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

Application Manual

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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
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

Table 1 Reference Publications

Obtain spare parts from the address below:

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

Telephone: +44 (0) 1332-253400
Fax: +44 (0) 1332-371061
Email: spares@jehall.co.uk
Website: www.jehall.com

3. General Description

The J & E Hall International HS H/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 H/L/M 3200 series compressors are capable of operating without cooling over a limited range, but when indicated, a suitable cooling system is required.

3.1. 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.

3.2. Construction

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

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

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

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

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

The main rotor is supported on a shaft the other end of which carries the motor rotor. The shaft is supported by an arrangement of rolling element bearings at 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.

3.2.1. Internal Relief Valve

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

3.3. The Compression Process

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

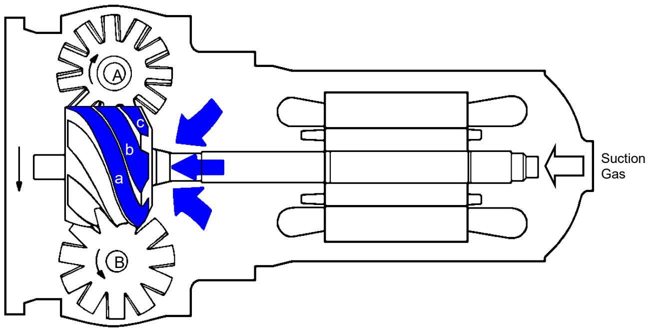
As the HallScrew is a positive displacement compressor, there are three separate stages in the compression cycle: suction, compression and discharge. These are illustrated in Fig 1.

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.



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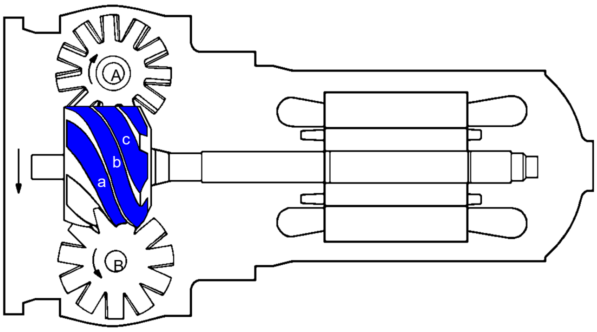
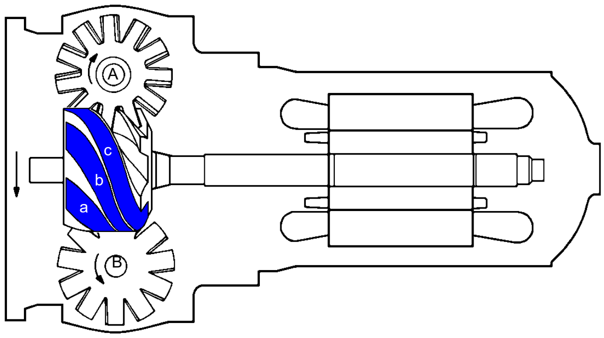


3. Compression

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

3.



4. Discharge

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

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

4.

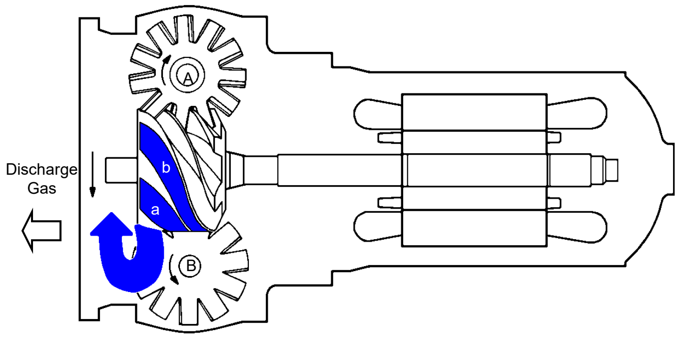


Fig 1 Compression Process

4. Capacity Control and Volume Ratio

HallScrew HS L/M 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).

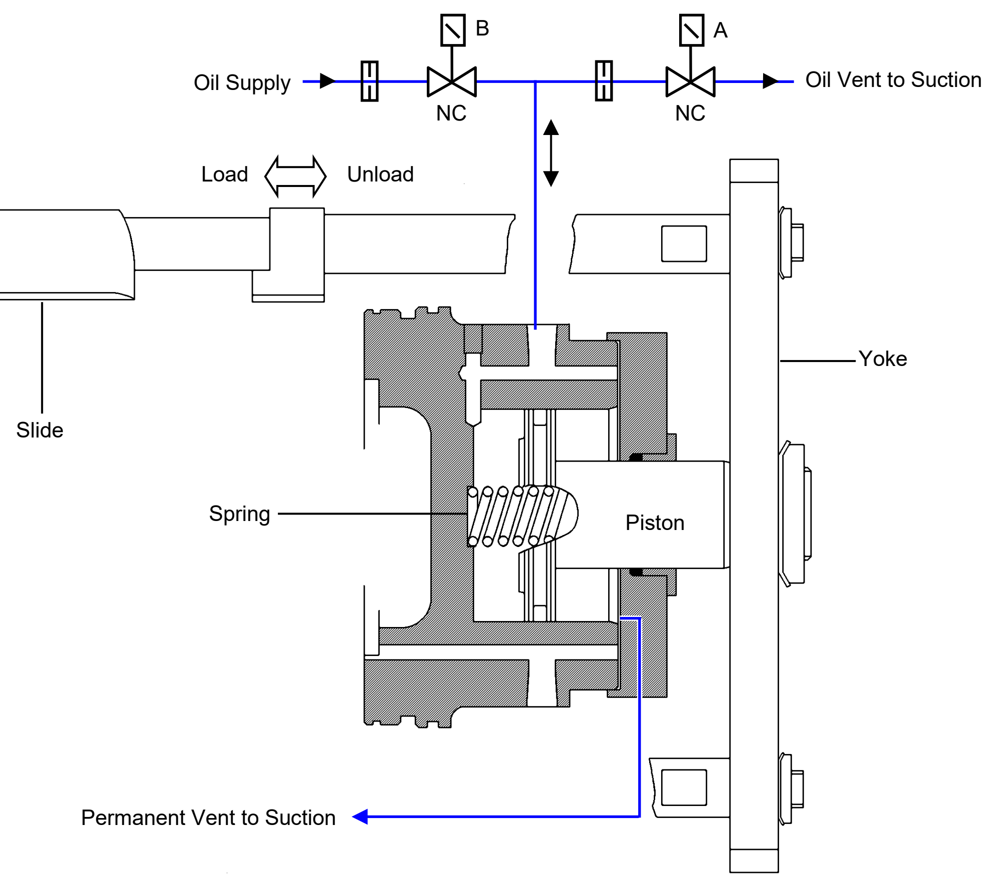


Fig 2 Capacity Control Mechanism

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.

4.1. 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.

4.1.1. Minimum Load Interlock

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

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

4.2. Continuously Variable Capacity Control

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

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

4.2.1. Controlled Stop

When the compressor is required to stop from a loaded condition, solenoid valve B is energised (open). High pressure oil is admitted to the capacity control 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.

4.2.2. 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.

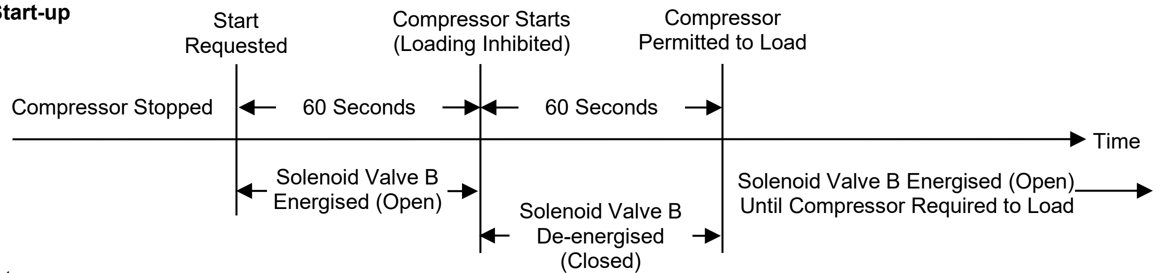
Unlike a controlled stop, unless the compressor was at minimum load before the uncontrolled stop occurred, the capacity control cylinder may contain some refrigerant vapour instead of being completely filled with oil. In this event a hydraulic lock will not be present and uncontrolled loading may occur 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	[1]Solenoid Valve B
Load compressor Oil is vented from the capacity control cylinder. The action of the suction/ discharge differential pressure on the slide/piston assembly overcomes the force of the unloading spring and moves the slide 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 4.2.2 Uncontrolled Stop.

Fig 3 Continuously Variable Capacity Control

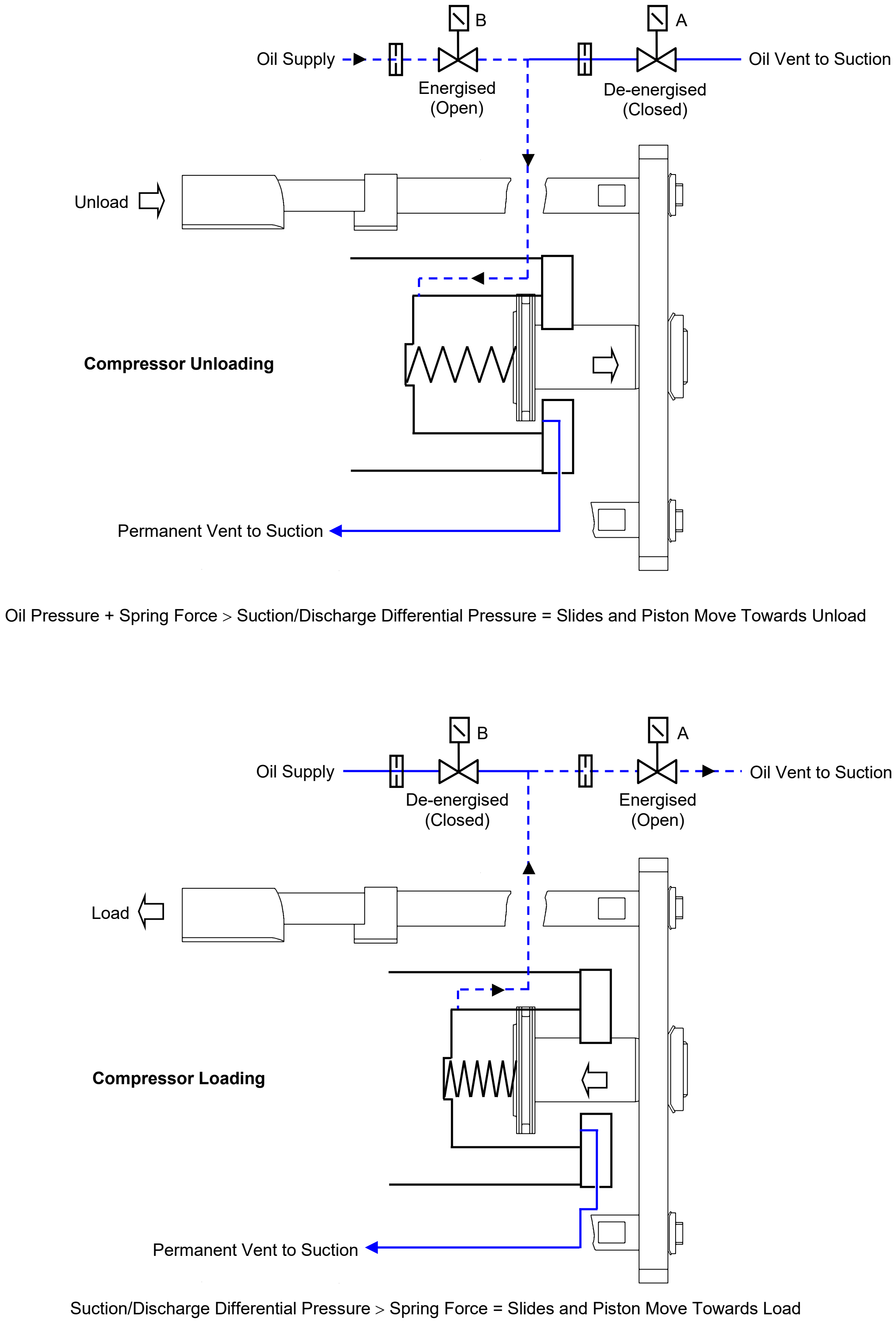


Fig 3 (continued) Continuously Variable Capacity Control

4.3. Capacity Control by Inverter Drive

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

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

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

4.3.1. Inverter Size

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

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

During pull down, 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 4.2. Continuously Variable Capacity Control.

4.3.2. Inverter Set-up

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

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

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.

4.4. Linear Variable Displacement Transducer (LVDT)

The LVDT provides a continuous 4 to 20 mA slide valve position signal between minimum load (25 %) and maximum load (100 %). The LVDT operates on the principle of using a coil (inductance element) to produce an electrical output proportional to the displacement of a separate movable indicator rod, 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.

5. 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 6. Oil Support System.

The oil performs three basic functions:

5.1. Capacity Control Actuation

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

5.2. Bearing Lubrication

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

5.3. Oil Injection for Sealing and Cooling

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

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

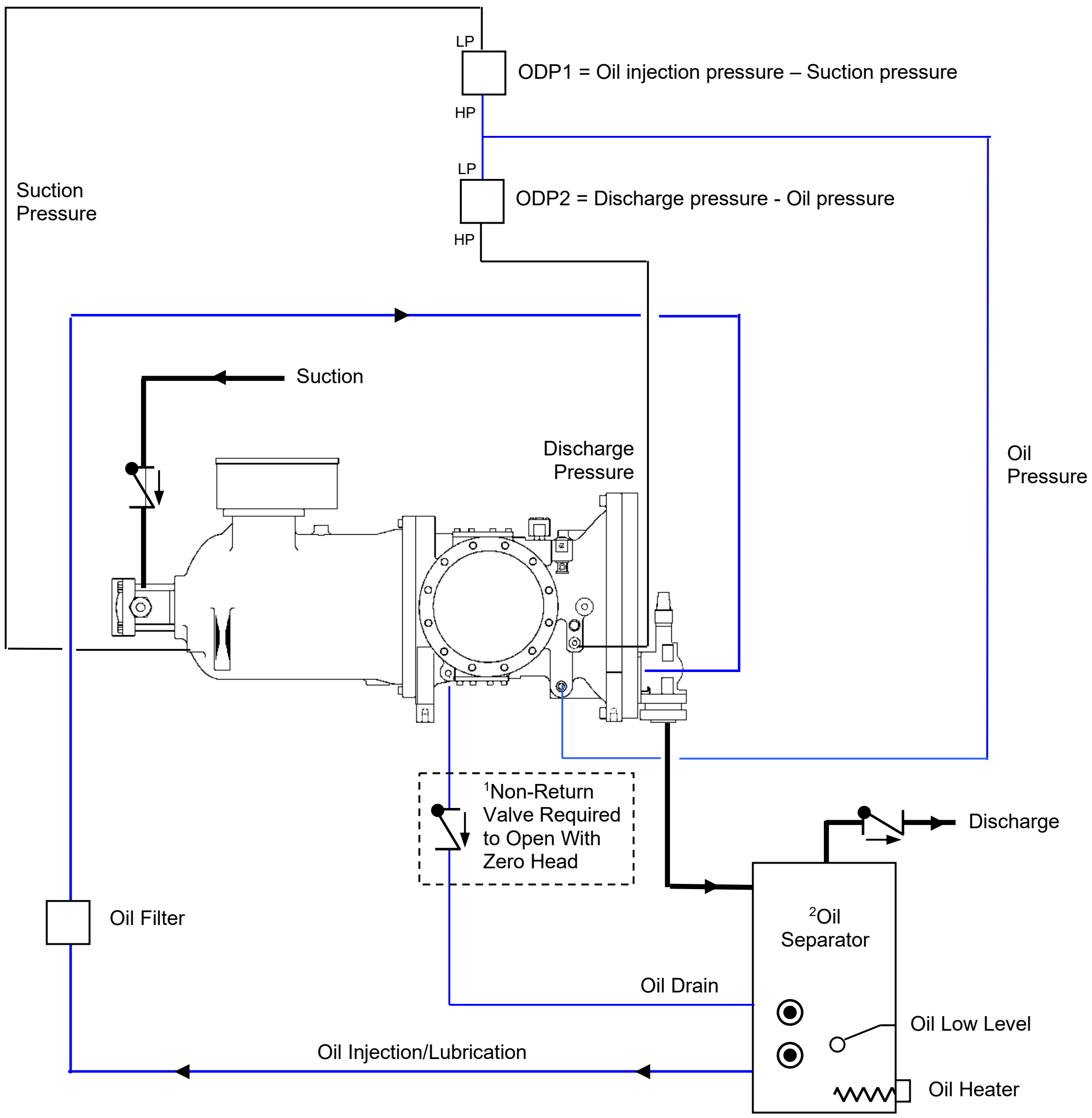
Compressor cooling can be accomplished by the direct injection of liquid refrigerant into the compression process. When liquid injection is not used, the oil injected for sealing absorbs a large proportion of the heat of compression, thus reducing the maximum discharge temperature, and is cooled externally via an oil cooler; refer to 6.10 Compressor Cooling.

6. Oil Support System

HS H/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 6.1. to 6.10. Failure to do so could result in deterioration of the compressor, both mechanically and functionally.

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



The oil support system must conform with the provisions described in 6.1. to 6.10

[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

6.1. Oil Injection/Lubrication

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

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

6.2. 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.

6.3. 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 6.2.

- 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** 9.

6.4. 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 6.2 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 6.3 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).

6.5. 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.

6.5.1. 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.

6.5.2. Oil Separator Provisions

In addition to the considerations discussed in 6.5.1 Oil Separator Design, the oil separator should comply with the following recommendations:

6.5.2.1. 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.

6.5.2.2. Oil Low Level Switch

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.

6.6. Oil Differential Pressure Monitoring

As already described in 5. Compressor Lubrication, Sealing and Cooling, HS H/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.

6.6.1. ODP1

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

ODP1 = Oil injection pressure – Suction pressure

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

Example:

Maximum suction pressure 3.0 bar abs (2 bar g)

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

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

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

6.6.2. 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.

6.7. 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.

6.8. 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 cm^2
	Paper or cellulose	5000 cm^2
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 External Oil Filter Minimum Specification

6.9. Lubricating Oils

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

For applications using any HFC refrigerant, Polyolester lubricants (POE) must be used.

For applications using R22, only a mineral oil or suitable alternative must be used; refer to Publication 2-59

6.10. Compressor Cooling

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

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

7. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type. For HS H/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.

7.1. Oil System

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

7.2. Suction Line

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

7.2.1. Liquid Separation in the Suction Line

If liquid is present in the suction line due to excessive carry over from the evaporator and velocities are low, 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.

7.3. Discharge Line

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

7.3.1. Discharge Superheat

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

13.0 K for R134a and R513A.

15.0 K for R404A, R452A and R507A.

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

7.4. Liquid Injection Lines

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

7.4.1. 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.

7.4.2. 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 and 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.

7.5. Economiser Connections

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

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

7.6. Safety Requirements for Compressor Protection

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

8. Electrical Connections

8.1. Compressor Starting

The HS H/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 preferred by J & E Hall International.

8.2. Motor Wiring Connections

Terminal box wiring is illustrated in Fig 5 and Fig 6. Refer to Appendix 1 Compressor Data for motor data. The standard terminal box rating is IP54, IP65 available to special order.

8.3. Thermistors

Compressor motor and discharge high temperature thermistors are fitted as standard and should be wired as illustrated in Fig 5.

8.4. Capacity Control Solenoids

The solenoids must be connected to a suitable plant controller that will energise the appropriate coil to load or unload the compressor via changes to the operation of the system into which the compressor is fitted. The measured variable may be chilled water temperature, suction pressure, etc.

Power must be supplied to the solenoids via a suitable pulse timer with a minimum pulse length of 0.1 to 0.5 seconds, depending upon the accuracy of control required.

Operation of the solenoid with load is not linear, more pulses will be required at low loads for the same change in load compared with operation at high load.

8.5. 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 %). Slide valve position is not linearly proportional to the actual capacity of the compressor and greater slide travel is required at low load compared with high loads for the same change in load.

The LVDT is only available without calibration, this must be done on the controller. However, a signal conditioning module is available for applications where this is not possible; refer to publication 2-205 MSI Linear Variable Displacement Transducer (LVDT) and Slide Valve Position Signal Conditioning Module available from J & E Hall International.

8.6. Heater

Connect the oil separator reservoir heater as described in 6.5.2.1.

8.7. Oil Low Level Sensor

Connect the oil separator low level sensor or switch as described in 6.5.2.2.

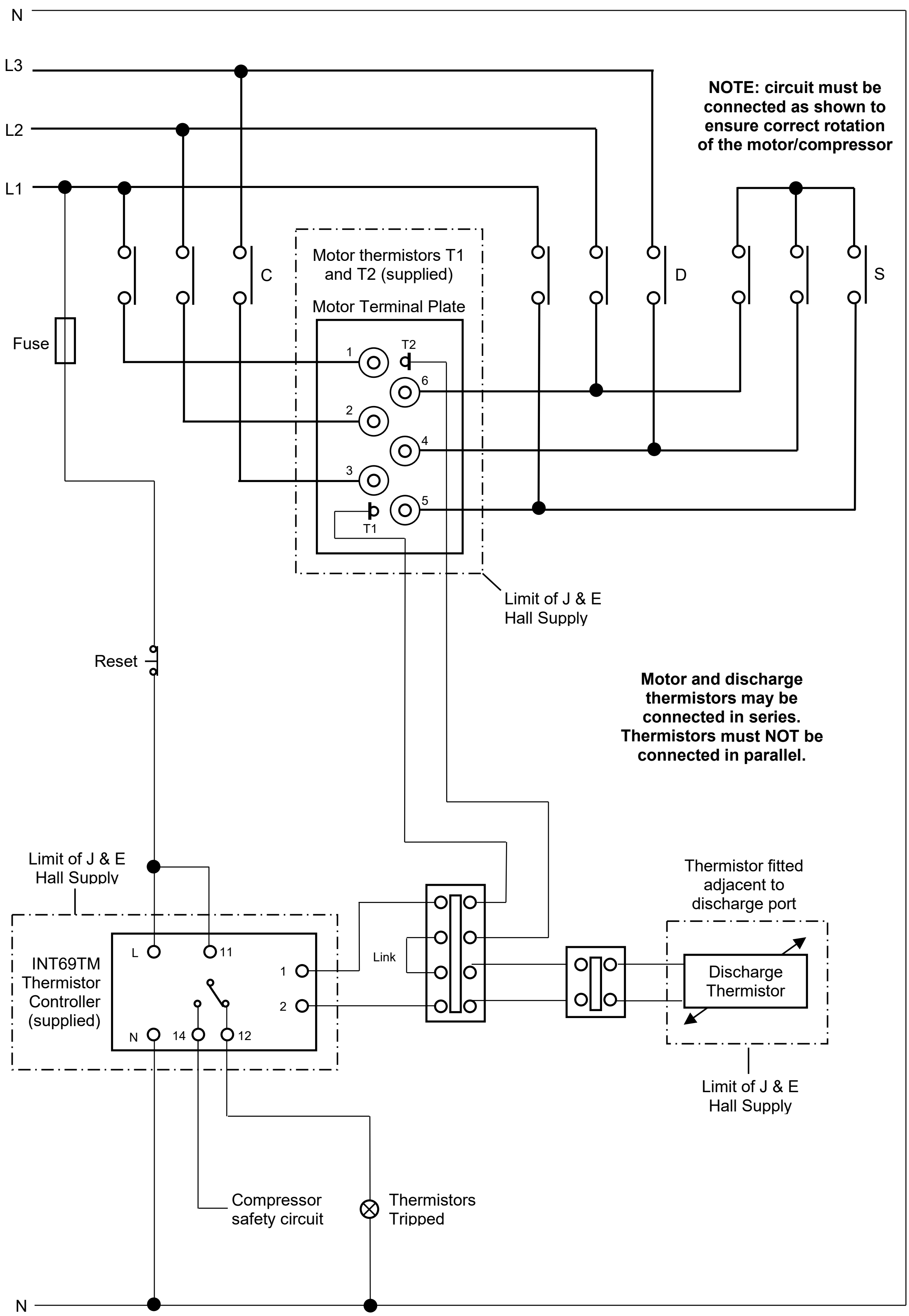


Fig 5 Motor Terminal Box Wiring: Star/Delta

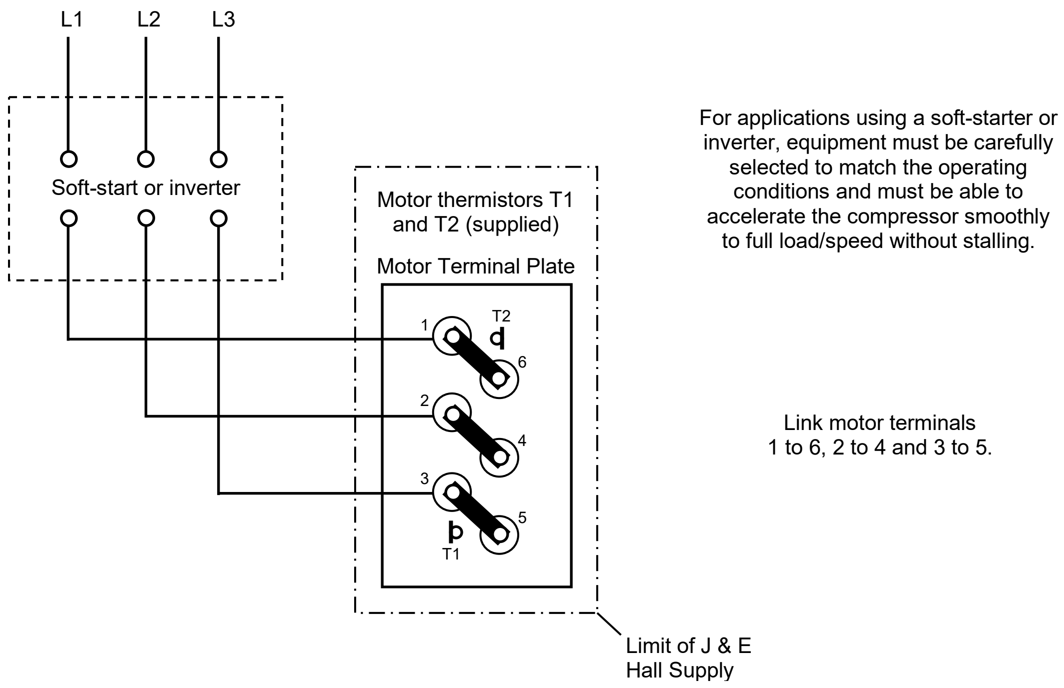


Fig 6 Motor Terminal Box Wiring: Soft-start and Inverter Drive

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	H	Semi-hermetic compressor for high temperature 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 R513A**	**All Other Refrigerant**	**R134a R513A**	**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 R513A**	**All Other Refrigerant**	**R134a R513A**	**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 R513A**	**All Other Refrigerant**	**R134a R513A**	**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 R513A**	**All Other Refrigerant**	**R134a R513A**	**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

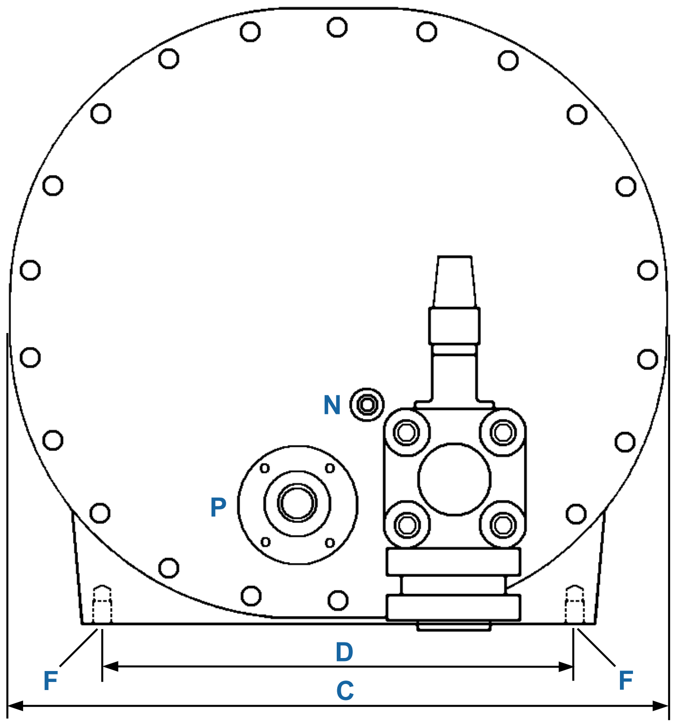
Temperature Limits		
Temperature Limits	Discharge temperature	100 °C (standard) 120 °C (special)
	Discharge minimum superheat	R134a and R513A = 13.0 K R404A, R452A and R507A = 15.0 K R22, R407C, R407F, R448A and R449A = 20.0 K

[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 6.
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 5.
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: 82 kW @ 50 Hz and 98 kW @ 60 Hz Motors

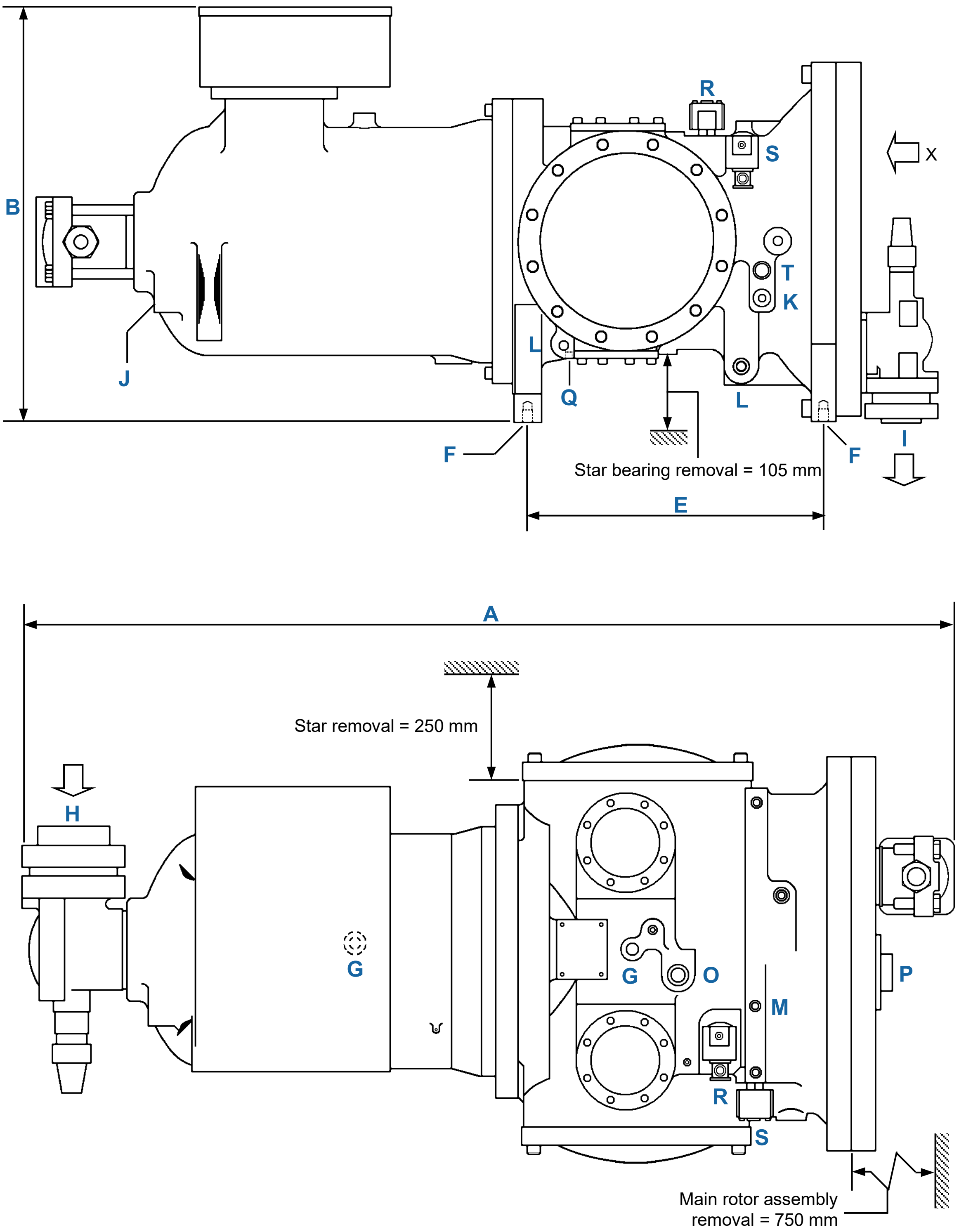


View on arrow X

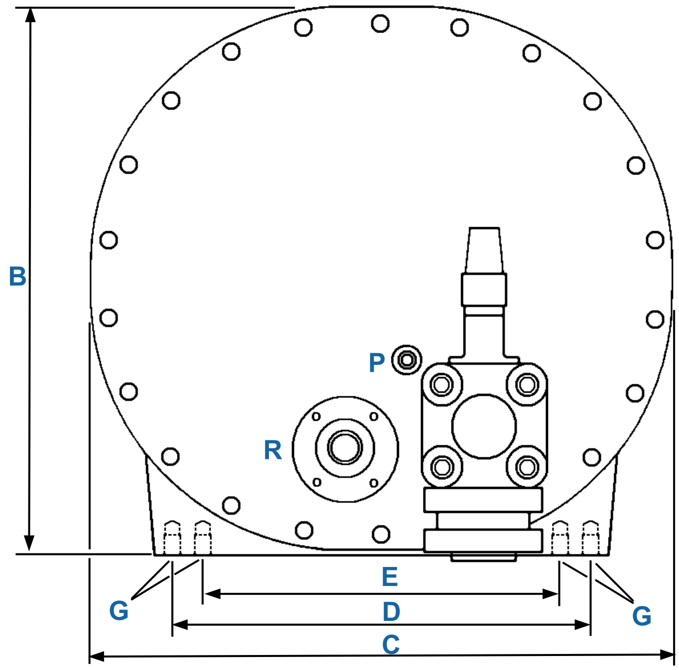
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall certified drawing D100349

	Description				Size
Dimensions	Overall (including suction and discharge stop valves)	Length	A		1298 mm
		Height	B		584.5 mm
		Width	C		565.6 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 1/2” NB (2 5/8” 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

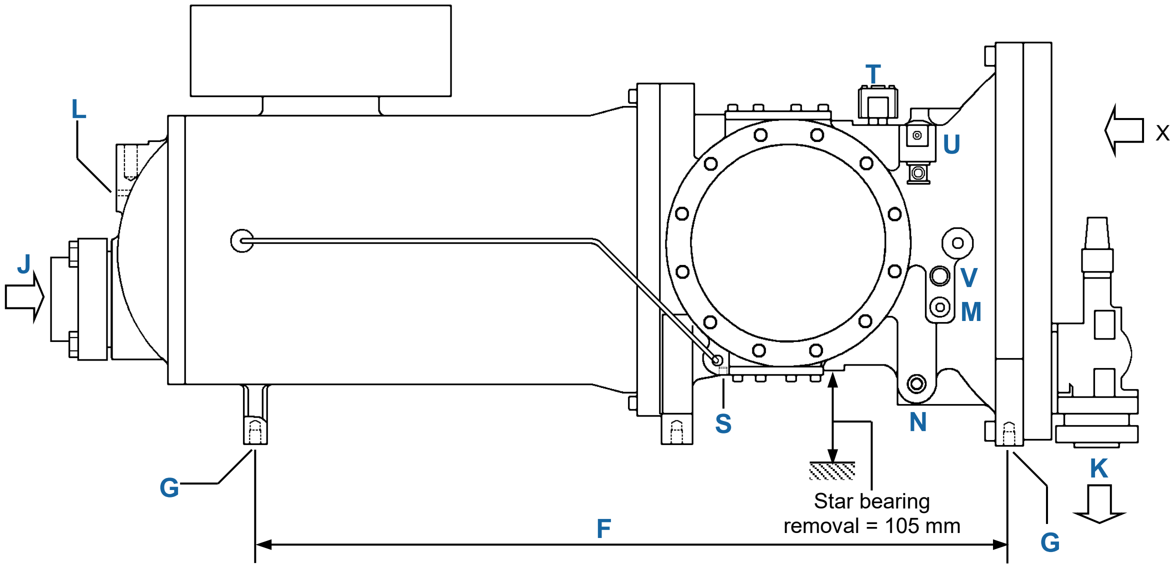


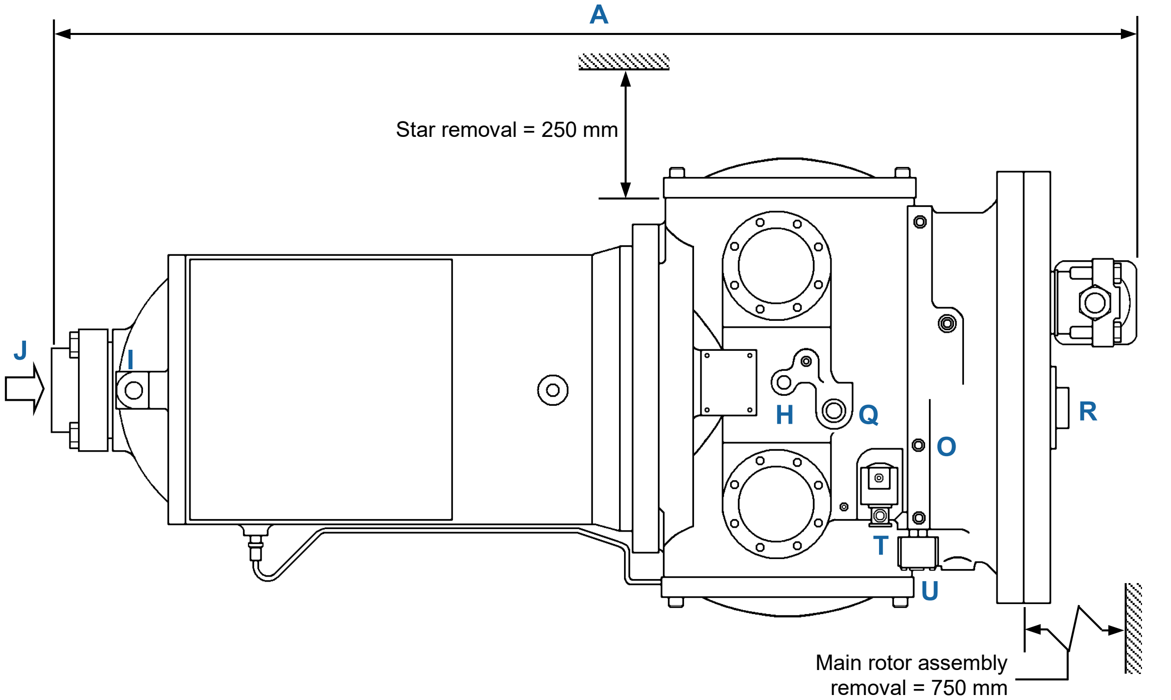
View on arrow X

Dimensions in mm unless stated otherwise. 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

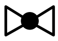
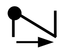
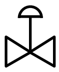
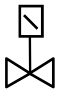
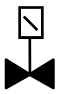
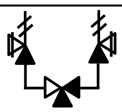
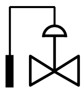
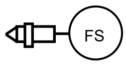
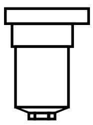
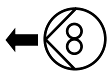
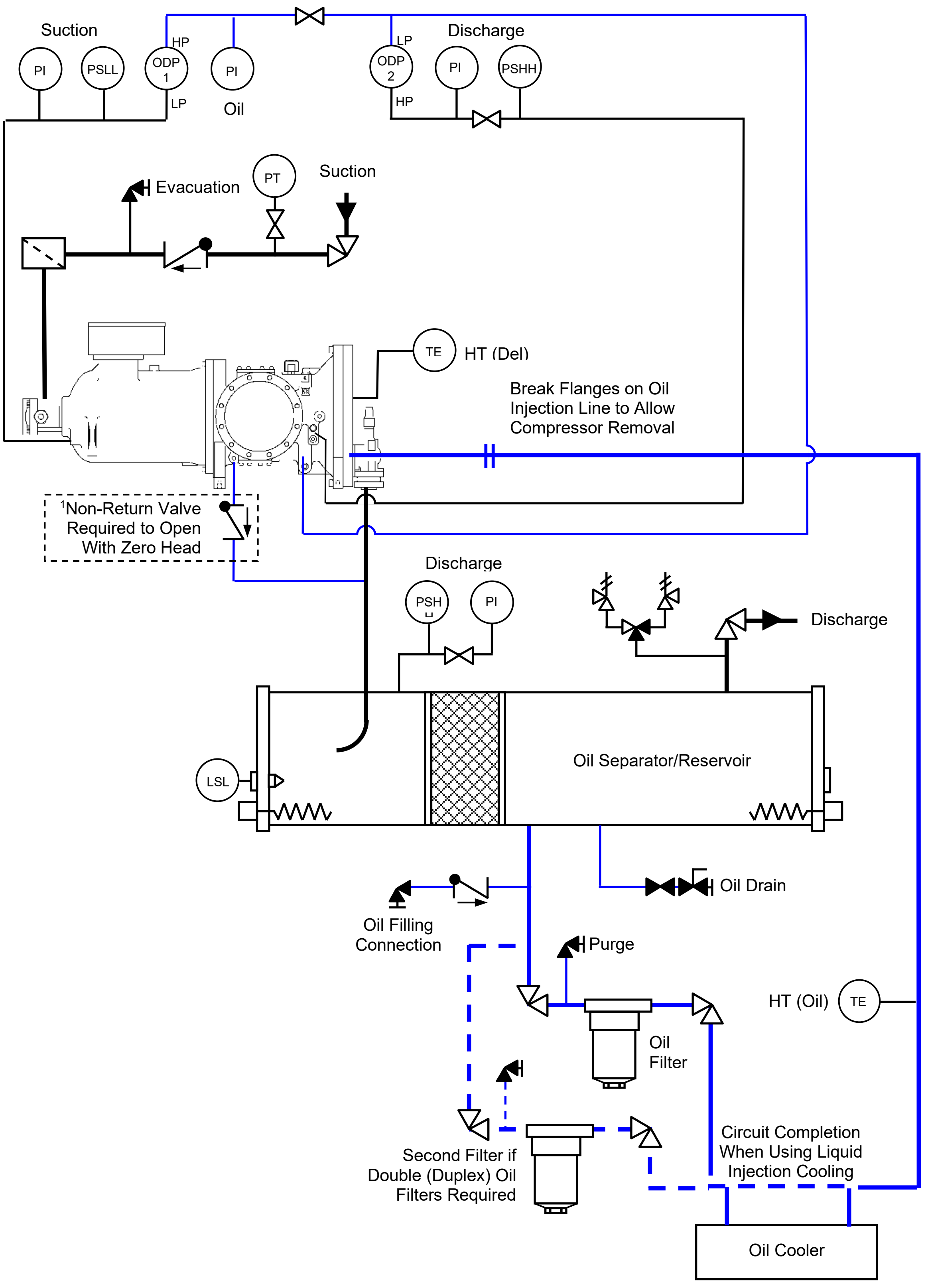
Normally Open	Locked Open	Normally Closed	Normally Closed and Capped	Description
				Valve, straight through
				Valve, right-angle
	Ball valve			Non-return valve
	Quick-acting drain valve, normally closed and capped			Control valve
	Relief valve			Solenoid valve (normally open)
	Relief valve (to atmosphere)			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
PI	Pressure gauge or transducer		ODP	Oil differential pressure switch
PSH	Discharge high pressure switch or transducer		LSL	Opto liquid level sensor or level switch
PSL	Suction low pressure switch or transducer		TE	High temperature thermistor or switch

Fig 7 Key to Schematic Flow Diagrams



[1]NRV is not required if the oil separator inlet is level or below the compressor discharge port.

Fig 8 Oil Support System for Single Compressor

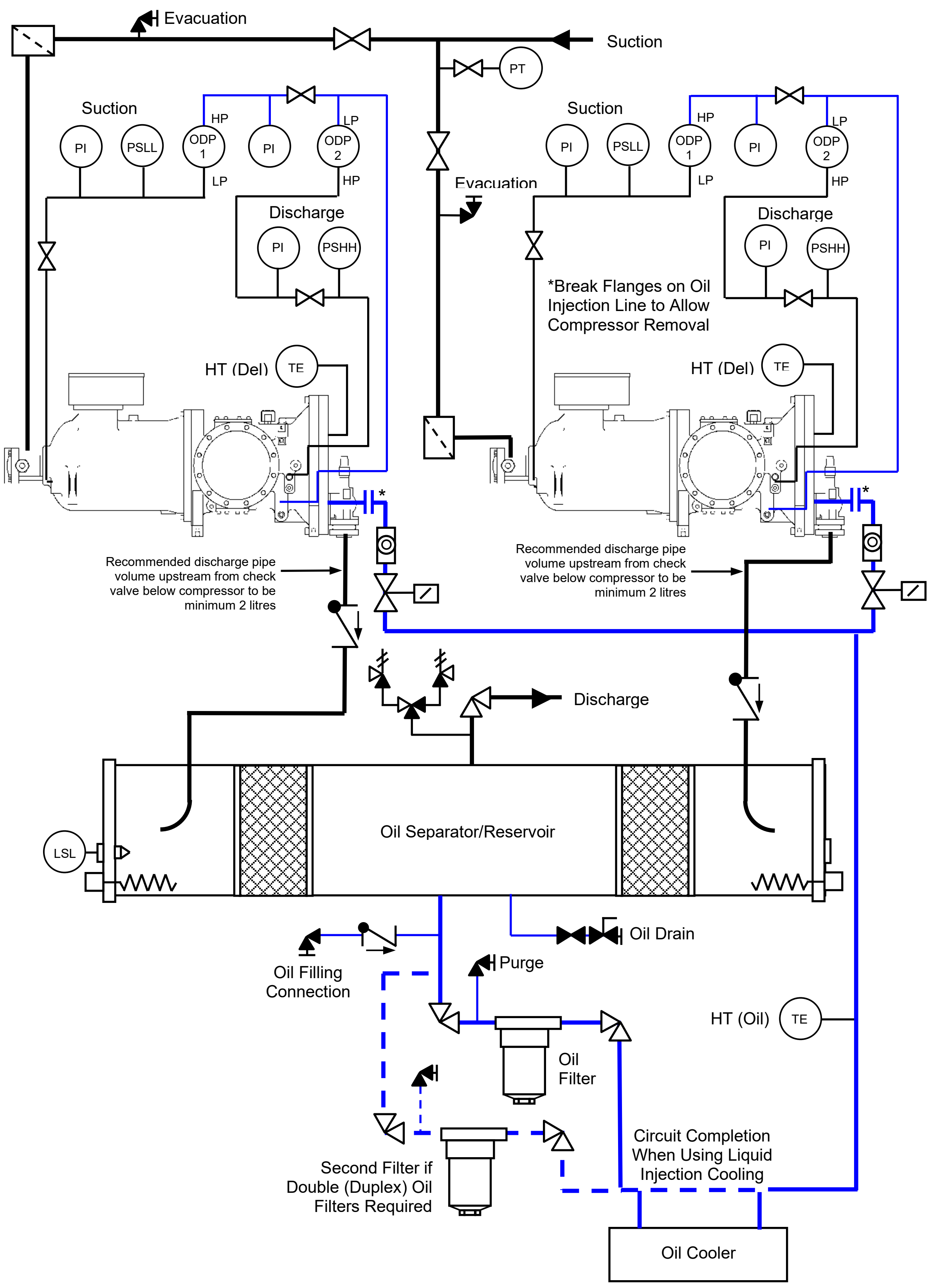
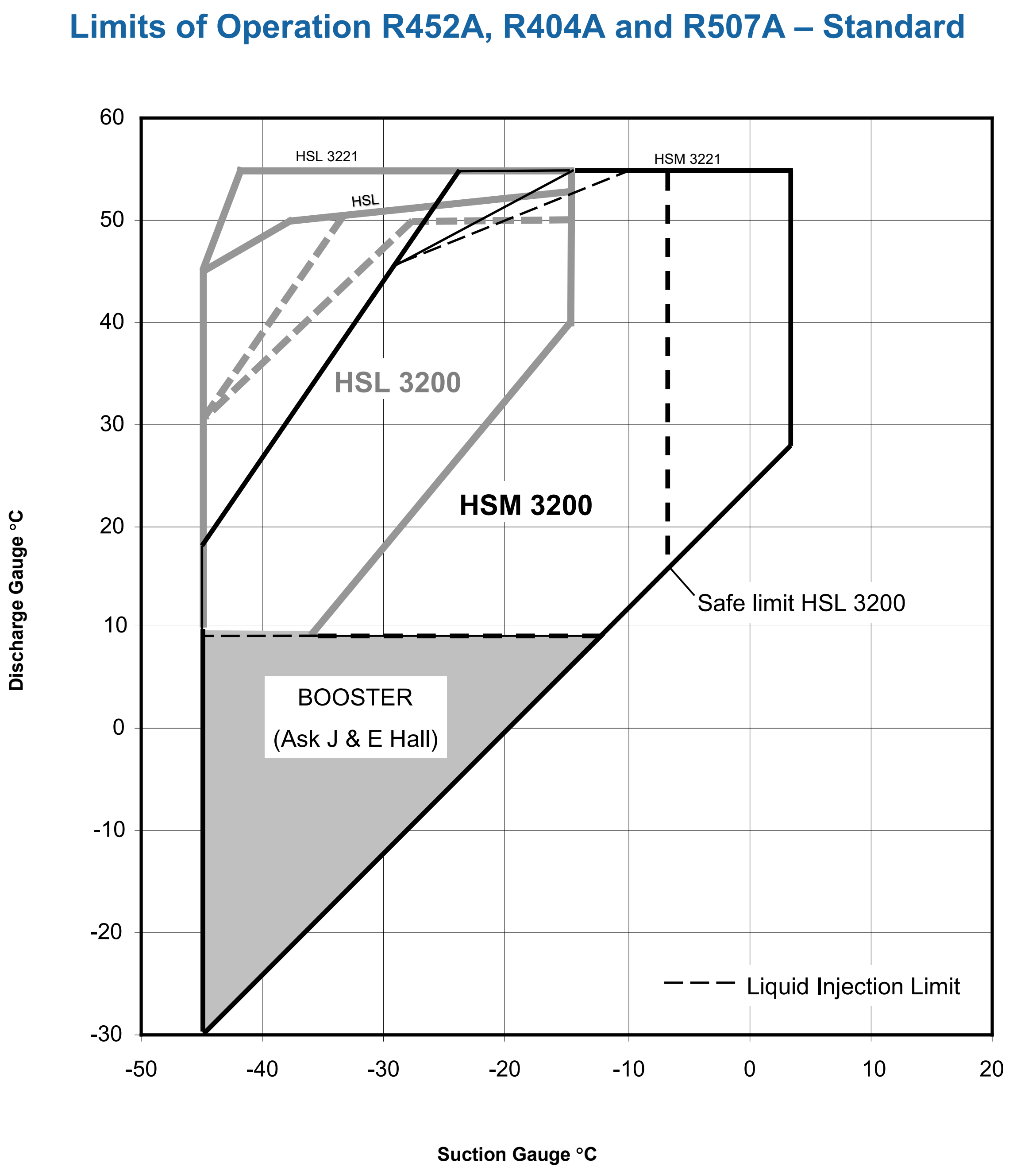


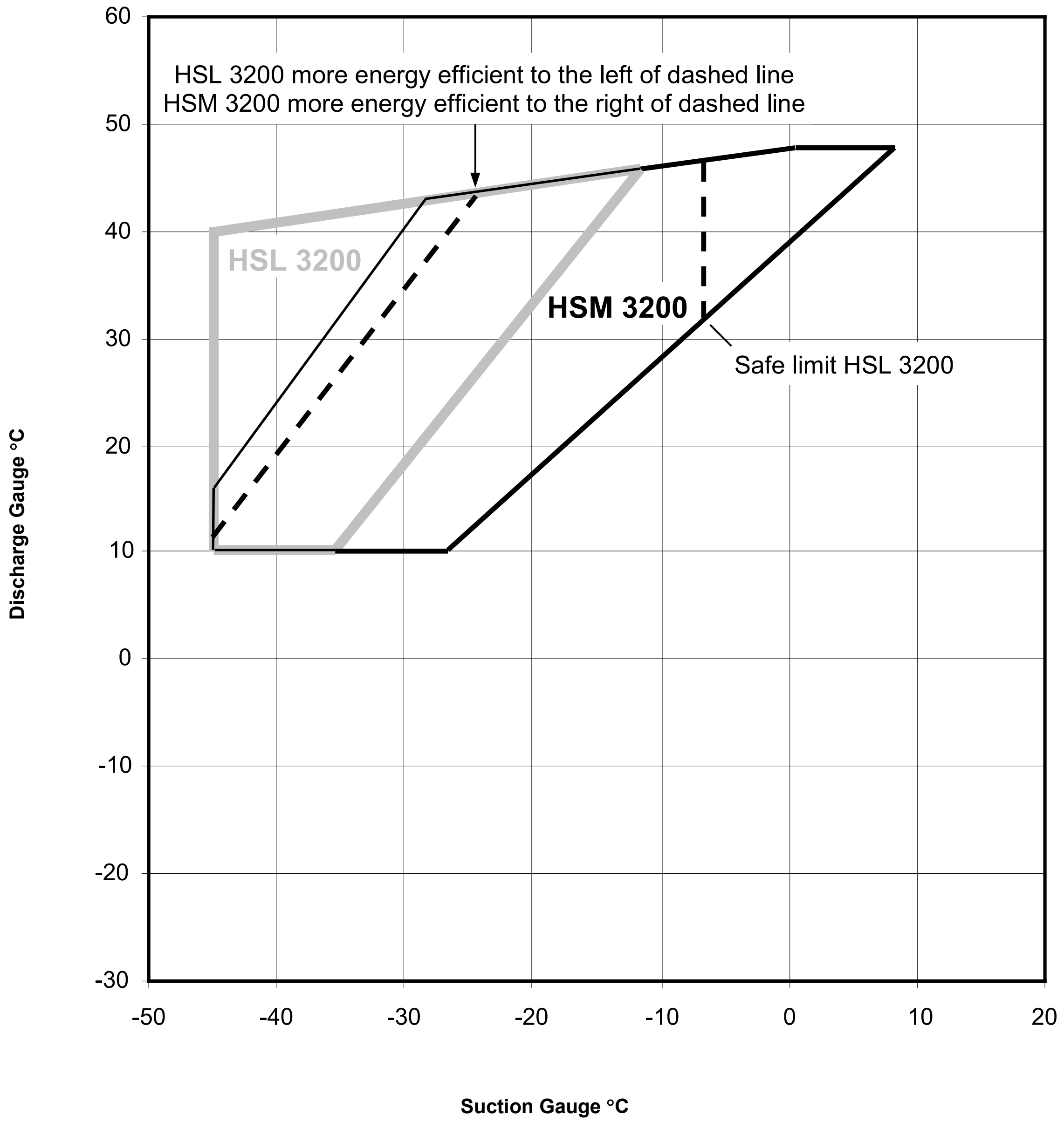
Fig 9 Oil Support System for Multiple Compressors

Appendix 3 Limits of Operation Envelopes



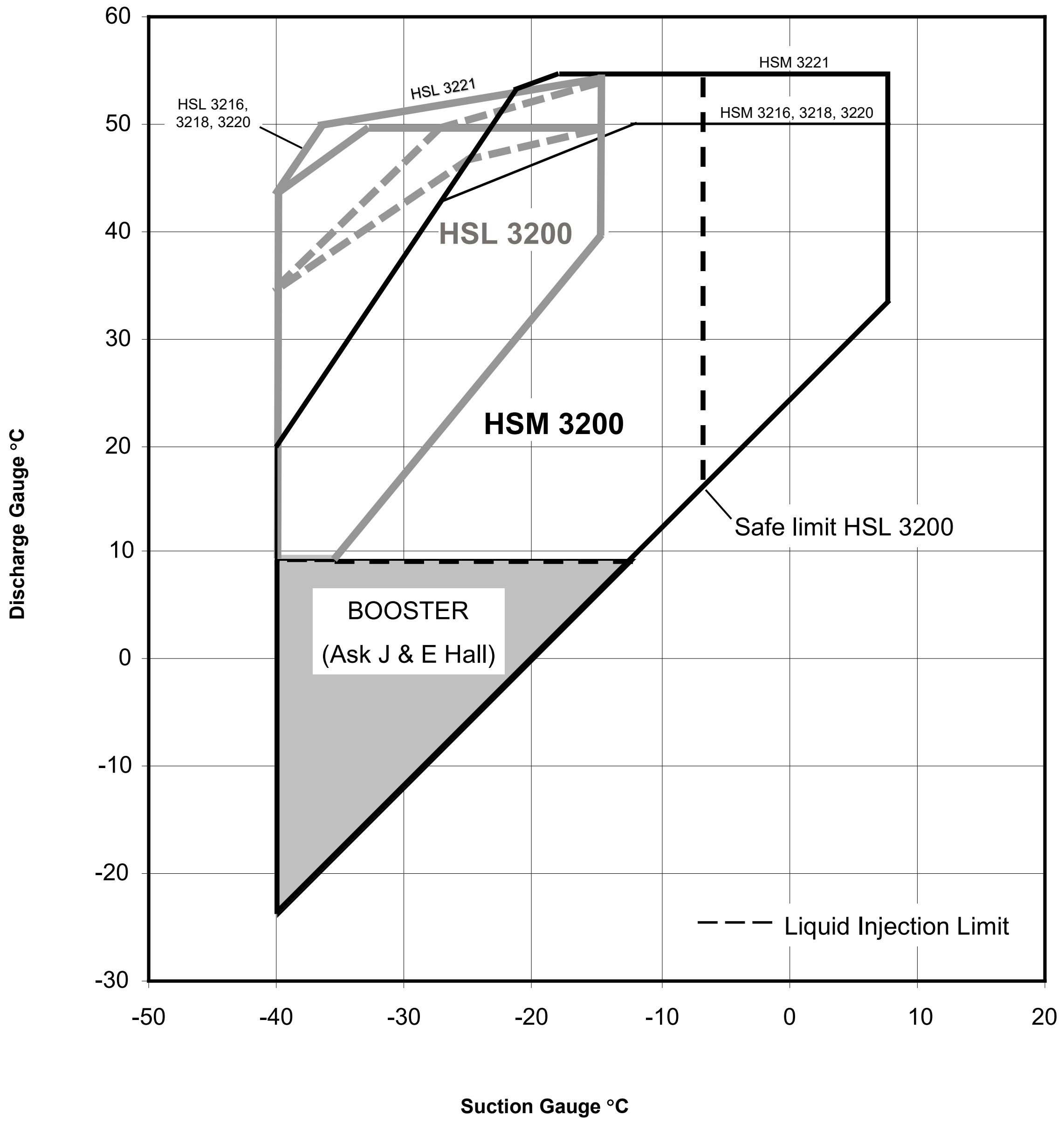
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R452A, R404A and R507A - Economised



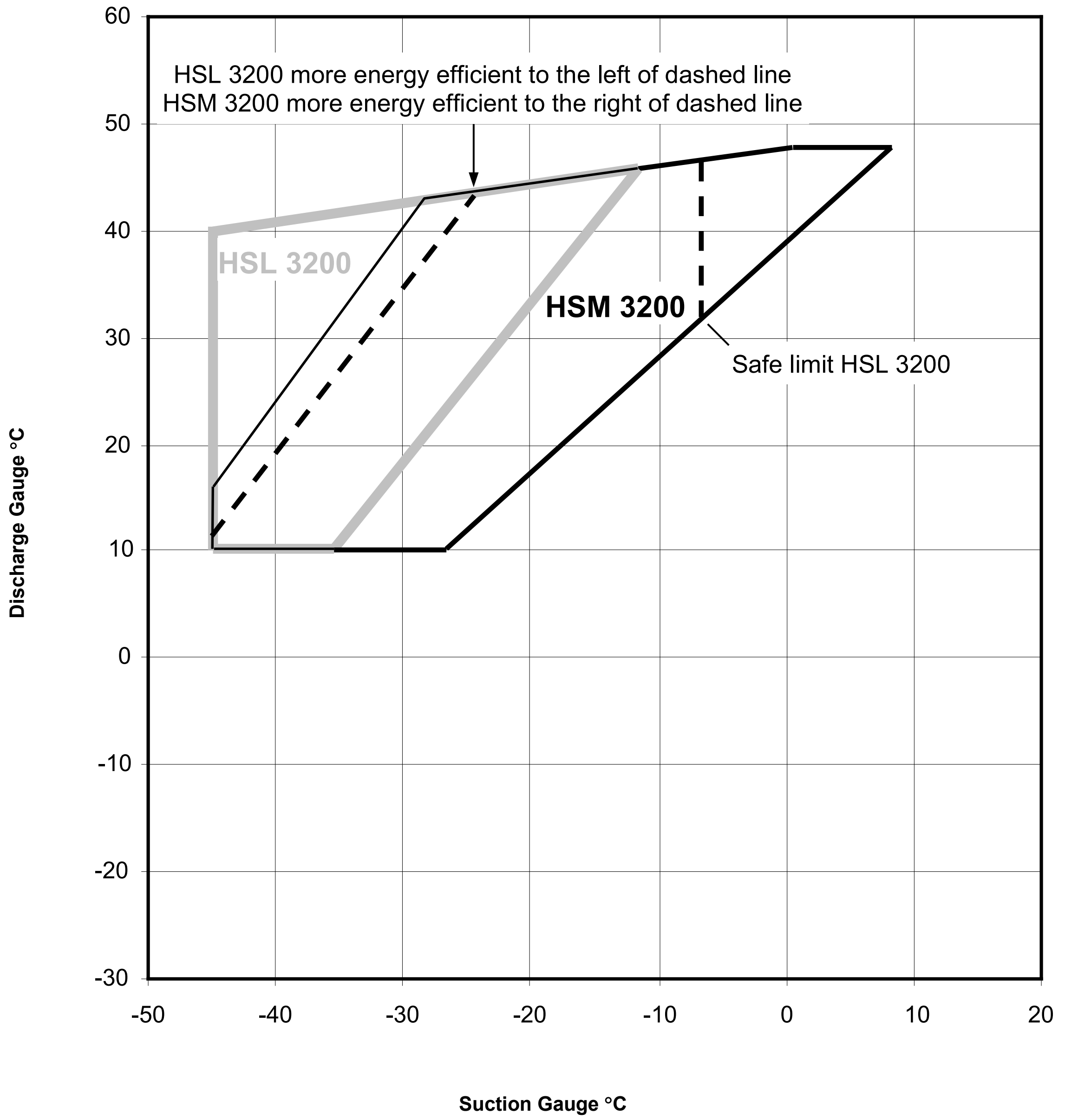
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R407F, R448A and R449A - Standard



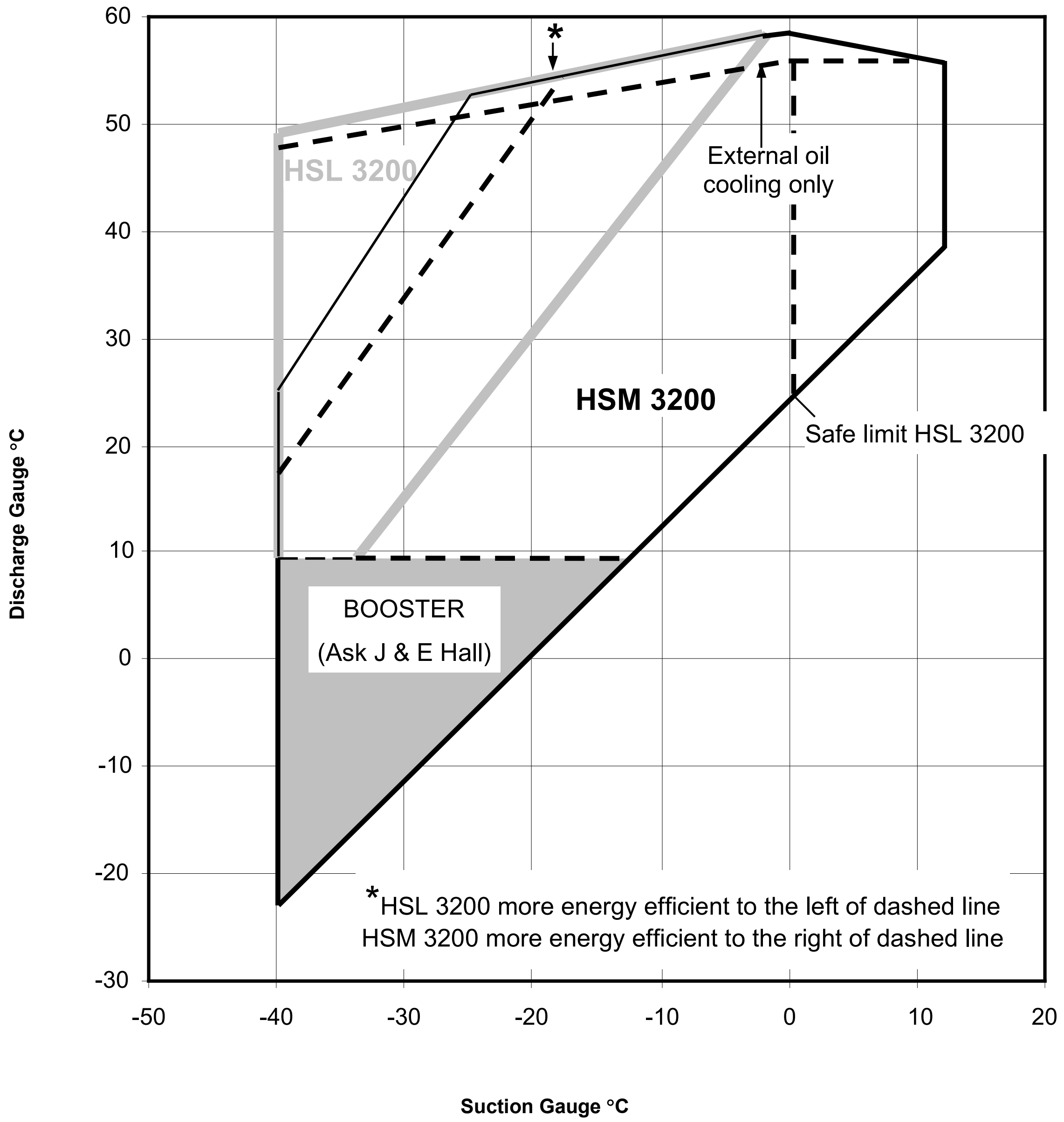
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R407F, R448A and R449A - Economised



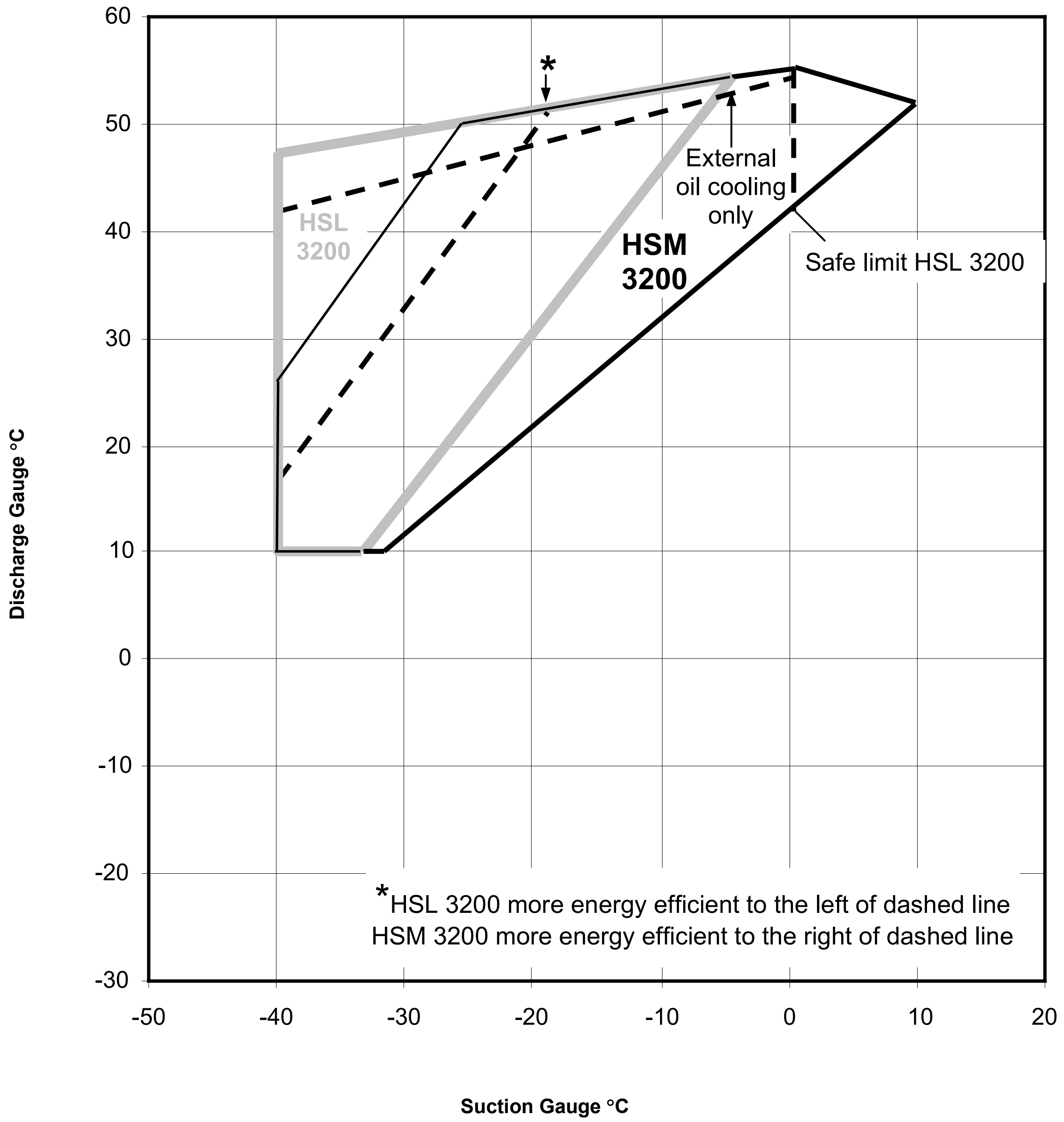
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 and R407C - Standard



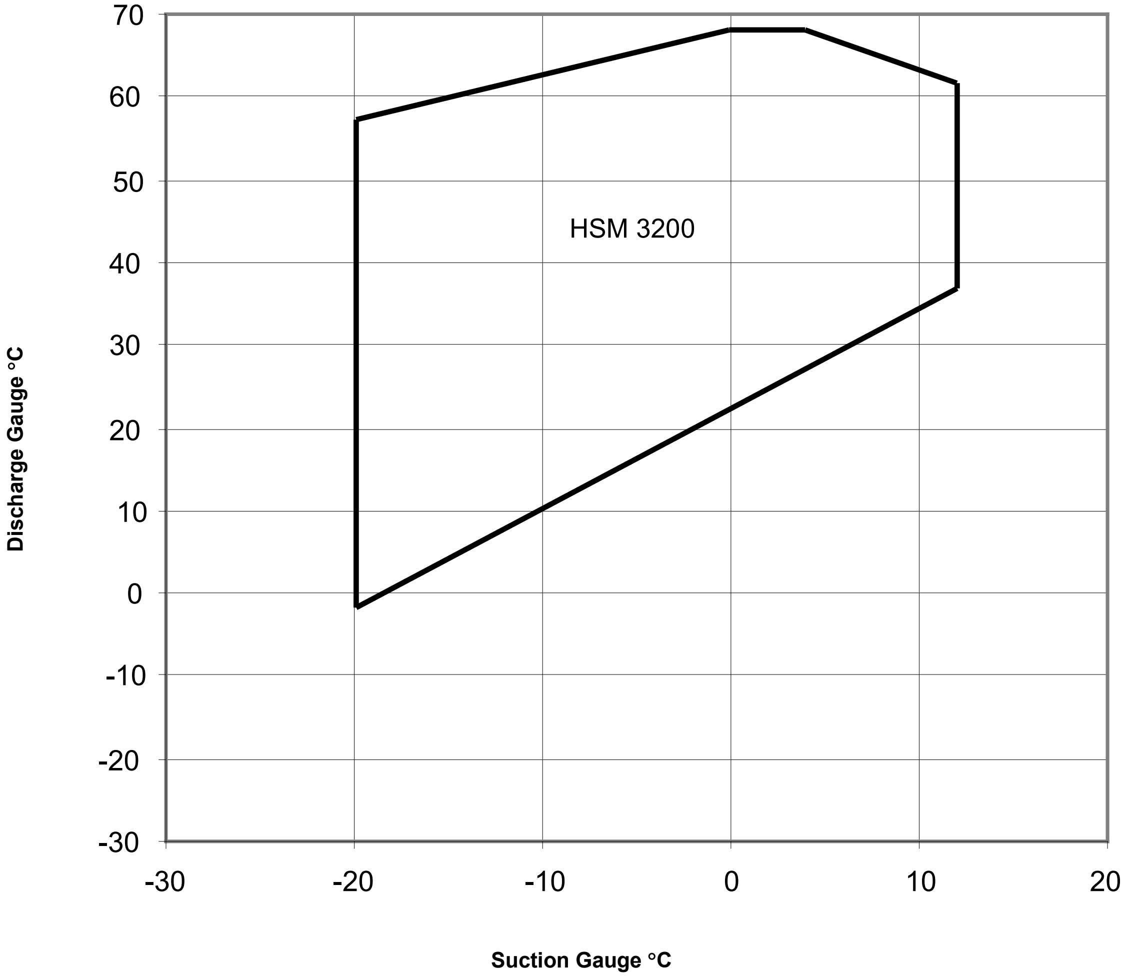
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R22 and R407C - Economised



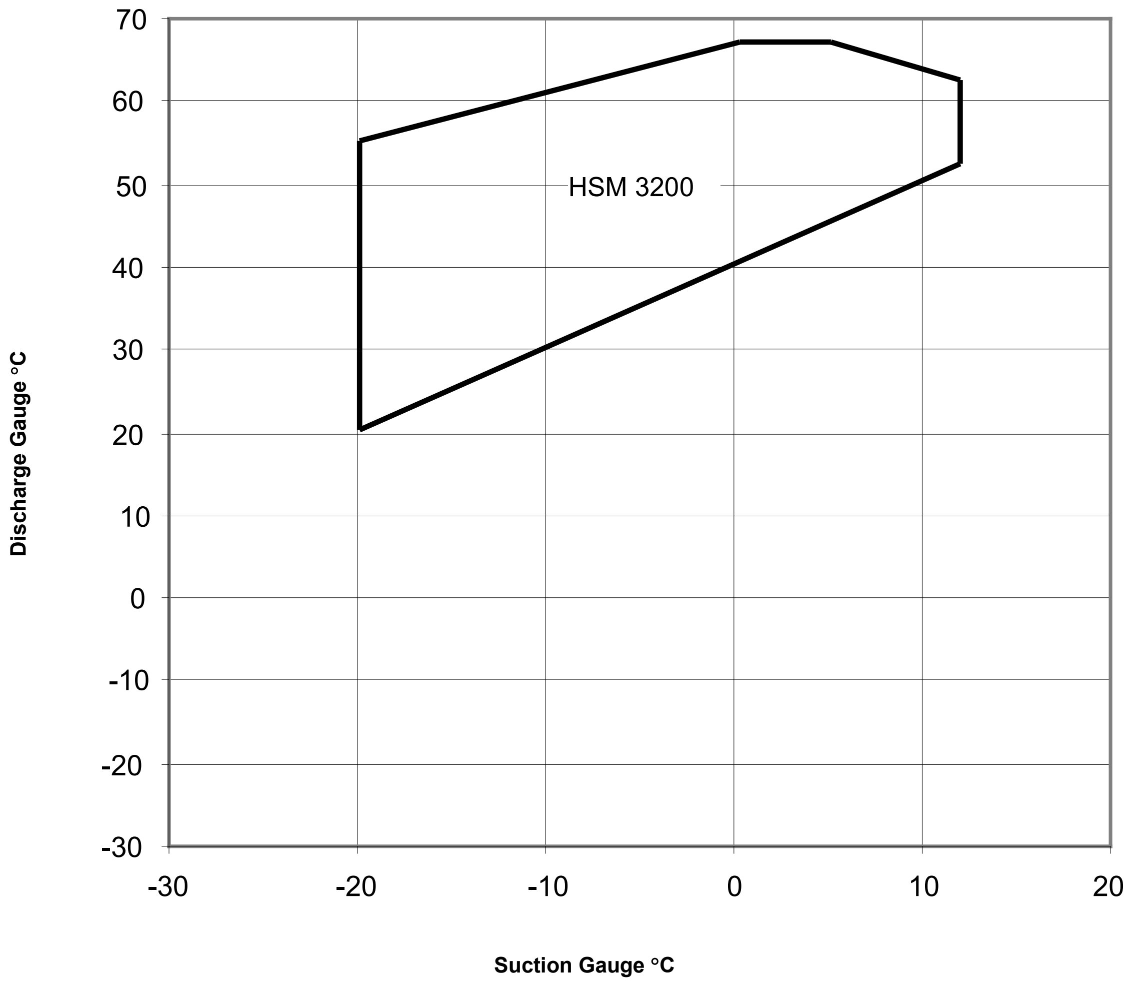
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R134a and R513A - Standard



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

Limits of Operation R134a and R513A - Economised



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

Appendix 4 Compressor Performance Data

For detailed selection use the J & E Hall International HallScrew compressor selection software.

NOTE: Continuous research and development may necessitate changes to specifications and data in this Application Manual and the J & E Hall International Compressor Selection Software.

Subcooling & Superheat Correction Factors

The performance data is based on 5.0 °C suction superheat and 5.0 °C liquid subcooling.

The suction superheat is assumed to be usefully obtained. Such superheat can be obtained in the evaporator or in a liquid to suction heat exchanger or similar vessel in the refrigeration circuit producing a beneficial effect.

The approximate effect of an increase in useful suction superheat is an increase in capacity of 0.17 % for every additional 1.0 °C superheat.

Non-usefully obtained superheat (such that might be picked up in the suction line due to heat exchange with the environment) will have a detrimental effect on performance.

The approximate effect is a loss in performance of approximately 0.7 % for each additional 1.0 °C of non-useful suction superheat.

It is important to ensure adequate suction superheat. Insufficient superheat can result in liquid carry over into the compressor, reducing performance and also resulting in inadequate discharge superheat for satisfactory oil separation.

Additional subcooling will have a beneficial effect on the system performance.

The approximate effect of an increase in liquid subcooling is an increase in capacity of 1.1 % for every additional 1.0 °C subcooling.

If the useful superheat is obtained in a suction to liquid heat exchanger then only the effect of the increase in suction superheat should be taken in to account. Otherwise the effect on performance will be added twice. Using the increase in suction superheat also includes the effect of the change in specific volume at the compressor suction.

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