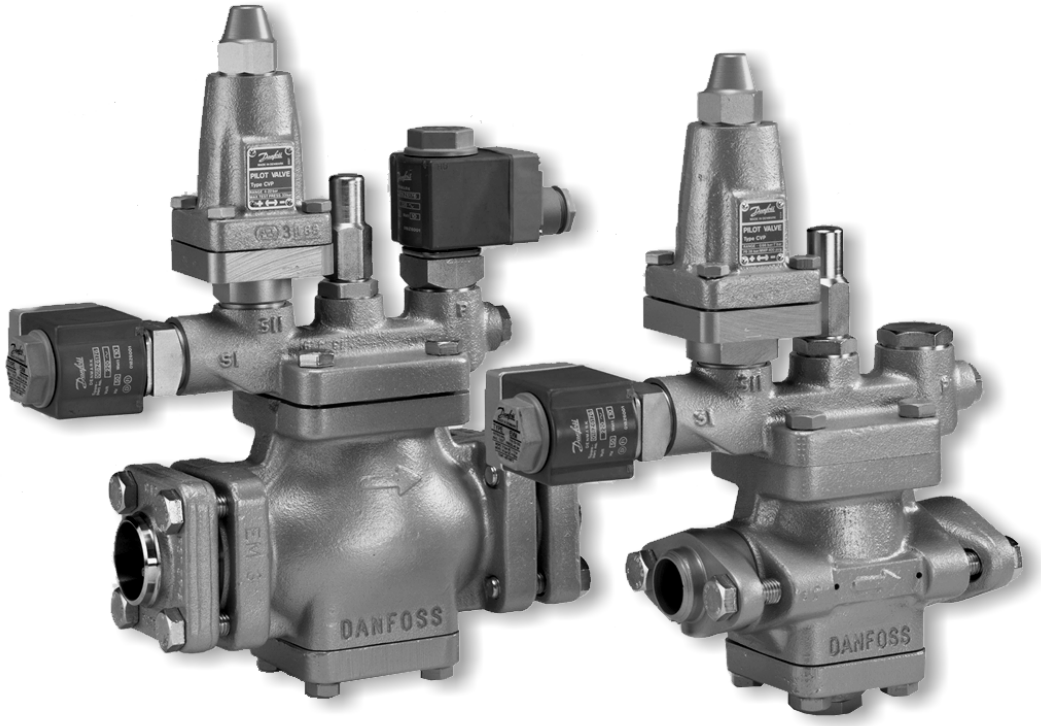
Refrigeration and Air Conditioning Controls

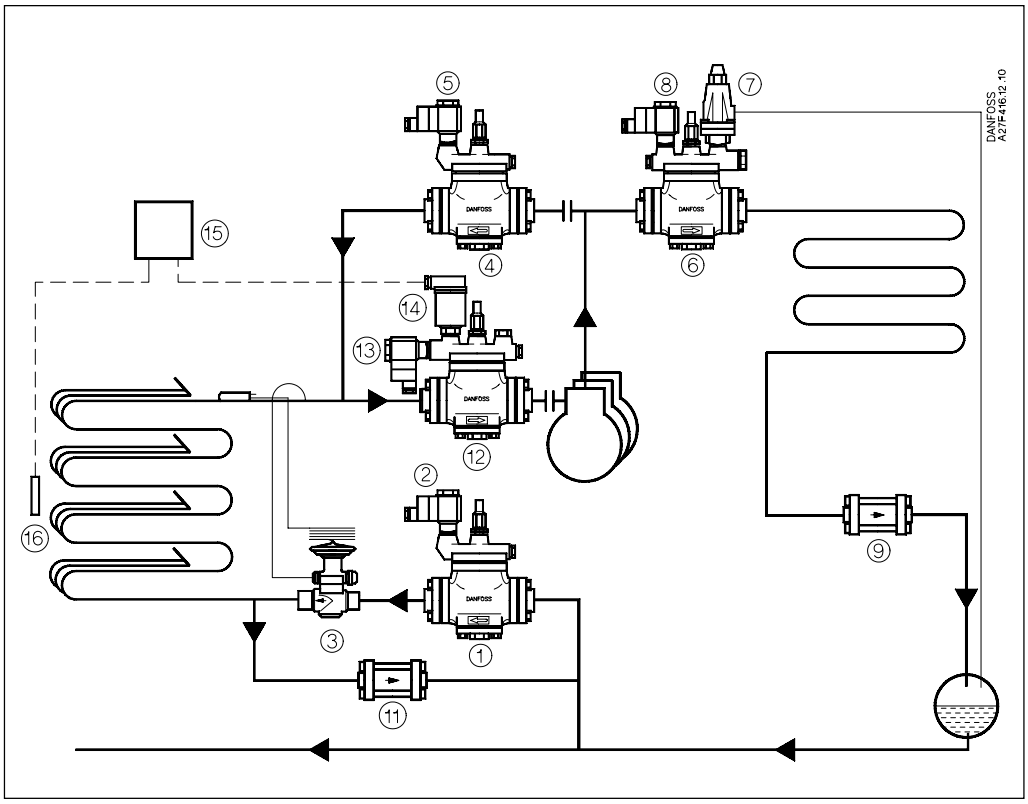
Applications

PM Modulating pressure and temperature regulators



REFRIGERATION AND AIR CONDITIONING

Introduction



Danfoss PM regulators have been on the market for more than ten years.
During that period they have shown their strength in countless applications in refrigerating, freezing and air conditioning systems.

Today they show this strength even more; the capacity range has been widened and the regulating performance has been enhanced with electronics:
The electronically controlled pilot valve CVQ regulates the media temperature in systems requiring extremely accurate temperature regulation.

PM regulators are supplied in two versions, PM 1 and PM 3:
The PM 1 version is designed for the fitting of one pilot valve, whereas it is possible to fit three pilot valves to the PM 3 version.
This gives several functions in the same valve.

PM regulators are also available as solenoid valves, designated PML

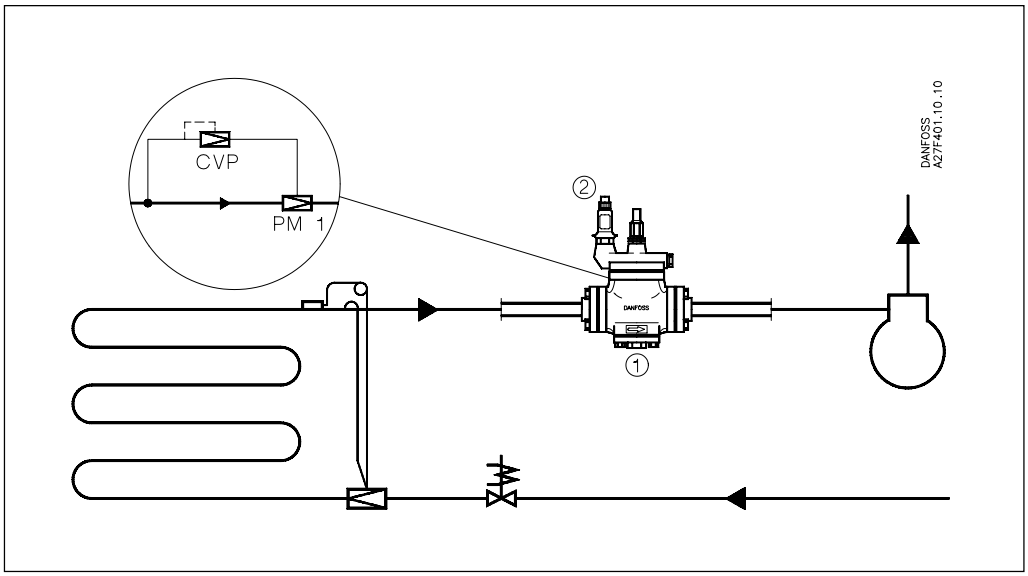
The regulators may be used with all types of fluorinated refrigerants and ammonia.

This publication deals with a number of applications that incorporate the PM.

If you have experience with other applications, please do not hesitate to contact Danfoss

Contents

A1 Evaporating pressure regulation



Maintains constant evaporating pressure and therefore constant evaporating temperature. Prevents too low an evaporating pressure and hence the formation of ice in, for example, water chillers.

Product list
(1) PM 1 Main valve
(2) CVP Constant pressure pilot

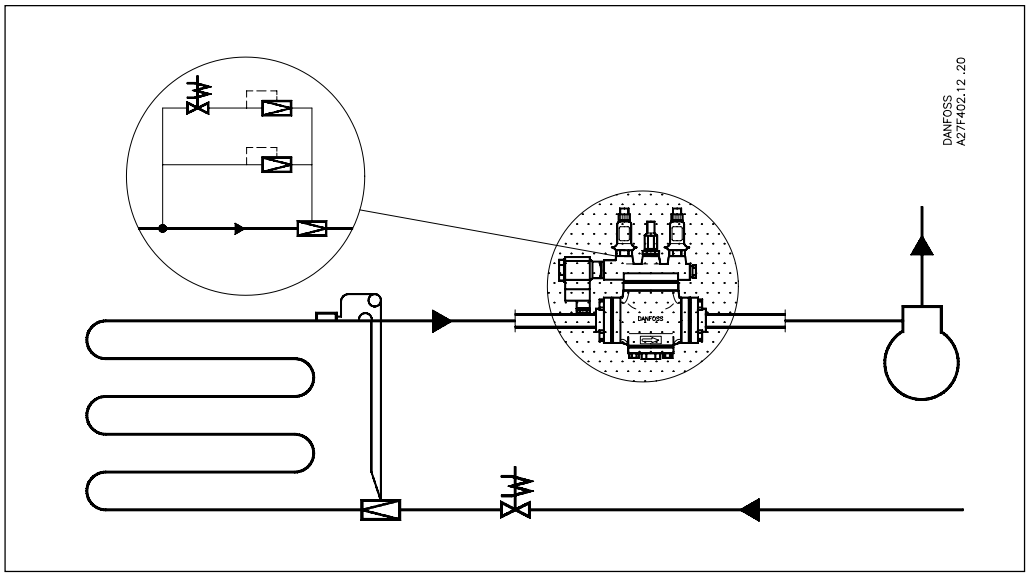
Setting
CVP
When the adjustment spindle is turned clockwise, the the the opening pressure (evaporating pressure/ evaporating temperature) will increase- and vice versa.

Type	Range	Factory setting	Change per turn of adjustment spindle
CVP	−0.66-+2 bar	Lowest adjustment setting (spring slack)	Approx. 0.5 bar
CVP	0-7 bar		Approx. 1 bar
CVP (HP)	6-22* bar		Approx. 1.8 bar

* 28 bar on special order.

Fine adjustment
Fine adjustment with pressure gauge.

A2 Evaporating pressure regulation



In the processing industry different evaporating temperatures/ air exhaust temperatures can be used with advantage.

When the parameters are fixed, one PM 3 with two CVP pilots in cascade control with forced control can perform such a task.

Product list

(1)	PM 3	Main valve
(2)	CVP	Constant pressure pilot
(3)	CVP	Constant pressure pilot
(4)	EVIVI	On / off pilot

Sizing
Capacity table Suction vapour.

Function
Main valve PM 3 (1) regulates as a function of the evaporating pressure, which is controlled by low-pressure pilots (2) or (3). The main valve will close when the pressure drops below the preset pressure of the pilots.

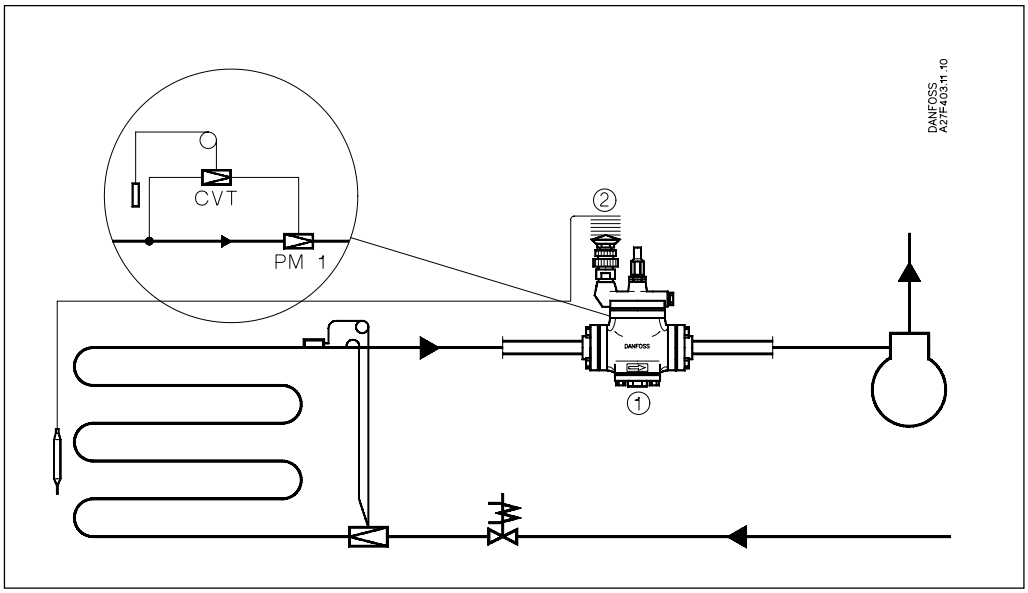
Example
Controlling two evaporating pressures in heat exchangers

	I	II
Outlet air temperature	+3°C	+8°C
Evaporating temperature	–20°C	+2°C
Change In temperature, at	5 K	6 K
Refrigerant	R 22	R 22
Evaporating pressure	3,6 bar	4,4 bar

I: EVM pilot (4) in position SI opens. Hence the evaporating pressure is controlled by CVP pilot (3), which is preset to the lowest pressure.

II: EVM pilot (4) closes. Now the evaporating pressure is controlled by CVP pilot (2), preset to the highest pressure.

B1
Media temperature regulation



Maintains constant temperature of the medium by evaporating pressure control.

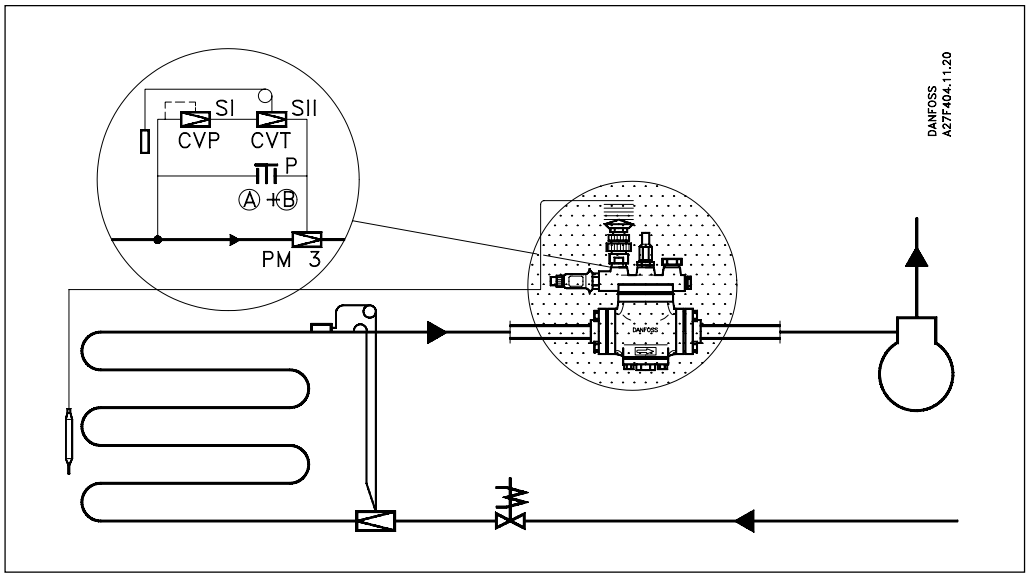
Product list
(1) PM 1 Main valve
(2) CVT Temperature controlled pilot

Setting
CVT
Loosen the locking ring. When the setting ring is turned clockwise, the opening temperature is reduced - and vice versa.

Type	Range	Factory setting	Change per turn of adjustment spindle
M	−40 - O°C	−300°C	Approx. 6°C
CVT	−10 - +25°C	0°C	Approx. 60°C
CVT	+20 - +60°C	+30°C	Approx. 6°C

Note:
The CV17 valve is a proportional regulator (P-band = 4°C). Its use for temperature control where high accuracy is required or where large load changes occur is therefore not recommended.

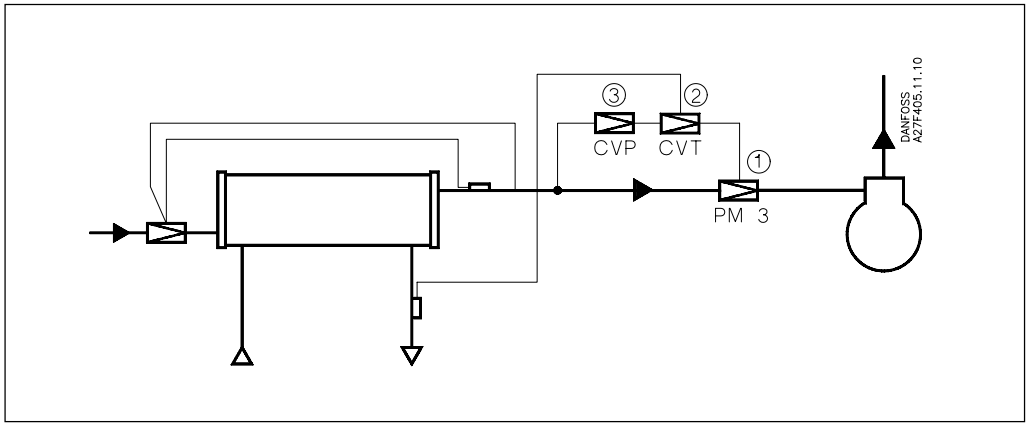
B2 Media temperature regulation



Regulates the temperature of the medium (water or air).

Frost protection.

Product list
(1) PM 3 Main valve
(2) CVT Temperature controlled pilot
(3) CVP Safety pilot (constant pressure)



Example
Temperature regulation of water chiller

Water temperature	+2°C
Evaporating temperature	–3°C
Change in temperature, Δt	5 K
Frost protection temperature	+0.5°C
Refrigerant	R 134a
Evaporating pressure	1.65 bar
Safety pressure	1.5 bar
(~0.5 bar –Δt = –4.5°C)	

The sensor for the CVT pilot valve (2) is mounted on the water outlet from the water chiller.

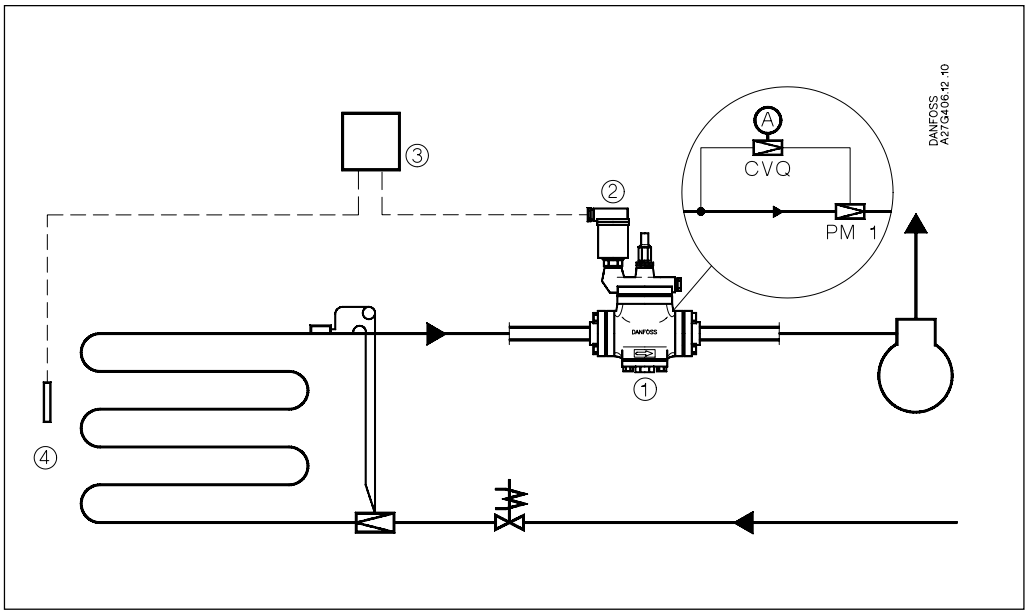
When the water temperature drops, CVT pilot valve (2) will begin closing main valve PM 3 (1). The main valve will regulate in such a way that the desired water temperature is maintained.

The CVP pilot valve is fitted in position SI with a safety setting so that the evaporating pressure cannot become lower than 1.5 bar - or the evaporating temperature not lower than 0.50 C.

The CVP pilot valve thus operates simultaneously with the CVT pilot and ensures that the lower limit of regulation is maintained.

Note:
In the event of widely fluctuating cooling requirements the evaporating pressure regulation may cause the compressor to stop at low pressure, unless the compressor has capacity regulation.

B3
Media temperature regulation with PI regulator



Maintains the temperature of the medium constant with an accuracy of ± 0.25°C (or better) by evaporating pressure regulation.

The system is very suitable for a large number of applications in the freezing, refrigerating and air conditioning sectors as well as in process industries with central control.

See also Refrigeration Controls catalogue, or CVQ manual, literature no. RS.4J.B1.02.

Product list

(1)	PM 1	Main valve
(2)	CM	Electric pilot (actuator)
(3)	EKS 61	Electronic temperature regulator
(4)	AKS 21M	Pt 1000D air sensor

Sizing
Capacity table: Suction gas.

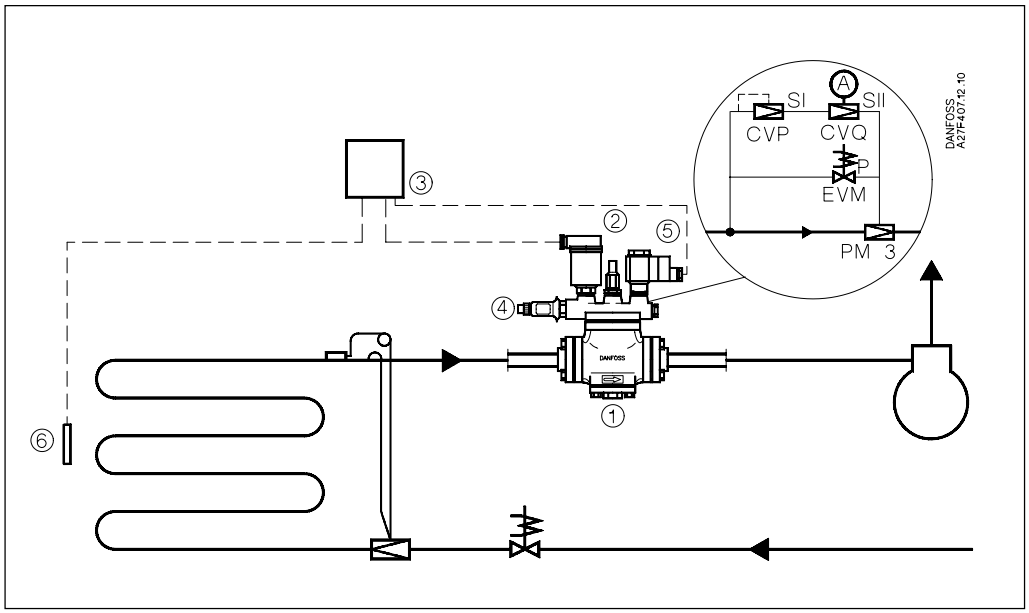
Function
Sensor AKS 21 M (4) is mounted in the cooled airstream after the evaporator.

Controller EKS 61 (3) compares the sensor temperature and the reference temperature set on EKS 61.

On changes in temperature (changed cooling requirement), EKS 61 will immediately perform stepless adjustment of the energy supply to CV0 pilot valve (2). This causes the degree of opening of the PM valve to change. Thus the refrigerant flow is changed and with K the evaporating temperature and room temperature.

Setting
See Refrigeration Controls catalogue, or CVQ manual, literature no. RS.4J.B-.02.

B4
Media temperature regulation with P1 regulator



Maintains the temperature of the medium constant with an accuracy of ± 0,25°C (or better). Frost protection and forced control.

Because it is capable of handling the cooling-down phase as well as the often long storage phase, this type of regulation is particularly suitable for the temperature control of fruit storage cold rooms.

Product list

(1) PM 3	Main valve
(2) CVQ	Electric pilot (actuator)
(3) EKS 61	Electronic temperature regulator
(4) CVP	Constant pressure pilot
(5) EVM	On / off pilot
(6) AKS 21 M	Pt 1000 Ω air sensor

Sizing

Capacity table Suction vapour.

Function

Sensor AKS 21 M (6) is mounted in the cooled airstream after the evaporator.

Controller EKS 61 (3) compares the sensor temperature and the preset temperature.

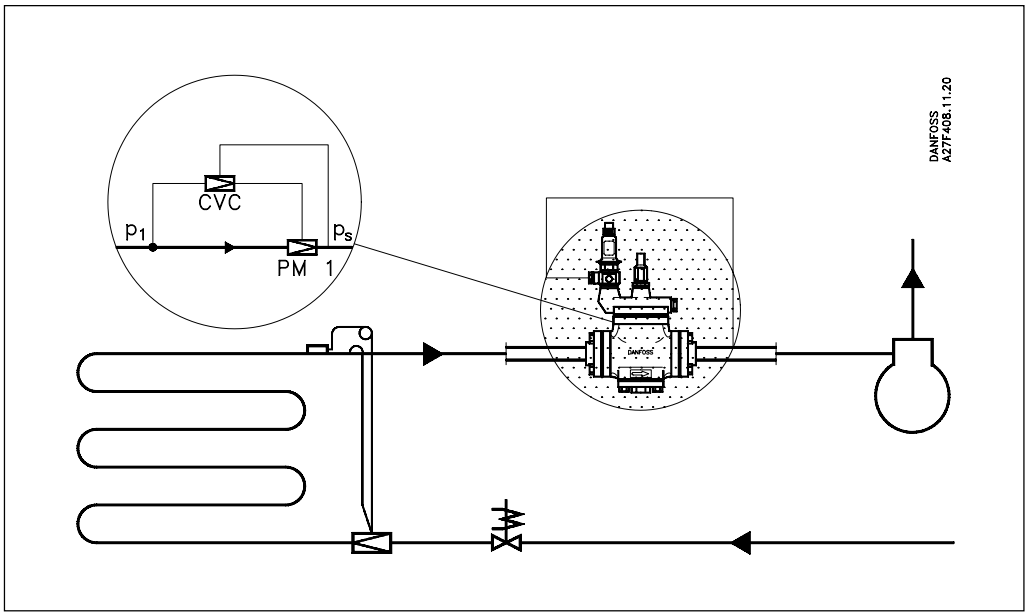
On changes in temperature (changed cooling requirements), EKS 61 will immediately perform a stepless adjustment of the energy supply to CVQ pilot (2).

The pilot then causes the degree of opening of the PM valve to change so that the flow of refrigerant and therefore the evaporating temperature and air temperature are changed.

In addition, EKS 61 takes care of the forced opening of EVM pilot (5) so that the compressor gives maximum output during the cooling-down phase of the fruit storage room.

CVQ pilot valve (2), together with CVP pilot valve (4), prevents evaporating temperature becoming too low during the storage phase. In this way, drying-out of the air and stored produce is prevented.

C1 Crankcase pressure regulation



Protects the compressor motor against overload caused by excessive suction pressure during start-up after standstill for some time or after defrosting.

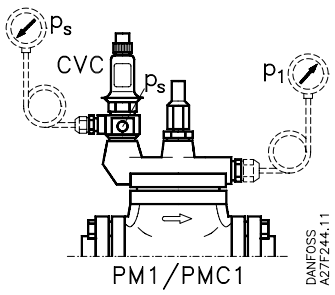
Function
When pressure p. exceeds the CVC setting, the PM valve closes and thus ensures that the upper limit of the compressor suction pressure is observed.

Product list
(1) PM 1 Main valve
(2) CVC Suction pressure pilot

Setting
CVC: When the spindle is turned clockwise, the opening pressure will increase - and vice versa.

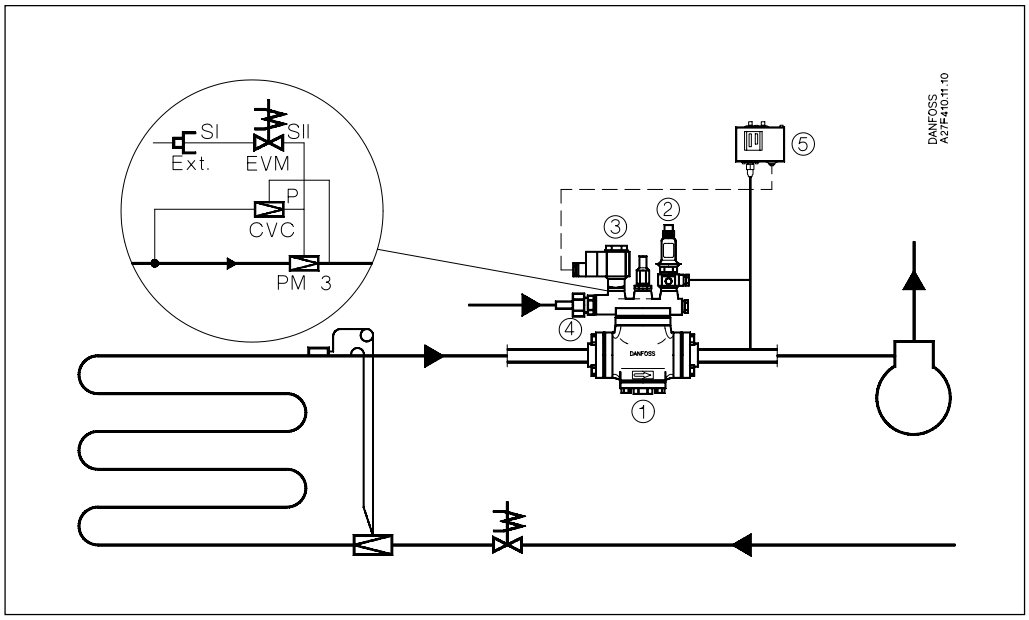
Type	Range	Factory setting spindle	Change per turn of adjustment	Number of turns for protection at –20*C		
				R 12	R 22	R 502
CVC	–0.45 -+ 7 bar	–0.45 bar (spring slack)	Approx. 1.5 bar	2/3	1 1/3	1 1/2

Fine adjustment



Fine adjustment with pressure gauge

C2
Crankcase pressure regulation



Protects the compressor motor against overload caused by excessive suction pressure with forced opening of the PM valve after the start-up phase (min. pressure drop).

Product list

(1)	PM 3	Main valve
(2)	CVC	Suction pressure pilot
(3)	EVM	On / off pilot
(4)	Ext.	External connection
(5)	KP 1	Pressure control

Sizing
Capacity table Suction vapour.

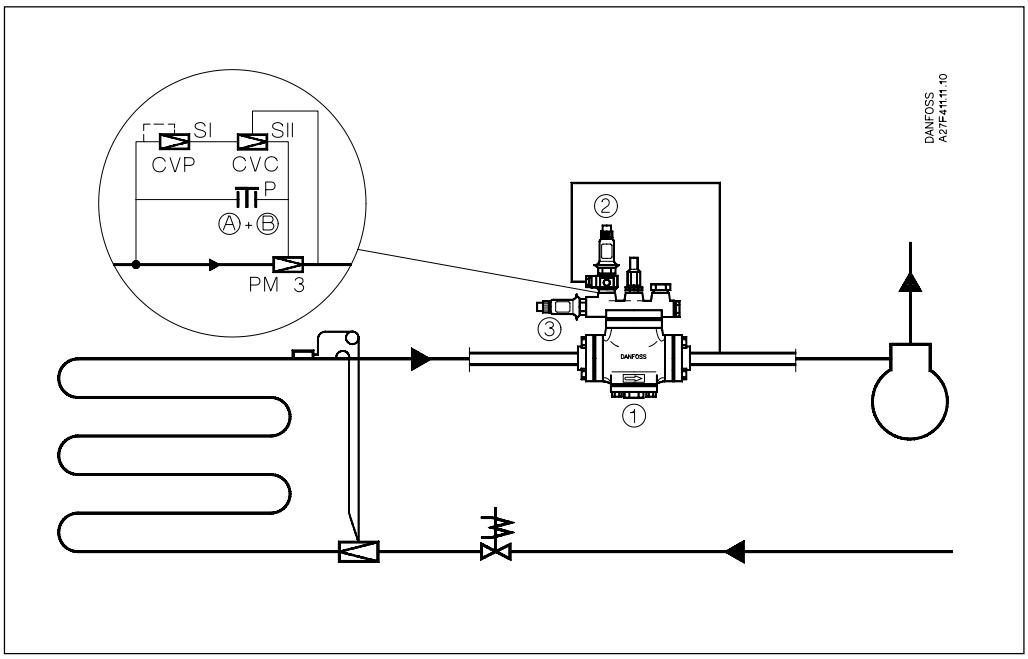
Function
When the pressure ahead of the compressor exceeds the setting of CVC pilot (2), PM 3 main valve (1) closes and thus maintains the upper limit of the suction pressure.

When the operating pressure has been reached, pressure control KP 1 (5) starts the forced opening of PM 3 (1). PM 3 (1) is then forced fully open by EVM pilot (3) and hot gas from the external connection, Ext. (4).

The hot gas regulation means that PM 3 can be sized for a very small Δp (as low as 0.02 bar).

Setting
See application CI.

C3
Crankcase pressure regulation



Protects the compressor motor against overload caused by excessive suction pressure and at the same time regulates the evaporating pressure.

Product list

(1)	PM 3	Main valve
(2)	CVC	Differential pressure pilot
(3)	CVP	Constant pressure pilot

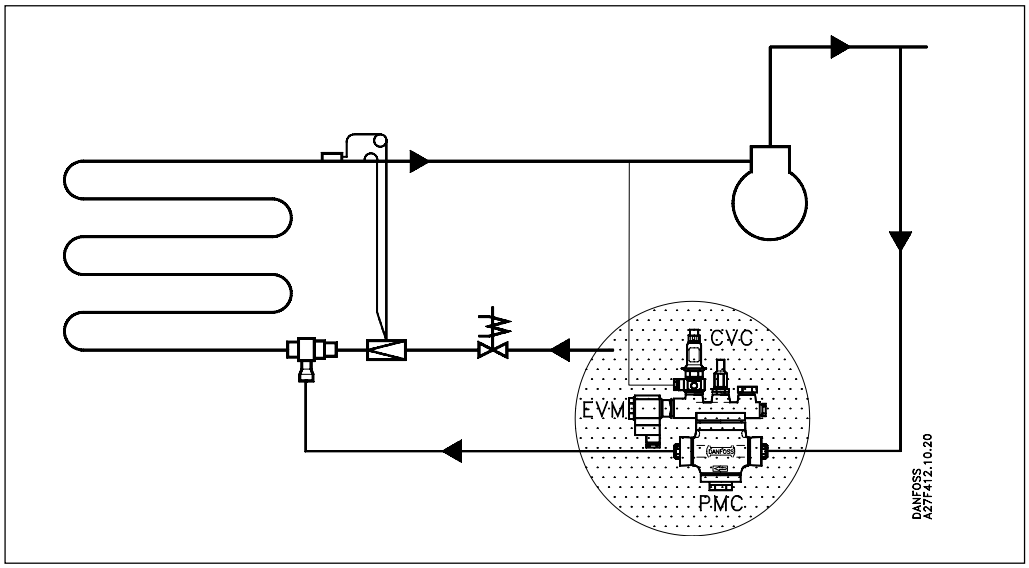
Sizing
Capacity table: Suction vapour.

Function
When the compressor suction pressure exceeds the setting of CVC pilot (2), PM 3 main valve (1) closes and thus maintains the upper limit of the suction pressure.

When the operating pressure has been reached, PM 3 (1) will be fully open, and pilot valves CVC (2) and CVP (3) will be open. If the pressure ahead of PM 3 drops below the CVP pilot setting, PM 3 will close and thus ensure that the evaporating pressure is limited.

Setting
See application CI.

D1
Capacity regulation



Adapts the fixed compressor capacity to the cooling requirements.

PMC 3 (1) capacity regulator may be used on standard compressors as well as on compressors with relief and fixed output increments.

Product list
(1) PMC 3 Main valve
(2) CVC Differential pressure pilot
(3) LG Liquid / gas mixer
(4) EVM "Pump down" pilot

Sizing
Capacity table for PMC: See next page or Refrigeration Controls catalogue, literature no. RK.00.H-.02.

Features
This type of hot gas supply offers many advantages:

- Instantaneous compensation for refrigerant superheat at the evaporator outlet.
- Increased hot gas velocity in the evaporator and improved return of oil. This is particularly important even 9 the evaporator is placed lower than the compressor.
- Limitation of the refrigeration output by compressor capacity adjustment to suit the evaporator capacity. This avoids short compressor operating cycles.
- Prevents too low an evaporating pressure and thereby ice formation in, for example, water chillers. With air coolers, the cooled air is prevented from becoming too dry.

Function
Main valve PMC (1) opens when the pressure ahead of the compressor drops below the reference pressure of CVC pilot (2).

Hot gas is injected between the thermostatic expansion valve and the distributor through a liquid/gas mixer, LG (3).
Adapts the fixed compressor capacity to the cooling requirements.

Setting
CVC:
When the adjustment spindle is turned clockwise, the main valve will open at a higher suction pressure.

Type	Range (suction pressure)	Factory setting	Change per turn of adjustment spindle
CVC	–0.45 - + 7 bar	–0.45 bar	Approx. 1.5 bar

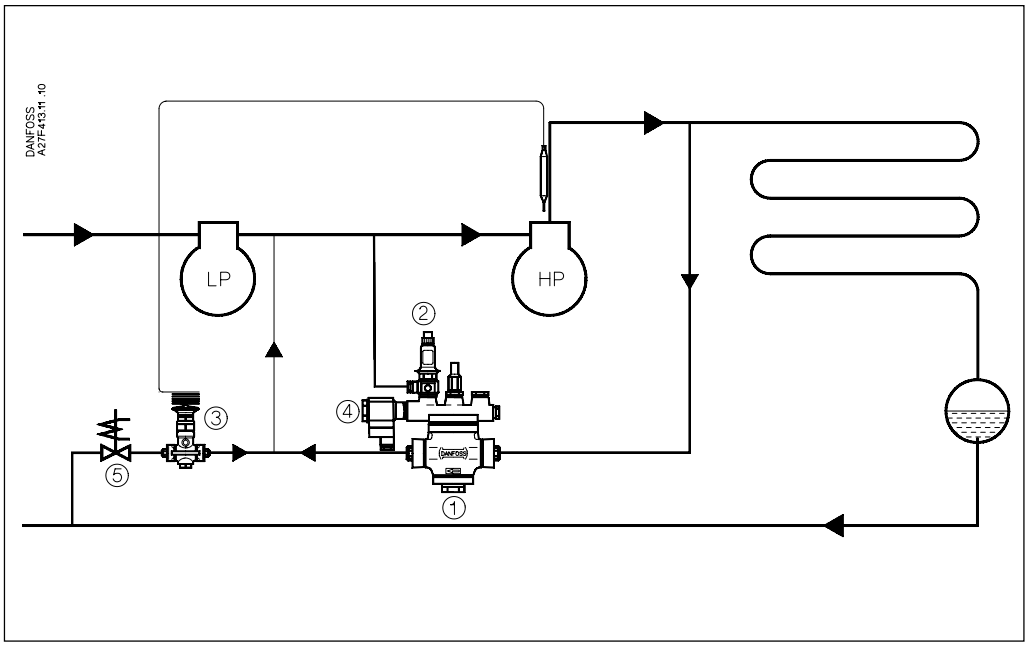
Fine adjustment
Fine adjustment with pressure gauge.

Capacity

Type	Size (= rated-R 12-cap.* in TR)	Rated capacity* kW				k,-value
		R 12	R 22	R 502	R 717	m 3 /h
PMC	5	18	32	30	85	1.5
	8	29	52	48	140	2.5
	12	44	77	72	210	3.6
	20	72	130	120	340	6.0

* Rated capacity at t_e = 10°C, t_c = 32°C, offset = 4°C

D2
Capacity regulation



Adapts the fixed compressor capacity to the cooling requirement.

PMC 3 (1) capacity regulator may be used on standard compressors as well as on compressors with relief and fixed output increments.

Product list

(1)	PMC 3	Main valve
(2)	TEAT	Thermostatic injection valve
(4)	EVM	*Pump down pilot
(5)	EVR/EVRA	Solenoid valve

Sizing
Capacity table for PMC See application D1 or Refrigeration Controls catalogue, literature no. RK.00.H-.02.

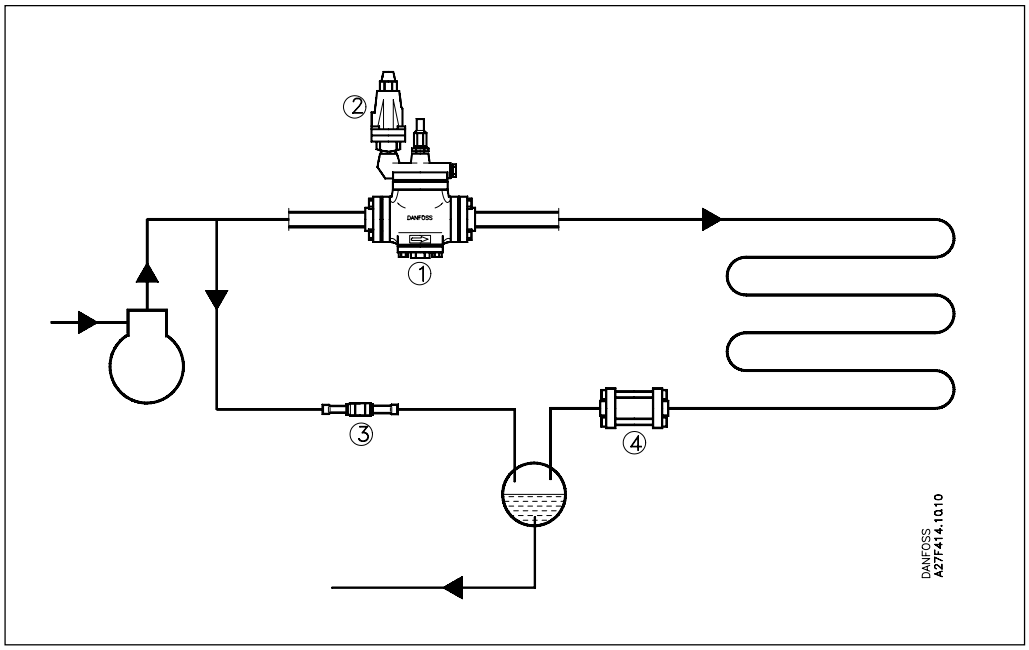
Function
Is often used in two-step compressor plant.

Main valve PMC 3 (1) opens when the pressure ahead of the compressor drops below the reference pressure of CVC pilot (2). This causes hot gas to be led into the suction line ahead of the HP compressor.

An excessive amount of hot gas may give rise to increased compressor outlet temperature. If this occurs, thermostatic expansion valve TEAT (3) will inject a quantity of refrigerant into the suction line, causing a suction temperature drop.

Setting and capacity
See application D1.

E1
Condensing pressure regulation



Maintains the condensing pressure constant and at a sufficiently high level in aircooled condensers in low ambient temperature.

Product list

(1)	PM 1	Main valve
(2)	CVP (HP)	Constant pressure pilot
(3)	NRD	Differential pressure valve
(4)	NRVA	Check valve

Sizing

Capacity table	Hot gas

Function

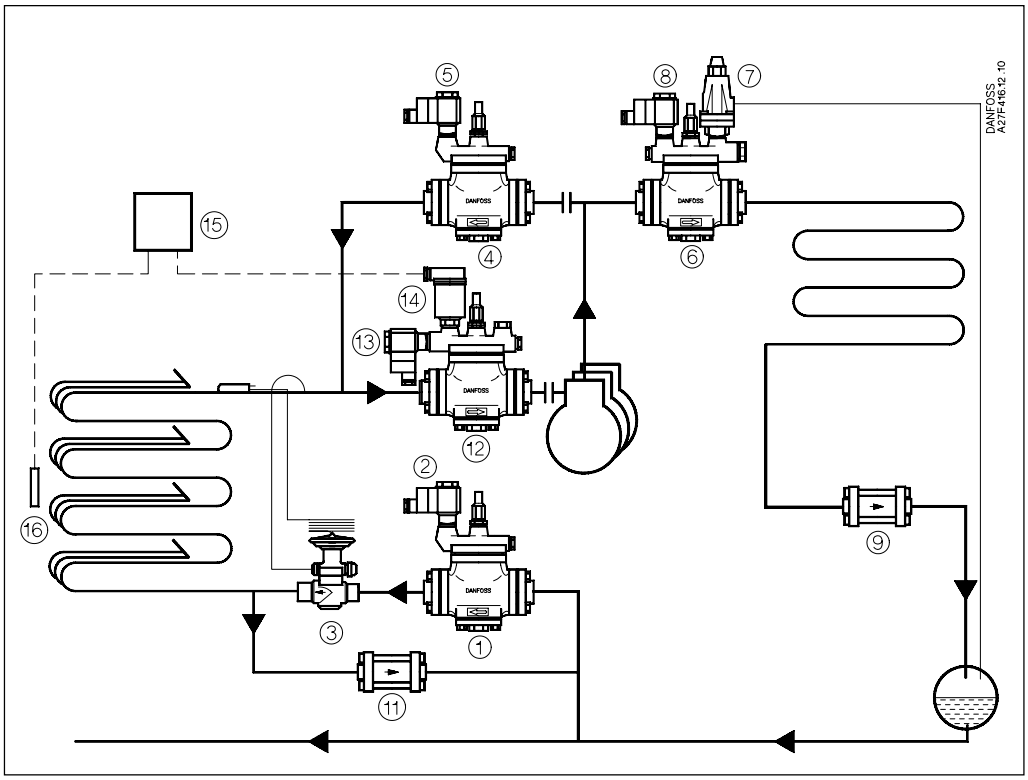
Main valve PM 1 (1) regulates in proportion to the compressor outlet pressure set on constant pressure pilot (2). The main valve closes when the pressure dops below the preset value.

NRD differential pressure valve (3) with a fixed setting of 1.4 bar ensures sufficient pressure in the receiver.

NRVA check valve (4) fitted next to the outlet from the condensor, ensures increased condenser pressure by variable liquid collection. This requires a sufficiently large receiver.

The NRVA check valve also prevents liquid flowing from the receiver back towards the condenser when the latter is colder during compressor shut-down periods.

F1
Hot gas defrosting from top of evaporator - direct expansion



This defrosting system is used on commercial and industrial central refrigerating systems with several evaporators and direct expansion.

Product list

(1)	PM 1	Main valve (shut-off valve)
(2)	EVM	On/off pilot
(3)	TE 20	Thermostatic expansion valve
(4)	PM 1	Main valve (shut-off valve)
(5)	EVM	On/off pilot
(6)	PM 3	Main valve (modulating)
(7)	CVPP (HP)	Differential pressure pilot
(8)	EVM	On/off pilot
(9)	NRVA	Check valve
(11)	NRVA	Check valve
(12)	PM 3	Main valve (modulating)
(13)	EVM	On/off pilot
(14)	CVQ	Electric pilot (actuator)
(15)	EKS 61:	Electronic temperature regulator
(16)	AKS 21M	Pt 1000 Ω air sensor

Sizing
Capacity table Hot gas.

Function
Refrigerating phase
Liquid passes through shut-off valve PM 1 (1) kept open by its pilot EVM (2).

Liquid injection occurs through thermostatic expansion valve TE 20 (3).

Main valve PM 3 (12) modulates the evaporating pressure in order to maintain the temperature of the air being cooled. The function is performed by CVQ pilot (14) which is itself controlled by electronic regulator EKS 61 (15) with air sensor AKS 21 M (16). Pilot valve EVM (13) is open.

Main valve PM 3 (6) in the high-pressure line is kept open by pilot E~ Defrosting valve PM 1 (4) is kept closed by pilot EVM (5).

Defrosting phase
Main valves PM 1 (1), PM 3 (6) and PM 3 (12) are closed - each by their own EVM pilot.

Main valve PM 1 (4) is opened by EVM pilot (5) and feeds hot gas against the direction of flow to the evaporators that need defrosting.

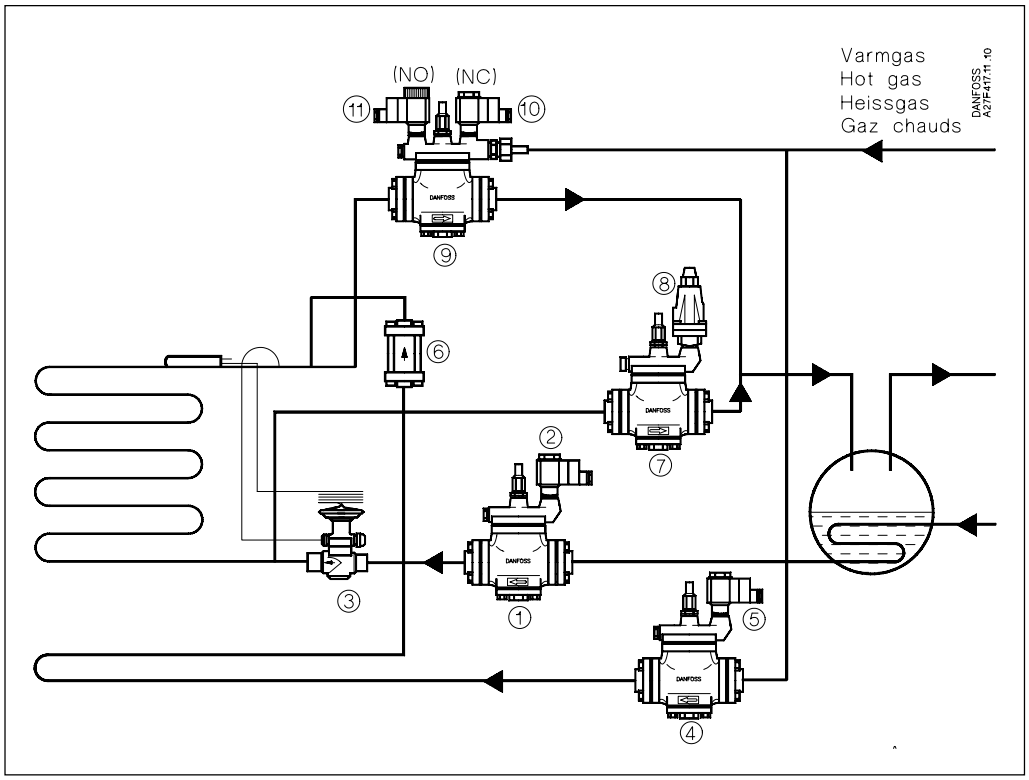
Note
To ensure that the evaporators are properly defrosted, at least two thirds of the plant must be under cooling and at most one third under defrosting - otherwise the output of hot gas will be insufficient.

During the defrosting phase main valve PM 3 (6), controlled by differential pressure pilot CVPP (HP) (7), will give priority to defrosting by creating sufficient differential pressure Ap between hot gas pressure and receiver pressure.

This pressure drop ensures that the liquid which is condensed during defrosting is pressed out into the liquid line through NRVA check valve (11).

Setting
Example
System with R 22
The CVPP (HP) (7) is preset at between 1 and 1.5 bar.

F2
Hot gas defrosting from top of vaporator direct expansion



This defrosting system is used on industrial refrigerating systems with direct expansion.

The use of PML (9) in the suction line provides complete tightness during the defrosting phase and a minimal pressure drop during the refrigerating phase.

The combination of a PM 1 (7) and a CVP (8) keeps the pressure at a sufficiently high level in the evaporator during defrosting.

Product list

(1)	PM 1	Main valve (shut-off valve)
(2)	EVM	On/off pilot
(3)	TE 55	Thermostatic expansion valve
(4)	PM 1	Main valve (shut-off valve)
(5)	EVM	On/off pilot
(6)	NRVA	Check valve
(7)	PM 1	Main valve (modulating)
(8)	CVP (HP)	Constant pressure pilot
(9)	PML	Main valve (shut-off valve) with very low pressure drop
(10)	EVM (NC)	On/off pilot
(11)	EVM (NO)	On/off pilot

Sizing

Capacity table Liquid and hot gas.

Function

Refrigerating phase
Liquid passes through main valve PM 1 (1) kept open by its pilot EVM (2).

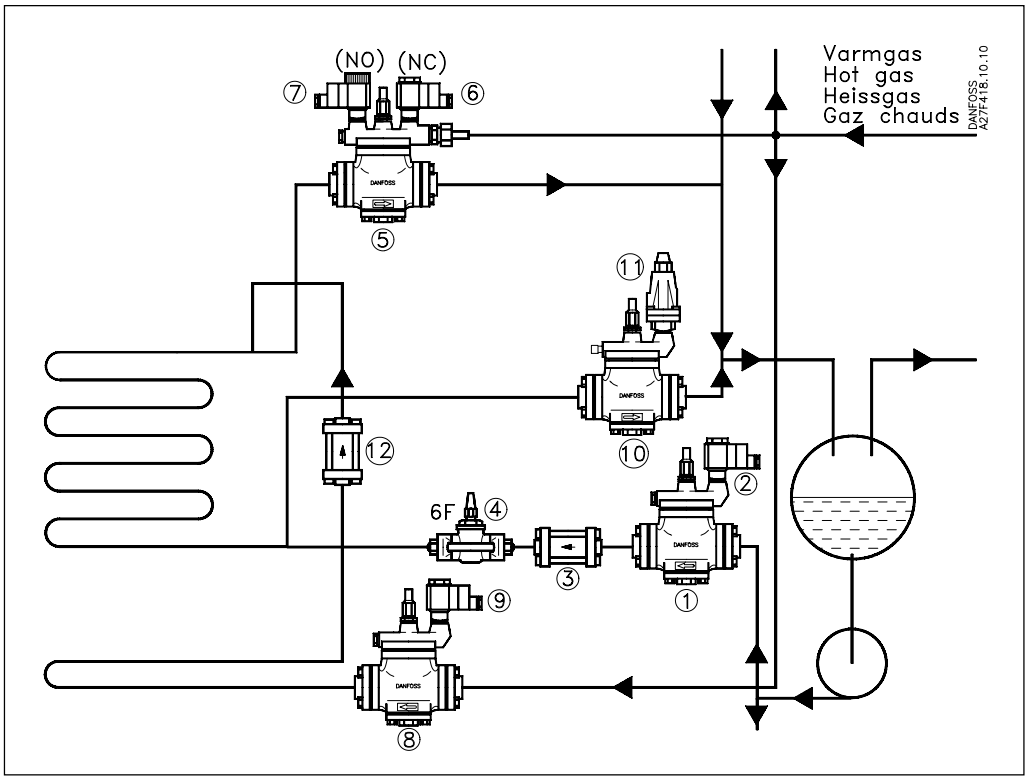
Liquid injection occurs through thermostatic expansion valve TE 55 (3). Vapour is led to the liquid separator through main valve PML (9) kept open by on/off pilots EVM (10) and (11).

During the refrigerating phase check valve NRVA (6) prevents liquid flowback towards the defrost tray heating element.

Defrosting phase
Main valves PM 1 (1) and PML (9) are closed and hot gas is led to the top of the evaporator through main valve PM 1 (4) which is controlled by on/off pilot EVM (5).

Condensed vapour returns to the liquid separator through main valve PM 1 (7), controlled by constant pressure pilot CVP (HP) (8), when the pressure in the evaporator exceeds the CVP (HP) setting - normally a pressure corresponding to approx. +5°C.

F3
Hot gas defrosting from top of vaporator - pump recirculation



This defrosting system is used on refrigerating systems with pump recirculation, including - in particular - systems with several evaporators and separate defrosting.

Product list

(1)	PM 1	Main valve (shut-off valve)
(2)	EVM	On/off pilot
(3)	NRVA	Check valve
(4)	6F	Throttle valve
(5)	PML	Main valve (shut-off valve) with very low pressure drop
(6)	EVM (NC)	On/off pilot
(7)	EVM (NO)	On/off pilot
(8)	PM 1	Main valve (shut-off valve)
(9)	EVM	On/off pilot
(10)	PM 1	Main valve (modulating)
(11)	CVP (HP)	Constant pressure pilot
(12)	NRVA	Check valve

Sizing
Capacity table: Liquid and hot gas.

Function

Refrigerating phase
Liquid is led from the pump and passes through main valve PM 1 (1), kept open by on/off pilot EVM (2); K then passes through check valve NRVA (3), which has a very low pressure drop.

Liquid Injection Into the evaporator occurs through throttle valve 6F (4). The liquid/vapour mixture is led to the liquid separator through main valve PML (5), kept open by hot gas and on/off pilots EVM (6) and (7). The main valve is therefore fully open, even when the pressure drop is very low. Main valves PM 1 (8) and (10) are closed.

Defrosting phase
Main valves PM 1 (1) and PML (5) are closed, and hot gas is led to the top of the evaporator through main valve PM 1 (8), controlled by on/off pilot EVM (9).

Check valve NRVA (3) prevents liquid flowback through main valve (1) into the pump line.

Condensed vapour returns to the liquid separator through main valve PM 1 (10), controlled by constant pressure pilot CVP (HP) (11); this makes it possible to maintain the pressure necessary for defrosting the evaporator and at the same time ensures the expansion of condensed vapour.

Heat recovery

Recovery of condenser heat in refrigerating systems wholly or partially without affecting the operation of the plant.

15%
In this case only 15% of the condenser heat is recovered, but at a high temperature level. The superheat is recovered.

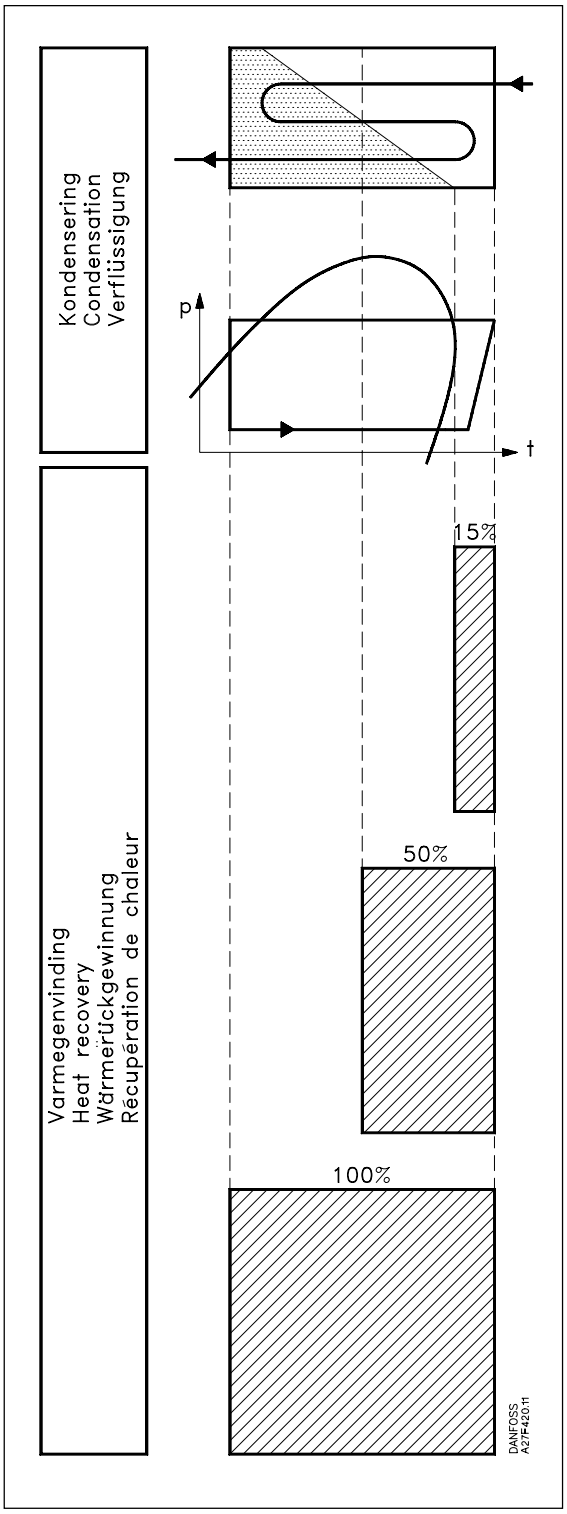
Application example
Production of domestic hot water

50%
This calls for a recovery system connected in series. The pressure drop will be the loss in the heat recovery condenser plus the loss in the main condenser.

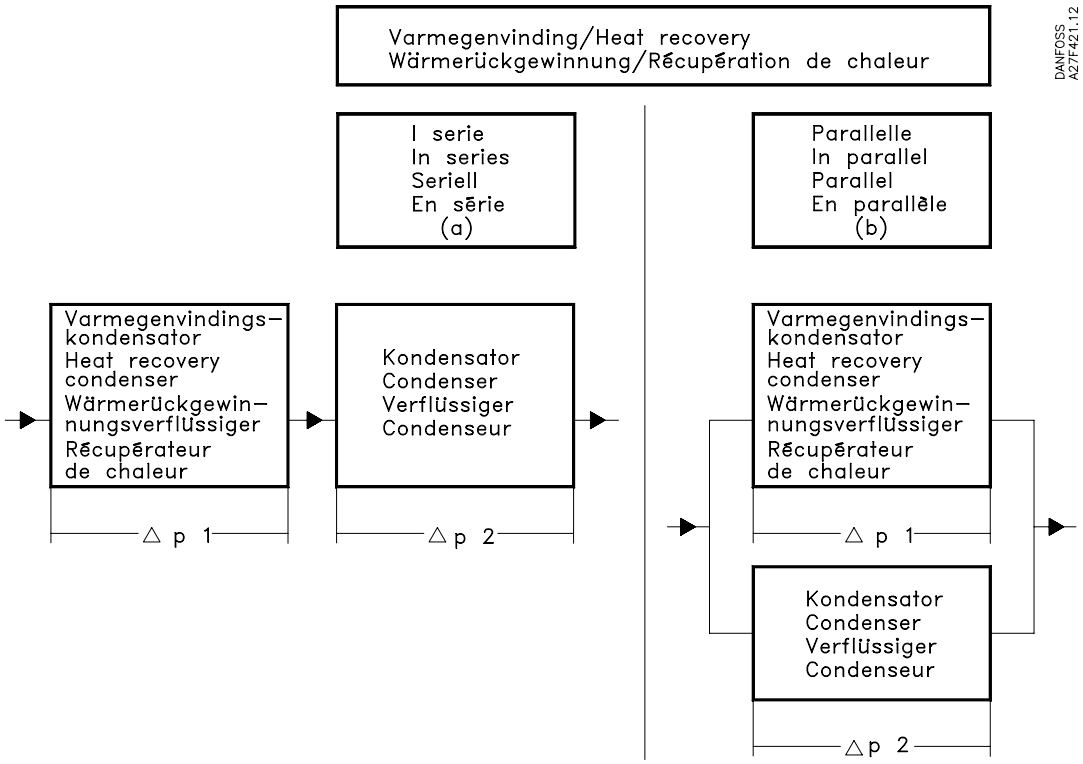
Application examples Heating of air
Preheating of water in a hot-water tank

100%
100 % recovery of condenser heat. The pressure drop is insignificant. However, it must be remembered that 9 capacity is reduced, recovered heat is also reduced.

Application examples Heating of air in air conditioning systems Office heating



Principle



Condensers mounted in series (a)

Liquid flow in main condenser
= Liquid flow in recovery condenser.

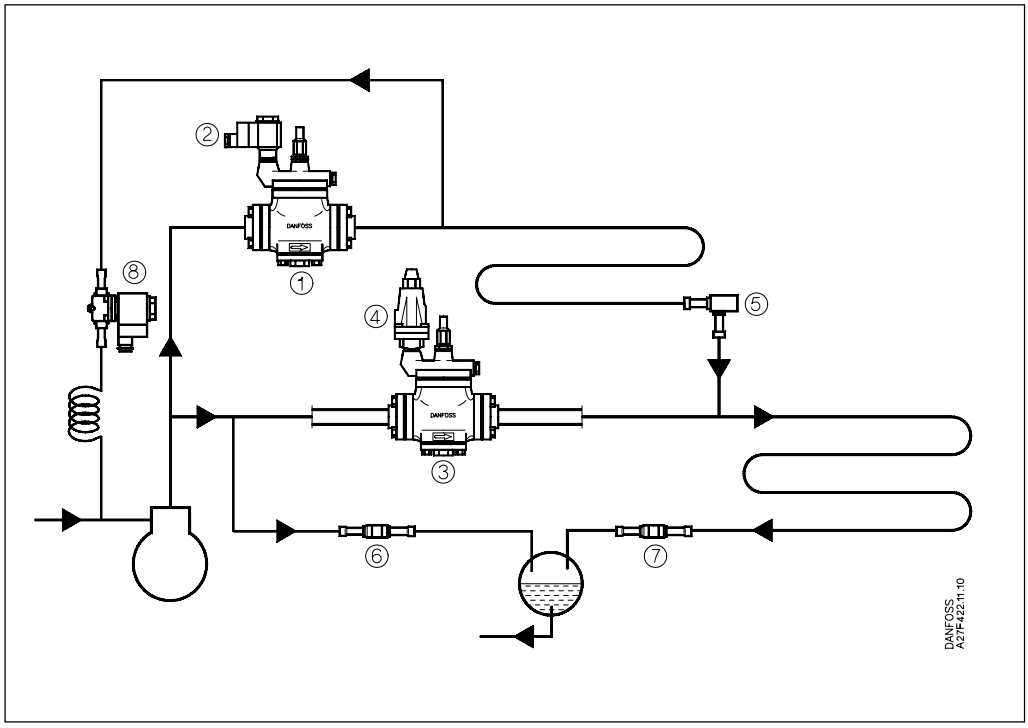
Total pressure loss
= pressure loss in recovery condenser
+ pressure loss in main condenser.

Condensers mounted in parallel (b)

Several recovery condensers arranged
In parallel.

Total pressure loss
= pressure loss in recovery condenser
or
pressure loss in main condenser.

G1
Heat recovery



Condensers mounted in series (a)

This heat recovery system is applicable to air as well as water.

Product list

(1)	PM 1	Main valve (shut-off valve)
(2)	EVM	On/off pilot
(3)	PM 1	Main valve (modulating)
(4)	CVP (HP)	Constant pressure pilot
(5)	NRV	Check valve
(6)	NRD	Differential pressure valve
(7)	NRV/NRVA	Check valve
(8)	EVR	Solenoid valve

Function

Refrigerating phase without heat recovery
Hot gas is led direct into the main condenser through main valve PM 1 (3) with constant pressure pilot CVP (HP) (4). Check valve NRV (5) prevents flowback towards the heat recovery condenser.

Recovery phase
Main valve (3) is Closed and main valve PM 1 (1) is opened by on/off pilot EW (2), activated by an electric clock, a thermostat, etc.

If the pressure gets too high, constant pressure pilot CVP (HP) (4) will open main valve PM 1 (3) so that part of the hot gas can flow towards the main condenser.

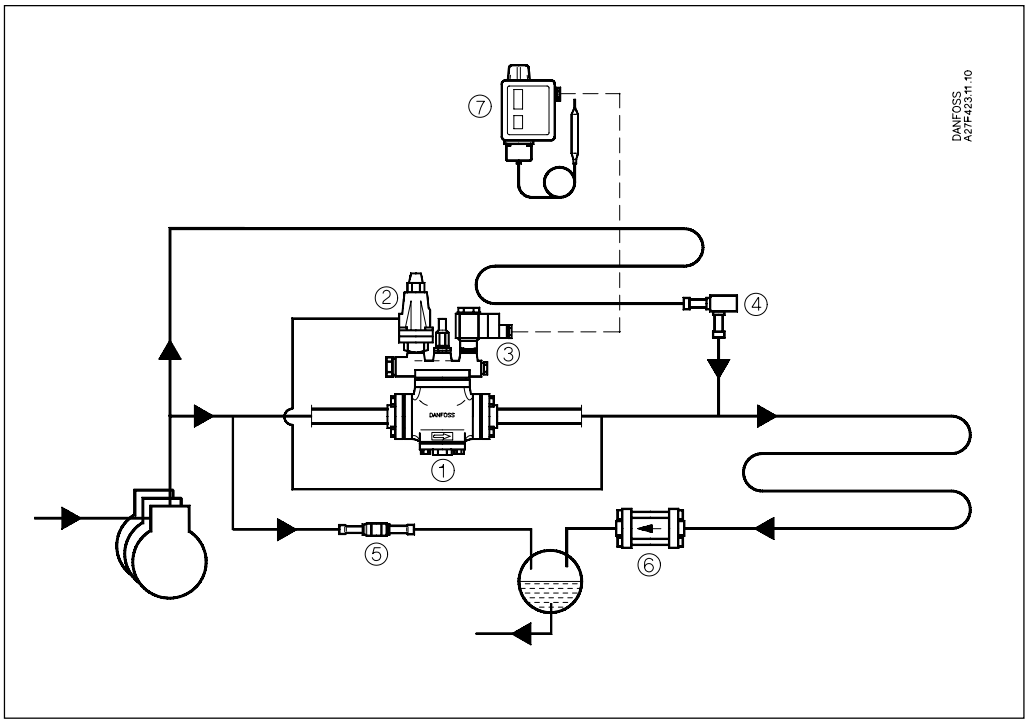
In summertime the heat recovery condenser is idle for extended periods of time.

To avoid the risk of accumulation of liquid in this condenser, a solenoid valve EVR (8) with capillary tube or throttling orifice ensures periodic evaporation of any condensate in the recovery condenser.

Differential pressure valve NRD (6) and check valve NRV (7) operate as described in application E1 (Condensing pressure regulation).

Setting
See application E1 (Condensing pressure regulation).

G2
Heat recovery



Condensers mounted in series (a)

This heat recovery system is applicable to central refrigeration plant with several compressors.

Product list

(1)	PM 3	Main valve (modulating)
(2)	CVPP (HP)	Differential pressure pilot
(3)	EVM	On/off pilot
(4)	NRV	Check valve
(5)	NRD	Differential pressure valve
(6)	NRVA	Check valve
(7)	RT	Thermostat

Function
As long as only a small proportion of compressor capacity is used, all gas will pass through the recovery condenser and then to the aircooled main condenser.

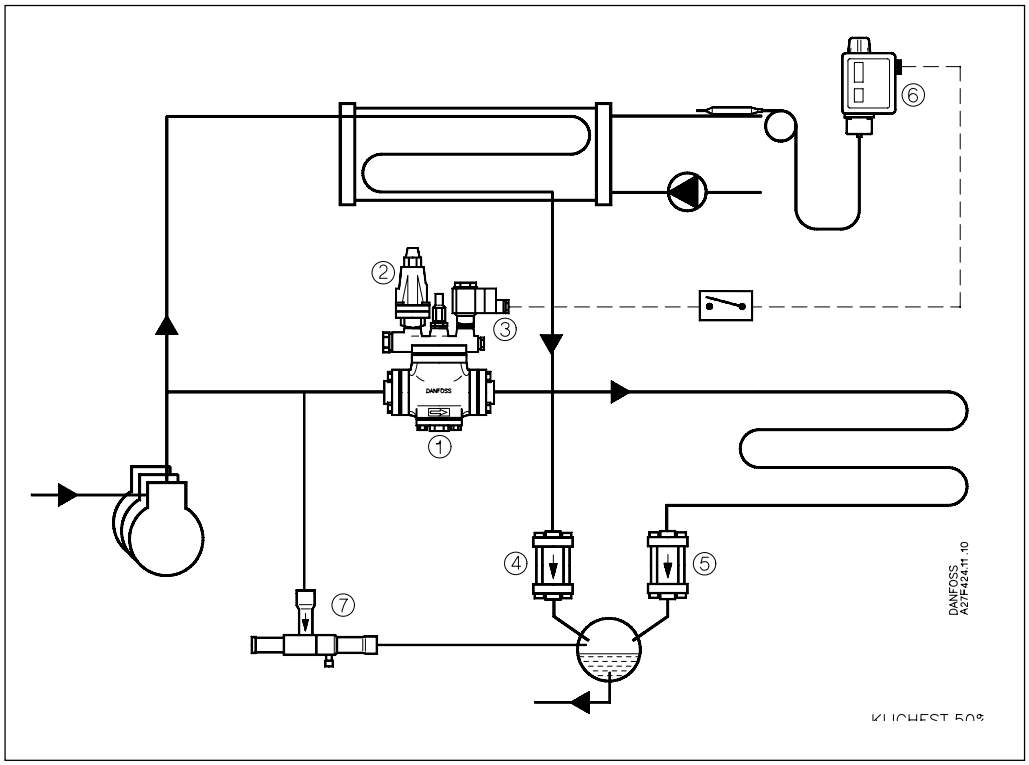
The greater the amount of compressor capacity used, the higher becomes the pressure drop in the recovery condenser. When this pressure drop exceeds the setting of differential pressure pilot CVPP (2), main valve PM 3 (1) partially opens and excess pressure gas is led direct into the main condenser.

When the desired water or air temperature has been reached by means of the heat recovery condenser, thermostat RT (7) activates on/off pilot EVM (3), and main valve PM 3 (1) will open fully.

Valves (4), (5) and (6) operate as described in application E1 (Condensing pressure regulations).

Setting
See application E1
(Condensing pressure regulation)

H1
Heat recovery



Condensers mounted in parallel (b)

This heat recovery system is applicable to systems with several compressors - e.g for the heating of central heating water.

Product list

(1)	PM 3	Main valve (modulating)
(2)	CVP (HP)	Constant pressure pilot
(3)	EVM	On/off pilot
(4)	NRVA	Check valve
(5)	NRVA	Check valve
(6)	RT	Thermostat
(7)	KVD	Modulating high-pressure regulator

Function
In normal operation main valve PM 3 (1) is kept open by on/off pilot EVM (3), activated by an external control connected to thermostat RT (6).

In wintertime, when the heating demand necessitates heat recovery, on/off pilot EVM (3) is closed, which in turn causes main valve PM 3 (1) to close.

If the condensing pressure exceeds the setting of constant pressure pilot CVP (HP) (2), main valve PM 3 (1) will open and excess pressure gas will be led to the main condenser.

Check valves NRVA (4) and (5) prevent flowback of refrigerant to the condensers.

Setting
See application E1 (Condensing pressure regulation).

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