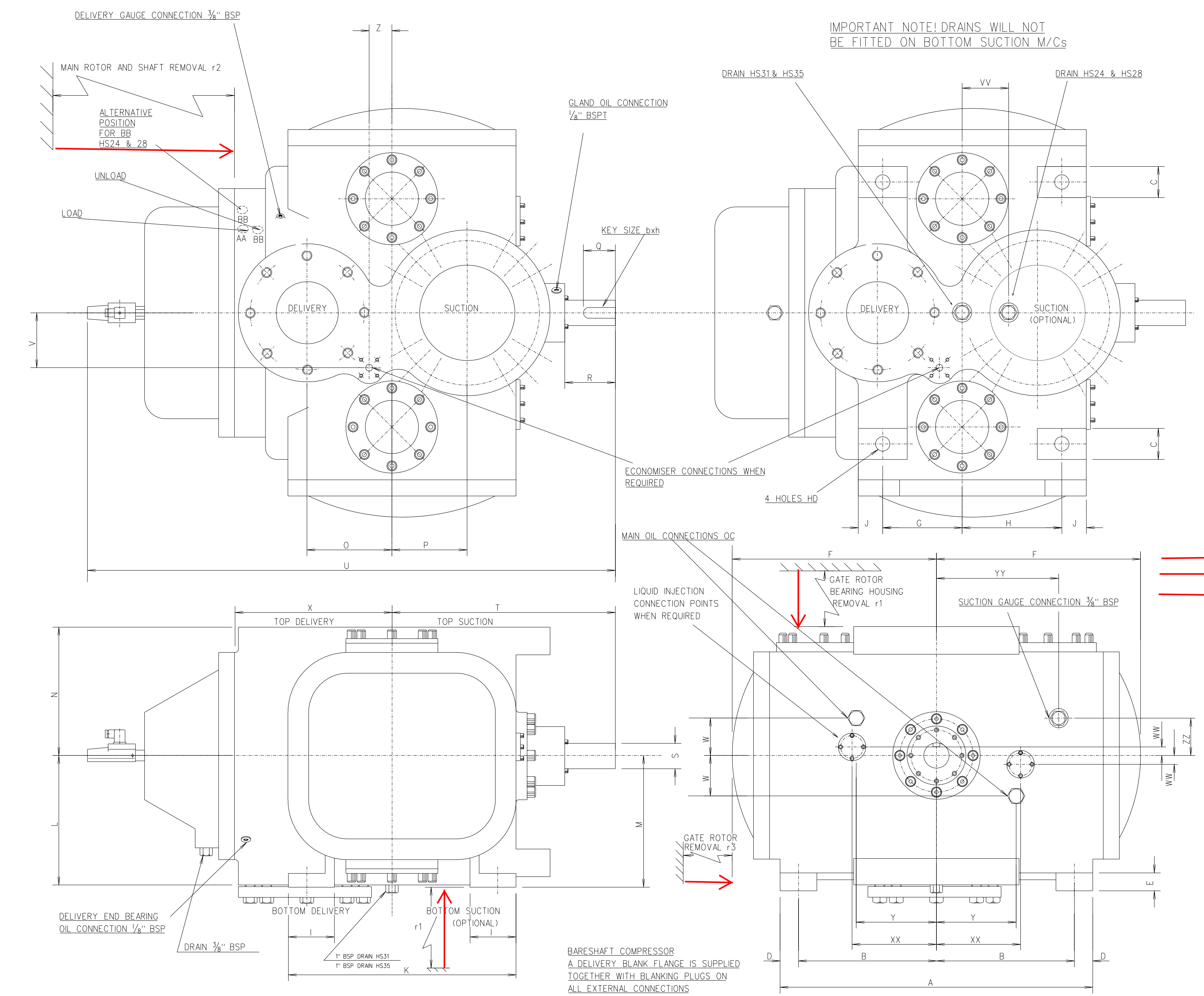
IF IN DOUBT ASK | DRAWING NOT TO BE SCALED | DRAWING No. D100344



DIMENSION REFERENCE	COMPRESSOR SIZE							
	HS 2024		HS 2028		HS 2031		HS 2035	
A	470		520		680		780	
B	210		235		300		330	
C	70		70		80		120	
D	25		25		40		60	
E	20		20		25		30	
F	357		390		444		500	
G	140		153		185		234	
H	140		153		230		234	
I	75		75		100		115	
J	25		25		40		40	
K	330		356		495		548	
L	218		250		280		320	
M	223		255		285		325	
N	218		250		280		320	
O	145.5		150		184		230	
P	117		150		164		135	
Q	56		70		90		110	
R	103		105		110		124	
S	45.000 / 44.984 DIA		50.000 / 40.984 DIA		55.000 / 54.981 DIA		60.000 / 59.981 DIA	
T	384		437.5		486		526	
U	975		1130		1150		1305	
V	100		123		120		116	
W	71.5		81.2		90		101.5	
X	273		293		342		395	
Y	134.5		152.7		169.5		191	
Z	37		40		50		52	
VV	70		79.5		-		-	
WW	14		17		19		22	
XX	139		164		183		204	
YY	210		240		266		350	
ZZ	60		75		120		100	
r1	115		100		155		172	
r2	553		625		697		763	
r3	250		285		315		355	
b x h	14x9		14x10		16x10		18x11	
	mm		mm		mm		mm	
OC	¾" BSP		¾" BSP		1" BSP		1" BSP	
HD	22 DIA		22 DIA		26 DIA		26 DIA	
APPROX WEIGHT	KG	lbs	KG	lbs	KG	lbs	KG	lbs
	449	990	564	1244	810	1786	1194	2633
DELIVERY FLANGES	100 NB BS4504 TABLE 40/3 8 HOLES M20 ON 190 PCD		125 NB BS4504 TABLE 40/3 8 HOLES M24 ON 220 PCD		150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD		150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD	
SUCTION FLANGES	125 NB BS4504 TABLE 40/3 8 HOLES M24 ON 220 PCD		150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD		200 NB BS 4504 TABLE 25/3 12 HOLES M24 ON 310 PCD		200 NB BS 4504 TABLE 25/3 12 HOLES M24 ON 310 PCD	
ALL FLANGE BOLT HOLES ARE EQUISPACED AND ON CENTRES								
MAIN ASSEMBLY No's	95154-401		95154-501		95154-601		95154-701	
⅛" BSP ACTUATOR CONNECTION POSITIONS	AA, BB,		AA, BB,		AA, BB,		AA, BB,	
LIQUID INJECTION & ECONOMISER CONNECTIONS	4 OFF M8 HOLES ON 45 PCD		4 OFF M8 HOLES ON 45 PCD		4 OFF M8 HOLES ON 45 PCD		4 OFF M12 HOLES ON 60 PCD	

CONTINUOUS RESEARCH AND DEVELOPMENT MAY NECESSITATE CHANGES FROM THIS SPECIFICATION

ISSUE NO	REVISION	DRAWN	D.O. CHK.	DESIGN CHK.	P.V.D. CHK.	APPRD BY
08						
07						
06						
05						
04						
03						
02						
01	FIRST ISSUE	AAE 24-7-03				

REF.DRGS

WEIGHT

CUSTOMER CONTRACT No | CUSTOMER | SITE LOCATION

J&E Hall® Limited
Unit 40/41 Pearson Way, Questor, Dartford, Kent, DA1 1JN, England

FPU No | REMARKS | ISSUED BY

MAT'L IDENT: YES / NO

TITLE: SERIES 2000 HALLSCREW COMPRESSOR MOUNTING DETAILS HS 2024 TO HS 2035

SCALE: N.T.S.

DIMN's IN mm

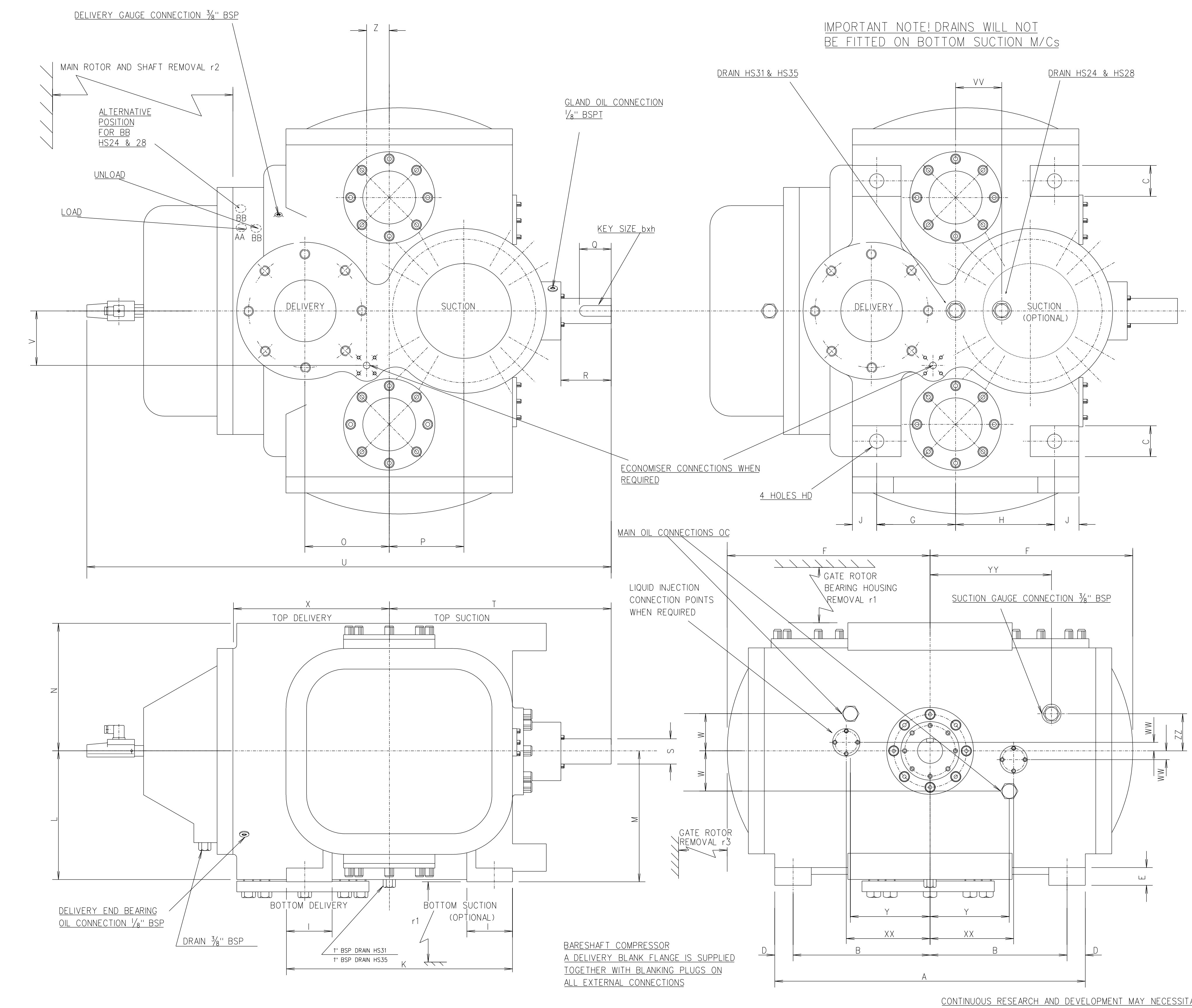
CONTRACT No

DRAWING No: D100344

SHEET No: 1 of 1 | ISSUE No: 01

SIZE A1

IF IN DOUBT ASK | DRAWING NOT TO BE SCALED | DRAWING No. D100344



DIMENSION REFERENCE	COMPRESSOR SIZE HS 2024	HS 2028	HS 2031	HS 2035
A	470	520	680	780
B	210	235	300	330
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D	25	25	40	60
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G	140	153	185	234
H	140	153	230	234
I	75	75	100	115
J	25	25	40	40
K	330	356	495	548
L	218	250	280	320
M	223	255	285	325
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P	117	150	164	135
Q	56	70	90	110
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U	975	1130	1150	1305
V	100	123	120	116
W	71.5	81.2	90	101.5
X	273	293	342	395
Y	134.5	152.7	169.5	191
Z	37	40	50	52
VV	70	79.5	-	-
WW	14	17	19	22
XX	139	164	183	204
YY	210	240	266	350
ZZ	60	75	120	100
r1	115	100	155	172
r2	553	625	697	763
r3	250	285	315	355
b x h	14x9	14x10	16x10	18x11
	mm	mm	mm	mm
OC	3/4" BSP	3/4" BSP	1" BSP	1" BSP
HD	22 DIA	22 DIA	26 DIA	26 DIA
APPROX WEIGHT	KG 449 / lbs 990	KG 564 / lbs 1244	KG 810 / lbs 1786	KG 1194 / lbs 2633
DELIVERY FLANGES	100 NB BS4504 TABLE 40/3 8 HOLES M20 ON 190 PCD	125 NB BS4504 TABLE 40/3 8 HOLES M24 ON 220 PCD	150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD	150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD
SUCTION FLANGES	125 NB BS4504 TABLE 40/3 8 HOLES M24 ON 220 PCD	150 NB BS4504 TABLE 40/3 8 HOLES M24 ON 250 PCD	200 NB BS 4504 TABLE 25/3 12 HOLES M24 ON 310 PCD	200 NB BS 4504 TABLE 25/3 12 HOLES M24 ON 310 PCD
ALL FLANGE BOLT HOLES ARE EQUISPACED AND ON CENTRES				
MAIN ASSEMBLY No's	95154-401	95154-501	95154-601	95154-701
1/8" BSP ACTUATOR CONNECTION POSITIONS	AA, BB,	AA, BB,	AA, BB,	AA, BB,
LIQUID INJECTION & ECONOMISER CONNECTIONS	4 OFF M8 HOLES ON 45 PCD	4 OFF M8 HOLES ON 45 PCD	4 OFF M8 HOLES ON 45 PCD	4 OFF M12 HOLES ON 60 PCD

CONTINUOUS RESEARCH AND DEVELOPMENT MAY NECESSITATE CHANGES FROM THIS SPECIFICATION

ISSUE NO	REVISION	DRAWN	D.O. CHK.	DESIGN CHK.	P.V.D. CHK.	APPRD BY	ISSUE NO	REVISION	DRAWN	D.O. CHK.	DESIGN CHK.	P.V.D. CHK.	APPRD BY
08							04						
07							03						
06							02						
05							01	FIRST ISSUE	AAE 24-7-03				

REF.DRGS

WEIGHT

J&E Hall® Limited
Unit 40/41 Pearson Way, Questor, Dartford, Kent, DA1 1JN, England

FPU No | REMARKS | ISSUED BY | MAT'L IDENT YES / NO

TITLE: SERIES 2000 HALLSCREW COMPRESSOR MOUNTING DETAILS HS 2024 TO HS 2035

SCALE N.T.S. | DIMN's IN mm

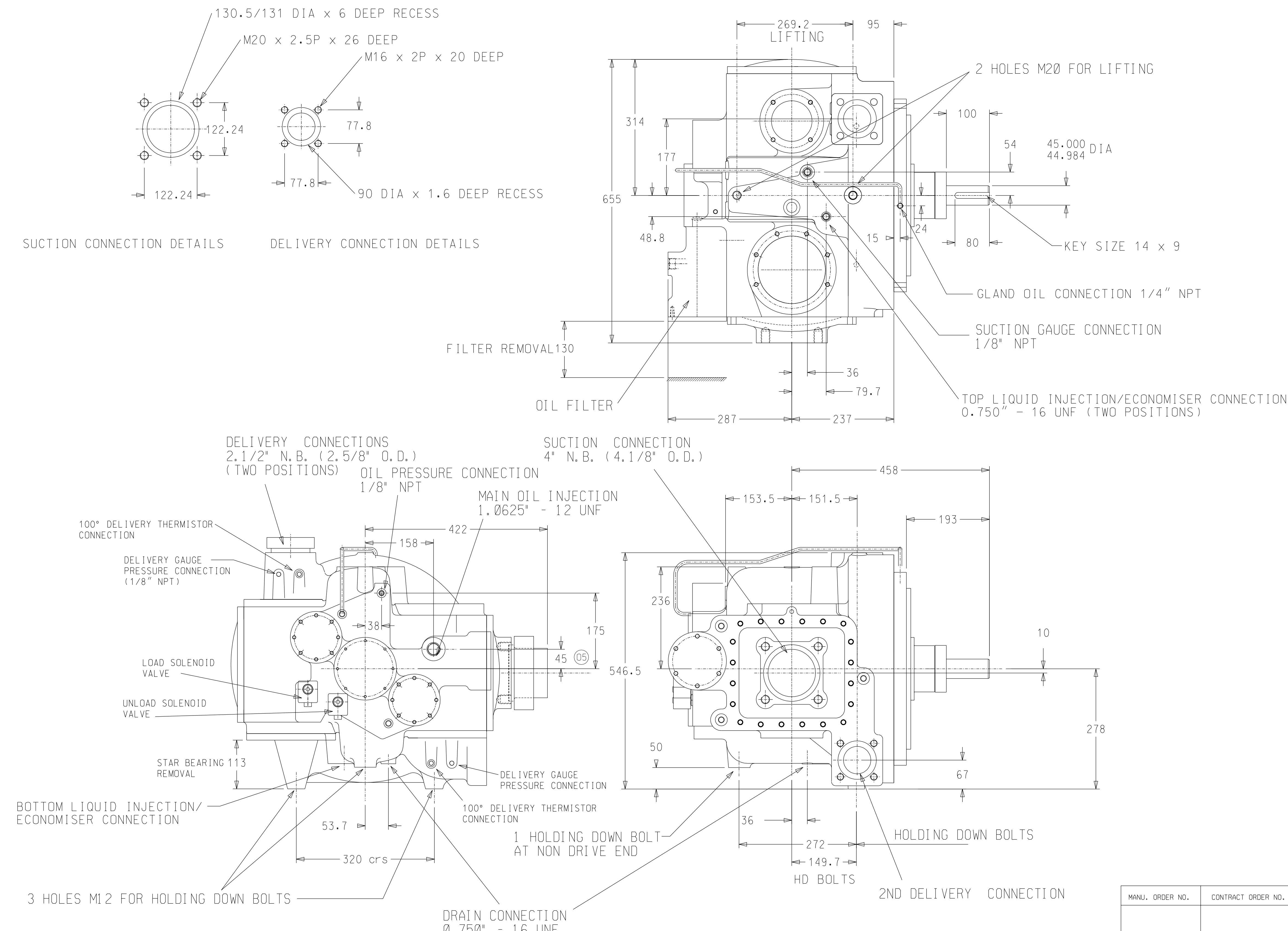
CUSTOMER CONTRACT No | CUSTOMER | SITE LOCATION | CONTRACT No | DRAWING No D100344 | SHEET No 1 of 1 | ISSUE No 01

SIZE A1

IF IN DOUBT ASK	DRAWING NOT TO BE SCALED	THIRD ANGLE PROJECTION	DRG. CODE NO. A114592

USED ON

REF. DRGS.



PATT.
C/SM
P&C
S.G.
PL.G.
FIT.
M/C
INSP.
ROUGHNESS NUMBERS
N8 TO N12
N7 TO N8
N6 TO N7
N5 TO N6
FINISH SYMBOLS

R/: ROUGH · 126 · MICRO INCHES OR 3.2 · MICROMETRES
N/: NORMAL · 64 TO 125 MICRO INCHES OR 1.6 TO 3.2 MICROMETRES
F/: FINE · 32 TO 63 MICRO INCHES OR 0.8 TO 1.6 MICROMETRES
S/: SUPERFINE · 16 TO 31 MICRO INCHES OR 0.4 TO 0.8 MICROMETRES
FOR JOINT FACES JN/: JOINT NORMAL JF/: JOINT FINE JS/: JOINT SUPERFINE
FINISHES TO TOL. THUS E.G. 8/-9-: 1 MICRO INS. 0.200 - 0.225 - 0.025 MICROMETRES

CAD DRAWING NOT TO BE MODIFIED

MANU. ORDER NO.	CONTRACT ORDER NO.	REMARKS

INSPECTION BY	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS
	5	45 DIM WAS 18	AAE 29/10/04	9		
	4	GENERAL UPDATE	AAE 30/07/03	8		
DATE APPROVED	3	GENERAL UPDATE	AAE 18/12/02	7		
	2	GENERAL UPDATE	AAE 11/12/02	6	1/8" NPT OIL PRESSURE CONNECTION ADDED	AAE 30/11/04

DRAWN AAE 7/3/02

SIZE A1

PROTECTIVE FINISH

PATT NO.

WEIGHT

SCALE NTS

DIMENSIONS IN MM

TEST PRESSURE

TOLERANCES EXCEPT WHERE OTHERWISE STATED. (BRACKETED) DIMNS. FOR REF. ONLY.
IMPERIAL UNITS
FRACT. DIMNS. : .020" METRIC UNITS.
DECIMAL DIMNS. : .010" : 0.5 MILLIMETRES

MATERIAL

TITLE

PHYSICAL DATA
HS04200 COMPRESSOR

J&E Hall® LIMITED
UNIT 40/41, PEARSON WAY, QUESTOR, DARTFORD, KENT. DA1 1JN. ENGLAND

DRAWING CODE NO. A114592

ISSUE NO. 06 SHEET NO. 1 OF 1

IF IN DOUBT ASK	DRAWING NOT TO BE SCALED	THIRD ANGLE PROJECTION	DRG. CODE NO. D1 00390

USED ON

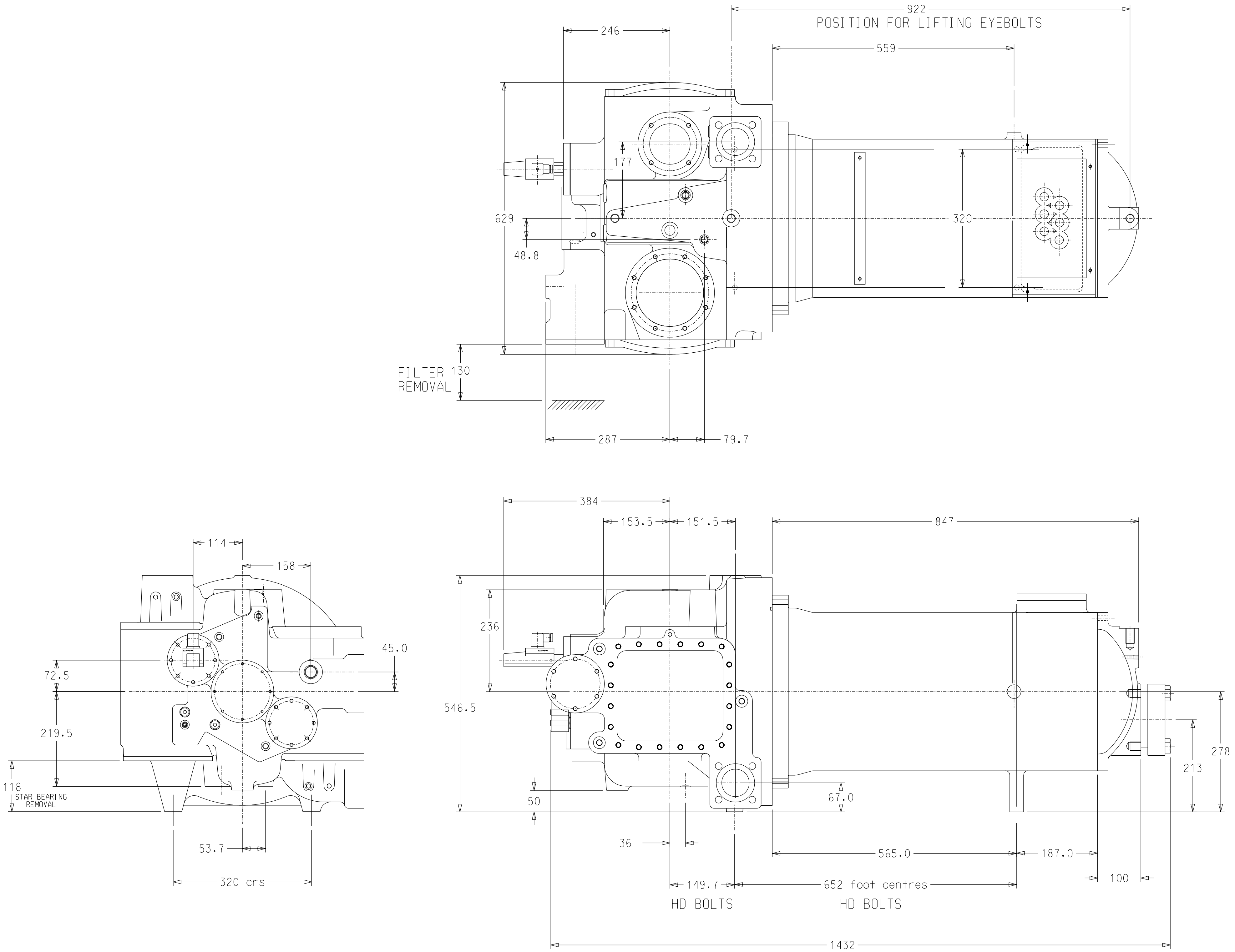
REF. DRGS.

PATT.
C/SM
P&C
S.G.
PL.G.
FIT.
M/C
INSP.

ROUGHNESS NUMBERS
N8 TO N12
N7 TO N8
N6 TO N7
N5 TO N6

FINISH SYMBOLS
R/ = ROUGH = 126 = MICRO INCHES OR 3.2 = MICROMETRES
N/ = NORMAL = 64 TO 125 MICRO INCHES OR 1.6 TO 3.2 MICROMETRES
F/ = FINE = 32 TO 63 MICRO INCHES OR 0.8 TO 1.6 MICROMETRES
S/ = SUPERFINE = 16 TO 31 MICRO INCHES OR 0.4 TO 0.8 MICROMETRES
FOR JOINT FACES JN/ = JOINT NORMAL JF/ = JOINT FINE JS/ = JOINT SUPERFINE
FINISHES TO TOL. THUS E.G. 10/8/ = 9 ± 1 MICRO INS. 0.25/0.20/ = 0.225 ± 0.025 MICROMETRES

CAD DRAWING NOT TO BE MODIFIED



MANU. ORDER NO.	CONTRACT ORDER NO.	REMARKS

INSPECTION BY	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS
	5			9		
	4			8		
	3			7		
DATE APPROVED	2			6		

DRAWN AAE 5/10/04

SIZE A1

PROTECTIVE FINISH
PATT NO.
WEIGHT
SCALE NTS
DIMENSIONS IN MM

TEST PRESSURE

TOLERANCES EXCEPT WHERE OTHERWISE STATED. (BRACKETED) DIMNS. FOR REF. ONLY.
IMPERIAL UNITS
FRACT. DIMNS. ± .020"
DECIMAL DIMNS. ± .010"
METRIC UNITS. ± 0.5 MILLIMETRES

MATERIAL

TITLE
PHYSICAL DATA
HSS4200 COMPRESSOR
SHOWING HBLVDT

J&E Hall® LIMITED
UNIT 40/41, PEARSON WAY, QUESTOR, DARTFORD, KENT. DA1 1JN, ENGLAND

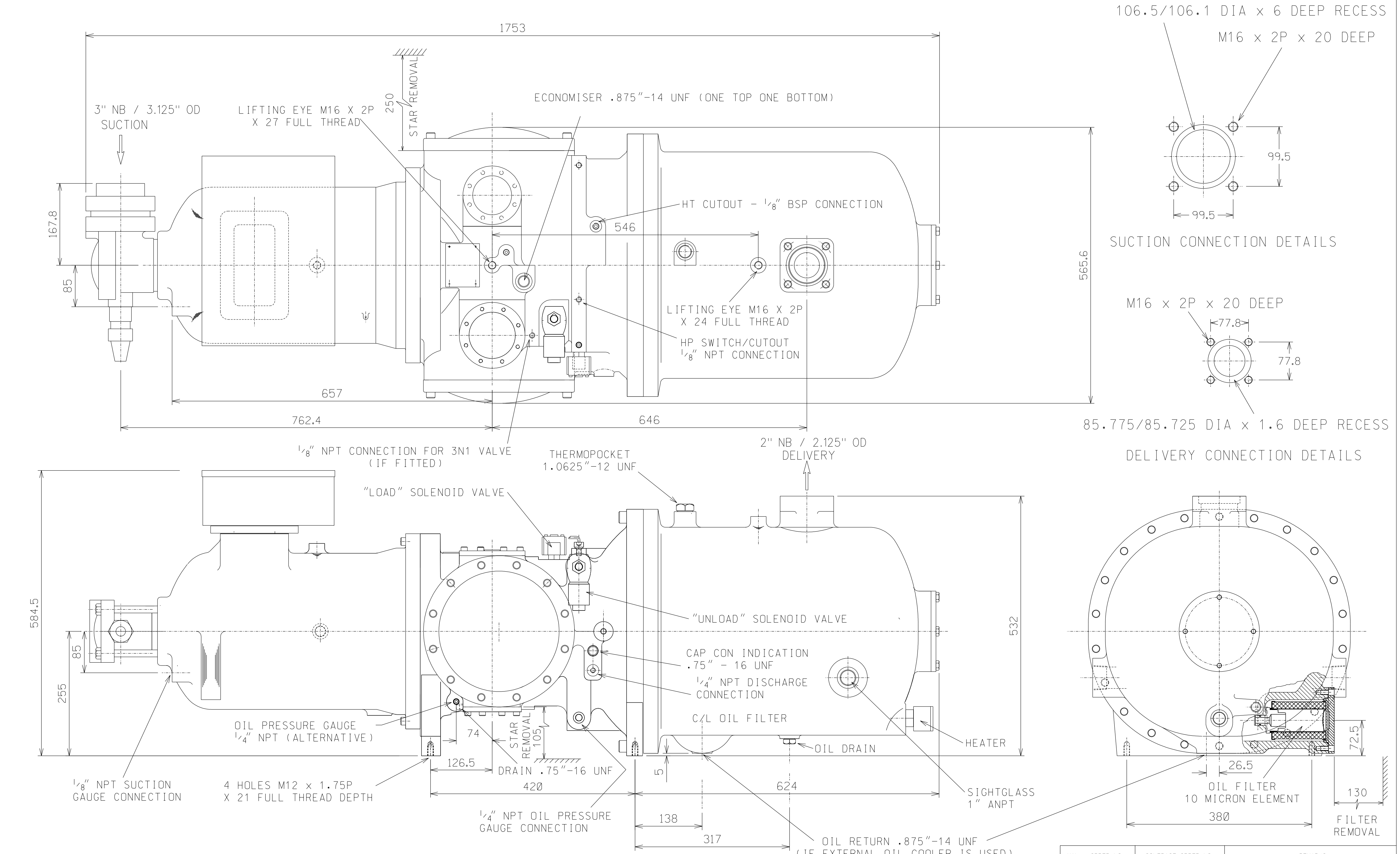
DRAWING CODE NO. D1 00390

ISSUE NO. 01 SHEET NO. 1 OF 1

IF IN DOUBT ASK | DRAWING NOT TO BE SCALED | THIRD ANGLE PROJECTION | DRG. CODE NO. D100364

USED ON

REF. DRGS.
3301997



PATT.
C/SM
P&C
S.G.
PL.G.
FIT.
M/C
INSP.
ROUGHNESS NUMBERS
N8 TO N12
N7 TO N8
N6 TO N7
N5 TO N6

FINISH SYMBOLS
R/ : ROUGH · 126 · 125 MICRO INCHES OR 3.2 · MICROMETRES
N/ : NORMAL · 64 TO 125 MICRO INCHES OR 1.6 TO 3.2 MICROMETRES
F/ : FINE · 32 TO 63 MICRO INCHES OR 0.8 TO 1.6 MICROMETRES
S/ : SUPERFINE · 16 TO 31 MICRO INCHES OR 0.4 TO 0.8 MICROMETRES
FOR JOINT FACES JN/ : JOINT NORMAL JF/ : JOINT FINE JS/ : JOINT SUPERFINE
FINISHES TO TOL. THUS E.G. 1/ · 9 : 1 MICRO INS. 0.20 · 0.225 : 0.025 MICROMETRES

CAD DRAWING NOT TO BE MODIFIED

DRAWN
7/11/03
AAE

SIZE A1

	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS
INSPECTION BY	5			9		
	4			8		
	3	DRAWING UPDATED	5/1/05 AAE	7		
DATE APPROVED	2	DRAWING UPDATED	14-12-04 AAE	6		

MANU. ORDER NO.	CONTRACT ORDER NO.	REMARKS

PROTECTIVE FINISH
PATT NO.
WEIGHT kg
SCALE NTS
DIMENSIONS IN MM

TEST PRESSURE
psig HYD
psig AIR

TOLERANCES EXCEPT WHERE OTHERWISE STATED. (BRACKETED) DIMNS. FOR REF. ONLY.
IMPERIAL UNITS
FRACT. DIMNS. : .020"
DECIMAL DIMNS. : .010"
METRIC UNITS.
: 0.5 MILLIMETRES

MATERIAL

TITLE
PHYSICAL DATA HS3200i COMPRESSOR
WITH INTERNAL OIL FILTER

J&E Hall® LIMITED
UNIT 40/41, PEARSON WAY, QUESTOR, DARTFORD, KENT. DA1 1JN, ENGLAND

DRAWING CODE NO. D100364

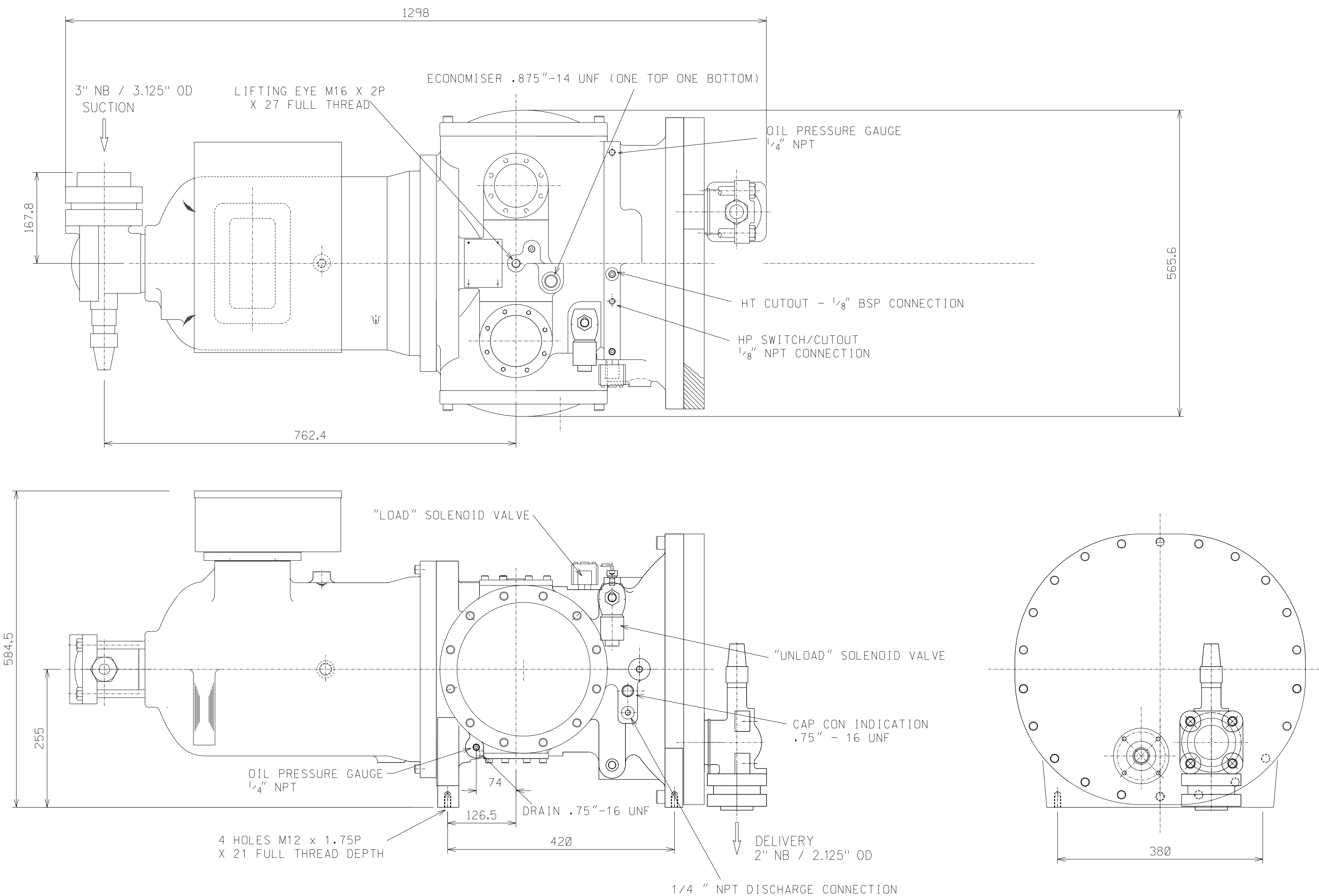
ISSUE NO. 03

SHEET NO. 1 OF 1

IF IN DOUBT ASK | DRAWING NOT TO BE SCALED | THIRD ANGLE PROJECTION | DRG. CODE NO. D100349

USED ON

REF. DRGS.
3301997



PATT.
C/SM
P&C
S.G.
PL.G.
FIT.
M/C
INSP.

ROUGHNESS NUMBERS
N8 TO N12
N7 TO N8
N6 TO N7
N5 TO N6

FINISH SYMBOLS
R/ = ROUGH = 126 + MICRO INCHES OR 3.2 + MICROMETRES
N/ = NORMAL = 64 TO 125 MICRO INCHES OR 1.6 TO 3.2 MICROMETRES
F/ = FINE = 32 TO 63 MICRO INCHES OR 0.8 TO 1.6 MICROMETRES
S/ = SUPERFINE = 16 TO 31 MICRO INCHES OR 0.4 TO 0.8 MICROMETRES
FOR JOINT FACES JN/ = JOINT NORMAL JF/ = JOINT FINE JS/ = JOINT SUPERFINE
FINISHES TO TOL. THUS E.G. 10/8/ = 9 ± 1 MICRO INS. 0.25/0.20/ = 0.225 ± 0.025 MICROMETRES

CAD DRAWING NOT TO BE MODIFIED

DRAWN
18/08/03
AAE

SIZE A1

INSPECTION BY	5			9			PROTECTIVE FINISH	
	4			8			PATT NO.	
	3			7			WEIGHT	kg
DATE APPROVED	2			6			SCALE	NTS
	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS	ISSUE NO	DESCRIPTION OF MOD.	DATE & INITIALS	DIMENSIONS IN	MM

TEST PRESSURE
psig HYD
psig AIR

TOLERANCES EXCEPT WHERE OTHERWISE STATED. (BRACKETED) DIMNS. FOR REF. ONLY.
IMPERIAL UNITS
FRACT. DIMNS. ± .020"
DECIMAL DIMNS. ± .010"
METRIC UNITS.
± 0.5 MILLIMETRES

MATERIAL

TITLE
PHYSICAL DATA
HSS3200 COMPRESSOR

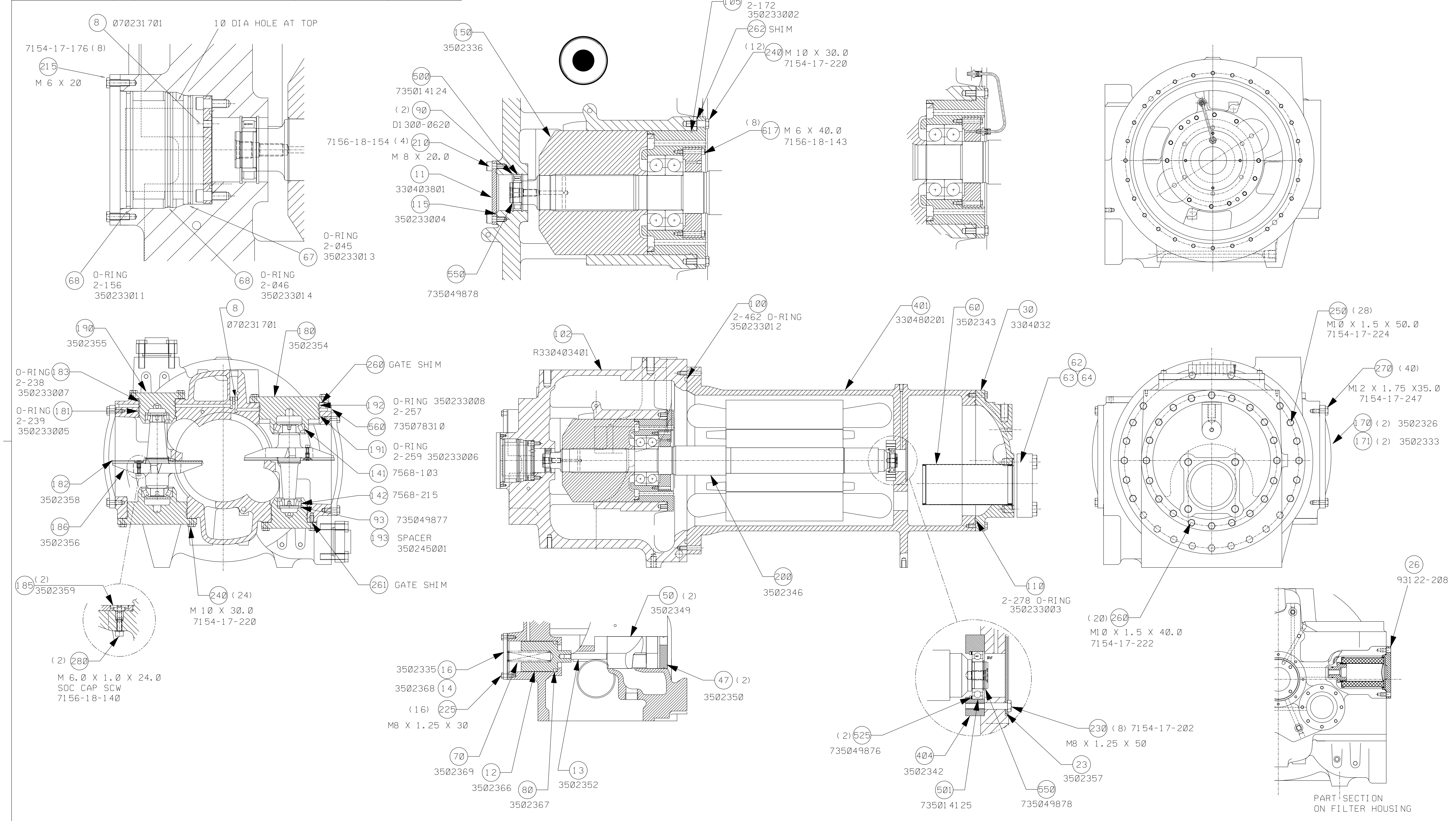
MANU. ORDER NO.	CONTRACT ORDER NO.	REMARKS

J&E Hall® LIMITED
UNIT 40/41, PEARSON WAY, QUESTOR, DARTFORD, KENT. DA1 1JN, ENGLAND

DRAWING CODE NO. D100349

ISSUE NO. 01
SHEET NO. 1 OF 1

PART NUMBER	REV.	PART DESCRIPTION	RAW MAT'L DESCRIPTION	RAW MAT'L PART NO.
330402501	00	ASSM/FR4 COMPr (FILTER)		



DOC	M.E.	ENG	DRN	DATE	ECO	DESIGN SOURCE	CADD DRAWING ATTACHED TO
			AAE	25-07-02			

REVISION CHANGE HISTORY | REV.

DOC	M.E.	ENG	DRN	DATE	ECO	REVISION CHANGE HISTORY	REV.

DIMENSIONING AND TOLERANCING CONFORMS TO ASME Y14.5M-1994

TOLERANCE DATA UNLESS OTHERWISE SPECIFIED
X. = . ANGLES = °
X.X = 0.
X.XX = 0.
FINISH: 13.2 MICROINCH ON MACHINED SURFACES

McQuay

ALL DIMENSIONS ARE IN MILLIMETERS

SCALE NONE — THIRD ANGLE PROJECTION

DRAWING NUMBER	REV.	SHEET
3304025D	00	1 OF 1

CADD REF.-

HallScrew HSO 4200 Series

Open Drive Single Screw Compressors

HSO 4221, HSO 4222 and HSO 4223

Installation, Operation and

Maintenance Manual

Safety

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

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

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

Personnel Permitted to Install, Commission and Maintain the Plant

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

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

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

⚠ WARNING

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

Mechanical

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

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

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

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

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

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

⚠ WARNING

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

Examination of Pressure Systems

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

Refer to 15.2.3. Examination of Pressure Systems.

Noise Hazard

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

Electrical

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

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

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

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

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

Lubricating Oils

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

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

Ammonia Refrigerant 717

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

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

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

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

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

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

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

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

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

Hydrochlorofluorocarbon and Hydrofluorocarbon Refrigerants

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

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

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

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

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

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

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

Contents

List of Figures

List of Tables

1. About this Publication

These instructions have been prepared according to the following standards:

BS 4884 : Technical Manuals:

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

BS 4899 : User's Requirements for Technical Manuals:

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

BS 4899 is based on the principles of BS 4884.

BS 5378 : Part 2 : 1982 Safety Signs.

1.1. Safety Warnings and Symbols

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

⚠ WARNING

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

⚠ CAUTION

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

NOTE: draws attention to important additional information.

1.2. Units of Measurement

Quantities are expressed in SI units or SI derived units.

1.3. Terminology

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

1.4. Ordering Extra Copies

Obtain extra copies of these instructions from the address below:

J & E Hall International
Engineering & Projects,
Invicta House,
Sir Thomas Longley Road,
Medway City Estate,
Rochester,
Kent ME2 4DP
England

Telephone: +44 (0) 1634-731-400
Fax: +44 (0) 1634-731-401
Email: helpline@jehall.co.uk
Website: www.jehall.co.uk

2. Misuses that Invalidate Guarantee

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

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

2.1. Application

The following is specifically prohibited:

(a) Operation outside the limits detailed in Appendix 1 Physical Data, Limits of Operation and Safety Requirements.

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

(c) Use of lubricating oils other than those specified by J & E Hall International; refer to Appendix 3 Approved Oils.

2.2. System Provisions

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

(a) On all systems other than those using R717 (ammonia), fit an adequately sized refrigerant filter/drier, preferably of the type using renewable cores. Fit a sight-glass/moisture indicator.

(b) If it is necessary to fit an external oil filter (refer to 7.8. External Oil Filter), the filter must be adequately sized and to the specification described in Table 2.

(c) Fit an adequately sized suction strainer having a mesh aperture of 250μ or better.

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

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

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

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

(g) The compressor will need cooling, either by direct injection of liquid refrigerant or by using an external oil cooler (water, air or refrigerant cooled); refer to 7.9. Compressor Cooling.

If liquid injection cooling or thermosyphon oil cooling is used, a preferential supply of liquid refrigerant must be provided for cooling purposes. The priority supply must be arranged so that the cooling requirement is satisfied before liquid can flow to the evaporator(s); refer to Fig 10.

(h) Fit, and maintain in an operational condition, the cut-outs and other safety devices described in Appendix 1 Physical Data, Limits of Operation and Safety Requirements, illustrated in Appendix 2 Oil Support System Schematic Flow Diagrams.

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

(i) The plant controller is required to supply load/unload pulses to the capacity control solenoid valves; refer to 4.3. HB Linear Variable Displacement Transducer (HBLVDT).

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

2.3. Prolonged Storage

If, for any reason, the compressor cannot be installed immediately and must be placed in prolonged storage, refer to 10. Prolonged Storage.

2.4. Commissioning Provisions

General commissioning procedures are described in 12. Commissioning and Operation.

The following provisions are considered mandatory:

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

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

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

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

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

When using polyolester synthetic oils, care must be taken to ensure that contact between air and the lubricant is minimised. Spare oil must be adequately protected against contamination; refer to 12.8. Adding Oil to the System.

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

(d) Connect and use the discharge high temperature thermistors, fitted as standard and should be wired as illustrated in Fig 13.

(e) Connect the compressor drive motor such that the compressor rotates clockwise when looking on the compressor shaft end (driven end); refer to 12.4. Checking Compressor Rotation.

3. General Description

The J & E Hall International HSO 4200 series of open drive compressors are the latest addition to the HallScrew family of oil injected, positive displacement, single screw compressors. Reflecting the very latest innovations in screw compressor technology, they have been specially developed for refrigeration, air conditioning and heat pump applications, and can be applied to single stage and multi-stage systems using all normal refrigerants as well as many other process gases.

3.1. Main Features

- For use with R22, R717 (ammonia), R134a, R404a, R407c and R507.
- 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.
- Thermistor discharge gas high temperature protection.
- Built-in oil filter.
- Clockwise rotation looking on the motor (driven) end for gas engine drive without intermediate gearbox.

3.2. Construction

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

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

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

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

Side covers are provided to allow easy access to the star rotors, star rotor shafts and bearings, without disturbing working tolerances. The suction connection, mounted on one side cover, can be taken from either side of the compressor.

It is necessary to fit a suction strainer immediately before the compressor suction inlet. The strainer is designed to trap any dirt circulating with the refrigerant which might otherwise enter and damage the compressor.

To prevent reverse rotation of the compressor at shutdown it is necessary to fit a non-return valve immediately after the oil separator discharge outlet; refer to 7.4.2. Discharge Non-return Valve.

3.2.1. Internal Relief Valve

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

At the present time the internal suction/discharge relief valve is only approved for use with R134a. For all other refrigerants an external discharge/suction bypass must be fitted.

3.3. The Compression Process

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

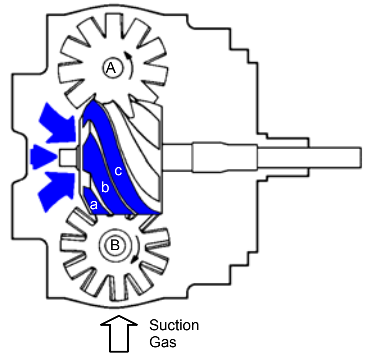
As the HallScrew is a positive displacement compressor, there are three separate stages in the compression cycle: suction, compression and discharge. These are illustrated in Fig 1.

1. and 2. Suction

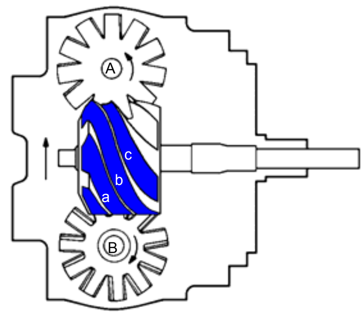
Main rotor flutes 'a', 'b' and 'c' are in communication at one end with the suction chamber via the bevelled rotor end face, and are sealed at the other end by the teeth of star rotor A. As the main rotor turns, the effective length of the flutes increases with a corresponding increase in the volume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

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

1.



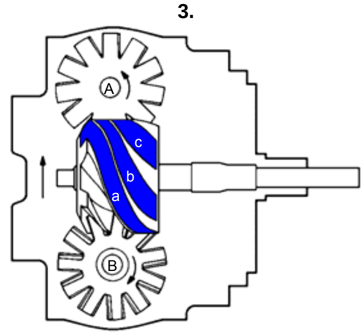
2.



3. Compression

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

3.



4. Discharge

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

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

4.

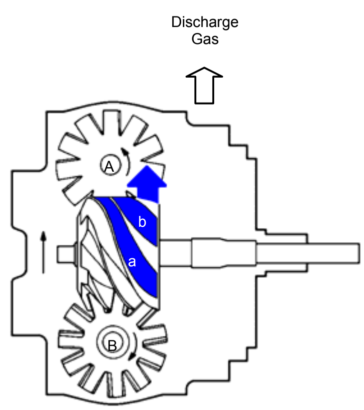


Fig 1 Compression Process

4. Capacity Control and Volume Ratio

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

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

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

The compressor is fitted with a pair of sliding valves, one for each half of the symmetrical compression process. These valves reduce pumping capacity by delaying the sealing of the flute volume together with the opening of the discharge port, altering the effective length of the main rotor flutes. The valves not only permit stepless capacity control down to approximately 25 % of full load (actual minimum value varies with operating conditions), but also maintain the best possible V_R over a wide capacity control range.

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.

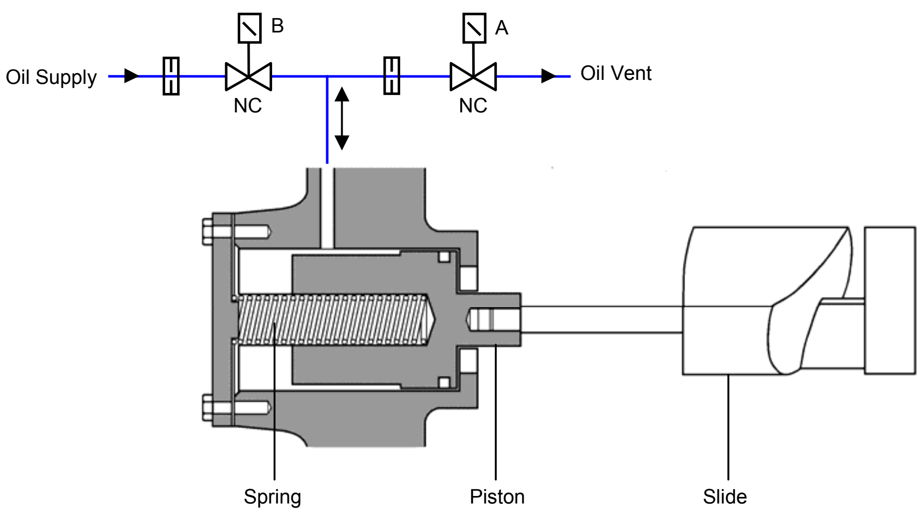


Fig 2 Capacity Control Mechanism

4.1. Slide Valve Actuation

While the compressor is running, the position of each slide valve is controlled by a hydraulic piston actuated by oil pressure. Two solenoid valves control the oil flow and venting of the piston cylinders.

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

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

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

4.1.1. Minimum Load Interlock

Starting at minimum load minimises motor starting current, starting torque and acceleration times. 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 HB linear variable displacement transducer (HBLVDT) provides an ‘at minimum load’ permit start signal.

4.2. Continuously Variable Capacity Control

The method of operation is illustrated in Fig 3.

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

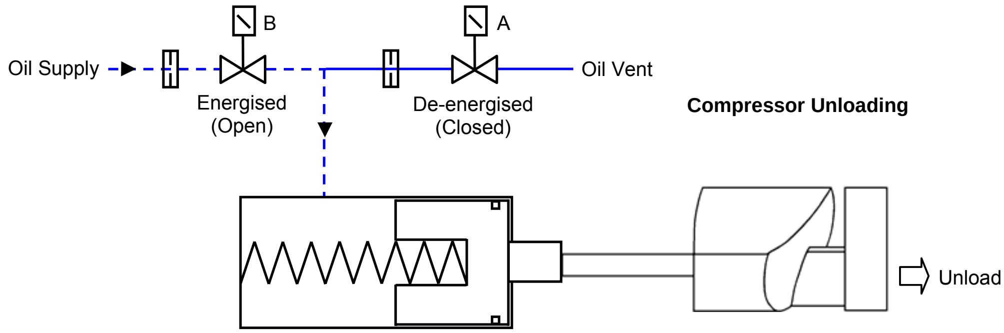
The plant controller energises and de-energises the solenoids to control the rate of loading/unloading. These signals must be provided by a suitable pulse timer with a minimum pulse length of ≥0.5 second.

4.2.1. Controlled Stop

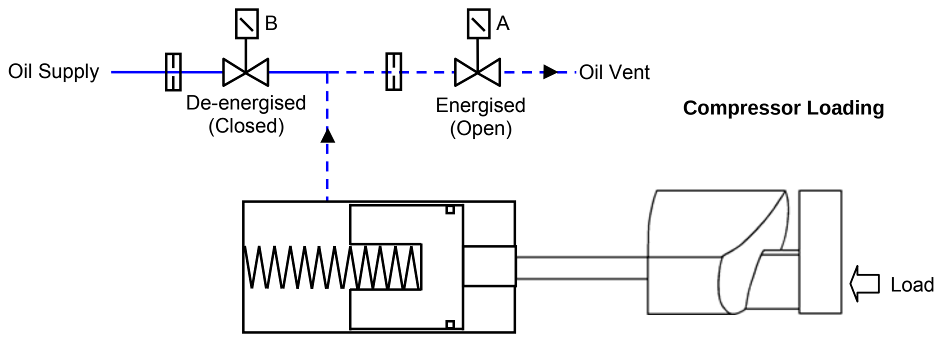
When the compressor is required to stop from a loaded condition, solenoid valve B is energised (open). High pressure oil is admitted to the capacity control cylinders. Oil pressure supplements the force of the spring acting on the unload side of each piston. The combined force is sufficient to overcome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

4.2.2. Uncontrolled Stop

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



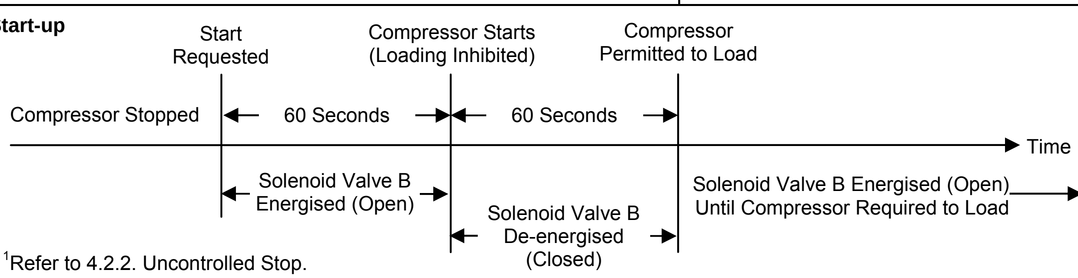
Oil Pressure + Spring Force > Suction/Discharge Differential Pressure = Slide and Piston Move Towards Unload



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

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

[1]Start-up



[1]Refer to 4.2.2. Uncontrolled Stop.

Fig 3 Continuously Variable Capacity Control

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

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

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

4.3. HB Linear Variable Displacement Transducer (HBLVDT)

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

The HBLVDT 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; refer to 4.3.3.

⚠ CAUTION

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

External wiring connections are illustrated in Fig 4.

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

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

4.3.1. 4 to 20 mA Calibration – Calibration Not Fitted to the HBLVDT

If the HBLVDT is not fitted with calibration, the 4 to 20 mA signal must be calibrated for maximum and minimum load via suitable software within the plant controller. For J & E Hall International Fridgewatch 2000 and 2100 Controllers, refer to the following publications:

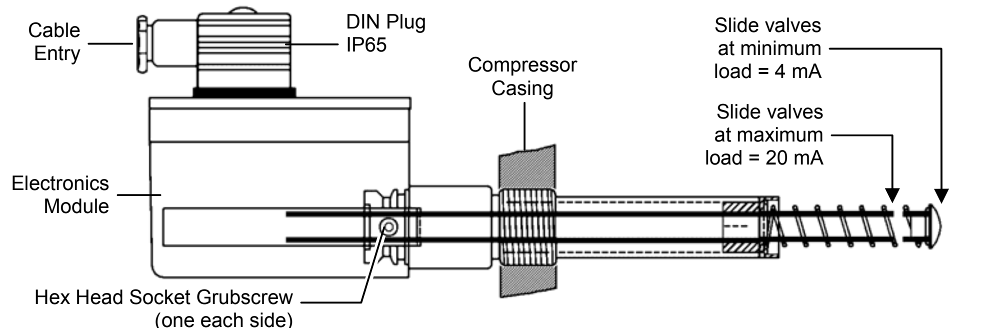
- Fridgewatch 2000, publication 3-55.
- Fridgewatch 2100, publication 3-56.

4.3.2. 4 to 20 mA Calibration – Calibration Fitted to the HBLVDT

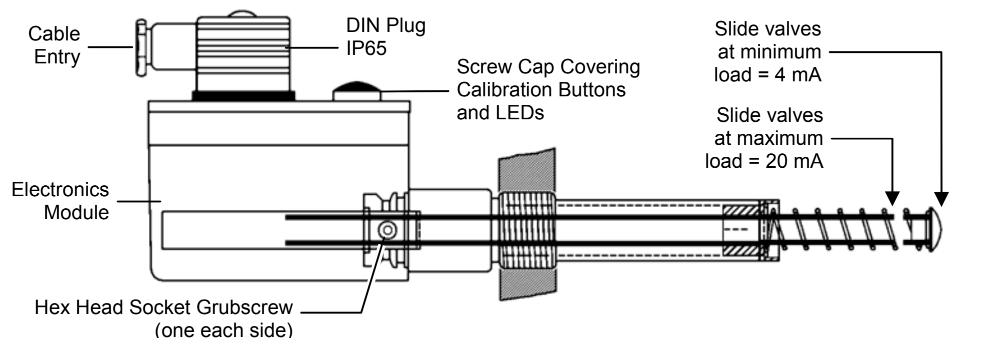
To use this procedure, sufficient heat load must be available to permit the compressor to run at maximum load long enough for the procedure to be completed.

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

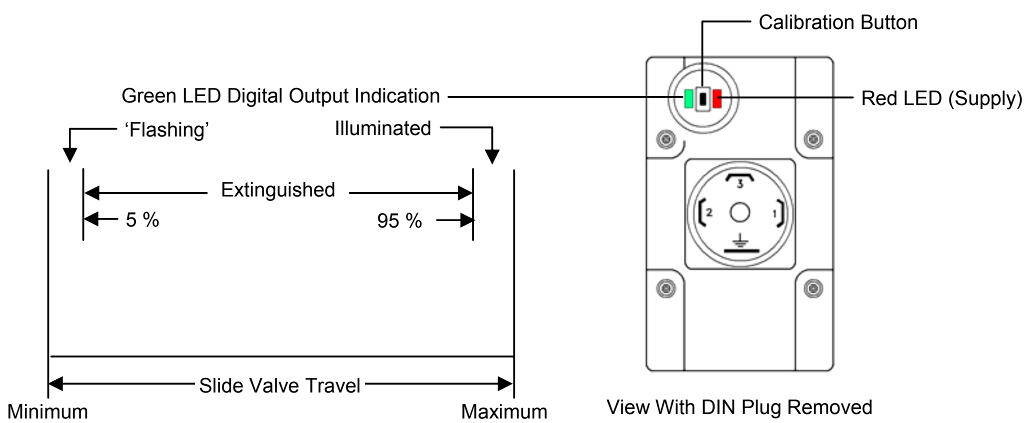
(a) Start the compressor if it was not already running. If the compressor will not start, refer to the notes at the end of this procedure.



HBLVDT Without Calibration



HBLVDT With Calibration



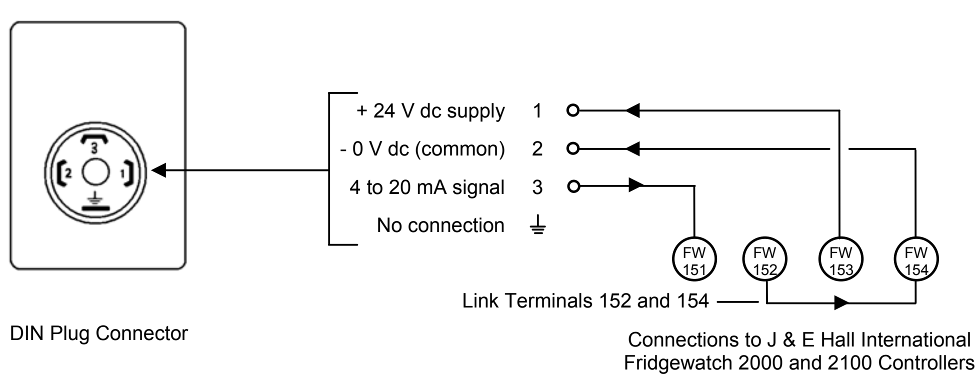


Fig 4 HBLVDT Arrangements and Wiring Connections

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

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

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

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

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

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

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

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

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

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

⚠ CAUTION

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

4.3.3. Fitting a New HBLVDT Electronics Module

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

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

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

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

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

(d) Reconnect the DIN plug and switch on the 24 V dc power supply to the HBLVDT. Check the calibration as described in 4.3.1. or 4.3.2.

5. Economiser Facility

The HallScrew compressor is provided with an economiser facility. This enables an additional charge of gas to be handled by the compressor, over and above that which is normally pumped. It is, in effect, a form of supercharging which has the net result of increasing refrigerating capacity by a significantly greater percentage than power consumption, hence improving the coefficient of performance (kW refrigeration/kW power input) or Coefficient of Performance (COP) of the compressor.

The economiser principle is illustrated on a pressure/enthalpy (p-h) diagram in Fig 5.

Suction gas is drawn into the main rotor flutes, these are sealed off in sequence by the star rotor teeth and compression begins. An extra charge of gas now enters the sealed flute through a port in the casing enclosing the main rotor. This gas supply is taken from an intermediate source at a slightly higher pressure than that prevailing in the flute at the instant the gas is introduced, hence the gas is induced to enter the flute. The original and additional charges of gas are then compressed and discharged in the normal way. The full load pumping capacity of the compressor at suction conditions is not affected by the additional flow through the economiser connection.

In common with all screw compressors. as the compressor unloads, the pressure at the economiser port falls towards suction pressure and the additional capacity and improved efficiency economiser system is no longer available.

As a guide to this effect, approximately half of the improvement due to using an economiser system will be lost by the time the compressor unloads to 90 % capacity, and falls to zero at around 70 % capacity.

The two most common methods of producing the intermediate gas source are as follows:

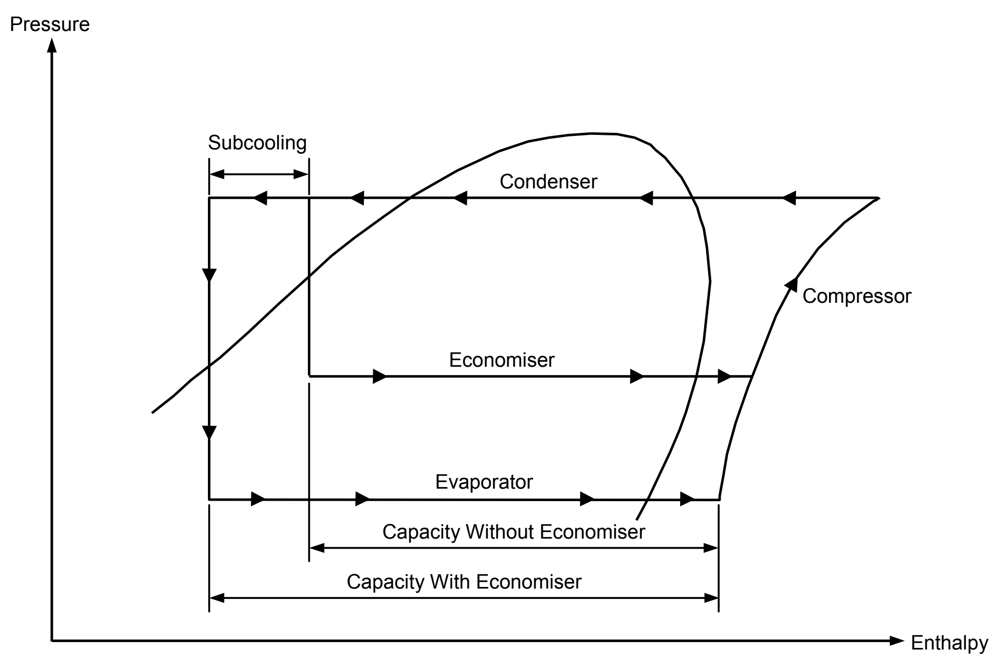


Fig 5 Economiser Cycle on Pressure/Enthalpy (p-h) Diagram

5.1. Subcooling of Liquid Refrigerant

The main liquid supply to the evaporator flows through a small heat exchanger (the economiser). A small quantity of liquid, taken from the main liquid supply before the economiser, is evaporated in the economiser in order to subcool the remainder. The subcooled liquid, when passed to the evaporator, provides a larger refrigeration capacity per kg than if it was not subcooled; the compressor still pumps the same mass of gas. Hence the net refrigeration capacity is increased.

The volume of gas capable of passing through the economiser connections is dependent upon the pressure in the economiser line. The volume of gas generated in the refrigeration system by the subcooling process is dependent upon the system mass rate of flow, the operating conditions and the subcooler performance. These two flows must be the same and hence an equilibrium economiser pressure is reached in practice.

The requirements outlined in the previous paragraphs are met by the system outlined in Fig 6. Service components such as isolating valves have been omitted for clarity.

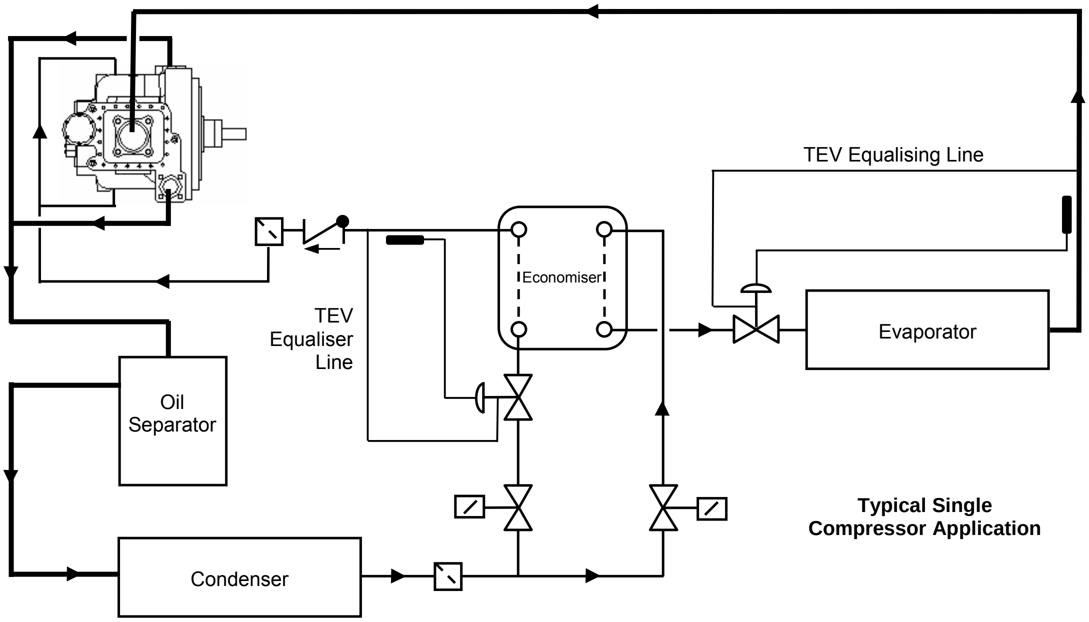
Liquid is metered into the economiser vessel through a thermostatic expansion valve (TEV) with the sensing bulb strapped to the vapour return line to the compressor economiser connection. The TEV must be fitted with the appropriate size orifice, and have a maximum operating pressure (MOP) in excess of the highest expected economiser gauge (20 °C to 25 °C).

A solenoid valve must be fitted in the liquid line feeding the TEV; refer to Fig 6. This solenoid valve should be electrically interlocked to energise (open) when compressor capacity exceeds approximately 50 %, and de-energise (close) when capacity falls below 50 %. The capacity control slide valve HB Linear Variable Displacement Transducer (HBLVDT) can be used for this purpose, refer to 4.3. HB Linear Variable Displacement Transducer (HBLVDT).

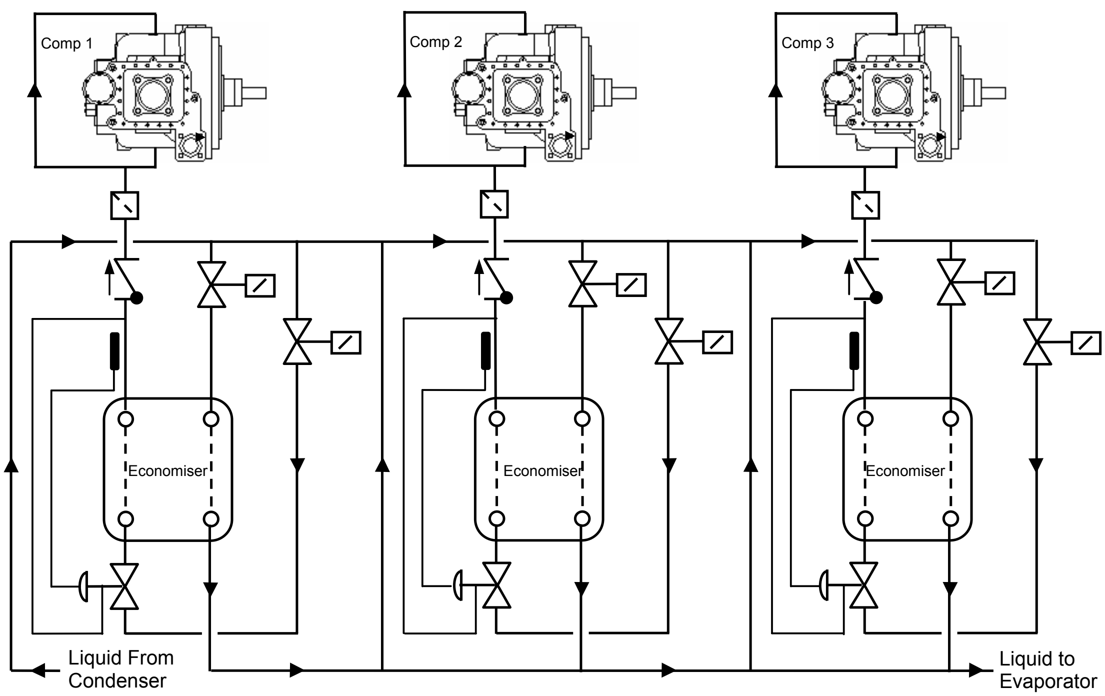
For multiple compressor applications operating in parallel, the preferred arrangement is to fit a separate economiser to each compressor, each fed by its own TEV; refer to Fig 6.

5.2. Side Load Operation

An alternative method of providing the intermediate gas supply is available in some multi-temperature applications where, for example, a higher temperature coldstore could operate at an elevated evaporating temperature compatible with the economiser port pressure. The refrigerant vapour generated by this store could then be returned to the economiser port without significantly affecting the low temperature capacity of the compressor.



Typical Single Compressor Application



Typical Multiple Compressor Application With Common Refrigerant Circuit

SOLENOID VALVE IN MAIN LIQUID LINE THROUGH THE ECONOMISER	SOLENOID VALVE BEFORE THE REGULATOR (THERMOSTATIC EXPANSION VALVE SHOWN)
Electrically interlocked to energise (open) when compressor x starts, de-energise (close) when compressor x stops.	Electrically interlocked to energise (open) when compressor x capacity > 50 %, de-energise (close) when compressor x capacity < 50 %.
x = 1 for compressor 1, x = 2 for compressor 2, x = 3 for compressor 3.	

Fig 6 Economiser Arrangements: Wiring to Liquid Line Solenoid Valves

6. Compressor Lubrication, Sealing and Cooling

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

⚠ CAUTION

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

The oil performs four basic functions:

6.1. Capacity Control Actuation

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

6.2. Bearing Lubrication

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

6.3. 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.

6.4. 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; refer to 7.9.1. When liquid injection is not used, the oil injected for sealing absorbs a large proportion of the heat of compression, thus reducing the maximum discharge temperature, and is cooled externally via an oil cooler; refer to 7.9.2.

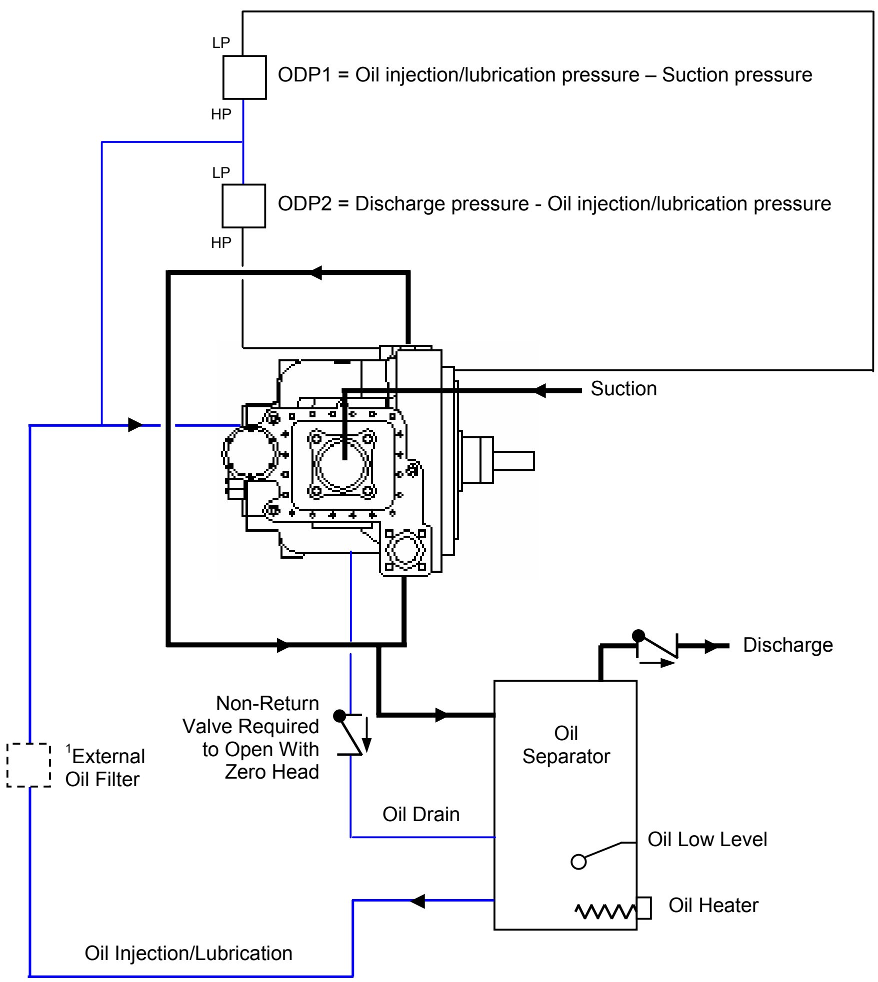
7. Oil Support System

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

CAUTION

The system into which the compressor is to be installed must fully comply with the recommendations in 7.1. to 7.9. and 8. Lubricating Oils. 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.



The oil support system must conform with the provisions described in 7.1. to 7.9.

[1]It is recommended to fit an external oil filter if the compressor is not applied to a factory built complete package unit. An external oil filter is a mandatory requirement when external oil cooling is used; refer to 7.8.

Fig 7 Oil Support System

7.1. Oil Injection/Lubrication

A single line provides oil for injection, lubrication and capacity control actuation. The connection size at the compressor can be found in Appendix 1 Physical Data, Limits of Operation and Safety Requirements.

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

7.2. Oil Drain

Oil which collects inside the compressor casing must be allowed to drain back to the oil separator when the compressor stops. An external drain line must be provided from the oil drain connection on the bottom of the compressor to the oil separator. The connection size can be found in Appendix 1 Physical Data, Limits of Operation and Safety Requirements.

To ensure the oil drain line functions correctly:

- The drain line must slope down all the way to the separator without traps or risers. If it is required to fit a service valve in this line, this should be a full-flow ball valve to minimise pressure drop.
- The drain line must incorporate a non return valve to allow oil to flow from the compressor to the separator during shut down, but prevent flow in the opposite direction when the compressor is running. The non-return valve is required to open with zero head.
- If the oil separator is not supplied packaged with the compressor, the separator must be sized and positioned to provided adequate oil return; refer to 7.4.1.
- A discharge non-return valve must be fitted after the oil separator to ensure that the compressor and separator are maintained at the same relative pressures after shutdown; refer to 7.4.2.
- For all low stage (booster) and other low pressure difference applications where a continuously running oil pump is used, when the plant starts there is a danger that the pump will partially fill the compressor with oil. For these applications it is necessary to fit an opto-electronic liquid sensor into the drain line, electrically interlocked to prevent the compressor from starting until the drain line is clear of liquid: refrigerant and/or oil.

7.3. Oil Separation

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

7.3.1. Oil Separator Design

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

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

Additionally, as the separator efficiency changes with load and operating conditions, then the amount of oil carried into the system through the separator will also vary. Therefore the oil remaining in the separator will vary by an equal amount. Thus either sufficient oil capacity must be provided in the separator to allow for this change in oil quantity or a more consistent separator performance must be attained. As high quantities of oil in the evaporator are detrimental to system performance it is normal to design the separator with as high an efficiency as is economically achievable. Even in this case the separator must provide sufficient oil volume above the normal operating volume to cater for the variation in efficiency. In addition the separator must have sufficient oil volume to provide an adequate dwell time to allow oil and refrigerant to reach their equilibrium condition.

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

7.4. Oil Separator Provisions

In addition to the considerations discussed in 7.3, the oil separator should comply with the following recommendations:

7.4.1. Oil Return

As already mentioned in 7.2. a drain line must be installed between the compressor casing and the oil separator. Therefore, the separator must be positioned at a suitable height such that the standing oil level (compressor stopped) is significantly below the bottom of the compressor.

The oil separator must have a sufficient free volume to accommodate the oil drainage from the compressor or oil returned from another part of the system.

7.4.2. Discharge Non-return Valve

A discharge non-return valve must be fitted after the oil separator to ensure adequate oil return from the compressor; refer to 7.2.

7.4.3. Oil Heater

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

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

7.4.4. Oil Low Level

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

For applications where a continuously running oil pump is used, the opto-electronic liquid sensor is fitted into the compressor drain line.

7.4.5. Oil Balance Lines

In installations using multiple compressors/oil separator units on the same refrigeration circuit, oil returning from the system must be distributed such that an adequate oil level is maintained in each oil separator. If an oil balance system is adopted that relies on solenoid valves to prevent oil returning to the separator when the compressor is stopped, these solenoid valves must be selected and tested as suitable for use with refrigeration oils. Many such valves fail to close, with the possibility of oil flowing through the non running oil system/compressor and filling the compressor. This can occur even when a non return valve is fitted after the separator.

7.5. Oil Circulation

An oil circulation pump can be dispensed with for most operating conditions using HSO 4200 series compressors. Oil circulation is maintained by the pressure difference generated between the high pressure side of the system and the pressure in the sealed main rotor flute at the point of oil injection. When the compressor stops, the unloading springs automatically return the capacity control slide valves to minimum load; refer to 4.1. Slide Valve Actuation.

Exceptions to the above occur when there is only a small system pressure difference. Typical examples are under low ambient conditions, low load operation and most low stage (booster) applications. If the difference between absolute discharge pressure, measured at the outlet from the oil separator, and twice the absolute suction pressure is less than 2 bar abs, pumped oil injection/lubrication is necessary using a full-flow oil pump running continuously while the compressor is operating. For HSO 4200 series compressors the minimum pumping capacity of the full-flow oil pump is 3.0 to 4.0 m^3/hr.

7.6. Oil Differential Pressure Monitoring

As already described in 6. Compressor Lubrication, Sealing and Cooling, HSO 4200 series compressors require an adequate supply of oil for injection, bearing lubrication and capacity control actuation.

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

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

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

7.6.1. ODP1

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

ODP1 = Oil injection/lubrication 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 suction pressure. If ODP1 is sensed by transducers then the pressure ratio from suction to oil (discharge) should be set to 2. If an oil differential pressure switch is used, this should be set to the maximum intended operating suction gauge, thus the switch will trip when the oil pressure is below twice the maximum operating suction pressure. On start up there is no system pressure differential, therefore, ODP1 must be timed out. The standard time out period is 30 seconds. If ODP1 is not achieved after this period alternative arrangements must be made. Refer to J & E Hall International for advice on the appropriate action.

7.6.2. ODP2

This is the differential across the oil injection line and should 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/lubrication pressure

7.7. Maintaining Discharge Pressure at Start up

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

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

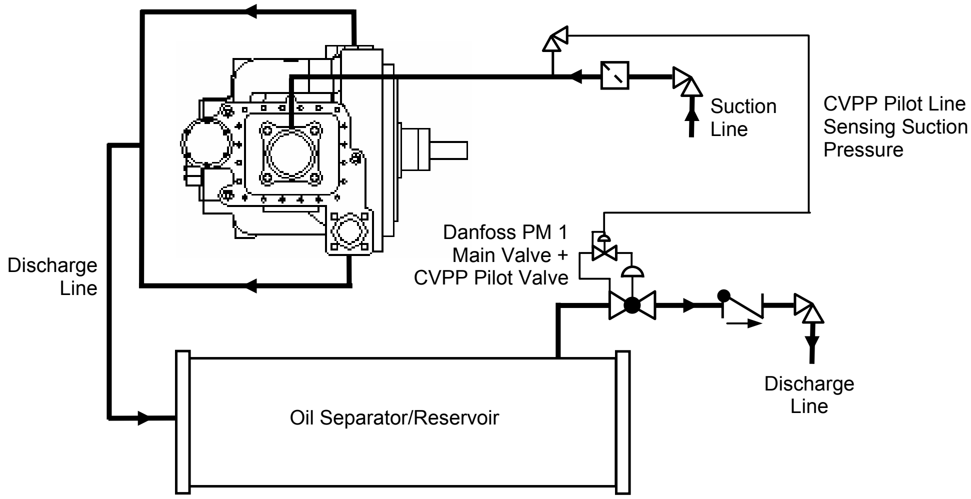


Fig 8 Maintaining Discharge Pressure at Start up

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.

7.8. External Oil Filter

HallScrew 4200 series compressors are fitted with a built-in oil filter. This filter is adequate for complete package unit applications where standards of system cleanliness can be guaranteed. However, for part packaged site erected systems or when the compressor is applied to an existing installation, the high levels of dirt likely to be encountered mean that the built-in filter will need to be changed at frequent intervals. For these applications it is recommended to fit an external oil filter to the minimum specification shown in Table 2. A bypass must **NOT** be included in the filter assembly.

NOTE: an external oil filter is also necessary when external oil cooling is used; refer to Table 1.

APPLICATION	METHOD OF COMPRESSOR COOLING	
	LIQUID INJECTION	OIL COOLER
Factory built complete package unit	Not required	Mandatory requirement
Factory built part package unit	Recommended	
Compressor applied to existing system		

Table 1 External Oil Filter Application

When it is necessary to use an external oil filter, the integral oil filter can be retained for initial commissioning and then removed together with the internal oil filter locating spigot piece; refer to 13.1.2. Oil Filter.

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

NOTE: All filter components must be suitable for use with the system oil and refrigerant. As refrigerant R717 (ammonia) attacks copper, nickel, tin, zinc and cadmium, filter components containing these metals or their alloys are prohibited from ammonia refrigeration systems.

Table 2 External Oil Filter Minimum Specification

7.9. Compressor Cooling

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

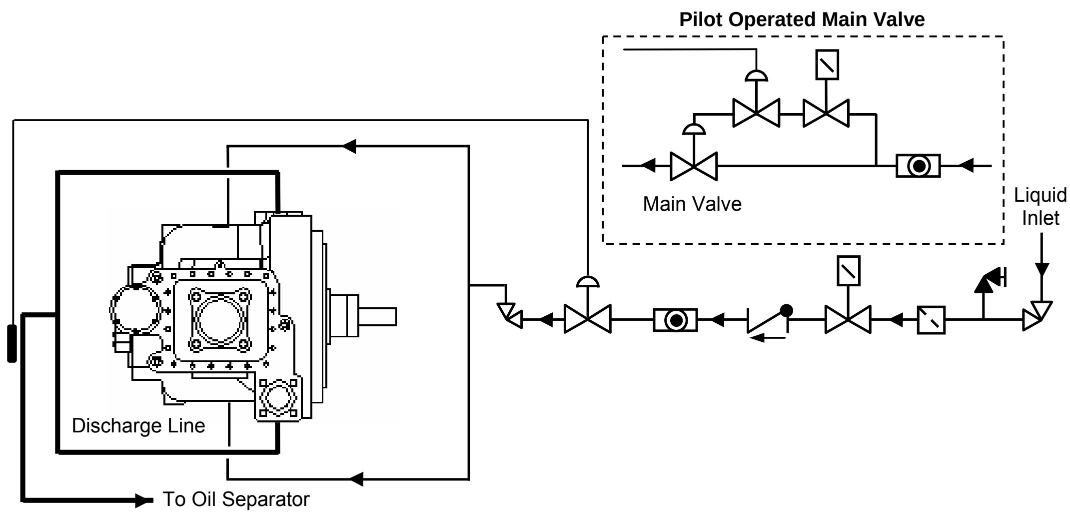
7.9.1. Liquid Injection Cooling

Liquid refrigerant is injected into the compressor main rotor flute, part-way through the compression process; a small reduction in compressor capacity may result.

The rate of injection is thermostatically controlled by a liquid injection valve which meters a precise quantity of refrigerant into the compressor according to changes in discharge gas temperature.

The injection valve's sensing bulb is either strapped to the discharge line, or installed in a bulb pocket in the line. The injection valve is normally set to limit discharge temperature to 75 °C, or 25 °C above condensation temperature if this is above 50 °C, whichever is the higher, to ensure satisfactory oil separator performance.

Liquid injection line components are illustrated and described in Fig 9.



Component	Function	Description	Publication[2]
Thermostatic injection valve	Meters a precise quantity of refrigerant into the compressor according to changes in discharge gas temperature.	Danfoss TEAT	4-44
		Alco 935	
Main valve	The main valve is pilot operated by the thermostatic injection valve.	Danfoss PMFH	4-65
Sight-glass (in line)	Visual indication that the line is full of liquid and provides early indication of a choked strainer.	-	-
Non-return valve	Prevents reverse flow of liquid.	Danfoss NRVA	4-43
Solenoid valve	Electrically interlocked to energise (open) when the compressor starts and de-energise (close) when the compressor stops.	Danfoss EVRA or EVJDA	4-08
		Refrigerating Specialities S8F	4-09
Strainer	Prevents dirt from entering and damaging the injection valve or solenoid valve.	Danfoss FA	4-168
Purge valve (normally closed and capped)	Facilitate cleaning the strainer and servicing components.	-	-
Stop valve			
Stop valve (locked open)			

[1]The configuration of liquid injection components applicable to a particular contract can be found from the system schematic flow diagram and from Part A : Specification in the plant instruction manual.
[2]These publications can be found in the J & E Hall International instruction manual for the plant.

Fig 9 Liquid Injection Cooling

The liquid injection system requires a preferential supply of high pressure liquid through an adequately sized supply line, taken from a source which ensures a preferential supply to the liquid injection valve. The line between the take-off point for the preferential supply and the entrance to the liquid injection valve must, at all times, be full of liquid refrigerant. Typical methods of achieving a preferential supply are illustrated in Fig 10.

Liquid injection pressure graphs can be found in the HSO 4200 Series Applications Manual, available from J & E Hall International.

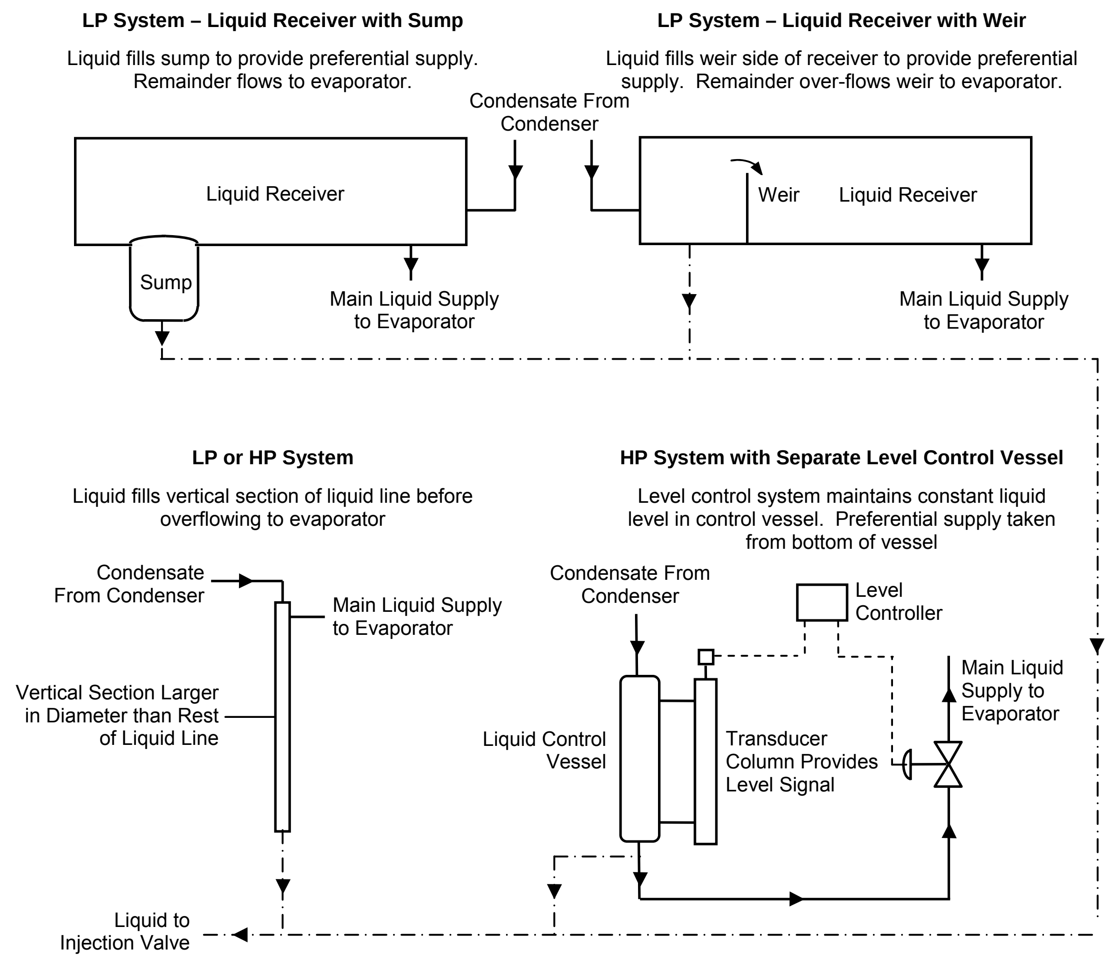


Fig 10 Typical Methods of Providing Preferential Supply for Injection

7.9.2. External Oil Cooling

While offering savings in initial capital cost, liquid injection cooling can result in a small loss of refrigeration capacity and increased power requirement at higher pressure ratios.

As an alternative to liquid injection, the oil injected for lubricating and sealing also performs the essential task of cooling the discharge gas by absorbing the heat of compression. The warm oil is cooled externally using a water, air or refrigerant cooled heat exchanger.

The oil cooler must be provided with some form of temperature control, otherwise the oil injection temperature may fall too low to provide a adequate discharge superheat and oil separation problems may be encountered. Suitable means of oil temperature control include a bypass around the heat exchanger, a pressure or temperature operated valve in the water inlet line (water cooled cooler) or fan dampers (air cooled cooler).

Examples of bypass temperature control are illustrated in Fig 11. Of the two methods, using a 3-way valve is preferred as this provides modulating control of oil temperature.

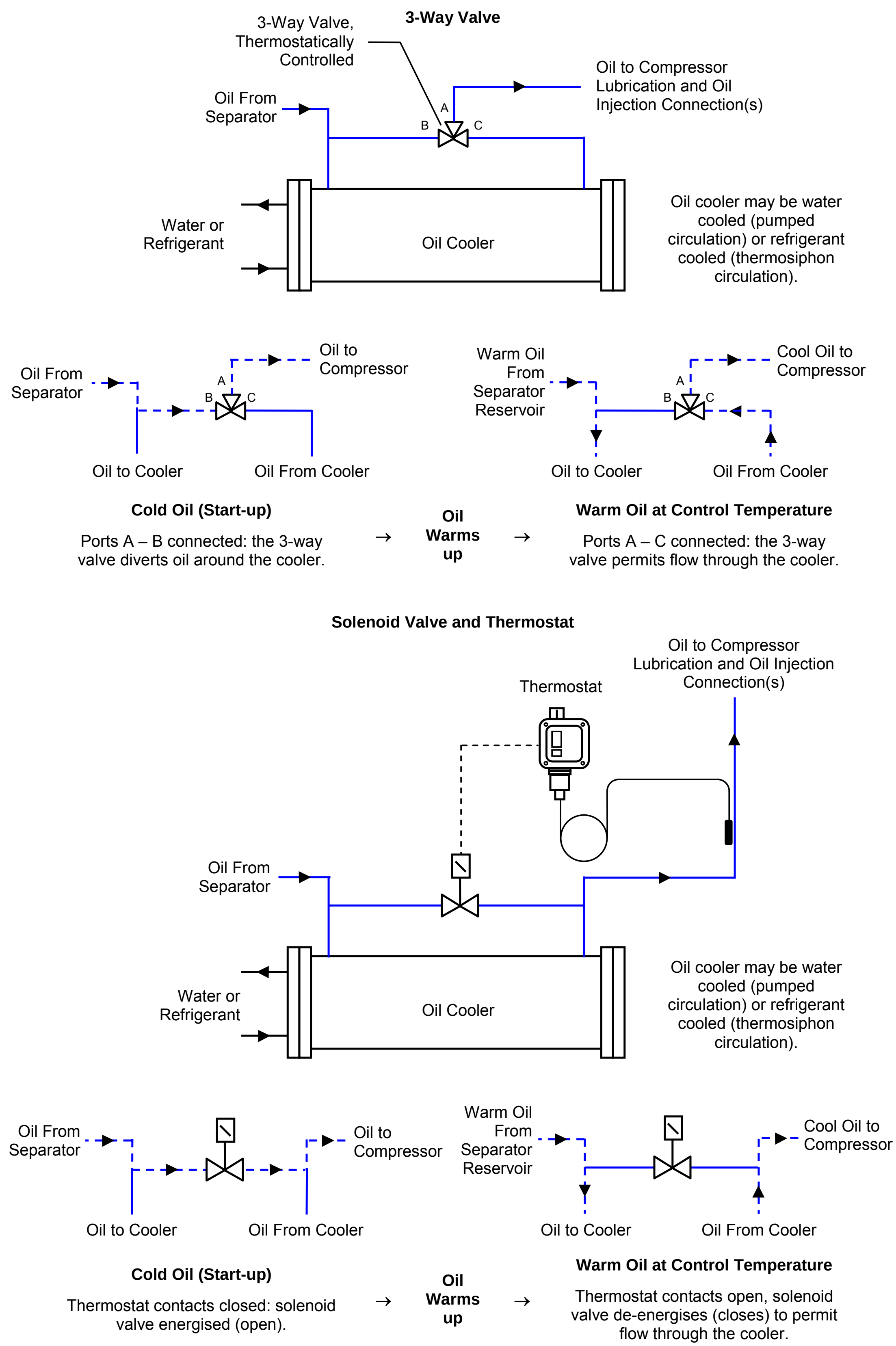


Fig 11 Oil Cooler Temperature Control

8. Lubricating Oils

Lubricants used in the HallScrew compressor not only provide sealing and cooling functions. The grade and type of lubricant chosen must provide these functions at the actual operating environment existing inside the compressor. In addition, as no oil separation system can be 100 % effective, the refrigeration system must be designed to adequately return any oil carried over into the system to the compressor. Therefore, the lubricant must be compatible with the refrigerant and the refrigeration system as a whole.

The lubrication criteria can be met for standard operating conditions by using a refrigeration quality oil as specified in Table 3 which is generally in accordance with BS 2626 : 1992 Lubricating Oils for Refrigeration Compressors.

Lubricating oils already approved for use with HSO 4200 series compressors are listed in Appendix 3 Approved Oils. Alternative oils from other suppliers may also be capable of providing adequate lubrication but approval to use such oils **MUST** be obtained from J & E Hall International if guarantees are not to be invalidated. Different types and makes of oils must not be mixed.

PARAMETER	MINERAL OILS		POLYOLESTER LUBRICANTS
	[1]EXTERNAL OIL COOLING	[2]LIQUID INJECTION OIL COOLING	[3]LIQUID INJECTION AND EXTERNAL OIL COOLING
Minimum ISO viscosity grade	68	[4]100	68
Minimum viscosity index	45	33	45
Maximum pour point	-30 °C	-20 °C	-25 °C
Minimum specific gravity @ 15 °C	0.88		
Maximum water content	40 ppm		50 ppm
Acid number	<0.05		<0.15

[1]Including liquid injection oil cooling where the condensing temperature is below 45 °C.
[2]For condensing temperatures above 45 °C.
[3]All condensing temperatures.
[4]ISO grade 150 or 220 oil is preferred, where available and suitable for the system. Higher grades enhance compressor performance.

Table 3 Minimum Specification of Mineral Oils and Polyolester Lubricants

8.1. Lubricant Types

Refrigeration compressor lubricants can be divided into three categories:

8.1.1. Mineral Oils

These are the standard choice for use with R22 and R717 (ammonia) refrigerants. Use of an approved oil from Appendix 3 Approved Oils will ensure that viscosity and lubricity are maintained at an acceptable level when diluted with refrigerant at the temperatures and pressures encountered within the compressor.

There is a wide variation in the characteristics of the mineral oils listed in Appendix 3 Approved Oils, which should enable the refrigeration system designer to select the most appropriate characteristics to match the system requirements. Wax content or floc point is important in direct expansion systems, adequate miscibility to ensure a single phase oil/refrigerant mixture is required for R22 flooded evaporator systems, whilst for systems using R717 (ammonia) refrigerant a sufficiently low pour point is necessary.

8.1.2. Synthetic Lubricants

Synthetic lubricants can have completely different characteristics, depending on the type.

Polyolester (POE) lubricants are the only lubricants that are approved for use with the new HFC refrigerants such as R134a, and are selected to provide suitable miscibility with HFC refrigerants.

Because of the high refrigerant content in polyolester lubricant, the required viscosity grade is higher than that necessary with mineral oils.

NOTE: polyolester oils are very hygroscopic and, typically, saturate at approximately 1,000 parts per million (ppm) from atmospheric moisture; this is some ten times the saturation of a typical mineral oil.

Oil for use in the compressor and refrigeration system must be kept in properly closing containers. Exposure to atmosphere for extended periods may result in the oil becoming contaminated with moisture and dirt which can cause harmful reactions in the system. For similar reasons, oil reclaimed from the system should not be reused.

Polyalphaolefin (PAO) lubricants have low pour points and low vapour pressures, making them suitable for use with low temperature ammonia systems that can accept an immiscible refrigerant/oil combination. These oil types are partially miscible with R22 and are available in high viscosity grades with high viscosity indexes. PAO lubricants can, therefore, be used in suitably designed direct expansion R22 systems. J & E Hall International should be consulted before using PAO lubricants.

Alkylbenzene lubricants have good miscibility with R22 refrigerant and can assist in oil recovery in low temperature flooded R22 systems. However, their very high refrigerant content can reduce the performance of screw compressors and increase oil injection rates into the compressor. In order to maintain adequate viscosity, higher viscosity grades are required. Because of this, these lubricants should only be used with HallScrew compressors if no other lubricant type is compatible with the system and only after prior consultation with J & E Hall International.

Polyglycol lubricants are not approved for use in HallScrew compressors using halocarbon refrigerants. However, recent developments have produced polyglycols which are miscible with ammonia; these oils are being considered for use in direct expansion systems. If the use of this oil type is proposed, J & E Hall International should be approached for approval and advice on the most appropriate grade.

NOTE: these oil types typically saturate at levels some ten times higher than for polyolester oils. It is, therefore, even more important to keep exposure to the atmosphere at an absolute minimum.

8.1.3. Semi Synthetic Lubricants

These oil types can be further subdivided into synthetic/mineral oil blends and hydrotreated mineral oils. The former type consists of a blend of mineral oil and alkylbenzene lubricant, which attempts to combine the advantages of both oil types; some grades are approved for use with HallScrew compressors in R22 systems and are preferable to alkylbenzene types. Hydrotreated oils can be used with ammonia systems where their low pour points and low vapour pressure can prove advantageous.

9. Integration into the Refrigeration Circuit

The compressor is an oil injected screw type and the system must contain an oil separator of sufficient capacity. The system must be designed to return any oil carried over into the system from the separator, back to the compressor. The suction return to the compressor must be dry gas in order to achieve full performance. Liquid return will be detrimental to performance although unlike reciprocating compressor is not harmful to the compressor in small quantities. However large quantities of liquid or oil returned to the compressor via the suction line can form an incompressible fluid in the rotor flutes with resultant damage to the compressor. Thus the system must be designed to prevent such occurrences.

9.1. Oil System

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

9.2. 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.

9.2.1. 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.

9.3. 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.

9.3.1. 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 20 ^{o}C.

9.4. Liquid Injection Lines

Liquid injection lines should be constructed such that injection is uniformly distributed to the upper and lower connections. However, when compressor cooling loads are low it is permissible to inject liquid into the top liquid injection connection only.

9.5. Safety Requirements for Compressor Protection

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

10. Prolonged Storage

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

10.1. Placing the Compressor into Store

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

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

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

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

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

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

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

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

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

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

At the end of the period in store, the protective grease must be removed and the sealing faces inspected for damage prior to installing and running the compressor; refer to 10.2. Taking the Compressor out of Storage.

(c) Suitably protect the compressor mainshaft extension from moisture and external damage by coating the shaft with Shell Enis Fluid MD or a thin film of grease, then covering with a plastic or rubber sleeve. External fittings, if any, should also be protected from damage.

(d) Leak test the compressor at frequent intervals to ensure that it retains the holding charge of nitrogen; refer to the **NOTE** in step (b). If pressure gauges are fitted these can be checked for a decrease.

(e) Carry out any special instructions for the long term storage of the compressor drive motor (if supplied); refer to the manufacturer's instructions.

10.2. Taking the Compressor out of Storage

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

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

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

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

(b) Remove the protective sleeve from the compressor mainshaft extension. Clean off the grease or, if Shell Enis Fluid MD was used, use white spirit or similar solvent to remove the protective film.

(c) Dismantle the gland assembly. Carefully clean the protective grease from the seal faces. If the faces are in a satisfactory condition they should be lightly oiled and the gland reassembled; if they are damaged, a new seal must be fitted.

(d) If necessary, refit the compressor drive half coupling.

(e) Finish installing the compressor as described under 11. Installing the Compressor.

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

11. Installing the Compressor

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

If the compressor has been in prolonged storage, carry out the instructions described under 10.2. Taking the Compressor out of Storage, before installation takes place.

11.1. Lifting the Compressor

Attach lifting tackle to 2 x M20 eyebolts screwed into the top of the compressor casing as shown in Fig 12. A crane or block and tackle will be required to lift the compressor. Check that the lifting equipment is stout enough to take the weight by referring to Appendix 1 Physical Data, Limits of Operation and Safety Requirements.

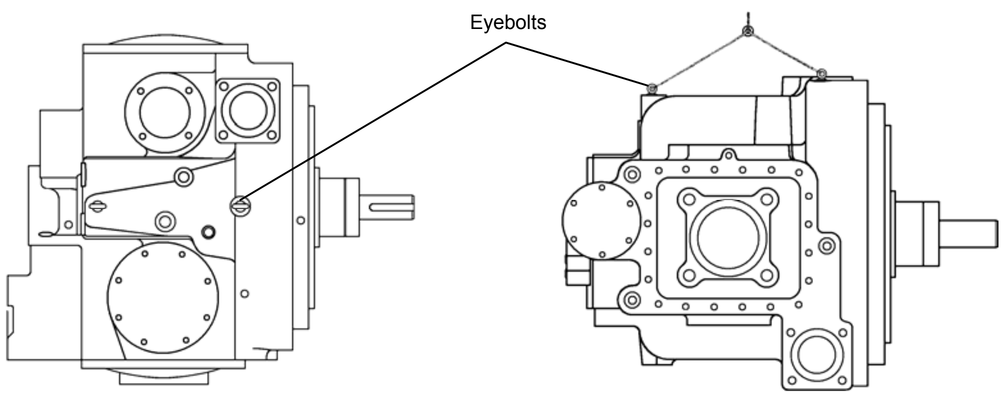


Fig 12 Lifting the Compressor

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

⚠ CAUTION

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

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

11.2. Making Connections

Pipeline connection sizes are detailed in Appendix 1 Physical Data, Limits of Operation and Safety Requirements.

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

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

(b) HSO 4200 series compressors use the same connection for liquid injection and the economiser facility. If the liquid injection/economiser facility is to be used, remove the blanking plugs from the connections. Connect the liquid injection and/or economiser lines to the ports.

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

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

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

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

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

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

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

(g) Rotate the mainshaft by hand to ensure that the motion-work turns smoothly and evenly.

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

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

⚠ WARNING

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

(i) Make electrical wiring connections as described in 11.3.

(j) Leak test and evacuate the system as described in 11.4

11.3. Electrical Wiring Connections and Interlocks

Make the following wiring connections and interlocks:

- Mains electrical supply to the compressor drive motor and motor starter. Refer to the motor and starter manufacturer's instructions.
- Electrical supply to the discharge high temperature thermistors; refer to 11.3.1. Thermistors.
- Electrical supply to the capacity control solenoid valves, these are marked 'load' and 'unload'; refer to Fig 14.
- Electrical supply to the capacity control slide valve position transducer; refer to 4.3. HB Linear Variable Displacement Transducer (HBLVDT).
- Electrical interlock to prevent the compressor starting unless the slide valves are at minimum load; refer to 4.1.1. Minimum Load Interlock.

11.3.1. Thermistors

Discharge high temperature thermistors are fitted as standard and should be wired as illustrated Fig 13.

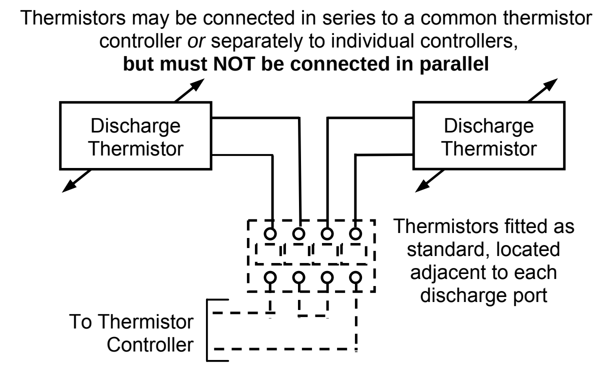


Fig 13 Discharge Thermistor Wiring

11.3.2. Capacity Control Solenoids

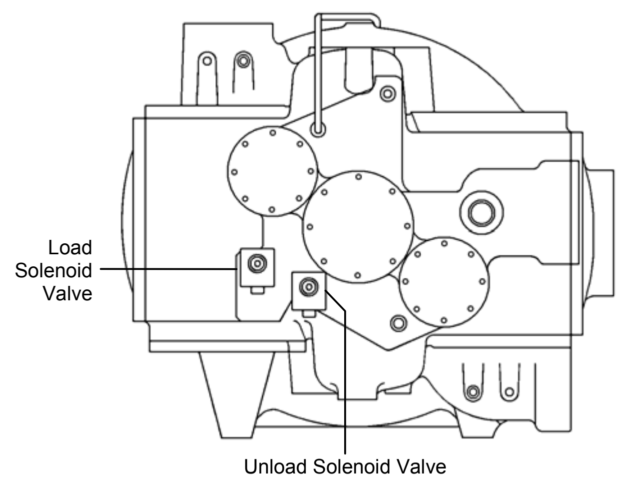


Fig 14 Capacity Control Solenoids

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 gauge pressure, etc.

Power must be supplied to the solenoid via a suitable pulse timer that must be capable of supplying a minimum pulse length of ≥0.5 second.

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.

11.4. Leak Testing, Evacuation and Charging

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

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

(a) Before the compressor/system evacuation process commences, energise (open) capacity control solenoid valve A; refer to Fig 2. Check that the compressor oil injection line is open to the system.

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

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

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

(e) Charge the system with refrigerant.

(f) Start the compressor for the first time; refer to 12. Commissioning and Operation. Carefully run in the compressor; refer to 13. Running-In the Compressor.

12. Commissioning and Operation

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

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

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

12.1. Checks Prior to the First Start

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

12.2. General Checks

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

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

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

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

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

⚠ CAUTION

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

- The discharge high temperature thermistor protection circuit, otherwise the thermistor will be damaged (these thermistors are supplied with the compressor). Thermistors for high temperature protection may also be fitted in the compressor drive motor windings and/or oil injection/lubrication line.
- Any part of the control system containing semi-conductor devices.

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

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

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

Repeat this check for thermistors that may be fitted in the compressor drive motor windings and/or oil injection/lubrication line.

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

12.3. Compressor Drive Motor

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

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

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

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

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

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

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

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

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

12.4. Checking Compressor Rotation

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

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

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

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

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

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

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

(d) Switch on the drive motor and check the direction of rotation. When looking on the end of the motor drive shaft the shaft should turn in an anti-clockwise direction.

(e) With the motor running, check that all safety controls operate at their correct settings and stop the drive motor.

(f) Stop the motor and isolate the electrical supply to prevent it accidentally restarting.

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

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

Refit the membrane/spacer assembly and coupling guard.

12.5. Lubrication System

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

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

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

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

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

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

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

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

(d) If the system is fitted with an oil pump, start-up or continuously running, start the pump and check it rotates in the correct direction.

Check and, if necessary, set the oil differential pressure regulator to relieve at 2.5 bar to 3.0 bar.

Stop the oil pump.

12.6. First Start

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

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

(b) Open the suction and discharge stop valves.

⚠ WARNING

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

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

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

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

(e) Check the following:

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

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

(g) Start the compressor.

The following descriptions refer to applications using oil differential pressure switches to sense system pressures.

No Oil Pump

After the compressor has started and been in operation for a short time, allowing sufficient time for the system pressure differential to become established, ODPS is brought into circuit. Oil is now being supplied to the compressor under the action of the system pressure differential monitored by ODPS. If the system pressure differential falls below the switch contacts open setting, ODPS will trip and stop the compressor motor.

Start-up Oil Pump

The oil pump starts before the compressor.

When sufficient oil pressure differential is available between the oil reservoir outlet and the pump delivery, i.e. at least 1.5 bar, contacts of ODPS2 close allowing the compressor start sequence to proceed.

After the compressor has started and been in operation for a short time, allowing sufficient time for the system pressure differential to become established, the oil pump is stopped and ODPS2 electrically bypassed.

At the same time ODPS1 is brought into circuit. Oil is now being supplied to the compressor under the action of the system pressure differential monitored by ODPS1. If the system pressure differential falls below the switch contacts open setting, ODPS1 will trip and stop the compressor motor.

Continuously Running Oil Pump

The oil pump and compressor start together.

Providing the drain line is clear of oil, the oil pump and compressor start together. ODPS is brought into circuit after allowing sufficient time for the oil pump to start and contacts of ODPS to close. ODPS will stop the compressor unless the oil differential pressure has risen to 1.5 bar during the start period, and continues to monitor this differential all the while the plant is in operation.

Demand Oil Pump

The demand oil pump, controlled by the Fridgewatch 2000 Controller, enables the system to run for most of the time without an oil pump, but if system pressure difference falls the oil pump runs as necessary. For a full description of operation refer to instruction manual 3-55 for the Fridgewatch 2000 Controller, available from J & E Hall International.

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

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

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

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

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

(j) Calibrate the HBLVDT 4 to 20 mA slide valve position signal for maximum and minimum load; refer to 4.3. HB Linear Variable Displacement Transducer (HBLVDT).

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

(l) Run-in the compressor; refer to 13. Running-In the Compressor.

12.7. Normal Starting and Running

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

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

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

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

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

⚠ WARNING

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

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

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

(e) Begin the compressor start sequence.

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

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

NOTE: in the case of prolonged shutdown periods, the procedures described under 15.8.9. Prolonged Shutdown should be followed.

12.8. Adding Oil to the System

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

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

Acid test all oil before adding it to the system; even new oil has been known to fail this test. Refer to Table 6.

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

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

13. Running-In the Compressor

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

13.1. Filters and Strainers

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

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

13.1.1. Compressor Suction Strainer

To prevent an excessive accumulation of dirt in the suction strainer, which would reduce the compressor's pumping efficiency, it is important to remove and clean the strainer basket during the plant's initial period of operation; suggested intervals are after 12 compressor operating hours and again at the end of 200 hours. If the strainer is partially choked with dirt when first cleaned, indicating that the system is particularly dirty, an additional cleaning after 100 hours may be necessary.

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

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

13.1.2. Oil Filters

HallScrew HSO 4200 series compressors are fitted with an integral oil filter, and may also be fitted with a separate external oil filter; refer to Table 1.

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

NOTE: if an external oil filter is used, the integral oil filter can be retained for initial commissioning and then removed at the end of 12 compressor operating hours, together with the internal oil filter locating spigot piece.

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

13.1.3. Changing the Compressor Integral Oil Filter

⚠ WARNING

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

⚠ WARNING

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

(b) Position a suitable container underneath the filter housing to catch the escaping oil.

(c) Unscrew and remove the capscrews securing the filter cover. Lift away the cover and joint.

(d) Remove and discard the dirty filter element.

Use a wad of lint free rag to remove any dirt, sediment etc., from inside the filter housing.

(e) Locate the new filter element over the spigot piece.

(f) Position a new joint onto the joint face on the filter housing.

Locate the filter cover. Insert the capscrews, tightening them evenly and alternately so that the cover is retained by even tension.

(g) Reinstate the electrical supply to the control panel and compressor drive motor.

(h) Restart the compressor. Check the filter cover for leaks.

13.1.4. Refrigerant Filter/Drier

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

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

13.2. Monitoring for Moisture

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

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

13.3. Lubricating Oil

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

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

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

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

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

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

13.4. Checking for Leaks

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

13.5. Compressor Drive Motor Coupling

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

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

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

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

13.6. Compressor and Drive Motor Holding-Down Bolts

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

14. Pumping Down and Opening Up the Compressor

⚠ WARNING

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

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

If a mechanical failure is suspected within the compressor, proceed to 14.3. Isolating the Electrical Supply, omitting the pumping down procedure.

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

14.1. Preparing for Pump Down

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

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

Close the discharge gauge valve and disconnect the gauge line. Connect a suitably sized refrigerant recovery unit to the gauge valve connection. If the system uses ammonia refrigerant, the recovery unit must be compatible for operation with this primary refrigerant.

14.2. Pumping Down the Compressor

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

Start and run the compressor.

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

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

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

14.3. Isolating the Electrical Supply

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

⚠ WARNING

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

14.4. Removing the Residual Refrigerant Gas

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

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

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

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

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

14.5. Opening up the Compressor

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

⚠ WARNING

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

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

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

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

Reassemble the compressor using the original or replacement components. New gaskets, 'O' rings and a new oil filter element must be used; refer to 7.8. External Oil Filter.

14.6. Re-instating the Compressor

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

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

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

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

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

Replace the mains fuses and reinstate the power supply.

Recommission the compressor; refer to 12. Commissioning and Operation.

15. Maintenance

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

15.1. Personnel Permitted to Maintain the Plant

It is essential that only authorised and competent personnel are allowed to open up the plant for maintenance, inspection or repair, or carry out any procedure which involves handling refrigerant or oil. A permit to work system should be introduced when the plant is commissioned and rigorously enforced thereafter.

Maintenance and repair work requiring the assistance of other skilled personnel, for example, welders, electricians, should only be undertaken under the supervision of a person competent in refrigeration.

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

⚠ WARNING

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

15.2. Maintenance and Repair

The refrigerating plant must be inspected regularly, supervised and properly maintained.

Maintenance must be undertaken in such a way that:

- Accidents to personnel are minimised.
- Damage to goods is prevented.
- System components remain in good working order.
- The purpose and availability of the system are maintained.
- Any leakage of refrigerant or oil is quickly identified and remedied.
- Wastage of energy is minimised.

15.2.1. General

Keep the plant and its surroundings clean and free of dirt, rubbish and debris. Accessibility must not be impaired.

It is essential that air, moisture and dirt should be prevented from entering the system. These three items, together with leakage of refrigerant, are major causes of failure in refrigeration plants.

When removing components from the system, for maintenance, renewal or any other reason, always thoroughly dry and warm the article and surrounding parts. Scrupulous care must be taken to blank open connections to the system as rapidly as possible.

After the final quantity of refrigerant charge has been established during commissioning, additional refrigerant is only required to replace leakage from faulty joints, etc. Before charging refrigerant, find and repair the leak. Refer to Part G : Charging with Refrigerant, and the publication for the refrigerant in Section 5.

For plants installed within the ECC, also refer to Maintenance and Repair in BS EN 378-4 : 2000.

15.2.2. Plant Integrity

As far as practicable, those parts of the plant which are not insulated should be examined for damage and corrosion. Damage must be repaired, corrosion removed, the surfaces cleaned, primed and repainted to the original specification; refer to Paint Finishes in Part C : Installation.

Insulated parts of the plant, especially piping, components and vessels subject to system pressure, should be visually inspected for damage and repaired as required. Pay particular attention to the condition of insulation vapour seals. Condensation can result in serious corrosion of the system, especially low pressure pipework and plant. This can progress unnoticed under lagging which is not effectively vapour sealed and is particularly rapid on plants which run intermittently and cycle through 0 °C.

The above maintenance procedure should form part of the 'written scheme of examination', a statutory requirement for plants installed within the United Kingdom; refer to 15.2.3. Examination of Pressure Systems.

15.2.3. Examination of Pressure Systems

Statutory regulations within the United Kingdom, principally The Pressure Systems and Transportable Gas Containers Regulations 1989 Part III Pressure Systems, require the user to produce a 'written scheme of examination', prepared by a competent person, to cover all parts of the plant subject to pressure and all protective devices. The nature and frequency of examination, peculiar to the plant, is determined by the competent person who draws up the scheme.

It is a requirement that the scheme be introduced before the plant is put into operation for the first time, and must be maintained for the life of the plant. Within the United Kingdom, any modifications to the plant **MUST** comply with The Pressure Systems and Transportable Gas Containers Regulations 1989. The written scheme of examination must be reviewed by the competent person and any modifications incorporated.

For plants not covered by UK legislation, or located outside the UK and not covered by local or national regulations or insurance requirements, it is still recommended that the plant be thoroughly examined by a competent person at regular intervals. How often it is necessary to make these checks depends on the plant operating conditions, the surrounding environment and the location, for example, on land or at sea.

15.2.4. Strength and Leak Testing

Following completion of any repair or modification to the system, after a change in use has occurred, or when the plant has been out of commission for more than two years, carry out the procedures described under Modifications to the Plant After Commissioning in Part D : Strength and Leak Testing.

15.2.5. Pressure Gauges, Safety Instruments and Controls

Pressure gauges and all instruments and controls installed as safety measures must be maintained in good working order and should be regularly checked, particularly after work has been carried out on the system.

15.2.6. Stop Valves and Relief Valves

Valve spindles should be kept clean and lightly oiled. If there is a leak of refrigerant or oil that cannot be cured by tightening the gland nut, it must be repacked. Capped valves should have their caps firmly in position to prevent tampering, loss of refrigerant or the entry of air and moisture.

Atmospheric relief valves and other external pressure relief devices should be tested as required by the manufacturer or insurance organisation, but at least every five years. After a pressure relief valve which discharges to atmosphere has been actuated, it should be replaced if it is not tight.

15.2.7. Repair of System Faults and Refrigerant Leaks

System faults and refrigerant leaks should be repaired promptly. If this cannot be done by the operating staff, a competent refrigeration service engineer should be instructed to repair the defect.

Every effort must be made to prevent refrigerant leakage and identify and remedy leaks as soon as they occur; refer to Leak Detection in the publication for the refrigerant in Section 5.

15.2.8. Repairs (Use of Arc and Flame Producing Equipment)

No repair work should be carried out until the following precautions have been taken:

- Isolation of the sections to be repaired, removal of all refrigerant (liquid and gas) and purging with inert gas; refer to 14. Pumping Down and Opening Up the Compressor.
- If the plant is installed indoors, the plant room must be thoroughly ventilated; run the ventilation fans if these are fitted. Doors and windows must be kept open during the repair.
- The presence of a second person for observation and assistance.
- Availability of protective equipment and, in the case of naked flames or arcs, fire extinguishing equipment ready to hand.

All non-routine work on systems containing liquid or gaseous hazardous refrigerants, for example, toxic, flammable, should be subject to a strict permit to work system under the control of a person who is fully aware of the potential hazards and the precautions required; refer to 15.1. Personnel Permitted to Maintain the Plant.

Work with a naked flame or arc should not be carried out on any system or equipment that contains, or has contained, flammable materials until all such materials (including vapours, oils and residues) have been either completely removed from the system or equipment or, alternatively, rendered non-flammable. Inert gas used for purging should be vented down to atmospheric pressure before burning or welding begins.

15.2.9. Decommissioning

The following references are to the publication for the refrigerant in Section 5.

- The precautions and procedures detailed under General Safety Considerations must be observed at all times.
- When decommissioning, as much as possible of the refrigerant should be transferred to suitable containers, using recovery equipment if required; refer to Pumping Down, Recovering Refrigerant Charge.

- Surplus or unusable refrigerant should either be recycled for reuse, be returned to the original supplier or similar organisation for reprocessing, or be disposed of as special waste through an organisation licensed for the disposal of hazardous waste. For transport and storage purposes suitable containers should be used and these should be appropriately labelled; refer to Disposal of Refrigerant.

15.3. Plant Maintenance Record (Log Book)

It is recommended to produce a plant maintenance record. This record can be a separate document or part of the plant performance record; refer to Appendix 6 Plant Performance Record.

The plant maintenance record should contain the following information as a minimum requirement:

- Itemised check list based on Table 5. Upkeep of the Written Scheme of Examination should be included as part of the maintenance requirement; refer to 15.2.3. Examination of Pressure Systems.
- Details of maintenance and repair work. This should include details of changes to and replacement of components. Component test certification should be included, if applicable.
- The quantities of refrigerant and oil which have been charged into the system, and the quantities of refrigerant and oil removed. If refrigerant or oil has been analysed, the results should be kept in the log book.
- The results of all periodic routine tests.
- Significant periods when the plant has been out of commission.

All entries into the maintenance record should include the date and time the work was carried out and the person and organisation responsible.

The maintenance record should always be available so that the plant's maintenance status can be easily checked.

⚠ WARNING

The plant should not be run unless all maintenance procedures are fully up to date. Failure to maintain the plant correctly may result in damage to the plant and possible injury to personnel.

15.4. Spare Parts

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

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

⚠ WARNING

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

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

- Material certification. The component is suitable for use with the system refrigerant, lubricating oil and secondary refrigerant (if used).
- Pressure test certification. The component is capable of withstanding the pressures likely to be encountered within the system.
- For plants located within the European Economic Area (EEC), components subject to pressure must, where necessary, be certified that they comply with the Pressure Equipment Directive (PED).
- Pressure relief devices require certification that they open at the set pressure and discharge at the required rate.

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

Obtain spare parts from the address below:

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

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

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

Refer to Appendix 5 HallScrew Spares Kits for details of compressor spares kits.

15.5. Filters and Strainers

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

Change the compressor oil filter element and clean strainers at the end of the first 200 hours operation, then at the intervals specified in 15.7. Maintenance Schedule. Experience of running the plant may suggest that strainers require cleaning at shorter intervals.

Filter and strainer locations for the compressor and oil support system are detailed in Table 4. Refer to the plant instruction manual for the location of filters and strainers in the refrigerant and cooled medium lines.

15.6. Running-in

At the end of the commissioning period, the running-in procedures, described under 13. Running-In the Compressor, must been carried out during the first 200 hours of operation.

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

Location	Filter or Strainer	[1]Publication for Cleaning Instructions
Compressor suction line.	Danvalve strainer	4-131
Compressor liquid injection line - *liquid injection cooling fitted*. Economiser (subcooler) line before the solenoid valve and thermostatic expansion valve - *if economiser fitted.*	Danfoss FA strainer	4-168
Compressor discharge line - if separate secondary oil separator fitted.	Domnick Hunter secondary oil separator coalescing elements	-
Compressor discharge/suction pressure relief, shutdown bypass line - *if fitted.*	[2]Danfoss PM 3 or Hansen HA4A main valve	4-22 or 4-220
Oil line before oil pump suction - if continuously running or demand oil pump fitted.	Herl right-angle strainer	4-67
[3]Compressor integral oil filter	13.1.3 Changing the Compressor Integral Oil Filter	-
[3]External oil filter Oil line after oil separator - *if no oil pump fitted.* Oil line before oil pump suction - *if start-up oil pump fitted.* Oil line after oil pump delivery - *if continuously running or demand oil pump fitted.*	[3]Fairy Arlon oil filter	4-115

[1]These publications can be found in the J & E Hall International instruction manual for the plant.
[2]Strainer forms integral part of main valve.
[3]If it is necessary to fit an external oil filter, the integral oil filter must be removed at the end of 12 compressor operating hours, together with the internal oil filter locating spigot piece; refer to 13.1.2. Oil Filter.

Table 4 Filter and Strainer Locations

15.7. Maintenance Schedule

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

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

Kits of parts, including instructions, are available from J & E Hall International to perform most of the compressor servicing operations described in the schedule.

Refer to Appendix 5 HallScrew Spares Kits for details.

15.8. Maintenance Intervals

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

15.8.1. Daily

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

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

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

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

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

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

The specimen log sheet illustrated in Appendix 7 Plant Performance Record shows the minimum number of readings which should be taken to enable an accurate assessment of the plant's performance to be made. In the case of a very large plant, many more readings need to be logged to complete the overall picture.

Particular attention should be paid to the following readings:

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

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

15.8.2. Weekly

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

While checking for leaks, inspect the exterior of the plant for damage or corrosion; refer to 15.2.2. Plant Integrity.

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

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

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

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

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

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

⚠ WARNING

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

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

15.8.3. Monthly

(a) Check the operation of the compressor capacity control system; refer to 4.3. HB Linear Variable Displacement Transducer (HBLVDT).

(b) If a Domnick Hunter secondary oil separator is fitted in the discharge line, check the pressure drop across the secondary oil separator. If the pressure drop exceeds 0.7 bar, change the filter elements.

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

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

For all plants *other* than those charged with ammonia (R717), record the acid content in Table 6.

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

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

(c) Renew the oil filter element(s).

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

For details of the oil filter, including the procedure for changing the external filter element, refer to publication 4-115 in Section 4.

(d) Clean strainers throughout the system; refer to Table 4.

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

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

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

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

For details of the refrigerant filter/drier, including the procedure for changing the drier cores, refer to publication 4-01 in Section 4.

For details of the refrigerant sight-glass/moisture indicator, refer to publication 4-04 in Section 4.

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

(f) Remove the membrane/spacer assembly from the compressor drive coupling. Examine the membrane spigots closely for signs of cracking, fretting or other wear. If any damage is evident a new membrane/spacer assembly should be fitted.

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

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

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

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

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

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

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

(c) Oil separator with single stage oil separation.

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

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

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

⚠ WARNING

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

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

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

(d) Renew the compressor drive coupling membrane/spacer assembly.

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

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

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

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

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

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

Examine the stars. Renew if damaged or worn.

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

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

(a) Pump down the compressor and isolate the compressor and oil separator/reservoir. The procedure to follow is described under 14. Pumping Down and Opening Up the Compressor.

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

15.8.9. Prolonged Shutdown

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

⚠ WARNING

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

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

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

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

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

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

15.9. Maintenance Check List

Table 5 illustrates the maintenance schedule as a 'Check List'.

PARA	DAILY	✓
15.8.1.	Check the oil separator/reservoir oil level.	
	Check and record system temperatures, pressures and flow rates.	
PARA	**WEEKLY**	✓
15.8.2.	Check for leakage of refrigerant and oil. Inspect the exterior of the plant for damage or corrosion.	
	Check valve caps are in place.	
	Check the sight-glass/moisture indicator for the presence of moisture.- *not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.*	
	Drain off any oil which has collected in the LP side of the system - *applicable to plants charged with ammonia (R717),* ***not*** *applicable to other refrigerants.*	
	On multi-compressor applications, changeover the role of lead, lag and/or standby compressor	
PARA	**MONTHLY**	✓
15.8.3.	Check the compressor capacity control system operates correctly	
	Check the pressure drop across the secondary oil separator - *separate secondary oil separator fitted in the discharge line*	
PARA	**EVERY YEAR, OR AT INTERVALS OF 5,000 OPERATING HOURS**	✓
15.8.4.	Check the condition of the system oil charge, renew if necessary	
	Renew the oil filter element(s)	
	Clean strainers throughout the system	
	Renew the refrigerant filter/drier cores - *not usually applicable to plants charged with ammonia (R717), applicable to all other refrigerants.*	
	Check pressure and temperature safety controls operate correctly	
	Check the condition of the coupling membrane/spacer assembly	
	Check the tightness of the fastenings securing the compressor and motor mountings	
	Check for air in the system. Check more frequently if operating conditions are such that the pressure in the suction line is below atmospheric.	
PARA	**EVERY 3 YEARS, OR AT INTERVALS OF 15,000 OPERATING HOURS**	✓
15.8.5.	Renew the system oil charge	
	Check the condition of the coalescing elements in the oil separator - *oil separator fitted with coalescing elements for two stage oil separation*	
	Renew the compressor drive coupling membrane/spacer assembly	
PARA	**EVERY 6 YEARS, OR AT INTERVALS OF 25,000 OPERATING HOURS**	✓
15.8.6.	Remove side covers, inspect the compressor	
PARA	**EVERY 12 YEARS, OR AT INTERVALS OF 50,000 OPERATING HOURS**	✓
15.8.7.	Examine the star bearings and main bearings. Renew if in doubt.	
	Examine the stars. Renew if damaged or worn.	
	Check the capacity control mechanism for 'drifting'	
PARA	**EVERY 24 YEARS, OR AT INTERVALS OF 100,000 OPERATING HOURS**	✓
15.8.8.	Dismantle the compressor and check parts for damage or wear. Renew the main bearings.	
REFERENCE TO OTHER MAINTENANCE SCHEDULES		
15.2. Maintenance and Repair.		
Grease compressor drive motor bearings according to the motor manufacturer's instructions.		

Table 5 Maintenance Check List

15.10. Oil Acid Content Record

Plants charged with refrigerant other than ammonia (R717).

Each time the oil's acid content is checked, record the value in Table 6.

ACID CONTENT	SIGNATURE	PRINTED NAME	DATE

Table 6 Oil Acid Content Record - Plants Charged with Refrigerant *other* than Ammonia (R717)

Appendix 1 Physical Data, Limits of Operation and Safety Requirements

Compressor Model Nomenclature

HS O 4 2 X X X X X

Solenoid Voltage

1 = 115 V 1 ph 50/60 Hz
2 = 230 V 1 ph 50/60 Hz

Refrigerants

A = R134a
B = R22
C = R407c
D = Not allocated
E = R507
F = R404a
G = Not allocated
H = R717 (ammonia)

For other refrigerants refer to J & E Hall International.

Lubricating Oil

E = Ester oil
M = Mineral oil

Capacity Control Slide Valve V_R

2 = 2.2 V_R
3 = 3.0 V_R
4 = 4.9 V_R

Compressor

21, 22 or 23
2 = Twin star
4 = Series 4000

Application

O = Open drive

HallScrew

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

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

Physical Data

Compressor Type	Single screw.
Compressor Rotation	Clockwise looking on the motor (driven) end. Under no circumstances should the compressor run in the reverse direction.
Method of Drive	Direct coupled to foot mounted drive motor.
Speed Range	1500 to 4000 rpm.
Physical Dimensions	Refer to Physical Dimensions and Connections
Weight	460 kg (all models).
Capacity and Power	Refer to selection data.
Capacity Control	Compressor capacity infinitely variable from 100 % to approximately 25 % of full load (depends on the operating conditions). Slide valve position indication by 4 to 20 mA Linear Variable Displacement Transducer (LVDT). DIN plug terminal box rating IP65.
Capacity Control Solenoids	115 V or 240 V ac (other voltages available on request). Terminal box rating IP65.

Swept Volume	**Swept Volume (m^3/hr)**	**HSO 4221**	**HSO 4222**	**HSO 4223**
	Compressor running @ 50 Hz (2 pole speed)	508	616	722
	Compressor running @ 60 Hz (2 pole speed)	609	739	866

[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 4221	81	62	73	73	77	75	69	62
	HSO 4222	82	62	74	74	79	76	70	63
	HSO 4223	83	61	75	75	80	77	71	64

[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.

Limits of Operation

Pressure Limits

The pressure limits detailed below **MUST NOT** be exceeded during installation, commissioning or operation of the plant.

			R717	R404A	R507
[1]Maximum Design Pressures	[2]High side		32.8 bar g	32.8 bar g	32.8 bar g
	Low side		14.8 bar g	14.8 bar g	14.8 bar g
[3]Operational Pressures	Maximum compressor operating suction pressure	2.2, 2.6 or 3.5 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 compressor operating discharge pressure		29.0 bar g	29.0 bar g	29.0 bar g
	Maximum compressor operating pressure differential (discharge – suction)		20.0 bar	23.1 bar	23.1 bar
	Minimum compressor operating pressure differential at minimum load (refer to operational envelope for further details)		3.0 bar	3.6 bar	3.6 bar
			R22	**R134A**	**R407c**
[1]Maximum Design Pressures	[2]High side		32.8 bar g	23.6 bar g	32.8 bar g
	Low side		14.8 bar g	10.1 bar g	14.8 bar g
[3]Operational Pressures	Maximum compressor operating suction pressure	2.2, 2.6 or 3.5 V_R	6.0 bar g	3.5 bar g	6.0 bar g
		4.9 V_R	4.0 bar g	3.5 bar g	4.0 bar g
	Maximum compressor operating discharge pressure		29.0 bar g	19.4 bar g	29.0 bar g
	Maximum compressor operating pressure differential (discharge – suction)		20.0 bar	17.5 bar	26.0 bar
	Minimum compressor operating pressure differential at minimum load (refer to Appendix 3 Limits of Operation Envelopes for further details)		3.0 bar	2.0 bar	3.0 bar

Temperature Limits

For normal refrigeration and air conditioning applications, the following temperature limits should be observed.

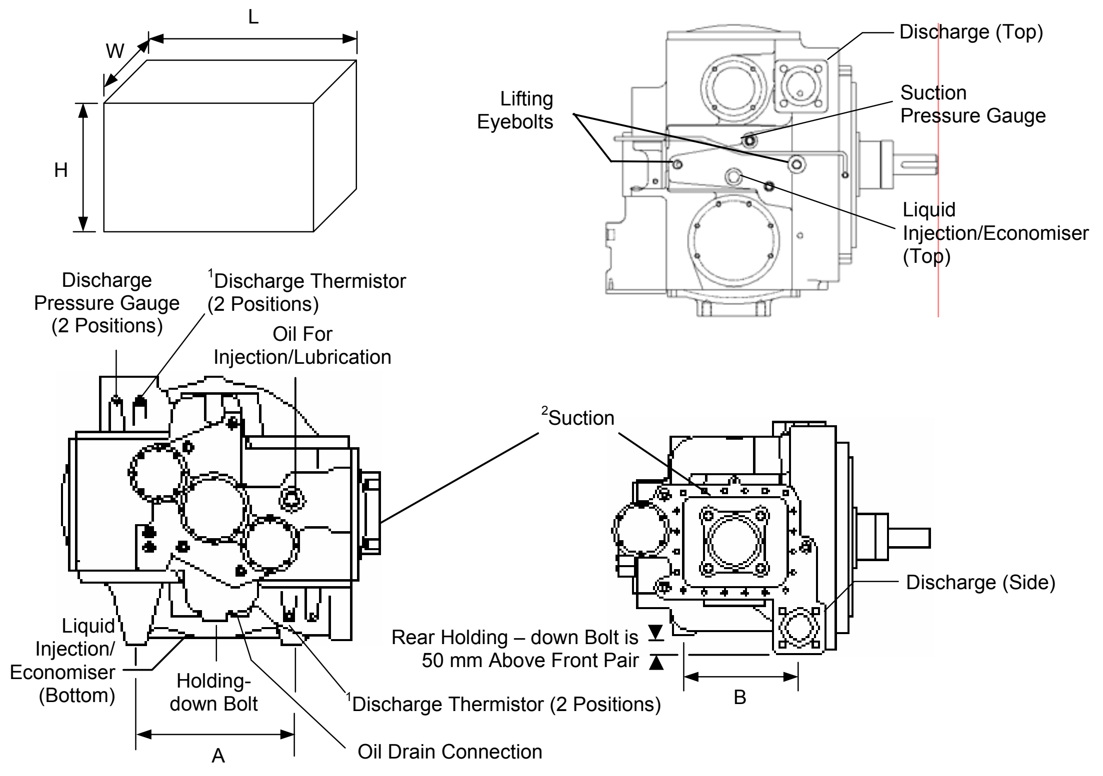
Temperature Limits With Liquid Injection Oil Cooling (Standard)	Discharge temperature	100 °C (standard) 120 °C (special)
	Discharge minimum superheat	20.0 °C
Temperature Limits With External Oil Cooling	Discharge temperature	100 °C
	Discharge minimum superheat	[4]20.0 °C

[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]In conformity with EEC standards, system relief valve opens.
[3]Oil separator pressure limits may be less than those applicable to the compressor.
[4]For values below 20.0 °C contact J & E Hall International.

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, refer to Physical Dimensions and Connections
Discharge pressure	Low	Pressure control or pressure transducer and programmable controller with suitable analogue inputs	According to the operating conditions	-
Discharge temperature	High	Thermistors (fitted as standard, located adjacent to each discharge port)	100 °C (standard) 120 °C (special)	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
		Alternative method: Differential pressure switch	Differential equal to highest operational suction pressure	-
Oil differential pressure 2 Discharge pressure - oil injection/lubrication pressure	High	Differential pressure switch or programmable controller with suitable analogue inputs	2 bar (max)	30 second delay required on starting only
Oil separator oil level	Low	Level switch or sensor	Trip on low level	Time delay (5 secs max) required during operation to prevent spurious trips
Oil temperature	High	Thermistor or HT cut-out	80 °C	Mandatory requirement if compressor fitted with external oil cooling

HSO 4200 Series Physical Dimensions and Connections



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

	DESCRIPTION			**SIZE**
Dimensions	Overall	Length	L	745 mm
		Height	H	546.5 mm
		Width	W	655 mm
	Holding-down bolt centres		A	320 mm
			B	652 mm
	Holding-down bolt		-	3 off M12 x 50 mm
	Lifting eyebolts		-	2 x M20

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

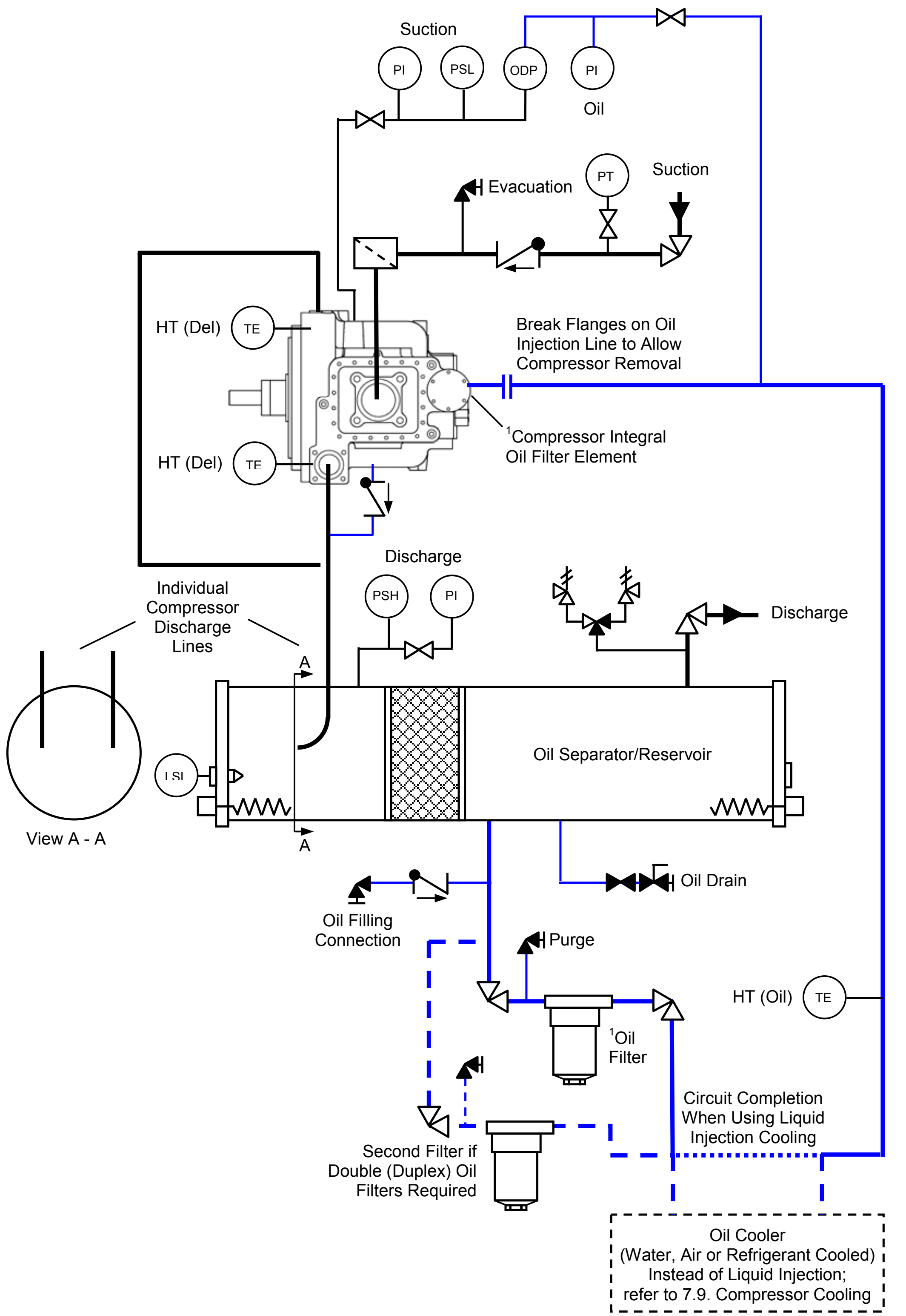
[1]Both discharge high temperature thermistors must be used, wired in series; refer to Fig 13.
[2]Suction can be taken from either side of the compressor.

Appendix 2 Oil Support System Schematic Flow Diagrams

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

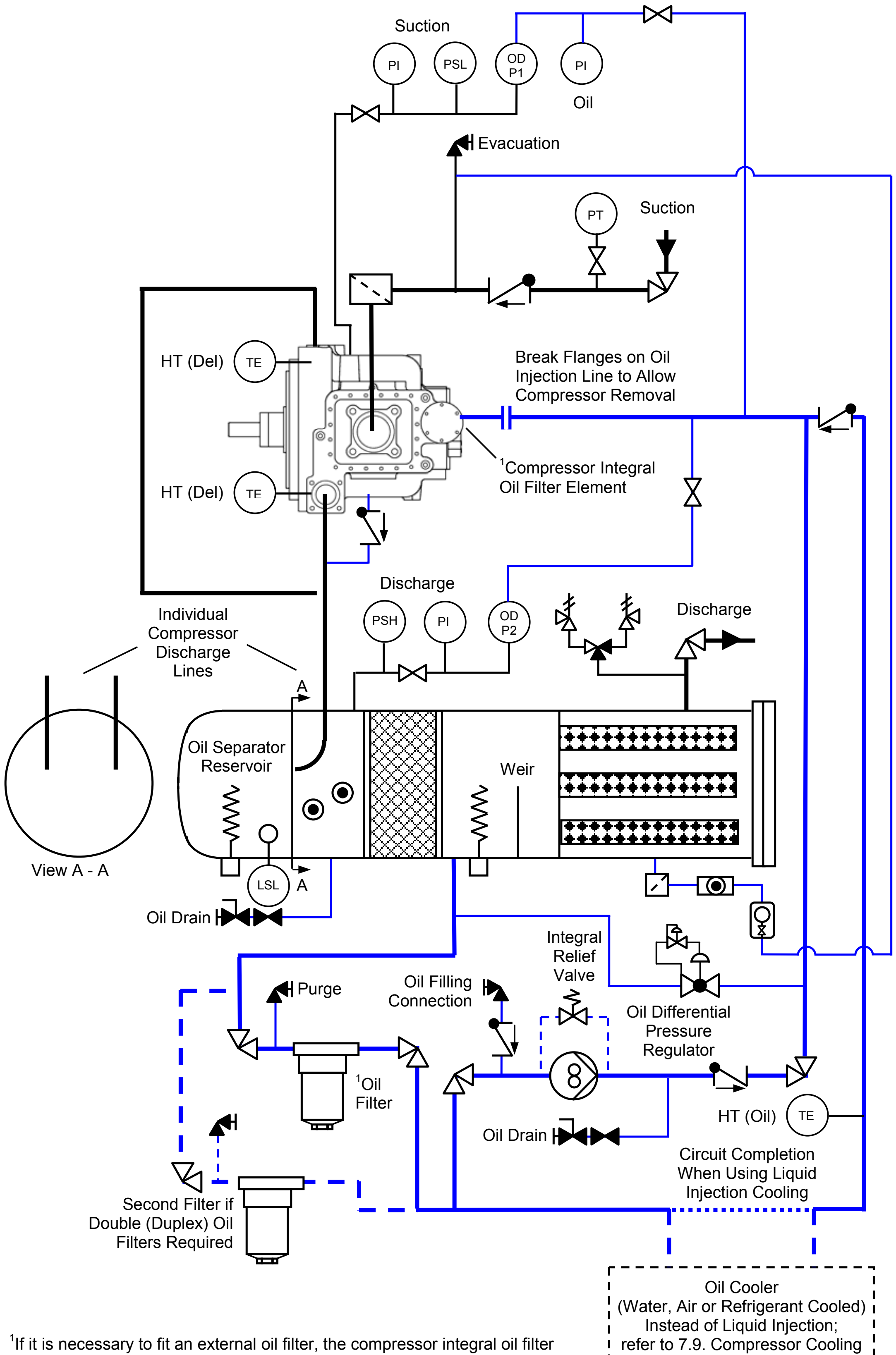
	Ball valve		Non-return valve
	Quick-acting drain valve, normally closed and capped		Control valve
	Relief valve		Solenoid valve (normally open)
	Relief valve (to atmosphere)		Solenoid valve (normally closed)
	Dual relief valve (to atmosphere)		Thermostatic expansion valve
	Sight-glass (on vessel)		Liquid drainer
	Sight-glass (in line)		Heater
	Strainer	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 15 Key to Fig 16, 17 and 18



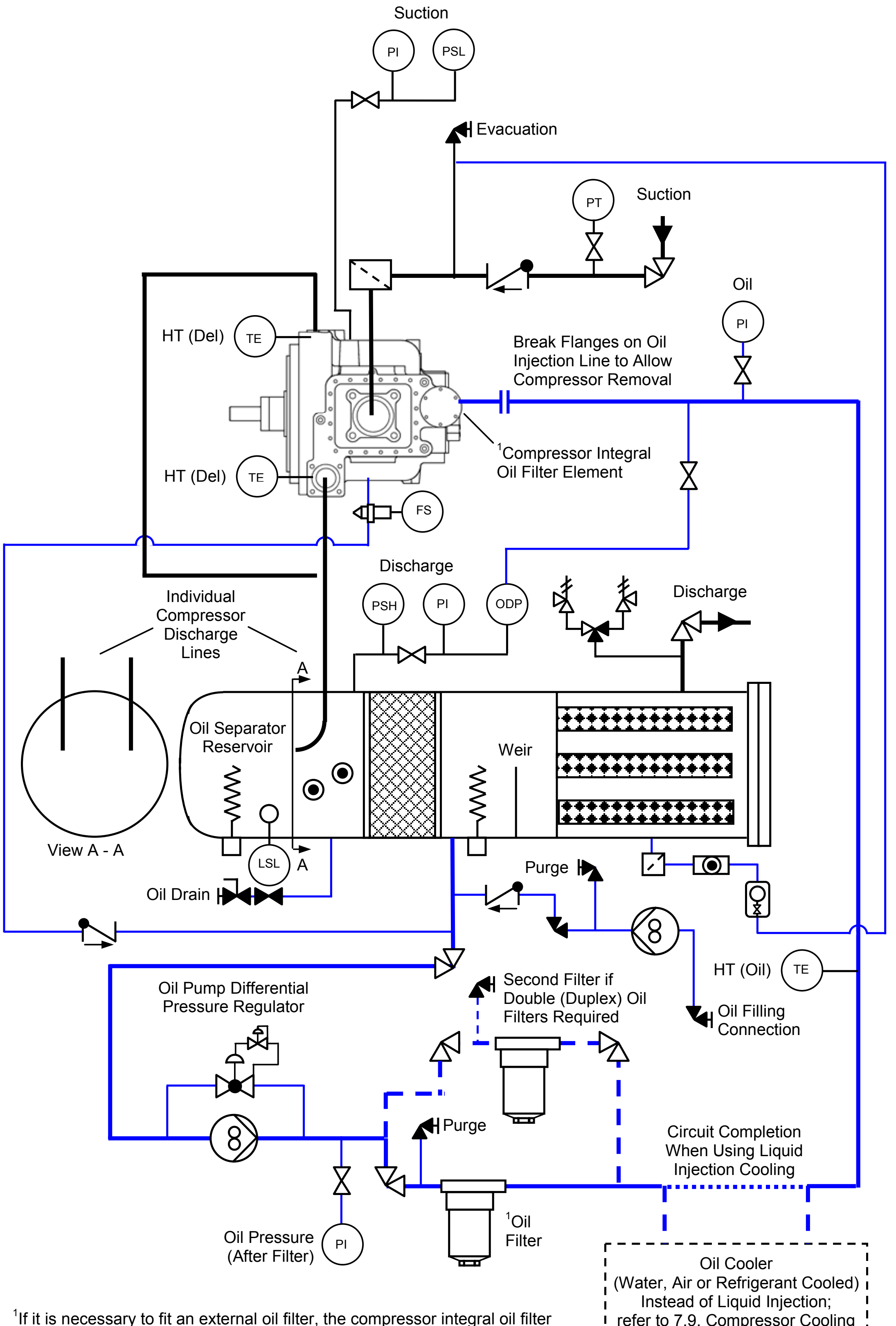
[1]If it is necessary to fit an external oil filter, the compressor integral oil filter element must be removed after commissioning; refer to 13.1.2. Oil Filters.

Fig 16 HSO 4200 Oil Support System - No Oil Pump



[1]If it is necessary to fit an external oil filter, the compressor integral oil filter element must be removed after commissioning; refer to 13.1.2. Oil Filters.

Fig 17 HSO 4200 Oil Support System - Start Up Oil Pump



[1]If it is necessary to fit an external oil filter, the compressor integral oil filter element must be removed after commissioning; refer to 13.1.2. Oil Filters.

Fig 18 HSO 4200 Oil Support System - Continuously Running Oil Pump

Appendix 3 Approved Oils

This table is for guidance purposes only. It is the responsibility of the system designer to ensure that a particular oil is compatible with the refrigeration circuit proposed. Approval must be obtained from J & E Hall International if it is desired to use any oil other than those included in the table.

The oils listed should **NOT** be mixed.

SUPPLIER	PRODUCT	TYPE	ISO VG	R717 (AMMONIA)	R22	R134A, R404A, R507 AND R407C
BP	Energol LPT46	Mineral	46	Yes	No	No
	Energol LPT68	Mineral	68	Yes	Yes	No
	Energol LPT100	Mineral	100	No	Yes	No
Castrol	Icematic 99	Mineral	68	Yes	Yes	No
	Icematic 299	Mineral	(55)	Yes	Yes	No
	Icematic 2294	PAO	68	Yes	[1]Limited	No
	Icematic 2295	PAO	220	No	[1]Limited	No
	[2]Icematic SW68	POE	68	No	No	Yes
	[2]Icematic SW100	POE	100	No	No	Yes
	[2]Icematic SW220	POE	220	No	No	Yes
	Icematic E100	POE	100	No	No	Yes
CPI Engineering	CP1009-68	Mineral	68	Yes	No	No
Elf	Frima FR68	Mineral	68	No	Yes	No
	Frima FR100	Mineral	100	No	Yes	No
	Frima NH46	Mineral	46	Yes	No	No
	Frima NH68	Mineral	68	Yes	No	No
	Planetelf ACD100LT	POE	100	No	No	Yes
Esso	Zerice 68	Mineral	68	Yes	Yes	No
	Zerice S100	AB	100	No	[1]Limited	No
	Zerice RS220	PAO	220	No	[1]Limited	No
Fina	Purfrigol MP68	Mineral	(55)	Yes	Yes	No
ICI	[2]Emkarate RL68H	POE	68	No	No	Yes
	[2]Emkarate RL68HP	POE	68	No	No	Yes
	Emkarate RL100S	POE	100	No	No	Yes
	Emkarate RL150S	POE	150	No	No	Yes
	[2]Emkarate RL220H	POE	220	No	No	Yes

Table 7 Approved Oils List

SUPPLIER	PRODUCT	TYPE	ISO VG	R717 (AMMONIA)	R22	R134A, R404A, R507 AND R407C
Mobil	Gargoyle Artic C Heavy	Mineral	46	Yes	No	No
	Gargoyle Artic 300	Mineral	(55)	Yes	Yes	No
	Gargoyle Artic SHC226	PAO	68	Yes	[1]Limited	No
	Gargoyle Artic SHC230	PAO	220	No	[1]Limited	No
	EAL Artic 100	POE	100	No	No	Yes
Petro Canada	Reflo 68A	Mineral	68	Yes	No	No
Shell	Clavus 46	Mineral	46	Yes	No	No
	Clavus 68	Mineral	68	Yes	Yes	No
	Clavus G68	Mineral	68	Yes	Yes	No
	Clavus G100	Mineral	100	No	Yes	No
Texaco	Capella WF 68	Mineral	68	Yes	Yes	No
Witco	Suniso 4GS	Mineral	(55)	Yes	Yes	No

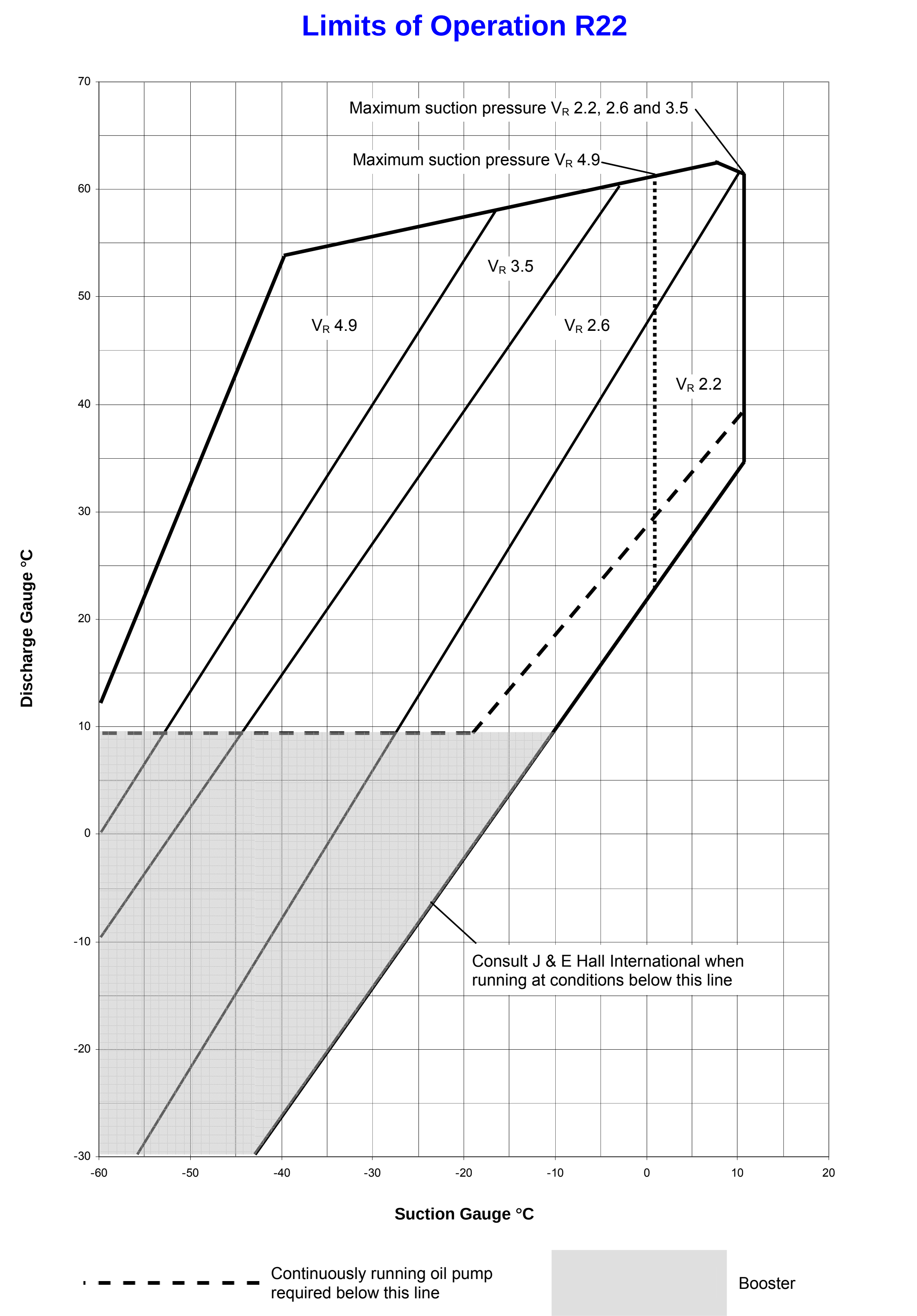
Key

AB = Alkylbenzene synthetic lubricant.
Mineral = Mineral based oil.
PAO = Polyalphaolefin synthetic lubricant.
POE = Polyolester synthetic lubricant.

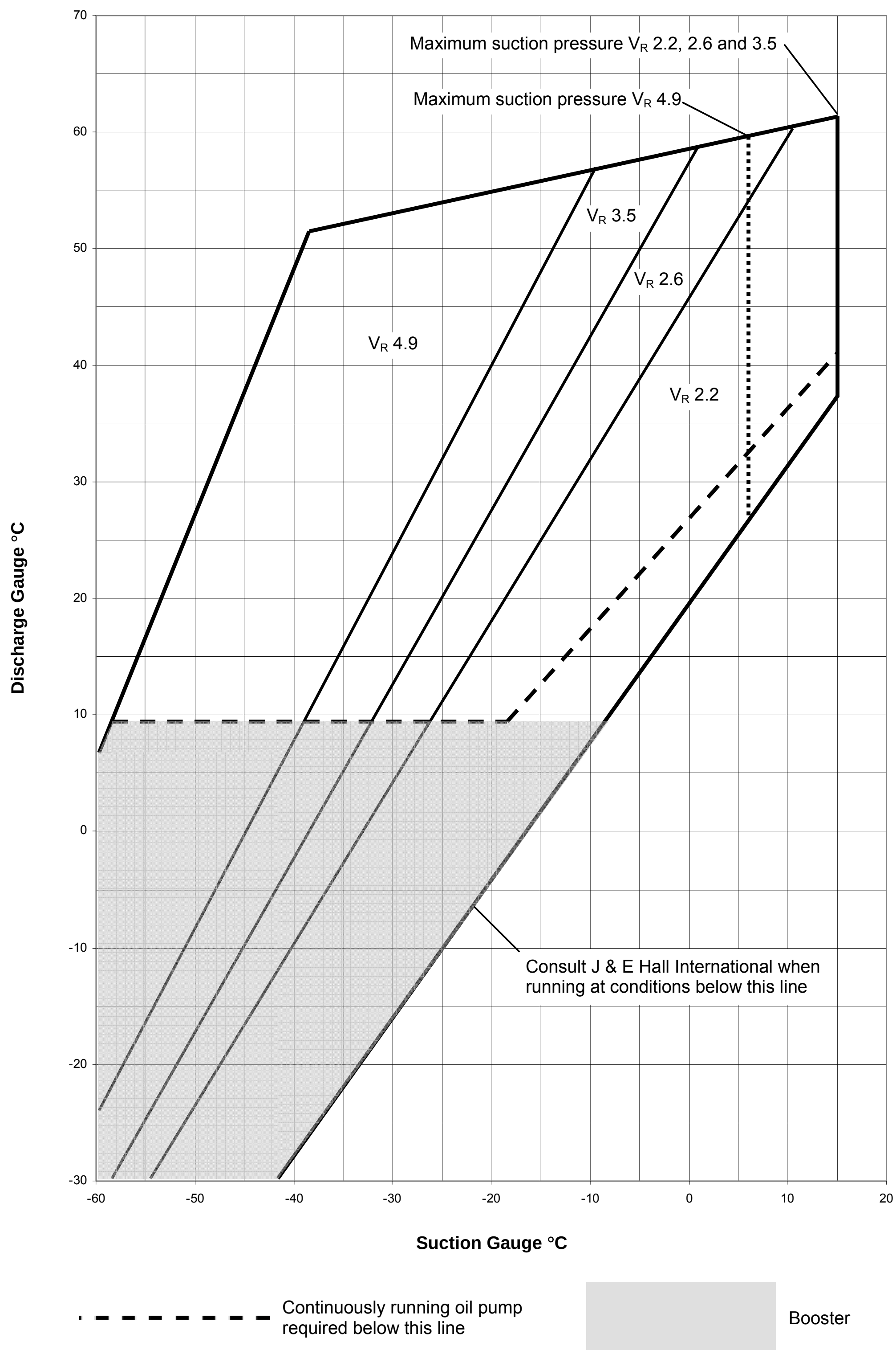
[1]Under certain specific conditions in particular system designs, use of the associated lubricant can be advantageous.
[2]These synthetic oils are the only lubricants approved for use with R134a refrigerant.

Table 7 (continued) Approved Oils List

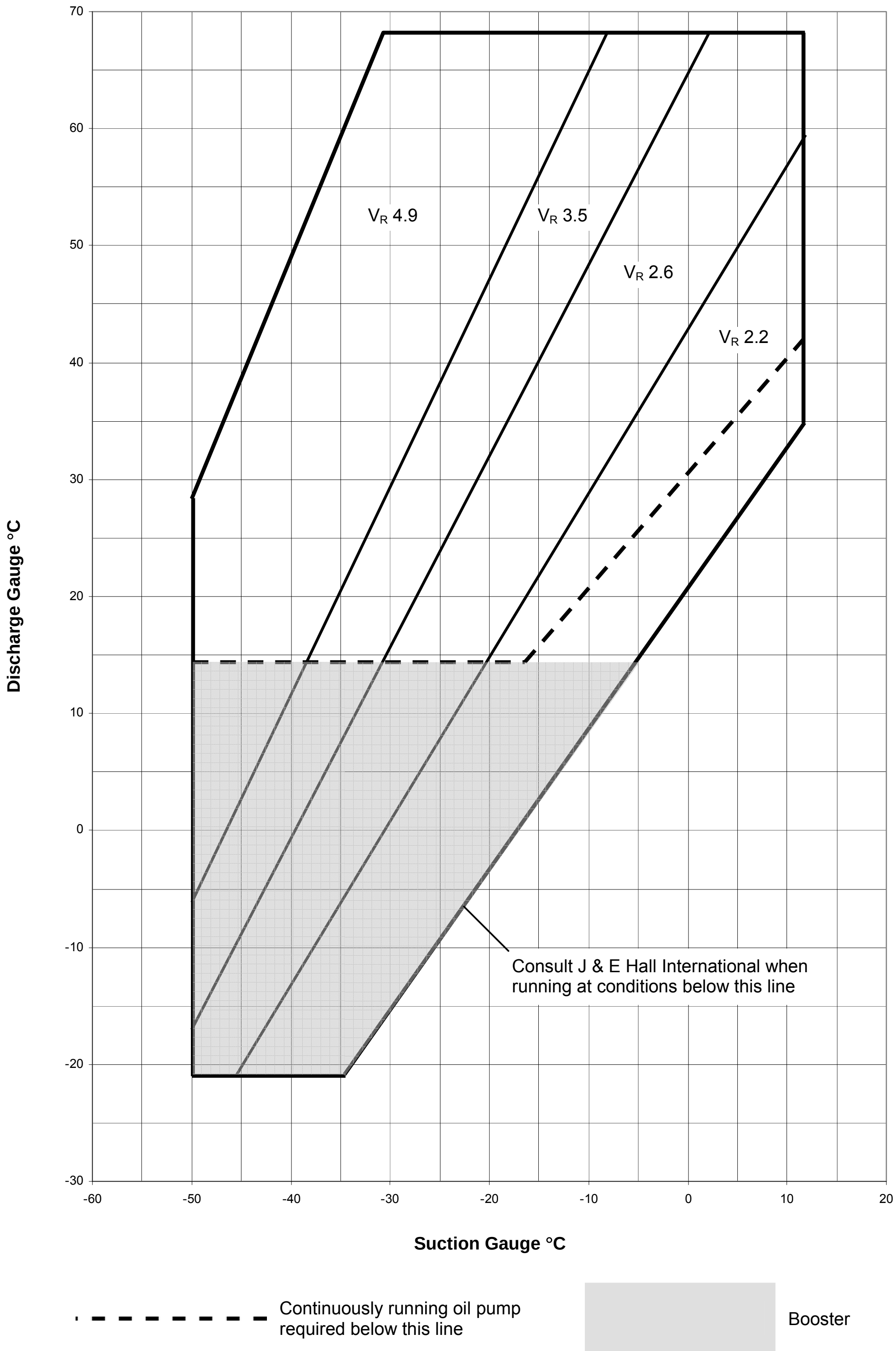
Appendix 4 Limits of Operation Envelopes



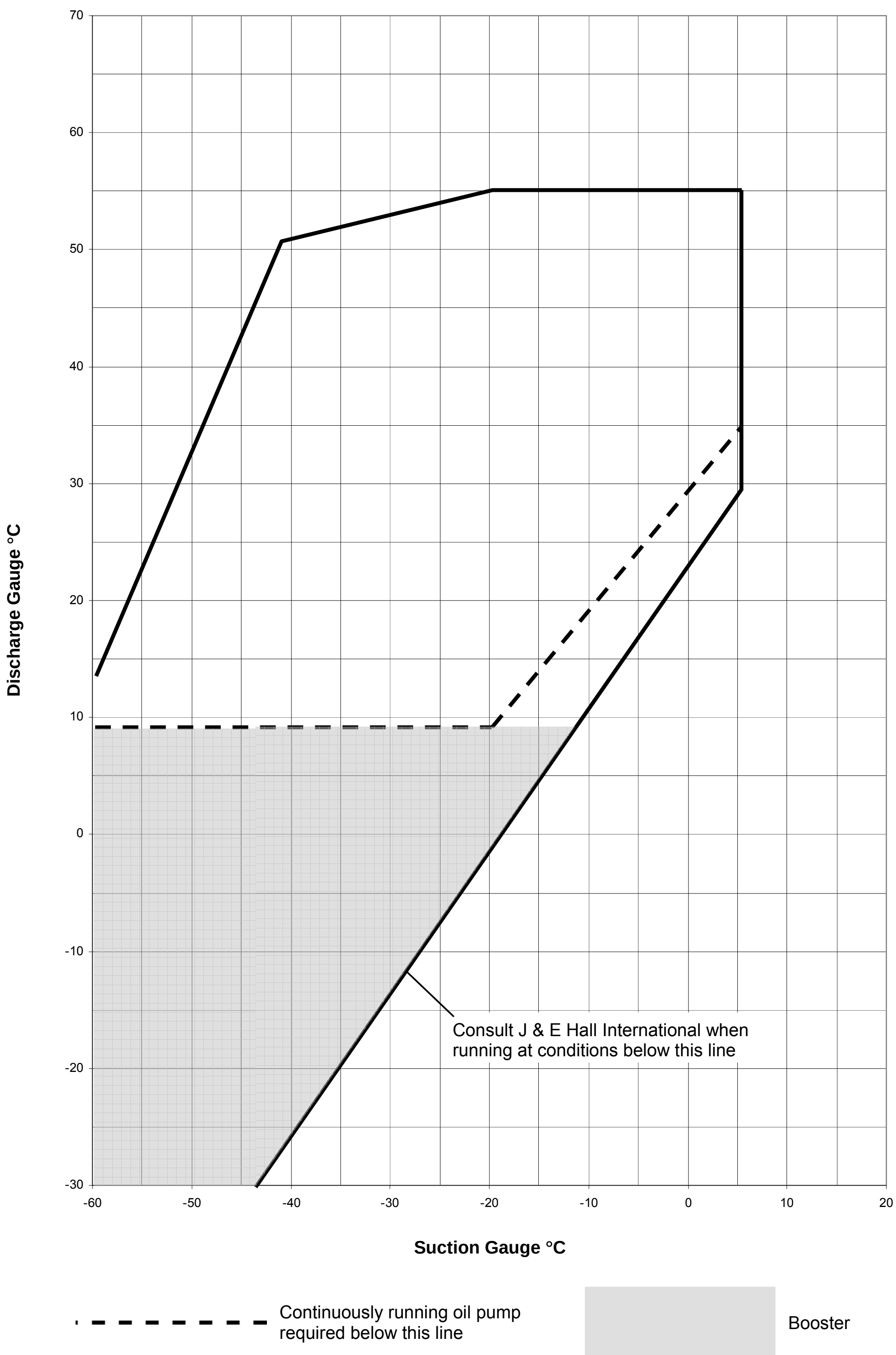
Limits of Operation R717 (Ammonia)



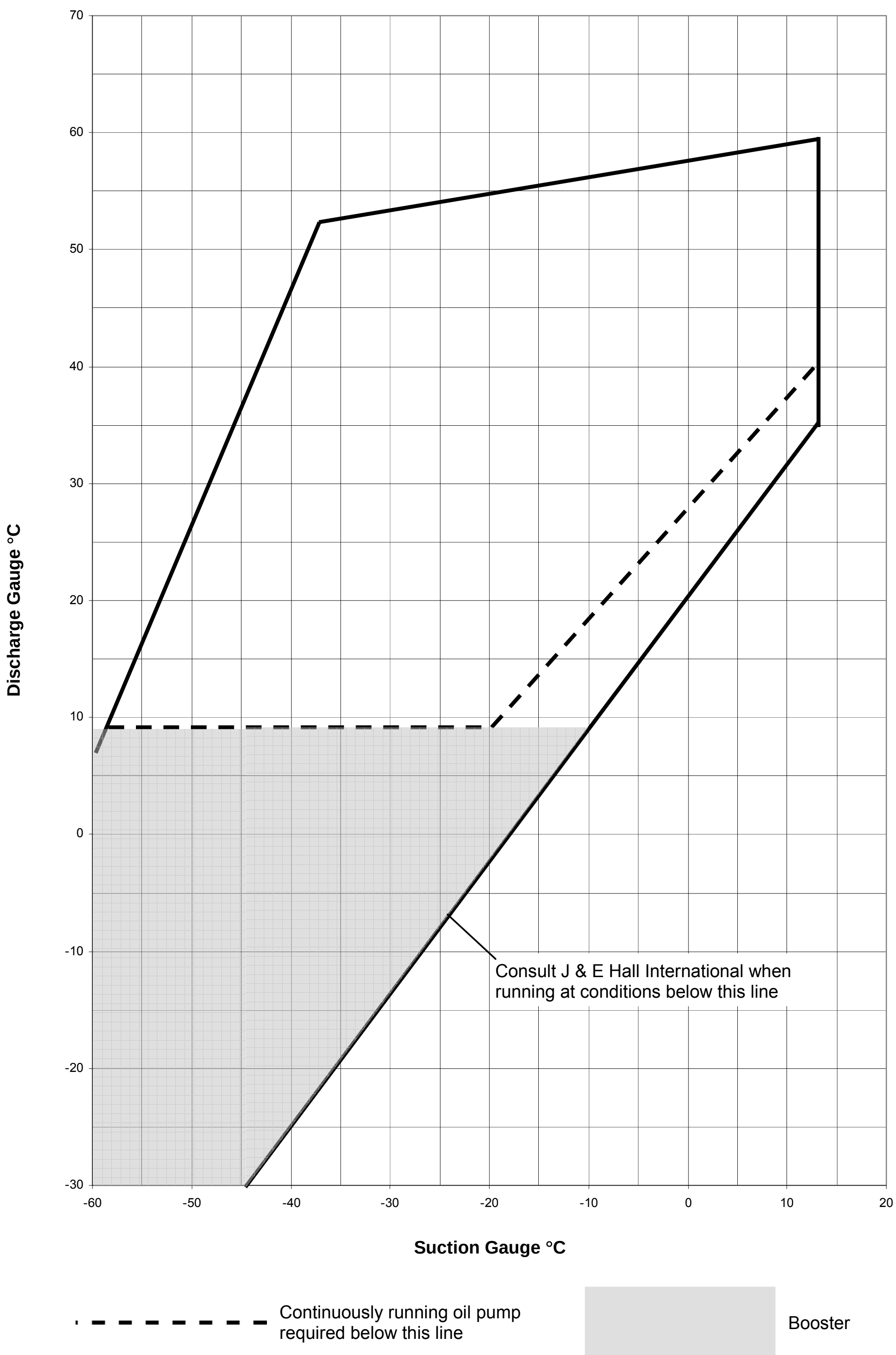
Limits of Operation R134a



Limits of Operation R404a and R507



Limits of Operation R407c



Appendix 5 HallScrew Spares Kits

Obtain spares kits from the address below:

J & E Hall International Telephone: +44 (0) 1332-253400
Parts Business, Fax: +44 (0) 1332-294119
Hansard Gate, Email: derby.spares@jehall.co.uk
West Meadows,
Derby DE21 6JN
England

Kit			HallScrew Compressor		
			HSO 4221 95459-0**-***	HSO 4222 95459-1**-***	HSO 4223 95459-2**-***
Gland Seal ([1]Silicon Carbide)			95813-402		
Stars			95813-401	95814-401	95815-401
Star Bearings			95813-404		
Capacity Control	Slide Valves	V_R 2.2	95823-403	95823-407	
		V_R 2.6	95823-404	95823-408	
		V_R 3.5	95823-405	95823-409	95823-411
		V_R 4.9	95823-406	95823-410	95823-412
	Cylinder	Piston Ring and 'O' Ring	95814-405		
		Piston, Piston Ring and 'O' Ring	95814-407		
		Cylinder Cover	95814-434		
	Solenoids	Solenoid Coil 115 V	95823-415		
		Solenoid Coil 230 V	95823-416		
	Slide Valve Position Transducer		95822-413		
Bearing Oil Supply Line			95822-412		
Oil Filter			95816-401		

** is part of the compressor configuration number *** is the unique compressor serial number

[1]Gland seals with silicon carbide seal faces are required for compressors applied to systems using ester lubricants and HFC refrigerants.

Table 8 Spares Kits for HSO 4200 Series Compressors

Appendix 6 Plant Performance Record

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

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

Methods of Recording Data

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

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

Log Book

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

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

It is also recommended to record the following information:

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

Date										
Time										
Log Taken By										
Compressor										
Hours Run										
% Capacity										
Net Oil Pressure at Compressor										
Oil Temperature (°C)										
Compressor Motor										
Speed (rpm)										
Volt										
Amp										
[1]**Gauge Temperatures**										
Evaporator (°C)										
Suction (°C)										
Intermediate (°C)										
Discharge (°C)										
Economiser (°C)										
Refrigerant Temperatures										
At Evaporator (°C)										
LP Suction (°C)										
LP Discharge (°C)										
HP Discharge (°C)										
Economiser (°C)										
[2]**Oil Cooler Cooling Medium**										
Inlet Temperature (°C)										
Outlet Temperature (°C)										
Rate of Flow (m^3/h)										
Condenser Cooling Medium										
Inlet Temperature (°C)										
Outlet Temperature (°C)										
Rate of Flow (m^3/h)										
[3]Ambient Dry Bulb Temperature (°C)										
[3]Ambient Wet Bulb Temperature (°C)										
Evaporator Cooled Medium										
Inlet Temperature (°C)										
Outlet Temperature (°C)										
Rate of Flow (m^3/h)										
Liquid Refrigerant Temperatures										
At the Condenser Outlet (°C)										
Before the Regulator (°C)										

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

Société JMB

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