Instruction Manual for Reciprocating Compressors
SBO 21, 22, 41, 42, 43

Preface

The aim of this instruction manual is to provide the operators with a thorough knowledge of the refrigeration plant and at the same time furnishing information about:

- The function and maintenance of the individual components;
- Service schedules;
- Procedure for dismantling and reassembling of the compressor.

The instruction manual also draws attention to typical sources of error, which may occur during operations, stating their cause and explaining what should be done to rectify them.

It is imperative that the operators familiarize themselves thoroughly with the contents of this instruction manual, both to ensure reliable, efficient operation and because YORK is unable to provide a guarantee against damage occurring during the warranty period if the damage is attributable to incorrect operation.

The contents of this instruction manual must not be copied or passed on to any unauthorized person without the permission of YORK.

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First Aid for Accidents with HFC/HCFC

Refrigerant Nos.: R22 - R134a - R404A - R507 - R407C, etc.

Generally

HFC/HCFC form colourless and invisible gasses, which are heavier than air and smell faintly of chloroform at high concentrations only. Under normal operating conditions they are non-toxic, non-inflammable, non-explosive and non-corrosive. When heated to above approx. 300°C they break down into toxic, acid gas components, which are strongly irritating and aggressive to nose, eyes and skin and generally corrosive. Besides the obvious risk of unnoticeable, heavy gases displacing the atmospheric oxygen, inhalation of larger concentrations may have an accumulating, anaesthetic effect which may not be immediately apparent. 24 hours medical observations are, therefore, recommended.

Basic Rules for First Aid

1. When moving affected persons from low-lying or poorly ventilated rooms where high gas concentrations are suspected, the rescuer must be wearing a lifeline, and be under continuous observation from an assistant outside the room.

2. Adrenaline or similar heart stimuli must not be used.

Inhalation

1. Move the affected person into fresh air immediately. Keep the patient still and warm and loosen clothing restricting breathing.

2. If the patient is unconscious, immediately call a doctor/ambulance with oxygen equipment.

3. Administer artificial respiration until a doctor authorizes other treatment.

Eye Troubles

1. Force eyelids open and rinse with a sterile isotonic (0.9%) NaCl-solution (salt water) or pure running water continuously for 30 minutes.

2. Contact a doctor, or get the patient to a hospital immediately for medical advice.

Skin Injuries - Frost Sores

1. Wash immediately with large quantities of lukewarm water to reheat the skin. Continue for at least 15 minutes, removing contaminated clothing carefully while washing.

2. Treat exactly like burns and seek medical advice.

3. Avoid direct contact with contaminated oil/refrigerant mixtures from electrically burnt-out hermetic compressors.

No plant can ever be said to be too safe.
Safety is a way of life.

Protecting the Environment

Increasing industrialisation threatens our environment. It is therefore absolutely imperative that we protect nature against pollution.

To this end, many countries have passed legislation in an effort to reduce pollution and preserve the environment. These laws apply to all fields of industry, including refrigeration, and must be obeyed.

Be especially careful with the following substances:

- refrigerants
- cooling media (brines etc)
- lubricating oils.

Refrigerants usually have a natural boiling point, which lies far below 0°C. This means that liquid refrigerants can be extremely harmful if they come into contact with skin or eyes.

High concentrations of refrigerant vapours are suffocating when they displace air; and if high concentrations of refrigerant vapours are inhaled they will attack the human nervous system.

When halogenated gasses come into contact with open flame or hot surfaces (over approx. 300°C) they decompose to produce poisonous chemicals, which have a very pungent odour, warning you of their presence.

In high concentrations, R717 causes respiratory problems, and when ammonia vapour and air mix 15 to 28 vol. %, the combination is explosive and can be ignited by an electric spark or open flame.

Oil vapour in the ammonia vapour increases this risk significantly as the point of ignition falls below that of the mixture ratio stated.

Usually the strong smell of ammonia will give ample warning of its presence before concentrations become dangerous.

The following table shows the values for refrigerant content in air, measured in volume %. Certain countries may, however, have an official limit, which differs from the one stated.

		Halogenated Refrigerants				Ammonia
		R134a	**R404A**	**R507**	**R22**	**R717**
	Unit					
TWA Time weighted average during a week	vol. %	0.1	0.1	0.1	0.1	0.005
Warning smell	vol. %	0.2				0.002

Further, it may be said about refrigerants:

- If halogenated refrigerants are released directly to the atmosphere they will break down the ozone layer in the stratosphere. The ozone layer protects the earth from the ultraviolet radiation of the sun. Halogenated refrigerants must, therefore, **never** be released to the atmosphere. Use a separate compressor to draw the refrigerant into the plant's condenser/receiver or into separate refrigerant cylinders.

- Most halogenated refrigerants are miscible with oil. Oil drained from a refrigeration plant will often contain significant amounts of refrigerant. Therefore, reduce the pressure in the vessel or compressor as much as possible before draining the oil.

Refrigerant evacuated from a refrigerant plant shall be charged into refrigerant cylinders intended for this specific refrigerant.

If the refrigerant is not to be re-used, **return** it to the supplier or to an authorized refuse disposal plant.

Halogenated refrigerants must never be mixed.

Purging a Refrigeration Plant

If it is necessary to **purge** air from a refrigeration plant, make sure you observe the following:

- Refrigerants must not be released to the atmosphere.

- Halogenated refrigerants **cannot** be absorbed by water. An approved air purger must be fitted to the plant. This must be checked regularly using a leak detector.

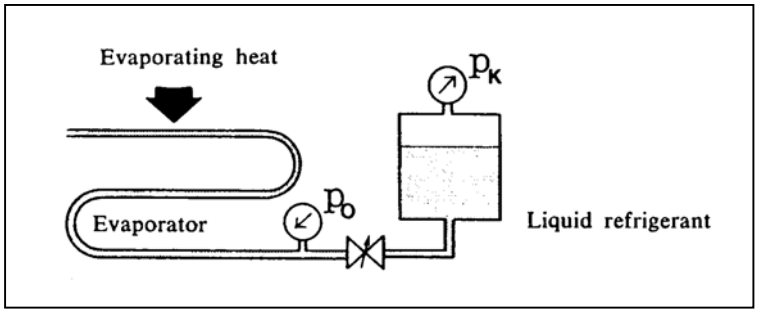
Refrigerant Circuit

Source: Danfoss. Refrigeration - An Introduction to the Basics No. RG.00.E1.02

A simple refrigerant circuit is built up as shown in the sketch below. In what follows, the individual components are described to clarify a final overall picture.

Evaporator

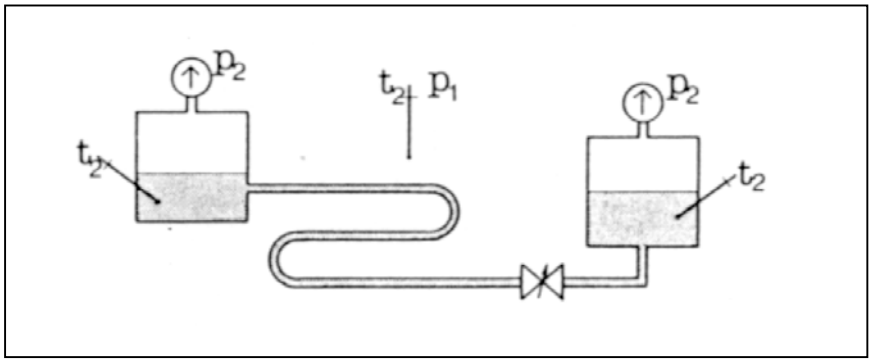
A refrigerant in liquid form will absorb heat when it evaporates and it is this conditional change that produces cooling in a refrigerating process. If a refrigerant at the same temperature as the ambient is allowed to expand through a hose with an outlet to atmospheric pressure, heat will be taken up from the surrounding air and evaporation will occur at a temperature corresponding to atmospheric pressure.
If in a certain situation pressure on the outlet side (atmospheric pressure) is changed, a different temperature will be obtained since this is analogous to the original temperature - it is pressure-dependent.



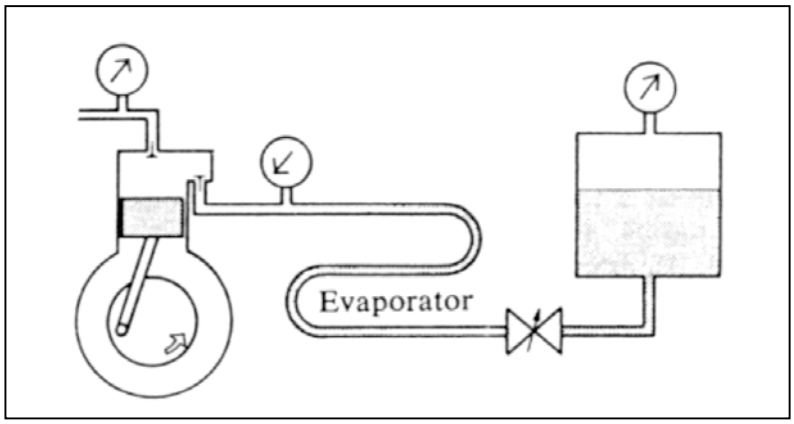
The component where this occurs is the evaporator, the job of which is to remove heat from the surroundings, i.e. to produce refrigeration.

Compressor

The refrigeration process is, as implied, a closed circuit. The refrigerant is not allowed to expand to free air.
When the refrigerant coming from the evaporator is fed to a tank the pressure in the tank will rise until it equals the pressure in the evaporator. Therefore, refrigerant flow will cease and the temperature in both tank and evaporator will gradually rise to ambient.



To maintain a lower pressure, and, with it a lower temperature it is necessary to remove vapour. This is done by the compressor, which sucks vapour away from the evaporator. In simple terms, the compressor can be compared to a pump that conveys vapour in the refrigerant circuit.

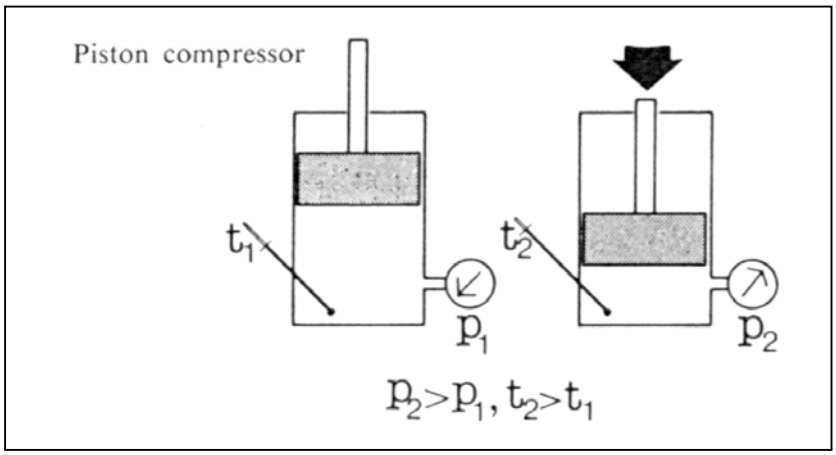


In a closed circuit a condition of equilibrium will always prevail. To illustrate this, if the compressor sucks vapour away faster than it can be formed in the evaporator the pressure will fall and with it the temperature in the evaporator. Conversely, if the load on the evaporator rises and the refrigerant evaporates quicker, the pressure and with it the temperature in the evaporator will rise.

Compressor, Method of Operation

Refrigerant leaves the evaporator either as saturated or weakly superheated vapour and enters the compressor where it becomes compressed. Compression is carried out as in a petrol engine, i.e. by the movement of a piston.

The compressor requires energy and does work. This work is transferred to the refrigerant vapour and is called the compression input.

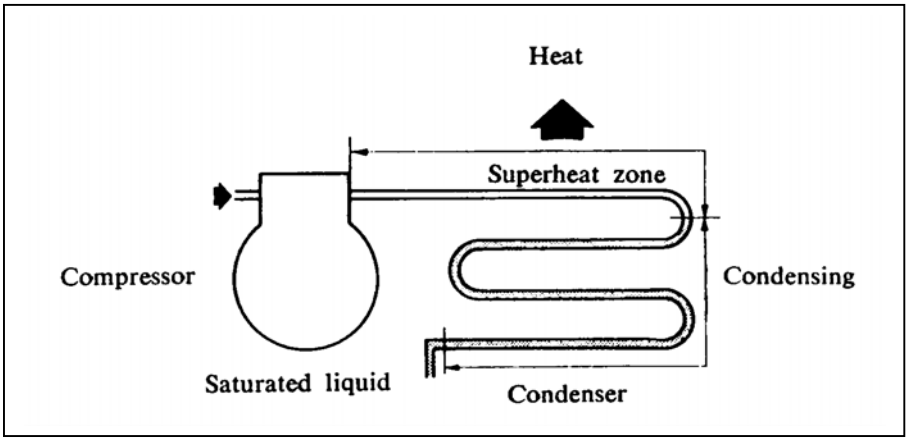


Because of the compression input, vapour leaves the compressor at a different pressure and the extra energy applied causes strong superheating of the vapour.

Compression input is dependent on plant pressure and temperature. More work is of course required to compress 1 kg vapour 10 at (~ bar) than to compress the same amount 5 at (~ bar).

Condenser

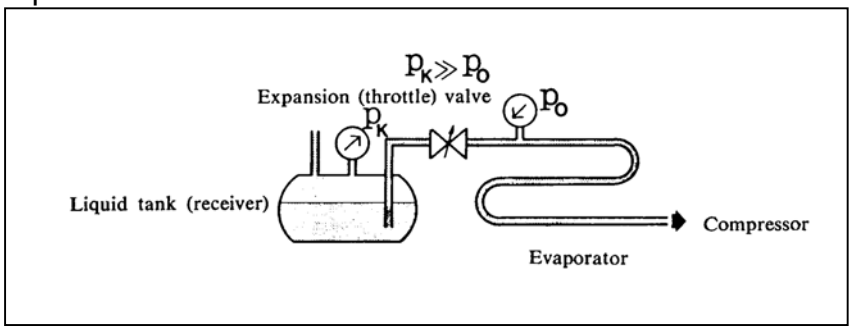
The refrigerant gives off heat in the condenser, and that heat is transferred to a medium having a lower temperature. The amount of heat given off is the heat absorbed by the refrigerant in the evaporator plus the heat created by compression input.



The heat transfer medium can be air or water, the only requirement being that the temperature is lower than that which corresponds to the condensing pressure. The process in the condenser can otherwise be compared with the process in the evaporator except that it has the opposite ”sign”, i.e. the conditional change is from vapour to liquid.

Expansion Process

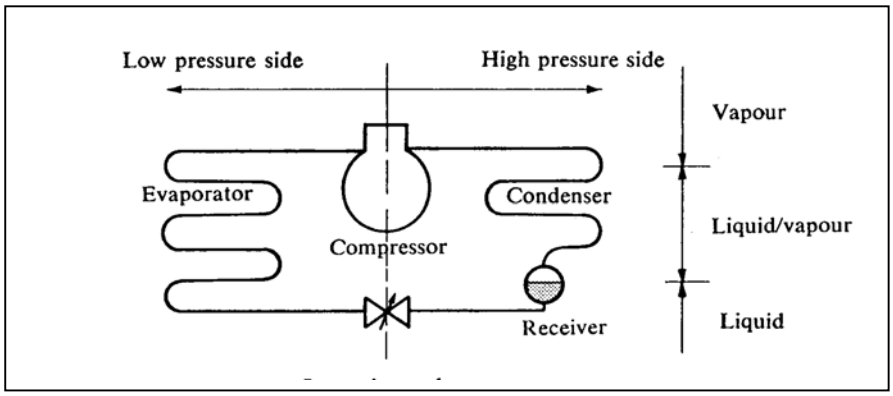
Liquid from the condenser runs to a collecting tank, the receiver. This can be likened to the tank mentioned under paragraph 3.1 on the evaporator.
The pressure in the receiver is much higher than the pressure in the evaporator because of the compression (pressure increase) that has occurred in the compressor. To reduce pressure to the same level as the evaporating pressure a device must be inserted to carry out this process, which is called throttling or expansion. Such a device is therefore known either as a throttling device or an expansion device. As a rule a valve is used - a throttle or expansion valve.



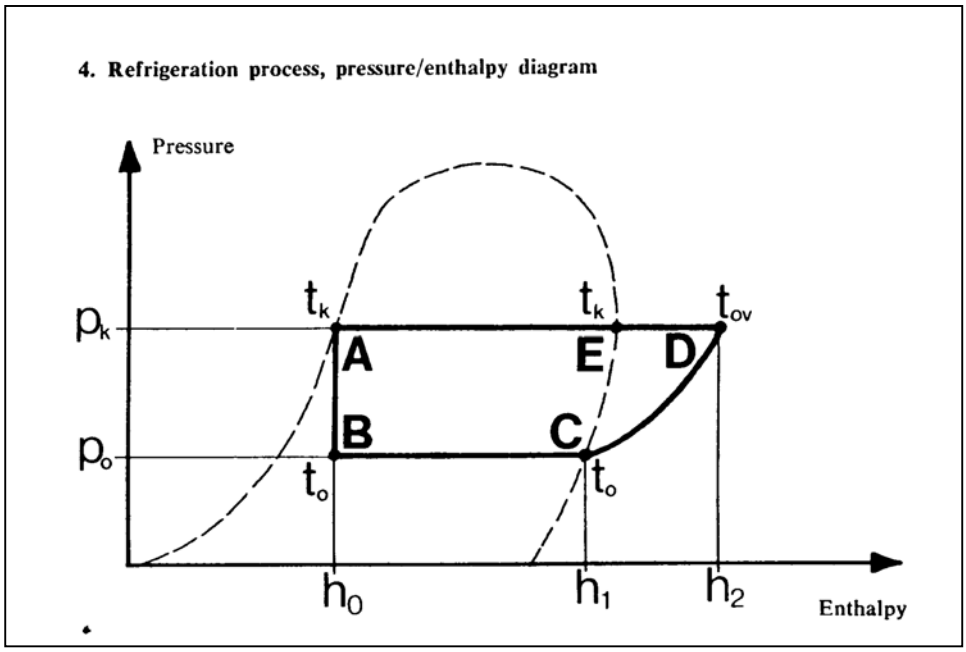
Ahead of the expansion valve the liquid will be a little under boiling point. By suddenly reducing pressure a conditional change will occur; the liquid begins to boil and evaporate. This evaporation takes place in the evaporator and the circuit is thus complete.

High and Low Pressure Sides of the Refrigeration Plant

There are many different temperatures involved in the operation of a refrigeration plant since there are such things as subcooled liquid, saturated liquid, saturated vapour and superheated vapour. There are however, in principle, only two pressures: evaporating pressure and condensing pressure. The plant then is divided into high pressure and low pressure sides, as shown in the sketch.



Refrigeration Process, Pressure/Enthalpy Diagram



The condensed refrigerant in the receiver is in condition A, which lies on the line for the boiling point of the liquid. The liquid has thus a temperature t_k (condensing temperature), a pressure p_k (condensing pressure) and an enthalpy h_o.

When the liquid passes through the expansion valve its condition changes from A to B. This conditional change is brought about by the liquid boiling because of the drop in pressure to p_o. At the same time a lower boiling point is

produced, t_o, because of the drop in pressure.

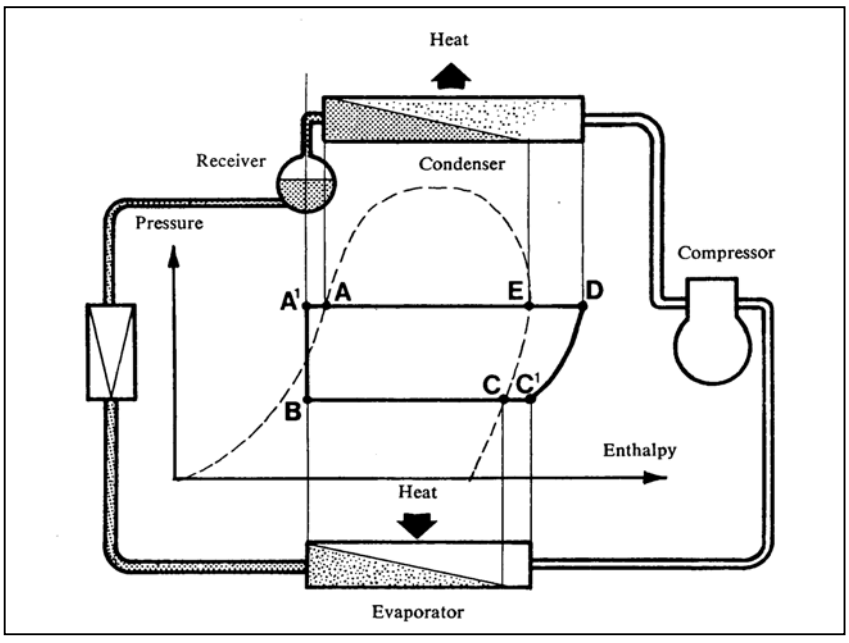
At the expansion valve, as heat is neither applied nor removed, the enthalpy is still h_o.

At the evaporator inlet there is a mixture of liquid and vapour while at the evaporator outlet point C is saturated vapour. Pressure and temperature are the same at point B, but since the evaporator has absorbed heat from the surroundings the enthalpy has changed to h_1.

When the refrigerant passes through the compressor its condition changes from C to D. Pressure rises to condensing pressure p_k.
The temperature rises to t_{ov}, which is higher than the condensing temperature t_k, because the vapour has been strongly superheated. More energy in the form of heat has also been introduced and the enthalpy therefore changes to h_2.

At the condenser inlet, point D, the condition is thus one of superheated vapour at pressure p_k. Heat is given off from the condenser to the surroundings so that the enthalpy again changes to main point A. First in the condenser there occurs a conditional change from strongly superheated vapour to saturated vapour (point E) then a condensation of the saturated vapour. From point E to point A the temperature (condensing temperature) remains the same, because condensation and evaporation occur at a constant temperature.

In practice the refrigerating process will appear slightly differently in a pressure/enthalpy diagram because normally less superheating of the vapour from the evaporator occurs and the liquid temperature ahead of the expansion valve can be weakly subcooled because of the heat exchange with the surroundings.



Lubricating Oils

Refrigeration compressors are lubricated by one of the following oil types, depending on the refrigerant, plant type and operating conditions:

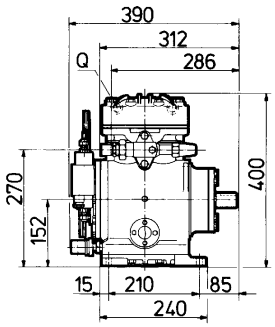
- semi-synthetic oil
- alkyl benzene-based synthetic oil
- polyalphaolefin-based synthetic oil
- glycol-based synthetic oil.

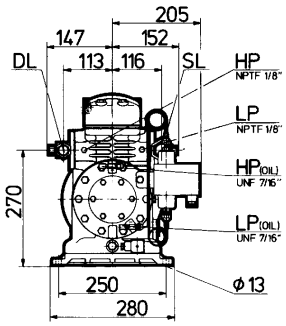
When you change the oil in the compressor or drain oil from the vessels of the refrigeration plant, always collect the used oil in containers marked “waste oil” and send them to an approved refuse disposal plant.

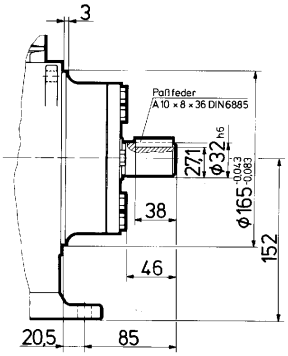
Note:
This instruction provides general information only. The owner of the refrigeration plant is responsible for ensuring that all by-laws are complied with.

Description of the Compressor

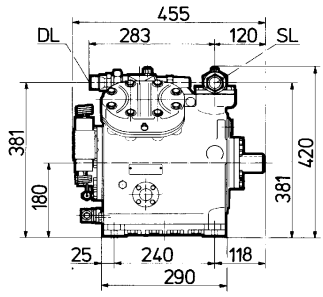
SBO21 and SBO22

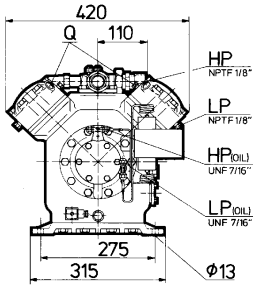


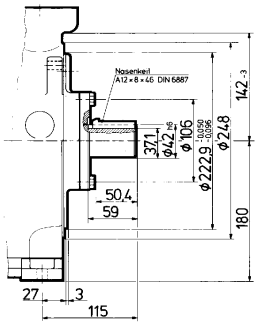




SBO41, SBO42 and SBO43







The SBO compressor type is a multi-cylinder reciprocating compressor comprising three sizes: SBO 21, SBO 22 with 2 cylinders and SBO 41, SBO 42 and SBO 43 with 4 cylinders.
In the standard design the SBO compressors are equipped with both suction and discharge stop valves, built-in suction filters, oil pumps, slide bearings and compressor belt pulley for V-belt drive.

The 4-cylinder compressors, SBO 41, SBO 42 and SBO 43, are available with capacity regulation stages ranging from 100% down to 50%.

Capacity regulation is controlled by means of a solenoid valve, fitted in a special top cover purpose-made for capacity regulation.

The compressor type can be determined by the nameplate, located on the side face of the compressor

Whenever you contact SABROE about the compressor, its serial number should be stated.

Handling of Compressor, Areas of Application,

Direction of Rotation

On the SBO compressors the direction of rotation is not indicated by an arrow, but is standard **clockwise** - seen from shaft end

Handling of Compressor and Unit

For lifting of the compressor the models are equipped with lifting eyes. As to the weight of the compressor, see table on **compressor data.**

Note:

> *The compressor block alone may be lifted in the lifting eyes.*
> *The same applies to the motor.*

The **unit** is lifted by catching the lifting eyes on the unit frame. These have been clearly marked with red paint.

Areas of Application of the Reciprocating Compressors

Compressor Types: SBO 21, 22, 41, 42, 43

In view of preventing an unintended application of the compressor, which could cause injuries to the operating staff or lead to technical damage, the compressors may only be applied for the following purposes:

The compressor may ONLY be used:

- As a refrigeration compressor with a number or revolutions and with operating limits as indicated in this manual or according to a written agreement with SABROE.

- With the following refrigerants:
  R22-R134a-R404A-R507-R407C

- All other types of gas may only be used following a written approval from SABROE.

The compressor must NOT be used:

- For evacuating the refrigeration plant of air and moisture,
- For putting the refrigeration plant under air pressure in view of a pressure testing,
- As an air compressor.

Emergency Switch

The compressor control system must be equipped with an emergency switch.

In case the compressor is delivered with a SABROE control system this emergency switch is found as an integrated part of the control.

The emergency heigh-pressure switch must be executed in a way to make it stay in its stopped position, following a stop instruction, until it is manually set back again. It must not be possible to block the emergency stop without a stop instruction being released.

The emergency low-pressure switch is automatically reset.

Vibration Data for the Compressors - All Types

Vibration data for SABROE compressors comply with the following norm:
ISO 2372 group C

Depending on the laying of the foundation and the size of the motor a screw compressor unit can - under normal circumstances - be classified in class III and IV according to the following table from ISO 2372. Reciprocating compressor units can be classified in class IV, likewise under normal conditions.

Vibration severity ranges and examples of their application to small machines (Class I) medium size machines (Class II), large machines (Class III) and turbo machines (Class IV)

Ranges of vibration severity		Examples of quality judgement for separate classes of machines			
Range	**ms-velocity V (in mm/s) at the range limits**	**Class I**	**Class II**	**Class III**	**Class IV**
0.28	0.28				
0.45	0.45	A			
0.71	0.71		A		
1.12	1.12	B		A	
1.8	1.8		B		A
2.8	2.8	C		B	
4.5	4.5		C		B
7.1	7.1	D		C	
11.2	11.2		D		C
18	18			D	
28	28				D
45	45				
71					

SABROE screw compressor unit: Group C, class III or IV.
SABROE reciprocating compressor unit: Group C, class IV.

Pay attention to the following, however:

- On placing the unit on the vibration dampers delivered by SABROE (additionally) the vibrations against the foundation are reduced by:

  - 80% for reciprocating compressor units

- However, a higher vibration level may occur if:

  Motor and compressor have not been aligned as described in the Instruction Manual.

  The pipe connections have been executed in a way that makes them force pull or push powers on the compressor unit or they may transfer vibrations to the unit, caused by natural vibrations or connected machinery.

  The vibration dampers have not been fitted or loaded correctly as indicated on the foundation drawing delivered together with the order.

Compressor Data for Reciprocating Compressors

SBO 21, 22, 41, 42, 43

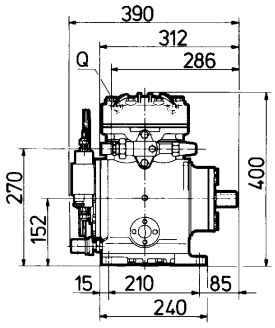
Operating Limits

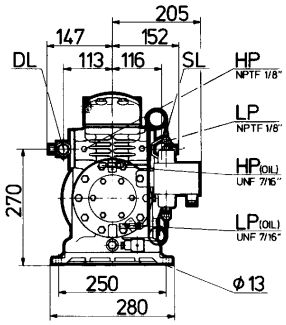
SABROE prescribes certain operating limits within which compressor and any additional equipment should be operating.

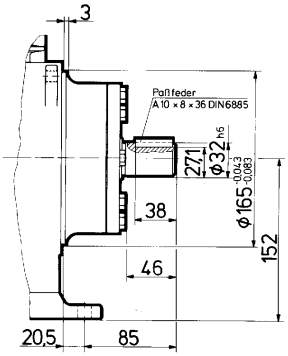
These operating limits for R22 and R134a as well as the main data of the compressor are stated in the following tables and diagrams.

Main data:

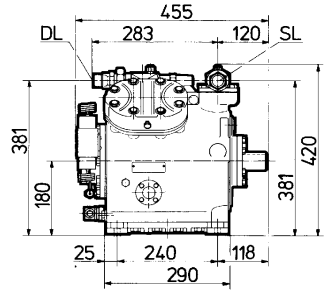
SBO21 and SBO22 compressors

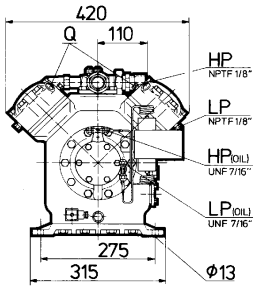


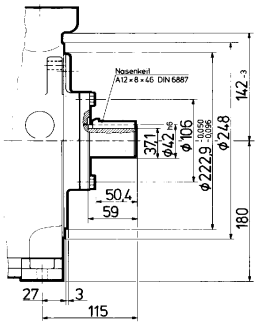




SBO41, SBO42 and SBO43 compressors







Technical Data of Compressors

Compressor type	Motor pulley ø mm	Compressor speed with motor speed 1450 min^{-1} (1) min^{-1}	Displacement m^3/h	Compressor speed with motor speed 1750 min^{-1} min^{-1}	Displacement m^3/h
SBO 21	130 (125)	810	10.9	975	13.2
	150 (140)	905	12.2	1095	14.8
	170 (160)	1035	14.0	1250	16.9
	190 (180)	1165	15.7	1405	19.0
	210 (200)	1295	17.5	1560	21.1
	230 (224)	1450	19.6	1750	23.7
	250 (250)	1620	21.9	-	-
SBO 22	130 (125)	810	15.6	975	18.8
	150 (140)	905	17.5	1095	21.1
	170 (160)	1035	20.0	1250	24.1
	190 (180)	1165	22.5	1405	27.1
	210 (200)	1295	25.0	1560	30.1
	230 (224)	1450	28.0	1750	33.8
	250 (250)	1620	31.3	-	-
SBO 41	130 (125)	810	21.9	975	26.4
	150 (140)	905	24.5	1095	29.7
	170 (160)	1035	28.0	1250	33.9
	190 (180)	1165	31,6	1405	38.1
	210 (200)	1295	35.1	1560	42.3
	230 (224)	1450	39.3	1750	47.4
	250 (250)	1620	43.9	-	-

Compres-sor type	Motor pulley	Compressor speed with motor speed 1450 min^{-1} (1)	Displace-ment	Compressor speed with motor speed 1750 min^{-1}	Displace-ment
	ø mm	min^{-1}	m^3/h	min^{-1}	m^3/h
SBO 42	130 (125)	810			
	150 (140)	905	29.4	1095	35.6
	170 (160)	1035	33.6	1250	40.6
	190 (180)	1165	37,8	1405	45,6
	210 (200)	1295	42.0	1560	50.7
	250 (250)	1620	52.6	-	-
SBO 43	130 (125)	810	31.3	975	37.7
	150 (140)	905	35.0	1095	42.4
	170 (160)	1035	40.0	1250	48.4
	190 (180)	1165	45.1	1405	54.4
	210 (200)	1295	50.1	1560	60,4
	230 (224)	1450	56.1	1750	67.7
	250 (250)	1620	62.7	-	-

(1) Minimum speed SBO 21 to SBO 43 750 min^{-1}

Compressor Oil Charge
V-Belt Type
Compressor Weight

Compressor type	Oil charge litres dm^3	Weight (2) kg	V-belts Number x Profile according to DIN 7753	Connections Suction line inch	Discharge line inch	Cooling water inch
SBO 21	1.75	51	2 x SPA	1 1/8"	7/8"	R 1/2"
SBO 22	1.75	52	2 x SPA	1 1/8"	7/8"	R 1/2"
SBO 41	4.0	77	2 x SPA	1 3/8"	1 1/8"	R 1/2"
SBO 42	4.0	77	2 x SPA	1 3/8"	1 1/8"	R 1/2"
SBO 43	4,0	77	2 x SPA	1 3/8"	1 1/8"	R 1/2"

(2) Weight without pulley
pulley SBO 21/SBO 22 = 4.2 kg
SBO 41/SBO 42/SBO 43 = 7.5 kg

Cylinder Number / Bore / Stroke

Compressor type	Cylinders		
	Number	Bore	Stroke
SBO 21	2	60	40
SBO 22	2	60	57
SBO 41	4	60	40
SBO 42	4	55	57
SBO 43	4	60	57

General Operating Instructions

for SBO 21, 22, 41, 42, 43 Reciprocating Compressors

Starting up Compressor and Plant

- The heating rod in the crankcase **must** be energized at least 12 hours before starting up the compressor in order to boil any refrigerant out of the compressor oil. At the same time, the suction stop valve must be open.

- Check oil level in crankcase. The oil level must always be visible in the oil sight glass. See section: *Charging the compressor with oil.*

- Check correct setting of safety automatics on compressor.

- Open discharge stop valve at compressor.

- Set capacity regulator at minimum capacity. (Not standard.)

- In order to avoid excessive pressure reduction in the compressor on start-up, the suction stop valve **must** be opened a few turns, as there is otherwise a risk of oil foaming in the crankcase.

- Open all other stop valves except for the main valve in the liquid line and possible by-pass valves serving other purposes.

  Start condenser cooling, brine pumps, fans at air coolers as well as any compressor cooling device. (All of this is usually done automatically)

Note:
If oil separator is used and the oil separator at standstill is colder than the condenser, the valve in the oil return pipe must not be opened until the oil separator has warmed up.

- Start compressor motor and check suction and oil pressures.

- Carefully continue opening suction stop valve to its full open position.

- Open main valve in liquid line.

- If the oil in the crankcase foams, or knocking sounds are heard from the compressor because droplets of liquid are being fed in with the suction gas, immediately throttle suction stop valve.

- The compressor is now operating. Increase capacity stepwise, allowing the compressor to adjust to new conditions before switching to next stage. Check carefully whether oil is foaming and whether oil pressure is correct.

- Check whether oil return from oil separator is working, the pipe should normally be warm. (If oil separator mounted)

- Do not leave the plant for the first 15 minutes after start-up and **never** before it has stabilized.

Stopping and Starting-Up Compressor during a Short Period of Standstill

Before stopping the compressor, its capacity must be reduced to the lowest capacity stage for a few minutes, before it stops. (Capacity regulating is not standard.)

During short periods of standstill, it is **not** necessary to shut off the suction stop valve and the discharge stop valve. The heating rod **must** be energized.

Compressor start-up must always take place at the lowest capacity stage, after which capacity is increased at suitable intervals, in order to avoid that a sudden excessive pressure reduction in the evaporation system causes slugging in the compressor and oil foaming in the crankcase.

Stopping the Plant for Brief Periods (Until 2-3 Days)

- Shut-off liquid supply to evaporators for a few minutes before stopping the plant.

- Stop compressor and shut-off suction and discharge stop valves. Close valve in oil return.

Stop of Condenser Cooling, Pumps, Fans and any Compressor Cooling.

- Cut-off power supply to both master and control currents.

Stopping the Plant for Lengthy Periods (More than 2-3 Days)

- Shut-off main valve after receiver and pump down evaporators. If necessary, adjust low-pressure cut-out on unit to a lower pressure during evacuation.

- Allow temperature in evaporators to rise, then repeat evacuation.

- When suction pressure has been reduced to slightly over atmospheric pressure, stop compressor. Shut-off suction and discharge stop valves and close-off stop valve in oil return.

- Shut-off condenser cooling. If there is a risk of freezing, draw-off coolant.

- Cut-off power supply to master and control currents.

- Inspect receiver, condenser and pressure vessels as well as piping connections and apparatus for leakage.

Pressure Testing of Refrigeration Plant

Before charging the plant with refrigerant, it must be pressure tested and pumped down.

Pressure test the plant with one of the following means:

- **dry** air - pressurized cylinders containing dry atmospheric air may be used - but **never** oxygen cylinders;

- air compressor for high pressure;

- nitrogen.

Important
*The plant compressors must not be used to pressurize the plant. Water or other fluids must **not** be used for pressure testing.*

If nitrogen is used, it is important to place a reducing valve with a pressure gauge between the nitrogen cylinder and the plant.

During pressure testing, it is important to ensure that pressure transducers and other control equipment are not exposed to the testing pressure. The compressor stop valves must also be closed during pressure testing.

Plant safety valves must normally be blanked-off during pressure testing, as their opening pressure is lower than the testing pressure.

Important
During this pressure testing, no person should be allowed to be present in rooms housing plant parts or in the vicinity of the plant outside the rooms.

- The entire unit must be pressure tested in accordance with the local regulations for pressure testing.

- The test pressure must **never** exceed the design pressure.

- If it is required that the compressor should be pressure tested together with the unit or with the plant, the testing pressure must **not** exceed:
  For reciprocating compressors: SBO: **25 bar**

- Please observe that manometers, pressure controls, pressure transmitters and other control equipment are **not** exposed to testing pressure.

- Afterwards, reduce the pressure to **10 bar** for a period of **24 hours** - for an initial leak test - as a tightly sealed plant will maintain this pressure throughout the period.

During the leak test, it is permitted to enter the room and approach the plant.

- By way of a second leak test, examine all welds, flange joints etc. for leakage by applying soapy water, while maintaining the **10 bar** pressure.

When pressure testing, compile a pressure test report containing the following:

- date of pressure testing,
- person carrying out the test,
- comments.

Pumping Down of the Refrigeration Plant

After the pressure testing, the refrigeration plant must be evacuated in order to eliminate atmospheric air and moisture. Evacuation must be carried out on all types of refrigeration plants, regardless of the type of refrigerant with which the plant is to be charged.

Please be aware of the fact that HCFC and HFC refrigerants mix only minimally with water, and it is therefore necessary to effect evacuation of such systems with particular care.

The boiling point of a fluid is defined as the temperature at which the steam pressure equals atmospheric pressure. For water, the boiling point is 100°C. Lowering of the pressure also lowers the boiling point of the water.

The table sets out the boiling point of water at very low pressures:

Boiling point of water °C	**At pressure**	
	mm Hg	**mbar**
5	6.63	8.80
10	9.14	12.3
15	12.73	17.0
20	17.80	23.7

For evacuation, use a vacuum pump, which bleeds the plant of air and steam.

The vacuum pump must be able to lower the pressure to approx. 0.1 mm Hg (mercury column) and must be fitted with a gas ballast valve. This valve

should be used wherever possible to prevent aqueous vapours from condensing in the vacuum pump.

Important:
Never use the refrigeration compressor to evacuate the plant.

For a satisfactorily performed evacuation, the final pressure must be lower than 5 mm Hg. Attention is drawn to the fact that there may be a risk of any water left in the refrigeration plant freezing if the ambient temperatures are lower than 10°C. In such instances, it will be necessary to supply heat to the component surroundings, as ice evaporates with difficulty.

It is recommended to carry out evacuation as follows:

- Evacuate to a pressure lower than 5 mm Hg.
- Blow dry air or nitrogen into the system to a pressure corresponding to atmospheric pressure. **Never use OXYGEN cylinders.**
- Repeat evacuation to reduce pressure to less than 5 mm Hg.
- Shut the vacuum pump off from the refrigeration plant and check that the pressure does not rise for the next couple of hours. If the system still contains water, this will evaporate and cause the pressure to rise, thereby indicating unsatisfactory evacuation and necessitating a repetition of the procedure.

Operating Log

In order to keep tabs on the operating state of the refrigeration plant, it is recommended that an operating log is kept. This operating log should be kept at regular intervals, thus providing important information about the cause of any undesired changes in the operating state. (See the following page).

Observation	**Measuring Point**	**Measuring Unit**
Time		Date and time
Suction pressure	• Compressor pressure gauge	°C or bar
Discharge pressure	• Compressor pressure gauge	°C or bar
Oil pressure	• Compressor pressure gauge	bar
Suction gas temp. (Option)	• Thermometer in suction pipe immediately before compressor	°C
Discharge gas temp. (Option)	• Thermometer in discharge pipe immediately after compressor, but before oil separator	°C
Oil level in compressor	• Oil level sight glass on compressor	Must be visible in oil sight glass
Recharging of oil on compressor	• See section on oil charging	Number of litres
Compressor motor consumption in amps	• Electric panel	Amps

At the same time, attention should be paid to the following:
(tick these off in the log, if you wish)

- whether the compressor's cooling system is functioning correctly,
- whether any unusual noises can be heard from the compressor,
- whether there are unusual vibrations in the compressor.

Servicing the Reciprocating Compressor

In order to ensure a problem-free operation, it is advisable to carry out regular servicing of the refrigeration plant. In this section, SABROE indicates some periodic services fixed on the basis of the number of operating hours from the first start-up or after an overhaul of the compressor.

The service schedules also depend on the speed of the compressor. If the compressor runs at less than 1200 rpm, SABROE permits extended service intervals. However, the compressor must always operate within the speed recommended by SABROE. See *Description of compressor*. Provided the compressor operates within the specified pressures and temperatures and the prescribed periodic services are performed, the compressor will have a long and efficient life.

- The following must therefore be checked **daily:**
  - Operating pressure
  - Operating temperatures
  - Oil level and pressure
  - Abnormal noise and vibrations

The actual operating conditions should daily be entered in an operating log. See the Operating Log section.

Removing Refrigerant from the Compressor

Before the compressor can be dismantled, the refrigerant must be removed from the compressor. This can be done in the following way:

1. Run the compressor at lowest capacity stage and throttle suction stop valve slowly until completely closed.

2. The compressor will then stop on the low pressure cut-out. This can be adjusted to stop the compressor at a pressure lower than normal.

3. Close the discharge stop valve and other piping connections to the compressor.

4. On HFC and HCFC compressors, remove remaining refrigerant gas using a pump-down compressor.

Scheduled Services

Note:
The following instructions apply to the compressor only. Servicing of the refrigeration plant is described in a separate section. Service the compressor motor according to your own instructions. For the various scheduled services, SABROE can supply ready-made spare parts sets, which it would be an advantage to have before carrying out the scheduled service.

In the event that the compressor cannot operate, start evacuation as described under pt. 3, and remember also to close the suction stop valve.

Scheduled services			Activity
No.	**Operating hours < 1200 rpm**	**Operating hours > 1200 rpm**	
1	75	50	1.1 Clean suction filter 1.2 Check tension of driving belts
2	300	200	2.1 Check or change oil. When changing oil, clean oil filter as well. See the following section: *Assessing the oil.* 2.2 Clean suction filter. 2.3 Check that the following functions correctly: Safety automatics Heating rod V-belt drive. 2.4 Retighten external piping connections. 2.5 Check oil return system from oil separator
3	7500	5000	3.1 Check or change oil. When changing oil, clean oil filter as well. See the following section: *Assessing the oil.* 3.2 Clean suction filter. 3.3 Check that the following functions correctly: Safety automatics Heating rod V-belt drive Oil return system from oil separator
4	15000	10000	4.1 Check or change oil. When changing oil, clean oil filter, too. See section: *Assessing the oil.* 4.2 Clean suction filter 4.3 Check the following: Oil cooling system Water cooling system for any deposits and clogging Safety automatics Heating rod V-belt drive Oil return system from oil separator Valves Cylinders Pistons, gudgeon pins and gudgeon pin bearings Piston and oil scraper rings Unloading valve Seal for leak 4.4 Change: V-belts
5	22500	15000	5.1 Check V-belt drive

Scheduled services			Activity
No.	**Operating hours < 1200 rpm**	**Operating hours > 1200 rpm**	
6	30000	20000	6.1 Change compressor oil, Change oil filter cartridge Clean crankcase 6.2 Clean suction filter 6.3 Check the following: Oil cooling system Water cooling system for any deposits and clogging Safety automatics Heating rod V-belt drive Valves Cylinders Pistons, gudgeon pins and gudgeon pin bearings Piston and oil scraper rings Unloading mechanism Seal for leak Oil pump and drive Check valves 6.4 Change: V-belts Half-sections of bearing for connecting rod
7	37500	25000	Same as service No. 5
8	45000	30000	Same as service No. 4
9	52500	35000	Same as service No. 3
10	60000	40000	Major overhaul; contact SABROE Refrigeration
	Then repeat scheduled services from No. 3 and onward.		

Lubricating Oil

Lubricating Oil Requirements

Above all, the refrigerating machine oil must provide satisfactory lubrication of the compressor, even at the relatively high temperatures occurring during compression. It must be incapable of cooking at such high temperatures and must not precipitate solid constituents such as paraffin or wax at the lowest occurring temperatures. The oil must not have any corrosive effect, whether alone or mixed with refrigerant.

Sabroe Marine delivers standard Sabroe oil

General Rules for Use of Lubricating Oil in Refrigeration Compressors

- Only fresh, clean refrigerating machine oil may be charged.
- Use grade of oil originally prescribed for compressor.
- As far as possible, avoid mixing different types of oil. Mixed oil is generally inferior to the two original oils. Mixing various types of oil may give rise to formation of sludge, which will lodge in valves and filters.
- Should it be necessary to switch to another brand of oil, this must be done at the same time as a complete change of oil in the compressor and draining off all oil from the refrigeration plant is carried out. **In the guarantee period, please do not change to another oil.**
- The refrigerating machine oil must be free of moisture, which may otherwise give rise to operating malfunctions and attacks of corrosion.

The oil should therefore be purchased in containers corresponding to the quantity to be used for one single topping-up. The oil containers must be kept carefully sealed.

Note:
It is inadvisable to re-use oil, which has been drained from a compressor or plant. This oil will have absorbed moisture from the air and may cause operating problems.
Always switch off the power to the heating rod before draining off the oil.

If, after reading the above, any doubt exists as to the type of oil which has been used in your compressor, you are recommended to contact SABROE, rather than risk charging the compressor with unsuited oil.

Charging Refrigeration Compressor with Lubricating Oil

The reciprocating compressors are delivered from Sabroe with 1. charge of oil.
Usually, it is not necessary to top-up with lubrication oil. It is, however, possible to pour oil into the compressor through the plug above the sight glass.

Expected Discharge Gas Temperatures

Suction Gas Superheat °C	Condensing Temp. °C	Condensing Pressure Bar	HFC - HCFC																					
			R134a Evaporating temperature or intermediate temperature °C					Condensing Pressure Bar	R22 Evaporating temperature or intermediate temperature °C					Condensing Pressure Bar	R404A/R507 Evaporating temperature or intermediate temperature °C					Condensing Pressure Bar	R717 Evaporating temperature or intermediate temperature °C				
			+10	0	-10	-20	-30		+10	0	-10	-20	-30		0	-10	-20	-30	-40		+10	0	-10	-20	-30
	20	5.7	38	41	43	48	55	8.2	37	48	61	76	91	11.0	40	42	46	53	62	7.6	53	71	91	110	131
	25	6.6	44	45	48	52	59	9.5	47	57	69	84	101	12.5	44	47	51	58	67	9.1	65	83	102	121	142
10	30	7.7	49	50	53	58	66	11.1	55	65	77	92	108	14.3	49	52	56	63	71	10.7	77	95	113	133	151
	35	8.8	53	54	58	64	74	12.7	68	74	85	99	115	16.2	54	57	61	67	75	12.6	89	106	123	141	160
	40	10.1	57	59	63	69	79	14.5	72	82	94	106	120	18.2	59	62	66	72	79	14.6	101	117	133	151	170
	45	11.5	61	63	67	74	82	16.6	81	90	100	112	126	20.5	65	67	71	77	83	16.9	110	126	143	161	-
	20	5.7	48	51	53	58	65	8.2	48	59	72	88	103	11.0	50	52	56	63	72	7.6	65	83	103	122	143
	25	6.6	54	55	58	62	69	9.5	57	68	80	95	110	12.5	54	57	61	68	77	9.1	77	95	114	132	153
20	30	7.7	59	60	63	68	76	11.1	65	76	88	102	117	14.3	59	62	66	73	81	10.7	89	106	125	142	162
	35	8.8	63	64	68	74	84	12.7	73	84	96	109	123	16.2	64	67	71	77	85	12.6	100	116	134	152	-
	40	10.1	67	69	73	79	89	14.5	82	92	103	115	128	18.2	69	72	76	82	89	14.6	111	127	144	162	-
	45	11.5	71	73	77	84	92	16.5	90	98	109	121	133	20.5	75	77	81	87	93	16.9	121	136	154	171	-
	20	5.7	58	61	63	68	75	8.2	59	70	83	97	113	11.0	60	62	66	73	82	7.6	78	96	115	134	153
	25	6.6	64	65	68	72	79	9.5	69	78	91	105	120	12.5	64	67	71	78	87	9.1	90	106	126	144	163
	30	7.7	69	70	73	78	86	11.1	75	86	98	111	125	14.3	69	72	76	83	91	10.7	102	118	136	154	-
30	35	8.8	73	74	78	84	94	12.7	84	95	106	118	131	16.2	74	76	81	87	95	12.6	112	128	146	163	-
	40	10.1	77	79	83	89	99	14.5	92	101	111	123	135	18.2	79	82	86	92	99	14.6	123	138	155	-	-
	45	11.5	81	83	87	94	102	16.5	99	108	117	128	139	20.5	85	87	91	97	103	16.9	132	148	165	-	-
			Discharge gas temp. °C						Discharge gas temp. °C						Discharge gas temp. °C						Discharge gas temp. °C				

Maintenance of SBO Reciprocating Compressors

Generally

When the compressor requires maintenance, it is important to follow the instructions given below. In order to make sure that the compressor is working correctly, the gauge measurements and screw torques must be strictly adhered to.

Before opening the compressor, it is expedient to ensure that you have spares of those seals and gaskets to be stripped down or dismantled. An O-ring, which has been exposed to oil and heat for any length of time, may have expanded so much that it cannot be refitted.

All seals and gaskets used are resistant to oil, HFC/HCFC. All O-rings are made of neoprene rubber.

In the following sections and paragraphs reference is made to position numbers on the assembly drawings at the end of this manual.

However, for SBO21 and SBO22 the position numbers may deviate from those of SBO41, SBO42 and SBO43. In such cases reference is made to the drawings for SBO41, SBO42 and SBO43.

Pump-Down

Before opening up the compressor for inspection, the pressure inside must be lowered to slightly above atmospheric pressure. This can be done in the following way, depending on whether the compressor is operational or defective:

The Compressor is Operational

Run the compressor at minimum capacity at normal operating temperature.

Adjust the low-pressure control so that the compressor stops at a suction pressure of approx. 0.1 bar.

Throttle the suction stop valve very slowly. Keep an eye on the suction pressure gauge.

The suction pressure must be lowered slowly enough to give the refrigerant dissolved in the oil time to escape without the oil foaming. This is of great importance in compressors running on HFC/HCFC.

Once the pressure is down to approx. 0.1 bar, stop the compressor and perform the following steps in the order specified:

- Close suction stop valve.
- Cut off power to compressor motor.
- Close discharge stop valve.
- Drain off last remains of refrigerant gas.
- Having ensured that power to compressor motor cannot be inadvertently connected, the compressor is ready for opening.

For this purpose, remove all fuses to the electric motor.

The Compressor is Inoperative

- Leave heating rod in crankcase connected for a couple of hours before the compressor is due to be opened in order to heat up oil. Warm oil does not contain much refrigerant.
- Suction stop valve must be open while heating rod is connected.
- Keep discharge stop valve closed.
- Close suction stop valve and disconnect heating rod.
- Equalize the pressure in the compressor.
- Once pressure has been equalized to atmospheric pressure, the compressor is ready for opening. Remember to make sure that power cannot be connected inadvertently and start the motor.

Consequently, remove all fuses to the electric motor.

Dismantling and Assembly

The following sections describe the individual components. When dismantling and assembling, parts should generally be fitted in the same position from which they were taken and should therefore be marked as they are removed. Further they should be thoroughly cleaned, checked and lubricated prior to being reassembled.

Valve Intermediate Plate
incl. Suction and Discharge Valves

The valves are plate valves, consisting of an intermediate plate, pos. 100 upon which suction and discharge valve plates are mounted. The intermediate plate is positioned right under the top cover. When the top cover has been removed this intermediate plate becomes visible and can be removed, too.

The intermediate plate is delivered with suction and discharge valve plates as one spare part, including complete gaskets.

Mounting

- Without causing any damage clean all gasket surfaces thoroughly of any gasket remains.

- Lubricate the new gaskets pos. 101 and pos. 102 in refrigerating machine oil and check that the gaskets are facing correctly in relation to the holes for the fixing screws.

- Check that the intermediate plate is positioned correctly before fitting top cover.

- Insert screws pos. 104 and tighten cross-wise with a torque moment as indicated in instruction on *Torque moments for screws and bolts.*

- After approx. 25 hours of operation screws and top cover should be retightened.

Shaft Seal

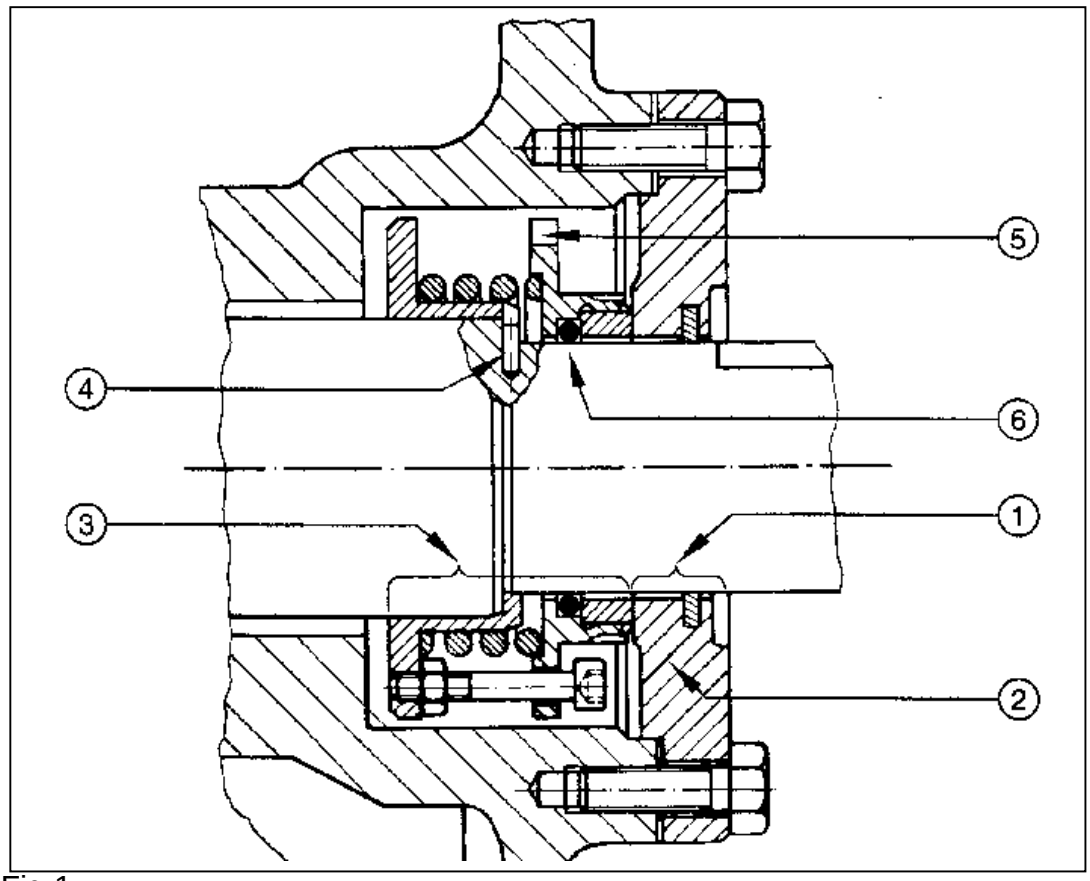


Fig 1

Generally

This series of open reciprocating compressors is fitted with a high quality shaft seal. This consists of a rotating and a stationary unit (see fig. 1).
This maintenance instruction describes the exchange of the shaft seal in case of damage.

Important Notice!
Work on the compressor or the refrigeration circuit may only be carried out by qualified personnel.

Inspection

A routine inspection of the shaft seal is not normally necessary. With regard to increased operational reliability it is, however, recommended to make an inspection in connection with an oil change, faults in the oil supply and also at regular intervals when operating with high discharge gas temperatures and oil temperatures. Special attention should be given to cracks in the O-ring, as well as wear, scoring and material deposits, oil carbon and copper plating on the sealing ring. An oil leak rate of 0.05 cm^3/h is within the tolerance.

Note:
During the running in period of the new shaft seal (about 250 hours) an increased oil leak rate may occur.

Possible Causes of Failure

- lack of lubrication (insufficient oil supply, high refrigerant concentration in the oil)
- heavy wear of driving parts (high proportion of dirt in the oil)
- axial play of crankshaft too large
- overheating (hardening and cracking of O-rings, oil carbon)
- strong vibration (insufficient fixing of coupling or drive pulley, drive not smooth enough, coupling or drive pulley displaced)
- belt tension too high

Removal

Preparation & Recommendations

Tools and Other Materials

- Hexagon spanner and key for internal hexagon
- Plastic hammer
- Hooks (to pull out rotating unit)
- Scraper, smoothing cloth (to remove gasket remains)
- Polishing cloth (to smooth the surface of the shaft)

The **pressure** in the compressor must first be **released**. According to the drive system, the drive pulley, motor, coupling housing, coupling and key should then be removed.

Attention!
Working on a compressor, which is under pressure, can lead to serious injury.

Removing the Shaft Seal

- Loosen the fixings of the shaft seal cover ((2) in Fig 1) evenly (pay attention to the spring tension of the shaft seal).
- Release the cover with light hammer taps if necessary and take off the stationary unit (1). Remove gasket remains.
- Carefully slide the rotating unit (3) from the shaft, which is secured against turning by a drive pin (4). If required the hooks can be located in the slot (5) to assist.

Attention!
This procedure must be carried out very carefully in order to avoid damaging the surface of the shaft.

Fitting

Preparation & Recommendations

When strong **wear to the drive parts** is suspected (contaminated oil, strong deposits) a precautionary compressor exchange or overhaul is urgently recommended.

The shaft, flange (gasket remains) and the shaft seal chamber should be cleaned very thoroughly. Any deposits on the shaft must be carefully removed. If necessary the surface can be smoothed with fine polishing cloth soaked in oil (not smoothing cloth).

Special Recommendations

- Always exchange the complete shaft seal when possible
- Never re-use old O-rings
- Do not touch the sealing surfaces

Fitting the Shaft Seal

- Oil the rotating sealing surface, O-ring and shaft with clean refrigeration oil. Do **not** oil the asbestos-free gasket or the flange surface.
- Slide the rotating unit (3) onto the shaft with a turning motion up to the shoulder in the shaft. The drive pin (4) must be located in the slot provided.
- Lightly oil the sealing surface of the stationary unit (1), then mount the whole unit including the gasket over the shaft. The gap between the crankcase flange and the cover should be approx 5 mm (spring tension).
- The fixing screws should be evenly tightened in a crosswise order with a torque wrench (torque 40 Nm).

Cleaning of Oil Filter

The oil filter should be cleaned at regular intervals. See section on *Servicing the compressor.* Please note in this connection that often the filter must be cleaned already after a short operating period following the initial start-up.

This is a consequence of the tiny dirt particles that will be coming from the plant during its first operating period.

Clean the oil filter in a suitable dissolvent and blow clean with pressurized air before refitting.

Suction Filter

Between suction stop valve pos. 60 and compressor a fine-meshed filter has been fitted pos. 57. The purpose of this filter is to prevent that impurities from the plant are conveyed with the gas flow into the compressor.

Clean the suction filter at regular intervals as stated in the section on *Servicing the reciprocating compressor.*

On cleaning the filter dismantle suction stop valve pos. 34 by removing screws pos. 59. The filter pos. 57 and gaskets pos. 58 can now be removed without the use of any tools.

Clean the filter in a suitable dissolvent and blow clean with pressurized air.

Stop Valves

Suction and discharge stop valves are used to cut off the compressor from the plant.

They are closed tightly by manual tightening. Hence, it is not advisable to use any tools in order to close the valve as this would just lead to overloading of the valve parts.

The valve spindle is fitted with a maintenance-free gasket which needs no replacement.

Further, the valve is fitted with a backsealing, which is brought into operation when the valve is completely open and the valve cone screwed back towards the cylinder head (anticlockwise rotation).

Note:
In case the compressor is operating, the valve cone should not be screwed completely back against the cylinder head as any safety pressure controls connected to the valve housing will hereby be blocked.

Capacity Regulation for Compressor SBO41, SBO42 and SBO43

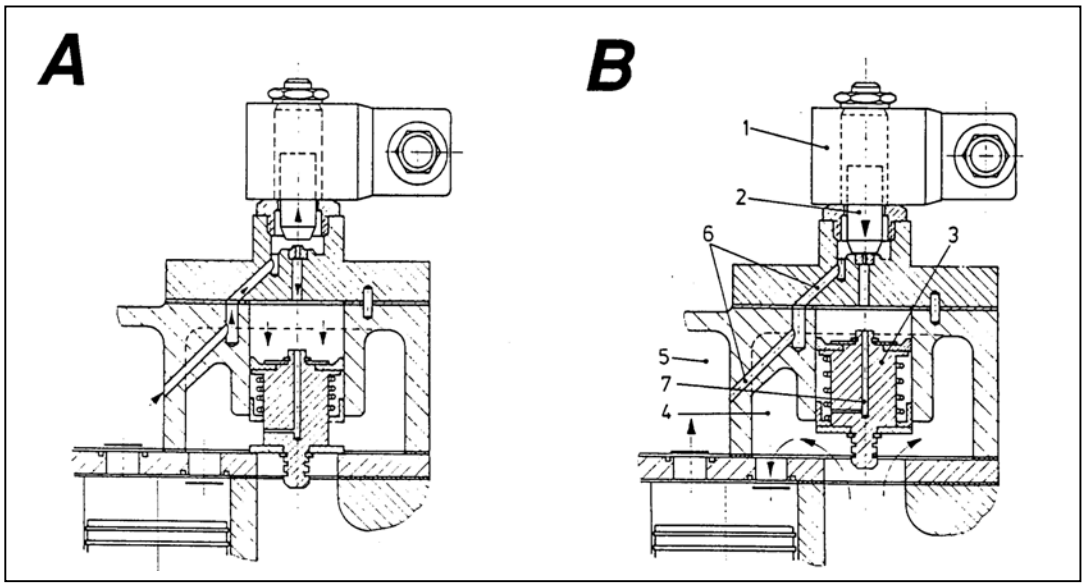
The SBO four-cylinder compressors can be delivered with a system for stage-wise capacity regulation, from 100% to 50%.

Function

Capacity regulation is obtained when the solenoid valve, fitted in the top cover, closes the access to the two cylinders, positioned under the same top cover. This makes the inlet pressure to the cylinder drop to zero bar. At the same time the compressor capacity is reduced to 50%. However, a little gas will be flowing through the closed solenoid valve, hereby ensuring the necessary cooling and lubrication of the cylinders.

This capacity regulation permits a certain reduction in power consumption.

Note:
Stop the compressor and check that the solenoid valve works correctly. At a current impulse to the solenoid valve the characteristic valve stroke must be heard!



(A) Controlled operation:
With the solenoid valve energized, the suction port in the corresponding cylinder head is shut off by means of a servo valve; the pistons of this cylinder row run idle without gas pressure.

(B) Normal operation:
With the solenoid valve de-energized, the gas ports in the valve plate and cylinder head are open.

Start Unloading

At a star-delta start of electric motors it is often considered necessary to limit the compression work of the machine at the starting moment in order to reduce the starting torque of the electric motor.

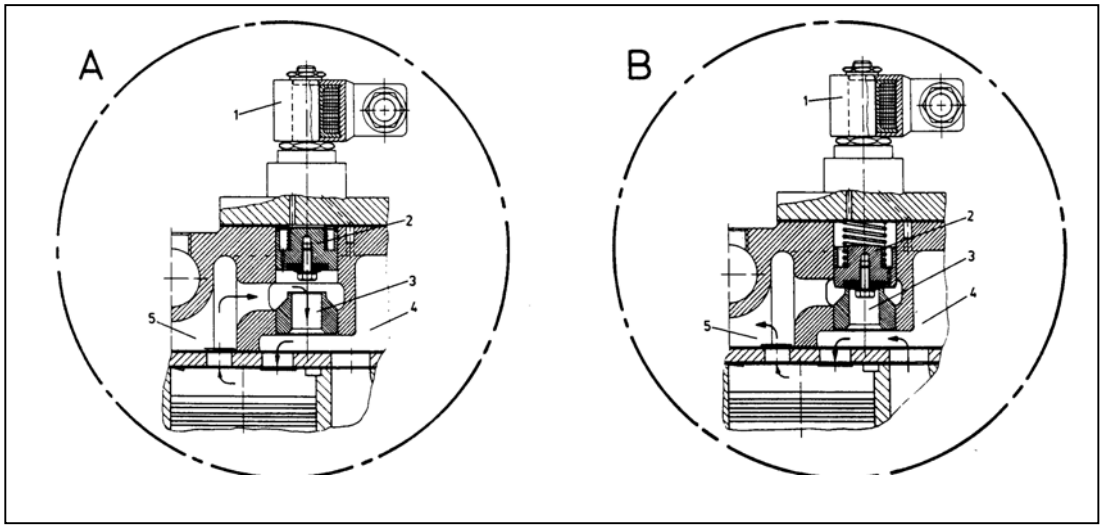
Usually, a solenoid valve is used in a by-pass arrangement which - in the starting-up phase - short-circuits the discharge side to the suction side of the compressor. At the same time, a non-return valve must be fitted in the discharge line to the condenser preventing the return flow of discharge gas to the compressor.

When the electric motor has reached its max. number of revolutions per minute, a switch takes place from star to delta start. The solenoid valve is closed and the compressor now works under normal conditions.

In a few cases a delaying relay must be used, keeping the solenoid valve open until the motor has reached its max. number of revolutions. The delaying relay is set at a delay of 1-2 sec. after a switch from star to delta has taken place.

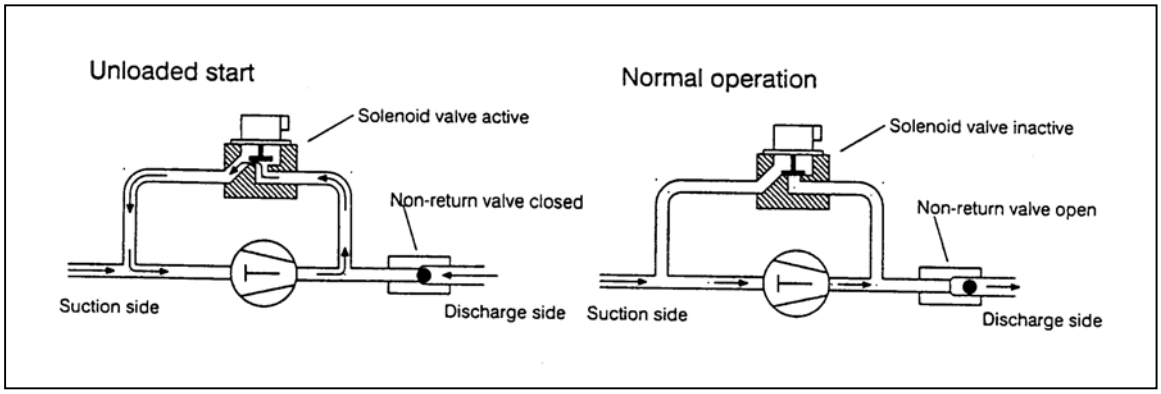
Integrated start unloading:

In the case of SBO 41, 42 and 43 compressors a solenoid valve with a by-pass arrangement is included in the delivery as an integrated part of the compressor.



Externally mounted start unloading:

Fit the non-return valve in the discharge line after the compressor.
Check that the solenoid valve is fitted with the flow arrow pointing from the high pressure to the low pressure side. A wrongly fitted valve or a leaky valve will lead to overheating and breakdown of the compressor.



Heating Rods for Oil Heating

The SBO compressors are delivered in a standard execution with built-in heating rod in the crankcase.

The purpose of the heating rod is to keep the oil in the crankcase warm even during standstill of the compressor. This ensures a low content of refrigerant in the oil.

Too much refrigerant in the oil makes it loose its lubricating properties. This may lead to damage of the movable parts in the compressor.

Further, the danger exists that the oil, during start-up of the compressor, foams so vigorously that the lubricating pressure will disappear.

Before start-up the heating rod should be switched on for at least 8 hours.

Note:
The heating rod must not be switched on if the oil level in the vessel is below minimum in the sight glass. While the compressor is operating, it is usually switched off. Further, remember to switch off the heating rod if the compressor crankcase is opened for inspection.

Compressor type	Effect Watt	Voltage Volt
SBO 21, 22, 41, 42, 43	70	230
SBO 21, 22, 41, 42, 43	70	110

Torque Moments for Screws and Bolts

On mounting, screws and bolts must be tightened with the moments indicated below:

Cylinder head/valve plate: tighten screws crosswise and at least in two steps (50% and 100%)

Normal screw fixings

	A	**B**	**C**
SBO **21, 22, 41, 42, 43**	Moment Nm	Moment Nm	Moment Nm
M6	51	51	51
M8	34	34	34
M10	34	34	34
M12	51	51	51
M16	34	51	51

A Without flat gasket
B With gasket free of asbestos and screw quality 10.9
C With gasket containing asbestos and screw quality 8.8

SBO **21, 22, 41, 42, 43**		Moment Nm
Oil pump	M8	23
Shut off valves with oval flange	M6/M8/M10	9.7 / 25 / 54
Sight glass fixing	M6*/M6**/M8	8 / 11 / 14
Plugs	NPTF 1/8"	10 - 13
Plugs	NPTF 1/4"	20 - 23
Plugs	NPTF 3/8"	42 - 47
Plugs	NPTF 1/2"	64 - 69
Plugs	NPTF 3/4"	98 - 108
Oil drain plug	M22 Al	90
Oil drain plug	M22 Cu	135 - 155
Oil drain plug	M26 Al	110
Oil drain plug	M26 Cu	155 - 175
Connecting rod screws	M6 (10.9)	16
Connecting rod screws	M8 (8.8)	25.5

* Quality 8.8 - flat gasket
** Quality 10.9 - for O-ring-version

Refrigeration Plant Maintenance

Operational Reliability

The main causes of operating malfunctions of the plant are:

1. Incorrect control of liquid supply to the evaporator
2. Moisture in the plant
3. Air in the plant
4. Anti-freezing liquid is missing
5. Congestion due to metal shavings and dirt
6. Congestion due to iron oxides
7. Congestion due to copper oxides
8. Inadequate refrigerant charge

Below, some information is given about ways of keeping contaminants out of the refrigerating system and at the same time facilitating day-to-day supervision of the refrigeration plant.

Pumping Down the Refrigeration Plant

Before dismantling any parts of the refrigeration plant for inspection or repair, pump-down must be carried out.

1. Open suction and discharge stop valves on compressor.

2. Close liquid stop valve after condenser or receiver so that liquid refrigerant can be collected in the tank. Any solenoid valves in the liquid line should be opened by force, adjusting the thermostat to its lowest position so that the liquid line can be bled of refrigerant. Adjust any constant-pressure valves to bring evaporator pressure down to atmospheric pressure.

3. Start up the compressor. Adjust regulating system to lower suction pressure.

4. **Keep a close eye on the suction pressure gauge!** When the suction pressure is equal to atmospheric pressure, stop the compressor and quickly shut off the discharge stop valve. Shut off any stop valve in the oil return line.

   If the receiver has an extra stop valve in the feed line, this can be closed; practically the entire refrigerant charge will then remain shut off in the receiver.

   Note:
   The receiver must not be overfilled! There should be a minimum gas volume of 5%.

5. A slight overpressure should normally remain in the piping system - this safeguards the system from penetration of air and moisture.

6. Before dismantling parts, **the operator should put on a gas mask.**

Dismantling Plant

In order to prevent moisture penetrating into the refrigeration plant during any repair work, it is advisable to follow the rules below:

1. No component should be opened unnecessarily.

2. When dismantling the system, the pressure in the system should be a little higher than atmospheric pressure.

3. Note:
   If the piping system is colder than the surroundings, there is a considerable risk of damp precipitation (condensation) on cold plant parts. Plant components to be dismantled **must** be warmer than the ambient temperature.

4. Only one point should be opened at a time.

5. Plug, close or at least cover opening with oiled paper or suchlike.

6. Be aware of the possibility of filters being very moist.

Leak Testing and Pump-Down of Refrigeration Plant

Before charging refrigerant into that part of the refrigeration plant which has been opened, this should be pressure-tested as described in the section entitled *Pressure testing.*

Afterwards, pump down in order to eliminate air and moisture. In this regard, consult the section *on Evacuation.*

Otherwise, follow the instructions given in the separate instruction manual on plant components.

Note:
If the oil in the crankcase of the piston compressor has been in contact with the atmospheric air for any length of time, it must be replaced with fresh oil of the same grade and make.

Trouble-Shooting on the Reciprocating Compressor Plant

Operating Conditions

Experience shows that pressure and temperature variations in a refrigeration circuit can provide information about the operating condition of the refrigeration plant.

In particular, suction and condenser pressures as well as the temperatures of suction and discharge gases may provide important information as to the operating conditions of the plant.

It often takes only very slight modifications of variable pressures and temperatures to produce considerable changes in operating conditions.

Using the following trouble-shooting chart, it is possible to ascertain the cause of and remedy for any operating disturbance.

Using the trouble-shooting chart

In the following chart, each individual error option is indicated by a code number in the left-hand column, the error being briefly described in the next column. The third column states code numbers for the possible **causes** of the error.

The code numbers refer to the subsequent chart.

The section entitled *Remedying malfunctions* states how to remedy the observed error.

See the following example for the correct procedure.

Example

Observed error: *discharge pipe temperature too low* - error code 15.

Cause codes:
26 (liquid in suction line)
32 (too much coolant/air to condenser)
39 (expansion valve produces too little superheating)

Any explanatory comments will be stated in the section that follows.

Error Code	Observed Error	Cause Code
1	Compressor fails to start	1, 2, 3, 4, 5, 6, 7, 9, 10,
2	Compressor starts and stops too often	12, 14. 9, 10, 11, 13, 21, 22, 23, 24, 32,
3	Compressor starts but stops again immediately	34, 35, 36, 37, 40, 41, 43, 44, 51, 52, 54, 56, 59.
4	Compressor operates	3, 5, 6, 9, 10, 11, 12, 13, 14,
5	continuously	15, 17, 18, 41, 42, 49, 50, 55, 61.
6	Abnormal noise from compressor	8, 21, 22, 24, 41, 46, 52, 53, 56, 60.
7	Insufficient capacity on compressor	16, 17, 18, 19, 26, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58. 13, 15, 17, 18, 20, 21, 22, 23, 24, 32, 34, 35, 36, 37, 40, 41, 44, 45,
8	Slugging in compressor during start up	46, 49, 50, 51, 52, 53, 56, 60. 16, 18, 26, 37, 38, 39, 44, 56, 61.
	Slugging in compressor during operation	21, 23, 26, 37, 39.
9	Excessive condenser	9, 25, 28, 29, 30, 31, 33.
10	pressure	22, 32, 51, 52, 54, 60.
11	Too low condenser pressure	13, 17, 26, 34, 39, 52, 53, 54, 5,
12	Excessive suction pressure	60.
13	Too low suction pressure	11, 13, 20, 21, 22, 23, 32, 35, 36, 37, 40, 41, 42, 44, 45, 56, 59.
	Too low oil pressure	12, 15, 17, 18, 26, 49, 50, 55.
14	Excessive discharge pipe temperature	11, 21, 22, 23, 28, 29, 30, 31, 33, 34, 35, 36, 37, 40, 41, 46, 52, 54.
15	Too low discharge pipe	26, 32, 39.
16	temperature	33, 34, 35, 36, 37, 40, 50, 52.
	Excessive oil temperature	
17	Oil level in crankcase falling	16, 18, 20, 26, 51, 57, 58.
18	Oil foaming vigorously in	16, 26, 39, 61.
19	crankcase	16, 18, 26, 37, 39.
	Crankcase "sweating" or frosting up	
20	Capacity regulating oscillating	13, 15, 16, 17, 18, 49, 55, 56.
21	Impossible to bleed plant	10, 43, 51, 52, 53, 54, 60.

Code	Case	Code	Case
1	No power - master switch does not cut in	31	Condenser needs cleaning
2	Blown fuses - loose wiring or connections	32	Too much coolant/air to condenser
3	Electrical voltage too low	33	Water valve closed
4	No control current	34	External pressure equalization on expansion valve closed
5	Motor protection device activated	35	Expansion valve partly clogged by ice, dirt, wax.
6	Control current circuit open	36	Expansion valve has lost charge
7	Pump/fan not started	37	Expansion valve sensor misplaced
8	Welded contacts in motor protection	38	Expansion valve is leaky
9	High-pressure cut-out has cut	39	Expansion valve provides too little superheating
10	Low-pressure cut-out has cut	40	Expansion valve produces excessive superheating
11	Low-pressure cut-out differential too small	41	Filters in liquid/suction lines clogged
12	Oil pressure cut-out has cut	42	Solenoid valve in liquid/suction lines closed
13	Capacity regulator incorrectly set	43	Solenoid valve leaky
14	Defrosting timer breaks current	44	Evaporator iced up or clogged
15	Oil charge insufficient	45	Cooling air being recirculated (short-circuited)
16	Compressor capacity too high during start-up	46	Excessive load on plant
17	Oil pressure too low (adjust oil pressure regulating valve)	47	Refrigerant collecting in cold condenser (close off by-pass)
18	Oil foaming in crankcase	48	Coupling misaligned or loose bolts
19	Oil overcharge	49	Oil pump defective
20	Poor oil return - oil in evaporators	50	Bearings worn out or defective
21	Restricted supply of refrigerant	51	Defective piston rings or worn cylinder
22	Refrigerant charge insufficient	52	Discharge valves defective or leaky
23	Refrigerant vapour in liquid line	53	Suction valves defective or leaky
24	Leaky refrigeration plant	54	Compressor by-pass open - leaky safety valve
25	Refrigerant overcharge	55	Compressor oil filter clogged
26	Liquid in suction line	56	Capacity regulator defective
27	At low temperature operation, degree of charge in evaporators rises	57	Solenoid valve in oil return

28	Insufficient coolant/air to condenser		clogged/ defective
29	Temperature of coolant/air too high	58 59 60	Filter in oil return clogged Compressor capacity too high Compressor capacity too low
30	Non-condensable gases in condenser	61	Heating element in crankcase defective

Remedying Malfunctions

1. Compressor fails to start:

1.6	Control current circuit open owing to activated: Pressure cut-outs Thermostats Motor protection device Defrosting timer	Pinpoint open switch and remedy cause of interruption.
1.9	High-pressure cut-out has cut	Reset pressure cut-out and investigate cause of high condenser pressure.
1.10	Low-pressure cut-out has cut	Compressor cannot start before suction pressure has risen above setpoint for pressure cut-out restarting.
1.12	Oil-pressure cut-out has cut	Compressor starts at reset. Check oil level. If oil foams in crankcase, see section 18.

2. Compressor starts and stops too often:

2.9	High-pressure cut-out cuts at high pressure	High condenser pressure - see section 9. Check condenser cooling and adjust pressure cut-out to correct breaking pressure - see table *Pressure and temperature settings.* Replace defective pressure cut-out.

2.10	Low-pressure cut-out cuts at too low suction pressure	Low suction pressure - see section 12. If low-pressure cut-out is set too high, adjust pressure cut-out.
2.11	Low-pressure cut-out differential is too small between stopping and starting	Increase differential pressure - see also special instructions.
2.13	Compressor capacity too high	Check operating conditions and, if necessary, reduce capacity.

2.41	Filter in suction line clogged	Check suction filters on compressor.
2.43	Solenoid valve in liquid line does not close tight	Check direction of flow. Replace defective valve.
2.52	Discharge valves on compressor are leaky	At compressor stop, pressure equalizes relatively quickly between suction and discharge side. Clean or change discharge valves.

3. Compressor starts, but stops again immediately:

3.5	Motor protection cuts	Look for cause of overloading. If star-delta start, set starting time at minimum.
3.10	Low-pressure cut-out has cut	Open any suction stop valve which is closed.
3.12	Defective oil-pressure cut-out	Replace cut-out - see special instructions.
3.15	Oil charge insufficient	Top up with oil and investigate cause of oil shortage.
3.18	Oil pressure failing owing to formation of foam in oil.	Reduce capacity. See sections 17 and 18.

4. Compressor operates continuously:

4.10	Thermostat or low-pressure cut-out does not cut at too low temperature/pressure	Adjust operating points.
4.21	Restricted supply of refrigerant to evaporator. Compressor working at too low suction pressure.	Remove dirt in filters and check function of expansion device as per special instructions.
4.22	Refrigerant charge insufficient.	Top up with refrigerant of correct type.

5. Abnormal noise from compressor:

5.16	Compressor capacity too high during start-up	Reduce capacity.
5.17	Oil pressure too low	See section 13.
5.26	Liquid refrigerant in suction line	Slugging. See points 7 and 8. Adjust expansion or float valves.
5.48	Incorrect alignment of motor and compressor. Loose bolts in coupling	Check alignment as per special instructions. Tighten with torque wrench.
5.50	Worn or defective bearings	Overhaul or replace
5.51 5.53 5.57 5.58	Too much oil circulating through the plant, resulting in too low oil level in compressor	Check oil level. Solenoid valve, filter or jets in oil return system may be clogged. Leaky suction valve ring plates, piston rings and worn-out cylinder may also produce such oil consumption.
5.56	Capacity regulation oscillating owing to failing oil pressure	Low oil pressure - see section 13.

6. Too little capacity on compressor:

6.15	Insufficient oil charge	Top up with fresh oil of same type and make.
6.44	Iced-up evaporator	Defrost evaporator; adjust defrosting time if required.
6.49	Defective oil pump and hence failing oil pressure	Repair or replace oil pump.
6.56	Defective capacity regulating system	Cause is most often failure in oil pressure or refrigerant in oil; see section 4.5.

7. Slugging in compressor during start-up:

	Slugging in the compressor should not occur, because at worst this can cause rupture of the valve ring plates and damage to the built-in relief devices. Furthermore, it can result in damage to the connecting rod bearings and cylinders if the coolant degreases the faces and impairs the lubricating capacity of the oil.	
7.18	Adsorption of (H)CFC refrigerant in oil. Sudden reduction in pressure across the oil sump (suction pressure) produces foaming	Reduce compressor capacity or start throttling suction stop valve. Follow instructions in section 18.
7.26	Refrigerant has condensed in suction line or crankcase. Suction line has free fall towards compressor	Heating element in crankcase should be connected for 6-8 hours before starting, so that refrigerant dissolved in oil can be decocted before starting compressor up. Start throttling suction stop valve - stop when hammering is heard. Liquid separator should be mounted in suction pipe.

8. Slugging in compressor during operation:

8.23	Refrigerant gas in liquid line	Expansion valve is oscillating.
8.39	Superheating of expansion valve is set too low	Adjust superheating, which should normally be 5-8°C

9. Excessive condenser pressure:

	In the event of abnormally high pressures in the refrigeration system, there is a risk of damage to the compressor. At very high pressures *(see pressure testing)*, the risk of the components in the refrigeration plant exploding can constitute a threat to life. Abnormally high pressures may occur in the case of: - extreme heating of plant parts (fire, solar radiation or other abnormal heating); - Volumetric expansion of fluids in sealed-off premises.	
9.25	Overfilling with refrigerant	Refrigerant fills condenser and reduces its effective area. Draw-off coolant.
9.28	Insufficient condenser cooling, e.g. if cooling water fails, fan/cooling water pump clogs, soiling, scaling or fouling of heat-transmitting surfaces	Regulate water/air supply or reduce compressor capacity, if called for. Check condenser as per instructions for same.
9.30	Presence of non-condensable gases (especially air) in condenser	Blow air out of condenser. Follow instructions for condenser.

10. Too low condenser pressure:

10.32	Excessive condenser cooling	Regulate condenser cooling
10.51	Defective piston rings or worn cylinders	Replace worn parts. See compressor instructions
10.52	Discharge valves are defective or leaky	See compressor instructions. Check valve ring plates and piston rings
10.54	By-pass between high-pressure side and suction side of compressor	Check compressor for internal leakage by performing **pressure-drop test.** See compressor instructions.
10.60	Compressor lacks capacity	Check whether compressor capacity corresponds to load on plant. Reduce condenser cooling.

11. Excessive suction pressure:

11.26	Error in setting of liquid regulation valve	Liquid refrigerant in suction line. Adjust, repair or replace expansion valve.
11.53	Leaky suction valves	See compressor instructions. Remove cylinder covers; check valve plates. Renew if needed.
11.54	Open by-pass between suction side and high-pressure side of compressor. Safety valves leaky, or opens prematurely.	Check system for any by-pass detectable as for instance a warm connection. Adjust or repair leaky valves.
11.60	Compressor lacks capacity.	Regulate compressor capacity. Check whether all cylinders are operating. Check function of capacity regulator.

12. Too low suction pressure:

	Abnormal low pressure in the refrigeration plant will increase the compression ratio of the compressor with a subsequent risk of damage to the compressor. The danger of air being sucked into the refrigeration plant also increases at abnormal low pressure.	
12.20	Oil in evaporator	Draw-off oil
12.22	Refrigerant charge of plant insufficient. Bubbles in liquid line sight glass and possibly a warm liquid line.	Check refrigerant charge. Charge plant with refrigerant. Find and seal any leak.
12.35	Freezing-up of expansion valve (HFC/HCFC plant)	Thaw out expansion valve with hot, wet cloths. Replace desiccant in drying filter.
12.36	Thermostatic expansion valve has lost charge	Valve fails to open - change valve.
12.40	Excessive superheating of suction gas	Regulate expansion valves to higher capacity
12.41	Filter in liquid line clogged	Check and clean filter in liquid line
12.42	Solenoid valve in liquid line fails to open	Coil may have blown. Control signal lacking.
12.59	Compressor has excessive capacity	Reduce compressor capacity. Check capacity regulating system.

13. Oil temperature too low:

13.15	Too little oil in compressor	Top up compressor with oil and investigate cause of oil consumption
13.18	Oil foams in compressor	See point 18
13.49	Oil pump defective	Repair or replace
13.50	Bearings worn	Repair or replace
13.55	Oil filter clogged	Change filter cartridge

14. Excessive discharge pipe temperature:

	If, after approx. 1 hour's operation, the discharge pipe temperature is more than 10°C higher than indicated in the table, the error may be due i.a. to:	
14.21	Excessive suction temperature as result of reduced refrigerant supply to evaporator (extensive superheating) owing to insufficient refrigerant charge	Check refrigerant charge
14.22	Excessive suction temperature as result of reduced refrigerant supply to evaporator (extensive superheating) owing to incorrectly adjusted liquid regulating valves	Check thermostatic expansion valves
14.52	Leaky discharge valves	Leaking discharge valves gives rise to generation of heat. Change defective valves.
14.54	Open by-pass between high and low-pressure side of compressor, e.g. leaky safety valve	Localize by-pass and remedy any leakages.

15. Too low discharge pipe temperature:

15.26	Low suction temperature as result of overflow of liquid refrigerant from evaporator	Adjust liquid regulating valve. Increase superheating.

16. Excessive oil temperature:

	During operation, the temperature of the compressor crankcase must be 40-70°C. When working with R717 and R22, it may be necessary to supply the compressor with oil cooling.	
	See point 14.	

17. Oil level in crankcase falling:

	Where HFC/HCFC refrigerants are used, there will be some blending of refrigerant and oil during the initial operating period. It may therefore prove necessary to top up the oil after initial start-up of the plant. **Note:** The oil level must always be visible in the oil level sight glass on the compressor.	
17.20	Filter in solenoid valve or nozzle in oil return line clogged	Oil return pipe must be warm during operations. Clean filter.
17.26	Liquid in suction line and crankcase may cause foaming in oil and thus increase oil consumption	Examine evaporator system and check superheating of suction gas.
17.51	Worn-out piston rings or cylinders	Renew piston rings and, if need be, renew pistons and cylinder linings.
17.57	Solenoid valve in oil return line defective	Coil in solenoid valve defective - Replace coil - Electrical control signal lacking

18. Heavy oil foaming in crankcase:

18.26	Liquid in suction line	See 17.26
18.61	Too much refrigerant dissolved in oil	Before starting compressor, heating element must have been on for at least 8 hours in order to boil refrigerant out of oil. During start-up phase, capacity should be connected at a slow rate to prevent a sudden drop of pressure on suction side with resultant foaming. Under normal operating conditions, compressor should operate under as stable pressure conditions as possible

19. Crankcase "sweating" or frosting up:

19.26	Liquid in suction line	See 17.26
19.37	Expansion valve sensor misplaced	Check positioning of expansion valve sensor - cf. instructions for expansion valve
19.39	Liquid regulating valve or float valve producing too much liquid	Increase superheating on thermostatic expansion valve

20. Capacity regulation oscillating:

20.18	Oil foaming in crankcase	See point 18

21. Impossible to bleed plant:

21.43	Solenoid valve leaky	Pinpoint and seal leak, or change leaky component
21.51	Defective piston rings	Check and replace any defective parts
21.52	Defective discharge valves	Check and replace any defective parts
21.53	Defective suction valves	Check and replace any defective parts

Alignment of Unit

When using vibration dampers, the machine room floor is assumed to have the necessary carrying capacity and to be level enough to enable adjustment of the vibration dampers.

Alignment of Compressor with Base Frame

Check that the entire footing of the compressor makes full contact with the milled-off faces of the base frame.

Perform this check with the bolts loosened. If slips occur at one or more resting surfaces, shim up before tightening. If unaligned, there is a risk of stresses occurring in the compressor frame, which will damage the bearings.

Alignment of Motor with Base Frame

Check the contact faces of the motor against the base frame in the same way as for the compressor.

Stresses from Pipe Connections

In order to prevent stress being transmitted from pipe connections between unit and plant, pipes must be placed in such a way that compressive stresses or tensile strains are not generated in the event of expansions or contractions due to temperature changes. Steel piping expands approx. 1 mm per metre per 100°C.

V-belt Drive for SBO Reciprocating Compressors

In case your SABROE compressor is belt-driven, use drive belts type SPA to calculate total length of V-belts:

$((D1 \times \pi + D2 \times \pi) / 2) + 2 \times C$

D1 = diameter of motor pulley
D2 = diameter of compressor pulley
C = distance between motor and compressor shaft

Mounting of V-belts

- Before mounting of V-belts the pulley tracks should be thoroughly cleaned of oil or dirt as well as checked for any grooves and bruises.
- Move the motor sufficiently to allow the belts to be fitted without having to apply force. Never force the belts over the pulleys as the power transmitting fibres can be damaged and the life of the belts considerably reduced.
- After fitting of the V-belts compressor and motor are once more pulled apart and aligned by means of a straightedge. The tracks must be flush with one another and the shafts completely parallel.
- In order to obtain the best possible operating conditions the belt tension must be correct. This is checked by pressing the belts in between the pulleys by hand. The belts should be equally tight and an even pressure by hand only lower them 3 to 5 mm.
- Let the transmission run for a couple of minutes, then check the degree of tightness.
- It is important to inspect the tightening at regular intervals as indicated in the section: *Servicing the reciprocating compressor.*
- On replacing worn V-belts the whole set must be replaced.
- One set of V-belts must always be within the same tolerance group.
- Never use belt grease.

Remember:
The protecting guard should always be mounted whenever the belt drive is operating.

Ordering of Spare Parts

When placing an order for spare parts, please state the following:

1. Shop No.

All compressors are fitted with an identification plate, which states the type and shop No. of the compressor and indicates what refrigerant is to be used.

2. Part No.

Spare parts drawings and parts lists inserted in an instruction manual identify spare parts by the following:

a) Spare part No. - which is a reference number to facilitate finding a part in the drawing and cross-referencing in the parts list or vice versa.

b) Designation of the part.

c) Part No. - a 7-digit number which refers to SABROE's stores.

When you order spare parts, please always advise at least the designation and part number. If you are in any doubt, add the spare part No., too.

3. Forwarding Instructions

When ordering spares, please advise the forwarding address, and the address to which the invoice should be sent. If appropriate, please state the name of your local bank, the way in which you want the goods transported and required delivery date.

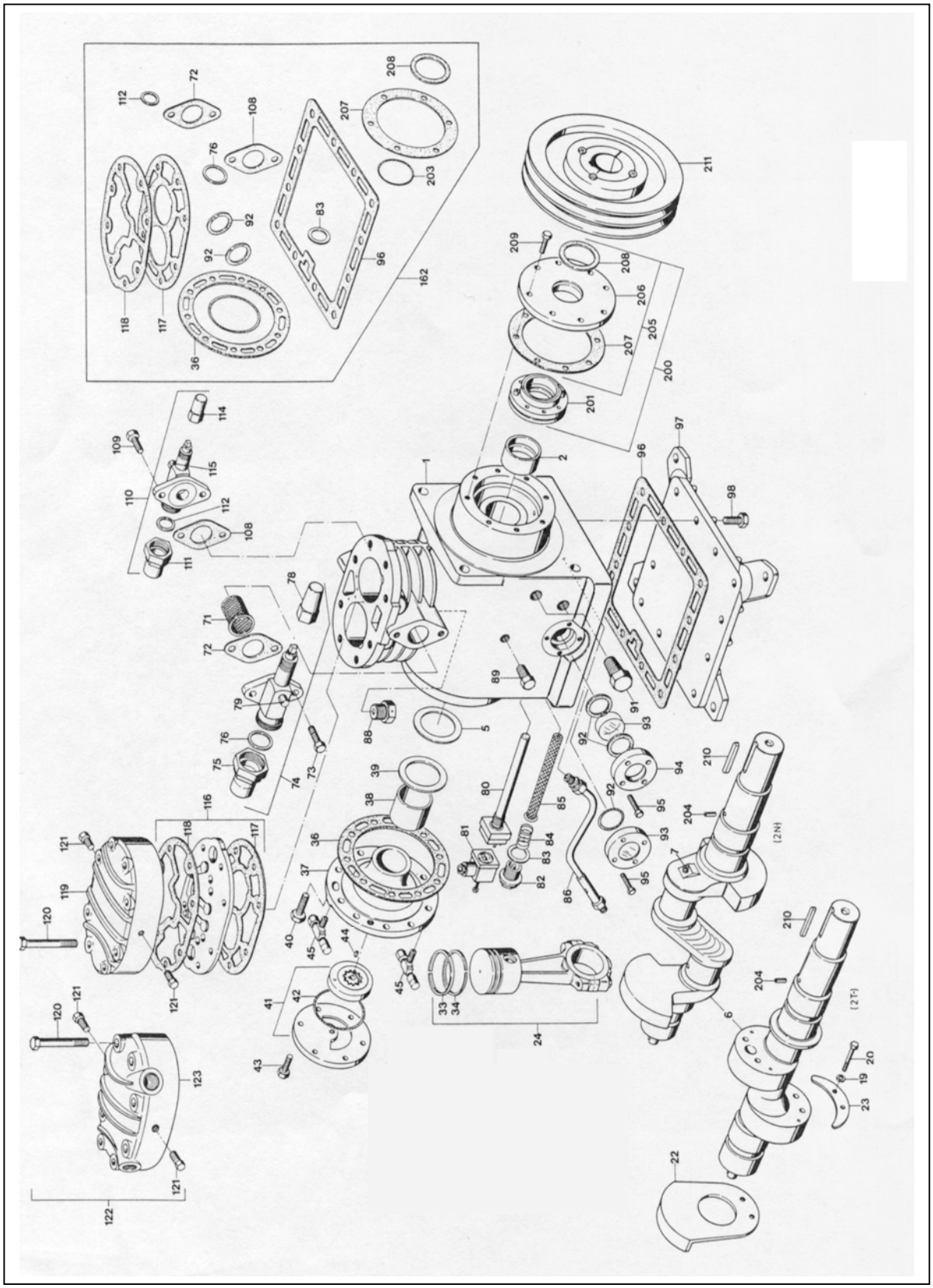
4. Classification Certificate

If you require a certificate from a Classification Society, please mark the order appropriately, as the inspection and issuing procedures take extra time and incur extra expenses.

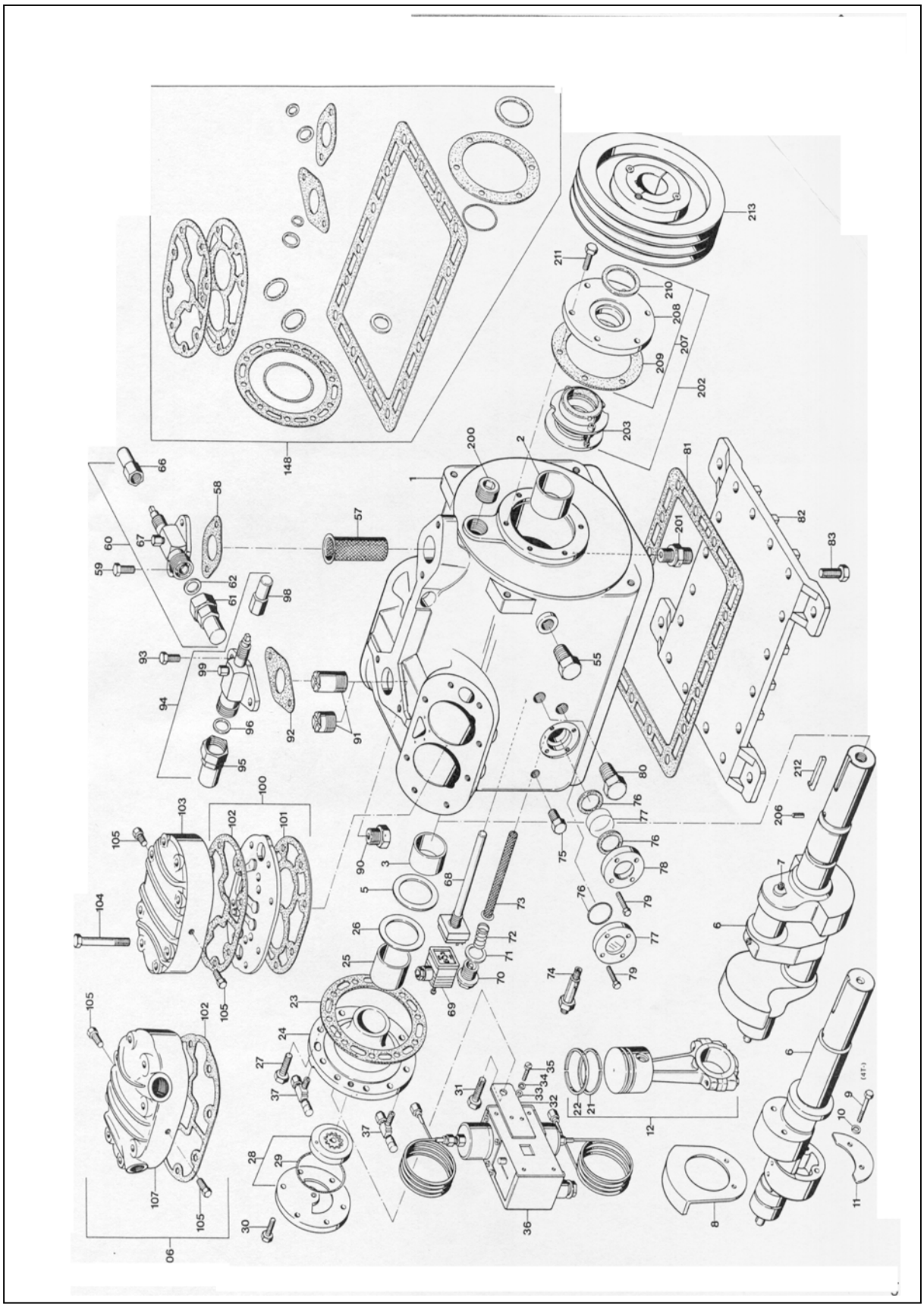
5. Quotation No.

If a quotation No. has been given during earlier correspondence, please refer to this when placing your order - it will help us to identify and execute your order quickly.

Spare part drawing for compressor type SBO21 and SBO22



Spare part drawing for compressor type SBO41, SBO42, SBO43



Spare parts list for compressor type SBO

Pos No.	Part. No.	Compressor Type					Description
		SBO 21	SBO 22	SBO 41	SBO 42	SBO 43	
24	1991.400	X					CONNECTING ROD WITH PISTON COMPLETE FOR SBO21
2	1991.401	X	X				BUSHING FOR CRANKSHAFT SBO21 AND SBO22
37/38	1991.402		X				BEARING CAP COMPLETE
5	1991.403	X	X				THRUST WASHER FRONT SIDE FOR SBO21/22
36	1991.404	X	X				GASKET FOR REAR BEARING FLANGE. SBO21 AND SBO22
41	1991.405	X	X				OIL PUMP COMPLETE FOR SBO21 AND SBO22
71	1991.406	X	X				SUCTIOM STRAINER FOR SBO21 AND SBO22
72	1991.407	X	X				GASKET
116	1991.448	X					VALVE PLATE COMPLETE FOR SBO21
116	1991.449		X				VALVE PLATE COMPLETE FOR SBO22
117	1991.476	X	X				LOWER VALVE PLATE GASKET FOR SBO21 AND SBO22
118	1991.410	X	X				UPPER VALVE PLATE GASKET FOR SBO21 AND SBO22
119	1991.521	X	X				CYLINDER HEAD, AIR COOLED FOR SBO21 AND SBO22
80/81	1991.412	X	X				CRANKCASE HEATER 70W/230V FOR SBO21 AND SBO22
80/81	1991.413	X	X				CRANKCASE HEATER 70W/110V FOR SBO21 AND SBO22
	1991.414	82	82	70	70	70	MAGNETIC PLUG FOR OIL FILTER
	1991.415	83	83	71	71	71	GASKET FOR OIL FILTER FOR SBO
	1991.416	84	84	72	72	72	THRUST SPRING FOROIL STRAINER
	1991.417	85	85	73	73	73	OIL STRAINER FOR SBO
200	1991.418	X	X				SHAFT SEAL COMPLETE FOR SBO21 AND SBO22
72/108	1991.419	X	X				GASKET FOR SUC/DISC. VALVE FOR SBO21 AND SBO22
112	1991.420	X	X				GASKET FOR DISCH. VALVE FOR SBO21 AND SBO22
110	1991.421	X	X				DISCH. STOP VALVE COMPLETE FOR SBO21 AND SBO22
74	1991.422	X	X				SUC. STOP VALVE COMPLETE FOR SBO21 AND SBO22
162	1991.423	X	X				SET OF GASKETS FOR SBO21 AND SBO22
211	1991.424	X	X				COMPRESSOR PULLEY FOR SBO21 AND SBO22
96	1991.425	X	X				BASE PLATE GASKETFOR SBO21 AND SBO22
24	1991.426		X				CONNECTING ROD WITH PISTON COMPLETE FOR SBO22

Pos no.	Part. No.	Compressor Type					Description
		SBO 21	SBO 22	SBO 41	SBO 42	SBO 43	
37/38/41	1991.427	X					BEARING CAP COMPLETE INCL. OIL PUMP FOR SBO21
38	1991.428	X	X				BEARING BUSH SBO21/22
86	1991.429	X	X				OIL RETURN SYSTEM FOR SBO21/22
200	1991.430	X	X				SHAFT SEAL COMPLETE FOR SBO21/22 R717 / R134a
207	1991.431	X	X				GASKET F. SHAFT SEAL COVER SBO21/22
2	1991.450			X	X	X	BEARING BUSH (MOTOR SIDE) FOR SBO41/42/43
3	1991.451			X	X	X	BEARING BUSH (CRANK. SIDE) SBO41/42/43
5	1991.452			X	X	X	THRUST WASHER (CRANK SIDE) SBO41/42/43
12	1991.453			X			CONNECTING ROD WITH PISTON COMPLETE SBO41
12	1991.454				X		CONNECTING ROD WITH PISTON COMPLETE SBO42
12	1991.455					X	CONNECTING ROD WITH PISTON COMPLETE SBO43
24	1991.456			X			BEARING CAP COMPLETE
24	1991.457				X	X	BEARING CAP COMPLETE
25	1991.458			X	X	X	BUSHING FOR CRANKSHAFT SBO41/42/43
26	1991.459				X	X	THRUST WASHER SBO42/43
23	1991.460			X	X	X	REAR BEARING FLANGE GASKETFOR SBO41/42/43
57	1991.461			X	X	X	SUCTION STRAINER FOR SBO41/42/43
58	1991.462			X	X	X	GASKET FOR SUC. VALVES BO41/42/43
60	1991.463			X	X	X	SUC. STOP VALVE COMPLETE FOR SBO41/42/43
94	1991.464			X	X	X	DISCH. STOP VALVE COMPLETE FOR SBO41/42/43
68	1991.465			X	X	X	CRANKCASE HEATER 100W/230V SBO41/42/43
68	1991.466			X	X	X	CRANKCASE HEATER 100W/110V SBO41/42/43
74	1991.467			X	X	X	OIL RELIEF VALVE FOR SBO41/42/43
	1991.468	93	93	77	77	77	SIGHT GLASS FOR SBO
	1991.469	92	92	76	76	76	O-RING FOR SIGHT GLASS
28	1991.470			X	X	X	OIL PUMP COMPLETE FOR SBO41/42/43
29	1991.471						O-RING FOR OIL PUMP
100	1991.472			X			VALVE PLATE COMPLETE SBO41

Pos no.	Part. No.	Compressor Type					Description
		SBO21	SBO22	SBO41	SBO42	SBO43	
100	1991.473				X		VALVE PLATE COMPLETE FOR SBO42
100	1991.474					X	VALVE PLATE COMPLETE FOR SBO43
101	1991.475				X		LOWER VALVE PLATE GASKET FOR SBO42
101	1991.476			X		X	LOWER VALVE PLATE GASKET FOR SBO41/43
102	1991.477			X	X	X	UPPER VALVE PLATE GASKET FOR SBO41/42/43
103	1991.478			X	X	X	CYLINDER HEAD, AIR-COOLED FOR SBO41/42/43
202	1991.479			X	X	X	SHAFT SEAL COMPLETE FOR SBO41/42/43
202	1991.480			X	X	X	SHAFT SEAL COMPLETE FOR SBO41/42/43
209	1991.481			X	X	X	GASKET F. SHAFT SEAL COVER SBO41/42/43
213	1991.482			X	X	X	COMPRESSOR PULLEY FOR SBO41/42/43
148	1991.483				X		SET OF GASKET SBO42
148	1991.484			X		X	SET OF GASKET SBO41 / SBO43
81	1991.485			X	X	X	BASE PLATE GASKET
92	1991.486			X	X	X	GASKET DISCH. VALVE
96	1991.487			X	X	X	GASKET DISCH. VALVE