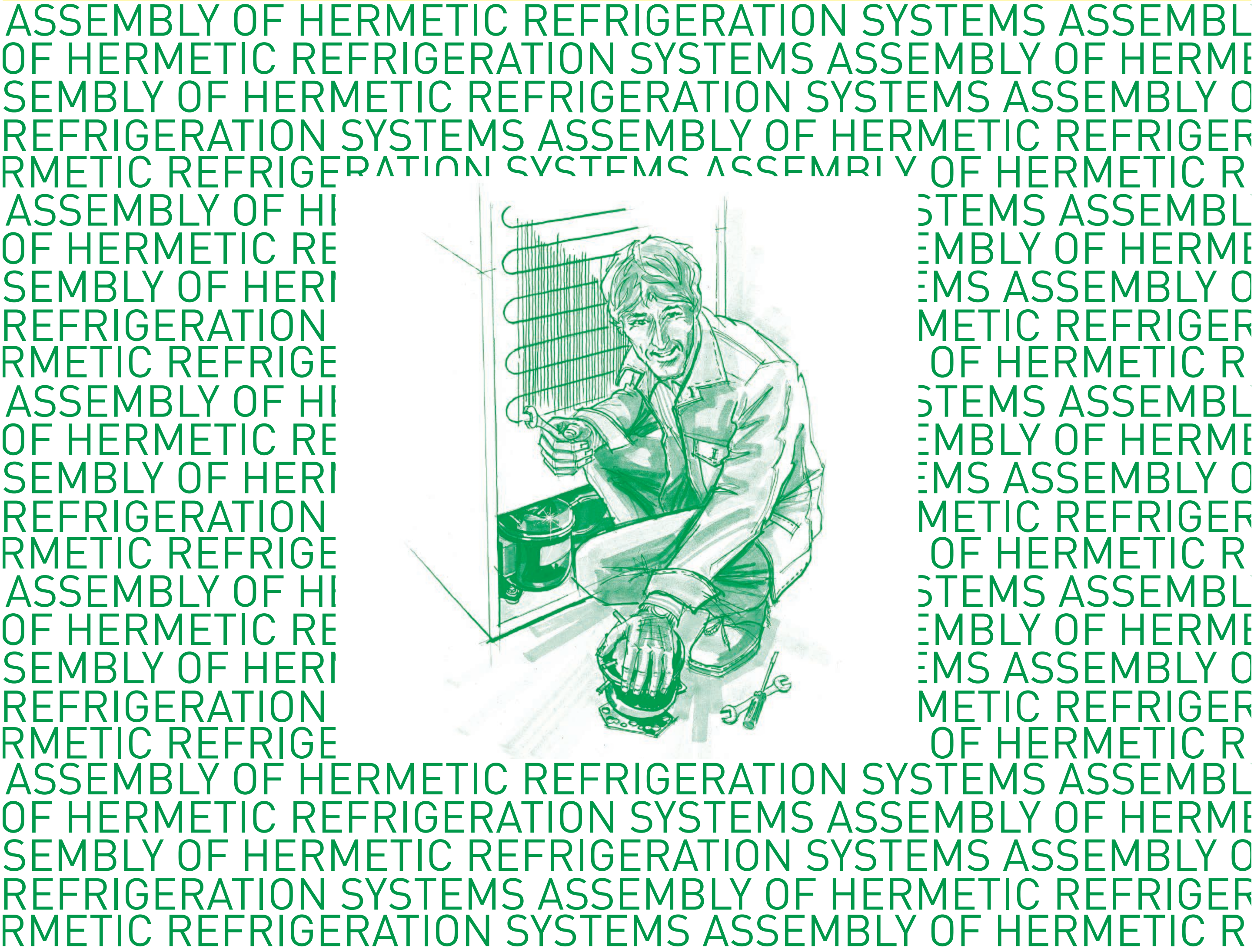
WITH MORE THAN 60 YEARS OF EXPERIENCE IN COMPRESSOR TECHNOLOGY AND HIGHLY COMMITTED EMPLOYEES, OUR FOCUS IS TO DEVELOP AND APPLY THE ADVANCED COMPRESSOR TECHNOLOGIES TO ACHIEVE STANDARD SETTING PERFORMANCE FOR LEADING PRODUCTS AND BUSINESSES AROUND THE WORLD.

60 YEARS 1956-2016

SECOP

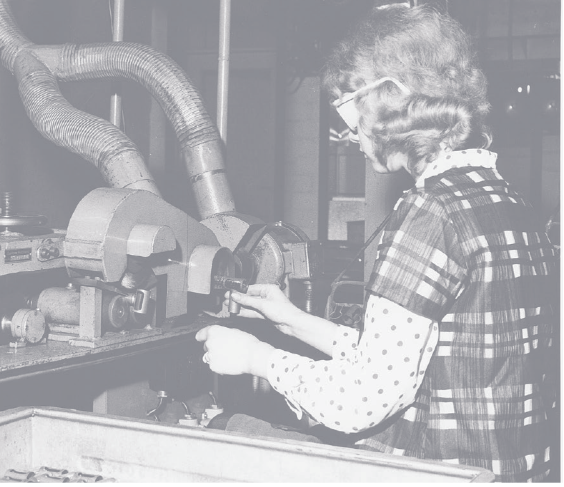
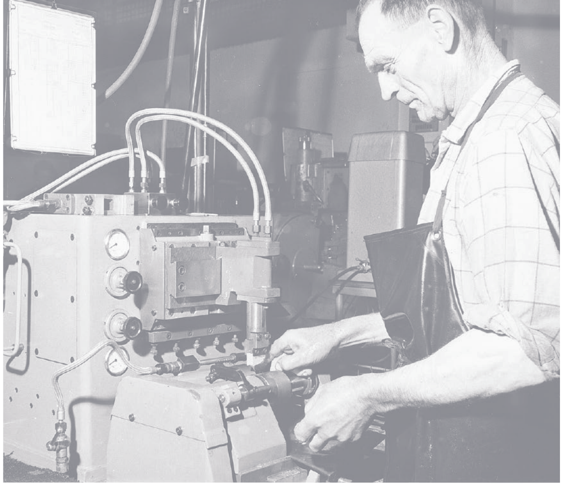
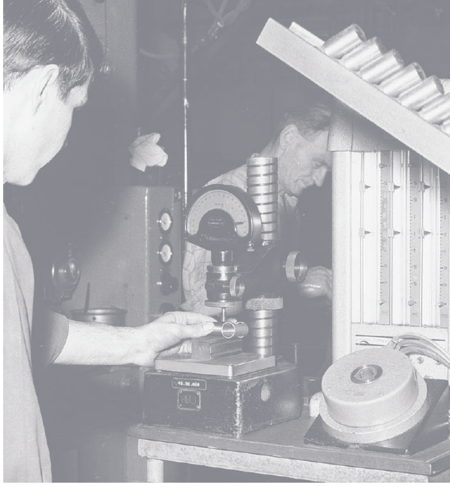
ASSEMBLY OF HERMETIC REFRIGERATION SYSTEMS

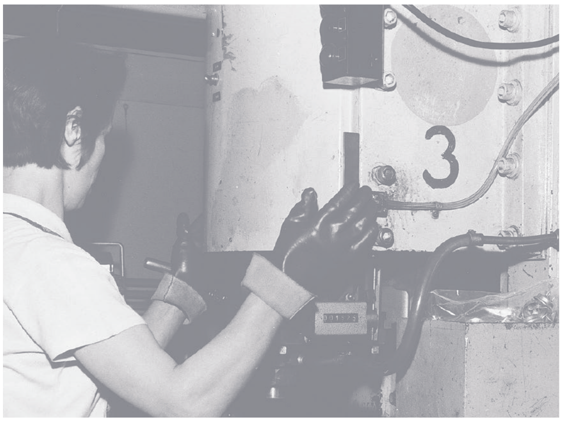

ASSEMBLY OF HERMETIC REFRIGERATION SYSTEMS ASSEMBL
OF HERMETIC REFRIGERATION SYSTEMS ASSEMBLY OF HERME
SEMBLY OF HERMETIC REFRIGERATION SYSTEMS ASSEMBLY O
REFRIGERATION SYSTEMS ASSEMBLY OF HERMETIC REFRIGER
RMETIC REFRIGERATION SYSTEMS ASSEMBLY OF HERMETIC R

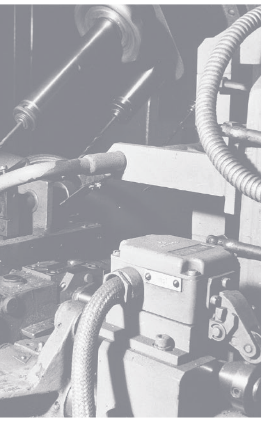
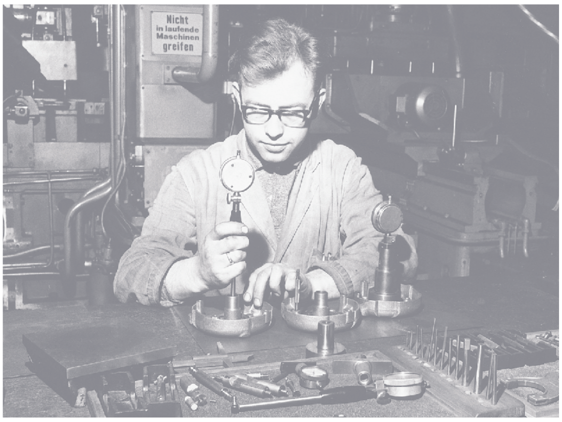
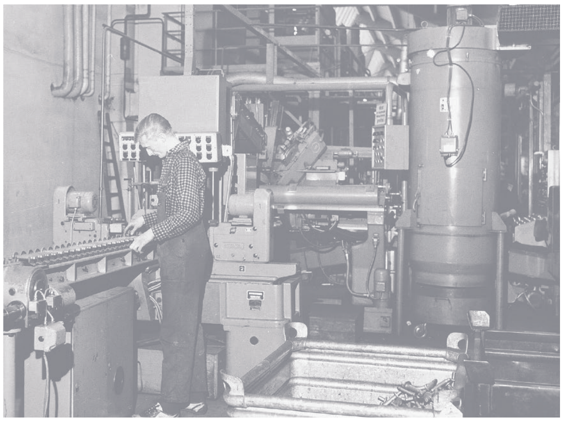
with kind permission of Danfoss

www.secop.com

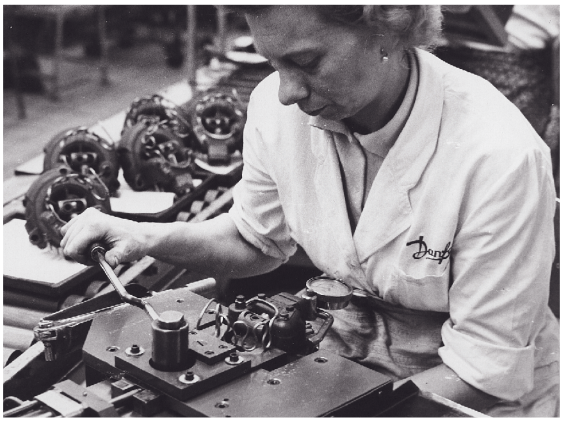
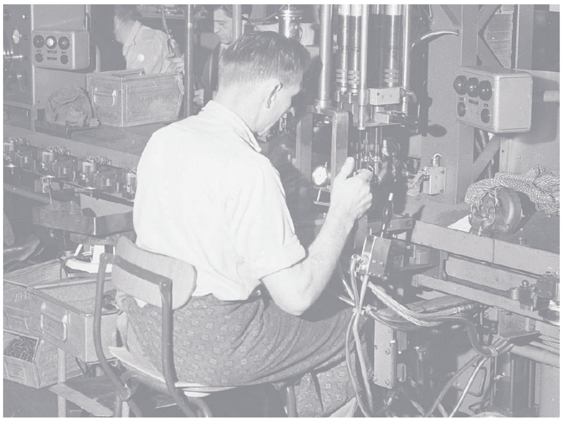
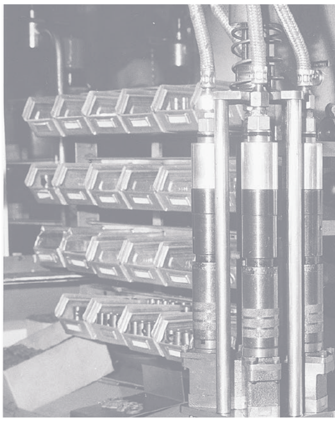
SETTING THE STANDARD

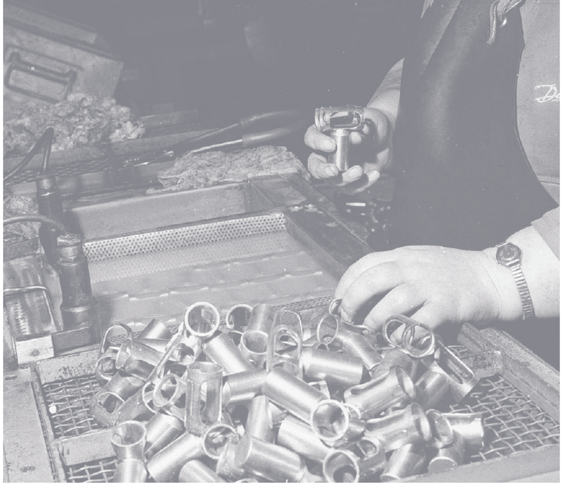
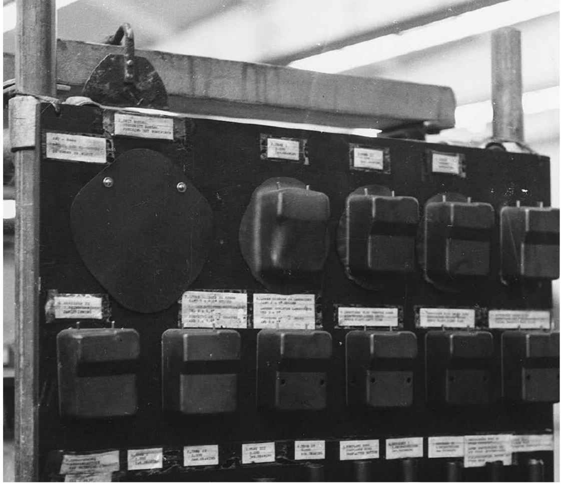
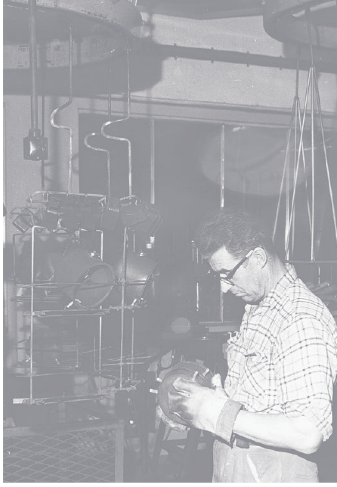
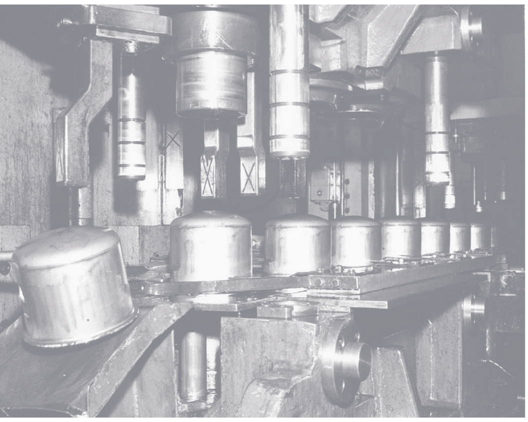
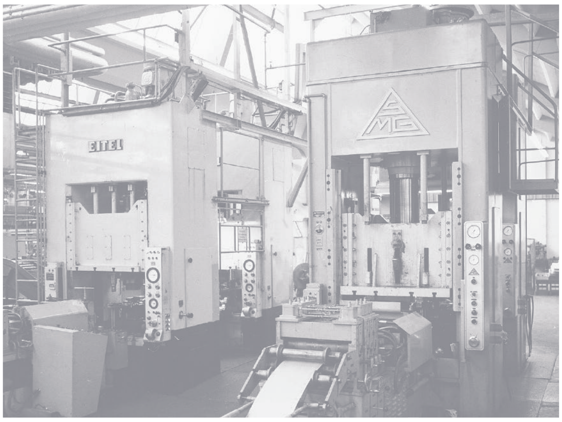
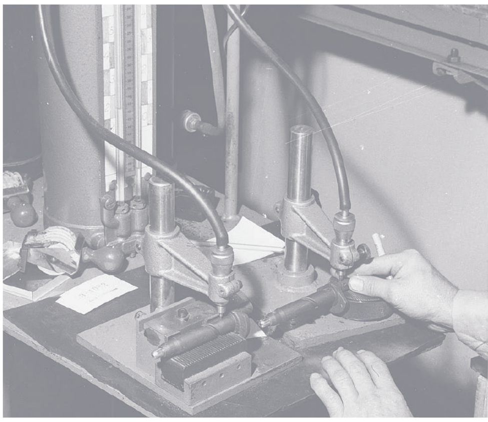




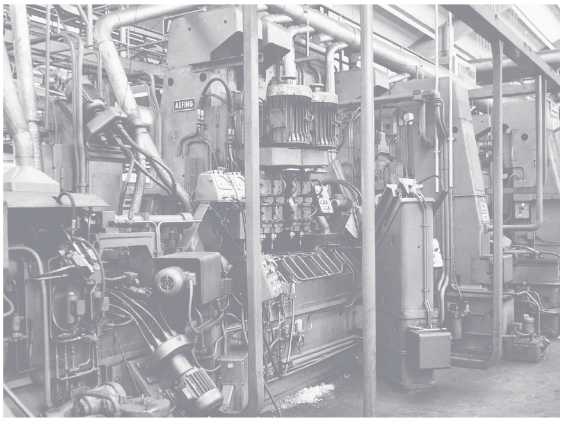
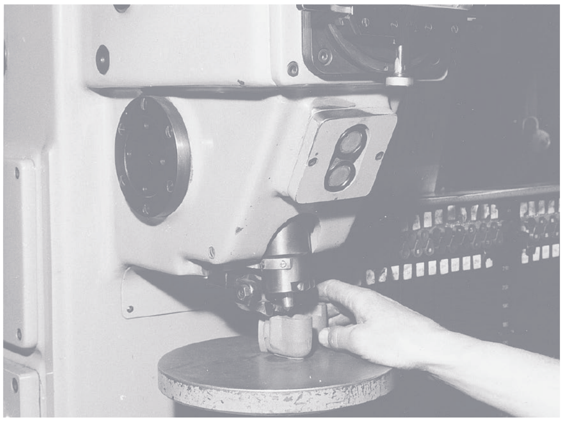

3

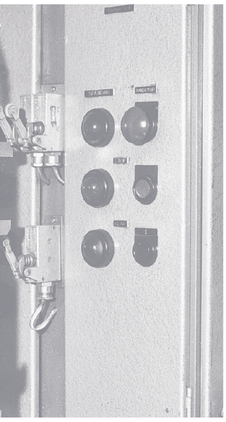
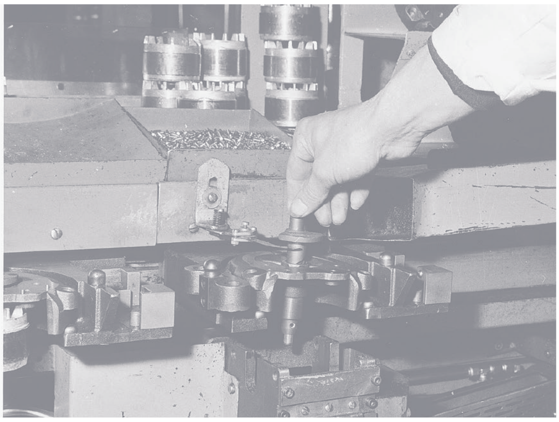
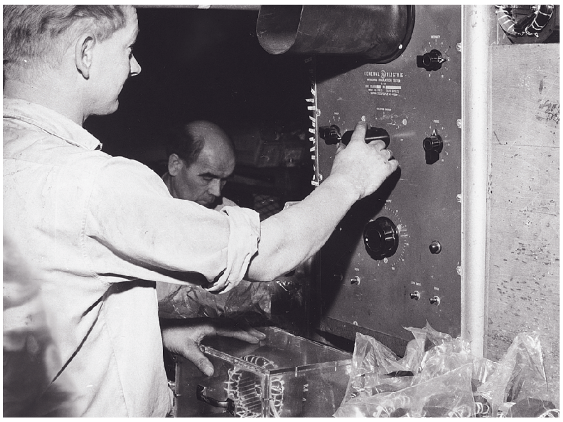


Nicht
in laufende
Maschinen
greifen


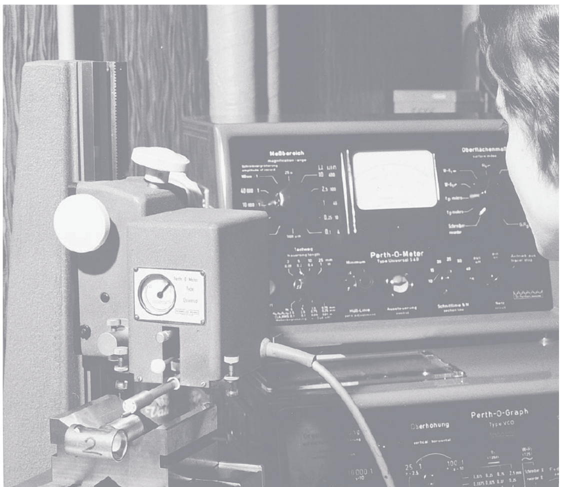
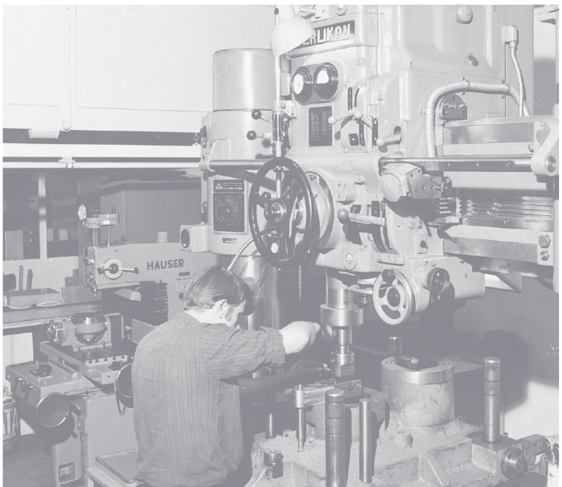
+GF+
WHEELABRAT
WD 3

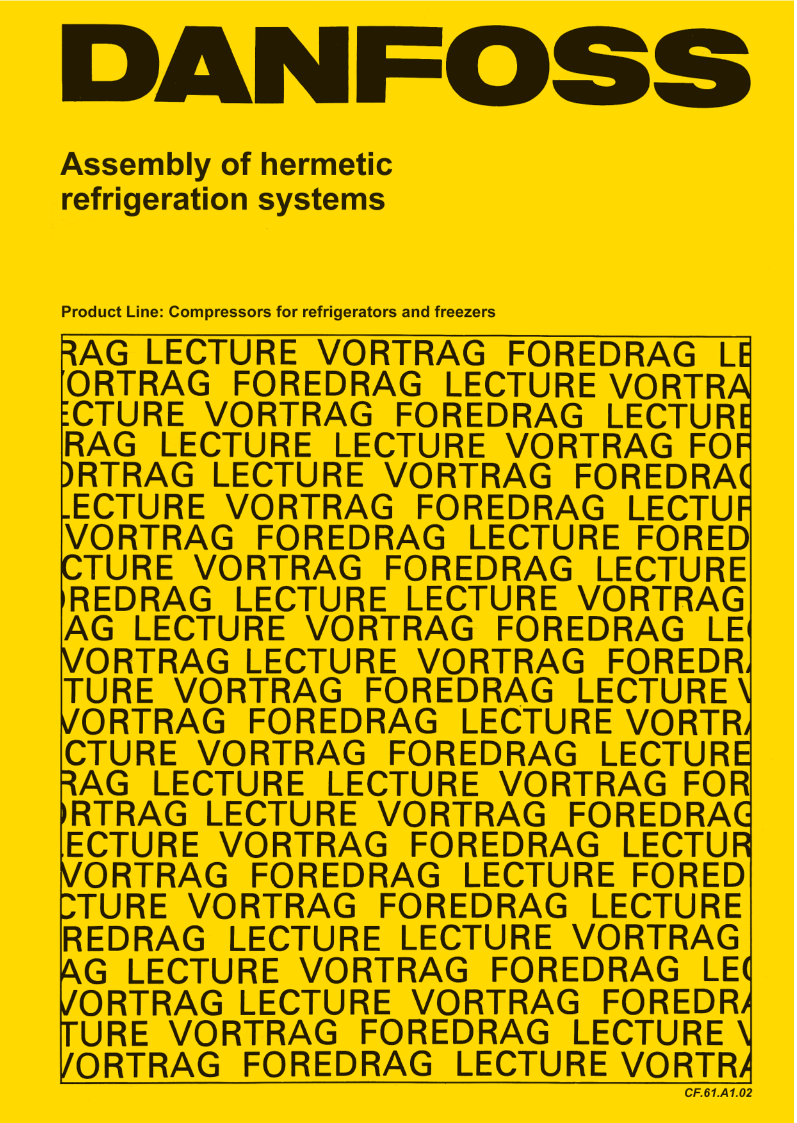

Danf








EITEL



ALFING



Meßbereich
Perth-O-Meter
Perth-O-Graph

HAUSER



DANFOSS

Assembly of hermetic refrigeration systems

Product Line: Compressors for refrigerators and freezers

CF.61.A1.02

This lecture reviews, theoretically and practically, the problems in assembling of hermetic refrigerating systems.

Usually, the lecture will interest only technicians with some experiences in hermetic compressors.

Reproduction - in whole or part - subject to our consent.

Assembly of Hermetic Refrigeration Systems

The object of this lecture is to draw attention to the principal conditions which form the basis of the work processes, and to show some practical methods for use in the assembly operations.

"What do you expect from a refrigeration system?"

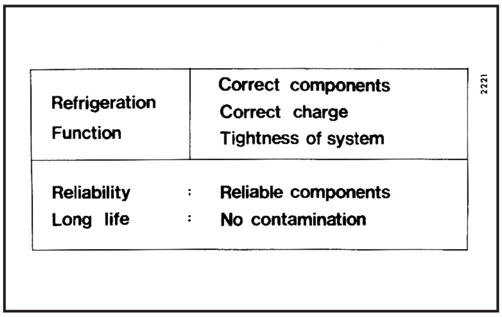
First you expect it to cool the refrigerator. In order to obtain the correct cooling function it is necessary that the individual components of the system are chosen correctly. This is a dimensioning and designing problem, and will, therefore, not be discussed here. We can, however, look upon the refrigerant charge as a part of the system, and therefore we must make the following demands in relation to the correct cooling function:

a) correct charge
b) tightness of the system.

Apart from the cooling function we naturally expect reliability and long lifetime. Therefore we can also demand:

c) reliable components
d) no contamination.

We will come back to items "a" and "b" later.



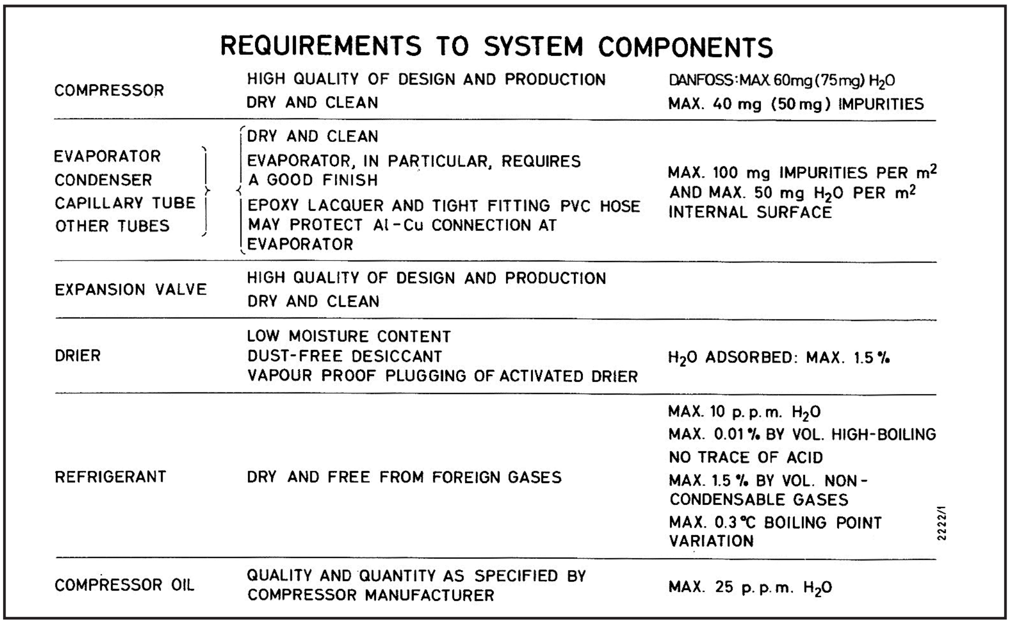
Refrigeration Function	Correct components Correct charge Tightness of system
Reliability : Long life :	Reliable components No contamination

2221

Fig. 1

1. Components

Let us first look at the components that form the refrigeration system.



REQUIREMENTS TO SYSTEM COMPONENTS

COMPRESSOR	HIGH QUALITY OF DESIGN AND PRODUCTION DRY AND CLEAN	DANFOSS: MAX. 60mg (75mg) H_2O MAX. 40 mg (50 mg) IMPURITIES
EVAPORATOR CONDENSER CAPILLARY TUBE OTHER TUBES	DRY AND CLEAN EVAPORATOR, IN PARTICULAR, REQUIRES A GOOD FINISH EPOXY LACQUER AND TIGHT FITTING PVC HOSE MAY PROTECT Al-Cu CONNECTION AT EVAPORATOR	MAX. 100 mg IMPURITIES PER m^2 AND MAX. 50 mg H_2O PER m^2 INTERNAL SURFACE
EXPANSION VALVE	HIGH QUALITY OF DESIGN AND PRODUCTION DRY AND CLEAN	
DRIER	LOW MOISTURE CONTENT DUST-FREE DESICCANT VAPOUR PROOF PLUGGING OF ACTIVATED DRIER	H_2O ADSORBED: MAX. 1.5 %
REFRIGERANT	DRY AND FREE FROM FOREIGN GASES	MAX. 10 p.p.m. H_2O MAX. 0.01 % BY VOL. HIGH-BOILING NO TRACE OF ACID MAX. 1.5 % BY VOL. NON-CONDENSABLE GASES MAX. 0.3 °C BOILING POINT VARIATION
COMPRESSOR OIL	QUALITY AND QUANTITY AS SPECIFIED BY COMPRESSOR MANUFACTURER	MAX. 25 p.p.m. H_2O

2222/1

Fig. 2

The compressor is the most complicated component, and one must admit that the requirements to the hermetic compressor are second to none in the refrigeration industry.

The compressor manufacturer seeks to keep a high quality level, but often realizes that this quality level is in contrast with the other system components and the way in which these are mounted.

Evaporator, condenser, capillary tube and other tubes must first and foremost be clean and dry.

The requirements to the evaporator as to surface finish are especially high, whether it is made of steel, aluminium or copper.

Aluminium evaporators with copper connection tubes require extra good protection of the Cu—Al butt welding. Danfoss stipulates epoxy—laquer protected by a tight fitting PVC sleeve of a quality free from taste and smell.

Reasonable requirements to evaporators and condensers:

Max. 100 mg dirt per m^2 internal surface
Max. 50 mg humidity per m^2 internal surface.

The expansion valve is, as a mechanical component, subject to the same requirements as the compressor.

The drier is often supplied activated, ready for use. In such a case a vapour—tight plugging is necessary. If the drier must be activated before use, the manufacturers instruction must be followed.

The refrigerants which are of interest in connection with the compressor is R12, R22 and R502. The refrigerants are sold under many different trade names but are on the whole produced by large, recognized firms. Therefore the quality does not differ much.

The ordinary trade quality can usually fulfil the following:

Max. 10 p.p.m (mg/kg) H_2O.
Max. 0.01 vol. % high boiling impurities.
No trace of acids.
Max. 1.5 vol, % non-condensable gasses.
Boiling point variation: max. 0.3°C.

Ordinary trade quality is usually sufficient for hermetic refrigeration systems, but the refrigerant must be transferred in the liquid phase (turn the cylinder up-side-down) to keep the content of non—condensable gasses and humidity at a minimum.

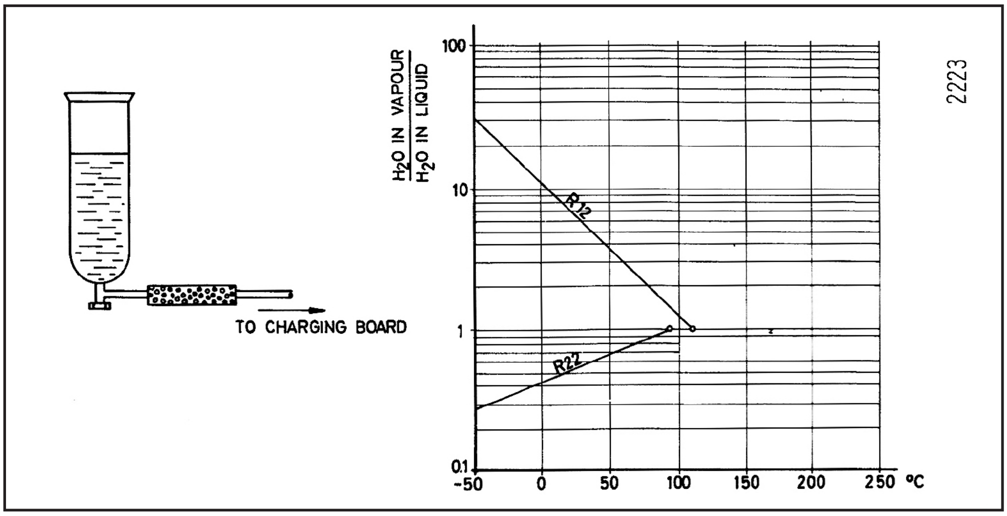


Fig. 3

Place a large, well activated drier in the liquid line between the refrigerant container and the charging station.

The compressor is most often charged with sufficient oil by the manufacturer.

No oil must be added.

If the oil must be changed during repair, the compressor manufacturers instruction must be followed as to oil type and amount.

2. Contamination

From the above it is obvious that the fundamental requirements to all components are that they must be:

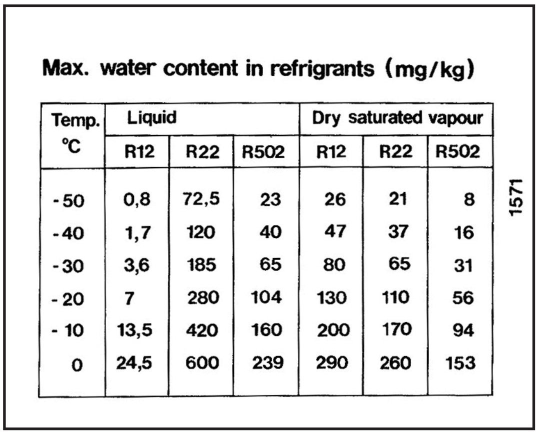
Dry and clean.

Therefore one must keep these requirements in mind during the assembly process.

Every refrigeration specialist knows that a refrigeration system must be dry. Some have learnt it the hard way.

If the water content in the refrigerant is critical, ice will be formed during the expansion in the throttling device, and will block the system.

Let us look at fig. 4. It shows the max. content of water for refrigerants in the liquid phase and the vapour phase respectively, at various temperatures. Notice how the max. possible water amount is reduced with reduced temperature.



Max. water content in refrigrants (mg/kg)

Temp. °C	Liquid R12	Liquid R22	Liquid R502	Dry saturated vapour R12	Dry saturated vapour R22	Dry saturated vapour R502
-50	0,8	72,5	23	26	21	8
-40	1,7	120	40	47	37	16
-30	3,6	185	65	80	65	31
-20	7	280	104	130	110	56
-10	13,5	420	160	200	170	94
0	24,5	600	239	290	260	153

1571

Fig. 4

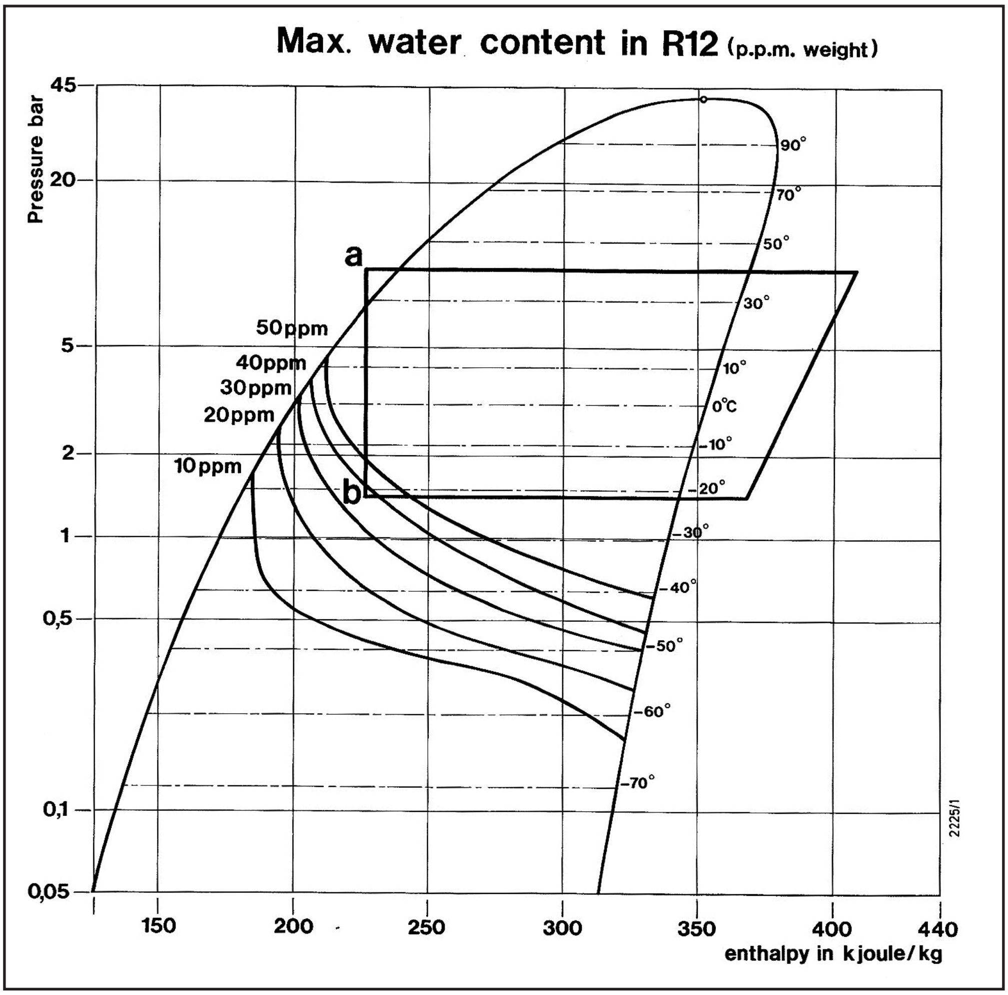
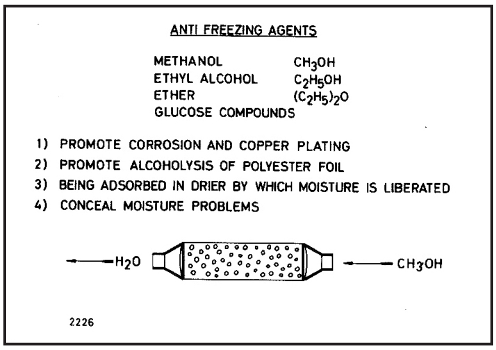


Fig. 5

The theoretical refrigeration process can be plotted in a Mollier diagram (fig. 5).
In the same diagram the curves for solubility of water in R12 can be plotted between the curves for liquid and saturated vapour.
In the process shown, the expansion takes place between A and B. The diagram shows that ice formation can be expected at a water content of 40 to 50 p.p.m.
Fig. 5 illustrates that the critical water content of a system is decided by conditions such as subcooling at the inlet of the throttling device, evaporating temperature and heat exchange during expansion.



ANTI FREEZING AGENTS

METHANOL CH_3OH
ETHYL ALCOHOL C_2H_5OH
ETHER $(C_2H_5)_2O$
GLUCOSE COMPOUNDS

1) PROMOTE CORROSION AND COPPER PLATING
2) PROMOTE ALCOHOLYSIS OF POLYESTER FOIL
3) BEING ADSORBED IN DRIER BY WHICH MOISTURE IS LIBERATED
4) CONCEAL MOISTURE PROBLEMS

H_2O
CH_3OH
2226

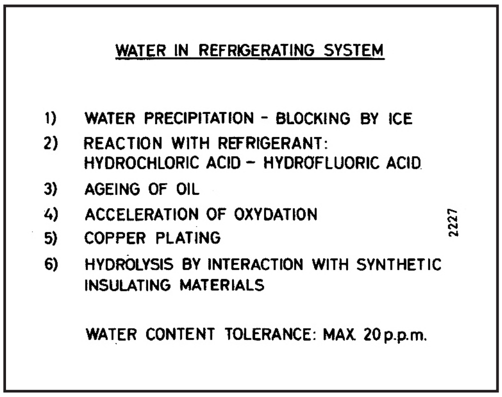
Fig. 6

In this connection the so-called anti—frost agents must be mentioned as well as the reason why the use of these should be avoided.
The anti-frost agents form a freezing mixture with the water deposits so that the system is not blocked. This is definitely the only function that the anti-frost agent has.

Anti-frost agents must be avoided because:

1. Corrosion and copper plating is promoted.
2. Polyester insulation is subject to alcoholysis.
3. The anti—frost agents take up capacity of the dryer which prefers alcohol to water.
4. The humidity problems are hidden.
   (When ise blocking takes place it is a warning that water is in the system and can start corrosion and other chemical reactions).

Item 2 is of special interest in the case of Danfoss compressors, as they are insulated with synthetic materials. Alcoholysis makes the insulation brittle so that it breaks at edges and folds.
Anti—frost agents do not present a permanent solution of moisture problems in a hermetic refrigeration system. At the most, the time for repair is delayed, but very often the final repair is more complicated.



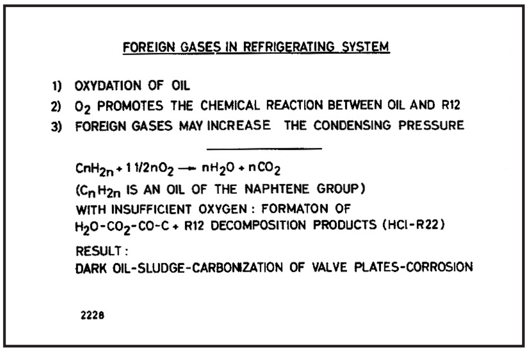
WATER IN REFRIGERATING SYSTEM

1) WATER PRECIPITATION - BLOCKING BY ICE
2) REACTION WITH REFRIGERANT:
HYDROCHLORIC ACID - HYDROFLUORIC ACID
3) AGEING OF OIL
4) ACCELERATION OF OXYDATION
5) COPPER PLATING
6) HYDROLYSIS BY INTERACTION WITH SYNTHETIC INSULATING MATERIALS

WATER CONTENT TOLERANCE: MAX 20 p.p.m.

Fig. 7

The solution of moisture problems is great care during the assembly processes (including dry components) and a well dimensioned dryer in the system.
Water is not only undesirable on account of ice blocking. For the other conditions, see fig. 7.
The so-called uncondensable gasses are also undesirable in refrigeration systems. These include foreign gasses such as oxygen, nitrogen etc.
The problem of increased condensing pressure on account of the presence of non—condensable gasses is well—known from larger refrigeration systems.



FOREIGN GASES IN REFRIGERATING SYSTEM

1) OXYDATION OF OIL
2) O_2 PROMOTES THE CHEMICAL REACTION BETWEEN OIL AND R12
3) FOREIGN GASES MAY INCREASE THE CONDENSING PRESSURE

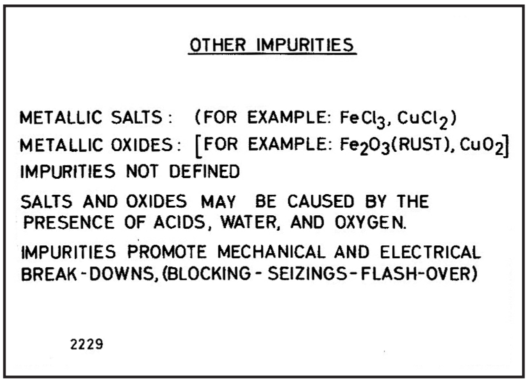
$CnH_{2n} + 1\,1/2nO_2 \rightarrow nH_2O + nCO_2$
(C_nH_{2n} IS AN OIL OF THE NAPHTENE GROUP)
WITH INSUFFICIENT OXYGEN : FORMATON OF
H_2O-CO_2-CO-C + R12 DECOMPOSITION PRODUCTS (HCl-R22)
RESULT :
DARK OIL-SLUDGE-CARBONIZATION OF VALVE PLATES-CORROSION

2228

Fig. 8

Experience has shown that the increase in condensing pressure is negligible on systems with capillary tube, if a reasonably good evacuation is carried out.

Oxygen is specially harmful on account of oil oxidization, and because the presence of oxygen promotes the chemical processes. The higher the compressor temperature, the more critical the condition will be.



OTHER IMPURITIES

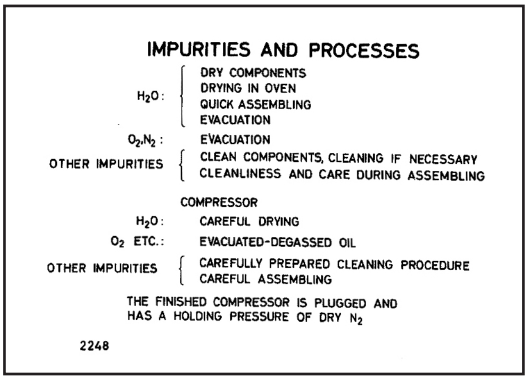
METALLIC SALTS : (FOR EXAMPLE: $FeCl_3$, $CuCl_2$)
METALLIC OXIDES : [FOR EXAMPLE: Fe_2O_3(RUST), CuO_2]
IMPURITIES NOT DEFINED

SALTS AND OXIDES MAY BE CAUSED BY THE PRESENCE OF ACIDS, WATER, AND OXYGEN.
IMPURITIES PROMOTE MECHANICAL AND ELECTRICAL BREAK-DOWNS, (BLOCKING - SEIZINGS - FLASH-OVER)

2229

Fig. 9

Other impurities can be substances such as metal salts($FeCl_2$, CuCl) and metal oxides($Fe_2 0_3$(rust), $Cu0_2$). Such compounds can arise from the presence of acid, water or oxygen in the system. The mentioned impurities, as well as other(undefinable) impurities can promote mechanical or electrical disturbances.



IMPURITIES AND PROCESSES

H_2O : DRY COMPONENTS
DRYING IN OVEN
QUICK ASSEMBLING
EVACUATION
O_2,N_2 : EVACUATION
OTHER IMPURITIES : CLEAN COMPONENTS, CLEANING IF NECESSARY
CLEANLINESS AND CARE DURING ASSEMBLING

COMPRESSOR
H_2O : CAREFUL DRYING
O_2 ETC.: EVACUATED-DEGASSED OIL
OTHER IMPURITIES : CAREFULLY PREPARED CLEANING PROCEDURE
CAREFUL ASSEMBLING

THE FINISHED COMPRESSOR IS PLUGGED AND HAS A HOLDING PRESSURE OF DRY N_2

2248

Fig. 10

In the above we have looked at conditions which can assist in shortening the life-time of the compressor and the refrigeration system. Perhaps you will argue that this is theory and even refer to the fact that actual practice has shown that "less is sufficient".

However, one must still have the requirement for long life—time in mind. One normally expects a life—time of approx. 15 years, and this is after all a long time.

One must also bear in mind the operating conditions that the system is subject to. The more a compressor is utilized, the greater the demand for care and cleanness because the reaction velocity of the chemical processes is doubled for every 10°C temperature rise. As the tendency goes towards more utilization and more severe operating conditions, this must urge you to take the conditions seriously.

3. Processes

Let us look at the processes and operations that are used. They are as follows:

3.0 Tube work
3.1 Cleaning of components
3.2 Dehydrating
3.3 Soldering
3.4 Evacuating and charging
3.5 Leak tests
3.6 Testing the finished unit

3.0 Tube work

The types of tube work necessary in connection with manufacture of hermetic refrigeration systems are: Tube straightening, tube cutting, de-burring as well as checking capillary tubes and manufacture of heat exchangers.
In a small production only a few of these operations will be necessary because most often the heat exchangers will be bought finished.
In a large production the problems that can arise in connection with the stated operations will be mainly of a production technical nature.
The following illustrations will give you an impression of how the problems can be overcome in a rational way.

Fig. 11 shows an example of tube straightening which is of interest if the tubes are delivered in coils.
Tubes can be cut as shown in Fig. 12.

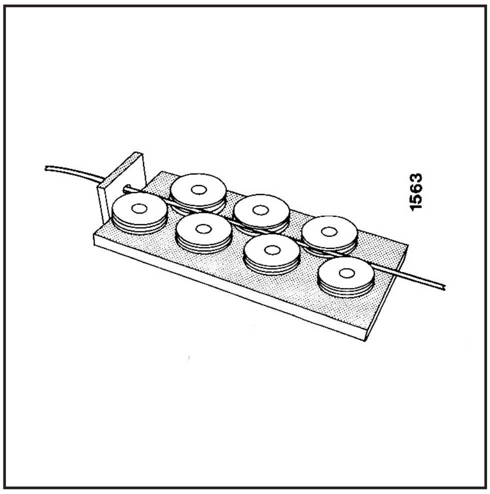


Fig. 11

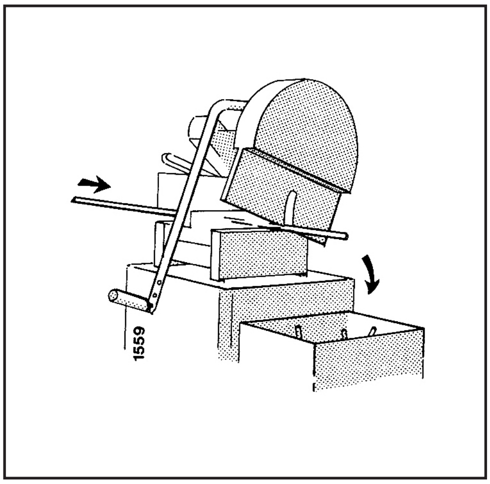


Fig. 12

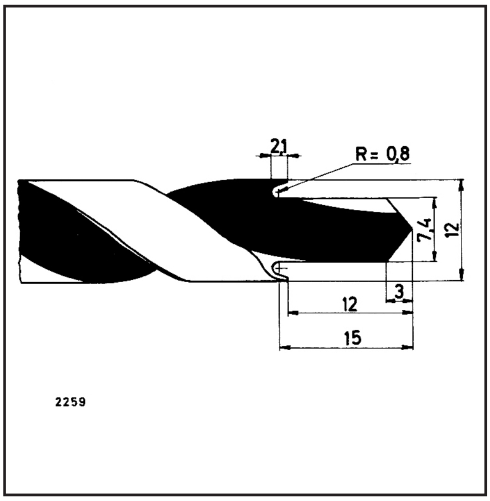


Fig. 13

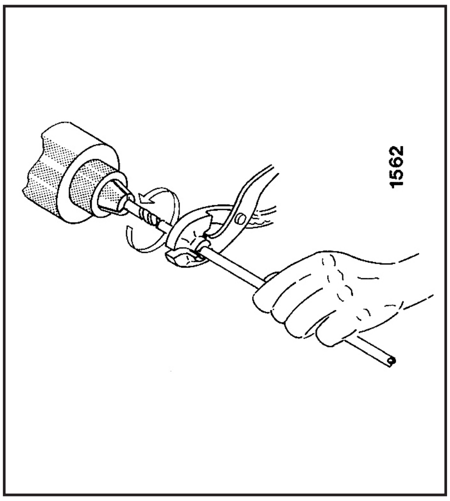


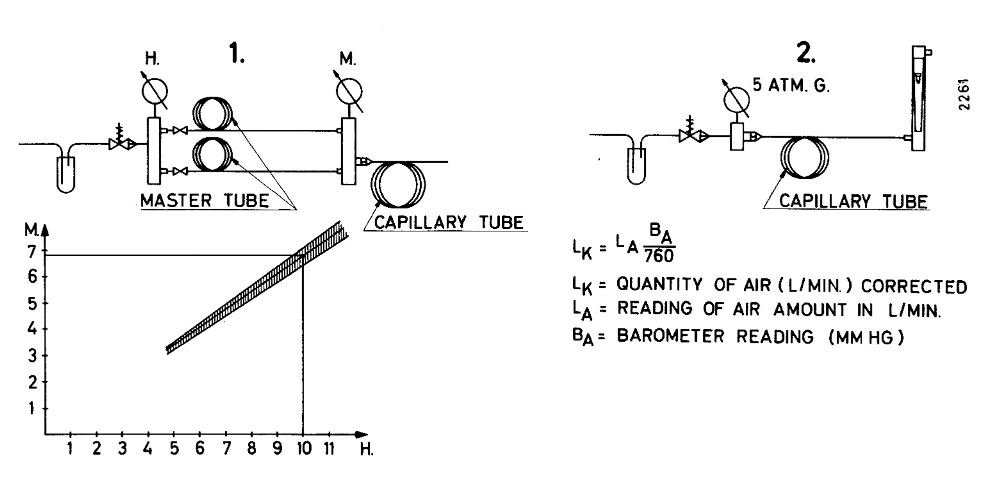
Fig. 14

It is important that burrs and metal particles etc. are removed. Fig. 13 shows a special de—burring drill which removes the burrs inside and outside the tube end at the same time.

Fig. 14 shows the set—up of the de—burring operation.

In a large production the resistance of the capillary tube must be inspected. This can be done as shown in fig. 15 by checking the intermediate pressure against a master tube, or by air flow respectively.

Fig. 15


1.
H.
M.
MASTER TUBE
CAPILLARY TUBE
M.
7
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 H.
2.
5 ATM. G.
CAPILLARY TUBE
2261

$$L_K = L_A \frac{B_A}{760}$$

L_K = QUANTITY OF AIR (L/MIN.) CORRECTED
L_A = READING OF AIR AMOUNT IN L/MIN.
B_A = BAROMETER READING (MM HG)

Fig. 16 and 17 show examples of how heat exchangers can be produced, in a primitive way and in a more advanced way respectively.

As to the quality of tubes, the so—called "refrigeration quality" should preferably be used, i.e. tubes which are delivered cleaned and dried, with the ends squeezed and soldered.

Fig. 16

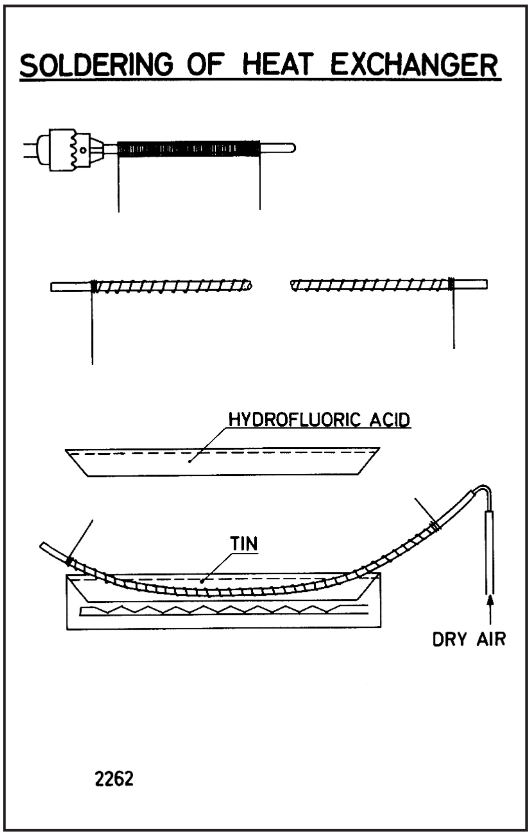
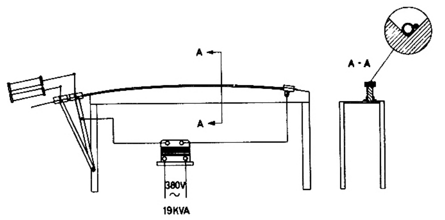

SOLDERING OF HEAT EXCHANGER
HYDROFLUORIC ACID
TIN
DRY AIR
2262

Fig. 17


A
A
A-A
380V
~
19KVA

ELECTROLYTIC TINPLATING OF HEAT EXCHANGER

1. ELECTROLYTIC DEGREASING
   CATHODIC, 4-6 V – 2-5 MIN. – 65 °C
   ANODIC, 4-6 V – 10-15 SEC. – 65 °C
2. RINSING IN RUNNING WATER
3. PICKLING IN NITRIC ACID 6-12 SEC. – MAX. 20 °C
4. RINSING IN RUNNING WATER
5. IN CYANIC BATH, FOR 1-2 MIN. – ROOM TEMPERATURE
6 RINSING IN RUNNING WATER
7. TIN BATH, 4-6 V – 75-85 °C – TIME = SPEC. THICKNESS OF COATING (SUGGESTED RATE OF DEPOSITING: 0,2μ/A/DM^2/MIN.)
8. RINSING IN DE-MINERALIZED WATER
9. RINSING IN RUNNING WATER
10. RINSING IN DE-MINERALIZED WATER – 85 °C – TIME = UNTIL HEAT EXCHANGERS REACH TEMPERATURE OF WATER
11. DRYING IN OVEN UNTIL HEAT EXCHANGERS ARE DRY

2263

3.1 Cleaning of components

It will always be an advantage if components such as evaporators, condensers and tubes are supplied in a dry and clean condition and with the tube ends tightly plugged. If a recognized supplier is used this will normally not give rise to any problems.

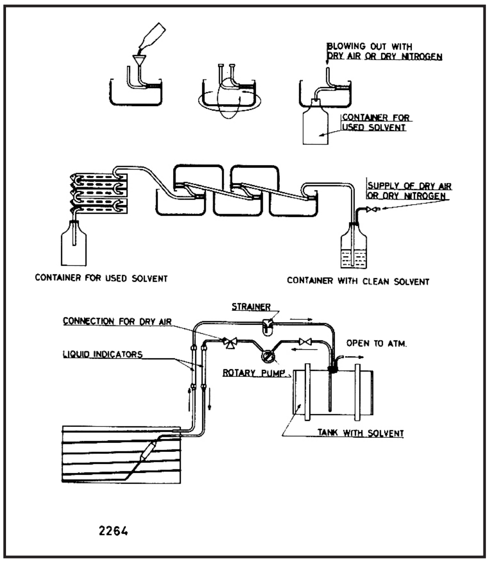

BLOWING OUT WITH DRY AIR OR DRY NITROGEN
CONTAINER FOR USED SOLVENT
SUPPLY OF DRY AIR OR DRY NITROGEN
CONTAINER FOR USED SOLVENT
CONTAINER WITH CLEAN SOLVENT
STRAINER
CONNECTION FOR DRY AIR
OPEN TO ATM.
LIQUID INDICATORS
ROTARY PUMP
TANK WITH SOLVENT
2264

Fig. 18

However, if the exceptional situation arises where the components are dirty, it is normally possible to clean them so that they can be used.

One must use a suitable solvent f.inst, chlorothene(CCl_3CH_3) or R113, and flush the contaminated components thoroughly. The solvent can be distilled and used again.

Especially if chlorothene is used it is very important that residual solvent is removed before the following assembly.
However, this is normally no problem in connection with a normal dehydrating process.

Fig. 18 shows examples of how such a cleaning process can be carried out.

3.2 Dehydrating

Dehydrating of hermetic refrigeration systems or components for same is carried out according to two different principles:

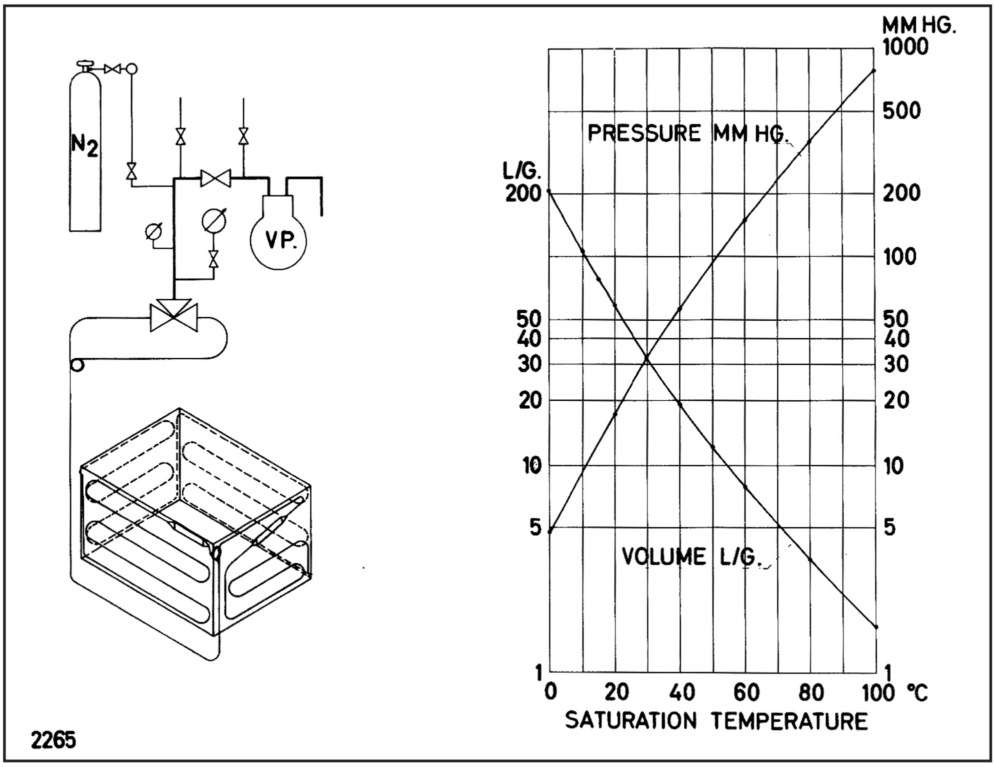
a) By means of vacuum
b) By means of heat and dry air.

In practice method b) will be combined with the vacuum method because the finished system will always be evacuated in connection with the charging process.
Whether the components are dehydrated individually or as subassemblies makes no great difference in actual practice, as long as the oil—charged compressor is not included. The principle behind the vacuum dehydrating process is the fact that the boiling point of water is reduced with reduced pressure.
At 20°C the pressure of saturated water vapour is 17.5 mm Hg.
To remove water which is adsorptively or hygroscopically bound a higher vacuum is required than indicated by the connection between temperature and vapour pressure.

Instead of using high vacuum for removing water it is often preferred to combine the evacuation with one or more pressure equalizations with a drying medium such as dry air, dry nitrogen or dry refrigerant. This promotes dehydrating.

In a small production where dry air and dehydrating oven are not available, a procedure as shown in fig. 19 can be of interest. The pressure equalization (flushing) is done with dry N_2, which is easily obtainable.

Fig. 19



However, the preferred method is dehydration with dry air and heat. The components are heated in order to accellerate the evaporation of any water. The dry air removes the water vapour.

The object of dehydrating in this way is to obtain equilibrium between the air and the component as regards moisture content. Therefore the initial condition of the air must be chosen suitably low, corresponding to the required final condition of the component. Dry air has a dew-point of -40°C to —50°C. At -50°C the air can contain 0.03 mg H_2O per liter.

At 100°C, air can contain approx. 1000 mg H_2O per liter.

Fig. 20

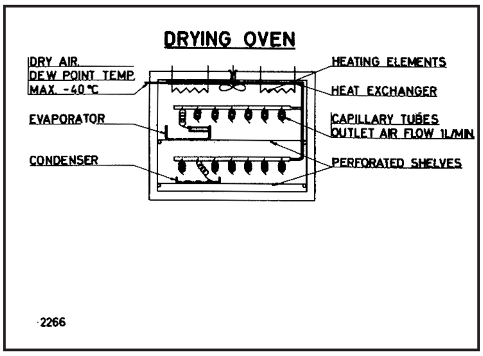

DRYING OVEN
DRY AIR.
DEW POINT TEMP.
MAX. -40 °C
EVAPORATOR
CONDENSER
HEATING ELEMENTS
HEAT EXCHANGER
CAPILLARY TUBES
OUTLET AIR FLOW 1L/MIN
PERFORATED SHELVES
2266

Fig. 21

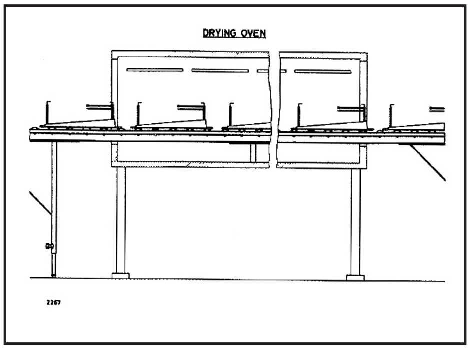

DRYING OVEN
2267

Fig. 20 shows how one can arrange pre-drying of the components before assembly.
Fig. 21 shows an oven for a systems assembly line. Here the components are heated to 110°C surface temperature, and they are blown through with dry air at a pressure of approx.6 bar before and after passing the oven.

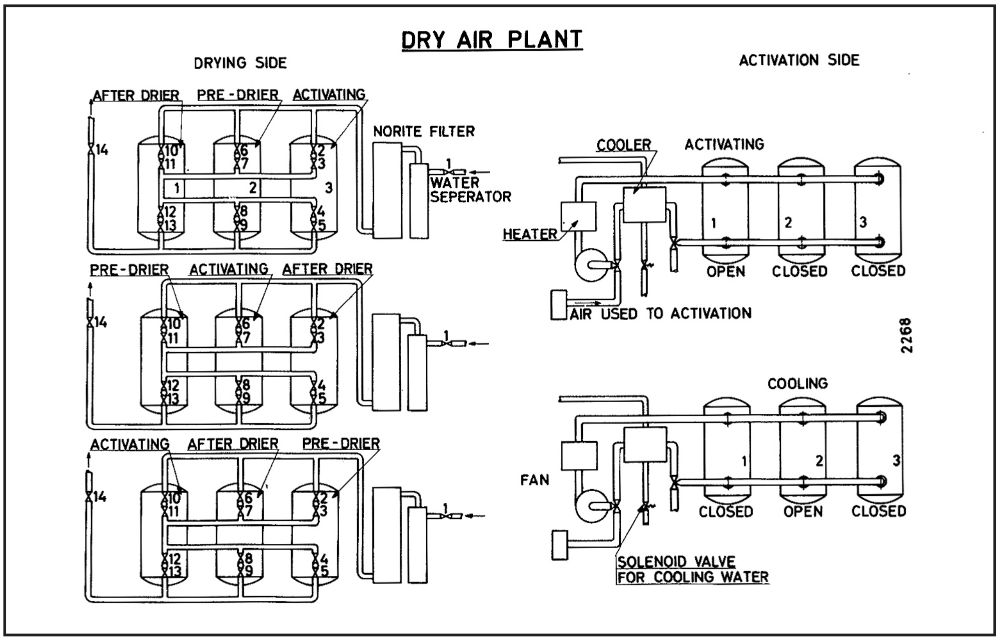

DRY AIR PLANT
DRYING SIDE
ACTIVATION SIDE
AFTER DRIER
PRE-DRIER
ACTIVATING
NORITE FILTER
WATER SEPERATOR
1
2
3
4
5
6
7
8
9
10
11
12
13
14
COOLER
ACTIVATING
HEATER
OPEN
CLOSED
CLOSED
AIR USED TO ACTIVATION
2268
COOLING
FAN
CLOSED
OPEN
CLOSED
SOLENOID VALVE
FOR COOLING WATER

Fig. 22

Dehydration by means of dry air naturally means that you must have an air drying unit available. Fig. 22 shows how such a unit operates. Generally the air is compressed before drying because the humidity content is reduced with increasing pressure.
If the Filters are filled with f.inst. silica-gel a dew-point of approx. —62°C, corresponding to 0.006 mg/1, can be obtained.

Ordinary compressed air can be dried by means of a sufficiently large drier, and in the case of small consumption, with reasonably good results, but naturally not as good as with a regular air drying unit. Fig. 23 shows a primitive air drying unit with blue-gel as drying agent. As shown here the unit is only suitable For drying air under low pressure. Dry air can also be produced by compression and cooling. The results depend on the chosen pressures and temperatures.

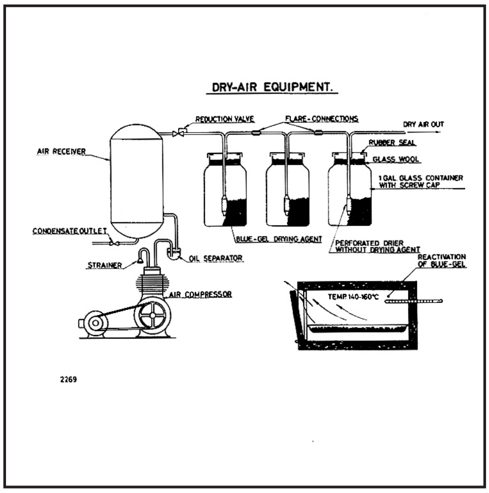

DRY-AIR EQUIPMENT.
REDUCTION VALVE
FLARE-CONNECTIONS
DRY AIR OUT
AIR RECEIVER
RUBBER SEAL
GLASS WOOL
1 GAL. GLASS CONTAINER WITH SCREW CAP
CONDENSATE OUTLET
BLUE-GEL DRYING AGENT
PERFORATED DRIER WITHOUT DRYING AGENT
OIL SEPARATOR
STRAINER
REACTIVATION OF BLUE-GEL
AIR COMPRESSOR
TEMP. 140-160°C
2269

Fig. 23

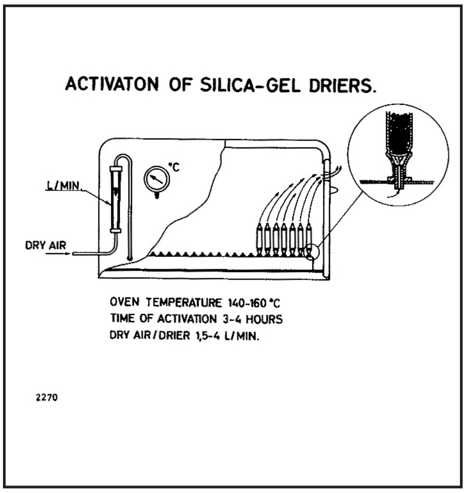

ACTIVATON OF SILICA-GEL DRIERS.
L/MIN.
°C
DRY AIR
OVEN TEMPERATURE 140-160 °C
TIME OF ACTIVATION 3-4 HOURS
DRY AIR/DRIER 1,5-4 L/MIN.
2270

Fig. 24

LMS driers should always be delivered ready for use, because this agent requires a relatively high activating temperature (min. 350°C) which will complicate the activating process.
Silica-gel driers are often delivered un—activated. In such cases an activating oven and an activating process as shown in fig. 24 can be of interest.

3.3 Assembly and soldering

It is a good rule, that all assembly must take place quickly and continuously especially if the components are dehydrated beforehand. No dehydrated components should be left open to the atmosphere for more than 15 minutes. Soldering operations on oil—charged compressors must take place in a neutral atmosphere. Therefore it is a good rule to blow a small amount of N_2 through the compressor during the operation. The N_2 flow must be so small, that it is only just detectable, so that the soldering process is not disturbed. (See fig. 25).

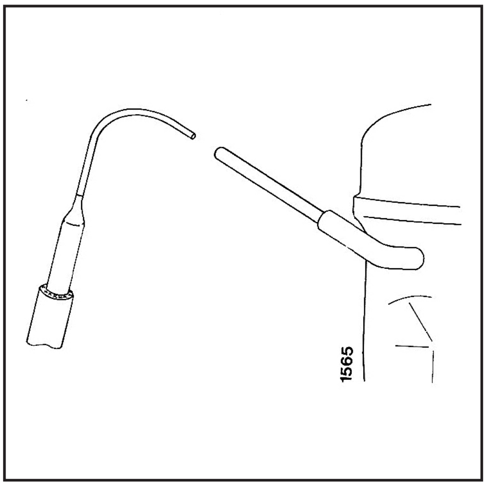


Fig. 25

Soldering material

A : Soldering material for use in assemblies with steel tube (Fe - Cu or Fe - Fe)
Min. 30% Ag + (Cu - Zn - Sn) + flux
Melting range : 655°C - 755°C

B : Soldering material for use in pure copper assemblies (Cu - Cu)
Phosphor alloys without flux
2 - 15% Ag + (Cu - P)
Melting range : 640°C - 740°C

Danfoss compressors TL, FR and SC have copper-plated connectors

Both A and B can be used.

Alcohol is used advantageously for diluting flux.

1549/1

Fig. 26

The most popular soldering materials are types with 30% silver or more and phosphor alloys. Data can be seen from fig. 26.

Phosphor alloys, which do not require the use of flux, can only be used where the two parts to be joined are copper to copper. Soldering material without phosphor (with higher Ag content) is applicable for all solderings, but it requires flux. The flux should be stirred with alcohol to form a paste. Thus you have the advantage that the solvent evaporates quickly leaving an even film of flux on the joint surface. At the same time the risk of introducing water in the system during the soldering process is reduced.

The flux can be removed after soldering by brushing the joint with hot water, or by means of low pressure steam.

An indication of the amount of silver solder necessary, is the fact that at Danfoss, 0.4 grams of silver solder is used per solder joint.
Whether to use a single torch or a double torch for soldering is a matter of opinion.

The following are guide—lines for the soldering process:
Use the "soft" heat in the torch flame when heating the joint.
Distribute the flame so that at least 90% of the heat concentrates around the connector and approx. 10% around the connection tube.

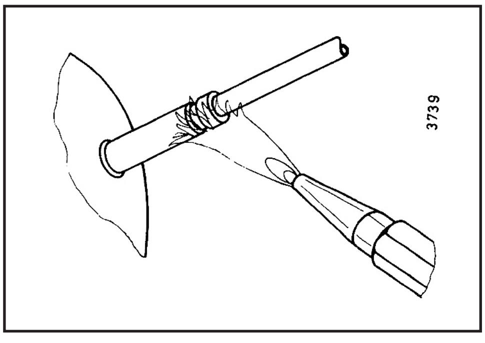


Fig. 27

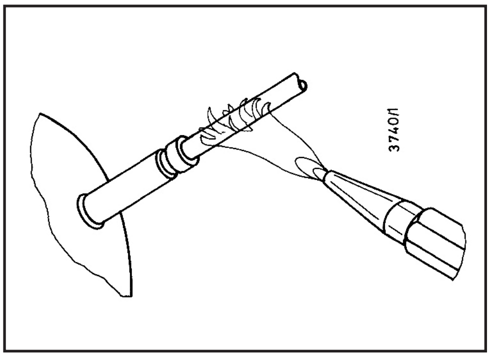


Fig. 28

Move the flame to the connection tube for a few sec. when the connector is cherry-red (approx. 500°C).

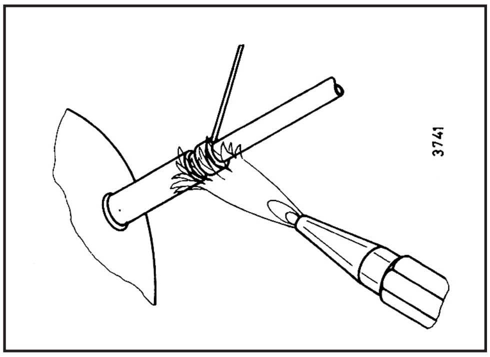


Fig. 29

Continue heating with the "soft" flame and apply solder.

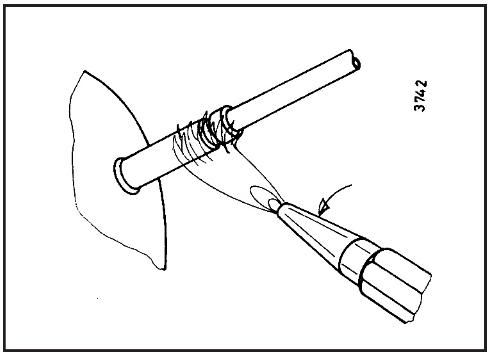


Fig. 30

Draw the solder down into the solder gap by slowly moving the flame toward the compressor; then completely remove the flame.

This soldering process can be performed by an operator, after practice, in 12 — 15 seconds.
With a double torch the same procedure can be used except that the step shown in fig. 28 can be omitted as heat distribution occurs simultaneously on both sides of the connector.

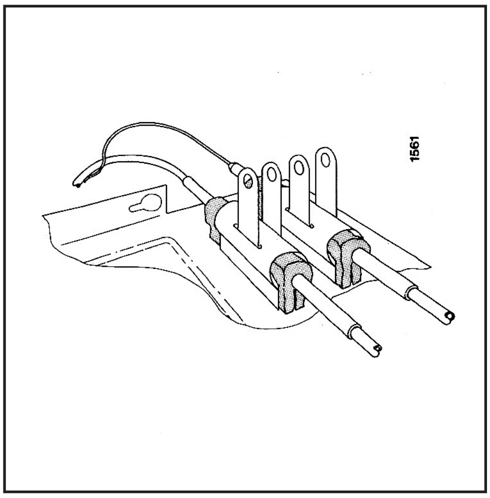


Fig. 31

If Sil—Fos is used for soldering the tubes to a compressor with copper connectors (e.g. a PW compressor), special care must be taken when heating the joint, because the connectors are soldered to the compressor housing with a silver solder, which has a much lower melting point than Sil-Fos. On aluminium evaporators with a butt—welded joint of copper—aluminium, special care must be taken that the protection on the buttwelded joint is not damaged. The protection can be laquer or PVC or both. If the protection is spoilt, a galvanic process will start and will soon result in a leak.

Fig. 31 shows how over—heating of this joint can be avoided.

The soldering of the capillary tube also requires special care, partly because it can easily become over—heated, and also because the capillary tube can easily be blocked.

Fig. 32 shows some details which ensure correct soldering of the capillary tube.

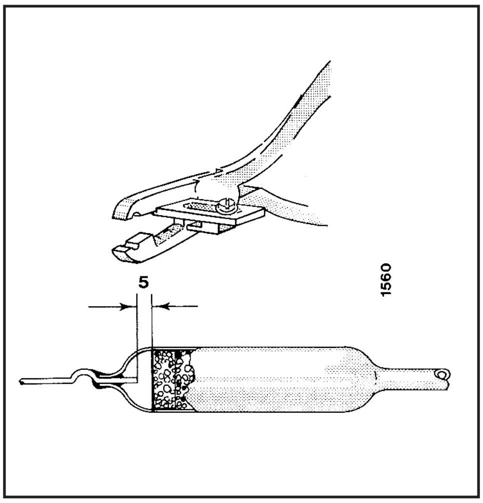


Fig. 32

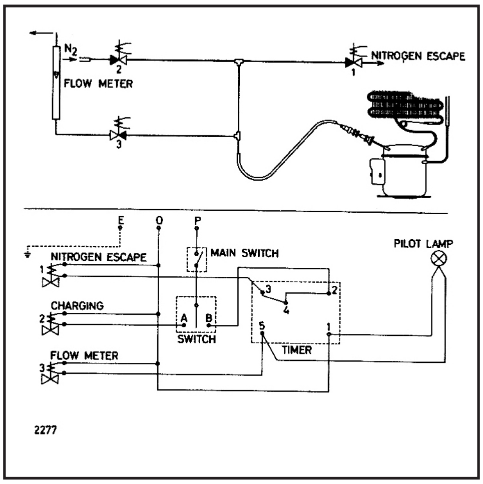


Fig. 33

In a series production it will be an advantage to carry out an inspection for blockings after all joints have been soldered, so that defective systems can be rejected before the refrigerant charging. Fig. 33 shows an apparatus for such an inspection.
The operating principle is as follows:
The refrigeration system is pressurized with dry nitrogen to a predetermined equalizing pressure (10 bar ±0.1 bar) by opening valve 2 while valves 1 and 3 are closed. Change-over switch in position "A".

When the change—over switch is turned to position "B" the pressure in the suction side of the system is released through valve 1. After a predetermined time interval the timer relay activates valve 3 and closes valve 1.
The pressure on the high pressure side of the system will escape first through valve 1 and later through valve 3.

The flow that takes place in a given time can be taken as a measure of the condition of the capillary tube.

The advantage of the described method is that the whole system can be soldered before the test is carried out. If the discharge tube was left unsoldered at the compressor discharge connector a simple flow measuring could take place.

3.4 Evacuating and charging

The main object of evacuating is to remove all non-condensable gasses from the system before charging it with refrigerant. At the same time a drying effect on the system is obtained. Evacuation can take place either from the suction and high pressure sides simultaneously or from the suction side alone.

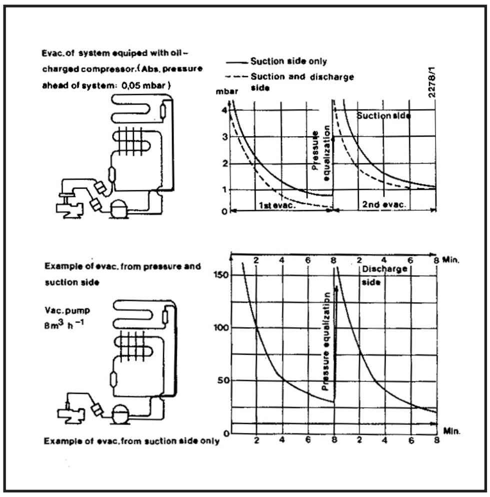


Fig. 34

The best vacuums are without doubt obtained by evacuating from 2 sides, however, the disadvantage is that there must be a process tube at the condenser outlet. This costs money, and is at the same time an extra source of leaks, because the number of joints is increased by 2. Especially in the case of series production it will pay to avoid this extra cost. If you evacuate from the suction side only, i.e. from the process tube on the compressor, the disadvantage is that you will not obtain a very good vacuum on the high pressure side of the system, because the air must be removed through the capillary tube.

The dimensions of the systems are to a great extent decisive as to which vacuums one can obtain. F.inst. the capillary tube dimensions and the volumes of the suction and high pressure side of the system will be influential.

A satisfactorily low content of non—condensable gasses can be obtained when evacuating only from the suction side by evacuating in 2 stages with an interjacent pressure equalization with refrigerant. In this way the residual air will be mixed with refrigerant and the percentage of foreign gasses will be reduced accordingly after the second evacuation.

As a main rule the aim should be a 1% vol. or lower content of foreign gases.

A large proportion of the residue gas left in a refrigeration system after the evacuation process is finished stems from the protection gas (N_2) which the compressor was charged with before assembly. This residue gas will normally combine with the oil in the compressor so much that it can only be removed by very long evacuation. On assembly lines, especially those that are part of integrated systems, long evacuation is undesirable and the solution to the problem would therefore be to have the compressors supplied without a protection gas overpressure.

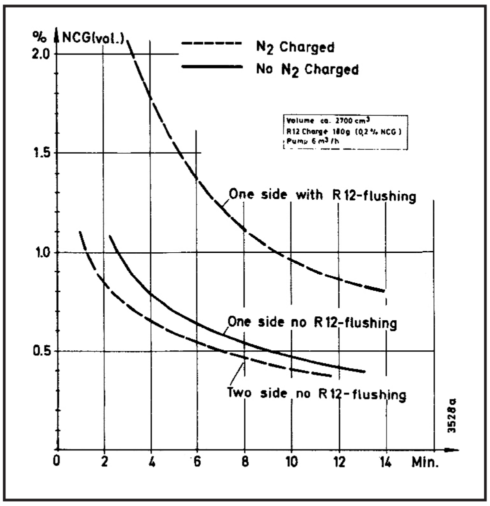


Fig. 35

Fig. 35 shows measuring results from evacuation experiments on typical domestic systems with a total volume of 2350 cm³ distributed 5% on the discharge side and 95% on the suction side; capillary tube Ø 0.71 X 3550mm. The vacuums obtained were measured direct on the system, at the compressor connector and at the outlet condenser. The results also show the difference in a system when fitted with a compressor with and without an overpressure of N_2.

The curves indicate that the evacuation time can be significantly reduced when the compressor is supplied without protection gas overpressure. This does mean that evacuation needs only to be used to remove the atmospheric air that becomes shut into the system when the final soldering is carried out. On modern production lines the widespread practice therefore is to perform complete evacuation using a fully automatic charging board.

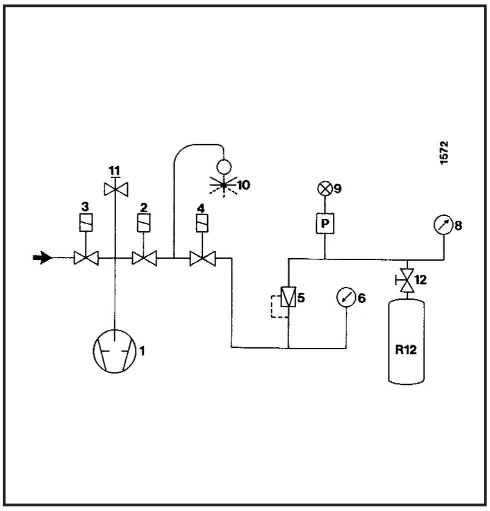


Fig. 36

Fig. 36 shows an arrangement for two stage evacuation with interjacent pressure equalization. By means of a time relay the set—up can be automatically controlled so that the operator only has to connect and disconnect.
The first evacuation takes place with the electrical connections linked so that the solenoid valves "3" and "4" are closed and solenoid valve "2" is open.
With a suitable vacuum pump a satisfactory vacuum should be obtained in approx. 7 minutes.

The flushing with R12 takes place when solenoid valve "2" closes while solenoid valves "3" and "4" open.

Opening of valve "3" causes the vacuum pump to be flushed with air whereby permanent contamination is avoided. Opening of valve "4" connects the refrigeration system with the refrigerant container. The flushing pressure is decided by the setting of the constant pressure valve "5".
The pressure control "7" activates the lamp "9" when the refrigerant pressure in the container becomes too low, i.e. the container must be replaced. The flushing process takes place in a very short time (approx. 10 seconds).
The second evacuation takes place in the same way as the First evacuation and the time is the same (approx. 7 minutes).

In the case of large production figures the described arrangement can successfully be placed on a turn-table or as a side station to the assembly line as shown in figs. 37 and 38.

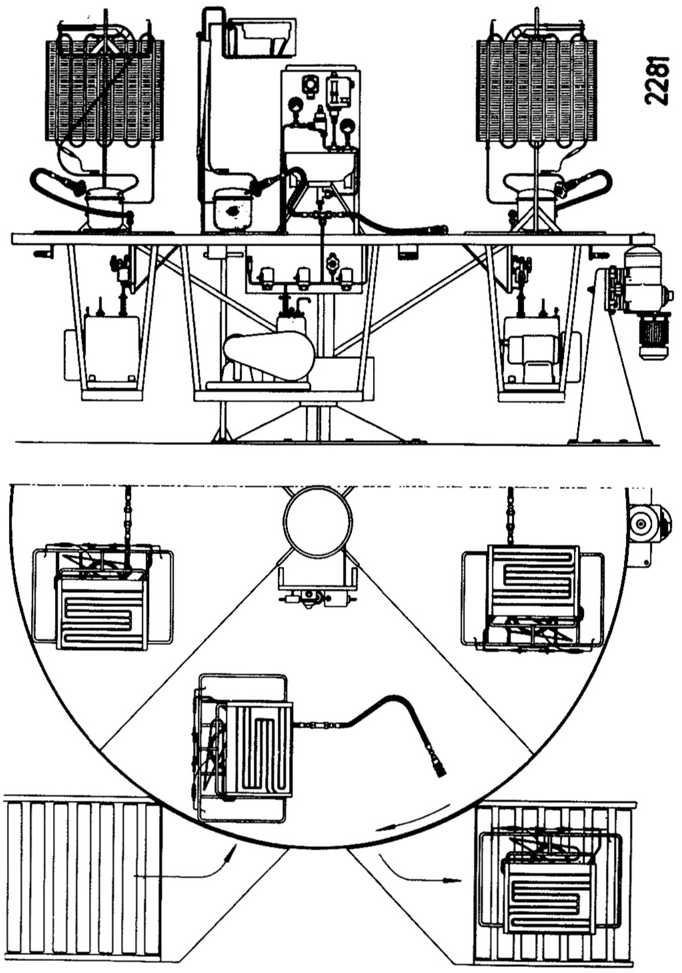


Fig. 37

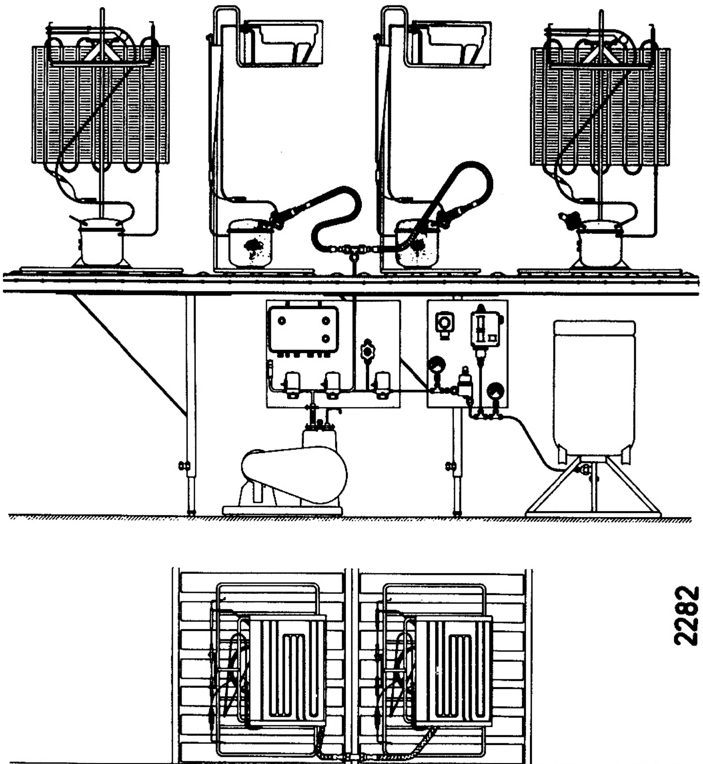


Fig. 38

After evacuation the system is transferred to the charging station.
To ensure quick connection and disconnection during evacuation as well as during charging it is an advantage to use the socalled quick connectors (see fig. 39).
The gasket "4" in the male part tightens round the process tube on the compressor when the hand wheel "2" is turned. On the end of the hoses at the evacuating and charging stations there are corresponding female parts. When male and female parts are joined the cones "7" and "8" are opened, thereby ensuring a safe and tight connection without loss of vacuum.

Fig. 39

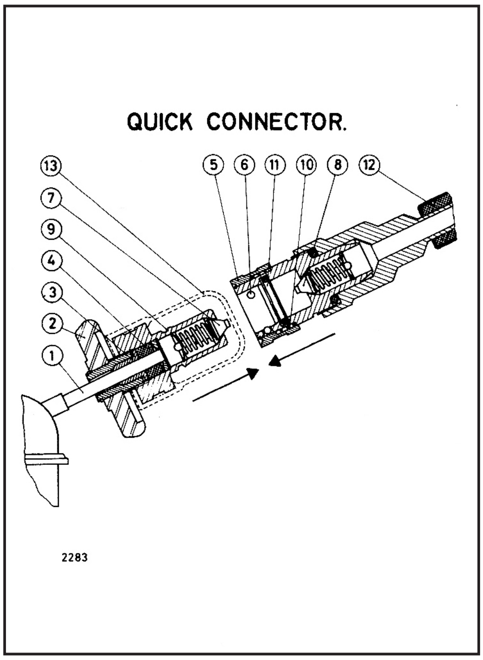
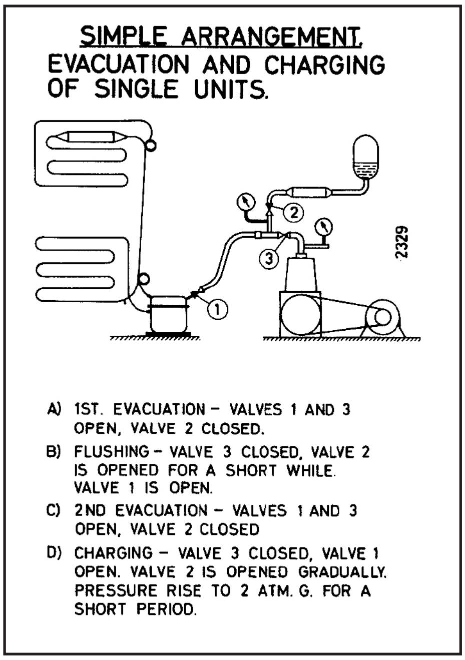


Fig. 40



A) 1ST. EVACUATION – VALVES 1 AND 3 OPEN, VALVE 2 CLOSED.
B) FLUSHING – VALVE 3 CLOSED, VALVE 2 IS OPENED FOR A SHORT WHILE. VALVE 1 IS OPEN.
C) 2ND EVACUATION – VALVES 1 AND 3 OPEN, VALVE 2 CLOSED
D) CHARGING – VALVE 3 CLOSED, VALVE 1 OPEN. VALVE 2 IS OPENED GRADUALLY. PRESSURE RISE TO 2 ATM. G. FOR A SHORT PERIOD.

When producing single units or during repair, evacuating and charging can take place as shown in fig. 40. By means of a vacuum pump and a service cylinder the same operations as described above are carried out in a simple way.

Refrigerant is gradually charged into the system until the evaporator is completely frosted up.
In series production a measuring glass is normally used to measure the amount of refrigerant charge, the correct amount being decided beforehand by experiments.

Fig. 41 shows a semi—automatic charging board which can be used for the whole evacuating and charging procedure, or if it is desired to utilize the charging board even more, it can be combined with a separate evacuating arrangement. (As fig. 36).

The charging board is operated as follows:

A) The system is connected to the charging hose pos. 19.
B) 1.st evacuation takes place with valve 1 open and valves 5, 2 and 3 closed. Vacuum can be checked by opening valve 3 and operating vacuum gauge 15.
C) R12 flushing takes place with valves 1 and 3 closed and valve 5 open, by opening valve 2 for a short period while the pressure equalization in the system takes place.
D) Second evacuation as first evacuation.

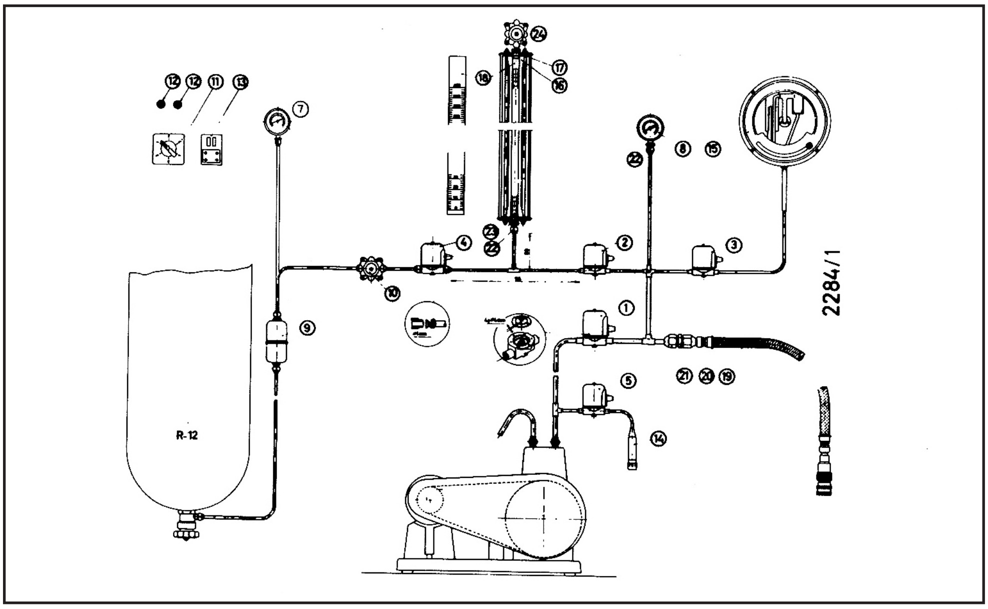


Fig. 41

Charging takes place by filling the predetermined amount of refrigerant into the measuring glass 18 by opening valve 4. With valves 4, 3 and 1 closed, valve 2 is opened so that the refrigerant flows into the system.

Towards the end of the charging process the compressor must be started, so that the pressure after each charging operation is drawn down to the same level in the measuring glass and the tubes.
The dimensions of the measuring glass, as well as the size of secondary volumes are very important conditions when designing a charging board such as fig. 41.

The measuring glass should be as narrow as possible in order to obtain the best possible reading accuracy. For charging domestic systems, an internal diameter of approx.
25mm would be suitable.

The volume of the connecting tubes between valves 2 and 4 and the measuring glass will also influence the accuracy of the charging, but as the error is nearly constant, compensation can be made by changing the scale on the measuring glass. The most accurate charge is obtained by metering the refrigerant by means of a piston in a cylinder.

On this type of charging board, which is shown in diagram in fig. 42, the compressor need not be started during the charging process.
Charging boards of this type are of special interest in the case of large production figures, and in order to obtain sufficient utilization it will always be combined with a pre-evacuating arrangement.

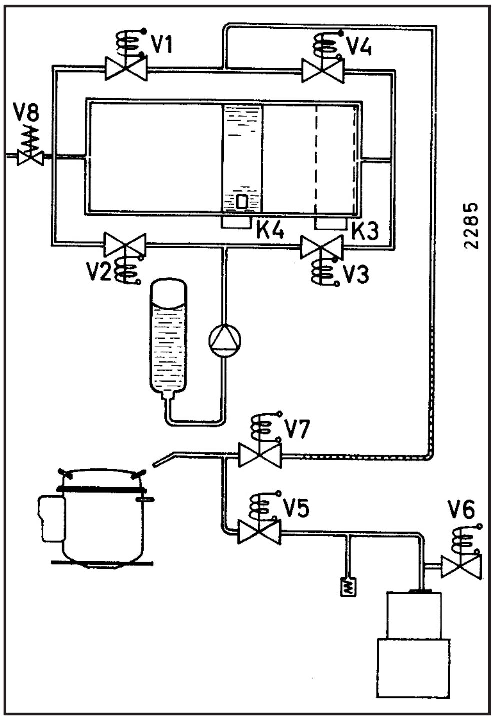


Fig. 42

In this way the operations at the charging board will be:

a) Connection
b) Check vacuum - re-evacuate - charge
c) Disconnect

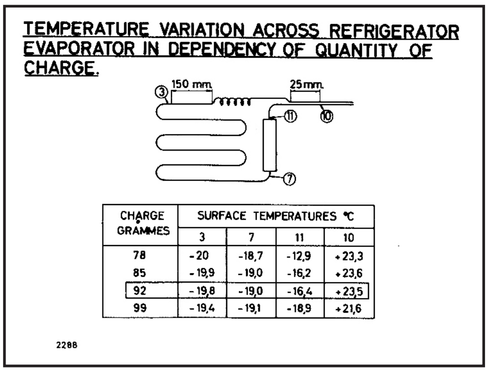
Depending on the make, operating cycles of 30 to 60 sec. can be obtained.
In charging boards of this kind the amount of refrigerant is adjusted by varying the piston stroke, which is controlled by electrical or mechanical means. The charging hose is always filled with refrigerant right up to the charging gun, this means that the compressor must not be started during the charging operation.
The temperature of the refrigerant influences the charging accuracy. One can compensate for the influence of the temperature variations by automatically adjusting the stroke of the piston according to the temperature.

Refrigerant charging

A normal requirement when using charging boards in production is that the refrigerant is supplied at a pressure 4-5 bar higher than the refrigerant pressure at the existing ambient temperature.
The incorporation of a pressure generator is therefore recommended. For example, a hermetically encapsulated gearpump can be installed in the liquid line to the charging board. This type of pump will provide the necessary operating pressure, and at the same time afford protection against undesired excess pressure.

3.5 Leak Tests

A refrigeration system can only operate satisfactorily through the duration of its life-time if it is tight. However, tightness is a word with a wide meaning, therefore we will first see how much refrigerant a system can lose before its operation is disturbed.
The best possible charge is decided by the full utilization of the evaporator surface. The utilization is characterized by the surface temperature obtained at stable conditions while the charge size is being determined.



TEMPERATURE VARIATION ACROSS REFRIGERATOR EVAPORATOR IN DEPENDENCY OF QUANTITY OF CHARGE.

CHARGE GRAMMES	SURFACE TEMPERATURES °C			
	3	7	11	10
78	-20	-18,7	-12,9	+23,3
85	-19,9	-19,0	-16,2	+23,6
92	-19,8	-19,0	-16,4	+23,5
99	-19,4	-19,1	-18,9	+21,6

Fig. 43

Fig. 43 shows an example of the temperature variation across an evaporator with various charges.
It can be estimated that the critical loss of charge is approximately 10 grams, in the case of small charges. (The smallest charge known by Danfoss is approx. 60 grams).
With a desired life—time of 15 years one must have possibility of inspecting for leaks less than 1 gram per year.
Before we look at the test methods that are available we can look at the physical quantities which influence the loss

through a leak.

If the pressure in a refrigerant container is only 0.75 kg/cm² higher than the ambient pressure, the refrigerant will flow out of the container with the same velocity as that of sound.

Bäckström* gives the following simplified formula for the amount of escaping gas.

$G = C_1 \times P_1 \times \sqrt{M}$ [kg/h · cm²]
C_1 = 15 for NH_3, CH_3Cl, SO_2 and several others and for air.
C_1 = 14 for CF_2Cl_2
P_1 = internal pressure in atm.abs.
M = molecule weight.

If the formula is simplified still more we get the following:

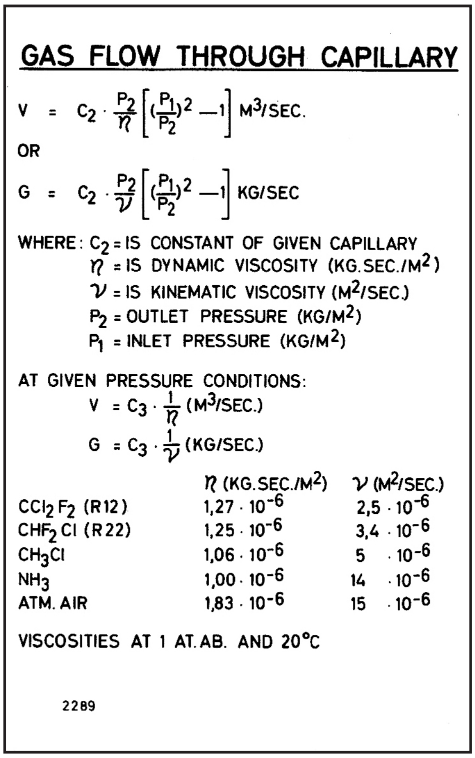
$$G = 154 \times P_{1_C} \qquad \text{for R12 (kg/h cm}^2\text{)}$$

and

$$G = 81 \times P_{1_C} \qquad \text{for air (kg/h cm}^2\text{)}$$

It is obvious that the escaped amount at the same pressure conditions is twice the size in the case of R12 as if it was air.

The above is not valid for the leak that one seeks by means of leak tests. Normally such openings are very small with a relatively long flow distance, so that they in reality are capillaries.



GAS FLOW THROUGH CAPILLARY

$$V = C_2 \cdot \frac{P_2}{\eta}\left[\left(\frac{P_1}{P_2}\right)^2 - 1\right] \text{ M}^3\text{/SEC.}$$

OR

$$G = C_2 \cdot \frac{P_2}{\nu}\left[\left(\frac{P_1}{P_2}\right)^2 - 1\right] \text{ KG/SEC}$$

WHERE: C_2 = IS CONSTANT OF GIVEN CAPILLARY
η = IS DYNAMIC VISCOSITY (KG.SEC./M²)
ν = IS KINEMATIC VISCOSITY (M²/SEC.)
P_2 = OUTLET PRESSURE (KG/M²)
P_1 = INLET PRESSURE (KG/M²)

AT GIVEN PRESSURE CONDITIONS:

$$V = C_3 \cdot \frac{1}{\eta} \text{ (M}^3\text{/SEC.)}$$

$$G = C_3 \cdot \frac{1}{\nu} \text{ (KG/SEC.)}$$

	η (KG.SEC./M²)	ν (M²/SEC.)
CCl_2F_2 (R12)	$1,27 \cdot 10^{-6}$	$2,5 \cdot 10^{-6}$
CHF_2Cl (R22)	$1,25 \cdot 10^{-6}$	$3,4 \cdot 10^{-6}$
CH_3Cl	$1,06 \cdot 10^{-6}$	$5 \cdot 10^{-6}$
NH_3	$1,00 \cdot 10^{-6}$	$14 \cdot 10^{-6}$
ATM. AIR	$1,83 \cdot 10^{-6}$	$15 \cdot 10^{-6}$

VISCOSITIES AT 1 AT.AB. AND 20°C

2289

Fig. 44

The following comments can be given to fig. 44.

a) C_2 and C_3 are constants at a given pore size (not without dimensions).

b) The leak increases square to the pressure ratio $\frac{P_1}{P_2}$

c) It is obvious from the simplified formula that the escaping volume is inversely proportional to the dynamic viscosity of the gas, and the escaping weight is inversely proportional to the kinematic viscosity of the gas.

d) The table shows that in regard to weight loss R12 is specially adverse. Under otherwise equal conditions twice as much R12 is lost as methyl chloride. One can also see that a much higher pressure is required when leak testing with air, to obtain the same leak as with R12, whether the leak is referred to volume or weight.

---

*(Matts Bäckström: Kyltechnikern page 227)

Leak testing in water

One of the simplest test methods is leak testing in water bath. From the above it was to be seen that it was necessary to have a much higher air pressure than the prevailing R12 pressure under operating conditions to obtain the same amount of leakage However, other conditions will also have influence.

If f.inst. the walls of the pore are covered with a liquid, f.inst. if the pore is filled with oil, the viscosity of the liquid will influence the escaping amount of air.

If there is liquid at the outlet opening of the pore, which is the case when leak testing in water, the surface-tension of the water will influence the amount of flow. A certain pressure difference is necessary to overcome the influence of the surface —tension of the liquid, as below:

$$\Delta p = 4 \text{ X } \delta / d$$

The pressure difference Δp in bar.

The surface—tension δ in kg x cm/cm^2.

The pore diameter d in μ.

For water: $\Delta p \times d = 2.9$

The surface—tension can be reduced by raising the temperature of the water, or by adding a softener, but the results obtained in this way are limited.
The surface—tension of water in dyn/cm is as follows:

Water at 20°C	73 dyn/cm
Water at 60°C	68 dyn/cm
Softened water	20 to 30 dyn/cm

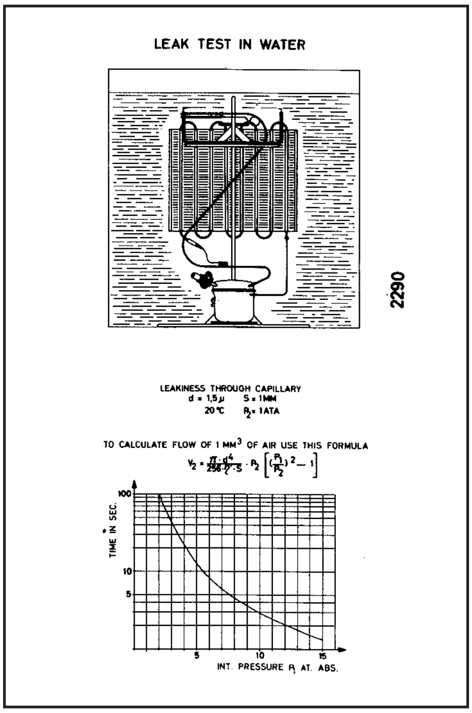

LEAK TEST IN WATER
2290
LEAKINESS THROUGH CAPILLARY
d = 1,5 μ S = 1MM
20 °C P2 = 1ATA
TO CALCULATE FLOW OF 1 MM3 OF AIR USE THIS FORMULA
V2 = π·d4 / 256·η·S · P2 [(P1/P2)2 − 1]
TIME IN SEC.
100
10
5
5
10
15
INT. PRESSURE P1 AT. ABS.

Fig. 45

If one is to have the possibility of finding small leaks when testing in water, there must be sufficient time for the test. An air bubble is about 1 mm^3 large, to form such a bubble,when the pore has a diameter of 1.5μ and a length of 1 mm the pressures and times shown in fig. 45 are necessary.

There is naturally a limit to the amount of pressure one can use for leak testing. The strength of the components must be considered, as well as the consumption of dry air or dry nitrogen.
Normally a test pressure of 10 bar is used and the leak test in water is considered a rough test which is to be followed by a more accurate test.

One must also realize that the leaks that are to be found are often filled with oil or flux, which reduce the flow possibilities. Only when the refrigeration system starts operating with refrigerant, the foreign matters will be gradually washed out of the pores and the leak will be detectable.

Also for this reason a sensitive test method is required after refrigerant charging and test run.

Important:
Oil-filled compressors must always be tested with dry nitrogen when leak testing in water.
Air will contaminate the de-gassed oil and will not be completely removed by evacuation.

The detector lamp

The detector lamp operates according to the fact that halogenated refrigerants such as R12, R22 and R502 are decomposed by contact with glowing copper.

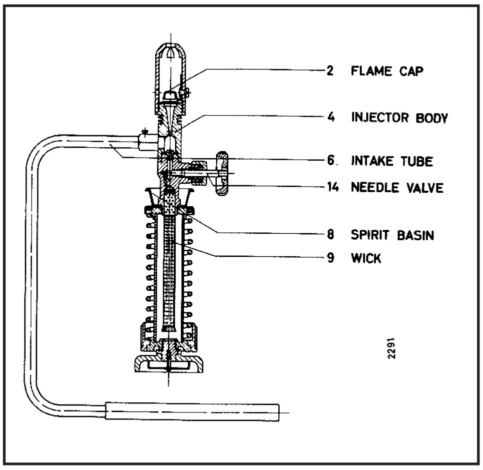


Fig. 46

The detector lamp shown in fig. 46 can be made as follows:

Burning alcohol in the cup 8 preheats the lamp. Then the alcohol flow is opened by means of the needle valve 14 and the flame is lit. Combustion air is supplied through the hose 6.
When the free end of the hose is passed over the surface of the object being tested, any possible leaks will add refrigerant to the air. The refrigerant will be decomposed by passing the flame cap and the flame will turn green in the case of small leaks and blue in case of large leaks. Because of the design, there will be a delay before the flame reacts to a leak.
Detector lamps for use with acetylene, butane and propane are also available. It is important that the fuel is free from halogens, as well as that the air in the test room does not have a high content of halogens.
The detector lamp must be regarded as unsuitable for hermetic refrigeration systems because its sensitivity is in the range of 1g R12/day.

Electronic leak detector

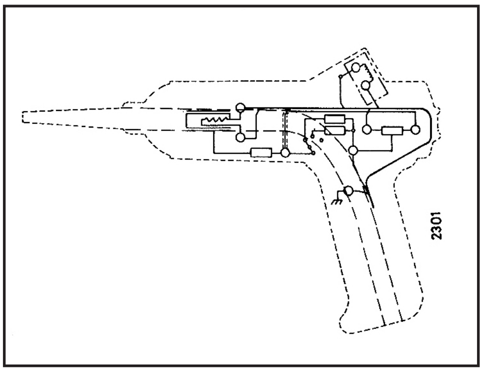


Fig. 47

In every series production of hermetic refrigeration systems the electronic leak detector is a necessity.
This instrument operates as follows:
Air is drawn from the test point across a glowing platinum wire. The glowing surface emits electrons and also a small amount of positive ions
In the presence of halogenated gasses the emission of ions is greatly increased, because the halogens are decomposed by the glowing platinum. In an electric field which has the platinum wire as cathode and a platinum cylinder as anode there will thus be a current of ions proportional to the content of halogens in the passing air stream. The current is amplified and registered

on a measuring instrument or by means of an acoustic signal.

The leak test takes place by passing the mouth—piece of the gun past all joints at a distance of approx. 5 mm and at a velocity of less than 50 mm/sec. A soldered joint must naturally be checked all round its circumference. The sensitivity, which varies among other things with the detecting velocity, is stated to be 0.3 g R12/year, but in practice it will not be so good.

Experience shows that the sensitivity of a leak detector is reduced in the course of time. This is specially the case if it is to a great extent subject to halogens, because the electrodes can in this way become briefly or perhaps even permanently contaminated. This happens because the cathode especially is charged with halogens, which only very slowly are released.

Also for this reason it is important that the larger leaks are sorted out before the leak detector test. It is often seen that a system for finding larger leaks is used, whereby the system is pressurized with a mixture of N_2 and R12 and then checked with a leak detector.
From the formula fig. 44 one can find the flow of halogens through a leak is not promoted by mixture with N_2. The only advantage is that the content of halogens is reduced so that large leaks will not spoil the electrodes.
It is also important that the test takes place in a room where the air has a low content of halogens. This means less than 10^{-3} vol.%. This can only be maintained by continuous supply of fresh air.

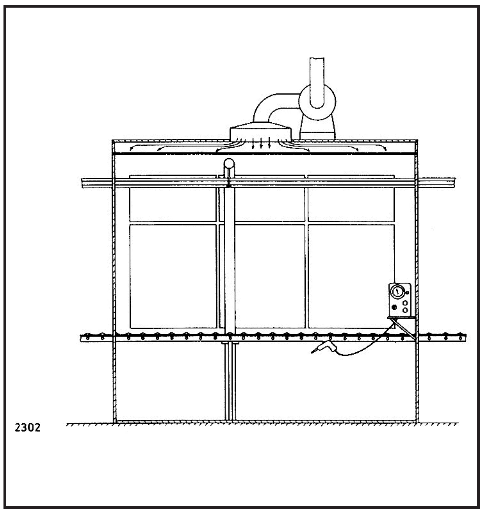


Fig. 48

Fig. 48 shows an example of the layout of a test cabin.

G.E. states a life—time of approx. 500 hours for the sensitive element of a leak detector.
Practical experience at Danfoss shows, however, that it is possible to increase the life-time to 600 to 700 hours.

This increase has mainly been achieved by keeping the halogen content of the air in the room where the test takes place at an absolute minimum.
Another important factor is that the air is free from dust particles and other foreign matters.
Depending on the size of the production the leak detector will have shorter or longer idle periods between two tests. For practical reasons (heating-up time) it will also continue to be in operation through short work breaks. (30 min.)

As these periods can be reckoned as loss in life—time, the sensitive element must be protected as well as possible, and it can be recommended to blow dry air into the gun in these periods by keeping a small overpressure in the gun holder. The conditions can be even more improved by passing the inlet air through a fine strainer.

Regeneration of sensitive elements

In the course of time an alkaline deposit will form on the surface of the sensitive element, thus reducing the sensitivity.
To compensate for this the current must be increased, whereby the deposit will be increased, and so deterioration of the sensitive element has started. The deterioration can however be postponed f.inst. by checking the amount of deposit at intervals and removing most of it by polishing it carefully. For this purpose a small electric motor, f.inst from a fan, is used, with a piece of fine emery paper fastened to the shaft.

This process is used for the anode (the platinum cylinder) while the deposit is removed from the cathode by soft hand polishing.
It must be emphasized that the polishing must be carried out with great care because the slightest deformation can spoil the elements.

Leak standard

As already mentioned the electronic leak detector is highly sensitive to leaks. If one is to have the full benefit of the instrument it is necessary to have a possibility of checking the sensitivity at regular intervals. This can be done in different ways.
Some leak detector manufacturers supply a "sniffing bottle" with halogen contents. It can be used to check that the leak detector is operating.
It is also well—known that cigarette smoke can make a leak detector react, but one must be careful that no ash is sucked into the gun, as it can spoil the elements.

As quality check, G.E. produces a so—called Halogen Leak Standard with the following ranges:

0 to 0.1 oz/year i.e. 0 to 2.8 g/year
0 to 1 oz/year i.e. 0 to 28 g/year

The accuracy is stated to be ±10% of full scale value.

The principle that G.E. uses can be seen in fig. 49.

Fig. 49

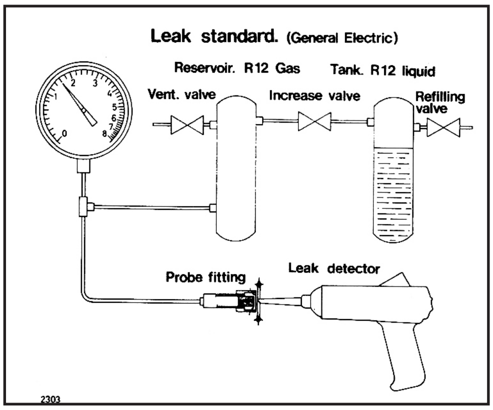
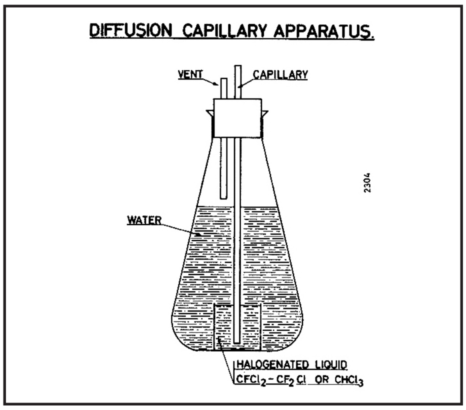

Leak standard. (General Electric)
Reservoir. R12 Gas
Tank. R12 liquid
Vent. valve
Increase valve
Refilling valve
Probe fitting
Leak detector
2303

Fig. 50


DIFFUSION CAPILLARY APPARATUS.
VENT
CAPILLARY
WATER
2304
HALOGENATED LIQUID
CFCl2 - CF2 Cl OR CHCl3

Another type of "Leak Standard" which was originally developed by Servel in USA can be seen in fig. 50.

The principle is that the diffusion through a capillary tube is calculated. The small flask is filled with R113 ($CFCl_2 - CF_2Cl$, boiling point 47.6°C) or chloroform ($CHCl_3$). Chloroform is best suited for small leaks (5 to 10 mg/day) R113 is best for larger leaks.

There is a water jacket around the small flask to prevent evaporation and to make the set—up less temperature dependent.

The ventilating tube ensures barometric pressure at the water surface.
The diffusion is adjusted to the desired leak by choosing a calculated, calibrated capillary tube.

The disadvantage of this leak—standard is that it is difficult to handle and sensitive to mechanical influence.

When calculating a standard leak consideration must be taken to the molecule structure of the halogen used in comparison to R12.

In the leak detector the gas is decomposed so that free halogen ions are formed, i.e. one expects that the signal is increased in dependence of the amount of halogen atoms.

However, E.M. Emery, Servel says that only the amount of chlorine atoms must be considered, when the equivalent R12 leak is calculated.
The conversion can be done as follows:

1.03 mg R113 ~ 1 mg R12
0.66 mg $CHCl_3$ ~ 1 mg R12

Emery gives the following reason for his statement:
Fluorine is very tightly bound to the carbon atom, much tighter than chlorine to carbon. Therefore only very few fluorine ions are formed.
This can be compared with the behaviour of fluorine compositions in a detector lamp. When the halogen—air mixture passes the red—hot copper cap, free halogen atoms or ions are formed on the surface of the copper, just as in the leak detector.

However, it can be proved that the detector lamp is not very sensitive to fluorinated refrigerants with little or no contact of chlorine. F.inst. the detector lamp is not applicable for pure fluorinated gasses such as CF_4. As the temperature in the detector lamp is at least as high as in the leak detector(700°C) one can reason that only the chlorine ions are active.

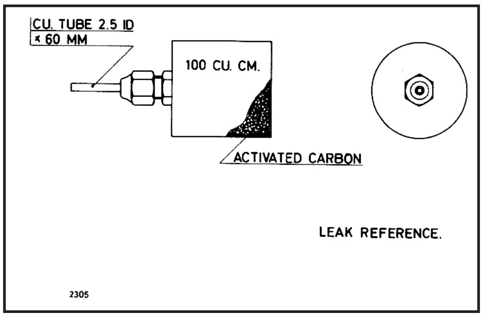


Fig. 51

A more robust calibration apparatus can be made of a tube filled with active carbon which has adsorbed some of the medium for which we are leak testing, in this case R12.

By weighing, the diffusion velocity which corresponds to the desired leak standard, can be found.
This velocity can be maintained, if the tube is kept tightly closed except during the short periods when it is in use.

Other test methods

As a curiosity we can mention the use of the mass spectromter for leak tests. The principle is that the refrigeration system is evacuated to a high vacuum, and influenced by a tracer gas, f.inst. helium, argon og hydrogen.
The apparatus is able to detect helium in a concentration of

1:2000000, and leaks of the size 10^{-9} standard cm^3/sec. ~ 3 X 10^{-2} cm^3/year, and is thus the most sensitive instrument available.

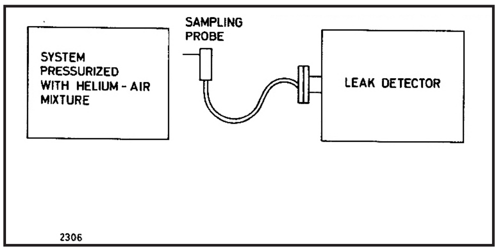

SAMPLING PROBE
SYSTEM PRESSURIZED WITH HELIUM - AIR MIXTURE
LEAK DETECTOR
2306

Fig. 52

Fig. 52, 53 and 54 show various procedures when using a mass spectrometer.
Fig. 52 shows a procedure such as with a normal leak detector.
The system is filled with a mixture of helium and air or nitrogen.

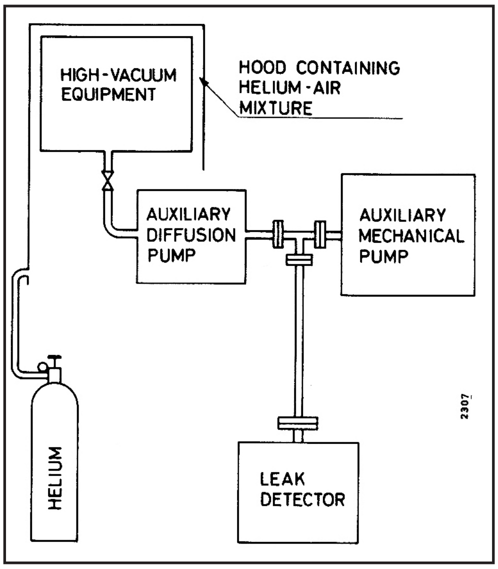

HIGH-VACUUM EQUIPMENT
HOOD CONTAINING HELIUM-AIR MIXTURE
AUXILIARY DIFFUSION PUMP
AUXILIARY MECHANICAL PUMP
HELIUM
LEAK DETECTOR
2307

Fig. 53

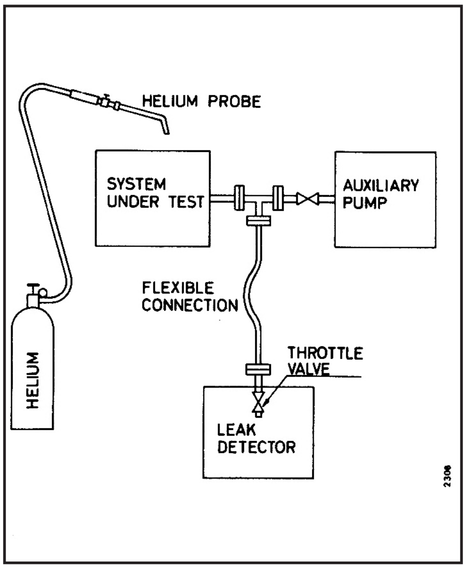

HELIUM PROBE
SYSTEM UNDER TEST
AUXILIARY PUMP
FLEXIBLE CONNECTION
THROTTLE VALVE
HELIUM
LEAK DETECTOR
2308

Fig. 54

Fig. 53 shows a system on a conveyor being taken through a hood filled with tracer gas, and to be connected to a detector later. 10% helium is sufficient in this case. Necessary vacuum:
2 x 10^{-4} mm Hg.
Fig. 54 shows the system evacuated to 1 micron (10^{-3} mm Hg).
The unit is sluiced outside with tracer gas.

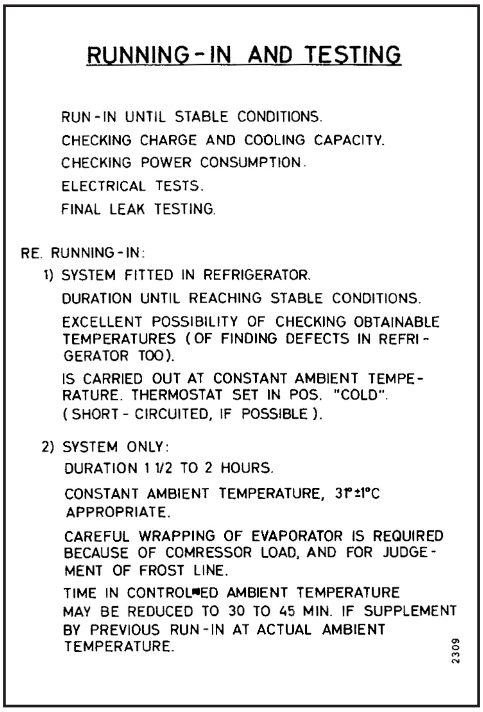
Fig. 52, 53 and 54 after Consolidated Electrodynamics Corporation.
These very accurate methods are only of interest in the case of very large production figures. The low vacuum implies that the compressors are without oil.

Testing

The finished refrigeration system must be subject to tests to ensure correct assembly and charging as well as satisfactory operation.
The tests can be devided in the following stages:

Running-in
Inspection of charge
Inspection of power consumption
Electrical tests
Final leak test

The running-in test will give the best results if it takes place with the system built into the cabinet. In this way the refrigerating ability of the system can be checked at the same time as the cabinet is inspected for defects (insulation, tightness of door gaskets, etc.).



RUNNING-IN AND TESTING

RUN-IN UNTIL STABLE CONDITIONS.
CHECKING CHARGE AND COOLING CAPACITY.
CHECKING POWER CONSUMPTION.
ELECTRICAL TESTS.
FINAL LEAK TESTING.

RE. RUNNING-IN:

1) SYSTEM FITTED IN REFRIGERATOR.
   DURATION UNTIL REACHING STABLE CONDITIONS.
   EXCELLENT POSSIBILITY OF CHECKING OBTAINABLE TEMPERATURES (OF FINDING DEFECTS IN REFRIGERATOR TOO).
   IS CARRIED OUT AT CONSTANT AMBIENT TEMPERATURE. THERMOSTAT SET IN POS. "COLD". (SHORT-CIRCUITED, IF POSSIBLE).

2) SYSTEM ONLY:
   DURATION 1 1/2 TO 2 HOURS.
   CONSTANT AMBIENT TEMPERATURE, 31°±1°C APPROPRIATE.
   CAREFUL WRAPPING OF EVAPORATOR IS REQUIRED BECAUSE OF COMRESSOR LOAD, AND FOR JUDGEMENT OF FROST LINE.
   TIME IN CONTROLLED AMBIENT TEMPERATURE MAY BE REDUCED TO 30 TO 45 MIN. IF SUPPLEMENT BY PREVIOUS RUN-IN AT ACTUAL AMBIENT TEMPERATURE.

2309

Fig. 55

Freezer cabinets and larger refrigerators are usually produced in such a way that the cabinet and the system are built up together, therefore the above test method is relevant in such cases.
Approval takes place on the grounds of the obtained temperatures f.inst. by means of temperature graphs.
The operating time is decided by the cooling-down time of the cabinet in question with the termostat adjusted to the coldest setting.
In series production of simple refrigeration systems, assembly, charging and testing often take place before mounting the system in the cabinet. When this procedure is used it is normally necessary to wrap the evaporator in a canvas cover so that the compressor is not overloaded by excessive heat input into the evaporator. It must also be ensured that the evaporator is not influenced by unnecessary heat input from the compressor or condenser.

A cover round the evaporator also promotes the possibility of getting a clear picture of the charging degree through the frosting-up.
The necessary operating time for a separate refrigeration system is the time it takes the compressor to obtain its operating temperature and become mechanically run—in, and the evaporator temperatures to become stabilized. These conditions are usually obtained after 1 1/2 to 2 hours continuous operation.

To ensure a correct test criterion it is important that running—in and testing takes place at constant ambient temperature. A test room temperature of 30 to 32°C is suitable, and in temperate climates it is quite practical because this temperature can be maintained by heating alone, if the test room is suitably arranged. In the warmest season the temperature can be kept at this level by moderate ventilation.

The temperature of the test room must be kept constant within ±1°C. If a higher test room temperature than 32°C is chosen the requirements to good wrapping of the evaporator are increased, and the risk of protector trip during the test run is increased.
If the systems are placed on a conveyor during running—in and testing, the main part of the running—in can quite well take place in uncontrolled temperature, if only the last 30 to 45 mins.of the running-in time are in controlled temperature just before the actual inspection takes place. If it is arranged in this way the investment is less, and experience shows that 30 to 45 mins.is sufficient time for stabilizing if the previous running-in has taken place at lower ambient temperature.

The correct operation of refrigeration systems is characterized by the following:

The power consumption is uniform within reasonable limits.

The evaporator must be uniformly frosted up, and the frost line must be nearly in the same place.

If the system is mounted in the cabinet, the cooling—down process must be uniform, and the obtainable minimum temperatures within previously accepted limits.

The power consumption is influenced by the operating conditions of the system. For this reason uniform ambient temperatures and correct wrapping of the evaporator is necessary.

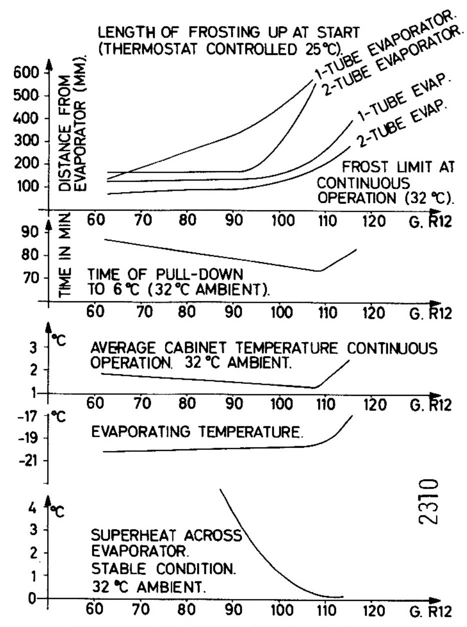
Deviations in the amount of charge will influence the power consumption. Corresponding deviations must be expected in the measured consumption of the compressors. The power consumption must be measured at rated voltage ±5 volts.

The evaporator surface must be uniformly frosted. Signs of defrosting during the running—in period can be a sign of a standstill during the period f.inst. caused by protector trip. Such disturbances can be caused by bad running-in conditions, over-charging or moisture in the system.

The full utilization of the evaporator surface is decisive for the optimum charge size. This is characterized by uniform surface temperatures from inlet to outlet. However, in a series production consideration must be taken to production tolerances(evaporator volume, the absolute charge size, compressor capacity, etc.), therefore a production charge is chosen so that the average system is slightly under-charged. This small under—charge is characterized by a few degrees superheat across the evaporator surface at stabilized conditions after the system is mounted in the cabinet.

Over-charging must be avoided because it causes increased condensing pressure and power consumption as well as displacement of the so-called frost line.

Fig. 56



INFLUENCE OF VARYING QUANTITIES OF CHARGE.
REFRIGERATOR, 130 L.

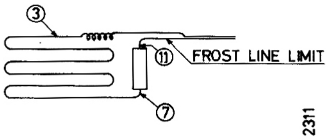
Displacement of the frost line is undesirable because of the risk of transferring moisture to the cabinet insulation. How critical this conditions is, depends on the length of suction line between the evaporator and the insulation.

The heat exchange between the capillary tube and the suction line in the so—called 2—pipe evaporators will to a great extent restrict the possibility of overfrosting in the case of small overcharges.

On 1-pipe evaporators where the heat exchange takes place inside the suction line one does not obtain such a fixed limit of the frost line.

Fig. 56 shows the influence of the amount of charge on 1-pipe and 2—pipe evaporators respectively,-after mounting in a cabinet.

CHECKING FROST LINE



REQUIREMENTS:
CAREFULLY WRAPPED EVAPORATOR
AMBIENT TEMPERATURE 32 °C.

CORRECT CHARGE IS CHARACTERIZED BY:
UNIFORM FROSTING.
FROST LINE LIMIT AS SHOWN IN SKETCH.
REASONABLE WATT CONSUMPTION.

PRODUCTION CHARGE:
DETERMINED BY SEPARATE LAB. TEST ON THE REFRIGERATION APPLIANCE.
SLIGHTLY UNDER CHARGED BECAUSE OF PRODUCTION TOLERANCES, I.E. A SLIGHT TEMPERATURE RISE ACROSS EVAPORATOR SURFACE.
TEST POINTS 3 AND 7 AS IDENTICAL AS POSSIBLE. SUPERHEAT FROM TEST POINTS 3 TO 11: 4-7 °C.

Fig. 57

On simple refrigeration systems one endeavours to keep the frost line midway between the evaporator outlet and the beginning of the heat exchanger, when the test takes place at 32°C and with the evaporator wrapped up. See fig. 57.

Test criteria with regard to frostline as well as to power consumption must, in series production, be stipulated specially for the design in question. This can best be done on a statistical basis.
To ensure correct compressor operation in difficult voltage conditions, start tests at over and under voltage can be carried out. Normally these relay tests will be carried out at 85% and 110% of rated voltage.
The most difficult start conditions occur at over voltage when the motor is cold, and at under voltage when the motor is warm. This means that the start test at over voltage must take place before the running-in test, and the start test at under voltage must take place after the running-in test. In both cases it must naturally be ensured that the system is pressure equalized.

As the start tests primarily are to ensure correct relay operation, it is obvious that the start tests are not justified if the system is not tested with its final electrical equipment.
If special "test electrical equipment" is used the start tests must take place on the refrigerator assembly line.

Experience shows that systems are very rarely rejected by the above tests, so the tests can therefore largely be looked upon as a waste of time.
The finished refrigerator must always be tested for electrical leaks to earth. This can be done with a megohmmeter, which can show the insulation resistance. The insulation resistance must always be 2 megohm or more at a measuring voltage of 500 volt d.c.

While the megohmmeter measures the leak current at a relatively low voltage, the high tension test apparatus expresses the security against the maximum prevailing voltages. It is normally recognized that compressors for 220 volt must be able to withstand a voltage of 1500 volt a.c. for 1 minute without flash-over.
This test is often substituted by a flash-over test at 1650 volt for a few seconds (3 to 5 sec.). As the high tension test gives most security against insulation defects, and at the same time is relatively easy to carry out, this test is often preferred to the insulation resistance test.

A high tension test carried out with an effect of f.inst. 150 to 300 mA, can be dangerous, and it is therefore necessary to take various precautions. For this reason a so-called effect—less test is often used, where the output is max. 5 mA. The latter test apparatus is naturally less effective than the former.

Approved systems are finished by squeezing and soldering the process tube (fig. 58). Squeezing is best done by means of pliers as shown in Fig. 59. Finally a leak test with halogen leak detector is carried out.

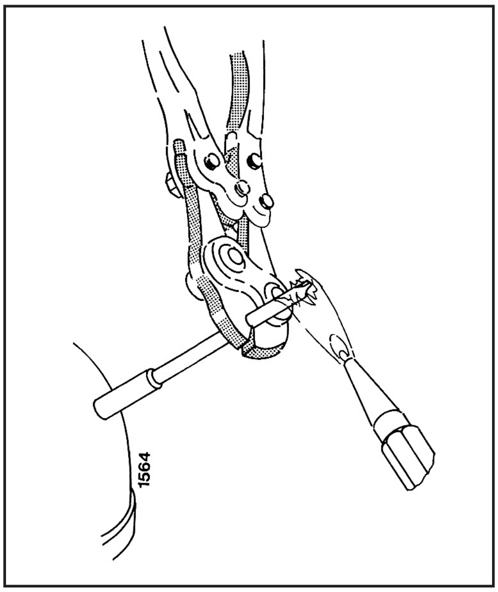


Fig. 58

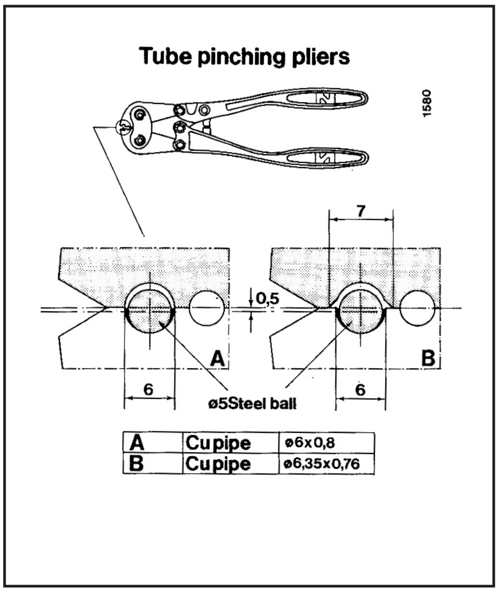

Tube pinching pliers
1580
7
0,5
A
B
6
6
ø5Steel ball
A Cupipe ø6x0,8
B Cupipe ø6,35x0,76

Fig. 59

Other tests

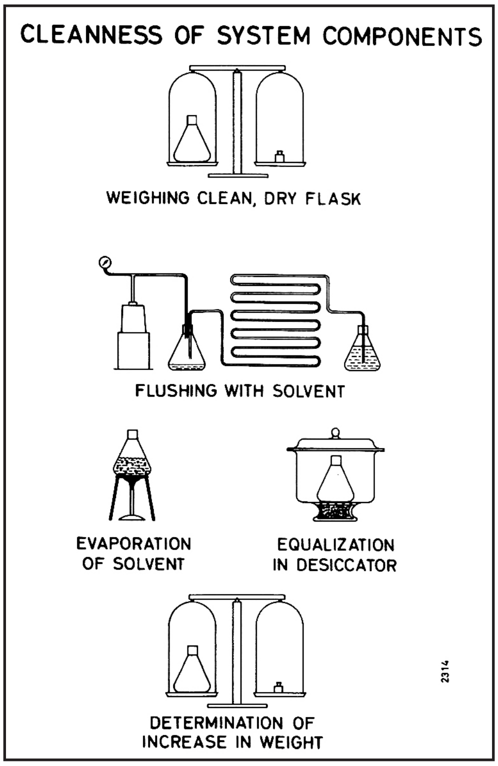

CLEANNESS OF SYSTEM COMPONENTS
WEIGHING CLEAN, DRY FLASK
FLUSHING WITH SOLVENT
EVAPORATION OF SOLVENT
EQUALIZATION IN DESICCATOR
DETERMINATION OF INCREASE IN WEIGHT
2314

Fig. 60

In series production of refrigeration systems and cabinets it is necessary to ensure good production quality by sampling tests of components and finished units. A few test methods which can be of interest can be mentioned here.
Cleanness of evaporators, condensers and tubes.

The procedure is that the object is flushed with a suitable detergent(carbon tetra chloride per —or trichlorethylene).
The detergent is evaporated and the weight of the residual impurities is found.

Dryness of components

Two methods are available, one where the moisture content is transferred to P_2O_5 and found by weighing, and the other is the so—called Electrolytical Water Analyzer. (See figs. 61 and 62).

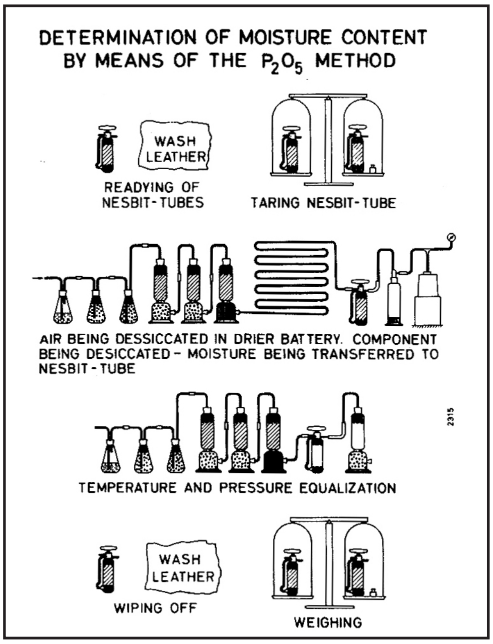
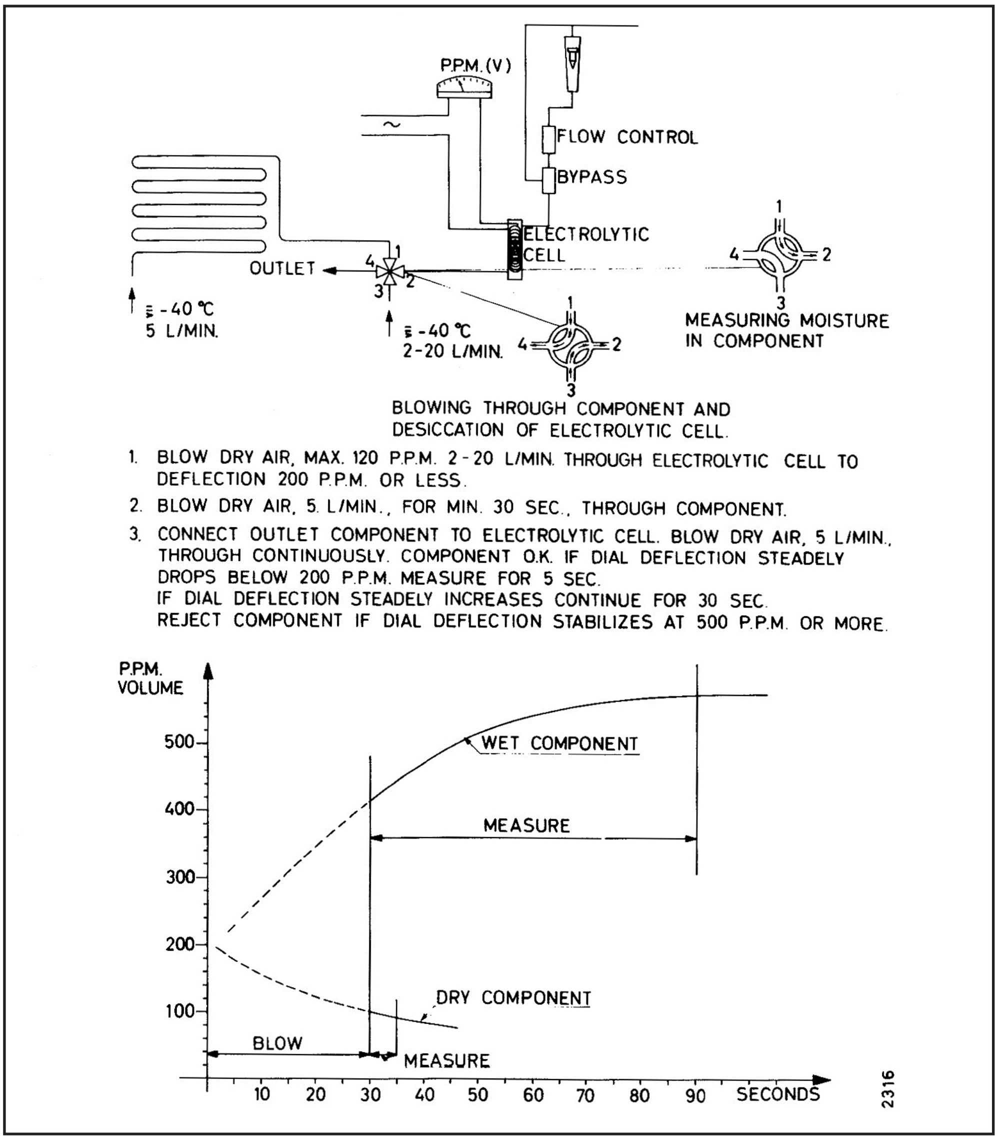

DETERMINATION OF MOISTURE CONTENT BY MEANS OF THE P_2O_5 METHOD
WASH LEATHER
READYING OF NESBIT-TUBES
TARING NESBIT-TUBE
AIR BEING DESSICCATED IN DRIER BATTERY. COMPONENT BEING DESICCATED - MOISTURE BEING TRANSFERRED TO NESBIT-TUBE
2315
TEMPERATURE AND PRESSURE EQUALIZATION
WASH LEATHER
WIPING OFF
WEIGHING

Fig. 61


P.P.M. (V)
~
FLOW CONTROL
BYPASS
ELECTROLYTIC CELL
OUTLET
1
2
3
4
≡ -40 °C
5 L/MIN.
≡ -40 °C
2-20 L/MIN.
MEASURING MOISTURE IN COMPONENT
BLOWING THROUGH COMPONENT AND DESICCATION OF ELECTROLYTIC CELL.
P.P.M. VOLUME
500
400
300
200
100
WET COMPONENT
MEASURE
DRY COMPONENT
BLOW
MEASURE
10
20
30
40
50
60
70
80
90
SECONDS
2316

1. BLOW DRY AIR, MAX. 120 P.P.M. 2 - 20 L/MIN. THROUGH ELECTROLYTIC CELL TO DEFLECTION 200 P.P.M. OR LESS.
2. BLOW DRY AIR, 5. L/MIN., FOR MIN. 30 SEC., THROUGH COMPONENT.
3. CONNECT OUTLET COMPONENT TO ELECTROLYTIC CELL. BLOW DRY AIR, 5 L/MIN., THROUGH CONTINUOUSLY. COMPONENT O.K. IF DIAL DEFLECTION STEADELY DROPS BELOW 200 P.P.M. MEASURE FOR 5 SEC.
   IF DIAL DEFLECTION STEADELY INCREASES CONTINUE FOR 30 SEC.
   REJECT COMPONENT IF DIAL DEFLECTION STABILIZES AT 500 P.P.M. OR MORE.

Fig. 62

Volume of evaporators

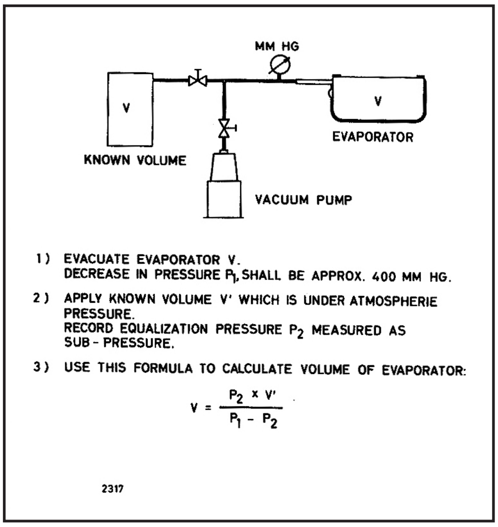

MM HG
V
V
EVAPORATOR
KNOWN VOLUME
VACUUM PUMP
1) EVACUATE EVAPORATOR V.
DECREASE IN PRESSURE P_1, SHALL BE APPROX. 400 MM HG.
2) APPLY KNOWN VOLUME V' WHICH IS UNDER ATMOSPHERIE PRESSURE.
RECORD EQUALIZATION PRESSURE P_2 MEASURED AS SUB-PRESSURE.
3) USE THIS FORMULA TO CALCULATE VOLUME OF EVAPORATOR:
$V = \frac{P_2 \times V'}{P_1 - P_2}$
2317

Fig. 63

The volume of the evaporator has a great influence on the amount of charge of the system.
In series production it must be required, that the supplied evaporators are of uniform volume. Fig. 63 shows a test method for use in the receiving inspection.

Water content in drying agents and driers

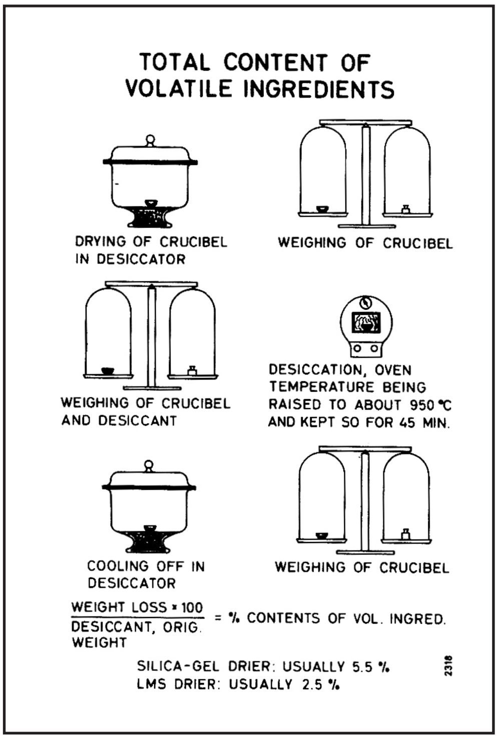

TOTAL CONTENT OF VOLATILE INGREDIENTS
DRYING OF CRUCIBEL IN DESICCATOR
WEIGHING OF CRUCIBEL
WEIGHING OF CRUCIBEL AND DESICCANT
DESICCATION, OVEN TEMPERATURE BEING RAISED TO ABOUT 950 °C AND KEPT SO FOR 45 MIN.
COOLING OFF IN DESICCATOR
WEIGHING OF CRUCIBEL
$\frac{\text{WEIGHT LOSS} \times 100}{\text{DESICCANT, ORIG. WEIGHT}}$ = % CONTENTS OF VOL. INGRED.
SILICA-GEL DRIER: USUALLY 5.5 %
LMS DRIER: USUALLY 2.5 %
2318

Fig. 64

Two test methods are available, you can either find the total amount of water in the drying agent or find the reversibly adsorbed water amount.

Total amount of volatile ingredients. (See fig. 64.)

The process is as follows:

The drying agent is removed from the drier.
2 to 4 grams are placed in a crucible that has been dried beforehand in a desiccator and weighed.
The weight of the crucible and the drying agent is determined.
The crucible and its contents are placed in an oven. The temperature is raised in the course of 1 hour to approx.
950°C. The crucible must stay in the oven for 30 to 45 minutes at this temperature. The crucible is then taken from the oven and placed in a desiccator for temperature equalizing to ambient temperature. The weight of the crucible with contents is determined once more.

The total amount of volatile ingredients is found as follows:

$$\frac{\text{Weight loss x 100}}{\text{Original weight of drying agent}} = \text{\% contents of volatile ingredients}$$

Limit values for activated silica-gel driers: Max. 5.5% and for LMS driers: Max. 2.5%.
The stated values are used by Danfoss but must be taken with certain reservations.
This test method has the disadvantage that the obtained result does not give an unambiguous expression of the adsorptive capa-

city of the drying agent, among other things because the destructive heating releases latent water which is included in the result.

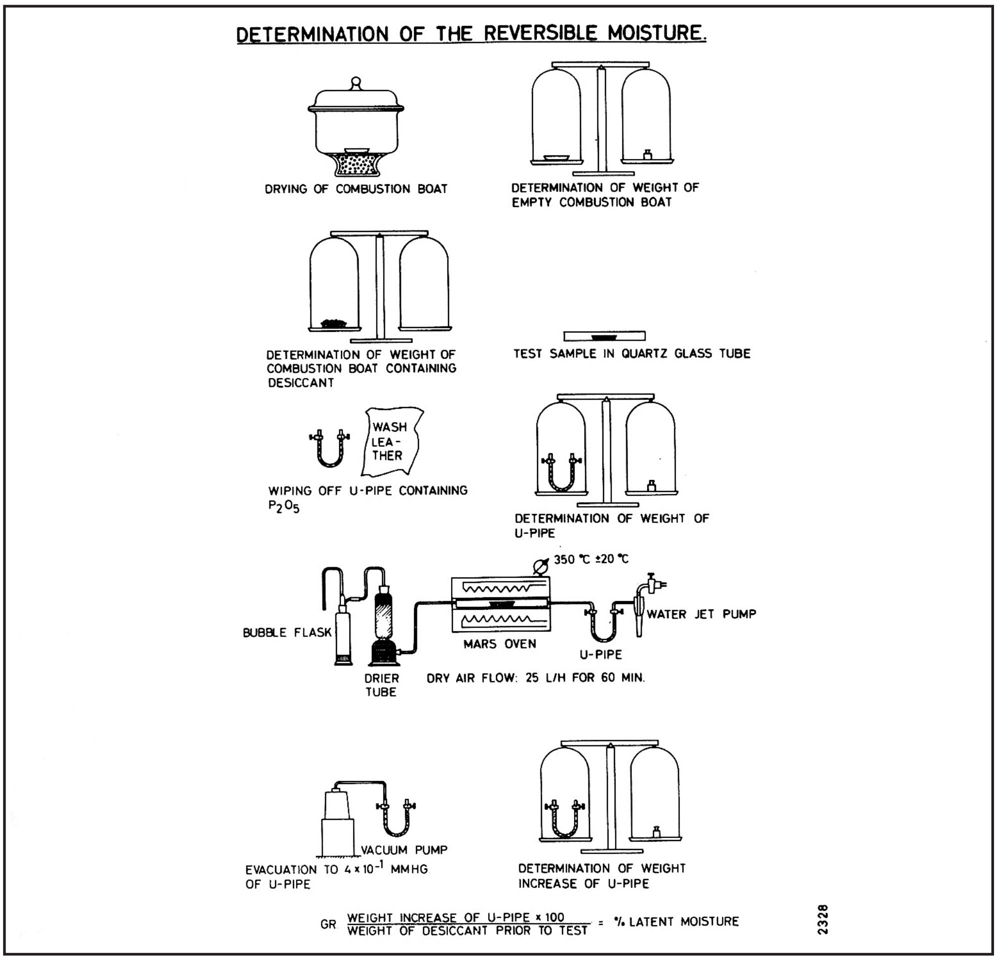

DETERMINATION OF THE REVERSIBLE MOISTURE.
DRYING OF COMBUSTION BOAT
DETERMINATION OF WEIGHT OF EMPTY COMBUSTION BOAT
DETERMINATION OF WEIGHT OF COMBUSTION BOAT CONTAINING DESICCANT
TEST SAMPLE IN QUARTZ GLASS TUBE
WASH LEATHER
WIPING OFF U-PIPE CONTAINING P_2O_5
DETERMINATION OF WEIGHT OF U-PIPE
350 °C ±20 °C
BUBBLE FLASK
MARS OVEN
U-PIPE
WATER JET PUMP
DRIER TUBE
DRY AIR FLOW: 25 L/H FOR 60 MIN.
VACUUM PUMP
EVACUATION TO 4×10^{-1} MMHG OF U-PIPE
DETERMINATION OF WEIGHT INCREASE OF U-PIPE
GR $\frac{\text{WEIGHT INCREASE OF U-PIPE} \times 100}{\text{WEIGHT OF DESICCANT PRIOR TO TEST}}$ = % LATENT MOISTURE
2328

Fig. 65

A more unambiguous test method, is to determine the adsorptively bound water. This is done by placing 5 to 20 gr. of drying agent in a crucible which has been dried in a desiccator and weighed beforehand. The weight of the crucible and its contents is determined quickly. Then the crucible and its contents are placed in a quartz tube with connection hoses which must be closed tightly. One of the hoses is connected to a dryer tube, the other is connected to a U-tube or nesbitt tube with P_2O_5 which has been weighed beforehand. With a water jet air pump, air is drawn through the dryer tube, quartz tube and the tube with P_2O_5 at a velocity of approx. 25 liters per hour.

The temperature of the quartz tube with the drying agent (LMS) is raised to 350°C ±20°C which is maintained for 60 minutes. Here the test is discontinued. The U-tube or nesbitt tube is removed from the set-up.
The increase in weight of the U-tube after it has been temperature equalized and evacuated to 4×10^{-1} mm Hg, expresses the amount of adsorptively bound water.

For LMS driers the limit value max. 2.0% can be used.

Moisture content in R12

Moisture content in R12 in supply containers as well as in run—in systems can be determined by means of either the so-called P_2O_5 method or by Electrolytic Water Analyzer.

When using the P_2O_5 method, a suitable amount of R12 (not less than 100 g) is taken from the supply container or from the warm and run-in system and transferred to a dehydrated, evacuated container.
The container is weighed.
By means of a set-up consisting of a drier battery and an adsorption battery the moisture is transferred from the refrigerant to the adsorption battery and the weight is determined.

Fig. 66 shows the stages of the method.

An expression of the amount of humidity in a refrigeration system can also be found by using the so-called "Electrolytic Water Analyzer". The principle of this method is that the amount of humidity is determined from a very small amount of refrigerant, which is transferred direct from an R12 container or a refrigeration system.
The humidity in the refrigerant is adsorbed by a phosphoric acid film. By electrolysis of the adsorbed moisture a current is created which is in proportion to the amount of humidity.

This method is much quicker than the P_2O_5 method but it does not give the same unambiguous picture of the moisture content in the total refrigerant charge of the system. However, this test method gives you a possibility of controlling the relative quality level, as well as being useful for receiving inspection of refrigerant.

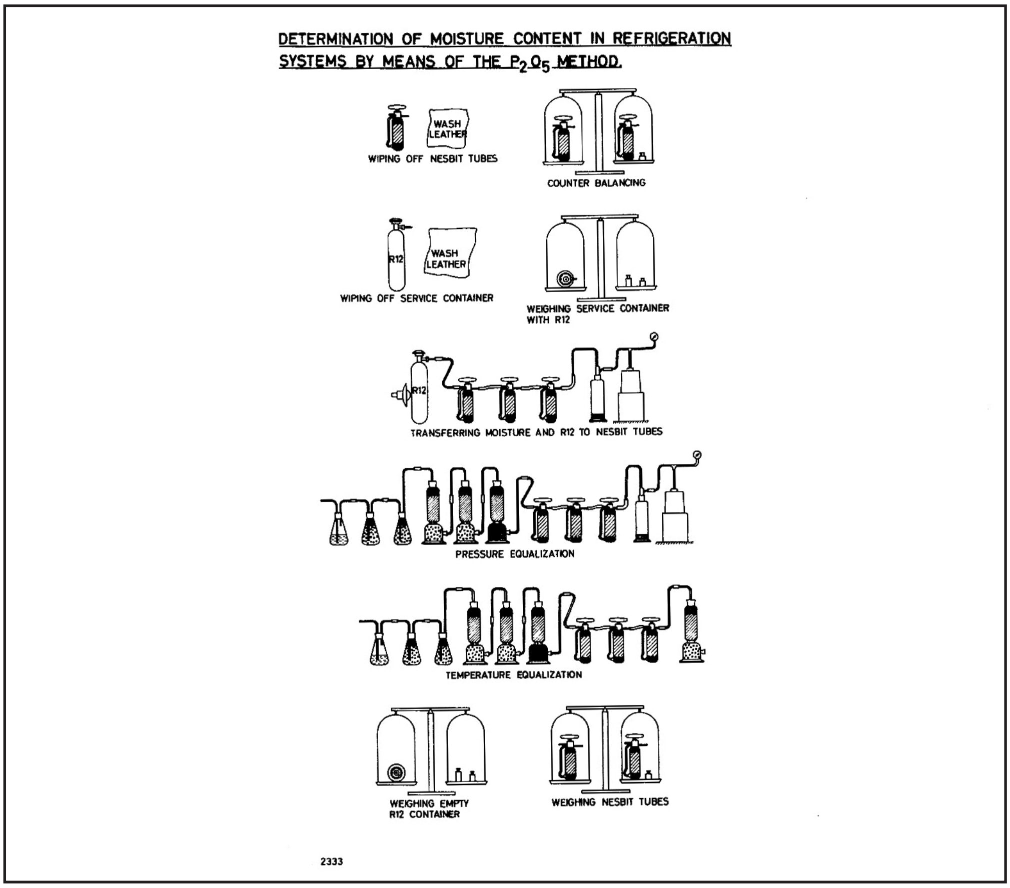
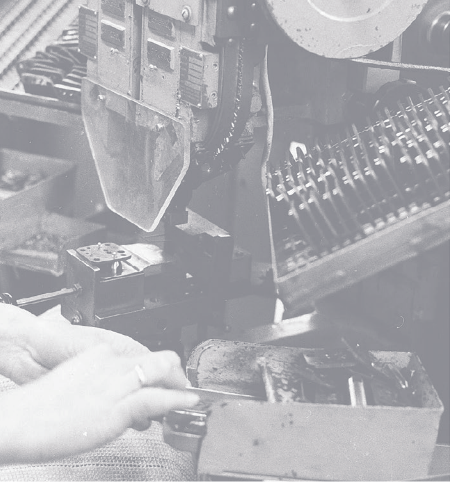
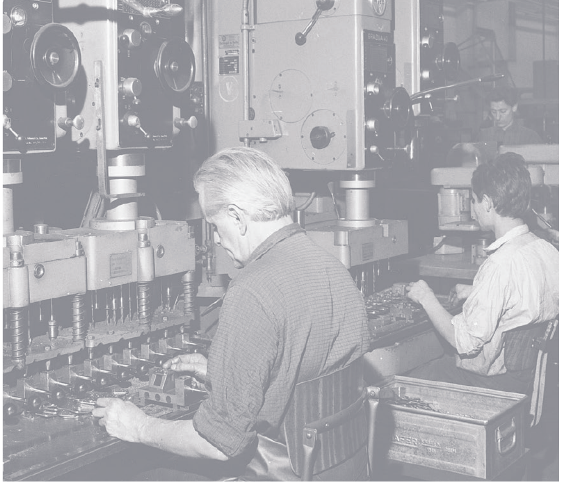
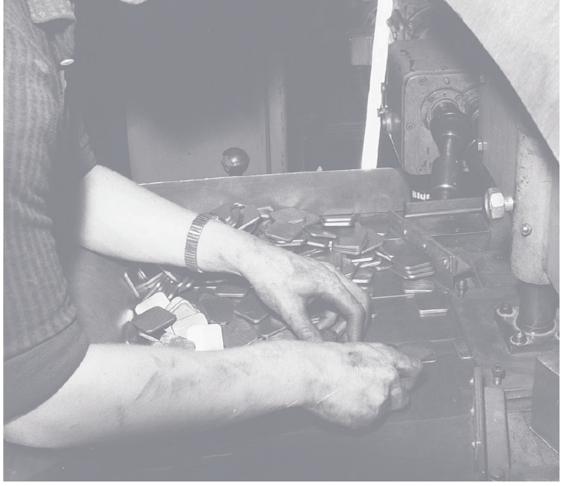

DETERMINATION OF MOISTURE CONTENT IN REFRIGERATION SYSTEMS BY MEANS OF THE P_2O_5 METHOD.
WASH LEATHER
WIPING OFF NESBIT TUBES
COUNTER BALANCING
R12
WASH LEATHER
WIPING OFF SERVICE CONTAINER
WEIGHING SERVICE CONTAINER WITH R12
R12
TRANSFERRING MOISTURE AND R12 TO NESBIT TUBES
PRESSURE EQUALIZATION
TEMPERATURE EQUALIZATION
WEIGHING EMPTY R12 CONTAINER
WEIGHING NESBIT TUBES
2333

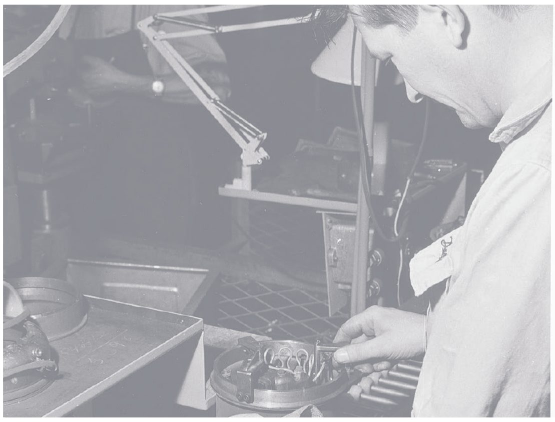
Fig. 66

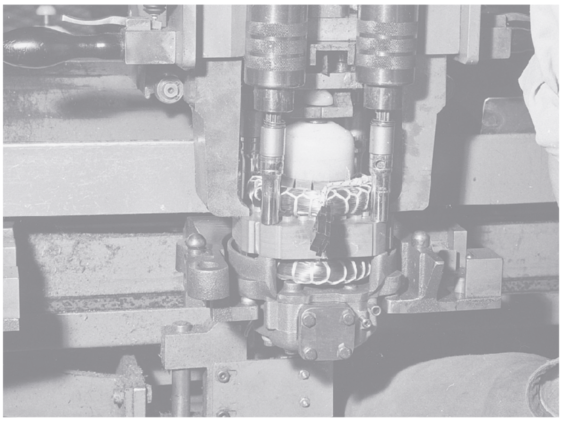
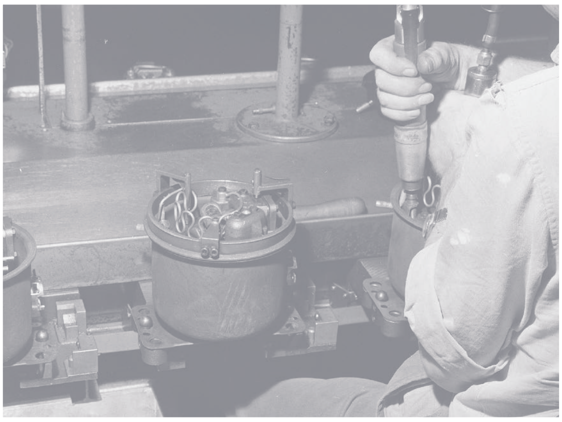
Fig. Survey of illustrations

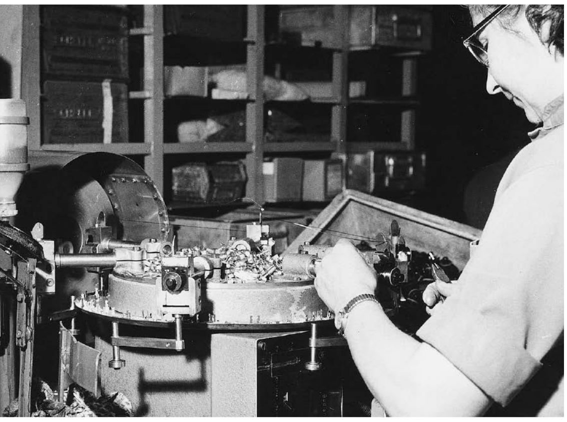
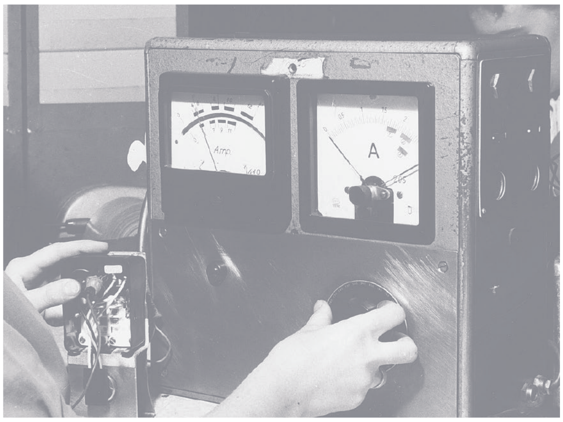
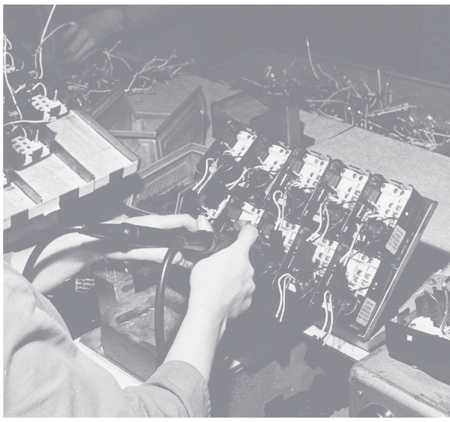
1 2221 General requirements
2 2222/1 Requirements to system components
3 2223 The ratio H_2O in vapour/H_2O in liquid for R12 and R22
4 1571 Max. water content in refrigerants
5 2225/1 Max. water content in R12 (Mollier diagram)
6 2226 Anti-freezing agents
7 2227 Water in refrigeration system
8 2228 Foreign gases in refrigeration system
9 2229 Other impurities
10 2248 Impurities and processes
11 1563 Tube straightening
12 1559 Tube cutting
13 2259 Deburring drill
14 1562 Deburring operation
15 2261 Checking capillary tubes
16 2262 Soldering heat exchanger
17 2263 Electrolytic tinplating of heat exchanger
18 2264/1 Cleaning components
19 2265 Drying components in the smaller production
20 2266 Drying oven
21 2267 Drying oven
22 2268 Dry air unit
23 2269 Dry air unit with blue—gel
24 2270 Activating silica-gel driers
25 1565 N_2 flow during soldering
26 1549 Soldering materials
27 3739 Soldering with single torch
28 3740 - - - -
29 3741 - - - -
30 3742 - - - -
31 1561 Cooling PVC-protection during soldering
32 1560 Making a stop on capillary tube before soldering
33 2277 Apparatus for checking the capillary tube for blockage
34 2278/1 Evacuation from suction side alone, as well as from both suction— and pressure side
35 3528a Evacuation test
36 1572 Arrangement used when evacuating in two stages with intermediate pressure equalization
37 2281 Evacuating station (turntable)
38 2282 Evacuating station (side station)
39 2283 Quick-connector
40 2339 Single arrangement for evacuation and charging
41 2284/1 Semiautomatic charging board
42 2285/1 Automatic charging board
43 2288 Temperature variation across evaporator in dependency of quantity of charge
44 2289 Gas flow through capillary
45 2290 Leak test in water
46 2291 Detector lamp
47 2301 Electronic leak-detector gun
48 2302 Test cabin
49 2303 Leak standard (G.E.)
50 2304 Diffusion capillary apparatus
51 2305 Leak standard (activated carbon)
52 2306 Mass spectrometer (system under pressure)
53 2307 Mass spectrometer (hood with tracer gas)

Fig.		
54	2308	Mass spectrometer (sluicing with tracer gas)
55	2309	Running—in and testing
56	2310	The influence of charge on 1— and 2—tube evaporators
57	2311	Checking frost line
58	1564	Soldering process tube
59	1580	Tube pinching pliers
60	2314	Cleannes of system components
61	2315	Determination of moisture content by means of the $P_2 0_5$ method
62	2316	Principle of Electrolytic Water Analyzer
63	2317	Determination of evaporator volume
64	2318	Total content of volatile ingredients
65	2328	Determination of the reversible moisture
66	2333	Determination of moisture content in refrigeration systems by means of the $P_2 0_5$ method



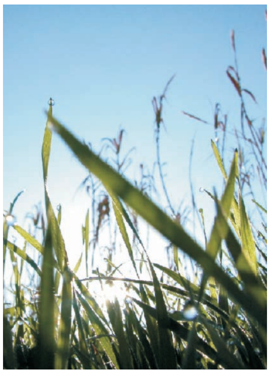


Amp
A


MERCER
MERCER

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 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.

Secop GmbH · Mads-Clausen-Str. 7 · 24939 Flensburg · Germany · Tel: +49 461 4941 0 · **www.secop.com**

Secop can accept no responsibility for possible errors in catalogues, brochures and other printed material. Secop reserves the right to alter its products without notice. This also applies to products already on order provided that such alterations can be made without subsequential changes being necessary in specifications already agreed. All trademarks in this material are property of the respective companies. Secop and the Secop logotype are trademarks of Secop GmbH. All rights reserved

Produced by Secop | April 2016