Contents

Foreword

The application guide is designed to be used as a reference document. The guide aims to provide answers to the various questions relating to industrial refrigeration system control and in answering these questions, the principles of the different control methods are introduced followed by some control examples, comprising Danfoss Industrial Refrigeration products. It is non capacity and performance related and operating parameters of each application should be considered accordingly before adopting any particular layout.

Not all valves are shown and the application drawings are not to be used for construction purposes.

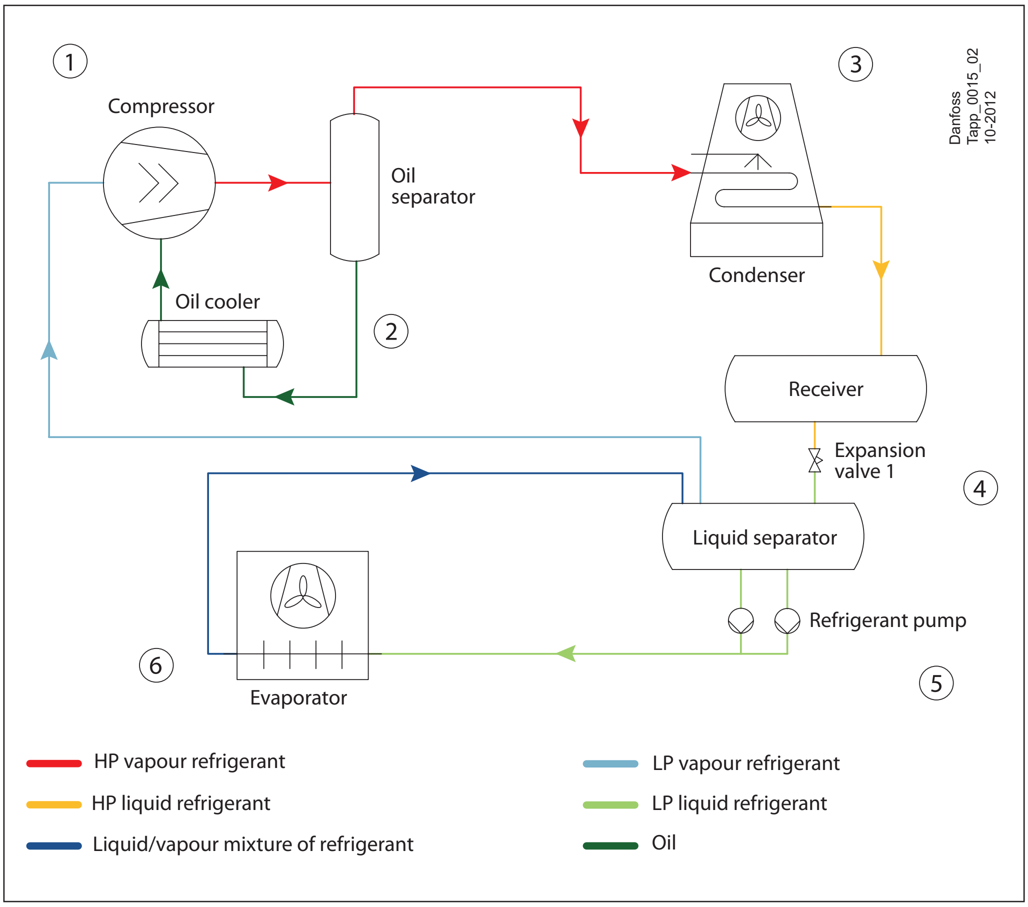
For the final design of the installation it is necessary to use other tools, such as the manufacturer's catalogues and calculation software (e.g. Danfoss Industrial Refrigeration catalogue and DIRcalc software).

DIRcalc is the software for calculation and selection of Danfoss Industrial Refrigeration valves. DIRcalc is delivered free of charge. Please contact your local Danfoss sales company.

Please do not hesitate to contact Danfoss, if you have questions about control methods, application and controls described in this application guide.

1. Introduction

Refrigeration System with Pump Circulation



① Compressor Control

Why?

- Primary: to control the suction pressure;
- Secondary: reliable compressor operation (start/stop, etc.)

How?

- Control the compressor capacity according to the refrigeration load by means of bypassing hot gas from the HP side back into the LP side, compressor ON/OFF step control or controling the rotating speed of the compressor;
- Install check valve on the discharge line in order to prevent reverse flow of the refrigerant to the compressor;
- Keep pressures and temperatures on the inlet and outlet of the compressor within the working range.

② Oil control

Why?

- Keep optimal oil temperature and pressure in order to guarantee reliable compressor operation.

How?

- Pressure: maintain and control the pressure differential across the compressor for oil circulation, maintain the crankcase pressure (only for piston compressors);
- Temperature: bypass some oil around the oil cooler; control the cooling air or water to the oil cooler;
- Level: return the oil in ammonia systems and low temperature fluorinated systems.

1. Introduction
(continued)

③ Condenser Control

Why?

– Maintain the condensing pressure above the minimum acceptable value in order to guarantee sufficient flow through the expansion devices;

– Ensure the right distribution of the refrigerant in the system.

How?

– On/off operation or control the speed of the condenser fans, control the flow of the cooling water, flood the condensers with liquid refrigerant.

④ Liquid Level Control

Why?

– Provide the correct flow of liquid refrigerant from the high pressure side to the low pressure side according to the actual demand;

– Ensure safe and reliable operation of the expansion devices.

How?

– Control the opening degree of the expansion device according to the change of the liquid level.

⑤ Refrigerant Pump Control

Why?

– Maintain the pump running in trouble free mode by maintaining the flow through the pump within the permissible operating range;

– Maintain a constant differential pressure across the pump in some systems.

How?

– Design a bypass loop so that the flow can be maintained above the minimum permissible flow;

– Shut off the pump if it fails to build up enough differential pressure.

– Install a pressure regulating valve.

⑥ Evaporating System Control

Why?

– Primary: maintain a constant media temperature;

– Secondary: optimise operation of the evaporators;

– For direct expansion systems: guarantee that no liquid refrigerant from the evaporators enters the suction line of the compressor.

How?

– Change the flow rate of the refrigerant into evaporators according to the demand;

– Defrost evaporators.

⑦ Safety Systems

Why?

– Avoid unintended pressure of the vessels;

– Protect the compressor from being damaged by liquid hammering, overloading, oil shortage and high temperature, etc;

– Protect the pump from being damaged by cavitation.

How?

– Install safety relief valve on vessels and other necessary places;

– Shut off the compressor and pump if the inlet/outlet pressure or differential is out of permissible range;

– Shut off the system of part of the system when the level in the liquid separator or the receiver exceeds the permissible level.

2. Compressor Controls

The compressor is the "heart" of the refrigeration system. It has two basic functions:
1. Maintain the pressure in the evaporator so that the liquid refrigerant can evaporate at the required temperature;
2. Compress the refrigerant so that it can be condensed at a normal temperature.

The basic function of compressor control, therefore, is to adjust the capacity of the compressor to the actual demand of the refrigeration system so that the required evaporating temperature can be maintained.

If the compressor capacity is bigger than the demand, the evaporating pressure and temperature will be lower than that required, and vice versa.

Additionally, the compressor should not be allowed to operate outside of the acceptable temperature and pressure range, in order to optimise its running conditions.

2.1 Compressor Capacity Control

The compressor in a refrigeration system is normally selected to be able to satisfy the highest possible cooling load. However, the cooling load during normal operation is usually lower than the design cooling load. This means that it is always necessary to control the compressor capacity so that it matches the actual heat load. There are several common ways to control the compressor capacity:

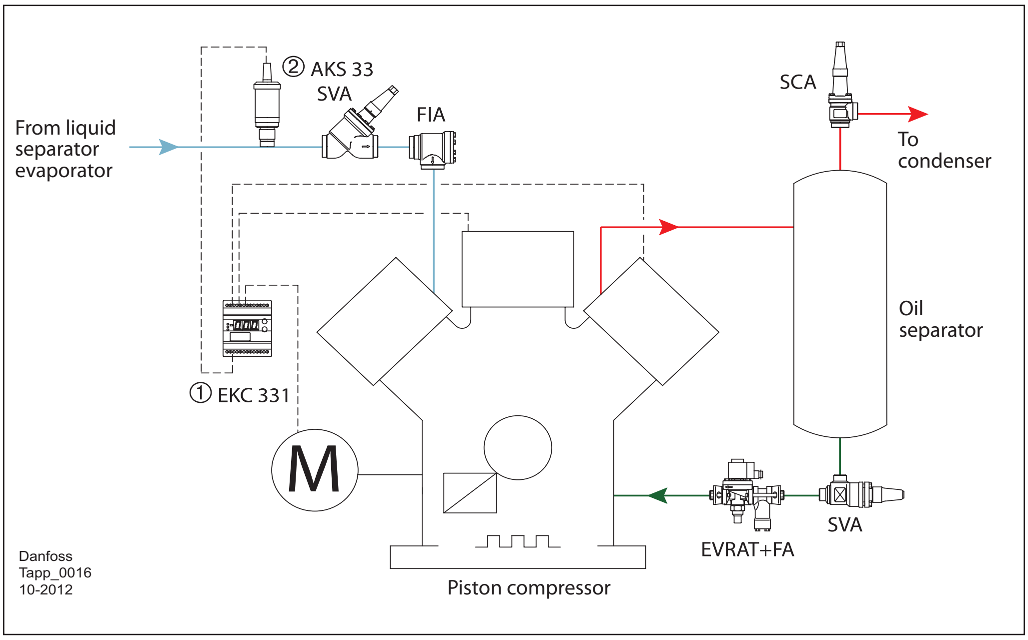
1. Step control.
This means to unload cylinders in a multi-cylinder compressor, to open and close the suction ports of a screw compressor, or to start and stop some compressors in a multi-compressor system. This system is simple and convenient. Furthermore, efficiency decreases very little during part-load. It is especially applicable to systems with several multi-cylinder reciprocating compressors.

2. Slide valve control.
The most common device used to control the capacity of a screw compressor is the slide valve. The action of the oil-driven slide valve allows part of the suction gas to avoid from being compressed. The slide valve permits a smooth and continuous modulation of capacity from 100% down to 10%, but the efficiency drops at part load.

3. Variable speed control.
Variable speed regulation. This solution is applicable to all kinds of compressors, and is efficient. A two-speed electric motor or a frequency converter can be used to vary the speed of the compressor. The two-speed electric motor regulates the compressor capacity by running at the high speed when the heat load is high (e.g. cooling down period) and at the low speed when the heat load is low (e.g. storage period). The frequency converter can vary the rotation speed continuously to satisfy the actual demand. The frequency converter observes limits for min. and max. speed, temperature and pressure control, protection of compressor motor as well as current and torque limits. Frequency converters offer a low start up current.

4. Hot gas bypass.
This solution is applicable to compressors with fixed capacities and more typical for commercial refrigeration. In order to control the refrigeration capacity, part of the hot gas flow on the discharge line is bypassed into the low pressure circuit. This helps to decrease the refrigeration capacity in two ways: by diminishing the supply of liquid refrigerant and releasing some heat into the low pressure circuit.

Application example 2.1.1: Step control of compressor capacity



HP vapour refrigerant
LP vapour refrigerant
Oil

① Step Controller
② Pressure Transmitter

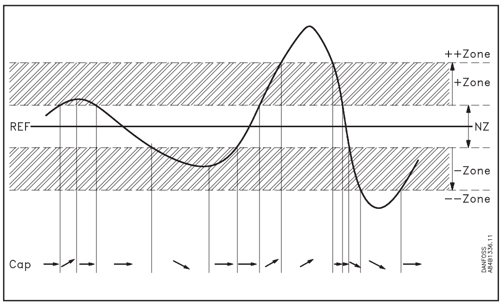
Step control solution for compressor capacity can be achieved by using a step controller EKC 331 ①. EKC 331 is a four-step controller with up to four relay outputs. It controls the loading/unloading of the compressors/pistons or the electric motor of the compressor according to the suction pressure signal from the pressure transmitter AKS 33 ② or AKS 32R. Based on a neutral zone control, EKC 331 can control a pack system with up to four equally sized compressor steps or alternatively two capacity controlled compressors (each having one unload valve).

EKC 331T version can accept a signal from a PT 1000 temperature sensor, which may be necessary for secondary systems.

Neutral Zone Control
A neutral zone is set around the reference value, in which no loading/unloading occurs.
Outside the neutral zone (in the hatched areas "+zone" and "- zone") loading/unloading will occur as the measure pressure deviates away from the neutral zone settings.

If control takes place outside the hatched area (named ++zone and --zone), changes of the cut-in capacity will occur somewhat faster than if it were in the hatched area.

For more details, please refer to the manual of EKC 331(T) from Danfoss.



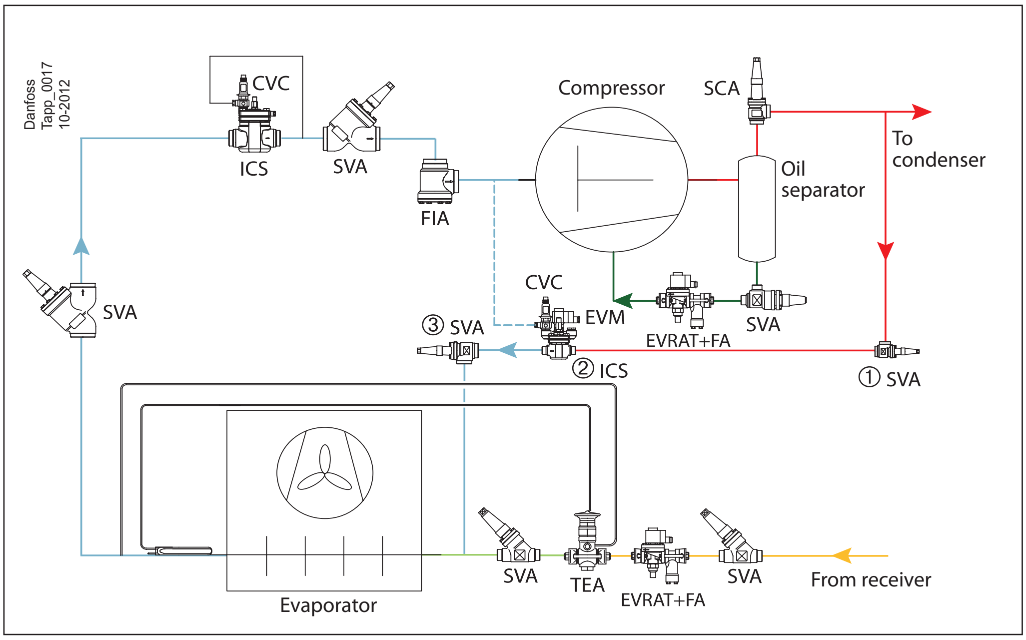
Technical data

	Pressure transmitter-AKS 33	Pressure transmitter-AKS 32R
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	–1 to 34	–1 to 34
Max. working pressure PB [bar]	55 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 85	
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	
Rated output signal	4 to 20 mA	10 to 90% of V supply

	Pressure transmitter - AKS 3000	Pressure transmitter - AKS 32
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	0 to 60 (depending on range)	–1 to 39 (depending on range)
Max. working pressure PB [bar]	100 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 80	–40 to 85
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	LP: –30 to +40 / HP: 0 to +80
Rated output signal	4 to 20 mA	1 to 5V or 0 to 10V

Not all valves are shown.
Not to be used for construction purposes.

Application example 2.1.2: Compressor capacity control by hot gas bypass



- HP vapour refrigerant
- HP liquid refrigerant
- LP vapour refrigerant
- LP liquid refrigerant
- Oil

① Stop valve
② Capacity regulator
③ Stop valve

Hot gas bypass can be used to control the refrigeration capacity for compressors with fixed capacity. The pilot-operated servo valve ICS ② with a CVC pilot valve is used to control the hot gas bypass flow according to the pressure on the suction line. The CVC is a back pressure controlled pilot valve, which opens the ICS and increases the flow of hot gas when the suction pressure is below the set value. In this way, the suction pressure ahead of the compressor is kept constant, therefore the refrigeration capacity satisfies the actual cooling load.

Technical data

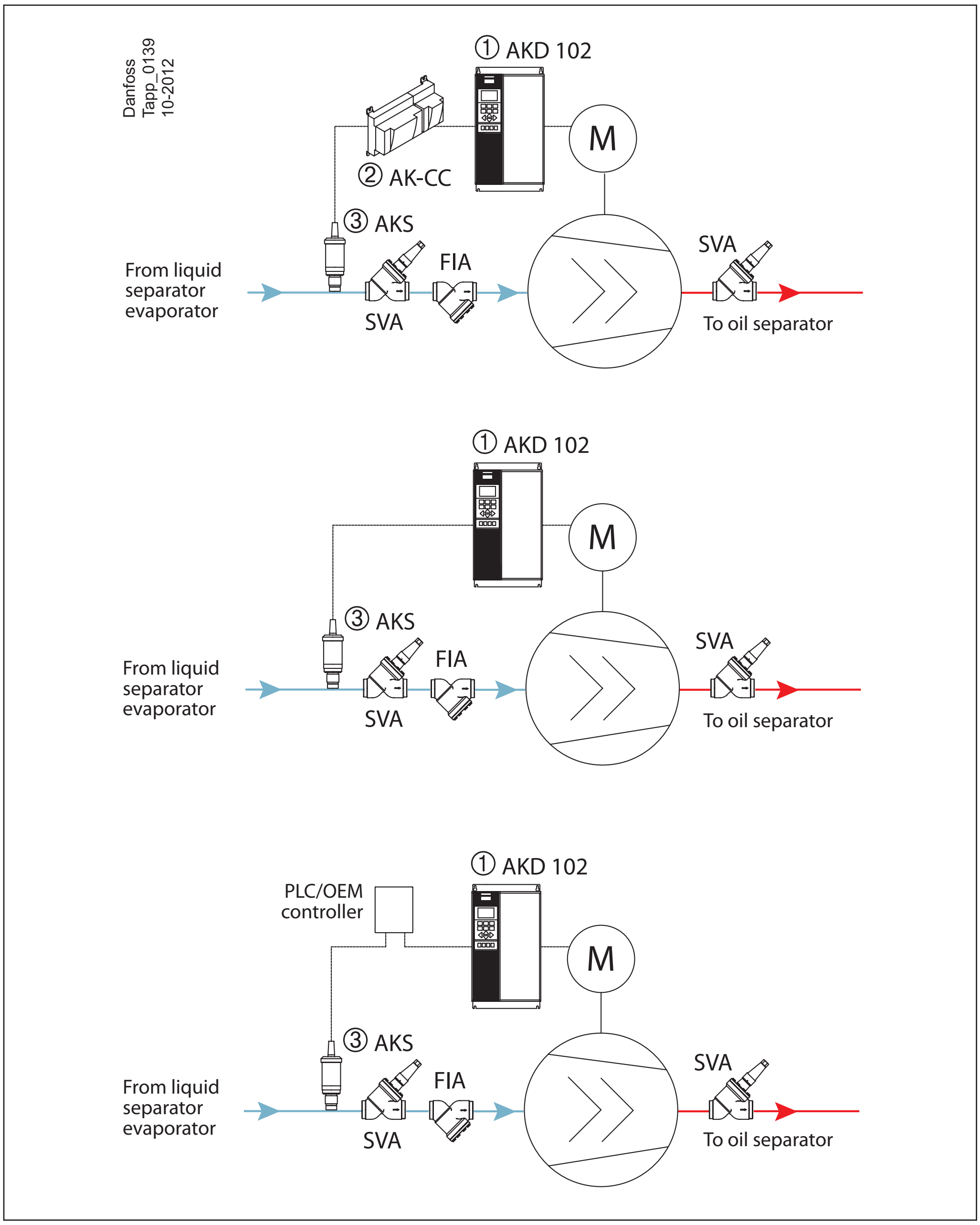
	Pilot-operated servo valve - ICS
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to +120
Max. working pressure [bar}	52
DN [mm]	20 to 150

	Pilot valve - CVC (LP)
Refrigerants	All common refrigerants
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	High pressure side: 28 Low pressure side: 17
Pressure range [bar]	–0.45 to 7
K_v value [m^3/h]	0.2

	Pilot valve - CVC (XP)
Refrigerants	All common refrigerants
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	High pressure side: 52 Low pressure side: 28
Pressure range [bar]	4 to 28
K_v value [m^3/h]	0.2

Not all valves are shown.
Not to be used for construction purposes.

Application example 2.1.3: Compressor variable speed capacity control



HP vapour refrigerant
LP vapour refrigerant

① Frequency converter
② Controller
③ Pressure transducer

Frequency converter control offer the following advantages:

- Energy savings
- Improved control and product quality
- Noise reduction
- Longer lifetime
- Simplified installation
- Easy to use complete control of the system

Technical data

	Frequency converter AKD 102		Frequency converter VLT FC 102 / FC 302
kW rating	1.1 kW to 45 kW	1.1 kW to 250 kW	Up to 1200 kW
Voltage	200-240 V	380-480 V	200-690 V

Not all valves are shown.
Not to be used for construction purposes.

2.2 Discharge Temperature Control with Liquid Injection

Compressor manufacturers generally recommend limiting the discharge temperature below a certain value to prevent overheating of values, prolonging their life and preventing the breakdown of oil at high temperatures.

From the log p-h diagram, it can be seen that the discharge temperature may be high when:

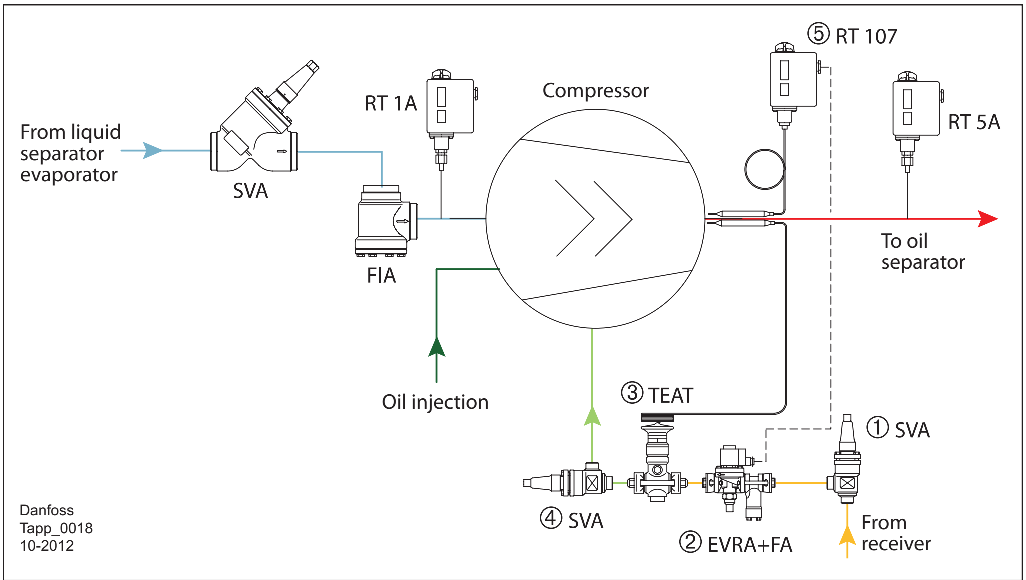
- the compressor runs with high pressure differential.
- the compressor receives highly superheated suction vapour.
- the compressor runs with capacity control by hot gas bypass.

There are several ways to reduce the discharge temperature. One way is to install water cooled heads in reciprocating compressors, another method is liquid injection, by which liquid refrigerant from the outlet of the condenser or receiver is injected into the suction line, the intermediate cooler, or the side port of the screw compressor.

Application example 2.2.1: Liquid injection with thermostatic injection valve

HP vapour refrigerant
HP liquid refrigerant
LP vapour refrigerant
LP liquid refrigerant
Oil

① Stop valve
② Solenoid valve
③ Thermostatic injection valve
④ Stop valve
⑤ Thermostat



When the discharge temperature rises above the set value of the thermostat RT 107 ⑤, RT 107 will energise the solenoid valve EVRA ② which will start liquid injection into the side port of the screw compressor.

The thermostatic injection valve TEAT ③ controls the injected liquid flow according to the discharge temperature, which prevents the discharge temperature from rising further.

Technical data

	Thermostat - RT
Refrigerants	R717 and fluorinated refrigerants
Enclosure	IP 66/54
Max. bulb temp. [°C]	65 to 300
Ambient temp. [°C]	–50 to 70
Regulating range [°C]	–60 to 150
Differential Δt [°C]	1.0 to 25.0

	Thermostatic injection valve - TEAT
Refrigerants	R717 and fluorinated refrigerants
Regulating range [°C]	Max. bulb temp.: 150°C P band: 20°C
Max. working pressure [bar]	20
Rated Capacity [kW]*	3.3 to 274

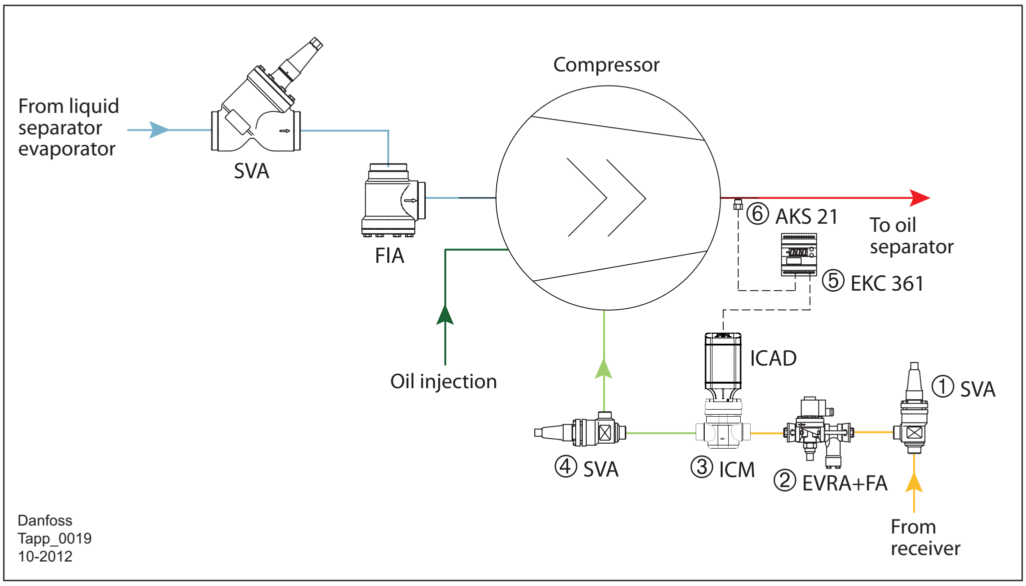
* Conditions: $T_e = +5°C$, $\Delta p = 8$ bar, $\Delta T_{sub} = 4°C$

Not all valves are shown.
Not to be used for construction purposes.

Application example 2.2.2: Liquid injection with motor valve

- HP vapour refrigerant
- HP liquid refrigerant
- LP vapour refrigerant
- LP liquid refrigerant
- Oil

① Stop valve
② Solenoid valve
③ Motor valve
④ Stop valve
⑤ Controller
⑥ Temperature sensor



An electronic solution for liquid injection control can be achieved with the motorised valve ICM ③. An AKS 21 PT 1000 temperature sensor ⑥ will register the discharge temperature and transmit the signal to the temperature controller EKC 361 ⑤. The EKC 361 controls the ICAD actuator which adjusts to opening degree of the ICM motor valve in order to limit and maintain the required discharge temperature.

Technical data

	ICM for expansion
Material	Body: Low temperature steel
Refrigerants	All common refrigerants including R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52 bar
DN [mm]	20 to 80
Nominal Capacity [kW]*	72 to 22,700

* Conditions: T_e = –10°C, Δp = 8.0 bar, ΔT_{sub} = 4K

	Actuator - ICAD
Media temp. range [°C]	–30 to 50 (ambient)
Control input signal	0/4-10mA, or 0/2-10
Open-close time with maximum selected speed	3 to 45 seconds depending on valve size

Not all valves are shown.
Not to be used for construction purposes.

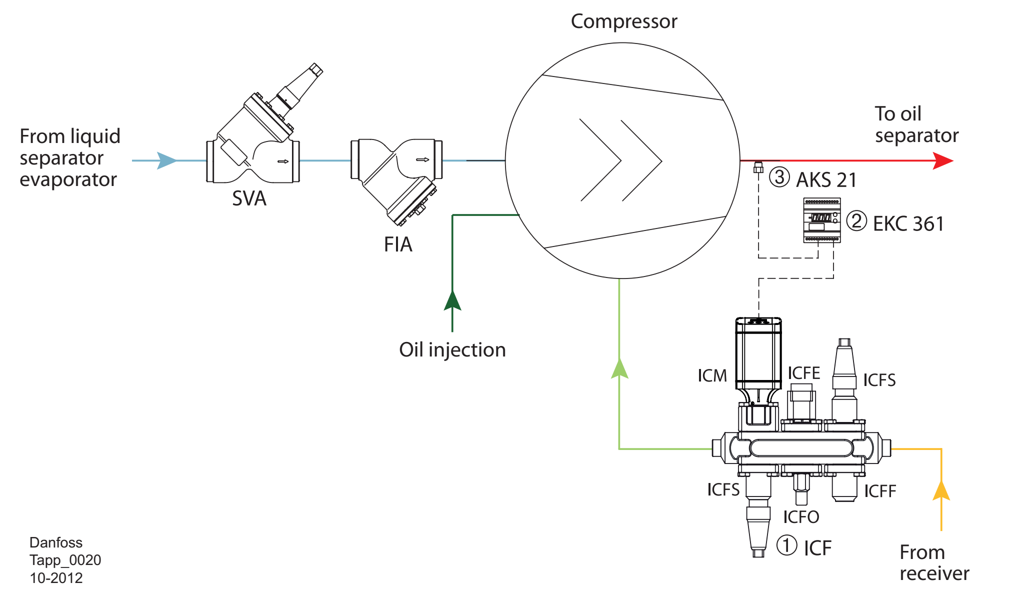
Application example 2.2.3: A compact solution for liquid injection with ICF

HP vapour refrigerant
HP liquid refrigerant
LP vapour refrigerant
LP liquid refrigerant
Oil

① Valve station with:

Stop valve
Filter
Solenoid valve
Manual opener
Motor valve
Stop valve

② Controller
③ Temperature sensor



For liquid injection, Danfoss can supply a very compact control solution ICF ①. Up to six different modules can be assembled into the same housing. This solution works in the same way as example 2.2.2, and is very compact and easy to install.

Technical data

	ICF control solution
Material	Body: Low temperature steel
Refrigerants	All common refrigerants including R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52 bar
DN [mm]	20 to 40

Not all valves are shown.
Not to be used for construction purposes.

2.3 Crankcase Pressure Control

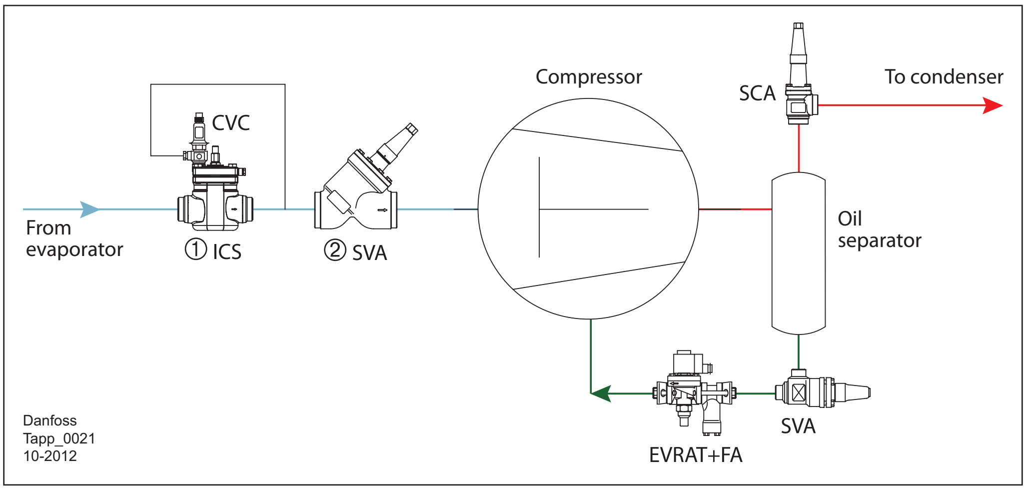
During start-up or after defrost, the suction pressure has to be controled, otherwise it can be too high, and the compressor motor will be overloaded.

The electric motor for the compressor may be damaged by this overloading.

There are two ways to overcome this problem:

1. Start the compressor at part load. The capacity control methods can be used to start compressor at part load, e.g. unload part of the pistons for multi-piston reciprocating compressors, or bypass some suction gas for screw compressors with slide valves, etc.
2. Control the crankcase pressure for reciprocating compressors. By installing a back pressure controlled regulating valve in the suction line, which will not open until the pressure in the suction line drops below the set value, suction pressure can be kept under a certain level.

Application example 2.3.1: Crankcase pressure control with ICS and CVC



HP vapour refrigerant
LP vapour refrigerant
Oil

① Crankcase pressure regulator
② Stop valve

In order to control the crankcase pressure during start-up, after defrost, or in others cases when the suction pressure may run too high, the pilot-operated servo valve ICS ① with the back pressure controlled pilot valve CVC is installed in the suction line. The ICS will not open until the downstream suction pressure falls below the set value of the pilot valve CVC. In this way, the high pressure vapour in the suction line can be released into the crankcase gradually, which ensures a manageable capacity for the compressor.

Technical data

	Pilot-operated servo valve - ICS
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to +120
Max. working pressure [bar]	52
DN [mm]	20 to 150
Capacity [kW]*	11 to 2440

* Conditions: T_e = –10°C, T_l = 30°C, Δp = 0.2 bar, ΔT_{sub} = 8K

	Pilot valve - CVC (LP)
Refrigerants	All common refrigerants
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	High pressure side: 28 Low pressure side: 17
Pressure range [bar]	–0.45 to 7
K_v value [m^3/h]	0.2

	Pilot valve - CVC (XP)
Refrigerants	All common refrigerants
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	High pressure side: 52 Low pressure side: 28
Pressure range [bar]	4-28
K_v value [m^3/h]	0.2

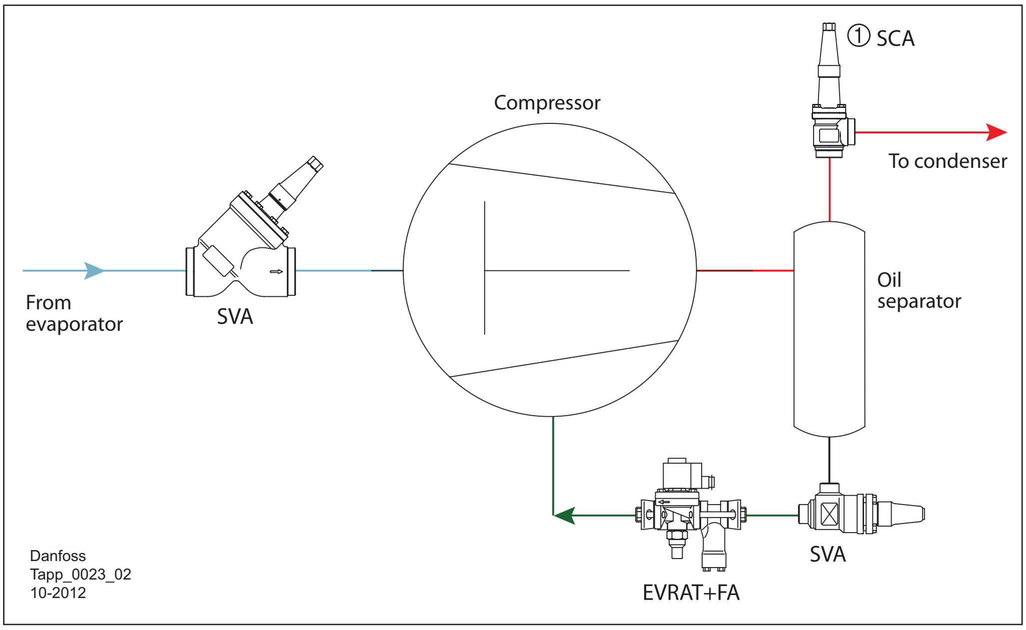
Not all valves are shown.
Not to be used for construction purposes.

2.4 Reverse Flow Control

Reverse flow and condensation of refrigerant from the condenser to the oil separator and the compressor should be avoided at all time. For piston compressors, reverse flow can result in liquid hammering. For screw compressors, reverse flow can cause reversed rotation and damage to the compressor bearings.

Furthermore, migration of refrigeration into the oil separator and further into the compressor at standstill should be avoided. To avoid this reverse flow, it is necessary to install a check valve on the outlet of the oil separator.

Application example 2.4.1: Reverse flow control



HP vapour refrigerant
LP vapour refrigerant
Oil

① Stop check valve

The stop check valve SCA ① can function as a check valve when the system is running, and can also shut off the discharge line for service as a stop valve. This combined stop/check valve solution is easier to install and has lower flow resistance compared to a normal stop valve plus check valve installation.

When selecting a stop check valve, it is important to note:

1. Select a valve according to the capacity and not the pipe size.
2. Consider both the nominal and part load working conditions. The velocity in the nominal condition should be near to the recommended value, at the same time the velocity in the part load condition should be higher than the minimum recommended velocity.

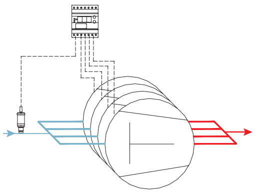
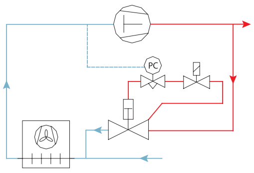
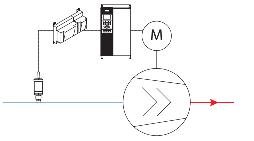
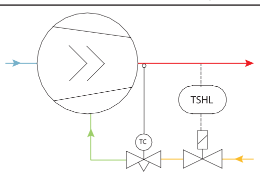
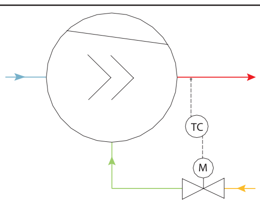
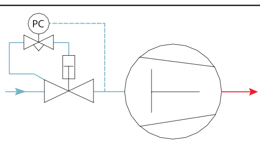
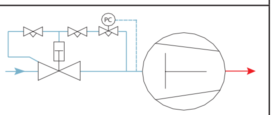
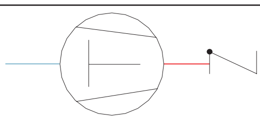
For details on how to select valves, please refer to the product catalogue.

Technical data

	Stop check valve - SCA
Material	Housing: special cold resistant steel approved for low temperature operation. Spindle: polished stainless steel
Refrigerants	All common non-flammable refrigerants, incl. R717.
Media temp. range [°C]	–60 to 150
Opening differential pressure [bar]	0.04 (0.3 bar spring availble as spare part)
Max. working pressure [bar]	52
DN [mm]	15 to 125

Not all valves are shown.
Not to be used for construction purposes.

2.5 Summary

Solution		Application	Benefits	Limitations
Compressor Capacity Control				
Step control of compressor capacity with EKC 331 and AKS 32/33		Applicable to multi-cylinder compressor, screw compressor with multiple suction ports, and systems with several compressors running in parallel.	Simple. Almost as efficient at part load as at full load.	The control is not continuous, especially when there are only few steps. Fluctuations in the suction pressure.
Compressor capacity control with hot gas bypass using ICS and CVC		Applicable to compressors with fixed capacities.	Effective to control the capacity continuously according to the actual heat load.The hot gas can help the oil return from the evaporator.	Not efficient at part load. Energy consuming.
Compressor variable speed capacity control		Applicable to all compressors with the ability to run at reduced speed.	Low start up current Energy savings Lower noise Longer lifetime Simplified installation	Compressor must be suited for reduced speed operation.
Discharge Temperature Control with Liquid Injection				
Mechanical solution for liquid injection with TEAT, EVRA(T) and RT		Applicable to systems where the discharge temperatures may run too high.	Simple and effective.	Injection of liquid refrigerant may be dangerous to the compressor. Not as efficient as intermediate cooler.
Electronic solution for liquid injection control with EKC 361 and ICM		Applicable to systems where the discharge temperatures may run too high.	Flexible and compact. Possible to monitor and control remotely.	Not applicable to flammable refrigerants. Injection of liquid refrigerant may be dangerous to the compressor. Not as efficient as intermediate cooler.
Electronic solution for liquid injection control with EKC 361 and ICF				
Crankcase Pressure Control				
Crankcase pressure control with ICS and CVC		Applicable to reciprocating compressors, normally used for small and medium systems.	Simple and reliable. Effective in protecting reciprocating compressors at start-up or after hot gas defrost.	Gives constant pressure drop in the suction line.
Crankcase pressure control with ICS and CVP				
Reverse Flow Control				
Reverse flow control with SCA		Applicable to all refrigeration plants.	Simple. Easy to install. Low flow resistance.	Gives constant pressure drop in the discharge line.

2.6
Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
AKD 102	PD.R1.B
AKS 21	RK0YG
AKS 33	RD5GH
CVC	PD.HN0.A
CVP	PD.HN0.A
EKC 331	RS8AG
EKC 361	RS8AE
EVRA(T)	PD.BM0.B

Type	Literature no.
ICF	PD.FT1.A
ICM	PD.HT0.B
ICS	PD.HS2.A
REG	PD.KM1.A
SCA	PD.FL1.A
SVA	PD.KD1.A
TEAT	PD.AU0.A

Product instruction

Type	Literature no.
AKD 102	MG11L
AKS 21	RI14D
AKS 32R	PI.SB0.A
AKS 33	PI.SB0.A
CVC-XP	PI.HN0.A
CVC-LP	PI.HN0.M
CVP	PI.HN0.C
EKC 331	RI8BE
EKC 361	RI8BF
EVRA(T)	PI.BN0.L

Type	Literature no.
ICF	PI.FT0.C
ICM 20-65	PI.HT0.A
ICM 100-150	PI.HT0.B
ICS 25-65	PI.HS0.A
ICS 100-150	PI.HS0.B
REG	PI.KM1.A
SCA	PI.FL1.A
SVA	PI.KD1.A
TEAT	PI.AU0.A

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3. Condenser Controls

In areas where there are large variations in ambient air temperatures and/or load conditions, it is necessary to control the condensing pressure to avoid it from falling too low. Too low condensing pressures results in there being insufficient pressure differential across the expansion device and the evaporator is supplied with insufficient refrigerant. It means that condenser capacity control is mainly used in the temperate climate zones and to a lesser degree in subtropical and tropical zones.

The basic idea of control is to control the condenser capacity when the ambient temperature is low, so that the condensing pressure is maintained above the minimum acceptable level.

This condensing capacity control is achieved either by regulating the flow of circulating air or water through the condenser, or by reducing the effective heat exchange surface area.

Different solutions can be designed for different types of condensers:
3.1 Air cooled condensers
3.2 Evaporative condensers
3.3 Water cooled condensers

3.1 Air Cooled Condensers

An air-cooled condenser consists of tubes mounted within a fin block. The condenser can be horizontal, vertical or V-shaped. The ambient air is drawn across the heat exchanger surface with axial or centrifugal fans.

Air-cooled condensers are used on industrial refrigeration systems where the relative air humidity is high. Controlling the condensing pressure for air-cooled condensers can be achieved in the following ways:

3.1.1 - Step Control of Air Cooled Condensers

The first method was using the required number of pressure controls in the form the Danfoss RT-5 and adjusting them to different set cut-in and cut-out pressures.

The second method of controlling the fans was by using a neutral zone pressure controller in the form of the Danfoss type RT-L. Initially it was used together with a step controller with the required number of contacts for the number of fans.

However this system reacted too fast and timers were used for delaying the cut-in and cut-out of the fans.

The Third method is today's step controller the Danfoss EKC-331.

3.1.2 - Fan speed control of air cooled condensers

This method of condenser fan control is mainly used whenever a reduction in noise level is desired due to environmental concerns.

For this type of installation Danfoss frequency converter AKD can be used.

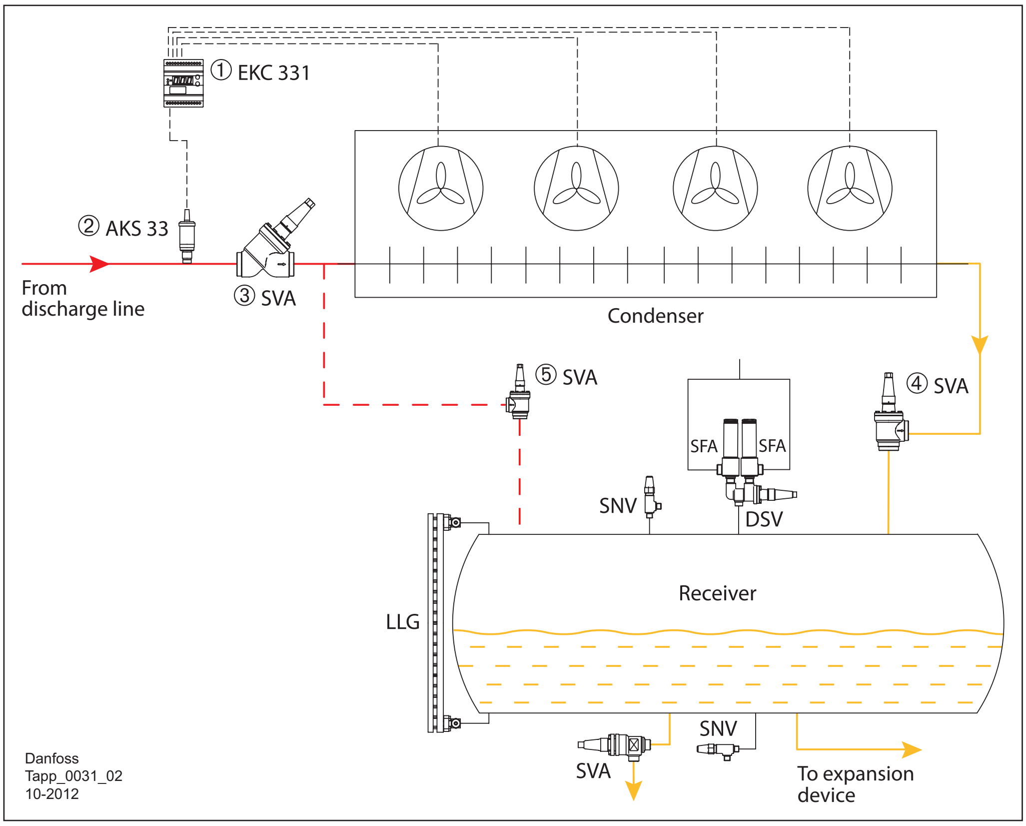
3.1.3 - Area control of air cooled condensers

For area or capacity control of air cooled condensers a receiver is required. This receiver must have sufficient volume to be able to accommodate the variations in the amount of refrigerant in the condenser.

Two ways this condenser area control can be done:

1. Main valve ICS or PM combined with the constant pressure pilot CVP(HP) mounted in the hot gas line on the inlet side to the condenser and ICV combined with a differential pressure pilot CVPP(HP) mounted in the pipe between the hot gas line and the receiver. In the pipe between the condenser and the receiver a check valve NRVA is mounted to prevent liquid migration from the receiver to the condenser.
2. Main valve ICS combined with the constant pressure pilot CVP(HP) mounted in the pipe between the condenser and the receiver and a ICS combined with a differential pressure pilot CVPP(HP) mounted in the pipe between the hot gas line and the receiver. This method is mainly used in commercial refrigeration.

Application example 3.1.1: Step control of fans with step controller EKC 331



HP vapour refrigerant
HP liquid refrigerant

① Step controller
② Pressure transmitter
③ Stop valve
④ Stop valve
⑤ Stop valve

EKC 331 ① is a four-step controller with up to four relay outputs. It controls the switching of the fans according to the condensing pressure signal from a pressure transmitter AKS 33 ② or AKS 32R. Based on neutral zone control, EKC 331 ① can control the condensing capacity so that the condensing pressure is maintained above the required minimum level.

For more information on neutral zone control, please refer to section 2.1.

The bypass pipe where SVA ⑤ is installed is an equalizing pipe, which helps balance the pressure in the receiver with the inlet pressure of the condenser so that the liquid refrigerant in the condenser can be drained into the receiver.

In some installations, EKC 331T is used. In this case the input signal could be from a PT 1000 temperature sensor, e.g. AKS 21. The temperature sensor is usually installed in the outlet of the condenser.

Note! The EKC 331T + PT1000 temperature sensor solution is not as accurate as the EKC 331 + pressure transmitter solution because the condenser outlet temperature may not entirely reflect the actual condensing pressure due to the liquid subcooling or the presence of incondensable gasses in the refrigeration system. If the subcooling is too low, flash gas may occur when the fans start.

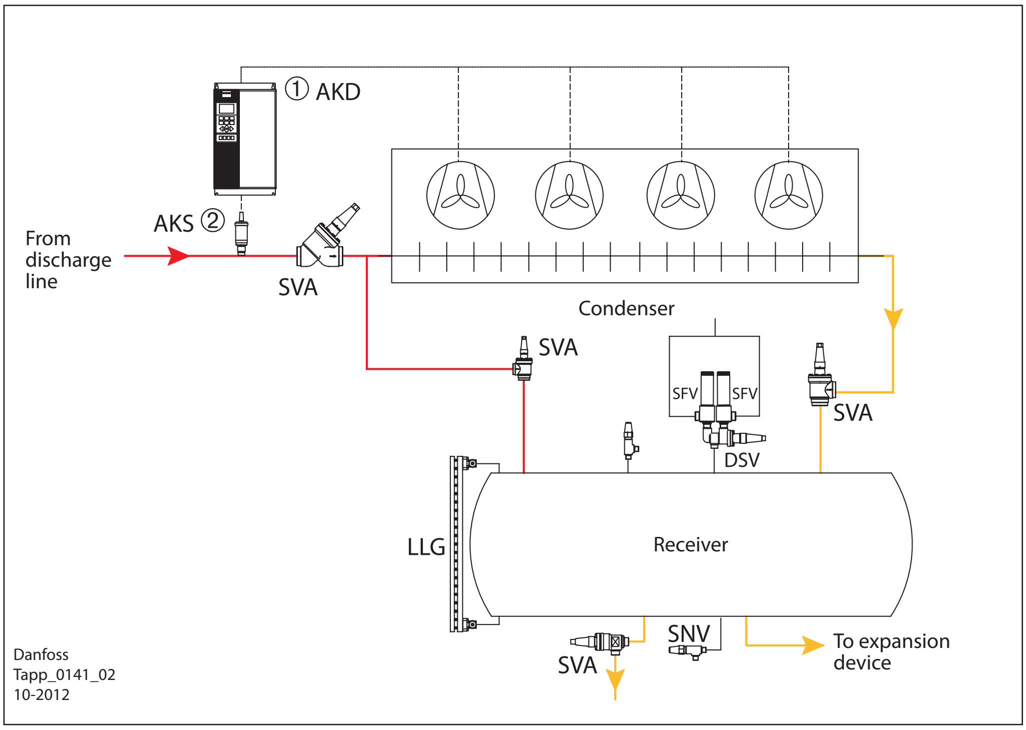
Technical data

	Pressure transmitter-AKS 33	Pressure transmitter-AKS 32R
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	–1 to 34	–1 to 34
Max. working pressure PB [bar]	55 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 85	
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	
Rated output signal	4 to 20 mA	10 to 90% of V supply

	Pressure transmitter - AKS 3000	Pressure transmitter - AKS 32
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	0 to 60 (depending on range)	–1 to 39 (depending on range)
Max. working pressure PB [bar]	100 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 80	–40 to 85
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	LP: –30 to +40 / HP: 0 to +80
Rated output signal	4 to 20 mA	1 to 5V or 0 to 10V

Not all valves are shown.
Not to be used for construction purposes.

Application example 3.1.2:
Fan speed control of air cooled condensers



HP vapour refrigerant
HP liquid refrigerant

① Frequency converter
② Pressure transducer

Frequency converter control offer the following advantages:

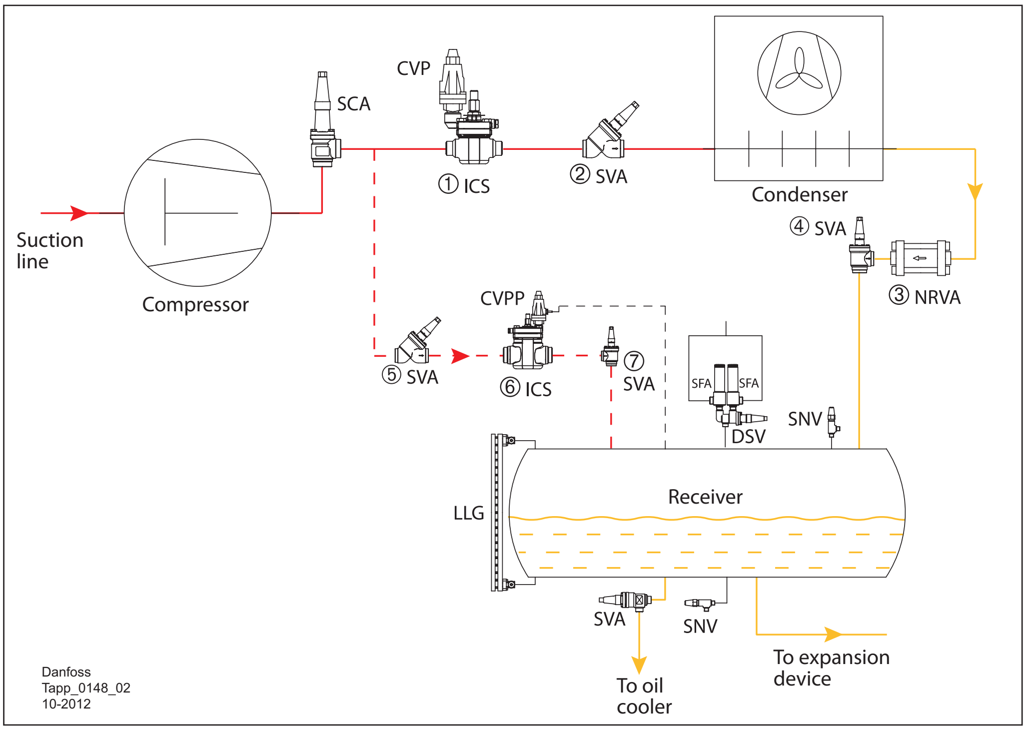
- Energy savings
- Improved control and product quality
- Noise reduction
- Longer lifetime
- Simplified installation
- Easy to use complete control of the system

Technical data

	Frequency converter AKD 102		Frequency converter VLT FC 102 / FC 302
kW rating	1.1 kW to 45 kW	1.1 kW to 250 kW	Up to 1200 kW
Voltage	200-240 V	380-480 V	200-690 V

Not all valves are shown.
Not to be used for construction purposes.

Application example 3.1.3: Area control of air cooled condensers



HP vapour refrigerant
HP liquid refrigerant

① Pressure regulator
② Stop valve
③ Check valve
④ Stop valve
⑤ Stop valve
⑥ Differential pressure regulator
⑦ Stop valve

This regulating solution maintains the pressure in the receiver at a sufficiently high level during low ambient temperatures.

The ICS pilot-operated servo valve ① opens when the discharge pressure reaches the set pressure on the CVP pilot valve. The ICS pilot-operated servo valve closes when the pressure drops below the set pressure of the CVP pilot valve.

The ICS pilot-operated servo valve ⑥ with the CVPP constant differential pressure pilot maintains sufficient pressure in the receiver. This differential pressure regulator ⑥ could also be an overflow valve OFV.

The NRVA check valve ③ ensures increased condenser pressure by liquid back up within the condenser. This requires a sufficiently large receiver. The NRVA check valve also prevents liquid flow from the receiver back into the condenser when the latter is colder during compressor shut-down periods

Technical data

	Pilot operated servo valve - ICS
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 150
Nominal capacity [kW]*	On discharge line: 20 to 3950 On HP liquid line: 179 to 37,000

* Conditions: R717, T_{liq}=30°C, $P_{disch.}$=12bar, ΔP=0.2bar, $T_{disch.}$=80°C, T_e=-10°C

	Differential pressure pilot valve-CVPP
Refrigerants	All common non-flammable refrigerants incl. R717
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	CVPP (LP): 17 CVPP (HP): up to 40
Regulating range [bar]	CVPP (LP): 0 to 7 CVPP (HP): 0 to 22
K_v value m^3/h	0.4

Not all valves are shown.
Not to be used for construction purposes.

Technical data (continued)

	Constant pressure pilot valve - CVP
Refrigerants	All common refrigerants including R717 and R744
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	CVP (LP): 17 CVP (HP): up to 40 CVP (XP): 52
Pressure range [bar]	CVP (LP): –0.66 to 7 CVP (HP): –0.66 to 28 CVP (XP): 25 to 52
K_v value m^3/h	CVP (LP): 0.4 CVP (HP): 0.4 CVP (XP): 0.2

	Overflow valve - OFV
Material	Body: steel
Refrigerants	All common refrigerants, incl. R717
Media temp. range [°C]	–50 to 150
Max. working pressure [bar]	40
DN mm	20/25
Opening differential pressure range [bar]	2 to 8

3.2 Evaporative Condensers

An evaporative condenser is a condenser cooled by ambient air combined with water sprayed through orifices and air baffles in counter flow with the air. The water evaporates and the evaporation effect of the water drops adds much to the condenser capacity

Today's evaporative condensers are enclosed in a steel or plastic enclosure with axial or centrifugal fans at the bottom or at the top of the condenser.

The heat exchanger surface in the wet air stream consists of steel pipes.
Above the water spray orifices (in the dry air) it is common to have a de-super heater made of steel pipes with fins to reduce the hot gas temperature before it reaches the heat exchanger in the wet air stream. In this way the building up of calcium scales on the surface of the main heat exchanger pipes is greatly reduced.

This type reduces the water consumption considerably compared to a normal water cooled condenser. Capacity control of an evaporative condenser can be achieved by either two speed fan or variable speed control of the fan and at very low ambient temperature conditions switching off the water circulation pump.

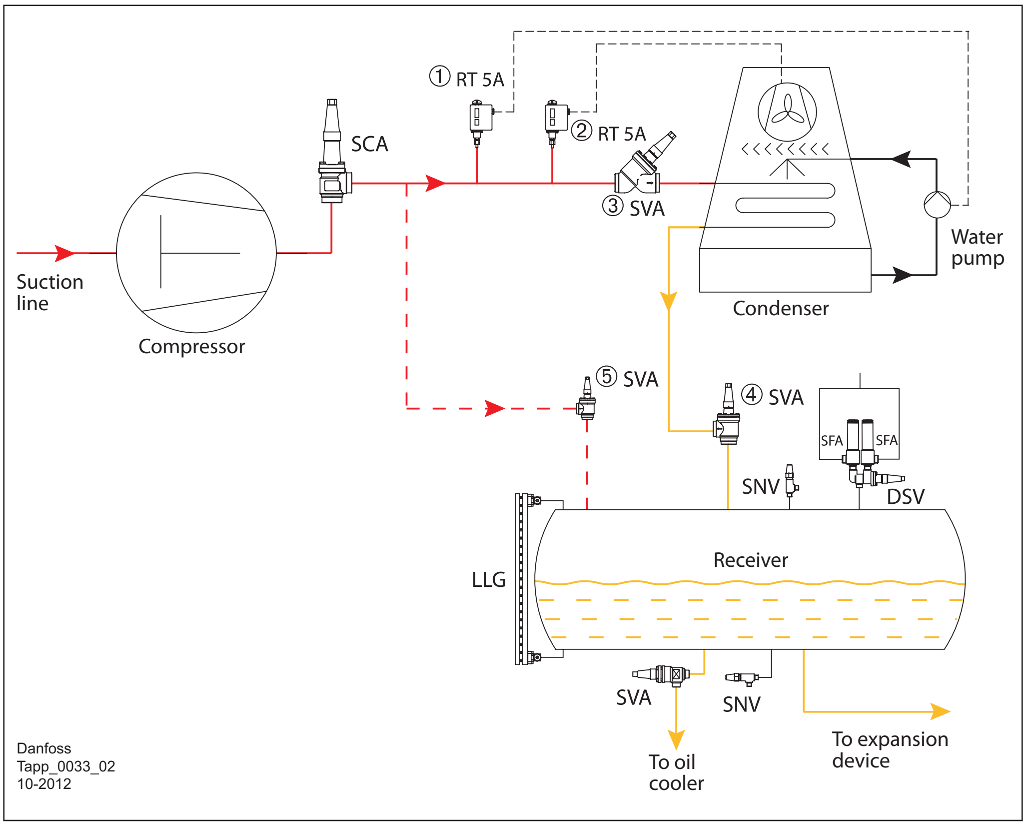
The use of evaporative condensers is limited in areas with high relative humidity. In cold surroundings (ambient temperatures < 0°C) frost damage prevention must be carried out by removing the water in the evaporative condenser.

3.2.1 - Control of Evaporative Condensers

Controlling the evaporative condensers condensing pressure or the condenser capacity can be achieved in different ways:

1. RT or KP pressure controls for fan and water pump control (as it was earlier).
2. RT-L neutral zone pressure control for fan and water pump control.
3. Step controller for controlling two speed fans and the water pump.
4. Frequency converters for fan speed control and water pump control.
5. Saginomiya flow-switch for alarm if water circulation fails.

Application example 3.2.1: Step control of evaporative condenser with pressure controller RT



HP vapour refrigerant
HP liquid refrigerant
Water

① Pressure controller
② Pressure controller
③ Stop valve
④ Stop valve
⑤ Stop valve

This solution maintains the condensing pressure, as well as the pressure in the receiver at a sufficiently high level in low ambient temperature.

When the inlet pressure of the condenser drops below the setting of the pressure controller RT 5A ②, the controller will switch off the fan, to decrease the condensing capacity.

In extremely low ambient temperature, when the condensing pressure drops below the setting of RT 5A ① after all the fans have been switched off, RT 5A ① will stop the water pump.

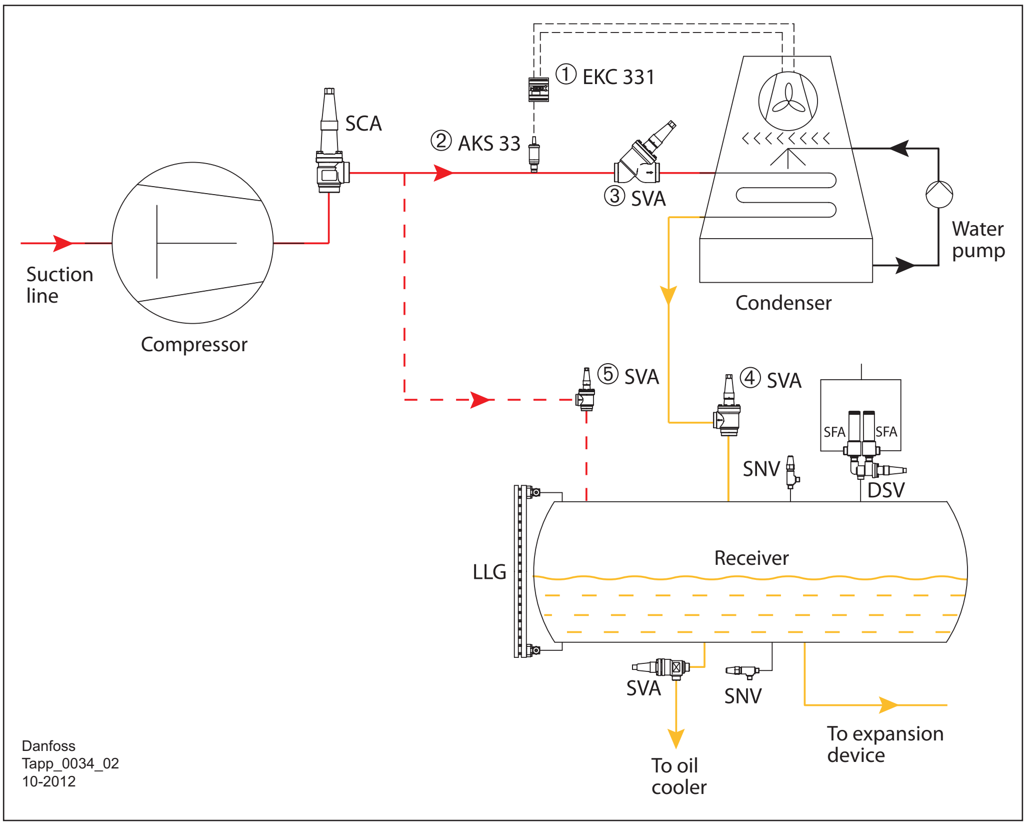
When the pump is stopped, the condenser and the water pipes should be drained to avoid scaling and freezing.

Technical data

	HP pressure control - RT 5A
Refrigerants	R717 and fluorinated refrigerants
Enclosure	IP 66/54
Ambient temp. [°C]	–50 to 70
Regulating range [bar]	RT 5A: 4 to 17
Max. working pressure [bar]	22
Max. test pressure [bar]	25

Not all valves are shown.
Not to be used for construction purposes.

Application example 3.2.2: Step control of evaporative condenser with step controller EKC331



HP vapour refrigerant
HP liquid refrigerant
Water

① Step controller
② Pressure transmitter
③ Stop valve
④ Stop valve
⑤ Stop valve

This solution works in the same way as example 3.2.1, but operated via step controller EKC 331 ①. For more information on EKC 331, please refer to page 7.

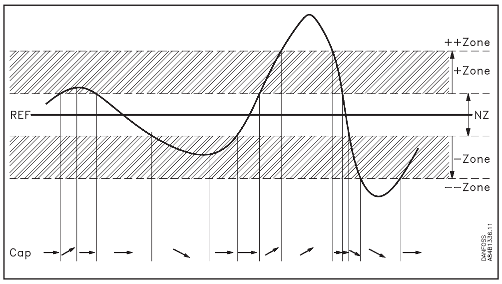
A capacity regulation solution for evaporative condensers can be achieved by using an EKC 331 power regulator and an AKS pressure transmitter. Sequential control for the water pump must be selected as the last step. Sequential control means that the steps will always cut in and out in the same order.

EKC 331T version can accept a signal from a PT 1000 temperature sensor, which may be necessary for secondary systems.

Neutral Zone Control
A neutral zone is set around the reference value, in which no loading/unloading occurs.
Outside the neutral zone (in the hatched areas "+zone" and "- zone") loading/unloading will occur as the measure pressure deviates away from the neutral zone settings.

If control takes place outside the hatched area (named ++zone and --zone), changes of the cut-in capacity will occur somewhat faster than if it were in the hatched area.

For more details, please refer to the manual of EKC 331(T) from Danfoss.



Technical data

	Pressure transmitter-AKS 33	Pressure transmitter-AKS 32R
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	–1 to 34	–1 to 34
Max. working pressure PB [bar]	55 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 85	
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	
Rated output signal	4 to 20 mA	10 to 90% of V supply

	Pressure transmitter - AKS 3000	Pressure transmitter - AKS 32
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	0 to 60 (depending on range)	–1 to 39 (depending on range)
Max. working pressure PB [bar]	100 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 80	–40 to 85
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	LP: –30 to +40 / HP: 0 to +80
Rated output signal	4 to 20 mA	1 to 5V or 0 to 10V

Not all valves are shown.
Not to be used for construction purposes.

3.3 Water Cooled Condensers

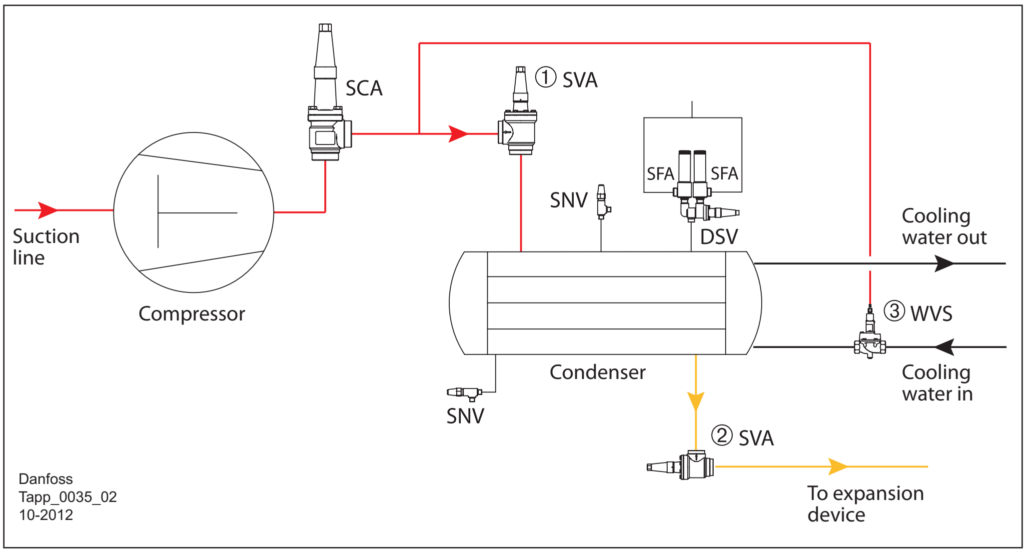
The water cooled condenser was originally a shell and tube heat exchanger, but today it is very often a plate heat exchanger of modern design.

Water cooled condensers are not commonly used, because in many places it is not allowed to use the large amount of water these types consume (water shortage and/or high prices for water).

Today water cooled condensers are popular in chillers, with the cooling water cooled by a cooling tower and re-circulated. It can also be used as a heat recovery condenser to supply hot water.

The control of the condensing pressure can be achieved by a pressure controlled water valve, or a motorised water valve controlled by an electronic controller to control the flow of the cooling water according to the condensing pressure.

Application example 3.3.1: Water flow control of water cooled condensers with a water valve



HP vapour refrigerant
HP liquid refrigerant
Water

① Stop valve
② Stop valve
③ Water valve

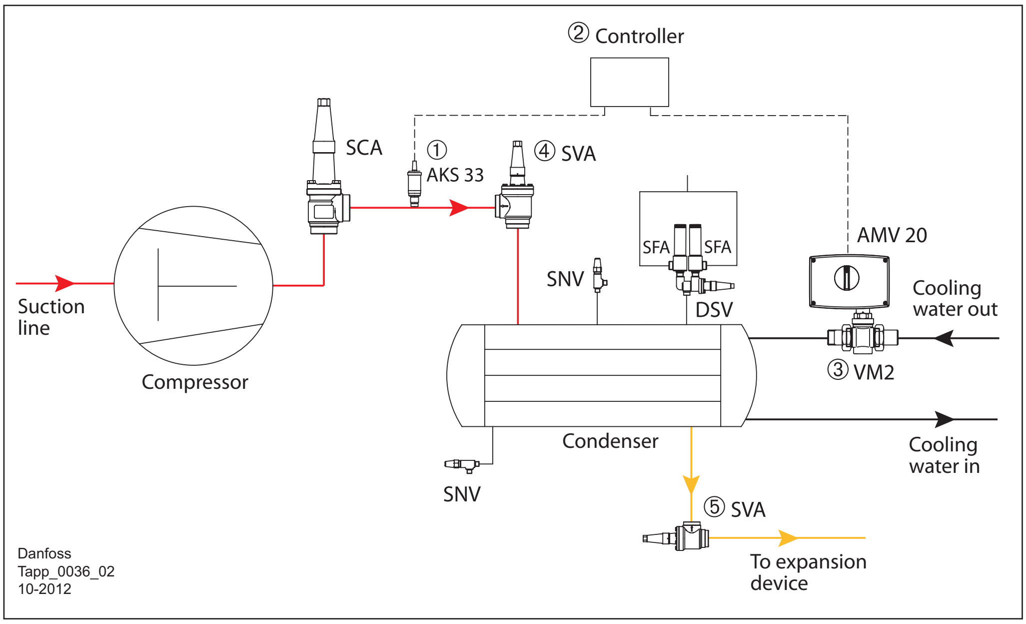
This solution maintains the condensing pressure at a constant level. The refrigerant condensing pressure is directed through a capillary tube to the top of the water valve WVS ③, and adjusts the opening of WVS ③ accordingly. The water valve WVS is a P-regulator.

Technical data

	Water valve - WVS
Materials	Valve body: cast iron Bellows: aluminium and corrosion-proofed steel
Refrigerants	R717, CFC, HCFC, HFC
Media	Fresh water, neutral brine
Media temp. range [°C]	–25 to 90
Adjustable closing pressure [bar]	2.2 to 19
Max. working pressure on refrigerant side [bar]	26.4
Max. working pressure on liquid side [bar]	10
DN [mm]	32 to 100

Not all valves are shown.
Not to be used for construction purposes.

Application example 3.3.2: Water flow control of water cooled condensers with a motor-valve



HP vapour refrigerant
HP liquid refrigerant
Water

① Pressure transmitter
② Controller
③ Motor-valve
④ Stop valve
⑤ Stop valve

The controller ② receives the condensing pressure signal from the pressure transmitter AKS 33 ①, and sends out a corresponding modulating signal to actuator AMV 20 of the motor valve VM 2 ③. In this way, the flow of cooling water is adjusted and the condensing pressure is kept constant.

In this solution, PI or PID control can be configured in the controller.

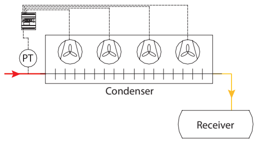
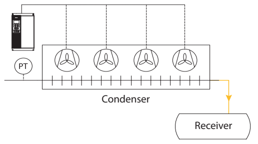
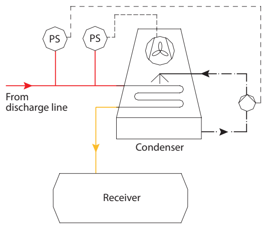
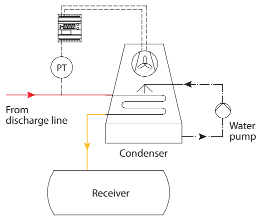
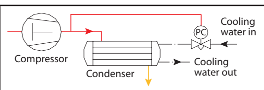
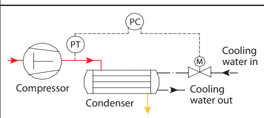
VM 2 and VFG 2 are motor-valves designed for district heating, and can also be used for water flow control in refrigeration plants.

Technical data

	Motor valve - VM 2
Material	Body: red bronze
Media	Circulation water/ glycolic water up to 30%
Media temp. range [°C]	2 to 150
Max. working pressure [bar]	25
DN [mm]	15 to 50

Not all valves are shown.
Not to be used for construction purposes.

3.4
Summary

Solution		Application	Benefits	Limitations
Air Cooled Condenser Control				
Step control of fans with step controller EKC331		Used mainly in industrial refrigeration in hot climates and to a much lesser degree in colder climates	Control of air volume in steps or with variable fan speed control; Energy saving; No use of water.	Very low ambient temperatures; Fan step control can be noisy.
Fan speed control of air cooled condensers		Applicable to all condensers with the ability to run at reduced speed.	Low start up current Energy savings Lower noise Longer lifetime Simplified installation	Very low ambient temperatures;
Evaporative Condenser Control				
Step control of evaporative condenser with pressure controller RT		Industrial refrigeration with very large capacity requirement	Large reduction in water consumption compared to water cooled condensers and relatively easy to capacity control; Energy saving.	Not applicable in countries with high relative humidity; In cold climates special precaution has to be taken so the water pipe is drained for water during water pump off periods.
Step control of evaporative condenser with step controller EKC331		Industrial refrigeration with very large capacity requirement	Large reduction in water consumption compared to water cooled condensers and relatively easy to capacity control; Possible to control remotely. Energy saving.	Not applicable in countries with high relative humidity; In cold climates special precaution has to be taken so the water pipe is drained for water during water pump off periods.
Water Cooled Condenser Control				
Liquid flow control with a water valve		Chillers, heat recovery condensers	It is easy to capacity control	Not applicable when water availability is a problem.
Liquid flow control with a motor valve		Chillers, heat recovery condensers	It is easy to capacity control the condenser and the heat recovery; Possible to control remotely.	This type of installation is more expensive than a normal set up; Not applicable when water availability is a problem.

3.5
Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
AKD 102	PD.R1.B
AKS 21	RK0YG
AKS 33	RD5GH
AMV 20	ED95N
CVP	PD.HN0.A
CVPP	PD.HN0.A

Type	Literature no.
ICS	PD.HS2.A
NRVA	PD.FK0.A
RT 5A	PD.CB0.A
SVA	PD.KD1.A
VM 2	ED97K
WVS	PD.DA0.A

Product instruction

Type	Literature no.
AKD 102	MG11L
AKS 21	RI14D
AKS 32R	PI.SB0.A
AKS 33	PI.SB0.A
AMV 20	EI96A
CVP, CVPP	PI.HN0.C
CVP-XP	PI.HN0.J

Type	Literature no.
ICS 25-65	PI.HS0.A
ICS 100-150	PI.HS0.B
NRVA	PI.FK0.A
RT 5A	RI5BC
SVA	PI.KD1.A
VM 2	VIHBC
WVS	PI.DA0.A

To download the latest version of the literature please visit the Danfoss website.

4. Liquid Level Control

Liquid level control is an important element in the designing of industrial refrigeration systems. It controls the liquid injection to maintain a constant liquid level.

Two main different principles may be used when designing a liquid level control system:

- High pressure liquid level control system (HP LLRS)
- Low pressure liquid level control system (LP LLRS)

High pressure liquid level control systems are typically characterised by:
1. Focus on the liquid level on the condensing side of the system
2. Critical refrigerant charge
3. Small receiver or even no receiver
4. Applies mainly to chiller units and other systems with small refrigerant charge (for example, small freezers)

Low pressure systems are typically characterized by:
1. Focus on the liquid level on the evaporating side of the system
2. Receiver is usually big
3. Large (enough) charge of refrigerant
4. Mainly applied to de-centralized systems

Both principles can be achieved, using mechanical and electronic components

4.1 High Pressure Liquid Level Control System (HP LLRS)

When designing a HP LLRS, the following points have to be taken into consideration:

As soon as liquid is "formed" in the condenser the liquid is fed to the evaporator (low pressure side).

The liquid leaving the condenser will have little or no sub-cooling. This is important to consider when the liquid flows to the low pressure side. If there is pressure loss in the piping or the components, flash-gas may occur and cause the flow capacity to be reduced.

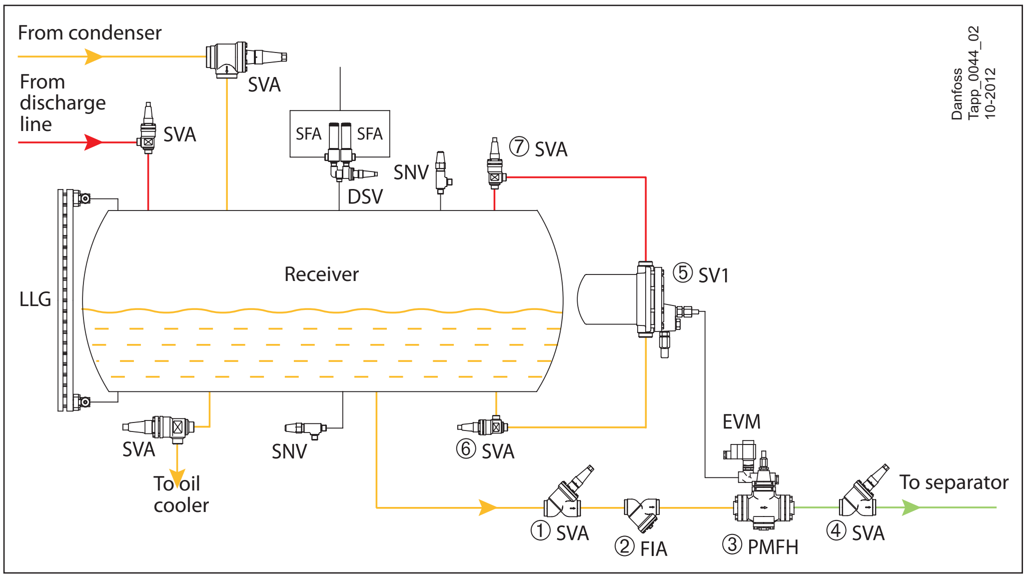
The refrigerant charge must be precisely calculated in order to ensure that there is adequate refrigerant in the system. An overcharge increases the risk of flooding the evaporator or the liquid separator causing liquid carry over into the compressor (liquid hammering). If the system is undercharged the evaporator will be starved. The size of the low pressure vessel (liquid separator/ shell-tube evaporator) must be carefully designed so that it can accommodate the refrigerant in all conditions without causing liquid hammering.

Because of the above reasons, HP LLRS are especially suitable for systems requiring small refrigerant charge, like chiller units, or small freezers. Chiller units usually do not need receivers. As a result of the above, HP LLRS are especially suitable for systems requiring a small refrigerant charge, e.g. liquid chiller units, or small freezers. Liquid chiller units usually do not need receivers, however, if a receiver is necessary in order to install pilots and provide refrigerant to an oil cooler, the receiver could be physically small.

Application example 4.1.1: Mechanical solution for HP liquid level control

HP vapour refrigerant
HP liquid refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Servo-operated main valve
④ Stop valve
⑤ Float valve
⑥ Stop valve
⑦ Stop valve



On large HP LLRS the SV1 ⑤ or SV3 float valve is used as a pilot valve for a PMFH ③ main valve. As illustrated above, when the liquid level in the receiver rises above the set level, the SV1 ⑤ float valve provides a signal to the PMFH main valve to open.

The receiver's function here is to provide a more stable signal for the SV1 float ⑤ to work with.

Technical data

	PMFH 80 - 1 to 500
Material	Low temp. spherical cast iron
Refrigerants	R717, HFC, HCFC and CFC
Media temp. range [°C]	–60 to + 120
Max. working pressure [bar]	28
Max test pressure [bar]	42
Rated capacity [kW]*	139-13900

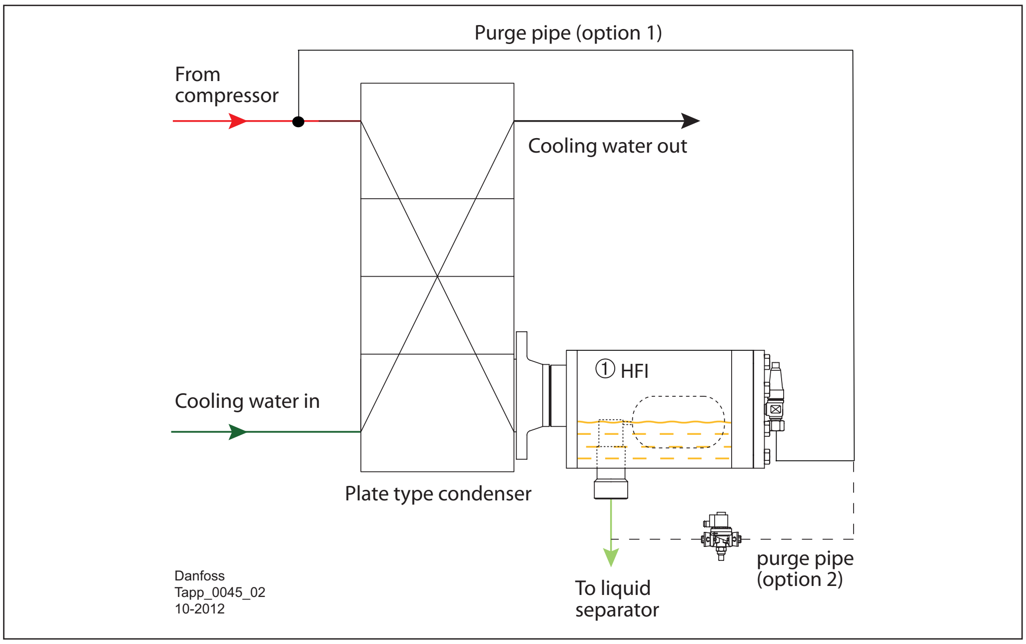
* Conditions: R717, +5/32°C, T_l = 28°C

	Float valve - SV 1 and SV3
Material	Housing: steel Cover: low temperature cast iron Float: stainless steel
Refrigerants	R717, HFC, HCFC and CFC
Media temp. range [°C]	–50 to + 65
P-band [mm]	35
Max. working pressure [bar]	28
Max test pressure [bar]	36
K_v value [m³/h]	0.06 for SV 1 0.14 for SV 3
Rated capacity [kW]*	SV1: 25 SV3: 64

* Conditions: R717, +5/32°C, T_l = 28°C

Not all valves are shown.
Not to be used for construction purposes.

Application example 4.1.2: Mechanical solution for HP liquid level control with HFI



HP vapour refrigerant
HP liquid refrigerant
LP liquid refrigerant
Water

① HP float valve

If the condenser is a plate heat exchanger, the mechanical float valve HFI ① can be used to control the liquid level.

The HFI is a direct acting high pressure float valve; therefore no differential pressure is required to activate the valve

It may be necessary to connect an equalization line to either the HP or LP side (Option 1 or 2) as shown on the drawing to remove refrigerant vapour from the float housing as this may prevent the liquid entering the float housing and thereby preventing the HFI-valve from opening.

Option 1 is the simplest solution. Option 2 requires that a solenoid valve is installed in the equalisation line.

If the HFI is not mounted directly on the condensers it is necessary to connect an equalization line.

Technical data

	HFI
Material	Special steel approved for low temperature application
Refrigerants	R717 and other non-flammable refrigerant. For the refrigerants with density greater than 700kg/m^3, please consult Danfoss.
Media temp. range [°C]	–50 to 80
Max. working pressure [bar]	25 bar
Max test pressure [bar]	50 bar (without float)
Rated capacity [kW]*	400 to 2400

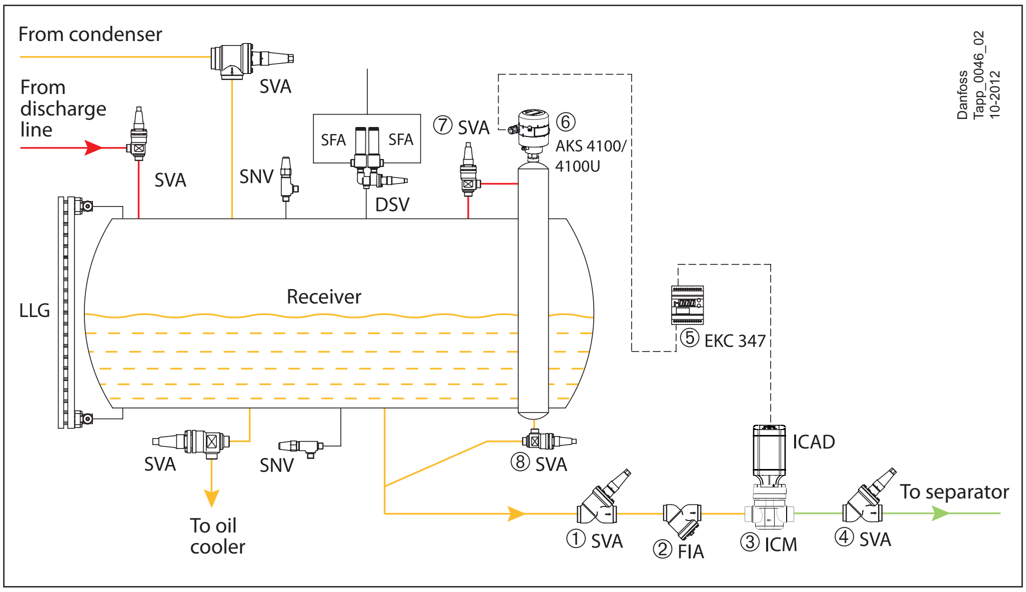
* Conditions: R717, –10/35°C

Not all valves are shown.
Not to be used for construction purposes.

Application example 4.1.3: Electronic solution for HP liquid level control

HP vapour refrigerant
HP liquid refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Motor valve
④ Stop valve
⑤ Controller
⑥ Level transmitter
⑦ Stop valve
⑧ Stop valve



When designing an electronic LLRS solution the liquid level signal can be given either by an AKS 38 which is a level switch (ON/OFF) or an AKS 4100/4100U which is a level transmitter (4-20 mA).

The electronic signal is sent to an EKC 347 electronic controller which controls the injection valve.

The liquid injection can be controled in several different ways:

- With a modulating motor valve type ICM with an ICAD actuator.
- With a pulse-width-modulating expansion valve type AKVA. The AKVA valve should be used only where the pulsation from the valve is acceptable.
- With a regulating valve REG acting as an expansion valve and an EVRA solenoid valve to implement ON/OFF control.
- The system illustrated is an AKS 4100/4100U ⑥ level transmitter which sends a level signal to an EKC 347 ⑤ liquid level controller. The ICM ③ motor valve acts as an expansion valve.

Technical data

	Motor valve - ICM for expansion
Material	Body: Low temperature steel
Refrigerants	All common refrigerants including R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 80
Nominal capacity [kW]*	73 to 22,700

* Conditions: R717, T_e = –10°C, Δp = 8.0 bar, ΔT_{sub} = 4K;

	Level transmitter - AKS 4100/4100U
Material	Thread and pipe: stainless steel Top part: cast aluminium
Refrigerants	R717, R22, R404a, R134a, R718, R744
Media temp. range [°C]	–60 to 100
Process pressure	-1 bar g to 100 bar g (-14,5 psig to 1450 psig)
Measuring range [mm]	800 to 8000

Not all valves are shown.
Not to be used for construction purposes.

4.2
Low Pressure Liquid Level Control System (LP LLRS)

When designing a LP LLRS, the following points have to be taken into consideration:

The liquid level in the low pressure vessel (liquid separator/ shell-tube evaporator) is maintained at a constant level. This is safe to the system, since a too high liquid level in the liquid separator may cause liquid hammering to the compressor, and a too low level may lead to cavitation of the refrigerant pumps in a pump circulation system.

The receiver must be big enough to accumulate the liquid refrigerant coming from the evaporators when the content of refrigerant in some evaporators vary with the cooling load, some evaporators are shut off for service, or part of the evaporators are drained for defrosting.

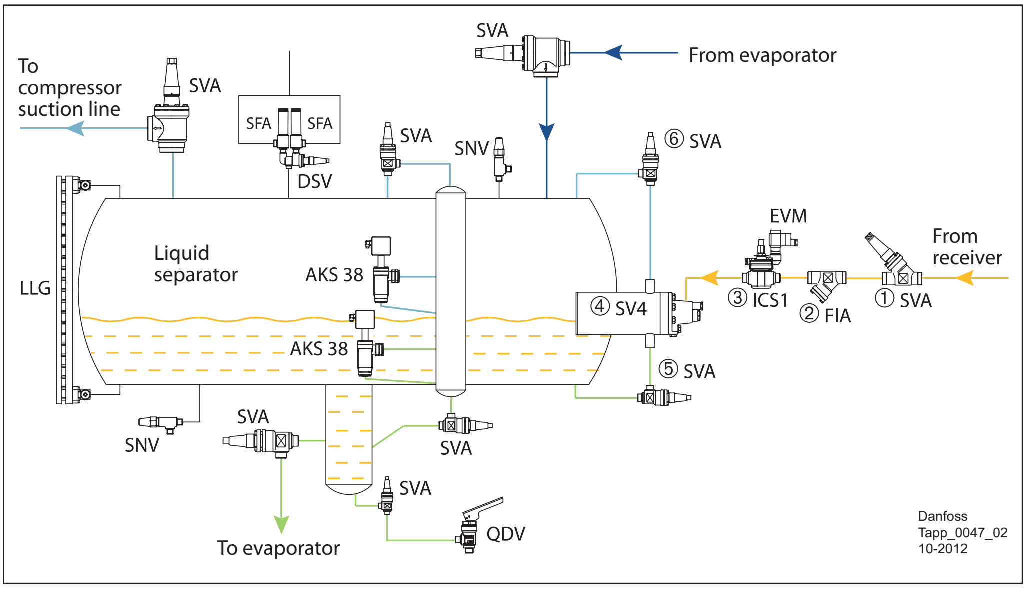
As a result of the above, LP LLRS are especially suitable for de-centralised systems in which there are many evaporators, and the refrigerant charge is large, like cold stores. With LP LLRS, these systems could run safely even though the refrigerant charge is impossible to be precisely calculated.

In conclusion, HP LLRS are suitable for compact systems like chillers; the advantage is the reduced cost (small receiver or no receiver). While LP LLRS are very suitable for de-centralised systems with many evaporators and long piping, like a large cold storage; the advantage being the higher safety and reliability.

Application example 4.2.1: Mechanical solution for LP liquid level control

HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Solenoid valve
④ LP float valve
⑤ Stop valve
⑥ Stop valve



SV float valves "monitor" the liquid level in low pressure vessels. If the capacity is small the SV ④ valves can directly act as an expansion valve in the low pressure vessel as shown.

Technical data

	SV 4-6
Material	Housing: steel Cover: low temperature cast iron(spherical) Float: stainless steel
Refrigerants	R717, HFC, HCFC and CFC
Media temp. range [°C]	–50 to +120
P-band [mm]	35
Max. working pressure [bar]	28
Max test pressure [bar]	42
K_v value [m^3/h]	0.23 for SV 4 0.31 for SV 5 0.43 for SV 6
Rated capacity [kW]*	SV4: 102 SV5: 138 SV6: 186

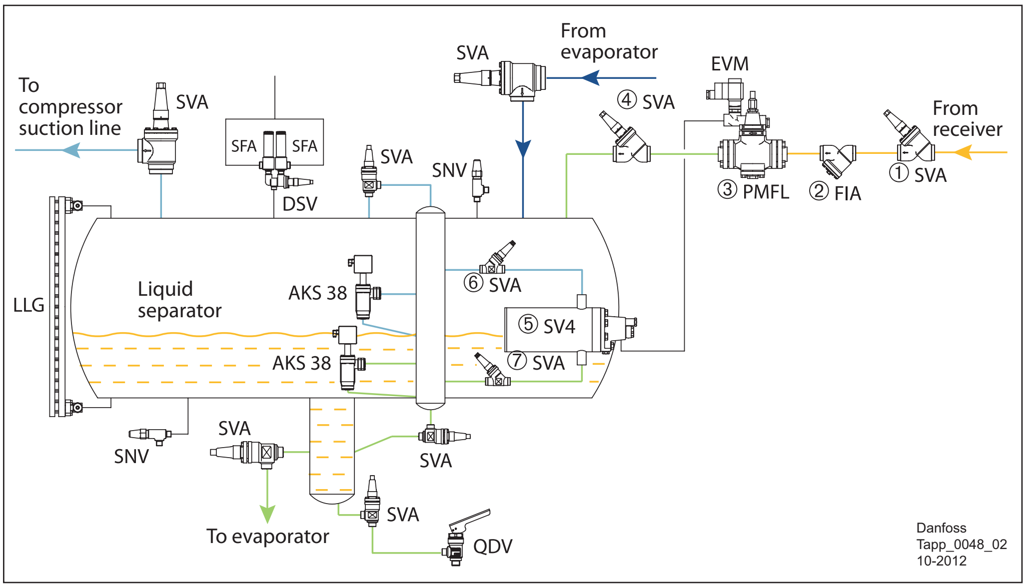
* Conditions: R717, +5/32°C, ΔT_{sub} = 4K.

Not all valves are shown.
Not to be used for construction purposes.

Application example 4.2.2: Mechanical solution for LP liquid level control

HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Servo-operated main valve
④ Stop valve
⑤ LP float valve
⑥ Stop valve
⑦ Stop valve



If the capacity is large, the float valve SV ⑤ is used as a pilot valve for the PMFL main valve.
As illustrated above, when the liquid level in the receiver falls below the set level, the float valve SV ⑤ provides a signal to the PMFL value to open.

Technical data

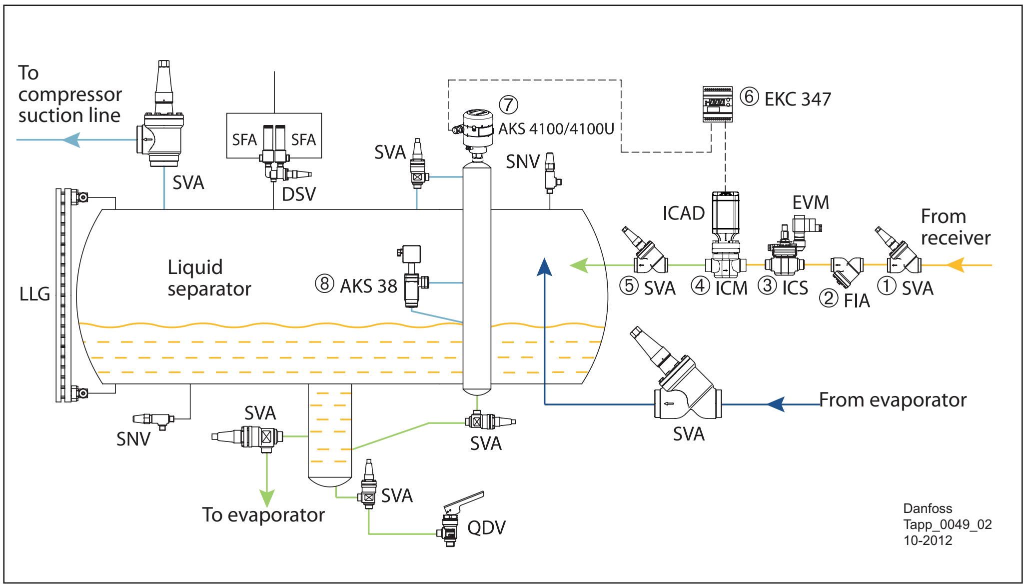
	PMFL 80 - 1 to 500
Material	Low temp. spherical cast iron
Refrigerants	R717, HFC, HCFC and CFC
Media temp. range [°C]	–60 to +120
Max. working pressure [bar]	28
Max test pressure [bar]	42
Rated capacity [kW]*	139-13,900

* Conditions: R717, +5/32°C, ΔT_{sub} = 4K.

Application example 4.2.3: Electronic solution for LP liquid level control

HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Solenoid valve
④ Motor valve
⑤ Stop valve
⑥ Controller
⑦ Level transmitter
⑧ Level switch



The level transmitter AKS 4100/4100U ⑦ monitors the liquid level in the separator and sends a level signal to the liquid level controller EKC 347 ⑥, which sends a modulating signal to the actuator of the motor valve ICM ④. The ICM motor valve acts as an expansion valve.

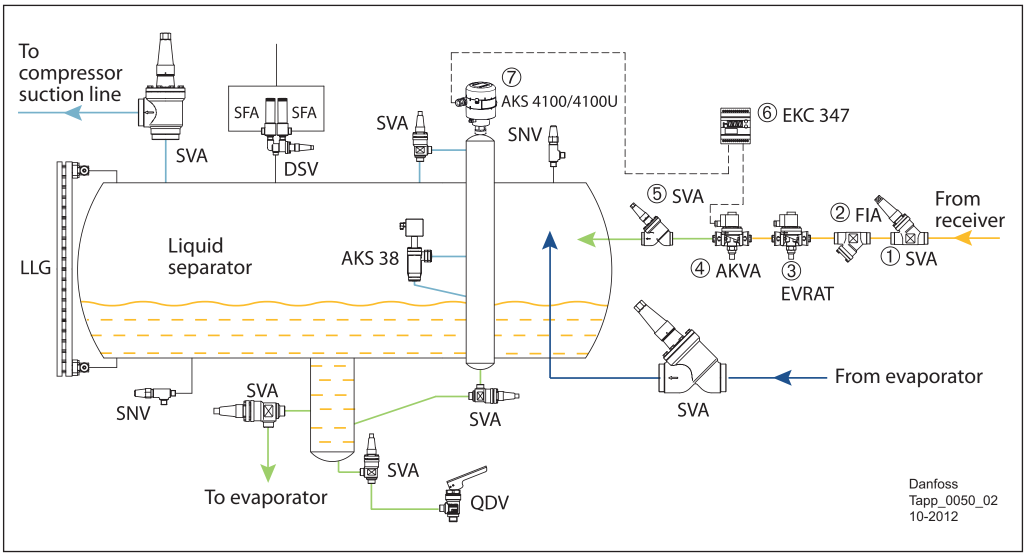
The liquid level controller EKC 347 ⑥ also provides relay outputs for upper and lower limits and for alarm level. However, it is recommended that a level switch AKS 38 ⑧ is fitted as a high level alarm.

Not all valves are shown.
Not to be used for construction purposes.

Application example 4.2.4:
Electronic solution for LP liquid level control

HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Solenoid valve
④ Electronically operated expansion valve
⑤ Stop valve
⑥ Controller
⑦ Level transmitter



This solution is similar to solution 4.2.3. However, with this example the motor valve ICM is replaced by a pulse width electronically operated expansion valve AKVA. The servo valve EVRAT ③ is being used as an additional solenoid valve to ensure 100% closure during "off" cycles.

The liquid level controller EKC 347 ⑥ also provides relay outputs for upper and lower limits and for alarm level. However, it is recommended that a level switch AKS 38 is fitted as a high level alarm.

Technical data

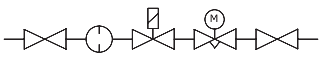
	AKVA
Material	AKVA 10: stainless steel AKVA 15: cast iron AKVA 20: cast iron
Refrigerants	R717
Media temp. range [°C]	AKVA 10: –50 to +60 AKVA 15/20: –40 to +60
Max. working pressure [bar]	42
DN [mm]	10 to 50
Nominal capacity [kW]*	4 to 3150

* Conditions: R717, +5/32°C, ΔT_{sub} = 4K.

Application example 4.2.5:
Electronic solution for LP liquid level control

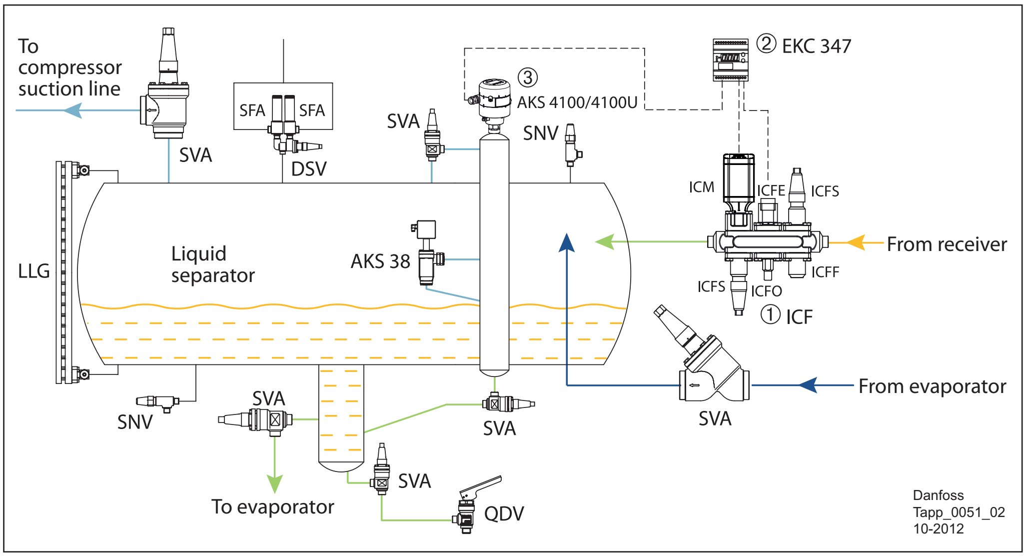
HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① ICF valve station including:



Stop valve
Filter
Solenoid valve
Manual opener
Motor valve
Stop valve

② Controller
③ Level transmitter

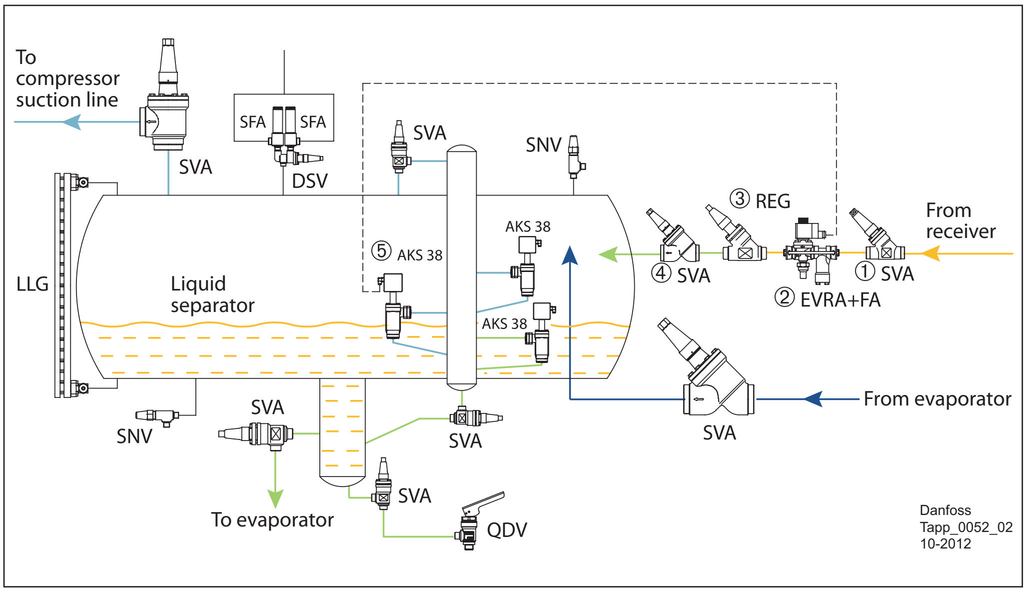


Danfoss can supply a very compact valve solution ICF ①. Up to six different modules can be assembled into the same housing, which is easy to install.

The module ICM acts as an expansion valve and the module ICFE is a solenoid valve.
This solution works in an identical manner to example 4.2.3. ICF solution similar to example 4.2.4 is also available. Please refer to ICF literature for further information.

Not all valves are shown.
Not to be used for construction purposes.

Application example 4.2.6: Electronic solution for LP liquid level control



HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Solenoid valve
③ Hand regulating valve
④ Stop valve
⑤ Level switch

This solution controls the liquid injection using on/off control. The level switch AKS 38 ⑤, controls the switching of the solenoid valve EVRA ②, in accordance with liquid level in the separator. The hand regulating valve REG ③ acts as the expansion valve.

Technical data

	AKS 38
Material	Housing: zinc chromate cast iron
Refrigerants	All common non-flammable refrigerants, including R717.
Media temp. range [°C]	–50 to +65
Max. working pressure [bar]	28
Measuring range [mm]	12.5 to 50

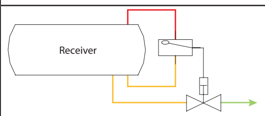
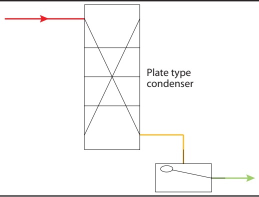
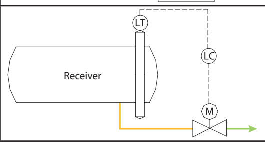
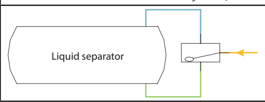
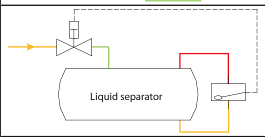
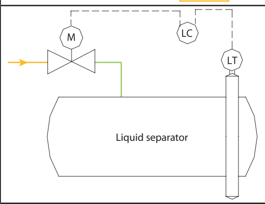
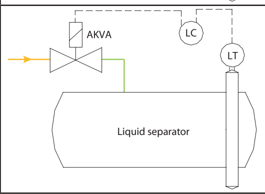
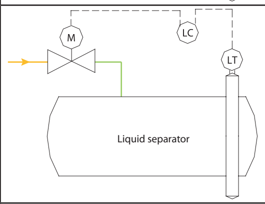
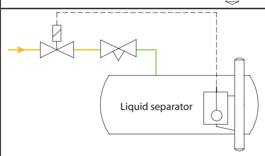
	REG
Material	Special cold resistant steel approved for low temperature operation
Refrigerants	All common non-flammable refrigerants, including R717.
Media temp. range [°C]	–50 to +150
Max. working pressure [bar]	52
DN [mm]	6 to 65
K_v value [m^3/h]	0.17 to 81.4 for fully open valves

	EVRA
Refrigerants	R717, R22, R134a, R404a, R410a, R744, R502
Media temp. range [°C]	–40 to +105
Max. working pressure [bar]	42
Rated capacity [kW]*	21.8 to 2368
K_v value [m^3/h]	0.23 to 25.0

* Conditions: R717, –10/+25°C, Δp = 0.15 bar

Not all valves are shown.
Not to be used for construction purposes.

4.3 Summary

Solution		Application	Benefits	Limitations
High pressure mechanical solution: SV1/3 + PMFH		Applicable to systems with small refrigerant charges, like chillers.	Pure mechanical. Wide capacity range.	Unable to control remotely, the distance between SV and PMFH is limited to several meters. A little bit slow in response.
High pressure mechanical solution: HFI		Applicable to systems with small refrigerant charges and with plate type condensers only.	Pure mechanical. Simple solution. Especially suitable for plate heat exchanger	Unable to provide thermosyphon oil cooling.
High pressure electronic solution: AKS 4100/4100U+EKC 347 + ICM		Applicable to systems with small refrigerant charges, like chillers.	Flexible and compact. Possible to monitor and control remotely. Covers a wide range of capacity.	Not allowed for flammable refrigerant.
Low pressure mechanical solution: SV4-6		Applicable to small systems.	Pure mechanical. Simple, low cost solution.	Limited capacity.
Low pressure mechanical solution: SV 4-6 + PMFL		Particularly applicable to de-central systems, like cold stores.	Pure mechanical. Wide capacity range.	Unable to control remotely, the distance between SV and PMFL is limited to several meters. A little bit slow in response.
Low pressure electronic solution: AKS 4100/4100U + EKC 347 + ICM		Particularly applicable to de-central systems, like cold stores.	Flexible and compact. Possible to monitor and control remotely. Covers a wide range of capacities.	Not allowed for flammable refrigerant.
Low pressure electronic solution: AKS 4100/4100U + EKC 347 + AKVA		Particularly applicable to de-central systems, like cold stores.	Flexible and compact. Possible to monitor and control remotely. Wide capacity range. Faster than motor valve. Fail safe valve (NC).	Not allowed for flammable refrigerant. The system needs to allow for pulsations.
Low pressure electronic solution: AKS 4100/4100U + EKC 347 + ICF		Particularly applicable to de-central systems, like cold stores.	Flexible and compact. Possible to monitor and control remotely. Covers a wide range of capacities. Easy to install.	Not allowed for flammable refrigerant.
Low pressure electronic solution: AKS 38 + EVRA + REG		Particularly applicable to de-central systems, like cold stores.	Simple. In-expensive.	Just 40 mm for level adjustment. Very dependant on the adjustment of the REG valve. Not suitable for systems with big capacity fluctuations.

4.4 Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
AKS 38	PD.GD0.A
AKS 4100/ 4100U	PD.SC0.C
AKVA	PD.VA1.B
EKC 347	PS.G00.A
EVRA(T)	PD.BM0.B
ICM	PD.HT0.B

Type	Literature no.
PMFH/L	PD.GE0.C
ICF	PD.FT1.A
REG	PD.KM1.A
SV 1-3	PD.GE0.B
SV 4-6	PD.GE0.D

Product instruction

Type	Literature no.
AKS 38	PI.GD0.A
AKS 4100/ 4100U	PI.SC0.D PI.SC0.E
AKVA	PI.VA1.C / PI.VA1.B
EKC 347	PI.RP0.A
EVRA(T)	PI.BN0.L
ICM 20-65	PI.HT0.A

Type	Literature no.
ICM 100-150	PI.HT0.B
PMFH/L	PI.GE0.D / PI.GE0.A
ICF	PI.FT0.C
REG	PI.KM1.A
SV 1-3	PI.GE0.C
SV 4-6	PI.GE0.B

To download the latest version of the literature please visit the Danfoss website.

5. Evaporator Controls

The evaporator is the part of the refrigeration system where the effective heat is transferred from the media you want to cool down (e.g. air, brine, or the product directly) to the refrigerant.

Therefore, the primary function of evaporator control system is to achieve the desired media temperature. Furthermore, the control system should also keep the evaporator in efficient and trouble-free operation at all times.

Specifically, the following control methods may be necessary for evaporators:

- Liquid supply control Section 5.1 and 5.2 describes two different types of liquid supply-direct expansion (DX) and pumped liquid circulation.
- Defrost (Section 5.3 and 5.4), which is necessary for air coolers operating at temperatures below 0°C.
- Multi-temperature changeover (Section 5.5) for evaporators that need to operate at different temperature levels.
- Media temperature control (Section 5.6) when the media temperature is required to be maintained at a constant level with high accuracy.

When introducing media temperature control and defrost, direct expansion (DX) evaporators and pumped liquid circulation evaporators are discussed separately, because there are some differences in the control systems.

5.1 Direct Expansion Control

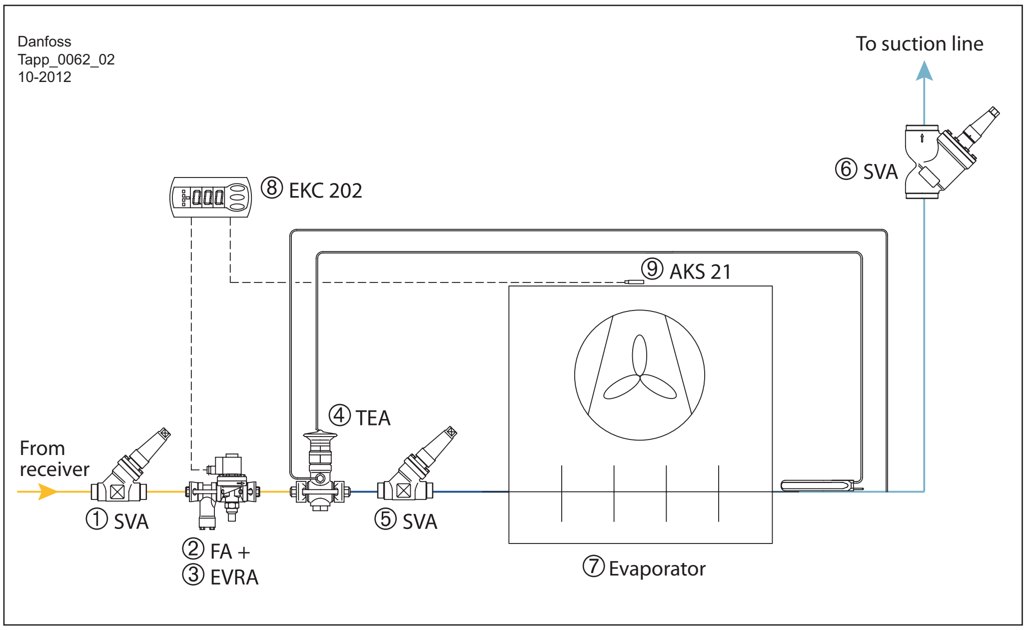
To design liquid supply for direct expansion evaporators, the following requirements should be satisfied:

- The liquid refrigerant supplied to the evaporator is completely evaporated. This is necessary to protect the compressor against liquid hammer.
- The media "off" temperature from the evaporator is maintained within the desired range.

The liquid injection is controled by a superheat-controlled expansion valve, which maintains the superheat at the outlet of the evaporator within a desired range. This expansion valve can be either a thermostatic expansion valve, or an electronic expansion valve.

The temperature control is normally achieved by ON/OFF control, which starts and stops the liquid supply to the evaporator according to the media temperature.

Application example 5.1.1: DX evaporator, thermostatic expansion



- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP vapour refrigerant

① Stop valve liquid inlet
② Filter
③ Solenoid valve
④ Thermostatic expansion valve
⑤ Stop valve evaporator inlet
⑥ Stop valve suction line
⑦ Evaporator
⑧ Digital thermostat
⑨ Temperature sensor

Application example 5.1.1 shows a typical installation for a DX evaporator without hot gas defrosting.

The liquid injection is controled by the thermostatic expansion valve TEA ④, which maintains the refrigerant superheat at the outlet of the evaporator at a constant level. TEA is designed for ammonia. Danfoss also supply thermostatic expansion valves for fluorinated refrigerants.

The media temperature is controlled by the digital thermostat EKC 202 ⑧, which controls the on/off switching of the solenoid valve EVRA ③ according to the media temperature signal from the PT 1000 temperature sensor AKS 21 ⑨.

This solution can also be applied to DX evaporators with natural or electric defrost.

Natural defrost is achieved by stopping the refrigerant flow to the evaporator, and keeping the fan running. Electric defrost is achieved by stopping the refrigerant flow to the evaporator and the fan and at the same time switching on an electric heater inside the evaporator fin block.

Evaporator Controller EKC 202
The digital thermostat will control all functions of the evaporator including thermostat, fan, defrost and alarms.

For more details, please refer to the manual of EKC 202 from Danfoss.

Technical data

	Thermostatic expansion valve - TEA
Refrigerants	R717
Evaporating temp. range [°C]	–50 to 30
Max. bulb temp. [°C]	100
Max. working pressure [bar]	19
Rated Capacity [kW]*	3.5 to 295

* Conditions: –15°C/+32°C, ΔT_{sub} = 4°C

	Solenoid valve - EVRA(T)
Refrigerants	R717, R22, R134a, R404a, R410a, R744, R502
Media temp. range [°C]	–40 to +105
Max. working pressure [bar]	42
Rated capacity [kW]*	21.8 to 2368
K_v value [m^3/h]	0.23 to 25.0

* Conditions: R717, –10/+25°C, Δp = 0.15 bar

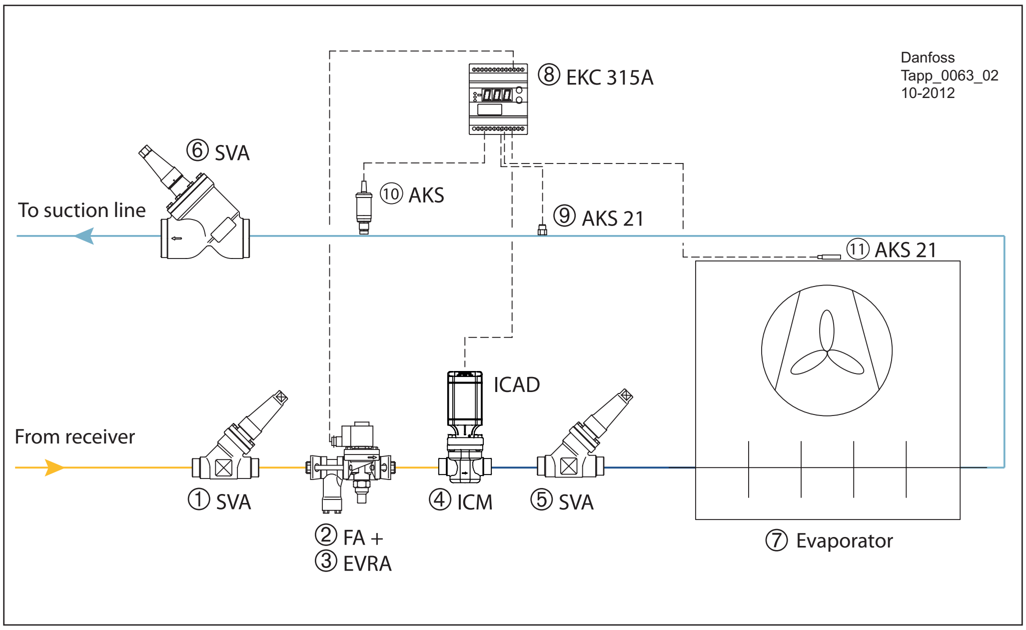
	Strainer - FA
Refrigerants	Ammonia and fluorinated refrigerants
Media temp. range [°C]	–50 to +140
Max. working pressure [bar]	28
DN [mm]	15/20
Filter insert	150μ stainless steel weave
K_v value [m^3/h]	3.3/7.0

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.1.2: DX evaporator, electronic expansion

- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP vapour refrigerant

① Stop valve liquid inlet
② Filter
③ Solenoid valve
④ Electronic expansion valve
⑤ Stop valve evaporator inlet
⑥ Stop valve suction line
⑦ Evaporator
⑧ Controller
⑨ Temperature sensor
⑩ Pressure transmitter
⑪ Temperature sensor



Application example 5.1.2 shows a typical installation for an electronically controlled DX evaporator without hot gas defrost.

The liquid injection is controled by the motor-valve ICM ④ controlled by the evaporator controller type EKC 315A ⑧. The EKC 315A controller will measure the superheat by means of the pressure transmitter AKS ⑩ and the temperature sensor AKS 21 ⑨ on the outlet of the evaporator, and controlling the opening of the ICM in order to maintain the superheat at the optimum level.

At the same time, the controller EKC 315A operates as a digital thermostat, which will control the on/off switching of the solenoid valve EVRA ③ depending on the media temperature signal from the temperature sensor AKS 21 ⑪.

Compared with the solution 5.1.1, this solution will operate the evaporator at an optimised superheat and constantly adapt the opening degree of the injection valve to ensure maximum capacity and efficiency. The surface area of the evaporator will be fully utilised. Furthermore, this solution offers a more accurate media temperature control.

Evaporator Controller EKC 315A
The Digital controller will control all functions of the evaporator including thermostat, expansion and alarms.

For more details, please refer to the manual of EKC 315A from Danfoss.

Technical data

	Motor valve - ICM for expansion
Material	Body: Low temperature steel
Refrigerants	All common refrigerants including R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 80
Nominal capacity [kW]*	73 to 22700

* Conditions: R717, T_e = –10°C, Δp = 8.0 bar, ΔT_{sub} = 4K;

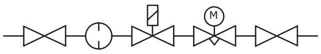
	Pressure transmitter - AKS 3000	Pressure transmitter - AKS 32
Refrigerants	All refrigerants including R717	All refrigerants including R717
Operating range [bar]	0 to 60 (depending on range)	–1 to 39 (depending on range)
Max. working pressure PB [bar]	100 (depending on operating range)	60 (depending on operating range)
Operating temp. range [°C]	–40 to 80	–40 to 85
Compensated temp. range [°C]	LP: –30 to +40 / HP: 0 to +80	LP: –30 to +40 / HP: 0 to +80
Rated output signal	4 to 20 mA	1 to 5V or 0 to 10V

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.1.3: DX Evaporator, Electronic expansion with ICF control solution

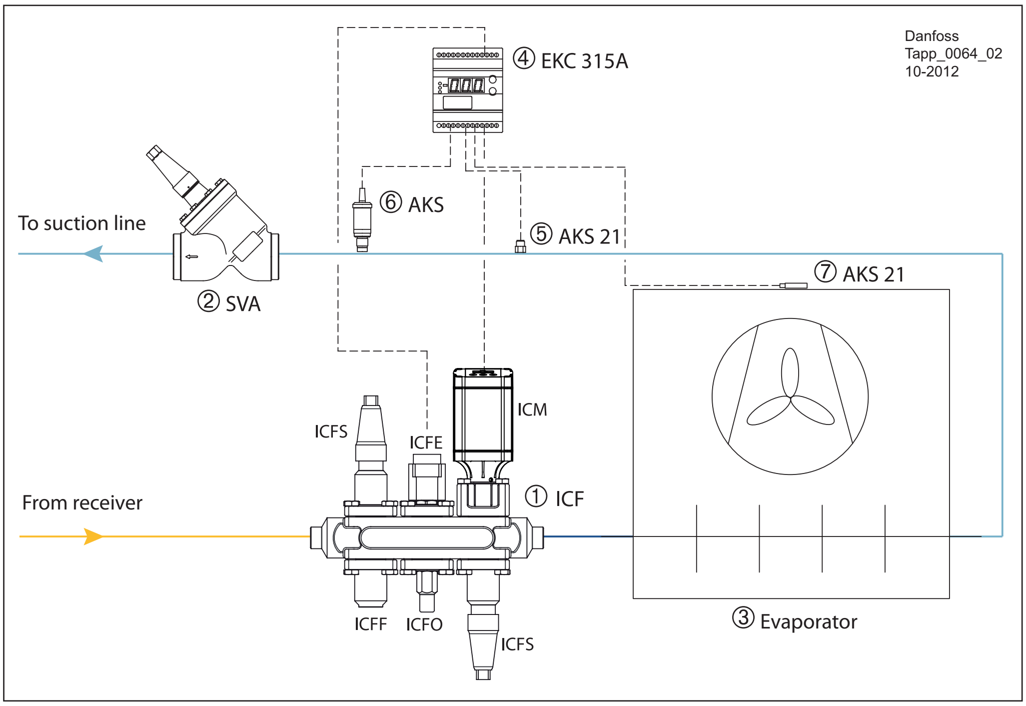
HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant

① ICF control solution with:



Stop valve liquid inlet
Filter
Solenoid valve
Manual opening
ICM electronic exp. valve
Stop valve evaporator inlet

② Stop valve suction line
③ Evaporator
④ Controller
⑤ Temperature sensor
⑥ Pressure transmitter
⑦ Temperature sensor



Application example 5.1.3 shows the new ICF control solution for an electronically controlled DX evaporator without hot has defrost similar to the example 5.1.2.

The ICF will accommodate up to six different modules assembled in the same housing offering a compact, easy to install control solution.

The liquid injection is controled by the motor-valve ICM which is controlled by the evaporator controller type EKC 315A ④. The EKC 315A controller will measure the superheat by means of the pressure transmitter AKS ⑥ and the temperature sensor AKS 21 ⑤ on the outlet of the evaporator, and control the opening of the ICM valve in order to maintain the superheat at the optimum level.

At the same time, the controller EKC 315A operates as a digital thermostat, which will control the on/off switching of the solenoid valve ICFE depending on the media temperature signal from the temperature sensor AKS 21 ⑦.

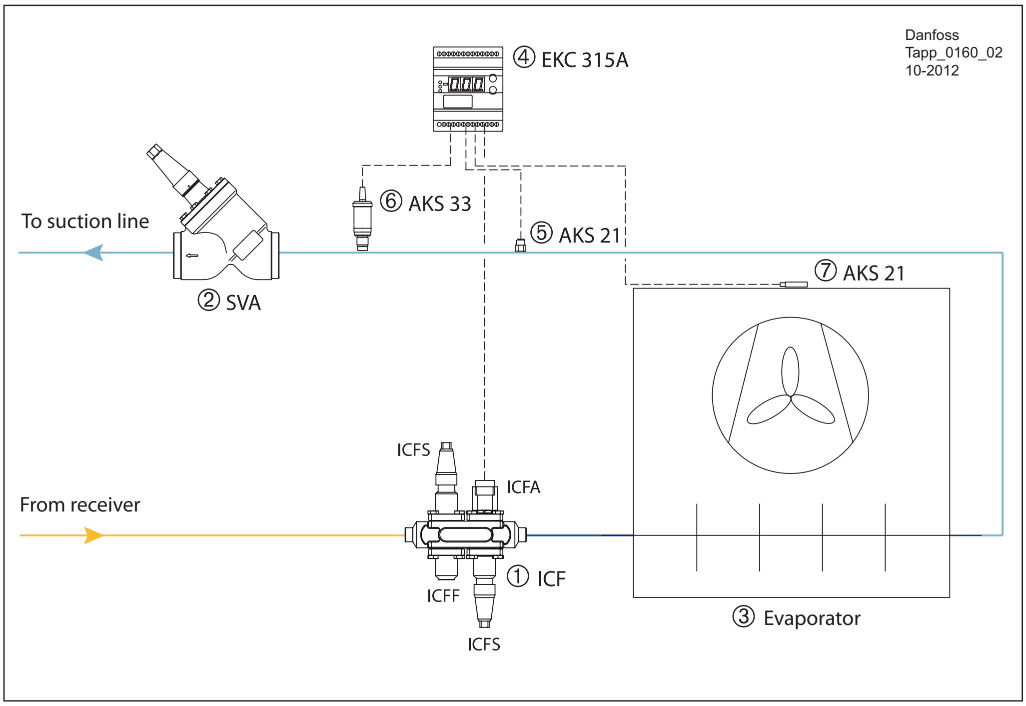
Similar to the example 5.1.1, this solution will operate the evaporator at an optimised superheat, and constantly adapt the opening degree of the injection valve to ensure maximum capacity and efficiency. The surface area of the evaporator will be fully utilised. Furthermore, this solution offers a more accurate media temperature control.

Evaporator Controller EKC 315A
The Digital controller will control all functions of the evaporator including thermostat, expansion and alarms.

For more details, please refer to the manual of EKC 315A from Danfoss.

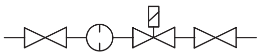
Not all valves are shown.
Not to be used for construction purposes.

Application example 5.1.4: DX evaporator and electronic expansion with ICF control



- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP vapour refrigerant

① ICF control solution with:



Stop valve liquid inlet
Filter
Expansion valve
Evaporator inlet stop valve

② Suction line stop valve
③ Evaporator
④ Controller
⑤ Temperature sensor
⑥ Pressure transmitter
⑦ Temperature sensor

This application example shows an ICF control solution for an electronically controlled DX evaporator without hot gas defrost.

The ICF can accommodate up to six different models in the same housing, offering a compact, easy to install control solution.

Liquid injection is controlled by the ICFA electronic expansion valve, which is controlled by the EKC 315A evaporator controller ④. The EKC 315A controllor measures the superheat by means of the pressure transmitter AKS 33 ⑥ and the temperature sensor AKS 21 ⑤ on the outlet of the evaporator, and controls the opening of the ICFA valve in order to maintain the superheat at the optimum level.

This solution operates the evaporator with optimised superheat and constantly adapts the opening degree of the injection valve to ensure maximum capacity and efficiency. The surface area of the evaporator is fully utilised. Furthermore, this solution provides more accurate media temperature control.

EKC 315A Evaporator Controller
The digital controller controls all evaporator functions, including thermostat, expansion and alarms.

For more details, please see the Danfoss EKC 315A manual.

The ICF control solution shown here can also be replaced by a conventional valve solution (SVA stop valve, FA/FIA filter, AKVA electronic expansion valve and a SVA stop valve).
The controller EKC 315A can be used with ICF and with a conventional valve solution.

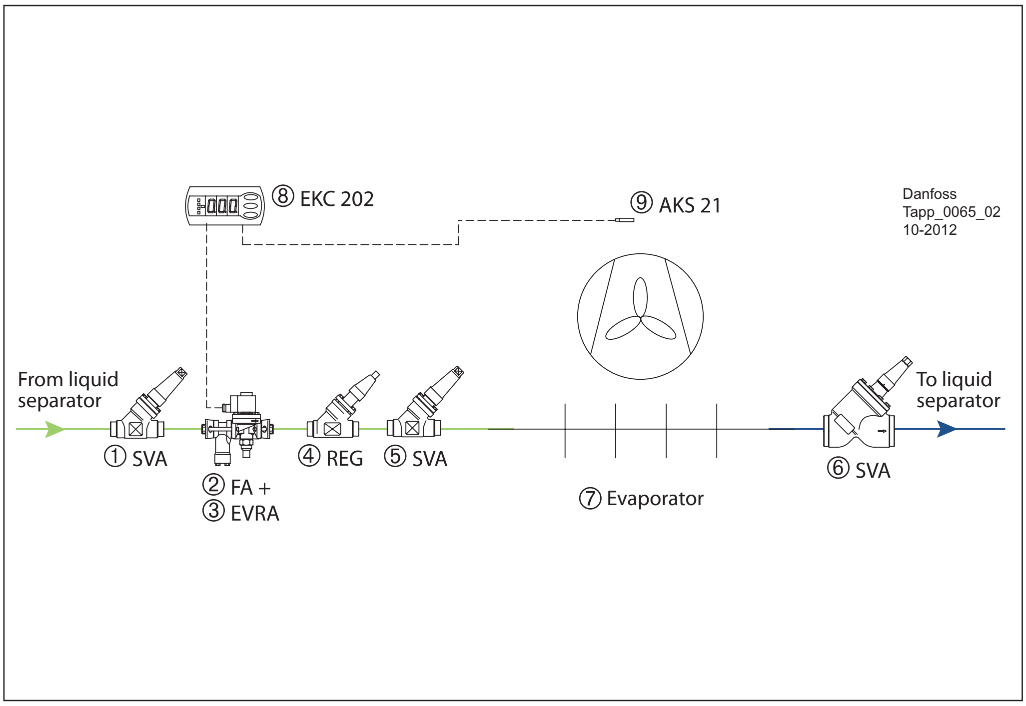
Not all valves are shown.
Not to be used for construction purposes.

5.2 Pumped Liquid Circulation Control

When compared to ammonia DX systems, ammonia pump circulation systems control becomes simpler as a well-dimensioned pump separator protects compressors against hydraulic shock.

The pump separator ensures that only "dry" refrigerant vapour is returned to the compressors. The evaporation control is also simplified as only a basic on/off liquid control to the evaporators is required.

Application example 5.2.1: Pumped liquid circulation evaporator, without hot gas defrost



Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① Stop valve liquid inlet
② Filter
③ Solenoid valve
⑥ Hand expansion valve
⑤ Stop valve evaporator inlet
⑥ Stop valve suction line
⑦ Evaporator
⑧ Digital thermostat
⑨ Temperature sensor

Application example 5.2.1 shows a typical installation for a pumped liquid circulation evaporator without hot has defrost, and can also be applied to pumped liquid circulation evaporators with natural or electric defrost.

The media temperature is maintained at the desired level by the digital thermostat EKC 202 ⑧, which controls the on/off switching of the solenoid valve EVRA ③ according to the media temperature signal from the PT 1000 temperature sensor AKS 21 ⑨.

The amount of liquid injected into the evaporator is controled by the opening of the hand regulating valve REG ④. It is important to set this regulating valve at the right opening degree.

Too high an opening degree will lead to frequent operation of the solenoid valve with resultant wear. Too low an opening degree will starve the evaporator of liquid refrigerant.

Evaporator Controller EKC 202
The Digital thermostat will control all functions of the evaporator including thermostat, fan, defrost and alarms.

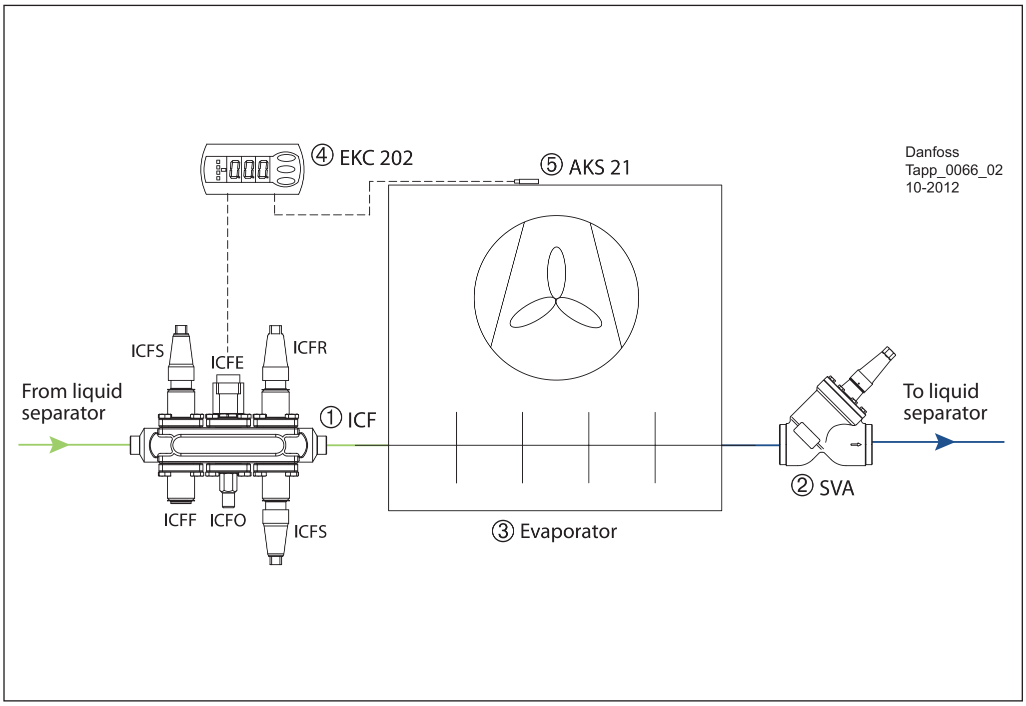
For more details, please refer to the manual of EKC 202 from Danfoss.

Technical data

	REG
Material	Special cold resistant steel approved for low temperature operation
Refrigerants	All common non-flammable refrigerants, including R717.
Media temp. range [°C]	–50 to +150
Max. working pressure [bar]	52
DN [mm]	6 to 65
K_v value [m^3/h]	0.17 to 81.4 for fully open valves

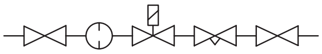
Not all valves are shown.
Not to be used for construction purposes.

Application example 5.2.2: Pumped liquid circulation evaporator, ICF control solution, without hot gas defrost



Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① ICF control solution with:



Stop valve liquid inlet
Filter
Solenoid valve
Manual opening
Hand expansion valve
Stop valve evaporator inlet

② Stop valve suction line
③ Evaporator
④ Digital thermostat
⑤ Temperature sensor

Application example 5.2.2 includes for the new ICF control solution operating identically to example 5.2.1 and can also be applied to pumped liquid circulation evaporators with natural or electric defrost.
The ICF will accommodate up to six different modules assembled in the same housing offering a compact, easy to install control solution.

The media temperature is maintained at the desired level by the digital thermostat EKC 202 ④, which controls the on/off switching of the solenoid valve ICFE in the ICF according to the media temperature signal from the PT 1000 temperature sensor AKS 21 ⑤.

The amount of liquid injected into the evaporator is controlled by the opening of the hand regulating valve ICFR. It is important to set this regulating valve at the right opening degree. Too high an opening degree will lead to frequent operation of the solenoid valve with resultant wear. Too low an opening degree will starve the evaporator of liquid refrigerant.

Evaporator Controller EKC 202
The digital thermostat will control all functions of the evaporator including thermostat, fan, defrost and alarms.

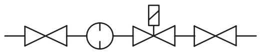
For more details, please refer to the manual of EKC 202 from Danfoss.

Not all valves are shown.
Not to be used for construction purposes.

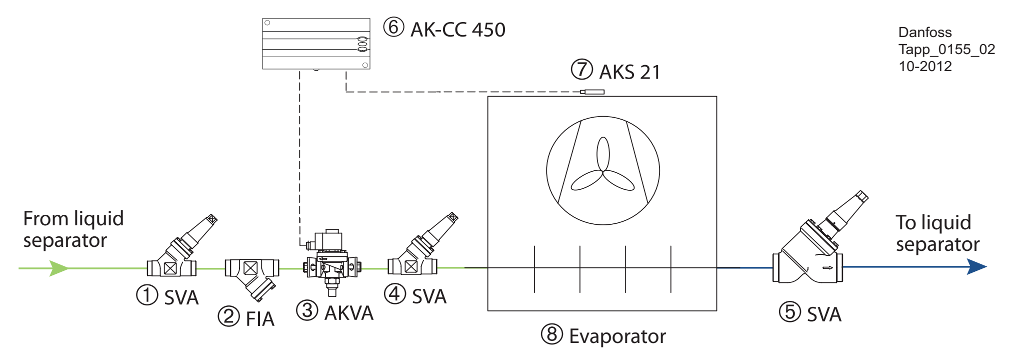
Application 5.2.3
Injecting liquid in an air cooler in a flooded system using pulse width modulation valve AKVA/ICFA, with electrical or brine defrost

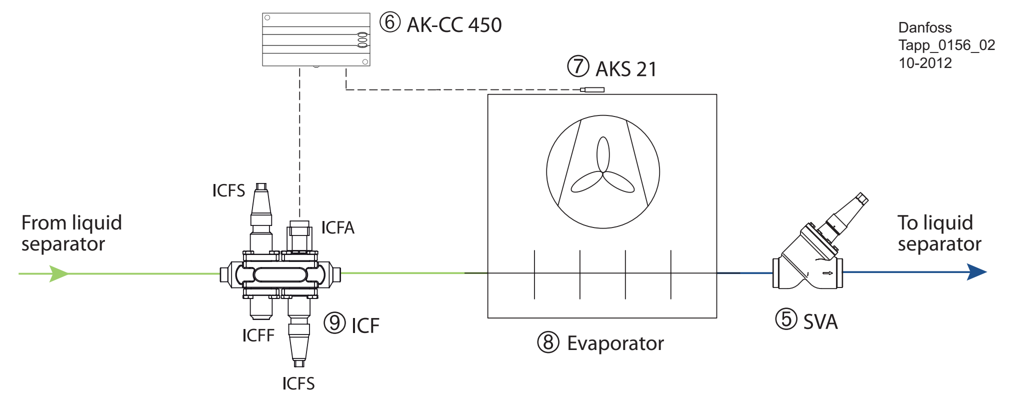
Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① Liquid line stop valve
② Filter
③ Electronically operated expansion valve
④ Evaporator inlet stop valve
⑤ Suction line stop valve
⑥ Digital thermostat
⑦ Temperature sensor
⑧ Evaporator
⑨ ICF control solution with:



Stop valve
Filter
Electronic expansion valve
Stop valve





In a traditional flooded system, liquid injection is controlled by a thermostat which constantly measures the air temperature.

The solenoid valve is opened for several minutes or longer until the air temperature has reached the set point. During injection the mass of the refrigerant flow is constant.

This is a very simple way to control the air temperature, but the temperature variation caused by the thermostat may cause unwanted side effects in some applications, such as dehumidification or inaccurate control.

Instead of injecting periodically, as described above, one can also constantly adapt the liquid injection to the actual need. This can be done with a PWM AKVA valve ③ or an ICF ⑨ with and ICFA solenoid module.

The air temperature is constantly measured and compared to the reference temperature.
When the air temperature reaches the set point, the AKVA valve ③ opening is reduced. This decreases the degree of opening during the cycle, resulting in less capacity. The duration of a cycle is adjustable between 30 sec. and 900 sec..

In a flooded system this means that the average refrigerant flow is constantly controlled and adapted to demand. When less refrigerant is injected, the circulation rate decreases.

The result of this is that more refrigerant will be evaporated, creating a certain amount of superheated gas in the air cooler.

A direct effect of this is a lower average surface temperature of the air cooler, resulting in a smaller ΔT between the refrigerant and the air.

This approach to liquid injection in a flooded system is very versatile. The amount of injected liquid can be controlled exactly, which increases the accuracy and the energy efficiency of the system.

For more details, please refer to the AK-CC 450 manual from Danfoss.

Not all valves are shown.
Not to be used for construction purposes.

5.3 Hot Gas Defrost for DX Air Coolers

In applications where the air cooler operates at evaporating temperatures below 0°C, frost will form on the heat exchange surface, with its thickness increasing with time. The frost build up leads to a drop in performance of the evaporator by reducing the heat transfer coefficient and blocking the air circulation at the same time. Therefore, these air coolers should be defrosted periodically to keep their performance at a desired level.

Different types of defrost commonly used in industrial refrigeration are:

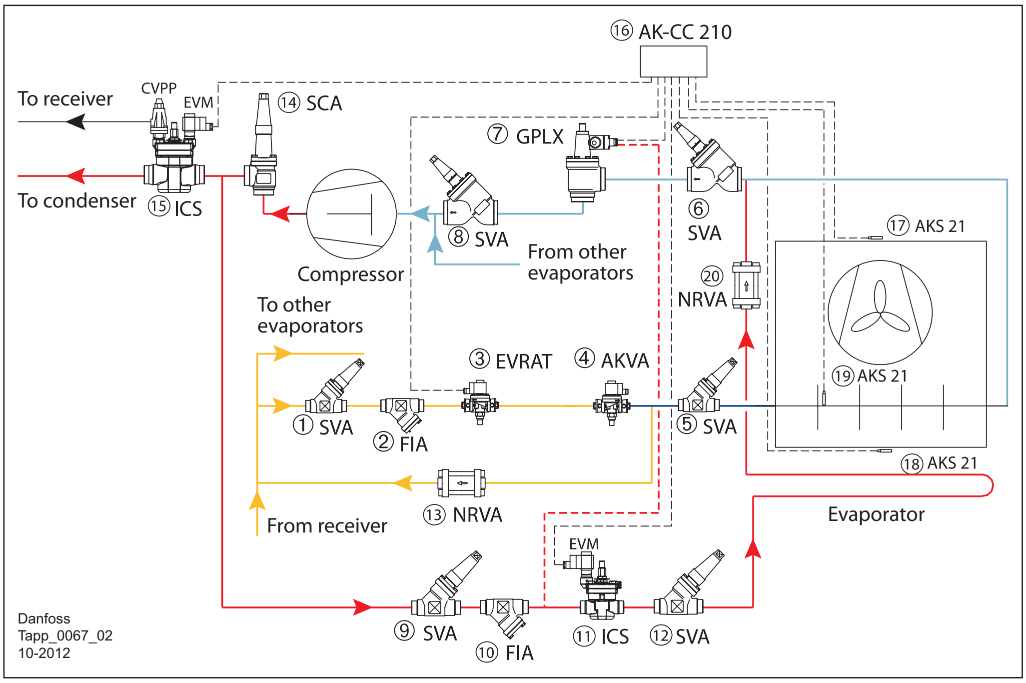
- Natural defrost
- Electric defrost
- Hot gas defrost

Natural defrost is achieved by stopping the refrigerant flow to the evaporator and keeping the fan running. This can only be used for room temperatures above 0°C. The resulting defrosting time is long.

Electric defrost is achieved by stopping the fan and the refrigerant flow to the evaporator and at the same time switching on an electric heater inside the evaporator fin block. With a timer function and/or a defrost termination thermostat, the defrosting can be terminated when the heat exchange surface is completely free of ice. Whilst this solution is easy to install and low in initial investment, the operating costs (electricity) are considerably higher than for other solutions.

For hot gas defrost systems, hot gas will be injected into the evaporator to defrost the surface. This solution requires more automatic controls than other systems, but has the lowest operating cost over time. A positive effect of hot gas injection into the evaporator is the removal and return of oil. To ensure enough hot gas capacity, this solution must only be used in refrigeration systems with three or more evaporators. Only a third of the total evaporator capacity can be under defrost at a given time.

Application example 5.3.1: DX evaporator, with hot gas defrost system



- HP vapour refrigerant
- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP vapour refrigerant

Liquid Line
① Stop valve liquid inlet
② Filter
③ Solenoid valve
④ Expansion valve
⑤ Stop valve evaporator inlet

Suction Line
⑥ Stop valve evaporator inlet
⑦ Two step solenoid valve
⑧ Stop valve suction line

Hot gas line
⑨ Stop valve
⑩ Filter
⑪ Solenoid valve
⑫ Stop valve
⑬ Check valve

Discharge line
⑭ Stop check valve on the discharge line
⑮ Differential pressure regulator
⑯ Controller
⑰ Temperature sensors
⑱ Temperature sensors
⑲ Temperature sensors
⑳ Check valve

Not all valves are shown.
Not to be used for construction purposes.

The application example illustrated above is a DX evaporator system with hot gas defrost. Whilst this method of defrosting is not common it is even less so for ammonia DX evaporator systems and more applicable to fluorinated systems.

Refrigeration Cycle
The solenoid valve EVRAT ③ in the liquid line is kept open. The liquid injection is controled by the electronic expansion valve AKVA ④.

The solenoid valve GPLX ⑦ in the suction line is kept open, and the defrosting solenoid valve ICS ⑪ is kept closed by its solenoid valve pilot EVM.

The check valve NRVA ⑳ prevents ice formation in the drain pan.

The servo valve ICS ⑮ is kept open by its solenoid valve pilot EVM.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid valve EVRAT ③ is closed. The fan is kept running for 120 to 600 seconds depending on the evaporator size in order to pump down the evaporator of liquid.

The fans are stopped and the GPLX closed. The GPLX ⑦ valve is kept in its open position by hot gas.

The hot gas condenses in the cold valve and produces liquid on top of the servo piston. When the pilot valves change position to close the valve, the pressure on the piston equalises to the suction pressure.

This equalisation takes time because condensed liquid is present in the valve.The exact time taken from when the pilot valves change position to complete closing of the valve depends on the temperature, pressure, refrigerant and valve size.

It is therefore not possible to state an exact closing time for the valves, but lower pressures generally result in longer closing times.

It is very important to take the closing times into consideration when hot gas defrost is used in evaporators.

A further delay of 10 to 20 seconds is required for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICS ⑪ is then opened by its solenoid valve pilot EVM and supplies hot gas to the evaporator.

During the defrost cycle the solenoid valve pilot EVM for the servo valve ICS ⑮ is closed so that ICS ⑮ is controlled by the differential pressure pilot CVPP.
ICS ⑮ then creates a differential pressure Δp between hot gas pressure and the receiver pressure. This pressure drop ensures that the liquid which is condensed during defrosting is forced out into the liquid line through check valve NRVA ⑬.

When the temperature in the evaporator (measured by AKS 21 ⑲) reaches the set value, defrost is terminated, the solenoid valve ICS ⑪ is closed, the solenoid valve EVM for ICS ⑮ is opened and the solenoid valve GPLX ⑦ is opened.

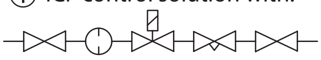
Because of the high differential pressure between the evaporator and the suction line, it is necessary to use a two step solenoid valve like the Danfoss GPLX or ICLX. GPLX/ICLX will have a capacity of only 10 % at high differential pressure, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line.

After the GPLX fully opens, EVRAT ③ is opened to restart the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

Application example 5.3.2: Liquid injection in an air cooler in a flooded system using pulse width modulation valve AKVA, with hot gas defrost.

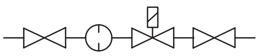
HP vapour refrigerant
Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① ICF control solution with:

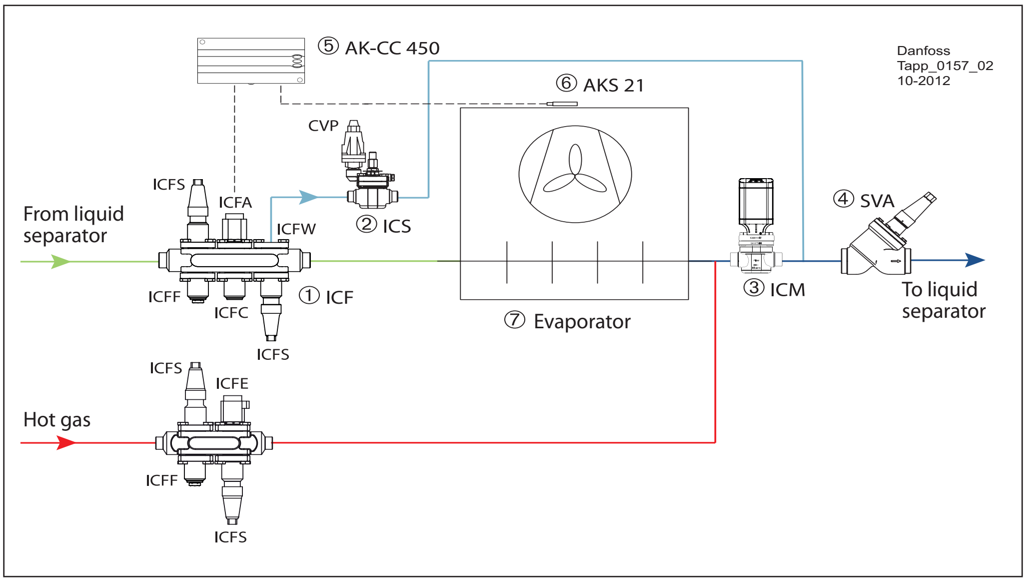


Stop valve
Filter
Electronic expansion valve
Check valve
Welding connection
Stop valve

② Pressure regulator
③ Pressure regulator
④ Suction line stop valve
⑤ Digital thermostat
⑥ Temperature sensor
⑦ Evaporator
⑧ ICF control solution with:



Stop valve
Filter
Electronic expansion valve
Stop valve



Application example 5.3.2 shows an installation for pumped liquid circulation evaporators with hot gas defrost using the ICF control solution. The ICF can accommodate up to six different modules in the same housing, easy to install control solution.

Refrigeration Cycle
The ICFA solenoid module of the ICF ① constantly adapts the liquid injection to the actual demand.
The motor valve ICM ③ in the suction line is kept open, and the defrosting solenoid valve ICFE in ICF ① is kept closed.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid module ICFA of the ICF ① is closed. The fan is kept running for 120 to 600 seconds, depending on the evaporator size, to pump down the liquid in the evaporator.
The fans are stopped and the ICM valve closed. This is followed by a delay of 10 to 20 seconds for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICFE in ICF ① is then opened and supplies hot gas to the evaporator.

During the defrost cycle, the condensed hot gas from the evaporator is injected into the low pressure side. The defrost pressure is controlled by the ICS and CVP. ②.

When the temperature in the evaporator reaches the set value or the defrost timer times out. defrost is terminated, the solenoid valve ICFE in ICF ① is closed, and after a small delay the motor valve ICM ③ is opened.

Because of the high differential pressure between the evaporator and the suction line, it is necessary to relieve the pressure slowly, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line.

The advantage of using the motor valve ICM ③ is that the defrost pressure can be equalized by slowly opening the valve. A cost effective way to do this is to use the ICM on/off mode and select a very low speed. It can also be achieved by using the modulating mode, with the opening degree and speed controlled entirely by the PLC.

After the ICM fully opens, the liquid supply solenoid valve ICFA in ICF ① is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

Not all valves are shown.
Not to be used for construction purposes.

Technical data

	Pilot operated servo valve - ICS
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 150
Nominal capacity [kW]*	On hot gas line: 20 to 4000 On liquid line without phase change: 55 to 11,300

* Conditions: R717, T_{liq} = 30°C, $P_{disch.}$ = 12bar, ΔP = 0.2bar, $T_{disch.}$ = 80°C, T_e = –10°C, Recirculation Ratio = 4

	Gas powered two-step solenoid valve - GPLX	Gas powered two-step solenoid valve - ICLX
Material	Body: low temp. steel	Body: low temp. cast iron
Refrigerants	All common non-flammable refrigerants, incl. R717.	All common non-flammable refrigerants, incl. R717.
Media temp. range [°C]	–60 to 150	–60 to 120
Max. working pressure [bar]	40	52
DN [mm]	80 to 150	32 to 150
Nominal capacity [kW]*	On dry suction line: 442 to 1910 On wet suction line: 279 to 1205	On dry suction line: 76 to 1299 On wet suction line: 48 to 820

* Conditions R717, ΔP = 0.05 bar, T_e = –10°C, T_{liq} = 30°C, Recirculation Ratio = 4

	Check valve - NRVA
Material	Body: steel
Refrigerants	All common refrigerants, incl. R717
Media temp. range [°C]	–50 to 140
Max. working pressure [bar]	40
DN [mm]	15 to 65
Nominal capacity [kW]*	On liquid line without phase change: 160.7 to 2411

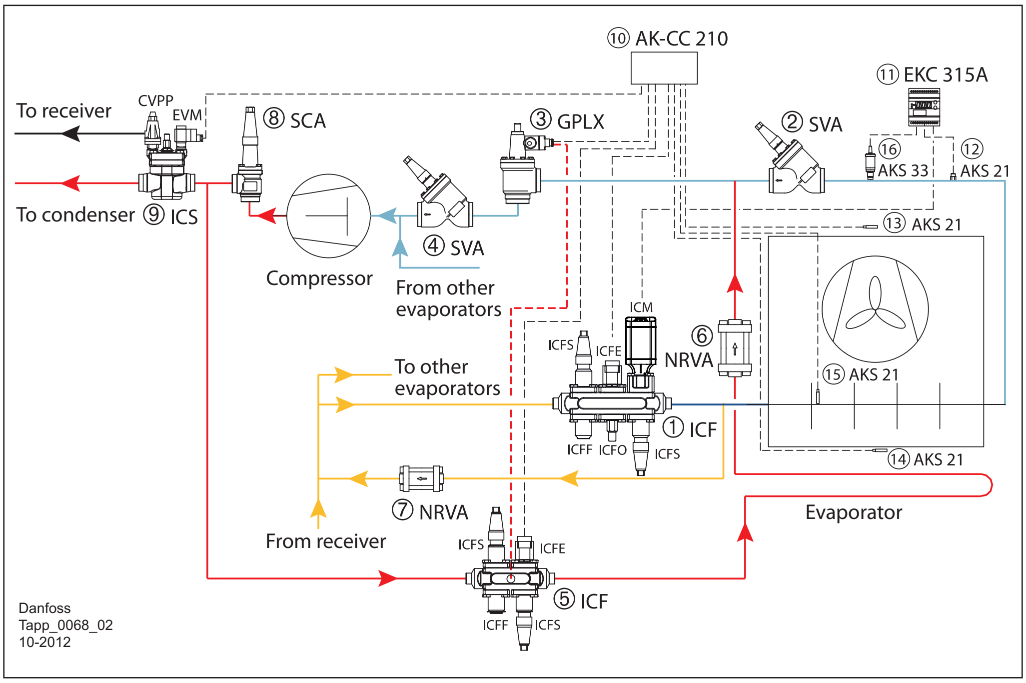
* Conditions: R717, ΔP = 0.2 bar, T_e = –10°C, Recirculation Ratio = 4

	Filter - FIA
Material	Body: steel
Refrigerants	All common refrigerants, incl. R717
Media temp. range [°C]	–60 to 150
Max. working pressure [bar]	52
DN [mm]	15 to 200
Filter insert	100/150/250/500µ stainless steel weave

	Motor valve - ICM as control valve
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 150
Nominal capacity [kW]*	On hot gas line: 2.3 to 4230 On wet suction line: 0.85 to 1570

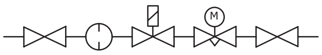
* Conditions: R717, T_{liq} = 30°C, $P_{disch.}$ = 12bar, ΔP = 0.2bar, $T_{disch.}$ = 80°C, T_e = –10°C, Recirculation Ratio = 4

Application example 5.3.3: DX evaporator, hot gas defrost system with ICF control solution



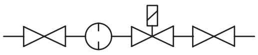
- HP vapour refrigerant
- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP vapour refrigerant

① Liquid Line ICF with:



Stop valve liquid inlet
Filter
Solenoid valve
Manual opening
ICM expansion valve
Stop valve evaporator inlet

② Stop valve evaporator outlet
③ Two step solenoid valve
④ Stop valve suction line
⑤ Hot gas line ICF with:



Stop Valve
Filter
Solenoid valve
Stop valve

⑥ Check valve
⑦ Check valve
⑧ Stop check valve on the discharge line
⑨ Differential pressure regulator
⑩ Controller
⑪ Superheat controller
⑫ Temperature sensors
⑬ Temperature sensors
⑭ Temperature sensors
⑮ Temperature sensors
⑯ Pressure transmitter

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.3.3 shows an installation for DX evaporators with hot gas defrost using the new ICF control solution.

The ICF will accommodate up to six different modules assembled in the same housing offering a compact, easy to install control solution

Refrigeration Cycle
The solenoid valve ICFE in the ICF ① in the liquid line is kept open. The liquid injection is controled by the motor-valve ICM in the ICF ①.

The solenoid valve GPLX ③ on the suction line is kept open, and the defrosting solenoid valve ICFE in ICF ⑤ is kept closed.

The servo valve ICS ⑨ is kept open by its solenoid valve pilot EVM.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid ICFE in ICF ① is closed. The fan is kept running for 120 to 600 seconds depending on the evaporator size in order to pump down the evaporator of liquid.

The fans are stopped and the GPLX closed. The GPLX valve ③ is kept in its open position by hot gas.

The hot gas condenses in the cold valve and produces liquid on top of the servo piston. When the pilot valves change position to close the valve, the pressure on the piston equalises to the suction pressure.

This equalisation takes time because condensed liquid is present in the valve.The exact time taken from when the pilot valves change position to complete closing of the valve depends on the temperature, pressure, refrigerant and valve size.

It is therefore not possible to state an exact closing time for the valves, but lower pressures generally result in longer closing times.

It is very important to take the closing times into consideration when hot gas defrost is used in evaporators.

A further delay of 10 to 20 seconds is required for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICFE in ICF ⑤ is then opened and supplies hot gas to the evaporator.

During the defrost cycle the solenoid valve pilot EVM for the servo valve ICS ⑨ is closed so that ICS ⑨ is controlled by the differential pressure pilot CVPP. ICS ⑨ then creates a differential pressure Δp between hot gas pressure and the receiver pressure.
This pressure drop ensures that the liquid which is condensed during defrosting is forced out into the liquid line through check valve NRVA ⑦.

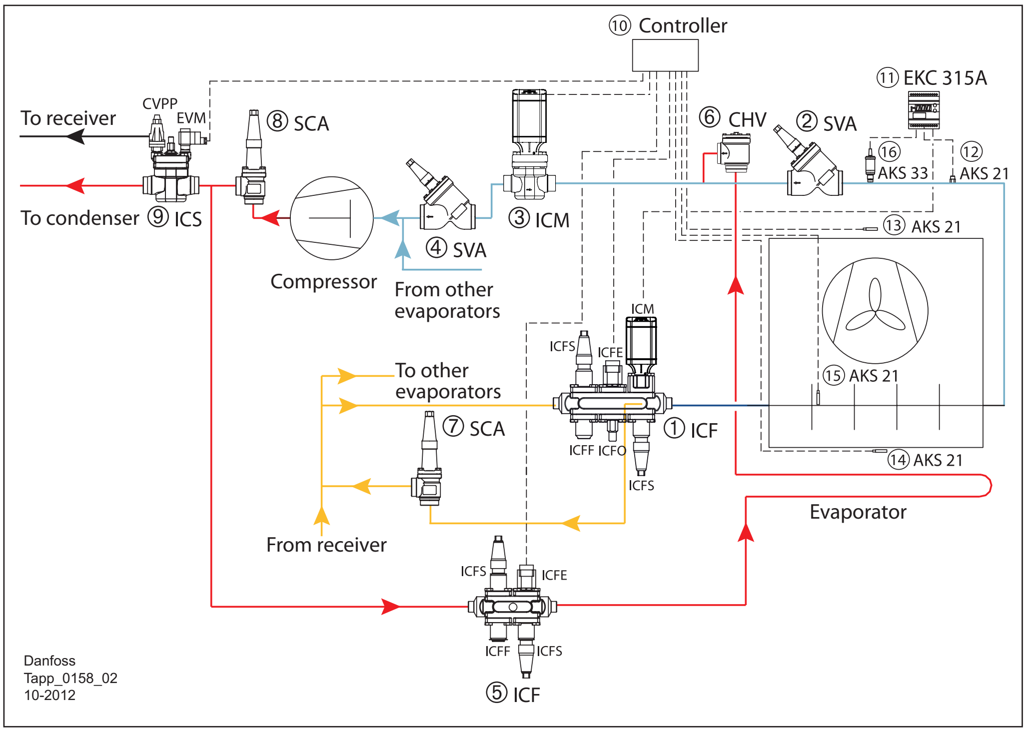
When the temperature in the evaporator (measured by AKS 21 ⑮) reaches the set value, defrost is terminated, the solenoid valve ICFE in ICF ⑤ is closed, the solenoid valve EVM pilot for ICS ⑨ is opened and the solenoid valve GPLX ③ is opened.

Because of the high differential pressure between the evaporator and the suction line, it is necessary to use a two step solenoid valve like the Danfoss GPLX ③ or ICLX. GPLX ③/ICLX will have a capacity of only 10 % at high differential pressure, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line.

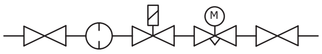
After the GPLX ③ fully opens, the liquid supply solenoid valve ICFE in ICF ① is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

Application example 5.3.4: DX evaporator, hot gas defrost system with ICF/ICM, fully welded

HP vapour refrigerant
HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant

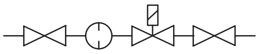


① Liquid Line ICF with:



Stop valve liquid inlet
Filter
Solenoid valve
Manual opening
ICM expansion valve
Stop valve evaporator inlet

② Stop valve evaporator outlet
③ Pressure regulator (motor valve)
④ Stop valve suction line
⑤ Hot gas line ICF with:



Stop Valve
Filter
Solenoid valve
Stop valve

⑥ Check valve
⑦ Check valve
⑧ Stop check valve on the discharge line
⑨ Differential pressure regulator
⑩ Controller
⑪ Superheat controller
⑫ Temperature sensors
⑬ Temperature sensors
⑭ Temperature sensors
⑮ Temperature sensors
⑯ Pressure transmitter

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.3.3 shows an installation for DX evaporators with hot gas defrost using the ICF control solution.

The ICF can accommodate up to six different modules in the same housing, easy to install control solution.

Refrigeration Cycle
The solenoid valve ICFE in the ICF ⑤ in the liquid line is kept open. Liquid injection is controlled by the motor valve ICM in the ICF ⑤.

The motor valve ICM ③ on the suction line is kept open, and the defrosting solenoid valve ICFE in ICF ⑤ is kept closed.

The servo valve ICS ⑨ is kept open by its solenoid valve pilot EVM.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid ICFE in ICF ① is closed. The fan is kept running for 120 to 600 seconds, depending on the evaporator size, to pump down the liquid in the evaporator.

The fans are stopped and the motor valve ICM ③ closed.

A delay of 10 to 20 seconds is required for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICFE in ICF ⑤ is then opened and supplies hot gas to the evaporator.

During the defrost cycle the solenoid valve pilot EVM for the servo valve ICS ⑨ is closed so that ICS ⑨ is controlled by the differential pressure pilot CVPP. ICS ⑨ then creates a differential pressure Δp between hot gas pressure and the receiver pressure.

This pressure drop ensures that the liquid which is condensed during defrosting is forced out into the liquid line through check valve SCA ⑦.

When the temperature in the evaporator (measured by AKS 21) reaches the set value, defrost is terminated, the solenoid valve ICFE in ICF ⑤ is closed, the solenoid valve EVM pilot for ICS ⑨ is opened and the motor valve ICM ③ is opened.

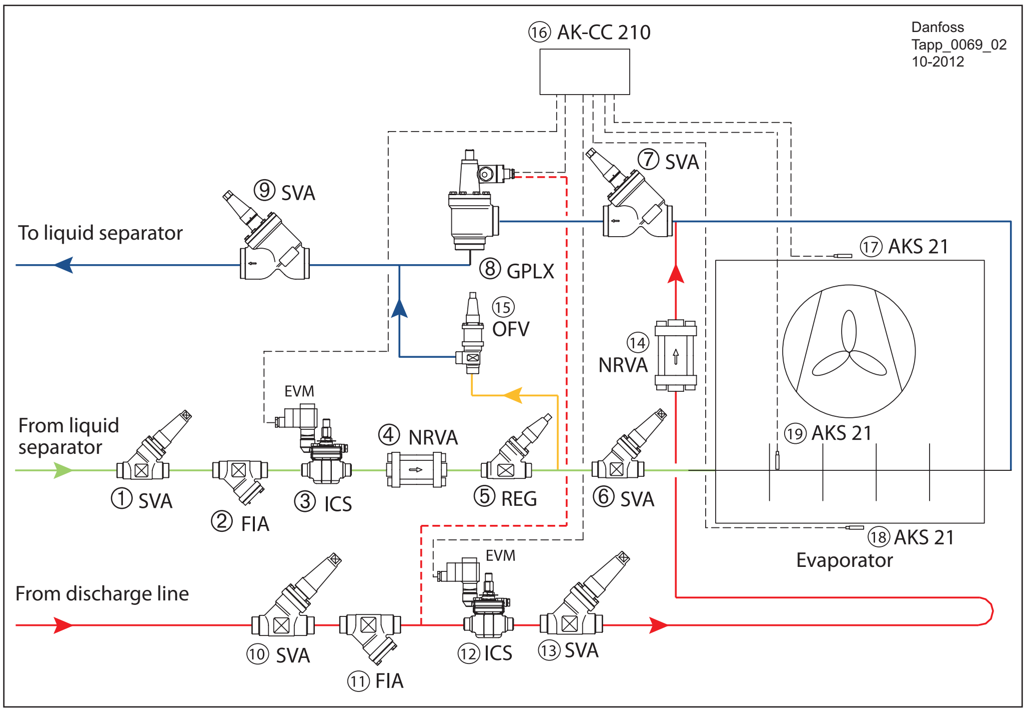
Because of the high differential pressure between the evaporator and the suction line, it is necessary to relieve the pressure slowly, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line.

An advantage of using the motor valve ICM ③ , a benefit is that the defrost pressure can be equalized by slowly opening the valve. A cost effective way to do this is using the on/off mode on the ICM and selecting a very low speed, or it can be achieved by using the modulating mode, so the PLC totally controls the opening degree and speed.

After the motor valve ICM ③ fully opens, the liquid supply solenoid valve ICFE in ICF ① is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator

5.4 Hot Gas Defrost for Pumped Liquid Circulation Air Coolers

Application example 5.4.1: Pumped liquid circulation evaporator, with hot gas defrost system



- HP vapour refrigerant
- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP liquid refrigerant

Liquid Line
① Stop valve liquid inlet
② Filter
③ Solenoid valve
④ Check valve
⑤ Hand expansion valve
⑥ Stop valve evaporator inlet

Suction Line
⑦ Stop valve evaporator outlet
⑧ Two step solenoid valve
⑨ Stop valve suction line

Hot gas line
⑩ Stop valve
⑪ Filter
⑫ Solenoid valve
⑬ Stop valve
⑭ Check valve

Overflow line
⑮ Overflow valve

Controls
⑯ Controller
⑰ Temperature sensor
⑱ Temperature sensor
⑲ Temperature sensor

Application example 5.4.1 shows a typical installation for a pumped liquid circulation evaporator with hot gas defrost.

Refrigeration Cycle
The solenoid valve ICS ③ on the liquid line is kept open. The liquid injection is controled by the hand regulating valve REG ⑤.

The solenoid valve GPLX ⑧ in the suction line is kept open, and the defrosting solenoid valve ICS ⑫ is kept closed.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid ICS ③ is closed. The fan is kept running for 120 to 600 seconds depending on the evaporator size in order to pump down the evaporator of liquid.

The fans are stopped and the GPLX closed. The GPLX valve ⑧ is kept in its open position by hot gas.

The hot gas condenses in the cold valve and produces liquid on top of the servo piston. When the pilot valves change position to close the valve, the pressure on the piston equalises to the suction pressure.

This equalisation takes time because condensed liquid is present in the valve.The exact time taken from when the pilot valves change position to complete closing of the valve depends on the temperature, pressure, refrigerant and valve size.

It is therefore not possible to state an exact closing time for the valves, but lower pressures generally result in longer closing times.

It is very important to take the closing times into consideration when hot gas defrost is used in evaporators.

A further delay of 10 to 20 seconds is required for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICS ⑫ is then opened and supplies hot gas to the evaporator.

During the defrost cycle, the overflow valve OFV ⑭ opens automatically subject to the differential pressure. The overflow valve allows the condensed hot gas from the evaporator to be released into the wet suction line. The OFV could also be replaced with a pressure regulator ICS+CVP depending on the capacity, or a high pressure float valve SV1/3 which only drains liquid to the low pressure side.

When the temperature in the evaporator (measured by AKS 21 ⑲) reaches the set value, defrost is terminated, the solenoid valve ICS ⑫ is closed, and the two-step solenoid valve GPLX ⑧ is opened.

After the GPLX fully opens, the liquid supply solenoid valve ICS ③ is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

The ICLX valve has the same function (two step solenoid valve) as a GPLX. The GPLX/ICLX has a capacity of only 10% at high differential pressure, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line

Technical data

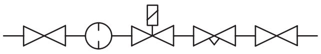
	Overflow valve - OFV
Material	Body: steel
Refrigerants	All common refrigerants, incl. R717
Media temp. range [°C]	–50 to 150
Max. working pressure [bar]	40
DN [mm]	20/25
Opening differential pressure range [bar]	2 to 8

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.4.2: Pump circulated evaporator, with hot gas defrost system using ICF valve station and SV 1/3 float valve

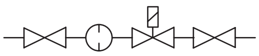
- HP vapour refrigerant
- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP liquid refrigerant

① Liquid Line ICF with:



Stop valve liquid inlet
Filter
Solenoid valve
Check valve
Hand expansion valve
Stop valve evaporator inlet

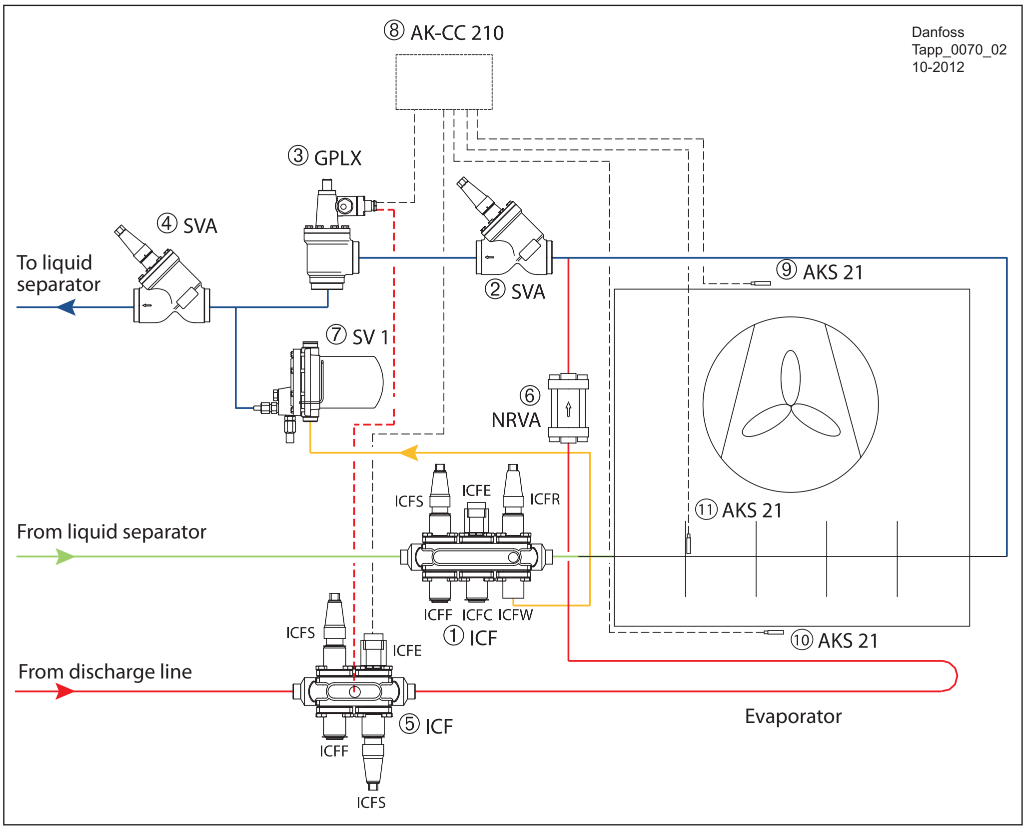
② Stop valve evaporator outlet
③ Two step solenoid valve
④ Stop valve suction line
⑤ Hot gas line ICF with:



Stop Valve
Filter
Solenoid valve
Stop valve

⑥ Check valve
⑦ Float valve
⑧ Controller
⑨ Temperature sensors
⑩ Temperature sensors
⑪ Temperature sensors

Not all valves are shown.
Not to be used for construction purposes.



Application example 5.4.2 shows an installation for pumped liquid circulation evaporators with hot gas defrost using the new ICF control solution and SV 1/3 float valve.

The ICF will accommodate up to six different modules assembled in the same housing offering a compact, easy to install control solution.

Refrigeration Cycle
The solenoid valve ICFE in ICF ① in the liquid line is kept open. The liquid injection is controled by the hand regulating valve ICFR in ICF ①.

The solenoid valve GPLX ③ in the suction line is kept open, and the defrosting solenoid valve ICFE in ICF ⑤ is kept closed.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid module ICFE of the ICF ① is closed. The fan is kept running for 120 to 600 seconds depending on the evaporator size in order to pump down the evaporator of liquid.

The fans are stopped and the GPLX closed. The GPLX valve ③ is kept in its open position by hot gas.

The hot gas condenses in the cold valve and produces liquid on top of the servo piston. When the pilot valves change position to close the valve, the pressure on the piston equalises to the suction pressure.

This equalisation takes time because condensed liquid is present in the valve.The exact time taken from when the pilot valves change position to complete closing of the valve depends on the temperature, pressure, refrigerant and valve size.

It is therefore not possible to state an exact closing time for the valves, but lower pressures generally result in longer closing times.

It is very important to take the closing times into consideration when hot gas defrost is used in evaporators.

A further delay of 10 to 20 seconds for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICFE in ICF ⑤ is then opened and supplies hot gas to the evaporator.

During the defrost cycle, the condensed hot gas from the evaporator is injected into the low pressure side. The injection is controlled by the high pressure float valve SV 1 or 3 ⑦ complete with special internal kit. Compared to the overflow valve OFV in the solution 5.4.1, this float valve controls the overflow according to the liquid level in the float chamber.

The use of a float valve ensures that the hot gas does not leave the evaporator until it is condensed into liquid, resulting in an increase in overall efficiency. Furthermore, the float valve is specifically designed for modulating control providing a very stable control solution.

When the temperature in the evaporator (measured by AKS 21 ⑪) reaches the set value, defrost is terminated, the solenoid valve ICFE in ICF ⑤ is closed, and after a small delay the solenoid valve GPLX ③ is opened.

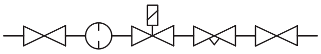
After the GPLX fully opens, the liquid supply solenoid valve ICFE in ICF ① is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

The ICLX valve has the same function (two step solenoid valve) as a GPLX. The GPLX/ICLX has a capacity of only 10% at high differential pressure, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line

Application example 5.4.3: Pump circulated evaporator, with hot gas defrost system, fully welded, using ICF valve station and ICS with CVP

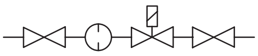
- HP vapour refrigerant
- HP liquid refrigerant
- Liquid/vapour mixture of refrigerant
- LP liquid refrigerant

① Liquid Line ICF with:



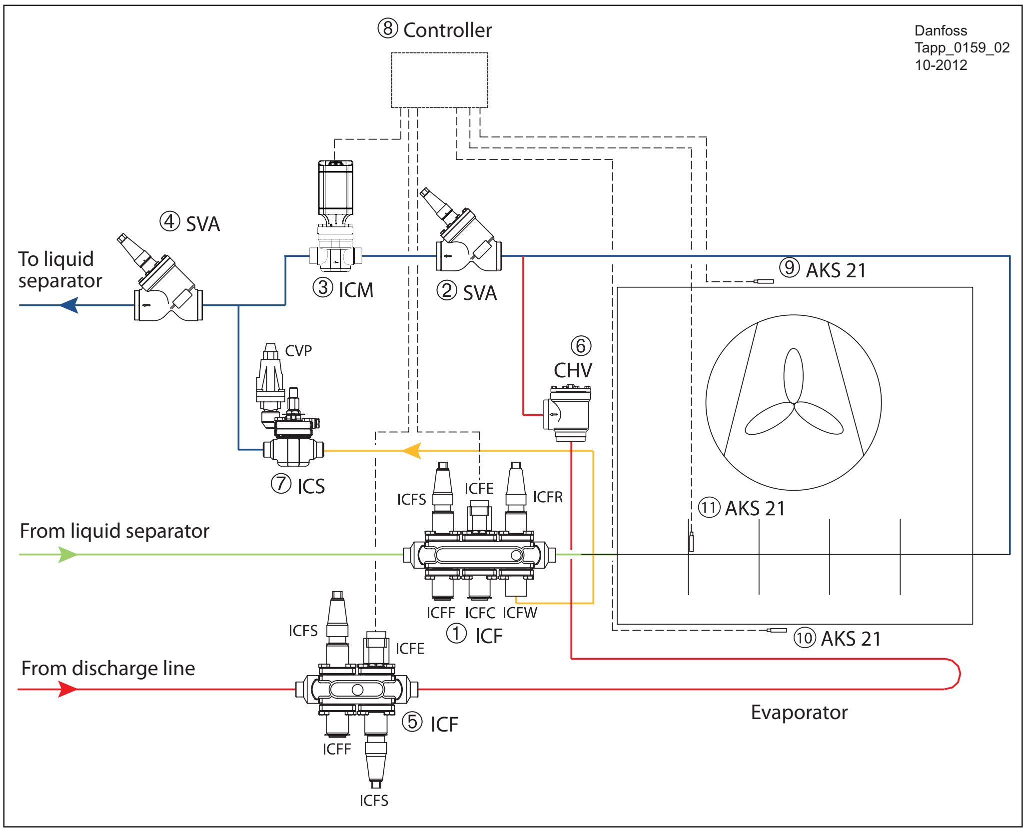
Stop valve liquid inlet
Filter
Solenoid valve
Check valve
Hand expansion valve
Stop valve evaporator inlet

② Stop valve evaporator outlet
③ Pressure regulator (motor valve)
④ Stop valve suction line
⑤ Hot gas line ICF with:



Stop Valve
Filter
Solenoid valve
Stop valve

⑥ Check valve
⑦ Pressure regulator
⑧ Controller
⑨ Temperature sensors
⑩ Temperature sensors
⑪ Temperature sensors



Application example 5.4.3 shows an installation for pumped liquid circulation evaporators with hot gas defrost using the new ICF control solution.

The ICF can accommodate up to six different modules in the same housing, easy to install control solution.

Refrigeration Cycle
The solenoid valve ICFE in ICF ① in the liquid line is kept open. The liquid injection is controlled by the hand regulating valve ICFR in ICF ①.

The motor valve ICM ③ in the suction line is kept open, and the defrosting solenoid valve ICFE in ICF ⑤ is kept closed.

Defrost Cycle
After initiation of the defrost cycle, the liquid supply solenoid module ICFE of the ICF ① is closed. The fan is kept running for 120 to 600 seconds, depending on the evaporator size, to pump down the liquid in the evaporator.
The fans are stopped and the ICM valve closed. A delay of 10 to 20 seconds for the liquid in the evaporator to settle down in the bottom without vapour bubbles. The solenoid valve ICFE in ICF ⑤ is then opened and supplies hot gas to the evaporator.

During the defrost cycle, the condensed hot gas from the evaporator is injected into the low pressure side. The defrost pressure is controlled by the ICS+CVP ⑦.

When the temperature in the evaporator (measured by AKS 21) reaches the set value, defrost is terminated, the solenoid valve ICFE in ICF ⑤ is closed, and after a small delay the motor valve ICM ③ is opened.

Because of the high differential pressure between the evaporator and the suction line, it is necessary to relieve the pressure slowly, allowing the pressure to be equalized before opening fully to ensure smooth operation and avoid liquid slugging in the suction line.

The advantage of using the motor valve ICM ③ is that the defrost pressure can be equalized by slowly opening the valve. A cost effective way to do this is to use the ICM on/off mode and select a very low speed. It can also be achieved by using the modulating mode thus the PLC totally controls the opening degree and speed.

After the ICM fully opens, the liquid supply solenoid valve ICFE in ICF ① is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze remaining liquid droplets on the surface of the evaporator.

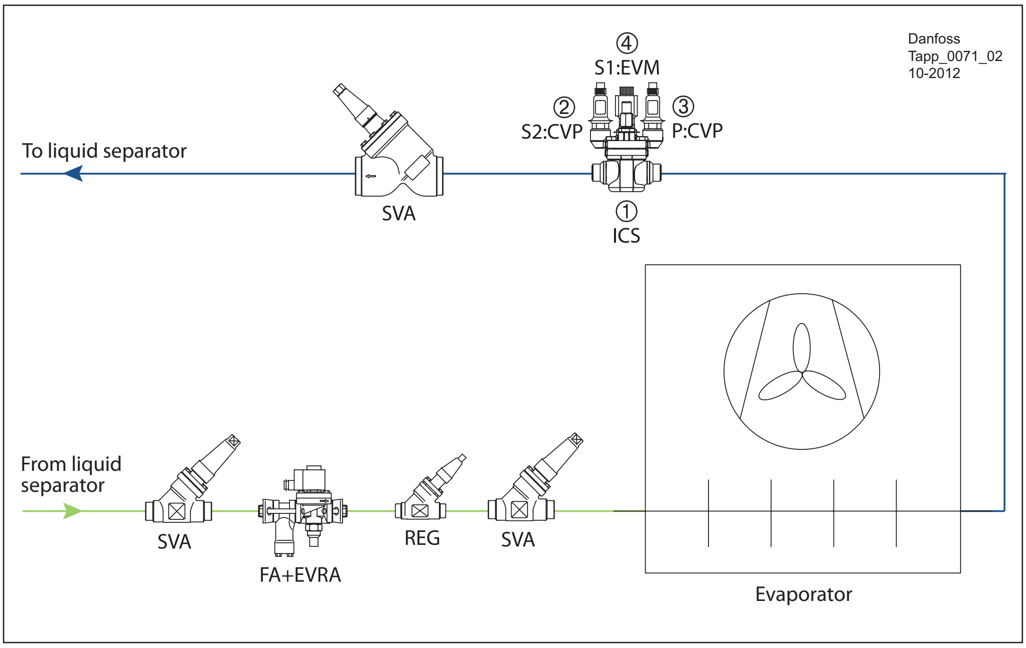
Not all valves are shown.
Not to be used for construction purposes.

5.5 Multi Temperature Changeover

In the process industry, it is very common to use an evaporator for different temperature settings.

When the operation of an evaporator is required at two different fixed evaporating pressures, this can be achieved by using one servo valve ICS with two constant pressure pilots.

Application example 5.5.1: Evaporating pressure control, changeover between two pressures



Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① Pressure regulating valve
② Pressure regulating pilot valve
③ Pressure regulating pilot valve
④ Solenoid pilot valve

Application example 5.5.1 shows a solution for controlling two evaporating pressures in evaporators. This solution can be used for DX or pumped liquid circulation evaporators with any type of defrost system.

The servo valve ICS is equipped with one EVM (NC) solenoid valve pilot in the S1 port and two CVP constant pressure pilots in the ports S2 and P respectively.

The CVP in the S2 port is adjusted to the lower operating pressure and the CVP in the P port is adjusted to the higher operating pressure.

When the solenoid in S1 port is energised, the evaporator pressure will follow the setting of the CVP pilot in S1 port. When the solenoid is de-energised, the evaporator pressure will follow the setting of the CVP pilot in the P port.

Example:

	I	II
Outlet air temperature	+3°C	+8°C
Evaporating temperature	−2°C	+2°C
Temperature change	5K	6K
Refrigerant	R 717	R 717
Evaporating pressure	3.0 bar	3.6 bar

S2: CVP is preset to 3.0 bar, and
P: CVP is preset to 3.6 bar.

I: EVM pilot opens.
Hence the evaporating pressure is controlled by S2: CVP.
II: EVM pilot closes.
Hence the evaporating pressure is controlled by P: CVP.

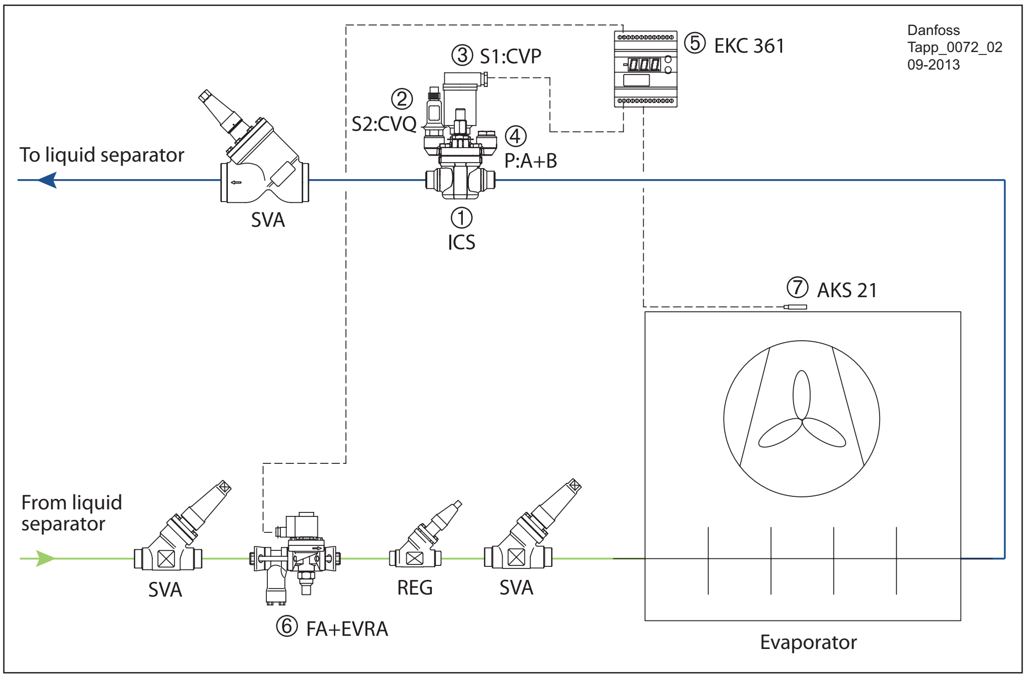
Not all valves are shown.
Not to be used for construction purposes.

5.6 Media Temperature Control

Solutions are provided for where there are stringent requirements for accurate temperature control in connection with refrigeration. E.g.:

- Cold room for fruits and food products
- Work premises in the food industry
- Process cooling of liquids

Application example 5.6.1: Media temperature control using pilot operated valve ICS



Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① Pressure regulating valve
② Pressure regulating pilot valve
③ Electronic pilot valve
④ Blind plug
⑤ Controller
⑥ Solenoid valve with filter
⑦ Temperature sensor

Application example 5.6.1 shows a solution for accurate media temperature control. Furthermore there is a need to protect the evaporator against a too low pressure to avoid freezing up of the products in the application.

This design can be applied for DX or pumped liquid circulation evaporators with any type of defrost system.

Control valve type ICS 3 with CVQ in S2 port, controlled by media temperature controller EKC 361 and CVP in the S1 port. The P port is isolated using the A+B blanking plug.

The CVP is adjusted according to the lowest pressure allowed for the application.

The media temperature controller EKC 361 will control the temperature in the application at the desired level, by controlling the opening of the CVQ pilot valve, and thereby controlling the evaporating pressure to match the required cooling load and temperature.

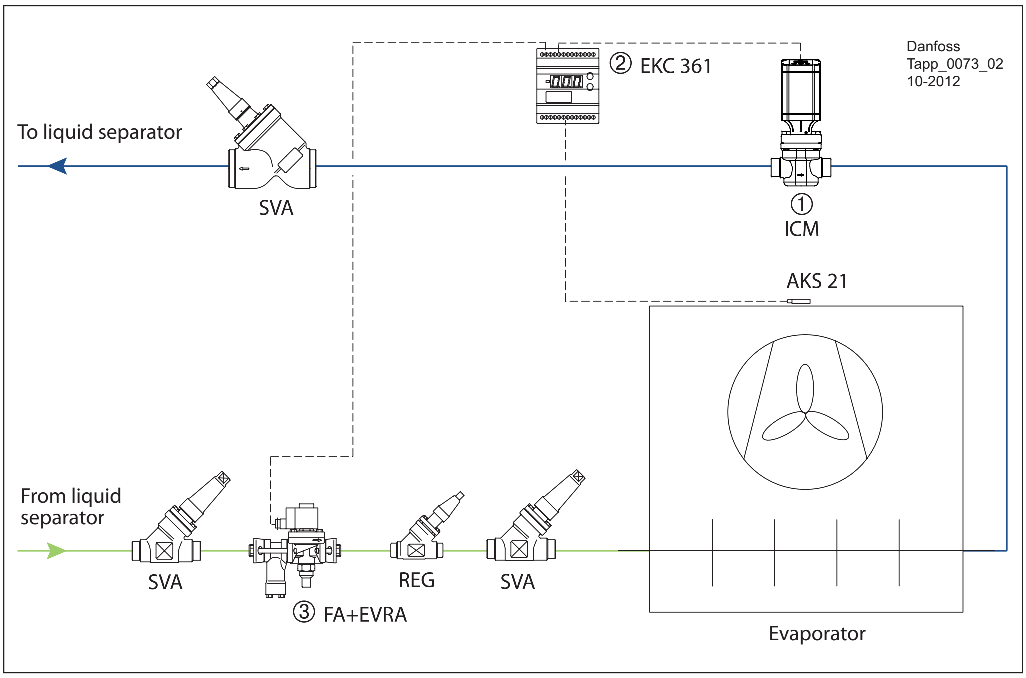
This solution will control the temperature with an accuracy of +/- 0.25°C. If the temperature falls below this range, the EKC controller can close the solenoid valve in the liquid line.

The media temperature controller EKC 361 will control all functions of the evaporator including thermostat and alarms.

For more details, please refer to the manual of the EKC 361 controller.

Not all valves are shown.
Not to be used for construction purposes.

Application example 5.6.2: Media temperature control using direct operated valve



Liquid/vapour mixture of refrigerant
LP liquid refrigerant

① Pressure regulator (motor valve)
② Controller
③ Solenoid valve with filter

Application example 5.6.2 shows a solution for accurate media temperature control without start/stop control.

This design can be used for DX or pumped liquid circulation evaporators with any type of defrost system.

Motor valve type ICM controlled by media temperature controller EKC 361 is selected.

The media temperature controller EKC 361 will control the temperature in the application at the desired level, by controlling the opening degree of the ICM motor valve, and thereby controlling the evaporating pressure to match the required cooling load and temperature.

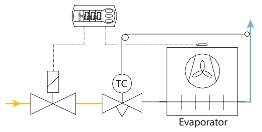
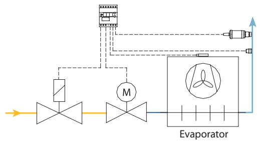
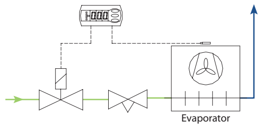
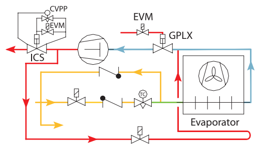
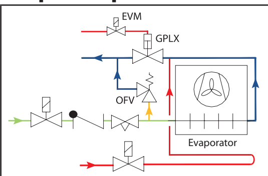
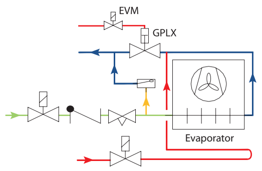
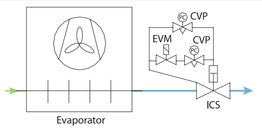
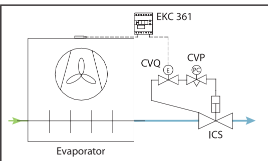
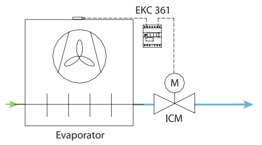
This solution will control the media temperature with an accuracy of +/- 0.25°C. If the temperature falls below this range, the EKC controller can close the solenoid valve in the liquid line.

The media temperature controller EKC 361 will control all functions of the evaporator including thermostat and alarms.

For more details, please refer to the separate manual of the EKC 361 controller.

Not all valves are shown.
Not to be used for construction purposes.

5.7 Summary

Solution		Application	Benefits	Limitations
Direct Expansion Control				
DX evaporator, thermostatic expansion control with TEA, EVRA, and EKC 202		All DX systems	Simple installation without separator and pump system.	Lower capacity and efficiency than circulated systems; Not suitable for flammable refrigerants.
DX evaporator, electronic expansion control with ICM/ ICF, EVRA and EKC 315A		All DX systems	Optimised superheat; Quick response; Possible to control remotely; Wide capacity range.	Not suitable for flammable refrigerant.
Pumped Liquid Circulation Control				
Pumped liquid circulation evaporator, expansion control with REG, EVRA and EKC 202		Pump circulating systems	High capacity and efficient evaporator	Fluctuations, and high refrigerant charge
Hot Gas Defrost Control-DX Air Coolers				
DX Evaporator with hot gas defrost		All DX systems	Quick defrost; The hot gas can bring out the oil left in the low temperature evaporator.	Not capable for systems with less than 3 evaporators.
Hot Gas Defrost Control-Pumped Liquid Circulation Air Coolers				
Pumped liquid circulation evaporator with hot gas defrost		All pump circulated systems	Quick defrost; The hot gas can bring out the oil left in the low temperature evaporator.	Not suitable for systems with less than 3 evaporators.
Pumped liquid circulation evaporator with hot gas defrost controled by SV1/3		All pump circulated systems	Quick defrost; The hot gas can bring out the oil left in the low temperature evaporator; The float valve is efficient and stable in regulating the hot gas flow.	Not suitable for systems with less than 3 evaporators.
Multi-temperature Changeover				
Multi-temperature control with ICS and CVP		Evaporators that need to work at different temperature levels	The evaporator can change over between 2 different temperature levels.	Pressure drop in suction line.
Media Temperature Control				
Media temperature control with ICS, CVQ and CVP		Very precise temperature control combined with minimum pressure (frost) protection. Option of running at different temperatures.	The CVQ will precisely control the temperature; CVP can keep the pressure above the required lowest level.	Pressure drop in suction line
Media temperature control with motor valve ICM		Very precise temperature control. Option of running at different temperatures.	The ICM will control the temperature very accurate, by adjusting the opening degree	Maximum capacity is ICM 65.

5.8 Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
AKS 21	RK0YG
AKS 33	RD5GH
AKVA	PD.VA1.B
CVP	PD.HN0.A
CVQ	PD.HN0.A
EVM	PD.HN0.A
EKC 202	RS8DZ
EKC 315A	RS8CS
EKC 361	RS8AE
EVRA(T)	PD.BM0.B
FA	PD.FM0.A

Type	Literature no.
FIA	PD.FN1.A
GPLX	PD.BO0.A
ICF	PD.FT1.A
ICM	PD.HT0.B
ICS	PD.HS2.A
NRVA	PD.FK0.A
OFV	PD.HQ0.A
ICLX	PD.HS1.A
REG	PD.KM1.A
SV 1-3	PD.GE0.B
SVA	PD.KD1.A
TEA	PD.AJ0.A

To download the latest version of the literature please visit the Danfoss website.

Product instruction

Type	Literature no.
AKS 21	RI14D
AKS 32R	PI.SB0.A
AKS 33	PI.SB0.A
AKVA	PI.VA1.C / PI.VA1.B
CVP	PI.HN0.C
CVQ	PI.VH1.A
EVM	PI.HN0.N
EKC 202	RI8JV
EKC 361	RI8BF
EVRA(T)	PI.BN0.L
FA	PI.FM0.A

Type	Literature no.
FIA	PI.FN1.A
GPLX	PI.BO0.A
ICF	PI.FT0.C
ICM 20-65	PI.HT0.A
ICM 100-150	PI.HT0.B
ICS 25-65	PI.HS0.A
ICS 100-150	PI.HS0.B
NRVA	PI.FK0.A
OFV	PI.HX0.B
ICLX	PI.HS1.A/B
REG	PI.KM1.A
SV 1-3	PI.GE0.C
SVA	PI.KD1.A
TEA	PI.AJ0.A

6. Oil Systems

Generally, industrial refrigeration compressors are lubricated with oil, which is forced by the oil pump or due to pressure difference between the high and the low pressure sides to the moving parts of the compressors (bearings, rotors, cylinder walls etc.). In order to guarantee reliable and efficient operation of the compressor the following oil parameters should be controlled:

- Oil temperature. This should be kept within the limits specified by manufacturer. The oil should have the correct viscosity and the temperature should be kept below the ignition point.
- Oil pressure. Oil pressure difference should be kept above the minimum acceptable level.

There are generally some supporting components and equipment within refrigeration systems for oil cleaning, oil separation from the refrigerant, oil return from the low pressure side, equalization of oil level in systems with several piston compressors and oil drain off points. Most of these are supplied by compressor manufacturer.

The oil system design of an industrial refrigeration plant depends on the type of the compressor (screw or piston) and on the refrigerant (ammonia, HFC/HCFC or CO2). Normally immiscible oil type is used for ammonia and miscible for Fluorinated refrigerants.
As oil systems are very compressor related, some of the above mentioned points have been described in compressor controls (section 2) and safety systems (section 7).

6.1 Oil cooling

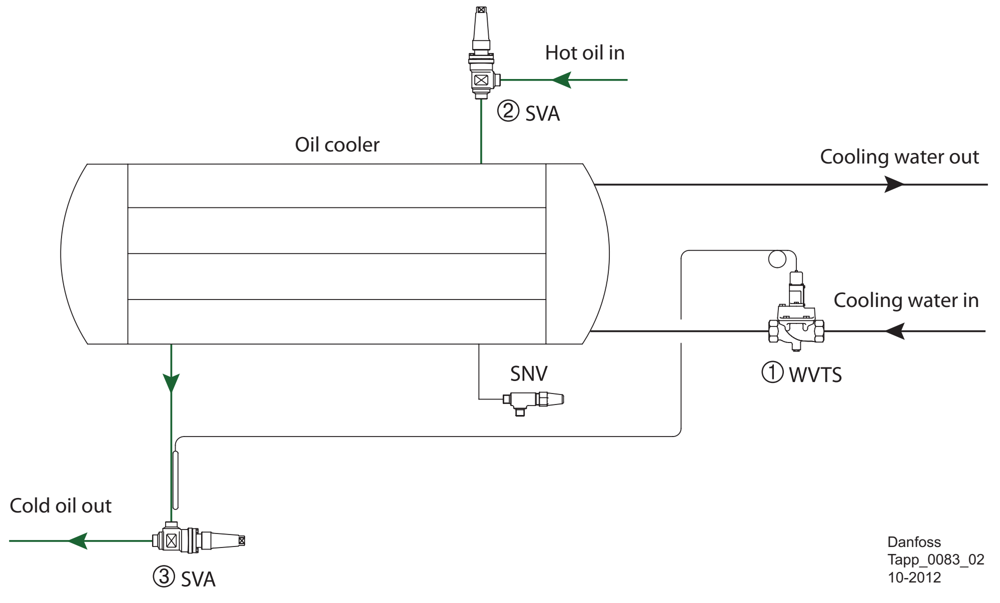
Refrigeration compressors (including all screw compressors and some piston compressors) generally require oil cooling. Too high discharge temperatures can destroy oil, which leads to the damage of the compressor. It is also important for the oil to have the right viscosity, which largely depends on the temperature level. It is not enough just to keep the temperature below critical limit, it is also necessary to control it. Normally, oil temperature is specified by the compressor manufacturer.

There are a few different types of oil cooling systems used in refrigeration. The most common types are:

- water cooling
- air cooling
- thermosyphon cooling

Oil can also be cooled by means of injection of the liquid refrigerant directly into the intermediate compressor port. For piston compressors, it is quite common not to have any special oil cooling systems at all, as temperature is less critical than for screw compressors, with the oil being cooled in the crankcase.

Application example 6.1.1:
Oil cooling with water



Water
Oil

① Water valve
② Stop valve
③ Stop valve

These types of systems are normally used in plants where it is possible to get cheap water source. Otherwise, it is necessary to install a cooling tower to cool down the water. Water cooled oil coolers are quite common for marine refrigeration plants.

The water flow is controlled by the water valve type WVTS ①, which controls the water flow according to the oil temperature.

Please contact your local Danfoss sales company to check suitability of components to be used with sea water as the cooling medium.

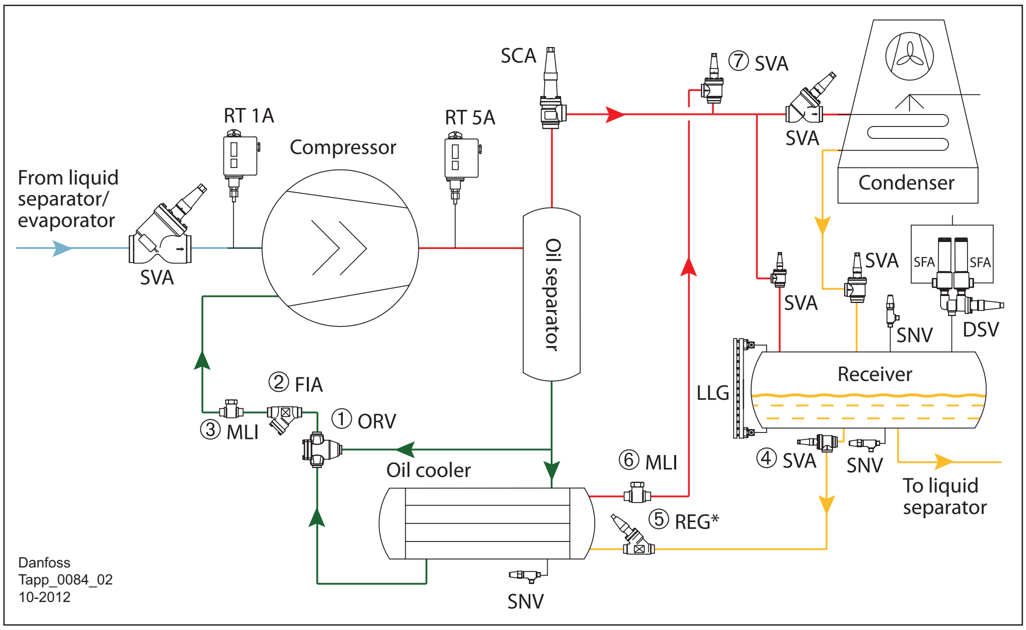
Technical data

	Water valve - WVTS
Materials	Valve body: cast iron
Media	Fresh water, neutral brine
Max. working pressure [bar]	10
Operating temp. range [°C]	Bulb: 0 to 90 Liquid: –25 to 90
DN [mm]	32 to 100
Max. K_v value [m³/h]	12.5 to 125

	Water valve - AVTA
Media	Fresh water, neutral brine
Max. working pressure [bar]	16
Operating temp. range [°C]	Bulb: 0 to 90 Liquid: –25 to 130
DN [mm]	10 to 25
Max. K_v value [m³/h]	1.4 to 5.5

Not all valves are shown.
Not to be used for construction purposes.

Application example 6.1.2: Thermosyphon oil cooling



HP vapour refrigerant
HP liquid refrigerant
LP vapour refrigerant
Oil

① Oil regulating valve
② Filter
③ Sight glass
④ Stop valve
⑤ Hand regulating valve
⑥ Sight glass
⑦ Stop valve

These types of systems are very convenient, as oil gets cooled inside the system. It is only necessary to oversize the condenser for the amount of heat taken from the oil cooler. Conversely, thermosyphon oil cooling requires additional piping on site and sometimes it is also necessary to install an additional priority vessel (in cases when the HP liquid receiver is placed too low or not installed).

High pressure liquid refrigerant flows from the receiver due to gravity force into the oil cooler where it evaporates and cools the oil. Refrigerant vapour rises back to the receiver or, in certain cases, to the condenser inlet. It is critical that the pressure drop in the feed and the return pipes is minimal.

Otherwise the refrigerant will not return from the oil cooler and the system will not function. Only minimal number of SVA stop valves should be installed. No pressure dependent solenoid valves are allowed. On the return pipe it is recommended to install a MLI ⑥ sight glass.

Oil temperature is maintained at the correct level by the ORV ① three-way valve. The ORV keeps the oil temperature within the limits defined by its thermostatic element. If the oil temperature rises too high then all the oil returns back to the oil cooler. If it is too low, then all the oil flow is bypassed around the oil cooler.

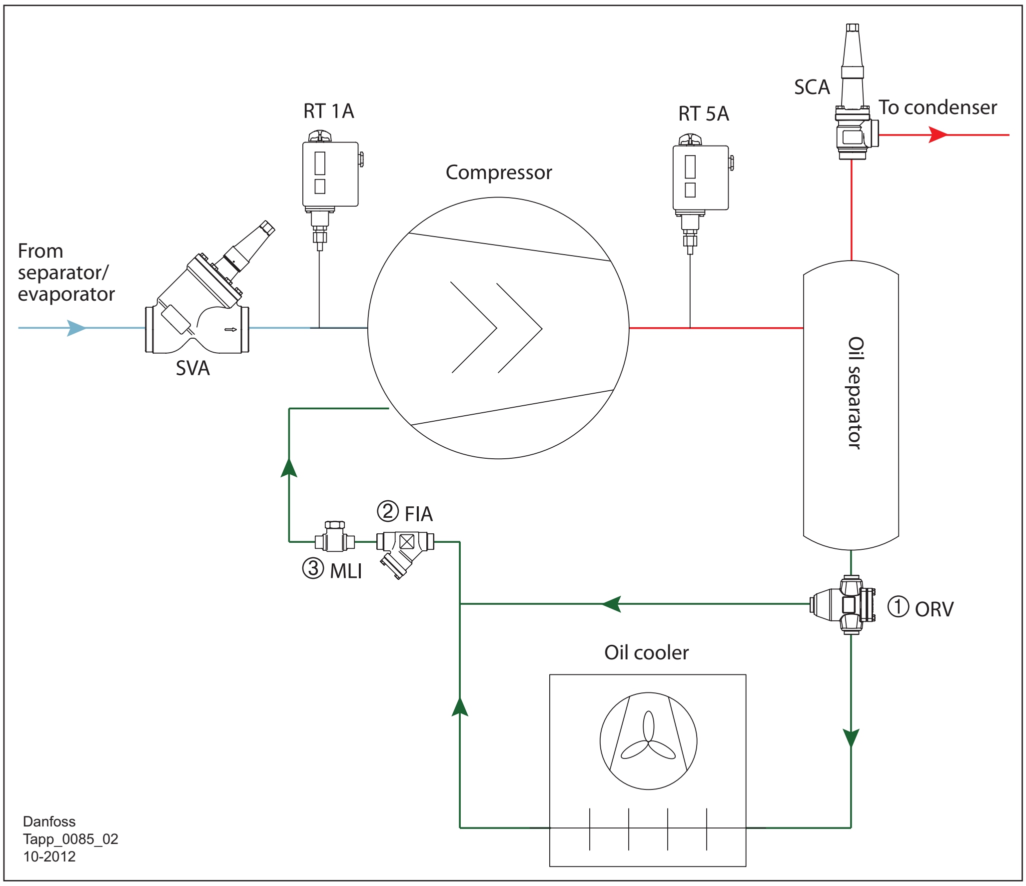
* REG regulating valve may be useful in case of largely oversized oil cooler.

Technical data

	Oil regulating valve - ORV
Materials	Valve body: cold resistant steel
Media	All common refrigeration oils and common refrigerants including R717
Max. working pressure [bar]	40
Temperature range [°C]	Continuous operation: –10 to 85 Short operation: –10 to 120
DN [mm]	25 to 80

Not all valves are shown.
Not to be used for construction purposes.

Application example 6.1.3:
Oil cooling with air



HP vapour refrigerant
LP vapour refrigerant
Oil

① Oil regulating valve
② Strainer
③ Sight glass

It is quite common to use air cooled oil coolers on the compressor units with semi-hermetic screw compressor refrigeration packs.

The oil temperature valve is controlled by the oil regulating valve ORV ①.

In this case ORV divides the flow from the oil separator and controls according to the change of the oil discharge temperature.

Not all valves are shown.
Not to be used for construction purposes.

6.2 Oil Differential Pressure Control

During normal running of the refrigeration compressor, oil is circulated by the oil pump and/or pressure difference between the HP and LP sides. The most critical phase is during start-up.

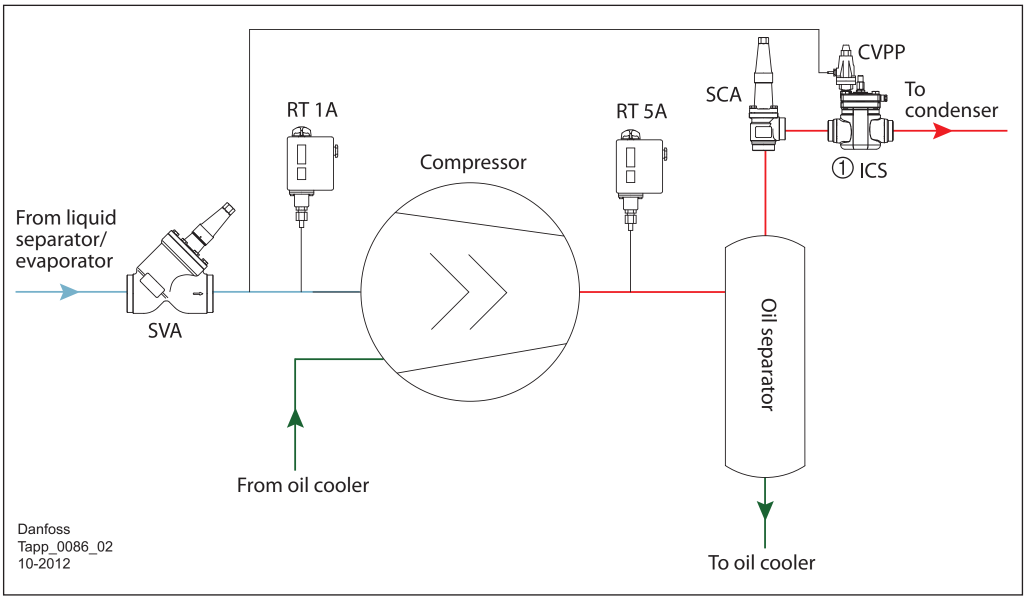
It is vital to have a quick build up of oil pressure otherwise the compressor may be damaged.

There are two basic ways to quickly build up oil differential pressure in the refrigeration compressor.

First is to use an external oil pump, and the second is to install a control valve on the compressor discharge line after the oil separator.

For the latter method it is necessary to check if the compressor manufacturer allows a few seconds of dry operation. Normally, this is possible for screw compressors with ball bearings but not possible for those with slide bearings

Application example 6.2.1: Oil differential pressure control with ICS and CVPP



HP vapour refrigerant
LP vapour refrigerant
Oil

① Differential pressure regulator

Oil cooler

In this application, a servo operated ICS ① complete with differential pilot CVPP should be used. The pilot line from the CVPP valve is connected to the suction line before the compressor. ICS ① is closed at the moment the compressor is started up.

As the piping between the compressor and the valve is very short, the discharge pressure increases rapidly. It requires very little time before the valve fully opens and the compressor runs at normal conditions.

The main advantage of this solution is its flexibility, as differential pressure could be readjusted on site, and ICS can also serve for some other functions using other pilots.

Technical data

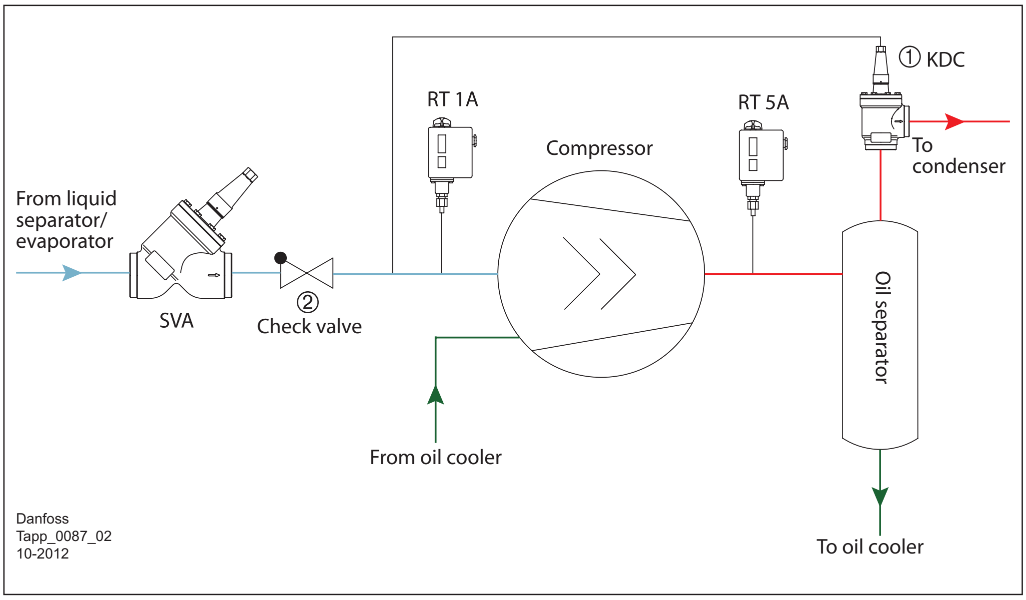
	Pilot operated servo valve - ICS
Material	Body: low temp. steel
Refrigerants	All common refrigerants, incl. R717 and R744
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	52
DN [mm]	20 to 150
Nominal capacity [kW]*	20 to 4000

* Conditions: R717, hot gas line, T_{liq} = 30°C, $P_{disch.}$ = 12bar, ΔP = 0.2bar, $T_{disch.}$ = 80°C, T_e = –10°C

	Differential pressure pilot valve-CVPP
Material	Body: stainless steel
Refrigerants	All common non-flammable refrigerants incl. R717
Media temp. range [°C]	–50 to 120
Max. working pressure [bar]	CVPP (LP): 17 CVPP (HP): up to 40
Regulating range [bar]	CVPP (LP): 0 to 7 CVPP (HP): 0 to 22
K_v value m^3/h	0.4

Not all valves are shown.
Not to be used for construction purposes.

Application example 6.2.2:
Oil differential pressure control with KDC



HP vapour refrigerant
LP vapour refrigerant
Oil

① Differential pressure regulator
② Check valve (normally built into the compressor)

The principle of operation for this example is the same as for example 6.2.1. The multifunctional compressor valve KDC ① opens until the pressure difference between the oil separator and the suction line exceeds the setting value and at the same time the pressure in the oil separator is greater than the condensing pressure.

KDC ① valve has some advantages, as it can also function as a check valve (it can not be open by the back pressure), and it gives smaller pressure drop when open.

However, KDC ① also has some limitations. The valve is not adjustable and there are a limited number of differential pressure settings available, and it is necessary to have a check valve ② in the suction line.

If this check valve is not present, there could be a very large reverse flow through the compressor from the oil separator. It is neither allowed to have a check valve between compressor and oil separator; otherwise it may require too long time for KDC to close.

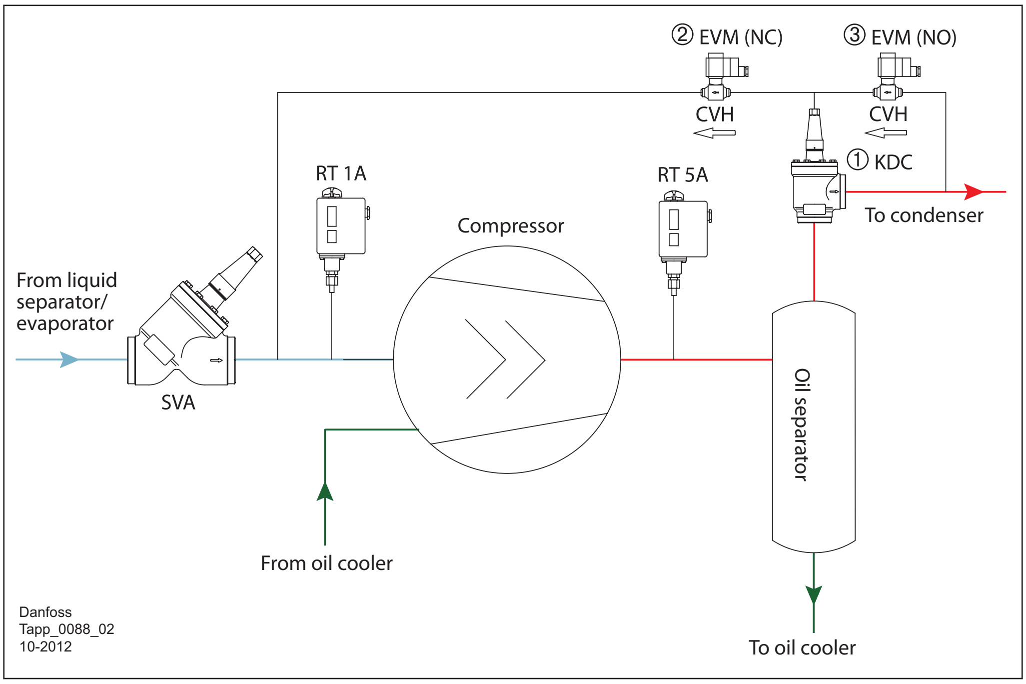
Technical data

	Multifunctional compressor valve - KDC
Material	Low temp. steel
Refrigerants	All common refrigerants including R717
Media temp. range [°C]	–50 to 150
Max. working pressure [bar]	40
DN [mm]	65 to 200
Nominal capacity [kW]*	435 to 4207

* Conditions: R717, +35°C/–15°C, ΔP = 0.05bar

Not all valves are shown.
Not to be used for construction purposes.

Application example 6.2.3: Oil differential pressure control with KDC and EVM pilots



HP vapour refrigerant
LP vapour refrigerant
Oil

① Multifunctional compressor valve
② Solenoid pilot (normally close)
③ Solenoid pilot (normally open)

When there is no possibility to install a check valve in the suction line or there is a check valve between the compressor and the oil separator, it is possible to use KDC ① equipped with EVM pilot valves.

These EVM pilots are installed in external lines using CVH bodies, as illustrated. During start up of the compressor the system works as in the previous example (6.2.2).

When the compressor stops, EVM NC ② should be closed and EVM NO ③ opens. That equalizes the pressure over the KDC spring and it closes.

Please note the installation direction of the CVH and EVM pilot valves.

Not all valves are shown.
Not to be used for construction purposes.

6.3 Oil Recovery System

The compressors within industrial refrigeration ammonia systems are generally the only components that which require oil lubrication. Therefore the function of the compressor oil separator is to prevent any of the lubricating oil passing into the refrigeration system.

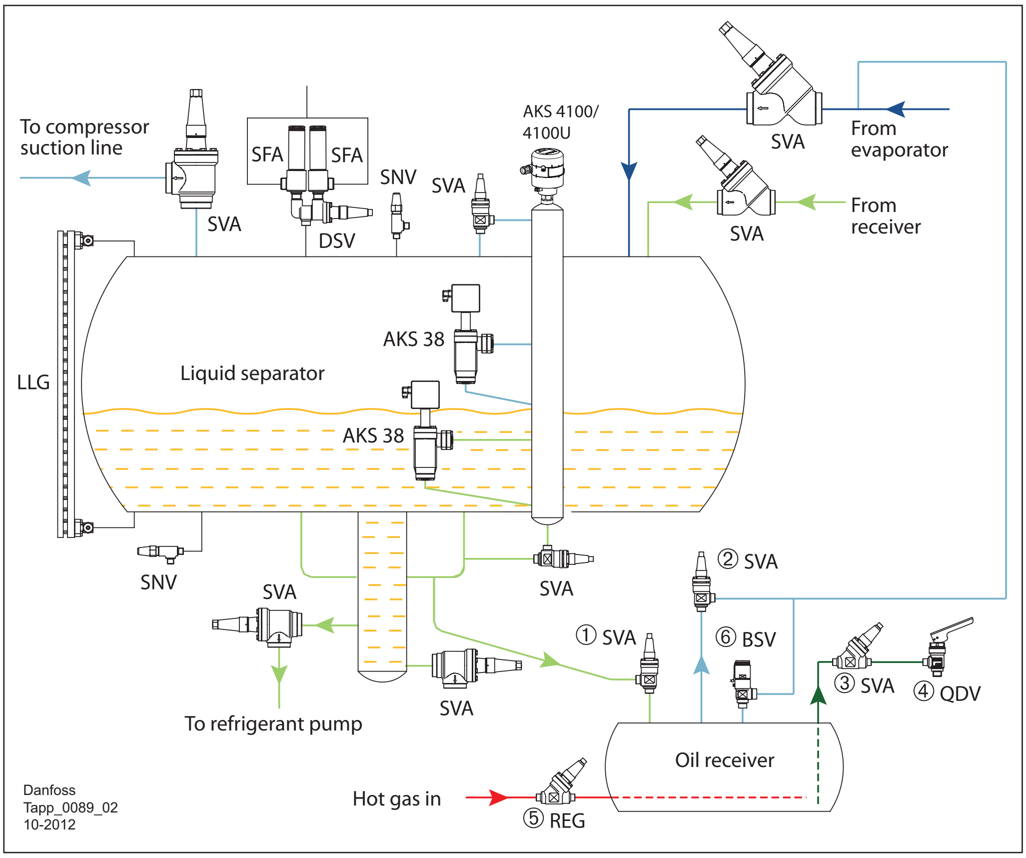
However, oil can carry over through the oil separator into the refrigeration system and often collects in the low pressure side in liquid separators and evaporators, decreasing their efficiency.

If too much oil carries over from the compressor into the system, the oil in the compressor will be reduced and there is then a risk of the oil level falling below the minimum limit set by the compressor manufacturer. Oil return systems are primarily used together with refrigerants that can be mixed with the oil e.g. HFC/HCFC systems. The oil return system can therefore have two functions:

- To remove oil from the low pressure side
- To feed the oil back to the compressor.

It is however extremely important to be aware that any oil removed from the low pressure side of the ammonia cooling system is usually unsuitable for further use with the compressor and it should be removed from the refrigeration system and discarded.

Application example 6.3.1: Oil drain from ammonia systems



HP vapour refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant
Oil

① Stop valve
② Stop valve
③ Stop valve
④ Quick closing oil drain valve
⑤ Regulating valve
⑥ Safety relief valve

In ammonia systems immiscible oil is used. As the oil is heavier than liquid ammonia, it stays in the bottom of the liquid separator and is unable to return to the compressor via the suction line.

Therefore, oil in ammonia systems is normally drained from the liquid separator into the oil receiver. It makes separation of oil from ammonia easier.

When draining the oil, close the stop valve ① and ②, and open the hot gas line, allowing the hot gas to increase the pressure and heat up the cold oil.

Then drain the oil using the quick closing oil drain valve QDV ④, which can be closed quickly after oil evacuation and when ammonia starts to come out.

Stop valve SVA ③ between QDV and the receiver must be installed. This valve is opened before evacuation of oil and closed afterwards.

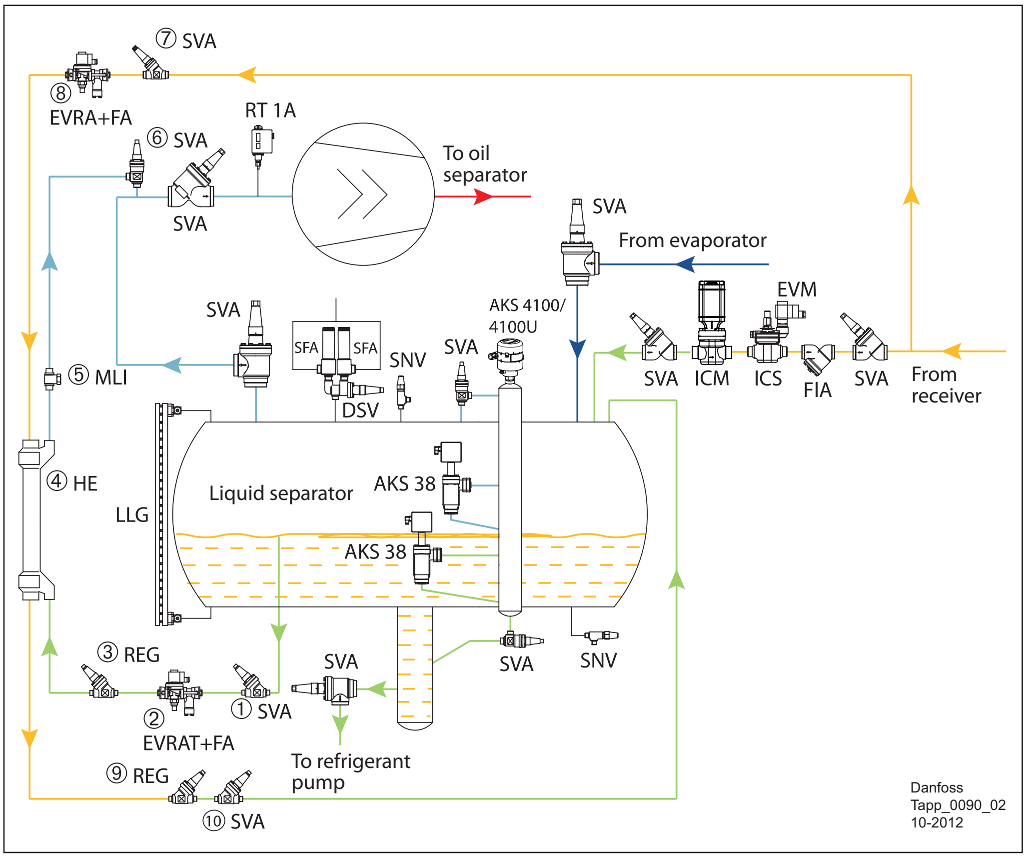
Necessary precautions during drain of oil from ammonia should be taken.

Technical data

	Quick closing drain valve - QDV
Material	Housing: steel
Refrigerants	Commonly used with R717; applicable to all common non-flammable refrigerants.
Media temp. range [°C]	–50 to 150
Max. working pressure [bar]	25
DN [mm]	15

Not all valves are shown.
Not to be used for construction purposes.

Application example 6.3.2: Oil drain from fluorinated systems



HP vapour refrigerant
HP liquid refrigerant
Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Solenoid valve
③ Regulating valve
④ Heat exchanger
⑤ Sight glass
⑥ Stop valve
⑦ Stop valve
⑧ Solenoid valve
⑨ Regulating valve
⑩ Stop valve

In fluorinated systems miscible oil is predominantly used. In systems using good piping practice (slopes, oil loops etc.), it is not necessary to recover oil, as it returns with the refrigerant vapour.

However in low temperature plants oil may stay in the low pressure vessels. Oil is lighter than commonly used Fluorinated refrigerants, so it's impossible to drain it in a simple way as in ammonia systems.

Oil stays on top of the refrigerant, and the level fluctuates together with refrigerant level.

In this system the refrigerant moves from the liquid separator into the heat exchanger ④ due to gravity.

Low pressure refrigerant is heated up by high pressure liquid refrigerant and evaporates.

Refrigerant vapour mixed with oil returns to the suction line. Refrigerant from the liquid separator is taken from the working level.

Regulating valve REG ③ is adjusted such a way that there are no drops of liquid refrigerant seen in the sight glass MLI ⑤. Danfoss heat exchange HE type could be used to recover the oil.

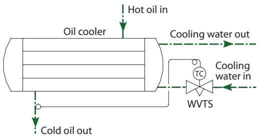
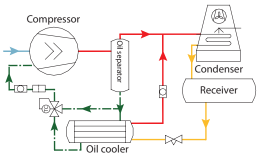
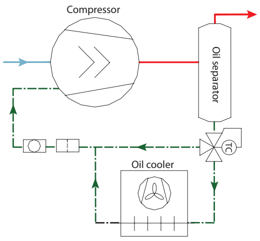
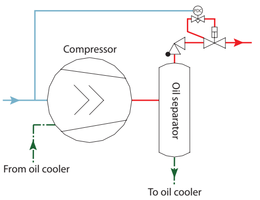
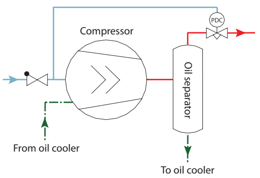
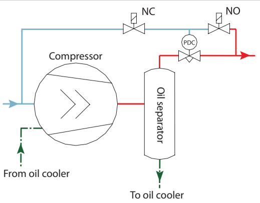
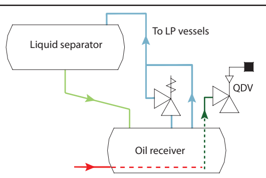
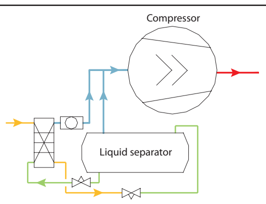
Refrigerant could also be taken from pump discharge lines. In this case it doesn't really matter if the refrigerant is taken from the working level or not.

Technical data

	Heat exchanger - HE
Refrigerants	All fluorinated refrigerants
Media temp. range [°C]	–60 to 120
Max. working pressure [bar]	HE0.5, 1.0, 1.5, 4.0: 28 HE8.0: 21.5
DN [mm]	Liquid line: 6 to 16 Suction line: 12 to 42

Not all valves are shown.
Not to be used for construction purposes.

6.4
Summary

Solution		Application	Benefits	Limitations
Oil Cooling Systems				
Water cooling, WVTS water valve		Marine installations, plants where cheap cold water source is available	Simple and efficient	Could be expensive, requires separate water piping
Thermosyphon cooling, ORV		All types of refrigeration plants	Oil is cooled by refrigerant without loss of installation efficiency	Require extra piping and HP liquid receiver installed on defined height
Air cooling, ORV		"Heavy commercial" refrigeration systems with power packs.	Simple, no additional piping or water required	Big fluctuations in oil temperature in different seasons possible; Air cooler may be too big for large installations
Differential Oil Pressure Control				
ICS + CVPP			Flexible, different settings possible	Requires installation of the check valve
KDC		Screw compressors (should be confirmed by compressor manufacture)	Requires no discharge check valve, pressure drop lower than ICS solution.	It is necessary to install check valve in the suction line, no change of setting possible
KDC+EVM			As previous, but installation of the check valve in the suction line is not necessary.	Requires external piping, no change of setting possible
Oil Recovery Systems				
Oil recovery from ammonia systems, QDV		All ammonia plants	Simple and safe	Requires hand operating
Oil recovery from fluorinated systems, HE		Low temperature Fluorinated systems	Doesn't require manual operation	Adjusting could be complicated

6.5 Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
BSV	PD.IC0.A
CVPP	PD.HN0.A
EVM	PD.HN0.A
FIA	PD.FN0.A
HE	PD.FD0.A
ICS	PD.HS2.A
KDC	PD.FQ0.A

Type	Literature no.
MLI	PD.GH0.A
ORV	PD.HP0.B
QDV	PD.KL0.A
REG	PD.KM1.A
SVA	PD.KD1.A

Product instruction

Type	Literature no.
BSV	PI.IC0.A
CVPP	PI.HN0.C
EVM	PI.HN0.N
FIA	PI.FN0.A
HE	PI.FD0.A
ICS 25-65	PI.HS0.A
ICS 100-150	PI.HS0.B
KDC	PI.FQ0.A

Type	Literature no.
MLI	PI.GH0.A
ORV	PI.HP0.A
QDV	PI.KL0.A
REG	PI.KM1.A
SVA	PI.KD1.A

To download the latest version of the literature please visit the Danfoss website.

7. Safety systems

All industrial refrigeration systems are designed with different safety systems to protect them against unsafe conditions, like excessive pressure. Any foreseeable excessive internal pressure should be prevented or relieved with minimum risk for people, property and the environment.

Requirements on the safety systems are heavily controled by authorities, and it is therefore always necessary to verify the requirements in the local legislation in various countries.

Pressure relief device e.g. pressure relief valves are designed to relieve excessive pressure automatically at a pressure not exceeding the allowable limit and reseat after the pressure has fallen below the allowable limit.

Temperature limiting device or temperature limiter is a temperature actuated device that is designed to avoid unsafe temperatures so that the system can be stopped partly or completely in case of a defect or malfunction.

Pressure limiter is a device that protects against high or low pressure with automatic resetting.

Safety pressure cut out
Safety switches are designed for limiting the pressure with manual resetting.

Liquid level cut out is a liquid level actuated device designed to prevent against unsafe liquid levels.

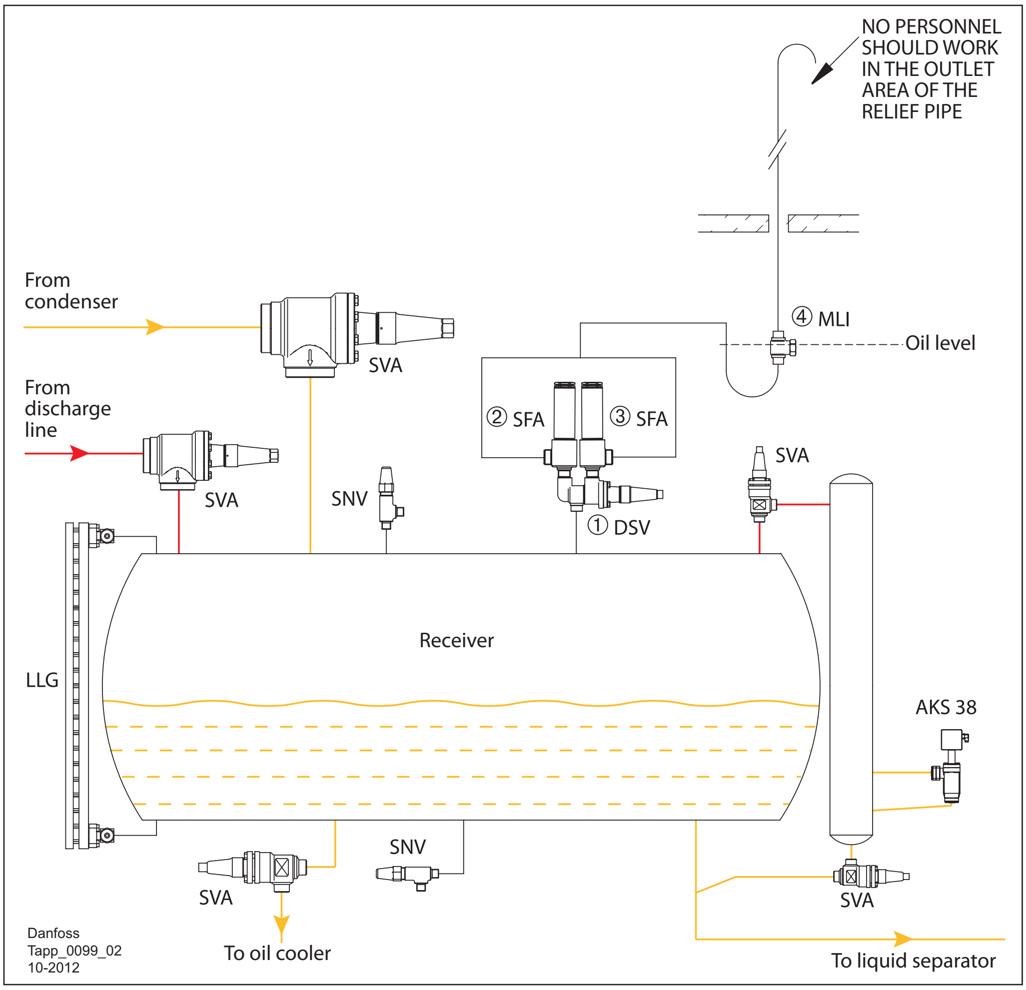
Refrigerant detector is a sensing device which responds to a pre-set concentration of refrigerant gas in the environment. Danfoss produces refrigerant detectors type GD, please see specific application guide for more information.

7.1 Pressure Relief Devices

Safety valves are installed in order to prevent the pressure in the system from rising above the maximum allowable pressure of any component and the system as a whole. In case of excessive pressure, safety valves relieve refrigerant from the refrigeration system.

Main parameters for safety valves are the relief pressure and reseating pressure. Normally the relief pressure should not exceed more than 10% of the set pressures. Furthermore, if the valve does not reseat or reseats at too low a pressure, there can be significant loss of system refrigerant.

Application example 7.1.1:
Safety valve SFA + DSV



HP vapour refrigerant
HP liquid refrigerant

① Double stop valve
② Safety relief valve
③ Safety relief valve
④ Sight glass

Pressure relief devices should be installed on all vessels in the systems, as well as on compressors.

Generally, back pressure dependent safety relief valves (SFA) are normally used. Safety valves should be installed with a changeover valve DSV ①, to enable the servicing of one valve whilst the other is still in operation.

Pressure relief devices should be mounted close to the part of the system they are protecting. In order to check if the relief valve has discharged to the atmosphere a u-trap filled with oil and with a sight glass MLI ④ mounted can be installed after the valve.

Please note: Some countries do not allow installation of u-trap.

Outlet pipe from the safety valve should be designed in such a way that people are not endangered in the event that refrigerant is relieved.

Pressure drop in the outlet pipe to the safety valves is important for the function of the valves. It is recommended to check the relative standards for recommendations on how to size these pipes.

Not all valves are shown.
Not to be used for construction purposes.

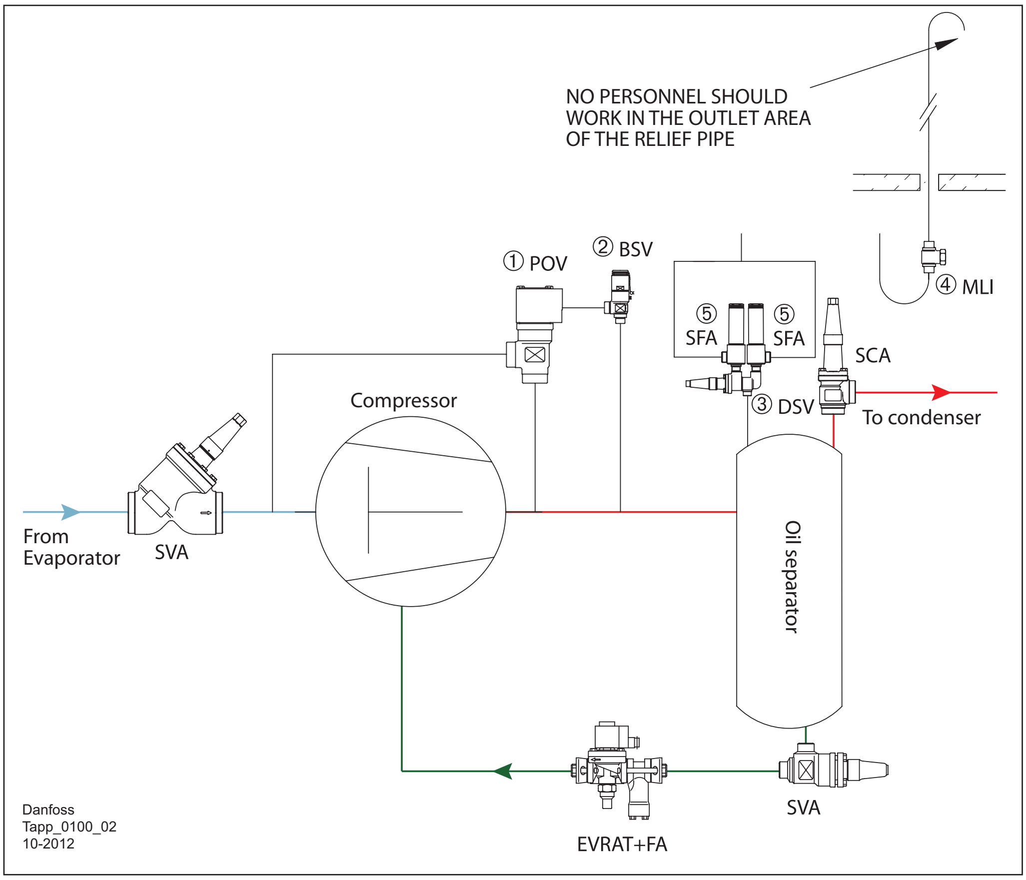
Technical data

	Safety relief valve - SFA 15 (Back pressure dependent)
Material	Housing: special steel approved for low temperature operation
Refrigerants	R717, R744 ,HFC, HCFC, other refrigerants (depending on the sealing material compatibility)
Media temp. range [°C]	–30 to 100
Flow area [mm^2]	133
Set pressure [bar]	10 to 40

	Safety relief valve - SFV 20-25 (Back pressure dependent)
Material	Housing: special steel approved for low temperature operation
Refrigerants	R717, R744 ,HFC, HCFC, other refrigerants (depending on compatibility with gasket material)
Media temp. range [°C]	–30 to 100
Flow area [mm^2]	SFV 20 : 254 / SFV 25 : 415
Set pressure [bar]	10 to 25

	Double stop valve - DSV 1/2
Material	Housing: special steel approved for low temp. operation
Refrigerants	All common non-flammable refrigerants incl. R717
Media temp. range [°C]	–50 to 100
Max. operation pressure [bar]	40
K_v value [m^3/h]	DSV1: 17.5 DSV2: 30

Application example 7.1.2: Internal safety valves-BSV and POV



HP vapour refrigerant
LP vapour refrigerant
Oil

① Pilot-operated internal safety valve
② Internal safety valve
③ Double stop valve
④ Sight glass
⑤ Safety relief valve

To relieve refrigerant from high pressure side to low pressure side only back pressure independent relief valves should be used (BSV/POV).

BSV ② can act either as a direct relief valve with low capacity or as a pilot valve for POV ① main valve. When the discharge pressure exceeds the set pressure, BSV will open the POV to relieve high pressure vapour into the low pressure side.

The back pressure independent relief valves are installed without change over valve. In case it is necessary to replace or readjust the valves, the compressor has to be stopped.

If a stop valve is mounted in the discharge line from the oil separator, it is necessary to protect the oil separator and the compressor against excessive pressure caused by external heat or compression heat.

This protection can be achieved with standard safety relief valves SFA ⑤ combined with a change over valve DSV ③.

Technical data

	Safety relief valve - BSV (Back pressure independent)
Material	Housing: special steel approved for low temperature operation
Refrigerants	R717, R744, HFC, HCFC and other refrigerants (depending on the sealing material compatibility)
Media temp. range [°C]	–30 to 100 as an external safety relief valve –50 to 100 as a pilot valve for POV
Set pressure [bar]	10 to 25
Flow area [mm²]	50

	Pilot-operated internal safety valve - POV
Material	Housing: steel
Refrigerants	R717, HFC, HCFC and other refrigerants (depending on the sealing material compatibility)
Media temp. range [°C]	–50 to 150 as a pilot valve for POV
Set pressure [bar]	15 to 25
Flow area [mm²]	POV 600: 835 POV 1050:1244 POV 2150: 2734
DN [mm]	40/50/80

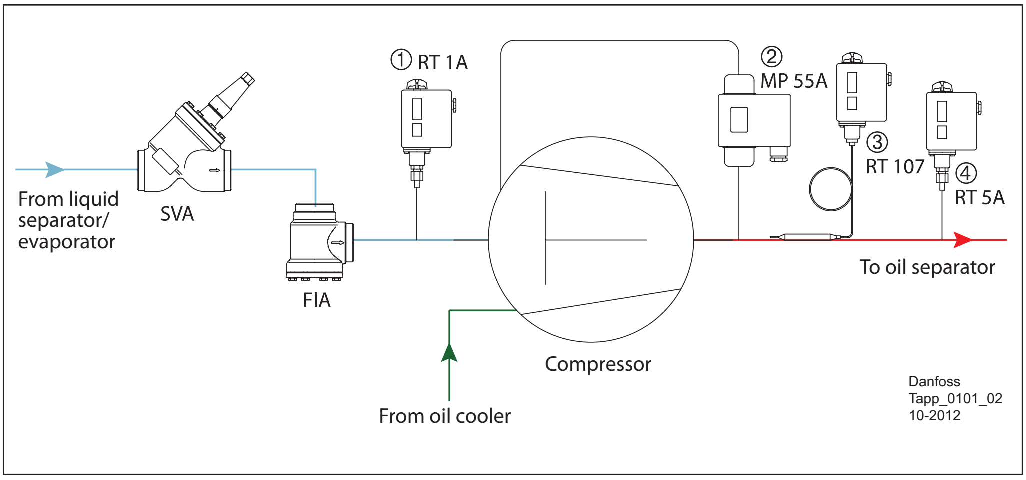
Not all valves are shown.
Not to be used for construction purposes.

7.2 Pressure and Temperature Limiting Devices

Application example 7.2.1: Pressure /temperature cut-out for compressors

HP vapour refrigerant
LP vapour refrigerant
Oil

① Low pressure cut-out
② Low differential pressure cut-out
③ High temperature cut-out
④ High pressure cut-out



To protect the compressor from too high discharge pressure and temperature, or too low suction pressure, switches KP/RT are used. RT1A ① is a low pressure control, RT 5A ④ is a high pressure control, and RT 107 ③ is a thermostat.

Setting of the high pressure controls should be below setting of the safety valves settings on the high pressure side. Setting on the low pressure switch is specified by the compressor manufacture.

For piston compressors oil differential switch MP 54/55 ② is used to stop the compressors in case of too low oil pressure.

The oil differential switch cuts out the compressor, if it does not build up enough differential pressure during start up after defined period of time (0-120 s).

Technical data

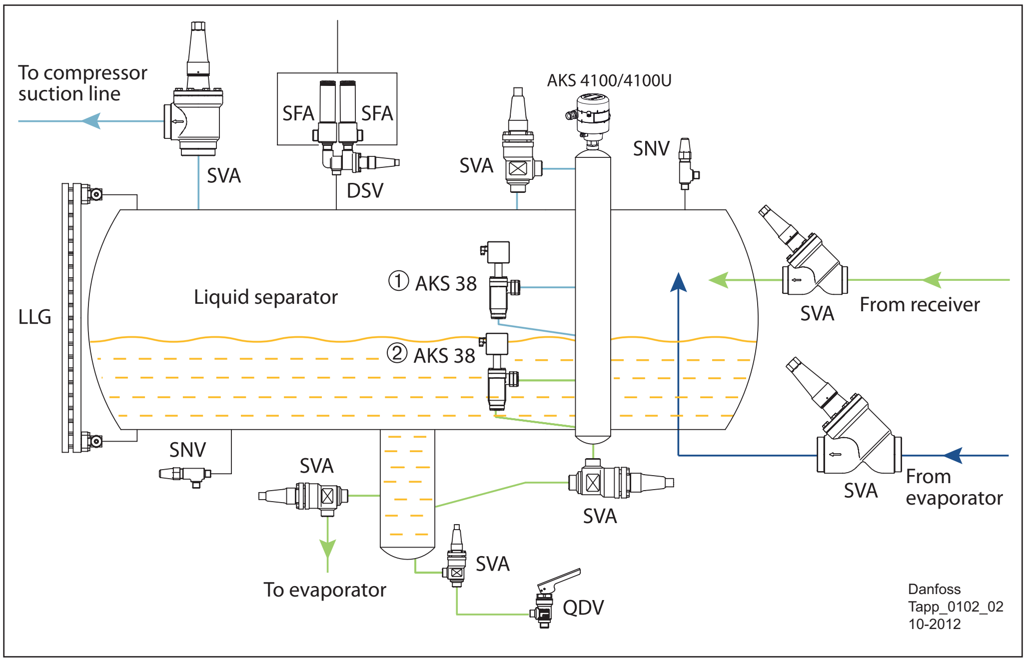
	Thermostat - RT
Refrigerants	R717 and fluorinated refrigerants
Enclosure	IP 66/54
Max. bulb temperature [°C]	65 to 300
Ambient temperature [°C]	–50 to 70
Regulating range [°C]	–60 to 150
Differential Δt [°C]	1.0 to 25.0

	Differential pressure control - MP 54/55/55A
Refrigerants	MP 54/55: fluorinated refrigerants MP 55A: R717
Enclosure	IP 20
Regulating range ΔP [bar]	MP 54: 0.65/0.9 MP 55/55A: 0.3 to 4.5
Max. working pressure [bar]	17
Max. test pressure [bar]	22
Operation range on LP side [bar]	–1 to 12

Not all valves are shown.
Not to be used for construction purposes.

7.3
Liquid Level Devices

Application example 7.3.1: Low / high level controls for liquid separator



Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① High level switch
② Low level switch

Vessels on the high pressure side and low pressure side have different liquid level switches.

High pressure receivers only need to have low level switch (AKS 38) in order to guarantee minimum refrigerant level to feed expansion devices.

Sight glass LLG for visual monitoring of the liquid level can also be installed.

Low pressure vessels normally have both low and high level switches. The low level switch is installed to make sure that there is sufficient head of refrigerant to avoid cavitation of pumps.

A high level switch is installed to protect compressors against liquid hammering.

Liquid level sight glass LLG for visual level indication should also be installed.

LLG liquid level indicators for low pressure vessels may require that a sight adapter is mounted which makes it possible to observe the level, even though there may be a certain amount of frost on the liquid level indicator.

Technical data

	Level switch - AKS 38
Material	Housing: zinc chromate cast iron
Refrigerants	All common non-flammable refrigerants, including R717.
Media temp. range [°C]	–50 to +65
Max. working pressure [bar]	28
Measuring range [mm]	12.5 to 50

	Sight glass - LLG
Refrigerants	All common non-flammable refrigerants, including R717.
Media temp. range [°C]	–10 to 100 or –50 to 30
Max. working pressure [bar]	25
Length [mm]	185 to 1550

Not all valves are shown.
Not to be used for construction purposes.

7.4 Refrigerant detector

Gas detection equipment is usually used in a fixed installation with a number of sensors located in areas where refrigerant might be expected to accumulate in the event of a plant leak.

These locations depend upon the layout of the machinery room and adjacent spaces, on the configuration of the plant and also on the refrigerant in question.

Before selecting the appropriate gas detection equipment, a number of questions have to be answered:

Which gases has to be measured and in what quantities?
Which sensor principle is the most suitable?
How many sensors are needed?, where and how should they be positioned and calibrated?
Which alarm limits are appropriate?, how many are required?, and how is the alarm information processed?

7.4.1 Sensor technology

Danfoss has, depending on the refrigerant and the actual ppm range required, selected the most appropriate sensor for the target refrigerant gas.

Which sensor is suitable to a given refrigerant?

	Semi-conducter	Electro-chemical	Catalytic	Infrared
Ammonia "low" concentration (< 100 ppm)	–	✔	–	–
Ammonia "medium" concentration (< 1000 ppm) [1]	(✔)	✔	–	(✔)
Ammonia "high" concentration (<10000 ppm)	✔	–	✔	(✔)
Ammonia "very high" concentration (> 10000 ppm)	–	–	✔	(✔)
Carbon Dioxide CO_2	–	–	–	✔
HC Hydrocarbons	(✔)	–	✔	(✔)
HCFC - HFC Halocarbons	✔	–	–	(✔)

✔ Best solution (✔) Suitable - but less attractive – Not suitable

[1]) Measuring range 0-1000 ppm. Can be adjusted in the whole range.

7.4.2
The need for gas detection

There are different reasons why gas detection is needed. It is obvious, that regulation is a very strong argument, but also

- reduced service cost (cost of replacement gas and the service call),
- reduced energy consumption cost due to lack of refrigerant,
- risk for damaging stock products due to a substantial leak,
- possible reduced Insurance cost,
- taxes on non environmentally friendly refrigerants,
- different refrigeration applications requires gas detection for different reasons.

Ammonia is classified as a toxic substance with a very unique smell, as such it is "self alarming". Still gas detectors are very useful to have in a machinery room, as often people are not present to take necessary actions. Further more, ammonia is the only common refrigerant lighter than air.

Hydrocarbons are classified as flammable. It is therefore very important to verify that the concentration around the refrigeration system does not exceed the flammability limit.

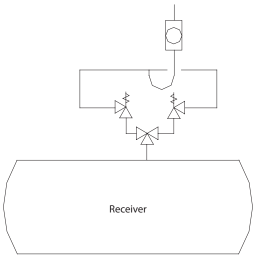
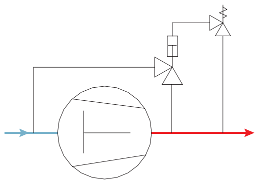
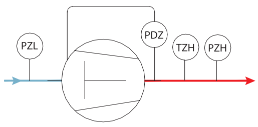
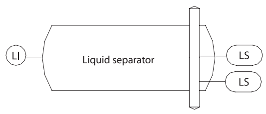
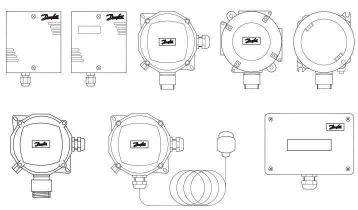
Fluorinated refrigerants all have a certain impact on the environment. It is therefore very important to avoid any leaks from these.

CO_2 (Carbon Dioxide) is directly involved in the respiration process, and has to be treated accordingly. Approx. 0.04% CO_2 is present in the air. With higher concentration, some adverse reactions are reported starting with increase in breath rate (~100% at 3% CO_2 concentration) and leading to loss of consciousness and death at CO_2 concentrations above 10%.

Oxygen - Oxygen deprivation sensors can be used in some applications, but they are not offered by Danfoss, and will not be described further in this guide.
Note: Oxygen sensors must never be used in CO_2 installations.

Legislation and standards
The requirements for gas detection are different in many countries worldwide.

7.5 Summary

Solution		Application
Safety Valves		
Safety valves SFA + change over valve DSV		Protection of vessels, compressors, and heat exchangers against excessive pressure
Overflow valve BSV + pilot operated overflow valve POV		Protection of compressors and pumps against excessive pressure
Pressure Cut Out Controls		
Pressure cut out: RT		Protection of compressors against too high discharge and too low suction pressure
Differential pressure cut out MP 55		Protection of reciprocating compressors against too low oil pressure
Thermostat RT		Protection of compressors against too high discharge temperature
Liquid level Devices		
Liquid level switch AKS 38		Protection of the system against too high/too low refrigerant level in the vessels
Liquid level glass LLG		Visual monitoring of liquid refrigerant level in the vessels
Refrigerant detection		
Gas detection sensors, GD		Detection of refrigerant gas in the atmosphere.

7.6 Reference Documents

For an alphabetical overview of all reference documents please go to page 146

Technical Leaflet / Manual

Type	Literature no.
AKS 38	PD.GD0.A
BSV	PD.IC0.A
DSV	PD.IE0.A
LLG	PD.GG0.A
MLI	PD.GH0.A
MP 55 A	PD.CG0.B

Type	Literature no.
POV	PD.ID0.A
RT 1A	PD.CB0.A
RT 107	PD.CB0.A
RT 5A	PD.CB0.A
SFA	PD.IF0.A
GD	PD.S00.A

Product instruction

Type	Literature no.
AKS 38	PI.GD0.A
BSV	PI.IC0.A
DSV	PI.IE0.A / PI.IE0.B1
LLG	PI.GG0.A
MLI	PI.GH0.A
MP 55 A	PI.CG0.E

Type	Literature no.
POV	PI.ID0.A
RT 1A	RI5BC
RT 5A	RI5BC
SFA	PI.IB0.A
GD	PI.S00.A

To download the latest version of the literature please visit the Danfoss website.

8. Refrigerant Pump Controls

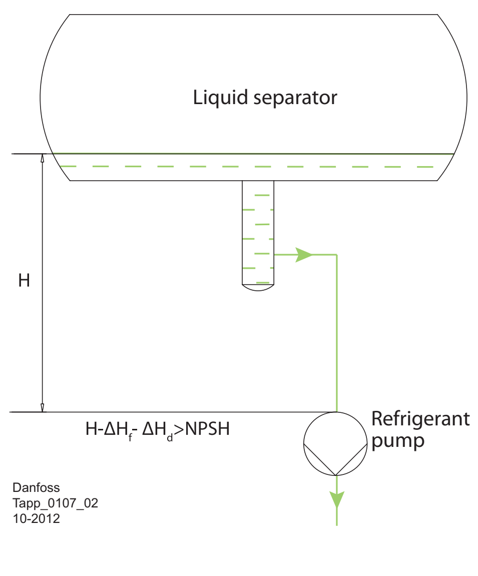
Generally, industrial refrigeration systems have pump circulation of liquid refrigerant. There are a few advantages of pump circulation compared with DX type systems:

- Pumps provide efficient distribution of liquid refrigerant to evaporators and return of vapour-liquid mixture back to the pump separator;
- It is possible to decrease the superheat to almost 0 K, thereby increase efficiency of the evaporators, without risk of liquid hammer in the compressor.

When installing the pump, care must be taken to prevent cavitation. Cavition can occur only if the static refrigerant liquid pressure at the pump inlet is lower than the saturation pressure corresponding to the liquid temperature at this point.

Therefore the liquid height H above the pump should at least be able to compensate the pressure loss of friction ΔH_f through the pipe and valves, the pipe inlet loss ΔH_d, and the acceleration of the liquid into the pump impellor ΔH_p (pump net positive suction head, or NPSH), as shown in fig. 8.1.

Fig. 8.1
Placing of the pump



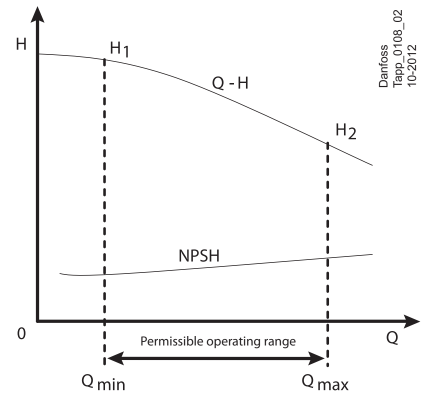
In order to keep the refrigerant pump in trouble-free operation, the flow through the pump should be maintained within the permissible operating range, fig. 8.2.

If the flow is too low, the motor heat may evaporate some of the refrigerant and result in dry running or cavitation of the pump.

When the flow is too high, the NPSH (Net Positive Suction Head) characteristic of the pump deteriorates to an extent that the available positive suction head becomes too low to prevent cavitation.

Therefore, systems should be designed for the refrigerant pump to keep this flow within the operating range.

Fig. 8.2
A typical Q-H curve for pumps



8.1 Pump Protection with Differential Pressure Control

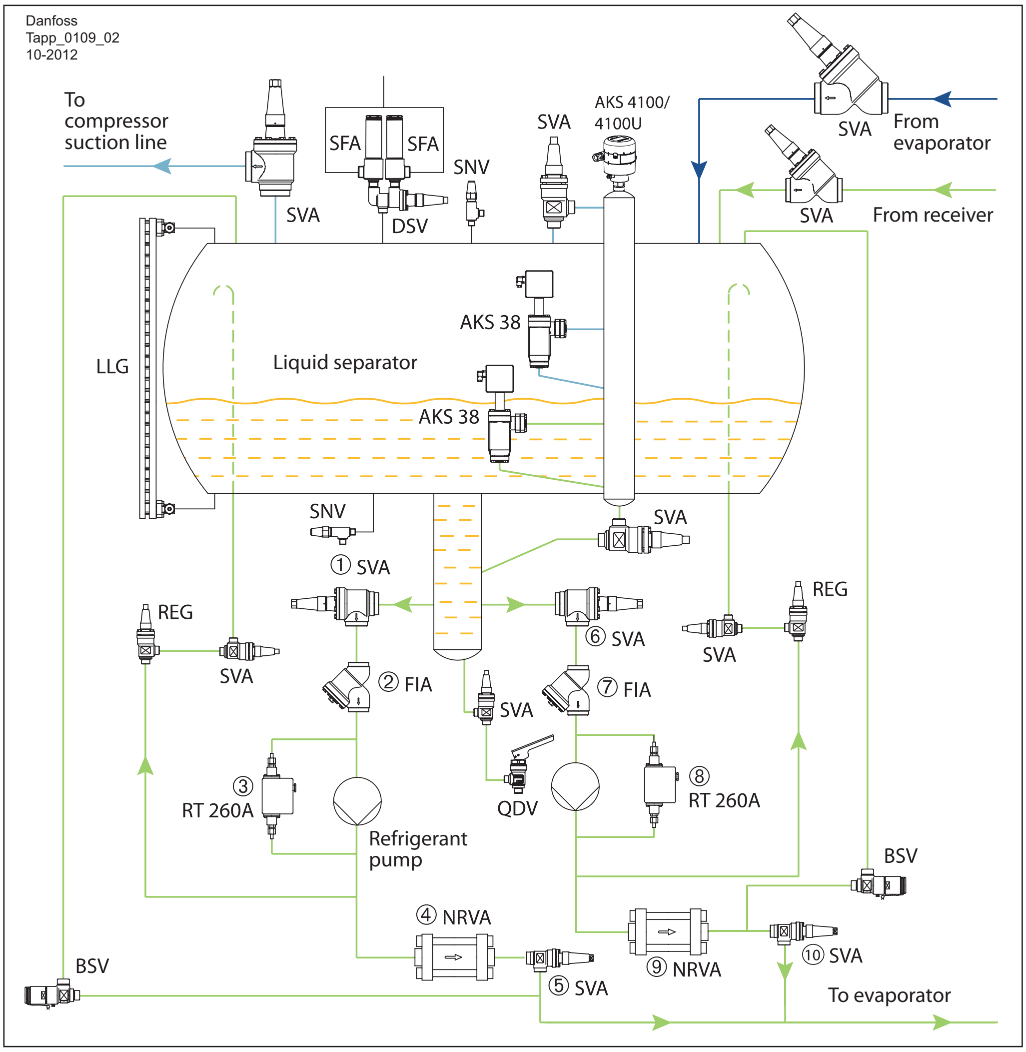
Pumps are easily damaged by cavitation. To avoid cavitation, it is important to maintain sufficient positive suction head for the pump. To achieve enough suction head, low level switch AKS 38 is installed on the liquid separator.

However, even if the low level switch is installed on the liquid separator is kept above the minimum acceptable level, cavitation can still occur.

For example, incorrect operations on the evaporators may cause increased flow through the pump, the low level switch may fail, and the filter before the pump may be blocked, etc.

All these may lead to cavitation. Therefore, it is necessary to shut down the pump for protection when the differential pressure drops below H_2 in fig. 8.2 (equivalent to Q_{max}).

Application example 8.1.1: Pump protection with differential pressure control RT 260A



Liquid/vapour mixture of refrigerant
LP vapour refrigerant
LP liquid refrigerant

① Stop valve
② Filter
③ Differential pressure switch
④ Check valve
⑤ Stop valve
⑥ Stop valve
⑦ Filter
⑧ Differential pressure switch
⑨ Check valve
⑩ Stop valve

Differential pressure controls are used for protection against too low pressure difference. RT 260A ③ and ⑧ are supplied without a timing relay and cause a momentary cut-out when the differential pressure drops below the pressure controls setting.

The filters FIA ② and ⑦ are installed on the pump line to remove particles and protect automatic control valves and pumps from damage, blockage, and general wear and tear. The filter can be installed in either suction line or discharge line of the pump.

If the filter is installed in the suction line before the pump, it will primarily protect the pump against particles. This is particularly important during initial clean-up during commissioning.

Since pressure drop can lead to cavitation, it is recommended to install a 500µ mesh. Finer meshes could be used during the cleaning up, but be sure to take into account the pressure drop when designing the piping. Additionally, it is necessary to replace the mesh after a period of time.

If a filter is installed in the discharge line, pressure drop is not as crucial and a 150-200µ filter can be used. It is important to note that in this installation, particles can still enter the pump before being removed from the system.

The check valves NRVA ④ and ⑨ are installed on the discharge lines of the pumps to protect the pumps against reverse flow (pressure) during standstill. The stop check valve SCA can also be used for this purpose (NRVA and SVA are replaced with the SCA, see application example 8.1.2).

Technical data

	Differential pressure control - RT 260A/252A/265A/260AL
Refrigerants	R717 and fluorinated refrigerants
Enclosure	IP 66/54
Ambient temperature [°C]	–50 to 70
Regulating range [bar]	0.1 to 11
Max. working pressure [bar]	22/42

Not all valves are shown.
Not to be used for construction purposes.