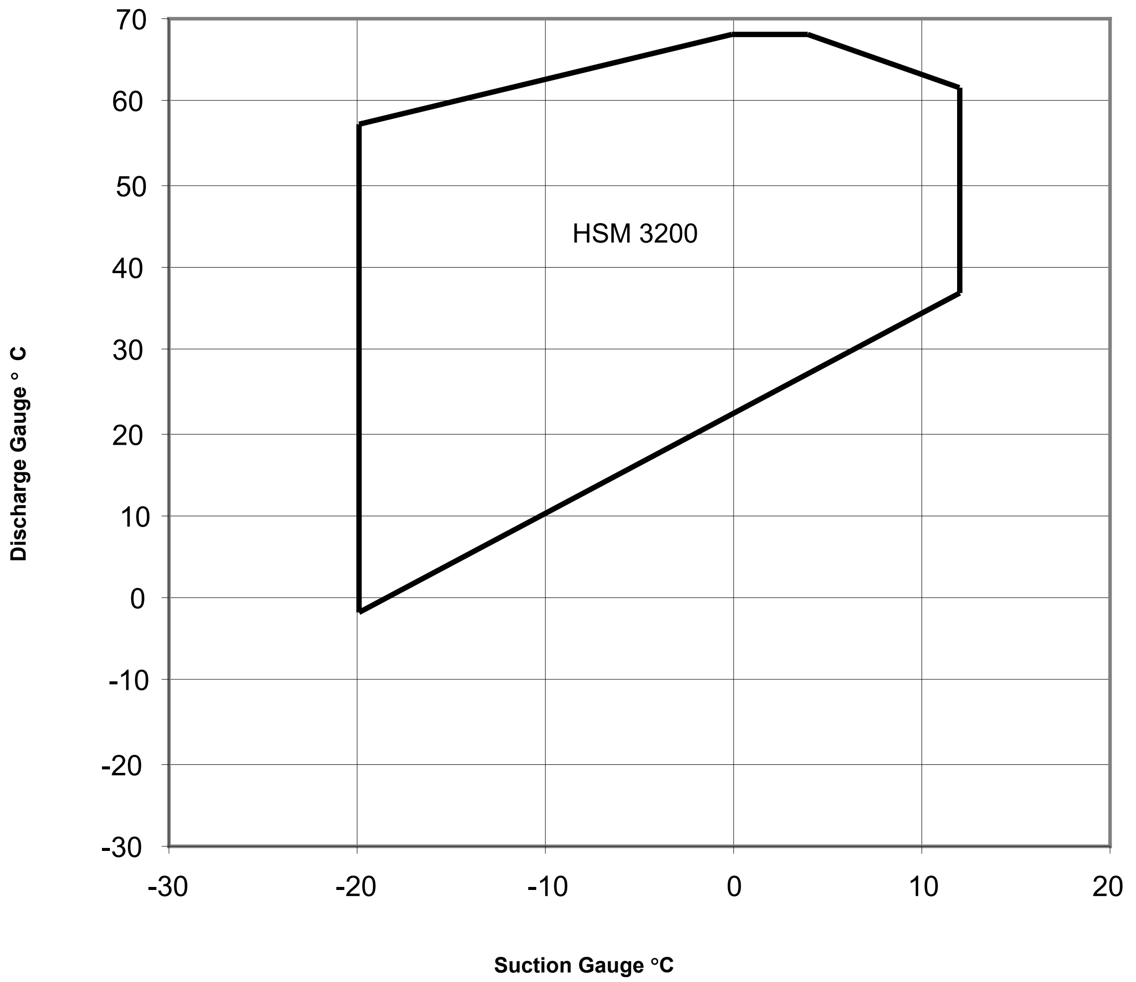
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 - Economised



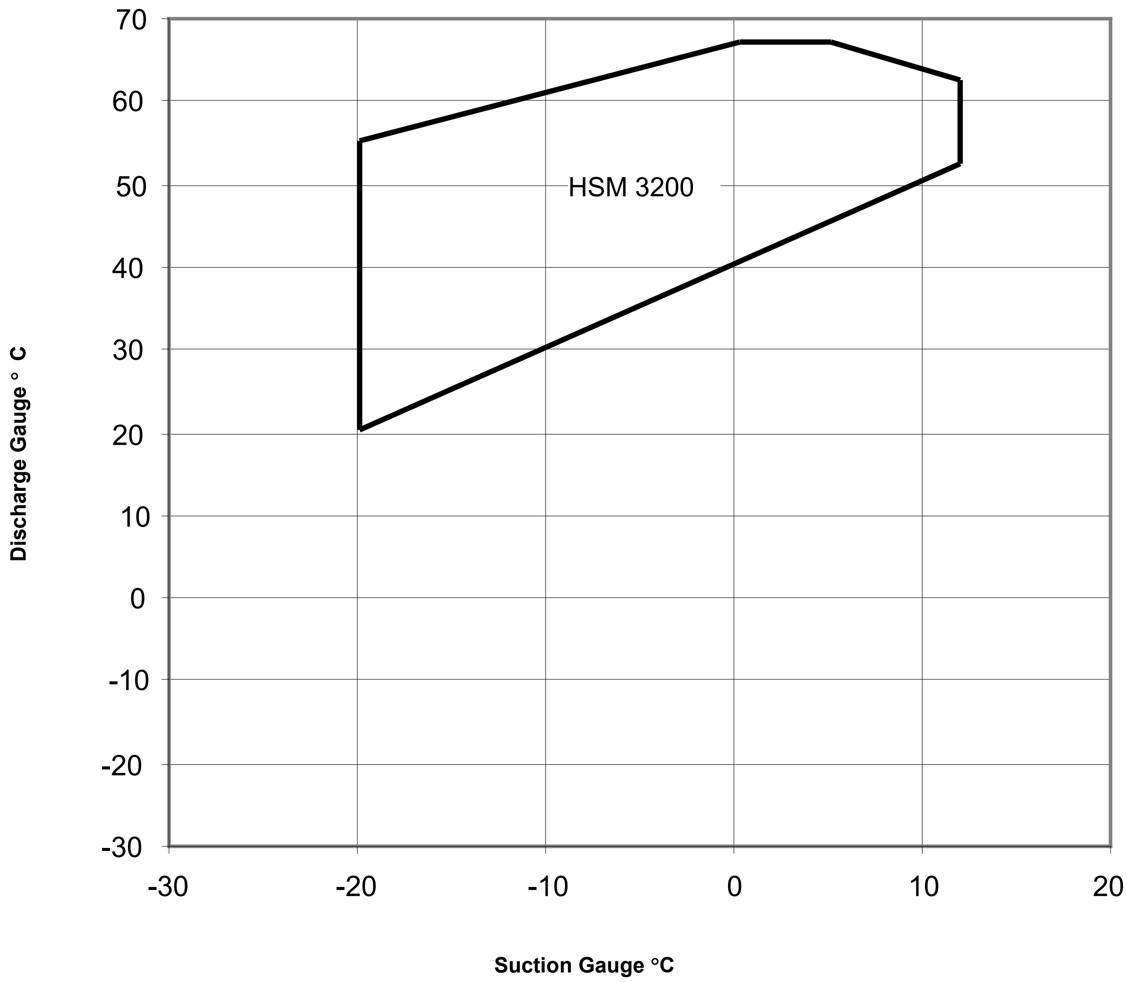
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R134a - Standard



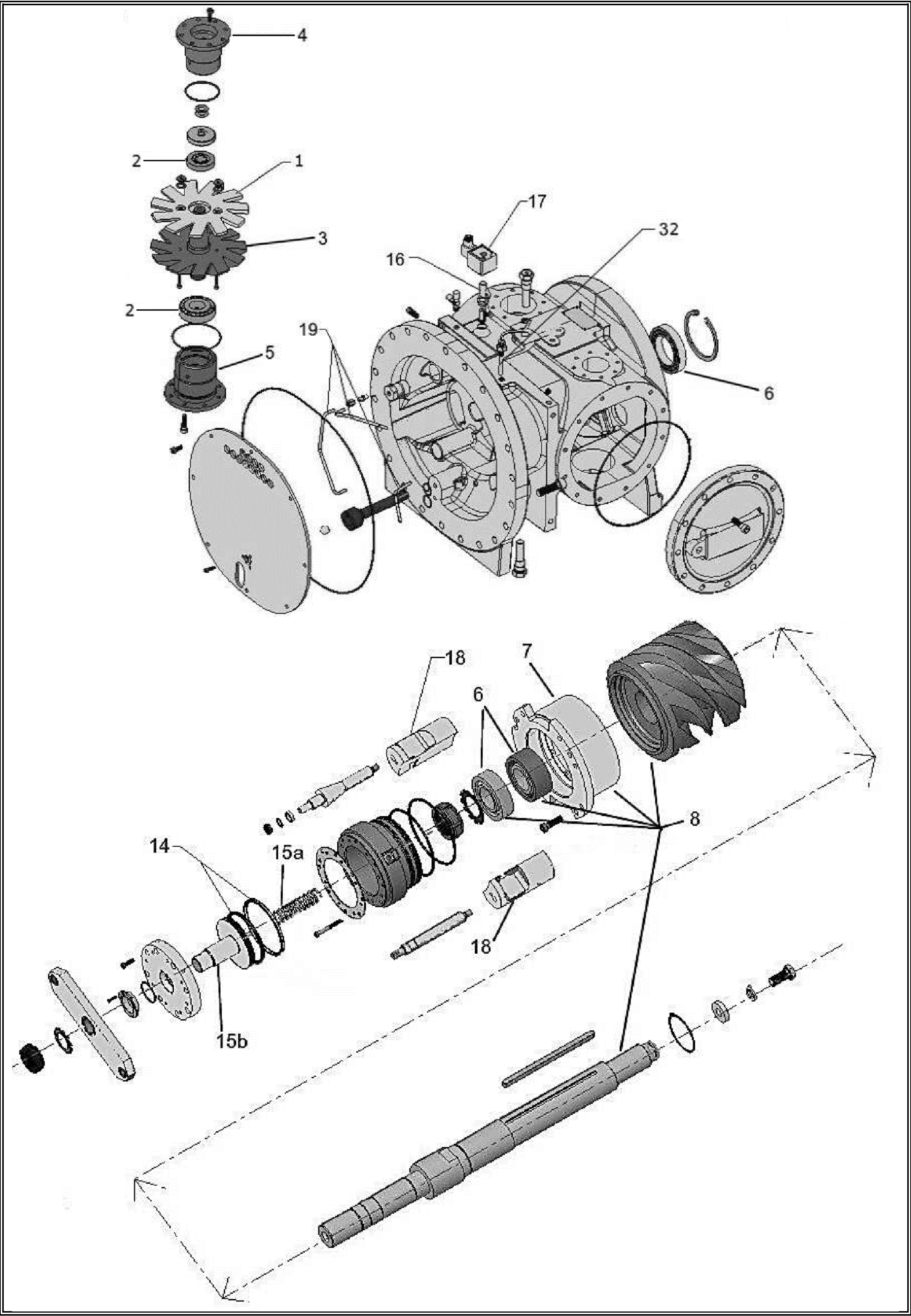
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

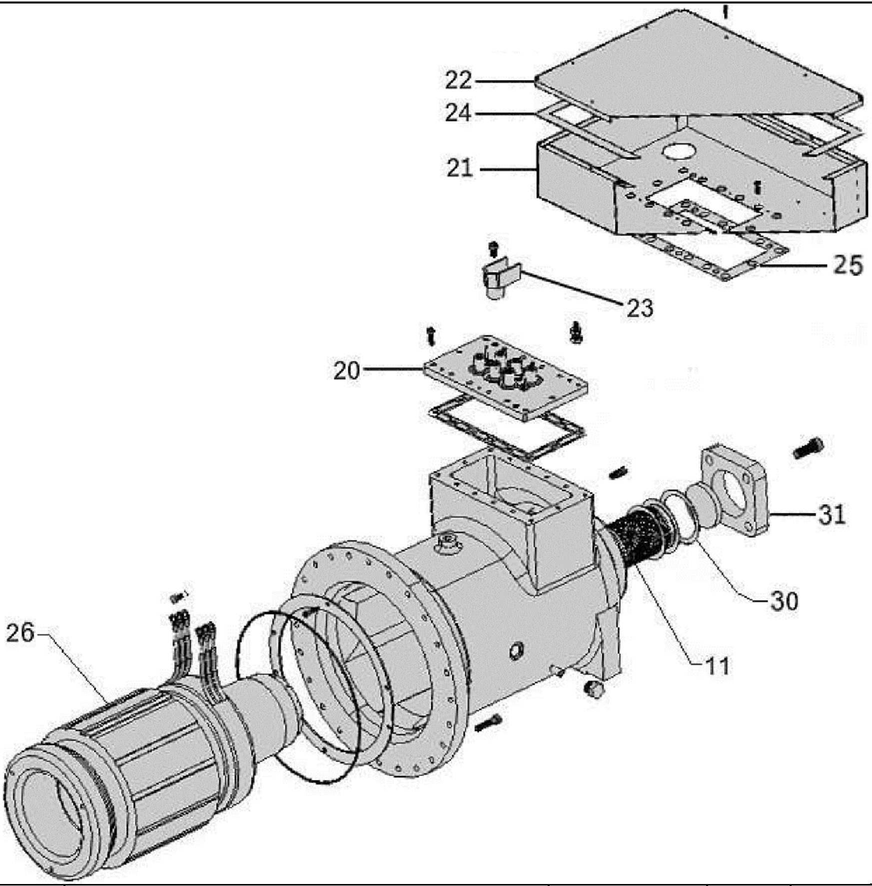
Limits of Operation R134a - Economised



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

Appendix 4 HS H/M/L 3200 Series Compressor Replacement Parts





Item		Description	Part Number	3216	3218	3220	3221
Star Rotors	1	Hallplas Star Kit (1 pair of stars)	N02280004	1			
			N02280005		1		
			N02280006			1	
			N02280027				1
Star Bearings	2	Star Bearing Kit (2 pairs of bearings)	N02050048	1	1	1	1
Star Rotors	3	Star Shaft Rotor and Backing	N02840006	2			
			N02840005		2		
			N02840004			2	2
Star Bearing Housings	4	Star Bearing Housing - Small	N02500012	2	2	2	2
	5	Star Bearing Housing - Large	N02500013	2	2	2	2
Main Bearings	6	Main Bearing Kit (Brass)	N02050169	1	1	1	1
Main Bearing Housing	7	Main Bearing Housing	N02500014	1	1	1	
			N02500015				1
Main Rotor Assembly	*Compressor serial numbers ending in -10, after February 2009 (kit includes all main bearings)*						
	8	Rotor, Shaft, Bearings and Bearing Housing Assembly (82 kW motor – does not include rotor)	N02240047	1			
			N02240048		1		
			N02240049			1	
			N02240050				1
-	9/10	*Not used*	-	-	-	-	

Item		Description		Part Number	3216	3218	3220	3221
Suction Strainer	11	Suction Strainer *(for all compressors other than 138/166 kW motor)*		N12010011	1	1	1	1
		Suction Strainer *(for 138/166 kW motor)*		N02490008	1	1	1	1
-	12/13	*Not used*		-	-	-	-	-
Capacity Control Piston	14	Piston Ring (Glyd Ring) and 'O' Ring		N02630003	1	1	1	1
	15a	Capacity Control Piston Spring		N02630046	1	1	1	1
	15b	Capacity Control Piston		N02630045	1	1	1	1
Capacity Control Solenoid Valves	16/17	Solenoid Valve Kit (Asco) (includes 2 valves and 2 coils)	115 V 50/60 Hz	N30010038	1	1	1	1
			230 V 50/60 Hz	N30010039	1	1	1	1
		Solenoid Valve Kit (Sporlan) includes 2 valves and 2 coils)	115 V 50/60 Hz	N30010041	1	1	1	1
			230 V 50/60 Hz	N30010042	1	1	1	1
	17	Solenoid Valve Coil (Asco)	115 V 50/60 Hz	N30020034	2	2	2	2
			230 V 50/60 Hz	N30020047	2	2	2	2
		Solenoid Valve Coil (Sporlan)	115 V 50/60 Hz	N30020039	2	2	2	2
			230 V 50/60 Hz	N30020045	2	2	2	2
		Solenoid Valve Coil (Asco)	24 V dc	N30020119	2	2	2	2
		Solenoid Valve Coil (Sporlan)	24 V dc	N30020046	2	2	2	2
Capacity Control Slide Valves	18	Capacity Control Slide Kit 2.2 V_R		N02860001	1			
				N02860002		1	1	
				N02860117				1
		Capacity Control Slide Kit 3.0 V_R		N02860003	1			
				N02860004		1	1	
				N02860118				1
		Capacity Control Slide Kit 4.9 V_R		N02860005	1			
				N02860006		1		
				N02860007			1	
				N02860119				1
Slide Valve Spacers	N/S	Capacity Control Slide Valve Spacers *(not fitted to HS 3220 and HS 3221 compressors)*		N13430013	2			
				N13430012		2		
Capacity Indicator	N/S	Linier Variable Displacement Transducer (LVDT)		N05390008	1	1	1	1
Oil Tubes	19	Bearing Oil Supply Tube Kit		N02210013	1	1	1	1
Motor Terminals	20	Motor Terminal Plate		N02470010	1	1	1	1
	21	Motor Terminal Box		N02580003	1	1	1	1
	22	Motor Terminal Box Lid		N02580004	1	1	1	1
	23	Motor Terminal Plastic Insulator		N13060020	6	6	6	6
	24	Gasket – Terminal Box Lid to Terminal Box		88144-205	1	1	1	1
	25	Gasket – Terminal Box to Terminal Plate		330874201	1	1	1	1
	N/S	10.5 mm Washers		N13540036	8	8	8	8
		M10 x 10 mm Screws		N13460108	6	6	6	6
		Screw and Nut (Earth)		N13460019	1	1	1	1
		Direct On Line (DOL) Link Kit (Option)		N09360001	1	1	1	1

Item		Description		Part Number	3216	3218	3220	3221
Motor Protection	N/S	Motor Protection INT69 TM	115 V 50/60 Hz	N05140010	1	1	1	1
			230 V 50/60 Hz	N05140011	1	1	1	1
			24 V 50/60 Hz	N05140035	1	1	1	1
			24 V dc	N05140036	1	1	1	1
Stator	26	Stator 400 V 50 Hz 82 kW/460 V 60 Hz 98 kW		N02330046	1	1	1	1
		Stator 208 V 60 Hz 82 kW		N02330042	1	1	1	1
		Stator 230 V 60 Hz 82 kW		N02330043	1	1	1	1
		Stator 380 V 60 Hz 98 kW		N02330044	1	1	1	1
		Stator 440 V 60 Hz 98 kW		N02330045	1	1	1	1
		Stator 575 V 60 Hz 82 kW		N02330047	1	1	1	1
Internal Relief Valves	N/S	Internal Relief Valve (31 bar)		N30070084	2	2	2	2
	N/S	Internal Relief Valve (24.5 bar for R134a only)		N30070079	2	2	2	2
Suction and Discharge Flanges	28	Gasket – Discharge Flange		N33070012	1	1	1	1
	29	Discharge Flange (2½” NB)		N13500043	1	1	1	1
	N/S	Discharge Tail for 2½” NB x 2 5/8” OD Pipe		N13050071	1	1	1	1
	30	Suction Flange (3” NB)		N13050073	1	1	1	1
	31	Gasket – Suction Flange		N33070030	1	1	1	1
	N/S	Suction Tail for 3” NB x 3 1/8” OD Pipe		N13050069	1	1	1	1
Discharge Thermistor	32	Discharge Thermistor 100 °C		N05060031	1	1	1	1
Shims	N/S	Shim Set		N02260015	1	1	1	1
Gasket and 'O' Ring Kits	N/S	Motor Replacement Gasket and ‘O’ Ring Kit		N33010069	1	1	1	1
	N/S	Full Gasket and ‘O’ Ring Kit		N33010032	1	1	1	1
Oil	N/S	Oil Acid Test Kit		N29580002	1	1	1	1
	N/S	Refer to publication 2-159 Lubricating Oils For HallScrew Compressors						

N/S = Not shown.

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: sales@jehall.co.uk
Website: www.jehall.co.uk

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

When ordering always quote the J & E Hall International contract number and the component serial number (if available).

The compressor design and construction are 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. If variations from normal are noted without delay, steps can 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 on the next page. Other variables, equally important, are peculiar to different plants; these must be observed and logged to obtain a complete picture of performance.

Log Book

Collate completed log sheets together to form a log book. On the first page, record basic information about the plant as detailed below.

For plants supplied by J & E Hall International, this date can be found in Part A : Specification in Section1 of the instruction manual.

- 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/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**					
	[1]% Capacity					
	Net Oil Pressure at Compressor					
	Oil Temperature (°C)					

Compressor Motor	**Speed (rpm)**					
	Volt					
	Amp					

[2]Oil Cooler Cooling Medium	**Inlet Temperature (°C)**					
	Outlet Temperature (°C)					
	Rate of Flow (m^3/h)					

[3]Gauge Temperatures	**Evaporator (°C)**					
	Suction (°C)					
	Intermediate (°C)					
	Discharge (°C)					
	Economiser (°C)					

Refrigerant Temperatures	At Evaporator (°C)					
	LP Suction (°C)					
	LP Discharge (°C)					
	HP Discharge (°C)					
	Economiser (°C)					

Condenser Cooling Medium	Inlet Temperature (°C)					
	Outlet Temperature (°C)					
	Rate of Flow (m^3/h)					
	[4]Ambient Dry Bulb Temperature (°C)					
	[4]Ambient Wet Bulb Temperature (°C)					

[5]Evaporator Cooled Medium	Inlet Temperature (°C)					
	Outlet Temperature (°C)					
	Rate of Flow (m^3/h)					

Liquid Refrig erant Tempe	At the Condenser Outlet (°C)					
	Before the Regulator (°C)					

[1]Compressor unloading step, slide valve position (SVP) or motor speed.
[2]Required for refrigerant or water cooled oil cooling.
[3]It is also desirable to give the gauge temperature readings approximately 15 minutes after the plant has stopped.
[4]Required for air cooled or force draught evaporative condensers.
[5]For alcohol, brine or glycol cooling applications, provide the % concentration of the aqueous solution.

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