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60 YEARS 1956-2016

SECOP

COMPRESSOR DESIGN
MECHANICAL AND ELECTRICAL

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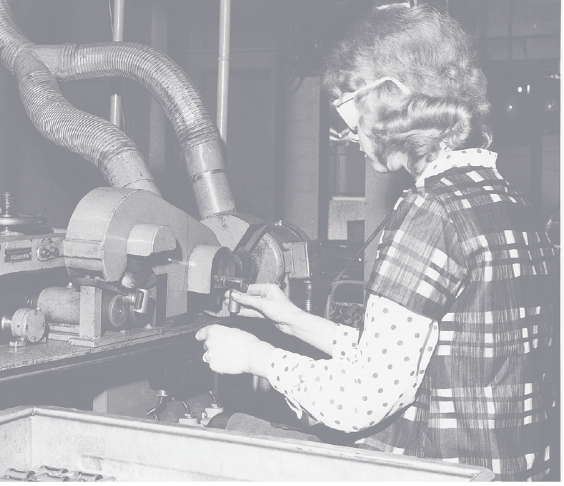
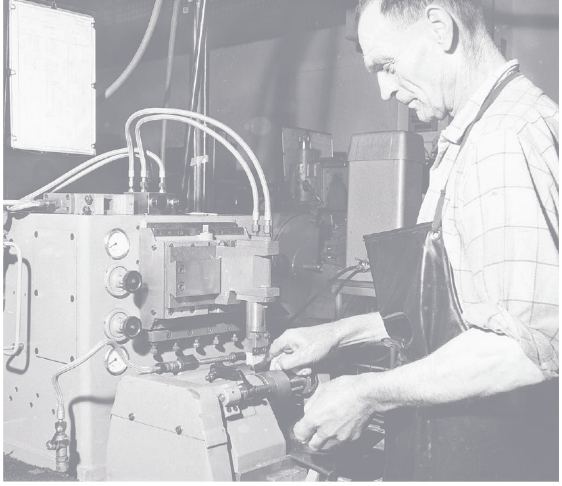
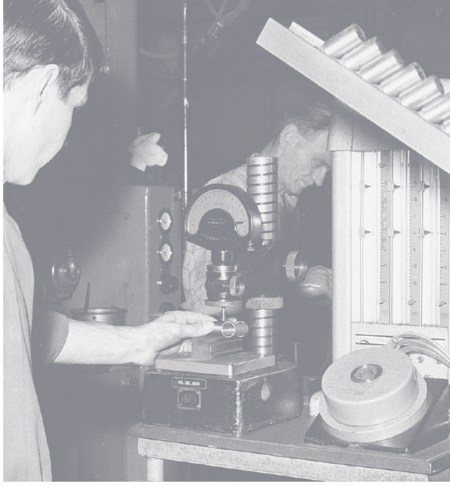

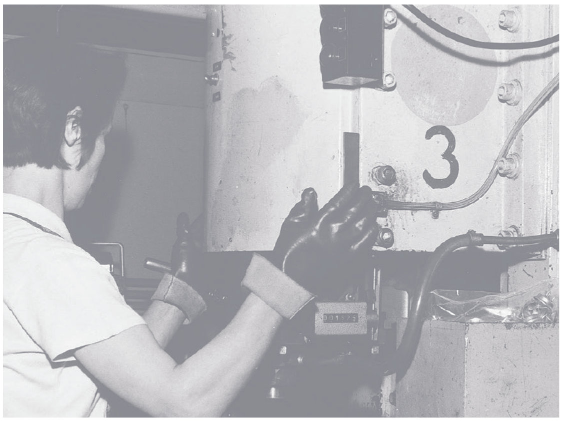
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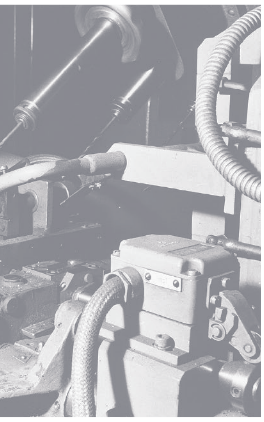
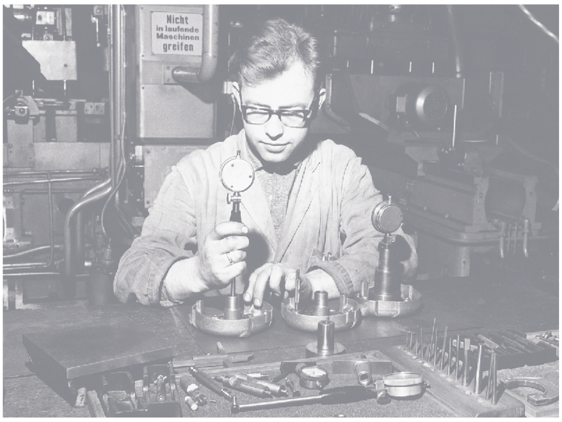
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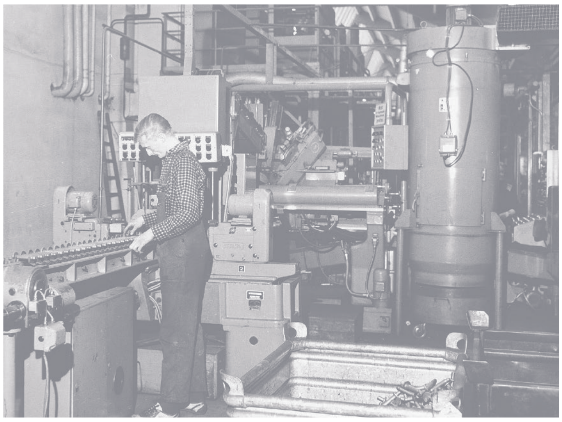

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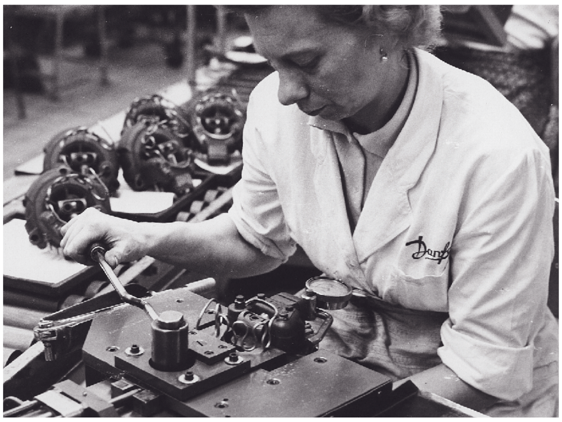
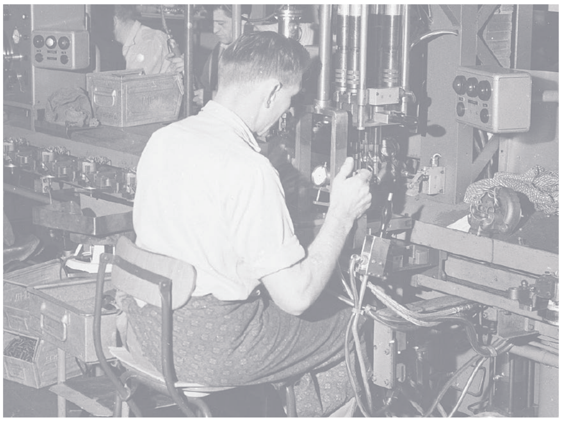
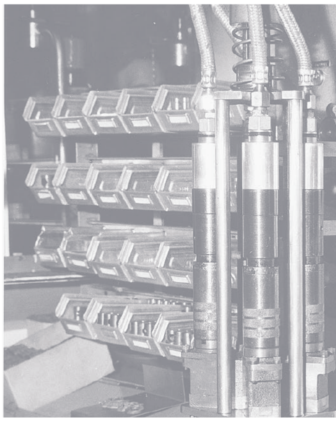



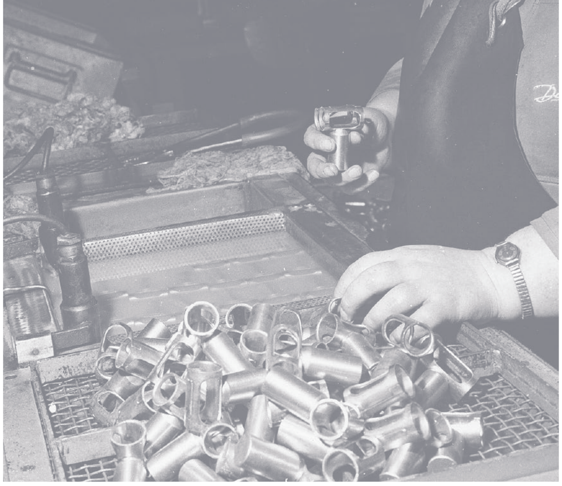
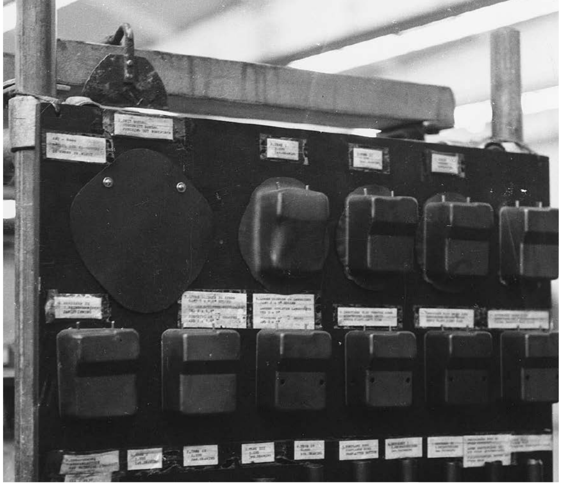
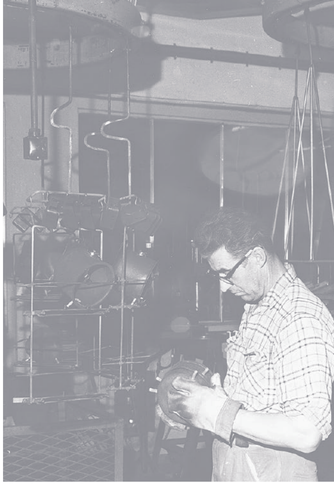
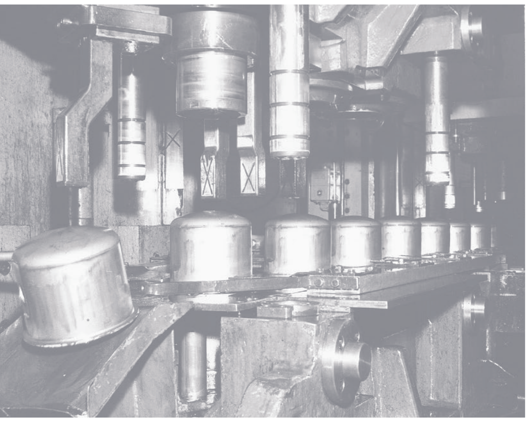
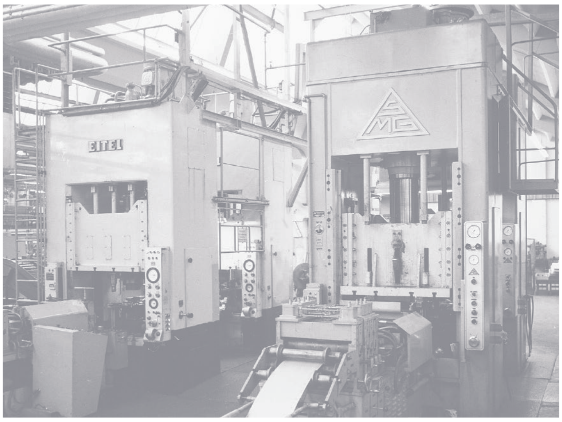
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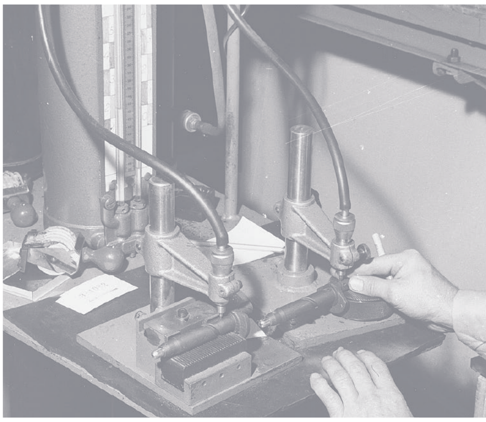

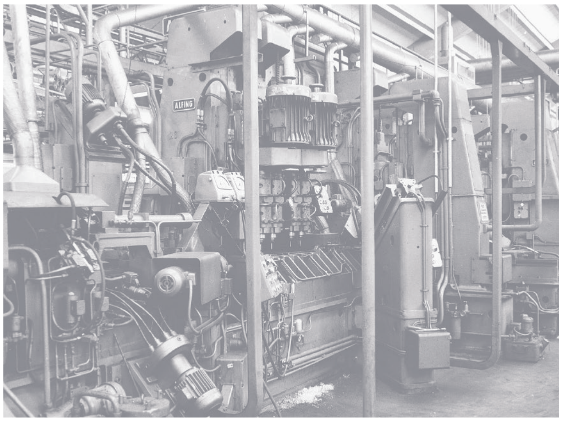
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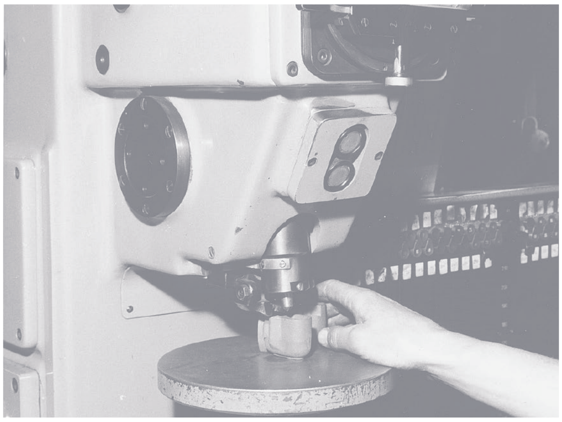

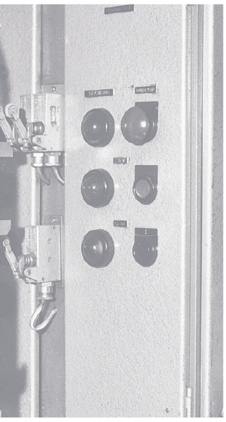
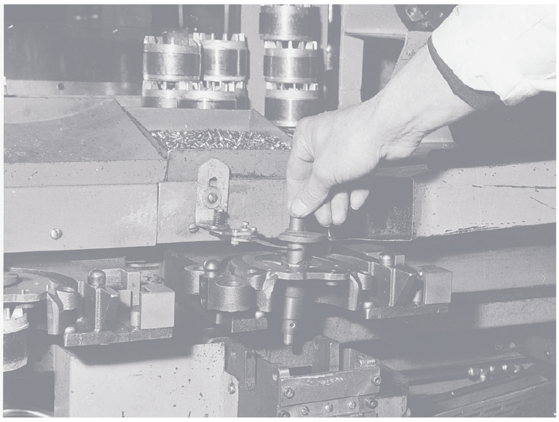
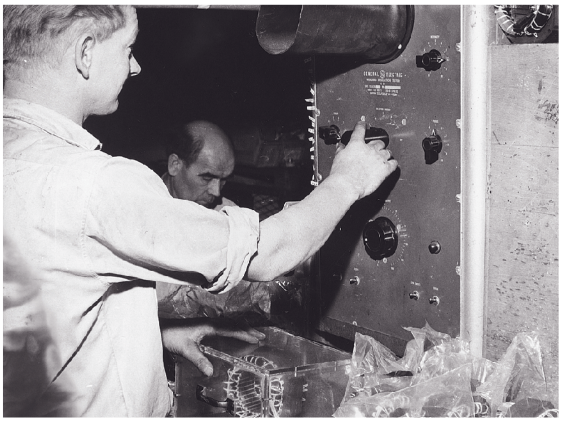


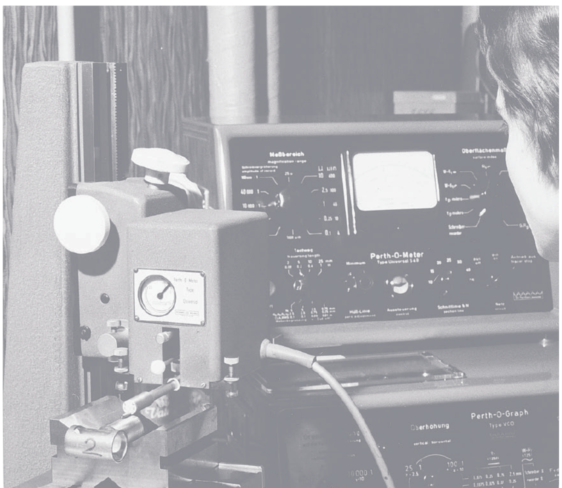
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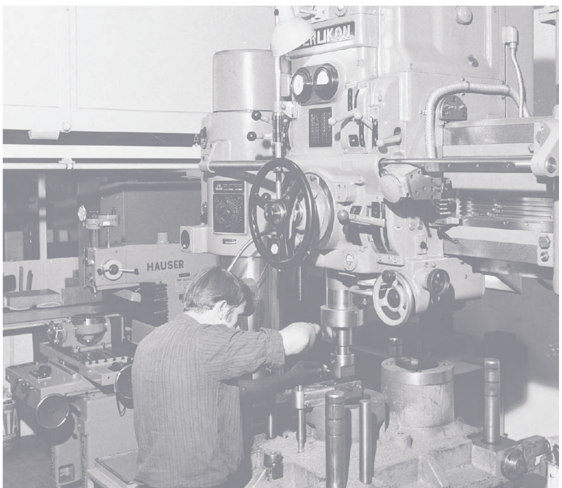

HAUSER


COMPRESSOR DESIGN

MECHANICAL AND ELECTRICAL

This booklet describes the development of the hermetic compressor as well as the mechanical and electrical designs of the Danfoss compressors.

This talk, which is primarily addressed to technicians with som knowledge of refrigeration, has an expected duration of approximately two hours.

Danfoss, HG-EA.
September 1974 (Revised April 1978)

1. General remarks

Refrigeration compressors can be divided into three groups:
The conventional, the semihermetic and the hermetic types, where each group has its own application.
The conventional compressor, which is driven by a motor via a belt drive, has a packing gland at the shaft, which in spite of all progress is a source of refrigerant loss.
In order to eliminate this source of error among others, the semihermetic and the hermetic compressors were designed. Either type has the compressor and the electric motor built integral, thus forming a unit with a common shaft and a common housing where the packing gland is omitted.

The semihermetic compressor is built into a housing, the parts of which are bolted together by means of flanged joints with gaskets inserted. The hermetic compressor, however, is built into a housing where the parts enclosing the compressor are welded together.
The semihermetic design is preferably used in sizes from approx. 1 hp and upwards.
The range below 1 hp is almost exclusively covered by the hermetic compressor, and this range includes the compressor sizes which are used, for example, in domestic refrigerators, domestic freezers, beverage coolers and small air-conditioning systems.

These compressor sizes will be described further in the following.

The first usable design of a hermetic compressor was produced in 1926 by General Electric Co. , and was put in production in the mid-thirties .
The development and production of the hermetic compressor have made fast progress, and small hermetic compressors are to-day used in countless refrigeration appliances. The refrigeration units used are so small that they can be quantity produced and leave the place of production with refrigerant charge and ready for operation.
Hence it is possible to take all the necessary precautions as regards careful cleaning and drying of the components used and to exert care during the assembly so that the customers may reckon on having a unit in which the internal sources of error have been recuced to an absolute minimum.

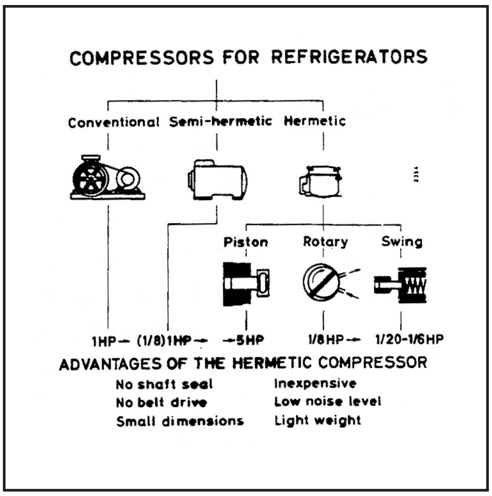


Fig. 1

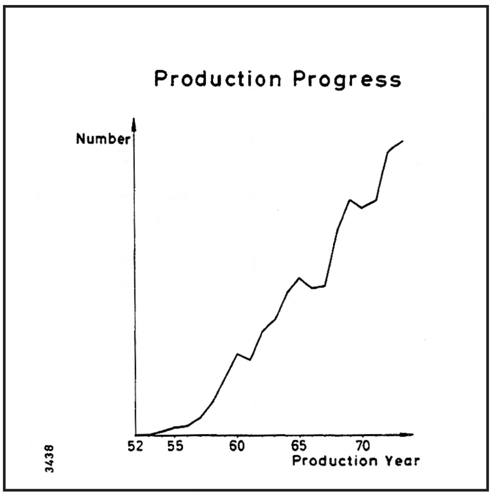


Fig. 2

Fig. 2 shows the product development for the Danfoss compressors since 1952. It can be mentioned that 4.7 million Danfoss compressors were produced in 1974.

2. Demands on hermetic compressors

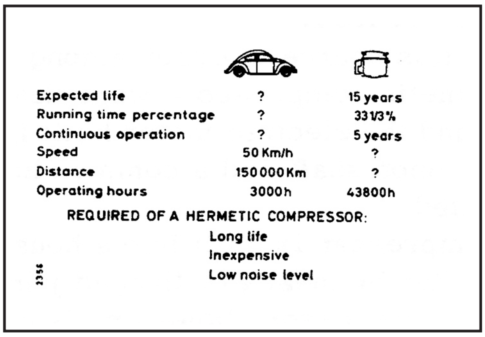


Fig. 3

To many people the modern car engine is one of the peaks of technology, but all the- same the demands made on the lifetime and reliability of such an engine are small as compared to the demands on a hermetic compressor mounted e.g. in a domestic refrigerator. It is not far beside the mark to estimate the life of a car engine at approx. 3000 hours of running, corresponding to 150.000 km at an average speed of 50 km/h.
A lifetime of approx. 15 years is expected from a hermetic compressor, and if the operating period is assumed to be 33 1/3%, the total is 43.800 operating hours.
This example is not meant to attack the quality of the car engine, but only as an illustration and explanation of the fact that most large-scale producers of compressors appear to be orthodox and cautious as regards their designs. Considering the guarantees given it can mean catastrophy to an enterprise to plunge into a hazardous experiment og production of doubtful compressor designs.
A good hermetic compressor must possess the following characteristics:

long life
low noise level
high efficiency (kcal/wh)
low production cost (kr./kcal/h).

3. Main types

There are the following three main types of hermetic compressor.

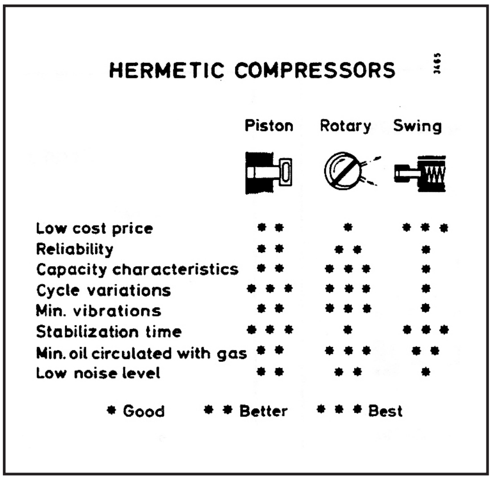


Fig. 4

3.1 Rotary compressor
3.2 Swing compressor
3.3 Piston compressor

Fig. 4 shows some of the advantages and disadvantages of the three types. The piston compressor covers the largest range as regards capacity and besides offers so many advantages as regards production and life that several firms which previously made rotary compressors have now switched over to production of piston compressors.

3.1 Rotary compressor

The rotary compressor does not convert the motor rotation into a reciprocating motion as in the piston compressor, but the rotation is utilized directly to produce a pumping effect.

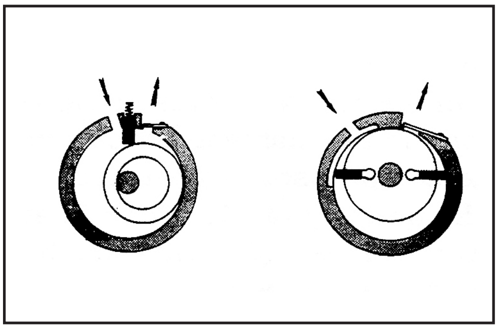


Fig. 5

Fig. 5 shows the two principles according to which a rotary compressor can be designed.

In either case an eccentric rotates in a concentric housing, while the lamella can rotate with the eccentric or be placed in the housing.

With either principle, a volume is increased or reduced, resulting in suction or compression.
In the rotary compressor the demands on tightness between the suction and pressure sides result in rather large frictional surfaces. One of the great problems of the rotary compressor is to achieve suitable oiling of these frictional surfaces, without the oil concentration becoming very high in the refrigerant to be delivered from the suction side of the compressor to its pressure side. Therefore, the compressed gas cannot be send directly into the refrigeration system, but will have to be relieved of the greater part of its oil content first. This problem has been solved by making the discharge connector of the compressor open into the mild steel casing enclosing the compressor and at the same time forming an oil reservoir. The compressor suction side is connected to the external suction connector of the casing through a tube. In this way the compressor casing receives the same pressure as the condenser, but the effect is that the casing acts as an oil separator so that a relatively oil—free refrigerant can be drawn from the top of the casing, to be sent through the condenser and into the system.

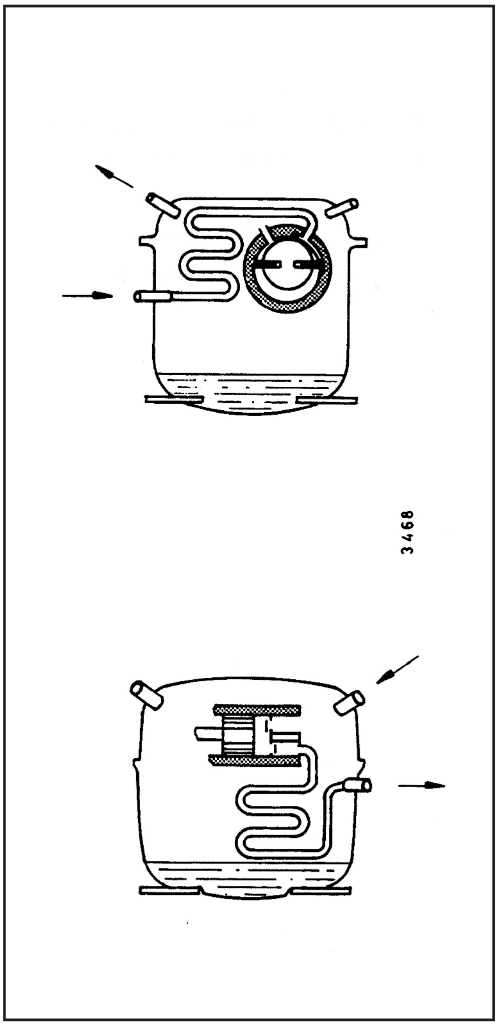


Fig. 6

The problem of achieving sufficient oiling is not so large in the piston compressor as it is in the rotary compressor, and the oil concentration in the refrigerant will not be higher than permissible for sending it directly into the condenser and onwards to the system.

In the piston compressor the compressed gas can, therefore, be send directly from the compressor through a tube to the external discharge connector of the casing. The suction connector of the compressor opens into the inside of the casing, which in this way receives the same pressure as the evaporator in the refrigeration system.

Since in this case the casing also forms an oil reservoir, the oil in the piston compressor is kept under a much lower pressure than the oil in the rotary compressor.
That the oil sump is in the pressure side of the rotary compressor means that fluctuations in the ambient temperature and hence in condensing pressure and compressor temperature will result in rather large variations in the quantity of R12 which is absorbed in the oil.
Hence also the quantity of free R12 varies which is available for circulation in the refrigeration system.
In small refrigeration systems with capillary tubing as throttling device and with a small R12 charge this may prove very unfortunate since under certain circumstances the evaporator may be undercharged, and overcharged under other circumstances.

In the piston compressor where the oil is always subjected to the same low pressure as the evaporator and is only subjected to very small pressure fluctuations, there will, therefore, be only small variations in the quantity of R12 absorbed in the oil. Changes in compressor temperature and hence the oil temperature have no practical effect at these low pressures. The free quantity of R12 which is available for circulation in the system in the case of piston compressors is, therefore, rather constant, and the evaporator charge can be controlled over a major load range.
Rotary compressors are most commonly used for air-conditioning, while they are not much used at low evaporating temperatures.

3.2 Swing compressor

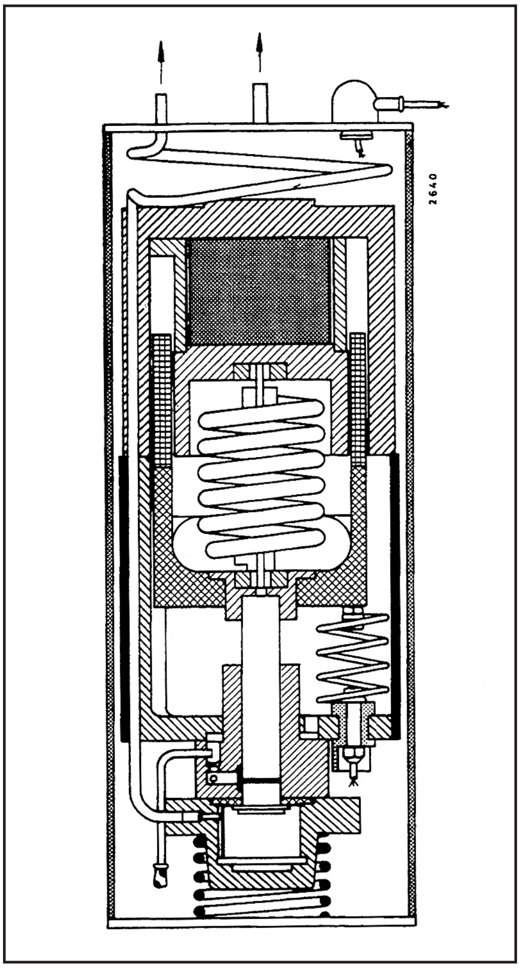


Fig. 7

The swing compressor, which is actually a piston compressor without rotating parts, is manufactured in modest numbers only and is used especially in small refrigeration appliances in trailers, motor boats and similar places. The reciprocating motion of the piston in the swing compressor comes from an iron core connected to the piston being moved into and out of a coil by an alternating voltage.
The greatest disadvantage of the swing compressor is that the capacity is considerably reduced during increasing condensing pressure and undervoltage, and the construction is, finally, sensitive to variations in the mains frequency.
Besides, it is difficult to reduce the vibration and noise levels to the same size as in a piston compressor, since the oscillating masses cannot be balanced.

3.3 Piston compressor

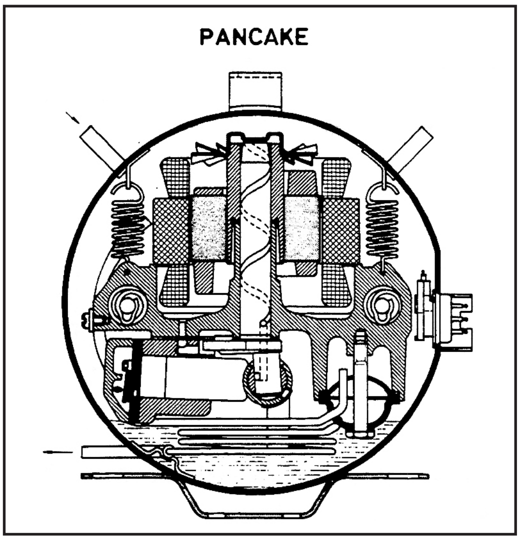


Fig. 8

The Pancake compressor, which is a piston compressor, was made by Danfoss for approx.
12 years. The design is described here because it has various interesting details, and because this compressor stamped the compressor market for many years.

In 1952 Danfoss started the production of the Pancake compressor which had a four-pole motor.

The conventional way of transmitting the rotary motion of the crank to the reciprocating motion of the piston is effected by a connecting rod. The Danfoss PEEWEE and PANCAKE compressors are, however, equipped with a transmission called a "Scotch yoke". In this Scotch yoke the connecting rod and the piston rod are replaced by a socalled crosshead and a crosshead guide at right angles to the centre line of the piston body.

The Scotch yoke offers many advantages both as regards machining and mounting since the structure is self-adjusting to deviations in rectangularity and parallelism. The risk of seizure is thus reduced relative to the connecting rod and piston rod where motion is only permitted on one plane.

The Scotch yoke is not, however, suitable for transmission of large forces since in this way the frictional forces will become too large. The limit to the application of the Scotch yoke is at approx. 1/3 hp. Above this value the problems of balancing the moving masses are increased, and the point where the construction becomes self-locking is close.

In the Pancake compressor, the capacity of the Scotch yoke to equalize offset between cylinder and crank is used in an interesting way for producing an oil pump giving very effective oiling of the moving parts of the compressor.

By making the cylinder axis form an angle og (9O-C)° with the crankshaft, a relative motion of the order of 2R tg C along the crank pin is obtained during half a revolution of the crank. When this volume is connected in the proper way to inlet and discharge channels, the oil pump is the result. Proceeding one more step and letting the pin form an angle on C° with the crankshaft, a rotary motion is obtained at the same time between piston and cylinder as well as between crosshead and crosshead guide. It means that a point on the piston does not follow a rectilinear course on the cylinder wall during a cranck revolution, but, on the contrary, an elliptic course. It will sustain the maintenance of an effective oil film and thus reduce the risk of seizure.

4. Stages of compressor development

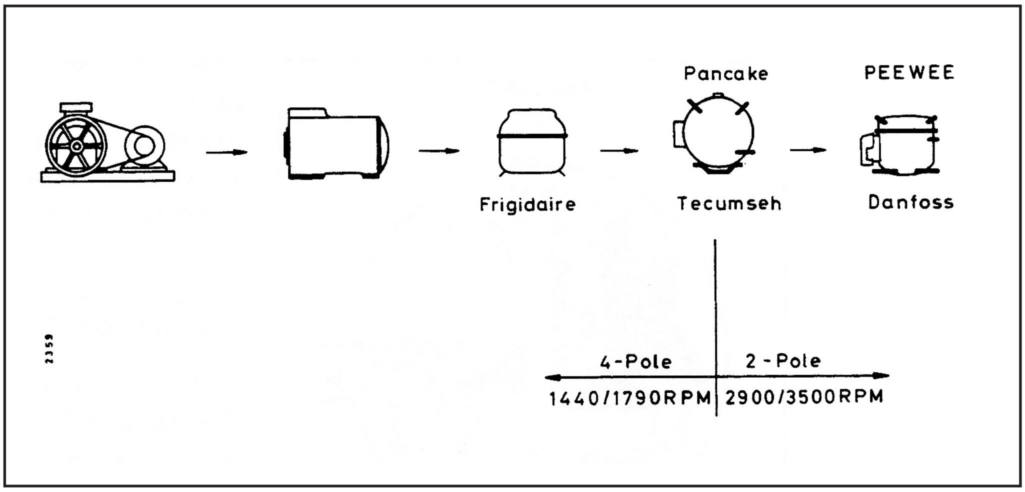


Fig. 9

Fig. 9 shows the most important development stages of domestic refrigeration compressors up to 1956.

In the case of the Pancake compressor the distinction is between 4—pole and 2-pole compressors. For many years the Pancake compressor was made with a 4-pole motor only. A growing demand for increased capacity and compressors with small outside dimensions resulted in Danfoss starting the development of the 2-pole motor which was introduced in the PEEWEE compressor.

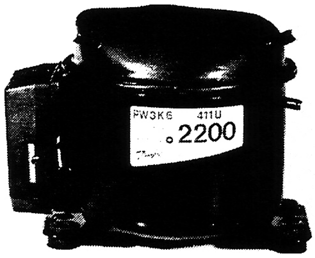
At the end of the fifties 2-pole motors were also introduced in the Pancake compressor.

5 . Danfoss compressors

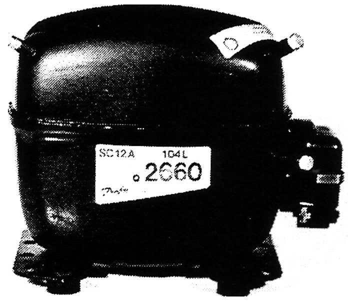
The Danfoss compressors are available in types PW, FR and SC, and for the following gives a description of the different designs.

Several construction elements are identical in principle, and they will be treated jointly for all three types of compressor.

PW



FR



SC

5.1 PW compressor

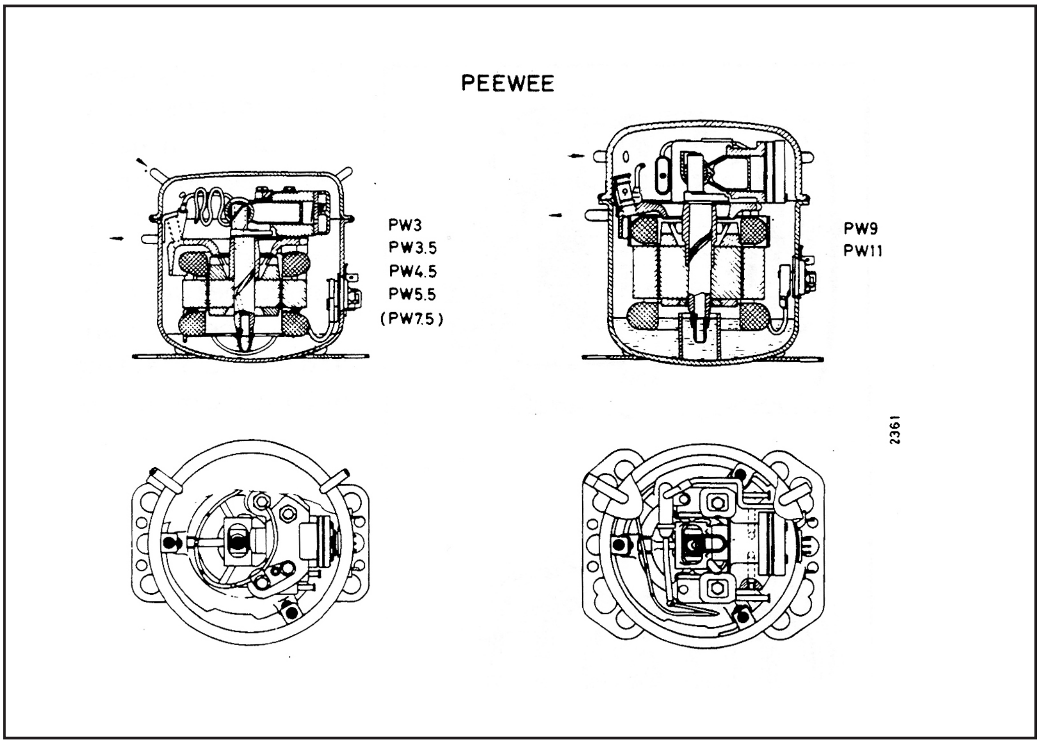


Fig. 10

The growing market demands for smaller compressors with a high capacity resulted in Danfoss starting the design in 1953 of a compressor with a 2—pole motor. The result was the PEEWEE type which was put in production in 1956.
The 2—pole motor has a speed of approx. 2900 at 50 Hz and approx. 3500 at 60 Hz. The PW compressor has been subjected to some modifications in the course of time, and the compressor is provided with an electromagnetic starting relay and a motor protector, either of which is mounted in a housing on the side of the compressor.

5.2 FR compressor

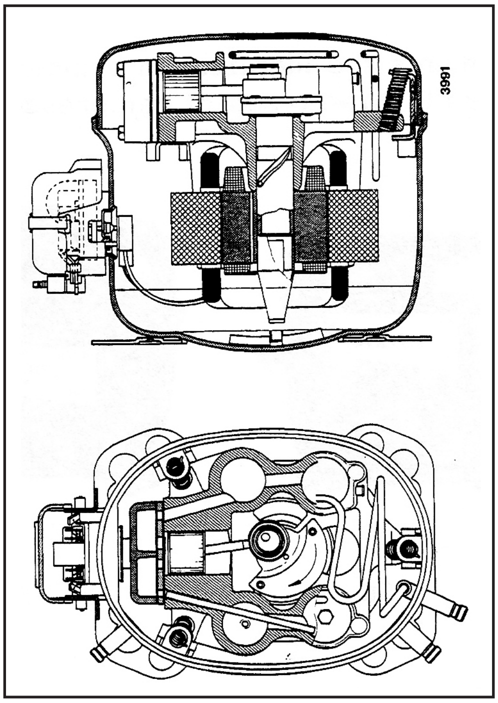


Fig. 11

This type of compressor, the production of which was started in 1974, will replace the largest PW compressors in the course of time.

As compared with PW, the FR compressor have been changed in such a way that the cylinder and crankcase form a unit, and the transmission consists of a connecting rod with a ball joint piston.

In the electric field, for example, a semiconductor as starting device(PTC) and a built—in winding protector have been introduced.

5.3 SC compressor

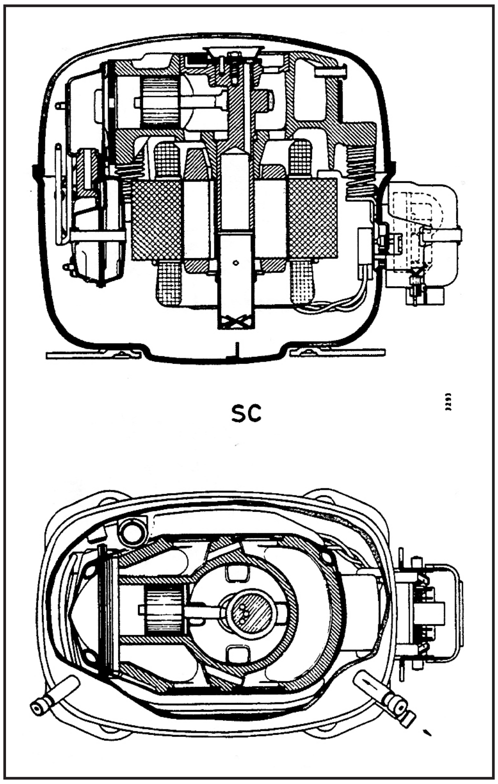


Fig. 12

The SC compressor has extended the compressor range, to reach into the commercial application too. The design can be seen from fig. 12, and it will be noted that there are some points of resemblance between FR and SC compressors. The SC compressors also use a PTC starting device and a built-in winding protector.

5.4 Valve system

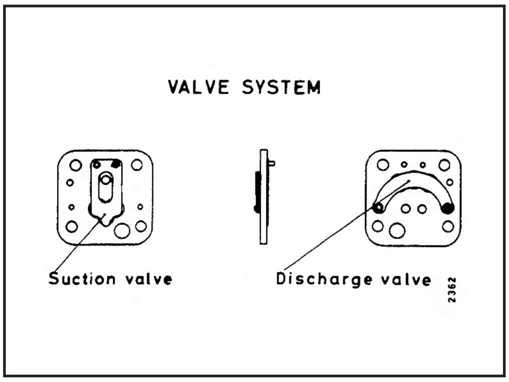


Fig. 13

The valves in the Danfoss compressors are designed as shown in principle in fig. 13.
The design of the valves determines the volumetric effeciency of the compressor to a very great extent, and all the valves are made of Swedish Flapper Valve Steel.
Note that the valves are not controlled mechanically, but open or close exclusively in dependence of the prevalent pressure differences.

5.5 Cylinder

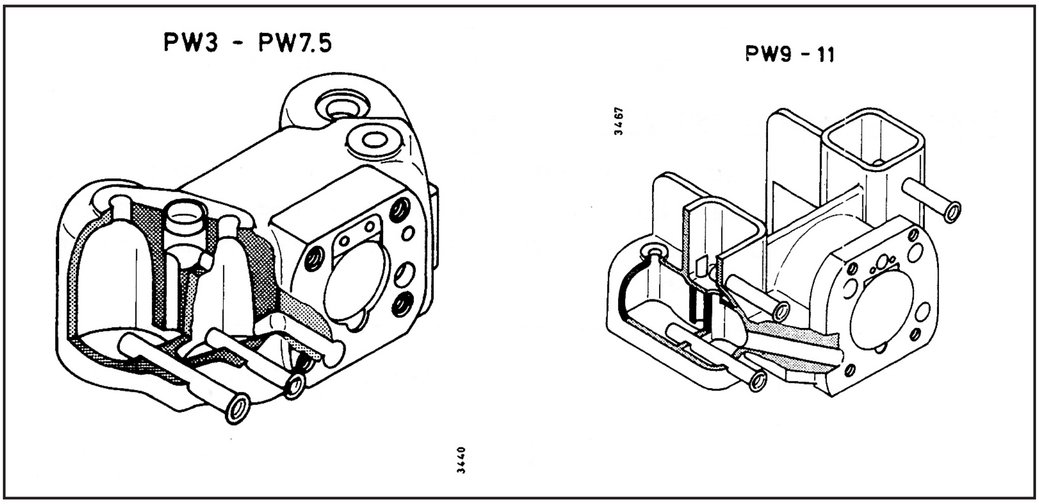


Fig. 14

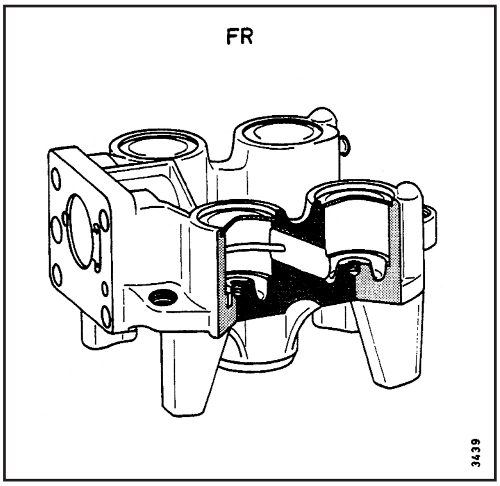
The same cylinder design with suction and discharge mufflers distributed on either side of the cylinder is used for the PW compressors PW3 up to and including PW7.5.
However, the PW7.5 compressor only uses suction mufflers, while separately mounted discharge mufflers are used.

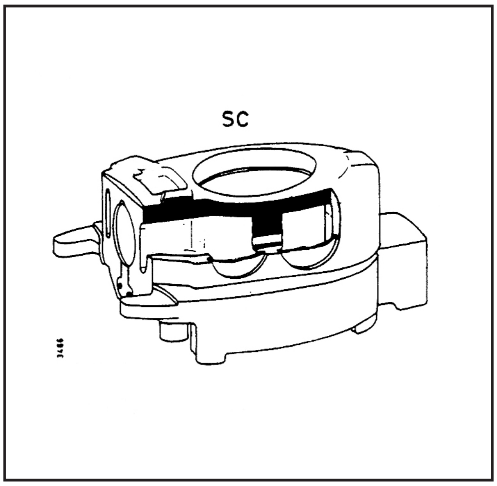
PW9 and PW11 compressors have suction mufflers distributed on both sides of the cylinder, and the discharge mufflers are mounted separately in connection with the discharge tube.

All the cylinders for Danfoss compressors are made of cast iron.

Fig. 15

Fig. 16





Figs. 15 and 16 respectively show the designs of cylinders used in FR and SC compressors.
It will be seen that both the cylinder and the crankcase are one unit.

5.6 Reduced lateral pressure on piston

If we take a look at a Danfoss compressor, it cannot be seen directly that the lateral pressure on the piston has been reduced by offsetting the centre line of the cylinder relative to the centre line of the crankshaft.

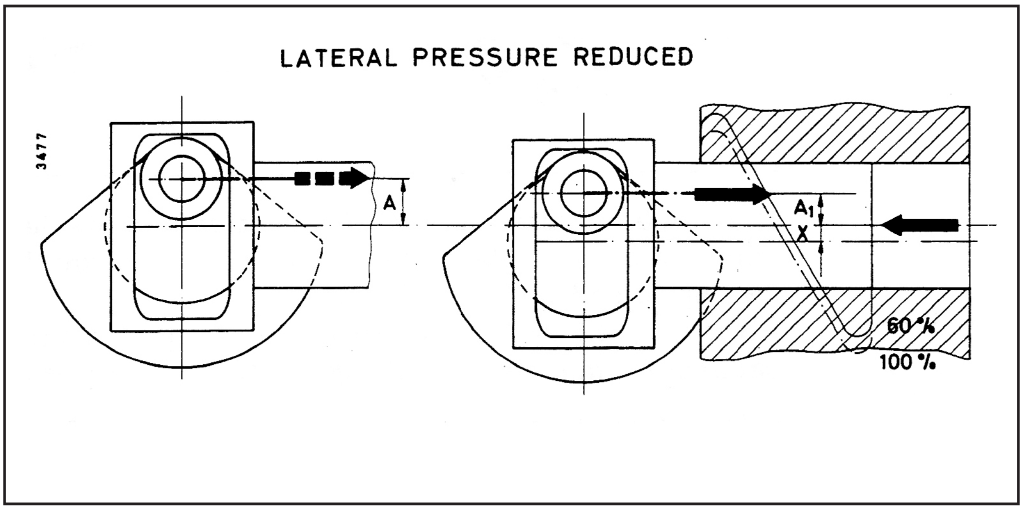


Fig. 17

The ordinary position of the cylinder and the crankshaft results in a reaction to the gas forces through the crosshead at the distance "A" from the crankshaft (see fig. 17). The force couple thus set up subjects the piston to an upsetting momentum which has to be balanced by a lateral pressure between cylinder and piston.
The lateral pressure varies with the crank position, but spreads when reaching the maximum, approximately as indicated by the curve marked 100%.
This lateral pressure will result in wear and noise, which in the Danfoss compressors have been reduced considerably by the said offset of the cylinder axis relative to the crankshaft.

The changed ratio of the size of the lateral forces when the centre line of the cylinder is offset by the distance x relative to the centre line of the crankshaft, is drawn in fig. 17.

It can be seen from this figure that the reaction to the gas forces now only acts at the distance
A1. The size of the force couple and hence the upsetting momentum have thus been reduced, resulting in a smaller lateral pressure between cylinder and piston. The offset x has been chosen so large that the maximum values of the lateral pressure are almost identical on both sides of the piston. It is impossible to achieve more than that, but it has also reduced the maximum values to almost 60% of the original size, and the importance of this has been very great as regards improved wear resistance and less noise.

5.7 Transmission

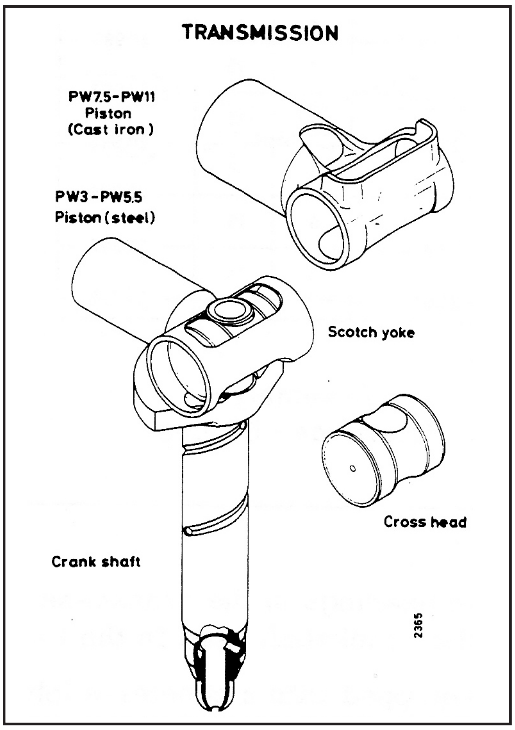


Fig. 18

All PW compressors use the Scotch yoke for transmission, while the FR and SC compressors use a ball joint piston.
Both the designs have the advantage of being self—equalizing to deviations in rectangularity and parallelism.
The PW compressors up to and including PM/5.5 have a shelled mild steel piston, and the larger PW compressors are equipped with cast iron piston.
The ball joint piston of the FR and SC compressors are made of steel.

All the pistons are without piston rings, and the tightness between piston and cylinder is obtained by means of very small clearances.

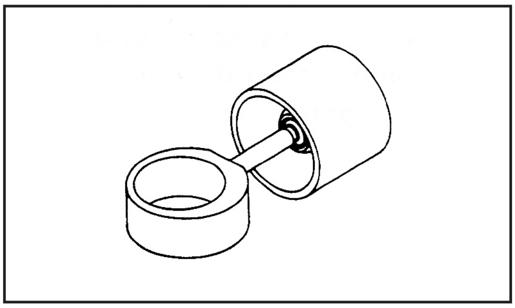


Fig. 19

5.8 Clearance between moving parts

The clearances between the single components in the Danfoss com—pressors are specified within narrow limits. It is possible to machine parts within a tolerance range of e.g. 6µ, but it is very expensive, and Danfoss has, therefore, chosen to machine the parts within a larger tolerance range and measure the different diameters afterwards, when the part is given a group No. depending on the dimension. Each group No. covers 3µ, and the group Nos. are adapted in such a way that mounting two parts belonging together and having the same group No. will give exactly the clearance required.

It means that all clearances in the compressor will be uniform within the compressors and as near the correct size as possible. Fig. 20 shows an example of how a cylinder and a piston are given group Nos.

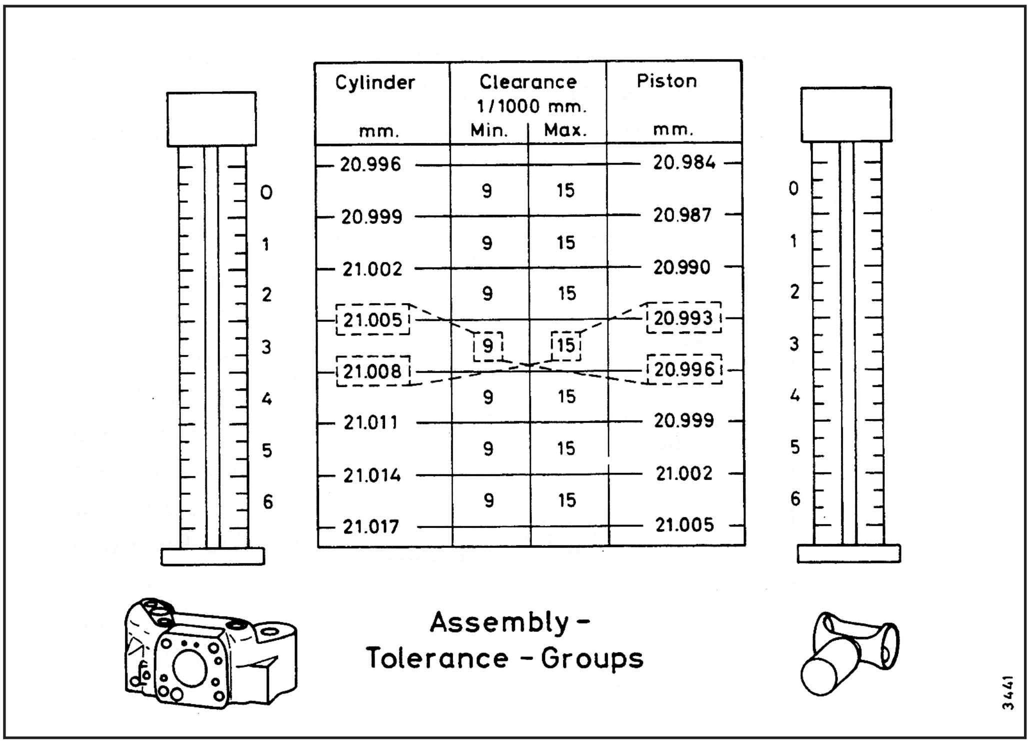


Fig. 20

5.9 Crankshaft

The crankshaft runs in bearings in the crankcase and is made of cast iron. Fig. 18 shows the crankshaft used in the PW compressor.

The crankshafts are equipped with a counterweight for balancing, and the thrust bearing is placed under the counterweight.

An oil coil along the entire length of the bearing sees to effective oiling of the bearing as well as transport of oil to the transmission. In the lower of the crankshaft, the oil pump is fitted which acts according to the centrifugal principle.

5.10 Oil pump

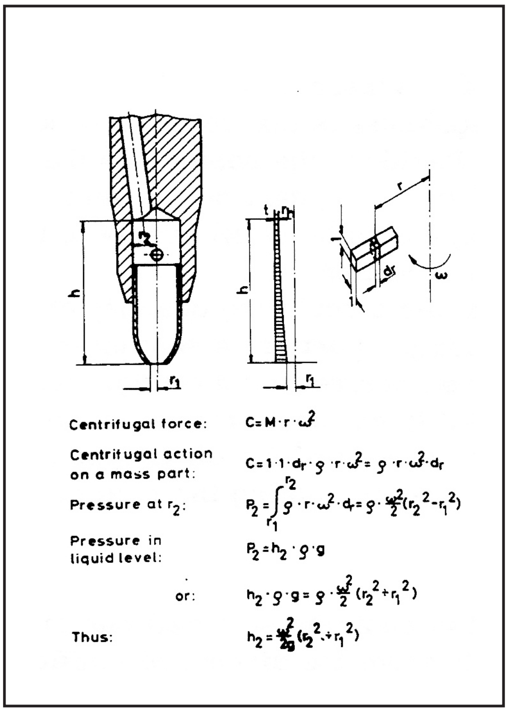


Fig. 21

Fig. 21 shows the theoretical explanation of the operating principle of the oil pump in the PW, FR and SC compressors. It appears from the figure that the oil in the pick-up tube has to form a cone where the heaviest particles, i.e. the oil, will be on the outside because of the centrifugal force, and the lighter parts, i.e. the absorbed refrigerant, will be nearer to the centre of the cone.
The pick-up tube acts as an centrifuge in this way, giving partial separation of the oil and the absorbed refrigerant.
In FR and SC compressors, a propeller at the end of the pick-up tube has increased the pump capacity.

The oil pump pumps a mixture of oil and refrigerant from the oil reservoir which is in the bottom of the compressor housing, since the oil has absorbed a certain amount of refrigerant due to the fact that the internal compressor housing is part of the suction side of the refrigeration system.

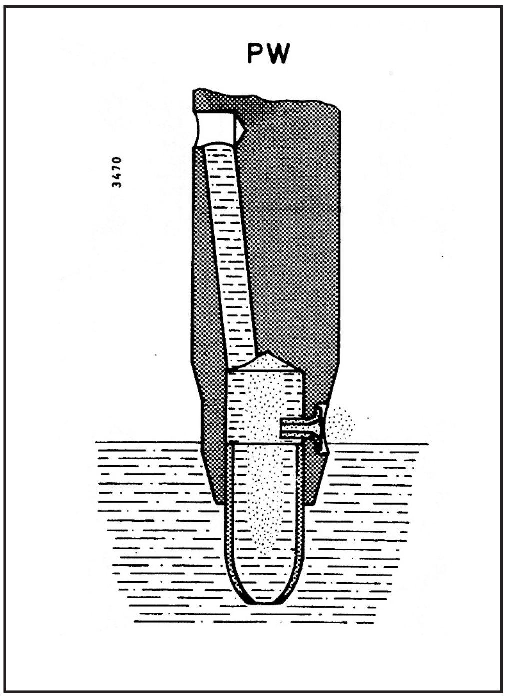


Fig. 22

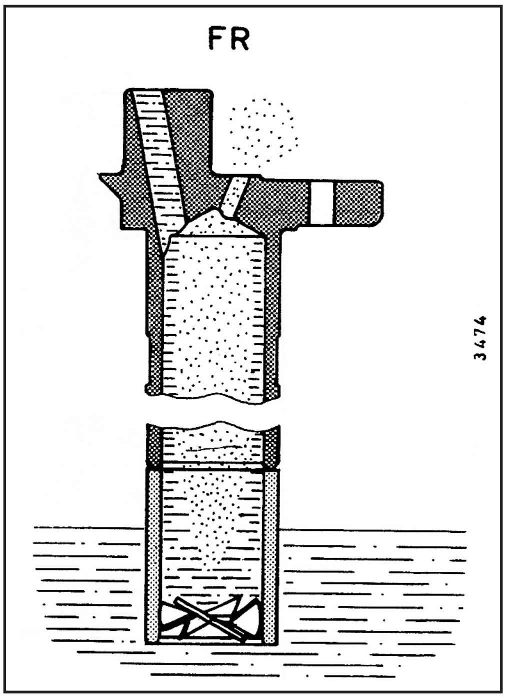


Fig. 23

The presence of refrigerant in the oil to the bearings may cause the oil to be forced away from a hot bearing because of strong expansion of the refrigerant in the oil.
This disadvantage has been eliminated in all the Danfoss compressors by degassing the oil before it reaches the the bearings.

Degassing the oil in the PW compressors is done by inserting a tubular rivet in the crankshaft near the centre of the pump where most of the refrigerant is situated. In FR and SC compressors the degassing hole is at the top of the crankshaft.
The effect of the oil degassing is that oil almost devoid of refrigerant reaches the bearings. Besides, the design has the effect that the pump capacity is only very little dependent on the suction pressure in the compressor housing, and a suitable oil supply to the bearings is thus ensured under all load conditions. Only a small portion of the circulating quantity of oil is used for oiling the bearings, while a larger portion is sent up through the crankshaft and is distributed on the compressor housing. Hence a good heat transmission is ensured from the motor to the compressor housing. In FR and SC compressors part of the oil is also conducted up through bores in the rotor to assist in cooling the motor.

5.11 Discharge tube

The compressed gas only contains so small quantities of oil that the gas can be sent directly from the discharge muffler to the discharge connector of the compressor. To have a high flexibility, at the same time transmitting as few vibrations to the compressor housing as possible, the discharge tube has been given a rather special design and is made of Bundy-tube.

5.12 Baseplate

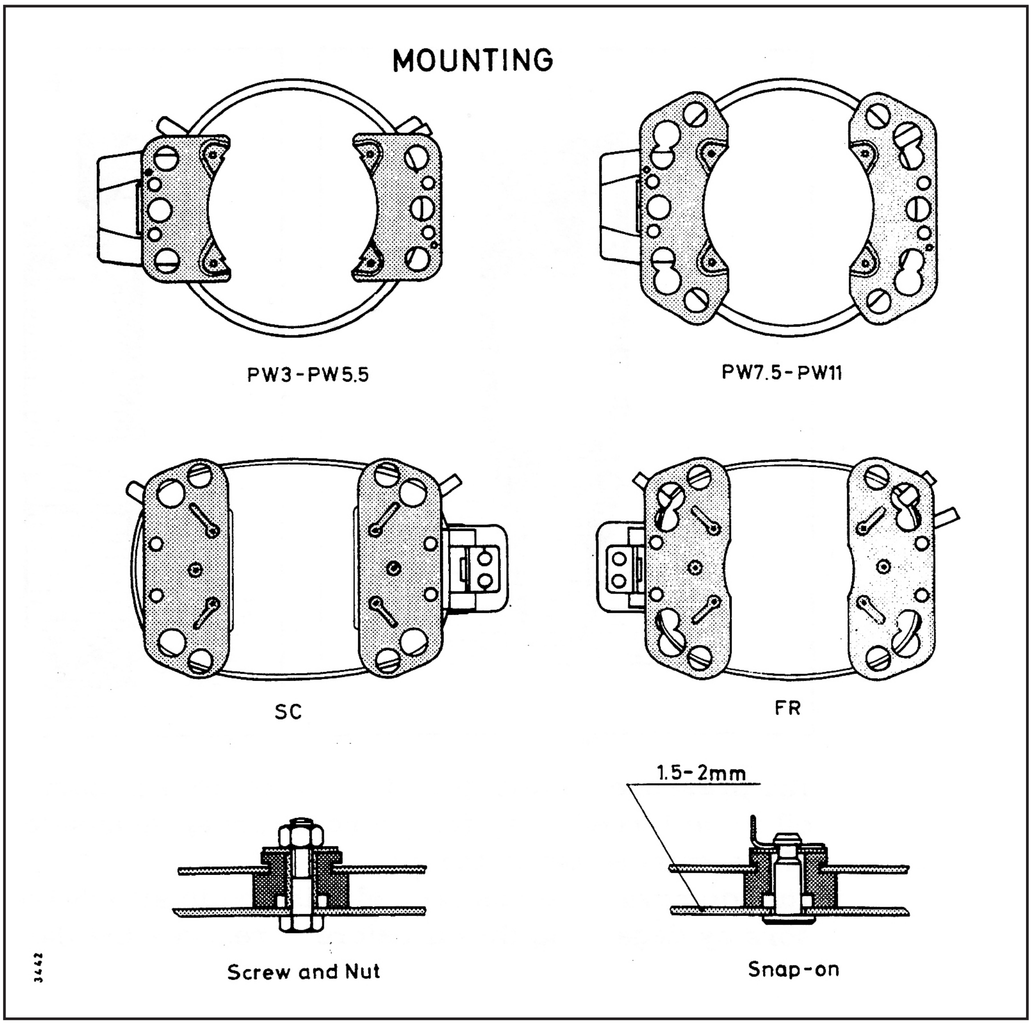


Fig. 24

The baseplate, which is made of steel plate and spot—welded to the compressor pot, serves to fix the compressor.

In the case of the large compressors, the holes in the baseplate which are remotest from the compressor, should be used.

Every compressor can be supplied with a mounting kit which consists of the components shown in fig. 24.

Simplified mounting of the compressor can be done by the use of the socalled snap-on system.
Either system incorporates four rubber grommets which serve to reduce the transmission of vibration from the compressor to the refrigerator cabinet.
By means of a nut and bolt the rubber grommet is inserted in a grommet sleeve for the purpose of preventing compression of the rubber grommet, which would eliminate the damping effect of the rubber.

The steel pin of the snap-on system is designed for fitting on baseplates of a thickness of 1.5 to 2mm.

5.13 Current lead-in

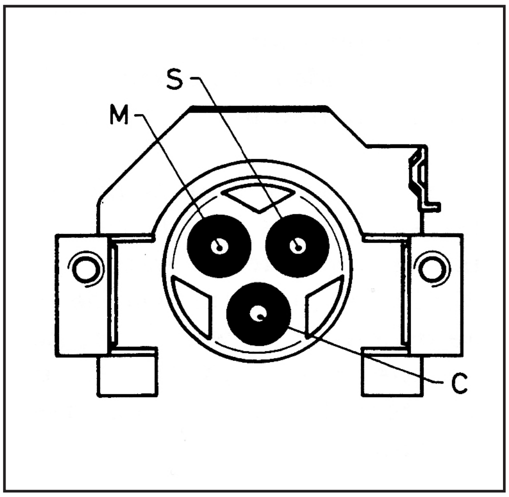


Fig. 25

A hermetic current lead-in hammer-welded to the compressor housing is used for accommodating the electric connections to the compressor. The three steel terminals of the current lead-in connected to the electric motor of the compressor are embedded in glass.
The same type of current lead-in is used for both PW, FR and SC compressors, and with the same orientation meaning that "main" is always at the top left, and common is at the bottom.

The lead-in is enclosed in a casing which serves to protect it, but the casing is primarily designed for fixing the electric equipment. Fig. 25 shows the casing of a PW compressor.

5.14 Selection of materials

The materials used in hermetic refrigeration compressors must be resistant to relevant refrigerants and temperatures.

These fundamental demands are especially decisive of the selection of electrical insulating materials and compressor oil.

The oil must be stable both at high and low temperatures. The highest temperatures occur in the valve system of the compressor and influence any coking tendencies. Oil circulated in the refrigeration system can be subjected to low temperatures. It is, therefore, also important that solid particles are not precipitated under such conditions since it may result in blocking of the capillary tube or the expansion valve.

In old compressor designs, winding temperatures higher than 120°C could not be permitted. This was due to the insulating materials used.

Press-spahn was used as slot and interleaving insulation; press-spahn is a paper product.
Cotton was used for banding, and the wire insulation was polyvinyl acetal varnish (Formvar).
It is typical of paper and cotton that these materials give off considerable quantities of water when the temperature exceeds approx. 120°C. The direct result of this decomposition of the insulating materials is a reduced compressor life, also because the quantities of water released assist in formation of oil coke in the valve system.

As long as competition permitted ample sizing of refrigerators and compressors, the "old" materials did not present major problems.

In the course of time there has, however, been a trend towards more compact constructions , and it has become general practice to utilize the compressors to the extreme limit, often under poor building-in conditions.
A prerequisite of improving this situation was procurement of more resistant materials. The effect was that Danfoss started a development project at the end of the fifties with a view to using synthetic materials in hermetic compressors.
A practical result of these endeavours was the introduction in 1963 of compressors in which winding temperatures of up to 140°C could be permitted.
Synthetic materials are now used in all Danfoss compressors. As the heating of these materials results in only very small quantities of decomposition products, the emission of water from the motor can now be regarded as an eliminated problem. On the other hand, the presence of considerable quantities of water may have a

MATERIALS AND TEMPERATURE LIMITS FOR DANFOSS COMPRESSORS

Motor :	Oil :	Wire insulation:	Other insulation :	Winding temp. max :
PW (K6 K11)			Polyester	130 °C
PW (K14–K22)	Clavus 929		(Mylar – Melinex –	
FR	Clavus 925	Polyester-	Hostaphan)**	140 °C
SC(12A-15A)*	Clavus 929	amidimid	Polybutylester	
SC(all others)	Zephron 150			

* 220V

**(Polyethyleneterephthallicacidester - foil)

3476/1

Fig. 26

destructive effect on the insulating materials. It is, therefore, still necessary to build the compressor integral with dry components and to keep the water content in the system low.
The synthetic materials can also be decomposed by the presence of anti—freeze agents like alcohol and glycol. Such additives have, however, become irrelevant as the synthetic materials do not give off water.

Together with the improvement of the electric insulating system, a development has taken place in the quality of refrigeration machine oils. This has been a prerequisite of ensuring good chemical and thermal stability of the entire system.

The higher thermal utilization which has become possible by means of the new insulating systems is, of course, followed by the possibility of higher valve temperatures than before.

Another consequential effect can be more difficult oiling conditions for the bearings in the most heavily loaded compressors under extreme conditions. Therefore, Danfoss recommends that the larger PW compressors as well as other newer designs should be used with oils which maintain a relatively high viscosity and are highly temperature-resistant.

Even if the Danfoss compressors contain materials which ensure an exceptional chemical stability, the prerequisite is still that the compressors should be used in clean and dry refrigeration systems, as laid down in the rules in force so far.

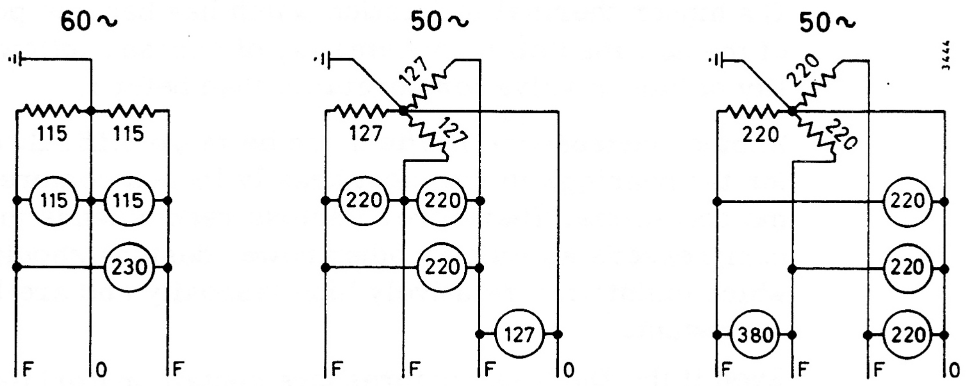
For the sake of good order, it should be mentioned that a winding termperature limit of 130°C is still observed in the smallest PW compressors (PW3 - PW5.5). This is, however, not due to consideration of the chemical stability, but merely mechanical conditions.

6. Mains voltage

The most common mains supply is 50 Hz with 220 volts between 1 phase and neutral and with 380 volts between 2 phases. This mains supply is found all over Europe, Africa, Asia and in Australia.

Another 50 Hz mains supply has 127 volts between 1 phase and neutral and 220 volts between 2 phases. This mains supply is found in a few districts in Ethiopia, Greece, Indonesia, Italy and in Spain. The 60 Hz mains supply, which is mainly found in North America, has only 115 volts between 1 phase and neutral and 230 volts between 2 phases.
In ordinary house installations it is normal to have a single phase and neutral, and the voltage between these is, therefore, of interest A 2-wire mains must be connected to a fixed load determined by the size of the mains fuse.
Large compressors must, therefore, be connected to a 4-wire mains supply.
It is important that the motor should always be connected to the correct voltage and frequency.

LINE VOLTAGES



Starting and operating voltages

Line voltage	% of rated voltage	Range
220 V	-15 to +10%	187 - 242 V
240 V (U.K.)	-10 to + 6%	216 - 254 V

Voltage range 187 - 254 V

Fig. 27

The CEE-Standards specify that a refrigerator must be able to start within +10% and -15% of the rated mains voltage, and this means between 187 and 242 V in the case of a 220 V motor.

The normal mains voltage is 240 V in England, but a few districts have 200 V.
Since it is necessary to reckon with voltage variations of up to 6%, it must be demanded in practice that a hermetic compressor for 220 / 240 V should be able to serve a voltage range of from 187 - 254 V.

7. Motor

The Danfoss compressors use single-phase, 2-pole asynchronous induction motors with a squirrel-cage rotor designed for resistance start. A few types are designed for capacitor start.

It will, no doubt, be usefull to go through the different terms.

Single-phase means that the motor is, normally, connected between one phase and neutral. -
2-pole has something to do with the speed, since a 2-pole motor at 50 Hz runs at a synchronous speed of 3000 rev/min.

A 4-pole motor runs synchronously at a speed of 1500 rev/min.

All the Danfoss compressors are equipped with 2-pole motors.

Why is a 2-pole motor preferred?
It is evident that the higher the number of compressor piston strokes per minute, the larger the work. A 2-pole compressor for a given capacity can, in other words, be made with smaller dimensions than a corresponding compressor with a 4-pole motor.

Asynchronous
By an asynchronous motor is understood a motor running at a slower speed than the synchronous speed.

As a matter of fact, a 2-pole motor runs at a speed of approx. 2900 rev/min only, and a 4-pole at approx. 1450 rev/min under load.

Induction motor

By an induction motor is understood a motor in which the current in the rotor is caused by an induction from stator to rotor through the effect of a transformer. The rotor current is, therefore, not supplied by a commutator and carbon brushes as is the case with D.C.motors. It means that formation of sparks does not occur, nor can this be permitted in an R12-atmosphere.

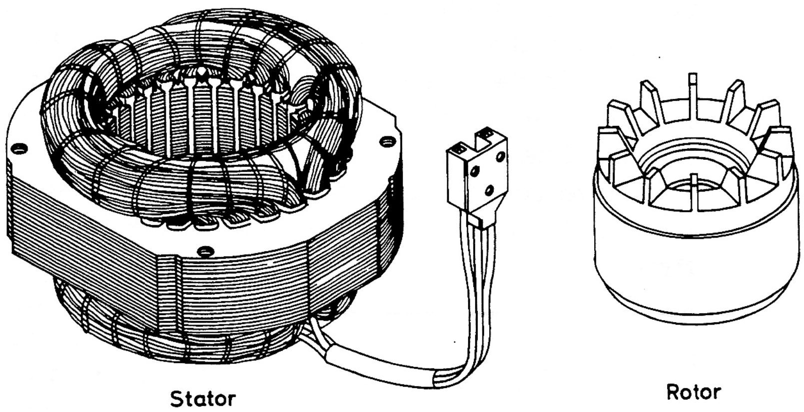
Squirrel-cage rotor

In a squirrel-cage rotor, the single conductors of the rotor are shorted ringwise. In the rotors of the Danfoss compressors, the rotor conductors and rings consist of a common cast aluminium grid.

Resistance start

In motors for resistance start, the start winding is made of wire of a smaller dimension than that of the main winding. The result is a large difference in ohmic resistance, causing the current in the star winding to be less inductive than the current in the main winding, and the required phase displacement is obtained.

DANFOSS MOTOR



Single-phase:	Connection between single phase and neutral.
Two-pole:	High r.p.m. - Small dimensions.
Synchronous:	Two-pole - 3000 r.p.m. at 50 cy. Four-pole - 1500 r.p.m. at 50 cy.
Asynchronous:	Two-pole about 2900 r.p.m. at 50 cy. Four-pole about 1450 r.p.m. at 50 cy.
Induction motor:	Transformer effect between stator and rotor. No commutator. No carbon brushes. No sparks.
Squirrel-cage rotor:	Al-conductors of rotor short-circuited in rings.
Resistance-start:	Higher resistance in start winding than in main winding.
Capacitor-start:	Higher starting torque per ampere starting current.

Fig. 28

Capacitor start

In the case of capacitor start, a capacitor is inserted in series with the start winding, when the current in this winding becomes capacitive. The current in the main winding is inductive, and the necessary phase displacement is then obtained.

7.1 Design of Danfoss motors

The motor consists of a stator (the static part) and the rotor (the rotary part).
Both components are made of packed iron lamellae, i.e. 0.5mm sheets insulated from each other.
The insulation between the single sheets consists of an oxide layer on the sheet surfaces.
The single sheets are stamped of sheet— or metal strip material and are given the dimensions required as well as the necessary number of slots for subsequent insertion of the windings. The stator units are assembled from the number of sheets necessary for the motor size, and the units are welded together at the corners. Next, the slots are insulated, and the coils (windings) are inserted. Polyester foil (mylar) is used as insulating material for the slots.

With the correct number of rotor sheets compressed, the aluminium rods are pressure die cast as well as the rings. The single sheets are twisted slightly relative to each other so that the rotor rods are given a taper. This is done to obtain steady running of the motor and to make the starting torque more independent of any odd position between the slots of stator and rotor.

7.2 Operating principle of the motor

In fig. 29 it is imagined that the rotor is rotating between a pair of pole shoes which are magnetized by a sine-shaped alternating current (1). When the rotor conductors pass a pole shoe, a voltage will be induced in the single conductors, having the effect of a current (2) in the rotor which sets up a field at right angles to the field from the stator. Due to the low ohmic resistance in the rotor relative to the inductive resistance, there will be a phase displacement between the two fields, i.e. they do not reach their maximum values at the same time.

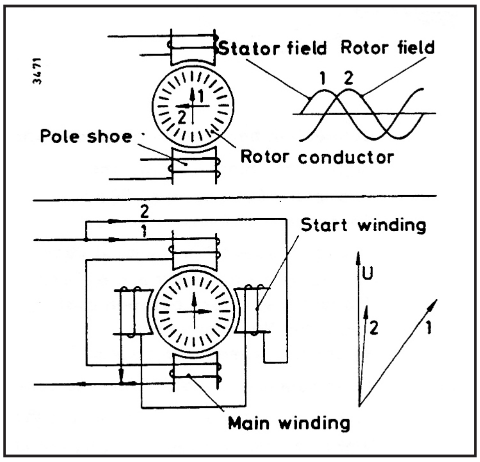


Fig. 29

The effect of these two fields, which are actually displaced both as regards directions of action and time, is a resultant rotating field which keeps the rotor running after it has started.
But how is the rotor started?
When the rotor stands still, no field is induced in the rotor which is at right angles to the stator field. A cross field is then set up artificially by placing a papir of magnet coils at right angles to the first ones. In this way there are two fields at right angles to each other.
By making this auxiliary winding of thin wire and hence with a high ohmic resistance, a phase displacement is created between the two fields, and as was the case before a resultant rotating field is set up.
Once the rotor has reached the speed required, the auxiliary winding (the start winding) is no longer required, and this winding is then cut by means of a starting device.

Besides, fast cut-out of the start winding is necessary since the winding will become hot very rapidly because of the high ohmic resistance, causing it to burn out if cut-out does not take place very shortly.

7.3 Motor characteristics

When you wish to buy a motor, it is not enough to place an order, for example, for a 1/10 hp or 1/8 hp motor and then assume that everything is all right. It is not, since the hp designation in itself is insufficient information about the characteristics of a motor. It is necessary to know the breakdown torque, efficiency, starting torque, starting current and the heating rate of the auxiliary winding.

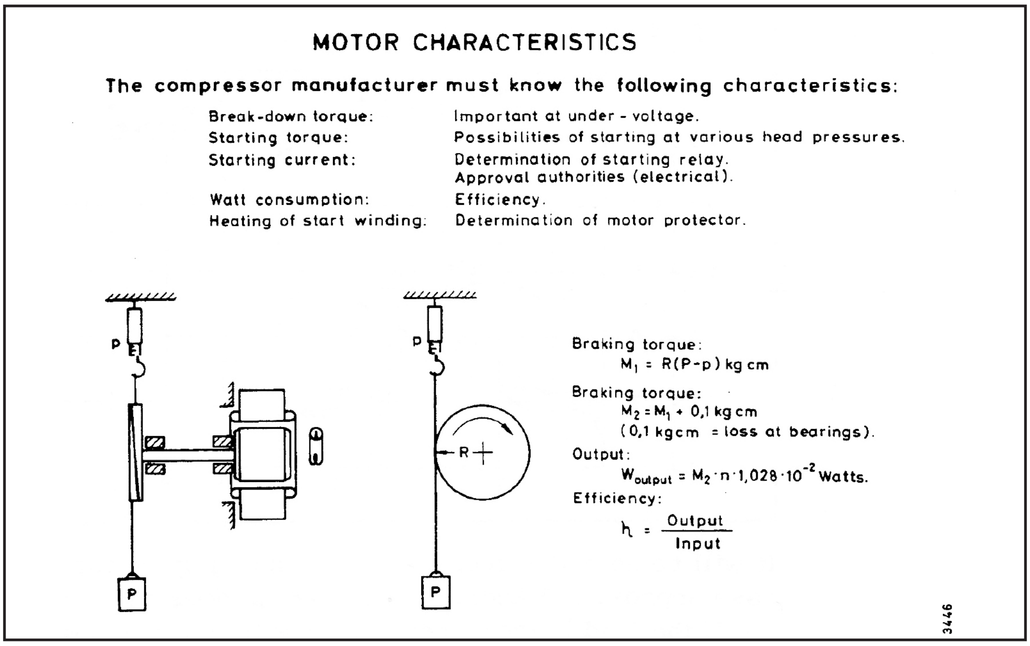


Fig. 30

This information can be obtained by taking measurements in a trial setup as shown in fig. 30, where partly the mechanical motor output and partly the electric input can be measured. The output is measured by means of a brake by loading the motor with weights suspend from the string round the brake disc. The braking torque is equal to the radius of the brake disc + half the thickness of the string multiplied by the weights minus the indication of the spring balance. If at the same time the speed has been determined by slip measurement, the motor output in watts can be calculated. The input is measured by the use of a wattmeter.
The efficiency is determined in the normal way as the ratio between the output and the input.

$$\eta = \frac{\text{watt output}}{\text{watt input}}$$

By braking with different loads, a number of points are obtained for watt output and input, efficiency, current consumption and speed, and the motor characteristics can then be drawn, as shown in fig. 31.

The speed is seen at the top. It falls evenly when the load increases up to a fixed load, in this case 6.8 kgcm, which is the highest load at which the motor can run. If the load is increased beyond this point, the motor will stop. It is said to "stall". This is called the breakdown torque.

A look at the efficiency curve shows a maximum value at a fixed load, and if the load is increased beyong this value, the efficiency will fall again. The aim is to make the maximum point on the efficiency curve coincide with the normal load of the motor, which is approx. 2.5 kgcm for this motor.
The efficiency tells something about the size of the losses in a motor, and as the losses mean heat development and hence a temperature rise in the motor, there is an interest in keeping these losses as low as possible and, therefore, the efficiency as high as possible.

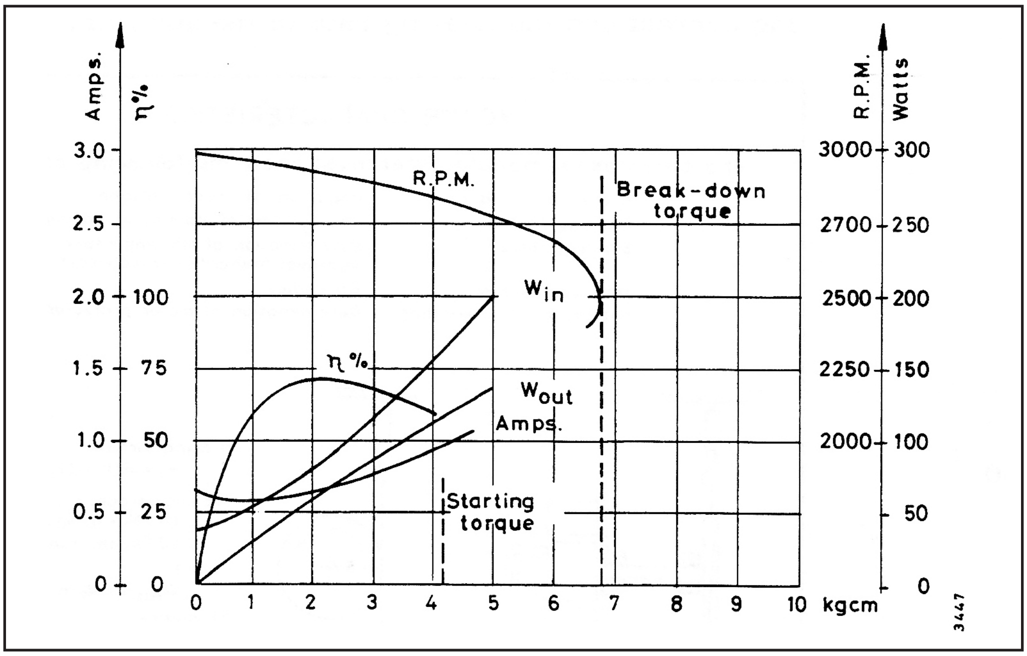


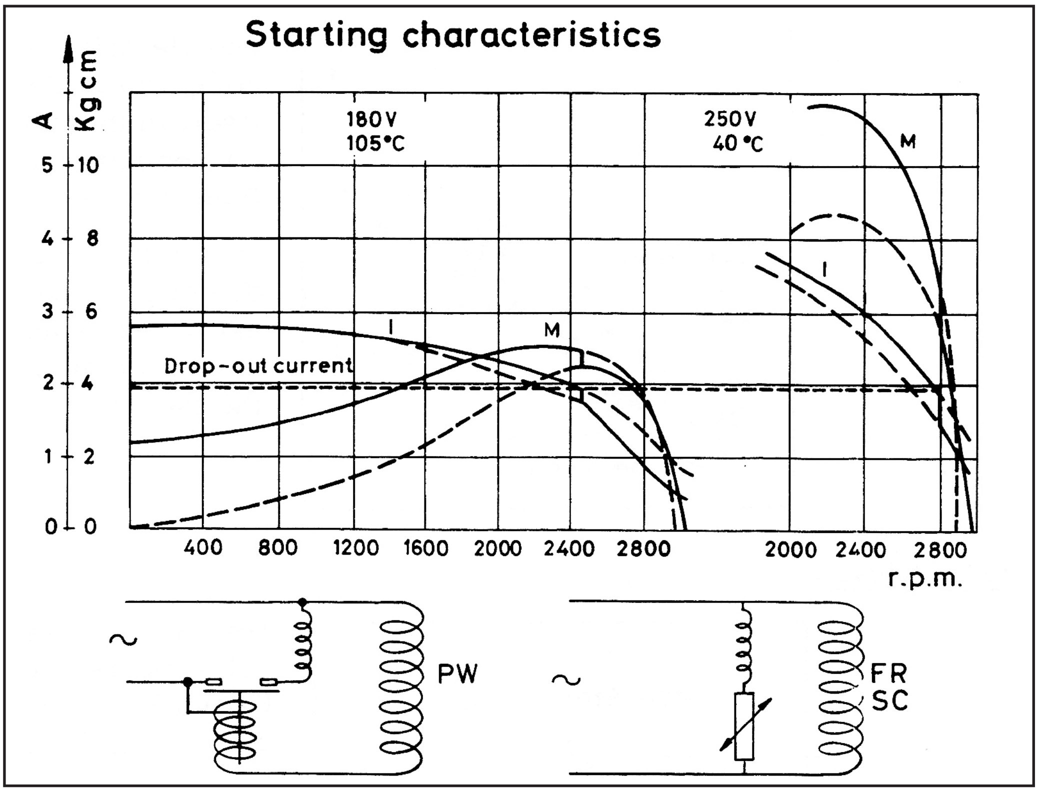
Fig. 31

It will be seen that from no-load running up to normal load (in this case approx. 2.5 kgcm) the amperage does not increase very much, but if the load is increased, there will be a somewhat heavier increase in the amperage.
These curves have been traced with only the main winding connected.

The diagram also shows the starting torque, in this case 4.2 kgcm, i.e. the torque of the motor when the rotor stands still and the start winding is cut in.
There are also other curves which are of interest to the evaluation of the characteristics of a motor. Fig. 32 shows the socalled acceleration curves, i.e. curves indicating the motor torque and the current in the main winding as a function of the speed.
It can be seen here that when the main winding alone is connected, the motor has no starting torque, since at no revolutions the torque curve passes through zero.
When the start winding is cut in, the torque curve rises, resulting in a certain starting torque at no revolutions.

It will be seen that there are two sets of curves. One set has been traced at 180 V and 105°C winding temperature corresponding to undervoltage and a warm compressor; the other set has been traced at 250V and 40°C corresponding to overvoltage and a cold compressor. The object of these curves is to ensure that a given motor can be used for starting by means of a current-dependent starting device both at over- and undervoltage as well as at cold and warm compressor.

Fig. 32



8. Electric equipment for PW compressors

Fig. 33

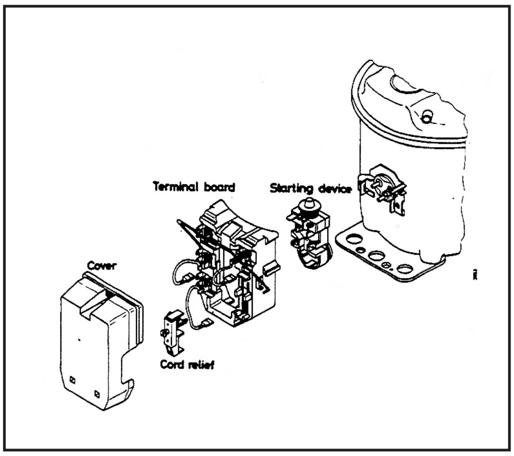
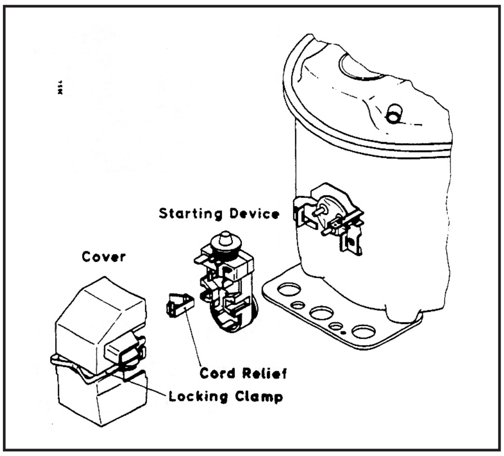


Fig. 34



The electric equipment contains the electric auxiliary components. The electric equipment for the PW compressors can be obtained in two versions, viz. "with terminal board" and "without terminal board". Either design incorporates the same starting device which consists of a start relay and a motor protector.

Both types of electric equipment have 6.3 mm quick connectors, and besides screw connectors can be used in the design with terminal board. The design without terminal board requires a special type connection box in the refrigerator for connection of the electric installations.

8.1 Electric equipment for FR and SC compressors

FR and SC compressors use the same type of electrical equipment. As far as function is concerned it is identical on both types of compressor and consists of a semiconductor starting device with 6.3 mm spade connections.

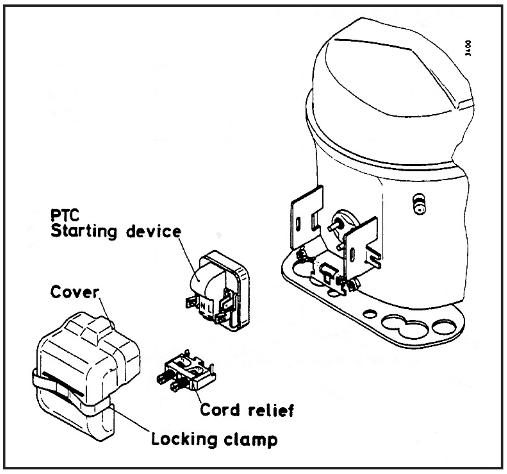


Fig.35

The electrical equipment on the FR compressor does however distinguish itself in that the screws on the connection terminals are accessible from the side, as shown in fig. 35.

The starting device is mounted directly on the compressor terminals. The FR and SC compressors have a winding protector built into the motor.

8.2 Starting device

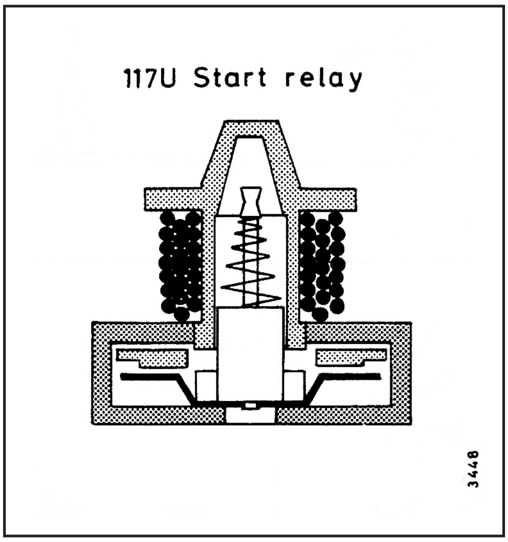


Fig. 36

The PW compressors use a start relay as starting device, while the FR and SC compressors use a semiconductor (PTC) as starting device.

It is the object of the starting device to cut in the start winding when the motor is to start, and to cut it out again when the motor has gained enough speed for the main winding to take over.
Fig. 36 shows the start relay which is used for the PW compressors.
This is a current relay consisting of an iron armature enclosed in a coil.
When a sufficiently strong current runs through the coil, the armature is pulled into the coil as a result of the induction, and a contact rail makes the circuit to the start winding.
Fig. 37 shows how the start relay is incorporated in the motor circuit. It will be seen that the relay coil is connected in series with the main winding, which means that it is actually the current in the main winding which determines when the start winding is to be cut in and out.
At the moment of starting the main winding is connected to the circuit, and as the main winding has no torque, the "locked rotor" conditions exists. A large current then runs through the coil of the start relay, and induction in the coil attracts the armature so that connection to the start winding is established via the contact rail in the relay.

The motor can then start as a result of the torque of the start winding. When the motor has reached a certain speed, the current in the main winding falls and hence also through the coil of the start relay. The current can now detain the armature no longer, and it will move out of the coil causing the connection to the start winding to be interrupted.

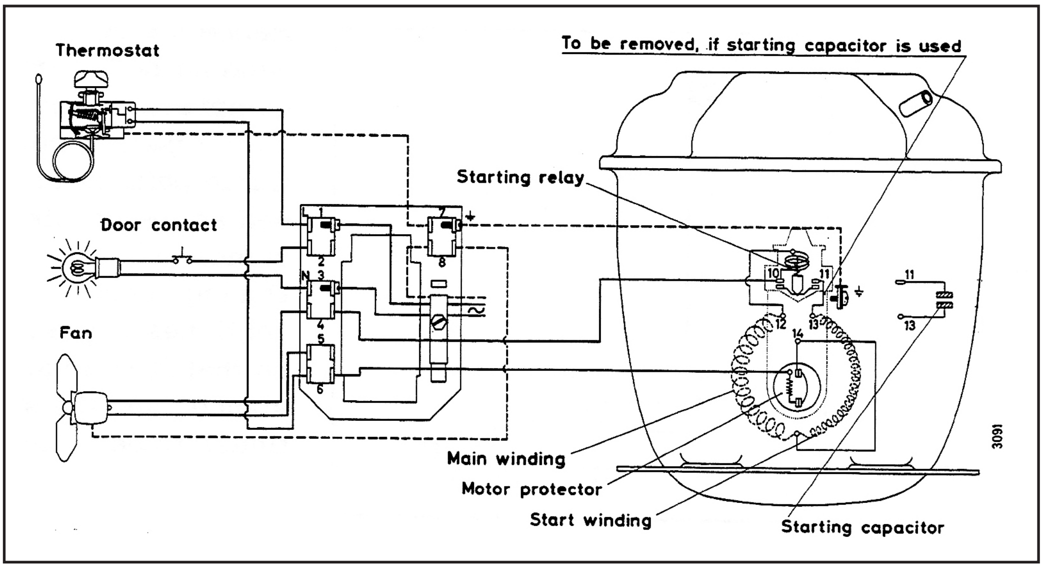


Fig. 37

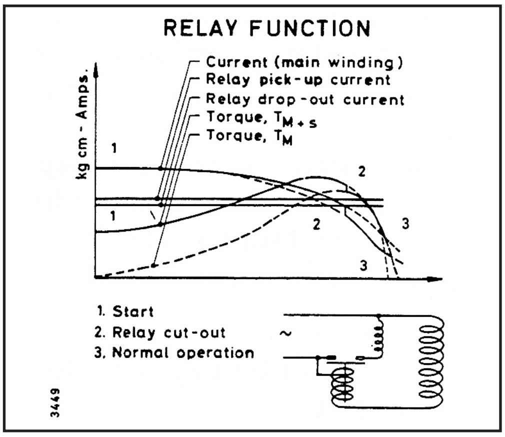


Fig. 38

Fig. 38 shows the current flow in the main winding and hence in the relay coil during start. It can be seen from this how well a relay is adapted to a given motor, i.e. whether the relay cuts out the start winding near the breakdown torque. It can be seen from this that there is only one relay which supplies the maximum torque during cut-out. If a relay with a larger drop-out current is selected, the torque is reduced, and selecting a relay with a smaller drop-out current will also give a reduced torque. In other words, the start relay used is important.

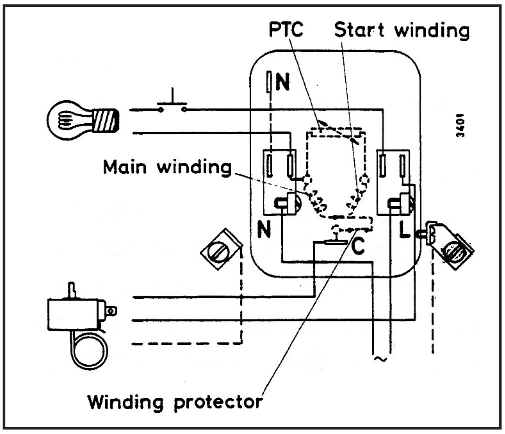


Fig. 39a

Fig. 39a shows the wiring diagram for an FR compressor and fig. 39b for an SC compressor, and it will be seen that the PTC, like start relay, is connected in series with the start winding.

When the voltage is supplied and the PTC has cooled off, the current will pass through the start winding, and the motor will start.

After a short while the current has heated the PTC to the Curie point, and the resistance increases to approx. a thousand times the original value. (See fig. 40).

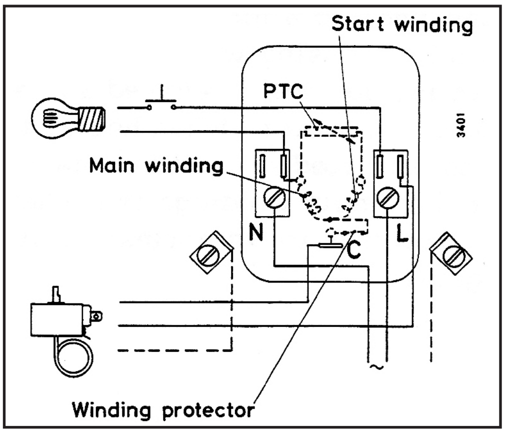


Fig. 39b

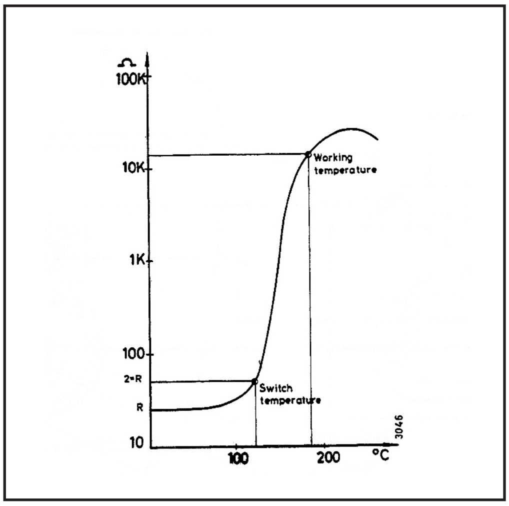


Fig. 40

Hence the connection to the start winding is "interrupted", and the compressor continues to operate on the main winding alone. The Curie point is in this context defined as the double value of the resistance at 50°C.
During operation a small current continues to pass through the PTC so that it maintains the high resistance, and the start winding continues to be "interrupted".

Important!
To obtain optimum starting conditions the PTC must be cooled, and it must be ensured that every-standstill period will be for a period of at least 5 minutes. Hence the PTC will have been cooled so much that another start can take place.
If the compressor is started without electric equipment, a very rapid temperature increase will occur in the start winding, since the start circuit has a reduced internal resistance when the PTC in the starting device of the electric equipment is not cut in.
If it is thus attempted to start the compressor without electric equipment, the winding protector cannot be expected to react, and a burned-out start winding may result.

9. Motor protection

The object of the motor protector is to protect the motor windings against overload in the best possible way, under the following conditions:

Locked rotor
Operation with start winding cut in
Operation with main winding cut in

In the case of the PW compressors, a motor protector fitted in the electric equipment is used, while the FR and SC compressors have a winding protector inserted in the motor windings.

9.1 Motor protector

The PW compressors incorporate a motor protector of the Klixon type consisting of a bakelite housing with a bimetal disc and a hot-wire. The bimetal disc is, normally, curved and makes contact, thus making the circuit to the motor. When heated to a fixed temperature, the bimetal is deflected from the contact points, and the circuit to both the start and main windings is broken. After sufficient cooling, the bimetal returns to its normal position and makes the circuit to the motor again.

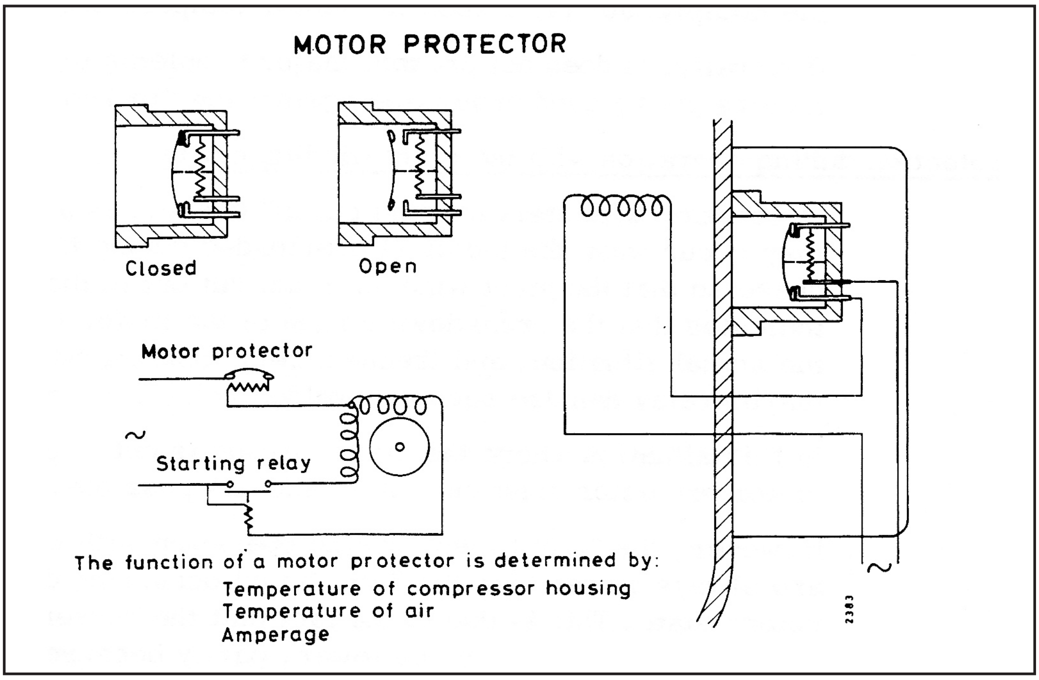


Fig. 41

It can be seen from fig. 41 that the motor protector is inserted in the electric circuit in such a way that it breaks the total current to the motor and hence the current to both main and start windings.

The motor protector is placed against the compressor housing and is affected by the following factors:

Temperature of compressor housing
Ambient temperature at motor protector
Amperage

The winding temperature thus only influences the function of the motor protector indirectly.

9.1.1 Protection when rotor is locked

The largest current take-up is during starting. If the rotor is prevented from rotating, this large current take-up can occur during a lengthy period, and the start winding temperature increases rapidly.

Under these conditions which are denoted "locked rotor" there is a demand for a rapidly reacting protective device which cuts out before the winding temperature exceeds 150°C.

The "degree of protection" of the motor during the "locked rotor" state can be expressed as the "trip time" of the motor protector which is determined by current and temperature and designates the time passed before the motor protector cuts out.
The shortest possible "trip time" is required within certain limits.

As the motor starting current is largest at overvoltage , the shortest "trip time" will occur at overvoltage and hot motor protector.

The longest "trip time" will occur at undervoltage and cold motor protector. The effect of the temperature of the motor protector on the "trip time" will be equalized to some degree since the starting current of the compressor falls when the motor temperature increases.

Generally, it does not present major problems to obtain motor protectors giving good protection against the "locked rotor" state.

9.1.2 Protection during operation with the start winding cut in

"Operation with start winding cut in" designates a situation which may occur when the motor is overloaded during the acceleration phase so that the start winding is not cut out in the normal way. It indicates that the breakdown torque of the motor is insufficient in the actual situation, and frequent relay operations may occur, and maybe relay damage such as "welded relay contacts".

In this situation where the start winding is cut in permanently, the motor protector must cut out as soon as possible.

However, the "trip times" during operation with start winding cut in are always longer than the "trip time" occurring during the "locked rotor" state. This is due to the fact that the current through the motor protector will always be lower, partly because the rotor rotates, and partly because the situation is especially connected with low—voltage conditions. The degree of protection will, therefore, always be inferior to that of the "locked rotor" state.

9.1.3 Protection of main winding during operation

It is also desirable that the motor protector should ensure that the compressor motor will not assume any critical temperature during operation.

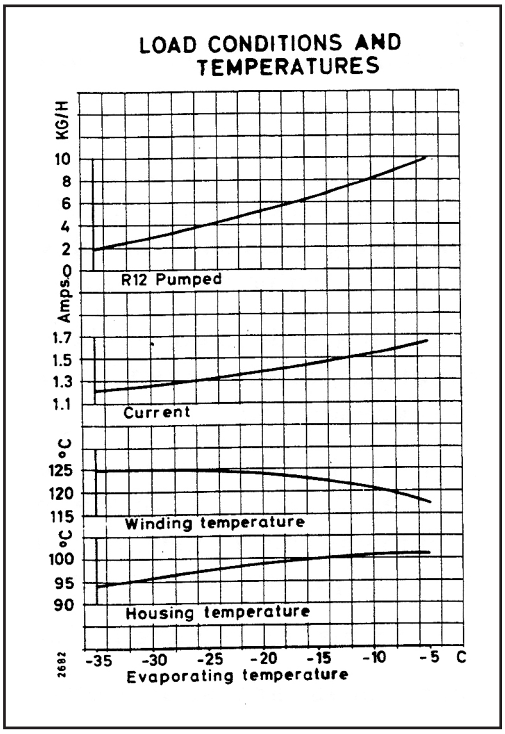


Fig. 42

It can be seen from fig. 42 that there is no proportionality between current take-up and winding temperature. For this reason it is, therefore is difficult to select a motor protector which ensures reasonable protection, and the difficulties are increased the larger the load variations to which the compressor motor is subjected. As the motor protector is actuated through a combined influence of current and heat from the compressor housing, conditions will occur where the motor protector gives mediocre protection of the main winding. In other cases, the motor protector selected will be liable to render overprotection. Externally mounted motor protectors, therefore, constitute a compromise to some extent as regards protection of the main winding. Experience shows, however, that burned-out main windings occur very seldom , and this must be taken as evidence that the protection principle used works satisfactorily.

To determine whether the motor protector used is sufficiently reliable, a 15-day test is performed. During this test the compressor with the rotor braked is connected to 1.1 x the rated voltage, and in the course of 15 days the motor protector cuts out and in continuously with the starting current of the motor as load.

After these 15 days the motor protector must still operate correctly, and the start winding temperature must not exceed a fixed temperature limit.
The "out time" of the motor protector is connected with the temperature when it cuts in again, and the "out time" must be so long as to allow for pressure equalization in the refrigeration system. Nor must the "out time" be longer than necessary, however, because of the heat ingress and hence the temperature increase in the refrigerator.
In order that the motor protector should not cut out too quickly when the compressor is hot during starting, the cut-out must be somewhat slow so that the compressor can gain full speed before any cut-out takes place.
It is impossible to say that a particular compressor type goes with a particular motor protector and then expect this motor protector to protect at a fixed winding temperature under all load conditions and operating conditions to which a compressor may be subjected.

The selection of a motor protector is based on experience and a certain knowledge of the problems which the user is up against.

A 100% protection of a compressor motor is impossible, but the incorporation of a winding protector in the windings will provide optimum protection from a technical point of view.
These windings protectors are used in FR and SC compressors.

9.2 Winding protector

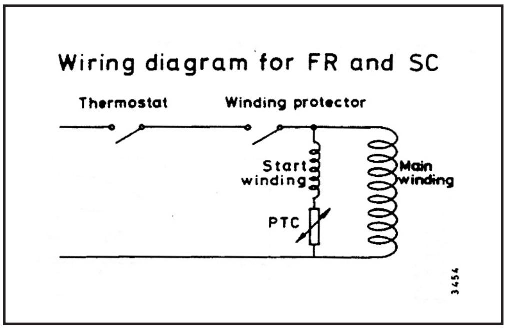


Fig. 43

The FR and SC compressors use winding protectors, and it can be seen from fig. 43 that the winding, protector is built into the lead to the motor and is inserted between the start and main windings. The winding temperature is then sensed directly, and satisfactory, protection of both start and main windings is achieved.

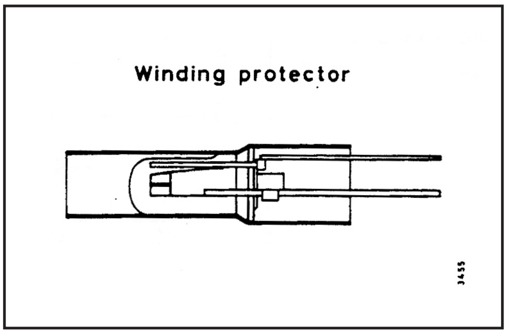


Fig. 44

The winding protector is built into a hermetic enclosure and consists of a bimetal with contacts. The enclosure is necessary, for one reason among others, because any formation of sparks in an R12 atmosphere will result in decomposition of the refrigerant.

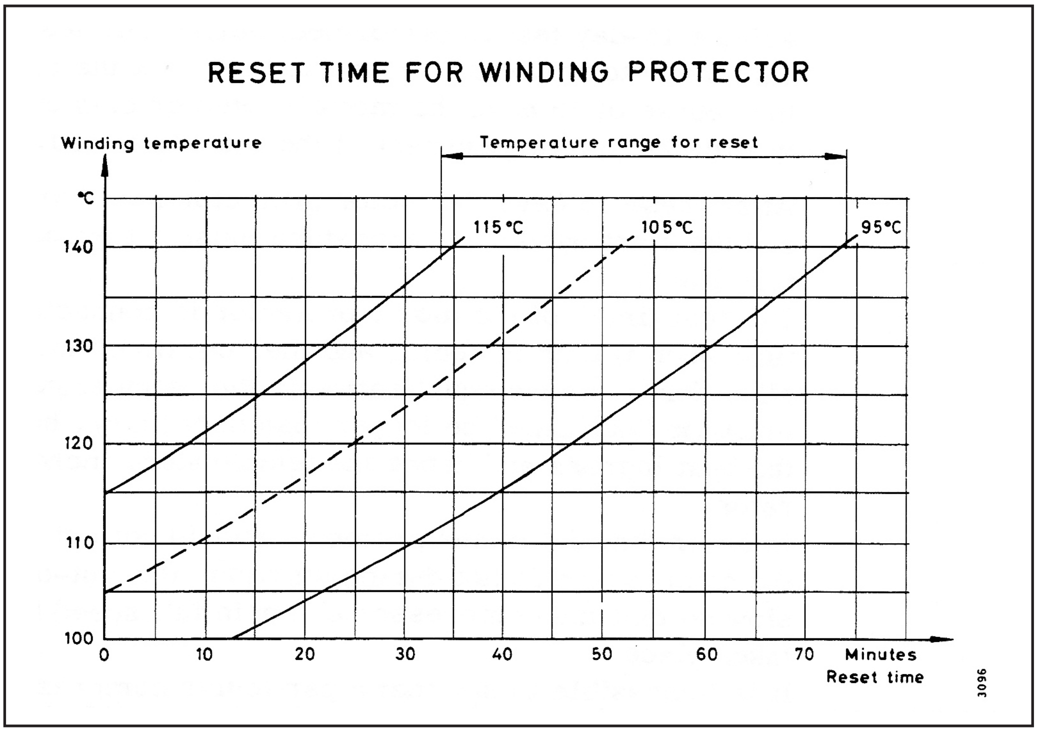


Fig. 45

Fig. 45 shows the reset time for a winding protector, and it can be seen that among other things it depends on where the winding protector lies in its tolerance range as well as at what winding temperature cut—out occurs.
If thus the compressor has been running for a very long time before the winding protector is cut out, so much heat has been accumulated in the motor in this way that the "out time" and hence the standstill time of the compressor may become relatively long.

10. Starting capacitor

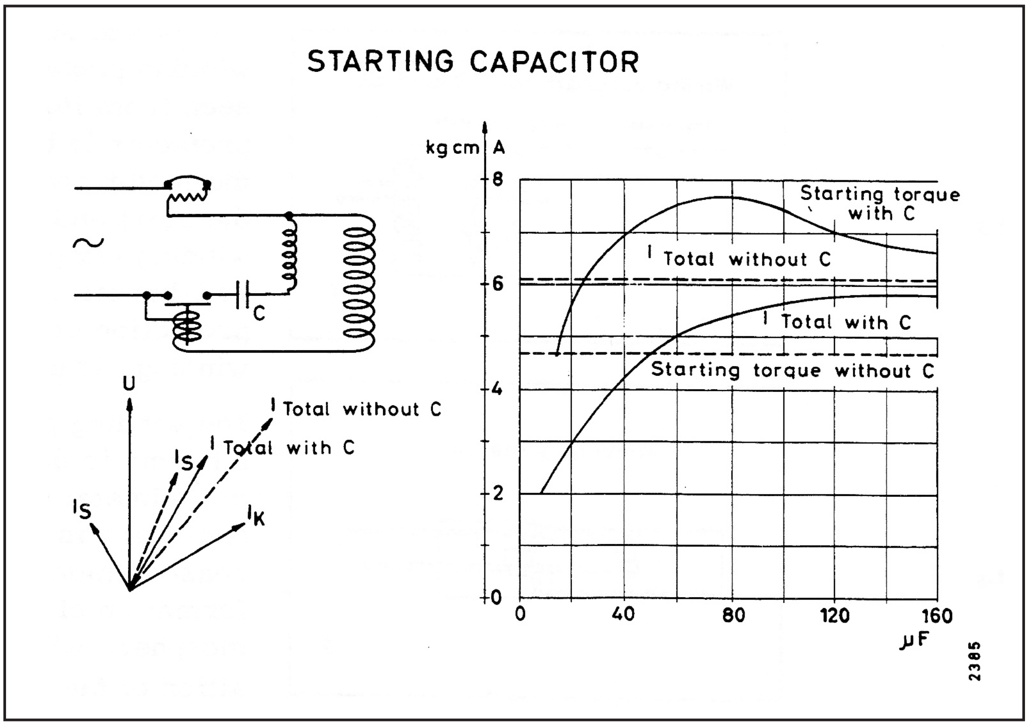


Fig. 46

The starting capacitor used in HST compressors is a socalled bipolar electrolytic capacitor with a high capacity (μ F) per unit of volume. Using a starting capacitor makes it possible to increase the starting torque of a motor without increasing the starting current.
Fig. 46 shows that the starting capacitor is connected in series with the start winding. The current vector is indicated in a vector diagram, and it shows the difference in the total current with and without a capacitor, among others. It also appears that the ratio between torque and current is changed dependent on the capacitor size.

If a high starting torque is required, for example, in the case of expansion valve operation, an HST compressor with a starting capacitor is chosen.
In these compressors the start winding has been changed to give, together with the starting capacitor, a starting torque which is equal to or larger than the breakdown torque of the motor.

In LST compressors designed for capillary tube operation a starting capacitor can be used with advantage as an emergency solution when difficult starting conditions prevail.
The current and torque curve in fig. 46 gives the below example of the influence of the starting capacitor.
At 15 μF the torque is the same as without a capacitor, but the current is reduced by approx. 50%. At 80 μF the torque has increased by approx. 60 — 70%, but the current has in this case only been reduced by approx. 10%.
If a high starting torque is required, for example, in areas with extremely low voltages, a large capacitor is preferred.

If, on the other hand, a small starting current is required, for example, to avoid too large voltage drops in weak mains, a small capacitor is preferred.

However, a starting capacitor cannot be inserted directly since it changes the current characteristics of the motor and hence affects the functions of the start relay and the motor protector.

It is normal that when the start relay cuts out the start winding, the current falls in the main winding and hence also in the relay coil, which sustains the relay function.
If a starting capacitor is used, the opposite may happen, i.e. when the relay cuts out the start winding, the current increases in the relay cuts in again. The result is that the relay will bounce, which may result in burning of the relay contacts, and it may finally act as a noise source.
During starting the motor protection is greatly dependent on the current-sensitivity of the motor protector, and changes in the current characteristic may, therefore, put the protection out of service, fully or partially, during "locked rotor".

Starting capacitors should, therefore, only be used on LST compressors after consulting Danfoss when it is a question of more than a few cases of emergency.
Attention is drawn to the voltage across the capacitor which may very well be 3-400 V with a 220 V compressor.

It should be noted that electrolytic capacitors are only designed for intermittent operation. Starting capacitors with an intermittence factor of 1.7% should be used for the Danfoss compressors, which means a maximum of 20 starts each with a duration of 3 seconds and equally distributed over one hour.

11. Development and inspection tests

Before a new compressor is put in production, it has been preceeded by comprehensive and lengthy development work as well as a multitude of different tests. Many of these tests are also performed after the compressor has been put in production in order to ensure that the product will comply with the specifications. Some components are tested 100%, and others are spot-tested.

DEVELOPMENT AND INSPECTION TESTS.

Volumetric test:	Pumping capacity. Tightness of valves and material. Watt consumption.
Final test:	Checking start and operation.
Refrigeration capacity:	Calorimeter-test.
Mechanical strength:	7days test. 4000-h test. Start and stop test.
Resistance to chemicals (life):	2000-h test.
Noise level:	Noise test.
Transport stability:	Vibration and drop tests, etc.

Fig. 47

The quality of the compressor operation is determined during the manufacture by means of the socalled "volumetric test" where the pumping capacity and wattage consumption of the compressors are determined, and where the oiling capacity, tightness of materials and valves, etc., are tested.

After welding together, every single compressor is pressure-tested at approx. 17 atm.g to test welds and solders.
The dried, welded-together compressor is subjected to a brief starting and operating test in connection with the oil charging. Every single compressor is also subjected to a high-tension test.

Other tests, which may often prove destructive, are based on spot-tests selected from statistic quality control. The most important of these tests will be mentioned in the following.

11.1 Calorimeter tests

The user of hermetic refrigeration compressors will be interested in knowing whether a compressor is suitable for a special job. Besides, he will also like to know the capacity of a given compressor. By the use of the calorimeter it is possible to obtain information about the capacity under different load conditions.

The calorimeter is an important tool during the development work, but it is also used for the production control.

A calorimeter can be constructed as shown in fig. 48.

The calorimeter consists of a pressure-tight calorimeter vessel which contains evaporator coils, an expansion valve which can be operated on the outside of the vessel, and an electric heating element and a secondary refrigerant. (R12 is used at Danfoss to obtain a reasonable level on the mercury pressure gauge.)

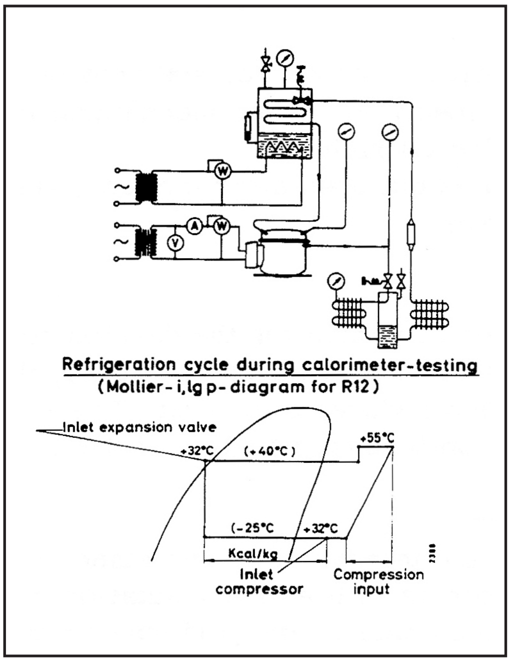


Fig. 48

The power supply to the heating element must be adjusted so that it corresponds to the amount of heat which can be removed by the evaporator coil when the calorimeter vessel temperature has been equalized to the ambient temperature.
The power can be measured in two different ways; either by means of a wattmeter or a kWh—meter measuring a fixed period.
Conversion of watts into kcal/h is done to the formula:
1 watt = 0.86 kcal.
The compressor must have reached operating temperature before the calorimeter test.

The calorimeter measurement can supply information about the following values:

- Capacity (kcal/h)
- Wattage consumption (watts)
- Current consumption (amperes)
- Temperature of pot (°C)
- Winding temperature (°C)
- Temperature in discharge connector (°C)
- Minimum operating voltage,

the following values being known at the measurement:

- Evaporating temperature (°C)
- Condensing temperature (°C)
- Ambient temperature (°C)
- Subcooling of liquid (°C)
- Superheating of gas (°C)
- Voltage
- Frequency
- Cooling of compress

11.2 7-day test

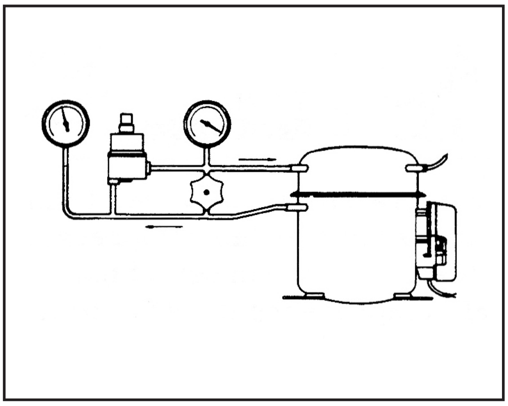


Fig. 49

This test is an accelerated lifetime test for the purpose of determining the mechanical strength of a compressor.
The compressor is provided with a tube system with an expansion valve between the discharge and suction connectors. The valve is set for a pressure corresponding to 90°C condensing temperature

The compressor operates at rated suction temperature for seven nights and days.
This test is generally recognized and provides good security, at the load conditions specified, of the mechanical characteristics of the compressor being all right.
The compressor is cut open after the test, and the single parts are examined for wear.

11.3 4000—hour test

This test is especially used for the development work, and the compressor is tested in the same way as during the 7-day test, only the pressure has been reduced to approx. 20 atm.g, but in this case the time of the continuous operation of the compressor is 4000 hours.

11.4 Testing the chemical stability

In order to test the temperature-resistance of the oils usable in the compressor as well as the insulation materials of the motor, 12-week test (2000 hours) are performed during which the compressor is made to run continuously 12 weeks at a winding tamperature which is 20°C higher than the temperature which is, normally, permissible for the compressor. If the oil and the insulation materials are all right after the test, there is a security that the compressor can be approved for winding temperatures which are 20°C below the temperature at which the test was performed.

11.5 Noise measurements

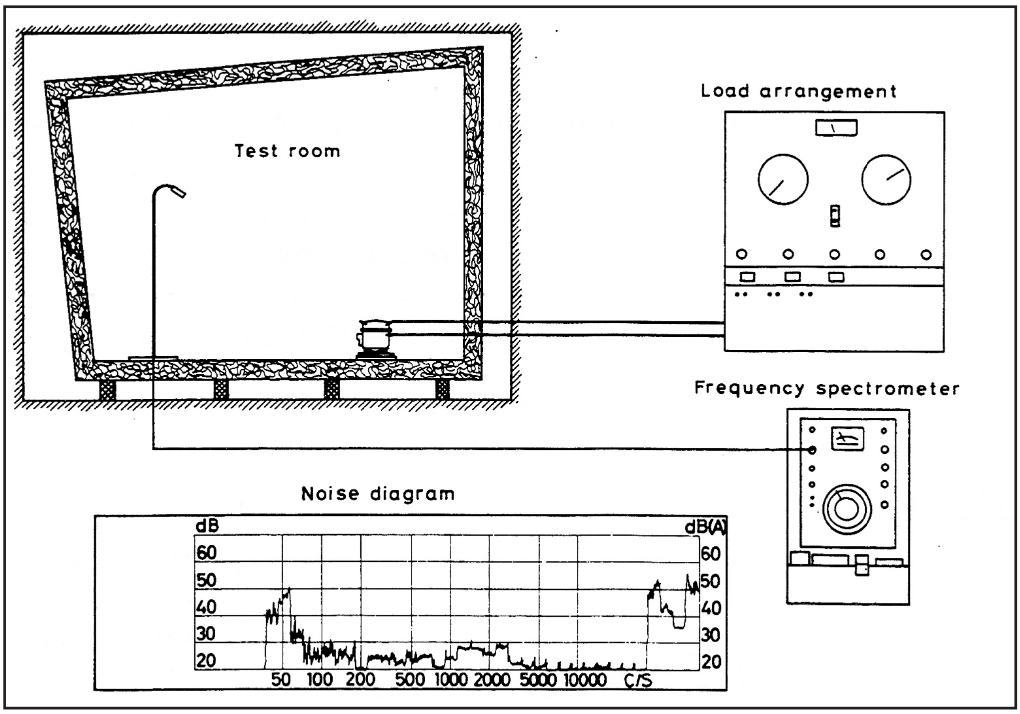


Fig. 50

As the hermetic compressor is used mainly in refrigerators in dwellings, it is necessary that the compressors should have an acceptable noise level, and a number of noise measurements are taken every day of compressors selected on a statistic spot-test basis.

The compressor is set to operate at a fixed load in a reverberant test room, and a noise measurement is taken when stable operating conditions prevail.
The noise level is recorded on record paper with a frequency graduation of from 10 to 20,000 Hz.
The record paper is synchronized with a frequency spectrometer set for increments of 1/3 octave band from one frequency to the next following. The spectrometer is equipped with filters in such a way that all frequencies are excluded, with the exception of the one at which measuring is done. Finally, the meter makes a summary of the noise levels at the single frequencies, resulting in a total noise level in dB(A).
It should be mentioned that it is impossible to compare noise measurements directly which are taken in different test rooms. If the operating conditions of the compressors are identical, a comparison can be made, however, through a conversion, but in that case it is necessary to know the volume, reverberation time and room noise level of the test room.

11.6 Transport stability

A hermetic compressor must also be able to resist transportation, either separately or mounted in a refrigerator. To this end, transport test are made continuously where the compressor is subjected to high stresses, for example, by vibration testing.

11.7 Other tests

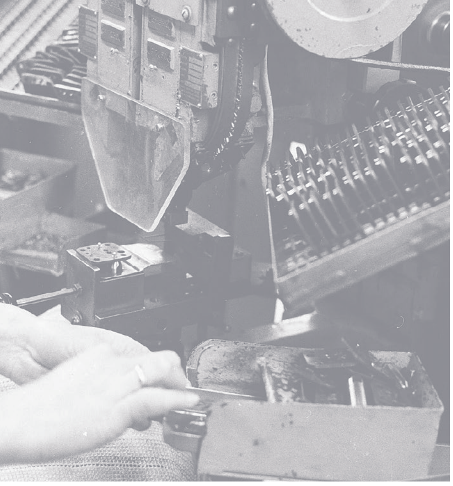
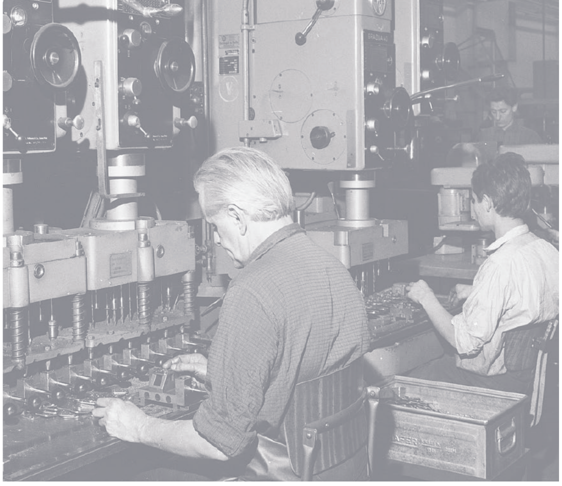
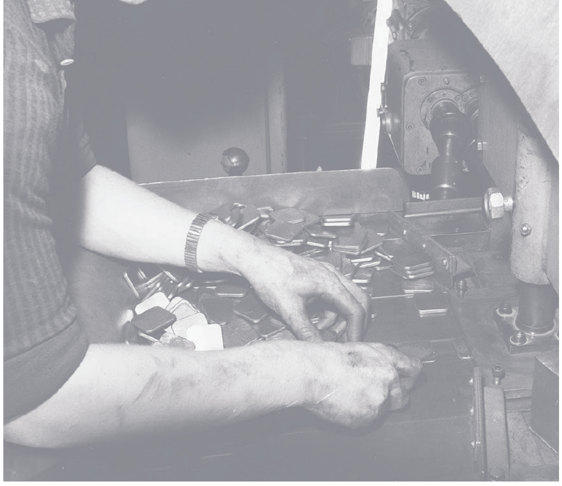
Among other tests to which the Danfoss compressors are subjected daily, can be mentioned e.g.:

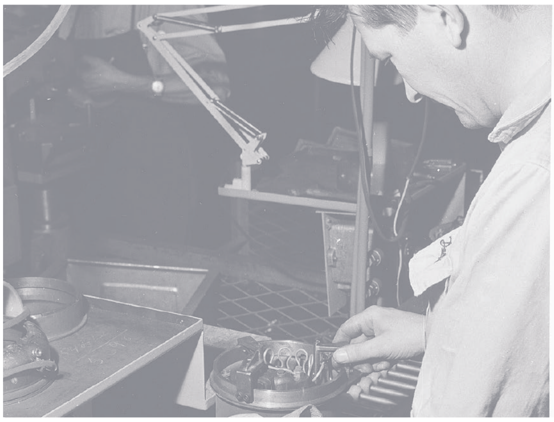
Measuring the moisture content
Measuring the dirt content
Measuring the moisture content of the oil used, etc., etc.

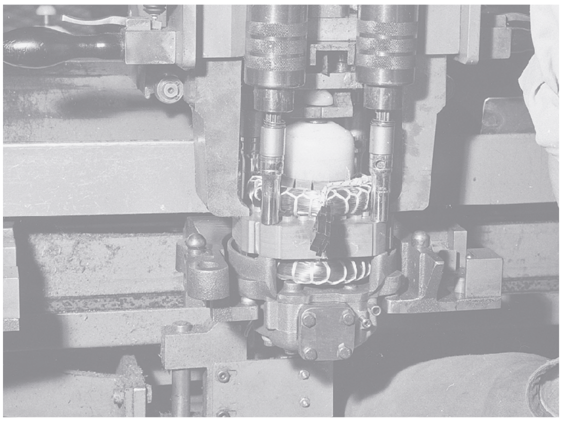
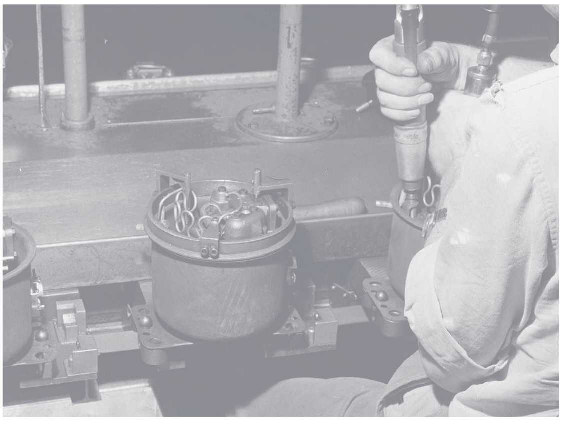
In order to keep the Danfoss compressors at a continuous high quality level, development work is done all the time, and now and then the designs are changed.

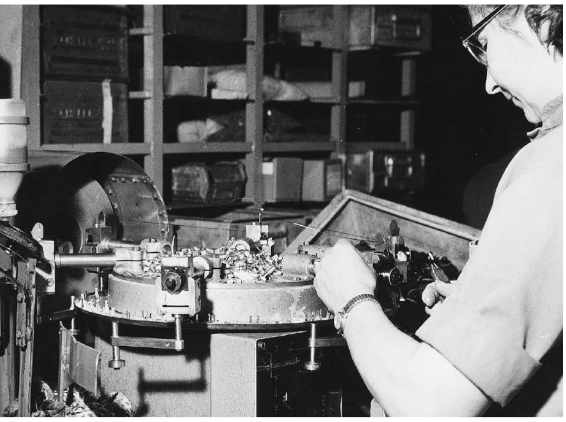
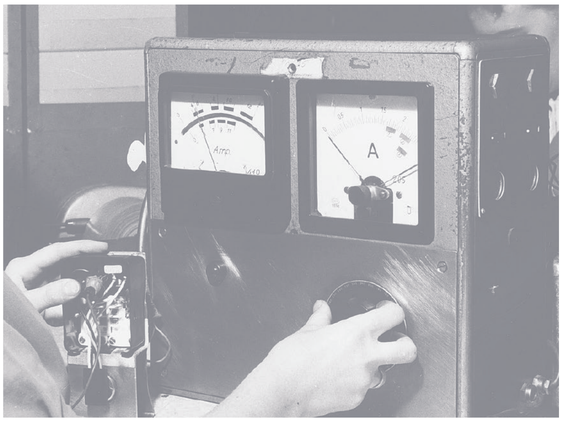
On concluding this talk we express the hope that the knowledge of the Danfoss compressors has been amplified for the benefit of present and future users.

Contents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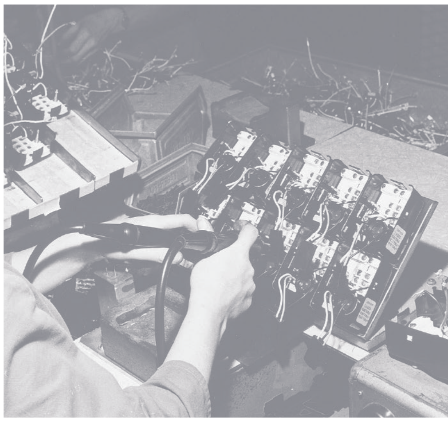



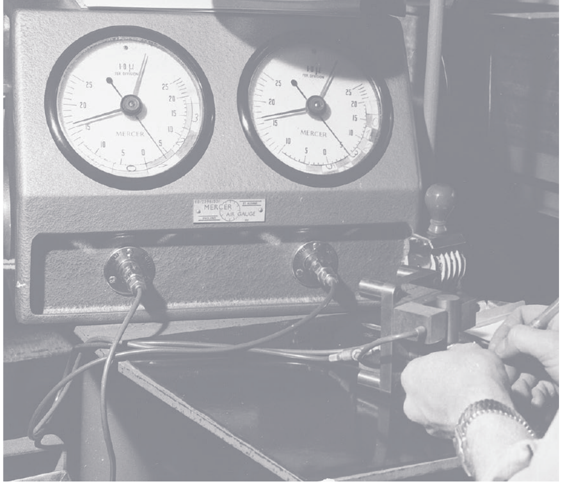
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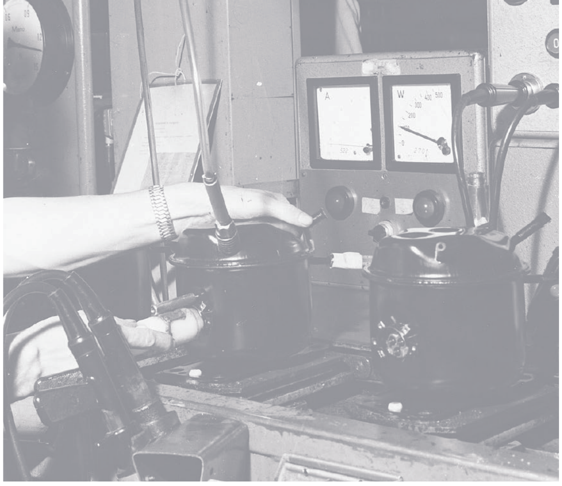
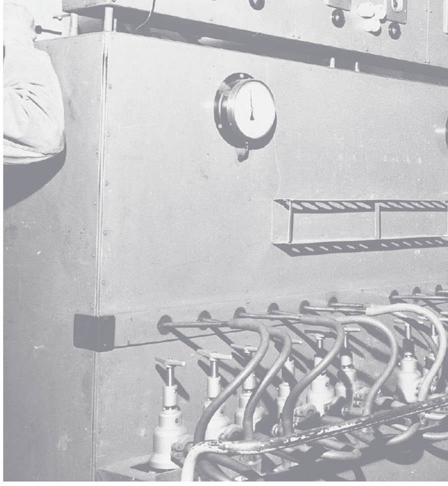
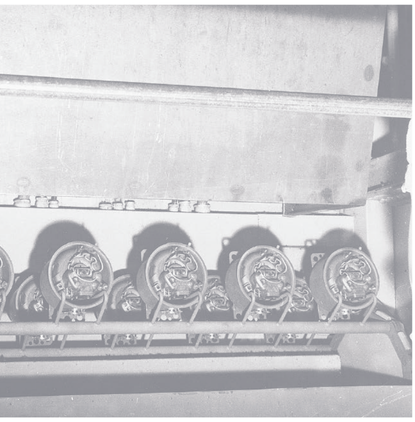
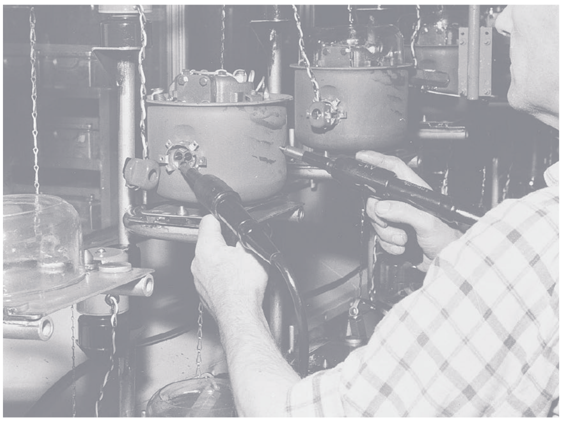
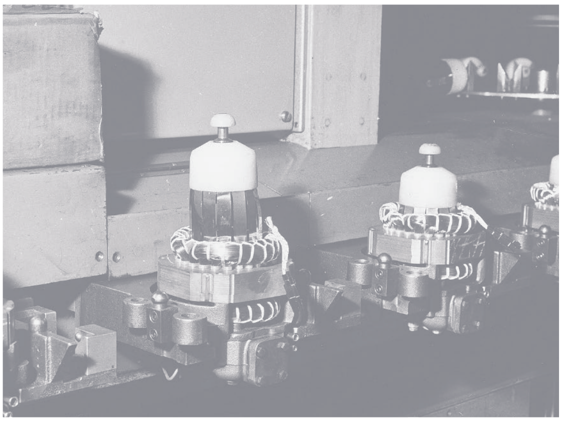
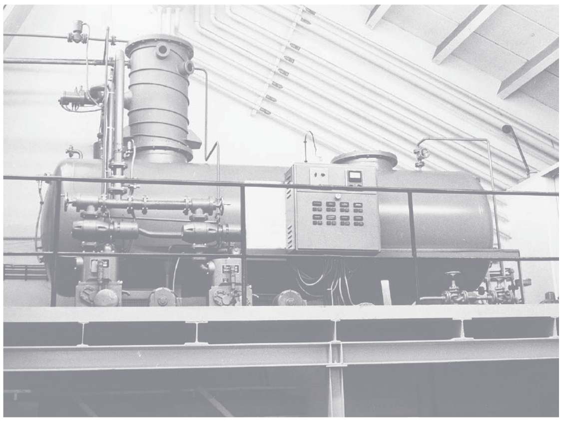
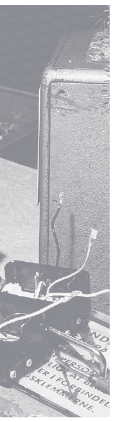
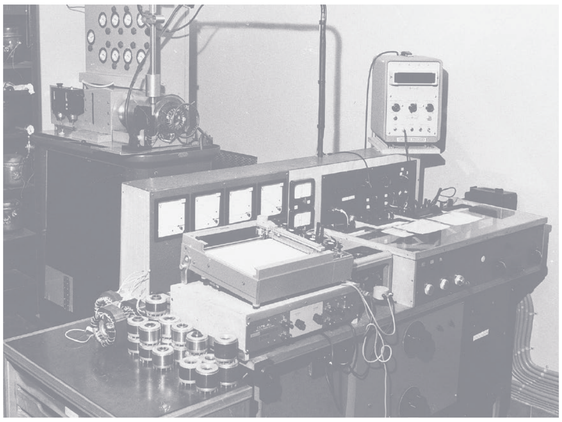
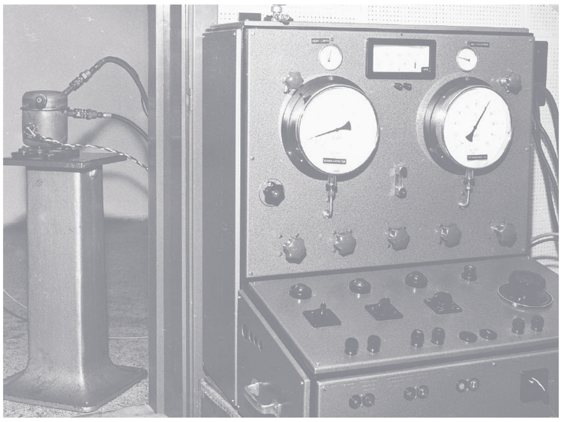
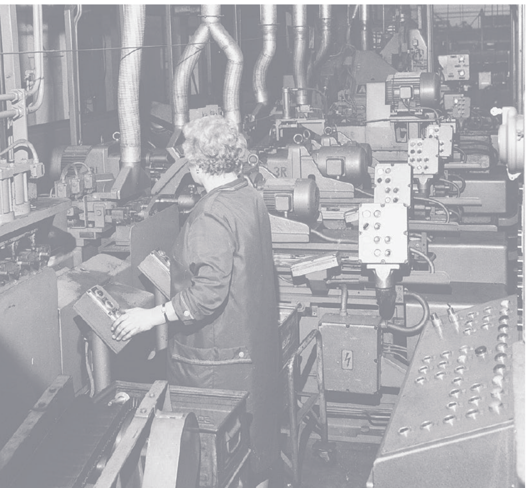
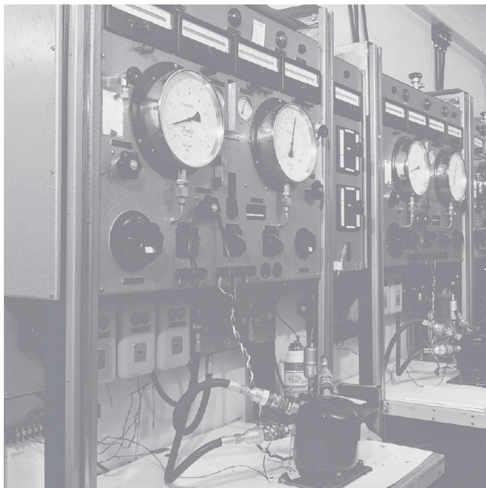






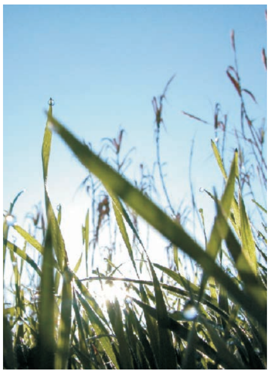




OUR IDENTITY

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

SECOP

1956
Production facility and headquarters in Flensburg, Germany founded.

1958
Start of production for PW compressors.

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

1972
Introduction of FR compressors.

1977
Introduction TL and BD compressors.

1990
Introduction of NL compressors.

1992
Introduction of 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 of 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 DC compressor.
Introduction of DLX and NLU compressors.

2013
Introduction of the XV compressor – opening a new chapter in refrigeration history.
Secop acquires ACC Fürstenfeld, Austria.

2015
New generation of energy-efficient propane compressors.
New variable speed platforms for household and light commercial applications.

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