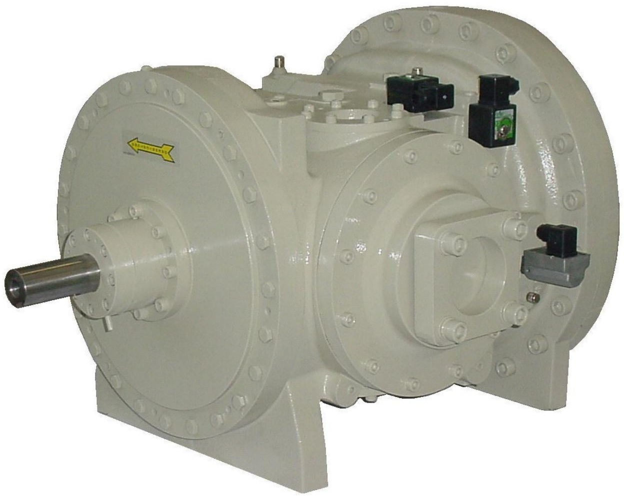
HallScrew HSO and HSI 3200 Series

Open Drive Single Screw Compressors

HSO/HSI 3216, HSO/HSI 3218, HSO/HSI 3220 and HSO/HSI 3221

Application Manual



HSO 3200

HSI 3200

Contents

1. General Description ... 5
1.1. Main Features ... 5
1.2. Construction ... 5
1.2.1. Internal Relief Valve ... 6
1.3. The Compression Process ... 6
2. Capacity Control and Volume Ratio ... 8
2.1. Slide Valve Actuation ... 9
2.1.1. Minimum Load Interlock ... 9
2.2. Continuously Variable Capacity Control ... 9
2.2.1. Controlled Stop ... 10
2.2.2. Uncontrolled Stop ... 10
2.3. Capacity Control by Inverter Drive ... 12
2.3.1. Inverter Size ... 12
2.3.2. Inverter Set-up ... 12
3. Compressor Lubrication, Sealing and Cooling ... 13
3.1. HSO 3200 Series Compressors ... 13
3.2. HSI 3200 Series Compressors ... 13
3.3. Lubrication Functions ... 13
3.3.1. Capacity Control Actuation ... 13
3.3.2. Bearing Lubrication ... 13
3.3.3. Shaft Seal Lubrication, Sealing and Cooling ... 13
3.3.4. Oil Injection for Sealing and Cooling ... 13
4. Oil Support System ... 15
4.1. Oil Injection/Lubrication – HSO 3200 Series Compressors ... 15
4.2. Oil Drain – HSO 3200 Series Compressors ... 15
4.3. Internal Oil Drain – HSI 3200 Series Compressors ... 15
4.3.1. Oil Heater – HSI 3200 Series Compressors ... 17
4.3.2. Oil Low Level Sensor (Option) – HSI 3200 Series Compressors ... 17
4.4. Oil Separation – HSO 3200 Series Compressors ... 17
4.4.1. Oil Separator Design ... 17
4.5. Oil Separator Provisions ... 18
4.5.1. Multiple Compressors ... 18
4.5.2. Discharge Non-return Valve ... 19
4.5.3. Oil Heater ... 19
4.5.4. Oil Low Level ... 19
4.5.5. Dual Compressor Circuits ... 19
4.6. Booster, Low Stage or Low Pressure Difference Applications ... 19
4.7. Oil Differential Pressure Monitoring ... 19
4.7.1. ODP1 ... 19
4.7.2. ODP2 ... 20
4.8. Maintaining Discharge Pressure at Start up ... 20
4.9. Oil Filter - HSO 3200 Series Compressors ... 21
4.10. External Oil Cooler/Oil Filter - HSI 3200 Series Compressors ... 21
4.11. Lubricating Oils ... 22
4.12. Compressor Cooling ... 22
5. 3N1 Three Function Valve for HSI 3200 Series Compressors (R134a Only) ... 23
6. Integration into the Refrigeration Circuit ... 24
6.1. Oil System ... 24
6.2. Suction Line ... 24
6.2.1. Liquid Separation in the Suction Line ... 24
6.2.2. Suction Strainer ... 24
6.3. Discharge Line ... 24

6.3.1. Discharge Superheat 24
6.4. Liquid Injection Lines 24
6.4.1. R134a Only 25
6.5. Economiser Connections 25
6.6. Safety Requirements for Compressor Protection 25
7. Electrical Connections 26
7.1. Thermistors 26
7.2. Capacity Control Solenoids 26
7.3. Linear Variable Displacement Transducer (LVDT) 26
7.4. Oil Low Level Sensor (Option) – HSI 3200 Series Compressors 26

List of Figures

Fig 1 Compression Process 7
Fig 2 Capacity Control Mechanism 8
Fig 3 Continuously Variable Capacity Control 10
Fig 4 Oil Support System – HSO 3200 Series Compressors 16
Fig 5 Maintaining Discharge Pressure at Start up 20
Fig 6 3N1 Three Function Valve for HSI 3200 Series Compressors (R134a Only) 23
Fig 7 LVDT External Wiring Connections 27
Fig 8 Oil Low Level Switch External Wiring Connections 27
Fig 9 Key to Schematic Flow Diagrams 38
Fig 10 Oil Support System for Single HSO 3200 Compressor 39
Fig 11 Oil Support System for Single HSI 3200 Compressor With External Oil Cooling 40
Fig 12 Oil Support System For Multiple HSO 3200 Compressors 41

List of Tables

Table 1 External Oil Filter Minimum Specification 21
Table 2 Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions 49
Table 3 Setting the Display to Read 0 at Minimum Load and 100 at Maximum Load 51
Table 4 Setting the Relay Switch Value 52

1. General Description

The J & E Hall International HSO/HSI 3200 series of open drive compressors are the latest addition to the HallScrew family of oil injected, positive displacement, single screw compressors. Reflecting the very latest innovations in screw compressor technology, they have been specially developed for refrigeration, air conditioning and heat pump applications, and can be applied to single stage and multi-stage systems using all normal refrigerants as well as many other process gases.

1.1. Main Features

- Generally for use with R22, R404a, R507a, R134a and R407c. For R410a, R717 (ammonia) and R23 ask J & E Hall International for use with HSI 3200 series.
- Integral oil separator option (HSI 3200 series where the ‘I’ stands for ‘integral’).
- Designed and tested to international standards.
- Robust construction.
- Improved machine clearance control for maximum efficiency.
- Oil injected for maximum reliability.
- Balanced loading on main bearings for maximum bearing life
- Enhanced slide valve geometry for capacity modulation with minimum loss of efficiency. Infinite adjustment between maximum (100 %) and minimum load (nominal 25 %).
- Simple, built-in capacity control using two solenoid valves.
- Single connection for oil injection/lubrication/capacity control, choice of suction connections.
- Economiser facility provided to improve operating efficiency, especially at high compression ratios.

  For further information refer to publication 2-129 Economiser Facility For HallScrew Compressors.
- Internal suction/discharge safety relief valve (not UL approved).
- Integral oil separator fitted with integral discharge check valve (HSI 3200 series only). Combined discharge stop valve, check valve and head pressure control valve available as optional extra (R134a applications only).
- Thermistor discharge gas high temperature protection.
- Built-in oil filter (HSI 3200 series only).

1.2. Construction

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

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

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

1.2.1. 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.

1.3. The Compression Process

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

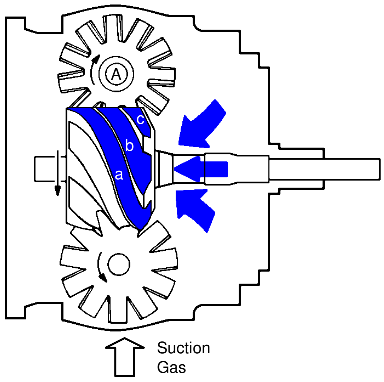
As the HallScrew is a positive displacement compressor, there are three separate stages in the compression cycle: suction, compression and discharge. These are illustrated in Fig 1.

1. and 2. Suction

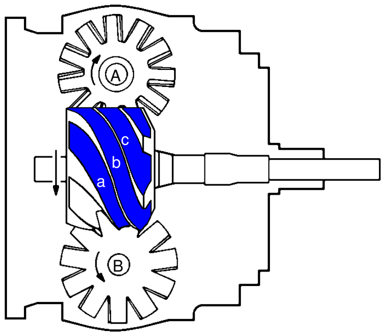
Main rotor flutes 'a', 'b' and 'c' are in communication at one end with the suction chamber via the bevelled rotor end face, and are sealed at the other end by the teeth of star rotor A. As the main rotor turns, the effective length of the flutes increases with a corresponding increase in the volume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

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

1.



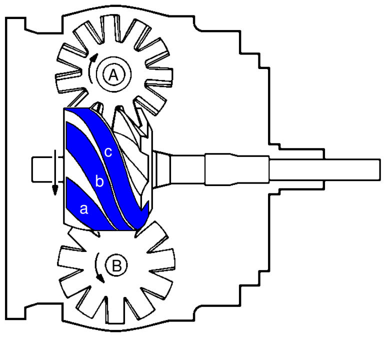
2.



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.

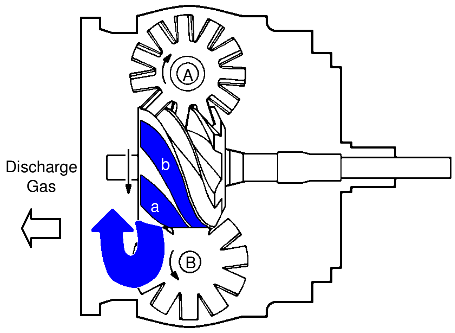


4. Discharge

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.



HSO 3200 Series Compressor Illustrated

Fig 1 Compression Process

2. Capacity Control and Volume Ratio

HallScrew HSO/HSI 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 overcompression or undercompression will occur, both of which result in internal losses. Although in no way detrimental to the compressor, inefficient compression will increase power consumption.

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

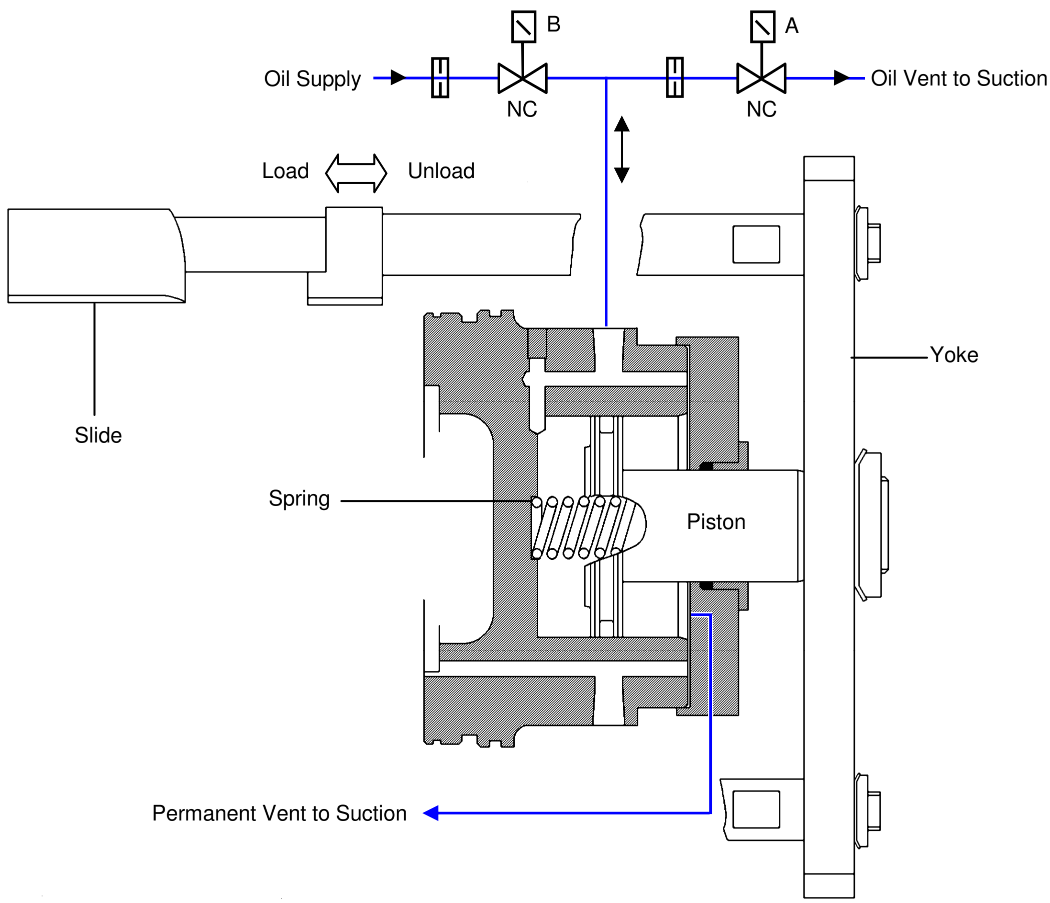


Fig 2 Capacity Control Mechanism

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

2.1. 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.

2.1.1. 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.

2.2. Continuously Variable Capacity Control

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

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

2.2.1. 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.

2.2.2. 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.

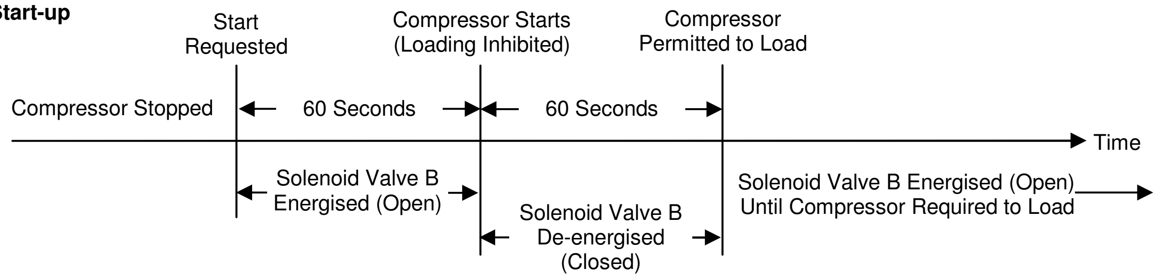
Unlike a controlled stop, unless the compressor was at minimum load before the uncontrolled stop occurred, the capacity control cylinder may contain some refrigerant vapour instead of being completely filled with oil. In this event a hydraulic lock will not be present and uncontrolled loading may occur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

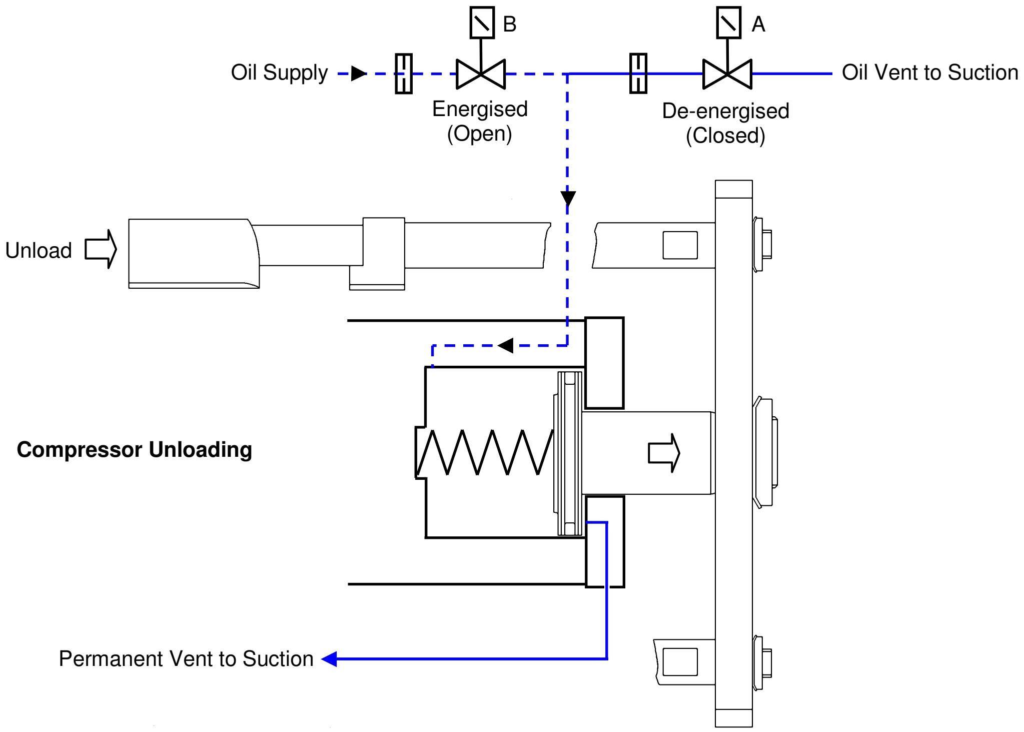
CAPACITY CONTROL ACTION	SOLENOID VALVE A	[1]SOLENOID VALVE B
Load compressor Oil is vented from the capacity control cylinder. The action of the suction/ discharge differential pressure on the slide/piston assembly overcomes the force of the unloading spring and moves the slide valves towards the maximum 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

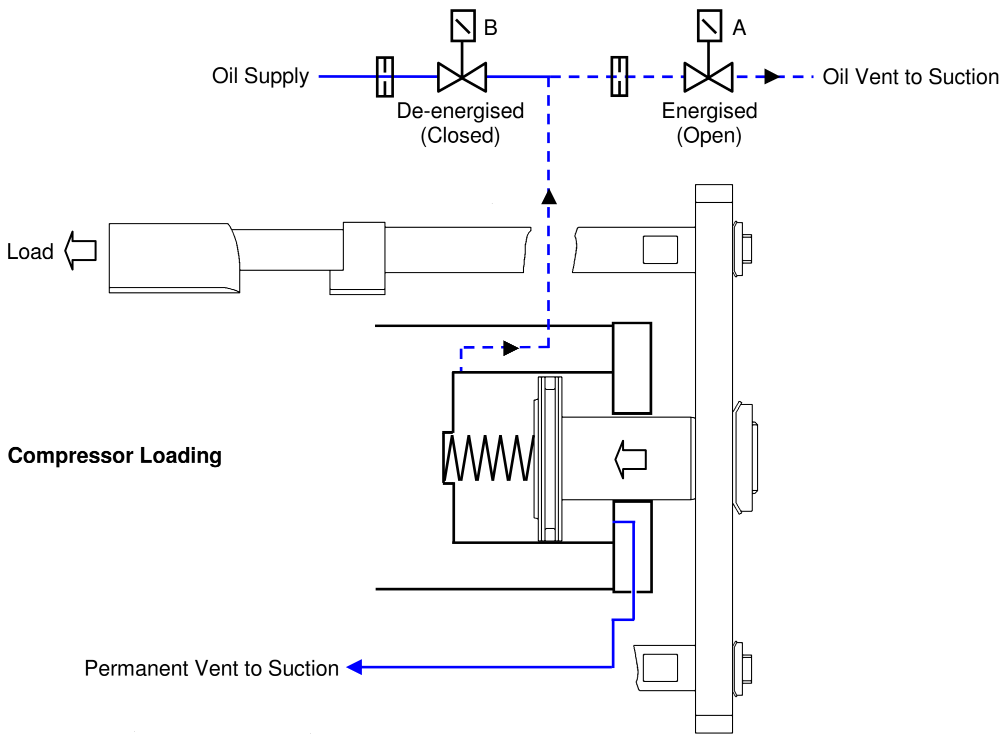


[1]Refer to 2.2.2. Uncontrolled Stop.

Fig 3 Continuously Variable Capacity Control



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



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

Fig 3 (continued) Continuously Variable Capacity Control

2.3. Capacity Control by Inverter Drive

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

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

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

2.3.1. 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.

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

During pull down, the current can be limited by either using the slide valve to run the compressor unloaded, or by throttling the suction. If it is required to use the slide valve during pull down, then normal manual slide valve control can be used; refer to 2.2. Continuously Variable Capacity Control.

2.3.2. Inverter Set-up

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

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

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

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

3. Compressor Lubrication, Sealing and Cooling

3.1. HSO 3200 Series Compressors

HSO 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.

It is essential to supply the compressor with an adequate supply of clean (filtered) oil at the correct temperature; refer to 4. Oil Support System.

3.2. HSI 3200 Series Compressors

HSI 3200 series compressors are fitted with an integral oil separator and oil filter.

3.3. Lubrication Functions

The oil performs four basic functions:

3.3.1. Capacity Control Actuation

Oil pressure is used to actuate the compressor capacity control mechanism; refer to 2.1. Slide Valve Actuation.

3.3.2. 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.

3.3.3. Shaft Seal Lubrication, Sealing and Cooling

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

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

3.3.4. Oil Injection for Sealing and Cooling

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

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

Compressor cooling can be accomplished by the direct injection of liquid refrigerant into the compression process. When liquid injection is not used, the oil injected for sealing absorbs a large proportion of the heat of compression, thus reducing the maximum discharge temperature, and is cooled externally via an oil cooler; refer to 4.12. Compressor Cooling.

4. Oil Support System

HSO 3200 series compressors require an external oil separator and oil support system; refer to Fig 4.

HSI 3200 series compressors are fitted with an integral oil separator and oil filter. For most applications, an external oil support system is not necessary.

The system into which the compressor is to be installed must fully comply with the recommendations in 4.1. to 4.12. 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.

4.1. Oil Injection/Lubrication – HSO 3200 Series Compressors

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.

4.2. Oil Drain – HSO 3200 Series Compressors

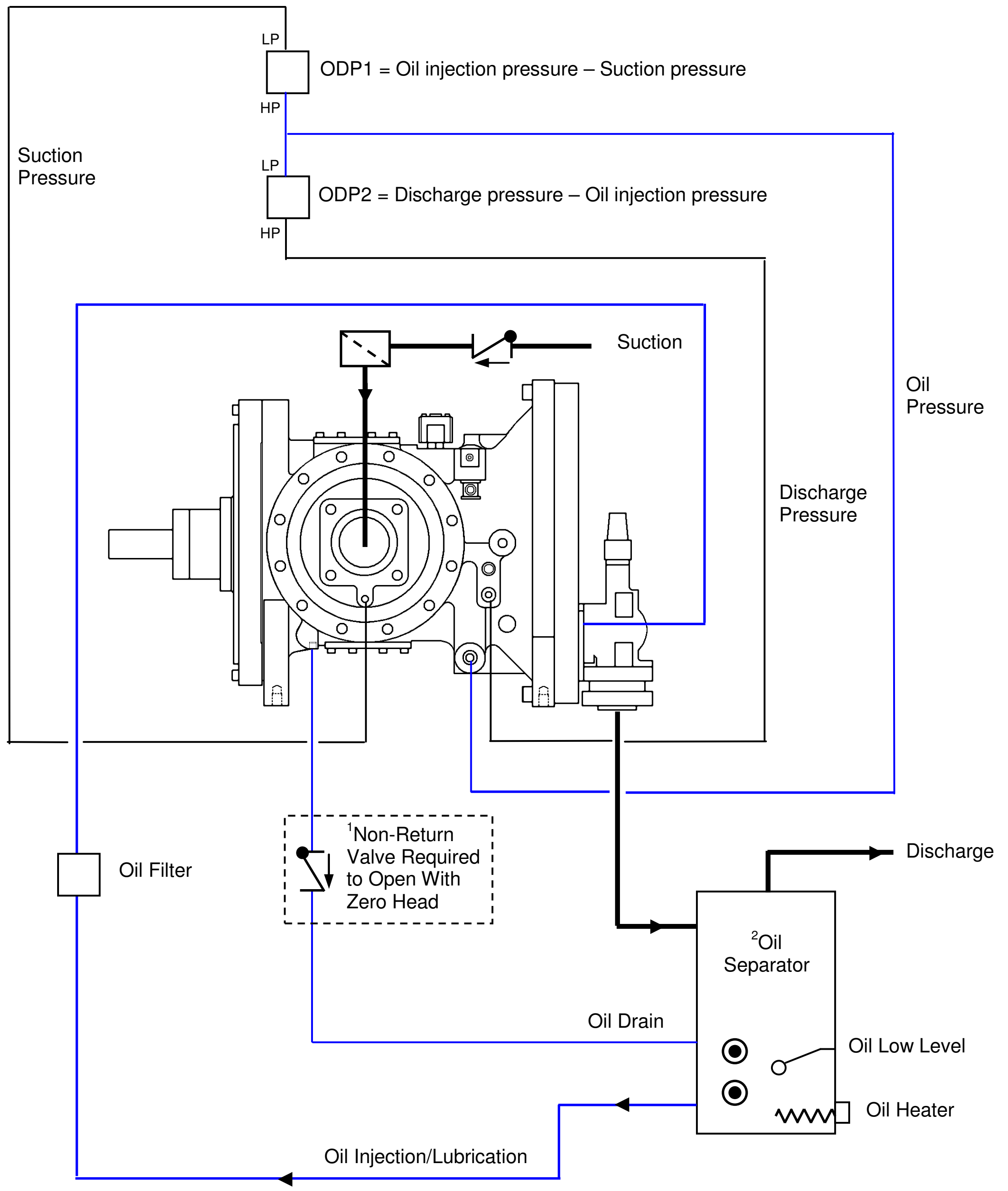
Oil which collects inside the compressor casing must be allowed to drain back to the oil separator when the compressor stops.

Single compressor operating with a single oil separator:

- 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).

4.3. Internal Oil Drain – HSI 3200 Series Compressors

An oil drain facility, including a non-return valve, forms an integral part of HSI 3200 series compressors. Oil which collects inside the compressor casing automatically drains back to the integral oil separator via the internal drain. An external drain line is not required.



The oil support system must conform with the provisions described in 4.1. to 4.12.

[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 – HSO 3200 Series Compressors

4.3.1. Oil Heater – HSI 3200 Series Compressors

The compressor integral oil separator is fitted with a heater 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 must be electrically interlocked to energise when the compressor stops.

4.3.2. Oil Low Level Sensor (Option) – HSI 3200 Series Compressors

Provision is made to fit a level sensor to the oil separator at a point corresponding to a dangerously low oil level. The sensor must be electrically interlocked to stop the compressor if the oil level falls to the danger level.

4.4. Oil Separation – HSO 3200 Series Compressors

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.

4.4.1. 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.

4.5. Oil Separator Provisions

In addition to the considerations discussed in 4.4.1, for multi compressor applications, the oil separator should comply with the following recommendations:

4.5.1. 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 4.5.2. to 4.5.4.

- For each compressor two solenoid valves must be provided in the oil injection line in parallel – one corresponding to the normal line size and a smaller one with flow coefficient Kv < 1.0. The smaller solenoid valve must be energised on compressor start and the main solenoid valve electrically interlocked to energise (open) when the delta contactor of the compressor starter is energised. The smaller solenoid valve can remain energised. Both solenoid valves must be , de-energised (closed) when the compressor stops. For inverter drives, the main oil injection solenoid valve must be energised with a timed delay after the start signal. The delay time should be approximately 3 to 5 seconds, by which time the compressor speed must be at least 1500 rpm.
- For each compressor, a non-return valve must be provided in the discharge line before the inlet to the oil separator. This dispenses with the need for a suction non-return valve.
- The suction to each compressor must be taken from a separate suction header located below the level of the compressor. The header should be insulated with the suction line in the normal way.
- If there is any possibility of liquid refrigerant collecting in the header during the off cycle, the header should be fitted with heater(s) or wound with heater tape underneath the insulation. The heater(s) must be electrically interlocked to de-energise when the first compressor starts and energise when the last compressor stops.
- The oil drain line from each compressor must be taken to the suction header.

A typical arrangement is shown in Fig 12 in Appendix 2 Oil Support System Schematic Flow Diagram.

4.5.2. Discharge Non-return Valve

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

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

4.5.3. Oil Heater

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

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

4.5.4. Oil Low Level

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

4.5.5. Dual Compressor Circuits

Refer to J & E Hall International.

4.6. Booster, Low Stage or Low Pressure Difference Applications

HSO/HSI 3200 series compressors may not be suitable for low pressure difference applications. Ask J & E Hall International.

4.7. Oil Differential Pressure Monitoring

As already described in 3. Compressor Lubrication, Sealing and Cooling, HSO/HSI 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.

4.7.1. 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.

4.7.2. 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.

4.8. 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.

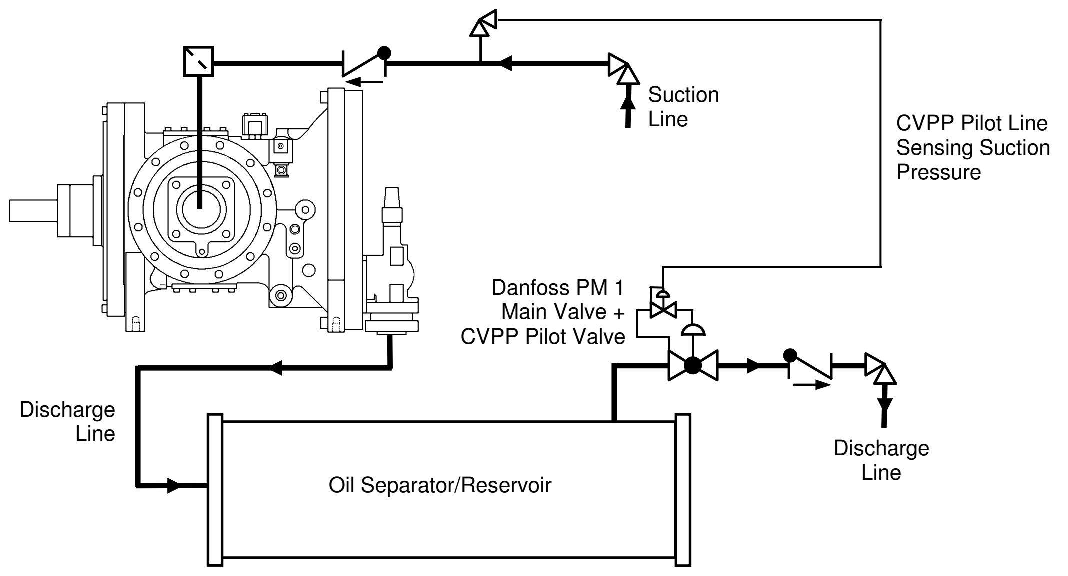


Fig 5 Maintaining Discharge Pressure at Start up

In circumstances where the minimum discharge pressure is difficult to achieve, even with the help of condenser head pressure control devices, a differential pressure regulator must be fitted in the discharge line immediately after the oil separator. Fig 5 shows a typical arrangement using a Danfoss PM 1 main valve and CVPP pilot valve.

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

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

4.9. Oil Filter - HSO 3200 Series Compressors

To ensure minimum wear on moving parts and to maximise bearing life, HSO 3200 series compressors, which are not fitted with an integral oil separator, must be fitted with an adequately sized external oil filter. The location of the filter is shown in Fig 4.

The external 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 1. 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. As refrigerant R717 (ammonia) attacks copper, nickel, tin, zinc and cadmium, filter components containing these metals or their alloys are prohibited from ammonia refrigeration systems.

Table 1 External Oil Filter Minimum Specification

4.10. External Oil Cooler/Oil Filter - HSI 3200 Series Compressors

HSI 3200 series compressors are fitted with an internal oil filter which is adequate for factory built chillers for which these compressors are designed, where system cleanliness can be guaranteed. The HSI 3200 series is also designed for liquid injection cooling, where necessary, to control the discharge temperature. High rates of liquid injection will de-rate the performance, so in these circumstances, particularly with refrigerants R407c and R22 with high condensing temperature, an external oil cooler can be used to enhance efficiency.

If an external oil cooler is to be fitted and/or an external oil filter is preferred, then a special kit is available, part number 93122-207, which allows the internal filter to be removed and provides an outlet for the oil to pass through an external circuit; refer to Fig 11. The minimum specification for an external oil filter is shown in Table 1.

4.11. Lubricating Oils

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

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

4.12. Compressor Cooling

The heat of compression must be removed either by the evaporation of liquid refrigerant injected directly into the compression process (liquid injection), or by using an external heat exchanger to cool the oil injected to seal the compression process.

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

5. 3N1 Three Function Valve for HSI 3200 Series Compressors (R134a Only)

As an option, for R134a applications only, the discharge connection can be fitted with a specially designed valve which combines the following functions in one compact assembly.

- Discharge stop valve.
- Discharge check valve.
- Head pressure control valve (useful for applications using an air cooled condenser).

Note: when fitting or refitting the 3N1 valve, the pilot line between the valve and the connection provided on the compressor sensing suction pressure must be fitted. Failure to do so will prevent the valve from opening.

The 3N1 valve replaces the non-return valve otherwise fitted in the oil separator housing discharge.

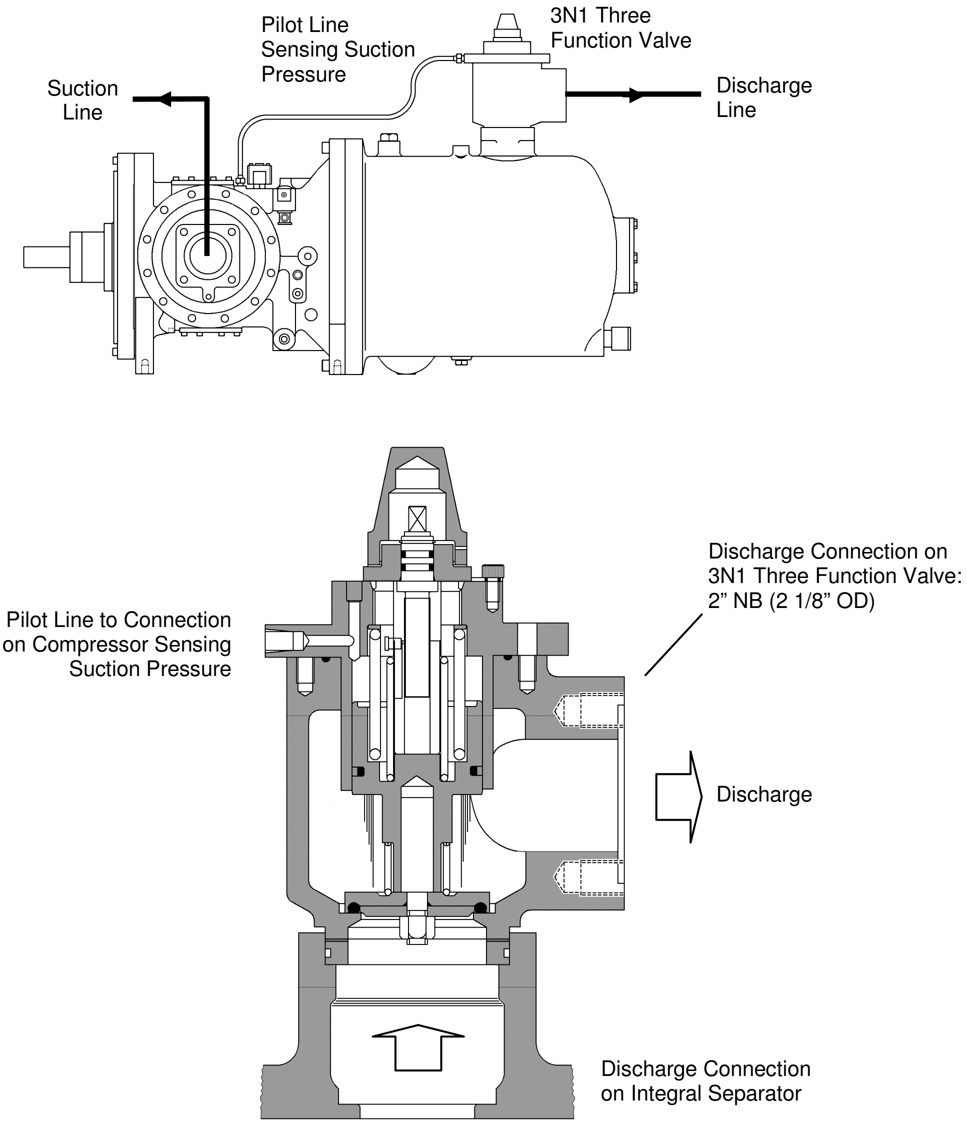


Fig 6 3N1 Three Function Valve for HSI 3200 Series Compressors (R134a Only)

6. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type. For HSO 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 will be detrimental to performance although unlike reciprocating compressor is not harmful to the compressor in small quantities. However large quantities of liquid or oil returned to the compressor via the suction line can form an incompressible fluid in the rotor flutes with resultant damage to the compressor. Thus the system must be designed to prevent such occurrences.

6.1. Oil System

The recommendation in 4. Oil Support System should be adhered to.

6.2. 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.

6.2.1. Liquid Separation in the Suction Line

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

6.2.2. Suction Strainer

HSO 3200 and HSI 3200 compressors are not fitted with a suction strainer. An adequately sized suction strainer must therefore be fitted in the suction line. 250 micron mesh size is recommended.

6.3. 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.

6.3.1. Discharge Superheat

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

6.4. Liquid Injection Lines

In general, liquid injection lines should be piped to the top and bottom liquid injection/economiser connections. Liquid injection lines should be of equal length so that liquid is distributed uniformly to both ports.

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

6.4.1. R134a Only

It may be possible to use just the top liquid injection/economiser port with a special orifice adaptor (as used for semi-hermetic compressors). This can be used in conjunction with a simple liquid line solenoid valve and thermostat. For more information refer to J & E Hall International.

6.5. 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.

6.6. 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.

7. Electrical Connections

7.1. Thermistors

A discharge high temperature thermistor is fitted as standard and should be wired to a suitable thermistor controller.

7.2. 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.

7.3. 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.

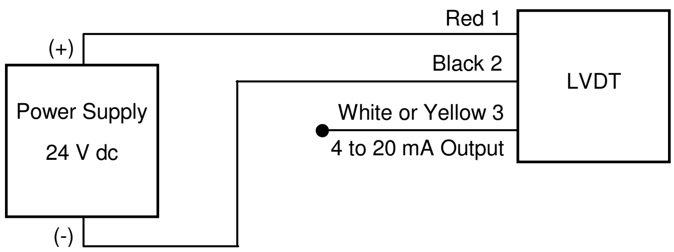
The LVDT is only available without calibration, this must be done on the controller. However, a signal conditioning module is available for applications where this is not possible.

External wiring connections are shown in Fig 7. Set up instructions for the signal conditioning module can be found in Appendix 5 Pepperl & Fuchs Signal Conditioning Module KFU8-USC-1.D Set-up.

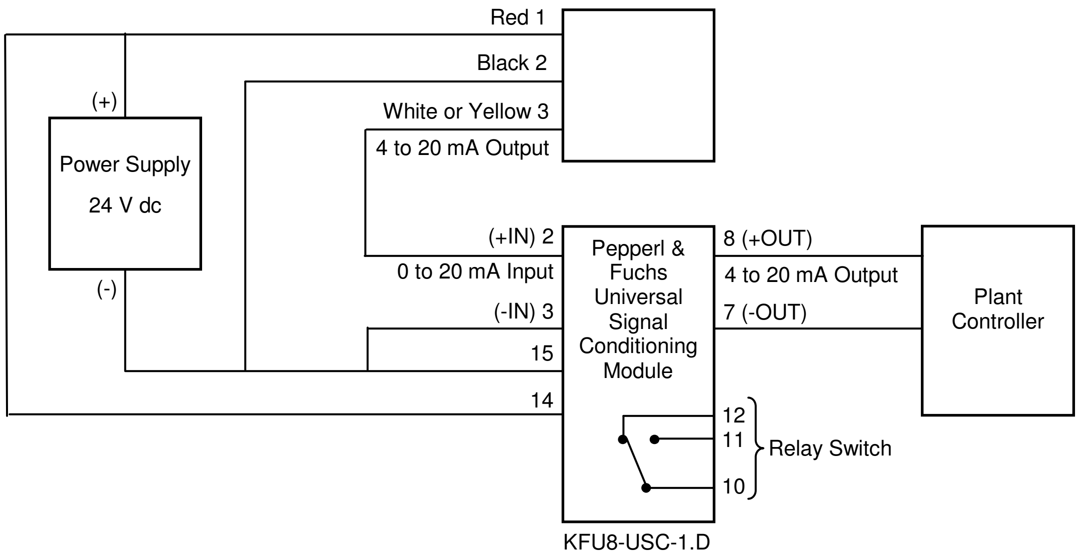
7.4. Oil Low Level Sensor (Option) – HSI 3200 Series Compressors

External wiring connections are shown in Fig 8.

A conditioning relay is required to provide a volt-free contact.



Wiring for MSI LVDT



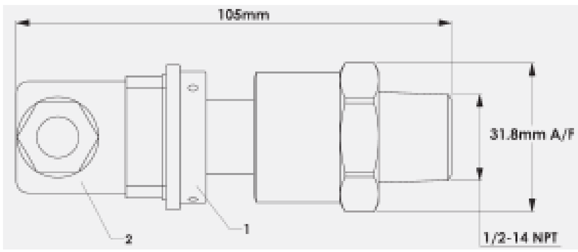
Wiring for LVDT and Pepperl &Fuchs Universal Signal Conditioning Module

Fig 7 LVDT External Wiring Connections

Henry S-9424DN Level Sensor

J & E Hall Part Number 131024330

Voltage: 24 V ac/dc
Resistive rating: 0.5 Amp
Contacts – power on and liquid present: NC
Interface: DIN plug



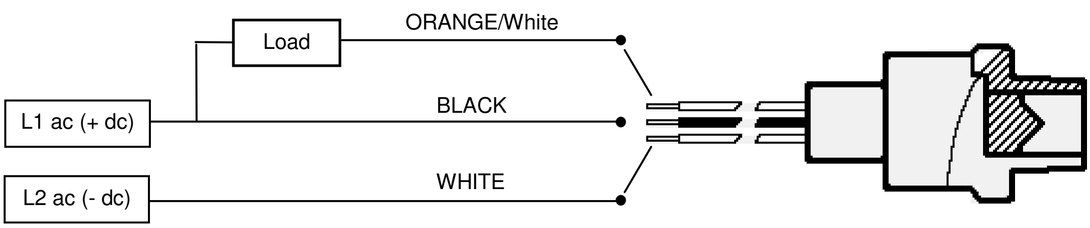


Fig 8 Oil Low Level Switch External Wiring Connections

Appendix 1 Compressor Data

- HSO/HSI 3200 Series: Compressor Model Nomenclature.
- HSO/HSI 3200 Series: Physical Data.
- HSO/HSI 3200 Series: Starting Torque Characteristics.
- HSO/HSI 3200 Series: Limits of Operation.
- Safety Requirements for Compressor Protection.
- HSO 3200 Series: Physical Dimensions and Connections.
- HSI 3200 Series: Physical Dimensions and Connections.

HSO/HSI 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
HS	X	3	2	X	X	X	0	0	X	X	X	X	X	X

Application	O	Open drive		
	I	Open drive with integral oil separator		
Compressor	32X	Series 3200 Twin Star 16, 18, 20 or 21		
Capacity Control Slide V_R	2	2.2 V_R		
	3	3.0 V_R		
	5	4.9 V_R		
Lubricant	E	Ester oil		
	M	Mineral oil		
Motor Power (Nominal)	0	Without motor		
Motor Voltage	0	No voltage (without motor)		
Refrigerant	A	R134a	F	R404a
	B	R22	G	R717
	C	R407c	H	R23
	D	R410a	X	Other
	E	R507a		
Voltage (Auxiliary)	1	115 V 1 ph 50/60 Hz	3	24 V dc
	2	230 V 1 ph 50/60 Hz	4	24 V ac
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 (standard)		
	B	Suction flange and discharge stop valve		
	C	Suction flange and 3N1 3 in 1 discharge valve		
	D	Suction and discharge stop valves		
	E	Suction stop valve and discharge flange		
	F	Suction stop valve and 3N1 3 in 1 discharge valve		
Economiser Kit	0	No economiser kit (standard)		
	1	Economiser kit		
Discharge Thermistor	A	No discharge thermistor		
	B	Discharge thermistor (standard)		

Example: HSI 3218/2/M/B/2

This describes a HallScrew 3218 twin star open drive compressor with integral oil separator fitted with 2.2 V_R capacity control slide valves, supplied with mineral oil. Compressor for operation with R22. Solenoid/oil heater voltage 230 V 1 ph 50/60 Hz.

HSO/HSI 3200 Series: Physical Data

Compressor Type	Single screw.
Compressor Rotation	Anti-clockwise looking on the motor (driven) end. Under no circumstances should the compressor run in the reverse direction.
Method of Drive	Direct coupled to foot mounted drive motor.
Speed Range	1500 to 4000 rpm.
Physical Dimensions	Refer to Physical Dimensions and Connections
Weights	HSO 3200: 475 kg (approx, all models, excluding suction and discharge stop valves).
	HSI 3200: 610 kg (approx, all models, excluding suction and discharge stop valves).
	3N1 three function valve (HSI 3200 series only) 12 kg
Capacity and Power	Refer to selection data.
Capacity Control	Compressor capacity infinitely variable from 100 % to approximately 25 % of full load (depends on the operating conditions). Slide valve position indication by 4 to 20 mA HB 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.
HSI 3200 Series Integral Oil Separator	250 W heater.
	Sump capacity 18 litres.

Swept Volume

Swept Volume (m^3/hr)	HSO/HSOI 3216	HSO/HSOI 3218	HSO/HSOI 3220	HSO/HSOI 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
HSO 3216	80	65	77	73	76	71	67	65
HSO 3218	80	65	78	73	77	72	69	68
HSO 3220	81	65	78	73	78	74	70	70
HSO 3221	82	66	79	74	79	75	71	71
HSI 3216	78	63	75	71	74	69	65	63
HSI 3218	78	63	76	71	75	70	67	66
HSI 3220	79	63	76	71	76	72	68	68
HSI 3221	80	64	77	72	77	73	69	69

[1]Sound pressure level data applies to the compressor only. The sound pressure level for a standard air-cooled compressor drive motor is usually higher.

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

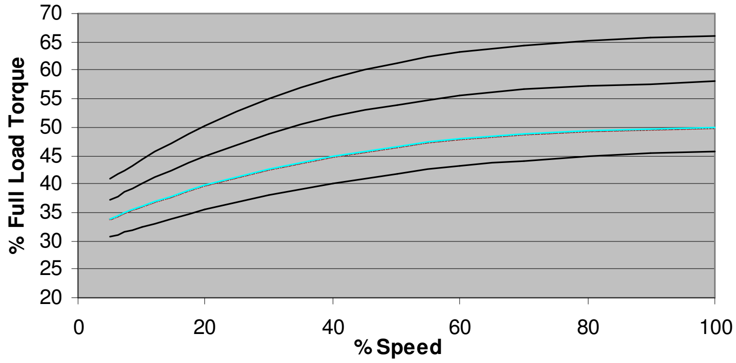
Sound pressure levels given in dB refer to 2×10^{-5} N/m^2 RMS.

HSO/HSI 3200 Series: Starting Torque Characteristics

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

% SPEED	% FULL LOAD TORQUE			
	SYSTEM PRESSURE RATIO			
	3	5	10	15
5	31	34	37	41
10	32	36	40	44
20	35	40	45	50
30	38	43	49	55
40	40	45	52	59
50	42	47	54	61
60	43	48	56	63
70	44	49	57	64
80	45	49	57	65
90	45	50	58	66
100	46	50	58	66

Does not include accelerating torque



COMPRESSOR MASS MOMENT OF INERTIA (MK^2)	
HSO/HSI 3216	0.14
HSO/HSI 3218	0.13
HSO/HSI 3220	0.11
HSO/HSI 3221	0.12

HSO/HSI 3200 Series: Limits of Operation

Pressure Limits

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

			R134A	**R407C**	**R717**
Maximum Design Pressures	[1]High side/low side test pressures		32.9 bar g	32.9 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	2.2 or 3.0 V_R	6.0 bar g	6.0 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	2.2 V_R	7	7	7
		3.0 V_R	10	10	10
		4.9 V_R	20	20	20
	Minimum pressure ratio	4.9 V_R	5	5	5
	Maximum compressor operating discharge pressure		26.0 bar g	29.6 bar g	26.0 bar g
	Maximum compressor operating pressure differential (discharge – suction)		20.0 bar	24.0 bar	20.0 bar
	Minimum compressor operating pressure differential at minimum load		2.0 bar	3.0 bar	3.0 bar
			R22	**R404a**	**R507a**
Maximum Design Pressures	[1]High side/low side test pressures		32.9 bar g	32.9 bar g	32.9 bar g
[2]Operational Pressures	Maximum compressor operating suction pressure	2.2 or 3.0 V_R	6.0 bar g	6.0 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	2.2 V_R	7	7	7
		3.0 V_R	10	10	10
		4.9 V_R	20	20	20
	Minimum pressure ratio	4.9 V_R	5	5	5
	Maximum compressor operating discharge pressure		29.6 bar g	29.6 bar g	29.6 bar g
	Maximum compressor operating pressure differential (discharge – suction)		24.0 bar	26.0 bar	26.0 bar
	Minimum compressor operating pressure differential at minimum load		3.0 bar	3.6 bar	3.6 bar

Temperature Limits

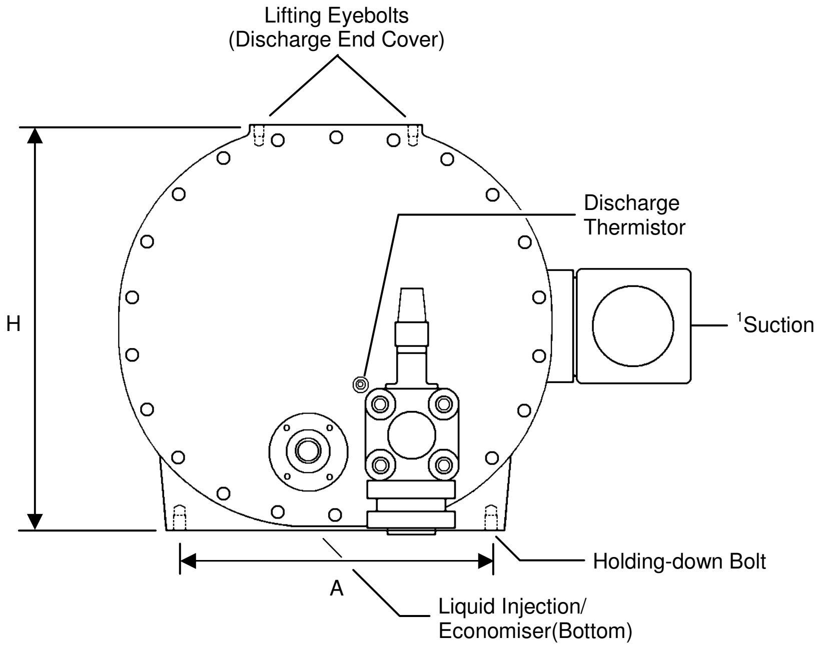
Temperature Limits	Discharge temperature	100 °C (standard) 120 °C (special)
	Discharge minimum superheat	R134a = 13.0 K R404a and R507a = 15.0 K R22 and R407c = 20.0 K R717 = 25.0 K

[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)	Standard recommended when liquid injection is controlled to 75 °C or within 25 °C of discharge gauge
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 or (refer to Fig 4) 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 (required for HSO 3200 series compressors)	Low	Level switch or sensor	Trip on low level	Time delay (5 secs max) required during operation to prevent spurious trips
Oil temperature	High	Thermistor or HT cut-out	80 °C	Mandatory requirement if compressor fitted with external oil cooling

HSO 3200 Series: Physical Dimensions and Connections

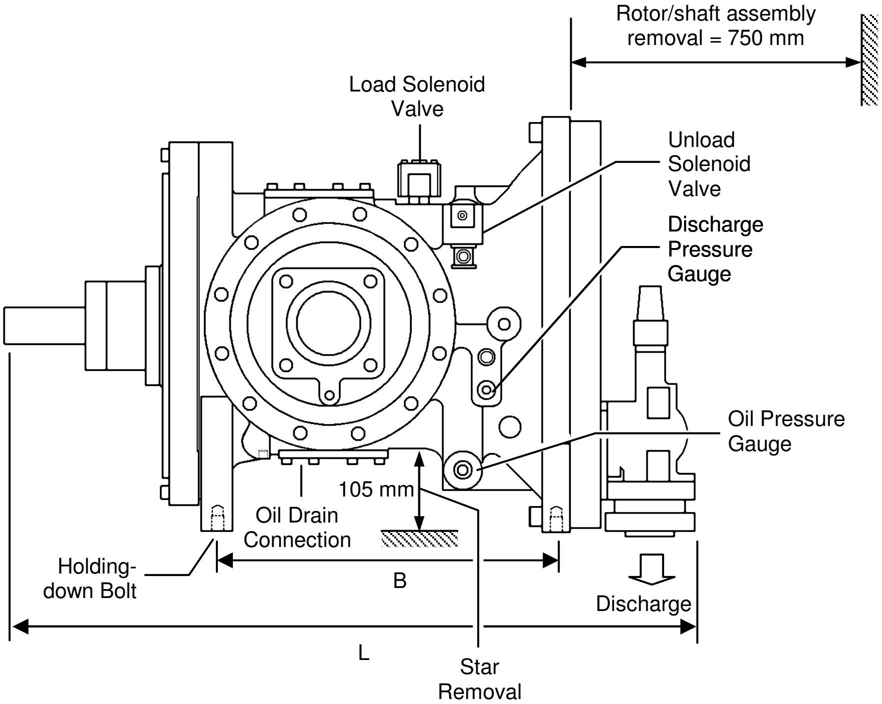


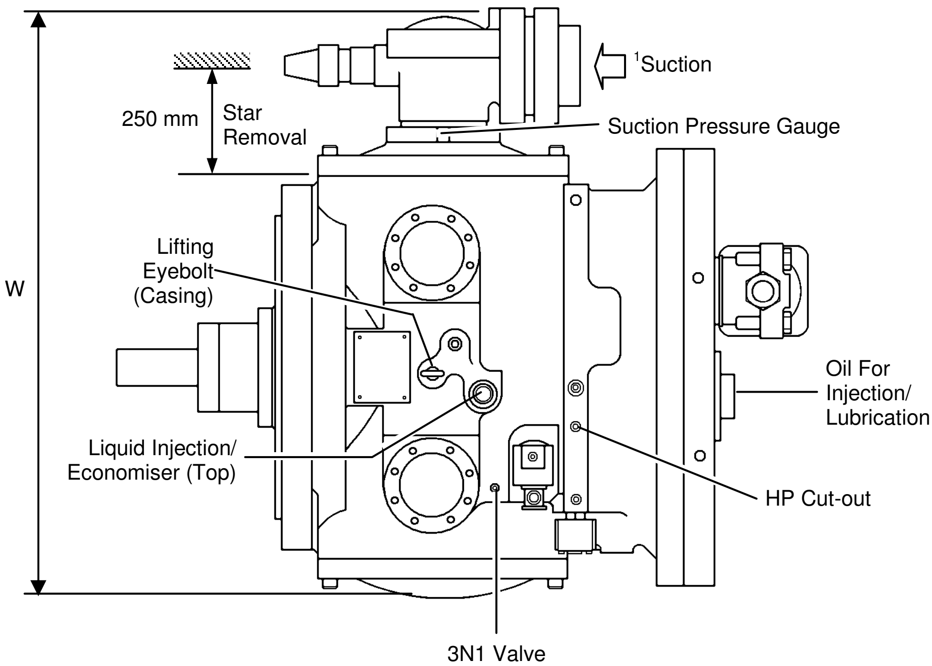
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall International certified drawing

Dimensions	**DESCRIPTION**			**SIZE**
	[2]Overall	Length	L	851 mm
		Height	H	505 mm
		Width	W	725 mm
	Holding-down bolt centres		A	380 mm
			B	420 mm
	Holding-down bolts		-	4 x M12 x 1.75P x 21 full thread
	Lifting eyebolts	Main casing	-	1 x M16 x 2P x 27 full thread
		Discharge end cover	-	2 x M12 x 1.75P x 22 full thread

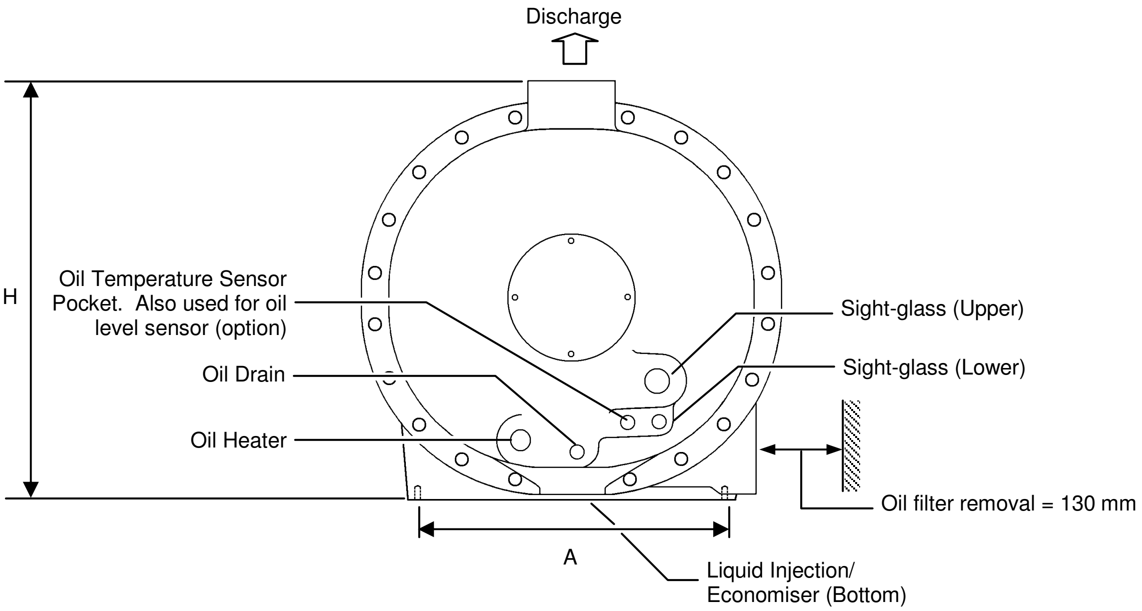
Connections	**DESCRIPTION**	**NO OFF**	**SIZE**
	[1]Suction	1	3” NB (3 1/8” OD)
	Discharge	1	2 1/2” NB (2 5/8” OD)
	Suction pressure gauge	1	1/8” NPT
	Discharge pressure gauge	1	1/4” NPT
	Oil pressure gauge	1	1/4” NPT
	3N1 valve	1	1/8” NPT
	HP cut-out	1	1/8” NPT
	Liquid injection/economiser (top and bottom)	2	1 1/16” (12 UNF)
	Oil injection/lubrication	1	1 1/16” (12 UNF)
	Oil drain	1	3/4” (16 UNF)

[1]Suction can be taken from either side of the compressor. [2]Including suction and discharge stop valves.


Rotor/shaft assembly removal = 750 mm
Load Solenoid Valve
Unload Solenoid Valve
Discharge Pressure Gauge
Oil Pressure Gauge
105 mm
Oil Drain Connection
Holding-down Bolt
B
Discharge
L
Star Removal


1Suction
250 mm
Star Removal
Suction Pressure Gauge
W
Lifting Eyebolt (Casing)
Oil For Injection/ Lubrication
Liquid Injection/ Economiser (Top)
HP Cut-out
3N1 Valve

HSI 3200 Series: Physical Dimensions and Connections

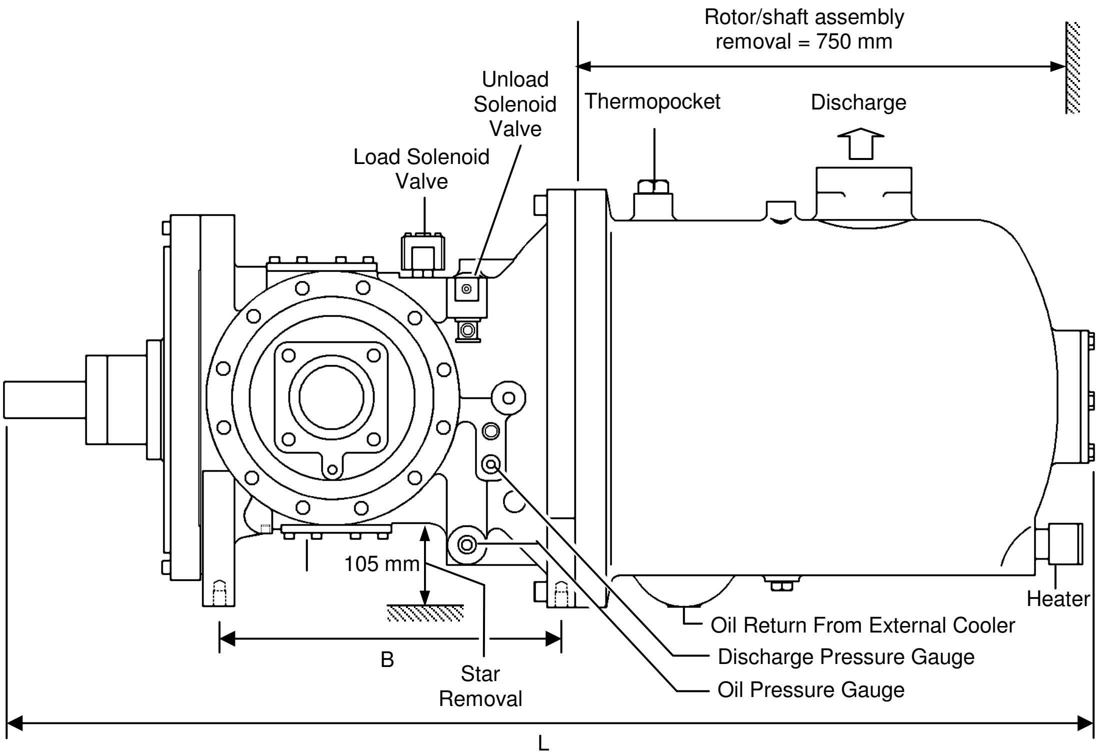


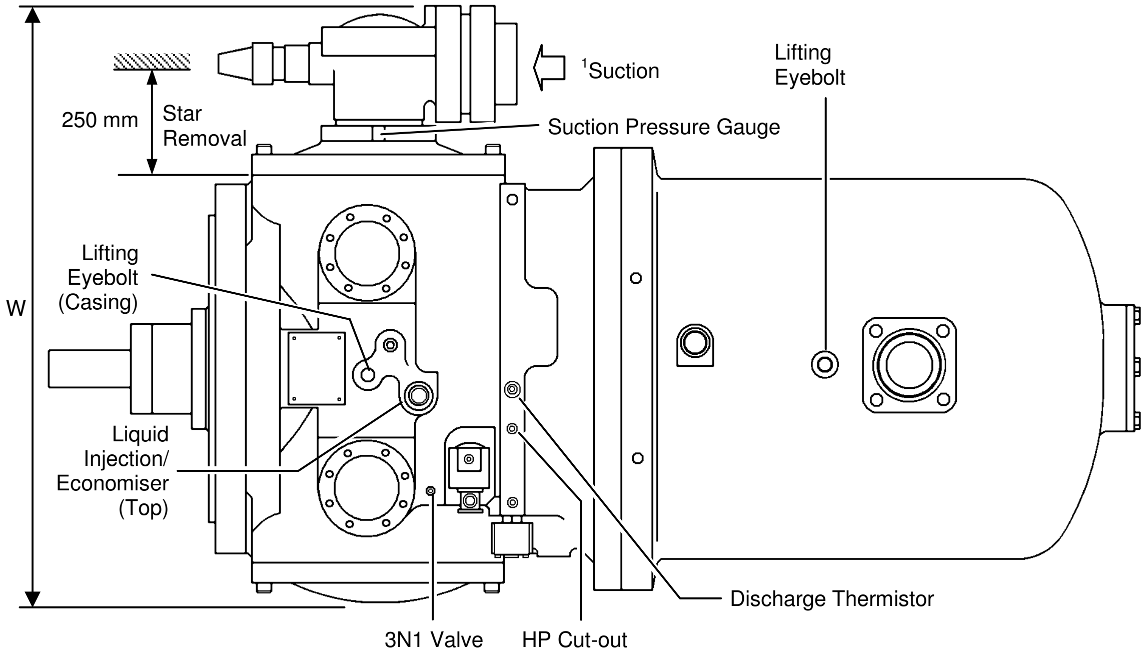
Dimensions in mm unless otherwise stated. Data provided as a guide only, refer to J & E Hall International certified drawing

	Description			**Size**
Dimensions	Overall[2]	Length	L	1304 mm
		Height	H	532 mm
		Width	W	724 mm
	Holding-down bolt centres		A	380 mm
			B	420 mm
	Holding-down bolts		-	4 x M12 x 1.75P x 21 full thread
	Lifting eyebolts		-	2 x M16 x 2P x 27 full thread

	Description	**No Off**	**Size**
Connections	Suction[1]	1	3” NB (3 1/8” OD)
	Discharge	1	2” NB (2 1/8” OD)
	Suction pressure gauge	1	1/8” NPT
	Discharge pressure gauge	1	1/4” NPT
	Oil pressure gauge	1	1/4” NPT
	3N1 three function valve	1	1/8” NPT
	HP cut-out	1	1/8” NPT
	Liquid injection/economiser (top and bottom)	2	1 1/16” (12 UNF)
	Oil drain	1	3/4” (16 UNF)
	Oil temperature sensor pocket	1	½” NPT
	Oil return from external cooler	1	7/8” (14 UNF)

[1]Suction can be taken from either side of the compressor.
[2]Including suction stop valve.


Rotor/shaft assembly
removal = 750 mm
Unload
Solenoid
Valve
Thermopocket
Discharge
Load Solenoid
Valve
105 mm
Heater
Oil Return From External Cooler
Discharge Pressure Gauge
B
Star
Removal
Oil Pressure Gauge
L


1Suction
Lifting
Eyebolt
250 mm
Star
Removal
Suction Pressure Gauge
Lifting
Eyebolt
(Casing)
W
Liquid
Injection/
Economiser
(Top)
Discharge Thermistor
3N1 Valve
HP Cut-out

Appendix 2 Oil Support System Schematic Flow Diagrams

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

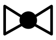
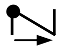
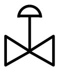
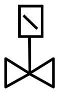
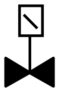
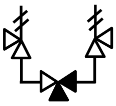
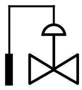
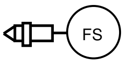
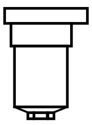
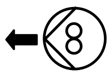
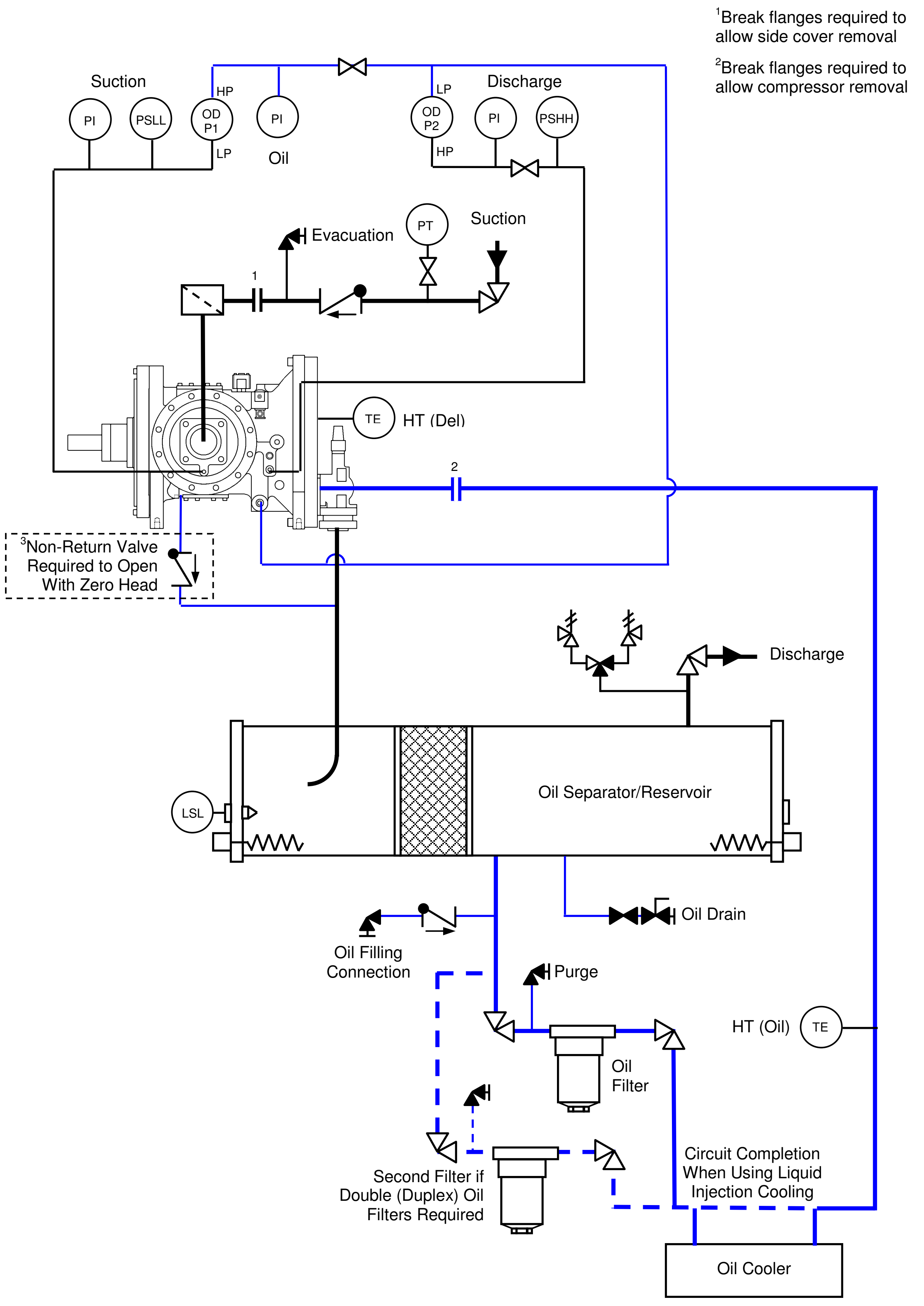
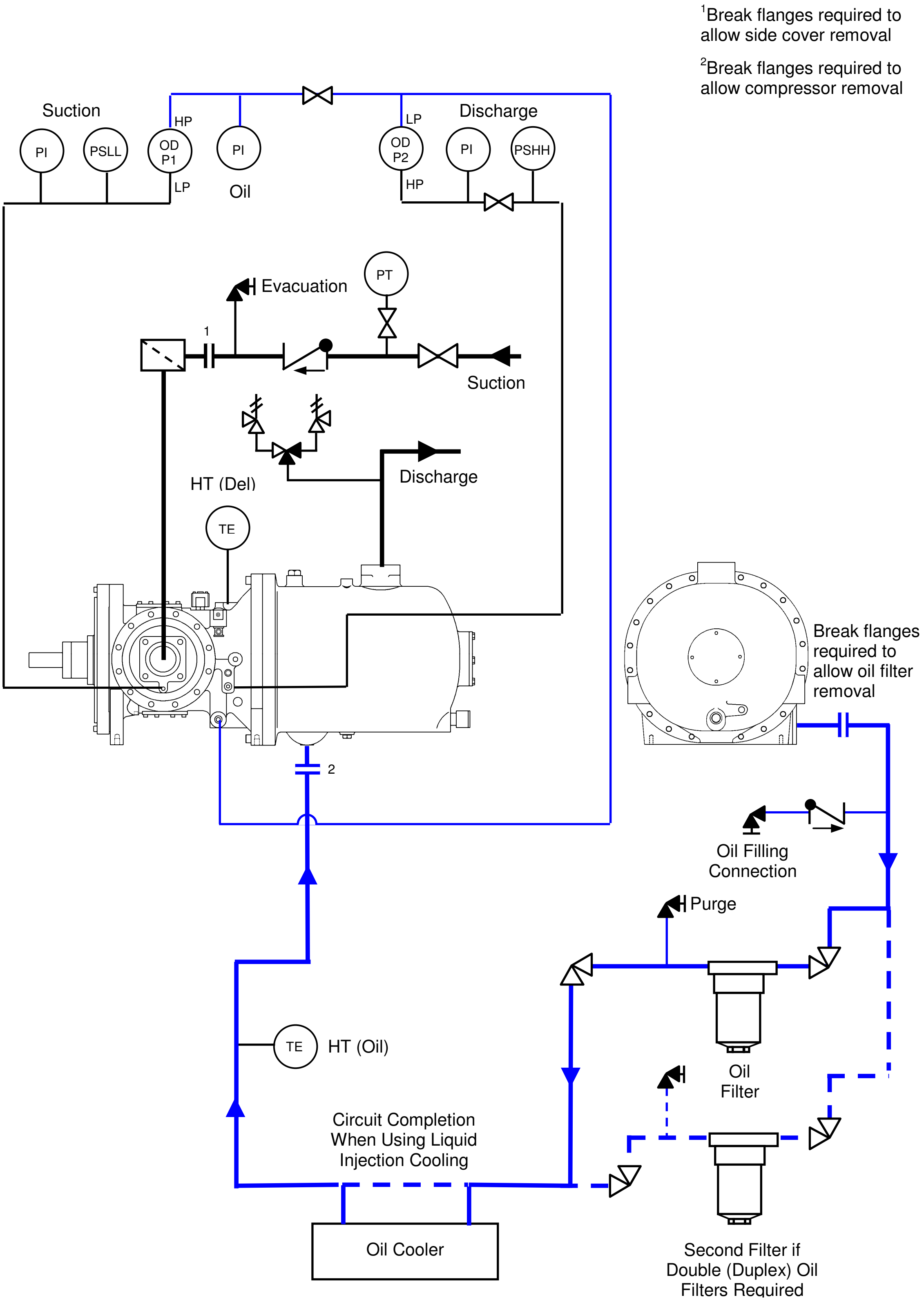
	Ball valve		Non-return valve
	Quick-acting drain valve, normally closed and capped		Control valve
	Relief valve		Solenoid valve (normally open)
	Relief valve (to atmosphere)		Solenoid valve (normally closed)
	Dual relief valve (to atmosphere)		Thermostatic expansion valve
	Sight-glass (on vessel)		Liquid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

Fig 9 Key to Schematic Flow Diagrams



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

Fig 10 Oil Support System for Single HSO 3200 Compressor



NOTE: internal oil filter must be replaced using special adaptor kit part number 93122-207 available from J & E Hall International; refer to 4.10. External Oil Cooler/Oil Filter - HSI 3200 Series Compressors

Fig 11 Oil Support System for Single HSI 3200 Compressor With External Oil Cooling

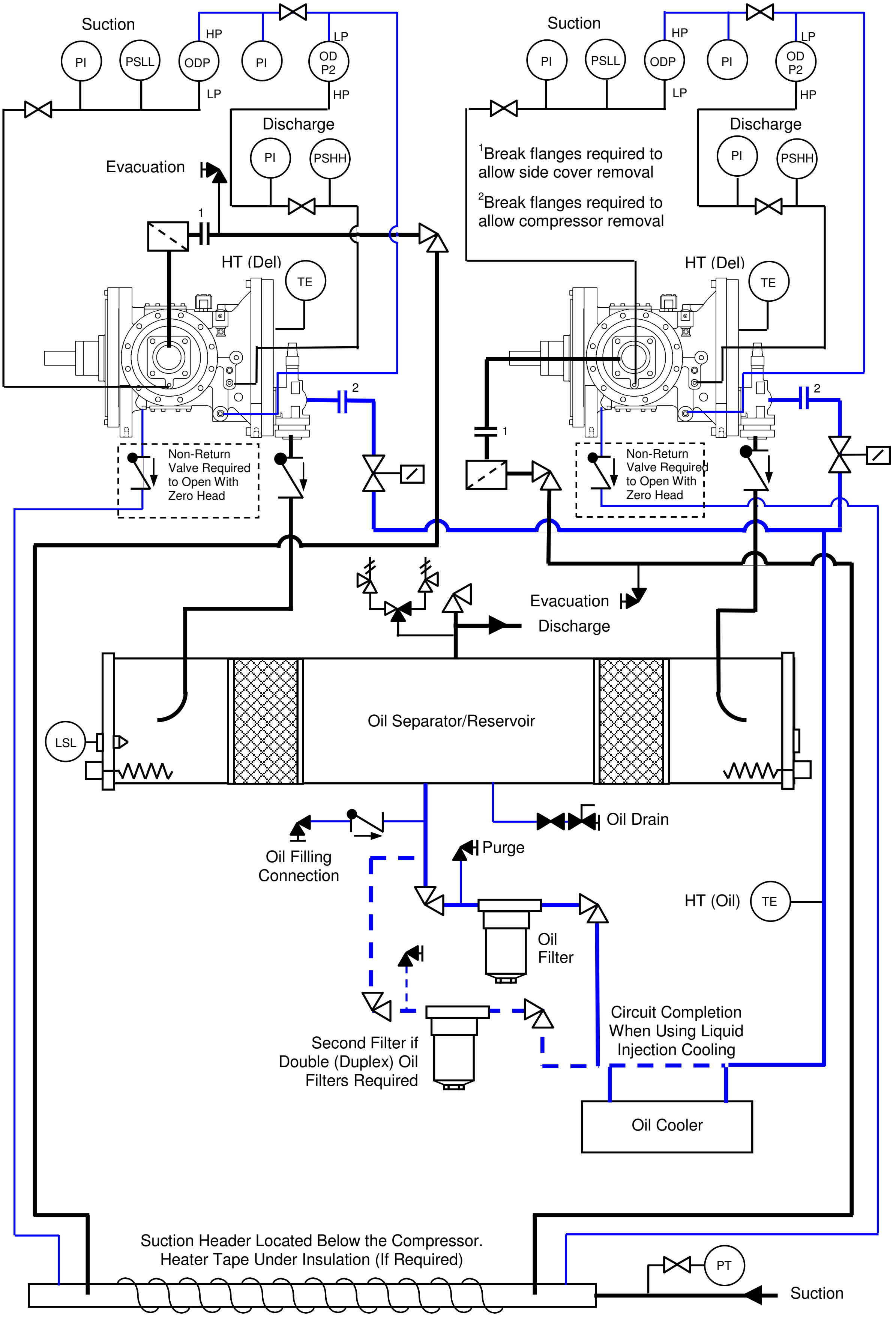
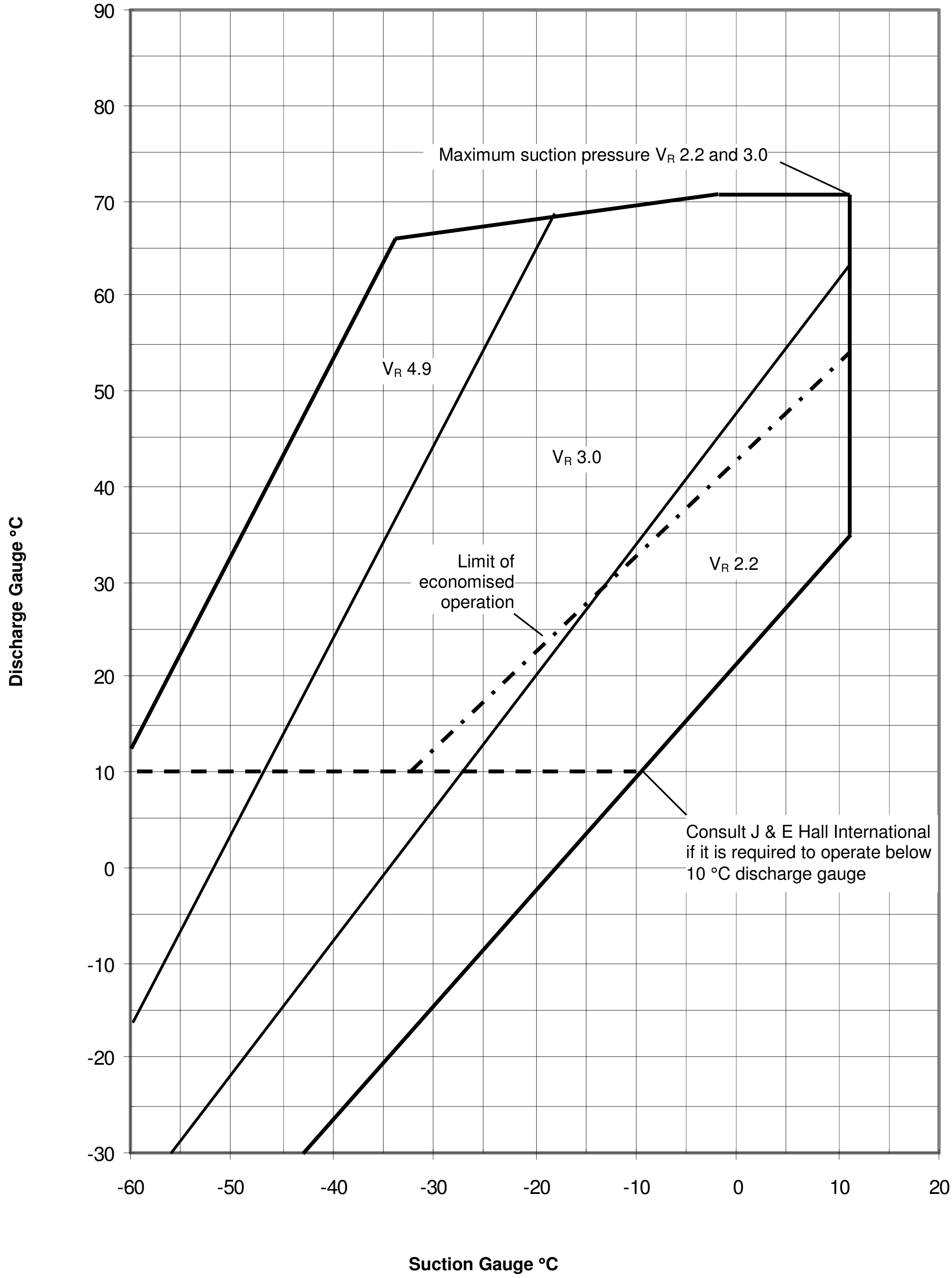


Fig 12 Oil Support System For Multiple HSO 3200 Compressors

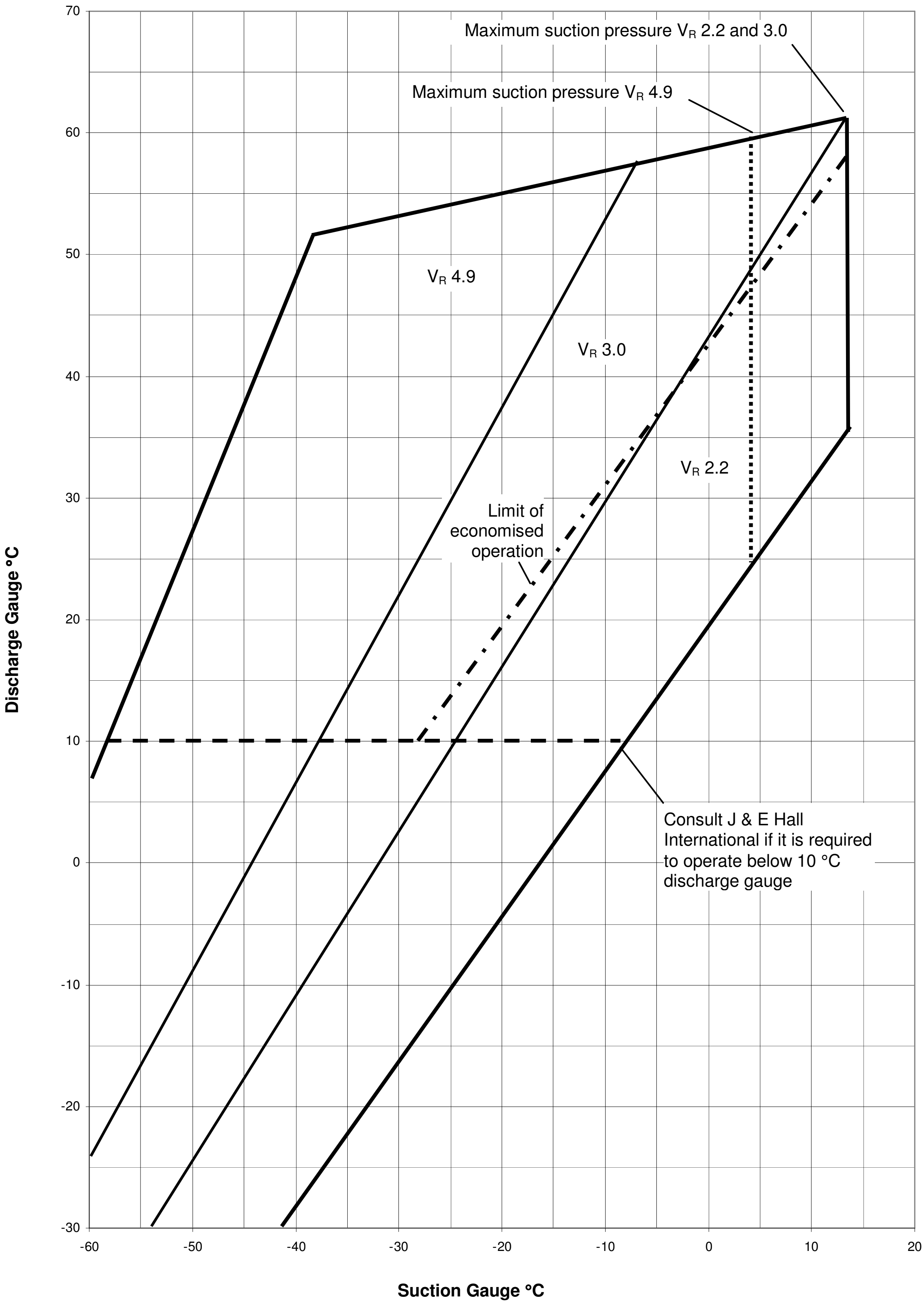
Appendix 3 Limits of Operation Envelopes

Limits of Operation R22



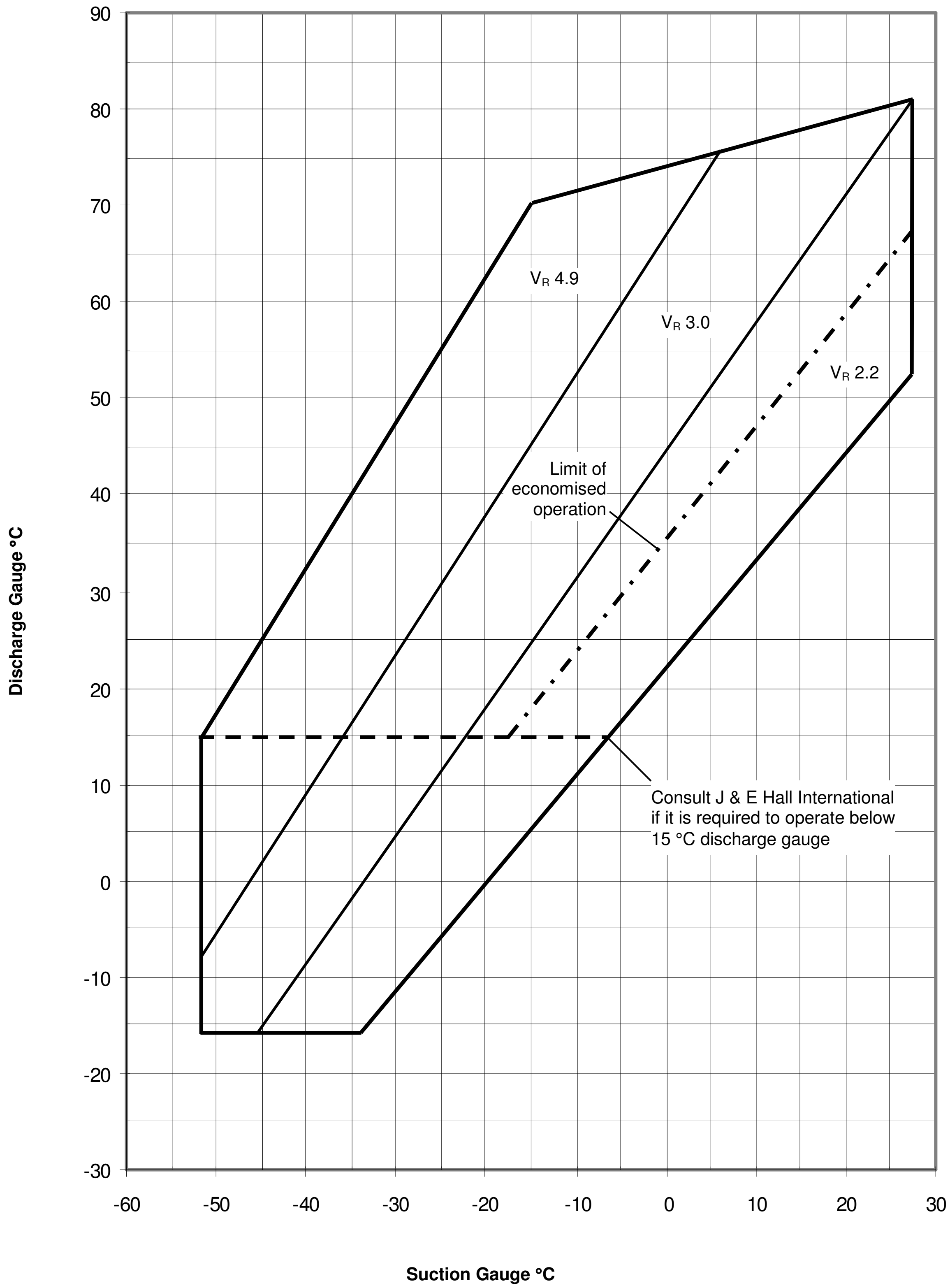
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R717 (Ammonia)



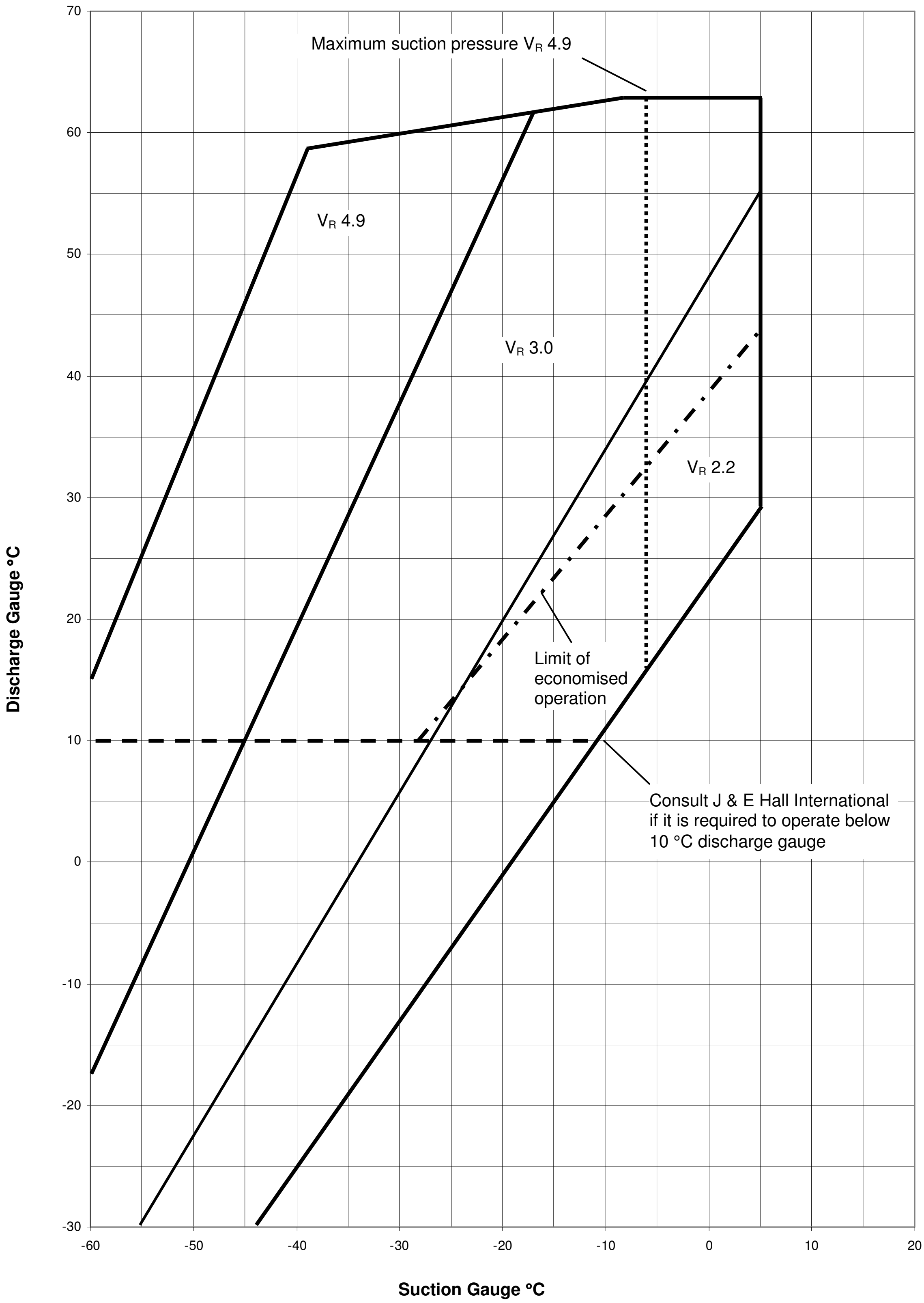
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R134a



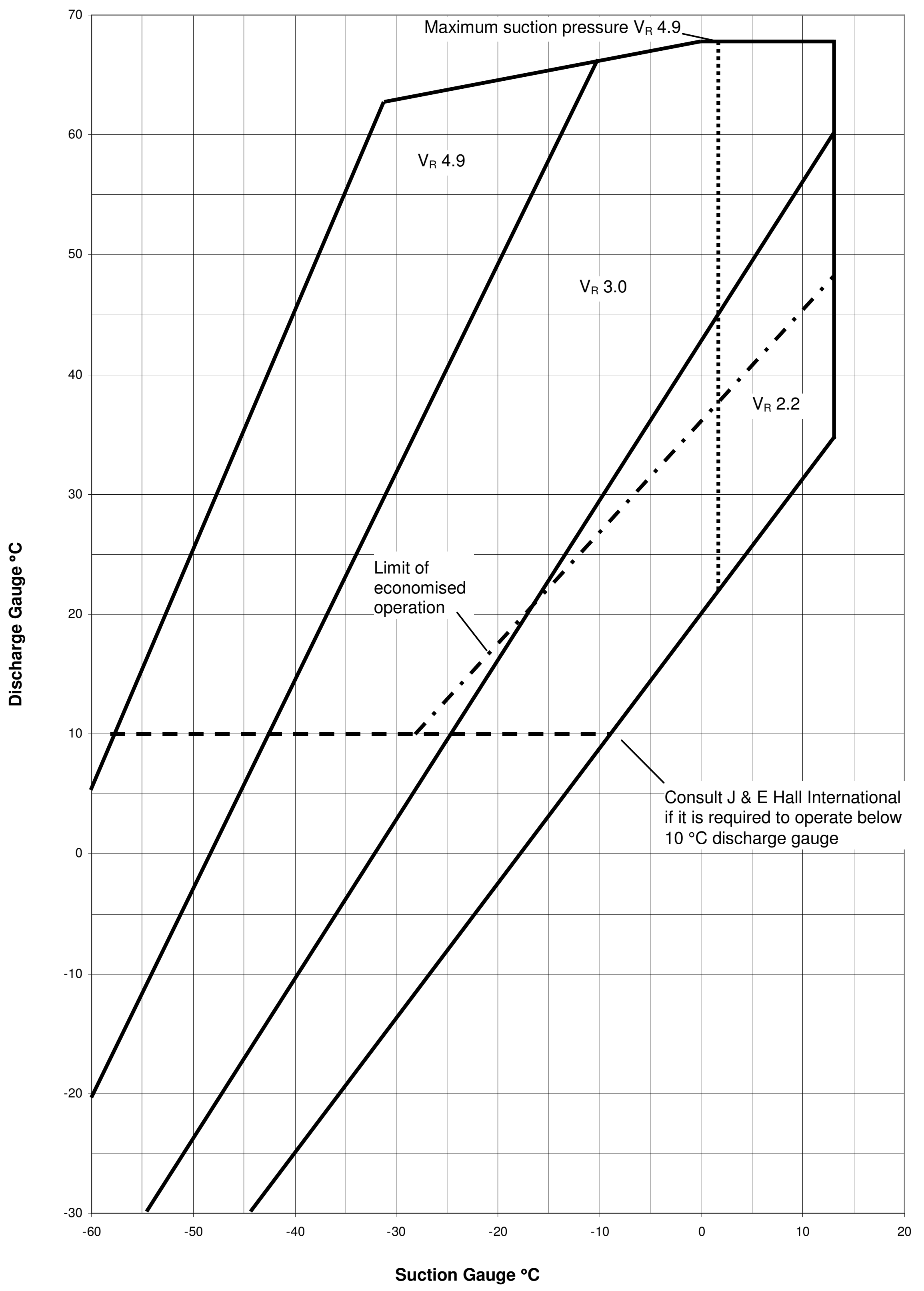
This diagram is approximate, for guidance only. Refer to HallScrew selection software for definitive envelopes.

Limits of Operation R404a and R507a



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

Limits of Operation R407c



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

Appendix 4 Compressor Performance Data

For detailed selection use the J & E Hall International HallScrew compressor selection software, available on CD.

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 ^{o}C suction superheat and 5.0 ^{o}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 ^{o}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 ^{o}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 ^{o}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.

Appendix 5 Pepperl & Fuchs Signal Conditioning Module KFU8-USC-1.D Set-up

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

Refer to Table 2.

The KFU8-USC-1.D module can be used simply to calibrate the output from the MSI LVDT to provide 4 mA and 20 mA signals, at the compressor minimum and maximum slide valve positions respectively, by following the instructions in Table 2. Setting the 'Start Value' (at minimum load) and setting the 'End Value' (at maximum load) are independent processes. The End Value setting can be made at any time after the Start Value setting. The values can be reset at any time. If necessary, the unit can be reset to the factory settings by following the instructions in the Pepperl & Fuchs manual included with the unit.

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

Refer to Table 3.

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

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

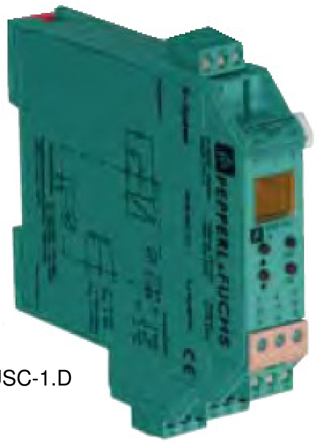
Unless the 'units' are reconfigured, the value displayed on the module is always the actual **input value** in mA from the LVDT. This is not particularly meaningful for the user.

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

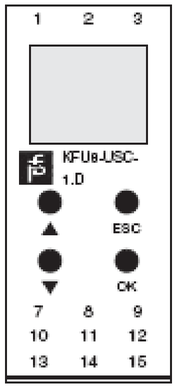
Setting the Relay Switch Value

Refer to Table 4.

Once the display units have been reconfigured to 'l' and the display values at minimum and maximum load slide positions are 0 and 100 respectively, the switch (Trip) point can be set as a value as if it were a percentage. The 'Hysteresis' value can also be set as equivalent to a percentage. Depending on how it is required for the switch hysteresis to operate with rising and falling values, the module can be configured accordingly; refer to the note at the bottom of Table 4. This is also demonstrated fully in the Pepperl & Fuchs manual included with the unit).



KFU8-USC-1.D



Display

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

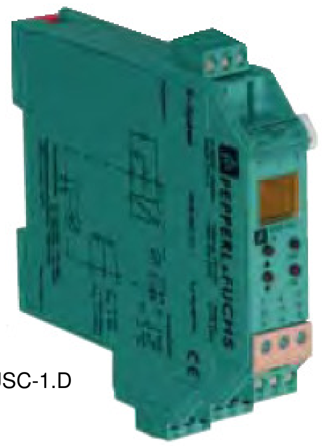
Table 2 Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

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

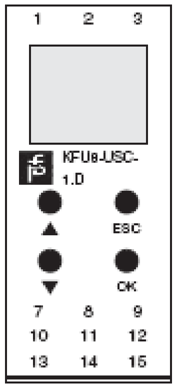
NOTE: Setting the 'Start Value' (at minimum load) and setting the 'End Value' (at maximum load) are independent processes. The End Value setting can be made at any time after the Start value setting.

Table 2 (continued) Basic Set up for 4 mA and 20 mA Output Values at Minimum and Maximum Slide Valve Positions

This procedure is optional but recommended for easy set up of the relay switch point (if used); refer to Table 4



KFU8-USC-1.D



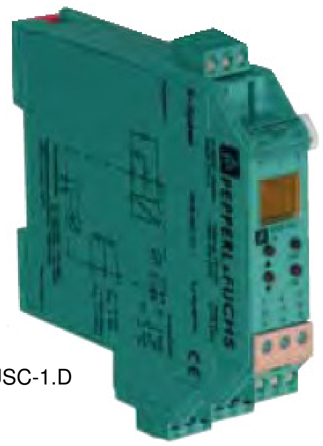
Display

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

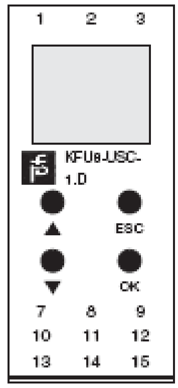
[1]Operation can be done with the slide valve in any position.
[2]The unit of % cannot be chosen for this application because of the special functionality given to it inbuilt in the unit (for example, if % is chosen as the unit then the required Factor cannot be set). Therefore it is suggested that 'l'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

Table 3 Setting the Display to Read 0 at Minimum Load and 100 at Maximum Load

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



KFU8-USC-1.D



Display

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

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

Table 4 Setting the Relay Switch Value

This page intentionally blank

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