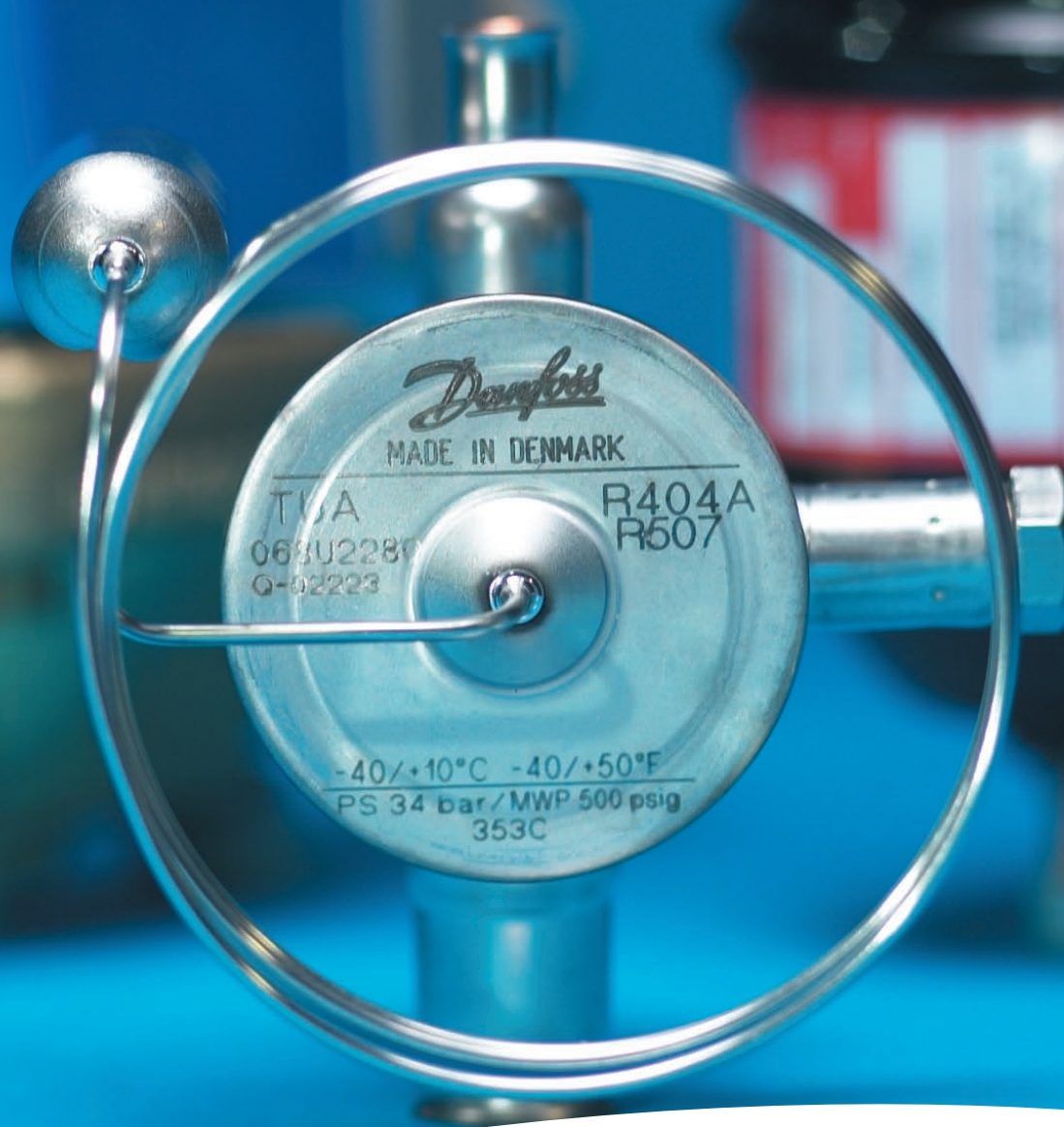




Automation of Commercial Refrigeration Plant





Automation of commercial Refrigeration Plant

The purpose of this manual is to show some examples of the use of Danfoss automatic controls for commercial refrigeration plants. A simple, hand-regulated plant is used as the starting point of a step-by-step automation and a short description of the function of each control is given.

For additional training material we refer to http://rc.danfoss.com/SW/RC_Training/En/Index.htm

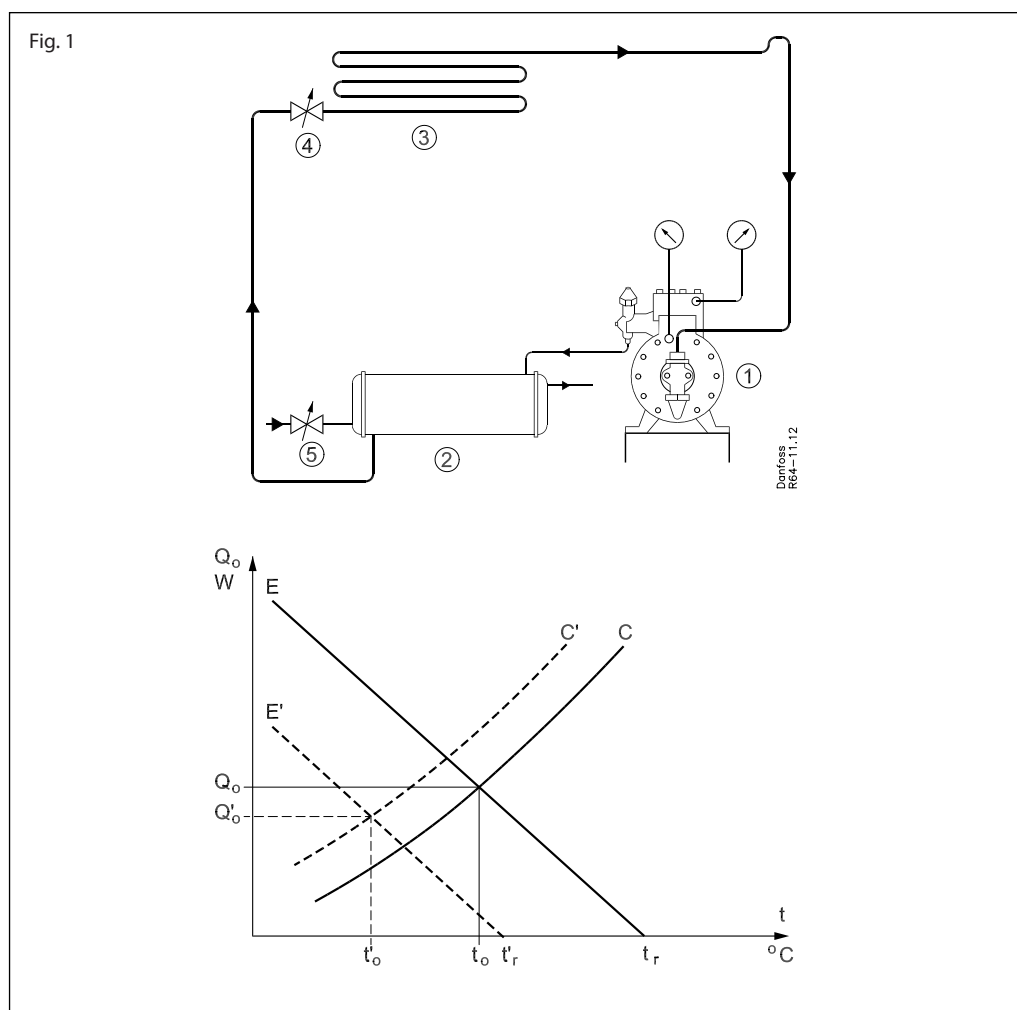


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Hand-regulated refrigeration plant



A hand-regulated refrigeration plant is usually built up of these components:

- Compressor (1)
- Condenser (2)
- Evaporator (3)

In order to maintain the cold store temperature t_r at the desired level, it is necessary to equip the plant with adjustable valves (4) and (5) in that changes in the loads on the evaporator and condenser under varying refrigeration demands can be reckoned on.

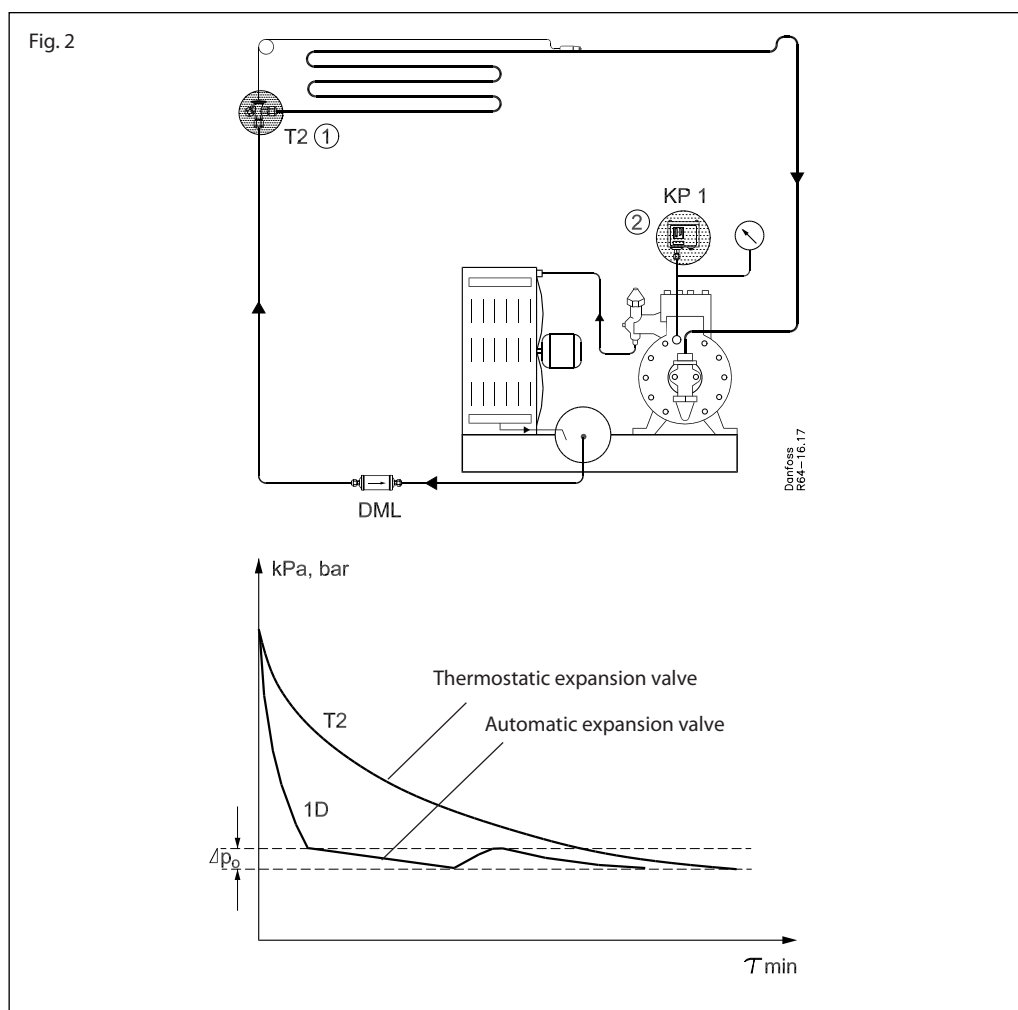
For example, the plant will be unable to maintain the same temperature summer and winter with permanently set regulating valves and a continuously operating compressor. This can easily be shown graphically, as illustrated in fig. 1.

The full lines represent summer operation and the dotted lines winter operation, (e.g. condensing temp. winter $+25^{\circ}\text{C}$, summer $+35^{\circ}\text{C}$). The C-curves represent compressor capacity, which rises with increasing evaporating

temperature t_o . The E-curves represent evaporator capacity, which rises with the increasing temperature difference $t_r - t_o$ between room temperature (t_r) and evaporating temperature (t_o). Where the C-curve (winter operation) and E-curve (summer operation) intersect each other, compressor, condenser and evaporator capacities are in equilibrium.

As can be seen from fig. 1, the room temperature will fall from t_r to t'_r when refrigeration demand falls from Q_o in summer to Q'_o in winter. To meet this condition the capacities of the compressor, condenser and evaporator must be adjusted, for example by regulating the compressor operation, and by throttling the water flow to the condenser and refrigerant liquid flow to the evaporator.

**Refrigeration plant with
thermostatic expansion
valve and air-cooled
condenser**



In this plant an air-cooled unit has replaced the water-cooled condenser. Air-cooled condensers are normally used where no cooling water is available or where the use of cooling water is forbidden.

Replacing the manual valve ahead of the evaporator with a thermostatic expansion valve (pos. 1) ensures that the evaporator is continuously supplied with the amount of refrigerant necessary to keep a constant superheat in proportion to the load.

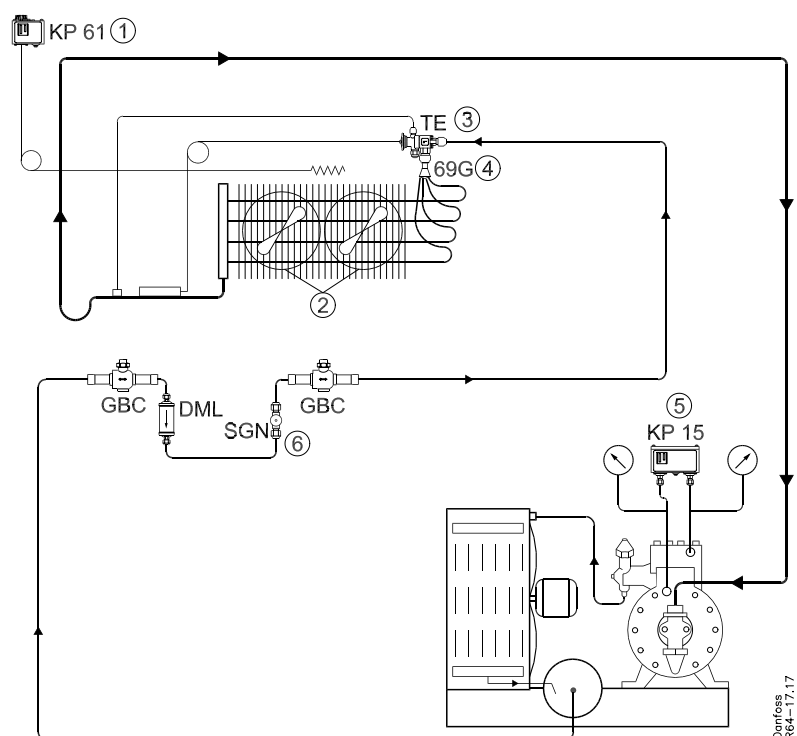
This of course presupposes that the selected expansion valve suits the evaporator concerned. A factor here is that in conditions of maximum load the expansion valve supplies precisely the amount of refrigerant the evaporator is able to evaporate. In addition the superheat setting of the valve must match the evaporator. Superheat is generally understood as being the number of °C the evaporator has minus the boiling point of the medium at the existing pressure and with all liquid evaporated.

Superheat in an evaporator is defined as $t_1 - p_s = \text{°C superheat}$, where t_1 is the temperature measured at the point on the evaporator where the expansion valve sensor is placed, and p_s is the pressure measured at the same point. (The relevant pressure is converted to °C).

For further details on superheat, see page 7.

Refrigeration with Finned evaporator

Fig. 3



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R64-17.17

Thermostat type KP 61 (1) cuts the fans (2) in and out depending on the room temperature.

Thermostatic expansion valve type TE (3) with external pressure equalization regulates liquid injection in the evaporator, dependent on the superheat but independent of the pressure drop across the evaporator.

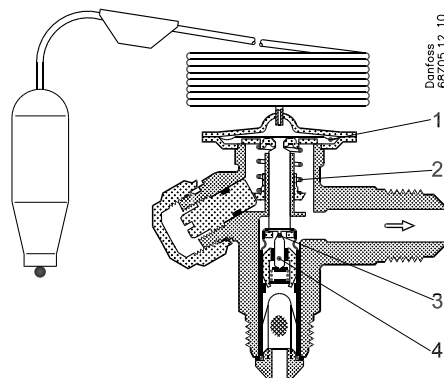
Liquid distributor type 69G (4) distribute refrigerant liquid equally to the individual evaporator sections.

The compressor is cut in and out on the low-pressure side of the combined high and low pressure control type KP 15 (5) depending on the suction pressure. In addition, the high-pressure side of this control gives protection against too high a condensing pressure by cutting out the compressor if it becomes necessary (e.g. when the ventilator is defected or the airflow is blocked (dirt)).

Sight glass type, SGN (6) indicates too high moisture content in the refrigerant and too little flow to the thermostatic expansion valve. The indicator changes colour when the moisture content is too great. Vapour bubbles in the sight glass can mean insufficient charge, insufficient sub cooling or partial clogging of the strainer.

Thermostatic expansion valve

Fig. 4



T 2

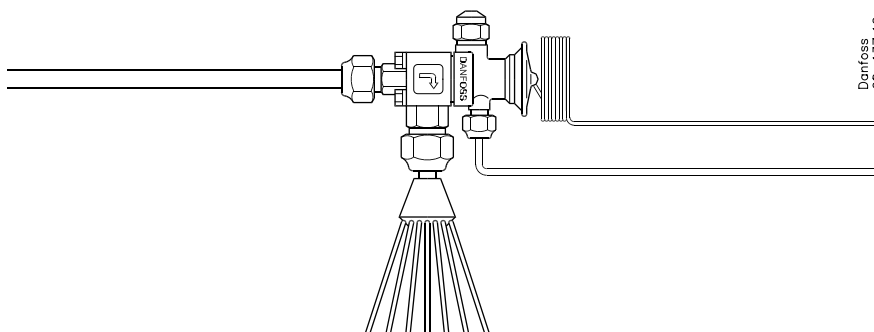
Thermostatic expansion valve type T 2, the bulb of which is placed immediately after the evaporator, opens on rising superheat. Pressure on the diaphragm (1) increases as bulb temperature increases and pressure under the diaphragm increases as the evaporating temperature increases. The pressure differential, which corresponds to the refrigerant superheat, manifests itself as a force, which tries to open the valve against the

opposite force of the spring (2). If the differential, i.e. superheat, exceeds the spring force the valve will open.

The orifice assembly, with orifice (3) and valve cone (4) can be changed. To suit capacity requirements, there are eight different sizes to choose from.

Thermostatic expansion valve with distributor

Fig. 5



TE 5 + 69G

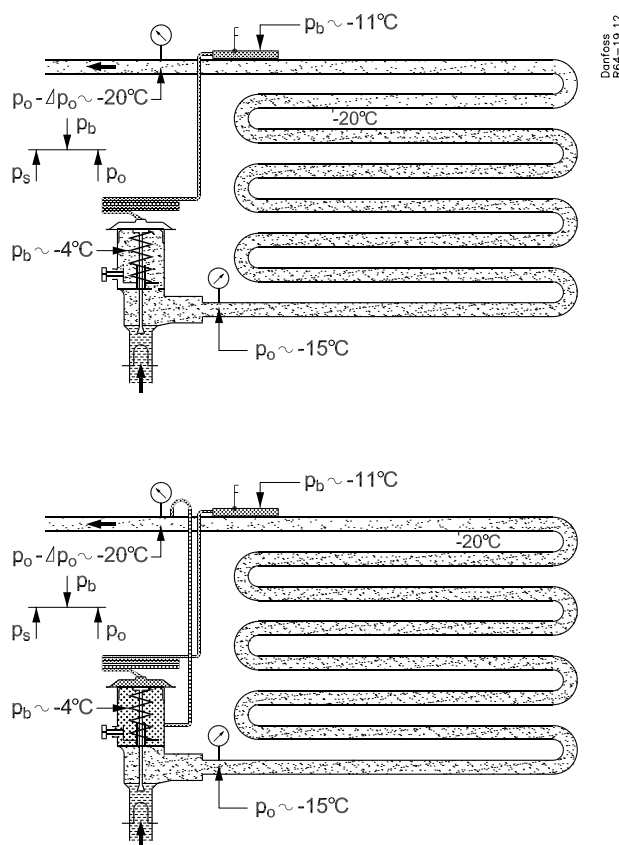
Distributor type 69G ensures an equal distribution of refrigerant to the parallel sections of the evaporator.

The distributor can be installed either direct on the thermostatic expansion valve as shown or in the line immediately after it. A distributor ought always to be fitted so that the liquid flow through the nozzle in the distributor pipes is vertical. This ensures that the effect of gravity on liquid distribution is as little as possible. All distribution pipes must be exactly the same length.

For evaporators with a large pressure drop, thermostatic expansion valves with external pressure equalization must always be used. Evaporators with liquid distributors will always have a large pressure drop; therefore always use external pressure equalization.

Expansion valves

Fig. 6



Upper diagram:

The diagram shows an evaporator, which is fed by a thermostatic expansion valve with internal pressure equalization.

The degree of opening of the valve is regulated by:

- Pressure p_b in the bulb and capillary tube acting on the upper side of the diaphragm and determined by the bulb temperature.
- Pressure p_o in the valve discharge connection acting under the diaphragm and determined by the evaporating temperature.
- Spring pressure p_s acting under the diaphragm and manually adjustable.

In the example shown, the pressure drop in the evaporator Δp is measured in °C refrigerant pressure $-15 - (-20) = 5^\circ\text{C}$. Provided that the valve spring has been manually adjusted to a pressure p_s corresponding to 4°C , it follows - in order to achieve equilibrium between the forces acting over and under the diaphragm - that $p_b = p_o + p_s \sim -15 + 4 = -11^\circ\text{C}$. That is, the refrigerant has to be superheated by $-11 - (-20) = 9^\circ\text{C}$ before the valve begins to open.

Lower diagram:

The same evaporator coil, but this time fed by a thermostatic expansion valve with external Pressure equalization connected to the suction line after the bulb.

The degree of opening of the valve is now regulated by:

- Pressure p_b in the bulb and capillary tube acting on the upper side of the diaphragm and determined by the bulb temperature.
- Pressure $p_o - \Delta p$ in the evaporator outlet acting under the diaphragm and determined by the evaporating temperature and the pressure drop in the evaporator.
- Spring pressure p_s acting under the diaphragm and manually adjustable.

Provided that, as stated above, pressure drop Δp in the evaporator corresponds to 5°C and spring pressure p_s in the valve to 4°C refrigerant pressure, it follows that $p_b = p_o - \Delta p + p_s \sim -15 - 5 + 4 = -16^\circ\text{C}$. That is, the refrigerant now has to be superheated by $-16 - (-20) = 4^\circ\text{C}$ before the valve begins to open.

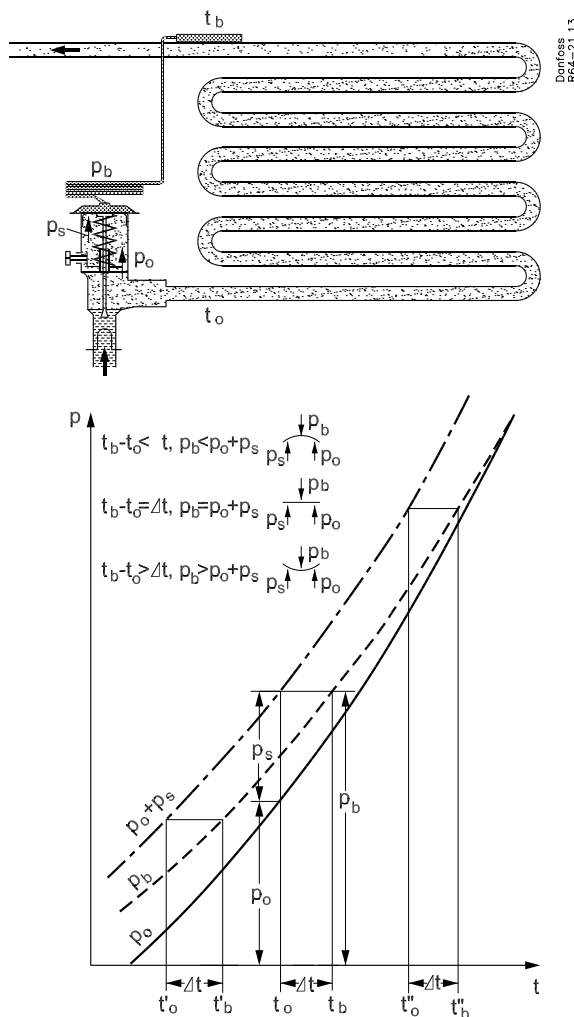
The amount of charge in the evaporator and hence its capacity become higher since a smaller portion of the evaporator surface is used for superheating.

Conclusion:

Thermostatic expansion valves with external pressure equalizing must always be used for evaporators with a large pressure drop. Evaporators with a liquid distributor will always have a large pressure drop; therefore always use external pressure equalization.

Thermostatic expansion valve, method of operation

Fig. 7



The thermostatic expansion valve is controlled by the difference between bulb temperature t_b and evaporating temperature t_o . The valve opens when the temperature differential rises, $t_b - t_o = \Delta t$, i.e. when refrigerant superheat rises the valve will have a larger opening rate. See fig. 6.

Solid curve p_o and dotted curve p_b gives vapour pressure for the refrigerant and charge respectively. Chain-dotted curve $p_o + p_s$ represents the refrigerant vapour pressure curve p_o offset in parallel with a constant spring pressure p_s , the factory setting for example.

At a given evaporating temperature, t_o , a pressure $p_o + p_s$ acts under the valve diaphragm and tries to close the valve. Pressure p_b acts over the diaphragm and tries to open the valve.

The figure shows equilibrium between $p_o + p_s$ and p_b at evaporating temperature t_o and bulb temperature t_b respectively. Practically speaking, differential $t_b - t_o$, the static superheat, is the same within the entire working range of the valve from t_o' to t_o'' .

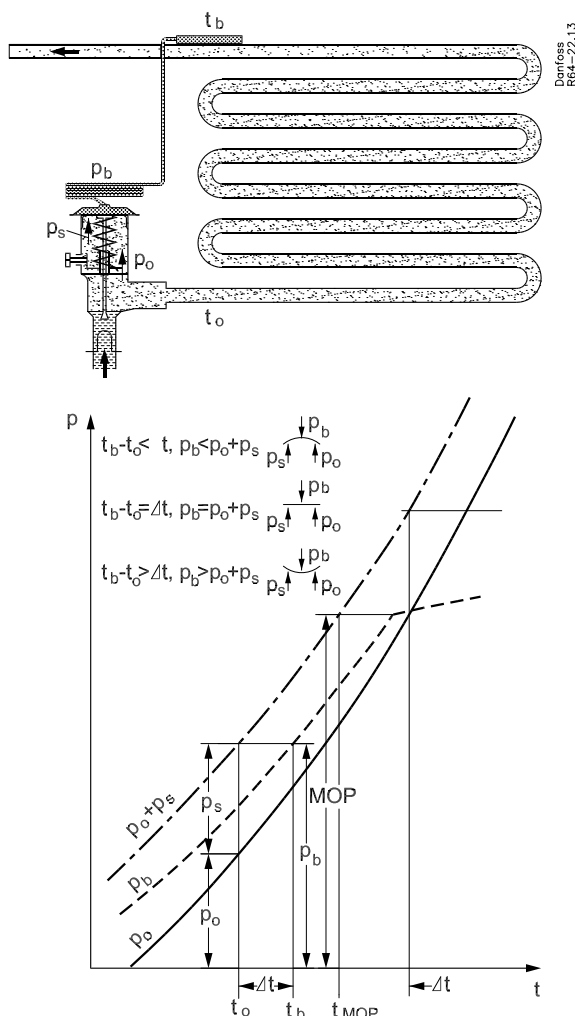
That is to say, irrespective of the evaporating temperature operated with inside the working range, the thermostatic expansion valve will regulate liquid injection so that refrigerant superheat after the evaporator is held to the value determined by spring pressure p_s . If the differential between bulb temperature t_b and evaporating temperature t_o is less than the static superheat Δt , the valve is closed ($t_b - t_o < \Delta t$; $p_b < p_o + p_s$).

If the differential between bulb temperature t_b and evaporating temperature t_o is greater than the static superheat Δt , the valve is open ($t_b - t_o > \Delta t$; $p_b > p_o + p_s$).

If the differential between bulb temperature t_b and evaporating temperature t_o is equal to the static superheat Δt , the valve is just about to open or just about to close ($t_b - t_o = \Delta t$; $p_b = p_o + p_s$).

Thermostatic expansion valve with MOP charge

Fig. 8



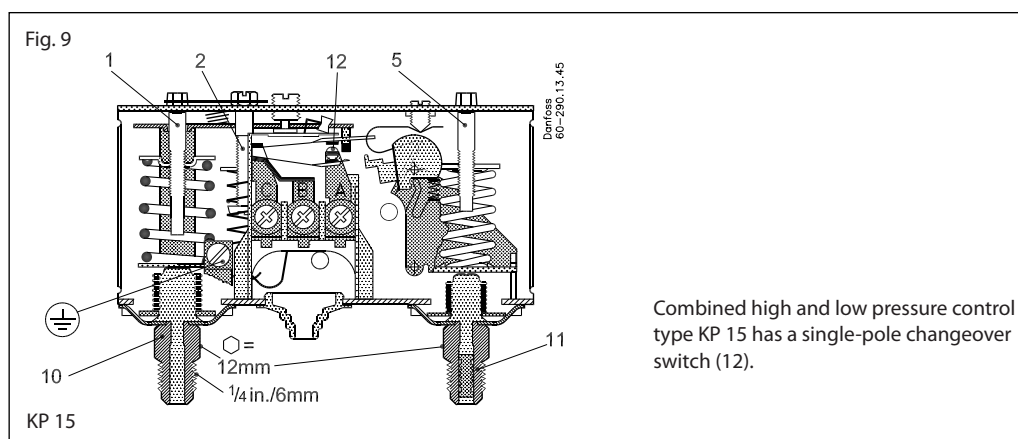
It can sometimes be desirable to use a thermostatic expansion valve with a limited working range - for example, in refrigeration plant with only one evaporator where cooling from a completely or partially temperature equalized condition occurs only as an exception (after repair or defrosting).

For such plants it may be cheaper to use a smaller compressor motor dimensioned in accordance with the load after cooling down. However, during cooling down such a motor will become overloaded and cut-out on the thermal overload protection.

To eliminate this risk, a thermostatic expansion valve with a MOP (Maximum Operating Pressure) charge can be used. This pressure-limited valve will only begin to open at a low evaporating temperature, t_{MOP} , since the charge is adapted to produce a bend in the vapour pressure curve P_b .

This means that static superheat Δt is very high at evaporating temperatures higher than t_{MOP} , i.e. in practice the valve will remain closed until the compressor has reduced the suction pressure sufficiently to ensure that the electric motor is not overloaded.

Combined high and low pressure control



Low-pressure side (LP):

The LP connector (10) is connected to the suction side of the compressor. When pressure falls on the low-pressure side the circuit between terminals 2 and 3 is broken. Turning the LP spindle (1) clockwise adjusts the unit to cut out (break the circuit between terminals 2 and 3) at a higher pressure. Turning the differential spindle (2) clockwise adjusts the unit to cut in again (make the circuit between terminals 2 and 3) at a smaller differential.

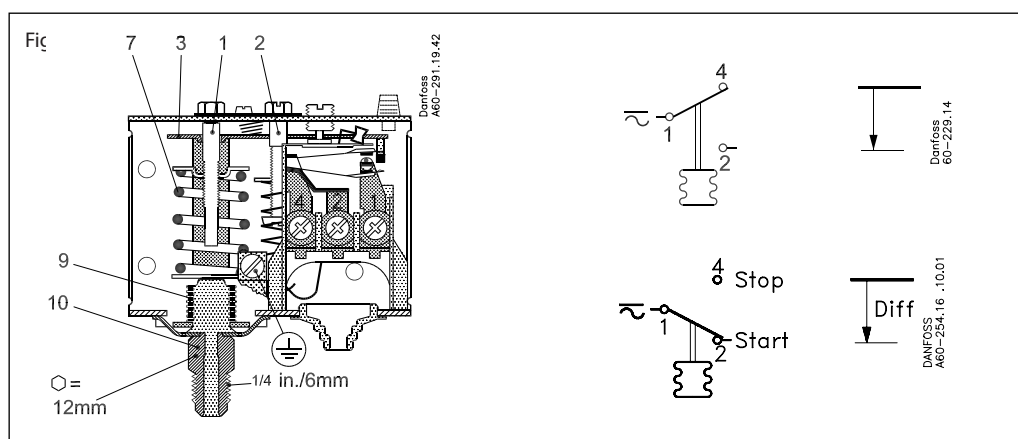
Start pressure = stop pressure + differential.

LP signal function between terminals A and B.

High-pressure side (HP):

The HP connector (11) is connected to the discharge side of the compressor. When pressure rises, on the high-pressure side the circuit between terminals 2 and 3 is broken. Turning the HP spindle (5) clockwise adjusts the unit to cut out (break the circuit between terminals 2 and 3) at a higher pressure. The differential is fixed. Stop pressure = start pressure + differential.

Low-pressure and High-pressure control



Low-pressure control type KP 1

Contains a single pole changeover switch (SPDT), which breaks the circuit between terminals 2 and 3 when pressure in the bellows element (9) fails (on failing suction pressure), i.e. the connector (10) must be connected to the suction side of the compressor.

Turning the range spindle (1) clockwise adjusts the unit to cut in - to make the circuit between terminals 2 and 3 at a higher pressure. Turning the differential spindle (2) clockwise adjusts the unit to cut out again - to break the circuit between terminals 1 and 2 at a smaller differential.

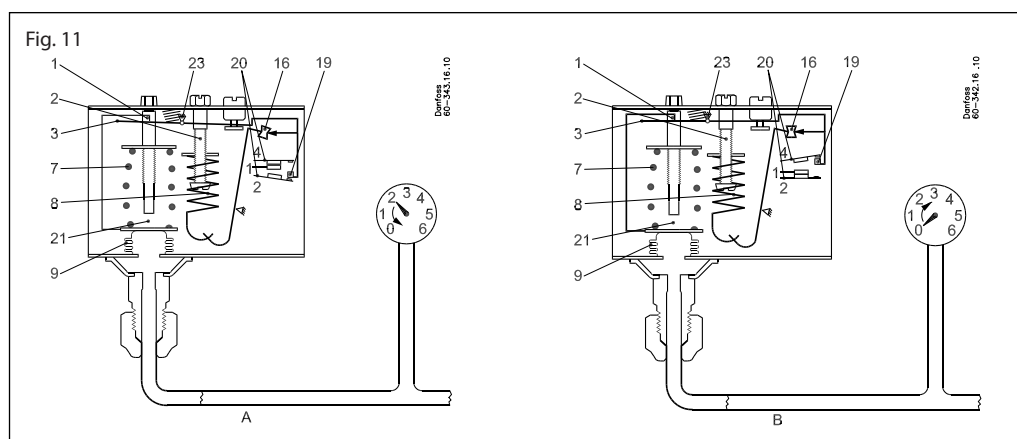
Start pressure = stop pressure + differential.

High-pressure control type KP 5

Is built up in the same way. Bellows, spring and scale are of course suitable for the higher working pressure. In this case, the switch breaks the circuit between terminals 1 and 2 when pressure rises in the bellows element (9), i.e. when condensing pressure rises (the connector must be connected to the discharge side of the compressor ahead of the shut-off valve).

Turning the range spindle clockwise adjusts the unit to cut out - to break the circuit between terminals 1 and 2 at a higher pressure. Turning the differential spindle (2) clockwise adjusts the unit to cut in again - to make the circuit between terminals 1 and 2 at a smaller differential. Stop pressure = start pressure + differential.

High-pressure control, method of operation



High-pressure control type KP 5 is connected to the high-pressure side of the refrigeration plant and stops the compressor when the condensing pressure becomes too high. The control contains a pressure-controlled single-pole changeover switch (SPDT) where the contact position depends on the pressure in the bellows (9). See fig. 11, drawings A and B.

Via the adjusting spindle (1) the main spring (7) can be set to exert a suitable counter-pressure to the bellows pressure. The down-ward resultant of these two forces is transferred by a lever (21) to the main arm (3), one end of which is fitted with a tumbler (16).

The tumbler is held in position on the main arm by a compressive force, which can be adjusted by using the spindle (2) to change the pull from the differential spring (8).

The forces from the bellows pressure, main spring and differential spring are thus transferred to the tumbler (16), which will tilt when the forces come out of equilibrium because of changes in the bellows pressure, i.e. the condensing pressure.

The main arm (3) can only take up two positions. In one position a force is exerted on each end of the arm and creates opposite torques around its pivot (23). See drawing A. If the bellows pressure decreases, the main spring exerts an increasing force on the main arm. Finally, when the counter torque from the differential spring is overcome, the main arm tilts and the tumbler (16) instantaneously change position so that the compressive force of the differential spring lies on a line near the arm pivot point (23). The counter-torque from the differential spring thus becomes almost zero. See fig. 11, drawing B.

The bellows pressure must now rise to overcome the force from the main spring because the spring force torque around the pivot point (23) must also fall to zero before the snap system can return to its initial position.

On falling bellows pressure (see fig. 11, drawing A), the main arm moves instantaneously to the position shown in fig. 11, drawing B when the bellows pressure is reduced to the stop pressure minus the set differential pressure.

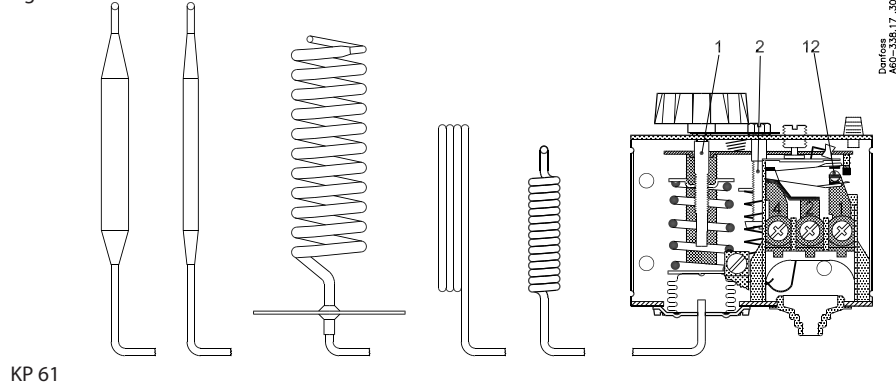
Conversely, the main arm moves instantaneously from the fig. 11, drawing B position to the fig. 11, drawing A position when the bellows pressure has risen to the stop pressure = start pressure + differential pressure. See also text for figs. 9 and 10 regarding adjustment of type KP.

The contact system is specially designed so that the make contact travels at the initial speed of the snap action until it reaches the fixed contact, while the break contact separates from the fixed contact at the maximum speed of the snap action. The system has been made possible by the use of a small striker (19) and accurately matched contact springs.

The contacts (20) make with a smaller force than they break, which means that in practice bounce during make is eliminated. The holding force during make is exceptionally high. At the same time the system gives an instantaneous break function so that the holding force is maintained 100% right up to break. For these reasons the system is able to operate with high currents and its function is not impaired by shocks. Compared with traditional designs, the system has given exceptionally good results in practice.

Thermostat

Fig. 12

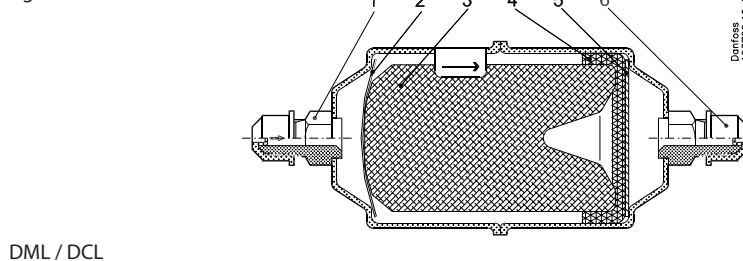


Thermostat type KP 61, which has a single pole changeover switch (12), makes the circuit between terminals 2 and 3 when bulb temperature rises, i.e. when room temperature rises.

Turning the range spindle (1) clockwise, increases the cut-in and cut-out temperature of the unit. Turning the differential spindle (2) clockwise decreases the differential between cut-in and cut-out temperatures.

Filter drier

Fig. 13

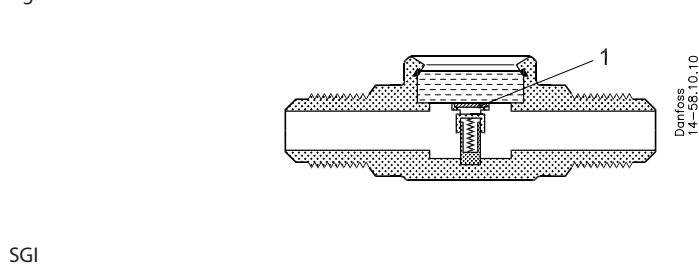


Filter drier type DML / DCL has a sintered charge, a so-called solid core (3). This is pressed by the spring (2) against the polyester mad (4) and corrugated perforated plate (5).

The charge or core in the filter drier consists of material which effectively removes moisture, harmful acids, foreign particles, sediment and the products of oil breakdown.

Sight glass

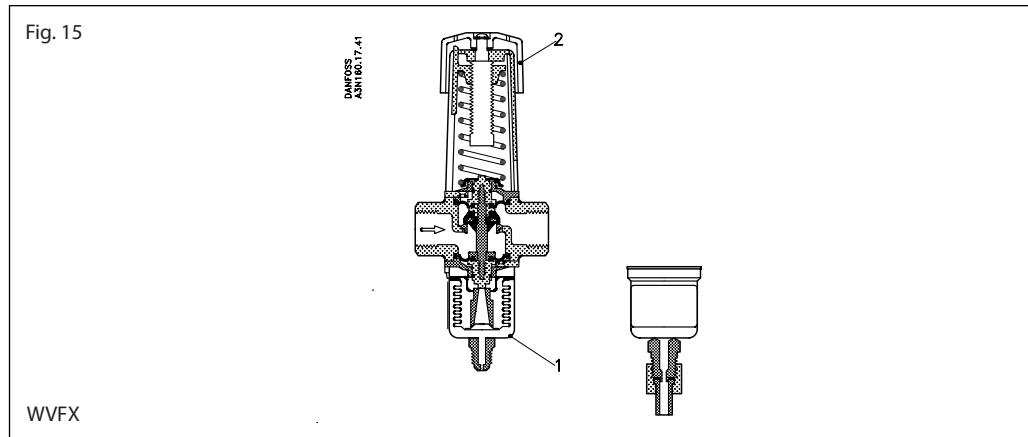
Fig. 14



Sight glass type SGI / SGN has a colour indicator (1) that changes from green to yellow when the moisture content of the refrigerant exceeds the critical value. The colour indication is reversible, i.e. the colour changes back from yellow to green when the plant has been dried, e.g. by replacing the filter drier.

Sight glass type SGI is for CFC, sight glass type SGN is for HFC and HCFC (R 22).

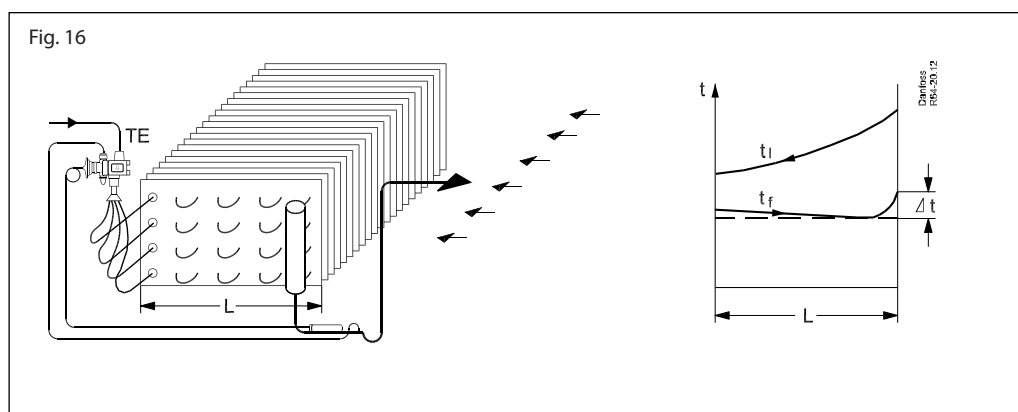
Automatic water valve



Automatic water valve type WVFX opens on rising pressure in the bellows element (1), i.e. when condensing pressure increases (the connector on the bellows housing must be connected to the refrigerant side of the condenser).

Turning the hand wheel (2) counter clock-wise tightens the spring, which means that the valve will open at a higher condensing pressure. If the hand wheel is turned clock-wise the valve will open at a lower condensing pressure.

Finned evaporator



The finned evaporator is designed for forced air circulation over the parallel evaporator coils. The air circulation should always be on the counter flow principle so that the evaporator coils are uniformly loaded. Therefore the relation between airflow and refrigerant flow ought always to be as shown in the upper figure.

In this way the largest temperature difference (see right hand figure) is ensured between the air t_i and the evaporator surface t_f at the refrigerant outlet of the evaporator. That is to say, refrigerant superheat Δt will be rapidly affected by a change in the temperature of the incoming air (the load) and will thereby rapidly give a signal to the thermostatic expansion valve to change the liquid injection.

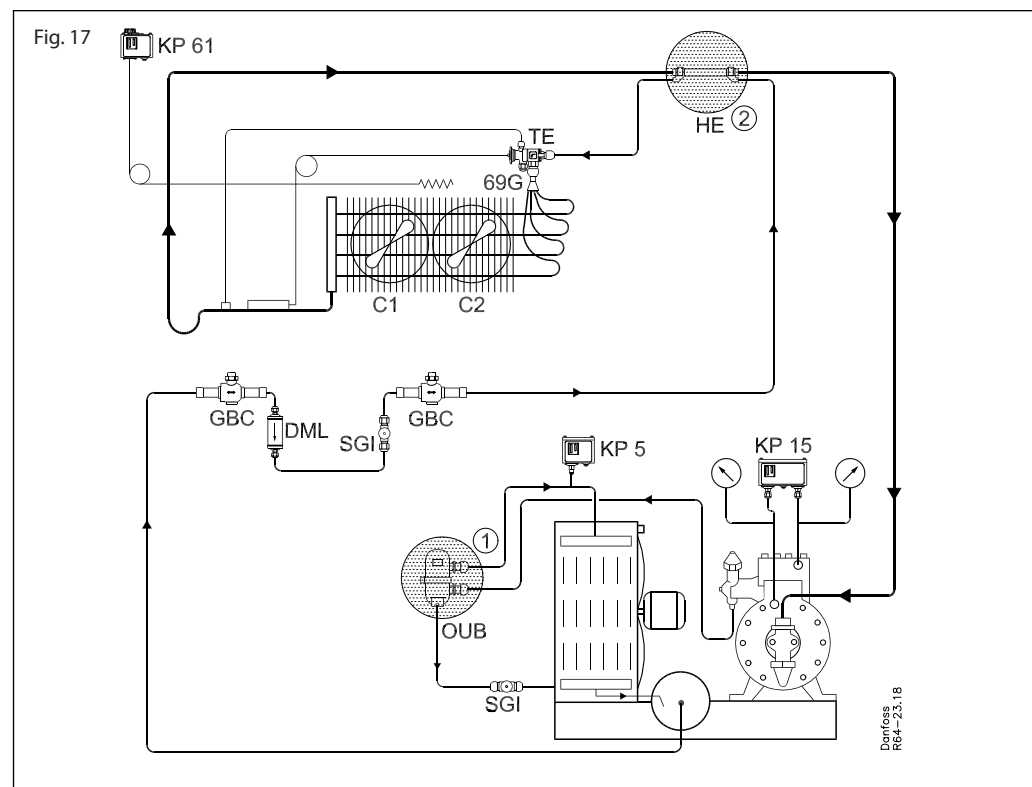
It is important that the evaporator coils are uniformly loaded. For example, with a downward vertical airflow through the evaporator, the incoming air will load the first evaporator coils more than subsequent coils. The rear coils will be the least loaded and will therefore determine to what degree the thermostatic expansion valve opens. If a small amount of refrigerant liquid from the rear evaporator coils passes the point where the bulb is located, the valve will close despite the fact that the first coils require a supply of refrigerant liquid because of a larger load, i.e. brisker evaporation.

The thermostatic expansion valve bulb must not be influenced by false effects; such as airflow through the evaporator and the bulb must therefore be placed on the suction line outside this airflow. If this is not possible, the bulb has to be isolated.



Note that a thermostatic expansion valve with external pressure equalization is used.

Refrigeration plant with oil separator and heat exchanger



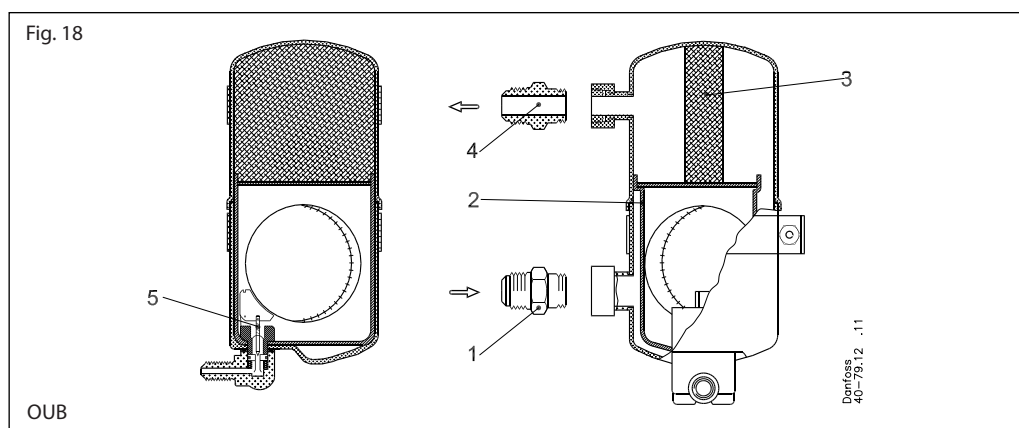
In principle, in refrigeration plant the oil should remain in the compressor. Out in the system it will do more harm than good because it will impair the capacity of the evaporator and condenser. Also, if the oil level in the crankcase becomes too low, there will be a risk of insufficient compressor lubrication. The best protection against these disadvantages is the installation of an efficient oil separator, type OUB (1).

Furthermore, a heat exchanger type HE (2) offers the following advantages:

- Superheating the suction gas provides greater protection against liquid knock in the compressor and counteracts formation of condensate or frost on the surface of uninsulated suction lines.
- Sub cooling the refrigerant liquid counter-acts the formation of vapour, which will reduce the capacity of the thermostatic expansion valve.
- Operating economy will often be improved because sources of loss such as un-evaporated liquid drops in the suction gas and insufficient sub cooling of the refrigerant liquid are completely or partially eliminated.

Oil separator

Fig. 18

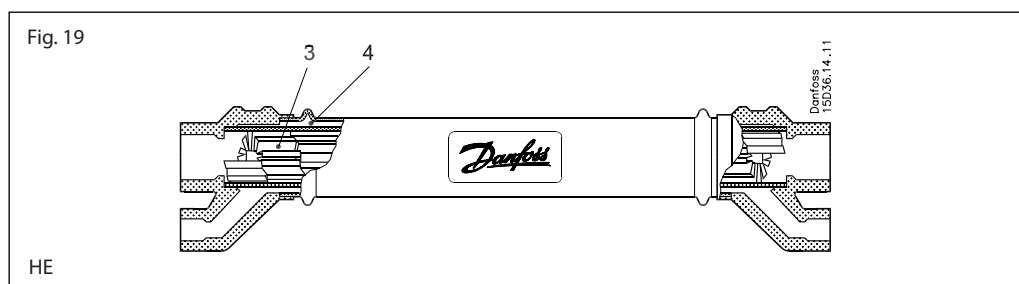


Hot high-pressure gas is supplied to the oil separator type OUB through the connector (1). The gas then flows around the oil tank (2) and through the filter (3) where the oil is separated. The vapour, now poor in oil, leaves the oil separator through the upper connector (4).

Separated oil is collected in the bottom of the oil tank (2), which is kept heated by the incoming vapour. In this way the separated oil is stored in a warm condition, i.e. with the lowest possible refrigerant content. A float valve (5) regulates oil return to the compressor.

Heat exchanger

Fig. 19

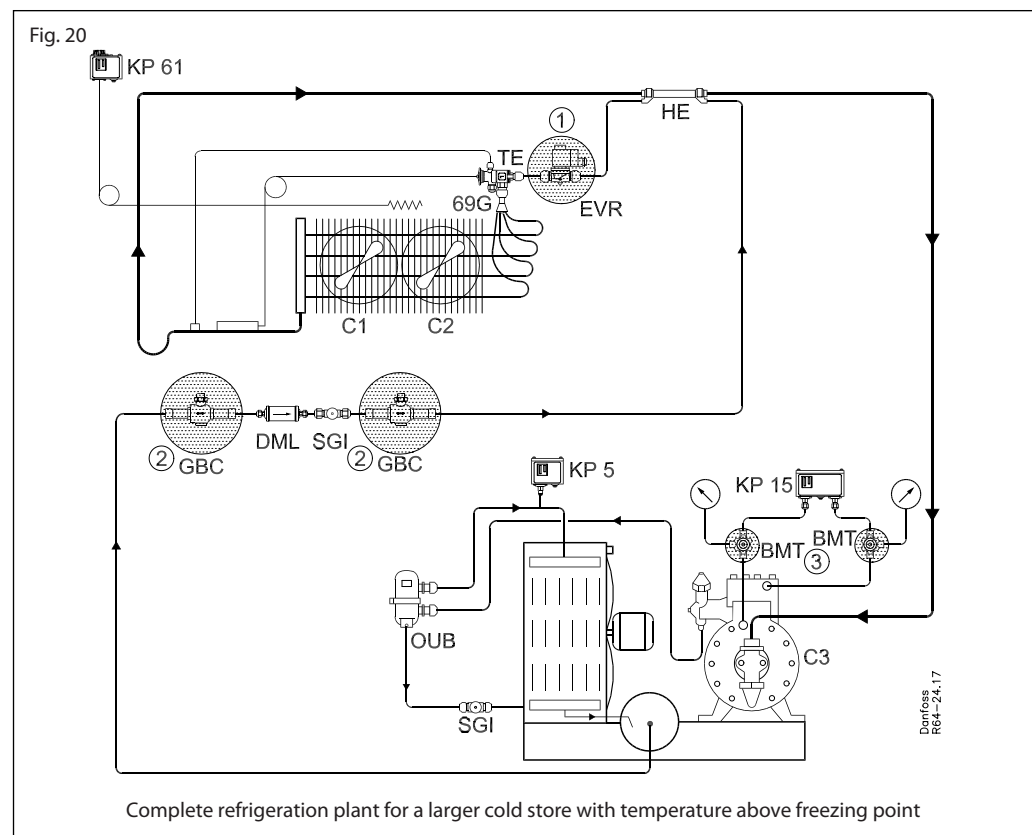


Heat exchanger type HE has been designed with a view to achieving maximum heat transmission at minimum pressure drop. The outer spiral-formed chamber (4) leads hot refrigerant liquid in a flow counter to the flow of cold refrigerant liquid in the inner chamber (3). Built in to the inner chamber are offset fin sections.

Heat exchanger type HE is manufactured in brass and copper and has very small dimensions in relation to its heat transmission capacity. The

spiral formed outer chamber (4) forces the hot refrigerant liquid over the entire heat transmission surface and prevents the formation of condensate on the outer jacket. The built-in offset fin sections in the inner chamber (3) produce turbulent flow in the refrigerant vapour. Heat transmission from liquid to vapour is thus very effective. At the same time, pressure drop is kept down to a reasonable level.

Refrigeration plant for a larger cold store



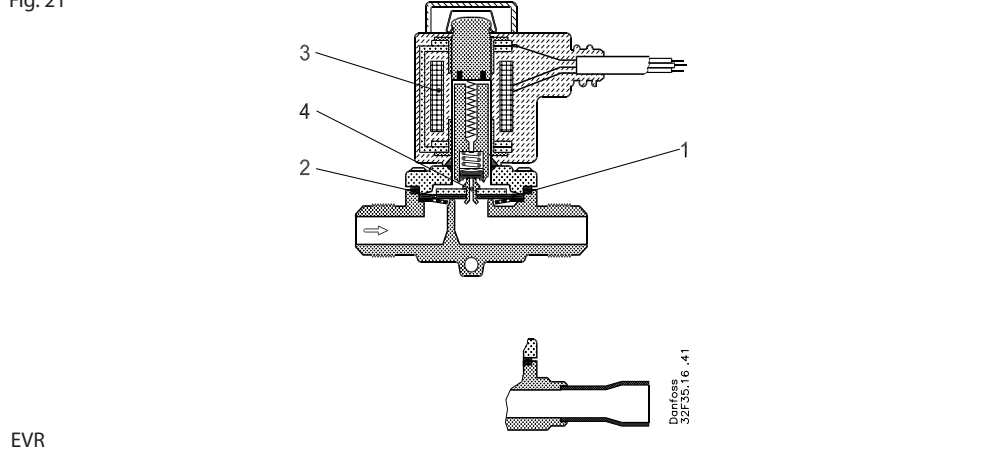
To ensure effective shut-off of the liquid line during compressor standstill periods, solenoid valve EVR (1) has been installed since bulb temperature may be expected to rise more rapidly than evaporating temperature and cause the thermostatic expansion valve to open. Protection against overcharging the evaporator during compressor standstill periods is provided by making the solenoid valve close at the same time as the compressor is stopped.

The liquid line is equipped with type GBC (2) or BML manual shut-off valves to make replacement of the filter drier easy.

Pressure on the high and low-pressure sides of the compressor can be read on the pressure gauges shown. The pressure gauges can be shut off with the three-way valves type BMT (3).

Solenoid valve

Fig. 21

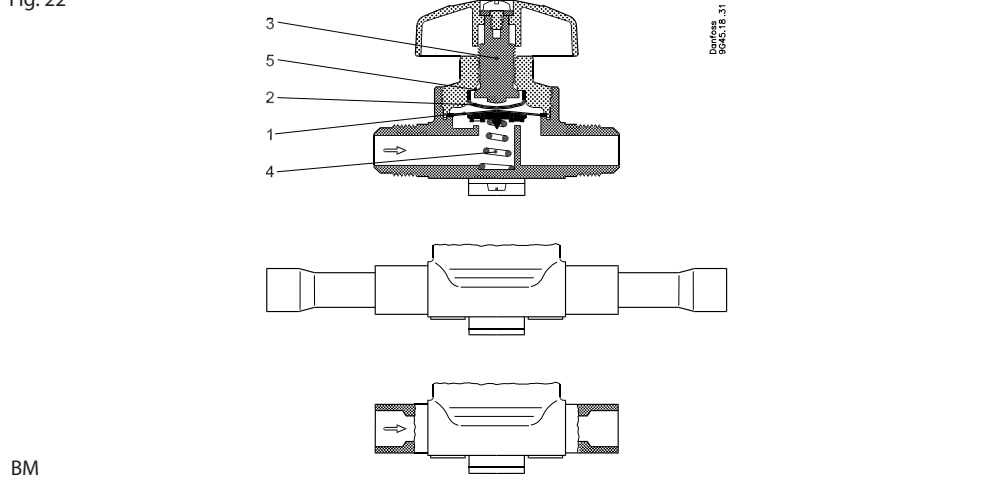


Solenoid valve type EVR is a servo-controlled electromagnetic shut-off valve. Through equalizing holes (2) the upper side of the diaphragm (1) is pressure-equalized with the valve inlet pressure on the underside. When current energizes the coil (3) the pilot orifice (4) is opened. This orifice has a larger through-flow area than the total area of the equalizing holes.

Pressure over the diaphragm is reduced by the flow through the pilot orifice to the valve outlet side and the larger inlet pressure on the underside lifts the diaphragm. When the coil is de-energized, the pilot orifice closes and the diaphragm is drawn onto the valve seat as the pressure over it increase through the equalizing holes.

Shut-off valve

Fig. 22

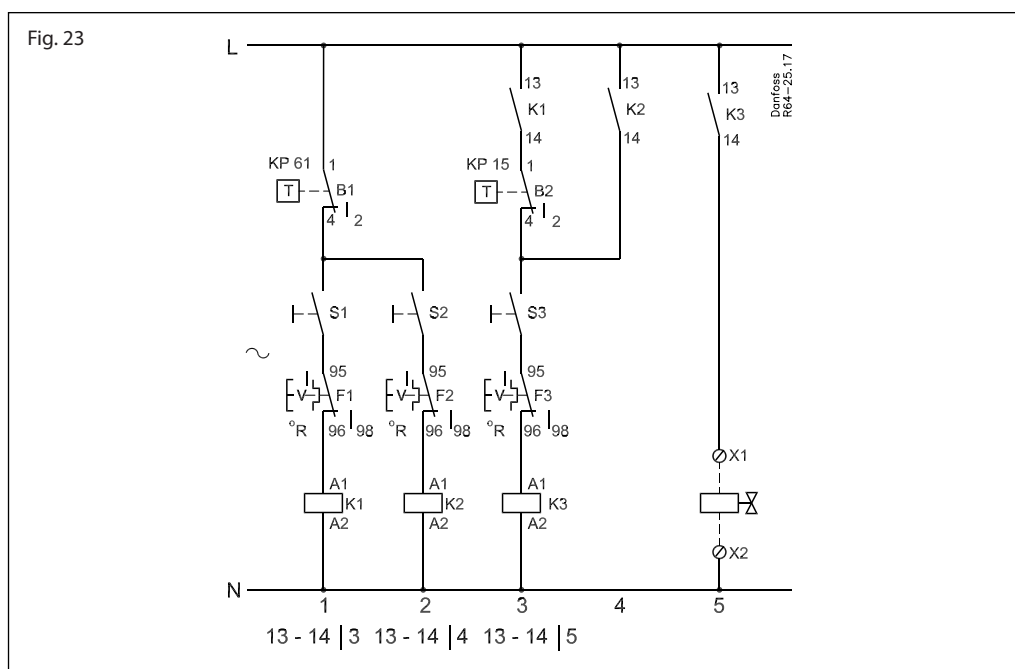


Shut-off valves types BM have a triple diaphragm seal (1) of stainless steel. A thrust shoe (2) prevents direct contact with the spindle (3). The spring (4) together with the pre-stressed diaphragm is able to hold the valve open at operating pressures down to $P_e = -1$ bar.

The counter seat in the cover (5) prevents the ingress of moisture. The valves are available in straight, and $1/4"$ T versions. Flow through the side port of the T version can be shut off leaving the end ports permanently open.

Key diagram, control current for refrigeration plant, fig. 20

Fig. 23



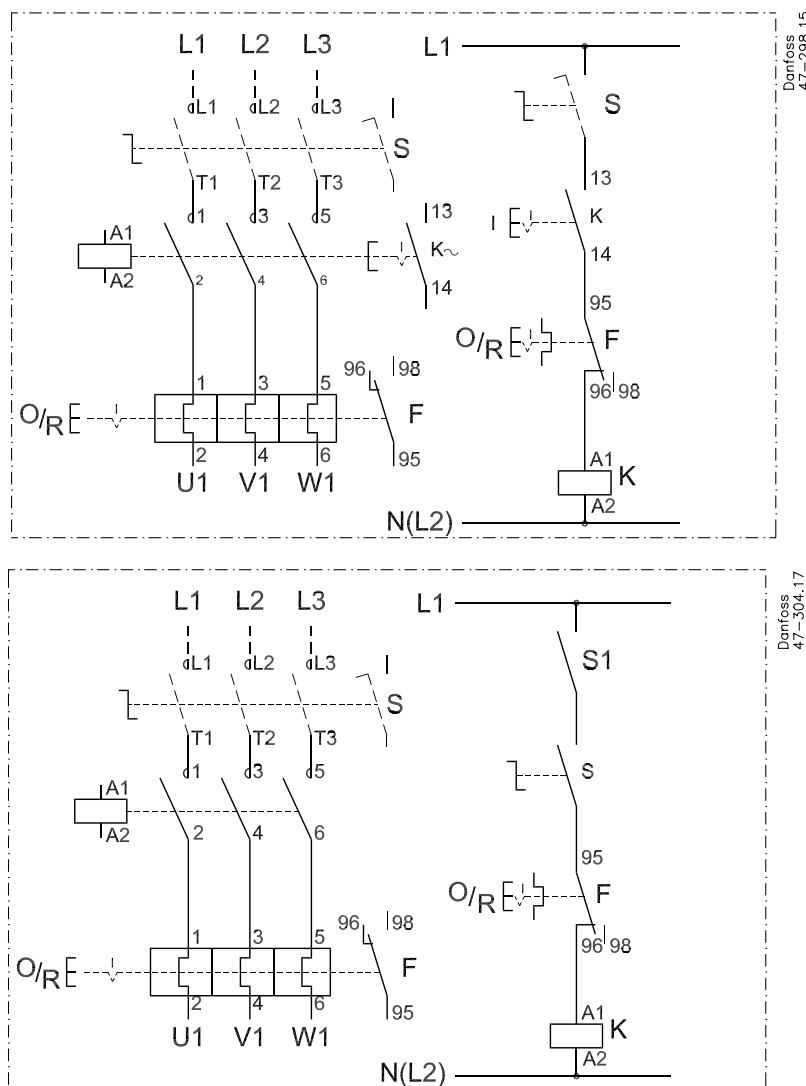
The diagram must be read from top to bottom and from left to right. The individual circuits are drawn so that no leads cross. Power-consuming components are shown at the bottom of the diagram. These include relay coils in the motor starters, solenoids coils, regulation motors, etc. Motor starter thermal relays F are shown adjacent to the contacts between terminals 95 and 96. Manual reset S is also shown. Relay auxiliary contacts K between terminals 13 and 14 are shown at the top of the diagram. Designations 13, 14, 95, 96, etc. correspond to those contained in Danfoss information on contactors and motor starters.

Relay coils K1 serve the auxiliary contacts between terminals 13 and 14. The auxiliary contacts are drawn in their de-energized coil position. Under the neutral wire and each relay coil there is an indication of in, which circuit the associated auxiliary contacts, can be found.

Terminal designation 13-14 is, by definition, always a make contact (NO), while terminal designation 11-12 is always a break contact (NC). The key diagram should be read as follows: When, on rising cold store temperature, thermostat type KP 61 cuts in (when switches S1 and S2 are made) between terminals 2 and 3, relays K1 and K2 in motor starters type CIT pull in and start the evaporator fans. At the same time the associated auxiliary contacts in circuits 3 and 4 are made. Relay K3 in compressor motor starter type CIT pulls in if the combined high and low pressure control type KP 15 is made between terminals 2 and 3, and if switch S3 is made. The compressor starts and at the same time the auxiliary contact in circuit 5 connects current to coil E in the EVR solenoid valve in the liquid line. The solenoid valve opens and refrigerant liquid is injected into the evaporator, regulated by thermostatic expansion valve type TE.

Motor starters

Fig. 24



The Danfoss motor starter range up to 420 A is made up of modules. It consists of a basic module (contactor type CI) onto which up to four auxiliary contact blocks (type CB) can be clipped as necessary. There is also a range of thermal relays (type TI). The left-hand diagram shows a motor starter with start- stop / reset function. The start contact (type CB-S) carries the terminal designation 13-14. The right-hand diagram shows a motor starter with stop/reset function, controlled via a thermostat, pressure control, or similar.

The motor starters are equipped with a thermal relay having three indirectly heated bimetals. Through a cut-out mechanism the bimetals break the bounce-free switch between terminals 95 and 96 in the event of overloading. Large current asymmetry between the three motor phases activates a built-in differential cut-out, which ensures an accelerated trip - as distinct from what occurs under a normal symmetrical overload. The cut-out is partly temperature-compensated; up to a temperature of 35°C it compensates for any rise in the ambient temperature not arising from overloading.

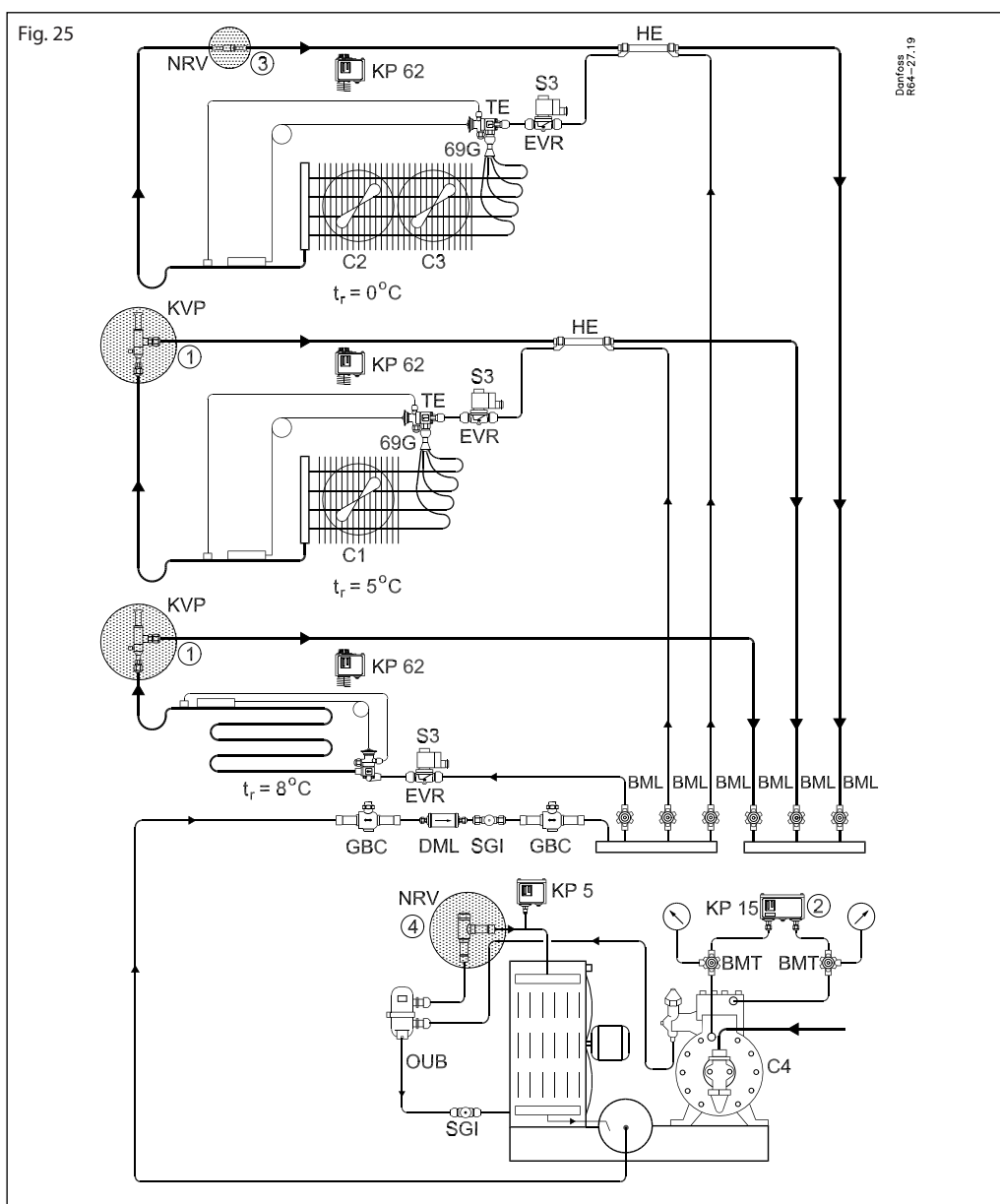
The motor starters are available in several versions. The examples shown are fitted with a manually lockable stop and reset for the thermal relay, i.e. the starters must be manually reset after thermal cut-out.

The modules are based on thermoplastic (CI) and Bakelite/thermoplastic (TI), and all main and auxiliary contacts are made of a special silver alloy. All steel parts are effectively corrosion protected.

Soft starter type MCII and circuit breaker type CTI are also available from Danfoss.

Central refrigeration plant
for cold store temperatures
above freezing point

Fig. 25



Temperature and relative humidity play a significant role in the keeping of foodstuffs and the various categories of ware must be stored in the most favourable conditions. There is use therefore for cold stores having different temperatures and humidities; not only the room temperature but also the evaporating temperature must be under control.

In the example shown, the following temperatures might be considered:

	Room temp.	Evaporating temp.
Vegetable store	+8°C	+3°C
Sliced meat and salad store	+5°C	-5°C
Meat store	0°C	-10°C

The room temperature in all 3 cold stores are controlled with KP-62 thermostats opening and closing the EVR solenoid valves.

Two evaporating temperature regulators type KVP (1) throttle the suction line after the evaporator in the +8°C and +5°C stores so that the evaporating temperatures are maintained at +3°C and -5°C respectively.

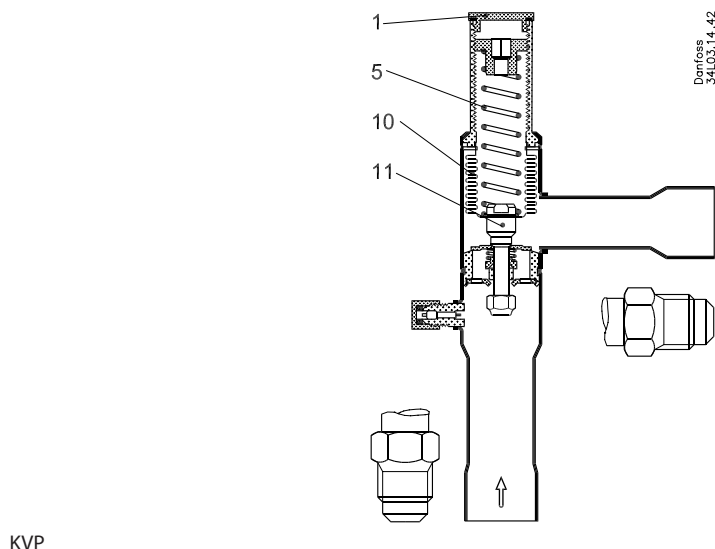
Combined high and low pressure control type KP 15 (2) cuts the compressor in and out at a suitably low suction pressure to maintain evaporating temperature in the 0°C store at -10°C.

During compressor standstill, check valve type NRV (3) prevents refrigerant from the evaporators in the +8°C and +5°C stores condensing in the coldest evaporator, i.e. the one in the 0°C store.

Check valve type NRV (4) affords protection against refrigerant condensing in the oil separator and compressor top cover if these components become colder than the evaporator during plant standstill periods.

Evaporating pressure regulator

Fig. 26



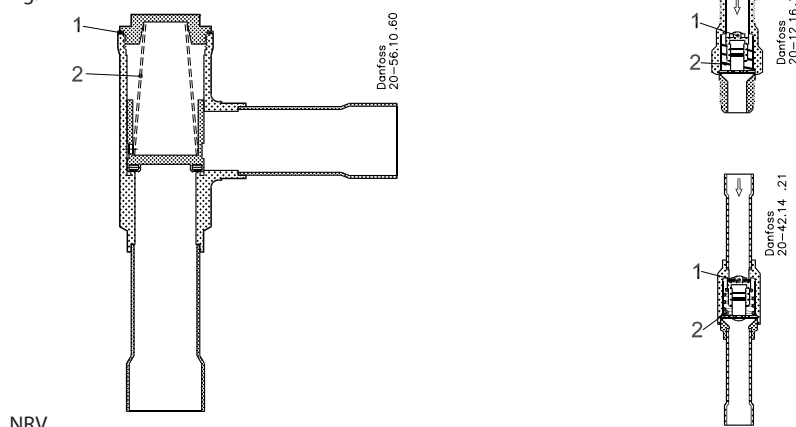
Evaporating pressure regulator type KVP opens when pressure rises on its inlet side, i.e. when pressure in the evaporator rises (increasing load). Turning the regulating screw (1) clockwise compresses the spring (5) and increases the opening pressure, i.e. evaporating temperature rises. The regulator has a bellows (10) of the same diameter as the valve plate (2). This means that pressure variations on the outlet side of the regulator have no effect on the automatic regulation of the degree of opening since

pressure on the top of the valve plate is balanced by pressure on the bellows. The regulator also incorporates a damping device (11) so that pressure pulsations in the plant do not affect the function of the regulator.

To make adjustment of the valve easier, it is fitted with a special pressure gauge connection (9), which makes it possible to fit or remove a pressure gauge without first having to empty the suction line and evaporator.

Check valve

Fig. 27



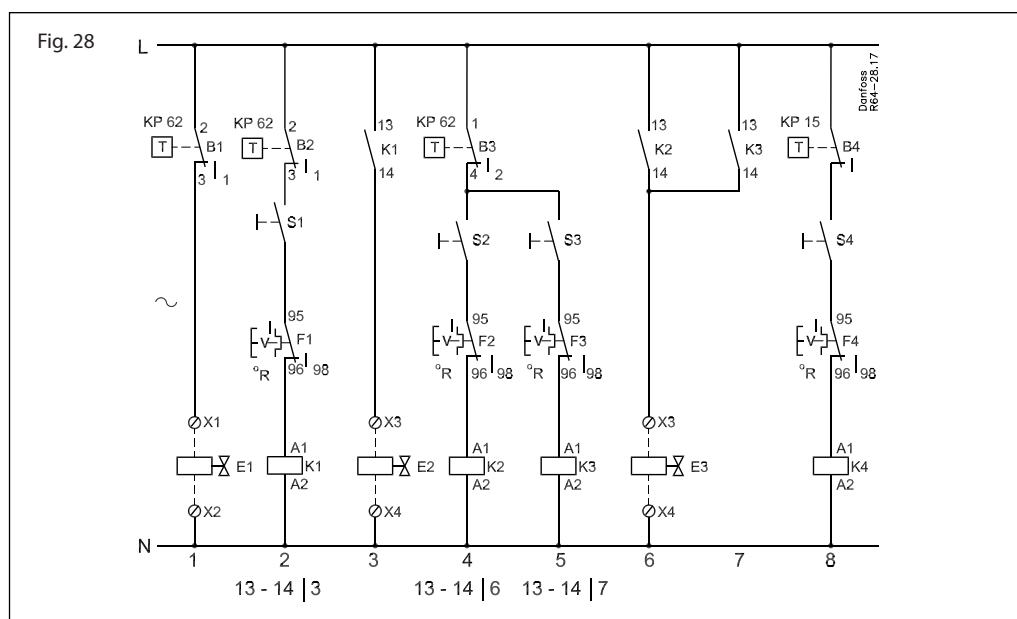
Check valve type NRV is available in straight or angle versions with flare as well as solder connections. Solely the pressure drop controls the function of the valve across it.

NRV straightway version:

The valve plate is fitted to a brake piston (1), which is held against the valve seat by a weak

spring (2). When the valve opens, the volume behind the brake piston becomes smaller. An equalizing hole (slot) allows the refrigerant to slowly escape to the outlet side of the valve. In this way the movement of the piston is broken; an arrangement that makes the check valve well suited for lines where pressure pulsations can occur.

Key diagram, control current for refrigeration plant fig. 25



Thermostat type KP 62 in the +8°C room controls solenoid valve E1 type EVR in the liquid line while the two other thermostats type KP 62 in the +5°C and 0°C rooms respectively control motor starters K1 and K3 type CIT for the evaporator fans, and solenoid valves K2 and K3 type EVR in the liquid lines.

Combined high and low pressure control type KP 15 controls motor starter K4 type CIT for the compressor motor.

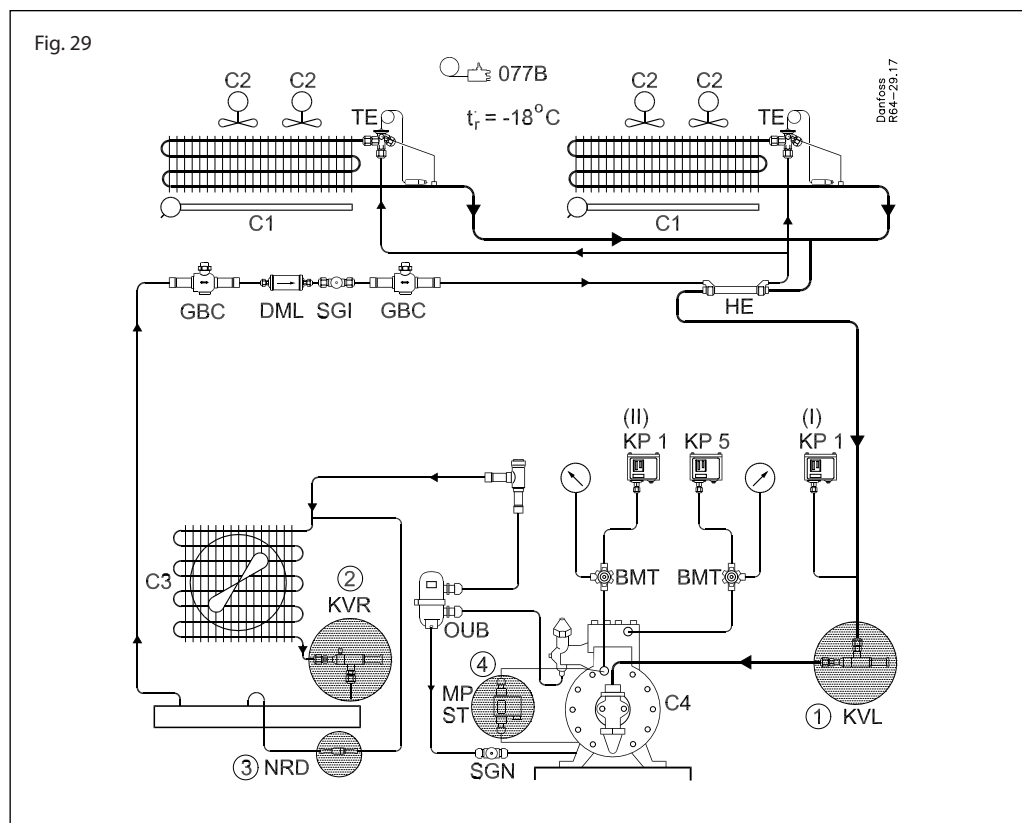
A condition for this function is that manual switches S1, S2, S3 and S4 must be made.

The compressor motor is thus only indirectly controlled by the room thermostats and is able; for example, to run for some time after all the thermostats have cut out.

However, since it is unlikely that all the room thermostats will cut out at the same time, this form of control will result in some after-evaporation, which can be advantageous as regards liquid hammer in the compressor but disadvantageous as regards the end of a refrigeration period. When a room thermostat cuts out, slight evaporation will still continue and the charge in the evaporator concerned will become smaller. When the room thermostat cuts in again, the effect of the smaller charge will be to make it more difficult for un-evaporated refrigerant to enter the suction line during the sudden priming at the beginning of the evaporator-operating period.

Refrigeration plant for freezer display counter

Fig. 29



As this plant operates most of the time at low evaporating temperatures, interrupted only by automatic defrosting once or twice every 24 hours, it is advantageous to have an electric compressor motor of a size corresponding to normal operating conditions, i.e. relatively small load at low suction pressure.

However, after a defrosting this small motor would be overloaded and there would be a risk of motor burn-out. As a safeguard against this risk a crankcase pressure regulator type KVL (1) is installed which first opens when suction pressure in front of the compressor has been reduced sufficiently to avoid overloading the motor.

Regulating system KVR (2) + NRD (3) is used to maintain a constant and sufficiently high condensing pressure in the receiver on air-cooled condensers at low ambient temperatures.

During winter operation the ambient temperature falls and with it the condensing pressure of the air-cooled condenser. The KVR regulates dependent on the inlet pressure and begins to throttle when the pressure drops below the set value. As a consequence, the condenser becomes partly charged with liquid and its effective area is reduced. In this way the required condensing pressure is re-established.

Since the actual regulating task during winter operation is to maintain the receiver pressure at a suitably high level, the KVR is combined with a type NRD differential pressure valve installed in the bypass line shown. The NRD begins to open at a differential pressure of 1.4 bars. When the

condensing pressure fails, the KVR begins to throttle. This increases the total pressure drop across the condenser + KVR. When this pressure drop reaches 1.4 bars, the NRD begins to open and thus ensures that the receiver pressure is maintained.

As a rule-of-thumb, it can be assumed that the pressure in the receiver is equal to the pressure set on the KVR minus 1 bar.

During summer operation, when the KVR is fully open, the total pressure drop across the condenser and KVR is less than 1.4 bars. Therefore the NRD remains closed.

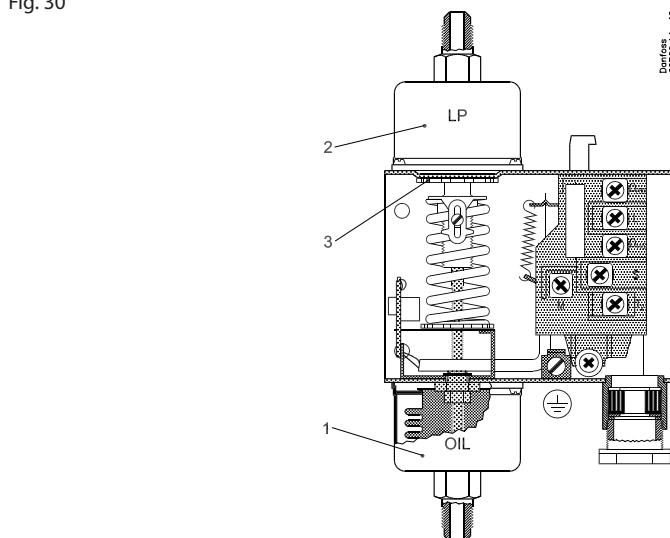
The charge can collect in the receiver during summer operation. Therefore the plant must be equipped with a sufficiently large receiver. The KVR can also be used as a relief valve between the high-pressure side and low pressure side to protect the high pressure side against too high a pressure (safety function).

The pressure-lubricated compressor with oil pump is protected against oil failure by differential pressure control type MP 55 (4). The control stops the compressor if the differential between the oil pressure and suction pressure in the crankcase becomes too low.

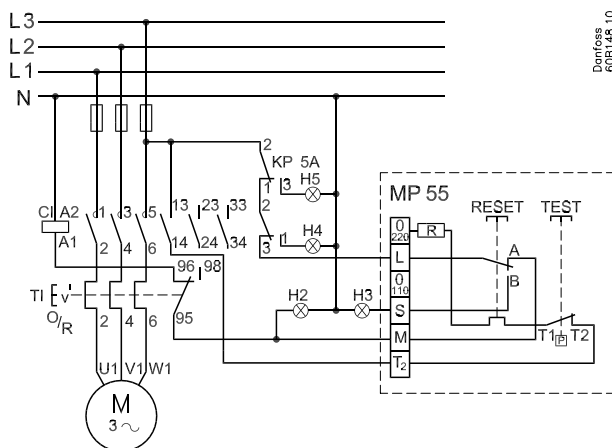
A type 077B thermostat is installed in the counter, with its sensor located in the cold room. If the temperature rises above the set value, a signal lamp lights up.

Differential pressure control

Fig. 30



MP 55



Differential pressure control type MP 55 is used as a safety pressure control on pressure-lubricated refrigeration compressors. After a fixed time delay the control stops the compressor in the event of oil failure.

The oil pressure element "OIL" (1) is connected to the oil pump outlet and the low-pressure element "LP" (2) is connected to the compressor crankcase. If the differential between oil pressure and pressure in the crankcase becomes less than the value set on the control, current to the time relay is cut in (contact $T_1 - T_2$ made, see wiring diagram).

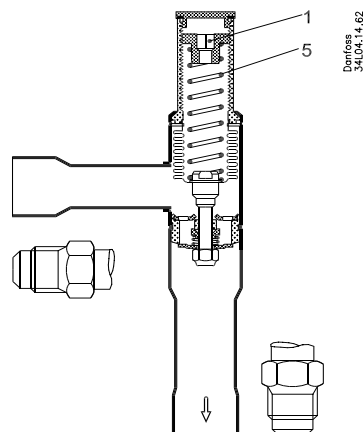
If contact $T_1 - T_2$ remains made for a lengthy period because of a fall in pressure in relation to the pressure in the crankcase (suction pressure), the time relay cuts out the control current to the compressor motor starter (time relay contact changes over from A to B, i.e. control current is broken between L and M).

The minimum permissible differential pressure, i.e. the minimum oil pressure at which under normal operation the differential pressure control sustains current to the time relay cut off (contact $T_1 - T_2$ broken), can be set on the pressure adjustment disc (3). Clockwise rotation increases the differential, i.e. increases the minimum oil pressure at which the compressor can still run.

The contact differential is fixed at 0.2 bars. Therefore, current to the time relay will be first cut off during start, when the oil pressure is 0.2 bars higher than the minimum allowable differential pressure. This means that at compressor start the oil pump must be capable of increasing the oil pressure to 0.2 bars more than the set minimum permissible oil pressure before the end of the time delay. Contact $T_1 - T_2$ must break so quickly after start that the time relay never reaches its A to B changeover point (break between L and M). See also key diagram, fig. 35.

Crankcase pressure regulator

Fig. 31



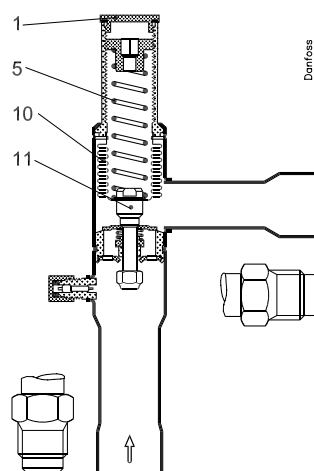
KVL

Crankcase pressure regulator type KVL opens on spindle (1) clockwise tightens the spring (5) and falling pressure on the outlet side, i.e. on falling

the regulator then begins to regulate at a higher pressure ahead of the compressor. Turning the pressure on the outlet side.

Condensing pressure regulator

Fig. 32



KVR

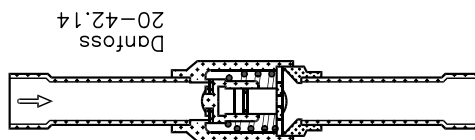
Condensing pressure regulator type KVR opens when pressure on its inlet side rises, i.e. when condensing pressure rises. Turning the spindle (1) clockwise tightens the spring (5) and increases

the opening pressure so that the condensing pressure rises.

Like the previously mentioned evaporating pressure regulator type KVP, all regulators are fitted with a pressure-equalizing bellows (10) to eliminate pressure variations on the inlet side of type KVL and the outlet side of type KVL. All regulators are also fitted with a damping device (11) so that pressure pulsations in the plant do not affect regulator function.

Differential pressure valve

Fig. 33

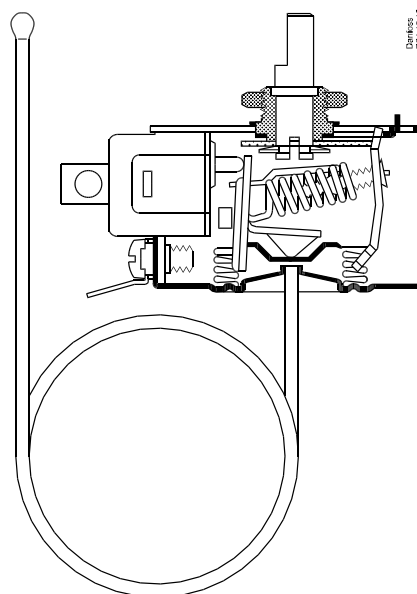


NRD

Differential pressure valve type NRD begins to open at a pressure drop of 1.4 bars and is fully open at 3 bars. When the valve is installed as a bypass, it ensures that the receiver pressure is maintained.

Evaporator thermostat

Fig. 34

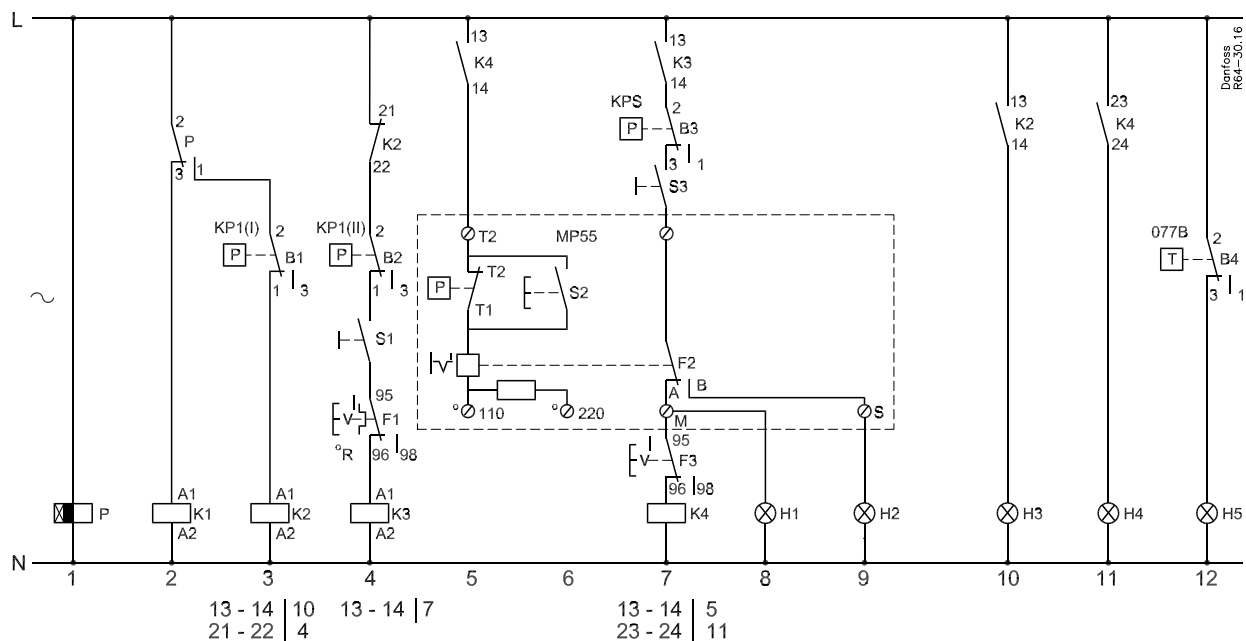


077B

The contact system in evaporator thermostat type 077B makes on rising temperatures. Turning the range spindle clockwise increase the cutin temperature of the thermostat, i.e. the temperature at which the signal lamp lights up.

Key diagram, refrigeration plant for freezer display counter, fig. 29

Fig. 35



Time switch P controls changeover contact t, circuit 2, which makes or breaks control current to contactors K1 and K2 type CI for the respective electric heating elements under the evaporators, and for the evaporator fans. When K2 is cut in, K1 is cut out, i.e. the evaporator fans are stopped during defrosting. At the same time, motor starter K3 type CIT for the condenser fan is cut out via the auxiliary contact (brake contact between 21 and 22) in circuit 4. A signal lamp H1 is switched on via the auxiliary contact (make contact between 13 and 14) in circuit 6. When motor starter K3 cuts out, the auxiliary contact (make contact between 13 and 14) in circuit 5 breaks and motor starter K4 type CIT for the compressor is cut out. Thus, the compressor also remains at a standstill.

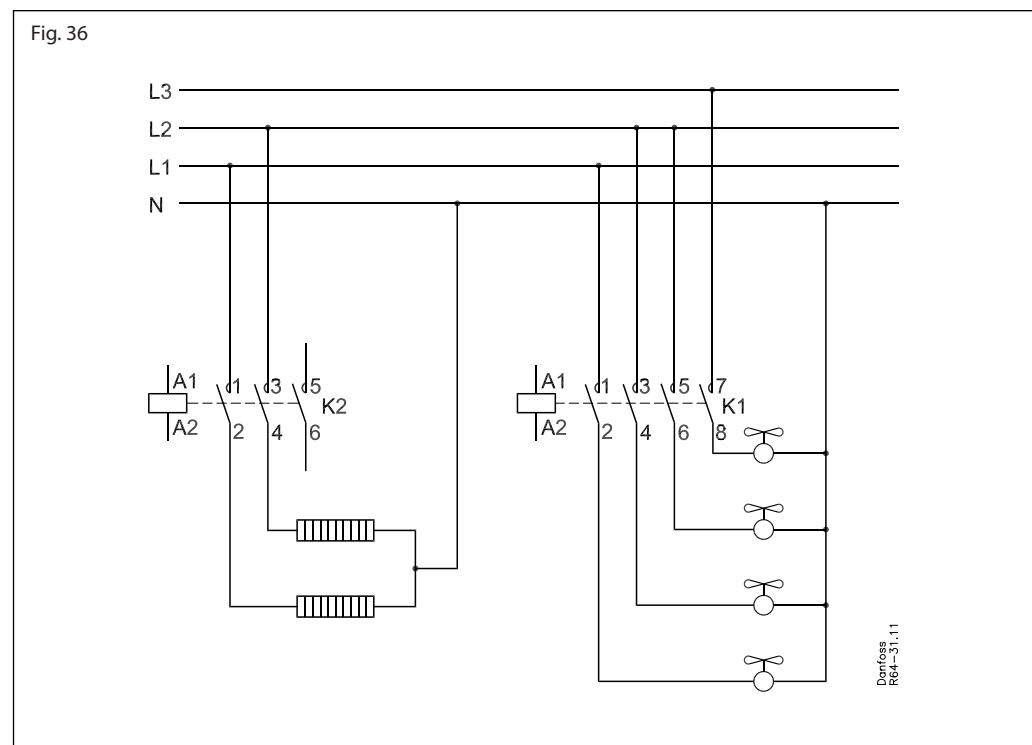
Pressure control type KP (1) is connected so that it cuts out on rising pressure. This cuts out defrosting when the suction pressure has increased to such an extent that there is no more frost on the evaporator. When contactor K2 is cut out, motor starter K3, and with it motor start K4 are cut in via the auxiliary contacts (make contact between 21 and 22) in circuit 4 and in circuit 5 (make contact between 13 and 14). Assuming switches S1 and S2 are made. This starts the condenser fan and the compressor. At the same time, signal lamp H1 is switched off via the make contact between 13 and 14 in circuit 6 and signal lamp H2 is switched on via the auxiliary contact (make contact between 13 and 14) in circuit 7. The evaporator fans are started after a period by time switch P cutting in contactor K1. During this delay the compressor is able to remove the heat accumulated in the

evaporators while defrosting was taking place, before the evaporator fans are started.

Low-pressure control type KP 1 (II) is connected to control the refrigeration plant during normal operation. High-pressure control type KP 5 stops the compressor but not the condenser fan when condensing pressure becomes excessive.

A thermostat type 077B switches on signal lamp H3 if the temperature in the display counter exceeds -18°C . The signal lamps are connected to a 12 V battery system so that lamp H3 is able to function even if a mains supply failure occurs.

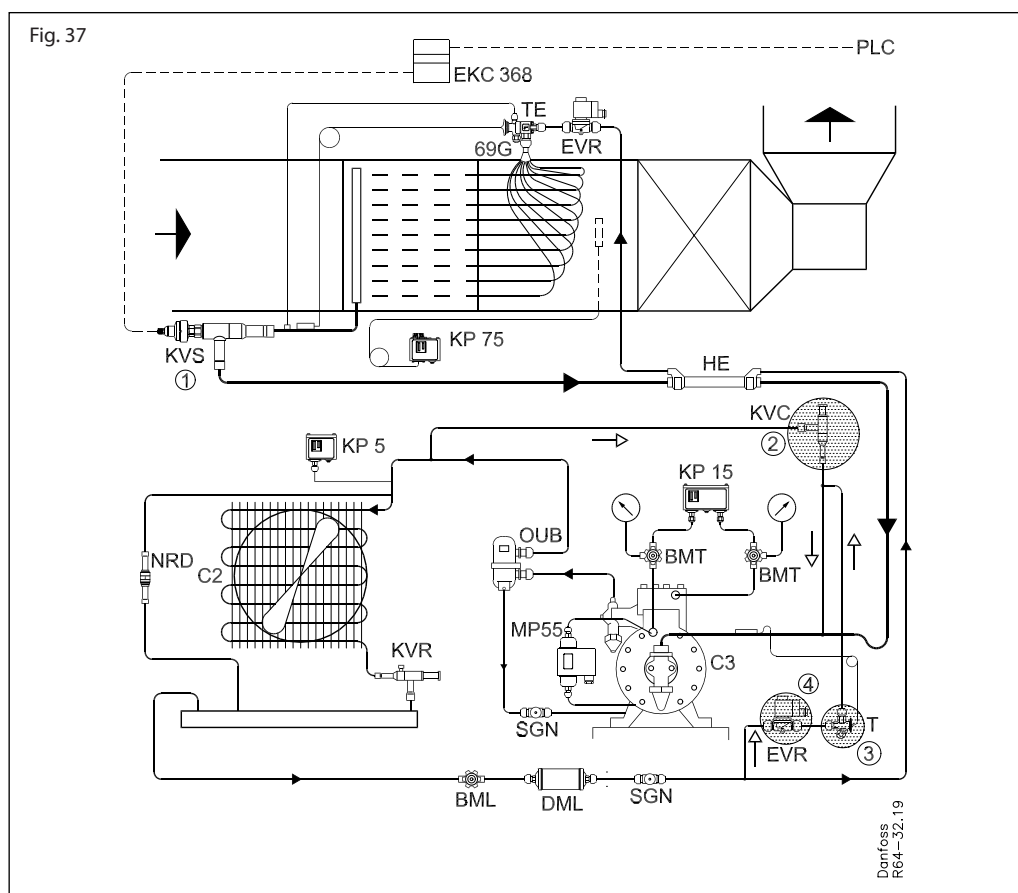
Main wiring diagram for contactors



Wiring diagram for contactors K1 and K2 type CI for the display counter refrigeration plant, fig. 29. For key diagram see fig. 35.

The changeover switch for time switch P controls the contactors so that one is cut in while the other is cut out. The main contacts 1-2 and 3-4 in contactor K2 are each connected to an electric heating element. Contactor K1 has four main contacts, each of which is connected to a single-phase fan (1-2, 3-4, 5-6, 13-14).

Refrigeration plant for ventilation air



An **electronically controlled suction pressure regulator** type KVS (1) is installed in the suction line. The electronic regulator receives signals from a central control unit, e.g. a PLC, which in turn receives signals from a temperature sensor located in the return air flow from the room in which the ventilation air is to be cooled.

The KVS valve opens if the temperature of the return air rises.

If the temperature registered by the sensor rises, the valve opens a little more, and suction pressure from the evaporator is increased. At the same time, the pressure drop across the valve is reduced as a result of reduced evaporation temperature and increased suction pressure. This increases the capacity of the evaporator and compressor.

If the temperature registered by the sensor falls, the valve closes a little more, and suction pressure from the evaporator is reduced. At the same time, the pressure drop across the valve is increased as a result of increased evaporation temperature and reduced suction pressure. This reduces the capacity of the evaporator and compressor.

As plant such as this must be capable of running irrespective of load, compressor capacity must be adjustable.

A **capacity regulator** type KVC (2) is suitable for this purpose as this regulator is able to prevent suction pressure from dropping to such an extent

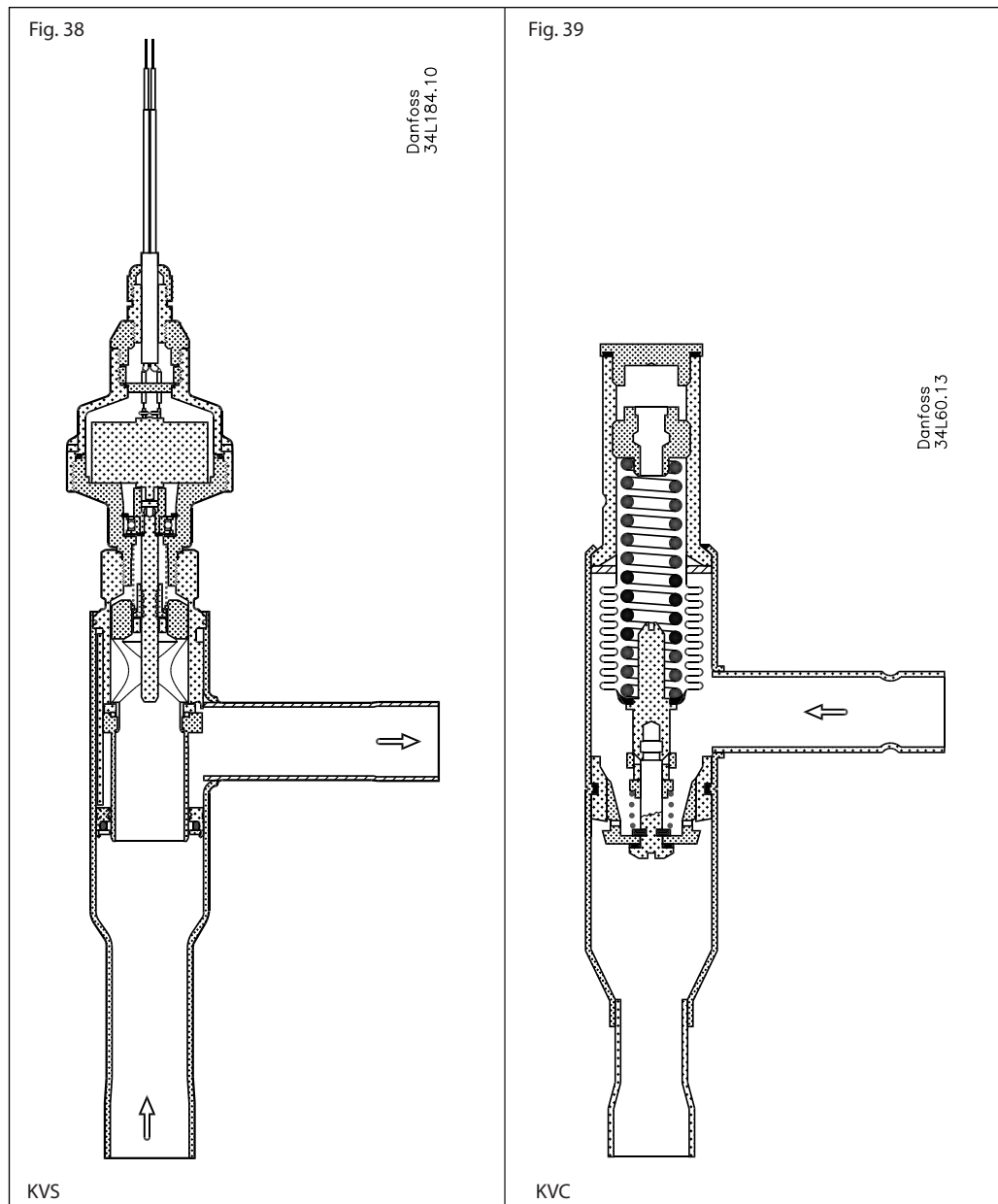
that the compressor is either shut off by the low-pressure cut-out or is subjected to suction pressure below the acceptable minimum. This is achieved by the KVC valve being set to start opening in order to prevent the above-mentioned limits from being crossed. This hot-gas bypass transfers some high-pressure gas from the pressure side of the plant to the suction side, thus reducing refrigeration capacity.

This type of capacity regulation results in a certain degree of suction gas superheating. As a result, the temperature of the high-pressure gas increases, thus increasing the risk that oil in the compressor pressure valves will become coked. In order to prevent this, a thermostatic expansion valve type T (3) is installed in a bypass between the liquid line and the suction line. The valve sensor is installed in the suction line immediately ahead of the compressor.

In case of excessive superheating in this region, the valve opens and some liquid is injected into the suction line. When this liquid evaporates, superheating is reduced and thus also the high-pressure gas temperature.

A solenoid valve type EVR (4) is installed immediately ahead of the thermostatic expansion valve (3) in order to prevent liquid refrigerant from entering the suction line when the refrigeration plant is shut down.

Continued overleaf...



Electronically controlled suction pressure regulator

KVS (1) is a suction pressure regulator, activated by a stepper motor. It alters the degree of opening in response to signals from the EKC 368 regulator which transmits pulses that cause the valve motor to rotate in one direction or the other depending on whether the valve is to be opened more or closed more.

Capacity regulator

The capacity regulator type KVC opens in response to falling pressure on the discharge side, i.e. falling suction pressure ahead of the compressor.

31

32

33



The Danfoss product range for the refrigeration and air conditioning industry

Compressors for refrigeration and air conditioning

These products include hermetic reciprocating compressors, scroll compressors and fan-cooled condensing units. Typical applications are air conditioning units, water chillers and commercial refrigeration systems.

Compressors and Condensing Units

This part of the range includes hermetic compressors and fan-cooled condensing units for household refrigerators and freezers, and for commercial units such as bottle coolers and drinks dispensers. We also offer compressors for heat pumps, and 12 and 24 V compressors for refrigerators and freezers in commercial vehicles and boats.

Appliance controls

For the regulation of refrigeration appliances and freezers Danfoss supplies a product range of electromechanical thermostats produced according to customer specifications; electronic temperature controls comprising models with and without displays; service thermostats – for servicing on all refrigerating and freezing appliances.

Refrigeration and air conditioning controls

Our full product range covers all control, safety, system protection and monitoring requirements in mechanically and electronically controlled refrigeration and air conditioning systems. The products are used in countless applications within the commercial and industrial refrigeration and air conditioning sectors.