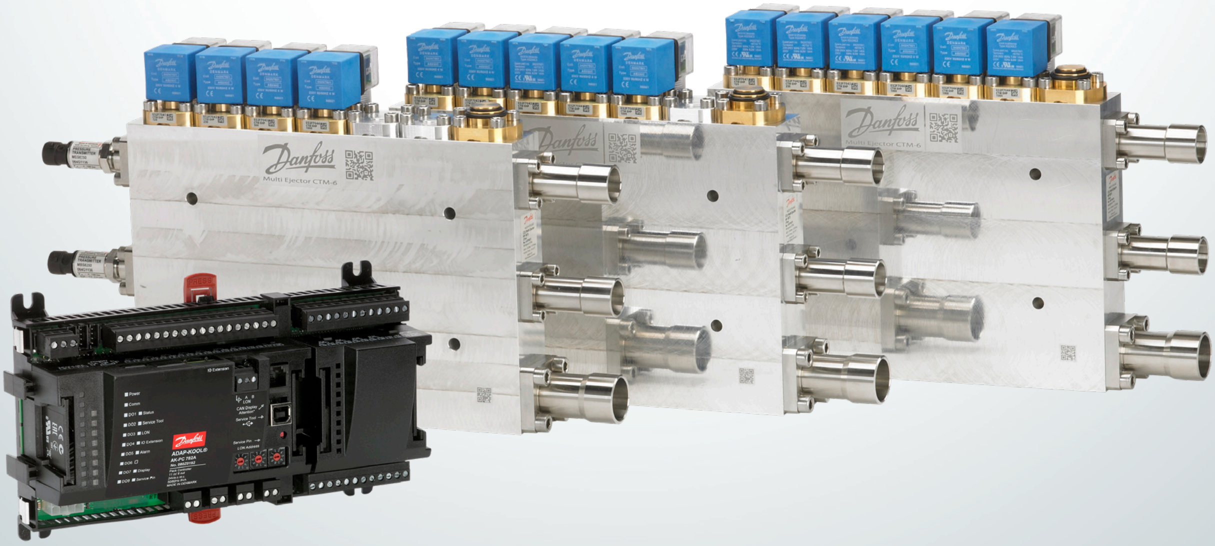
ENGINEERING
TOMORROW

Application Guide

Low pressure lift ejector system
Multi Ejector solution incl. Multi Ejector Low Pressure (LP 935/1435/1935) and AK-PC 782A



Contents

1. General description

Low pressure lift ejector systems are simpler systems than high-pressure ejector systems, because they do not need the parallel compressor in order to work and give an energy saving (see diagram on next page). In winter time, the system works like a normal booster system where the gas bypass valve controls the receiver pressure with set pressure differential, and the evaporation pressure is controlled by adjusting the compressor capacity according to the needed MT evaporators' suction pressure.

At 23 – 25 °C out of the gas cooler, the ejector starts to pump all gas from the MT evaporators and lift to the receiver with a pressure lift of approximately 3 bar. The consequence of this is a better COP of the system. The higher suction pressure will also result in higher mass flow in the same compressor and thereby a first cost saving due to a smaller installed capacity. The first cost saving can be as much as 30% at high ambient temperatures and 15% energy saving compared to a booster system.

1.1 System design with Low Pressure lift ejector

The LP ejector can be considered as an add-on to the standard system, however there are some additional components, and a different control strategy needs to be applied.
Below are the most important points to take into account when designing such a system (see diagrams on page 4):

Setpoints and operational modes
As described, an LP ejector system can operate with two different modes: the standard mode in low ambient temperatures and the ejector mode in high temperatures. How it changes from one mode to the other and the setpoint and signals required for this are listed below:

- In the winter condition, the ejector is working as a high-pressure valve and is not providing any or not enough suction mass flow to put the system into ejector operation. The system is performing as a standard system, but with receiver pressure controlled with a pressure differential of 3 bar between the pressure in the receiver (P-rec) and the common MT evaporators' suction line. The pressure signal is coming from the sensor located before the check valve (Po-MT). The pressure in the gas cooler is controlled based on the refrigerant outlet temperature (Sgc) and the optimum COP algorithm.
- Ambient temperatures of 17 – 18 °C result in 24 – 25 °C out of the gas cooler measured by the temperature sensor Sgc, corresponding to gas cooler pressure 64 to 66 bar(a). At ambient temperatures of 17 – 18 °C there is enough expansion work in the system for the LP ejector to take all the mass flow from the MT evaporators and lift it to the receiver. Since the gas bypass valve is controlled on the basis of pressure difference between the receiver and MT evaporator pressure, and not fixed pressure, the valve will start to open more and more. Setpoint for the valve would typically be 3 bar difference and if the ejector can provide a higher lift, the gas bypass valve will be 100% open.

Components
The system requires some additional components. Additionally the design criteria for some components are different:

- Gas Bypass Valves: It will be challenging to have one valve fulfilling good control in both Standard and Ejector mode. In the first mode there is limited amount of gas released to suction MT compressors with a constant pressure difference of 3 bar, while in the second one (LP ejector mode) there is a large amount of gas with a minimum possible pressure drop; our solution is with 2 x Gas Bypass Valves (GBV). GBV #1 is a standard one and works in all conditions, and GBV #2 mounted in parallel with big KV value operating when the system turns into LP Ejector mode. The idea is to have as little as possible pressure drop across the two GBVs, as this pressure drop will count as loss to the LP ejector's recovered work.
- Another option is to use a 2-way ball valve motor mounted in parallel to GBV #1 which can give even better system performance as the pressure drop in the gas bypass line will be minimal.
- Pressure sensors: The reference sensor for controlling MT compressors should be mounted on the common MT evaporators' suction line "Po_MT", before the check valve. In systems with MT and LT evaporators it can happen that the MT evaporator load drops below the minimum MT compressor capacity which will lead to pump down situation and possible turning off of the MT compressors. On the other hand, LT evaporators can have a load and LT compressors will run. To protect LT compressors' from high pressure cut-out, a new Psuc_MT sensor is introduced. If the pressure exceeds the set offset pressure, the Psuc_MT will become reference sensor for controlling the MT compressors.
- Electronic Expansion Valves and evaporators: The LP ejector pressure lift is relatively low. Therefore, the system needs to be designed accordingly, and the EEV (Electronic Expansion Valve) for MT evaporators should be selected according to the system requirements and limitation. The pressure losses in evaporator and distributors should be investigated and designed to be a portion of the minimum pressure lift that the ejector can provide (3 bar). Larger evaporators and distributors may provide too high pressure loss for the LP system. If the losses in the evaporator are high, then it should be ensured that the system will operate with high pressure in the gas cooler to provide adequate pressure lift. That can either occur when there is high ambient temperature or when Heat Recovery is activated in the system. The pressure losses should be considered in the selection of the EEV
- Compressors: Compressor selection is made using the receiver pressure at the highest ambient temperature (design condition). This is

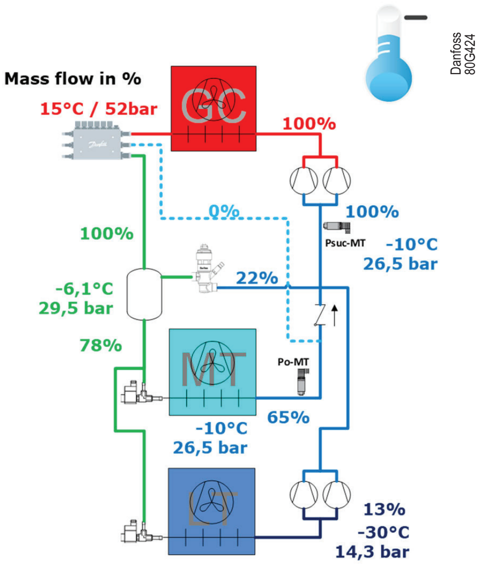
typically 6 – 7.5 bar higher than the evaporation pressure and will yield smaller compressors typically 20 – 30%, resulting in reduction of the first cost of the system. The small compressor steps in the system can be useful in the part load situation during the cold periods.

Oil management
In booster/winter mode, the system has a safe oil return, but when the system is in Ejector mode, the oil will end in the receiver and will stay there if no action is taken on it. There are many ways to recover the oil and get it back to the compressor. If the oil separator has a low efficiency, the oil problem will be bigger. Part of a safe oil return can be the LT compressors. The LT compressors receive an oil-rich gas mixture from the LT evaporators. The oil is passed through the LT compressors and can be transferred to the MT compressors as LT discharge is connected directly to the MT compressor suction. However, as the LT evaporators' load varies during the year, sufficient oil return cannot be expected. That depends on the load ratio between the MT and LT compressor capacity, the oil quantity in the system and the efficiency of the oil separator.

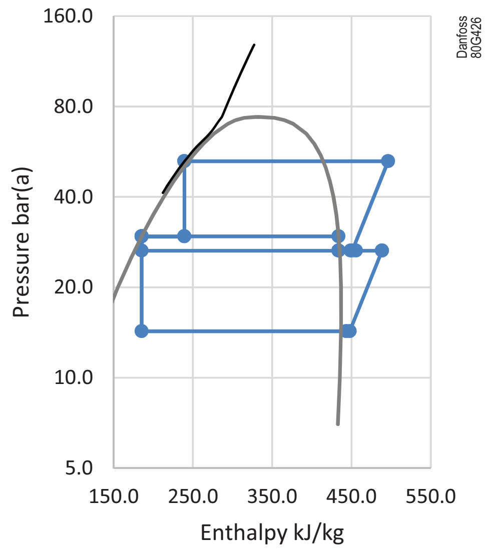
To be certain, an oil recovery system is needed. By using the second pressure differential reference "DeltaP High" and a low oil level sensor mounted on the oil receiver, the system can be changed from LP Ejector mode to Standard mode. This ensures that oil will return to the MT compressors.

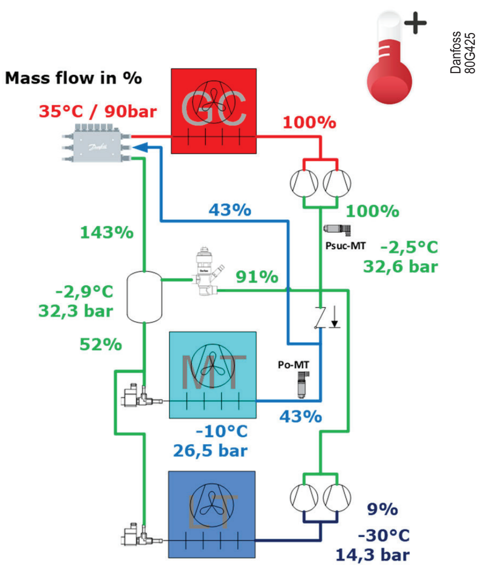
1.2 Example system load

MT (Medium Temperature) evaporators load 50 kW
LT (Low Temperature) evaporators load 10 kW

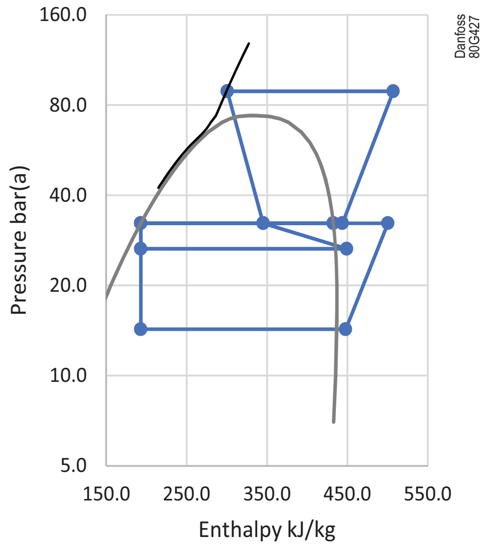


Pressure in receiver controlled by pressure differential.
Parameter DeltaP low = 3 bar





Pressure in receiver result of LP ejector lift > 3 bar



1.3 Overall control strategy and objectives

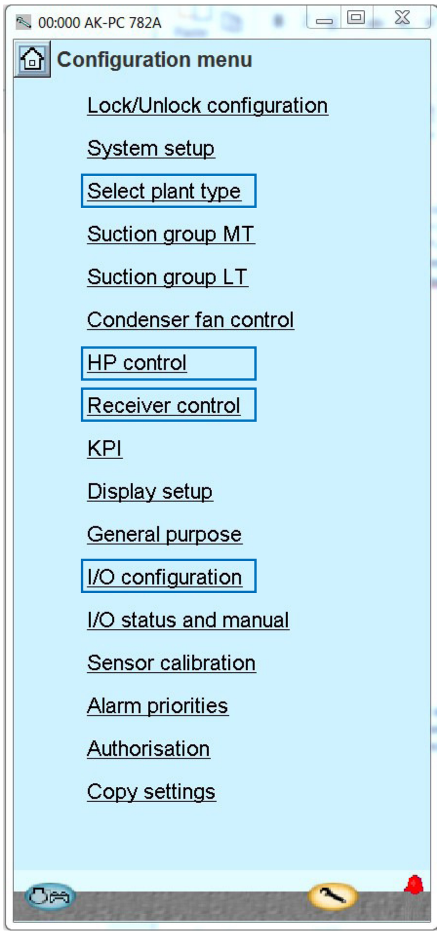
The overall control objective is to maintain a sufficiently low pressure difference between the receiver pressure (Prec) and the evaporation pressure (Po-MT) in order for the LP-ejector to lift the total refrigerant flow from the refrigerated cabinets up the receiver pressure level. The designated MT-compressor will in this case compress the gas (vapor) refrigerant directly from the receiver. The pressure difference between the sensors Prec and Po-MT, should however be large enough for the injection valves to supply the required refrigerant flow to the refrigerated cabinets. If the motive energy for the ejector is not big enough to perform the required pressure lift, the check valve will open and the MT compressor will take the refrigerant flow directly from the refrigerated cabinets (instead of the ejector).

Note that in LP ejector mode, the check valve restricts the flow direction from the compressor suction port (Psuc-MT) towards the MT evaporator outlet (Po-MT). This means that if the suction pressure (Psuc-MT) increases, it cannot be detected in the Po-MT measurement. It is therefore important to device a control strategy that keeps Psuc_MT in control as well.

In the section below the control strategy and configuration of the PC782A to support the LP-ejector application will be described.

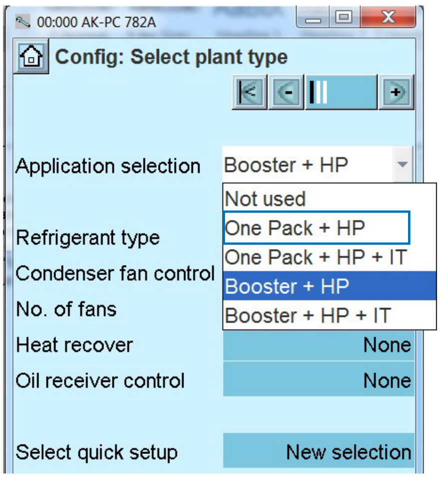
2. Configuration PC782A

In the PC782A, the LP-system is not considered as a dedicated "Plant type" but rather a special case of a booster system (without IT compressor). This means that in order to support the LP-ejector system, a number of configurations need to be made in respectively: "Select Plant Type", "Suction Group MT", "HP-control", "Receiver control" and "I/O configuration".



2.1 Select plant type

The LP-ejector system is considered a Booster/One pack system without any IT compressors, therefore it is only possible to configure the Delta P control of the receiver from these plant type selections: "One Pack + HP" and "Booster + HP".



2.2 Suction group MT (Capacity control)

The control objective for the compressor capacity control is to maintain a given reference for the evaporation pressure (measured with the Po-MT sensor as indicated in the drawing to the right) by adjusting the MT compressor capacity. Meanwhile it should be ensured that the suction pressure (measured by Psuc-MT) is limited.

The check valve ensures that the flow can only go from the location of the Po-MT sensor towards the Psuc-MT sensor and not reverse. This efficiently means that:

Psuc-MT ≥ Po-MT

Control sensors

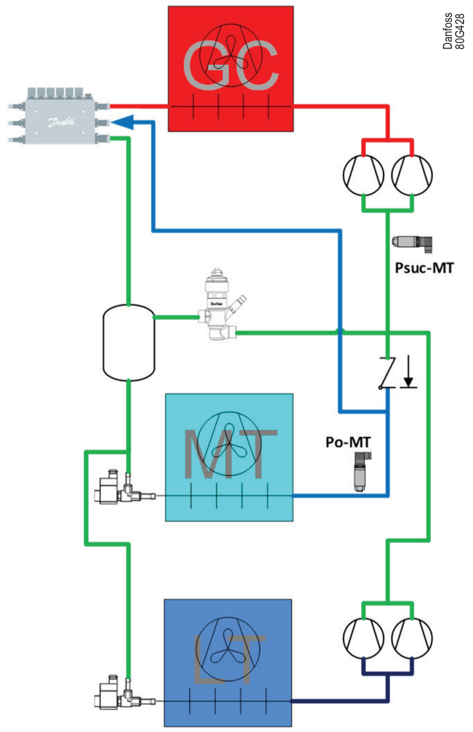
Choosing Po-MT as the control sensor ensures that the evaporation pressure is controlled as desired, however this leaves Psuc-MT uncontrolled which means that it will not be protected against high pressure. This can lead to dangerous situations especially in situations where the LT compressors are starting, and the MT compressors are at a standstill. As the LT discharge port is connected to the MT comp. suction port, it is not detected by the Po-MT sensor if the LT starts and the Psuc-MT increases. Hence, Po-MT and Psuc-MT are both used as control sensors in such a way that the one with the "most critical" reading is used as input for the MT compressor capacity control.
The "most critical" sensor value is determined in the following way: The maximum expected pressure lift that the LP-ejector is capable of is ΔP_max=8 bar ("Psuc max offset"), so this will also be the maximum pressure difference that should be expected/allowed between Psuc-MT and Po-MT under normal operation.

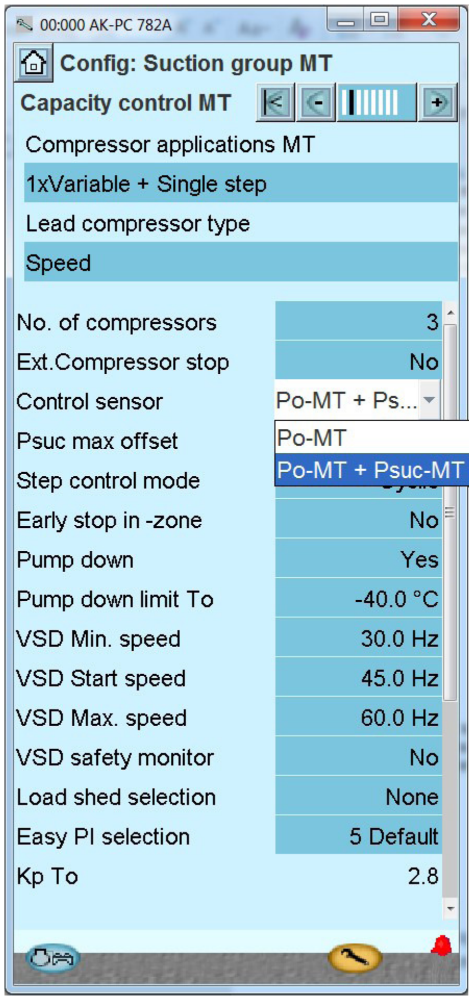
This means that the capacity control has two objectives:
1. Keep Po-MT close to the Po-MT reference ("To-MT reference")
2. Keep Psuc-MT close to the Psuc-MT reference ("Tsuc reference"), where

Psuc reference=Po-MT reference+Psuc max offset

The decision of which is "most critical" is simply determined by which of the two controller objectives that has the largest control error.

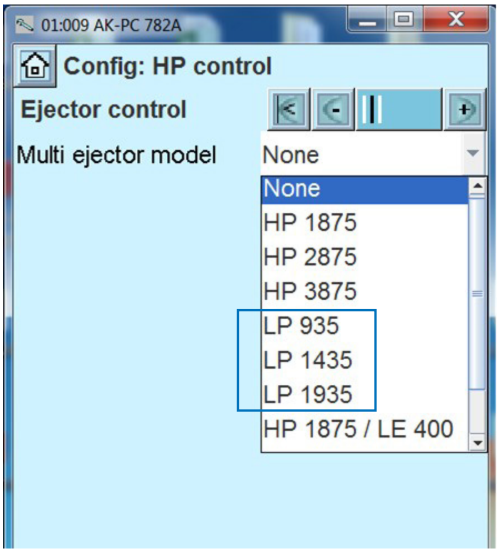
Under the suction group for the MT, the selection of running with two control sensors, Po and Psuc, is made. By selecting "Po-MT + Psuc-MT" as control sensor, the capacity control and the receiver control are prepared for the DeltaP control intended for the LP-ejectors. With this selection, the setting of "Psuc max offset" appears below - the default value is 8 bar.





2.3 HP control

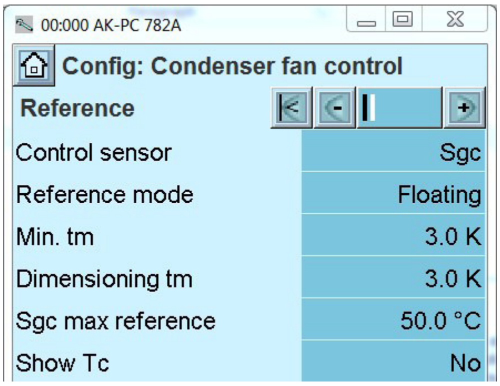
As for all the Multi Ejector types the LP-ejector is used as actuator for controlling the gas cooler pressure. This means that the individual ejector step will be coupled in and out in order to maintain the optimal gas cooler pressure (Pgc,ref) according to ambient temperature (Sc3) and temperature reference out of gas cooler (Sgc, ref).

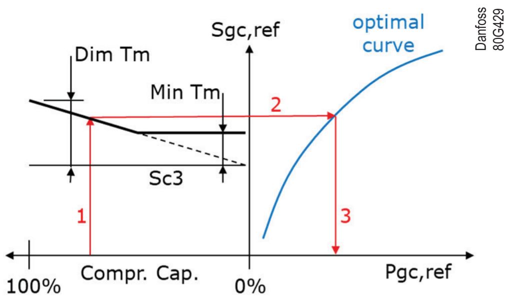


2.4 Condenser fan control

The set-up is the same as for a booster system.

Note the Pgc,ref is determined based on Sgc,ref, which is again determined based on Sc3 (ambient temperature). In case the measured Sgc drifts more than 2K above the Sgc,ref, the Pgc,ref will follow the measured Sgc instead of the Sgc, ref.





2.5 Receiver control

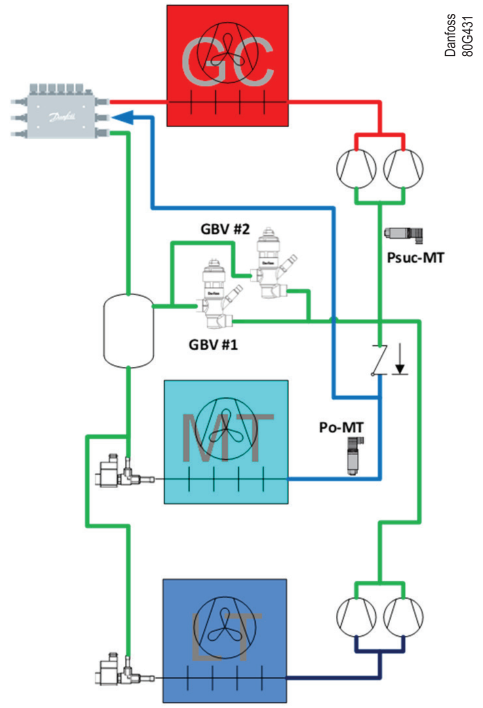
The receiver pressure is controlled using the gas bypass valve (GBV). One or two valves in sequential control mode might be used mainly to ensure low pressure drop across the GBV in the ejector mode where the MT compressor sucks directly from the receiver through the GBV.

The receiver pressure is controlled with a fixed “Delta P Low”(default 5 bar, but in a real system preferably 3 bar) over the expansion valves and MT evaporators.

Prec reference = *Po-MT* reference + Delta P low

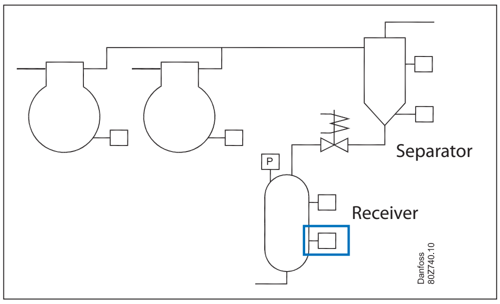
Note that reference calculation for the receiver is based on the reference of “Po-MT” and not the measured value, meaning that the “Prec reference” will remain constant irrespectively of the actual value of Po-MT. This avoids the risk of Prec getting pulled down into the neutral zone of the MT compressors, e.g. during a pump down, which would lead to a critical deadlock situation where no cooling is provided.

By setting the control sensor to “Po-MT + Psuc-MT” the receiver is prepared for Delta P control. In the receiver two predefined Delta P references “Delta P low” and “Delta P high” are configured. It is possible to switch between the two references by activating a digital input (DI). “Delta P High enable” is now visible under the I/O configuration.



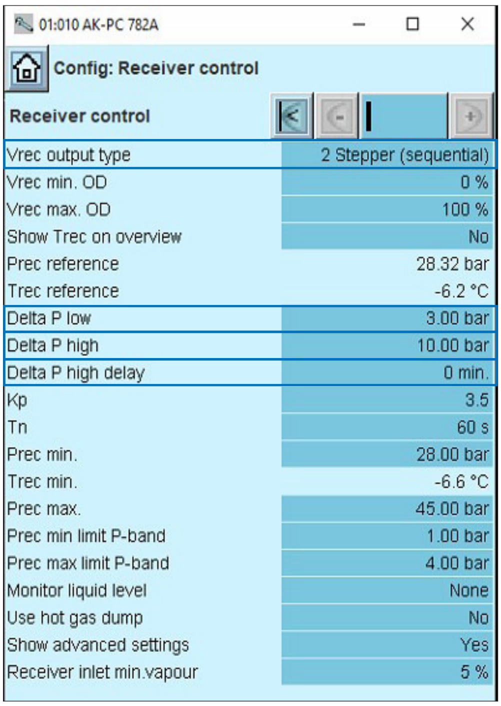
Oil return

In the ejector mode, oil will accumulate in the receiver and not return to the MT compressors. Therefore, a special oil return strategy must be devised. An oil-return cycle must be executed when the low oil level switch in the oil receiver indicates critical oil level. Oil-return strategy efficiently means shifting to standard mode. This can be done by increasing the receiver pressure to a level where the LP-ejector cannot lift (to the “Delta P high” setpoint). This means that GBV will start closing and the check valve will open, allowing the oil to return to the MT compressor from the evaporator outlet.



Vrec output type

In winter mode, the GBV#1 secures that the receiver pressure is maintained around the requested setpoint. In the LP ejector mode it will not be possible for the GBV#1 to keep the receiver pressure at or below its reference though the valve/valves are fully open. This is because the LP-ejector in this scenario can lift the total evaporated flow of refrigerant out of the MT evaporators up and above the “Prec reference”. This will cause the receiver control to saturate the GBVs at 100% and the check valve to close, bringing the system into LP ejector mode. In ejector mode, the MT compressors will remove the gas (vapor) refrigerant directly from the receiver (as the check valve is closed), but they will do so through the fully open GBV. It is therefore important in the ejector mode to reduce the pressure drop across the GBV(s), as this results in increased compressor work. This is the reasoning for the request for supporting two sequential operated GBVs. The GBVs can be different sizes.

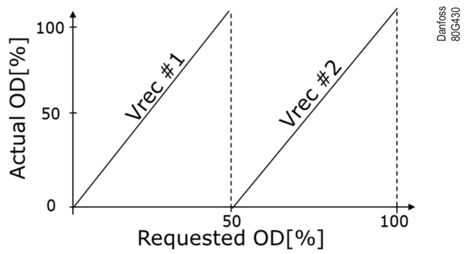


01:010 AK-PC 782A

Config: Receiver control

Receiver control	
Vrec output type	2 Stepper (sequential)
Vrec min. OD	0 %
Vrec max. OD	100 %
Show Trec on overview	No
Prec reference	28.32 bar
Trec reference	-6.2 °C
Delta P low	3.00 bar
Delta P high	10.00 bar
Delta P high delay	0 min.
Kp	3.5
Tn	60 s
Prec min.	28.00 bar
Trec min.	-6.6 °C
Prec max.	45.00 bar
Prec min limit P-band	1.00 bar
Prec max limit P-band	4.00 bar
Monitor liquid level	None
Use hot gas dump	No
Show advanced settings	Yes
Receiver inlet min.vapour	5 %

As with 2 Stepper (sequential) the requested Opening Degree is split evenly. The "Kp" default was 7 but should now be 7/2=3.5



Delta P low
"Delta P low" is the intended setpoint for operation when the LP-ejector is sufficient (lifting the total mass flow to the receiver).

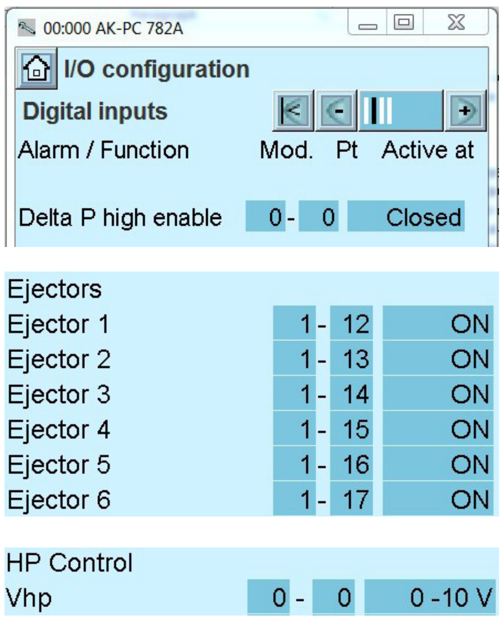
Note: The "Delta P low" setting must be larger than half the neutral zone of the MT capacity control (which is $\frac{5K}{2}$ = 2.5 ~ 2.3 bar), hence avoiding that the receiver pressure can enter the neutral zone of the MT. This can otherwise lead to a situation where the MT compressor will not start after a standstill. The setpoint for "Delta P low" should be lower than the pressure lift that the ejector is capable of, but large enough to secure the necessary pressure drop over the expansion valves. Recommended setting is 3 bar (default setting is 5 bar).

Delta P high
"Delta P high" is the setpoint that the receiver will follow when the DI "Delta P High enable" is enabled. The intention is that if the oil level in the oil receiver is low, this DI is triggered causing the reference to go to a level higher than what the ejector is capable of lifting (more than 8 bar, the "Psuc Max Offset").This efficiently causes the check valve to open (see description in the receiver control), enabling the oil return to the compressor. Default setting is 10 bar (larger than "Psuc Max Offset" default 8 bar).

Delta P high delay
"Delta P high delay" is a user defined delay timer which delays the switchback from the "Delta P high" to the "Delta P low" setpoint. The intention is that if the "Delta P high" has been triggered due to a low oil-receiver level, then the system should stay in this "oil-return mode" for a certain time (Delta P high delay) after the low oil level has disappeared. This in order to secure a sufficient return of oil (see also section below on oil return). Default setting is 0 min.

2.6 IO configuration

When the AK-PC controller has been configured for control of an LP ejector system, several input and output need to be configured.
This includes the new Psuc_MT sensor (analogue input), the signal for changing mode for oil return (digital input) and the output used for controlling the Multi Ejector (Digital Output).

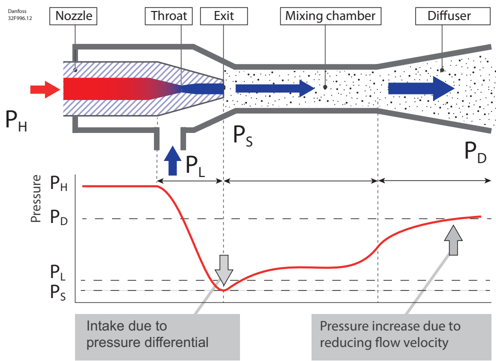


The outputs used for controlling the smallest ejectors must be of the Solid State Relay type (SSR).
In this example the four smallest ejectors are configured to be controlled by the four SSR outputs available on the AK-PC controller (IO points 1-12 to 1-14).

The ejector always has higher priority than the HP valve. So although it is configured, it will not be used except in the P-bands at high/low Pgc. In most cases it is preferred to operate without the HP valve. In this case the output type for the HP valve can be left unconfigured.

3. What is an ejector, and how does it work?

An ejector is a device that utilizes the energy from the high pressure work. The ejector converts the high pressure potential energy in the motive flow (primary) into kinetic energy, drawing a flow from the suction port (secondary flow).
The process, shown in the diagram to the right, is driven by the high pressure CO_2 gas leaving the gas cooler. The gas enters the ejector at the high pressure port (PH) and flows through the throat, causing the flow to accelerate. At the exit of the ejector nozzle, the gas is at supersonic speed, creating a low pressure (PS). As low pressure (PS) is lower than the pressure (PL) at the suction (secondary) nozzle, CO_2 is flowing from the suction port into the ejector. The two flows are mixed in the mixing chamber and the pressure is gradually increased. The flow finally enters the diffuser at the end of the ejector. Because of the conic diffuser shape, the flow gradually slows down, and the pressure is increased. This means that the kinetic energy of the flow (velocity) is converted to potential energy (pressure).
After leaving the diffuser, the gas is at a higher pressure (PD) than the suction pressure (PL).

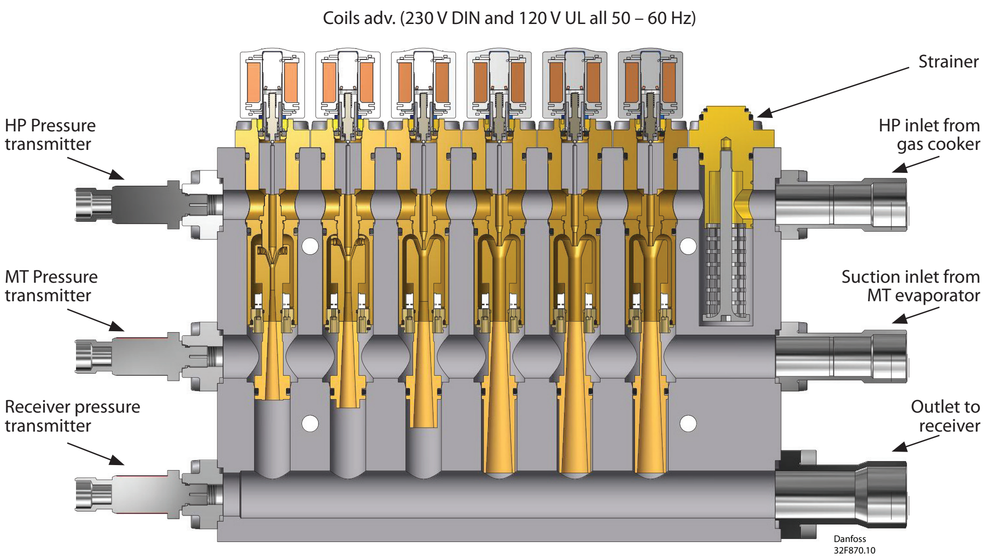


3.1 Danfoss Multi Ejector design

All ejectors in the Danfoss portfolio have a high pressure inlet for CO_2 gas coming from the gas cooler, a suction inlet from MT evaporators and an outlet for returning the gas and liquid to the receiver.
The coils activating the individual ejectors are available from 110 – 230 V, 50 and 60 Hertz.
The gas ejectors are delivered with three pressure transmitters, used for pressure control in the pack controller.
Each block has a variable number of ejectors of different sizes mounted vertically.

Multi Ejectors LP are available with 4 to 6 ejectors. The capacity demand is matched by using different numbers and combinations of ejectors. The characteristics of the ejectors remain the same no matter how many ejectors are in use. On each individual ejector a built-in non-return valve prevents backflow, removing the need for external check valves in suction lines.

Each individual ejector and the strainer are easily serviced by simply removing the four mounting screws, using a flat screwdriver to lift the ejector or strainer, and pulling it out of the block. The strainer can easily be taken apart for cleaning or replacement.



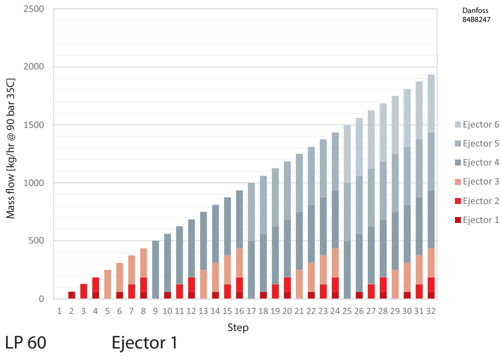
All pressure transmitters MBS 8250 with round Packard, radiometric output and 7/16-20 UNF (same type as CCMT valves)

3.2 Multi Ejector Capacity Control

Multi Ejector capacity control is achieved through a binary coupling of various capacities of a number of ejectors. The Multi Ejector LP, for example, comes in three versions. The 4-ejector version has ejectors providing 60 kg/h, 125 kg/h, 250 kg/h and 500 kg/h resulting in a total of 935 kg/h of motive mass flow.

The 5-ejector version has an additional 500 kg/h ejector providing a total of 1435 kg/h of motive mass flow.

The 6-ejector version has two additional 500 kg/h ejectors providing a total of 1935 kg/h of motive mass flow. This allows to modulate capacity in 32 steps between 0 and 1935 kg/h. But if more capacity is required, a second Multi Ejector can be added which will be controlled parallel to the first one.



LP 60	Ejector 1
LP 125	Ejector 2
LP 250	Ejector 3
LP 500	Ejector 4, 5, 6

The AK-PC equalizes the number of on/off switches between equal sized ejectors to optimize the electrical and mechanical lifetime of the AK-PC.

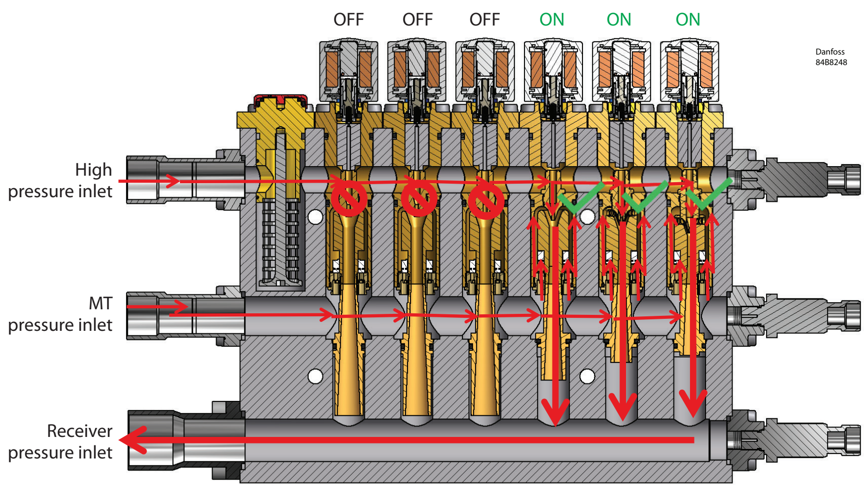
3.3 How does the Multi Ejector solution work?

There are 4 different ejector cartridge sizes for LP Multi Ejectors (approx. 60, 125, 250 and 500 kg/h). The largest ejectors are placed closest to the connectors.

Multi Ejector blocks								
Type	Code no.	Product name	Ejector 1	Ejector 2	Ejector 3	Ejector 4	Ejector 5	Ejector 6
			kg/h	kg/h	kg/h	kg/h	kg/h	kg/h
CTM 6	032F5678	CTM Multi Ejector LP 935	60	125	250	500		
CTM 6	032F5693	CTM Multi Ejector LP 1435	60	125	250	500	500	
CTM 6	032F5679	CTM Multi Ejector LP 1935	60	125	250	500	500	500

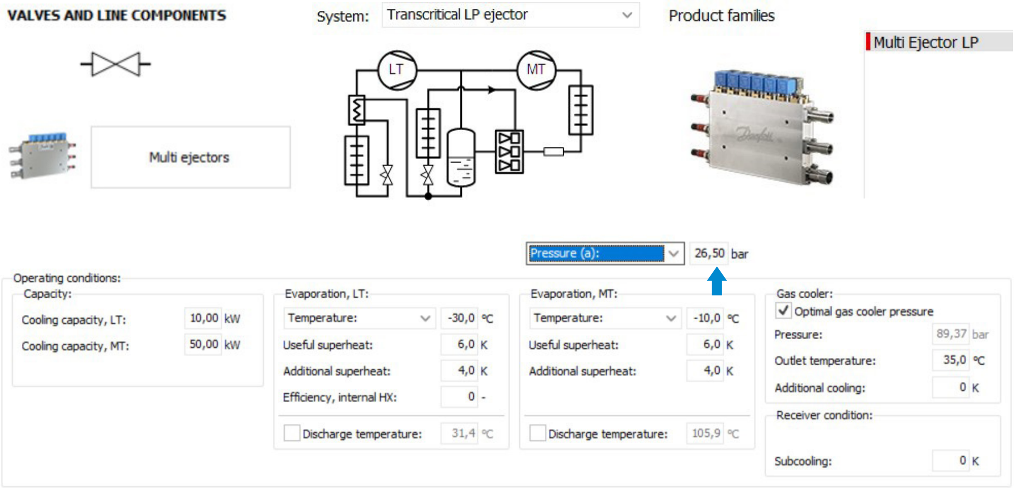
The flow enters the Multi Ejector through the strainer in front of the high pressure inlet. The AK-PC controller decides which ejector is activated to meet the requested capacity. Through the open nozzle, the high-pressure flow is transformed into high velocity flow. The high velocity creates a very low pressure, making the suction of the MT possible.

The flow from the MT suction inlet enters the ejector through the check valve, mixing with the high velocity flow. The mixed flow is slowed down in the diffuser part of the ejector, transforming the velocity to pressure. From here the mixed flow is lead to the receiver and thereby recovering a part of the expansion work.



4. Coolselector®2 Selecting components

4.1 LP ejector selection



Selection: Multi Ejector LP 1935

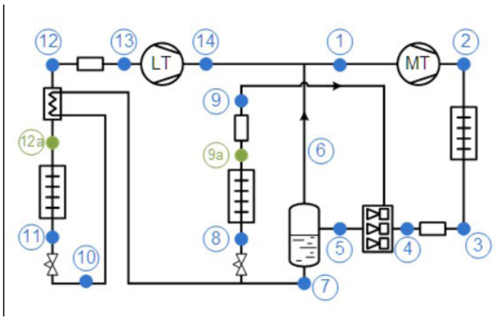
Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_BP [kg/h]	m_comp_MT [kg/h]	Entrainment ratio	P_receiver [bar]	T_receiver [°C]
○	Multi Ejector LP 935	2	95	144,0	719,3	1512	1656	0,43	32,29	-2,9
◉	Multi Ejector LP 1935	1	94	144,0	719,2	1512	1656	0,43	32,29	-2,9

DeltaP … LP ejector pressure lift
DeltaP=P_receiver – Po_MT = 32,3-26,5 = 5,8 bar
m_comp_MT … Motive flow
m_evap_MT … Suction flow
m_BP … Gas By-pas flow
er … Entrainment ratio

$$er = \frac{m_{evapMT}}{m_{compMT}} = \frac{719}{1656} = 0,43$$

Envelope | **Performance details**

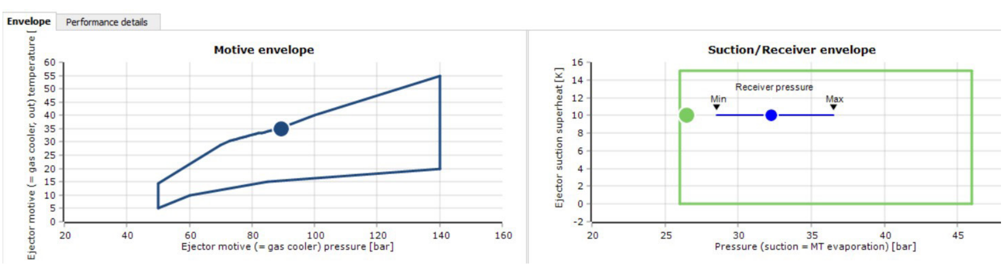
Point	Description	Temperature [°C]	Pressure [bar]	Density [kg/m^3]	Enthalpy [kJ/kg]	Entropy [kJ/(kg·K)]	Quality [-]
1	MT compressor suction	0,7	32,29	85,57	438,3	1,883	1,00
2	MT compressor discharge (estimated)	90,4	89,37	172,8	498	1,929	1,00
3	Gas cooler out	35,0	89,37	652,3	300,8	1,322	1,00
4	Gas cooler out, additional cooling	35,0	89,37	652,3	300,8	1,322	1,00
5	Ejector out, inlet receiver	-2,9	32,29	132,7	345,6	1,54	0,64
6	Gas, receiver out	-2,9	32,29	89,05	432,5	1,861	1,00
7s	Liquid, receiver saturated	-2,9	32,29	945,4	193,2	0,9759	0,00
7	Liquid, receiver out	-2,9	32,29	945,4	193,2	0,9759	0,00



Gas quality in receiver

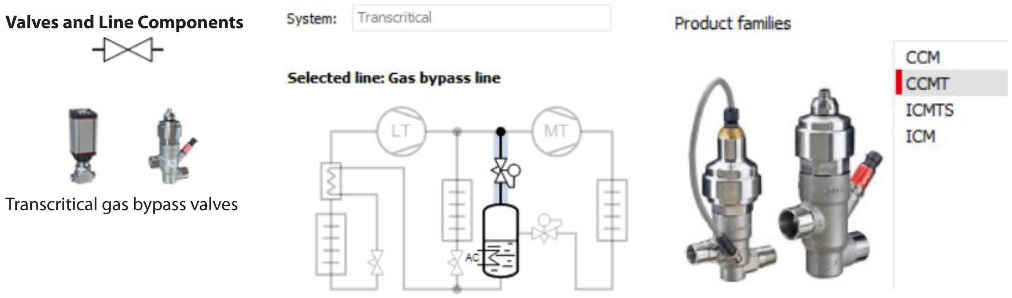
$$x = \frac{m_{BP}}{m_{compMT} + m_{evapMT}} = \frac{1512}{1656 + 719} = 0,636 \sim 0,64$$

Operating envelope

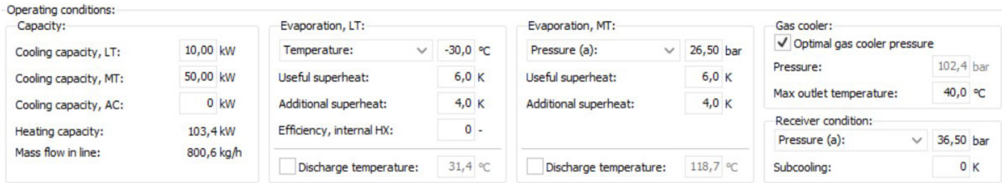


4.2 GBV, Gas By-Pass #1 valve selection

Select Gas By-Pass valve like for standard Booster system, because even you will run in summer time in LP ejector mode; there will be a time where we will turn the system to standard operation with Prec Delta P high to get oil back.



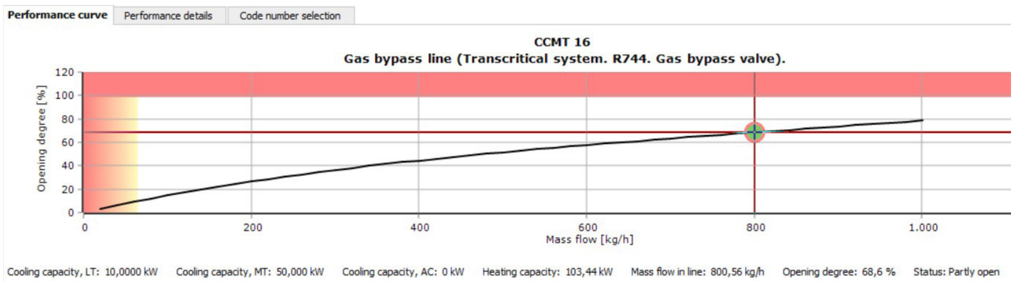
Selection Sgc 40 °C ; DeltaP high 10 bar



Gas bypass line (transcritical system, R744, Gas bypass valve)

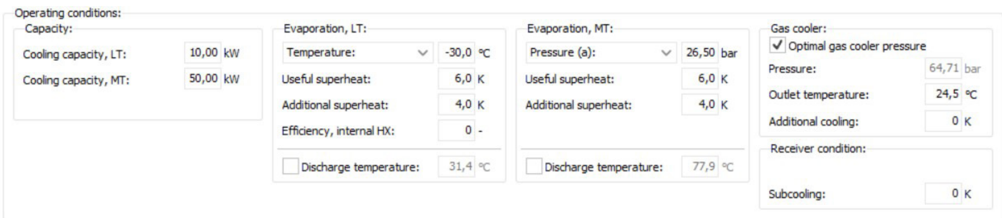
Selection: CCMT 16 **Selected code number: 027H7231**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	DT_sat [K]	Result
○	CCMT 2	15	146,3	2,300	547	10,00	9,85	11,8	⚠
○	CCMT 4	15	387,2	6,087	207	10,00	9,85	11,8	⚠
○	CCMT 8	15	688,4	10,82	116	10,00	9,85	11,8	⚠
◉	CCMT 16	25	1377	65,50	58	10,00	3,38	11,8	✓
○	CCMT 24	25	2065	98,25	39	10,00	3,38	11,8	✓



Selection Sgc 24 – 25 °C; DeltaP low 3 bar; Standard mode

LP ej selection to find out Sgc temperature when the ejector pressure lift exceeds DeltaP Low



Selection: Multi Ejector LP 1935

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_BP [kg/h]	m_comp_MT [kg/h]	Entrainment ratio	P_receiver [bar]	T_receiver [°C]
○	Multi Ejector LP 935	2	92	139,8	698,5	1202	1342	0,52	29,59	-6,1
◉	Multi Ejector LP 1935	1	92	139,8	698,3	1202	1342	0,52	29,56	-6,1

DeltaP … LP ejector pressure lift

DeltaP=P_receiver – Po_MT = 29, 56-26, 5 ~ 3 bar

GBV #1 selection

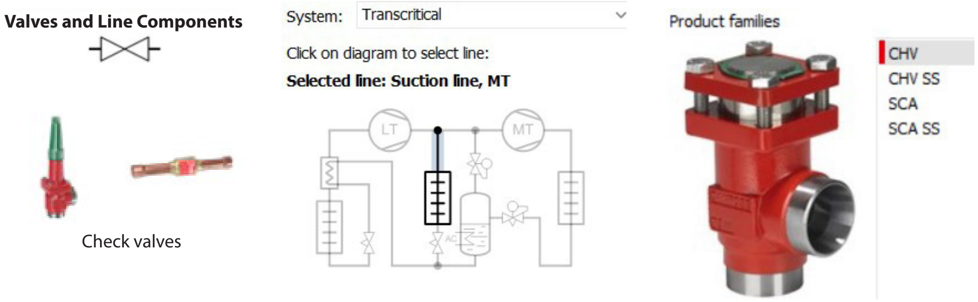
Gas bypass line (transcritical system, R744, Gas bypass valve)

Selection: CCMT 16 **Selected code number: 027H7231**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	DT_sat [K]	Result
○	CCMT 2	15	78,67	1,237	560	3,000	6,96	3,8	⚠
○	CCMT 4	15	208,3	3,274	212	3,000	6,96	3,8	⚠
○	CCMT 8	15	370,2	5,820	119	3,000	6,96	3,8	⚠
◉	CCMT 16	25	740,4	35,23	59	3,000	2,39	3,8	✓
○	CCMT 24	25	1111	52,84	40	3,000	2,39	3,8	✓

Conclusion:
We receive very similar results for high ambient temperature and DeltaP high (10 bar) and at temperature out of the gas cooler 24 – 25 °C and DeltaP low (3 bar)

4.3 Check valve selection



Operating conditions:

Capacity:		Evaporation, LT:		Evaporation, MT:		Gas cooler:	
Cooling capacity, LT:	10,00 kW	Temperature:	-30,0 °C	Pressure (a):	26,50 bar	☑ Optimal gas cooler pressure	
Cooling capacity, MT:	50,00 kW	Useful superheat:	6,0 K	Useful superheat:	6,0 K	Pressure:	102,4 bar
Cooling capacity, AC:	0 kW	Additional superheat:	4,0 K	Additional superheat:	4,0 K	Outlet temperature:	40,0 °C
Heating capacity:	103,0 kW	Efficiency, internal HX:	0 -			Receiver condition: Pressure (a):	29,50 bar
Mass flow in line:	697,8 kg/h	☐ Discharge temperature:	31,4 °C	☐ Discharge temperature:	119,9 °C	Subcooling:	0 K

Selection criteria:

○ Pressure drop:	Default bar	○ Saturation temperature drop:	0,1 K
◉ Velocity:	15,00 m/s		

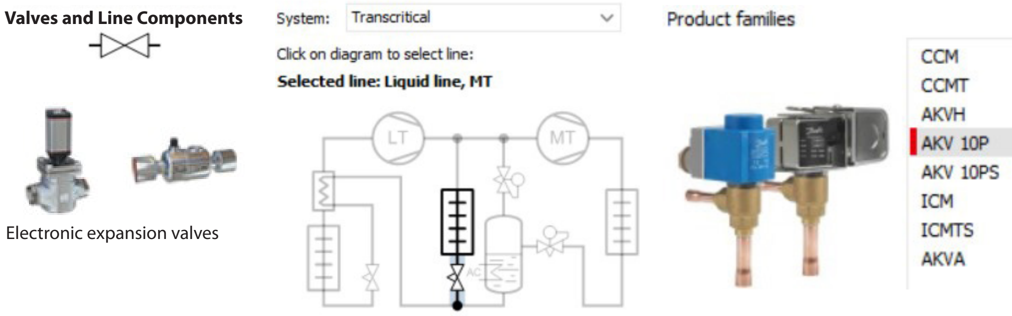
Suction line, MT (Transcritical system. R744. Check valve).

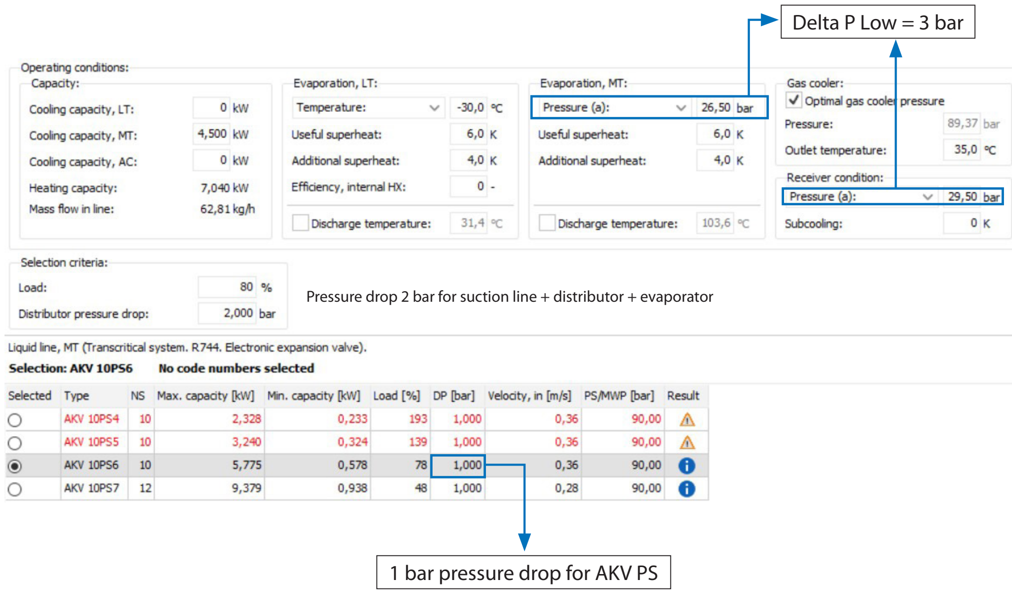
Selection: CHV 15 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]
◉	CHV 15	15	8	0,080	0,040	8	0,118	0,2	-	121	17	13,59
○	CHV 20	20	10	0,080	0,040	9,952	0,076	0,1	-	97	21	7,62
○	CHV 25	25	24	0,080	0,040	13,42	0,042	0,1	-	40	50	4,67
○	CHV 32	32	30	0,080	0,040	13,56	0,041	0,1	-	32	62	2,74
○	CHV 40	40	30	0,080	0,040	13,56	0,041	0,1	-	32	62	2,04

4.4 Evaporator EEV selection

In section "System design with Low Pressure lift ejector" point 5 it was explained what the limitations for selecting right AKVP/PS are. If e.g. the pressure differential Delta P Low is 3 bar and we assume the pressure loss on suction line is 1 bar, and distributor + evaporator additionally 1 bar, then there is 1 bar pressure difference for MT EEV left.





Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	PS/MWP [bar]	Result
○	AKV 10PS4	10	2,328	0,233	193	1,000	0,36	90,00	⚠
○	AKV 10PS5	10	3,240	0,324	139	1,000	0,36	90,00	⚠
◉	AKV 10PS6	10	5,775	0,578	78	1,000	0,36	90,00	ℹ
○	AKV 10PS7	12	9,379	0,938	48	1,000	0,28	90,00	ℹ

5. Multi Ejector Solution™

Danfoss offers a wide range of market leading Multi Ejectors. Supported by 3 MBS 8250 sensors, coils with LED plug.

Multi Ejector LP 935
The Multi Ejector Low Pressure (LP) with a nominal motive mass flow capacity of 935 kg/h is the smallest in the LP range and consists of 4 LP ejectors, 2 blanks and 1 strainer.

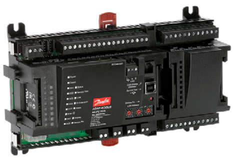
It is recommended for stores with a refrigeration load in the range of 18 – 35 kW.

Multi Ejector LP 1435
The Multi Ejector Low Pressure (LP) with a nominal motive mass flow capacity of 1435 kg/h consists of 5 LP ejectors, 1 blank and 1 strainer.

It is recommended for stores with a refrigeration load in the range of 18 – 53 kW.

Multi Ejector LP 1935
The Multi Ejector Low Pressure (LP) with a nominal motive mass flow capacity of 1935 kg/h is the biggest in the LP range. It consists of 6 LP ejectors, and 1 strainer.

It is recommended for stores with a refrigeration load in the range of 18 – 72 kW.



Controller AK-PC 782A
Danfoss offers a wide range of market leading Pack Controllers.
Being the flagship and best in class controller for transcritical CO_2 packs controls, the AK-PC 782A offers the highest possible efficiency with the Multi Ejector, CTM.
The complete application control features:

- Complete booster pack control of up to 3 suction groups (max. 12 compressors) and high pressure system
- Significant savings with heat recovery for tap water and heat reclaim
- Extensive control of oil flow and pressurization
- Best in class safety monitoring and fail-safe functions
- Minimal energy consumption while ensuring optimal food quality
- Auto-configured, easy-to-use graphical representation with Danfoss System Manager
- Independent, customized control and monitoring of auxiliary function

Temperature sensors and pressure transmitters
Danfoss offers a comprehensive range of sensors for temperature and pressure sensors developed to meet the requirements of the entire pack application.
The sensor range delivers the following key features and benefits:

- Long term reliability minimize system downtime
- Robust construction protects again mechanical shock and vibration
- Temperature sensor design ensures fast response time and precise measurement
- Hermetically sealed pressure element ensures no leakage
- Pressure transmitter output calibrated for perfect fit to the application
- Pulse snubber ensures protection against liquid hammering, cavitation or pressure peaks