GEA Refrigeration Division

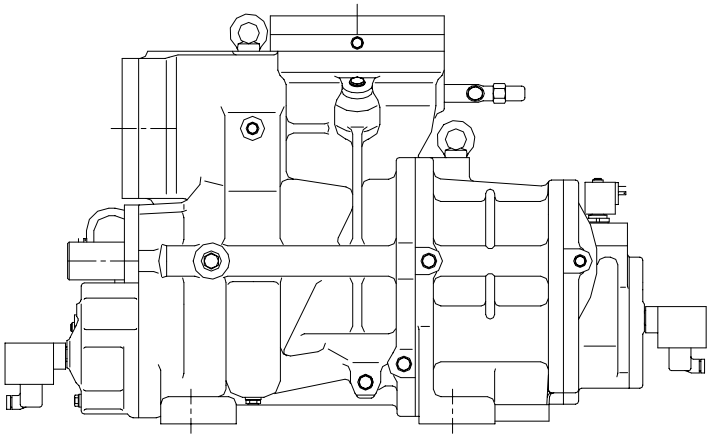
FES Systems Inc.

GRASSO SCREW COMPRESSOR

GM SERIES COMPRESSORS

MODELS H, L, M & N

Used on 110GM, 125GM, 160GM & 195GM Compressor Packages



SERVICE MANUAL

OVERALL CONCEPT
SCREW COMPRESSORS
GM SERIES, TYPES H, L, M, N

- Introduction
- Compression
- Capacity control
- Vi Adjustment

INTRODUCTION

Screw compressors of oil flooded construction with continuously variable capacity control and an adjustable Vi volume ratio are compactly designed and have the following integrated subassemblies:

- Check valve suction side
- Suction filter
- Flanged oil pump
- Solenoid valve blocks to control the capacity control and Vi adjustment

Special compressor types without integrated subassemblies may be designed for special application fields. See compressor parts list.

The two rotors have a distinctive spiral gearing with asymmetrical profile. They operate with a very small clearance and are completely encased.

The male rotor driven by the motor has 5 lobes and it drives the female rotor with 6 lobes. Cylindrical roller bearings with increased load carrying capacity absorb the radial forces and angular contact ball bearings absorb the axial forces. A balance piston is arranged on the male rotor shaft to reduce the force acting on the angular contact ball bearings. A mechanical contact seal ensures that the driving shaft is sealed.

The capacity of the compressor and its internal volume ratio Vi can be adjusted by means of two adjustable slides, the control slide and the Vi slide.

The slides are adjusted hydraulically by the flanged or external oil pump. Hermetically sealed display systems which function inductively are used to indicate the position of the slides.

The entire oil supply system is arranged inside the casing. Oil connections for functional oil and cooling oil are connected to the oil system of the screw compressor unit only.

The functional oil fulfils the following purposes :

- lubrication of the bearings,
- equalisation of the axial forces,
- full load/ part load adjustment via oil pump,
- Vi adjustment,
- lubrication/sealing of the shaft seal.

The solenoid valves for the oil drainage system integrated in the compressor for full load/part load control and for Vi control are arranged directly on the compressor.

The cooling oil flows into the working area of the compressor. The purpose of this oil is to cool the compression process. It lubricates the rotor profile and seals the gaps between the lobe flanks and casing.

The oil which is fed into the compressor flows together with the compressed refrigerant and exits the compressor by the discharge nozzle. It then enters an oil separator which is connected downstream and the refrigerant and oil are separated.

The compressor has a second suction opening (the economizer port) for feeding in a further volume flow.

A connection is provided for oil return from the refrigerating plant.

Two separates connections to the working area is provided for injection of liquid refrigerant. This allows for additional cooling of the compression process.

Another connection at the pressure casing is provided for a connecting tube which comes from the oil separator to prevent gas pulsations in the lower part-load range at high operating pressure levels.

The standard compressor designs have a fixed Vi volume ratio. They are available with Vi values of 2.6, 3.6, 4.8 and 5.5. Furthermore, a compressor type designed for operation under low pressure conditions (booster) are available as a special variant.

The compressor has gauge connections for measuring the temperature and pressure on the suction and discharge side and the oil system.

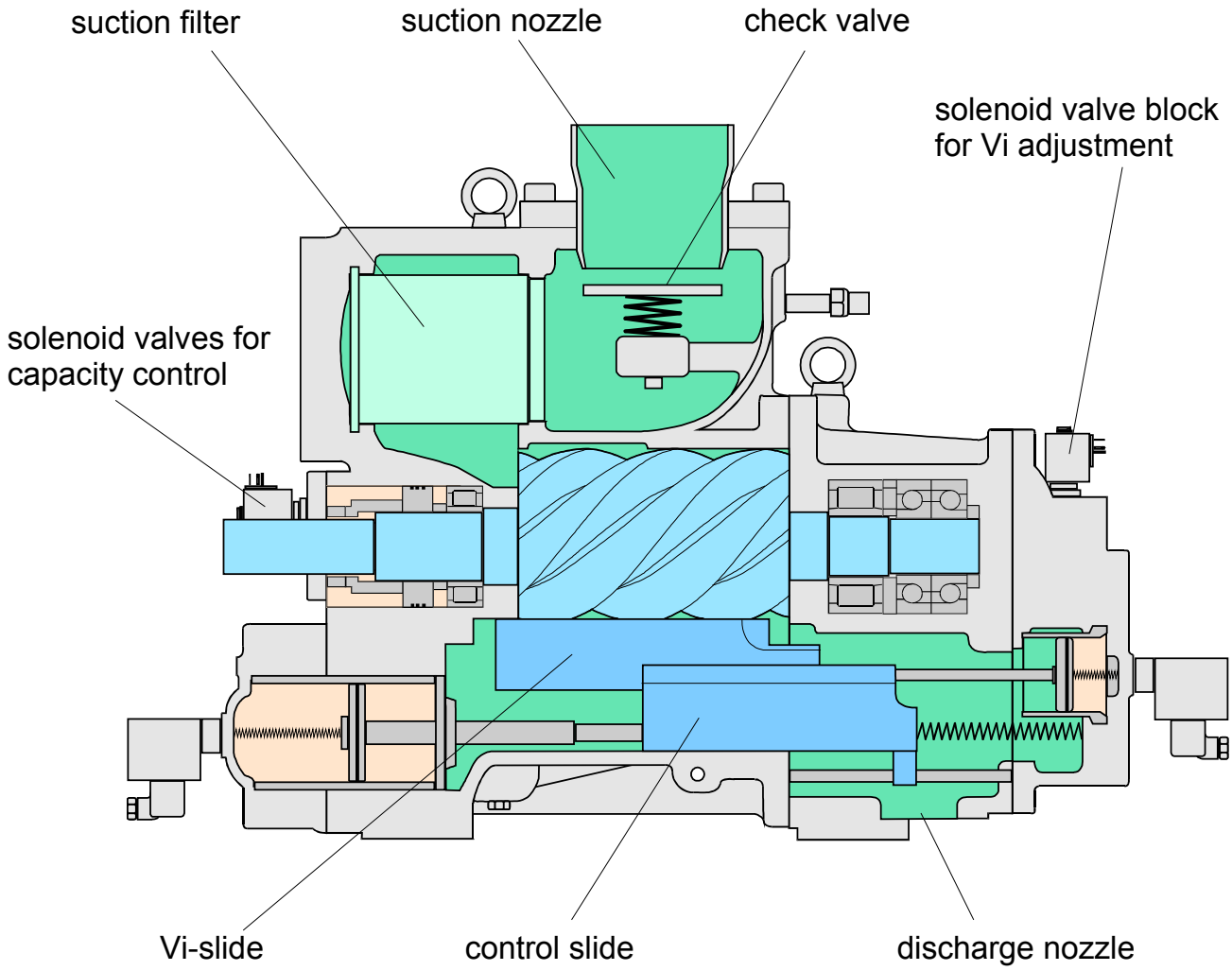


Figure 1: Schematic diagram of the screw compressor

COMPRESSION

While the rotors are turning, the meshing shifts from the suction side to the discharge side. A V-shaped space is formed between 2 male and female lobes in each case which increases to a maximum size (Suction process: Figure 2; 1-3, View of the upper side of the rotors).

As the rotor continues to turn, the V-shaped space is closed by the new meshing on the suction side. This space gradually becomes smaller as the meshing continues (Compression process: Figure 2; 4-5, View of the lower side of the rotors).

The reduction in size takes place on the lower side of the rotors towards the discharge side. The compression process ends when the lobe space reaches the control edges which are incorporated in the casing and control slide or Vi slide (Figure 2; 6). The control edges are part of the outlet opening which has an axial and a radial part.

The position of the control edges determines the size of the compressed volume and thus the level of compression. As the rotors continue to turn, the compressed volume is pushed out of the lobe space which diminishes to zero into the discharge area of the compressor. The process described above is repeated for every subsequent lobe space, thus achieving an almost continuous delivery.

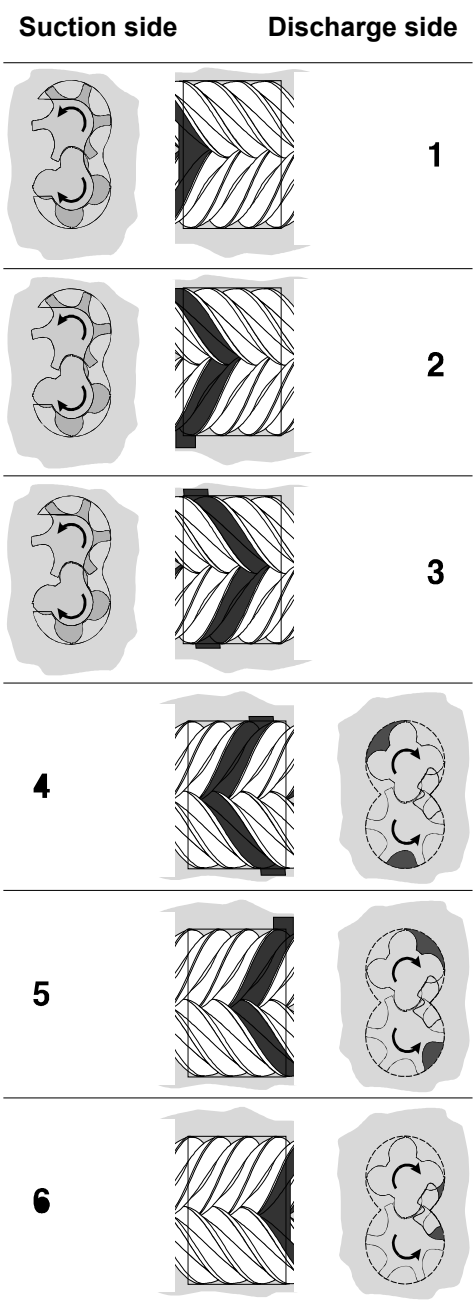


Figure 2: Compression process

CAPACITY CONTROL/VI ADJUSTMENT

Capacity control is based on the control of the volume. It functions according to the principle of effectively shortening the stroke. This is achieved by means of the control slide which is part of the casing wall. When the control slide is adjusted, a bypass opening emerges which provides a connection to the suction area of the compressor (Figure 3).

By means of the capacity control the volume flow of the compressor is continuously adjustable between 100% and about 10%.

When in the minimum position, the control slide reduces compression work to a minimum thus ensuring unloaded startup of the compressor.

INTERNAL VOLUME RATIO VI:

The internal volume ratio Vi is a characteristic number of the screw compressor. It is the ratio of the lobe space volume at the beginning of compression to the lobe space volume at the end of compression.

The end of compression and internal volume ratio Vi are determined by the size of the outlet opening, i.e. the position of the control edges at the radial outlet opening. In compressors with adjustable Vi this opening is arranged in the Vi slide (Figure 3). Control slide and Vi slide together form part of the lower wall surface of the working area. Different Vi adjustments can be set by moving the Vi slide to various axial positions in the full load or upper part load operating range. This also alters the position of the control edges.
The volume ratio Vi can be adjusted to suit the external operating conditions (suction pressure, discharge pressure) in such a way that the pressure in the lobe space is about the same as the external discharge pressure by the time it reaches the outlet opening. So there is minimum loss during compression and a minimum level of driving power is necessary in each case.
The optimum position of the Vi slide is calculated by the programmable control equipment of the compressor according to an empirical algorithm.
Compressors which have a fixed volume ratio Vi are not fitted with a Vi slide. In this case the volume ratio Vi is determined by the size of the radial outlet opening arranged in the control slide.

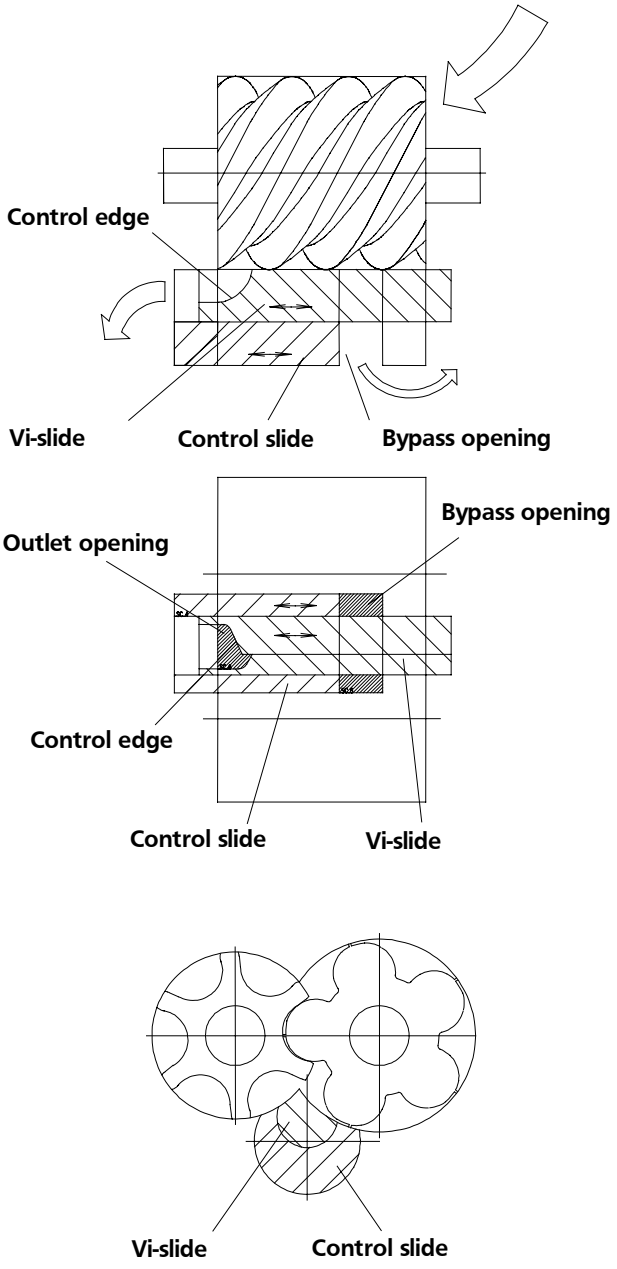


Figure 3: Principle of capacity control and Vi-adjustment

DESCRIPTION OF DESIGN
SCREW COMPRESSORS
GM SERIES, TYPES H, L, M, N

- Casing
- Check valve/ filter suction side
- Rotors
- Bearings
- Shaft Sealing
- Oil pump
- Capacity control/ Vi-adjustment
- Solenoid valve blocks
- Display System of Slide Position

CASING

The casing is made of grey cast iron and designed in two parts, the rotor casing and a pressure casing. The two casings are bolted together at a vertical parting joint. The connecting flanges of the suction side and the discharge side are arranged horizontally.

The casing parts, covers and flanges are sealed with O-rings.

Screw plugs are provided for oil drainage.

Covering flanges with guide surfaces for the Vi slide are attached to the front wall of the working area on the suction side.

CHECK VALVE/FILTER SUCTION SIDE

Check valve and suction filter are arranged on the upper side of the rotor suction casing .The filter insert has a filter mesh size of 100 µm and the gas flows from inside to outside.

The filter insert can be changed by removing the filter cover.

The connection flange on the suction side has to form by a pipe bend to ensure that the check valve is accessible (by removing the pipe bend).

The compressor is optionally fitted with or without check valve and suction filter. A vibration damper is fitted on the check valve. A spring-loaded pin bears with low force on the valve stem. The spring force is adjustable and can be varied from the outside with the compressor operating. A connection point for temperature measurement is provided on the suction filter casing. A connection point for pressure measurement is available upstream of the check valve.

ROTORS

Rotors are made of C 45 material. Male and female rotors each have different profile diameters. The speed ratio of the male to female rotor is 5 : 6.

The shaft section of the male rotor where the shaft seal is arranged is chrome-plated. The rotor profile is manufactured with high precision by means of the hobbing process, thus attaining excellent coefficients of performance.

BEARINGS

As a result of compression, radial and axial forces act on the rotors. These forces are absorbed by appropriate bearing elements.

The radial forces are absorbed by high performance cylindrical roller bearings with a solid cage. Bearings of differing sizes are installed on the discharge side of the male and female rotor. This takes into account the different force levels while utilizing the available space.

Angular contact ball bearings, which are installed crosswise in pairs, absorb the axial forces. In addition, they ensure precise axial guidance and positioning of the rotors. The angular contact ball bearings are equipped with a solid cage for the special requirements in the screw compressor. They have radial clearance at the outer rings towards the casing which precludes a radial load and increases their service life. The outer rings are firmly tightened axially to prevent them from rotating.

Large axial forces act on the male rotor. A balancing piston is therefore arranged on the male rotor shaft end on the suction side of the compressor to unload the axial bearing.

The balancing piston is loaded on one side with the lubricating oil under compression discharge pressure and produces an axial counterforce. This helps to extend the service life of the bearings.

SHAFT SEAL

The driven male rotor is sealed on the shaft bushing on the suction end by means of an oil sealed mechanical contact seal. This seal has a balanced design so as to achieve a maximum service life.

In the standard design, the counter ring arranged in the cover is made of a special grey cast iron alloy, and the the elastic seal ring rotating with the shaft is made of antimony bound hard carbon. An O-ring is used as secondary sealing between the slide ring and the shaft. The sealing space which is under compression discharge pressure is supplied with lubricating oil. This space is sealed off towards the inside area of the compressor by the balancing piston. The sealing surfaces of the carbon ring and counter ring face one another without contact. They are separated from one another by a thin oil film. Although there is a slight amount of oil leakage, a high service life is obtained.

OIL PUMP

The oil of the oil pump is required to activate the hydraulic device of the capacity control. The oil pump is flanged at the front of the rotor casing. The female rotor drives the oil pump. A partial flow from the space of the shaft seal is conducted via internal oil drainage holes to the suction side of the oil pump.
The oil from the discharge side of the oil pump enters the solenoid valve block of the capacity control via the external pipe.

An overflow valve under the solenoid valve block controls the pressure of the pump and conducts the excess oil to the internal oil system of the compressor. The pressure transmitter for measuring the pressure of the oil pump is installed at the solenoid valve block. The flanged oil pump at the compressor does not exist when the package has a external oil pump.

CAPACITY CONTROL / VI ADJUSTMENT

Control slide und Vi slide form part of the lower wall surface of the working area. Both slides are operated individually by means of separate hydraulic systems.

A bypass opening emerges when the control slide is adjusted. It provides a connection to the suction area of the compressor via ducts in the casing.

The size of the radial outlet opening of the working area can be altered by adjusting the Vi slide.

The control slide can be shifted axially from the full load position towards the pressure casing. On the suction side it is connected to a hydraulic piston by means of a piston rod. The piston can be loaded with oil of the oil pump in either direction and it slides within a cylinder which is closed on both ends. Internal oil drainage ducts and solenoid valves arranged on the compressor fill up and empty the cylindrical spaces of the hydraulic piston.

A tension spring is attached to the control slide. This tension spring adjusts the slide to the minimum position without using the oil pump, such as when the compressor is taken out of service.

In the upper part load range, the Vi slide is adjusted together with the control slide in order to maintain the Vi volume ratio at an energetically optimum level.

The effective rotor length can be continuously shortened and the volume flow reduced by adjusting the control slide.

The minimum part load position results when the edge of the control slide on the suction side closes the passing tooth space at the latest before the axial outlet opening on the discharge side is reached. The control slide moves underneath the axial outlet opening in the pressure casing.

A tappit on the face area of the control slide on the discharge side slides along a rod and serves as an antirotation device.

Stop sleeve for limiting the MIN position of the control slide

With respect to screw compressors co-operating with other machines and in which a check valve is arranged on the discharge side, the adjustment path of the control slide is reduced while the MIN position of the slide is limited by a premature stop (in the 35%, 30%, or 15% position). The limitation is obtained by means of a stop sleeve mounted on the piston rod behind the piston (see figure). The sleeve is mounted onto the piston rod and secured in a fixed position by 2 O-rings.

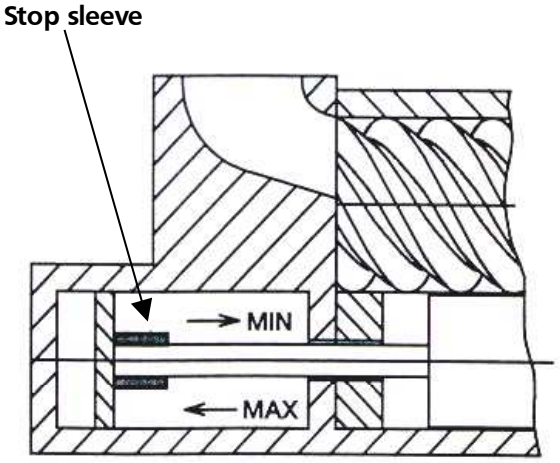


Figure 1: Stop sleeve for limiting the MIN position of the control slide

During compression the difference between suction and discharge pressure acts on the front end of the control slide by means of which an adjustment towards the suction side, i.e. towards full-load, takes place. For small pressure differences, the resulting adjustment force is not high enough. It is increased by loading the back of the hydraulic piston with oil of the oil pump. The cylinder space at the front of the piston is thereby discharged to the suction side.

The control slide is shifted towards the pressure casing, i.e. towards part load, by loading the front side of the hydraulic piston with oil of the oil pump and discharging the back side to the suction space.

The Vi slide is arranged across the entire length of the working area and is guided inside the control slide. The

radial outlet opening is located on the discharge side of the working area.

A rod and piston is attached to the discharge side of the Vi slide face area to adjust the position of the slide towards the discharge side (Vi enlargement or outlet window reduction). The piston slides inside a cylinder. By reducing the pressure in the cylinder area to the same level as the suction pressure of the compressor, a force develops on the piston which adjusts the position of the Vi slide towards the discharge side.

Positioning of the Vi slide towards the suction side (Vi-reduction or outlet window enlargement) occurs by the prevailing pressure difference between the discharge and suction pressure on the front sides of the slide. Here oil under discharge pressure enters the cylinder area thus balancing the forces acting on the piston.

The cylinder area is filled and drained via internal drainage holes and solenoid valves which are attached to the closure flange of the compressor.

Compressors of the standard design which have a fixed volume ratio Vi are not fitted with a Vi slide. The control slides are provided with an outlet opening corresponding to a Vi of 2.6, 3.6, 4.8 or 5.5.

The Vi level must be determined before the compressor is manufactured. This value depends on the subsequent operating conditions (suction pressure, discharge pressure).

SOLENOID VALVE BLOCKS

The hydraulic spaces of capacity control and Vi adjusting device are connected to the oil system of the oil pump or to the compressor suction space by the solenoid valve blocks.

The valve blocks are screwed to a flat surface of the casing fitted with boreholes which serve as a connection to the compressor suction side and to the hydraulic spaces. The solenoid valve block is connected to the oil pump by a separate connection.

In addition to the solenoid valves, control valves are attached to the blocks. The adjusting speed of control slide and Vi slide can be influenced by means of these valves by controlling the flow rate.

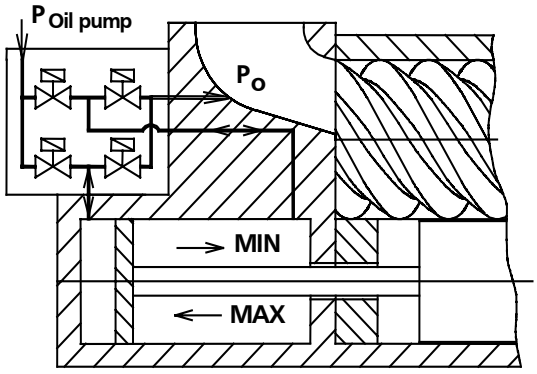


Figure 2 Functional diagram of the solenoid valve block of the capacity control

DISPLAY SYSTEM OF SLIDE POSITION

The positions of control slide and Vi slide are recorded by separate position sensor display systems (**H**ermetical **D**ifferential **T**ransformer HDT) arranged on the respective covers.

By means of two connected tension springs of different lengths the large length of adjustment of the slide/piston rod/hydraulic piston complex can be reduced to a small length which corresponds to the measuring range of the position sensor. A long pin is attached to the junction of both springs where a small length of adjustment appears. The end of the pin slides into a coil of the position sensor thus generating a test signal by altering the inductivity.

Depending on the position of the control slide, i.e. depth of pin immersion, the position sensor supplies an output signal of between 4 and 20 mA.

The position of the Vi slide is recorded in the same manner. The compressor control device computes the optimum Vi values. Based on these values, the Vi slide is set to the preset position recorded by the sensor.

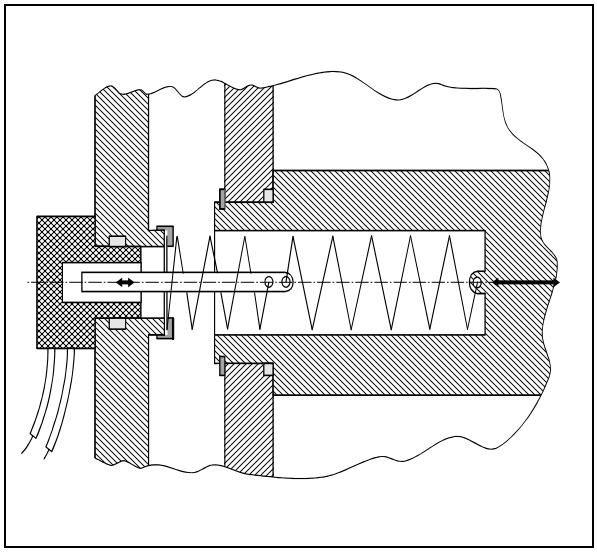


Figure 3 Functional diagram of the position sensor system of control slide and Vi slide

CONNECTIONS, OIL PASSAGE
SCREW COMPRESSORS
GM SERIES, TYPES H, L, M, N

- P + I Diagrams
- Connections, Threads
- Input Voltage
- External Connections
- Internal Oil Passage

P+I DIAGRAMS

The following concerning the internal oil circuit solely applies to the standard application of the compressor in single stage / high pressure operation.

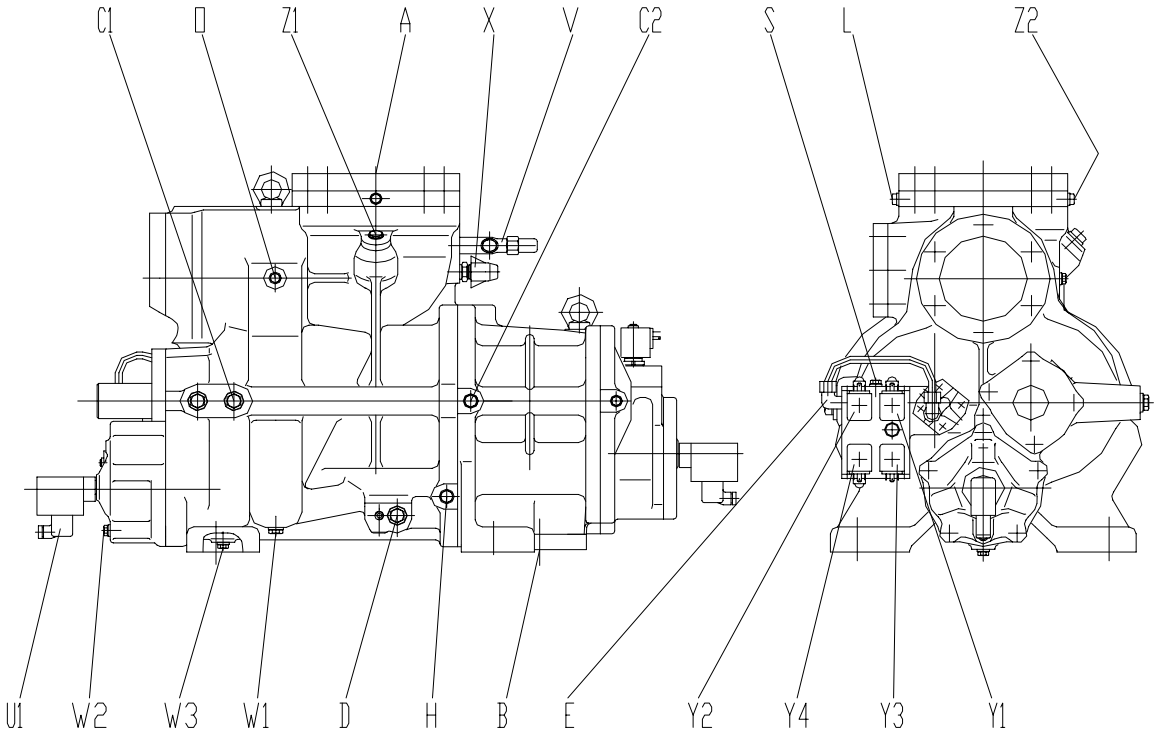
CONNECTIONS / THREADS

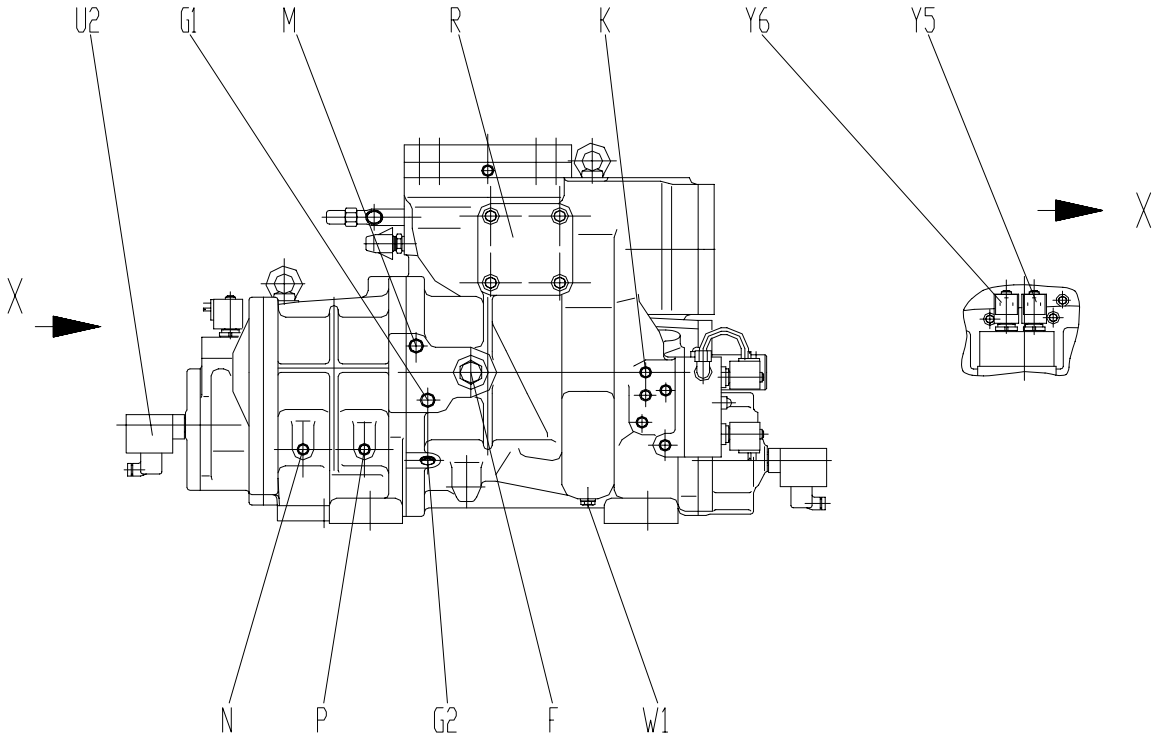
Item	Purpose	Nominal width/ threads	
		H / L	M / N
A	Suction nozzle	DN 125	DN 150
B	Discharge nozzle	DN 80	DN 100
C1	Functional oil	M 22 x 1,5	M 22 x 1,5
C2	Functional oil	M 16 x 1,5	M 22 x 1,5
D	Oil injection compression chamber	M 22 x 1,5	M 26x1,5
E	Oil supply capacity control from oil pump	G ¼	G ¼
F	Economizer	M 42 x 2	M 48x2
G1	Refrigerant liquid injection (LP)	M 16 x 1,5	M 22 x 1,5
G2	Refrigerant liquid injection (HP)	M 16 x 1,5	M 22 x 1,5
H	Gas pulsation protection	M 16 x 1,5	M 22 x 1,5
K	Additional oil injection	M 12 x 1,5	M 16 x 1,5
L	Measure suction pressure	M 16 x 1,5	M 16 x 1,5
M	Oil return oil separator	M 16 x 1,5	M 16 x 1,5
N	Measure discharge pressure	G ¼	G ¼
O	Measure suction temperature	M 12 x 1,5	M 12 x 1,5
P	Measure discharge temperature	M 12 x 1,5	M 12 x 1,5
R	Connection overflow valve	DN 80	DN 80
S	Measure pressure oil pumpe	G ¼	G ¼
V	Ventilation compressor (valve 105)	M 16 x 1,5	M 16 x 1,5
W1	Oil drain plug	M 16 x 1,5	M 22 x 1,5
W2	Oil drain plug	M 12 x 1,5	M 12 x 1,5
W3	Oil drain plug	M 12 x 1,5	M 22 x 1,5
X	Vibration damper	--	--
Z1	Additional connection	M 16 x 1,5	M 16 x 1,5
Z2	Additional connection	M 16 x 1,5	M 16 x 1,5

INPUT VOLTAGE

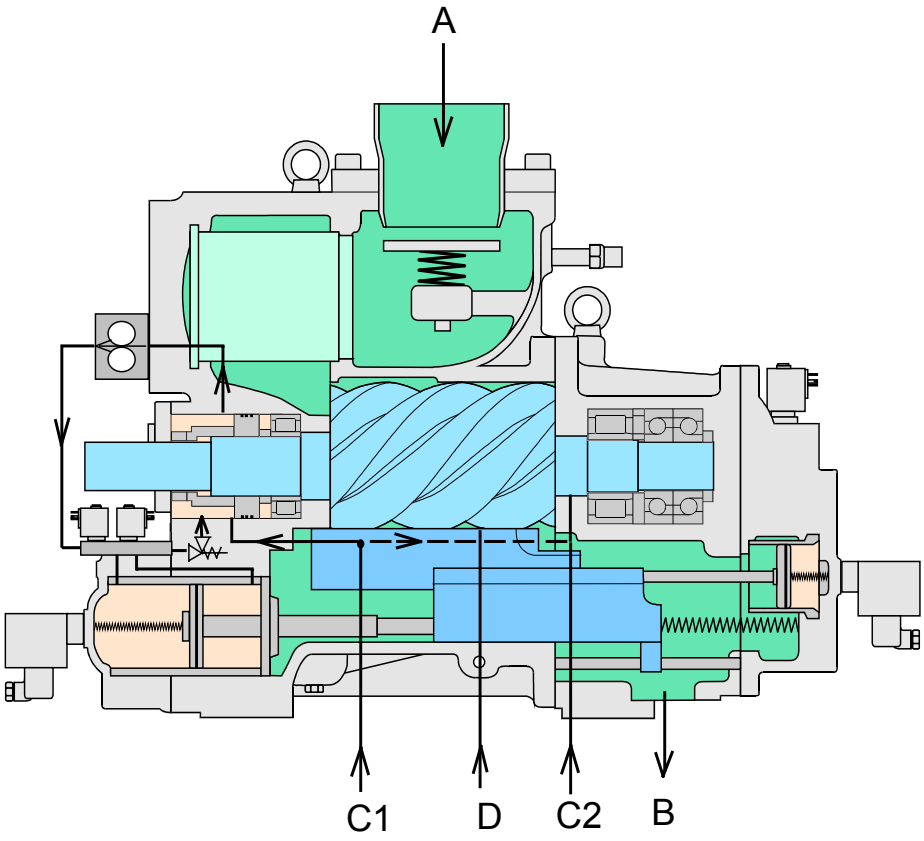
Item	Purpose	Input	Output
U1	Position sensor (123) for position display control slide	24 V (DC)	4 - 20 mA
U2	Position sensor (123) for position display Vi-slide	24 V (DC)	4 - 20 mA
Y1/Y4	Solenoid valves capacity control , direction full load	240 V AC 220 V AC	
Y2/Y3	Solenoid valves capacity control , direction part load	110 V AC 48 V AC	
Y5	Solenoid valve Vi-enlargement	42 V AC 24 V DC	
Y6	Solenoid valve Vi-reduction	220 V AC, expl.-proof	

EXTERNAL CONNECTIONS





INTERNAL OIL PASSAGE



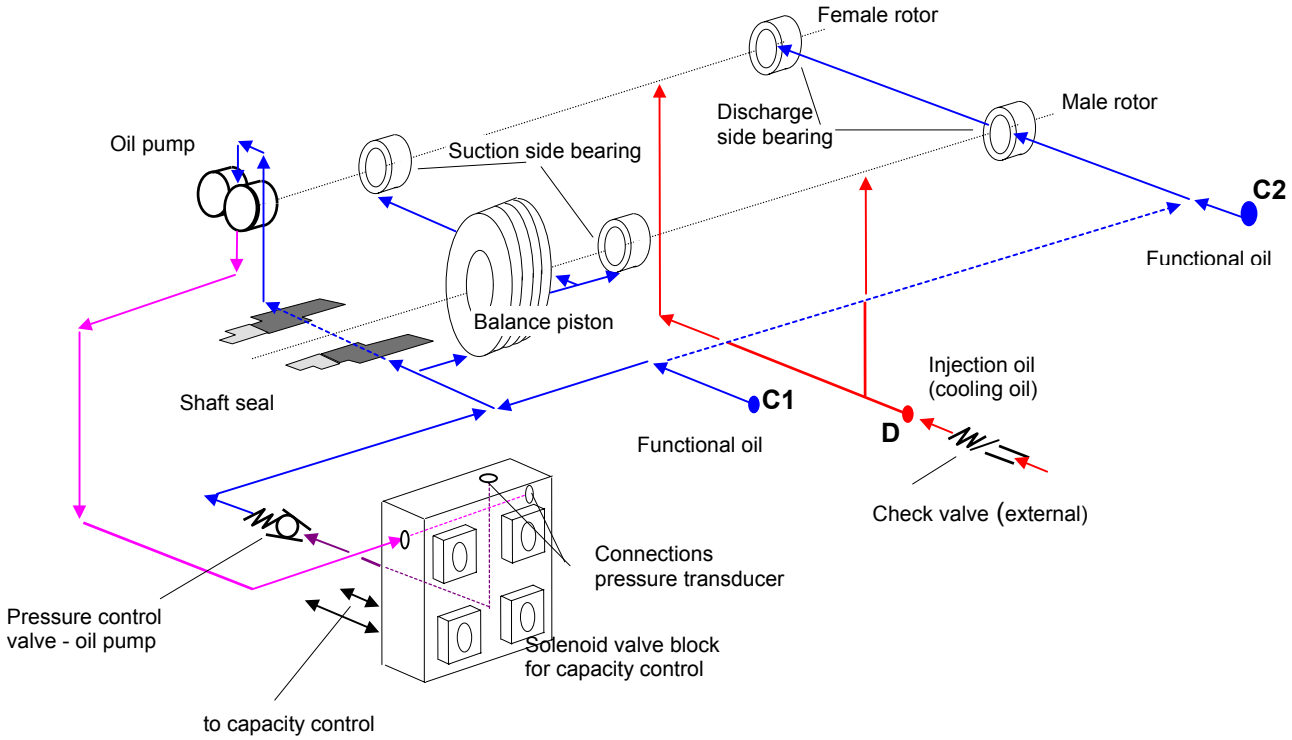


TABLE OF CONTENTS

1. IMPORTANT INSTRUCTIONS

- Apart from technicians authorized by the manufacturer, repair work on the screw compressor may only be undertaken by skilled operating personnel or qualified technicians in compliance with these safety instructions.
- Before commencing any repair work the screw compressor unit must be removed from operation according to the operating instructions, all refrigerant evacuated and the unit depressurized.
- Preparations for maintenance work on the compressor are to be undertaken in such a manner that it is only necessary for the machine to be open for a short period.
- The sealing and locking devices which have become accessible must be renewed.
- Utmost cleanliness during assembly is absolutely essential for continued trouble free operation.
- After maintenance and repair work has been carried out, the parts must be cleaned with an organic degreasing agent and treated with the refrigeration equipment lubrication oil of the same brand used in the plant.
- The compressor must be evacuated when all work operations have been completed after which a pressure and vacuum test must be carried out (see sections 12 and 13).
- Instructions for prolonged shutdown periods:
- When the compressor is shut down for a long period of time (longer than one week), the following is recommended:

  → Close the shut-off valves on the suction and the discharge side of the screw-compressor unit.

  → Turn the coupling of the compressor by one eighth of a shaft turn every four weeks.
- When the compressor is to be stored separately, it must be filled with dry nitrogen after it has been evacuated (0.5 bar (7 psi) excess pressure).

2. INTRODUCTION

A description of maintenance and repair work for the subassemblies mechanical contact seal, capacity control, Vi adjusting device and axial bearing is given in these instructions.

The screw compressor can remain connected to the unit during the maintenance and repair operations described here since subassemblies are only partially disassembled. Repair of the compressor when completely disassembled requires specific technological prerequisites and is therefore not described here.

We recommend the operator of the compressor to ensure that maintenance and repair work is carried out according to the time schedules specified in the FES Instruction and Operation Manual.

See specified chapters for criteria of subassembly replacement.

The figures in brackets ( ) after an individual part refers to the reference number of the part given in the FES Parts Manual. To order a part, refer to the FES Parts Manual for the FES Part Number.

Refer to the table in section 14 for the tightening torque values.

The specialized tools used are denoted with T. and are shown in the List of Specialized Tools given in section 15.

3. SHAFT SEAL

The sealing surfaces of the carbon and counter ring of the shaft seal (40) are separated from one another by a thin oil film whereby a slight amount of leakage occurs but a long service life is achieved. The leakage oil is discharged through the oil drain tube (44A).

The oil leakage rate is mainly influenced by
- condition of wear of mating materials
- discharge pressure
- oil viscosity (oil temperature and oil brand)
- presence of refrigerant in the oil
- frequency of starts and stops

Oil leakage rate guaranteed:

The value of the leakage rate given refers to the following operating conditions:

Oil supply temperature: 130°F

Speed: 3600 RPM

Leakage rate

Types H, L, M, N: 10 drops per minute

Due to differing operating conditions, such as
- increased oil pressure at the shaft seal,
- increased entering oil temperature,
- use of refrigerant soluble oils,
- increased speed,
- frequent starts and stops,
- presence of liquid refrigerant in oil

the values given may rise by three times without causing impermissible wear on the shaft seal.

When the leakage rate is exceeded due to
- wear on the sealing surfaces
- damaged O-rings
- damaged seat on the rotor shaft,

the shaft seal has to be replaced.

Disassembly

- Remove compressor coupling half according to operators instructions for the coupling.
- Remove the sealing cover (44) together with the counter ring of the seal using two jacking screws.
- Pull off the part of the seal which is located on the shaft manually or by using two hooks as shown in Figure 1.

  In the case where the seal is difficult to remove, it can be pulled off together with the balancing piston (36). Two tapped holes are provided to use the removal device T11 as shown in Figure 2.
- Press the counter ring out of the cover (44).

☞ **Note: If the cover and counter ring cannot be guided through the shaft ends of compressor and motor together, they must be separated beforehand.**

- If signs of wear (heavy abrasion or deep grooves) are visible on the front sides of the carbon or counter ring, renew the seal.

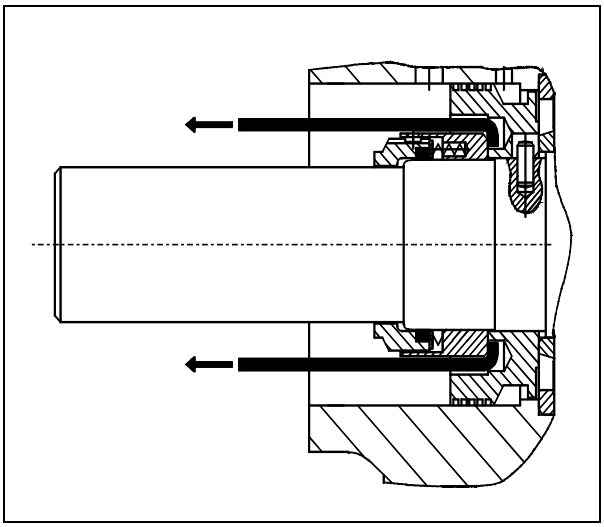


Figure 1: Dismantling the shaft seal

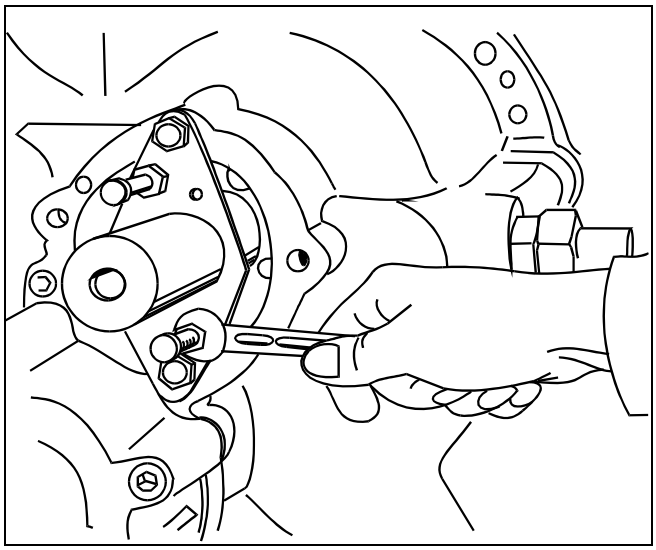
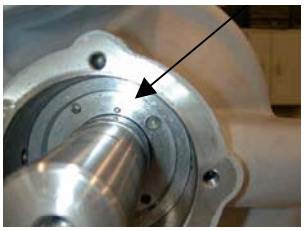


Figure 2: Removing the balance piston with device T11

Assembly

- If the balancing piston (36) has been removed, device T11 can be used according to figure 2 for assembly. The balancing piston is thereby pressed onto the shaft by means of the threaded rods which must be screwed into the corresponding tapped holes of the tool.
- Push the spring assembly and carbon ring with a new O-ring (39) onto the rotor shaft so that the cylindrical pin (38) projects into the corresponding borehole of the spring assembly, see the arrows in the photos below.



- Insert O-ring (42), the outer O-ring (41), and insert the counter ring of the seal in the cover (44).
- Push the cover over the shaft end and assemble it to the casing.

☞ **Note:**
If the cover and inserted counter ring cannot be guided through the shaft ends of compressor and motor together, they must be individually pushed onto the rotor shaft first and then connected to one another.

4. CAPACITY CONTROL

Recommended times for the renewal of seal sets (105, 105A, 115, 115A) and tension springs (120/119) are given in the FES Operation Manual. In practice, the length of these operation times can be longer or shorter than recommended.

4.1 Repair Criteria

When malfunctions of the capacity control system occur, first check to see whether the oil supply system above the valve block (51) (solenoid valves, throttle valves) and the display system are in working order. If so, repair work is necessary after occurrence according to the following criteria:

- Control slide cannot be adjusted towards part load operation.
- Under manual setting, the control slide moves spontaneously towards its full load position.

  ⇒ **Change the seal set (105/105A) of the piston (101)**

- Capacity adjustment towards full load does not function in the case of lower operating pressure differences

  ⇒ **Renew the seal set (115/115A) of the piston rod (116)**

- The specified flow values were not attained in the min. or max. positions of the control slide (despite adjustment of position sensor HDT in compliance with item 7.2)

  ⇒ **Renew tension springs (120 and 119)**

4.2 Disassembly

a)

- Disassembly of the seal flange (66). In compressors with a Vi adjusting device, first remove the display system from the cover (90) according to section (6.2,a) and then detach the cover.

Attention
When removing the display system, the Vi slide must be in the Vi max. position. Observe the note in section 6.2, a) for disassembly.

- Loosen the screw (67) to release the tension spring (73).
- **ATTENTION!**
  Remove the tooth lock washer (700) between the screw in piece of the tension spring and the closure flange (21)! See photo below.

- Instead of using the screw (67), screw a threaded rod of the removal device T2 into the screw in piece of the tension spring.

b)

- Loosen the screw plug (74) from the hydraulic space of the capacity control and drain the oil.
- Loosen the side screw plugs of the hydraulic spaces next to the valve block (51) (*figure 3*).
- Adjust the control slide (113) to the max. end position (towards the suction side) by hand with the aid of a piece of threaded rod.

c)

- Removing the position sensor (123) from the cover of the capacity control (104):

  Loosen the hexagon socket head attachment screw on the lower side of the rectangular casing and remove the position sensor.

  The pressure pipe (X) can be seen Figure 4.

- Unthread the pressure pipe.
- Pull the position sensor rod (125) out of the cover (104) by hand as far as the hook and disassemble the inside tension springs (119) (*figure 5*).
- The position sensor rod, tension spring support (121) and outer tension spring (120) remain assembled.

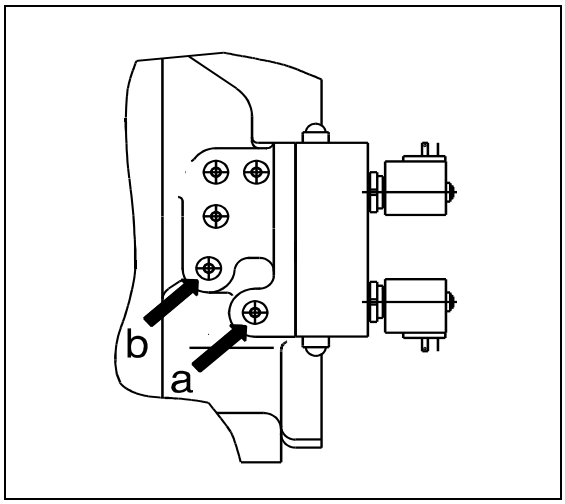


Figure 3: Arrangement of the screw plugs in the hydraulic spaces of the capacity control
a:front hydraulic space
b: rear hydraulic space

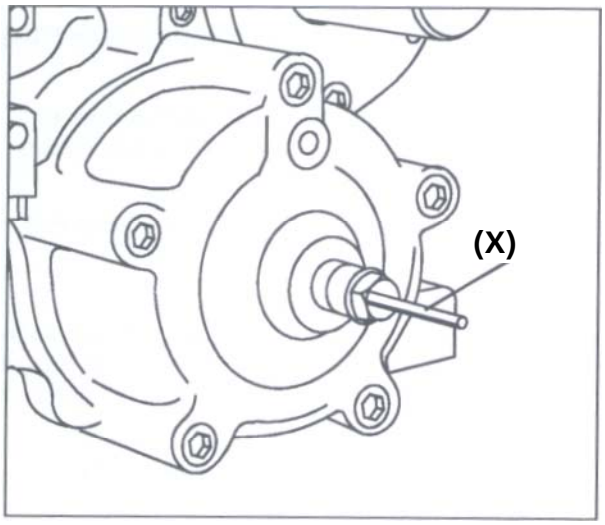


Figure 4: View of the pressure pipe (X) after removal of the position sensor (123)

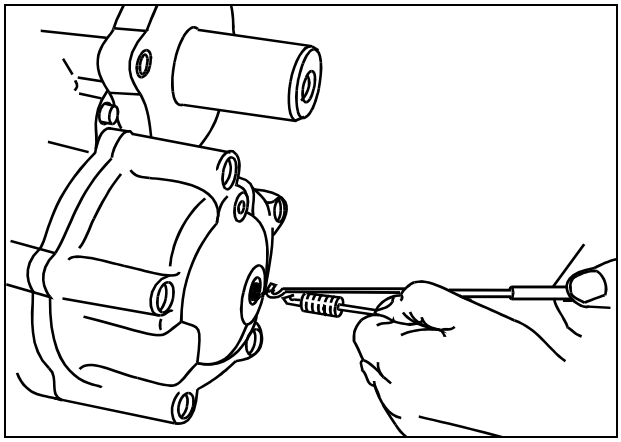


Figure 5: Position sensor rod removed (125) for removal of the inner tension spring (119)

d)

- Loosen the screws (106), then remove the cover (104).
- Unlock the lock plate (128) and loosen grooved nut (127) using tool T6 (*figure 6*).
- Remove piston (101) by means of removal device T2 (*figure 7*).

e)

- Remove cylinder (108) and cylinder limitation (114) also using removal device T2. The device should be applied according to figure 7. However, the removal bolts must be screwed into the cylinder limitation.

4.3 Changing the Seals

Changing the seal set (105/105A) of the piston (101)

- Remove the old sealing ring and replace the O-ring.
- Heat the new sealing ring to a temperature of 90°C (194°F) in a water bath.
- Pull the sealing ring over the flat chamfer of the piston.
- Briefly insert the piston in the cylinder to calibrate the seal. Use 2 threaded rods from device T2 for insertion.

Changing the seal set (115/115A) of the cylinder limitation (114)

- Remove the old seal and insert a new O-ring in the cylinder limitation.
- Heat the sealing ring to a temperature of approx. 90ºC (194°F), press it together so that it is uniform and insert it in the groove, then roll it in towards the circumference using round material.
- Briefly push the cylinder limitation onto the front piece of the piston rod (116) to calibrate the seal. Use 2 threaded rods of device T2 to do so.

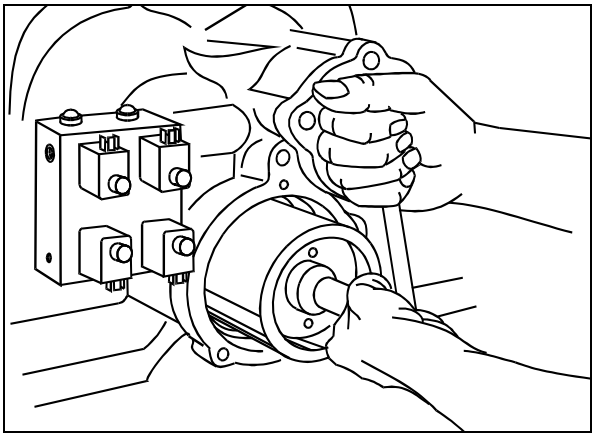


Figure 6: Loosening or tightening the grooved nut (127) using tool T 6

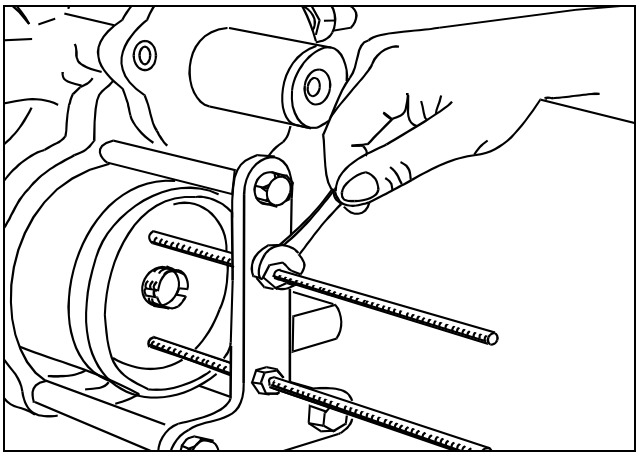


Figure 7: Removing the piston (101) or cylinder (108) and cylinder limitation (114) using removal device T 2

4.4 Changing the tension springs

- The work operations described below also applies to the tension springs (120 and 119) of the capacity control and the tension springs (92 and 93) of the Vi adjusting device.
- Removal of the position sensor (123), position sensor rod (125) and cover must be carried out according to the work operations described for the corresponding subassemblies. The pistons (101/ 98) remain attached when only the tension springs are replaced.
- Remove the outer tension springs (120) from the position sensor rod and unhook it from the tension spring support (121).
- Hook the new outer tension springs to the tension spring support.
- Loosen the snap ring (126) from the piston rod and pull out the inner tension springs (119/92) together with the tubular housing (118/95) and screw plug (117) by means of assembly hook T10.
- Unthread the screw plug from the spring end and thread it into the new tension spring.
- Insert the tubular housing with the assembled tension spring and screw plug into the piston rod and secure with a new snap ring (126).
- Further work operations are described in sections 5.5 and 6.5.

☞ **Attention!**
Always renew tension springs in pairs according to procurement of spare parts!

4.5 Assembly

a)

- The seal sets (105, 105A and 115, 115A) of the piston (101) and cylinder limitation (114) must be assembled according to section 5.3, Changing the Seals.
- Prepare the following new O-rings for assembly: Item numbers 111, 124, 110, 109, 107

b)

- Insert O-ring (109) in the far corner of the casing.
- Push the cylinder limitation (114) over the held piston rod (116) to the furthest casing limit stop using 2 screws of removal device T2.
- Insert the O-ring (110) in the casing groove.
- Push the cylinder (108) into the casing.
- Insert the O-ring (107) in the piston rod and attach piston (101) and a new lock plate (128).
- See figure 6 for further details on how to pull on the piston with the grooved nut (127) using the grooved nut wrench T6.
- Secure the grooved nut with a lock plate.
- If the piston and piston rod have become displaced during assembly, pull them out again as far as the limit stop (towards the suction side).

c)

- Assemble O-ring (109), attach the cover (104) and fasten it with the screws (106).

d)

- Install the assembly hook T10 through the center opening of the cover and pull out the inner tension spring (119) by using this tool (figure 8).
- Assemble the hook of the position sensor rod (125) onto the pulled out tension spring which the outer tension spring (120) and the tension spring support (121) are already attached.
- Allow the whole assembly to spring back to the support in the cover.
- Screw in the pressure pipe together with the O-ring (124) located below it.
- Push the position sensor (123) over the pressure pipe.

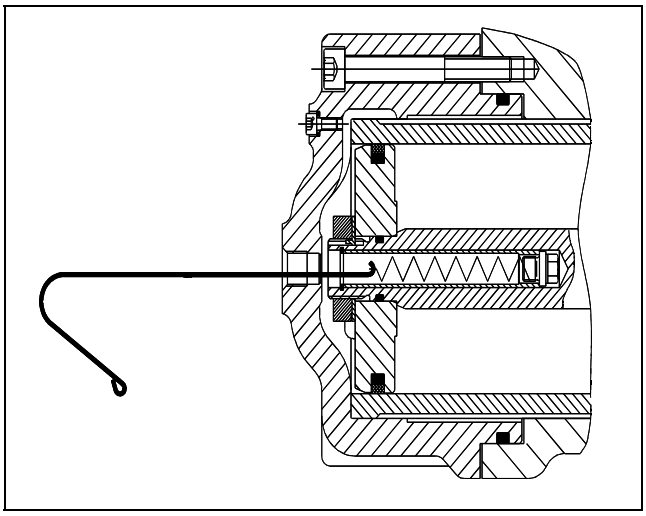


Figure 8: Removing the inner tension spring (119) by means of the assembly hook T10 to attach the position sensor rod (125)

e)

- Place the control slide (113) in the min position (towards the discharge side) by using the threaded rod of device T2. Install the rod through the corresponding opening on the discharge side of the closure flange (21) and thread it into the tension spring.
- Calibrate the position sensor on the suction side cover of the capacity control (104) according to section 7.2.
- Loosen the threaded rod and assemble a socket head screw in its place. **ATTENTION:** Install a new tooth lock washer (700) between closure flange (21) and the screw in piece of the tension spring (73)! This pretensions the tension spring (73). For compressors with Vi adjustment, place the sealing ring (100) under the screw head.
- Attach the seal flange (66). For compressors with Vi adjusting device, assemble the cover (90) according to section 6.5, b) and c).

f)

- Install and tighten the screw plugs and seal washers (74, 75) to the lower side of the compressor and the screw plugs next to the valve block (51) according to figure 3.

5. VI ADJUSTING DEVICE

5.1 Repair Criteria

An indication of when the Vi adjusting device does not work properly is by an increased current consumption of the driving motor when the compressor operates at full load. The reason for this is that the Vi slide (78) is in the wrong position. The oil supply system above the valve block (51) must be checked to see whether it is working (solenoid valves) before the hydraulic subassembly which adjusts the slide is removed. Furthermore, the display system (position sensor, (123)) must also be checked to see whether it functions properly.

5.2 Disassembly

a) Removing the display system from the cover (90):

- Loosen the hexagon socket head attachment screw on the lower side of the rectangular casing from the position sensor (123) and remove the position sensor. The pressure pipe (X) can now be seen (according to figure 4).
- **Adjusting the Vi slide to the Vi max. position:** Unthread the screw plug (91). Place a M6x150 threaded rod through the opening and thread it into the Vi piston (98). Pull the Vi piston to the limit stop of the cover (90) by means of the rod. Remove the threaded rod.
- Unthread the pressure pipe.
- Remove the position sensor rod (125) from the cover (90) by hand only until the tension spring support (121) can be seen. Turn it approx. 90° with the other hand and unhook the outer tension spring (93) from the hook of the position sensor rod (125). The outer tension spring and tension spring support remain assembled.
- Allow the position sensor rod to spring back, unhook by turning it out of the inner tension spring (92) and then remove it.

b) Remove the cover (90).

c) Remove the locking ring (94) and pull off the piston (98) by means of two M6x150 threaded rods.

5.3 Changing the Seal Set (84/84A)

- Remove the old sealing ring and replace the O-ring which is located under it.
- Heat the new sealing ring to a temperature of 90°C (194°F) in a water bath.
- Pull the sealing ring over the flat chamfer of the piston.

- Briefly insert the piston in the cylinder to calibrate the seal. Use the M6 threaded rods to do so.

5.4 Changing the Tension Springs

Refer to section 5.4 for details on how to change tension springs (92 and 93).

5.5 Assembly

a)

- Insert new O-ring (265) in Vi rod (82).

- Insert Vi piston (98) in the cylinder (96), push it onto the Vi rod and secure it with a new locking ring (94).

☞ **Attention!**
Observe the position of the cylindrical pin in order to ensure the correct mounting position of the Vi piston to the Vi rod.

b)

- Adjust the Vi slide with the piston to the Vi max. position by pulling the piston into the position as shown in figure 9.
- Insert the new O-ring (87) in the closure cover (90) and attach the latter.

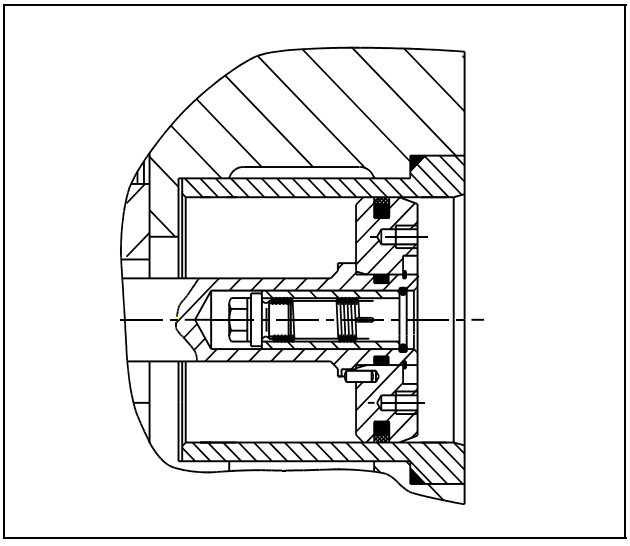


Figure 9: Position of the Vi piston in the Vi max. position

c) Assembly of the display system:

- Place the position sensor rod (125) through the center opening of the cover and attach it's hook to the inner tension spring (92) by rotating it.
- Push the tension spring support (121) with the attached outer tension spring (93) over the position sensor rod.
- Pull out the position sensor rod only as far as needed to assemble the outer tension spring over the hook of the postion sensor rod and attach it.
- Allow the whole complex to spring back to the limit stop of the cover.
- Screw in the pressure pipe together with the O-ring (121) located below it.
- Push the position sensor (452) over the pressure pipe and adjust according to the top portion of section 7.3.

6. POSITION SENSOR DISPLAY SYSTEM (HDT)

Remove or assemble the display systems of the capacity control and Vi adjusting device according to sections 5 and 6.

6.1 Connection Values of the Position Sensor

The connection values of position sensor (452) can be seen in figure 10.

☞ **Caution**
The position sensor (452) must only be operated with 24 V DC (max. 30 V). A higher voltage level will destroy the sensor!

6.2 Calibrating the Display System of the Capacity Control

- When the display system is calibrated, the minimum and maximum output values of the position sensor are set.

  Output values:
  MIN - position: **$4^{+0.2}$ mA** (0% - 1.5%)
  MAX- position: **$20^{+0.5}$ mA** (100% - 103%)

- The compressor's position transducer "HDT" (Hermetic Differential Transducer) has two adjustment controllers to correlate the slide position with the output signal (see figure 11).
  Adjustment controller "O" moves the midpoints of the output signal. Adjustment controller "V" alters both endpoint simultaneously (±20%).

- The display system must be recalibrated when output signals are defective or when the tension springs (460, 461/462) have been changed.
- The compressor must be depressurized before calibration can take place. Furthermore, the screw plugs must be loosened according to figure 3.
- Remove the seal flange (438) on the discharge side or for compressors with Vi adjustment, remove the cover (47). The display system must be disassembled according to section 6.2,a) before removing the cover (47).
- Loosen the hexagon socket head cap screw (565) and screw a threaded rod (from device T2) into the screw in piece of the tension spring (459). Also refer to section 5.2,a).

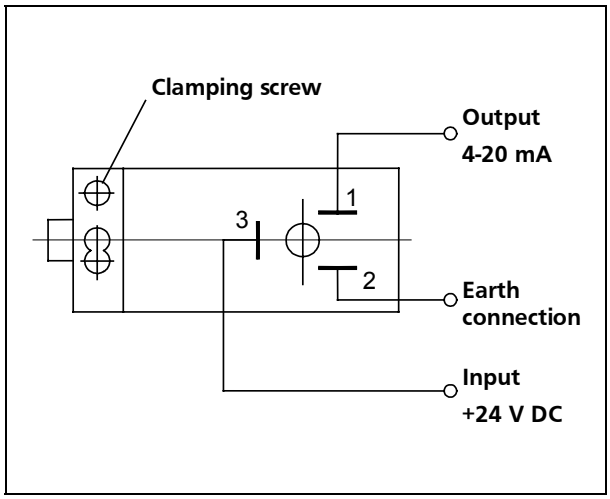


Figure 10: Connection values of the position sensor (123)

- Loosen the clamping screw on the position sensor (123) of the capacity control cover (104).
- Push the position sensor towards the cover until it reaches the limit stop.
- Then pull the position sensor back approx. 2 mm (1/16“).
- Tighten the clamping screw on the position sensor (123) (approx. 3 Nm (2 ft-lbs)).

Calibrating:

1. Refer to section 3, page 17, of the FES Instruction and Operation Manual.

7. AXIAL BEARINGS

7.1 Axial clearance Measurement

In the course of compressor operation, there will be an **increase of the axial clearance** due to the load acting on the axial bearings leading to an axial displacement of the rotors towards the suction side, and hence to a decrease of the suction end face gap (face gap: distance between the face area of the rotor profile and the casing). When the permissible axial clearance is going to be exceeded, there is the danger that the rotors will interfere with the suction casing whereby considerable damage might occur. In addition, the discharge end face gap will increase with growing axial clearance. The compressor capacity will decrease when the permissible axial clearance is exceeded.

Measure the axial clearance to check bearings.

During axial clearance measurement, the compressor remains mounted on the package. The time intervals for measurement are given in the FES Operation Manual.

Recommendation:
1 measurement per year, but at least after operating every **5,000** to **8,000** hours.

The measurement method described below is easily feasible and is intended, however, for an approximate determination of the axial clearance only and is no assessment of the general condition of the bearings. We recommend to have the measurement carried out by qualified personnel for finding out the actual condition of the bearings.

Preparation for Measurement:

- Depressurize the compressor
- Remove the coupling guard
- Remove intermediate piece of coupling

Male rotor:

- Loosen the screws (46) of the cover (44) of the shaft seal and force the cover out by means of two 5 mm jacking screws (releasing the shaft seal)
- Mount a dial indicator (T8) with a magnetic measuring stand (T13) on the coupling housing or the package frame.
- Set the feeler of the dial indicator at the compressor side coupling flange or at the face end of the male rotor shaft. Care must be taken to ensure that the gauge feeler is parallel to the axis of the rotor.

Female rotor:

- Remove the pump delivery tube (140), the oil pump (142) and the driving shaft (146) or, if no oil pump is mounted, remove the pump flange (142).
- Screw measuring pin (T7) into the driving disk (143) fastened at the female rotor or into the hexagon head screw.

Taking Measurements:

Male rotor

- Push the male rotor with suitable lever towards the discharge side (force of 100 – 150 N (22 – 34 lbs.))
- Remove lever and take a reading on the dial indicator
- Push the rotor towards the suction side and remove lever prior to taking a new reading on the dial indicator
- The difference between dial readings indicates the size of the existing axial clearance of the male rotor.

Female rotor

- Mount dial indicator with a magnetic base on the compressor casing or package frame.
- Set the feeler of the dial indicator at the face of the measuring pin. Care must also be taken to ensure that the gauge feeler is parallel to the axis of the rotor.
- Push the rotor alternately with suitable lever at the measuring pin both towards the discharge and suction side as in the case of the male rotor.
- Take measurements as in the case of the male rotor.
- The difference between dial readings indicates the size of the existing axial clearance of the female rotor.

☞ **Maximum permissible value of axial clrearance of male rotor and female rotor:**
Types H/L: 0.15 mm (0.006 in)
Types M/N: 0.20 mm (0.008 in)

Repair Criteria

- Increase of the axial clearance is a normal phenomenon and will not adversely affect the load carrying capacity of the bearing.
- When the permissible axial clearance is exceeded, the axial bearings are to be dismantled and replaced.

- The use of new bearings will restore the required value of the discharge end face gap as is inherent to a newly manufactured compressor.

Completion of Measurement

- Remove measuring pin from female rotor shaft and mount oil pump (142) including the driving shaft (146) and pump delivery pipe. For simplicity of mounting, push the driving pin onto the oil pump shaft beforehand and install them altogether afterwards.
- Tighten screws on cover (44) of the shaft seal.
- Mount intermediate piece of coupling and install the coupling guard.

7.2 Dismantling of the Axial Bearings

a) Depressurize the compressor, remove the coupling guard and the coupling on the compressor shaft.

b) Loosen the screws (46) of the shaft seal cover (44) and use two jacking screws to displace the cover about 6 mm (0.25“) to remove the seal.

c) Remove the closure flange on the discharge side (21):

- Dismount the closure flange (66) and the cover (90) in the case of Vi adjusting device. Remove the display system from the cover (90) beforehand according to section 6.2,a).
- Loosen the screw (67) in order to relieve the tension spring (73).
- In compressors with a Vi adjusting device remove locking ring (94) and piston (98).
- Loosen the screws (63) and remove the flange (21).
- Remove the male and female thrust pieces (22,16).

d) Lock the male rotor on the coupling side, using an auxiliary tool such as a rod, to prevent it from rotating.

Alternatively,

remove the coupling half on the compressor side and lock the rotor using the clamping device T4 according to (*figure 11)*.

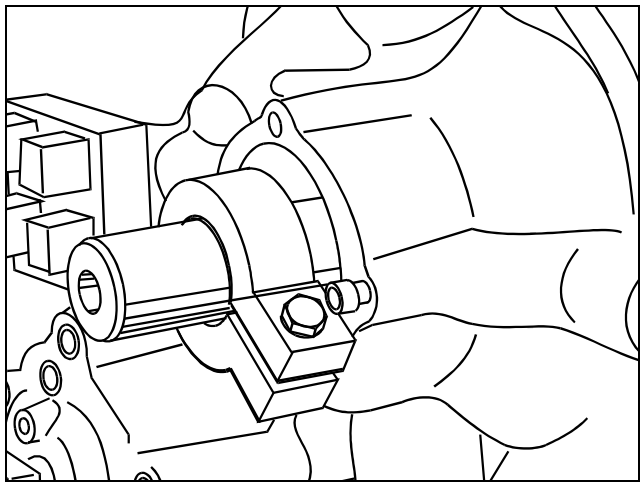


Figure 11: Locking the male rotor using clamping device T4 for dismantling the axial bearings

e) Bend the tab of the lock plates (24) and unthread the grooved nuts (23) using tool T5 (*figure 13*).

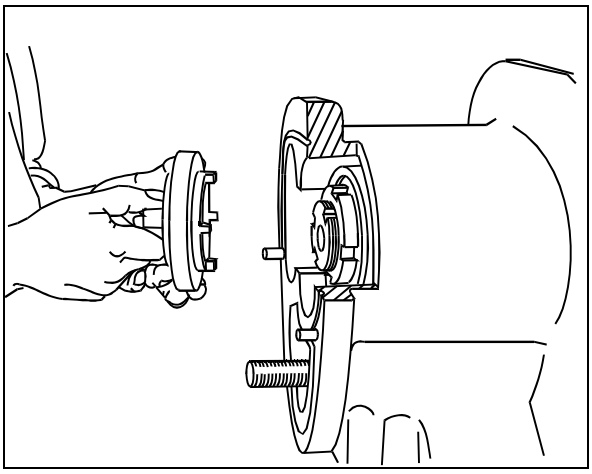


Figure 12: Applying the grooved nut wrench T5 to unthread the grooved nuts (23) of the axial bearings

f) Remove the axial bearings (12) from the rotor shafts:

- Insert the puller hooks of device T1 into both slots of the shafts, pass them below the inner bearing rings and I-rings (12, 25) as far as their inside grooves and rotate by 90 degrees.
- Fasten the hook to the transverse bracket of the device with nuts and remove the bearing with I-rings according to *figure 13*.

☞ **Caution!**
The design of the I-rings of the male rotor is very similar to that of the female rotor (the ring for the male rotor is approx. 3 mm (0.125 in)

wider). Do not mistake these parts during assembly!

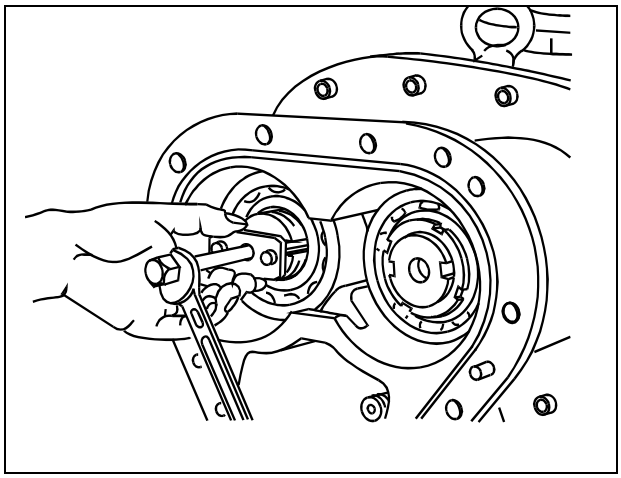


Figure 13: Dismantling the axial bearings (13) using removal device T1

7.3 Assembly

a) Insert the I-rings (12, 25)

b) Mount the axial bearings using tool T3 according to *figure 14*

☞ **Caution:**
Use caution concerning the mounting positions of the individual bearings!

Standard compressor/booster:

The wide face areas of the inner bearing rings must be directed to one another.

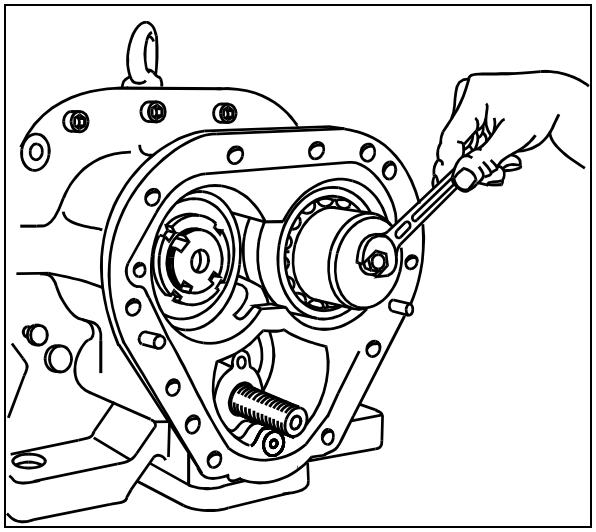


Figure 14: Assembly of the axial bearings (13) using mounting device T13

c) Lock the male rotor on the coupling side to prevent it from rotating, see Dismantling of the Axial Bearing, item b).

d) Insert new lock plates (24).

- Attach the grooved nut (23) and tighten it using the grooved nut wrench T5 (*figure 15*)
  Tightening torque Types H, L: 400 Nm (295 ft-lbs.)
  Tightening torque Types M, N: 300 Nm (220 ft-lbs.)

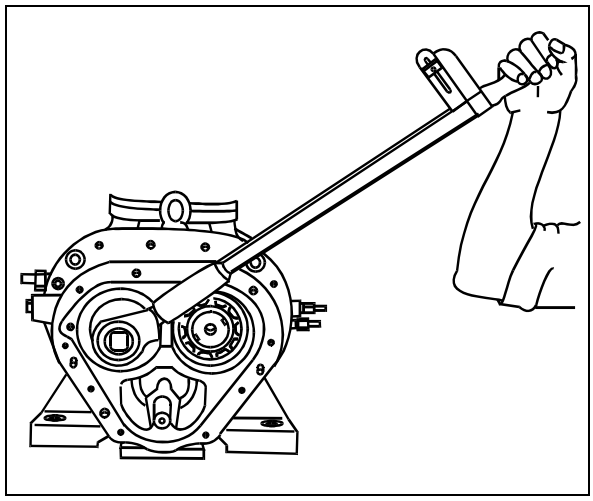


Figure 15: Tightening the grooved nut (23) of the axial bearings using grooved nut wrench T5

- Lock the grooved nut with lock plate (press one tongue into a groove of the nut).

e) Completion of Measurement:

- Insert thrust pieces (22, 16) in the casing by allowing the parts to slightly project over the casing edge and align them in such a way that the pin (20) is inserted into the respective bore holes when assembling the closure flange (21).
- Assembly of the closure flange (8).
- In compressors with Vi adjustment, assembly of the piston (98) and insertion of the locking ring (94). Bring the Vi slide to the Vi-max. position shown in figure 9.
- Screw in the socket head screw (67) and tighten it as far as the limit stop. This pretensions the tension spring (73) again. In compressors with Vi adjustment, place the sealing ring (100) under the head of the screw.
- Attach the closure flange (66) and the cover (90).

- In compressors with Vi adjustment, attach the display system to the cover (90) according to section 6.5,c).

f) Check the face gap according to the description given in section 8.1

Note:
When installing new axial bearings (13) according to specifications of the compressor manufacturer (see List of Parts), the original face gap sizes will be maintained.

g) Tighten the screws (46) on the cover of the shaft seal.

- Tighten the coupling half on the compressor side and assemble the coupling guard.

8. SOLENOID VALVE BLOCKS

Technical Data

Power supply:	24 VDC, 120 VAC, 220 VAC
Function:	Normally closed (NC)
Design:	Seat valve
Nominal size:	2.5 mm (0.098 in)

8.1 Solenoid Valve Block for the Capacity Control

Functioning and Operation

The hydraulic spaces of the adjusting piston (101) of the capacity control are filled and drained via the solenoid valve block (51).
There are 4 connection holes on the base of the block which match the 4 boreholes of the casing support surface. These boreholes provide a connection to the internal oil system (pressure p), to the suction side of the compressor (suction pressure p_o) and to hydraulic spaces "T" and "V" (see figure 16). The valve block is supplied with oil from an oil pump (pressure p_{oil}) via side connection **E**.

Two solenoid valves are opened, one for each adjusting direction (MIN, MAX). The valves are controlled as follows and a description can be seen in figures 16 and 17.

Control direction MAX:	Valves Y1 / Y4	open
	Valves Y2 / Y3	closed
Control direction MIN:	Valves Y2 / Y3	open
	Valves Y1 / Y4	closed

The relief valve **8** ensures a maximum excess pressure of Δp = 7.0 bar (102 psi), compared with the suction pressure, in space V for MAX control direction. This valve must be fully opened before initial operation.

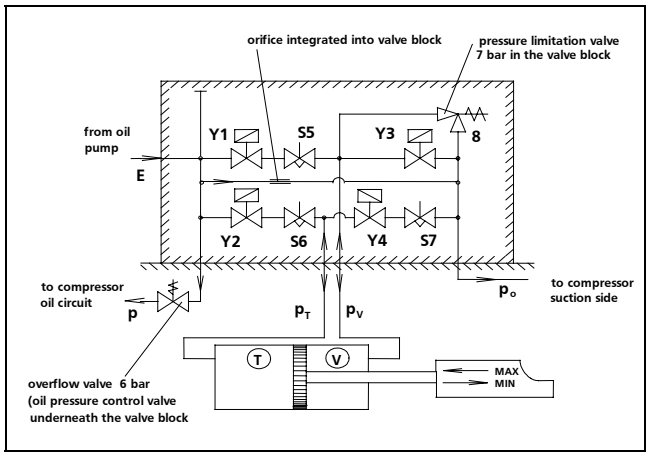


Figure 16: Functional diagram of the solenoid valve block of the capacity control

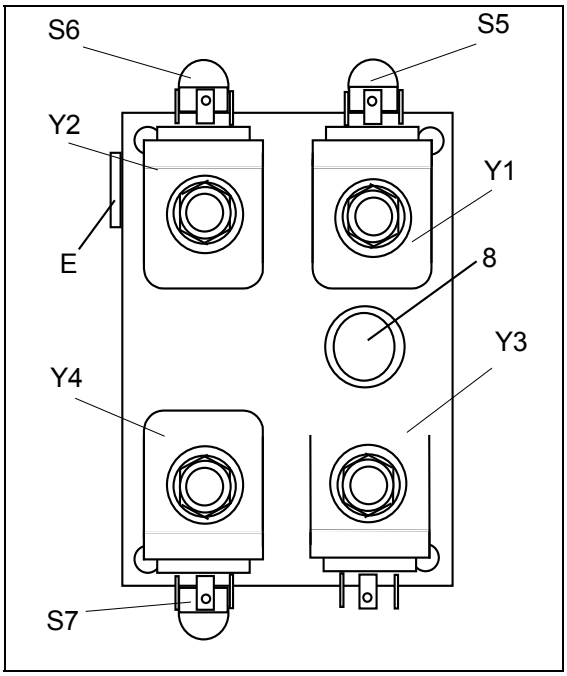


Figure 17: Outer view of the solenoid valve block of the capacity control

Setting the Adjustment Speed

The purpose of control valves S5, S6 and S7 is to control the flow rate. The valves are used to set the adjustment speed as follows:

- MAX direction: Actuate valve S5
  MIN direction: Actuate valve S6

The adjusting speed can be reduced by throttling the valves.

- Adjustment duration between the two end positions MAX ↔ MIN: 30 - 60 sec.
  (aim to reach 60 seconds).

The adjustment duration should be about the same in both directions.

Valve S7 is opened by turning it 2 turns from its closed state.

This setting is generally maintained. If the adjusting speed towards MAX is too low even if valve S5 is fully open, valve S7 can be used for fine adjustment by opening it further.

- Setting must take place with warm oil.

Changing the Parts

The following system malfunctions may occur:

– The valves will not open.
– The valves will not close.
– The adjusting speed cannot be adjusted with the control valves.
– Pressure in space "V" is too low although the relief valve 8 has been adjusted.

The cause of the malfunctions can either be attributed to an electrical or a mechanical fault. This can be determined by checking the block.

The following parts are replaceable and can be ordered as spare parts set:

- Throttle screws of control valves 5, 6 and 7
- Relief valve 8
- Plunger of the valves
- Conical spring of the valves
- O-rings

Solenoid parts (51) also are available as a spare part.

If the individual valve seats have deteriorated the entire block must be renewed along with the underlying O-rings (50).

8.2 Solenoid Valve Block for the Vi-adjustment

Functioning and Operation

The solenoid valve block (81) controls the filling and drainage of the hydraulic spaces of the Vi piston (98) of the Vi adjusting device (78). The block has 3 connection holes in its base which correspond to boreholes on the opposite surface of the compressor casing. These boreholes provide a connection to the oil system of the compressor and via external pipes to the suction side of the compressor (suction pressure p_O) as well as to hydraulic space "K" (see figure 18).

The solenoid valves for Vi adjustment are controlled as follows (see figure 19).

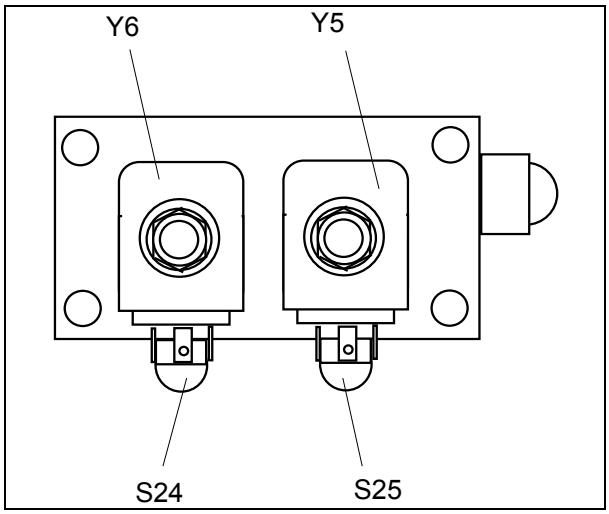


Figure 18: Functional diagram of the solenoid valve block of the Vi adjustment

Vi enlargement:	Valve Y5	open
	Valve Y6	closed
Vi reduction:	Valve Y6	open
	Valve Y5	closed

Setting the adjustment speed

The purpose of control valves 24 and 25 is to control the flow rate to set the adjustment speed. The adjustment speed can be reduced by throttling the valves.

– Vi enlargement: Actuate valve S25
  Vi reduction: Actuate valve S24
– Adjustment duration between Vi-MAX and Vi-MIN: 30 - 60 sec.
  Set the valves in such a way that the adjustment duration is about the same for both directions.
– Setting must take place with warm oil.

Changing the Parts

Possible malfunctions:

– Valves will not open or close so that Vi adjustment is not possible.

– Adjustment speed cannot be controlled.

Cause of malfunction:

Electrical or mechanical fault which can be determined by checking the block.

The following parts are replaceable and can be ordered as spare parts set:

- Throttle screws of control valves 24 and 25,
- Plunger of the valves,
- Conical spring of the valves,
- O-rings

Solenoid parts (51) are separate spare parts.

If the individual valve seats have deteriorated the entire block must be renewed together with the underlying 0-rings (50).

9. CHECK VALVE/ VIBRATION DAMPER/ FILTER SUCTION SIDE

a) Criteria for Maintenance or Changing Parts

- Change the filter when the pressure drop is $\Delta p >$ 0.2 bar (3 psi). When changing the filter, verify the check valve moves freely or whether the drop in pressure is caused by jamming.
  Note:
  We recommend inspection of the filter insert when the compressor is switched off and depressurized for other maintenance work.
- If there are rattling noises or vibrations at the check valve, the spring force of the vibration damper has to be changed. In this instance, remove the castle nut (691) arranged atop on the outside of the filter/valve body with the compressor operating. Subsequently, turn the stem (685) arranged underneath alternately for as long as the rattling noises will cease. If the noises cannot be eliminated this way, replace the compression spring (686).
- The check valve should be inspected when the compressor rotates backwards longer than 15 seconds after it has been switched off.

b) Removing and Changing the Parts

- Work on the compressor or compressor unit can only be carried out when it is in the depressurized state. To do so, close the shut-off valves on the suction and discharge side of the compressor and all other pipes leading to the compressor. Then depressurize the compressor casing at valve V (beside the suction nozzle).

Suction filter

- Remove the suction filter element (133) after loosening the screws (131) and removing the cover (130). Clean or renew the filter insert depending on the type and amount of contamination.

Check valve

- The check valve (137) and the tube piece flanged to the compresor suction nozzle together form a unit. The flange screws of the tube piece on the compressor and suction pipe must first be loosened before the check valve can be dismantled. The tube piece can then be pulled out of the suction nozzle.
- Verify the valve disk moves freely and remove it. **Attention!** Before taking out the valve disk, it is imperative to remove the vibration damper (see below). If necessary, renew pressure spring of the check valve, and refinish and dress guide borehole in the casing and rod of the valve disk. If the seal seat has deteriorated, renew the valve disk and refinish the sealing surface on the front end of the tube piece.

  If refinishing is not possible due to extreme deterioration, the entire check valve (137) must be renewed.
- Assembly is carried out in reverse order.
- Install the vibration damper last.

Vibration damper

- For replacement of the compression spring (686) of the vibration damper or when carrying out operations on the check valve, depressurize the compressor as described above. Subsequently, unthread the castle nut (691) and stem casing (684) with stem (685) and remove compression spring (686) and dampening pin (674) from the compressor casing.
- When the vibration damper was found to be leaking, replace O-ring (692) and seal washer (657).
- After replacement of parts, perform assembly in the reverse order.

10. OIL PUMP

a) Criteria for Changing the Components

The pressure transmitter is installed at the solenoid valve block (51) and measures the pressure of oil pump. The pressure is allowed to be 2 bar (29 psi) below the discharge pressure.

Causes of malfunction of the oil pressure:

- Fouled filter insert
- Gas inclusion in the oil
- Defective overflow valve
- Defective oil pump

b) Removal and Installation

- Depressure the compressor.
- Remove the pipe at the solenoid valve block.
- Loosen the screws (141).
- Remove the oil pump (142) manually from the casing.
- Remove and check the driving shaft (146).
- Check the driving disk on the shaft of female rotor. The change of the driving disk is only possible, if the female rotor is removed (only in special machine workshop).
- Assembly of the new oil pump. Replace the driving shaft (146) if worn. The O-rings (147, 148) must be renewed.
- For simplicity of mounting, push the driving pin onto the oil pump shaft beforehand and install them altogether afterwards.

11. RADIAL BEARINGS

Within the scope of repair measures, we recommend a simple inspection of the condition of the cylindrical roller bearings. This inspection is possible when the shaft seal has been removed together with the balancing piston or if it was necessary to prematurely dismount the angular contact ball bearings. The cylindrical roller bearings are visible and accessible from the side in this partially dismounted state.

The largest gap between the rollers and the inner bearing ring can be measured on the upper bearing half with a feeler gage.

Clearance limit:

Bearing on the discharge side: 0.10 mm (0.004 in)

Bearing on the suction side: 0.12 mm (0.005 in)

If the clearance limit is exceeded or if there is a large clearance between the rollers and the cage, the compressor must be completely disassembled and the bearings replaced.

12. PRESSURE TEST

The screw compressor must be tested under pressure using dry nitrogen.

Seal all refrigerant and oil connections before starting the pressure test.

The pressure must be slowly increased to the maximum operating pressure of the respective refrigerating plant, however, at least to a level of 28 bar (406 psi) excess pressure. Check for leaks by applying a soap solution by brush to all outside connections.

The holding time of the test pressure is at least 30 minutes. Retain a logged record of the pressure test.

13. VACUUM TEST

Produce a vacuum with a vacuum pump. The screw compressor must be evacuated to a vacuum of 35 torr (0.7 psi). Measure and record the pressure level after 4 hours. During this period the pressure may rise to 40 torr (0.8 psi).

14. TIGHTENING TORQUES FOR SCREWS AND NUTS

Item	Component/Subassembly	Tightening Torque [Nm] *(ft-lbs.)*	
		Type H, L	Type M, N
131	Screw, Suction filter cover	70 + 10 *(52 + 7 ft-lbs.)*	70 + 10 *(52 + 7 ft-lbs.)*
139	Screw, Check valve suction side	180 + 10 *(133 + 7 ft-lbs.)*	210 + 10 *(155 + 7 ft-lbs.)*
46	Screw, Cover for shaft seal	40 + 10 *(30 + 7 ft-lbs.)*	70 + 10 *(52 + 7 ft-lbs.)*
106	Screw, Cover for capacity control	40 + 5 *(30 + 3.5 ft-lbs.)*	70 + 10 *(52 + 7 ft-lbs.)*
63	Screw, Closure flange	70 + 10 *(52 + 7 ft-lbs.)*	180 + 10 *(133 + 7 ft-lbs.)*
99	Screw, End cover / Cover for Vi-adjustment	40 + 5 *(30 + 3.5 ft-lbs.)*	70 + 10 *(52 + 7 ft-lbs.)*
23	Grooved nut, Axial bearings	250 – 300 *(185 – 220 ft-lbs.)*	400 – 500 *(295 – 370 ft-lbs.)*
141	Screw, Oil pump	25 + 5 *(19 + 3.5 ft-lbs.)*	25 + 5 *(19 + 3.5 ft-lbs.)*
123	Pressure pipe, Position sensor	40 + 5 *(30 + 3.5 ft-lbs.)*	40 + 5 *(30 + 3.5 ft-lbs.)*
123	Clamping screw, Position sensor	3 +1 *(2 + 1 ft-lbs.)*	3 + 1 *(2 + 1 ft-lbs.)*
127	Grooved nut, Piston rod capacity control	70 + 10 *(52 + 7 ft-lbs.)*	70 + 10 *(52 + 7 ft-lbs.)*

15. LIST OF SPECIALIZED TOOLS

15.1 LIST OF TOOLS FOR SCREW COMPRESSOR TYPES H AND L.

The following is a list of all the specialized tools necessary for the maintenance and repair work described in this service manual for compressor types H and L.

Item	Qty	Description	Part No.
T1	1	Puller for thrust (axial) bearings	390-T04510-096
T2	1	Removal and mounting device for capacity control	390-T04510-095
T3	1	Mounting device for axial bearing	390-T04510-090
T4	1	Clamping device for male rotor	390-T04510-094
T5	1	Grooved nut wrench for male rotor	390-T04510-093
	1	Grooved nut wrench for female rotor	390-T04510-129
T6.1	1	Grooved nut wrench for piston rod	390-T04510-083
T6.2	1	Washer for piston rod grooved nut wrench	390-T04510-084
T7	1	Barrel gauge for axial bearing slackness measurement	390-T04510-092
T8	1	Dial indicator (gauge)	390-T04710-002
T10	1	Assembly hook HDT	390-T04510-128
T11	1	Puller for for balance piston	390-T04510-097
T12	1	Extension feeler for dial indicator (gauge)	390-T04710-003
T13	1	Magnetic measuring stand	390-T04710-021
		Complete tool set	**390-T04510-900**

THE TOOLS CAN BE OBTAINED BY ORDERING THE RESPECTIVE PART NUMBER.

15.2 LIST OF TOOLS FOR SCREW COMPRESSOR TYPES M AND N.

The following is a list of all the specialized tools necessary for the maintenance and repair work described in this service manual for compressor types M and N.

Item	Qty	Description	Part No.
T1	1	Puller for thrust (axial) bearings	390-T04520-080
T2	1	Removal and mounting device for capacity control	390-T04520-079
T3	1	Mounting device for axial bearing	390-T04520-089
T4	1	Clamping device for male rotor	390-T04520-078
T5	1	Grooved nut wrench for rotors	390-T04520-077
T6.1	1	Grooved nut wrench for piston rod	390-T04510-083
T6.2	1	Washer for piston rod grooved nut wrench	390-T04510-084
T7	1	Barrel gauge for axial bearing slackness measurement	390-T04510-092
T8	1	Dial indicator (gauge)	390-T04710-002
T10	1	Assembly hook HDT	390-T04510-128
T11	1	Puller for for balance piston	390-T04520-081
T12	1	Extension feeler for dial indicator (gauge)	390-T04710-003
T13	1	Magnetic measuring stand	390-T04710-021
		Complete tool set	**390-T04520-910**

THE TOOLS CAN BE OBTAINED BY ORDERING THE RESPECTIVE PART NUMBER.