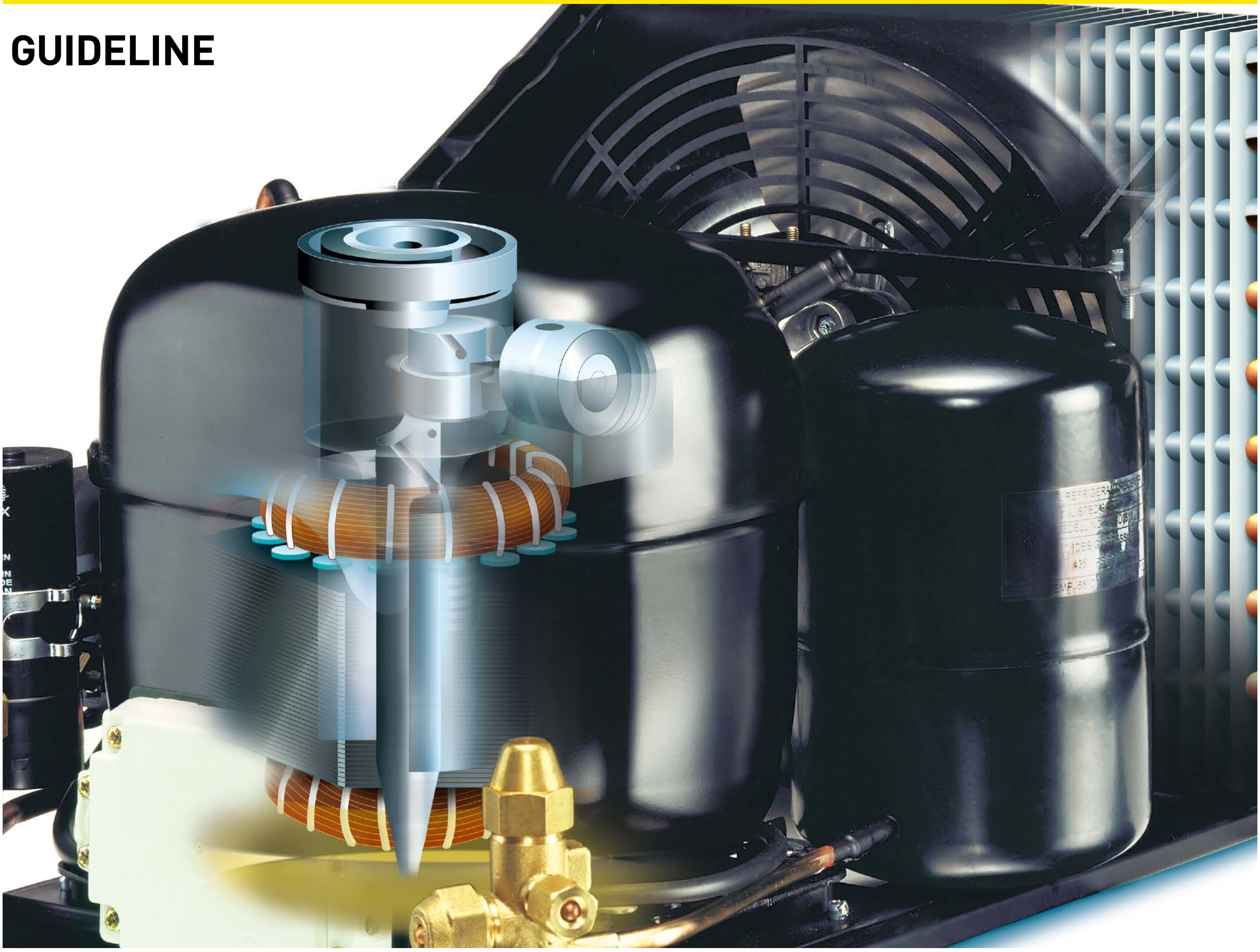
WITH MORE THAN 50 YEARS OF EXPERIENCE IN COMPRESSOR TECHNOLOGY AND HIGHLY COMMITTED EMPLOYEES, OUR FOCUS IS TO DEVELOP AND APPLY THE ADVANCED COMPRESSOR TECHNOLOGIES TO ACHIEVE STANDARD SETTING PERFORMANCE FOR LEADING PRODUCTS AND BUSINESSES AROUND THE WORLD.

REPAIR OF HERMETIC REFRIGERATION SYSTEMS

SECOP

GUIDELINE



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1. GENERAL

Repairs of refrigerators and freezers require skilled technicians who are to perform this service on a variety of different refrigerator types. Previously service and repair was not as heavily regulated as now due to the new refrigerants, some of which are flammable.

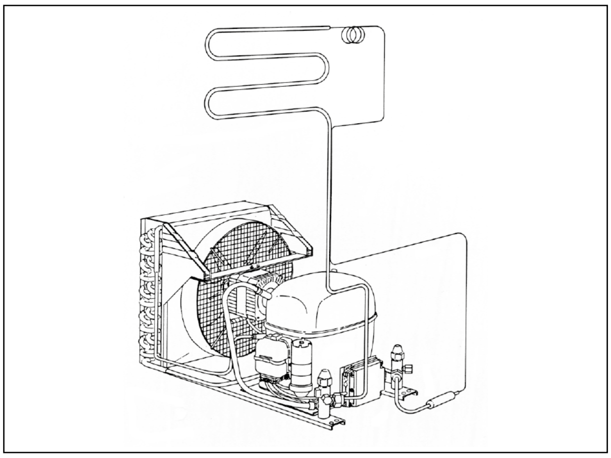

Fig. 1: Hermetic refrigeration system with capillary tubes

Fig. 1 shows a hermetic refrigeration system with a capillary tube as the expansion device. This system type is used in most household refrigerators, small commercial refrigerators, ice cream freezers and bottle coolers.
Fig. 2 shows a refrigeration system using a thermostatic expansion valve. This system type is mainly used in commercial refrigeration systems.

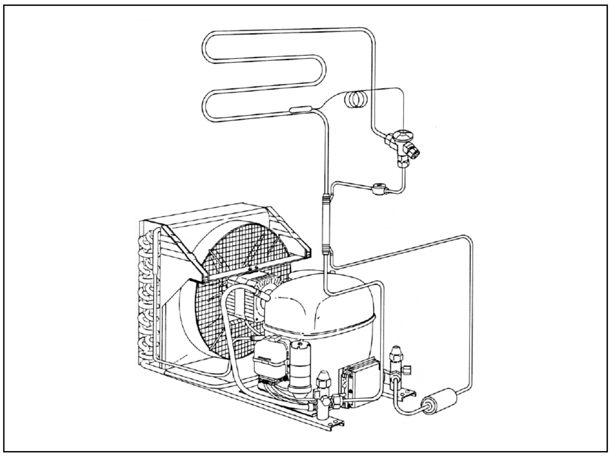

Fig. 2: Hermetic refrigeration system with expansion valve

Repair and service is more difficult than new assembly, as conditions "in the field" are normally worse than in a production site or in a workshop. A requirement for satisfactory service work is that the technicians have the right qualifications, i.e. good workmanship, thorough knowledge of the product, precision and intuition.

The purpose of this guide is to increase the knowledge of repair work by going through the basic rules. The subject matter primarily deals with reference to repair of refrigeration systems for household refrigerators "in the field" but many of the procedures may also be transferred to commercial hermetic refrigeration installations.

1.1 Fault location

Before performing any operations on a refrigeration system the progress of the repair should be planned, i.e. all necessary replacement components and all resources must be available. To be able to make this planning the fault in the system must first be known.

For fault location, tools must be available as shown in Fig. 3. - suction and discharge manometer, service valves, multimeter (voltage, current and resistance) and a leak tester. In many cases it can be concluded from the user's statements which faults could be possible, and for most faults a relatively accurate diagnosis can be made. However, a requirement is that the service technician has the necessary knowledge of the product's function and that the right resources are available. An elaborate fault location procedure will not be gone through here, however, the most common faults where the compressor does not start or run are mentioned in the following.

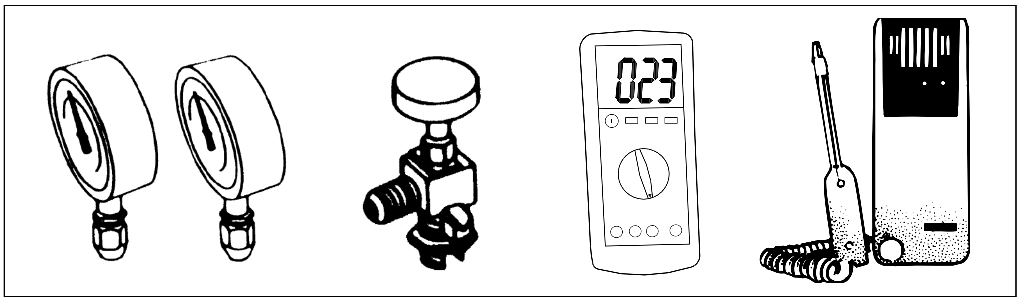

Fig. 3: Pressure gauges, service valve, multimeter and leak tester

Main switch released
One potential fault may be a defective fuse, and the reason may be a fault in the motor windings/ motor protector, a short circuit or a burnt current lead-in on the compressor. These faults require the compressor to be replaced.

Compressor
The starting device and compressor motor may be a wrong choice. The compressor motor or winding protector may be defective, and the compressor may be mechanically blocked.
Frequent reasons for reduced refrigeration capacity are coking or copper platings due to moisture or non-condensable gases in the system.
Blown gaskets or broken valve plates are due to peak pressures being too high and short-time pressure peaks as a result of liquid hammering in the compressor, which may be due to a high refrigerant charge in the system or a blocked capillary tube.
The voltage may be too low or the pressure too high for the compressor.
Non equalized pressure causes the motor protector to cut out after each start and will eventually result in a burnt motor winding.
A defective fan will also affect the compressor load and may cause motor protector cut outs or blown gaskets. In the case of an unsuccessful start and cold compressor up to 15 minutes may pass until the winding protector cuts the compressor out. If the winding protector cuts out when the compressor is hot up to 45 minutes may pass until the protector cuts the compressor in again.
Before starting a systematic fault location it is a good rule to cut off the voltage to the compressor for 5 minutes. This ensures the PTC starting device, if any, is cooled sufficiently to be able to start the compressor.
Should a brief power failure occur within the first minutes of a refrigeration process, a conflict situation (interlocking) may arise between the protector and the PTC. A compressor with a PTC starting device cannot start in a system that is not pressure-equalized, and the PTC cannot cool so quickly. In some cases it will take up to 1 hour until the refrigerator runs normally again.

High and low pressure switches
Cut out of the high pressure switch may be due to a condensing pressure too high, probably caused by lack of fan cooling.
A cut-out low pressure switch may be due to insufficient refrigerant charge, leakage, evaporator frost formation or partial blockage of the expansion device.
The cut out may also be due to a mechanical failure, wrong difference setting, wrong cut-out pressure setting or irregularities in pressure.

Thermostat
A defective or incorrectly set thermostat may have cut out the compressor. If the thermostat loses sensor charge or if the temperature setting is too high, the compressor will not start. The fault may also be caused by a wrong electrical connection.
A differential (difference between cut in and cut out temperature) too low will cause short compressor standstill periods, and in connection with a LST compressor (low starting torque) this might lead to starting problems.
See also point 1.2 " Replacement of thermostat".

A careful fault determination is necessary before opening the system, and especially before removing the compressor from the system. Repairs requiring operations in a refrigeration system are rather costly. Before opening old refrigeration systems it may therefore be appropriate to make sure that the compressor is not close to breaking down though it is still functional.
An estimation can be made by checking the compressor oil charge. A little oil is drained in to a clean test glass and is compared with a new oil sample. If the drained oil is dark, opaque and containing impurities, the compressor should be replaced.

1.2 Replacement of thermostat

Before replacing the compressor it is a good idea to check the thermostat. A simple test can be made by short-circuiting the thermostat so the compressor gets power directly. If the compressor can operate like this then the thermostat must be replaced.
For replacement it is essential to find a suitable type, which may be difficult with so many thermostat types in the market. To make this choice as easy as possible several manufacturers, i.e. Danfoss, have designed so-called "service thermostats" supplied in packages with all accessories necessary for thermostat service.
With eight packages, each covering one type of refrigerator and application, service can be made on almost all common refrigerators. See Fig. 4.

Fig. 4: Service thermostat package

The application area of each thermostat covers a wide range of thermostat types. Moreover, the thermostats have a temperature differential between cut in and cut out sufficient to ensure satisfactory pressure equalization in the system standstill periods.

In order to achieve the requested function the thermostat sensor (the last 100 mm of the capillary tube) must always be in close contact with the evaporator. When replacing a thermostat it is important to check whether the compressor operates satisfactorily both in warm and cold position, and whether the standstill period is sufficient for the system pressure equalization when using a LST compressor.

With most thermostats it is possible to obtain a higher temperature differential by adjusting the differential screw. Before doing this it is recommended to seek advice in the thermostat Data Sheet which way the screw must be turned.
Another way of obtaining a higher differential is to place a piece of plastic between the sensor and the evaporator, since 1 mm plastic results in approx. 1°C higher

1.3 Replacement of electrical equipment

The cause for faults may also be found in the electrical equipment of the compressor, where it is possible to replace the starting relay/PTC starting device, motor protector, starting or run capacitor.
A damaged starting capacitor may be caused by the thermostat differential setting being too low, since the starting capacitor must be maximum cut in 10 times/hour. If a fault is found on the winding protector built into many hermetic compressors the entire compressor must be replaced.

When replacing a compressor the electrical equipment must be replaced as well, since old electrical equipment used with a new compressor may cause a compressor breakdown later.

1.4 Replacement of compressor

If the failure is a defective compressor, the technician must take care to select a compressor with the correct characteristics for the appliance.
If a compressor corresponding to the defective one is available, and if it is intended for a non regulated refrigerant, no further problems will arise. However, in many cases it is impossible to provide the same compressor type as the defective one, and in this case the service technician must be aware of some factors.
If it is a question of changing from one compressor manufactured to another it can be difficult to select the correct compressor, and therefore different parameters have to be considered. Compressor voltage and frequency must correspond to voltage and frequency on location. Then the application area must be considered (low, medium or high evaporating temperatures).

The cooling capacity must correspond to the one of the previous compressor, but if the capacity is unknown a comparison of the compressor displacements will be applicable. It would be appropriate to select a compressor slightly larger than the defective one.
For a capillary tube system with pressure equalization during the standstill periods a LST compressor (low starting torque) can be used, and for a system with expansion valve or no pressure equalization a HST compressor (high starting torque) is to be chosen. Of course a HST compressor may also be used in a capillary tube system.
Finally the compressor cooling conditions must also be considered. If the system has an oil cooling arrangement, a compressor with an oil cooler must be selected.
In a service situation a compressor with an oil cooler instead of a compressor without oil cooler can be used without problems, since the spiral can be completely ignored when it is not required.

1.5 Replacement of refrigerant

The best solution for a repair is to select the same refrigerant as used in the present system.
Secop compressors are supplied or were supplied in versions for the refrigerants R12, R22, R502, R134a, R404A/R507/R407C and for the flammable refrigerants R290 and R600a.
The refrigerants R12 and R502, which are covered by the regulations in the Montreal Protocol, may be used in very few countries only, and the refrigerants will eventually be phased out of production altogether.
For heat pump systems the refrigerant R407C is now used instead of R22 and R502.
The more environmentally acceptable refrigerant R134a has replaced R12, and the refrigerants R404A and R507 have replaced R22 and R502 in many applications.

The flammable refrigerants R290 and R600a
Maximum charge of these refrigerants in a system is 150 g according to today's relevant appliance standards, and they must be applied in small refrigerators only.
The flamable refrigerants must only be used in refrigeration systems meeting the requirements of EN/IEC 60335-2-24 or -2-89, including demands for flammable refrigerants. The service personnel must be specially trained for the handling. This implies knowledge of tools, transport of compressors and refrigerant as well as all relevant rules and safety regulations.
If open fire or electrical tools are used near the refrigerants R600a and R290, this must take place in conformity with current regulations.
The refrigeration systems must always be opened with a tube cutter.

Change from the refrigerants R12 or R134a to R600a is not permitted, since the refrigerators are not approved for use with flammable refrigerants, and the electrical safety has not been tested according to current standards. The same applies to change from the refrigerants R22, R502 or R134a to R290.

Blend refrigerants

Refrigerant	Trade name	Composition	Replacing	Application area	Applicable oils
R401A	Suva MP39	R22, R152a, R124	R12	L - M	Alkylbenzene
R401B	Suva MP66	R22, R152a, R124	R12	L	Alkylbenzene
R402A	Suva HP80	R22, R125, R290	R502	L	Polyolester Alkylbenzene
R402B	Suva HP81	R22, R125, R290	R502	L - M	Polyolester Alkylbenzene

Refrigerant blends
At the same time as the new environmentally acceptable refrigerants (R134a and R404A) were introduced, some refrigerant blends for service purposes were also introduced. They are more environmentally acceptable than the previously used CFC refrigerants (R12 and R502).
In many countries the refrigerant blends were only permitted for a short period, which meant that they were not widely spread in connection with small hermetic refrigeration systems.
Use of these refrigerants cannot be recommended for series production but they can be used for repair in many cases, see the table above.

Add in
This designation is used when filling up an existing refrigeration system with another refrigerant than the one originally charged. This is especially the case when problems arise which must be solved with as small an operation as possible.
Correspondingly, R22 systems were replenished with a small amount of R12 in order to improve the flow of oil back to the compressor. In several countries it is not allowed to add in on CFC systems (R12, R502,...)

Drop in
This term means that during service on an existing refrigeration system i.e. → 90% of the original mineral oil is poured out and replaced by synthetic oil, and a new suitable filter drier is mounted. Furthermore, the system is charged with another compatible refrigerant (i.e. blend).

Retrofit
The term retrofit is used about service on refrigeration systems replacing the CFC refrigerant by an environmentally acceptable HFC refrigerant. The refrigeration system is flushed, and the compressor is replaced by an HFC compressor. Alternatively the compressor oil is replaced by a suitable Ester oil. The oil must be changed several times after short operating periods, and the filter drier must be replaced.

In the case of oil replacement a statement from the compressor manufactorer on material compatibility is necessary.

2.
RULES FOR REPAIR WORK

To enable a hermetic refrigeration system to work as intended and to achieve a reasonable service life the content of impurities, moisture and non condensable gases must be kept on a low level. When assembling a new system these requirements are relatively easy to meet, but when repairing a defective refrigeration system the matter is more complicated. Among other things, this is due to the fact that faults in a refrigeration system often start disadvantageous chemical processes, and that opening a refrigeration system creates possibilities for contamination.
If a repair is to be carried out with a good result a series of preventive measures is necessary. Before stating any details about the repair work, some general rules and conditions have to be explained.

2.1
Opening of the system

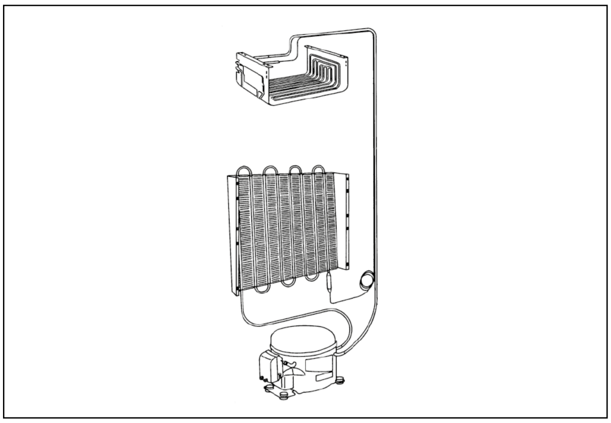

Fig. 5: Hermetic refrigeration system with capillary tube

If the refrigeration system contains a flammable refrigerant like e.g. R600a or R290, this will appear from the type label. A Secop compressor will be provided with a label as shown in Fig. 6.

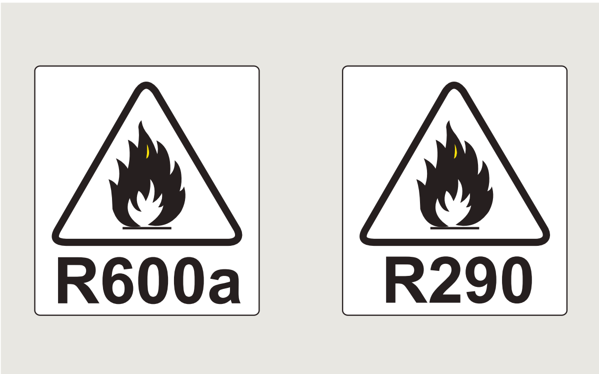

Fig. 6: Label on compressor for R600a & R290

Service and repair of such systems demand specially trained personnel. This implies knowledge of tools, transport of compressor and refrigerants as well as the relevant guidelines and safety rules.
When working with the refrigerants R600a and R290 open fire may only occur as described in existing guidelines.

Fig. 7 shows a piercing valve for mounting on the process tube, thus enabling an opening into the system for draining off and collecting the refrigerant as per instructions.

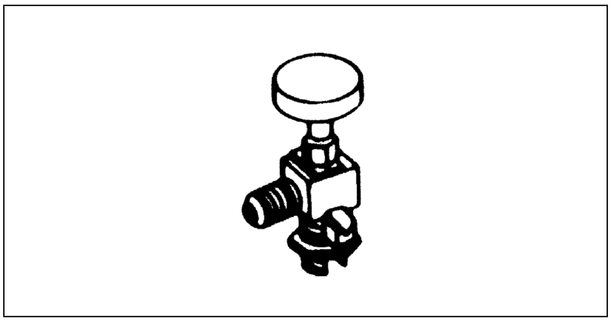

Fig. 7: Piercing valve

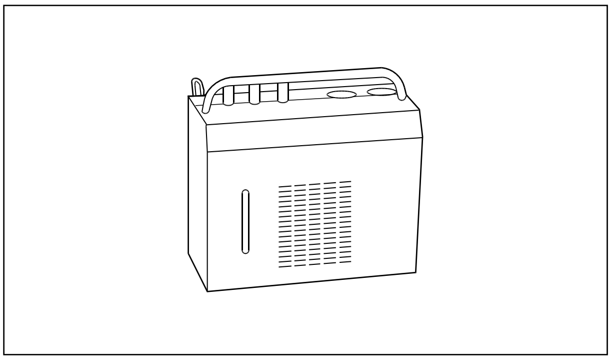

Fig. 8: Recovery unit for refrigerants

Before starting to cut tubes in the refrigeration system it is recommended to clean the tubes with an emery cloth in the places to be cut. Thus the tubes are prepared for the subsequent soldering, and entry of dirt grains into the system is avoided.
Only use tube cutter, never metal-cutting saw, for cutting tubing in a refrigeration system. Merely a small burr left in the system can cause a subsequent compressor breakdown. All refrigerants must be collected as per instructions.
When a capillary tube is cut it is essential not to admit burrs or deformations to the tube. The capillary tube can be cut with special pliers (see Fig. 9), or with a file a trace can be produced in the tube which can then be broken.

Fig. 9: Special pliers for capillary tubes

2.2 Brazing under an inert protective gas

A system charged with refrigerant must never be heated or soldered, especially not when the refrigerant is flammable. Soldering on a system containing refrigerant will cause formation of refrigerant decomposition products.
Once the refrigerant is drained off, an inert protective gas must be filled into the system. This is done by a thorough blow-through with dry nitrogen. Before the blow-through the system must be opened in one more place.

If the compressor is defective it would be appropriate to cut the suction and pressure tube outside the compressor connectors, not opening the process tube. However, if the compressor is functional, it is recommended to cut the process tube. Blow-through must be done first through evaporator and then through condenser. An inlet pressure of approx. 5 bar and a blow-through of approx. 1-2 minutes would be satisfactory on appliances.

2.3
Filter drier

The filter drier is absorbing the small water amounts released through the life of the system. It acts as a trap strainer and prevents blocking of the capillary tube inlet and problems with dirt in the expansion valve.

If a refrigeration system has been opened the filter drier must always be replaced to ensure sufficient dryness in the repaired system.

Replacement of a filter drier must always be done without the use of a torch. When heating the filter drier there is a risk of transferring the absorbed moisture amount to the system. The possibility of a flammable refrigerant being present must also be considered.
In case of a non-flammable refrigerant, a blowpipe flame may be used but the capillary tube must be broken and then dry nitrogen must be blown through the filter towards the open air while the filter drier is detached.
Normally a filter drier can absorb a water amount of approx. 10% of the desiccant weight. In most systems the capacity is not utilized, but in cases of doubt about the filter size it is better to use an oversized filter than one with a small capacity.
The new filter drier must be dry. Normally this is no problem but it must always be ensured that the filter drier sealing is intact to prevent moisture collection during storage and transport. The filter drier must be mounted in a way that the flow direction and gravitation have an effect in the same direction.

Thus it is prevented that the Molecular Sieve (MS) balls wear each other and produce dust, which may block the capillary tube inlet. This vertical position also ensures a quicker pressure equalization in capillary tube systems. See Fig. 10.

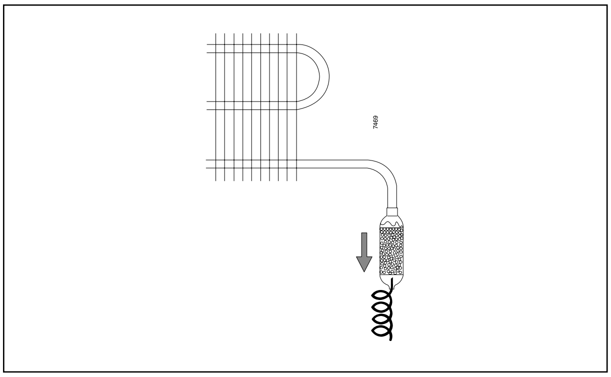

Fig. 10: Correct location of filter drier

As water has a molecule size of 2.8 Ångstrøm, molecular sieve filters with a pore size of 3 Ångstrøm are suitable for the normally used refrigerants. The water molecules are absorbed in the pores of the desiccant, whereas the refrigerant can freely pass through the filter.

Compressor	Filter drier
P and T	6 gram or more
F and N	10 gram or more
SC	15 gram or more

UOP Molecular Sieve Division, USA (earlier Union Carbide)	4A-XH6	4A-XH7	4A-XH9
R12	x	x	x
R22, R502	x		x
R134a, R404A		x	x
HFC/HCFC blends			x
R290, R600a		x	x
Grace Davision Chemical, USA		574	594
R12, R22, R502		x	x
R134a			x
HFC/HCFC blends			x
R290, R600a			x
CECA S.A., France		NL30R	Siliporite H3R
R12, R22, R502		x	x
R134a		x	x
HFC/HCFC blends			x
R290, R600a			x

2.4
Moisture penetration during repair

A repair must always be done quickly, and no refrigeration system must be open to the atmosphere for more than 15 minutes, to avoid moisture intake. Therefore it is a good rule to have all replacement components made ready before the system is opened.

If it is not possible to complete the repair continuously, the open system must be carefully sealed off and charged with a slight overpressure of dry nitrogen to avoid moisture penetration.

2.5
Preparation of compressor and electrical equipment

Rubber grommets are to be mounted in the compressor base plate while the compressor is standing on its base plate. If the compressor is placed upside down oil will gather in the connectors, which leads to soldering problems. Never use rubber grommets from a defective compressor because they are often aged and harder than new rubber grommets.
Remove the cap (Capsolute) from the process connector of the new compressor and solder a process tube into the connector. Leave the compressor closed until it is to be soldered into the system.
It is recommended to plug all connectors on compressor, filter drier and system if for some reason the repair is delayed.

The aluminium caps on the connectors must not be left in the finished system.

The caps are only intended to protect the compressor during storage and transport and do not provide tightness in a system under pressure. The caps make sure that the compressor has not been opened after it left Secop. If the caps are missing or are damaged, the compressor should not be used until it has been dried and the oil has been replaced.

Never reuse old electrical equipment.

It is always recommended to use new electrical equipment with a new compressor, since use of old electrical equipment with a new compressor may lead to the compressor soon developing defects.
The compressor must not be started without a complete starting device. Since part of the starting circuit resistance lies in the starting device, start without the complete starting device does not provide good starting torque and may result in a very quick heating of the compressor start winding, causing it to be damaged.

The compressor must not be started in vacuum.
Starting the compressor in vacuum may cause a breakdown inside between the pins of the current lead-in, since the insulation property of the air is reduced at falling pressure.

Fig. 11 shows a wiring diagram with PTC starting device and winding protector. A run capacitor connected to the terminals N and S will reduce energy consumption on compressors designed for this.

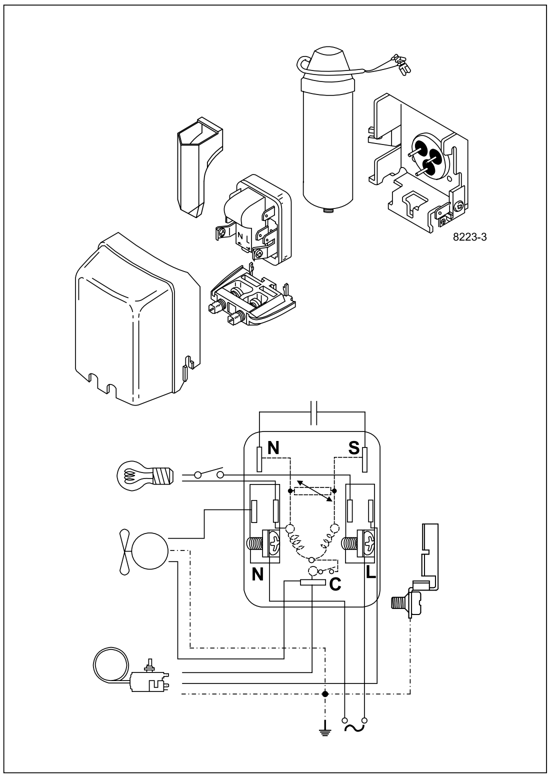

Fig. 11: Wiring diagram with PTC and winding protector

Fig. 12 shows a wiring diagram with starting relay and starting capacitor as well as a motor protector mounted outside the compressor.
Fig. 13 shows a wiring diagram for large SC compressors with CSR motor.

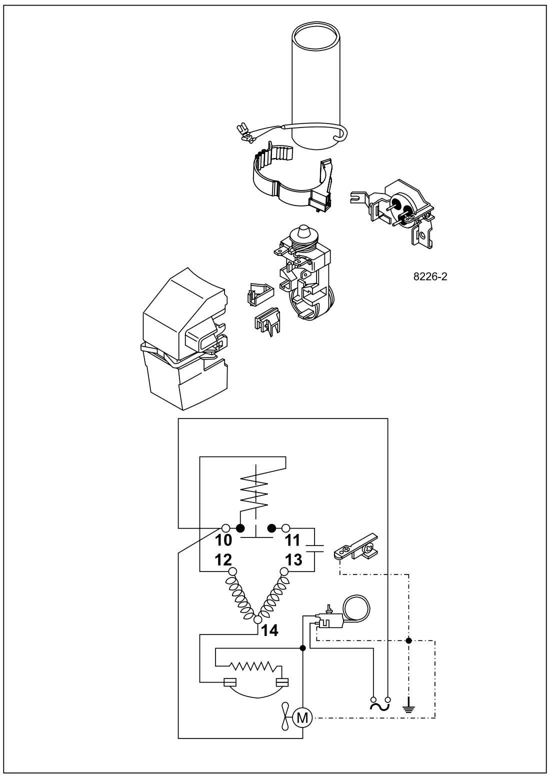

Fig. 12: Wiring diagram with starting relay and starting capacitor

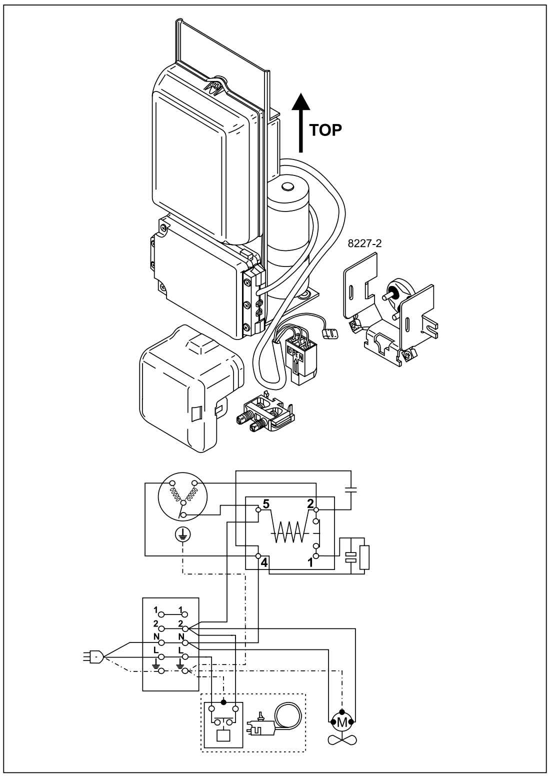

Fig. 13: Wiring diagram for CSR motor

2.6 Soldering

Creation of the correct soldering fit is important. Recommended soldering gaps for brazing joints.

If the connection tube is made of steel a solder without phosphor and with a melting point below 740°C must be used.

	Material	**Material**
Silver brazing solder	Copper tubes	Steel tubes
Easy-flo	0.05 - 0.15 mm	0.04 - 0.15 mm
Argo-flo	0.05 - 0.25 mm	0.04 - 0.2 mm
Sil-fos	0.04 - 0.2 mm	Not suitable

The connectors of most Secop compressors are copperplated steel tubes welded into the compressor housing. The welded connections cannot be damaged by overheating during soldering.
It is possible to drift the 6.2 mm connectors to 6.5 mm, which fits a ¼" (6.35 mm) tube, but it is not recommended to drift the connectors more than 0.3 mm. During drifting a backstop is necessary to prevent the connector from breaking off. See Fig. 14.

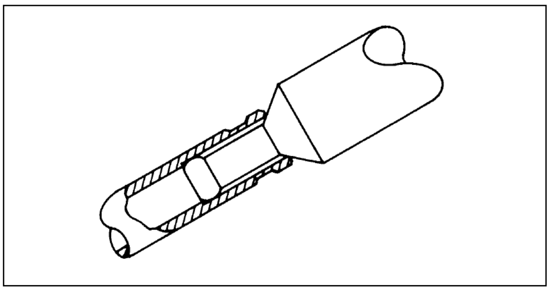

Fig. 14: Drifting of connector

Instead of drifting the connectors a reducing pipe as shown in Fig. 15 can be used.

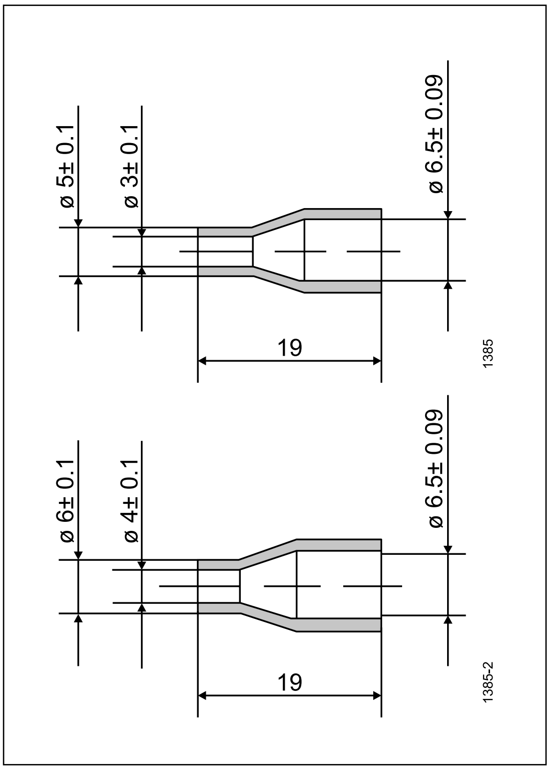

Fig. 15: Reducing pipe

Soldering of connectors to a copper tube may be done with a solder containing 2% silver. The so-called phosphorus solder may also be used provided that the connected tube is made of copper.

It can also be appropriate to use just one solder for all joints, and in this case it is recommended to use a solder with a silver content of at least 30% to keep the melting temperature in the solder as low as possible. Thus overheating of the brazing joints is avoided. A flux must be used with the solder, and it is recommended to stir this into alcohol instead of water (approx. 1/3 flux in 2/3 alcohol). In this way the risk of water entering to the system is reduced.
After soldering the flux residues must be removed by brushing the joint.

To achieve a sufficiently high torch flame temperature it is recommended to use both acetylene and oxygen or propane and oxygene since e.g. bottled gas provides a temperature too low.

Brazing of steel connectors is slightly different from brazing of copper connectors.

Below you will find guidelines for brazing of steel connectors:

During heating the temperature must be kept as close to the solder melting point as possible. Overheating will cause damage of the tube surface, which reduces the chances for a good joint.

Use the soft heat in the torch flame when the joint is heated.
Distribute the flame in a way that at least 90% of the heat is concentrated around the connector and approx. 10% around the connection tube. See Fig. 16.

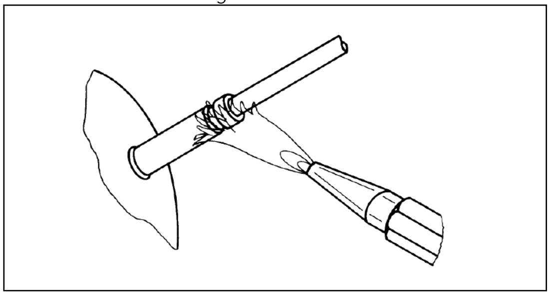

Fig. 16: Soldering process for steel connector

When the connector is cherry red (approx. 750°C), the flame must be moved to the connection tube for a few seconds. See Fig. 17.

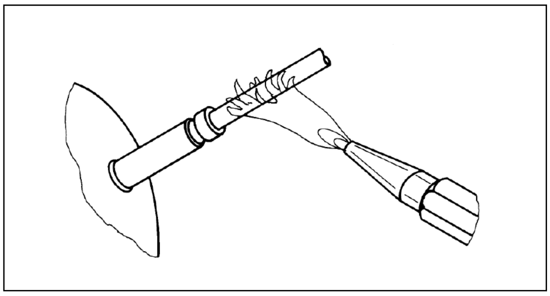

Fig. 17: Soldering process for steel connector

Continue heating the joint with the soft flame and add solder. See Fig. 18.

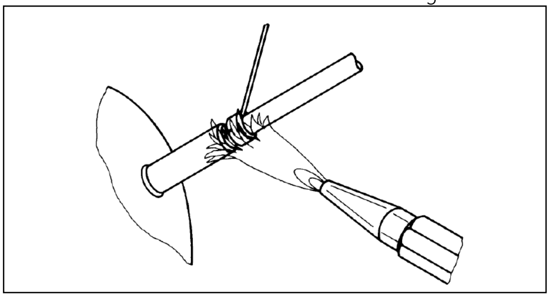

Fig. 18: Soldering process for steel connector

Draw the solder into the soldering gap by slowly moving the flame towards the compressor and then removing the flame. See Fig. 19.

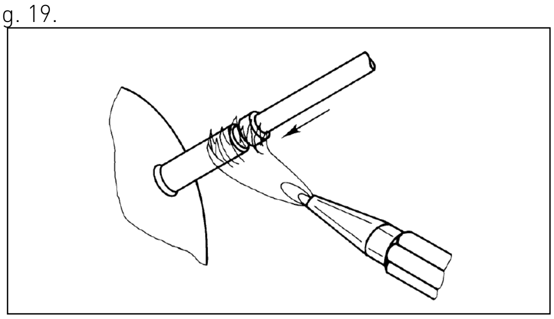

Fig. 19: Soldering process for steel connector

Soldering of capillary tubes requires quite some precision, partly because overheating will quickly occur, and partly because the capillary tube is easily blocked.

When the capillary tube is mounted into the filter drier it can be put so far in that it pushes against the filter mesh. This may cause blockages, as the refrigerant can only pass a limited part of the filter mesh. On the other hand the capillary tube may not be put far enough into the filter drier, thus risking it to be closed by solder. These problems can be avoided by using capillary tube pliers as shown in Fig. 20.

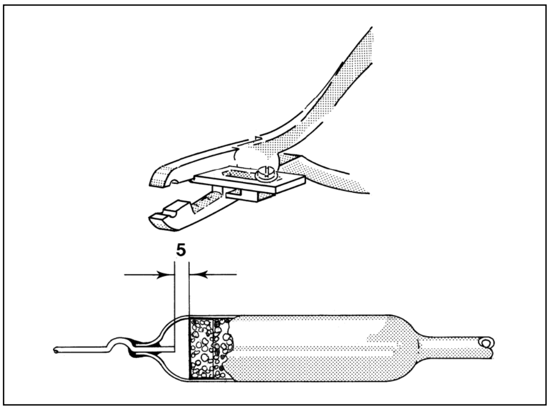

Fig. 20: Capillary tube correctly located in the filter drier

Depending on the routine a large or small torch size must be used. In some cases it may be appropriate to use a double torch as shown in Fig. 21, as both sides of the joint can then be heated at the same time.

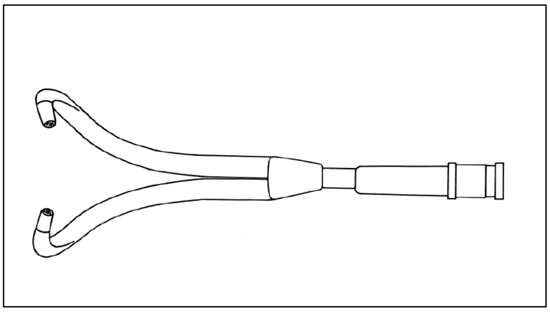

Fig. 21: Double blowpipe

Refrigeration systems containing the flammable refrigerants R600a and R290 must not be soldered. In these cases a LokRing® connection can be used.

2.7
LokRing® connections

During service on systems with flammable refrigerants LokRing® connections may be used for tube joints, especially for closing the process tube. With a LokRing® connection as shown in Fig. 22 tight tube joints can be established, in aluminium, copper and steel. Before assembly the tube ends must be carefully cleaned with steel wool or an emery cloth, and the cleaning must be done with rotating movements to avoid scratches along the tubes, which may complicate sealing. Make sure that no dirt is entering the system.

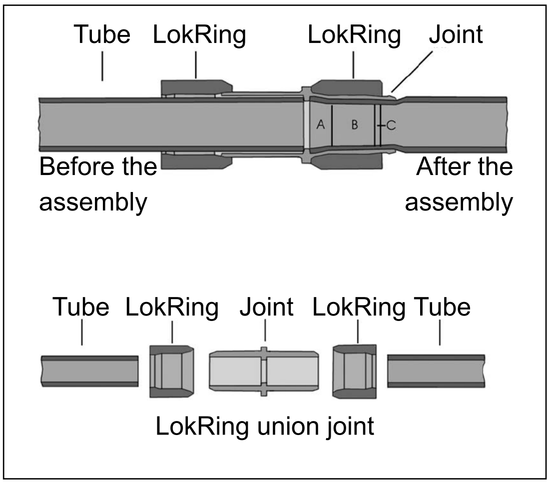

Fig. 22: LokRing® connection

To ensure a tight sealing the tube ends must be moistened with LokPrep®, since this material fills irregularities in the tube surface, if any. Once the tube ends have been inserted in the LokRing® connection until stop the tubes must be turned to obtain a good distribution of LokPrep® on the tube surfaces. Subsequently the joint must be pressed together with a special tool as shown in Fig. 23.

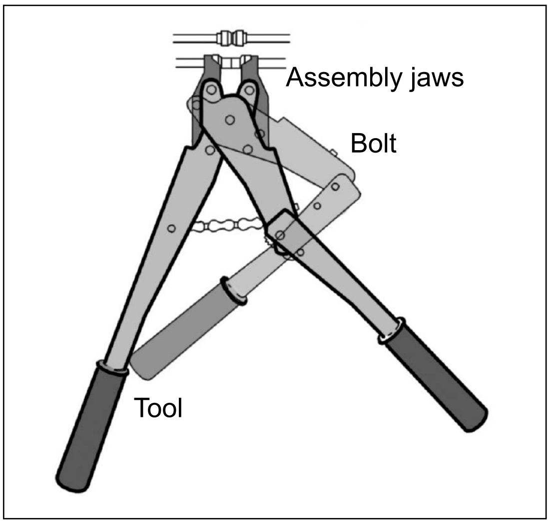

Fig. 23: Tool for LokRing®

After 2-3 minutes LokPrep® has hardened, and the joint in stable.

2.8 Evacuation

When a refrigeration system is assembled it must be carefully evacuated (remove air from the system), before it is charged with refrigerant. This is necessary to achieve a good repair result. The main purpose of the evacuation is to reduce the amount of non-condensable gasses (NCG) in the system, and secondarily a limited drying will take place. Moisture in the system may cause ice blocking, reaction with the refrigerant, ageing of the oil, acceleration of oxidation processes and hydrolysis with insulation materials.

Evacuation of refrigerating system.

Non-condensable gasses (NCG) in a refrigeration system may mean increased condensing pressure and thus greater risk of coking processes and a higher energy consumption.
The content of NCG must be kept below 1 vol. %.

The evacuation may be done in different ways depending on the volume conditions on the suction and discharge side of the system. If the evaporator and compressor have a large volume, one-sided evacuation may be used, otherwise double-sided evacuation is recommended.

One-sided evacuation is made through the compressor process tube but this method means slightly worse vacuum and slightly higher content of NCG. From the discharge side of the refrigeration system the air must be removed through the capillary tube, which results in a substantial restriction. The result will be a higher pressure on the discharge side than on the suction side.
The main factor for the NCG content after evacuation is the equalized pressure in the system, which is determined by the distribution of volumes. Typically, the volume on the discharge side will constitute 10-20% of the total volume, and therefore the high end pressure has less influence on the equalized pressure here than the large volume and low pressure on the suction side.

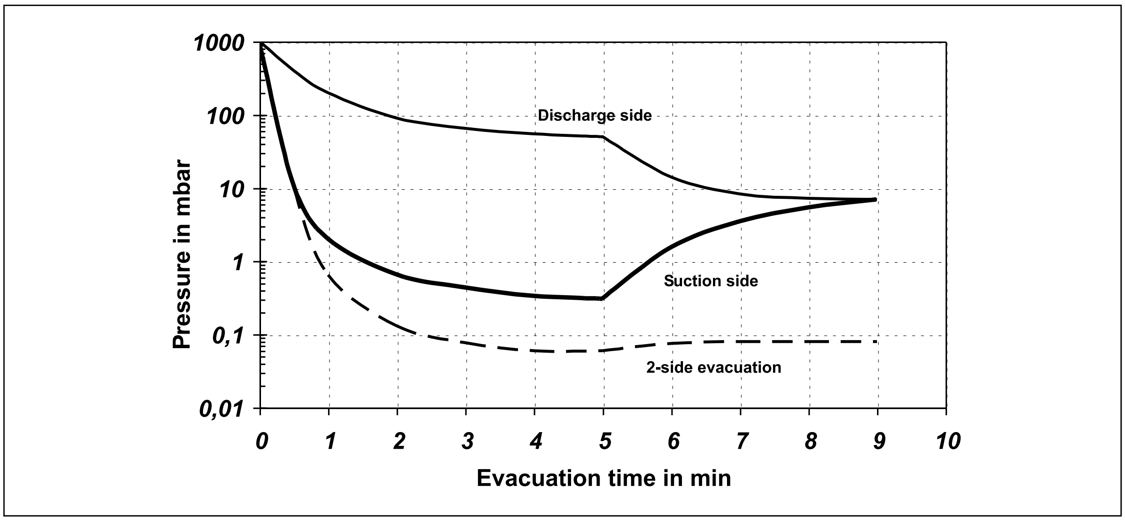

Fig. 24: Evacuation process

Calculation example concerning the amount of NCG after evacuation in a system with:

- Discharge side: $pD = 50$ mbar volume $VD = 15\%$
- Suction side: $ps = 0.3$ mbar volume $Vs = 85\%$

Example:
After the evacuation:

- Total volume $V = 2.25$ l
- Discharge side $p_1 = 50$ mbar
  $V_1 = 15\% = 0.3375$ l
- Suction side $p_2 = 0.3$ mbar
  $V_2 = 85\% = 1.9125$ l

$$P_{equilized} = \frac{p_1 \cdot V_1 + p_2 \cdot V_2}{V_{total}}$$

$$P_{equilized} = \frac{50 \cdot 0.3375 + 0.3 \cdot 1.9125}{2.25} = 7.755 \text{ mbar}$$

Typical operating point of example appliance with R134a.

Evaporating temperature –30°C suction pressure 0.844 bar.
Condensing temperature +44°C discharge pressure 11.30 bar.
Pressure ratio 13.39.

NCG will be pumped with the refrigerant and be compressed with the same pressure ratio.

$(p \cdot V)_{NCG} = 7.755 \cdot 2.25 = 17.45$ mbar l

$(p \cdot V)_{R134a} = p_1 \cdot V_1 + p_2 \cdot V_2 =$
$0.844 \cdot 1.9125 + 11.30 \cdot 0.3375 = 5.4279$ bar l

$$NCG_{vol} = \frac{(p \cdot V)_{NCG}}{(p \cdot V)_{R134a}} = \frac{17.45}{5.4279 \cdot 100} \cdot 0.0032 = 0.32\%$$

This calculation does not take into account the quantity of air absorbed in the compressor's oil filling, which can vary from 0 to 10 vol.%. This means that the NCG content will be slightly higher in practice.

One-sided evacuation must be done until a sufficiently low pressure is obtained in the condenser. Here it might be necessary with one or more short evacuations with intervening pressure equalizations.

Double-sided evacuation must be done until a sufficiently low pressure is obtained.
These procedures require the components to have a low moisture content when being mounted.
By means of the double-sided evacuation it is possible to obtain a low pressure in the system within a reasonable time. This means that a leak test is possible before charging the refrigerant.

Fig. 24 shows a typical course of a one-sided evacuation from the compressor process tube. It also shows a pressure difference in the condenser, which may be remedied by increasing the number of pressure equalizations.
The broken line shows a procedure where the two sides are evacuated at the same time. When time is limited, the final vacuum depends only on the vacuum pump capacity and the content of volatile components or non-condensable gasses in the oil charge.

Fig. 25 shows an example of an evacuation process with built-in leak test. The vacuum obtained depends on the process chosen.

Double-sided evacuation gives the best result and must be recommended.

Once a vacuum below 1 mbar is obtained, the system must be pressure equalized before the final evacuation and charge of refrigerant.
Normally mbar is used as an expression of a vacuum but other entities are also used, e.g.;
1 mbar = 0.75 torr = 0.75 mmHg
1 mbar = 100 Pascal = 7.5E2 micron

In a tight system there will always be a certain pressure rise when the connection to the vacuum pump is closed due to desorption of moisture from inner surfaces in the system and evaporation of volatile components from the compressor oil charge. In practice a pressure rise of approx. 0.1 mbar is anticipated. This pressure rise is often used as an indication of the degree of dryness and tightness in the system and is very much used during service.

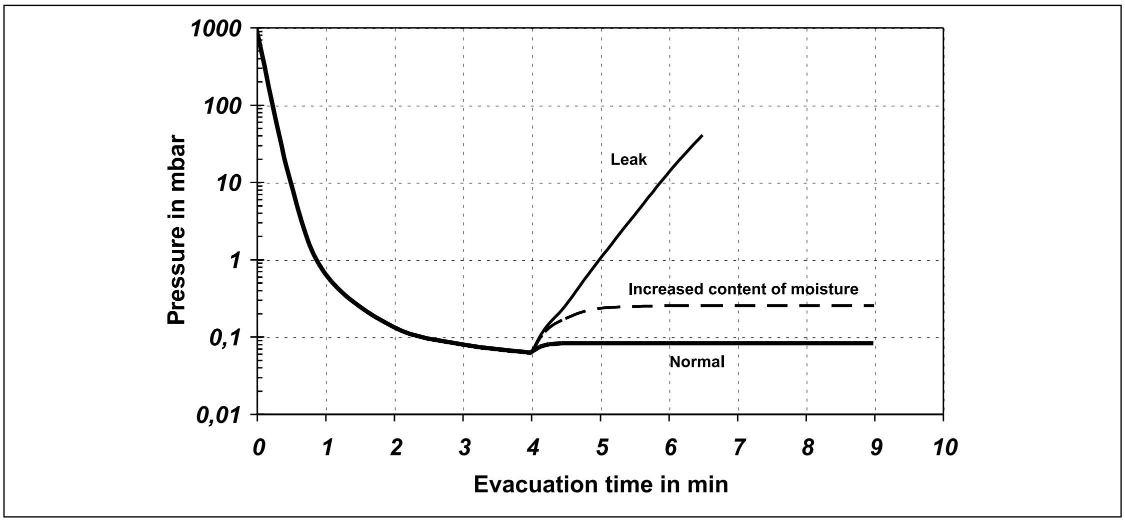

Fig. 25: Evacuation process with leak test

2.9
Vacuum pump and vacuum gauge

In order to perform a sufficient evacuation a good vacuum pump must be available. See Fig. 26.

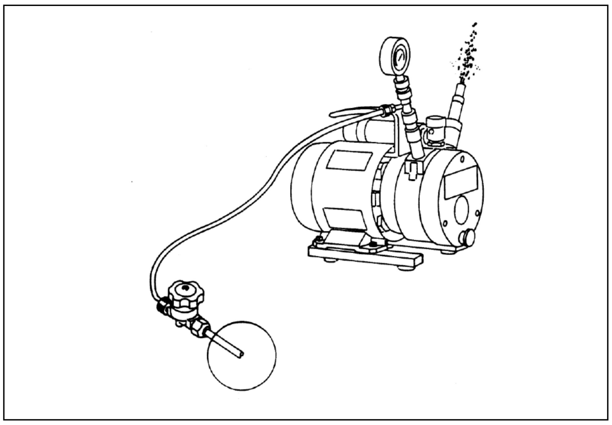

Fig. 26: Vacuum pump

For stationary use a two-stage 20 m^3/h vacuum pump can be recommended but for service a smaller two-stage 10 m3/h vacuum pump is better suited due to its lower weight.
A hermetic refrigeration compressor is not suitable for the purpose since it is not able to produce a sufficiently low pressure. Also, a compressor used as a vacuum pump would be overheated and damaged. The insulation resistance of the air is reduced at falling pressure, and therefore an electrical breakdown at the current lead-in or in the motor of the hermetic compressor will quickly occur.
The same vacuum pump may be used for all types of refrigerants provided that it is charged with Ester oil.
A flameproof vacuum pump must be used for refrigeration systems containing the flammable refrigerants R600a and R290.

There is no point in having a suitable vacuum pump available if the vacuum obtained cannot be measured. Therefore it is strongly recommended to use an appropriate robust vacuum gauge (Fig. 27) able to measure pressure below 1 mbar.

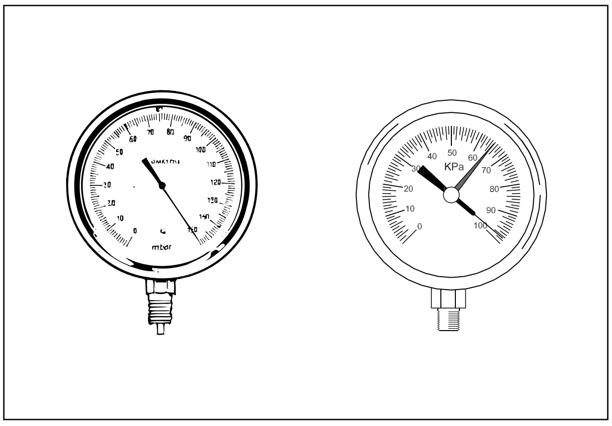

Fig. 27: Vacuum gauge

3.
HANDLING OF REFRIGERANTS

To ensure a reasonable refrigeration system life the refrigerant must have a maximum moisture content of max 20 ppm (20 mg/kg).
Do not fill refrigerant from a large container into a filling bottle through several container sizes, as with every drawing-off the water content in the refrigerant is increased considerably.

Flammable refrigerants R290 and R600a
R600a must be stored and transported in approved containers only and must be handled according to existing guidelines.

Do not use open fire near the refrigerants R600a and R290.
The refrigeration systems must be opened with a tube cutter.

Conversion from refrigerants R12 or R134a to R600a is not permitted, since the refrigerators are not approved for operation with flammable refrigerants, and the electrical safety has not been tested according to existing standards either. The same applies to conversion from refrigerants R22, R502 or R134a to R290.

3.1
Charging with refrigerant

Normally, charging with refrigerant is no problem with a suitable charge and provided that the equipment present charging amount of the refrigeration system is known. See Fig. 28.

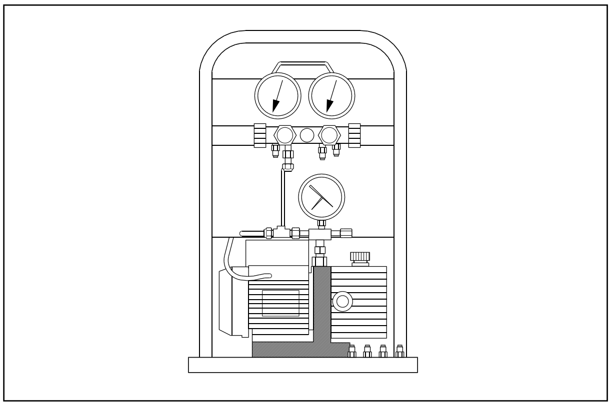

Fig. 28: Charging board for refrigerant

Always charge the refrigerant amount and type stated by the refrigerator manufacturer. In most cases this information is stated on the refrigerator type label.
The different compressor brands contain different amounts of oil, so when converting to another brand it may be advisable to correct the amount of refrigerant.
Charge of refrigerant can be made by weight or by volume. Flammable refrigerants like R600a and R290 must always be charged by weight. Charging by volume must be made with a refrigerant charging cylinder.
The refrigerant R404A and all other refrigerants in the 400 series must always be charged as liquid.

If the charging amount is unknown, charging must be done gradually until the temperature distribution above the evaporator is correct. However, mostly it will be more appropriate to overcharge the system and then gradually draw off refrigerant until the correct charge has been obtained. The refrigerant charge must be made with running compressor, refrigerator without load and with the door closed.

The correct charge is characterized by the temperature being the same from inlet to outlet of the evaporator.
At the compressor suction connector the temperature must be approx. ambient temperature. Thus transfer of moisture to the refrigerator insulation is avoided. See Fig. 29.

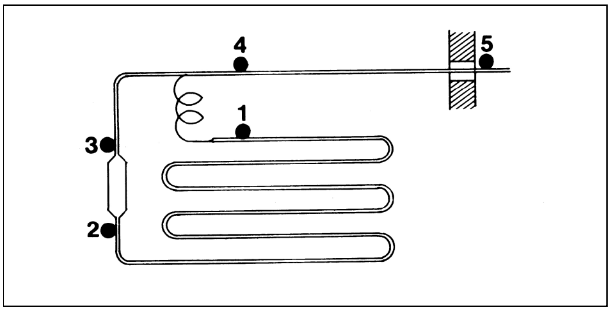

Fig. 29: Evaporator temperatures

Systems with an expansion valve must be charged with refrigerant until there are no bubbles in the sight glass, which should be placed as close to the expansion valve as possible.

3.2
Maximum refrigerant charge

If the permissible limit of refrigerant charge stated in the compressor Data Sheet is exceeded the oil will foam in the compressor after a cold start and may result in a damaged valve system in the compressor. The refrigerant charge must never exceed the amount that can be contained in the condenser side of the system.

Compressor type	Max. refrigerant charge			
	134a	R600a	R290	R404A
P	300 g	120 g	-	-
T	400 g*	150 g	150 g	600 g
D	-	150 g	-	-
TL ... G	600 g	150 g	150 g	-
N	400 g*	150 g	150 g	-
F	900 g	150 g	-	850 g
S	1300 g	-	150 g	1300 g
G	2000 g	-	-	2000 g
SC Twin	2200 g	-	-	2200 g

Please also refer to the compressor Data Sheets, as the present maximum refrigerant charge may deviate on single types from the statements in the form. The maximum charge of 150 g for R600a and R290 is an upper safety limit of the appliance standards, whereas the other weights are stated to avoid liquid hammer.

3.3
Test

Before finishing a repair the complete refrigerator must be tested to make sure that the expected result has been achieved. It must be ensured that the evaporator can be cooled down and thus enable the requested temperatures to be obtained.
For systems with a capillary tube as the throttling device it is important to check if the compressor runs satisfactorily on the thermostat. Further it must be checked if the thermostat differential allows for sufficient standstill periods for pressure equalization so an LST compressor (low starting torque), if any, can start and operate without tripping on the motor protector.
In areas where undervoltage may occur it is important to test operating conditions at 85% of the nominal voltage, since both starting and stall torque of the motor will decline when the voltage is falling.

3.4
Leak test

A hermetic refrigeration system must be tight, and if a refrigerator is to have a reasonable lifetime it is necessary to keep any leaks below 1 gram refrigerant annually.
Many refrigeration systems with the flammable refrigerants R600a and R290 have charging amounts below 50 g, in these cases the leaks should be below 0.5 g refrigerant annually. This requires high-quality electronical test equipment that can measure these small leak rates.
It is relevant to test all soldered joints of the system, also in places where no repair has been made. The joints on the discharge side of the system (from the compressor discharge connector until condenser and filter drier) must be examined during operation of the compressor, which results in the highest pressures. Evaporator, suction tube and compressor must be examined while the compressor is not operating and the pressure in the system is equalized, as this results in the highest pressures here. See Fig. 30.
If no electronic detector (Fig. 30) is available the joints may be examined with soapy water or with spray, but of course small leaks cannot be found with these methods.

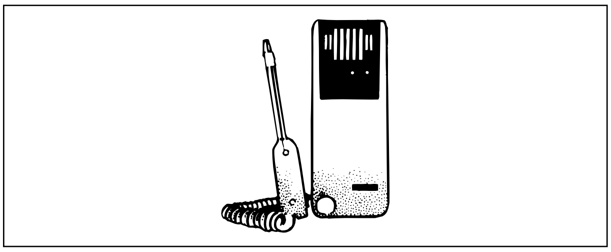

Fig. 30: Leak detector

4.
REPLACEMENT OF DEFECTIVE COMPRESSOR

Below a procedure for replacement of a defective compressor in a hermetic refrigeration system is outlined, following the fundamental rules. A precondition is that there is a refrigerant overpressure in the system and that the system is not contaminated with moisture. The refrigerant must correspond to the original refrigerant.
During fault finding the compressor is found to be defective. If it turns out that the motor has burnt resulting in strong contamination of the system then another procedure is required.

4.1
Preparation of components

By starting with preparation of the replacement components later delays with opened system are avoided, and thus also increased risk for admission of moisture and impurities.
A process tube with process valve must be mounted into the process connector of the new compressor.
In some cases it may be an advantage to mount a piece of connecting tube into the compressor suction connector.
By doing so the later connection of the suction tube to the compressor can take place further away from the compressor if mounting conditions in the machine compartment are narrow.
When the compressor is ready process valve and connectors must be closed. Further, the correct filter drier type must be ready but the cover must remain intact.

4.2
Removal of charge

Place a piercing valve connection to a recovery unit on the compressor process tube. Puncture the tube and collect the refrigerant according to guidelines. Follow the rules described earlier.

4.3
Removal of defective compressor

Cut the compressor suction and discharge tube with a tube cutter approx. 25-30 mm from the connectors in question. Beforehand, the places to be cut must be trimmed with emery cloth preparing the soldering.
If the compressor is to be tested later, the tube ends must be closed with rubber plugs.
To facilitate any analysis or guarantee repair later the compressor must be provided with the cause for the fault and the refrigerator production date. Compressors for R600a and R290 must always be evacuated and sealed before they are returned to refrigerator manufacturer or dealer.

4.4
Removal of refrigerant residues

To avoid decomposition of any refrigerant residues in the system during the subsequent soldering operations the system must be thoroughly blown through with dry nitrogen. This is done by connecting the connection tube from the bottle with dry nitrogen first to the cut suction tube and afterwards to the cut discharge tube.

4.5
Removal of filter drier

The filter drier at the condenser outlet should be cut with a tube cutter but another method may also be used. Produce a slight flow of dry nitrogen through the discharge tube to the condenser and maintain this flow while the filter is carefully removed with a torch. Avoid heating the filter enclosure itself.

4.6
Cleaning of solder joints and reassembly

Soldering silver must be removed from the condenser outlet. This is best done by brushing it off while the soldering silver is still liquid. The other tube ends are to be prepared for soldering in case this was not yet done. Take care that dirt and metal grains are not admitted to the system when trimming soldered joints. If necessary, blow through with dry nitrogen while trimming.
The new filter drier must be mounted at the condenser outlet, and the filter must be kept covered until assembly can take place. Avoid heating the filter enclosure itself with the flame.
Before soldering the capillary tube into the filter a slight stop must be produced on the tube as described earlier to ensure the tube end to be at the right place in the filter to avoid blockings. Be careful during soldering of the capillary tube and avoid burnings.
Mount the compressor, which already during preparation must be provided with rubber grommets. Mount the electrical equipment and connect the wires. Evacuation and charge are to be made as described in chapters 2.8 and 3.1. Test to be made as described in chapters 3.3 and 3.4. When the process tube is squeezed and soldered the process valve must be removed.

5. FROM R12 TO OTHER REFRIGERANTS

As long as new or recycled R12 refrigerant is available this should be used. It is impossible to provide R12 and illegal to use it. It should be thoroughly considered whether repair is worth while. It is hardly worth it to repair old small refrigeration systems if it involves replacement of the compressor. Another consideration is use of an alternative refrigerant instead of R12.

5.1 From R12 to alternative refrigerants

For low and medium evaporating temperatures R401A and for low evaporating temperatures R401B has been used as replacement for R12, however, use of these so-called refrigerant blends cannot be recommended. If R12 is not available or if it is not permitted to use, R134a is recommended. See also chapter 1.5.

5.2 From R12 to R134a

A conversion from R12 to R134a involves a considerable risk of possible residues of decomposed refrigerant, especially chlorine ions, or intact refrigerant and residues of mineral oil or alkylbenzenes staying in the system. Therefore a procedure must be established during which these undesirable substances are brought down to a level not causing substantial inconvenience in the repaired refrigeration system. Before starting conversion to R134a it must be ensured that the original compressor motor has not "burnt". If this is the case, the compressor should not be replaced since the contamination risk is too high.
Conversion to R134a always requires a compressor replacement since an original R134a compressor must be mounted even if the R12 compressor is intact. The following procedure must be performed continuously. If interruptions should occur, all open tubes and tube connections must be plugged. It is assumed that the system is clean and that there is a simple evaporating circuit.

- If the system has lost its charge the leak must be traced.
- Mount a service valve on the compressor process tube.
- Collect the refrigerant which is left.
- Equalize to atmospheric pressure with dry nitrogen.
- Remove compressor and filter drier from the system.
- Flush through all system components with dry nitrogen.
- Perform the repair.
- Mount a new R134a compressor with corresponding cooling capacity.
- Mount a new filter drier with desiccant 4AXH7 or 4AXH9 or equivalent.
- Evacuate and charge the system with R134a.

For LBP systems the optimum R134a charge will be smaller than the original R12 charge. It is recommended to start by charging 75% of the original charge and then gradually increase the charge until the system is balanced.

- Seal the process tube.
- Check if there are leaks.
- Operate the system.
- After the repair is finished it should always be marked on the system which refrigerant and compressor oil type it contains.
- After reassembly the system will be functional but minor oil residues from the R12 system will circulate, which may in periods disturb injection in the evaporator, especially in capillary tube systems. Whether this is vital for the practical use of the refrigeration system depends on the amount of oil residue.

5.3 From R134a to R12

A procedure corresponding to the one described in chapter 5.2 can be used. Use an original R12 compressor, R12 refrigerant and a filter drier of the type 4A-XH6, 4A-XH7 or 4A-XH9. Note that the R12 charge will be bigger than the original R134a charge and that in most countries the use of R12 is not permitted, but in some special cases it can be an alternative.

5.4 From R502 to R404A

It is assumed that the compressor is defective and must be replaced by an original R404A compressor but the new compressor must be charged with approved Polyolester oil. The filter drier must be replaced by a new filter with a desiccant of the type 4A-XH9. Oil residues from the original compressor, mineral oil or alkyl benzene, must be removed from the system components. If the system is very contaminated it must be thoroughly flushed with dry nitrogen. In exceptional cases the compressor oil can be replaced. The subsequent procedure is described in chapter 5.2.

6.
SYSTEMS CONTAMINATED WITH MOISTURE

For systems contaminated with moisture it applies that the degree of contamination may be vary greatly, and the scope of the repair will vary accordingly. Systems containing moisture can be divided into two categories, namely the ones with a low degree of contamination and the ones with a high degree of contamination.
Systems with a low degree of contamination are intact and maintain a refrigerant overpressure. Systems with a high degree of contamination, however, are characterized by having been in contact with the atmosphere or moisture has been added directly. The two types of defect will be treated independently.

6.1
Low degree of contamination

This defect is usually characterized by the cooling often being interrupted due to ice blocking in the capillary tube or in the expansion valve. With heat supply the ice blocking is gradually removed, but if the refrigerant circulates the blocking will quickly build up again.
This defect may be due to following reasons:

The system has not been assembled carefully enough.
The components used may have been moist.
A refrigerant with a moisture content too high may have been used.
The system will often be new or it has just been repaired. Usually the moisture amounts are small, and therefore the defect can normally be remedied by replacement of refrigerant and filter drier. The procedure is as follows.

a) Open the system at the process tube and collect the refrigerant.
It is an advantage to first let the compressor run until it is hot. In this way the moisture and refrigerant amount left in the motor or in the oil is reduced.
When ice is blocking capillary tube or expansion valve it is possible to run the compressor hot but the system will not run.
If the capillary tube or expansion valve are accessible, the place of blocking may be kept hot with a heating lamp or a cloth with hot water to obtain circulation of the refrigerant.
The evaporating temperature in the system may also be increased by heating the evaporator. Do not use an open flame for heating.

b) After collecting the refrigerant the system must be blown through with dry nitrogen. Nitrogen injection must take place through the compressor process tube, and first the suction side and then the discharge side must be blown through, first directing the nitrogen flow from the compressor through the suction tube and evaporator and out through the capillary tube, then through compressor and condenser and out through the filter drier at the condenser outlet. It is an advantage to blow through with so much pressure that any oil in the components is removed.

c) Replace filter drier and process tube as described earlier. It pays to use an oversized filter drier.

d) When the system is reassembled, evacuation must be carried out very carefully. Charge and test according to earlier mentioned guidelines.

6.2
High degree of contamination

If there is a rupture in a refrigeration system and the refrigerant overpressure escapes, moisture contamination will take place. The longer the time the system is open to the atmosphere the higher the degree of contamination. If the compressor is operating at the same time, conditions are further worsened. The admitted moisture amount will distribute in the compressor, filter drier and other system components depending on their ability to hold the moisture.
In the compressor it will especially be the oil charge that absorbs the water. In the evaporator, condenser and tubes the contamination will primarily be determined by the oil amounts present here. Of course the largest water amounts will be in compressor and filter drier. There is also a high risk that valve coking has started damaging the compressor Therefore compressor and filter drier must be replaced during the normal repair procedure.

a) Remove the compressor from the system with a tube cutter.
b) Break the capillary tube at the condenser outlet, and blow through the condenser with dry nitrogen as protective gas.
Remove the filter drier.
Repeat the blow-through with increased pressure to remove oil from the condenser, if any. Cover condenser inlet and outlet.

c) Treat suction line heat exchanger and evaporator in the same way. The opportunity of an efficient blow-through is improved if the capillary tube is broken off at the evaporator inlet. Blow-through with nitrogen will then take place in two paces; first suction tube and evaporator, then capillary tubes.
If the reason for the repair is a broken capillary tube the operations must be changed to replace the entire heat exchanger.

d) Reassemble the system with a new compressor and a new filter drier in the right size.

6.3 Evacuation

Evacuation must be done with special care, and subsequently charge and test according to normal rules. The outlined procedure is best suited for simple refrigeration systems.
If the system has difficult access and the design is complex the following procedure may be better suited.

e) Remove the compressor from the system and treat it according to point a.

f) Break the capillary tube at the condenser outlet.
Blow through with nitrogen through suction and discharge tube.

g) Mount a new oversized filter drier at the condenser outlet. Connect the capillary tube to the filter drier.

h) When the system, excl. compressor, is intact again carry out a drying.
This is made by at the same time connecting suction and discharge tube to a vacuum pump and evacuate to a pressure lower than 10 mbar.
Pressure equalize with dry nitrogen.
Repeat evacuation and pressure equalization.

i) Mount the new compressor. Then evacuate, charge and test.

6.4 Drying of compressor

In some markets it may be necessary to repair a moist compressor in a workshop, and one is then obliged to manage somehow. The drying process described here can give the wanted result, provided that the process is closely complied with.

Draw off the compressor oil charge.
Then flush the compressor inside with ½-1 litres of a non-flammable low pressure refrigerant or solvent.
Plug the compressor with the solvent inside and shake it thoroughly in all directions to get the refrigerant in touch with all inside surfaces.
Collect the solvent as stipulated.
Repeat the operation once or twice to ensure that no substantial oil residues are left in the compressor.
Blow through the compressor with dry nitrogen.
Connect the compressor to an arrangement as shown in Fig. 31.

Plug the discharge connector.
The connections to the compressor suction connector must be vacuum tight. This can be achieved by soldered joints or by use of a suitable vacuum hose.
Bring the compressor up to a temperature between 115°C and 130°C before starting the evacuation. Then start the evacuation that must bring the pressure in the compressor down to 0.2 mbar or lower.
The joints in the vacuum system must be tight in order to achieve the required vacuum. The moisture content in the compressor will also influence the time for reaching the vacuum.
If the compressor is highly contaminated a few pressure equalizations with dry nitrogen to atmospheric pressure will enhance the process.
Shut off the connection to the vacuum instrument during the pressure equalization.
Temperature and vacuum must be maintained for approx. 4 hours.
On finishing the drying process the pressure in the compressor must be equalized to atmospheric pressure with dry nitrogen and the connectors must be sealed.
Charge the compressor with the specified oil type and amount and mount it into the refrigeration system.

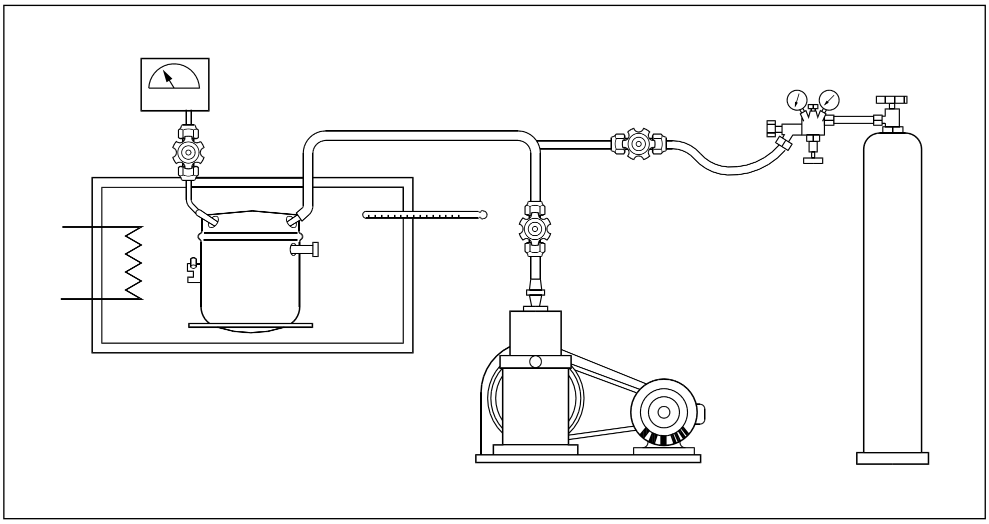

Fig. 31: Drying of compressor

6.5
Oil charge

In some cases it can be necessary to replenish a compressor with oil if it has lost some of the charge. On some Secop compressors the amount of oil is stated on the type label, however, not on all, so the present oil type and amount must be found in the compressor Data Sheet.

It is absolutely essential to use the oil approved for the compressor in question. If a lost oil charge in a compressor must be replaced, it must generally be assumed that approx. 50 ccm of the oil charge will be left in the compressor when it is emptied completely by draining oil off from a connector.

7. LOST REFRIGERANT CHARGE

The term "lost charge" covers cases where the wanted cooling function is not achieved because there is no sufficient amount of refrigerant in the system.

The repair procedure implies a refrigerant overpressure in the system so that the contamination problems that may be caused by penetrating moisture can be disregarded. "Lost charge" is characterized by the fact that the intended cooling is not achieved. The running time is long, and the compressor may run continuously. The build-up of rime on the evaporator is only partly and perhaps only around the injection place. The compressor will operate at low evaporating pressures, and this means low power and current consumption. The compressor will have a higher temperature than normal due to the reduced refrigerant transport.

The difference between "lost charge" and "blocked capillary tube" consists in the prevailing condenser pressure, however, after some time the pressure will be the same in both cases.

"Blocked capillary tube" results in the refrigerant being pumped into the condenser, and the pressure becomes high. As the evaporator is pumped empty, however, the condenser will become cold.
If the blocking is complete no pressure equalization will take place during standstill. With "lost charge", however, the pressure in the condenser will be lower than normal.

A considerable part of the repair procedure consists of finding the cause of the defect. If this is not done it will only be a question of time until the defect occurs again.

In case of blocking of the capillary tube in small systems they will normally be scrapped, but if large expensive systems are concerned a replacement of the suction line heat exchanger may be approproate.
The main steps in the repair procedure can be as follows (only for non-flammable refrigerants).

a) Mount a service valve on the compressor process tube.
   Mount a pressure gauge and use this for fault determination.

b) Increase the refrigerant pressure in the system to 5 bar.

c) Examine all joints to see if there is any oil oozing out.
   Perform a thorough search with leak test equipment until the leak is found.

d) Release the overpressure from the system.
   Break the capillary tube at the condenser outlet.
   Blow through the system with dry nitrogen.

e) Replace filter drier as described earlier.
   Replace the process tube and repair the leak.

f) Evacuate the system and charge it with refrigerant.
   Subsequently make a new leak test and test out the system.
   After a pressure test of the system with high pressure perform a slowly starting evacuation with a large vacuum pump since otherwise the oil can be pumped out of the system.

8.
BURNT COMPRESSOR MOTOR

A burnt motor has destroyed the wire insulation. Burning means motors where the wire insulation is decomposed. A real burning is characterized by the wire insulation in the motor having been exposed to critical temperatures for a long time. If the temperature conditions in a compressor are changed in a way that the insulation material assumes a critical temperature for a long time then burning will take place. Such critical conditions may arise when the ventilation conditions are reduced (e.g. due to a defective fan), when the condenser is dirty or at abnormal voltage conditions.

The fault “lost charge” may have a corresponding effect. Part of the motor cooling is done by means of the circulating refrigerant. When the refrigeration system loses charge the evaporating pressure becomes abnormally low, less refrigerant is circulated per time unit, and the cooling is reduced. In many cases a motor protector mounted in the electrical equipment cannot protect against such conditions. The motor protector is activated both by current and by temperature. If the current consumption is low, a high temperature is required around the protector to cause cut-out. However, at falling evaporating temperatures the temperature difference between motor and compressor housing will increase due to the poorer heat transmission. Winding protectors placed directly in most motors provide a better protection in this situation, since they are primarily activated by the motor winding temperature.

If the wire insulation is decomposed very high temperatures will arise at the short-circuited wires. This may cause further decomposition of refrigerant and oil. As long as the compressor is functional, the entire process may cause circulation of breakdown products and thus contaminate the system.
When certain refrigerants are breaking up acid may be generated. If no cleaning is made in connection with a compressor replacement, the start of the next breakdown is already programmed.
Motor defects in hermetic compressors in household refrigerators are relatively rare.
Normally, failures in the start winding are not causing contamination of the system but a short-circuit in the main winding may very well result in contamination.

8.1 Oil acidity

As a burnt motor may result in contamination of the system with acid products, the acidity can be taken as a criterion whether the system requires a thorough cleaning. The compressor itself and the discharge side of the system up to the filter drier will be the most contaminated part of the system. Once the refrigerant is removed from the system the compressor oil will show contamination or acidity. A simple assessment can be made with an oil sample in a clean test glass. If the oil is dark, sludgy and perhaps contaminated with decomposed particles from the motor insulation, and it smells acidly there is something wrong.

8.2 Burnt system

Repair of a burnt system with products of decomposition is not recommended, and if a repair has to be performed anyway it is absolutely necessary to remove the products of decomposition from the system to avoid contamination and thus breakdown of the new compressor. The following procedure can be used.

a) Remove the defective compressor.
Blow through the tubes to remove old oil.
b) Mount a new compressor and a Danfoss DAS suction line burnout filter in the suction tube in front of the compressor to protect it against contamination products.
Replace the filter drier at the condenser with a DAS filter.
c) Evacuate and charge the system.
Then let the system operate continuously for at least 6 hours.
d) Check the oil for acidity.
If the oil is ok no further cleaning is required.
Remove the filter in the suction line.
Blow through the capillary tube thoroughly.
Mount a new filter drier at the condenser outlet, e.g. Danfoss DML.
Evacuate the system and charge it with refrigerant.
e) If the oil is acid under item d, replace the suction line filter and let the system operate for another 48 hours and then check the oil. If the oil is ok, follow item d).

9.
FAULT LOCATION ON PL / DL / TL / NL / FR COMPRESSORS

This chapter is directed especially to the service network, for household appliances and similar. For detailed information on compressors see the specific Data Sheets.
Compressors type PL, DL, TL, NL, FR and partly SC are equipped with a PTC starting device (Fig. 32) or a relay and start capacitor (Fig. 33). The motor protector is built into the windings.

In the event of a start failure, with a cold compressor, up to 15 minutes can elapse before the protector cuts out the compressor.

When the protector cuts out and the compressor is warm, it can take up to 1hour before the protector cuts in the compressor again.

The compressor must not be started without the electrical equipment.

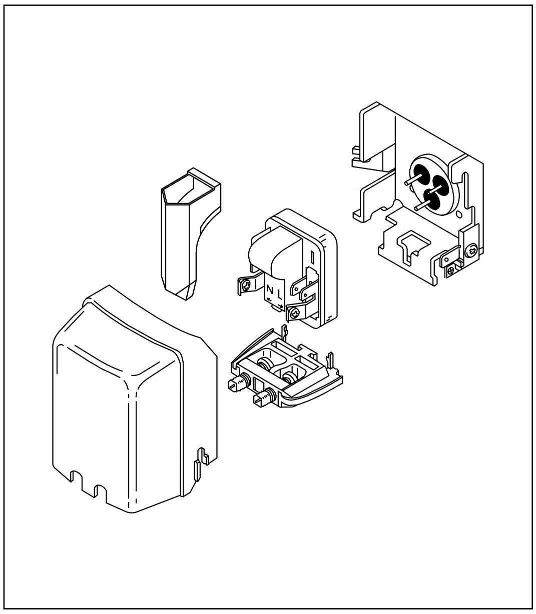

Fig. 32: PTC starting device

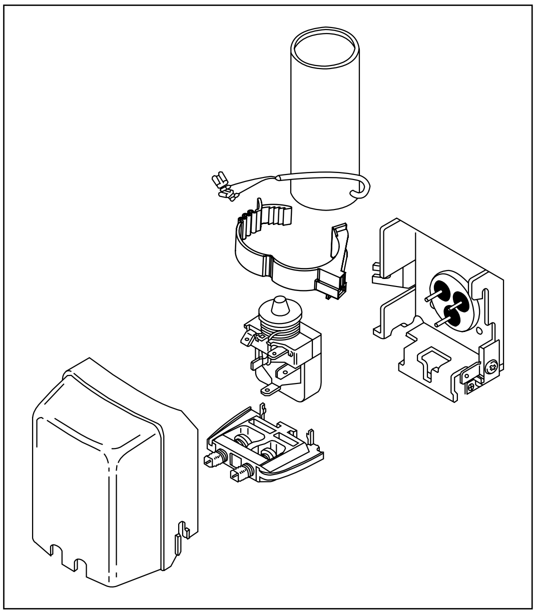

Fig 33.: Starting relay

9.1
Fault location

Before beginning systematic fault location, a good rule is to cut the supply voltage for at least 5 minutes. This ensures that the PTC starting device has cooled off and is ready for start.
A voltage drop or blackout within the first minutes of a pull down of the appliance with cold compressor, can lead to an interlocking situation. A compressor with PTC can not start at non equalized pressure and the PTC does not cool down so fast. It can take more than 1 hour until the appliance then operates normally again.

9.2
Electrical quick check

To avoid unneccessary protector operation and consequent waiting time, it is important to carry out fault location in the sequence given below. Tests are made according to desriptions on following page.
- Remove electrical equipment
- Check electrical connection between main and start pins of compressor terminal
- Check electrical connection between main and common pins of compressor terminal
- Replace compressor, if above connection checks failed
- Else, replace electrical equipment

If the compressor still does not operate, most probably it is no electrical compressor failure. For more detailed fault location, see the tables (chapter 11. and 12.)

10. FAULT LOCATION DETECTABLE FAULTS

10.1 Check main and start winding

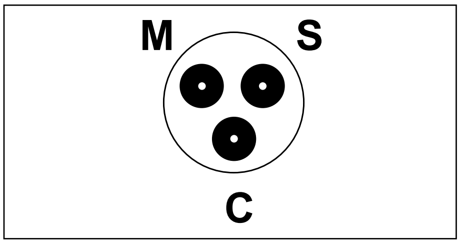

Fig. 34: Compressor terminals

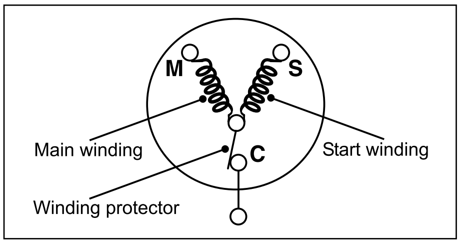

Fig 35: Windings and protector

Resistance between pins M (main) and S (start) on compressor terminals is measured with an ohm-meter (see Figure 34)

- Connection: Main and start windings normally OK
- No connection: Main or start winding defective: Replace compressor

At cold compressor (ca. 25°C) the values are ca. 10 to 100 Ohm for 220-240 V compressors. For partial short circuit detection, exact values are needed from Data Sheets of the specific compressor, which can be found on our website.

10.2 Check protector

Resistance between pins M (main) and C (common) on compressor terminals is measured with an ohm-meter (see figure 34 and 35.)

- Connection: Protector OK
- No connection: Compressor cold: Protector defective: Replace compressor
  Compressor hot: Protector could be OK, but cut out: Wait for reset

10.3 Check relay

Remove relay from compressor. Measure connection between connectors 10 and 12 (see figure 36):

- No connection: Relay defective: Replace relay

Measure connection between connectors 10 and 11:
In normal vertical position (like mounted, solenoid upward):

- Connection: Relay defective: Replace relay
- No connection: OK

In top-down position (solenoid downward):

- Connection: OK
- No connection: Relay defective: Replace relay

10.4 Check PTC

Remove PTC from compressor. Shake by hand. Pin C can slightly rattle.

- Internal rattle noise (except pin C): PTC defective: Replace PTC

Measure resistance between pins M and S (see figure 37). Resistance value between 10 and 100 Ohm at room temperature for 220 V PTC.

- Connection: PTC working: OK
- No connection: PTC defective: Replace PTC

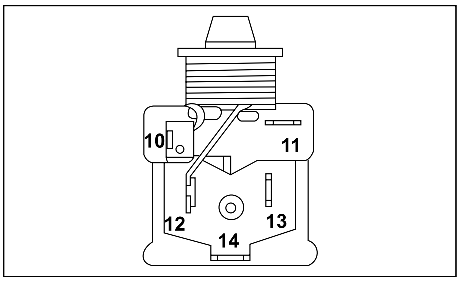

Fig. 36: Relay connections

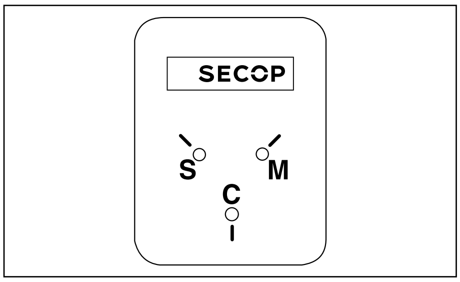

Fig 37: PTC connections (backside)

11. FAULT LOCATION TABLE I

Customer claim	First analysis	Possible cause	Check	Activity (depends on result)
No/reduced cooling	Compressor does not run	Compressor gets no or bad power supply	Voltage at plug and fuse	
			Appliance energized	
			Thermostat function	
			Cables and connections in appliance	
			Voltage at compressor terminals	
		Defective starting equipment	Relay function by shaking to hear if armature is working	Replace relay
			Start capacitor function	Replace start capacitor
			PTC by shaking	Replace if noise appears
			PTC resistance 10 to 100 Ohm between M and S pin	Replace PTC
		Compressor with PTC can not start at pressure difference	Stop time long enough for pressure equalization	Adjust thermostat difference
		PTC defective	PTC resistance 10 to 100 Ohm between M and S pin	Replace PTC
		Relay defective	Relay function by shaking, to hear moving of armature	Replace relay and capacitor
		Compressor overloaded	Condenser pressure and ventilation	Ensure proper ventilation
			Ambient temperature too high according to type label of appliance	
		Defective motor windings	Check winding resistances	Replace compressor
		Defective protector	Check protector with ohmmeter	Replace compressor
		Mechanically blocked compressor	Start with proper starting equipment, voltage and conditions, windings and protector OK	Replace compressor
	Compressor runs 100%	No or low refrigerant charge	Recharge and search for leaks	Ensure leakfree system and proper charge, replace drieer
		Too high ambient temperature	Ambient temperature according to type label of appliance	
		Too high condensing temperature	Condenser and compressor ventilation	Ensure proper ventilation and wall distance
		Capillary partly blocked	Recharge and search for leaks, measure suction pressure. Capillary blocked, if pressure very low	
		Valves coked or damaged	Recharge and search for leaks	Replace compressor, if still not cooling properly
	Compressor runs on/off	Thermostat not OK	Thermostat type and function	Replace thermostat
		Wrong refrigerant charge	Recharge and search for leaks	Ensure leakfree system and proper charge, replace drier
		Ice block built up on evaporator	Check for ice on evaporator	Defrost properly
			Thermostat function and settings	Replace thermostat
			Internal no-frost fan function	
		Compressors trips on motor protector	Compressor load, compressor and condenser ventilation	Ensure proper ventilation and wall distance
			Compressor voltage supply for minimum 187 V	Ensure proper power supply
			Compressor voltage supply for drop outs. Check thermostat and appliance cables for loose connections	Fix all connections
			Motor windings resistance for partly short circuit or earth connection	Replace compressor

12. FAULT LOCATION TABLE II

Customer claim	First analysis	Possible cause	Check	Activity (depends on result)
Noise	Rattle or humming	Tube touching cabinet	Tube placing	Bend tube to their right place, carefully
		Compressor touching cabinet	Compressor mounting and rubber feet	Place rubber feet and mounting accessories correctly
		Broken internal suspension spring or discharge tube	Listen to compressor with screw-driver against compressor with edge and to your ear with grip	Replace compressor, if abnormal sounds
		Resonance	Find vibrating mounting parts	Place or fix correctly
		Fan noise	Vibration of fan or fan mounting	Fix fan and blade, replace, if defective
	Banging at start or stop of compressor	Compressor block hit-ting housing internally	Compressor overload by pressure	Clean condenser if dusty. Make sure, that ventilation gaps for air circulation are satisfactory
			Fan function	
			Refrigerant charge	Recharge, if too high
			Pressure equalization before start and number of on/off cycles	Adjust thermostat, if stop time less than 5 min
			Ambient temperature according to type label	Take appliance out of function, if ambient too hot
	Relay clicking frequently after start	Compressor over-loaded	Ventilation to compressor and con-denser. Check fan function	Clean condenser if dusty. Make sure, that ventilation gaps for air circulation are satisfactory
		Relay defective	Right relay type for compressor	Replace relay, if wrong
Fuses are blown by appliance	Short circuit in appliance	Defective cabling in appliance	All connecting cables and power supply cord for loose connections, short circuits	Fix connections properly
		Defective thermostat	Thermostat connections	Fix connections properly
		Ground connection	Resistance from line/neutral to earth	
	Short circuit in compressor	Defective terminals	For burns on the terminal pins	Replace electrical accessories
		Short circuit between cables at terminals	Connectors and cables at com-pressor	Insulate cables and connectors
		Short circuit in compressor motor	Resistance values in windings	Replace compressor, if short circuited
			Resistance between terminals and earth	
	Fuse blows at compressor start	Supply voltage too low	Supply voltage at compresor start >187 V	
		Fuse loaded by too many appliances	Total fuse load	Connect applaince to different fuse
		Resettable fuse too quick acting	Fuse load and type	If possible replace by slightly slower type
		Partly short circuit to earth	Resistance between terminals and earth	Replace compressor, if short circuited
	Starting capa-citor exploded	Defective relay	Relay function by shaking, to hear moving of armature	Replace relay and capacitor
		Wrong relay type	Relay type	Replace relay and cap
		Extremely many starts and stops of com-pressor	Relay type	Replace relay and cap
			Thermostat defect or differences too small	Adjust or replace thermostat
	Starting relay cap blown off	Short circuit in com-pressor motor	Compressor motor resistances	Replace compressor

OUR IDENTITY

At Secop we are committed to our industry and are genuinely passionate about the difference we are able to make for our customers. We understand their business and objectives and the challenges of today's world of refrigeration and cooling systems.

We work in a straightforward way, being open, direct and honest because we want to make things clear and easy.

Our people are committed to increasing value for our customers and constantly strive for better performance, knowing that our own progression and success is dependent on theirs.

OUR JOURNEY SO FAR

1956
Production facility and headquarters in Flensburg, Germany founded

1958
Start up production of PW compressors.

1970
Introduction of SC compressors.
The birth of a standard setting platform in the light commercial market.

1972
Introduction FR compressors.

1977
Introduction TL and BD compressors.

1990
Introduction NL compressors.

1992
Introduction PL compressors.

1993
Start of production with natural refrigerant R600a (Isobutane)

Production facility in Crnomelj, Slovenia founded.

1999
Start of production with natural refrigerant R290 (Propane).

2002
Production facility in Zlate Moravce, Slovakia founded.

2005
Introduction GS compressors.

2008
Production facility in Wuqing, China founded.

2010
Introduction SLV-CNK.2 and SLV-CLK.2 variable speed compressors.
Introduction BD1.4F Micro compressor.

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