GRASSO

- JAN. 1992

BEDIENINGSVOORSCHRIFT / BETRIEBSANLEITUNG
INSTRUCTION MANUAL/MANUEL D'INSTRUCTIONS

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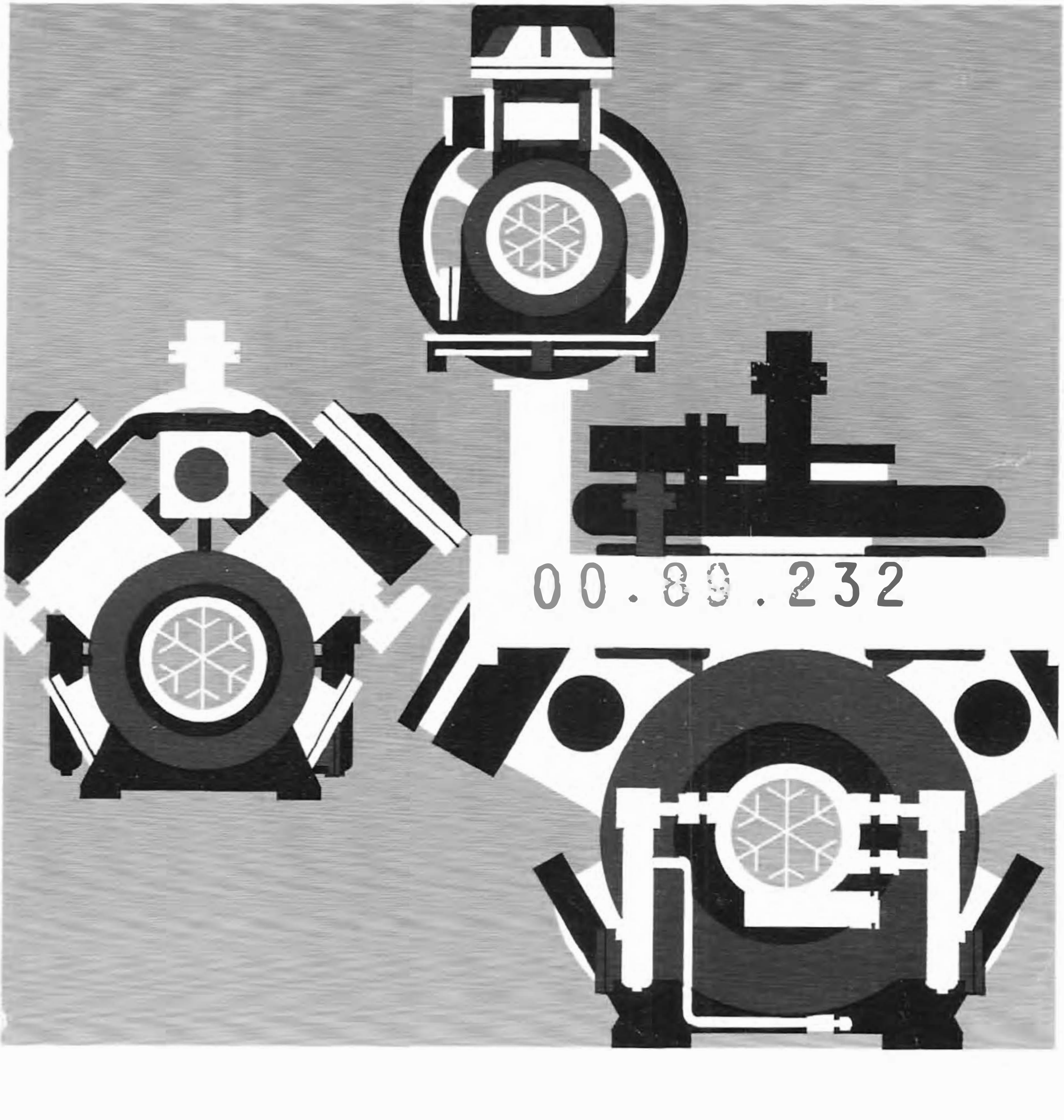

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2.10 OIL TYPES TO BE USED

Table 2.1 contains the oil types which are released for GRASSOSCREW compressors.

Some of the oil types listed in this table are marketed under other names. These oils can also be used, provided their identity can be proved beyond any doubt.
The use of other oils, not named in this table is permitted only after approval by the compressor manufacturer.
For most applications an oil type, having a kinematic vicosity at 40 °C of 68 cSt for NH_3 and 68 to 150 cSt for R22, will do.

IMPORTANT

Used or filtered oil should never be added to a refrigeration screw compressor under any circumstances. Use only new oil from an oil manufacturer (any of the major oil companies or their approved dealers).

The oil must be changed every three months or 2000 hours unless their quality is guaranteed by a qualified oil laboratory. Maximum time six months. See paragraph 6.6 for further details of oil analysis.

Should you have other types of compressors in your system, it is recommended that you investigate changing their oil grade to that of the screw compressor. The screw compressor oil is usually satisfactory in other types of compressors, but the compressor manufacturer must be consulted for approval. This will minimize any possibility of the incorrect grade being added to the screw compressor.

Grasso Products assumes no responsibility for the quality, performance, availability or viscosity of the products in table 2.1 below.

TABEL 2.1 OIL TYPES TO BE USED

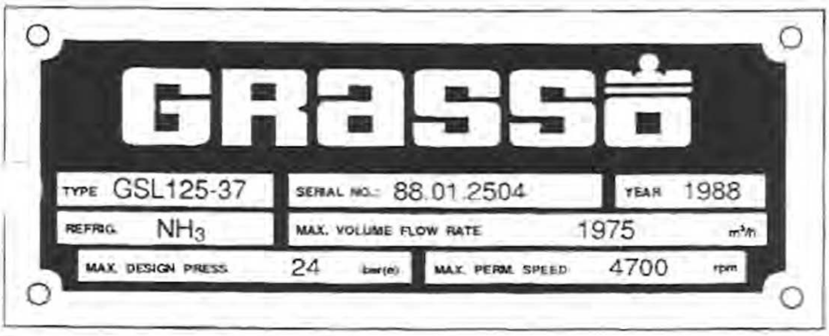
BRAND OR SUPPLIER	TYPE	VISCOSITY AT 40 °C cSt	VISCOSITY AT 50 °C mPa	VISCOSITY AT 50 °C °Engler
BP	* Energol LPT 68	68	36	5.5
ESSO	* Zerice 68	63	34	5.0
KUWAIT	Stravinsky	55	29	4.4
MOBILOIL	Gargoyle Arcti 300	55	30	4.6
SHELL	* Clavus Oil 68	68	35	5.4
SUN-OIL	Suniso 4 GS	54	29	4.4
TEXACO	* Capella D WF 68	64	35	5.4

Oil types marked with an asterisk (*) have a viscosity grade number designation according to ISO-Standard 3448.

READ THE INSTRUCTION MANUAL CAREFULLY PRIOR TO INSTALLATION AND COMMISSIONING OF THE GRASSO-SCREW REFRIGERATING COMPRESSOR PACKAGE

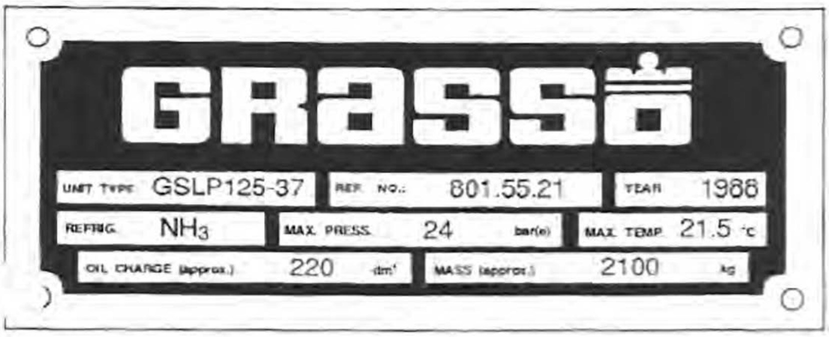
This instruction manual is intended as a guide for the installation contractor as well as for trained personnel of the end user in charge of the operation and maintenance of the refrigeration plant.
In addition to data concerning construction and operation of the standard compressor and compressor package, the manual contains installation, operating, inspection, maintenance and service instructions, which should be followed in order to ensure satisfactory operation of the package over many years to come.
It is strongly recommended to read the instruction manual carefully so as to become familiar with design and operation of the package prior to looking up particular information.
However in individual cases the design and the construction of the package may differ from standard, in which event the instruction manual may no more be applicable at certain specific points. In such cases consult the plant operation manual or contact the installation contractor for the actual flow diagram, wiring diagram and lay-out drawing of the package in question.

All enquiries should state the type designation and serial number of the compressor as well as the reference number of the package. These identification numbers are stamped on metal name plates of compressor and package as shown below.



Example of compressor name plate (black)

fitted next to the top name plate upon the compressor housing



Example of package name plate (red)

fitted onto upper side beam underneath the compressor

2. DESCRIPTION AND PRINCIPLE OF OPERATION OF THE GRASSOSCREW COMPRESSOR GSL

2.1 GENERAL

- GRASSOSCREW GSL is the designation for a series of rotary positive displacement compressors, made under license of the Swedish firm SRM (Svenska Rotor Maskiner). These so-called "Lysholm" screw compressors, equipped with only two main rotating parts, have been developed and designed for general industrial use as a normal (HP) single-stage machine or as (LP) booster in refrigerating, freezing, air conditioning and heat pump installations, normally operating with the refrigerants NH_3 (R717) and R22.
- These compressors are mainly intended for direct drive via a flexible coupling by a three-phase, two-pole electric motor; consequently at a speed approaching 3000 rpm or 3600 rpm for 50 Hz and 60 Hz supply frequency respectively.
- The compressor series GSL covers a total number of 7 types, characterized by different rotor diameters and lengths and having a swept volume increasing from 630 up to 4880 m^3/h (50 Hz direct drive). These individual types are indicated by adding direct to GSL the swept volume in m^3/h, divided by 10 and rounded up or down to 5. In principle each type can be supplied with four different so-called built-in volume ratios, denoted by the figures 22, 26, 37 or 48 after the swept volume in the type designation, indicating a built-in volume ratio of 2.2, 2.6, 3.7 and 4.8 respectively.

  Example: **G S L 2 4 0 - 3 7**

  - G – Grassoscrew
  - S L – Large capacity series
  - 2 4 0 – Swept volume (divided by 10 and rounded off)
  - 3 7 – Built-in volume ratio (multiplied by 10)

  In the case of a complete compressor package, the character "P" is added to the type designation:
  Example: G S L <u>P</u> 2 4 0 - 3 7.
  For a complete survey of all compressor types, technical data and limits of operation, refer to paragraph 2.9.
- The structure of the Grassoscrew compressor, in its most simplified form, is schematically represented in figure 2.1, where the right hand part is a vertical cross-section and the left hand part a vertical longitudinal section.

  This figure shows that the compressor consists of two parallel, intermeshing helically grooved rotors (1, 2) with equal (outer) diameter and length, supported by integral shaft ends in one horizontal plane and enclosed on all sides by a specially shaped (double-cylindrical) inner housing (3) with very slight radial and axial clearance. The so-called male rotor (1), having four convex lobes (thus four interlobe spaces, called flutes or grooves), is driven direct from outside (9) in the direction indicated and drives the so-called female (2) rotor which has six concave lobes (thus six flutes or grooves). The male rotor lobes function as pistons that roll and slide within the female rotor flutes, thereby imparting a rotating motion with 2/3 (=4/6) times its speed to the female rotor. In any vertical cross-section both the male and female lobes have the latest non-symmetrical profile.

  One end face of the aforementioned inner housing (3) is provided with a specially curved axial inlet port (5), which communicates with the suction chamber (7) inside the gastight outer housing (4). At the opposite lower end of the rotors there is an outlet port (6) in the inner housing, which consists of an axial and radial part and communicates with the discharge chamber (8) inside the outer housing.

2.2 PRINCIPLE OF OPERATION

As the Grassoscrew is a positive displacement compressor, the following three successive phases can be distinguished:

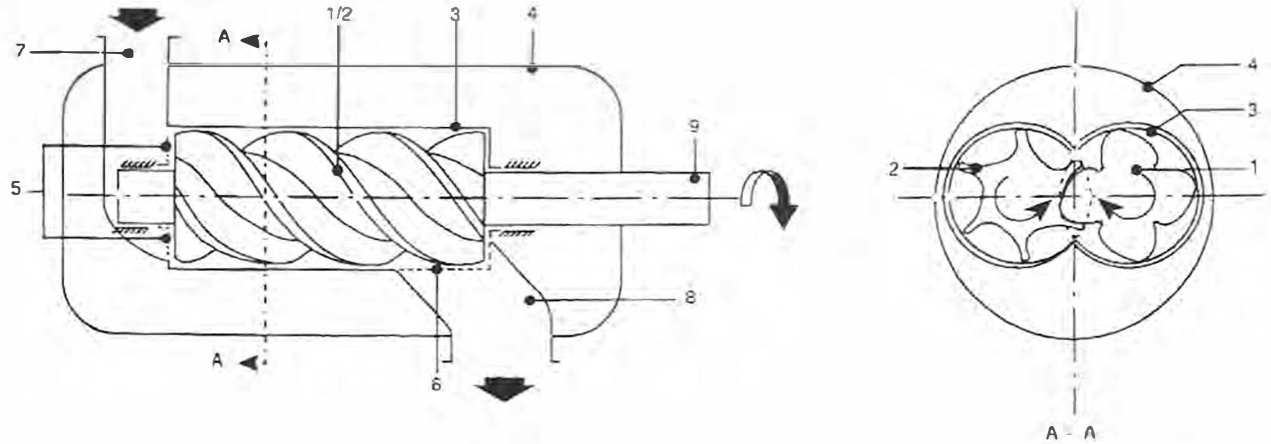
- **Suction phase**
  A pair of male lobe and female flute unmesh on the inlet port side and suction gas flows axially in the increasing volume formed by the corresponding male-female groove pair until the lobe and flute are completely unmeshed and the groove pair is no more in communication with the inlet port. Refer to the successive groove pair stages (positions) **a**, **b**, **c** and **d** in the top picture of fig. 2.2.
- **Compression phase**
  When remeshing of the male lobe and female flute starts at the inlet end, the trapped gas is gradually reduced in volume. Simultaneously, while being compressed in this way, the charge of gas is moved helically toward the discharge end as the lobes' and flutes' mesh point moves along axially. Refer to the successive groove pair stages (positions) **e**, **f** and **g** in the bottom picture of fig. 2.2.
- **Discharge phase**
  Compression ceases, when the groove pair concerned comes into communication with the outlet port, thus causing the discharge of the compressed refrigerant gas to take place until the groove pair volume is reduced to zero. See groove pair stage (position) **h** in the bottom picture of fig. 2.2.

The complete cycle, thus described for one groove pair, takes place continuously four times per revolution of the male rotor, resulting in a uniform, hardly pulsating overall gas flow through the compressor.

2.3 BUILT-IN VOLUME AND PRESSURE RATIO

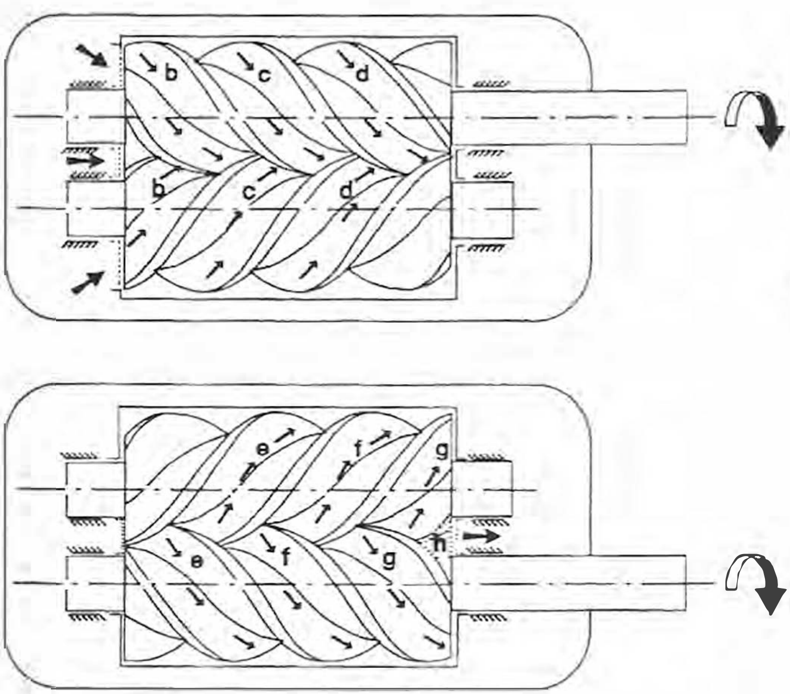
Like other rotary positive displacement compressors without suction and discharge valves, the Grassoscrew has a so-called built-in or fixed volume ratio.
This is the ratio of the volume of one male-female rotor groove pair at the moment the inner housing just seals off this groove pair from the suction side (= volume of beginning of compression) and the volume of the same groove pair at the time that it comes into communication with the outlet port (end of compression).

For each refrigerant this "built-in volume ratio" corresponds to a so-called "built-in or fixed pressure ratio". For the standard built-in volume and pressure ratios, refer to the table in paragraph 2.9.



1. male rotor
2. female rotor
3. inner housing
4. outer housing
5. axial inlet port
6. axial/radial outlet port
7. suction chamber
8. discharge chamber
9. drive end (male rotor)

FIG. 2.1 BASIC CONCEPT



top view of fig. 2.1

bottom view of fig. 2.1

FIG. 2.2 PRINCIPLE OF OPERATION

2.4 CONSTRUCTION OF THE COMPRESSOR (see fig. 2.3)

- The very rigid compressor casing, made of low porosity cast iron, consists of a double wall stator (4) shut off on either side by an inlet and discharge housing (1 and 8), in which the rotor shafts run in sleeve bearings, and an outlet housing (10) on driving end. The stator as a whole is formed by a gas tight outer shell encompassing a double cylindrical inner housing (6) in which the rotors operate with a very slight clearance. The annular space (5) between outer shell and inner housing is connected with the suction chamber (2) and serves as by-pass for the return gas when the compressor operates under part-load.
- The dynamically balanced male and female rotor (7 and 19), including their integral shaft ends, are made of a special hot rolled malleable steel and supported in flange mounted steel backed babbit sleeve bearings (3), which take up the radial load. The axial load on both rotors is largely compensated by one oil pressurized balance piston (15), rotating with the male rotor shaft and situated on suction side in line with this shaft. The remaining axial force is taken up by two angular contact ball bearings (9) mounted on each of the rotor shafts on discharge side. These ball bearings also serve for accurate axial positioning of the rotors inside their double cylindrical housing. The journals and the seal area of the rotor shafts are chromeplated for longer life.
- The rotor shaft passage to the outside is provided with an oil flooded, carbon face rotary shaft seal (36). Refer also to paragraph 2.5.
- A slide valve capacity control system provides efficient, surge-free, infinitely variable modulation from 100% down to 10%. The system uses a mechanically positioned pilot valve (23) to control oil flow to and from the hydraulic cylinder (26) which moves the slide valve (28). Refer also to paragraph 2.6.

  The suction connection (33) is located on top of the stator. The discharge connection (20) is provided in the front of the outlet housing (10) on the driving end of the compressor casing.
- Except in the rotor grooves at the end of compression and in the discharge chamber (21) communicating with the outlet port in the inner housing and the discharge connection, suction pressure prevails in the entire compressor casing.
- All compressor types, in standard version, are equipped with two so-called "economizer" connections. One of them, the main connection (34), is located near the top on the discharge housing (8). The other additional connection (35) is situated on the other side of the same housing on rotor shaft level. For NH_3 only the main connection is used; for R22 both connections are used simultaneously and in parallel.

  When no economizer system is applied, both connections are plugged off.

2.5 ROTARY SHAFT SEAL (see figure 2.4)

To pass the male rotor shaft gastight to the outside, the compressor is provided with a conventional type of rotary shaft seal, the design of which, however, has been adapted to the special conditions of high speed and high pressure difference. The parts of this seal are retained in a shaft seal housing (5) mounted inside the outlet housing (6).
The sealing between rotating and stationary parts is effected on the slide face between a carbon slip ring (10) rotating with the rotor shaft and a stationary counter-slip surface, being an integral part of the shaft seal cover (9) and made of a special iron alloy. The sliding surfaces of both slip ring and seal cover are polished to extreme finish and lapped.

The slip ring can slide axially over the rotor shaft and is pressed onto the counter-slip surface by means of coil springs (15). It is carried by a spring holder as a part of the shaft seal cage (4), which itself is secured on a drive disc (16) by a drive pin (2). The whole assembly rotates together with the rotor shaft due to a securing pin (17) that connects the drive disc and the thrust ball bearing lock nut (1). To ensure the sealing between slip ring and rotor shaft a secondary seal (12) is provided.

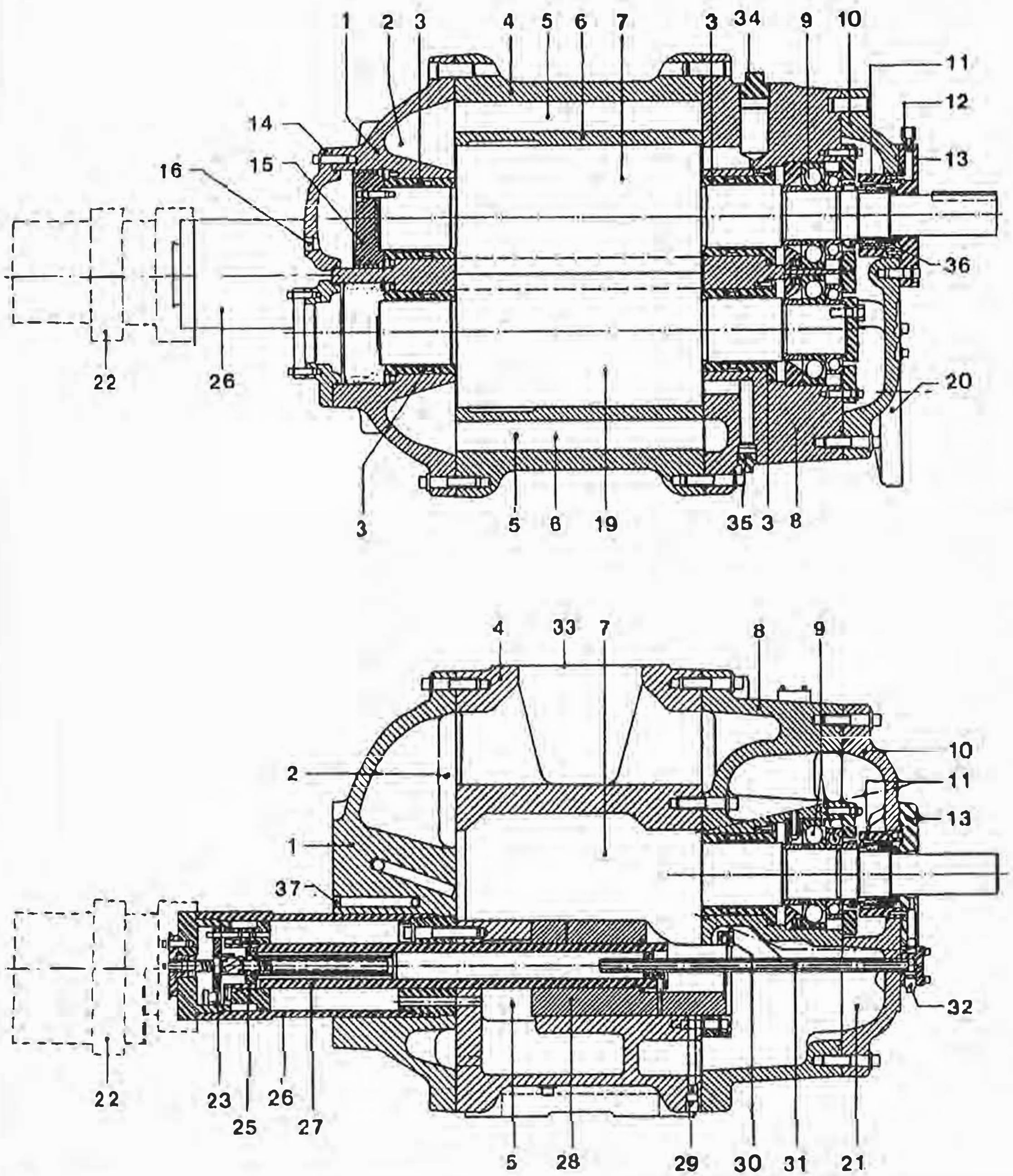
The shaft seal housing (5) is secured against rotation by a lock pin (13) fitted into a recess of the shaft seal cover.

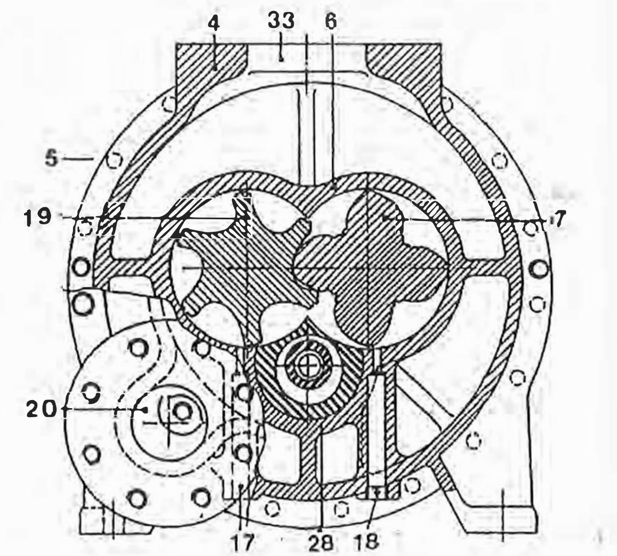
To remove the frictional heat developed by the slip faces, the entire shaft seal is incorporated in the lubricating oil circuit via the oil supply port (7) and the oil overflow hole (3).

2.6 CAPACITY CONTROL SYSTEM

- The capacity control of the Grassoscrew GSL, i.e. reduction of the suction volume at constant speed, is achieved by causing the beginning of compression to take place later. As shown schematically in figure 2.5 this is realised by allowing each rotor groove pair, after it has been sealed off from the inlet port, to remain in communication with the suction chamber (16) for some length of time via a return port (8) in the lower cylindrical part of the rotor housing. Consequently, the suction gas trapped in the rotor grooves is partially bypassed to the suction chamber. The return port, of which the size is infinitely variable between zero and a maximum value (corresponding to full load operation and minimum capacity respectively) is created by a specially shaped slide valve (17), which forms an integral part of the bottom of the rotor housing and can be moved in either direction parallel to the axis of the rotors by means of a rod (5). In this way almost loss-free and stepless capacity control is obtained, having a practical range of from approx. 10 to 100 %.
- The slide valve rod (5) is connected to a single acting piston (4) in a cylinder (6) which uses hydraulic force (oil pressure) to unload the compressor. Because of the gas pressure difference across the slide valve (suction pressure on one side and discharge pressure on the other) there is a large force to the left tending to close the slide valve or to load the compressor. By admitting high pressure oil into the outboard chamber (2) behind the piston, or

FIG. 2.3 CONSTRUCTION OF THE COMPRESSOR





1. bearing cover inlet end
2. suction chamber
3. sleeve bearing
4. stator (rotors and slide valve housing)
5. annular suction and by-pass space
6. double cylindrical inner housing
7. male rotor
8. bearing cover outlet end
9. angular contact ball bearing
10. outlet cover
11. shaft seal housing
12. connection for oil supply to shaft seal
13. shaft seal cover
14. cover of balance piston chamber
15. balance piston of male rotor
16. connection for oil supply to balance piston
17. oil injection connection to female rotor
18. oil injection connection to male rotor
19. female rotor
20. discharge (outlet) connection
21. discharge chamber
22. electric slide valve actuator
23. capacity control pilot valve
24. ball nut and ball screw assembly
25. capacity control piston
26. hydraulic cylinder of capacity control
27. capacity control slide valve rod
28. capacity control slide valve
29. connection for oil supply to capacity control slide valve lubrication
30. slide valve supporting guide
31. high pressure oil supply pipe
32. connection for oil supply to capacity control slide valve positioning
33. suction (inlet) connection
34. main economizer connection
35. additional economizer connection
36. rotary shaft seal
37. connection for oil supply to (fe)male inlet bearings

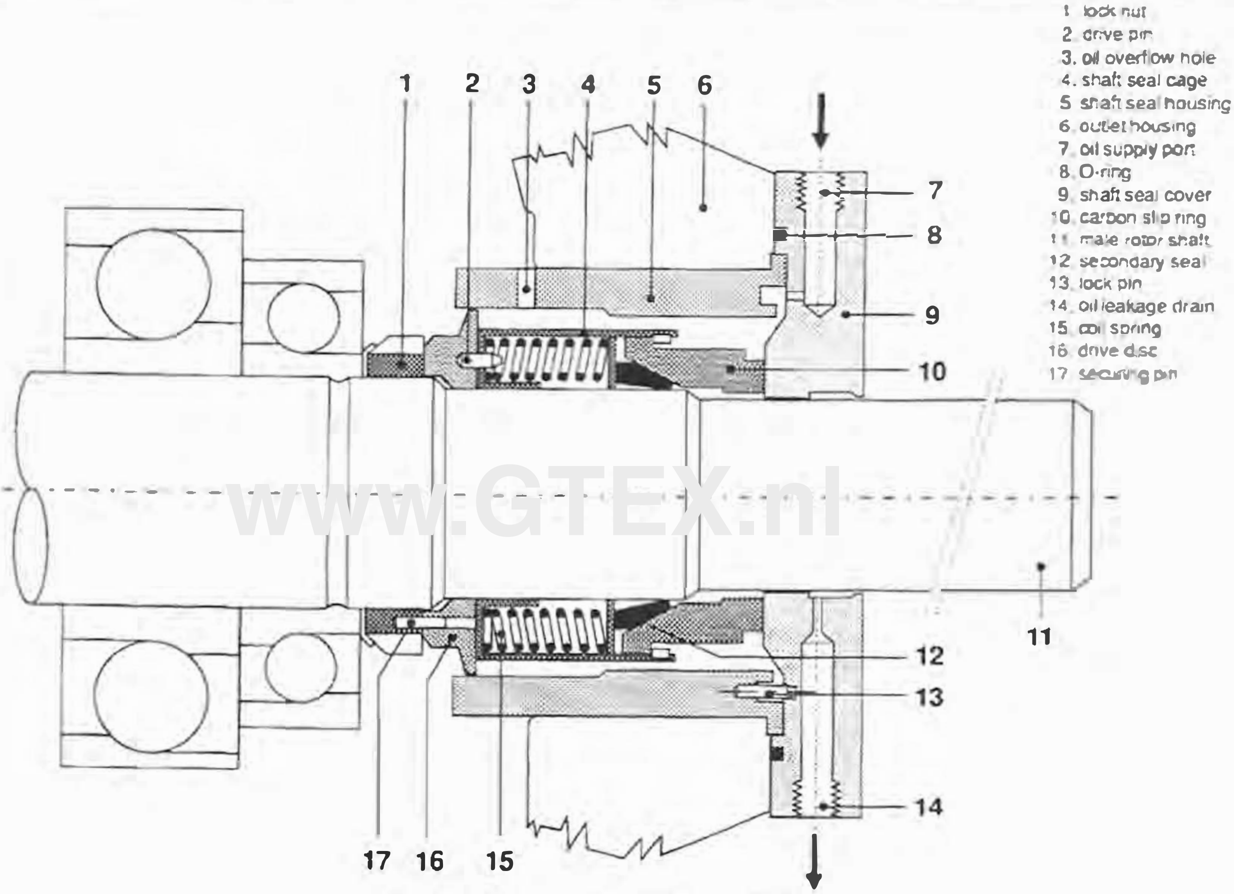


FIG. 2.4 ROTARY SHAFT SEAL

by draining oil from this chamber, the slide valve can be moved to any desired position between full-load and minimum capacity.

A pilot valve is used to control the oil flow towards and from the outboard chamber. This valve consists of a vertical disc (11) with a horizontal pin (3), which fits in a horizontal bore in the piston.

As the pilot valve is moved forward in the unloading direction the oil supply port A (radial channel in piston) is opened by a recess in the pin which allows the oil, supplied via the telescope pipe (18) and the hollow slide valve rod (5), to enter the outboard chamber and to push

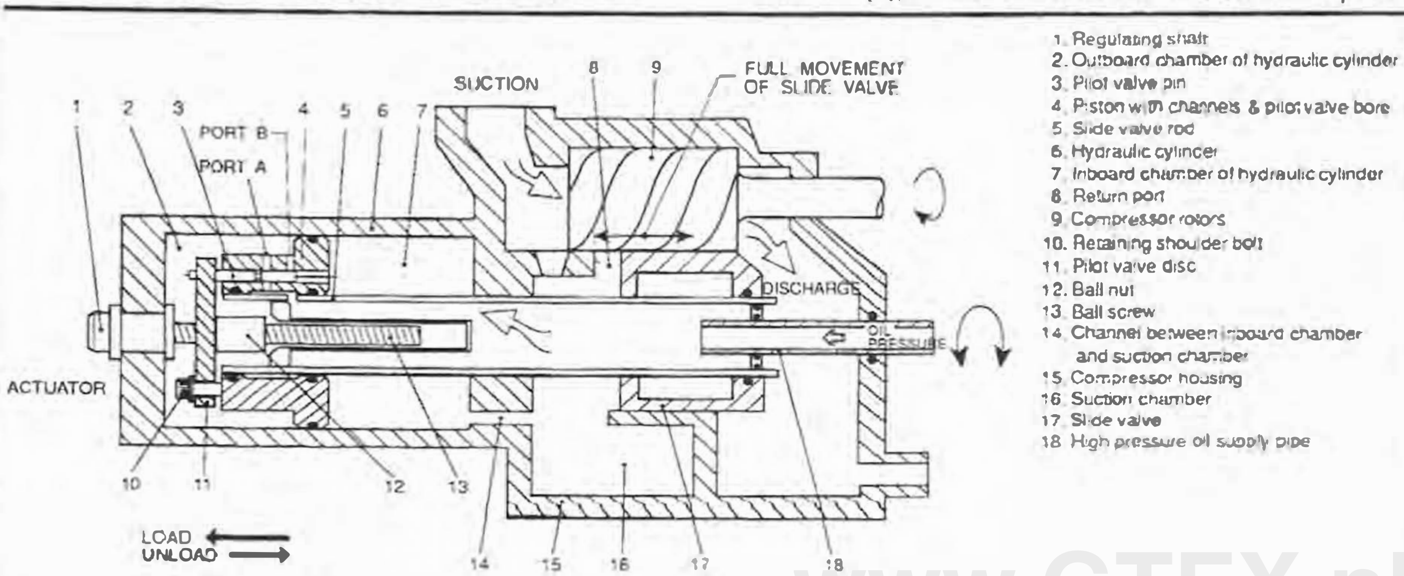


FIG. 2.5 SCHEMATIC DRAWING OF CAPACITY CONTROL SYSTEM

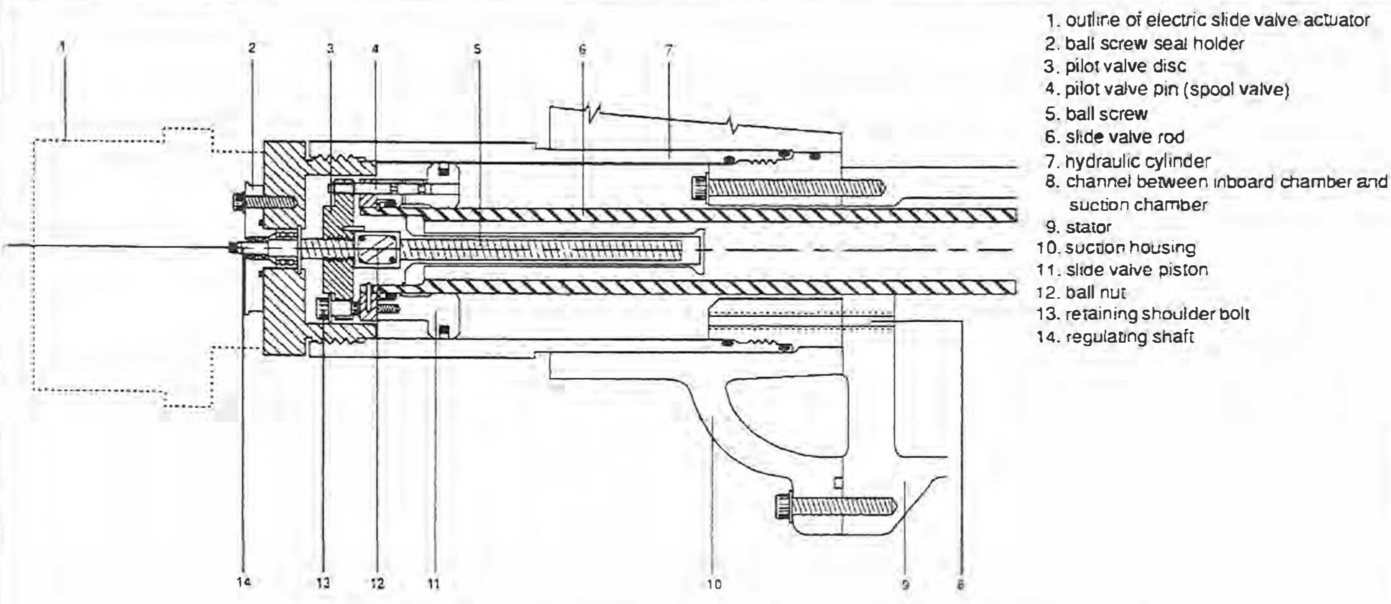


FIG. 2.6 HYDRAULIC CYLINDER WITH PISTON AND PILOT VALVE

the piston-rod-slide valve assembly in the unloaded position.

As the pilot valve is moved backward (to the left), the drain port B (another radial piston channel) is opened which allows the oil to drain from behind the piston into the inboard chamber (7) of the hydraulic cylinder and the gas force to push the piston-rod slide valve assembly to the loaded position. The oil drain mentioned is possible, because the inboard chamber is not filled with oil but communicates via a channel (14) with the compressor suction chamber (16).

- Since the piston-rod-slide valve assembly follows the pilot valve exactly, the refrigerating capacity can be regulated by just positioning the pilot valve. Adjusting of the pilot valve from the outside of the compressor takes place via a very simple and reliable mechanism, consisting of a ball nut (12, connected to the disc 11) and ball screw (13) assembly, which is rotated by a small electric motor in a so-called slide valve actuator mounted on the outside of the hydraulic cylinder and coupled to the regulating shaft (1).

For a detailed description of this so-called "Electric slide Valve Actuator" (EVA), refer to paragraph 3.4.

IMPORTANT!

When starting the compressor, the slide valve and thus the EVA-indicator should always be in "minimum capacity" position.

- For the actual design of this so-called internal by-pass control system, refer to fig. 2.3, pos. 23 to 32, and to fig. 2.6, which shows a longitudinal drawing of only the hydraulic cylinder.
- To prevent the slide valve from touching the rotors by rotating around its axial axis or by being lifted out of its bore (by oil pressure), a guiding device (30 in fig. 2.3) is provided on the discharge end of the valve, mounted just outside the stator on its end face. Refer to fig. 2.7 for design details of this device, which basically consists of a horseshoe shaped guide support and two adjustable guide shoes resting on each upper side of the slide valve.

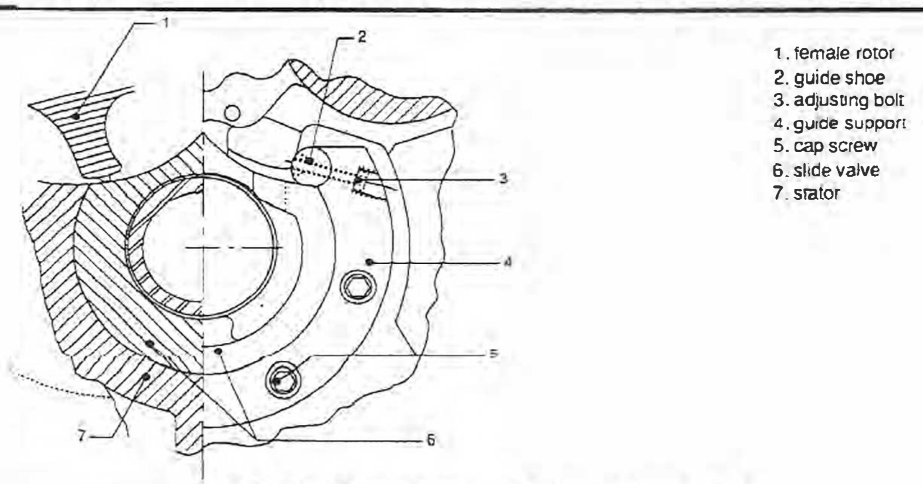


FIG. 2.7 SLIDE VALVE GUIDING DEVICE

2.7 OIL SUPPLY FOR INJECTION AND LUBRICATION

It is extremely important that the intermeshing male and female rotor lobes effectively seal off each other mutually without giving rise to wear. Moreover, the inevitable gap along the rotor circumference between the successive grooves must be thoroughly sealed off as well. To achieve this, a sufficient quantity of oil is injected into the compressor and mixed with the refrigerant as the rotors turn in compressing the gas. This oil has a multiple function. Its main functions are lubrication and the internal sealing referred to. In addition, the oil takes care of intensive cooling during compression and has a silencing effect. Furthermore, oil has to be supplied for all other compressor lubricating purposes and for the operation of the capacity control system.

As represented schematically in fig. 2.8, two separate, parallel oil supply flows to the compressor can be distinguished, viz.:

- An oil flow under (refrigerant) discharge pressure for direct injection into the rotor grooves (X14 and X15) and for supply to the balance piston (X8).
  The oil injection, separately for male and female rotor, takes place via a fixed opening in the bottom of each cylindrical part of the inner rotor housing. The openings are situated in such a way as to cover each male and female rotor groove pair for a short period of time just before compression commences, consequently immediately after the groove pair has been sealed off from the inlet. Therefore, the existing installation pressure difference(= discharge or condensing pressure minus suction or evaporating pressure) is sufficient to inject the required oil quantity*.

- An oil flow under pump pressure (= discharge pressure + 3 bar) for the capacity control slide valve positioning (X10) and lubrication (X11), for supply to the shaft seal (X9) and for bearing lubrication (X6, X12 and X13).
  The oil pump mentioned is the electrically driven gear pump as described furtheron in paragraphs 3.1 and 3.2.

For the exact location of all the compressor oil connections, refer to paragraph 2.8.

* In the case that the installation pressure difference is less than 1.5 bar, there is no guarantee any more for sufficient oil injection into the rotor grooves.
Therefore, apart from the pressure supply to the balance piston of the male rotor, all of the oil supply to the compressor has then to be covered by a pump at a pressure of 3 bar above (refrigerant) discharge pressure. This full-flow pump is a continuously operating, electrically driven gear pump, and mounted in the main oil supply line from the oil separator to the oil cooler.
As a result there are two different compressor package oil systems, which are described in detail in chapter 3.2.

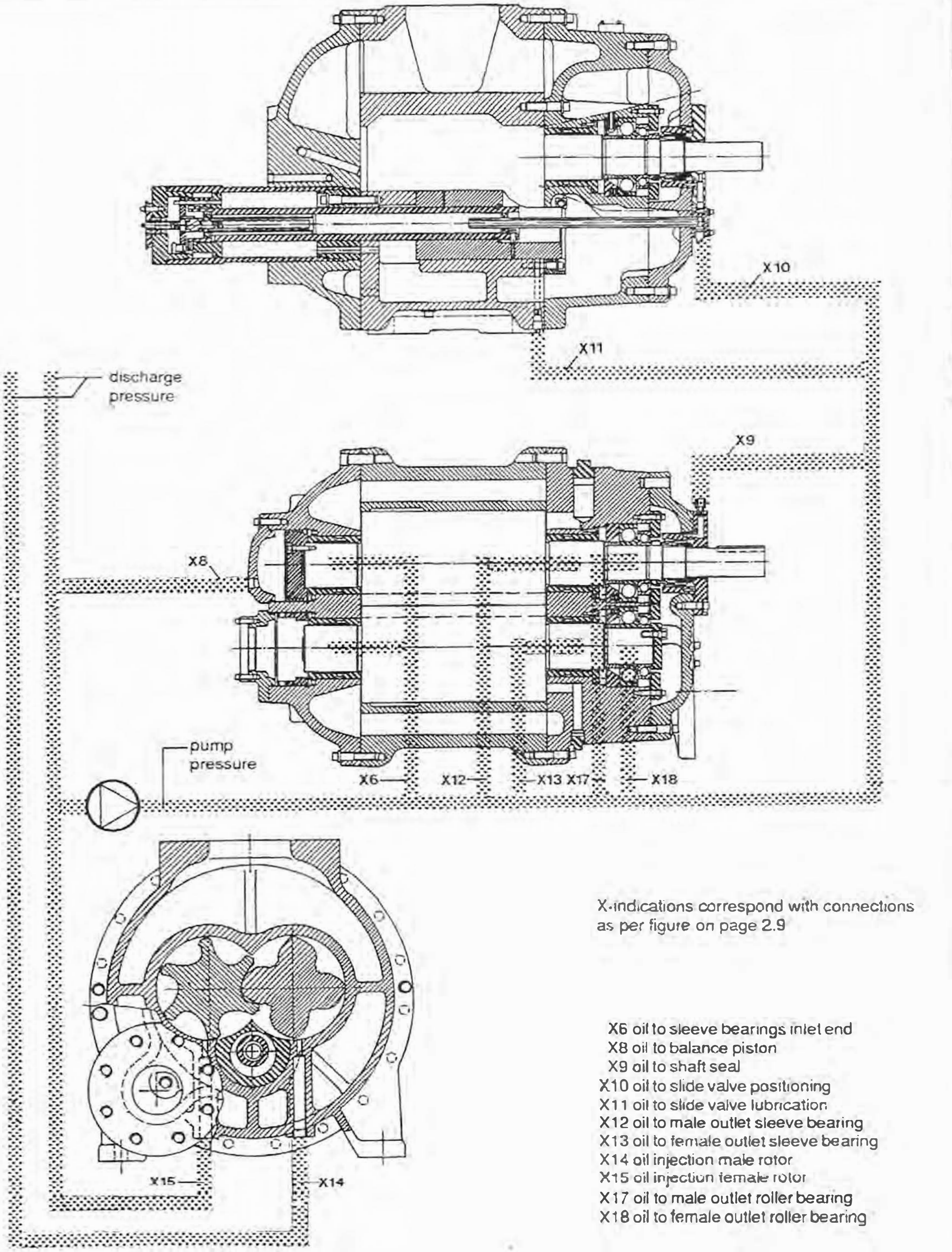
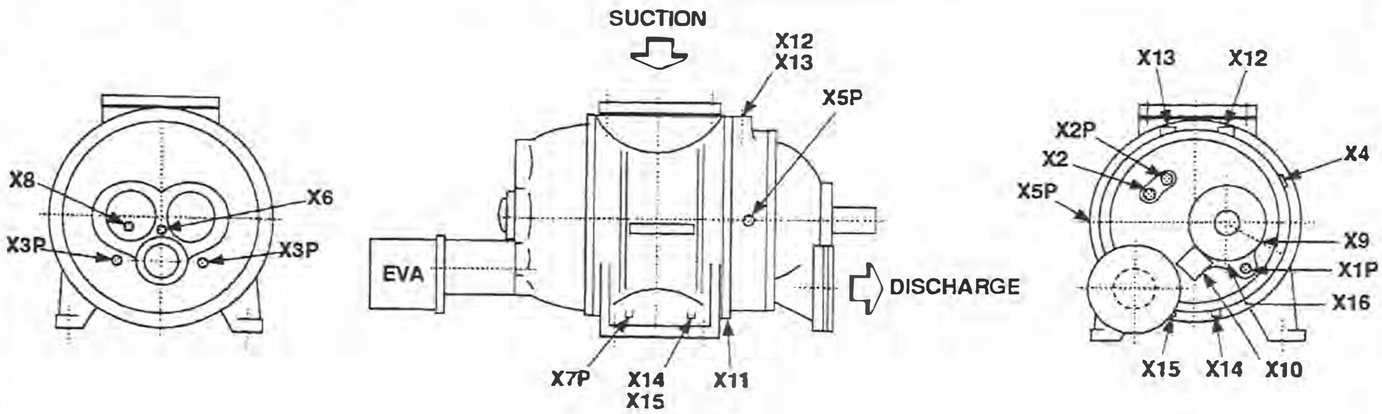
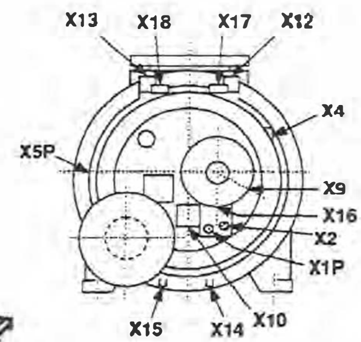


FIG. 2.8 OIL SUPPLY FOR INJECTION AND LUBRICATION

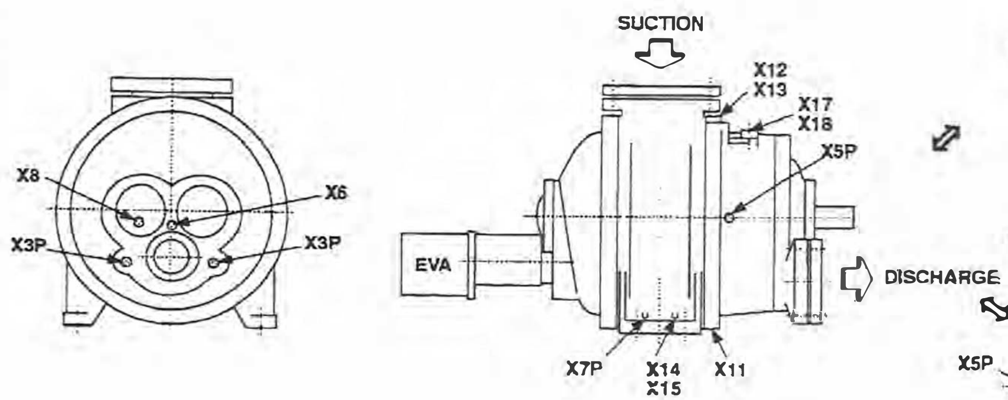
2.8 REVIEW OF COMPRESSOR CONNECTIONS



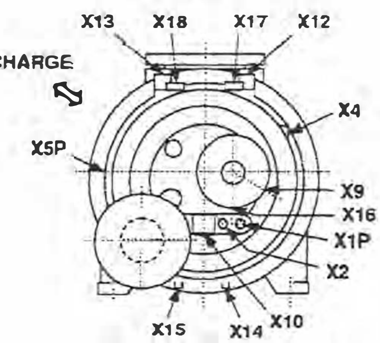
compressor type GSL 65



compressor types GSL 85/125



compressor types GSL 85 to 240



compressor types GSL 165/180/240

X1 DISCHARGE TEMPERATURE
X2 DISCHARGE PRESSURE
X3 SUCTION PRESSURE
X4 ECONOMIZER MAIN CONNECTION
X5 ECONOMIZER ADDITIONAL CONNECTION
X6 OIL TO (FE)MALE INLET BEARINGS
X7 STATOR DRAIN
X8 OIL TO MALE BAL;ANCE PISTON
X9 OIL TO SHAFT SEAL
X10 OIL TO CAPACITY CONTROL SLIDE VALVE POSITIONING
X11 OIL TO CAPACITY CONTROL SLIDE VALVE LUBRICATION
X12 OIL TO MALE OUTLET SLEEVE BEARING
X13 OIL TO FEMALE OUTLET SLEEVE BEARING
X14 OIL INJECTION MALE ROTOR
X15 OIL INJECTION FEMALE ROTOR
X16 OIL LEAKAGE DRAIN OF ROTARY SHAFT SEAL
X17 OIL TO MALE OUTLET ROLLER BEARING
X18 OIL TO FEMALE OUTLET ROLLER BEARING

P = NORMALLY PLUGGED

2.9 TECHNICAL DATA AND LIMITS OF OPERATION

COMPRESSOR TYPE			GSL65	GSL85	GSL125	GSL165	GSL180	GSL240	GSL480
Built-in volume ratio	number in type designation		22 / 26 / 37 / 48						
	numerical value (-)		2.2 / 2.6 / 3.7 / 4.8						
Built-in pressure ratio (-)		NH_3	2.8 / 3.4 / 5.4 / 7.6						
		R22	2.6 / 3.1 / 4.8 / 6.6						
Outer male and female rotor diameter (mm)			163	204	204	255	255	255	408
Rotor length/diameter ratio (-)			1.70	1.15	1.70	1.15	1.25	1.70	1.70
Theoretical displaced volume ("swept volume") at 2950 rpm (m^3/h)			627	829	1240	1638	1781	2408	4876*
Mass of bare compressor (kg)			445	703	794	1247	1270	1370	3900
Direction of rotation			Clockwise, when facing driven end						
Range of stepless capacity control			10 - 100%						
Male rotor speed (rpm)	normal		2950						1450
	max.		3600						1450
Suction pressure (bar eff.)	min.		-0.6						consult manufacturer via installer
	max.	NH_3	8.0 / 6.2 / 3.5 / 2.2						
		R22	8.7 / 6.9 / 4.2 / 2.8						
Evaporating temperature (°C)	min.	NH_3	-50						
		R22	-58.5						
	max.	NH_3	+21.5 / +14.8 / +1.7 / -7.1						
		R22	+22.4 / +15.2 / +1.4 / -7.9						
Actual suction temperature (°C)	min.		-51						
Discharge pressure (bar eff.)	max.		24.0						
Condensing temperature (°C)	max.	NH_3	+58						
		R22	+61						
Discharge temperature (°C)	max.		+93						
Pressure ratio (-)	max.		18 (arbitrary)						
Pressure difference (bar)	min.		1.5**						
	max.		20						
Oil temperature at compressor inlet (°C)	min.		+37						
	max.		+65						

* Swept volume for type GSL 480 is based on 1450 rpm, which is the practical max. speed for this type.

** This minimum value is valid only for compressor packages with oil injection into the rotor grooves by pressure difference.

Mind! The figures, mentioned in the table above apply only to the compressor GSL itself. The operation limitations related to the packages should take precedence of the design limitations of the compressor. For settings of pressure and temperatures safety devices refer to paragraph 4.14.

3.1 PRINCIPLE OF OPERATION OF THE COMPRESSOR PACKAGE

Since correct operation of the compressor largely depends on the injection of sufficient oil quantities, the functional method of operation of the package can be divided into two separate systems: the (refrigerant) gas system and the oil system. Refer to the basic flow diagrams in figure 3.1.

The (refrigerant) gas system

The gas drawn from the evaporator enters the compressor package via an inlet device consisting of a suction stop valve, a suction check valve and a suction gas strainer, which is mounted on top of the compressor.
After compression, the mixture of discharge gas and injected oil is fed into an oil separator, in which the oil is separated from the gas and collected. From the oil separator the discharge gas leaves the compressor package to the condenser via a discharge check valve and a discharge stop valve. The separated oil continuates its way to an oil cooler in preparation for re-injection.

The discharge check valve prevents high pressure gas or liquid from the condenser from entering the oil separator during shut-down. The suction check valve prevents high pressure gas from escaping from the oil separator via the compressor to the evaporator, thus reducing back-spin of the compressor after stopping. However, the latter phenomenon may nevertheless occur, depending on the gas volume present between check valve and compressor inlet. In that case a by-pass line, provided with a normally closed by-pass valve, will be fitted between the compressor suction line and the oil separator (not indicated in fig. 3.1). This by-pass valve opens as soon as the package is stopped, so that high pressure gas can flow to the suction side in order to quickly eliminate the pressure difference across the compressor.

The oil system (also refer to paragraph 2.7)

From the oil separator the oil, of which the temperature is lower than and the pressure is equal to those of the discharge gas, flows via an oil cooler and a strainer to an oil distribution line. From there the oil is fed to the compressor for injection into the female rotor grooves, to the balance piston and to the electrically driven lubrication oil pump. This pump delivers, via a generously main flow oil filter, the oil for the lubrication of shaft seal and bearings and for the lubrication/positioning of the capacity control slide valve.
The excess of the oil pump capacity is returned from the oil discharge manifold to the oil separator via an overflow relief valve to regulate the lubricating (= pump) pressure.

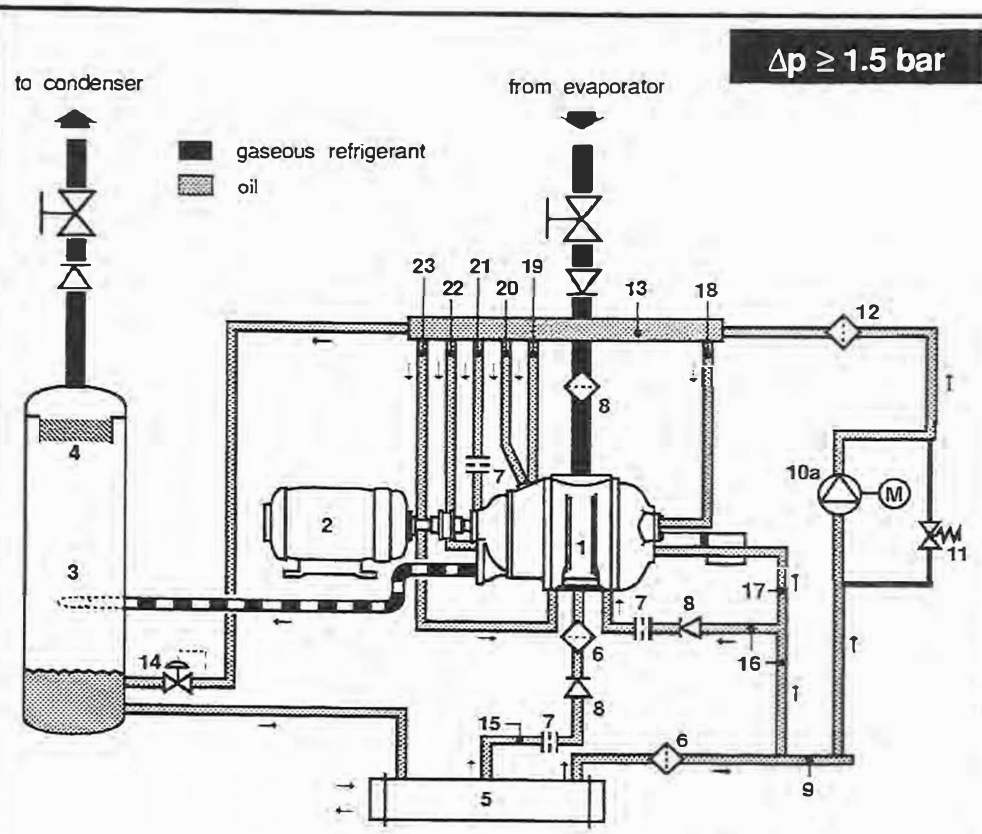
The oil line for injection into the male rotor grooves is branched from the top of the oil cooler shell.

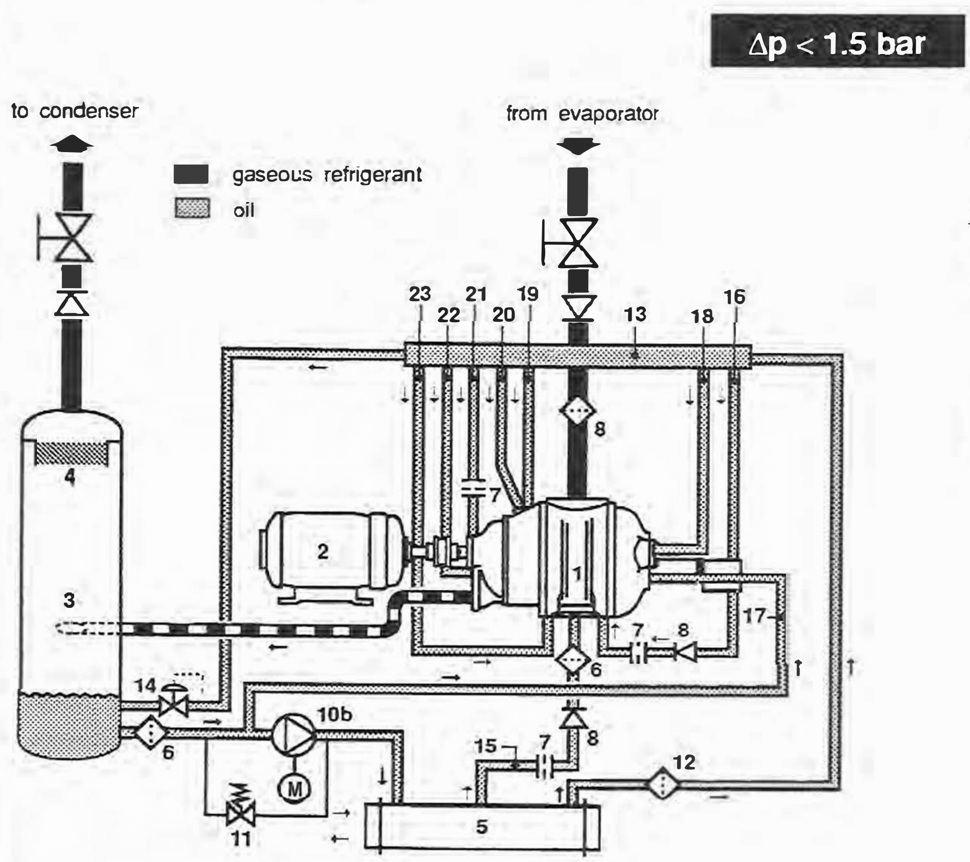
Only if the difference between condensing and evaporating pressure (= Δp) is smaller than 1.5 bar, a full-flow (electric motor driven) oil pump is necessary.
For this alternative oil system, which is only applied under certain booster conditions, refer to the bottom picture of figure 3.1.

3.2 DESIGN DETAILS OF THE COMPRESSOR PACKAGE

The detailed lay-out and flow diagram of the standard compressor package is shown in figures 3.2 to 3.5, of which the figures 3.2/3.3 and 3.4/3.5 correspond respectively with the basic refrigerant and oil flow diagrams as described in para. 3.1. The only difference between the figures 3.2 and 3.3 and between 3.4 and 3.5 is the method of oil cooling applied.
According to these flow diagrams the following main parts of the standard package can be distinguished:

- A standard Grassoscrew compressor GSL (1), complete with electric drive motor (2) and flexible coupling (3) with coupling guard (4). For a detailed description of the compressor refer to Chapter 2.
- A servo-motor operated capacity control (EVA, 5) mounted onto the hydraulic cylinder of the compressor. Refer to para. 3.4 for detailed information.
- An inlet device, consisting of a suction stop valve (27), check valve (26) and strainer (25, filtrating rating 100 microns), incorporated in one single housing, which is mounted on top of the compressor on the suction connection.
  A small diameter bypass line (blow-down line 24) with stop valve, fitted across this device, allows the package to be de-pressurized by hand, if needed.
- A vertical (primary) oil separator (7), complete with a spring-loaded pressure safety valve (8), an oil level sight glass (9) and a 500 W heating element (10). In certain cases a secondary oil separator (100) may have been installed on request of the installer or contractor. For a description of the oil separators refer to para. 3.3.
- A water cooled or refrigerant liquid cooled "shell and tube" type oil cooler (18b and 18a respectively) in which the water or refrigerant flows through the tubes and the oil through the shell around the tubes, guided by a number of baffles.
  From the top of the oil cooler shell the oil line for degassing and injection into the male rotor grooves is branched.
  In case of water cooling (fig. 3.3 and 3.5) a water flow regulating valve (19b), controlled by the oil temperature in the oil discharge manifold (21b) may have been provided.
  In case of refrigerant liquid cooling (fig. 3.2 and 3.4) the oil outlet line may have been provided with a three-way regulating valve (19a, also controlled by the temperature in the oil discharge manifold), combined with a bypass line to the oil inlet line.
- A main flow oil filter (20) with pressure drop sensing switch (20a). The filter consists of a cylindrical housing with cover, in which a removable synthetic fibre filter (10 - 15 microns) is mounted. The pressure drop (differential pressure) sensing switch activates a warning signal as soon as the pressure drop across the filter element, due to pollution, becomes excessive.
- A lubricating oil pressure regulator (11), mounted onto the (primary) oil separator, and which allows the oil to pass at a certain pressure only, thus determining the pressure in the lubricating system.





1. compressor
2. electric drive motor
3. oil separator
4. demistor
5. oil cooler
6. oil strainer
7. oil flow orifice
8. oil check valve
9. oil distribution line

10a. lubrication oil pump

10b. full-flow oil pump

11. oil pump safety relief valve
12. oil filter
13. oil discharge manifold
14. oil pressure regulator (pilot controlled)
15. oil injection to male rotor (X14)
16. oil injection to female rotor (X15)
17. oil to balance piston of male rotor (X8)
18. oil to male and female rotor inlet bearings (X6)
19. oil to male rotor outlet bearings* (X12)
20. oil to female rotor outlet bearings* (X13)
21. oil to shaft seal (X9)
22. oil to cap. contr. slide valve (positioning) (X10)
23. oil to cap. contr. slide valve (lubrication) (X11)

* End of oil line branched into two separate connections on compressor for sleeve and roller bearing respectively

X-indications placed between brackets correspond with connections as per figure on page 2.8

FIG. 3.1 BASIC REFRIGERANT AND OIL FLOW DIAGRAMS

1. …ssoscrew compressor GSL
2. electric drive motor
3. flexible coupling
4. coupling guard
5. electric slidevalve actuator (EVA)
6. Base frame
7. primary oil separator
8. spring loaded pressure safety valve
9. oil level sight glass
10. oil heating element
11. oil pressure regulator
12. charging, drain and isolating valves
13. oil system isolating valves
14. solenoid valve (part of item 31)
15. oil strainer
16a. lubrication oil pump
17. oil pump safety relief valve
18a. refrigerant liquid cooled oil cooler
19a. three way by pass oil flow regulating valve
20. main flow oil filter
20a. pressure drop sensing switch
21a. oil distribution line
21b. oil discharge manifold
22. oil check valve
23. oil orifice
24. blow down line
25. suction gas strainer
26. suction check valve
27. suction stop valve
28. discharge check valve
29. discharge stop valve
30a. economizer pressure gauge
30b. discharge pressure gauge
30c. suction pressure gauge
30d. oil pressure gauge
30e. max. discharge pressure safety switch
30f. min. suction pressure safety switch
30g. min. oil/discharge differential pressure safety switch (for starting only)
30h. min. oil/discharge differential pressure safety switch
30i. max. suction pressure safety switch
30j. max. discharge temperatue safety switch with built-in discharge temperature digital read-out
30k. max. oil temperature safety switch with built-in oil temperature digital read-out
30l. suction temperature digital read-out
30m. injection gas temperature digital read-out
30n. capacity control digital read-out (part load in percentage of full load capacity)
31. solenoid valve controlled, servo operated by-pass valve (not always present)
50. economizer manifold
100. secondary oil separator with automatic float valve for oil return

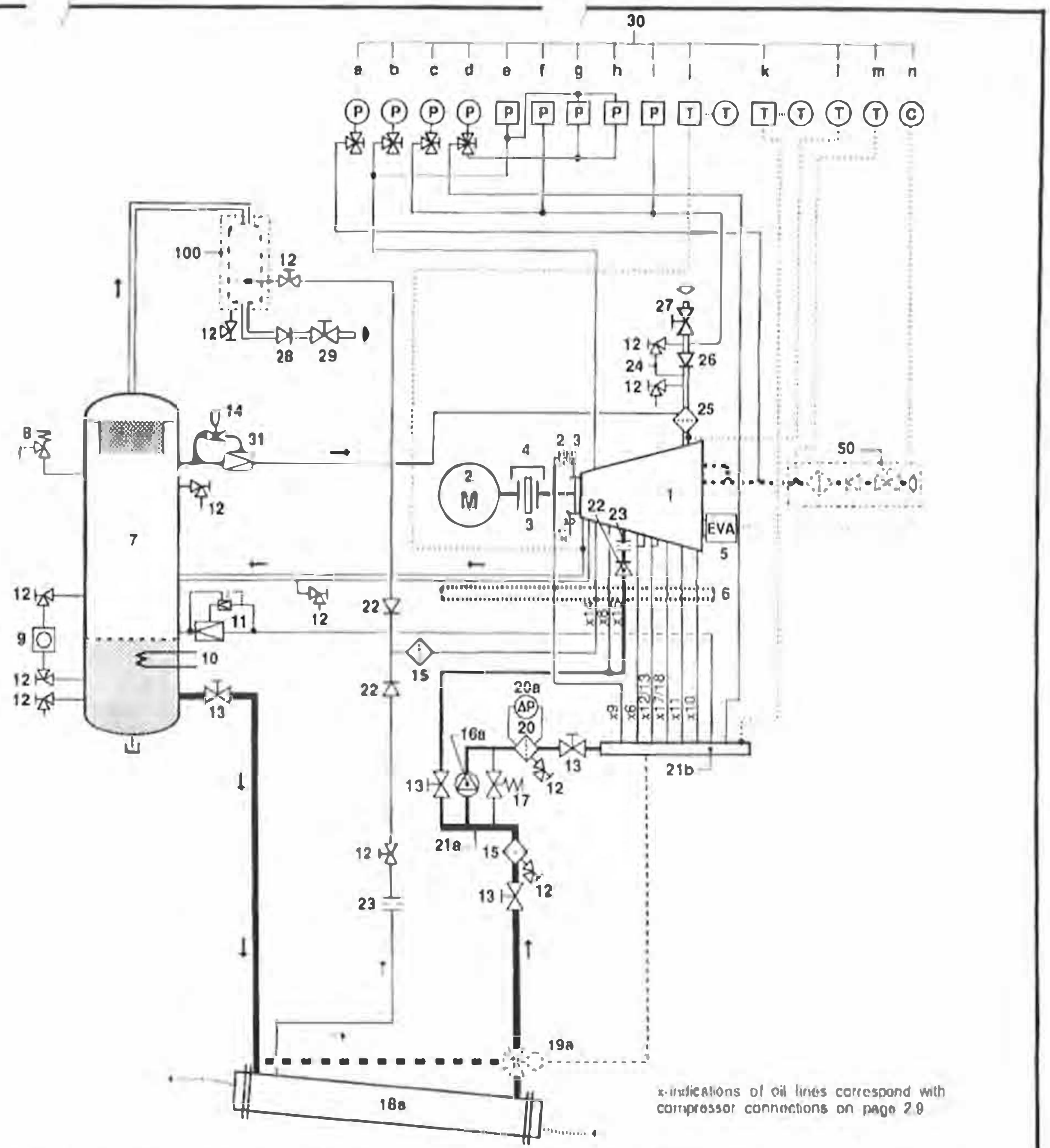
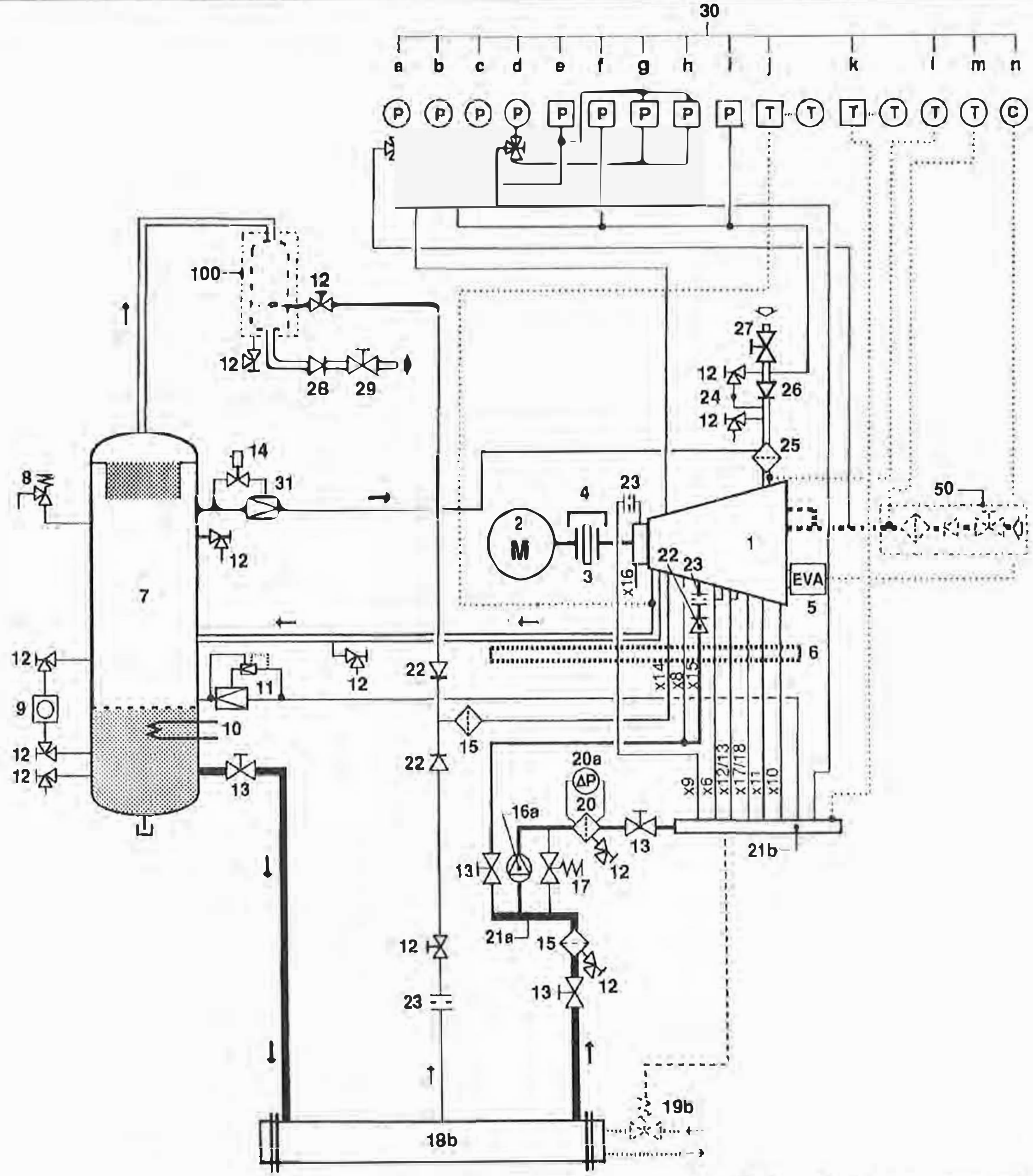


FIG. 3.2 DETAILED REFRIGERANT AND OIL FLOW DIAGRAM FOR PACKAGE WITH OIL PUMP FOR LUBRICATION ONLY AND REFRIGERANT OIL COOLER

1. Grassoscrew compressor GSL
2. electric drive motor
3. flexible coupling
4. coupling guard
5. electric slide valve actuator (EVA)
6. Base frame
7. primary oil separator
8. spring-loaded pressure safety valve
9. oil level sight glass
10. oil heating element
11. oil pressure regulator
12. charging, drain and isolating valves
13. oil system isolating valves
14. solenoidvalve (part of item 31)
15. oil strainer
16a. lubrication oil pump
17. oil pump safety relief valve
18b. water cooled oil cooler
19b. water flow regulating valve
20. main flow oil filter
20a. pressure drop sensing switch
21a. oil distribution line
21b. oil discharge manifold
22. oil check valve
23. oil orifice
24. blow down line
25. suction gas strainer
26. suction check valve
27. suction stop valve
28. discharge check valve
29. discharge stop valve
30a. economizer pressure gauge
30b. discharge pressure gauge
30c. suction pressure gauge
30d. oil pressure gauge
30e. max. discharge pressure safety switch
30f. min. suction pressure safety switch
30g. min. oil/discharge differential pressure safety switch (for starting only)
30h. min. oil/discharge differential pressure safety switch
30i. max. suction pressure safety switch
30j. max. discharge temperatue safety switch with built-in discharge temperature digital read-out
30k. max. oil temperature safety switch with built-in oil temperature digital read-out
30l. suction temperature digital read-out
30m. injection gas temperature digital read-out
30n. capacity control digital read-out (part-load in percentage of full-load capacity)
31. solenoid valve controlled, servo operated by-pass valve (not always present)
50. economizer manifold
100. secondary oil separator with automatic float valve for oil return



x-indications of oil lines correspond with compressor connections on page 2.9

FIG. 3.3 DETAILED REFRIGERANT AND OIL FLOW DIAGRAM FOR PACKAGE WITH OIL PUMP FOR LUBRICATION ONLY AND WATER COOLED OIL COOLER

1. Grassoscrew compressor GSL
2. electric drive motor
3. flexible coupling
4. coupling guard
5. electric slide valve actuator (EVA)
6. Base frame
7. primary oil separator
8. spring-loaded pressure safety valve
9. oil level sight glass
10. oil heating element
11. oil pressure regulator
12. charging, drain and isolating valves
13. oil system isolating valves
14. solenoid valve (part of item 31)
15. oil strainer
16b. full-flow oil pump
17. oil pump safety relief valve
18a. refrigerant liquid cooled oil cooler
19a. three-way by-pass oil flow regulating valve
20. main flow oil filter
20a. pressure drop sensing switch
21b. oil discharge manifold
22. oil check valve
23. oil orifice
24. blow down line
25. suction gas strainer
26. suction check valve
27. suction stop valve
28. discharge check valve
29. discharge stop valve
30a. economizer pressure gauge
30b. discharge pressure gauge
30c. suction pressure gauge
30d. oil pressure gauge
30e. max. discharge pressure safety switch
30f. min. suction pressure safety switch
30g. min. oil/discharge differential pressure safety switch (for starting only)
30h. min. oil/discharge differential pressure safety switch
30i. max. suction pressure safety switch
30j. max. discharge temperature safety switch with built-in discharge temperature digital read-out
30k. max. oil temperature safety switch with built-in oil temperature digital read-out
30l. suction temperature digital read-out
30m. injection gas temperature digital read-out
30n. capacity control digital read-out (part-load in percentage of full-load capacity)
31. solenoid valve controlled, servo operated by-pass valve (not always present)
50. economizer manifold
100. secondary oil separator with automatic float valve for oil return

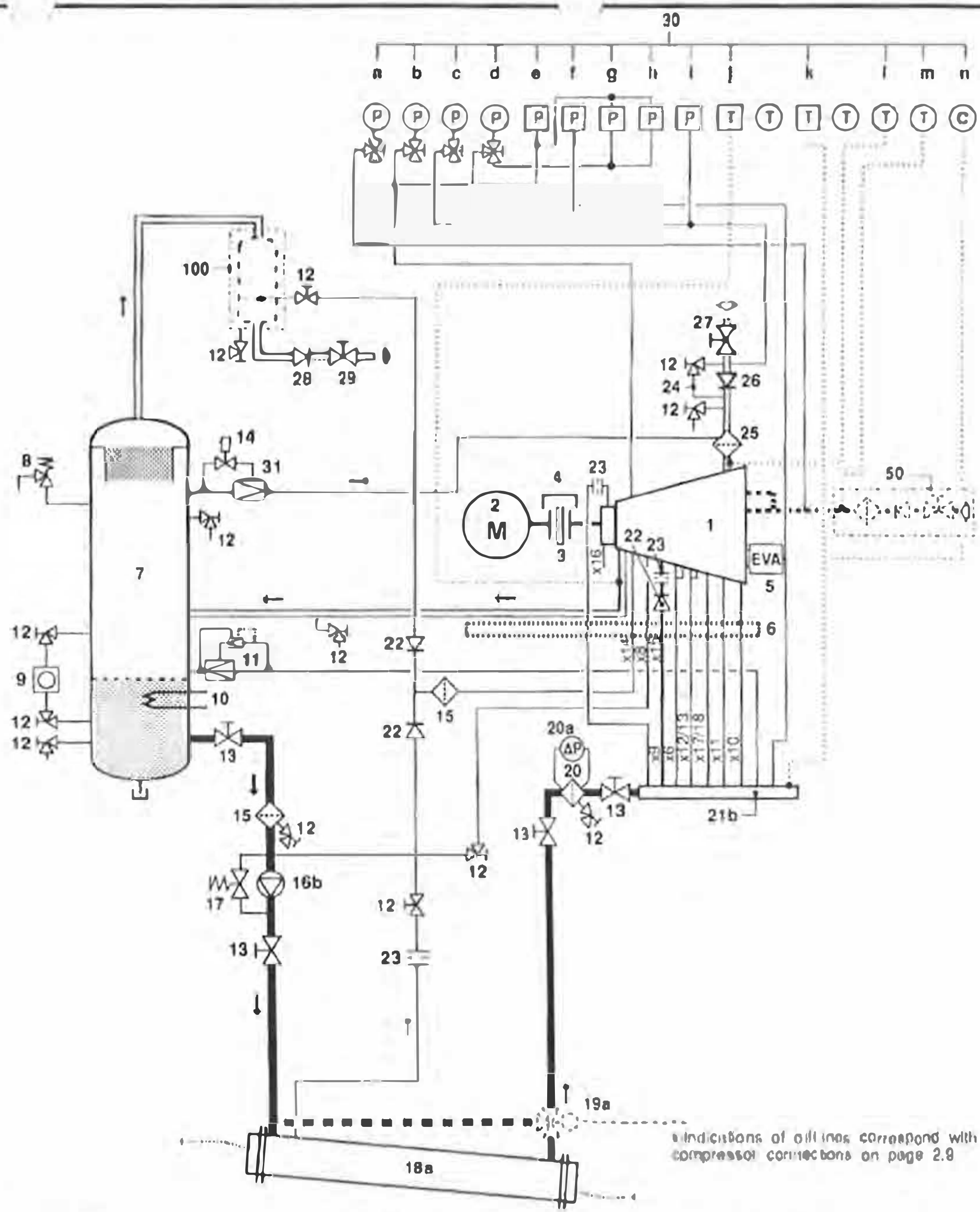
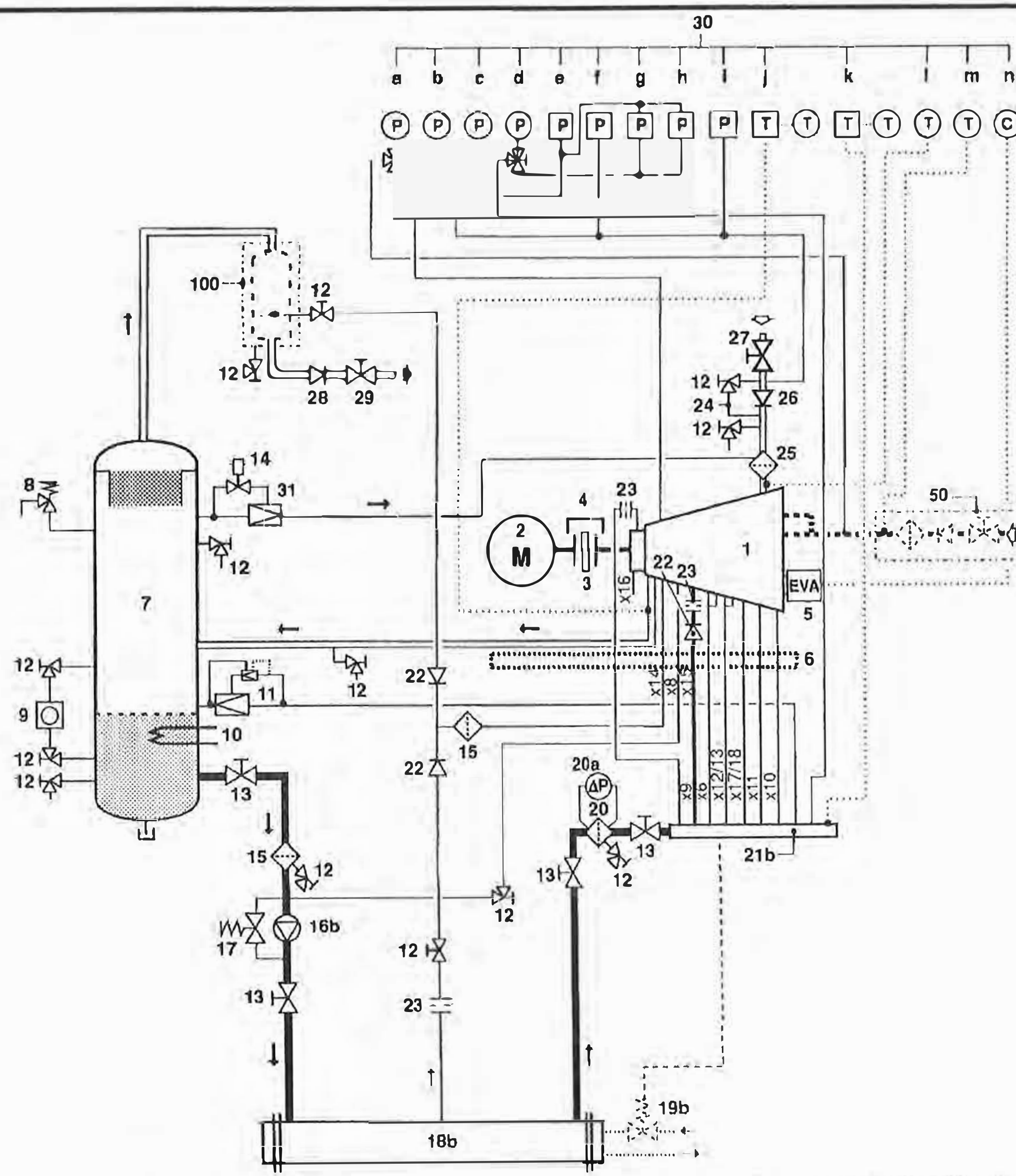


FIG. 3.4 DETAILED REFRIGERANT AND OIL FLOW DIAGRAM FOR PACKAGE WITH FULL-FLOW OIL PUMP AND REFRIGERANT COOLED OIL COOLER

1. Grassoscrew compressor GSL
2. electric drive motor
3. flexiblecoupling
4. coupling guard
5. electric slide valve actuator (EVA)
6. Base frame
7. primary oil separator
8. spring-loaded pressure safety valve
9. oil level sight glass
10. oil heating element
11. oil pressure regulator
12. charging, drain and isolating valves
13. oil system isolating valves
14. solenoid valve (partof item 31)
15. oil strainer
16b. full-flow oil pump
17. oil pump safety relief valve
18b. water cooled oil cooler
19b. water flow regulating valve
20. main flow oilfilter
20a. pressure drop sensing switch
21b. oil discharge manifold
22. oil check valve
23. oil orifice
24. blow down line
25. suction gas strainer
26. suction check valve
27. suction stop valve
28. discharge check valve
29. discharge stop valve
30a. economizer pressure gauge
30b. discharge pressure gauge
30c. suction pressure gauge
30d. oil pressure gauge
30e. max. discharge pressure safety switch
30f. min. suction pressure safety switch
30g. min. oil/discharge differential pressure safety switch (for starting only)
30h. min. oil/discharge differential pressure safety switch
30i. max. suction pressure safety switch
30j. max. discharge temperatue safety switch with built-in discharge temperature digital read-out
30k. max. oil temperature safety switch with built-in oil temperature digital read-out
30l. suction temperature digital read-out
30m. injection gas temperature digital read-out
30n. capacity control digital read-out (part-load in percentage of full-load capacity)
31. solenoid valve controlled, servooperated by-pass valve (not always present)
50. economizer manifold
100. secondary oil separator with automatic float valve for oil return



x-indications of oil lines correspond with compressor connections on page 2.9

FIG. 3.5 DETAILED REFRIGERANT AND OIL FLOW DIAGRAM FOR PACKAGE WITH FULL-FLOW OIL PUMP AND WATER COOLED OIL COOLER

- Depending on the operating conditions (so, not always): a solenoid valve controlled, servo-operated (by gas pressure) by-pass valve (31), mounted in a by-pass line between oil separator and suction side of the package. When the package is stopped, the solenoid valve is energized, causing the by-pass valve to open and the pressure inside the package to equalize. The minimum pressure difference to open the valve is 0.2 bar.
- A pressure gauge and safety switch cabinet, in which most of the measuring and safety devices (30) of the package are installed. For more details about these and other instruments, refer to para. 3.5 "Instruments and safety devices".
- The necessary stop valves (13), check valves (22) and small sized valves (12) for isolating, charging or draining the compressor package or parts of it.
- An economizer manifold (50, if present) fitted to the standard economizer connection(s) on the compressor housing (see also 34 and 35 in figure 2.3). The inlet pipe of this manifold, which is to be connected to the economizer cooler of the plant, is provided with a stop valve, a check valve and a strainer.

All components and the interconnecting piping are assembled on a solid steel base frame (6). Figure 3.6 shows how a complete standard package lookes like in reality.

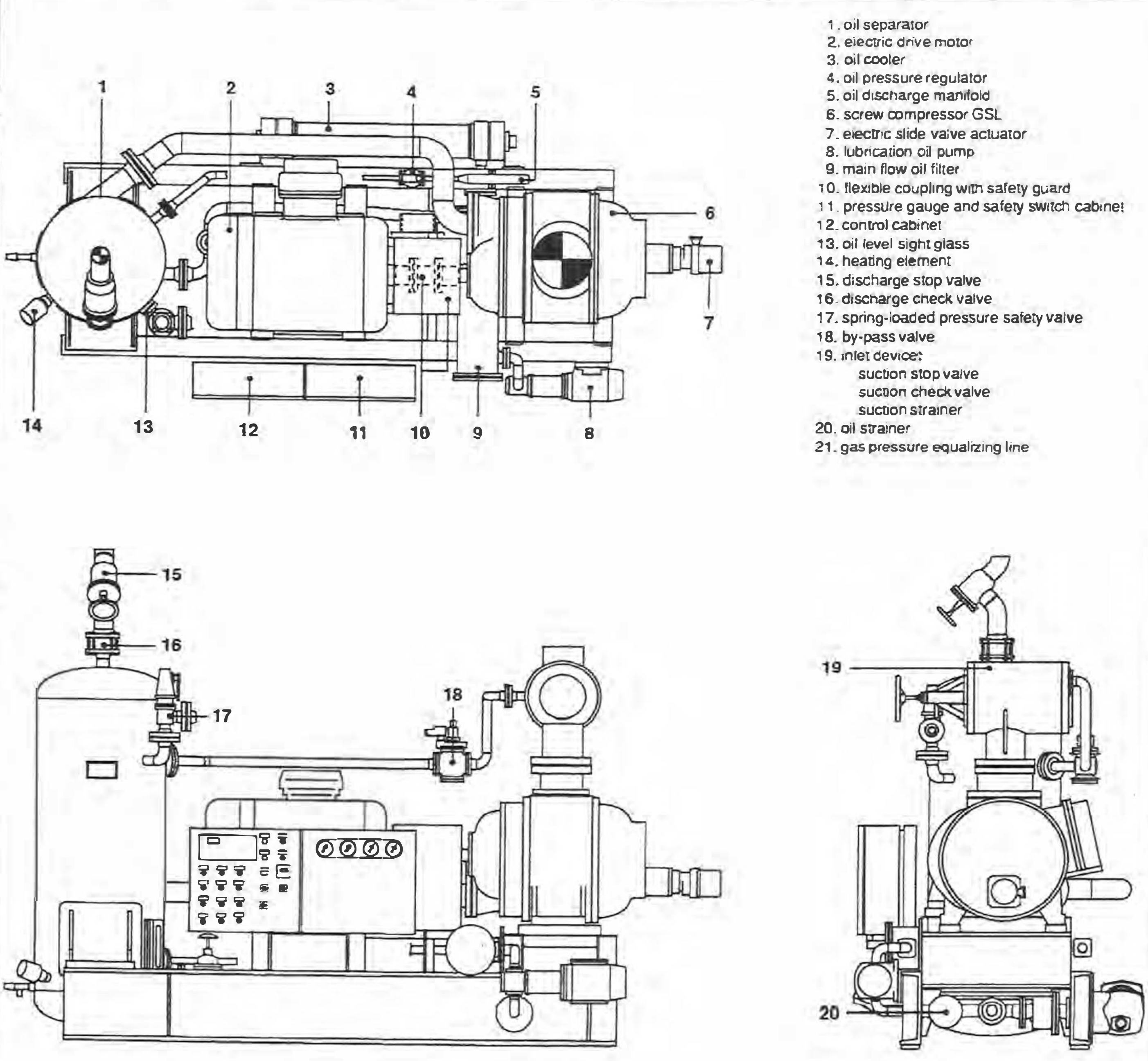


FIG. 3.6 COMPONENT IDENTIFICATION OF STANDARD PACKAGE GSLP

3.3 OIL SEPARATOR(S)

Separation of the oil from the discharge gas of the compressor takes place in one or two oil separators.

In cases in which it does not matter that a slight quantity of oil enters the refrigeration system with the discharge gas, only the primary oil separator is used. This separator is a vertical pressure vessel of large volume, in which the gas flow undergoes such changes in velocity and direction that heavier drops of oil are thrown out and drip downwards. Any smaller drops of oil are retained in a steel fibre filter element (demistor) prior to the gas leaving the oil separator.

The separated oil is collected at the bottom of the separator, which also acts as oil sump of the package. For inspection of the oil level an oil level sight glass is fitted. A heating element in the bottom part of the separator ensures that the oil temperature is maintained at the desired level during standstill of the package.

In refrigeration systems requiring the oil carry-over to be minimized, a secondary oil separator is installed behind the primary oil separator (see flow diagrams, fig. 3.2 to 3.5). This secondary oil separator consists of a divided cylindrical vessel in which a removable coalesceing element is fitted. The separated oil, after reaching a certain level, is returned under discharge pressure via an automatic float valve to the male rotor oil injection line of the compressor.

3.4 ELECTRIC CAPACITY CONTROL ADJUSTING DEVICE

GENERAL

To operate the capacity control regulating shaft of the compressor (see fig. 2.6) manually (by push-buttons) or automatically (by the control system of the installation), a simple and reliable electric adjusting device, called the "Electrical slide Valve Actuator" (EVA) is used. This is a standard accessory, factory-mounted on and in line with the hydraulic cylinder of the compressor as shown in fig. 3.6.
Apart from two different position indicators (explained further on), there is only one type and size of this device available, suitable for all compressor types and for all existing built-in volume ratios.

DESCRIPTION OF STANDARD DEVICE

Fig. 3.7A represents a longitudinal section of the electric slide valve actuator. It consists of a small reversible electric motor (9) with brake mechanism (8) and speed reductor (4) which drives in either direction a central output shaft (11) and a cam post (7), all mounted inside an aluminium housing (10), which on its turn, is bolted by means of an intermediate bush (3) to a disc on the hydraulic cylinder of the compressor, so that the output shaft is coupled via a carrier pin (2) in line with the compressor regulating shaft (1).

When the capacity control slide valve inside the compressor has reached either its full load (max. capacity) or minimum load (min. capacity) position, the adjusting motor is stopped automatically by means of two micro limit switches (6), mounted on a adjusting plate inside the housing and each of them activated by one of the two cams (5), fitted around the cam post (7). The minimum capacity limit switch (that is the second switch seen from below) has a twofold function; it also serves to prevent the compressor-motor from being started as long as the capacity control mechanism is not yet in its minimum position. See also electric wiring diagram in Paragraph 3.6.

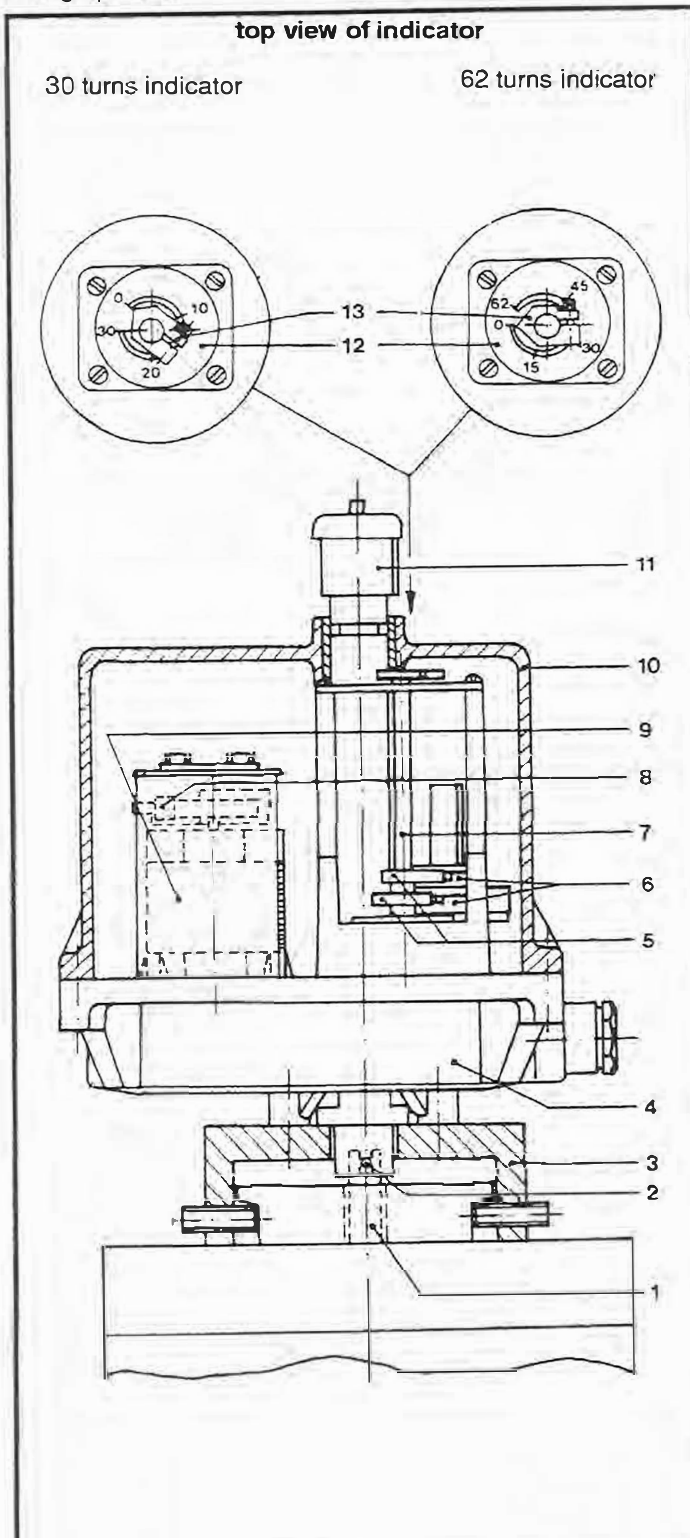


FIG. 3.7A ELECTRIC SLIDE VALVE ACTUATOR

Compressor type	Built-in volume ratio φ_v
GSL 65	2.2 - 2.6 - 3.7
	4.8
GSL 85	2.2 - 2.6 - 3.7
	4.8
GSL125	2.2 - 2.6 - 3.7
	4.8
GSL165	2.2 - 2.6 - 3.7
	4.8
GSL180	2.2 - 2.6 - 3.7
	4.8
GSL240	2.2 - 2.6 - 3.7
	4.8
GSL480	2.2 - 2.6 - 3.7
	4.8

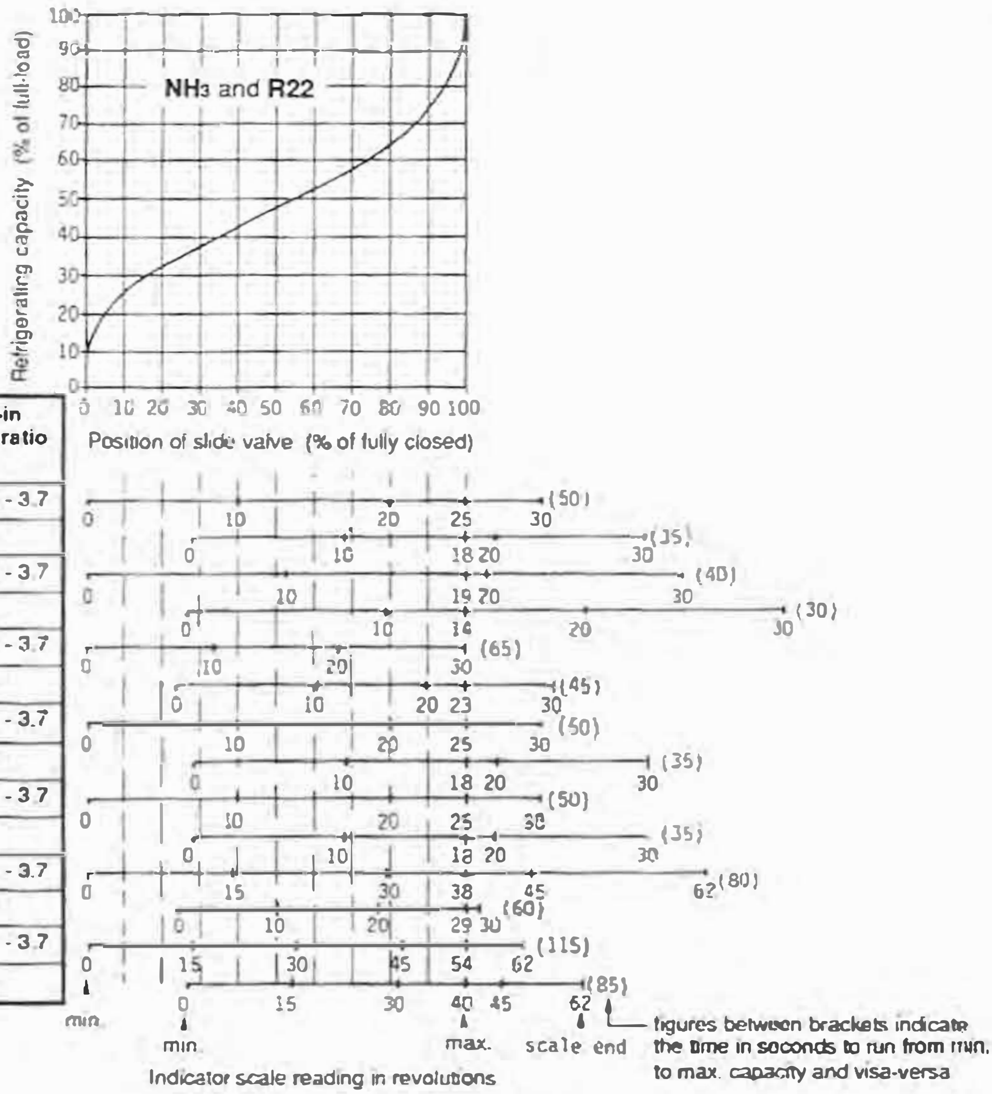


FIG. 3.7B PART-LOAD REFRIGERATING CAPACITY

Both the min. and max. capacity limit switch may also be used to indicate, by two signal lamps, whether the capacity control adjusting device is either moving to min. or max. capacity (one of the signal lamps on) or is standing still (both lamps off).
The free end of the cam post is provided with an indicator - pointer (13) on a scale (12) -, visible from the outside through a sight glass in the end face of the housing and indicating the number of revolutions completed by the output shaft (and thus by the regulating shaft of the compressor) from the minimum load position of the slide valve inside the compressor, corresponding with the zero position of the pointer. When the slide valve is at its maximum load (fully closed end stop) position, the pointer has not necessarily reached the end of the scale but is somewhere in-between, depending on compressor type and built-in volume ratio. The reason is, that there are only two standard position indicators available with a scale ranging from 0 to 30 (printed numbers 0, 10, 20 and 30) and from 0 to 62 (printed numbers 0, 15, 30, 45 and 62) revolutions respectively.

Refer to the graph in figure 3.7B which represents the relation between the various scale readings in revolutions, the linear displacement (position) of the slide valve and the corresponding refrigerating capacity, both expressed in percentage of full-load.

For example: A compressor model GSL240 with built-in volume ratio of 3.7 only needs 38 of the 62 revolutions available on the indicator to move from minimum to maximum capacity. So according to figure 3.7B, at 50% slide valve position (=48% capacity) the indicator pointer will show about 19 and not 31 = 50% of 62.

OPTIONAL COMPONENTS (refer to figure 3.8A, overleaf)

The standard electric slide valve actuator may have been completed with the following optional supplements:

- Up to three extra micro switches with corresponding adjustable cams, fitted on top of the standard limit switches

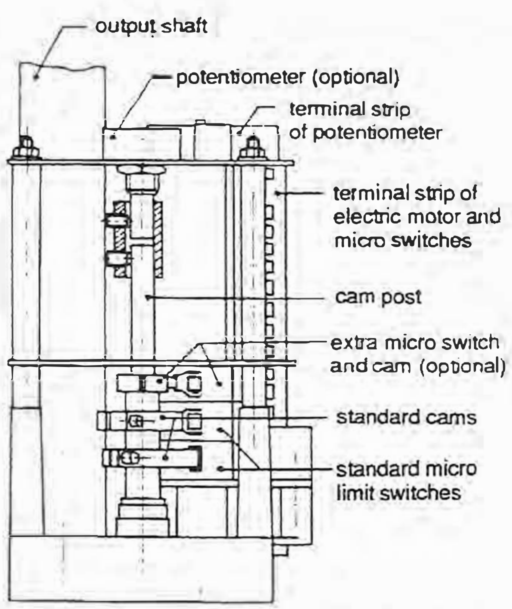


FIG. 3.8A SUPPLEMENTS FOR ELECTRIC SLIDE VALVE ACTUATOR

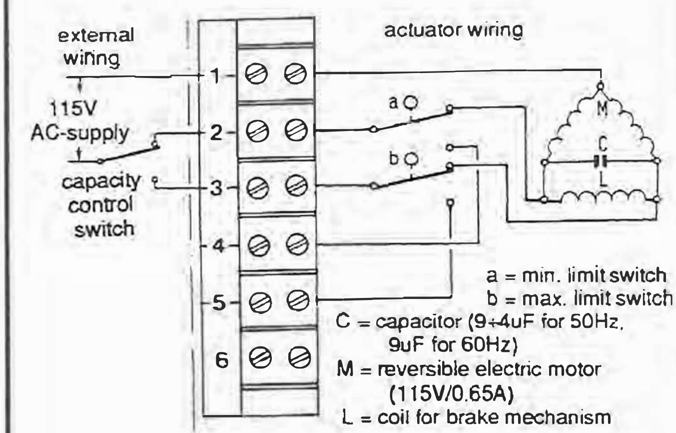


FIG. 3.8B INTERNAL WIRING DIAGRAM OF SLIDE VALVE ACTUATOR

and cams respectively. These micro switch and cam combinations can be used for any switch purpose in the installation in dependence on the actual (part-load) capacity of the compressor in question.

- Only one extra micro switch in combination with a potentiometer (see fig. 3.8A). The potentiometer is used for remote electric indication (analog or digital read-out) of the position of any part of the capacity control mechanism or the corresponding actual refrigerating capacity. It is mounted on the free end of the cam post instead of the pointer plus scale.
  So, in this case the standard "mechanical" indicator is not available any more.

ELECTRIC WIRING

Inside the housing (10) in fig. 3.7A a terminal strip is fitted, which is factory wired to the standard limit switches and adjusting motor. Fig. 3.8B shows this terminal strip and the internal electric wiring diagram. In principle all external wiring remains to be carried out by the installer in the field. Only in case the package is provided with a control cabinet all the electric wiring has been done by the manufacturer according to the wiring diagram in Paragraph 3.6.

3.5 INSTRUMENTS AND SAFETY DEVICES

The standard compressor package is equipped with a number of instruments and safety devices as shown in the flow diagrams of figures 3.2 to 3.5. Their purpose is to check the correct operation of the package according to the system design conditions and to protect the compressor and package against malfunctioning or even breakdown if somewhere abnormal operating conditions arise.

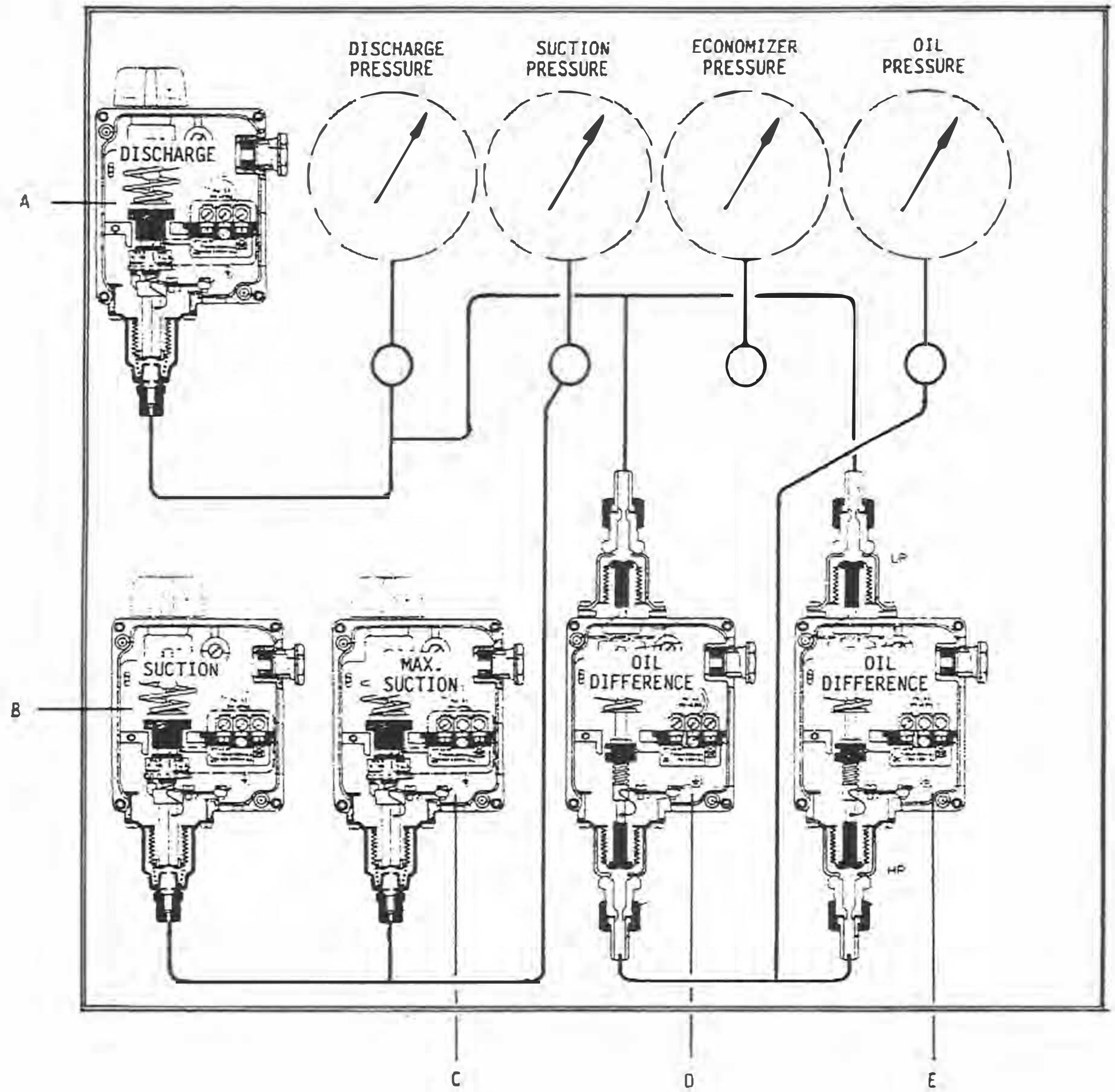
The following measuring devices are installed:

- Three pressure gauges for suction pressure (30c), discharge pressure (30b) and lubricating (= pump) oil pressure (30d) respectively. These pressure gauges are grouped together behind a window inside a closed cabinet situated on the package front side. If the package is equipped with an economizer manifold (50), the cabinet contains an additional pressure gauge (30a).
- Three digital read-outs (30l, 30j & 30k) to indicate the actual (superheated) suction temperature, the discharge temperature and the oil temperature downstream the oil cooler respectively. If the package is equipped with an economizer manifold (50), an additional digital; read-out (30m) is provided to indicate the actual injection gas temperature.
  The oil and discharge temperature digital read-out form part of the max. oil and max. discharge temperature safety switch respectively. See also further on under safety devices.
  The suction and injection temperature read-out are separate devices with their own sensing elements fitted via a sealed connector inside the relevant lines.
- A digital read-out (30n) to indicate the actual (part-load) capacity in percentage of the full-load capacity.
- An oil level sight glass (9) on the oil separator to check whether the proper amount of oil is available inside the separator.

The following safety devices are installed:

- An electronic "max. discharge temperature" safety switch (30j) which can be set at values between 0 and 100 °C. This safety switch incorporates a digital read-out to indi-

PRESSURE GAUGE AND SAFETY SWITCH ARRANGEMENT IN INSTRUMENT CABINET OF THE GSLP - PACKAGE



A = RT6AB
B = RT1A
C = RT1A
D = RT260A
E = RT260A
— NH_3 - one stage for V_i 4.8

A = RT6AB
B = RT1A
C = RT5A
D = RT260A
E = RT260A
— NH_3 - one stage for V_i 2.2/2.6/3.7

A = RT5A
B = RT1A
C = RT1A
D = RT260A
E = RT260A
— NH_3 - booster for whole V_i-range

A = RT6B
B = RT1
C = RT1A
D = RT260A
E = RT260A
— R22 - one stage for V_i 4.8

A = RT6B
B = RT1
C = RT5A
D = RT260A
E = RT260A
— R22 - one stage for V_i 2.2/2.6/3.7

A = RT5
B = RT1
C = RT1A
D = RT260A
E = RT260A
— R22 - booster for whole V_i-range

FIG. 3.9 INSIDE VIEW OF SAFETY SWITCH AND PRESSURE GAUGE CABINET

cate the actual discharge temperature; by pressing a button on the front side of the read-out the set value of the safety switch will be shown. The safety switch is controlled by its temperature, sensing element fitted via a sealed connector inside the discharge line close to the discharge connection of the compressor. The discharge temperature safety switch constitutes the most important protection of the compressor, because deviations from the normal operating conditions (such as shortage of oil, too high an oil temperature, too high a pressure ratio, excessive superheating of the suction gas) are always leading immediately to a considerable rise of the discharge temperature.

- An electronic "maximum oil temperature" safety switch (30k) which guards the temperature of the oil leaving the oil cooler and can be set to a value between 0 and 65 °C. This safety switch also incorporates a digital read-out to indicate the actual oil temperature; by pressing a button on the front side of the read-out the set value of the safety switch will be shown.
  The temperature sensing element is fitted via a sealed connector inside the oil discharge manifold.
- A "max. discharge pressure" safety switch (30e) which protects the package and plant against a discharge pressure beyond the design conditions or operating limits.
- A "min. suction pressure" safety switch (30f) which protects the package and plant against suction pressure below the design conditions or operating limits.
- A "max. suction pressure" safety switch (30i) which protects the compressor against excessive internal groove end pressure due to a high suction pressure in combination with the built-in pressure ratio of the compressor. It also keeps the compressor capacity control in the "min. capacity"-position during starting of the package in a system with high pressure on the suction side.
- A "min. discharge/oil differential pressure" safety switch (30h) which protects the compressor against running with insufficient lubricating oil supply to bearings, capacity control slide valve and shaft seal.
- A second "min. discharge/oil differential pressure" safety switch (30g) which prevents the compressor drive motor from being started until sufficient lubricating oil pressure has been built up by the lubrication (16a in fig. 3.2 and 3.3) or full-flow (16b in fig. 3.4 and 3.5) oil pump. So, this safety switch is only of importance during starting of the package.
- A spring-loaded pressure safety valve (8) on the oil separator, which protects the package under any circumstances against excessive pressure built-up. The valve is factory-adjusted at 21.5 bar(e) and sealed.
- A pressure drop sensing switch (20a) fitted on the main flow oil filter, to provide for a visible and/or an audible warning signal when the filter is clogging (pressure difference has reached 1 bar).

All safety devices, with the exception of the spring-loaded pressure safety valve and the pressure drop sensing switch, are mounted inside a closed cabinet on the package front side as per fig. 3.9, which also contains all pressure gauges. In case a control cabinet has been delivered with the package as well, the temperature safety switches, all temperature measuring devices and capacity indicator are located inside this control cabinet.
The safety switches are to be incorporated in the control current circuit of the package in such a way that the compressor stops as soon as one of the switches is actuated due to an unsafe condition (refer also to the next paragraph 3.6).

3.6 OPERATION OF THE STANDARD CONTROL CURRENT CIRCUIT.

General
As the trouble-free operation of the compressor depends in particular on the injection of the correct quantity of oil into the rotor grooves and an adequate lubricating oil pressure for the bearings, slide valve and shaft seal, the operational sequence of the safety switches in the control current wiring diagram is such, that the compressor can start and remain in operation only, when the oil system works properly. Therefore sufficient lubricating oil pressure should have been built-up before the compressor can be started.
To ensure easy starting of the electric drive motor during compressor start-up, the capacity control slide valve must be in its "minimum"-position and the by-pass valve between suction and discharge (if present) should be open.
When the package is at standstill, the heating element in the oil separator should be operating; its task is to keep the viscosity of the oil low enough and to prevent, as much as possible, the refrigerant from dissolving in the oil.

The foregoing conditions are met by the control current wiring diagram shown in fig. 3.9. This control current circuit comprises the following safety switches:

- Thermal protection of compressor drive motor (F1) and automatic thermal protection of oil pump motor (F2);
- Max. discharge pressure safety switch (S5), min. suction pressure safety switch (S6) and max. suction pressure safety switch (S3);
- Min. differential pressure safety switch between oil and discharge pressure (S13) which prevents the compressor drive motor from being started until sufficient lubricating oil pressure has been built-up by the lubrication or full-flow oil pump. So this safety switch is only of importance during starting;
- Min. differential pressure safety switch between oil and discharge pressure (S4) to ensure sufficient lubricating and injection oil pressure after the starting period;
- Max. oil and max. discharge temperature safety switch (S7 and S8 respectively);
- Pressure drop sensing switch (S9) on main flow oil filter;
- Max. and min. limit switch (S16 and S17) of the capacity control slide valve actuator.

Starting the package

When the compressor package is at standstill and the main switch S1M is closed, the capacity control slide valve actuator moves automatically to the position "minimum capacity".

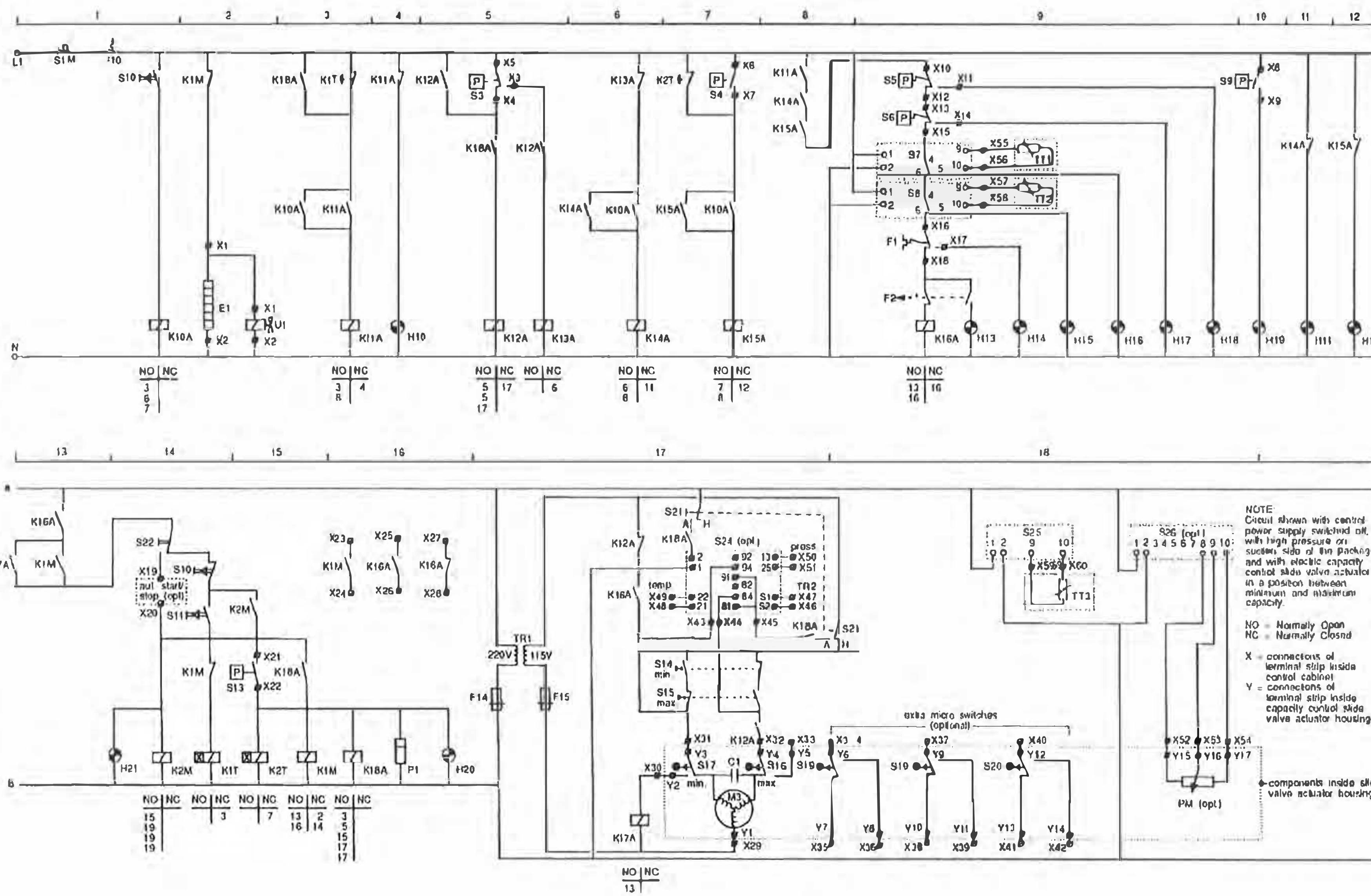


FIG. 3.9 STANDARD CONTROL CURRENT WIRING DIAGRAM

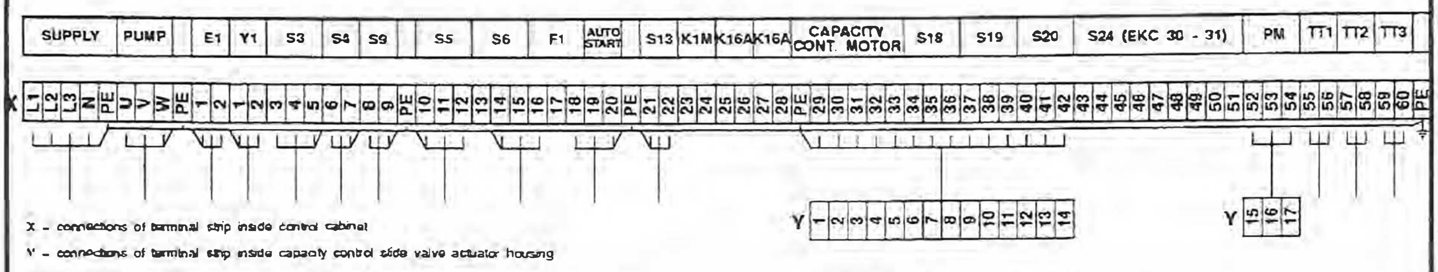


FIG. 3.10 TERMINAL STRIP INSIDE CONTROL CABINET

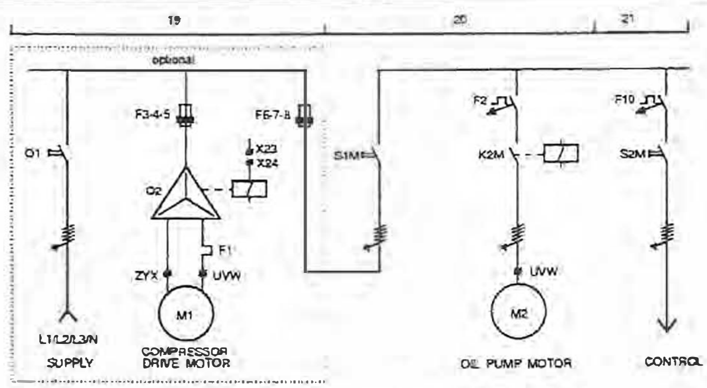


FIG. 3.11 MAIN POWER SUPPLY

INDEX TO FIG. 3.9, 3.10 and 3.11

C1 Capacitor for capacity control adjusting motor

E1 Heating element

F1 Thermal protection of compressor drive motor
F2 Automatic protection of oil pump motor
F3-4-5 Fuse protection of compressor drive motor
F6-7-8 Fuse protection of main power control cabinet ¹)
F10 Automatic protection of control cabinet
F14-F15 Fuse protection of transformer

H10 Oil pressure for bearing lubrication too low
H11 Suction pressure too high
H12 Oil pressure too low
H13 Oil pump motor overloaded
H14 Compressor drive motor overloaded
H15 Discharge temperature too high
H16 Oil temperature too high
H17 Suction pressure too low
H18 Discharge pressure too high
H19 Pressure difference over main flow oil filter too high
H20 Package in operation
H21 Oil pump in operation

K1M Auxiliary starting relay of compressor drive motor
K2M Starting relay of oil pump motor
K1T Time lag relay (15 - 300 sec.)
K2T Time lag relay (15 - 300 sec.)
K10A Auxiliary relay for resetting of protections
K11A Auxiliary relay for K1T
K12A Auxiliary relay for S3
K13A Auxiliary relay for S3
K14A Auxiliary relay for S3
K15A Auxiliary relay for S4
K16A Auxiliary relay for failures
K17A Auxiliary relay for "minimum capacity"
K18A Auxiliary relay for K1M

M1 Compressor drive motor ¹)
M2 Oil pump motor
M3 Capacity control adjusting motor

P1 Service hour counter ¹)
PM Potentiometer ¹)

Q1 Main switch power supply ¹)
Q2 Starting equipment compressor drive motor ¹)

S1M Main switch control cabinet
S3 Maximum suction pressure safety switch
S4 Min. oil/discharge differential pressure safety switch
S5 Maximum discharge pressure safety switch
S6 Minimum suction pressure safety switch
S7 Maximum oil temperature safety switch and temperature indicator
S8 Maximum discharge temperature safety switch and temperature indicator
S9 Pressure drop sensing switch on main flow oil filter
S10 Push button "Package stop/reset"
S11 Push button "Package start"
S13 Min. oil/discharge diff. pressure safety switch (during starting only)
S14 Push button "Minimum capacity"
S15 Push button "Maximum capacity"
S16 Limit switch maximum capacity
S17 Limit switch minimum capacity
S18 Extra switch of capacity control ¹)
S19 Extra switch of capacity control ¹)
S20 Extra switch of capacity control ¹)
S21 Selector switch "hand/automatic" for capacity control
S22 Selector switch "hand/automatic" for starting and stopping
S24 Aut. capacity controller/motor current limiting unit ¹)
S25 Suction temperature indicator
S26 Capacity control indicator ¹)

TR1 Transformer (220V/115V)
TR2 Current transformer (part of S24)
TT1 Sensing bulb of oil temperature
TT2 Sensing bulb of discharge temperature
TT3 Sensing bulb of suction temperature

U1 Solenoid pilot valve of by-pass valve

¹) if present

Consequently relay K17A (line 17) is energized and its contact K17A in line 13 closes.
By pressing stop/reset button S10, relay K10A (line 1) is energized and energizes on its turn relays K11A, K14A, and K15A in line 3, 6 and 7 respectively; their contacts in line 8 will close and signal lamp H10 ("Bearing lubrication too low") in line 4 goes out.
As all safety switches in line 9 are normally closed (including S7 and S8, but only when the power supply is switched on) relay K16A becomes energized as well and its contact in line 13 closes.
The compressor package can now be started by pressing button S11 (line 14), causing the oil pump motor relay K2M and time lag relay K1T to be energized. Also signal lamp H21 (oil pump in operation) lights up. Three contacts of K2M in line 19 will switch on the oil pump motor and another contact K2M (line 15) shunts start button S11, so that the latter can now be released.
As the oil pump is in operation lubricating oil pressure will be built-up, causing the differential pressure switch S13 (line 15) to close and compressor drive motor relay K1M, auxiliary relay K18A and time lag relay K2T to be energized. Also signal lamp H20 ("Package in operation") lights up and the service hours counter P1 starts running.

One of the contacts of K1M in line 16 will switch on the compressor drive motor via a motor star/delta switch Q2 (if present) in line 19; a second contact K1M (line 2) switches off the heating element E1 and de-energizes the solenoid pilot valve Y1 of the by-pass valve (by-pass valve closes) and a third contact K1M shunts contact K17A (line 13). By opening a fourth contact K1M in line 14, time lag relay K1T is de-energized, causing relay K11A (via contact K1T in line 3) to remain energized.
Contact K1M (line 14) should open within 60 seconds after time lag relay K1T has been energized (therefore sufficient lubricating oil pressure should have been built up) otherwise the compressor drive motor will stop (contact K11A in line 8 opens).

Simultaneously with starting relay K1M auxiliary relay K18A is energized. Two contacts of aux. relay K18A shunts contact K1T (line 3) and differential pressure switch S13 (line 15) respectively and by closing a third contact K18A in line 5, the maximum suction pressure safety switch S3 becomes operative.
The two remaining contacts K18A in line 17 closes, causing the automatic capacity controller/compressor drive motor current limiting unit S24 (if present) to become operative.
Also simultaneously with starting relay K1M time lag relay K2T is energized. Contact K2T (line 7) opens 30 seconds after time lag relay K2T has been energized, so that the differential pressure safety switch S4 in line 7 becomes operative.
Differential pressure safety switch S4 closes as soon as a sufficient pressure difference between oil pressure and discharge pressure has been built up, whereby a new current circuit is formed. This current circuit enables to open contact K2T in line 7 approx. 30 seconds after time lag relay K2T has been energized without the compressor drive motor being stopped (contact K15A in line 8 opens).

As the package is operating now, max. suction pressure safety switch S3 (line 5) will close as a result of the rapid fall in suction pressure and will energize auxiliary relay K12A, causing the capacity control to become operative (contact K12A in line 17 opens).

Capacity control of the compressor

As soon as the suction pressure has fallen below the value preset on the max. suction pressure safety switch, the refrigerating capacity can be adapted steplessly to the required cooling load by means of the slide valve actuator on the compressor. The adjusting motor of this slide valve actuator (line 17) may be actuated manually by two push buttons S14 and S15, which can be selected by selector switch S21 included in the control current wiring diagram. In the reverse position of selector switch S21, the adjusting motor is actuated by the pilot switch of an automatic capacity controller/compressor drive motor current limiting unit S24 (if present).
In this way it is possible to set the capacity control slide valve into any given position between minimum and maximum capacity.

When the capacity control slide valve reaches its minimum or maximum position, the adjusting motor is switched off by limit switches S17 or S16 respectively, located in the slide valve actuator housing.

For remote electric indication of the position of the capacity control slide valve, a potentiometer (if present) mounted inside the slide valve actuator and an indicator S26 (if present) can be included in the control current circuit.

Furthermore, extra micro switches (if present) S18, S19 and S20 (if present; line 18) can be mounted in the actuator housing to serve any switch purpose in the installation depending on the actual (part-load) capacity of the compressor involved.

Stopping the package

The package is stopped by pressing button S10, in which event auxiliary starting relays K18A, K1M and K2M and time lag relays K1T and K2T are released. All contacts of these relays return again to their initial position; consequently the heating element becomes operative again, the solenoid pilot valve is energized (by-pass valve opens) and the adjusting motor of the capacity control slide valve actuator automatically moves back to the minimum position.

The package automatically stops when unsafe conditions arise and in which case one of the aforementioned safety switches or thermal protections become operative. Any unsafe condition is indicated by one of the signal (warning) lights (H10 - H19) included in the control current circuit.

4.1 GENERAL

This chapter contains instructions for the proper installation of Grassoscrew compressor packages. Before the package is ready for commissioning and initial start up, the following must be completed in the order given:

4.2 START-UP SERVICE OUTLINE

1. The package is to be leveled securely, anchored to the foundation and grouted according to para. 4.4 in order to assure stability of the coupling alignment as in paragraph 4.7.
2. All refrigeration piping is to be completed as in para. 4.6. Relief valves are to be properly vented.
3. The water piping is to be completed with the water valve installed for water cooled packages as in para. 4.6.
4. The system and the compressor package are to be pressure tested for leaks as in para. 4.9.
5. The system is to be evacuated to remove air and moisture as in para. 4.10.
6. The coupling is to be aligned within the specifications in para. 4.7.
7. The electrical wiring is to be completed as per wiring diagrams. Do not energize the compressor control cabinet until oil is added or the oil heater is disconnected.
8. The compressor is to be filled with the correct type and amount of lubricating oil as in para. 4.11.
9. The oil is to be warmed up as in para. 4.12.
10. The control cabinet is to be energized to check the safety switches and the capacity control as in para. 4.14.
11. The direction of rotation of the motor is to be checked as in para. 4.16.
12. The electric valve actuator is to be checked as in paragraph 4.15.

The Supplier-Representative will supervise the following with customer:

1. Check the general installation.
2. Check the coupling alignment.
3. Check the electrical safety controls.
4. Check capacity control actuator adjustment.
5. Start the compressor for the first time and adjust all the packages valves and controls.
6. Explain compressor operation to the operating personnel.

4.3 RECEIPT OF THE PACKAGE

Immediately on arrival of the Grassoscrew compressor package unpack all the crates and boxes and check the items against shipping lists for any possible shortages. Examine the compressor, package components and loose items for possible damage in transit. Notify the carrier of any shortages or damages and enter the appropriate claim with them. Prior to despatch from the works the package has been charged with dry nitrogen; therefore all stop valves are closed and all flanged connections are sealed with a blind plate and gasket between flange and counterflange.

In order to prevent penetration of moisture and impurities, it is recommended to leave the nitrogen charge in the package until it is installed. Also the plastic covers on the stop valves should be kept in position. If the package should be stored, it must be kept at all times in a dry location to prevent corrosion damage. If the package is to stored for a prolonged period of time, the unit should be checked occassionally that the holding charge of dry nitrogen remains above atmospheric pressure. This will prevent corrosion from any moisture that might enter the compressor package.

4.4 FOUNDATION REQUIREMENTS

The compressor package can be mounted and secured to any hard rigid and level surface which is adequate to support the weight of the package. Since the screw compressor is a relatively vibration free rotary machine, it does not have to be mounted on an inertia block (heavy foundation) or pad. In multiple machine installation of 350 HP (250 kW input power) or larger or in locations with excessive floor vibration of external source, it may be necessary to mount the package on an inertia block or pad and isolate the package and pad from the floor.
To carry out installation, testing and future servicing, sufficient space around the package should be available.

4.5 INSTALLATION OF THE PACKAGE

Check the foundation anchor bolts spacings with the hole spacings in the package frame base.

Lift the package by placing slings at each hoisting eye of the steel base frame. Use spreader bars or timber under the slings to prevent damage to the piping and components. Do not sling from the pipework, the inlet device or the eyebolt holes in the motor. Eyebolts have been provided for lifting component pieces only and not the entire package.

If the mounting surface is not level, use shims under the frame to distribute the weight evenly over the entire frame. Any gross distortion of the frame when the anchor bolts are tightened will complicate the alignment of the coupling.
Do not grout the package frame to the foundation at this stage. Grouting with an expanding grout around the entire base is necessary after the refrigerant piping is connected and the compressor and motor are roughly aligned (approximately 1mm) total indicating reading). The grouting will then minimize any base deflections that may affect the coupling alignment.

4.6 CONNECTING THE (PACKAGE) SYSTEM PIPING

The size and location of the refrigerant suction, discharge, economizer and water connections, can be found on the

dimensional drawing supplied with each package. For standard packages, the location of connections is given in fig. 3.6 "Component identification drawing of standard package".
The suction line and discharge line should be installed and supported such that there is no load exerted on the compressor body or the oil separator from either static forces or vibration.
External forces from the piping can distort the coupling alignment and cause major bearing and shaft seal problems.

Refrigerating system lines:

Before installing suction and discharge line, remove the plastic protection cap of the suction and discharge stop valve and inspect the stop valve connections as well as the lines themselves for the presence of dirt.
The lines can be welded direct onto the welding ends of the stop valves; the stop valves need not therefore be dissassembled. Prior to welding, the stop valves should be opened entirely and then closed one full turn.

CAUTION!

In order to prevent the possibility of any liquid carry-over, the plant in which the Grassoscrew compressor package is to be installed, should meet the same requirements as if it has been designed to operate with a reciprocating compressor (package).

4.7 MOUNTING AND CHECKING COUPLING

In general the package will be supplied complete with a drive motor which is connected to the compressor by means of a double flexible coupling. But, to prevent damage to the compressor and drive during transport, the **intermediate elastic elements** of the coupling are shipped unassembled and packed together with the package.
This symmetrically constructed all-steel coupling (shown in fig. 4.1) consists of two flanges (1 and 7), two stainless steel plate packs (3) and a spacer (6). The steel pack is an integral assembly consisting of individual plates and bushings, captured by retainer rings (4). Since all junction points are built up this way, the plate pack represents a compact unit.

The shaft ends of both compressor and motor are equipped with a coupling flange. Although the motor and compressor shaft have been aligned in the works misalignment might have occured due to deformation of the base frame during transport and installation. Therefore it is recommended to check the alignment once more prior to reinstallation of the intermediate elastic elements.

The alignment procedure described hereafter incorporates also procedure steps for reinstalling the electric motor in the case the compressor drive motor might have been moved for servicing or replacement.

IMPORTANT

The compressor and compressor drive motor is supplied leveled and secured to the package base frame with high grade fasteners. Do not loosen the bolts or disturb the compressor and motor. Tighten the compressor and electric motor mounting bolts as they may have loosened in shipment.

A) PREPARATION FOR ALIGNMENT

- The compressor package should be leveled and securely anchored without base distortion as in para 4.4.
- Check to make sure the motor feet and the package mounting pads are free of dirt and burrs.
- Clean motor shaft and compressor shaft coupling flanges and the coupling elements as well.

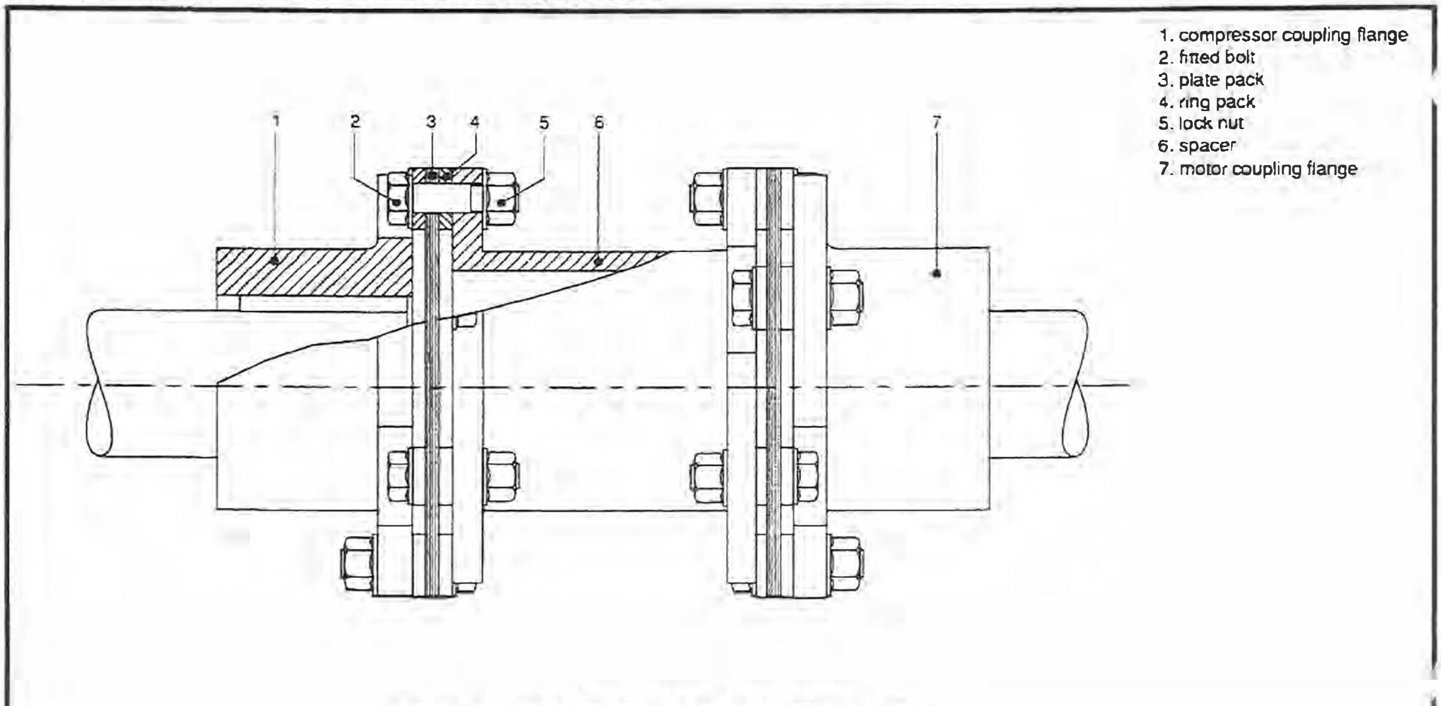


FIG. 4.1 DOUBLE FLEXIBLE COUPLING

- Have available the following (measuring) tools:
  - clean feeler gauges from 0.025 mm to 0.5 mm
  - two dial indicators with attachments and indicator jig (see fig. 4.2)
  - a straight edge
  - a crow bar or strong lever to lift the drive motor
  - shims with various thicknesses
  - (metric) spanners

B) MOTOR AXIS ALIGNMENT (only if electric motor have been recovered after servicing or replacement)

1) Temporarily place the electric motor onto the base frame and move the motor to the compressor shaft end until the distance between both shaft ends is about 100 or 140 mm, depending on used coupling size.

2) Using a straight edge, roughly align motor axis with the compressor axis and finally check and/or correct the shafts interspace.

3) Note the axis level difference between the shafts of compressor and motor. This difference shows the total shim spacing between motor feet and base frame.

4) To facilitate easy alignment ensure that the motor shaft is lower than the compressor shaft (so that height increases are possible with shims).

5) Remove the motor.

6) Press the motor coupling flange onto the motor shaft end until the end faces of motor shaft and coupling are flush.

C) PRELIMINARY ALIGNMENT

7) Definitely place the motor onto the base frame and securely align the coupling so as described hereafter in the final alignment procedure.

8) Mount the steel plate packs with spacer inbetween in such a way that the bolt holes are aligned opposite the recesses.
Assembling rule: Always fit the ring packs (4 in fig. 4.1) onto the flanged parts.

9) Tighten up all coupling fasteners as given in Table (4.1), install the coupling guard only after motor rotation check and proceed with Paragraph 4.9 "Package pressure test.

D) FINAL ALIGNMENT

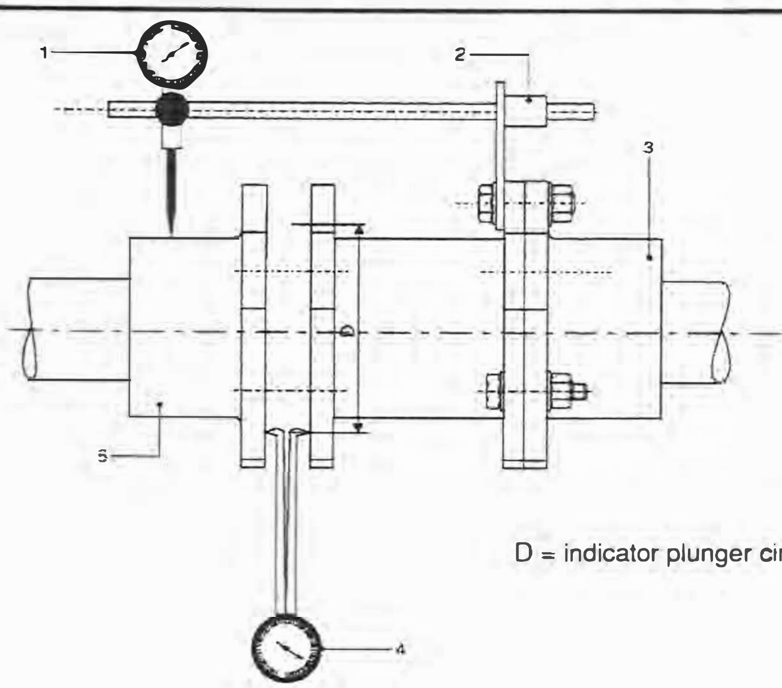
a) Refer to figure 4.2 mount the cleaned spacer without the plate packs onto the motor coupling flange and tightened bolts.

b) Clean the plane flange surface and the hub of the compressor coupling.

c) Again refering to figure 4.2 attach the concentricity dial indicator securely to the compressor coupling hub using a dial indicator jig. Move the dial indicator to zero degrees (top position of hub) and set indicator to zero. Check attachment of the indicator by rotating the shafts of compressor and motor together 360 degrees or one revolution. If the dial reading should not return to zero check the indicator jig mounting.

d) ***IMPORTANT***

The maximum allowable coupling concentricity and angularity misalignment is 0.05 mm (total indicator reading).



1. concentricity misalignment dial indicator
2. indicator mounting jig
3. electric motor coupling flange
4. angularity misalignment dial indicator (in elevation and plan)
5. compressor coupling flange

D = indicator plunger circle diameter

FIG. 4.2 ALIGNMENT ARRANGEMENT

e) When making shim changes, use a small number thick shims rather than a large number of thin shims to prevent excessive compression of the shim packs when the mounting bolts are tightened.

f) When making shim changes, change and secure one foot at a time. Tighten the bolt only enough to prevent the motor moving about while making shim changes.

g) Whenever shims are changed and the motor is moved, the mounting bolts should be tightened evenly and cross wards. This minimizes misalignment caused by the motor shifting when tightening the bolts and by the motor pads not being level.

h) Rotate both the compressor shaft and motor shaft together in 90° or quarter turn steps and record each indicator reading at each quarter step. Turn both hubs together ensures that readings are recorded at the same point at each hub eliminating the effect of any irregularities on the rims or faces of the hubs.

i) To check the angularity misalignment the use of a gauged inside caliper is recommended as shown in fig. 4.2. To check the angularity misalignment at least four check points are to be made in 90° or quarter turn steps eg on top (0°), 90°, bottom (180°) and 270°.

j) The angularity in elevation misalignment from 0.00 mm at 0° (top level) to -0.15 mm at 180° (bottom level) indicates that the rear of the motor is higher than the front in relation to the compressor. The total indicator reading is 0.15 mm.

k) Calculate the distance to move the motor feet as follows:

- (refer to fig. 4.2) measure the angularity indicator plunger circle diameter D (for example 150 mm.
- measure the distance between the front and rear motor mounting bolts (be L), for example 750 mm.
- the angularity as measured in j) above be M.
- thickness to be added or removed be S.

Now the shim thickness to be added or removed can be calculated as follows:

$$S = \frac{L.M}{D} \qquad \frac{750 \text{ X } 0.15}{150} = 0.75 \text{ MM}$$

Remove 0.75 mm of shim from the rear motor feet and tighten the motor bolts.

l) Recheck the angularity misalignment as in steps h) to k).

m) The concentricity misalignment from 0.00 mm at point 90° to 0.20 mm at point 270° indicates that the motor is lower than the compressor. The total indicator reading is 0.20 mm.

n) The distance to move the motor feet is half of the concentricity misalignment from m) above; this is 0.10 mm

o) Add 0.10 mm of shim to each of the four motor feet and tighten the mounting bolts.

p) Recheck the concentricity misalignment.

q) The angularity in plan misalignment (motor displaced clockwise or counterclockwise in relation to the compressor) can be checked with the procedure for angularity in elevation misalignment and calculate with the same formula, except, "M" represents the angularity in plan misalignment and "S" is the distance the motor feet have to be moved from side to side.

r) Tighten the motor mounting bolts.

s) Recheck the angularity in plan misalignment.

t) Recheck the concentricity in plan misalignment.

u) Reverse the checking procedure by adjusting the dial indicator to zero at point 180° (bottom).

v) Check the spacing between motor shaft and compressor shaft to make sure there is sufficient room to accept the coupling spacer. This should be 100 or 140 ± 1.0 mm.

w) Tighten the motor mounting bolts cross wards.

x) Finally recheck the alignment as in step t).

y) Remove the spacer and proceed to step "8" and "9" in "C".

TABLE 4.1
TIGHTENING TORQUES OF COUPLING BOLTS

Hub dia. (mm)	Thread size (metric)	Key width (mm)	Tightening torque (N.m)
ø 91	M8	13	25
ø 105	M10	17	50
ø 112	M12	19	95
ø 128	M16	24	200
ø 132	M20	30	400
ø 145	M20	30	400

4.8 CONNECTING OF POWER SUPPLY AND SYSTEM WIRING

When the package is delivered with a standard control- and pressure gauge/safety switch cabinet, most of the electric wiring - according to fig. 3.9 - is done by the manufacturer prior to despatch from the works.
Connecting the main power supply to the control cabinet and to the starting equipment of the compressor drive motor (see fig. 3.10 and 3.11) has to be done by the installer on site.
Further electrical connections to be made to the terminal strip inside the control cabinet (see fig. 3.10) are:

- heating element (1 - 2)
- thermal protection of compressor drive motor (16 - 18)
- automatic start/stop (19 - 20)
- starting relay of compressor drive motor (23 - 24)
- switch purpose by extra micro switches (34 - 36, 37 - 39 and 40 - 42)*
- automatic capacity controller and motor current limiting unit (46 - 51)*:

- temperature sensor of capacity controller (48 - 49)
- pressure sensor of capacity controller (50 - 51)
  BEWARE: Connection X50 = exclusively for DC+
- current transformer of current limiting unit (46 - 47)

The provisions marked with an asterisk (*) are optional. Therefore if these provisions are omitted, the corresponding connections are out of use.

4.9 PACKAGE PRESSURE TEST

The package components have all been pressure tested prior to leaving the factory. The compressor unit should, however, be leak-checked at the job site to detect leaks which may be present due to rough handling during shipment. This test should be done simultaneously with the system pressure test and system leak check.

Do **not** add oil to the package prior to pressure testing.

IMPORTANT

Whenever the compressor package is colder than the condensing temperature, admit only enough high pressure refrigerant to bring the package up to the test pressure and then close the inlet stop valve. This minimizes the amount of liquid condensing in the package which could damage the compressor on start up.

4.10 SYSTEM EVACUATION

Any free moisture and air in a system will mix with the refrigerant and oil to form harmful organic contaminants in resinous sludge and wax like forms which will plug the oil filters and strainers and damage the compressor. The system must be evacuated to remove both the air and the moisture. This evacuation can be done with a high vacuum pump capable of reducing the absolute pressure to 1.3 bar or less.

Do not evacuate with oil in the separator as the oil prevents any trapped moisture from boiling off.

The following procedure is recommended:

a) Ensure all leaks have been corrected by pressure testing as in paragraph 4.9.

b) Blow the system down to atmospheric pressure.

c) As many vacuum pumps contain brass which is attacked by ammonia in the presence of moisture, remove any ammonia remaining in the system from the pressure test by adding dry nitrogen to a pressure of about 0.7 bar(e). Again blow the system down to atmospheric pressure.

d) Open all the interconnecting stop valves between the low and high pressure sides.

e) Install a vacuum gauge at the oil filter drain valve or some other convenient system connection. Open the drain valve.

Attach the vacuum pump by hose to the blowdown valve on the oil separator.

g) Open the blowdown valve.

h) Start the vacuum pump and evacuate the system to 1.33 bar(a). Depending on the internal volume of the system, the amount of air and water present, the ambient temperature and the size of the vacuum pump this may take from half an hour to ten hours. Should the ambient temperature be less than 0 °C, evacuate the system to 0.20 Torr (26.6 Pa).

j) Close the blowdown valve.

k) Stop the vacuum pump.

l) Record the system absolute pressure.

m) Wait two hours and repeat steps f, g, h, j, k and l.

n) Wait for two hours and read the system absolute pressure again. If the pressure has not increased, dehydration has complete. If the pressure has increased, repeat steps as in "m".

o) If the vacuum fails to hold after several dehydration attempts, check the system for leaks and again repeat steps as in "m".

p) Close the blowdown valve and the vacuum gauge valve.

q) Charge the system with refrigerant at the charging valve.

4.11 INITIAL OIL CHARGE

IMPORTANT

Used or filtered oil should <u>never be</u> added to a refrigeration screw compressor under any circumstance. Use only new oil from an oil manufacturer (any of the major oil companies or their approved dealers) as in the oil table in para 2.10.

Before charging any oil into the screw compressor package, see para. 2.10.

Sufficient oil should be charged into the (primary) oil separator reservoir via the oil charging valve to establish a level in the oil level sight glass. Refer for oil capacity the oil cooler indentification plate.
When the desired oil level is reached, most of the oil system pipes, oil cooler, oil filter and compressor are filled up too.

Check that the bearings are prelubricated by loosening a nipple on the discharge journal oil supply line at the compressor bearing and pump a small additional amount of oil until oil weeps at the loosened nipple. Make a final check by pumping further oil and noting the pressure increase on the oil pressure gauge. Revolve the compressor drive shaft by hand a few times to prevent liquid hammer at first start and to topping up the oil separator to the main level of the upper sight glass.

4.12 INITIAL OIL WARM UP

Supply power to the compressor panel before the arrival of the Suppliers representative. This will allow the oil in the oil reservoir to warm to operating temperature and will help facilitate a smooth start-up. With power to the motor off, power supplied to the panel and the oil temperature below 40 °C verify that the oil heater is on by checking the current drawn.

Alternatively check the heater element by noting the relative temperature of the separator at the element and the opposite side.

The machine should never be started until the oil is 20 °C or 5.5 °C above saturation temperature of the package pressure whichever is higher. Ideally, the temperature should be 27 °C to 38 °C.

4.13 ELECTRICAL CHECK

Before attempting to start the compressor, the electrical control system, safety switch- es and capacity controls must be checked in a simulated operating condition.

IMPORTANT

Be sure there is oil in the separator so the oil heater will not burn out.

The simplest and most reliable method of checking the electrical system is to feed the power supply to the control panel with the main drive motor power disconnected. This can be accomplished by disconnecting the motor power at the main power disconnect. If the control power is also supplied from the main disconnect, a separate temporary source should be obtained or the motor starter should be disconnected.

4.14 SAFETY SWITCH ADJUSTMENT AND CHECK

All switches are to be adjusted to values shown in Table 4.2.

LOW OIL PRESSURE SAFETY SWITCH

Setting of the safety switches is effected by turning the main spindle with a spanner. The set value can be read from a graduated scale in the front cover (see fig. 4.3).
Setting of the differential safety switches takes place by turning the setting disc with a screwdriver; this setting disc is accessible after the front cover has been removed. The set value can be read from a graduated scale.
Setting of the temperature safety switches is effected by turning the adjusting knob, situated in the centre of the front cover. The individual settings and adjustments safety switches are given in table 4.2.

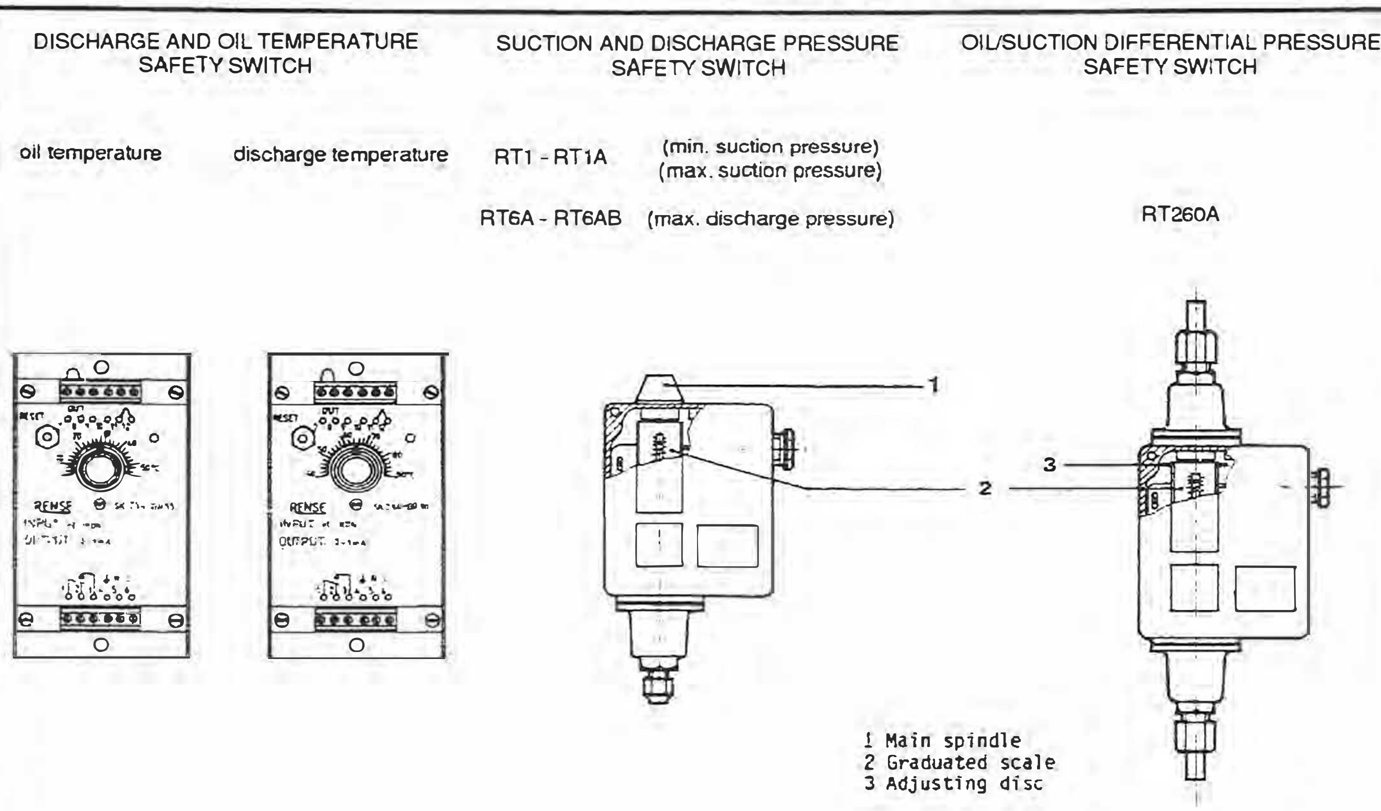


FIG. 4.3 SETTING OF SAFETY SWITCHES

TABLE 4.2
ADJUSTMENT AND SETTINGS OF SAFETY SWITCHES

SAFETY SWITCH	ADJUSTMENT/SETTING
Max. discharge temperature [1])	normal setting: 10 K above discharge temperature with package operating under design conditions max. setting: 93 °C
Max. oil temperature [1])	normal setting: 5 K above oil temperature at oil cooler outlet at selected operating conditions max. setting: 65 °C
Max. discharge pressure [1])	normal setting: 1 bar above discharge pressure with package operating under design conditions [2]) max. setting: 21.5 bar
Min. oil/discharge differential pressure	normal setting: 1.5 bar above discharge pressure max. setting: 4.0 bar
Min. suction pressure [1])	normal setting: 1 bar below suction pressure with package operating under design conditions [2]) min. setting: -0.6 bar
Start control pressure	normal setting: 0.5 bar above discharge pressure max. setting: 4 bar
Max. suction pressure	normal setting: depends on built-in volume ratio of compressor and the refrigerant used, according to the following table:

refrigerant	built-in volume ratio				
	2.2	2.6	3.7	4.8	
NH_3	8.0	6.2	3.5	2.2	bar(e)
R22	8.7	6.9	4.2	2.8	

1 bar = 10 N/m = 100 kPa = 1.02 kgf/cm = 14.5 psi

FOOTNOTES OF TABLE 4.2

[1]) These safety switches are provided with a locking device so that, when cut out, the compressor package does not become operative automatically on return of the original temperature or pressure. To unlock, an external reset button is used but only after the reason for cut out has been investigated.

[2]) When setting the max. discharge pressure safety switch or the min. suction pressure safety switch, it must be checked whether the difference between discharge pressure and suction pressure never exceeds the max. allowable value of 20 bar.

4.15 CAPACITY CONTROL ELECTRIC VALVE ACTUATOR CHECK

With the main motor disconnected, the min. oil safety switch jumpered and the control system energized to simulate operation, the following items should be checked;

a) Run the capacity control valve to the maximum position with the manual load switch on the control cabinet. The capacity indicator on the end of the camshaft should read the maximum number of turns of the compressor in question.

b) Press the manual "load" switch and manually trip the maximum position roller switch. The shaft should rotate one full revolution from the maximum position to the maximum position stop before the micro switch stops the motor.

c) If there are more or less turns of the output shaft, adjust the maximum position cam as in paragraph 6.12.

d) Return the output shaft to the maximum position from the maximum position stop.

e) Mark the output shaft with a pencil or felt pen.

f) Check the minimum position cam setting by rotating the capacity control motor counterclockwise from the maximum position setting with the manual "Unload" switch on the control panel and counting the number of revolutions of the marked output shaft. Table 4.3 shows the correct number of revolutions of the marked output shaft for the system to move the capacity control valve from the maximum to minimum position. Note the capacity indicator may or may not read minimum when the number of turns is correct.

g) If there are more or less turns of the output shaft, adjust the minimum position cam as in paragraph 6.12.

h) Again, run the capacity control valve to the maximum position with the manual "load" switch.

j) With the capacity control valve at the maximum capacity position, push the stop button and the capacity control should move to the minimum position. If it does not move to the minimum position, check the unloading wiring circuit.

k) Check the operation of both micro switches. Run the capacity control valve in the "load" and "unload" directions. The motor should "torque out".

TABLE 4.3

REVOLUTIONS OF THE OUTPUT SHAFT TO MOVE THE CAPACITY CONTROL VALVE FROM MAXIMUM TO MINIMUM (UNLOADED) POSITION

COMPRESSOR MODEL	2.2, 2.6 & 3.7 BUILT-IN VOLUIME RATIO	4.98 BUILT-IN VOLUME RATIO
GSL65	25	18
GSL85	19	14
GSL125	30	23
GSL165	25	18
GSL180	25	18
GSL240	38	29
GSL480	54	40

The given number of revolutions in both columns are split up in two range of turns namely, up to and including 30 turns or 62 turns.

* Volume ratio is given in the model number for each package, shown on the name plate on top of the compressor discharge housing by a tenfold value (the last two numbers).

4.16 MOTOR ROTATION CHECK

Remove the coupling spacer if fitted.

Check to see that the motor turns freely by hand. Supply power to the motor starter and rotate the start button to the "Auto-Start" position. Bump the motor by pushing the start button then pushing the stop button. Verify the motor rotation by observing the motor shaft coupling hub.

IMPORTANT

The motor shaft will rotate counterclockwise when facing the motor shaft end when motor rotation is correct.

If the motor rotates in the wrong direction, disconnect the power supply to the starter at the circuit breaker and reverse two of the phases by interchanging two of the three electrical lines at the starter or at the motor terminal box. Rotate the starting switch to the "Manual-Reset" position. Disconnect power from the motor starter. Do not mount the coupling spacer and coupling guard.

5.1 START-UP

After all the installation functions covered in chapter 4 have been completed, it will be possible to perform start-up service. It is necessary that key plant operating personnel be available to go through the start-up, since a great deal of knowledge can be obtained in this manner. The operations covered in this chapter will be performed at start-up under the supervision of a Grasso Refrigeration Representative.

IMPORTANT

See Paragraph 4.2 before scheduling start-up.

5.2 PRE-START CHECK LIST

The following Paragraph covers only the initial start of the compressor and not the remainder of the refrigeration system. Be sure that all necessary system valves are open and that the refrigeration system is ready for start-up. Use the following check list to guarantee that no items of importance regarding the compressor package have been overlooked.

a) Package is charged with refrigerant.

b) Motor starter breaker disconnected from the electric supply line.

c) Safety switches set to the values in paragraph 4.14.

d) All safety switches verified for correct operation.

e) The oil in the separator sump is 20 °C or 5.5 °C above saturation temperature of the package pressure whichever is higher (at least two hours prior to start-up).

f) Oil level established in sight glass.

g) Cooling water to oil cooler turned on if water cooled.

h) Liquid refrigerant supply to compressor on if superfeeded.

Stop valves to the pressure gauges are open.

k) Suction stop valve still closed and discharge stop valve is open.

l) Coupling turns freely by hand (coupling guard still not installed).

m) Direction of drive motor and oil pump rotation (shown on the oil pump name plate) checked.

n) Capacity control actuator indicator at minimum.

o) Capacity control selection switch in manual.

p) Starting switch in the "Manual-Reset" position.

q) Consult the contractors plant operation manual.

When the above items are verified, the compressor is ready for the initial start.

5.3 STARTING THE COMPRESSOR PACKAGE

When starting the compressor package, a distinction should be made between:

1) **Starting the compressor for the first time after the plant has been delivered ready to operate.**
For manually controlled plants as well for those operating automatically, the starting procedure given in the instructions hereafter [steps a) through g)] should be followed exactly.

2) **Restarting the compressor in a plant already operational.**
In the case of manually controlled plants, proceed in accordance with the instructions given in the contractors plant manual.
In the case of automatically operating plants, the starting procedure is incorporated in the control system and it does not generally require, therefore, any particular care.

IMPORTANT

Compressors refilled with oil returned to the stator due to a total current break down, may never be restarted automatically. To prevent liquid hammer it is necessary to restart the compressor manually again.

3) **Restarting the compressor after the plant has been out of operation for a long period of time (e.g. on account of seasonal standstill or maintenance work).**
For manually controlled plants as well as for those operating automatically, proceed in accordance with the instructions given under steps a) through g).

The starting procedure is as follows:

a) Start the compressor after removing the fuses of the compressor drive motor (only the lubrication oil pump is in operation) to ensure that the entire oil system (together with the shaft seal housing) is filled with oil.

b) Stop the compressor again after about 30 seconds and rotate the compressor drive shaft a few turns by hand in order to allow excess of oil to escape from the compressor housing into the oil separator.

c) Definitely install the coupling guard.

d) Refit the drive motor fuses.

e) Start the compressor. Slowly open the suction stop valve (be careful that no liquid carry-over occurs, especially in plants with lower suction lines). Run the compressor at its lowest capacity setting for a half hour and check whether all pressure gauge readings are normal. During starting and for a period no longer than 20 minutes thereafter, then oil temperature is allowed to be below the minimum limit of 40 °C, but never below 20 °C.

f) Set the capacity control to the required position. This setting is visible on the scale of the indicator plate behind the window of the actuator control cover.
If necessary, check the control all over the whole range.

g) If available, switch over to automatic operation.
After the compressor has run fully automatically for an hour and the pressures and temperatures have remained stable for 15 minutes, list all readings in a data record. In this way, any deviations from the correct operating conditions can be found easily.

5.4 STOPPING THE COMPRESSOR PACKAGE

The compressor package can be stopped at any moment desired.
Consult the contractors plant operation manual for further action required, especially in the case of manually controlled plants.

5.5 AFTER START-UP MAINTENANCE

After the compressor has run for twenty-four hours, clean the suction strainer, oil strainers and change the oil filter if its pressure drops exceeds 1 bar.
Check the compressor shaft seal for excessive leakage of more than 10 drops per minute. If excessive, replace the seal as in paragraph 7.5.

IMPORTANT

Whenever the compressor stops, it runs in the reverse direction for several seconds.
After the discharge check valve closes, the high pressure refrigerant in the oil separator expaonds back through the compressor to the closed suction check valve which causes the compressor to run in reverse. It is a completely normal action and is no cause for alarm.
Continued back spin for more than 5 seconds indicates excess leakage through the check valves.

5.6 STEPS FOR LONGER SHUT-DOWN PERIODS

The compressor operates with an oil/refrigerant mixture, and therefore short shut-down periods will not affect the compressor operation.
To shut down a compressor for long term period, tightly shut both the suction and discharge stop valves and the economizer stop valve (if fitted with economizer). Disconnect the power source from the compressor drive motor and the electrical control cabinet.
Place a moisture absorbing compound (eg a dessicant such as silica gel) inside the control cabinet and the electric valve actuator.

Place warning tags on the electric system and all closed stop valves. Those who do not know the machine is shut down for a long term must not attempt to start the compressor until it is ready for normal operation.

It will be sufficient to start-up after opening the discharge stop valve. As soon as the compressor has reached its maximum speed, the discharge stop valve can be closed again after stopping the compressor.

REMARK

Every month while the compressor is shut down, turn the compressor and motor over several turns.
During a shut-down period under cold weather conditions, the water cooled parts of the plant should be drained or the cooling water circulation maintained in order to prevent damage due to frost.

Prior to starting up after a shut down, change the oil and pump down the compressor.
Before pushing the start button, check that the oil in the separator sump is above 20 °C [see item e) in paragraph 5.2].

6.1 GENERAL

Although the maintenance for your Grassoscrew compressor is minimal, it must be carried out for compressor long life. The instrumentation and indicators provided will alert you of the first sign of a maintenance requirement. Observe these instruments and indicators at regular intervals and be certain that the machine is performing properly.
Become familiar with the normal operating sound of the compressor and if something does not sound just right, shut down the machine.
Excessive vibration is a good indication that something is wrong. This precaution may save the cost of a major repair.

Keep the compressor package clean to minimize dirt entering the compressor whenever components are opened during routine maintenance. Before cleaning a component with a solvent to remove gum resin like deposits, remove all the O-rings as they can be chemically attacked. To ensure no traces of solvent will be left to react with the oil and refrigerant, thoroughly dry the component with an air blast.

6.3 DAILY OPERATION

After a routine start has been made, observe the instruments and be sure the gauges indicate the correct reading for that particular phase of operation.
After the machine has warmed up, check the overall compressor and instrument cabinet to make sure it is running properly. Particular attention should be given to the following:

- Oil pressure gauge
- Oil temperature gauge
- Discharge temperature gauge

Also check the setting of the suction, oil and discharge pressure safety switches. A log of the operating temperatures, pressures and service requirements can be invaluable in troubleshooting.
It is recommended that a log be kept of all readings at least every eight hours.

6.2 INSPECTIONS SCHEDULES (Compressor package stays in operation)

CHECK POINTS	FREQUENCY daily	weekly	monthly	REMARKS
Oil level in primary oil separator	•			The oil level must be between 1 and 3 quarters height of the sight glass. For topping up oil, refer to paragraph 6.8,
Colour of oil behind sight glass of separator	•			The oil should be transparently clear. A white colour points to not dissolved refrigerant (foam).
Oil pressure	•			The indication of the oil pressure gauge should be 3 bar higher than the value shown by the discharge pressure gauge.
Pressure drop over oil filter	•			Check for corresponding indication (warning signal).
Oil temperature on cooler outlet	•			The normal operating temperature must be between 40 & 50 °C.
Oil leakage	•			Allowable shaft leakage 10 drops per hour. Remedy any other visible oil leakage.
Heating element in oil separator			•	During standstill of the package, the heating element must be operative.
Setting of safety switches			•	Refer to Chapter 4, paragraph 4.14.
Switching frequency of the compressor		•		The time interval between stopping and starting of the compressor drive motor should be at least 10 minutes.
Capacity control		•		At maximum capacity position the indicator should read the maximum revolutions as given in table 4.3 on page 4.8 for each compressor model.
Capacity control actuator cam settings			•	Switch-on and switch-off stops can be read just as given in paragraph 6.12.
Number of operating hours		•		Check the number of operating hours in view of any maintenance tasks to be carried out.

Apart from the above check points, the sound produced by the compressor provides a proper standard for its mechanical condition. If abnormal sounds are audible, their cause should be traced and removed immediately in order to prevent serious breakdowns at inconvenient times.

While the compressor is running each sight glass contains foaming oil and small vapor bubbles. When clear vapor appears in the top sight glass the oil level may be low. The oil level can be accurately checked when the compressor has stopped and the oil has settled in the separator sump for about ten minutes. The oil level should be visible in the sight glass, between the two red marks.

WARNING

Do not remove caps, plugs, or other components when the compressor is running or pressurized.
Stop compressor and relieve all internal pressure before doing so.

IMPORTANT

Used or filtered oil should never be added to a refrigerant screw compressor under any circumstance. Use only new oil (as in paragraph 2.10) from an oil manufacturer.

If the addition of oil becomes too frequent, a problem may have developed causing this excessive loss. See fault-finding (paragraph 6.13) under high oil consumption for a probable cause and remedy.

6.4 MAINTENANCE AFTER THE INITIAL 200 HOURS OF OPERATION

After the initial 200 hours of operation a few maintenance tasks are necessary to free the system of foreign materials which may have accumulated during assembly and installation. Other procedures, stated below are required to sure that the initial operation of the machine is correct.

1) Change the oil
2) Replace the oil filter
3) Clean the oil strainers
4) Clean the gas suction strainer
5) Check the settings of the capacity control cams
6) Check the pressure gauge calibration (0 bar when open to atmosphere)
7) Tighten all bolts, especially motor and compressor mounting bolts
8) Check compressor shaft seals for excessive leakage of 10 drops per minute. A small oil loss of 1 or 2 drops per minute is normal.
9) Check coupling alignment
10) Check low oil pressure safety switch
11) Check high oil temperature safety switch
12) Check high discharge temperature safety switch
13) Restart and check all operating temperatures and pressures

6.5 SAFETY CONTROLS

The operation of all safety controls should be checked at least monthly (as in paragraph 4.14) as a safety switch failure can result in an expensive repair. It is especially important to regularly check the low oil pressure protective circuit for fusing of the switch or delay timer contacts or failure of the delay timer coil.

6.6 OIL ANALYSIS

The oil injection screw compressor has proved to be a most reliable and successful compressor, but because of the washing action of the oil, the oil quality must be checked closely for maximum compressor life. Since it is impossible to look at the oil and determine its quality, chemical analysis by a qualified concern signifies when to change the oil. Oil analysis has proved to be of great value in preventing lubrication problems by diagnosing poor quality or contamination before significant damage has been done.

If in doubt to use the oil further more, take an oil sample every 1,000 hours but at least every three months and send it for laboratory analysis. If an unfavourable report is returned indicating a general deterioration of the oil charge (e.g. increased acidity high moisture content etc.), the old package system oil should be drained off and separators refilled with the correct charge of fresh oil (not reclaimed) of the original grade.

6.7 MAINTENANCE SCHEDULE

The schedule (see next page) is intended as a minimum maintenance schedule and indicates after how many operating hours a/o terms maintenance operations have to be carried out. Abnormal conditions may require more frequent action as determined by your daily listed readings. The yearly maintenance jobs should ideally be carried out before the start of the annual season.
For most of the maintenance tasks, the compressor must be put out of action.

In order to prevent this from having to take place at inconvenient times, the tasks should as much as possible be effected during a shut-down period.
The schedule has been drawn up in such a manner that several operations can be carried out simultaneously, which results in reduced maintenance costs.

6.8 TOPPING UP OIL WITH COMPRESSOR OPERATING

Oil can be topped up whilst the package is operating. Use the same oil as is already in the package (for the oil types to be used, see Paragraph 2.10).

Oil should be preferably be added after the compressor has stopped or been shut down. Add sufficient oil into the oil separator to bring the oil level into the sight glass (1 to 3 quarters height) with a hand or electric pump capable of pumping oil against a pressure of 7 bar.

When the compressor is running use a hand or an electric pump to add oil through a 100 mesh strainer into either of the normally plugged connections on each side of the electric valve actuator in the suction housing of the compressor.

MAINTENANCE TASK	HOURS OF OPERATION [1])					
	0 - 50	200	2500	5000	7500	ETC.
Cleaning of oil pump filter and/or renewal of main oil filter (see par. 6.9	x	x	x	x	x	
Cleaning of suction gas strainer (see par. 6.11)	-	x	x	x	x	
Oil change [2])	-	x	-	-	-	
Inspection and, if required, replacement of filter element in secondary oil separator [3])	after 3 years					
Checking coupling alignment and tightening of coupling bolts	yearly					
Tightening of motor and compressor mounting bolts	yearly					
Inspection rotor end play	yearly or 5,000 hours					
Inspection capacity control valve guide	20,000 hours					
General overhaul of compressor unit	after six years or 40,000 operating hours					

) Depending on degree of contamination

[2]) Every three months or 2,000 hours unless using oil analysis. Maximum time six months. Refer to Par. 6.6 "Oil analysis"

[3]) If fitted

For most of the maintenance tasks, first evacuate the compressor package in order to remove the refrigerant gas.
After completion of maintenance, purge the compressor package.

Oil can also be charged by reducing the suction pressure below atmospheric pressure and if no hand or electric oil pump available.
The procedure is as follows:

a) Connect a hose to the oil charging valve on the suction side.

b) Fill the hose with oil and emerge its free end in a reservoir containing a sufficient amount of oil.

c) Close the suction stop valve to such an extent that the suction pressure falls below the atmospheric pressure. If necessary, shunt the electric contacts of the minimum suction pressure safety switch (do not forget to remove this shunting after completion of maintenance work).

d) Keep the oil charging valve open till the oil in the oil separator has reached the required level again. Take care that no air is being drawn in.

e) Slowly open the suction stop valve in order to prevent liquid carry-over.

f) Remove the hose and replace the cap nut with gasket on the charging valve.

6.9 MAINTENANCE OF MAIN OIL FILTER, OIL STRAINER AND OIL PUMP FILTER

Since there are two different oil systems, the GSLP Packages can be distinguished in two designs; with a full-flow oil pump for systems with a low oil pressure difference of max. 1.5 bar and with a lubrication oil pump (for systems with a high oil pressure difference of 1.5 bar and over.

In general, the maintenance tasks described hereafter can be used for both package designs.
For flow diagrams needed for tracing of the part identification numbers, refer to pages 3.3 to 3.6.

MAIN FLOW OIL FILTER

A warning signal activated by the pressure drop sensing device, indicates when the main flow oil filter element (20), due to pollution, requires replacement.

In the case of a single oil filter, the compressor package has to be stopped.
In the case of a double oil filter, the spare filter stop valve must be opened and the stop valves of the polluted oil filter closed without stopping the compressor.
To replace the main flow oil filter elements proceeds as follows:

a) Carry out the shut down procedure in paragraph 7.3.

b) With lubrication-oil pump:
Close the filter isolating stop valves (13), oil pump suction stop valve (13) and stop valve (13) in the balance piston oil supply line.
With full-flow-oil pump:
Close the filter outlet stop valves (13)

c) Open the oil drain valve (12) at the bottom of the filter housing and drain the oil.

d) Remove the filter cover and withdraw the filter element after removing the lock nut and retaining plate.

e) As the oil flows through the filter element from the outside inwards, the accumulated sediment should be removed from the filter housing.
Take care that no dirt enters the outlet line during cleaning of the filter housing.

f) Insert a new filter element, refit the retaining plate and fasten the lock nut.

g) Refit the filter cover. Mind the condition of the sealing ring so as to prevent leaks from developing later.

h) Close the oil drain stop valve at the bottom of the filter housing again.

i) Check the oil level in the separator and, if required, top up oil.

OIL PUMP SUCTION STRAINER

In full-flow oil pump designed packages also the oil pump suction strainer element (15) requires maintenance. To remove this filter element proceed as follows:

a) Carry out the shut down procedure in paragraph 7.3

b) Close the filter inlet stop valve (13), the stop valve and the isolating valves (13).

c) Open the drain valve of filter (15) and catch up the oil in an oil tray.

d) Withdraw the filter element and clean it thoroughly, refit the filter in its housing and close the drain valve.

e) Slacken the nipple coupling on top of the filter housing for a few (two or three) turns and then slowly open the filter inlet stop valve (13).

f) This oil pump filter housing will be purged now due to the incoming oil stream. If the oil is leaking via the slackened nipple coupling, tighten this nipple coupling and at last, open stop valves and isolating valves (13).

g) To start up the compressor, reverse the shut down procedure in paragraph 7.3.

6.10 MAINTENANCE OF THE OIL PUMP

Generally the full-flow oil pump and the lubrication oil pump, are free of maintenance. For maintenance, repairing and servicing the suppliers instructions, supplied to the packages, should be followed.

6.11 CLEANING OF SUCTION GAS STRAINER

The filtering surface area of the strainer element is sufficient to ensure effective filtration over many years of operation, provided that the refrigerant gas system has no worthwile contamination. The strainer element has to be inspected and cleaned according to the maintenance schedule of the package. Should the strainer be clogged due to a very dirty system, this will show up in reduced compressor capacity. To clean the strainer element proceeds as follows:

a) Carry out the shut down procedure as in paragraph 7.3.

b) Remove the fasteners from both the suction combination cover and flanged connection of the pressure equalizing line and remove the cover (if necessary. loosen cover with a "soft" hammer); remove also the gasket.

c) Carefully withdraw the strainer element from the strainer housing without damaging the gauze.

d) Clean the element with a light solvent. Then thoroughly dry the element preferably with an air blast.

e) Check the gauze for damage.

f) Insert the strainer element into the housing, refit the cleaned or new gasket and place the cover with tightened nuts after the flanges of the pressure equalizing line are mutually connected.

g) Purge the compressor and at last the refrigeration installation as stated in the plant manual.

6.12 (RE)ADJUSTMENT ELECTRIC SLIDE VALVE ACTUATOR

The compressor package is delivered with an adjusted electric slide valve actuator. Prior to starting the compressor for the first time, the micro end switches of the electric valve actuator have to be adjusted so that the adjusting motor is cut out, as soon as the capacity control slide valve inside the compressor has reached one of its end stops (maximum or minimum capacity).
This original setting may have been deranged during work on the capacity control system, in which event it is necessary to readjust the capacity control mechanism.
To readjust the limit cams proceeds as follows:

a) Disconnect the control cabinet from the electric supply line.

b) Remove the black knob for manual control by loosening the internal set screw.

c) Remove the four cover mounting screws and remove the electric valve actuator cover.

d) Release motor brake.

e) Move the capacity control slide valve to the maximum (fully loaded) position by turning the output shaft clockwise with a suitable wrench untill it stops at the maximum position stop. At the end of this (mechanical) stop a slight resistance is noticeable.

IMPORTANT

To prevent damaging the ball bearing spindel <u>Do not overtorque</u> the output shaft!

f) Turn the output shaft one full revolution back.

g) Mark the output shaft end with a felt pen or pencil.

h) If the maximum position cam is loose on the camshaft or is suspected of having moved relative to the camshaft, carry out steps j, k and l. Otherwise carry out steps m, n, o and p.

i) Loosen the set screw on the maximum position cam (the first cam away from the compressor which actuate the red wired micro switch) with a 3/32 Allen wrench.

j) Rotate the maximum position cam clockwise on the shaft until the roller switch just opens. Listen for a click or check electrical continuity with an ohm-meter.

k) Tighten the set screw in the maximum position cam very tightly to prevent loosening. The capacity indicator plate on the end of the cam shaft should read maximum. If it does not read in this maximum position, loosen the cam set screw and turn the indicator pointer to the correct number of revolutions as given in table 4.3 on page 4.8.

l) Check to see the indicator pointer read the maximum number of revolutions as given in table 4.3 on page 4.8. Correct the position of the indicator pointer if necessary by loosening the set screw with a 3/32 Allen wrench and, after resetting the pointer, tighten the set screw very tightly to prevent loosening.

m) Move the capacity control slide valve to the minimum for fully unloaded position by turning the output shaft counterclockwise the number of revolutions as given in table 4.3. The indicator pointer should read zero. If necessary, reset this pointer to zero with an 3/32 Allen wrench.

n) Correct the minimum position cam as given in steps k, l and m for the maximum position cam.

o) Put actuator in brake position. Reconnect the control cabinet to the electric supply line and check the above adjustments with power to the electric valve actuator as in paragraph 4.15.

p) Mount the actuator cover and install the four mounting screws. Start the compressor.

6.13 FAULT-FINDING TABLE

. ne fault-finding table below may be helpful to quickly trace and remedy failures that interfere with the proper operation of the package. It is emphatically pointed out that the cause of a failure must often be sought in the refrigeration installation itself. Therefore, it is necessary in addition to this fault-finding table, also to consult the plant operation manual.

FAULT	CAUSE	REMEDY
A) Compressor will not start	1. One of the safety switches tripped	1. Remove cause. Check setting and reset
	2. No power supply to control circuit	2. Check power supply
	3. Minimum position cam slipped	3. Readjust per para. 6.12 and tighten set screw
	4. Minimum position micro switch on actuator defective	4. Purge system
	5. Oil pump defective	5. Check that the motor is running in correct direction. Repair
	6. Plugged oil strainer in oil pump suction line	6. Clean
	7. Start-up oil pressure switch out of adjustment or defective	7. Adjust or repair
B) Compressor shuts down immediately after starting	1. Low oil pressure	1. See C
	2. The return valve after oil pump leaks excessively, allowing oil to drain from filter when compressor stops	2. Replace return valve
	3. High discharge pressure	3. Check condenser fan and water pump and if necessary purge condenser
	4. Low suction pressure	4. Open suction valves. Check capacity control to see if it unloads automatically
	5. High oil or discharge temperature	5. See F and G
C) Low oil pressure	1. Oil pressure relief valve and/or oil pressure regulating valve out of adjustment or defective	1. Adjust or repair
	2. Plugged oil strainer	2. Clean strainer
	3. Plugged oil filter	3. Replace filter element
	4. Low oil charge	4. Check oil level with compressor shut down

FAULT	CAUSE	REMEDY
C) Low oil pressure (continued)	5. In minimum position, discharge pressure too low for oil circulation 6. Liquid refrigerant in oil 7. Low oil viscosity	5. Check capacity control cam settings and actuator motor shaft returns. Readjust 6. Stop liquid carryover. Check oil heater. Check low oil safety switch 7. Change oil
D) High oil pressure	1. Oil pressure relief valve and/or oil pressure regulating valve out of adjustment or defective 2. Oil temperature too low	1. Adjust or repair 2. See E
E) Low oil temperature or drops rapidly	1. Oil cooler capacity too high 2. Liquid carryover 3. Water regulating valve or refrigerant regulating valve out of adjustment or defective	1. Decrease water supply 2. Install liquid separator in suction line 3. Adjust or repair
F) High oil temperature (oil temperature safety switch may become operative)	1. Oil cooler capacity too low due to: 1a. Pollution 1b. Too little or too warm cooling water 2. Oil cooler regulating valves out of adjustment or defective	1a. Clean. Check water treatment 1b. Increase water supply 2. Adjust or repair
G) High discharge temperature (water cooled only)	1. High oil temperature 2. Plugged oil strainer 3. Abnormal operating conditions, e.g. abnormally high suction pressure, high suction superheat or high discharge pressure	1. See F 2. Clean strainer 3. Check system
H) Low suction pressure	1. Suction stop valve not open wide enough 2. Refrigerant charge in plant low 3. Throttle control valve for feeding evaporator not wide open enough 4. Evaporator too much frosted 5. Suction pressure gauge defective 6. Capacity control not modulating	1. Fullly open 2. Add refrigerant 3. Readjust control 4. Defrost 5. Repair or replace 6. See J
I) High suction pressure	1. By-pass valve remains open 2. Polluted suction gas strainer 3. Throttle control valve for evaporator feeding not open wide enough 4. Suction pressure gauge defective 5. Capacity control not modulating	1. Repair 2. Clean strainer 3. Readjust control 4. Repair or replace 5. See J

FAULT	CAUSE	REMEDY
J) Capacity control not operating	1. Capacity control actuator out of adjustment	1. Adjust per para. 6.12
	2. Circuit breaker defective	2. Replace
	3. Actuator motor defective	3. Replace
	4. Cam slipped	4. Reset per para. 6.12 and tighten set screw
	5. Micro switch defective	5. Replace
K) High oil consumption	1. Excessive oil charge	1. Check oil level with compressor off. Drain excess oil
	2. Oil heating element defective (allowing refrigerant to condense during an off cycle)	2. Replace heater
	3. Discharge check valve defective	3. Repair or replace
	4. Economizer check valve defective	4. Repair or replace
L) High discharge pressure	1. Discharge stop valve not wide open enough	1. Fully open
	2. Condenser capacity too small due to:	
	2a. Pollution	2a. Clean
	2b. Too little or too warm cooling water	2b. Increase water supply
	2c. Fans out of operation	2c. Switch on fans
	3. Air in the system	3. Purge system
	4. Discharge pressure gauge defective	4. Repair or replace
M) Compressor vibrating or noisy	1. Liquid refrigerant in suction vapor	1. Check evaporator controls
	2. Coupling out of alignment	2. Realign
	3. Rotor end play excessive	3. See paragraph 7.10
	4. Rotor hitting slide valve	4. Check capacity control guide adjustment. See para. 7.12. Readjust or replace

7.1 INTRODUCTION

The following paragraphs outline the various servicing procedures for the Grassoscrew Compressor Packages Series GSLP.
Most of these procedures can be carried out on site without the necessity to remove neither the compressor nor the electric motor from the package base frame. Since the compressor - including slide valve actuator - is assembled with only UNC-threaded bolts and nuts, it is necessary to use suitable tools. The fact is that all these bolts are provided with a decagonal (twelve-sided) head (referred to in this manual as "Ferry head screw"), which means that box or ring spanners have to be used instead of open end spanners.

For assistance with any detail of service or servicing of an item not covered by this manual, please consult Grasso.

7.2 GENERAL RECOMMENDATIONS

To prevent needless downtime, have available on site all parts that may be needed to carry out the repair before commencing any work.

To prevent dirt from entering opened components, keep the surrounds clean and cover the exposed working areas with plastic whenever possible.

Before cleaning a component with a solvent to remove gum or resin like deposits, remove all the O-rings as they can be chemically attacked. Alternatively check the compatibility of the solvent with the O-rings which are neoprene or Buna-N. Unfortunately those solvents which most readily remove carbon deposits (eg thrichlorethylene) rapidly attack both neoprene and Buna-N. To ensure no traces of solvent will be left to react with the oil and refrigerant, thoroughly dry the component with an air blast. Immediately clean every entirely dismantled component, then check it roughly for wear or damage and oil the machined surfaces of bright parts. Oiling these parts is particularly important when they are not reassembled until quite some time after. Otherwise they are sure to become rusty.

7.3 SHUTDOWN PROCEDURE

WARNING!

Before commencing work on any item on the package, ensure that the following are carried out for your own personal protection.

a) Whenever the compressor is to be shut down for service, place warning tags on the electrical system and the line valves. Others who do not know the machine may be faulty or is being repaired must not attempt to start the compressor until the servicing is complete and it is ready for normal operation. Exposed electric wiring must always carry a warning tag even though it is disconnected from the power supply.

b) Stop the compressor with the stop button on the control cabinet.

c) Disconnect the starter from the power supply.

d) Disconnect the control cabinet from the power supply.

e) Close compressor suction stop valve and discharge stop valve.

f) If the compressor is fitted with an economizer port, close the economizer stop valve.

g) Relieve the gas pressure in the package by opening the pressure safety valve on the oil separator to either a pump out compressor or to atmosphere. If using a pump out compressor, pull the package pressure to atmospheric pressure [1 bar(a) on the suction pressure gauge] and open the pressure safety valve on the separator to atmosphere.

h) Leave the pressure safety valve open to the atmosphere all the time while working on the compressor.

7.4 BOLT TIGHTENING TORQUES

The tightening torques for servicing the various bolts and screws used in the compressor are given in table 7.1. All fasteners (eg. the Ferry head screws) used in the compressor unit, are high tensile Grade 8 only and they must always be torqued to condition B when the compressor is serviced.

TABLE 7.1

Fastener		Tightening torques in N.m				
Dia	Pitch	Grade 8**				
inch	Thread inch	*Condition				
		A	B	C	D	E
1/4	20	16.3	12.2	10.8	8.1	14.9
5/16	18	34	24	23	16.9	31
3/8	16	61	47	42	31	54
1/2	13	149	108	100	75	134
5/8	11	298	230	199	149	268
3/4	10	515	380	346	258	464
7/8	9	813	624	545	407	732
1	8	1220	922	818	610	1098

TIGHTENING TORQUES FOR THREADED BOLTS

A) Non-lubricated solvent-cleaned and dry

B) Lubricated with rust preventative or zinc plated

C) Lubricated with oil or grease

D) Lubricated with dry lube film or graphite/oil mixture

E) Lubricated with loctite or sealants

7.5 SHAFT SEAL REPLACEMENT (refer to fig. 7.1)

REMOVAL

a) Carry out the shutdown procedure in paragraph 7.3.

b) Remove the coupling guard, coupling spacer and coupling flange with key from the compressor shaft.

c) Disconnect oil supply line and drain line from the shaft seal cover.

d) Loosen evenly the bolts from the shaft seal cover.

e) Remove the shaft seal cover (9). The flange can be broken loose by tapping with a "soft" hammer.

f) Remove the shaft seal housing (5). Use screws in the three tapped holes to remove the housing easily. If the pin (13) is sheared or bent, remove from seal housing (5).

g) Remove the rotating seal assy by pulling it off the shaft by hand.

h) If the pin (2) is sheared or bent, remove from drive ring (16).

PREPARATION

a) The seal has a secondary seal (12) which seals against the shaft. Check that this secondary seal ring is uniform around its periphery even though the seal is brand new.

b) Place the seal (4) on a clean flat surface with the carbon face up.

c) Check the shaft for any burrs or sharp edges which could cut the seal when it is later slid over the shaft. Remove all burrs and brake all sharp edges.

IMPORTANT

Be careful not to let any material get into the bearing area.

d) Inspect and clean the shaft where the seal is going to be mounted especially in the vicinity of the secondary seal. Remove oil carbon deposits with a light solvent (such as mineral or methylated spirits).

e) Clean all parts thoroughly. Wipe off any foreign material and use a light solvent to remove old carbon deposits. Check all parts for burrs and break any sharp edges which are found.

f) Make sure both the oil supply orifice and the oil drain line in the new cover (9) are open and the threads are clean.

g) Oil the shaft and the inside of the rotating seal member (4) with clean refrigerating oil. Check that the carbon face is absolute clean with no surface scratches.

INSTALLATION

a) If a new pin (2) is required, install in drive ring (16) by tapping with a hammer. Install the seal assy over the shaft. Slide the seal down the shaft until it contacts the drive disc (16). Check to make sure that the seal assy fits over the drive pin (2).

IMPORTANT

The seal assembly must be started squarely over the shaft by hand force. If the seal assembly becomes locked on the shaft, remove and start again. Excessive force should not be necessary. Extreme caution must be exercised not to damage the lapped carbon surface and to keep it clean and not to damage the inner O-ring of the seal assy.

b) ***IMPORTANT***

Tap very lightly and evenly with a blunt punch or large screw driver around the seal body casing to move the seal up against the drive ring. Use care not to hit the carbon.

c) Make sure that the (new) roll pin (13) is mounted in the seal housing (9).

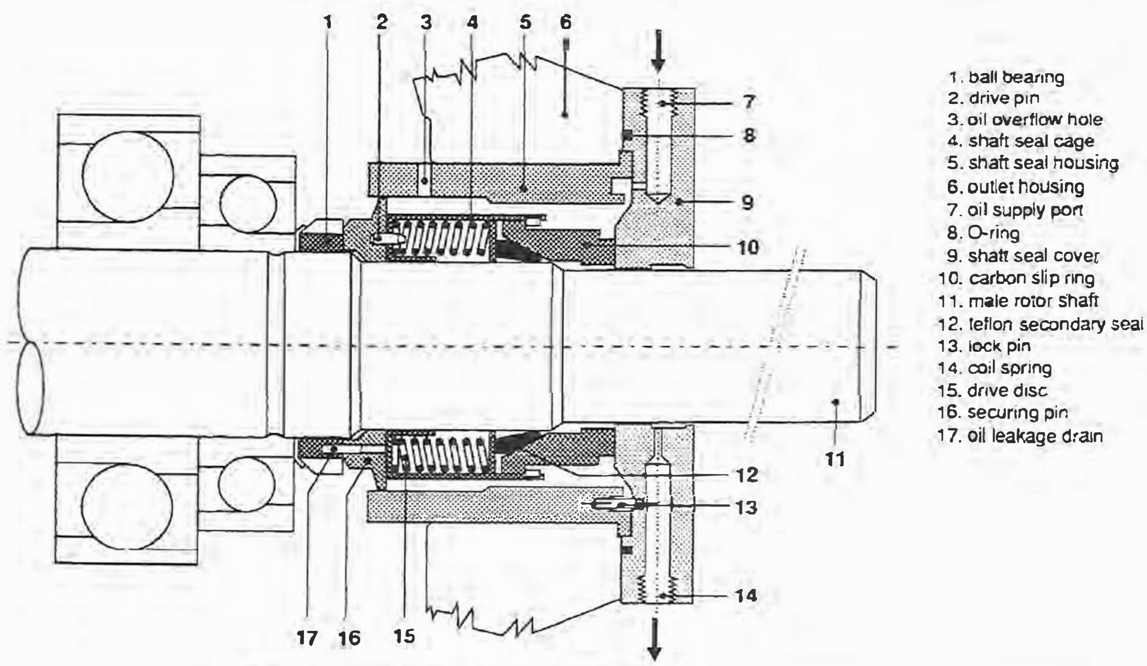


FIG. 7.1 SHAFT SEAL ASSEMBLY

d) Mount the seal housing making sure that the overflow hole (3) is pointing upwards.

e) Inspect the new stationary seal cover (9) for any surface imperfections and oil the surface with clean refrigeration oil.

f) Replace the O-ring (8) in cover plate (9) with a new one.

IMPORTANT

Always install a new seal cover plate with a new seal assy.

Mount the new seal cover plate, aligning it with the roll pin (13), and tighten the screws diagonally and evenly so as not to crack the carbon. Tighten the 1/2 inch screws to a torque of 108 N.m (80 lbft).

g) Connect the oil supply tube and the drain line.

h) Run the oil pump to replenish the seal housing.

i) Turn the compressor shaft a few turns by hand.

j) Close the pressure safety valve.

k) Open the suction stop valve slowly to pressurize the package.

l) Check that the seal is not leaking.

m) Open the discharge stop valve.

n) If the compressor is fitted with an economizer port, open the economizer stop valve.

o) Mount the coupling spacer and coupling guard.

p) Reconnect the control cabinet to the electric supply line.

q) Reconnect the starter to the electric supply line.

r) Start the compressor

7.6 CAPACITY CONTROL ELECTRIC VALVE ACTUATOR SERVICING (refer to figure 7.2)

The actuator is constructed with an adequately greased gear case section, this lubricant need never be changed. however, through disassembly, etc., should it become necessary to refill, we recommend use of Esso Beacon P290 for - 40 °C to + 65.5 °C or Esso Beacon P325 for - 53.8 °C ambient temperatures.
The items to be inspected can be limited to only the checks of cam settings and micro limit switch settings.

(A) INSPECTION

a) Stop the compressor with the stop button on the control cabinet.

b) Remove the black knob (1) for manual control by loosening the internal set screw.

c) Remove the four cover mounting screws (3) and remove the electric valve actuator cover (2).

d) Release motor brake by depressing the actuator brake solenoid (5).

e) Measure live voltage to insure that actuator is receiving full rated voltage.

f) Check cam/travel limit switch position to insure that one switch is not made and that the actuator is within its normal open-close rotation limits. This check can be made using a volt meter connect between one side of the incoming line (common) and one leg of the motor or capacitor. This check should show power between common and one leg only.
Power at the common and both legs or no power at all, would indicate cam and or wiring adjustment(s) are required.

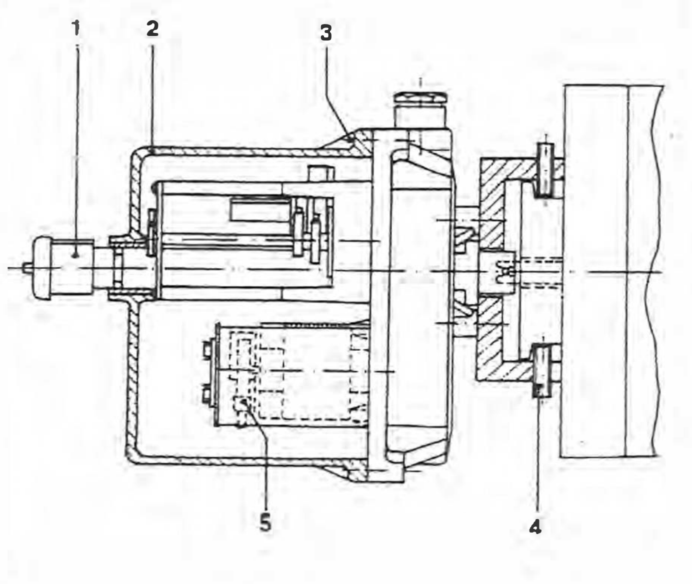


FIG. 7.2 ELECTRIC VALVE ACTUATOR ASSEMBLY

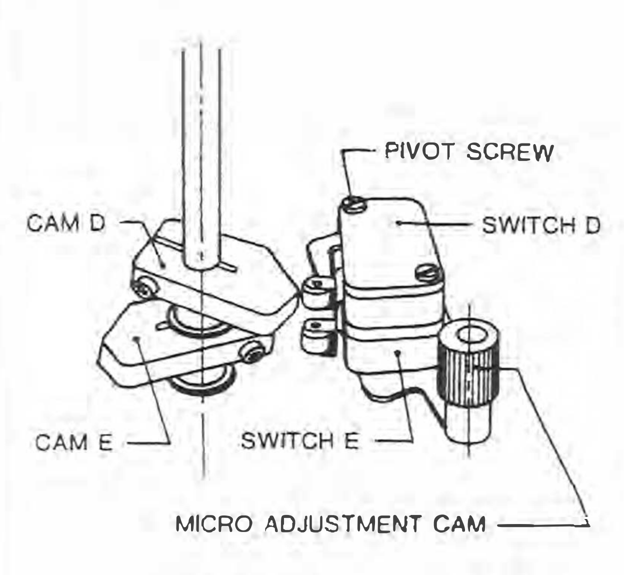


FIG. 7.3 CAM/SWITCH ADJUSTMENTS

g) For cam readjustment(s) refer to paragraph 6.12 steps e to p. In the event that the cam readjustment-procedure does not give the necessary travel control, the micro-adjustment cam has to be repositioned as given in step h) after procedure step l) in para. 6.12.

h) To set travel by adjusting switch plate (refer to fig. 7.3):
- Loosen pivot and micro-adjustment screw.
- In the event of actuator under-travel, rotate micro adjustment cam to swing switch outward from the cam post.
- In the event of actuator over-travel, swing switch into the cam post.
- Tighten pivot and micro-adjustment screw.
- Proceed to procedure step m) to p) in para. 6.12

7.7 CAPACITY CONTROL SHAFT SEAL SERVICING (refer to figure 7.4)

REMOVAL

a) Carry out the shut down procedure in paragraph 7.3.

b) Loosen the two socket head cap screws (4 in fig. 7.2) and remove the complete electric valve actuator assembly. The flexible electrical conduit should allow the EVA to be moved out of the way without disconnecting the conduit.

c) Remove the three cap screws (12) from the seal holder (11).

d) Withdraw the seal holder, using care to prevent scratching the O-ring on the shaft.

e) Remove the two seals (15) from the seal holder.

f) Examine the seal for wear, cracks and deformities in the O-ring.

INSTALLATION

a) Remove any burrs from the seal holder.

b) Smear thread sealer on the outside diameters of the seals to prevent leakage. Be sure to place the seals back to back as shown in figure 7.4 so they will seal against either a positive pressure or a vacuum. Press the new seals into the seal holder using care not to deform or bend the seals.

c) Check to see that the shaft is clean and free from burrs to prevent damage to the seals.

d) Replace the O-ring (16) in the seal holder groove.

e) Mount the seal holder over the shaft and push it into place, taking care not to damage the O-ring.

f) Tighten the three cap screws (12).

g) Mount the electric valve actuator using care to align the pin in the actuator shaft with the slot in the end of the ball screw shaft.

h) Install the two socket head cap screws (4 in fig. 7.2) to secure the EVA assembly to the compressor.

i) Close the pressure safety valve.

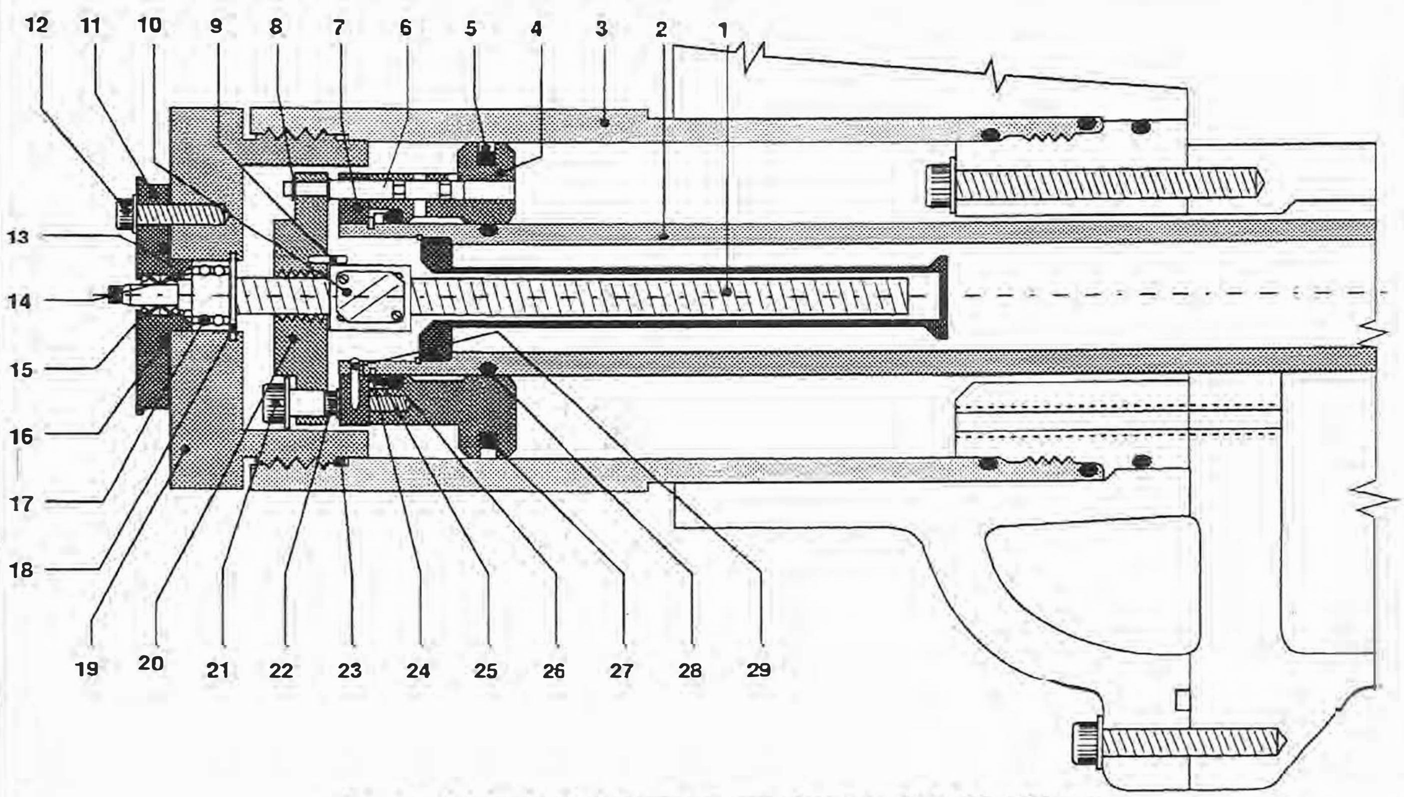


FIG. 7.4 CAPACITY CONTROL PILOT VALVE ASSEMBLY

j) Open the suction stop valve and discharge stop valve.

k) [illegible] of the replaced seals for leaks.

l) If the compressor is fitted with an economizer port, open the economizer stop valve.

m) Reconnect control cabinet to the electric supply line.

n) Operate the EVA manually to check its operation as in paragraph 4.14. If the limit switches do not stop the motor at the minimum or maximum position, the cams must be reset as in paragraph 6.12.

o) Reconnect the starter to the power supply.

p) Start the compressor.

7.8 CAPACITY CONTROL PILOT VALVE ASSEMBLY (refer to figure 7.4 on previous page)

(A) REMOVAL OF PILOT VALVE ASSEMBLY

a) Carry out the shutdown procedure in paragraph 7.3.

b) Check that the capacity control valve has returned to the minimum or fully unloaded position on shut down by examining the indicator plate on the end of the electric valve actuator. This moves the pilot valve assembly away from the end cover (19), which is a requirement for step j) below.

c) Loosen the two socket head cap screws (4 in figure 7.2) on each side of the actuator base plate and remove the complete electric valve actuator assembly. The flexible electrical conduit should allow the EVA to be moved out of the way without disconnecting the conduit.

d) Remove the 3 cap screws (12) from seal holder (11).

e) Withdraw the seal holder, using care to prevent scratching the O-ring on the shaft.

f) Examine the O-ring for wear, cracks and deformities and if necessary replace the O-ring as in paragraph 7.7.

g) Fit a strap or chain wrench around the end cover circumference (19).

h) Turning the strap or chain wrench in the counter clockwise direction, unscrew the end cover (19) from the capacity control cylinder (3).

i) When the end cover is loose from the capacity control cylinder, pull the end cover by hand away from the compressor. The pilot valve assembly (consisting of valve plate (20), pilot valve (6), piston (4) and ball nut (10) is pulled toward the maximum or fully loaded position in the end of the hydraulic cylinder by the ball screw (which is attached at one end to the ball nut and at the other end to the end cover). Pull the end cover far enough for access to the three shoulder screws (21) on the valve plate (20) or until the piston comes to a stop against the retaining ring (24) attached to the hydraulic cylinder (2).

j) Remove the three shoulder screws (21) with an Allen wrench, using care not to bend or damage the pilot valve (6) connected to the valve plate (20).

k) With the valve plate and pilot valve loose from the piston, remove the end cover and ball screw complete with the subassembly of valve plate, pilot valve and [illegible] The piston (4) and locating plate (7) will remain behind in the end of the cylinder.

l) Remove the O-ring (23) from the end cover.

(B) DISASSEMBLY OF PILOT VALVE ASSEMBLY

a) Remove the snap ring (18).

b) Remove the ball screw (1) with attached bearing (17) from the end cover. Support the end cover on wooden supports with the ball screw hanging down and tap the end of a screwdriver inserted into the end slot of the ball screw.

c) Remove the retaining snap ring (14) and support ring (13) from the ball screw.

d) Remove the bearing (17) from the ball screw by supporting the outer race and lightly hitting the end of the shaft.

e) Remove the E-rings (8) from the pilot valve (6).

f) Remove the pilot valve from the valve plate.

g) Remove the roll pin (9) from the valve plate.

h) Unscrew the valve plate from the ball nut.

IMPORTANT

Do not attempt to unscrew the ball screw shaft from the ball nut.

i) If it is not required to remove the hydraulic cylinder and piston, proceed to (E) next page.

(C) REMOVAL OF HYDRAULIC CYLINDER & PISTON

a) Remove the pilot valve assembly as in (A) before.

b) Loosen the cylinder (3) by turning it counterclockwise with a strap wrench. Remove it carefully.

c) Remove the slide ring (5) and back up O-ring (27) from the piston (4).

d) Remove the three screws (22) holding the locating plate (7) to the piston (4).

e) Remove the locating plate.

f) Remove the internal retaining snap ring (24).

g) Slide the piston off the capacity control valve rod (2). The piston rod shim (25) and the O-ring (26) behind the retaining ring will be pushed out by the piston.

h) Remove the O-ring (28) from the piston rod (2).

(D) INSTALLATION OF HYDRAULIC CYLINDER & PISTON

a) Clean and inspect all the parts and replace as necessary. Examine the hydraulic cylinder for any uneveness in the sliding surface.

b) Mount a new O-ring (28) on the piston rod (2).

c) Mount the piston (4) on the rod.

d) Install a new O-ring (26), piston rod shim (25) and retaining ring (24).

e) Mount the piston locating plate (7) on the piston with the roll pin (29) in the end slot at the bottom of the piston rod.

f) Install and tighten the three screws (22) holding the locating plate to the piston. Use Loctite 242 on the screw threads.

g) Mount a new O-ring (27) and slide ring (5) on the piston. Lightly oil the O-ring and adjacent surfaces.

h) On GSL165, 180 and 240 compressors only, install a new O-ring on the cylinder (3). Lightly oil the O-ring.

i) Screw the cylinder (3) into place using care not to scratch or cut the slide ring (5).

(E) ASSEMBLY OF PILOT VALVE

a) Clean and examine the ball screw (1) for wear (including the end slot) and if necessary replace both the ball screw and ball nut (10).

b) Clean and examine the remaining parts and replace as necessary.

c) Screw the valve plate (20) onto the ball nut (10).

d) Drill a hole 3/16 inch in diameter, 6 mm (1/4 inch) deep in the valve plate adjacent to the ball nut and insert a roll pin (9) to prevent the ball nut rotating and unscrewing from the valve plate.

e) Mount the pilot valve (6) in the valve plate.

f) Secure the pilot valve with E-rings (8) on either side of the valve plate.

g) Install the bearing (17) on the ball screw shaft. A light press is required on the bearing inner race.

h) Lock the bearing on the shaft with a support ring (13) and a retaining snap ring (14).

i) Install the bearing into the end cover (19) with a light press fit.

j) Secure the bearing with the retaining snap ring (18).

(F) INSTALLATION OF PILOT VALVE ASSEMBLY

a) Mount a new O-ring (23) on the end cover (19).

b) Insert the pilot valve (6) through the locating plate (7) into its bore in the piston and mount the valve plate to the piston.

c) Install the three shoulder screws (21), using care not to bend or damage the pilot valve (6). Use Loctite 242 on the screw threads.

d) Screw the end cover into the hydraulic cylinder.

e) Tighten the end cover with a bar between the two 3/8 inch - 16 UCN 50 mm (2 inch) long screws inserted into the tapped holes for the cap screws (12). Use care not to damage the ball screw shaft.

f) Mount the seal cover (11) complete with the two back to back seals (15) and the O-ring (16) as in paragraph 7.7.

g) Mount the electric valve actuator using care to align the pin in the coupling with the slot in the end of the ball screw shaft.

h) Install the two socket head cap screws (4 in fig. 7.3).

i) Jumper the low oil pressure switch.

j) Connect the control cabinet to the electric supply line.

k) With the main motor power disconnected, and the control cabinet energized to simulate operations, check the electric valve actuator switch settings as in paragraph 4.14.

l) Remove the jumper from the low oil pressure switch.

m) Close the pressure safety valve.

n) Open the suction stop valve and discharge stop valve.

o) If the compressor is fitted with an economizer port, open the economizer stop valve.

p) Reconnect control cabinet to the electric supply line.

q) Reconnect the starter to the electric supply line.

r) Start the compressor.

7.9 ROTOR END PLAY INSPECTION

The condition of the thrust bearings can be determined by a simple measurement of the rotor end play. A predetermined force is applied to the end of the shaft and the axial movement of the shaft is measured.

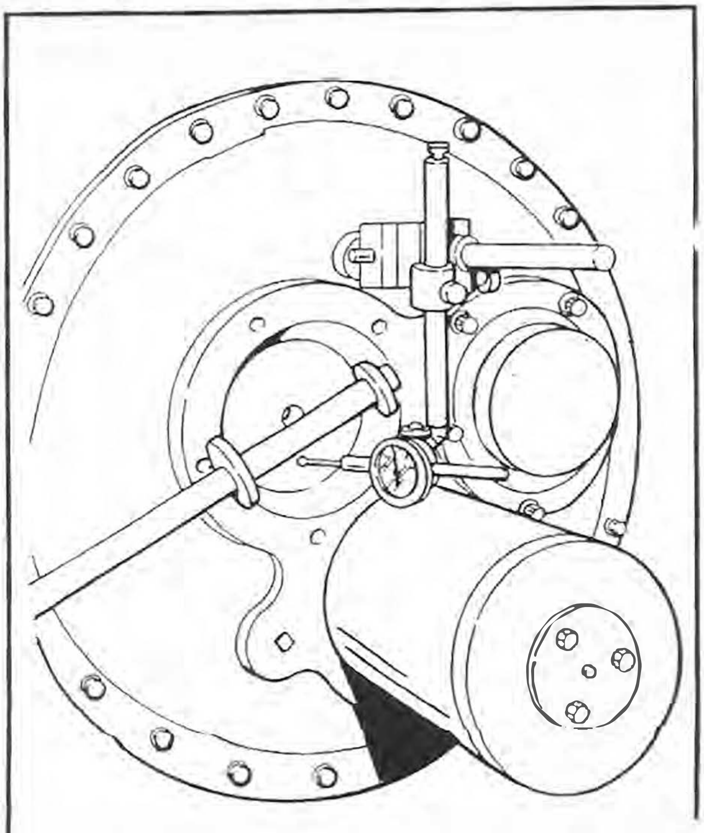


FIG. 7.5 MEASUREMENT OF ROTOR END PLAY

TABLE 7.3 ROTOR END PLAY TOLERANCES	
MEASURED END PLAY	CONDITION AND ACTION
(0.0005 to 0.0010 inch) 0.0127 to 0.0254 mm	Bearings are sound.
(0.010 to 0.0020 inch) 0.0254 to 0.0508 mm	Bearings are questionable. Remove the coupling, piping, shaft seal and outlet cover as in section 7.11. Inspect the out board bearing raceway and rolling elements for visible damage (eg pit marks, scoring or loose cages). Re-inspect every 1,000 hours if no sign of pitting or scoring.
(0.0020 inch and above) 0.0508 mm and above	Remove the coupling, piping, shaft seal and outlet cover as in paragraph 7.11. Inspect the outboard bearing raceway and rolling elements for visible damage (eg pit marks, scoring or loose cages). Push the rotor by hand (50lb or 200 N on the lever) to the discharge end of the compressor. Measure the clearance between the end face of the rotor and the discharge housing by inserting feeler gauges through the discharge port with the capacity control slide valve in the maximum position. This clearance should be (0.002 inch to 0.005 inch) 0.0508 mm to 0.127 mm for all models. Contact Grasso with the measurements of both the end play and the rotor axial clearance and the **compressor serial number** as the thrust bearings may have to be replaced.

a) Carry out the shutdown procedure in paragraph 7.3.

b) Referring to fig. 7.5, remove the male rotor inlet bearing cover including O-ring by removing the bolts. Use screwdriver to part the cover from the inlet housing.

c) Install an eye bolt from table 7.4 in one of the tapped holes which is exposed on the end of the balance piston. Screw in an eye bolt from table 7.4 in place of the screw taken out of the male rotor inlet bearing cover.

d) Install a second eye bolt from table 7.4 into the inlet housing.

e) Install a (three inch) 76.2 mm contact point extension on a dial indicator.

f) Mount a magnetic dial indicator on the compressor casting with the contact point of the dial indicator touching the male or female rotor, depending on which rotor is being checked.

g) Set the dial indicator reading to zero.

h) With a (3/4 inch) 19 mm diameter by (one foot) 305 mm long bar placed through both eye bolts and by using the eye bolt in the inlet housing as a fulcrum, apply hand force [approx. (50 lbs) 220 N] using a back and forth movement to create end play (see figure 7.5 for a typical set up).

i) Read the end play movement on the dial indicator when the hand force is applied to the bar.

j) Compare the rotor end play with the tolerances in table 7.3 above.

k) After one rotor is checked, follow the same procedure for the second rotor.

l) Reassemble parts with new gaskets and O-rings (eg cover and (fe)male rotor inlet bearing).

m) Tighten the ferry head screws to the torques for Grade 8 condition B fasteners in table 7.1 in para. 7.4.

n) Close the pressure safety valve.

o) Open the suction stop valve and discharge stop valve.

p) If the compressor is fitted with an economizer port, open the economizer stop valve.

q) Reconnect the control cabinet to the electric supply line.

r) Reconnect the starter to the electric supply line.

s) Start the compressor.

TABLE 7.4 EYE BOLT DETAILS

Model	Rotor eye bolt			Housing eye bolt		
	Thread dia.	Pitch	Shank length	Thread dia.	Pitch	Shank length
	inch	thread/ inch	inch	inch	thread/ inch	inch
GSL65	5/16	18	3.5	1/2	13	1.5
GSL85 GSL125	3/8	16	4.0	1/2	13	1.5
GSL165 GSL180 GSL240	3/8	16	5.0	5/8	11	1.75

7.10 THRUST BEARING INSPECTION

A) REMOVAL OF OUTLET END COVER (refer to figure 7.6)

a) Carry out the shut down procedure in paragraph 7.3.

b) Place the capacity control slide valve in the maximum position by rotating the output shaft clockwise (manually or with a suitable wrench after pulling out the black knob).

c) Remove the coupling guard.

d) Remove the coupling spacer (incl. plate packs), the rotor coupling flange and key.

e) **Do not** move either the compressor or the motor.

f) Remove the high discharge temperature thermostat bulb from the discharge pipe.

g) Remove the discharge pipe between the compressor and the oil separator.

h) Remove the discharge pressure stop valve from the outlet cover and disconnect the shaft seal oil supply line.

i) Loosen evenly the bolts between the shaft seal cover and the outlet housing.

j) Remove the shaft seal cover (9 in fig. 7.1). Break the flange loose with a rubber hammer.

k) Remove the seal housing (5 in fig. 7.1). Use screws in the three tapped holes to remove the housing if necessary.

l) Remove the rotating seal by pulling it off the shaft by hand.

m) Remove the oil supply line to the square cap which supplies oil to actuate the capacity control slide valve.

n) Remove the four Ferry head screws from the square cap. Twist (to break any binding of the oil supply tube so it can come out with the cap) and remove the square cap.

o) The oil supply tube may come out attached to the cap. If not, pull out the oil supply tube from the compressor by hand through the discharge port.

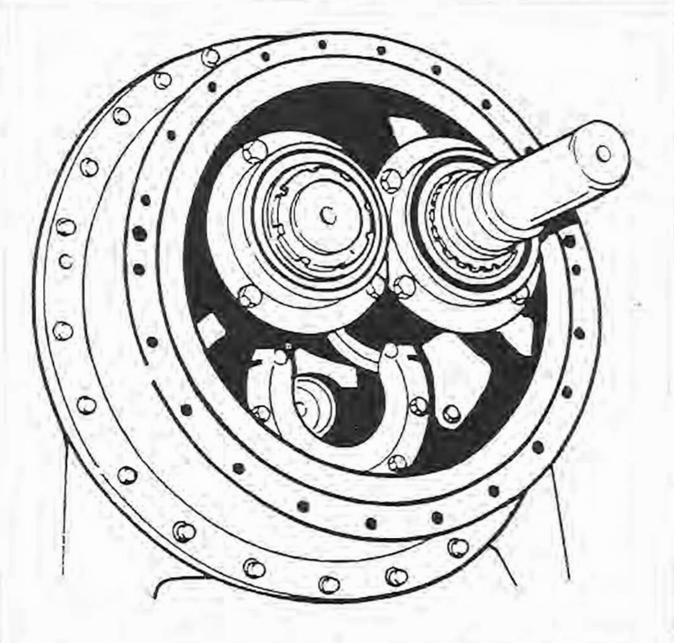


FIG. 7.6 REMOVAL OF OUTLET END COVER

p) Remove the Ferry head screws from the circumference of the outlet cover including the screw(s) in the discharge port.

q) Jack the outlet cover away from the discharge housing using three screws in the specially provided tapped holes in the flange of the outlet cover.

r) Maintain the outlet end cover as parallel to the outlet end as possible to prevent damage to the dowel pin holes in the cover.

s) Remove the outlet cover using care to avoid any contact between the outlet cover and the male rotor shaft. Lift the cover away from the compressor through the coupling space between the compressor shaft and the motor shaft.

t) Prevent dirt from entering the compressor by covering the discharge end with plastic or a clean cloth.

B) INSPECTION OF THRUST BEARINGS
(refer to figure 7.7)

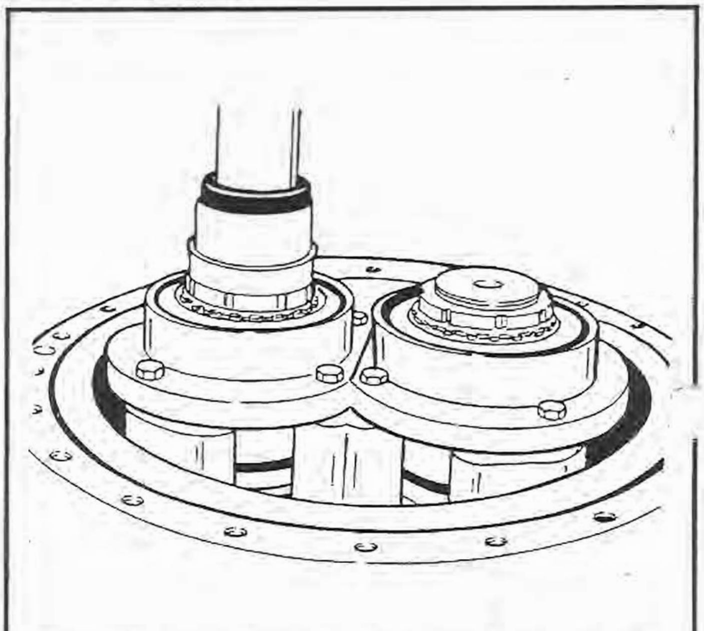


FIG. 7.7 INSPECTION OF THRUST BEARINGS

a) Inspect the raceway and rolling elements of the outboard bearings for pit marks or scoring and loose cages. Use a flash light and mirror as necessary.

b) Examine the raceway and rolling elements of the inboard bearings using a flashlight and mirror. Although these inboard bearings are difficult to examine visually, **do not** remove the locknuts and outboard bearings for better access.

c) Contact Grasso if at all in doubt about the condition of the thrust bearings.

d) Inspect the capacity control valve guides as in paragraph 7.11.

C) INSTALLATION OF THE OUTLET END COVER

a) Make sure the discharge end of the compressor is clean and no dirt has entered the compressor.

b) Clean the outlet cover flange and and the outlet bearing housing or discharge housing.

c) Install a new O-ring into the groove in the flange of the discharge housing. Keep the O-ring in place by apllying a little grease in the O-ring groove.

d) Smear a film of Locktite 515 on the flange face of the outlet cover.

e) Lift the outlet cover into place avoiding any contact with the male rotor shaft.

f) Secure the outlet cover with two Ferry head screws in the top half of the outlet cover.

g) Install the dowel pins.

h) Install the screws around the circumference of the outlet cover and tighten to the torque for Grade 8, Condition b bolts in table 7.1 in paragraph 7.4.

i) Make sure the new bolt seals are used under the head of the screws which are mounted through the discharge port of the outlet cover.

j) Install a new O-ring on the oil supply tube.

k) Insert the oil supply tube into the compressor.

l) Install a new O-ring in the square cap.

m) Install the square cap with the four Ferry head screws.

n) Install the oil supply line to the square cap.

o) Prepare the shaft seal parts and shaft as in para. 7.5.

p) Install the shaft seal as in paragraph 7.5.

q) Install the discharge pressure control tubing in the outlet cover.

r) Install the discharge pipe with new flange gaskets.

s) Install the discharge temperature thermostat bulb in the discharge pipe.

t) Install the coupling as in paragraph 4.6. Install the coupling guard.

u) Close the pressure safety valve.

v) Open the suction stop valve and the discharge stop valve.

w) If the compressor is fitted with an economizer port, open the economizer stop valve.

x) Reconnect the control cabinet to the electric supply line.

y) Reconnect the starter to the electric supply line.

7.11 CAPACITY CONTROL VALVE GUIDES INSPECTION (refer to fig. 7.9)

The capacity control valve is positioned and kept from rotating and therefore touching the rotors by a capacity control valve guide. This is a separate valve guide mounted loose on the end of the stator and has two machined shoes supporting each upperside of the valve. The piston also assists in positioning the slide valve. The bore through which the piston is moving is machined to very close clearance and therefore prevents the valve from moving vertically upwards into the rotor.

A) INSPECTION

a) Carry out the shutdown procedure in paragraph 7.3.

b) Place the capacity control valve in the maximum position by rotating the output shaft clockwise. This prevents the capacity control valve from being knocked when the outlet end cover is removed.

c) Remove the coupling, piping, shaft seal and outlet end cover as in paragraph 7.10.

d) Return the capacity control valve to the minimum or fully unloaded position by rotating the output shaft counterclockwise. This moves the capacity control slide valve out from underneath the rotors for visual inspection.

e) Examine the capacity control slide valve for wear and contact marks from the rotor. If there has been any contact between the rotors and the valve it will appear as contact marks on either or both of the top surfaces of the valve. If there are any contact marks on the valve the valve guides (4) will have to be readjusted.

f) Check the clearance between the valve guide and the capacity control valve. Insert equal thicknesses of feeler

CAPACITY CONTROL VALVE GUIDES

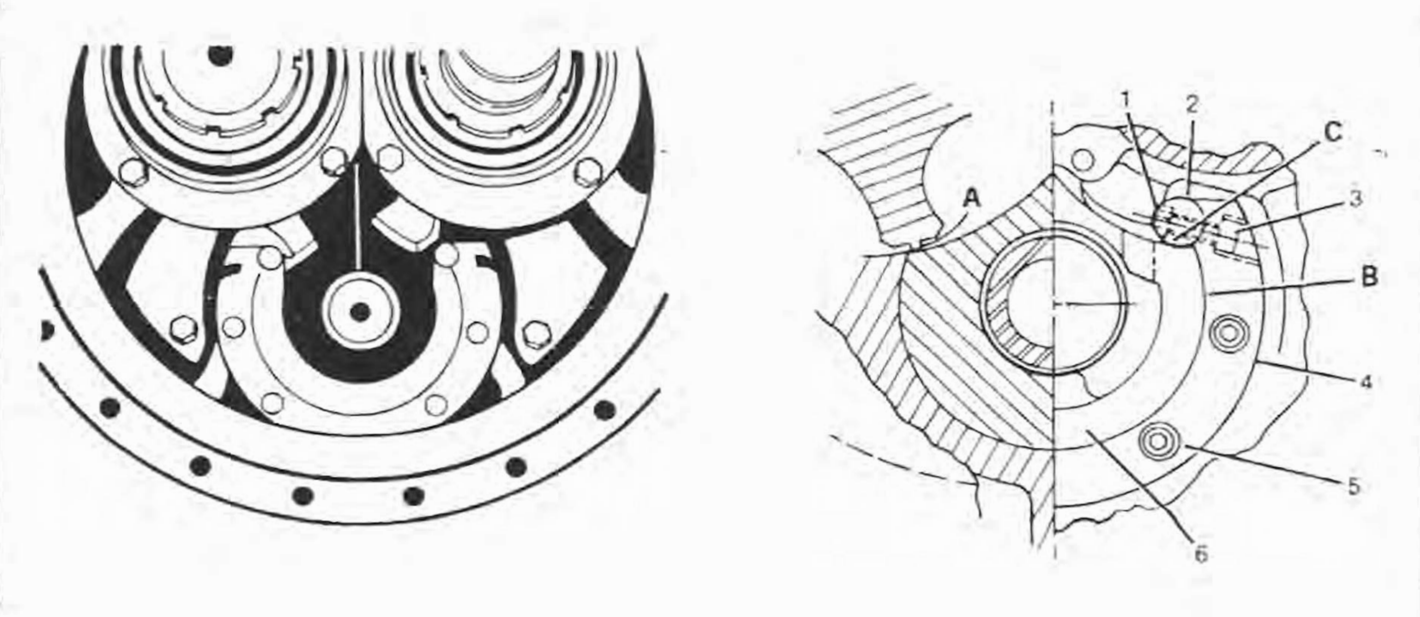


FIG. 7.8 CAPACITY CONTROL VALVE GUIDE

gauges on each side of the valve between the valve guide surface and the valve as close to the outside edge of the valve as possible. This is shown as position C in figure 7.8. If the clearance exceeds (0.0025 inch) 0.0635 mm on each side, the valve guide has to be adjusted.

B) INSTALLATION AND ADJUSTMENT OF VALVE GUIDES

a) Remove the valve guide by unscrewing the four cap screws (5).

b) Clean the face of the valve guide where it mounts on the stator.

c) Rotate the rotor such that both the male (not shown) and the female lobes (shown) are near the outer edges of the capacity control valve.

d) Insert equal shim thicknesses (eg feeler gauges) through the discharge port between the valve and the outside diameter of each of the rotors, to rotate the capacity control valve to the correct angular position relative to the rotors.

e) Place loctite 515 on the valve guide surface that will be mounted on the stator.

f) Mount the valve guide (4).

g) Place loctite 242 on the threads of the cap screws (5).

h) Install and sug up the cap screws (5) by hand.

i) Insert feeler gauges of (0.002 inch) 0.0508 mm between the stator and each side (near the top) of the valve to center the valve in the stator.
This is shown as position B.

j) Insert feeler gauges of (0.001 inch) 0.0254 mm between each guide shoe (2) and the surface of the valve . This is shown as position C.

k) Press down evenly with one hand on top of each guide shoe (2) to make sure that the guide shoes are seated in full contact with the (0.001 inch) 0.0254 mm feeler gauges and (in turn) the valve surface.

l) Tighten the cap screws (5) gradually and evenly. This will minimize any shifting of the valve guides as the screws are tightened.

m) With the valve guide in place, remove all the shims and all the feeler gauges from positions A, B and C.

n) Move the capacity control valve by hand to ensure it moves freely. Make sure that the circular portion of the valve does not hit the guide.

o) Install the outlet cover, shaft seal, piping and coupling and start the compressor as in paragraph 7.10 (C) item v) through y).