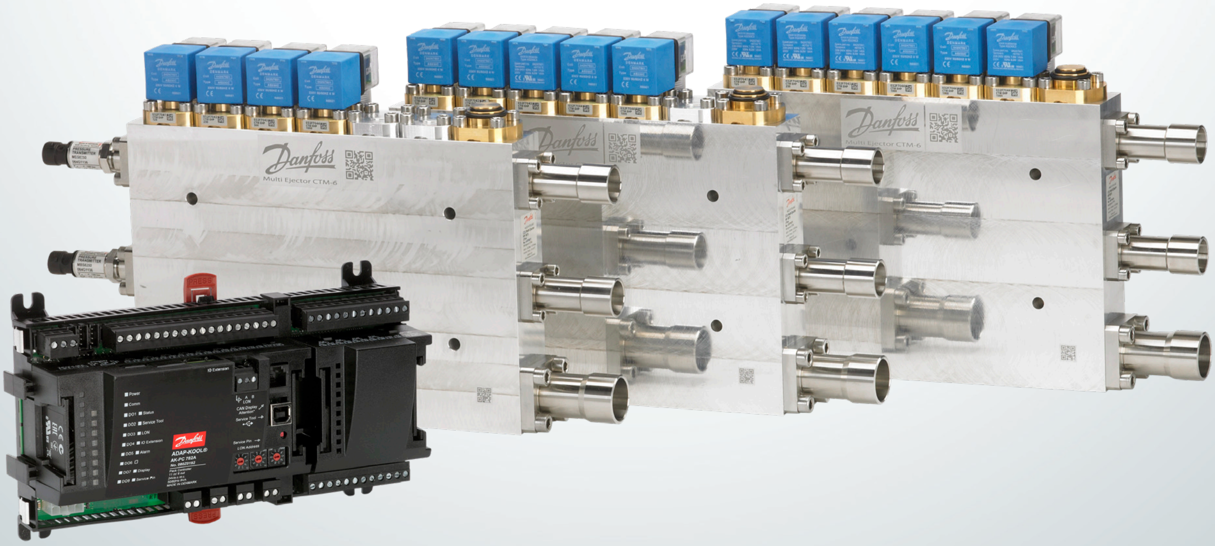
ENGINEERING
TOMORROW

Application Guide

High pressure lift ejector and liquid ejector systems



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1. High Pressure lift ejector system - a general description

A parallel compression system is one of the concepts that can be used in warmer climates to enhance the efficiency of a transcritical CO_2 system. The system is using the same layout as the booster system with an extra suction group connected to the receiver. For parallel compressors and their suction line we will use the designations IT (intermediate) compressors and IT suction group.

In cold periods, the system works as a booster system, but in warmer periods the amount of flash gas after high pressure expansion grows and parallel compressors should take over while the gas bypass valve should close. Depending on the variable capacity IT compressor selection and its minimum mass flow capacity, typical ambient conditions for changeover should be between 15 °C and 20 °C. At this condition the gas mass flow in the receiver that needs to be bypassed increases to 25 – 30% of gas cooler mass flow and should be taken by the gas bypass valve (GBV) or preferably the IT suction group.

In very warm periods, close to ambient conditions 40 °C, the mass flow ratio between MT suction and IT suction will be MT 55% / IT 45%. Because of the higher suction pressure of the parallel compressors, the system efficiency will rise allowing to reduce installed MT/IT compressors total swept volume comparing to the standard booster system. Depending on yearly climate conditions, the parallel compression system will provide an annual energy reduction compared to standard booster system at a level between 5 – 9%.

The High-Pressure lift ejector (HP ejector) is an add-on to enhance the parallel compression system.

An ejector is a device that utilizes the expansion work from the high-pressure expansion. This expansion work is transformed into compression work that compresses some of the MT evaporator flow into higher pressure (receiver). Since the expansion work is given by the conditions (temperature and pressure out of the gas cooler together with the receiver pressure), the compression work is also given (assuming constant efficiency). That means that the system offers some flexibility.

We can adjust the pressure in the receiver in a way such that the ejector produces a high lift (pressure difference between receiver and MT evaporator), but since the expansion work is given, the flow cannot be high at the same time. If the receiver pressure is then lowered and the ejector thereby enabled only to produce a low lift, the mass flow will be higher. However, it will reach some limits, based on developed chocked flow in the suction flow. When chocked limits are reached, the suction flow can be higher, despite the low requested pressure lift.

The suction mass flow is controlled by the entrainment ratio (ratio between suction mass flow and motive mass flow). The entrainment ratio is a characteristic of the ejector and depends on the ejector geometry and operational conditions (pressure temperatures and densities in the inlets and outlet of the ejector).

er (entrainment ratio):

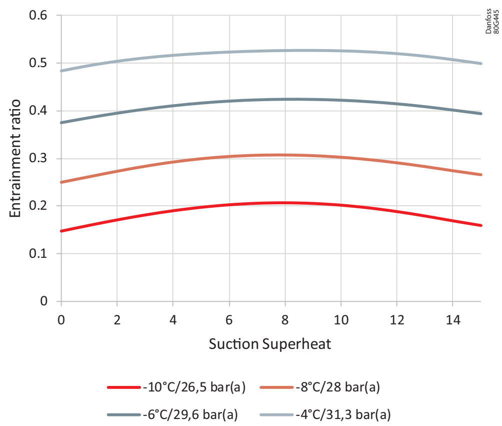
$$er = \frac{m_{suction}}{m_{motive}}$$

The optimal entrainment ratio is between 20 – 25% and the pressure lift between 5 – 14 bar. The pressure lift will be highest at high ambient temperatures where we need most of the ejector's benefit. There is also a dependency on suction flow super heat, as laboratory experiments show that the highest entrainment ratio is between 4 K and 12 K and our recommendation is to take the flow from the MT evaporators instead of common suction line from MT evaporators and LT compressors as the superheat can be higher depending on LT/MT ratio. The high superheated gas in the suction line will also result in reduced system performance (COP).

Reduced COP can also occur if the LT mass flow is relatively high in comparison to residual MT evaporators' flow, resulting in significantly high MT compressors' suction superheat and high discharge temperatures at extreme ambient conditions. To avoid this, an LT discharge desuperheater can be applied or liquid injected into the MT compressors' suction line to maintain acceptable superheat at those conditions.

To the right is an example with different MT evaporating temperatures (pressures) and ejector suction superheat between 0 K and 15 K but keeping constant:

- Temperature out of the gas cooler = 35 °C
- Pressure in the gas cooler = 90 bar(a)
- Pressure in the receiver = 38 bar(a)



The high-pressure flow (ejector motive flow) from the gas cooler enters the ejector which in this system works like a high-pressure control valve. The opening of the different ejectors is controlled in order to maintain the high pressure with the purpose of achieving optimum system COP. The pressure/temperature curve and the gas cooler outlet, contributing to optimum COP of the system, is predefined and integrated in the Danfoss pack controllers. In the ejector, energy from the high-pressure side is used to entrain gas from the suction side of the MT evaporators and lifts it to the receiver. In the receiver, the gas and liquid are separated and if the amount of gas is higher than the minimum capacity of the IT suction group, the controller should use IT compressors instead of a gas bypass valve.

The benefit of the HP ejector is that it unloads the MT compressors and enhances the IT compressors by feeding gas that should be compressed by the MT compressors. If we consider the same design criteria for a variable capacity IT compressor and its minimum mass flow, the typical ambient conditions for engaging the IT compressors will be lower than in a parallel system without HP ejectors.

In well-designed IT suction group it will be possible to start compressors at ambient conditions from 15 – 20 °C, while comparing to system with HP ejectors, and allowing the receiver pressure fluctuation by using the IT optimize function (one of the receiver control options in AK-PC 782A pack controller), the typical ambient conditions that can enable IT compressors will be 5 – 7K lower. This control strategy will contribute with more hours utilizing the IT suction group during the year.

When using HP ejectors and the IT Optimize function in regions with ambient conditions up to 40 °C, the mass flow ratio between MT suction and IT suction will be MT 35% / IT 65%. This will give a significant reduction in annual energy consumption compared to a standard booster system, between 9 – 15%, depending on yearly climate conditions and the ratio between LT and MT load.

The energy consumption reduction is considered without implemented Heat Recovery. When Heat Recovery is applied in CO2 transcritical systems, the pack controller will increase the pressure in the gas cooler to above the critical point (74 bar(a)) in order to enable more heat rejection. By doing this, the HP ejector will again have a high potential to lift mass flow from the MT evaporators to the receiver, like in warm ambient conditions.

As for parallel compression, the oil management of the parallel compressor enhanced with a high-pressure ejector needs special attention because the mass flow ratio for the parallel compressor is high. However, it is possible to build a system with safe oil return if the oil carry-over is managed.

1.1 System design with a High Pressure lift ejector (HP)

Systems with High Pressure lift ejectors (HP ejectors) are in many ways identical to parallel compression systems, but the ejector enhances the operation of the parallel compressors. The ejector takes mass flow from MT compressors and delivers it through the receiver to the IT compressors. Consequently, the MT compressors can be reduced in size and since the parallel compressors are running at a higher suction pressure the total swept volume will be reduced.

Oil return to the MT compressors are just as on the standard system with gas bypass. The oil/refrigerant mixture will even be richer on oil. As there is no oil returning to the parallel compressors through the suction line, extra attention needs to be paid to this part of the oil management system.

Design of MT/IT suction groups

To extract the maximum performance of a system with ejectors it is important to be careful when sizing the MT and IT suction group. For the ejector and the overall system to yield a high performance the receiver pressure should follow the variable reference that as realized by the "IT-optimize" reference mode for the IT compressor. This however make it less trivial to size the compressor groups (IT and MT) as it is important to look at part load performance and not only at the high design temperature and maximum system load. Temperatures out of the gas cooler between 15 – 20 °C and a part load operation with a load of approximately 40 – 60% of the full load condition (depending of the application) should be considered. As the load on the IT compressors are highly depended on the ejector and the receiver pressure, they should be able to cover a larger load span than a system without ejectors, this makes it difficult to construct an efficient system with only one parallel IT compressor.

If cost is the driver, the performance at the very warmest conditions can be sacrificed by designing the compressors at part load condition and then accept that the energy performance at maximum load and maximum temperature is not ideal. This is the same consideration as with parallel compression systems. In case of maximum load and maximum temperature, the receiver pressure is allowed to increase and therefore the entrainment ratio is decreasing, leaving more gas to the MT compressors. In this way the system can be cost optimized with only a small penalty on energy.

The same design analogy can be applied to HP ejectors by installing a High Pressure expansion valve in parallel to it in order to cover the gas cooler mass flow that cannot be taken by the HP ejectors at very high temperature conditions. It is possible to install more HP ejectors connected in parallel, and in AK-PC 782A it is possible to configure up to four ejector blocks in this way.

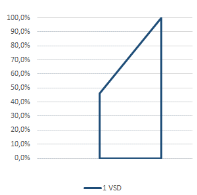
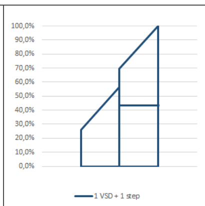
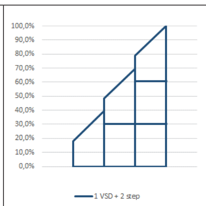
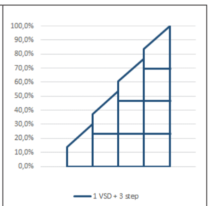
Parallel IT compressor capacity control

For MT and LT compressors suction groups, it is important to have possibility to match the actual compressor suction mass flow with the system load. If there is no match, it will result in suction pressure oscillations when cutting in capacity steps (for increasing capacity) or cutting out steps (for decreasing capacity). For that reason, one or two Variable Speed Drives (VSD) are used on leading compressors. When considering the design of IT suction compressors, having an as linear capacity control as possible is even more important, because oscillations in the receiver pressure control will affect both the MT/LT evaporating pressure and the gas cooler pressure, resulting in an unstable system with compressors and fans running capacity oscillations.

Higher receiver pressure oscillations can lead to the IT compressors frequently reaching their pump down limit. The pump down limit pressure level will switch off IT compressors and start GBV operation resulting in even more unstable system operation. It is important to avoid long periods with the MT and IT running large part of the installed capacity in part load. At part load the compressor is really inefficient. We have seen that installing an ejector which removes load from the MT and adds to the IT cause longer periods of both MT and IT running part load causing overall worse efficiency compared to not running with the ejector. This is also an important argument for splitting the capacity on more compressors.

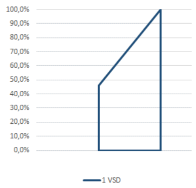
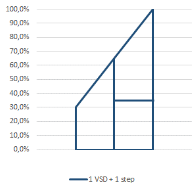
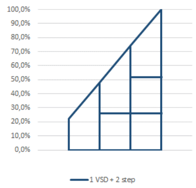
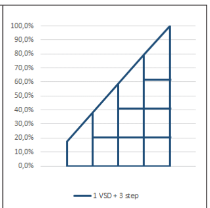
Compressor suction group capacity control:

Example 1:
All compressors are same nominal size.
The first compressor has VSD control from 30 – 65 Hz. The rest are single step compressors.

				
Compressor index[1)]	130	130 + 100 = 230	130 + 100 + 100 = 330	130 + 100 + 100 + 100 = 430
Starting capacity[2)]	46%	26%	18%	14%
Gap between compressor steps[2)]	-	13%	9%	7%

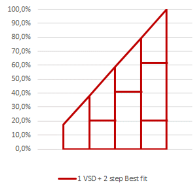
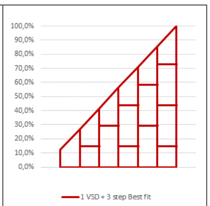
[1)] Compressor index represents capacity of each compressor as a relative number.
[2)] Capacities represented as % of total suction line mass flow capacity.

Example 2:
The first compressor has VSD control from 30 – 65 Hz. The rest are single step compressors, but 30% smaller capacity compared to VSD nominal capacity at 50 Hz.

				
Compressor index[1)]	130	130 + 70 = 200	130 + 70 + 70 = 270	130 + 70 + 70 + 70 = 340
Starting capacity[2)]	46%	30%	22%	17%
Gap between compressor steps[2)]	-	0%	0%	0%

[1)] Compressor index represents capacity of each compressor as a relative number.
[2)] Capacities represented as % of total suction line mass flow capacity.

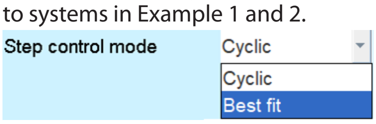
Example 3:
The first compressor has VSD control from 30 – 65 Hz. First single step compressor is 30% smaller capacity compared to VSD nominal capacity at 50 Hz. Second and third double size of first single step compressor. This configuration is applicable in systems with 1 VSD and 2 or more single step compressors with Step control mode "Best fit".

				
Compressor index[1)]	-	-	130 + 70 + 140 = 340	130 + 70 + 140 + 140 = 480
Starting capacity[2)]	-	-	17%	12%
Gap between compressor steps[2)]	-	-	0%	0%

[1)] Compressor index represents capacity of each compressor as a relative number.
[2)] Capacities represented as % of total suction line mass flow capacity.

Conclusions:

- Example 1: More single step compressors will allow us to start the VSD compressor much earlier in relation to total suction group capacity. Second, with more compressors there will be smaller gaps between capacity control.
- Example 2: Using 30% smaller capacity single step compressors in comparison to nominal VSD compressor, will result in linear capacity control (VSD control from 30 – 65 Hz). Drawback of such configuration is less total capacity comparing to Example 1. because all single step compressors are smaller.
- In Danfoss pack controllers it is possible to select a "Best-fit" option which makes it possible to select different sizes of single step compressors (Example 3.). To achieve linear control and higher capacity, it is important that the first single step compressor has 30% less capacity than a VSD nominal capacity at 50 Hz. Other bigger size compressors should not be larger than double size of the first single step compressor. Having this kind of regulation, it is possible to achieve a higher total capacity comparing to systems in Example 1 and 2.



- Examples 2 and 3 presents optimal sizing compressors to achieve linear control and maximum overall capacity. In reality, it is good to have certain capacities overlapping in the area between two steps it does not immediately trigger stating a new compressor and lower the speed on the VSD.
- When evaluating IT suction group design, to avoid system oscillations, it is extremely important to have linear capacity control. By doing this we can utilize IT compressors and HP ejectors in optimum way through the year and provide energy savings.

Single parallel compressor system design

The ideal solution is to have - as a minimum - two IT parallel compressors and two MT compressors with linear capacity control, but very often this is not possible in smaller systems due to cost reasons. Therefore, it is often seen that there is only one parallel compressor. If this parallel compressor is selected for maximum load, it would give the optimum performance at high ambient temperatures, but it will give very poor performance in the medium ambient temperature, where there are many operating hours. The turning point, when the IT compressor should start and the gas bypass valve should be closed, is the condition where the minimum gas mass flow IT compressor capacity (at minimum speed) should match the gas mass flow in the receiver. The challenge of selecting the right compressor is even bigger considering that lower ambient conditions (lower pressure in the gas cooler), will result with higher compressor capacity comparing to high extreme ambient conditions.

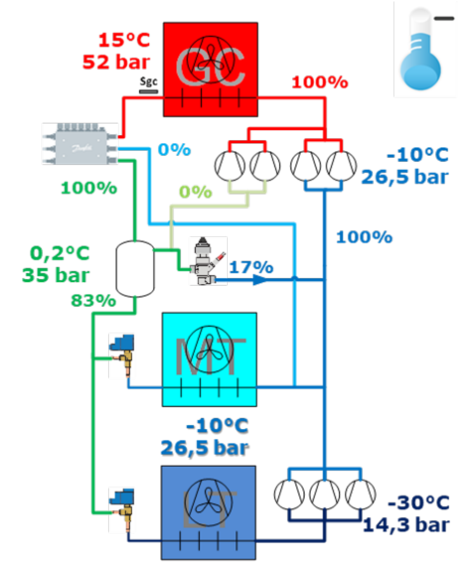
As a result of the above considerations and compromises, single parallel compressor systems should be sized for the part load condition and medium temperature conditions to achieve more operation hours. With such configuration at full load condition and high ambient temperature, an IT compressor will run at full speed and the suction pressure (receiver pressure) for the IT compressor is allowed to rise to a determined limit, causing the gas bypass valve to open and release the surplus gas mass flow that the IT compressor cannot handle to the MT compressors. This will of course increase the load on the MT compressors and should be taken into account when designing the MT suction group.

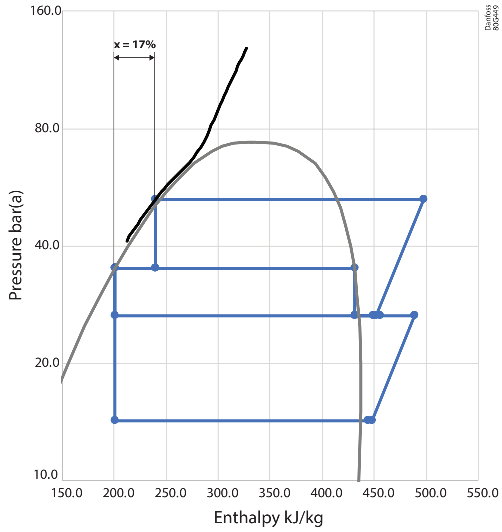
Maximum utilization of parallel compressor system with HP ejectors design

In general, when selecting the compressors, the following scenarios need to be considered:

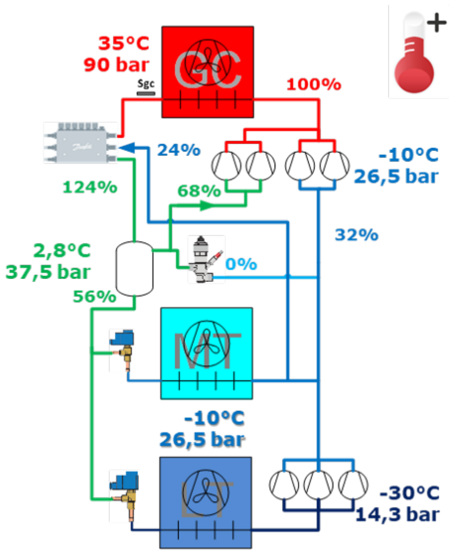
- In a well-designed system with IT compressors and HP ejectors the change-over between the gas bypass valve and the IT compressors' operation happen at ambient temperatures between 12 – 15 °C. So below that turning point, the minimum mass flow that the IT compressors can handle needs to be added to the MT compressor mass flow capacity. This is not a huge issue as the gas quality is low and the MT compressors will have more capacity because the pressure in the gas cooler will be low too.
- *Receiver pressure:* The system can be tuned by optimizing the receiver pressure. This functionality is embedded in the Danfoss AK-PC 782A controller and is activated by selecting Reference mode for the IT compressors with the function "IT optimize". At higher temperatures out of the gas cooler (Sgc), the receiver pressure is lifted gradually, depending on the MT suction and the gas cooler pressure. If the receiver pressure is too low, savings will be lower because the pressure is too close to the MT suction pressure. A higher receiver pressure also yields a smaller compressor due to the higher suction pressure. Keep in mind that a higher suction pressure also gives a higher oil carry-over, so the compressor and oil management need to be able to handle it. There is a limitation on the receiver pressure given by the manufacturer receiver design.
- *Gas cooler mass flow:* Due to mass flow balances in systems with a HP ejector there will be a higher mass flow through the gas cooler than in parallel compressor systems only. Depending how you control the pressure in the receiver, the mass flow increase will be different. If you run with the "IT optimize" function at high ambient temperatures increase will be up to 3%. If you run with constant pressure in the receiver, the increase at high ambient temperatures can be 6% higher.

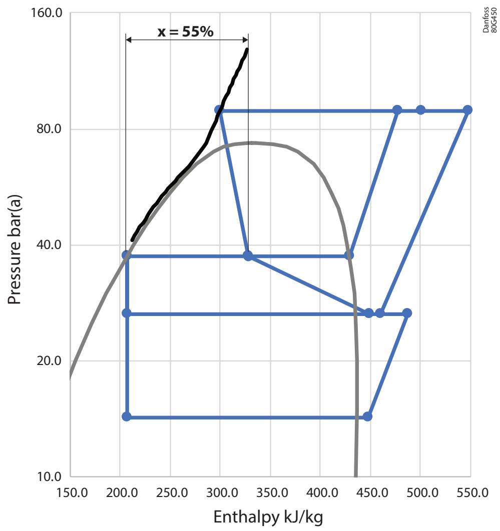
1.2 Example of system load with a High Pressure lift ejector





At above conditions (Po-MT/Prec/Pgc), the HP ejector is unable to make a necessary lift of 8.5 bar and the amount of gas after the HP expansion is relatively small, so the system works as a standard booster. To enable the ejector to provide a lift at specified Po-MT/Pgc conditions it will be necessary to decrease the Prec pressure to 32 bar(a). This can be achieved using the receiver control mode "IT optimize" and allowing lower minimum pressure reference in the receiver. There is also a feature for keeping a minimum pressure difference between the receiver and the MT suction.





In warm ambient conditions, the HP ejector has the ability to create a higher pressure lift. To optimize system efficiency, we can gradually increase the receiver pressure and by doing this control the ejector suction mass flow, keeping the entrainment ratio between 0.2 and 0.25. At above conditions, the ejector suction mass flow is 24% of the motive mass flow (er = 0.24). Any gas after the HP expansion and the ejector suction gas must be taken by the IT compressors.

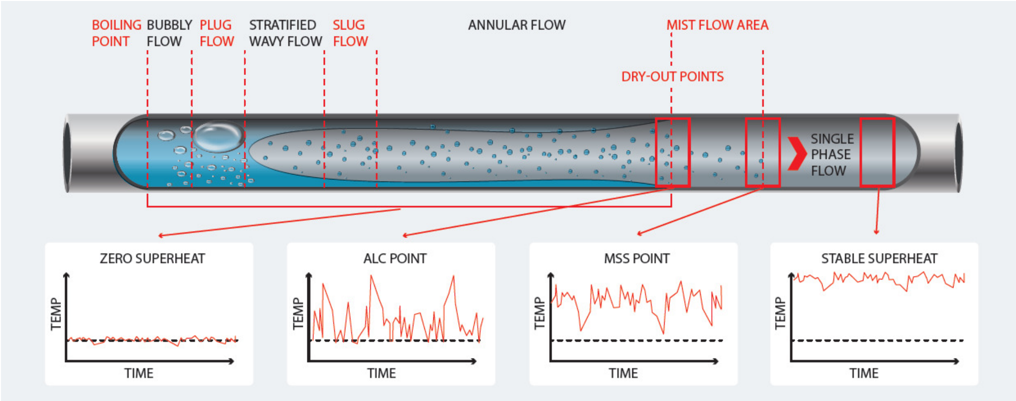
2. The Liquid Ejector (LE) system – a general description

The Liquid Ejector is designed for both standard booster and parallel compression systems. The working principle in the Liquid Ejector is similar to the gas ejectors. The Liquid Ejector is optimized to lift liquid from the suction accumulator and returning it to the receiver. In a Liquid Ejector system, the evaporators operate with a very low superheat and a fraction of liquid is returned to the suction accumulator, located downstream of the evaporators. With the support of an appropriate and intelligent case controller with an Adaptive Liquid Control (ALC) algorithm, the evaporator functions more efficiently at a higher suction pressure. This enables the suction pressure to be raised, thereby reducing the energy consumption on the compressors. Typically, the pressure in MT evaporators will be increased, utilizing network Master Control function Po optimization by 3.5 – 5 bar.

As the Liquid Ejector is powered by the work which would have been otherwise lost, there is no additional energy used to accomplish this.

2.1 Superheat control including new Adaptive Liquid Control (ALC)

Superheat across an evaporator, represented with a single tube:



- Zero superheat can be measured in all of the evaporator where fluid exists (until Dry-Out point).
- The ALC point (Adaptive Liquid Control point) can be found at the Dry-Out point on the borderline between the Annular Flow area and the Mist Flow area. With ALC the highest evaporator efficiency is realized but with droplets of refrigerant leaving the evaporator, which is not a safe situation compressor wise, so a suction accumulator must be applied.
- The MSS point (Minimum Stable Superheat) can be found on the borderline between the Mist Flow area and the Single Phase Flow. With MSS control the highest evaporator efficiency is achieved while all liquid is evaporated and only superheated gas is leaving the evaporator, which is a safe situation compressor wise.
- Dry SH control. Stable superheat can be measured when the superheat is higher than the MSS point.

The key to achieving the performance benefits enabled by the Liquid Ejector is the use of the Adaptive Liquid Control (ALC) algorithm available in the newest generation of Danfoss case controllers. This algorithm makes full use of the entire surface of the evaporator, maximizing its efficiency and operating with the lowest possible superheat (close to 0 K).

The amount of liquid is difficult to estimate, but a good estimate form experience is approx. 10% from the MT evaporators that are in liquid mode (by using the Danfoss evaporator/case controllers with the ALC functionality), also only those evaporators which are maximum loaded are in liquid mode, resulting in a reduced amount of returned liquid. In general, the experience shows that approx. 30% of the evaporators are running in liquid mode at a given time, so the amount of liquid returned is then approximately 10% x 30% = 3% of the total MT evaporators' mass flow returning to the suction accumulator.

This assumption is valid for systems with many evaporators of similar size like in a supermarket application (more than 10). For systems like cold storage plants with only a few evaporators where some of them can represent a high ratio in total MT evaporator capacity, the amount of liquid returned as a percentage of the total MT evaporator mass flow can be significantly higher.

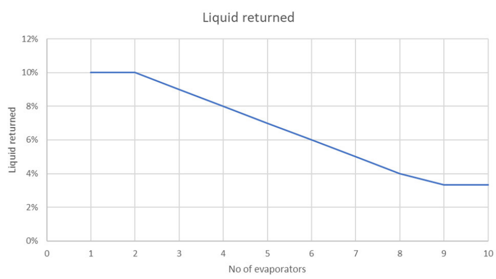
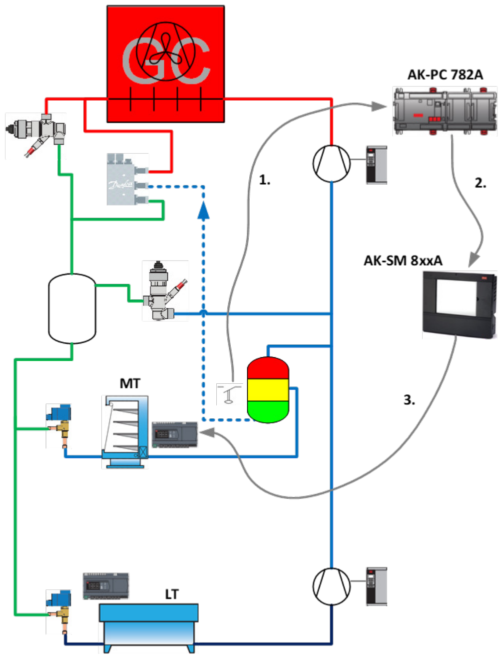


Fig. 1: Returned liquid estimation of returned liquid as a function of evaporators quantity.

2.2 CO_2 Adaptive Liquid Management (CALM™)

The Danfoss solution for managing liquid in transcritical CO_2 refrigeration applications is based on enhanced versions of case controllers (AK-CC 550A, AK-CC55, AK-CC 750A), pack controller AK-PC 782A, system managers of the range AK-SM 8xxA and Liquid Ejector. This solution is called CO_2 Adaptive Liquid Management (CALM) and represents a major step forward in refrigerant management. CALM ensures integration between the case controls, pack controls and system managers, enabling a safe operation in Liquid Ejector systems in all conditions.

To operate CALM™ it is necessary to set up the system in the following way:



Pack Controller:
It is important to enable the Po optimization feature on the MT suction line driven by a System Manager AK-SM 8xxA. This Master Control network feature constantly analyzes the most loaded MT evaporator controllers and adjusts the MT evaporation pressure in the pack controller AK-PC 782A within specified limits.

Case (evaporator) Controllers with ALC superheat control feature:
Modulated thermostat control should be enabled. By using this feature, the amount of liquid from the MT evaporators is limited as only the most loaded will operate with ALC superheat or at the minimum SH.

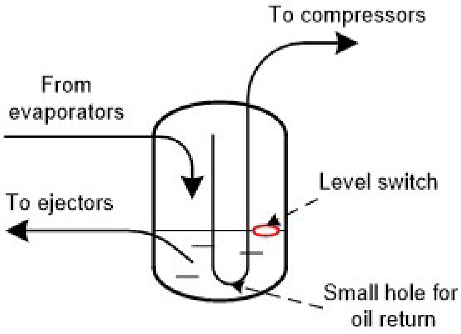
CALM™ solution:

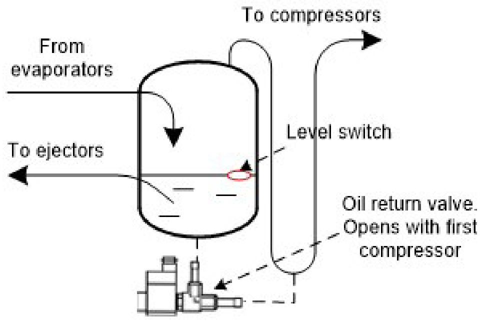
1. If Liquid Ejectors are unable to take all the liquid collected in the suction accumulator, the liquid level will rise. When the liquid level switch (ideally positioned 1/3 from the bottom of the total height) indicates too high a level, a digital signal triggers AK-PC 782A input.
2. Information about high level is transmitted via a communication line to the System Manager AK-SM 8xxA.
3. By using a communication line to the MT evaporator controllers, superheat control will switch from ALC to MSS (dry SH control) and stop releasing liquid to the MT return line.
4. When the liquid level in the suction accumulator drops to an acceptable level, the system will send a signal to the evaporator controllers to start the ALC superheat control algorithm.

2.3 Suction accumulator design

The suction accumulator is an important element in the system and very critical. It needs to be sized so that it can handle the liquid returned in case the ejector stops working, and you must design the system with oil return to the MT compressors.

Oil return can be done in following ways:



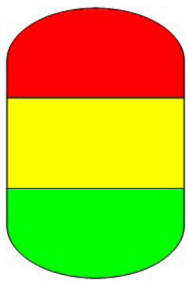


The simplest way is to have a U-tube in the suction accumulator with a hole at the lowest point where an oil rich mixture will be returned to the compressor. The other option is to do the same but move the hole into a solenoid valve or motor valve so the return can be controlled. For both principles it is important that the suction port for the ejectors is higher than the oil return port. If this is not the case, the ejector will take all the oil and there will be nothing to return to the compressors. It is important in the design of the system to ensure that liquid trapped in the oil has evaporated before it reaches the compressors.

Sizing the suction accumulator

There are several ways to estimate the size - here is one proposal. To do the sizing, some assumptions must be made:

- Worst case is that 3% of the flow returning to the suction accumulator is liquid. If there are less than 10 evaporators, this number needs to be higher - see Figure 1. "Returned liquid estimation as a function of evaporators quantity"
- The time for dry out if we go from ALC superheat mode to MSS superheat mode is set to 10 min. Experiences from the field indicate that it takes approx. 5 min for the system to dry out, but it will depend on the installation.
- The suction accumulator is divided into 3 equal size sections where the lower third is the part we use for normal operation, the second third is the part where the system is emptied and the last third is safety to ensure the liquid can be separated. These distribution levels can of course be made differently.



Liquid separator with 3 equal levels

Example:
Based on the above information, liquid that is returning can be calculated based on an MT evaporator's cooling capacity.

An MT cooling capacity of 100 kW will result in an evaporator flow around 1540 kg/hr (depending on the MT evaporating pressure and the pressure in the receiver):

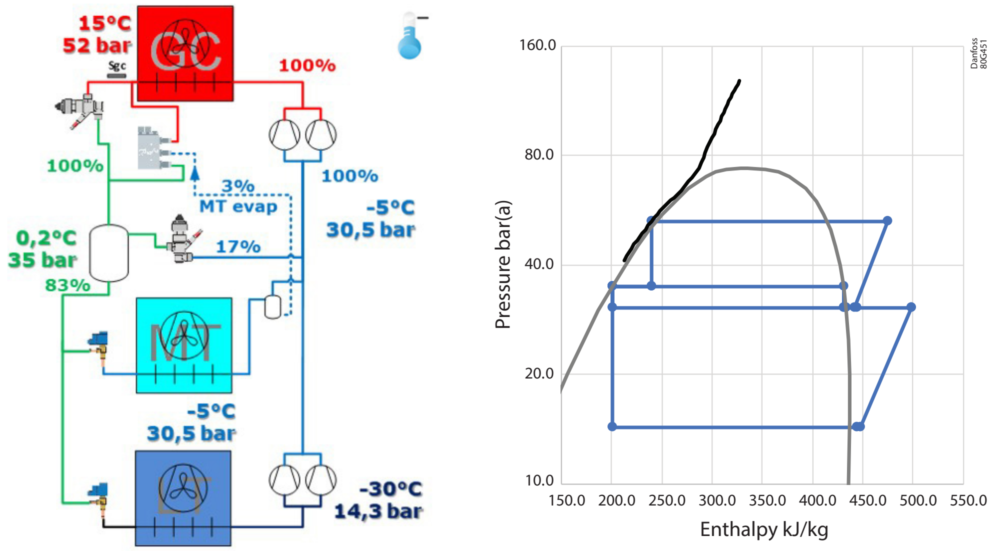
$$\dot{m}_{liquid} = \dot{m}_{gas} \times \theta_{liquid}$$

$$\dot{m}_{liquid} = 1540 \, {}^{kg}/_{h} \times 3\%$$

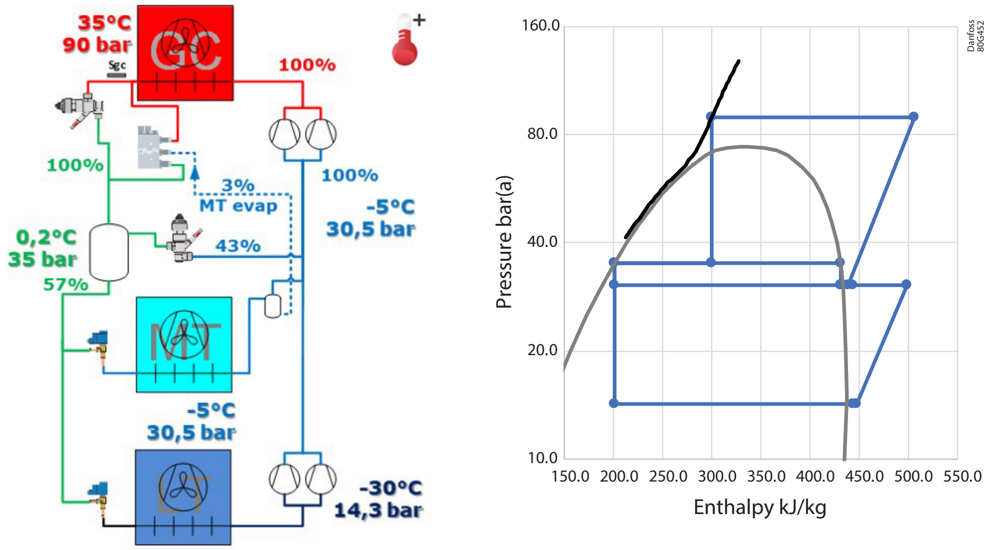
$$\dot{m}_{liquid} = 47 \, {}^{kg}/_{h}$$

With the assumptions made above, the maximum holding time is set to 10 min. That means that the accumulator's yellow zone should be able to hold 47/6 = 7,8 kg and with some safety ~ 9 liters. The total size of the suction accumulator should be 100 kW with an MT system of approximately 3 x 9 = 27 liters. The suction accumulator CALM operation level switch must be placed between the green and the yellow zone (at 1/3 level) and will send MT evaporators back to MSS superheat mode (dry SH control). The safety level switch that protects the MT compressors from liquid slugging must be placed between the yellow and the red zone.

2.4 Example of system load with Liquid ejector



The MT evaporation pressure is 4 bar higher than in a standard system due to the ALC superheat control. The pressure difference between the receiver and Po-MT is 4.5 bar, enabling the Liquid Ejector to lift also in colder ambient conditions. We can control the pressure difference Prec – Po_MT all year round allowing LE operation.



In warm ambient conditions all is the same as in cold ambient conditions. We could have a higher pressure difference Prec – Po_MT, but not more than 7 – 8 bar as the LE is not able to create a higher pressure lift.

3. System design with a High Pressure lift ejector (HP) and a Liquid Ejector (LE)

This solution is meant for medium to large sized commercial refrigeration systems with parallel compression. The system will benefit from both technologies - HP and LE - and it is the most optimized solution with Danfoss ejectors. By utilizing the ALC superheat control, there will be zero or very low superheat from the MT evaporators' return line. The common suction line to gas and liquid ejectors should be connected in the same way as in an LE system, I.e. in the suction accumulator's lower part, but not at the very bottom because that should be used for oil return process.

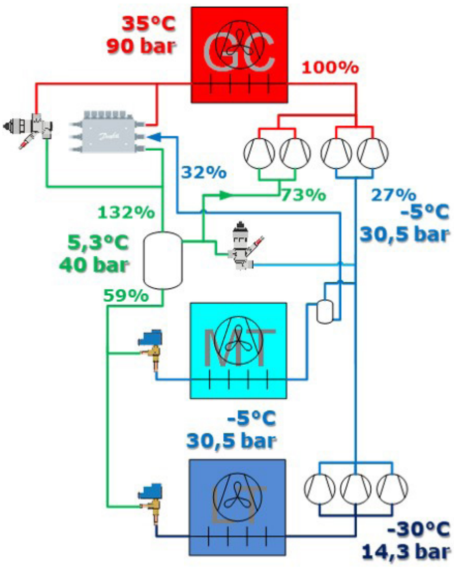
In cold ambient conditions, a LE has the possibility to lift liquid, allowing MT evaporators to work at higher evaporation temperatures. By also having HP ejectors operating and taking liquid and gas from the suction accumulator, it is possible to have a higher pressure in the receiver in warm ambient conditions, enabling better operating conditions for parallel compressors under such conditions. A higher pressure in the receiver will support the IT suction group in becoming even more efficient.

The LT compressors' discharge flow will be mixed with residual flow from the MT evaporators, resulting in a lower MT compressor superheat than in standard booster systems.

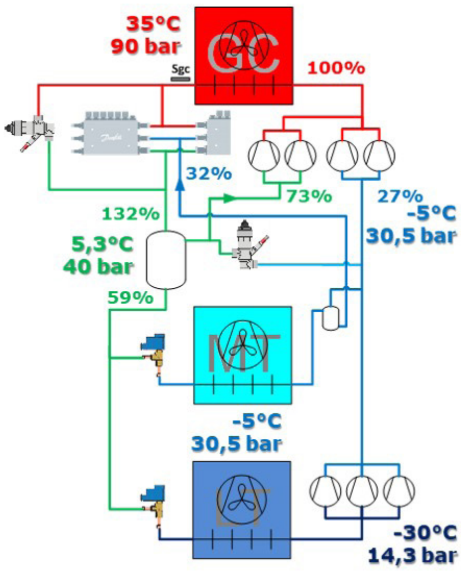
To simplify the installation for medium sized systems, Danfoss offers Combi ejectors - a combination of HP and LE ejectors in one component. There should be one suction line to the Combi ejector block connected to the lower part of the suction accumulator.

The ejectors (gas and liquid) control the gas cooler pressure. Depending on the ejector envelopes and the pressure conditions in the system, the pack controller AK-PC 782A decides which ejector cartridge that will open first: liquid or gas ejector.

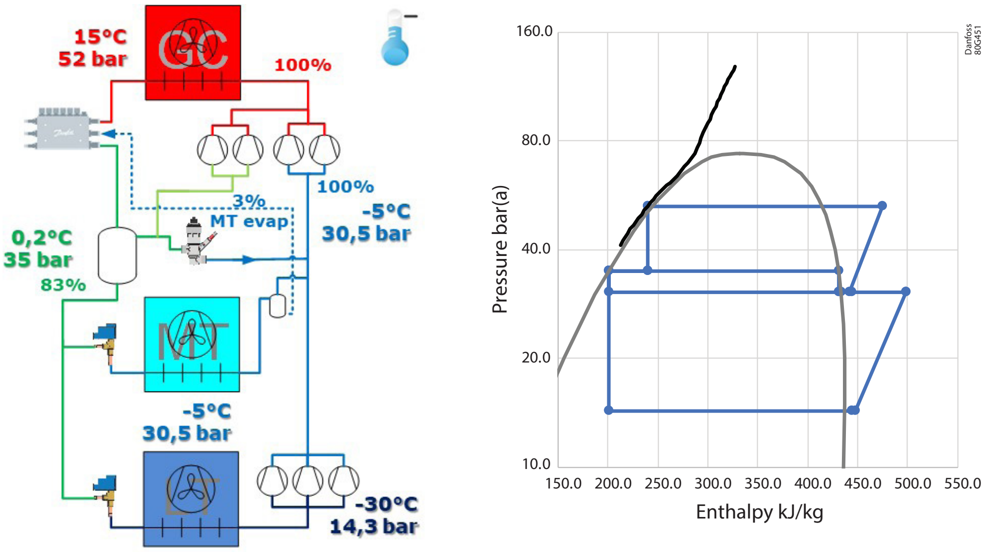
HPV+Combi
The below outline shows a solution for medium to large sized commercial refrigeration systems with parallel compression. Combi ejector with HP/LE combination all in one block.



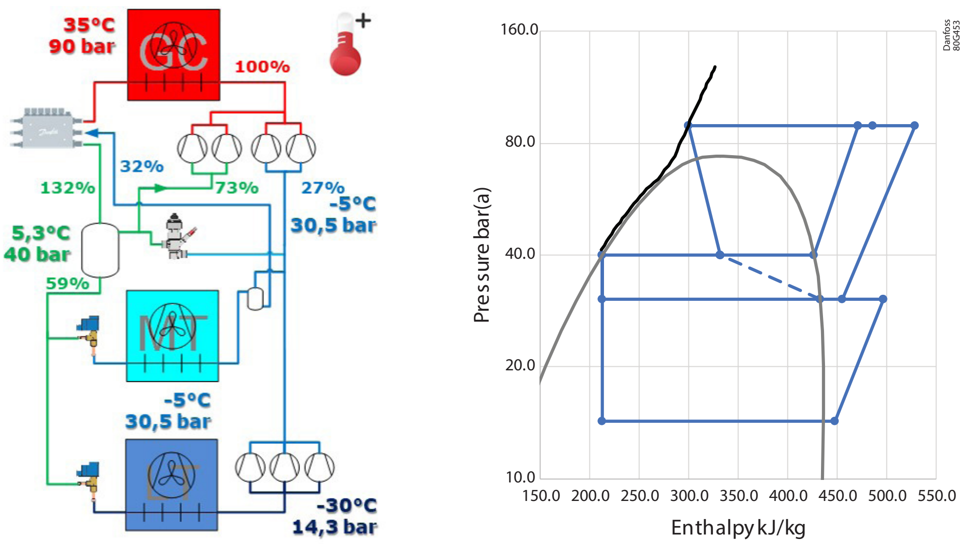
HPV+HP+LE
The below outline shows a solution for large sized commercial refrigeration systems with parallel compression. Separate HP and LE ejector blocks.



3.1 Example of system load with Combi (HP + LE) ejector



In cold ambient conditions the system benefits from CALM, resulting in a higher MT evaporation pressure.



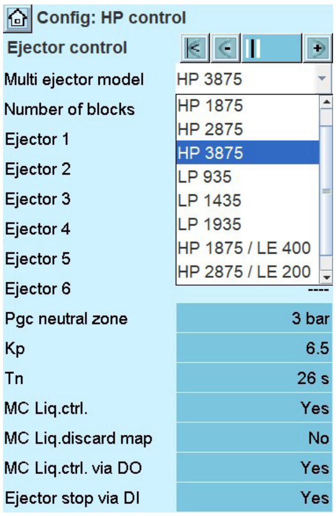
When ambient temperatures become higher, the HP ejector has the capability to take gas + liquid. This can create a higher pressure lift, which enables an increase in the receiver pressure for further optimization of the IT suction group.

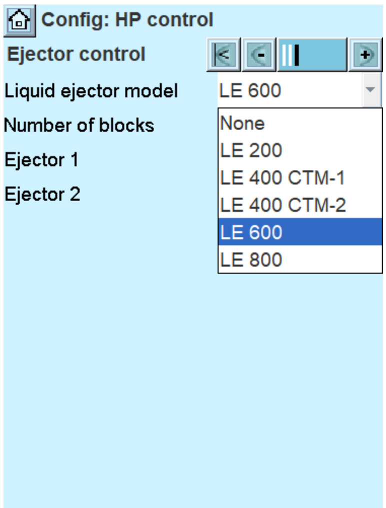
4. Configuration of the AK-PC 782A

No matter if it is an HP-, LE-, or HP+LE ejector solution, setting the AK-PC 782A for supporting the various ejector solutions is fully integrated in the controller. This will only impact the settings that need to be made for the "HP control" and the selection of reference mode in the IT compressor settings.

4.1 HP control

Under the HP control, the selection of the various supported ejector blocks is made. The ejector can be selected either as pure HP-ejector block in combination with LE-ejector block or as combi blocks – see figure below. Note that if more HP-ejector blocks are selected ("Number of block" larger than 1) they will be operated in parallel and hence only one set of DOs is assigned. Hence, ejector 1 from the parallel blocks should all be connected to the designated ejector DO point under the IO configuration. Selecting multiple LE ejector blocks will result in individual DO points for each ejector cartridge.





Here it is also selected whether the CALM solution (MC Liq. Ctrl.) should be activated or not (see explanations above).

The HP valve and the multi ejectors are all considered as actuators for controlling the gas cooler pressure. This means that the HP controller needs to prioritize the actuation between the HP valve, HP ejector and LE ejector.

The prioritization is roughly speaking done in two steps:

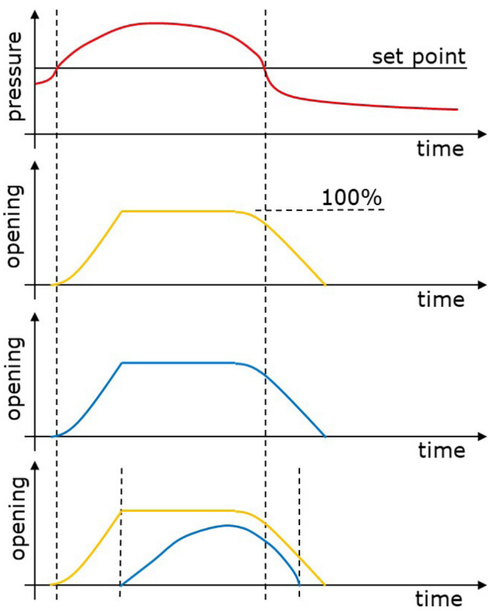
1. First, it is decided whether the HP valve or the multi ejector (HP+LE) is going to be used for actuation – the multi ejector always has first priority, meaning that if more actuation is needed and there is spare capacity available on the multi ejector (HP+LE), it will be actuated. Only when no more ejector capacity is available, will the HP valve be activated. The figure below illustrates the behavior during rising and falling gas cooler pressure:

The gas cooler pressure is controlled with ejectors with a high-pressure valve or both (as installed).

Ejectors only:
The ejector opening degree (required capacity) increases when the pressure is too high and closes when the pressure is too low.

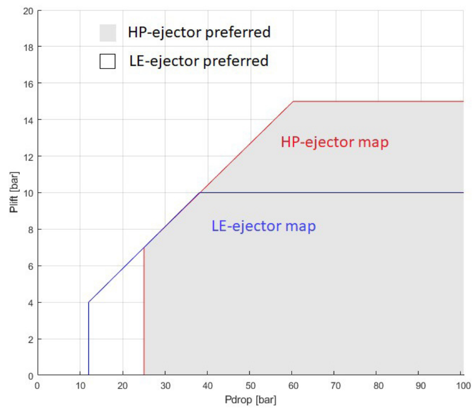
High-pressure valve only:
The high-pressure valve opening degree increases when the pressure is too high and closes when the pressure is too low.

Ejectors and High-pressure valve:
The ejectors operate first, and the high-pressure valve only comes into action when the ejectors are fully utilized. The ejectors remain fully open until the high-pressure valve has closed.



2. The second step of prioritization is between the HP ejector and the LE ejector. This prioritization is done based on the ejector maps. The figure to the right shows the areas in which the preferred ejector type is the HP ejector or the LE ejector respectively, depending on the pressure lift (Plift=Prec-P0-MT) and the pressure drop (Pdrop=Pgc-Prec).

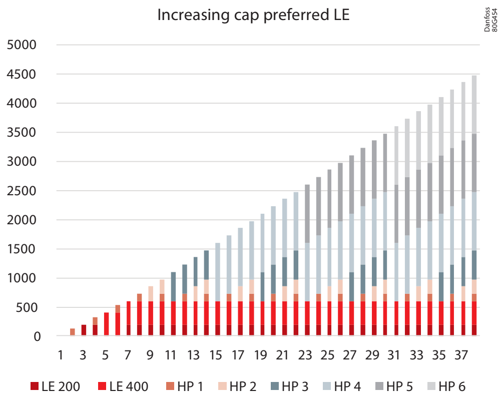
   Note: the max pressure lift for the LE ejector has been increased to 10 bar in PC782A v.2.71 from 8 bar in previous versions.

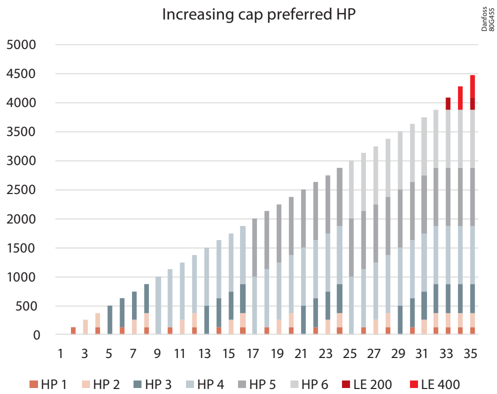


For details in switching patterns, please see the graph below.

The ejectors steps are combined to form a capacity as close as possible to the requested capacity by the control. In case the same capacity can be obtained by combinations of liquid and gas ejector respectively the controller will:
- For increasing capacity demand open for the prioritized ejector type
- For decreasing demand close for the lowest prioritized ejector type

See also the figures below for HP 3875 and LE 600:





All the standard settings around the gas cooler i.e. fan control, high-pressure curve etc. still applies when running with ejectors, however there are a couple of dedicated settings that only apply for the ejector:

1. When controlling the pressure using the ejector block, the ejector capacity is modulated in steps like indicated in the figures above. Practically, this means that the HP controller is likely to be switching between two steps to maintain a certain pressure reference. To avoid too frequent switching, a neutral zone (Pgc neutral zone) on top of the high-pressure reference is implemented. This allows the pressure to drift (default 3 bar) above the pressure reference without stepping up in ejector capacity, hence reducing the number of switches of ejector capacity.
2. When the ejectors are actively controlling the gas cooler pressure, the PI-controller tuning factors (Kp or Tn) are set separately.
3. To enable the CALM™ solution it is necessary to start the Master Control feature "MC Liq. ctrl."
4. If the condition of being inside the ejector envelopes to enable CALM™ wants to be avoided, you can select feature "MC Liq. discard map" to "No".

Config: HP control	
Ejector control	
Multi ejector model	HP 3875
Number of blocks	1
Ejector 1	----
Ejector 2	----
Ejector 3	----
Ejector 4	----
Ejector 5	----
Ejector 6	----
Pgc neutral zone	3 bar
Kp	6.5
Tn	26 s
MC Liq.ctrl.	Yes
MC Liq.discard map	No
MC Liq.ctrl. via DO	Yes
Ejector stop via DI	Yes

5. "MC liq.ctrl. via DO" is using Digital Output on AK-PC 782A to send a signal to the evaporator controllers' bypassing network unit AK-SM. Note that if a DO is used, be careful to make the connections such that if the cable is removed the ALC will be stopped. By default, the ALC is enabled when the DO is closed.
6. It is possible to disable ejectors by dedicated DI (Digital Input).

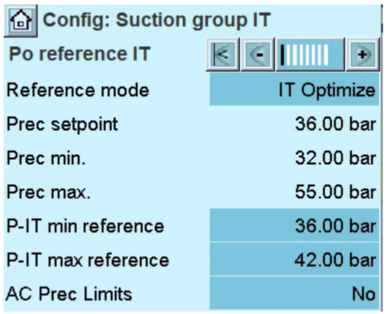
4.2 Receiver control

For plant types without IT compressors but with e.g. an LE ejector, it is important to configure a receiver setpoint, which secures that the operating point of the ejector stays inside the ejector map (see figure in previous section). For the LE ejector the pressure lift should not be higher than around 9 – 10 bar (for AK-PC 782A version 2.71 and up) to avoid losing LE ejector efficiency. This means that if e.g. the ToMT = -10 °C ~ 25.5 bar, the receiver setpoint "Prec setpoint" should not be set higher than around 25.5+7 = 32.5 bar to ensure that there is always lift from the LE ejectors.

For systems with IT compressors it is possible to select between various reference modes for the IT compressor. It is generally recommended to use the "IT-Optimize". This will strive to adjust the setpoint for the IT compressor to optimize the system efficiency – however it does not ensure that the maximum pressure lift for the ejectors are obeyed. To ensure the maximum pressure lift stays inside the ejector envelope, the maximum IT reference (P-IT max. reference) should be limited.

To give an example: assuming that a system is running with HP ejectors, the maximum pressure lift is around 15 bar. Further assume that the reference for the To-MT is -8 °C (~27 bar), then the maximum receiver pressure reference (P-IT max. reference) should be limited to 27+15 = 42 bar.

Same considerations should be done when working with Liquid Ejectors only but minimum and maximum references need to be aligned.



Note: When running in the IT-Optimize mode the reference to the receiver can be as high as the bottom of the receiver P-band, if not limited by P-IT max. reference. This means that if the neutral zone of the IT-compressor overlaps with the P-band, then the receiver valve is forced open before the second IT compressor is started. This can result in the second to last IT-compressors not activating when needed the most. (This is an issue for systems with two or more IT-compressors).

To avoid this, the following settings are recommended:

P-IT min reference = Prec setpoint (used for Vrec – Gas Bypass Valve)

P-IT max reference < Prec max – Prec max Pband – NZ/2+1 = 55 -3 - 3/2+1 = 51.5 bar

4.3 CALM™ set-up in Pack Controller AK-PC 782A

For systems with HP and/or LE ejectors it is possible to utilize the CALM™ solution (see explanation of the CALM™ function in a previous section). Under the HP Control, the CALM™ can be selected by enabling the "MC. Liq.ctrl." The "MC. Liq. Ctrl" is a safety control feature that monitors the operation of the ejectors and of the liquid level in the suction accumulator to ensure safe operation without liquid getting back to the compressors. There are several criteria for when ALC is allowed:

- If no ejectors are configured, then ALC is not allowed.
- In the suction accumulator (a receiver in the suction line of the MT compressors) there MUST be a level switch. When the liquid hits this level switch or there is an error on the switch, then ALC is NOT allowed for the next 30 minutes The countdown timer is set to 30 minutes every time it hits this condition. This time should be enough to empty the suction accumulator.
- If the ejectors are not able to lift (meaning that no ejectors are operated inside the map of according to ejector type) or no ejector are open, then ALC is not allowed for the next two minutes. This is to prevent ALC at uncertain ejector pumping capacity. The countdown timer returns to two minutes every time it is outside the map or the last ejector is closed.
- Both timers must be 0 before ALC is allowed.
- If at least one ejector is active and operated inside the ejector map, then it is expected to be able to pump/lift liquid and therefore ALC is allowed if the former criteria is fulfilled.

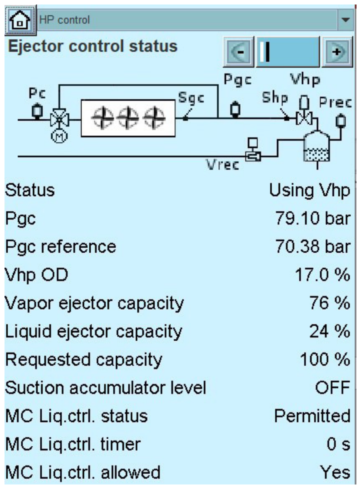
Following "MC liq.ctrl status" can be observed:
- Timer
- No lift
- Permitted
- High level

To check whether the ejectors are operated inside their maps, following the pressure drop (Pdrop) and pressure lift (Plift) is used.

Pdrop = Pgc reference - Prec reference*

Plift = Prec reference* - PoMT

Where Prec reference* = Max (Prec reference, Prec filtered 60 sec). This means that if the measured Prec is above its reference for approximately 60 sec then this will be used in the calculations of Pdrop and Plift.



4.4 I/O Configuration

When the AK-PC controller has been configured for control of an HP/LE ejector system, several Digital outputs and Digital inputs need to be configured.

This includes outputs used for controlling the Multi Ejector (I/O configuration Digital outputs) and if using the CALM™ solution input for Suction accumulator level switch (I/O configuration Digital Inputs).

The outputs used for controlling the smallest HP ejectors and LE 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 782A controller (IO points 1-12 to 1-15).

If multiple HP ejector blocks are selected (“Number of block” larger than 1), they will be operated in parallel and only one set of DOs is assigned. Therefore, Ejector 1 from the parallel blocks should all be connected to the same designated ejector DO point under the IO configuration. If selecting more LE ejector or combi blocks each liquid ejector cartridge needs individual DO in IO configuration.

I/O configuration

Digital outputs

Load	Mod.	Pt	Active at
Ejectors			
MC Liq.ctrl.	6	8	ON
Ejector 1	1	14	ON
Ejector 2	1	15	ON
Ejector 3	1	16	ON
Ejector 4	1	17	ON
Ejector 5	1	18	ON
Ejector 6	1	19	ON
Liquid ejectors			
Liq. ejector 1 block 1	1	12	ON
Liq. ejector 2 block 1	1	13	ON

Digital inputs

Alarm / Function	Mod.	Pt	Active at
Suction accumulator..	3	8	Closed
Ejector stop	3	7	Closed

4.5 CALM™ set-up in System Manager AK-SM 8xx

In the pack controller the decision whether to allow ALC is made, which means that the decision should be communicated to the case controllers via the System Manager. For this feature there are two options: either hardwired via a pack controller DO (selecting “MC.Liq.ctrl. via DO” explained at the end of chapter 4.1 HP control) or via the fieldbus.

After configuring MT and LT suction groups, proceed to menu Control → Refrigeration → Suction.

Select MT Suction Group and then enable following Master Control functions:

- Suction Optimization
- Adaptive Liquid Management (this feature is only available for AK-CC55 evaporator controllers)

Location: Configuration ▶ Control ▶ Refrigeration ▶ Suction

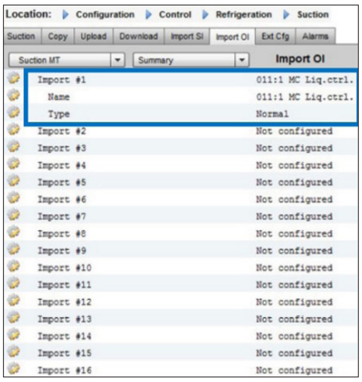
Suction | Copy | Upload | Download | Import SI | Import OI | Ext Cfg | Alarms | Alarm Select

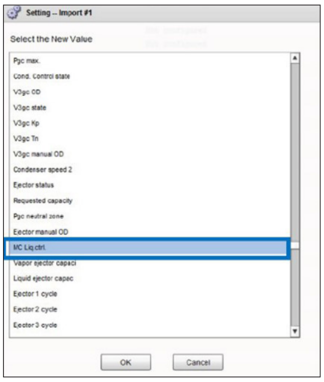
MT suction | System settings

Suction Optimization	Yes
Period	1200 sec
Filter	900 sec
Kp	1.0
Tn	900 sec
Max Float	4.0K
Allow float below target	Yes
Post defrost delay	20 min
Stop suction optimization when	
Number of case controllers offline	2
Post delay	15 min
Offlines No Float alarm	Normal
Action	1
User file	None
Evap shutdown when injection off	Yes
Adaptive Liquid Management	Yes

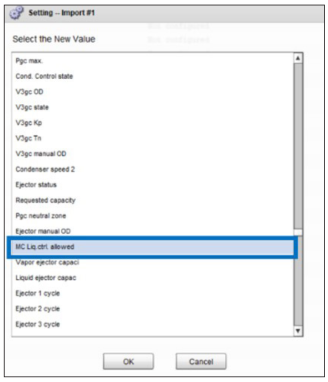
For other evaporator controllers with ALC superheat control (AK-CC 550A, AK-CC 750A but also AK-CC55), it is possible to set up the CALM™ feature manually via Custom Schedule.

1. Import the right controlling parameter from AK-PC 782A to the AK-SM - "MC liq.ctrl allowed" - so it can be used in the Custom Scheduler



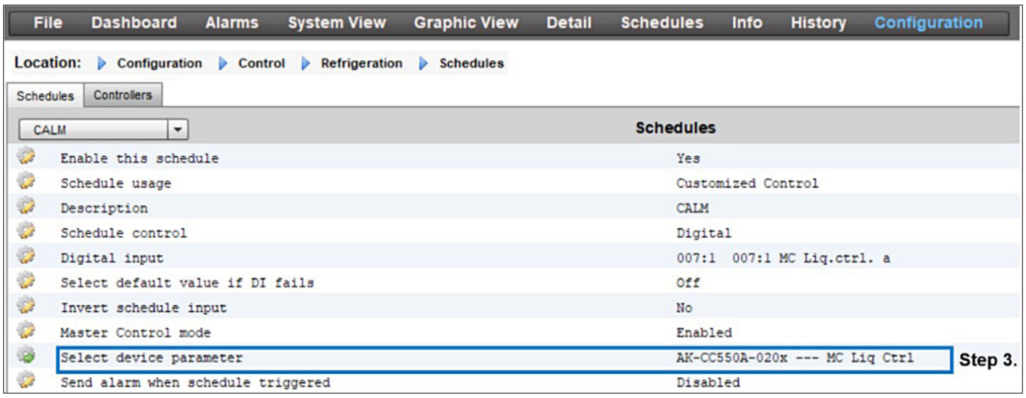


AK-SM 782A sw 2.08, 2.12, 2.21

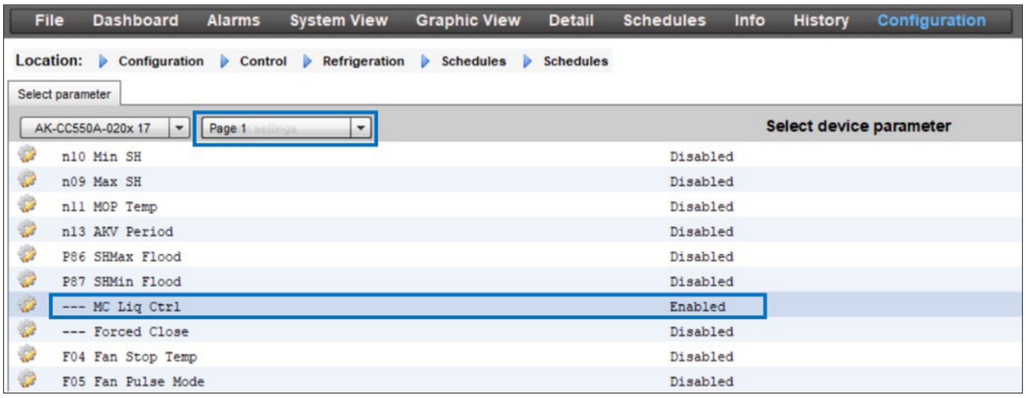


AK-SM 782A sw 2.65 and higher

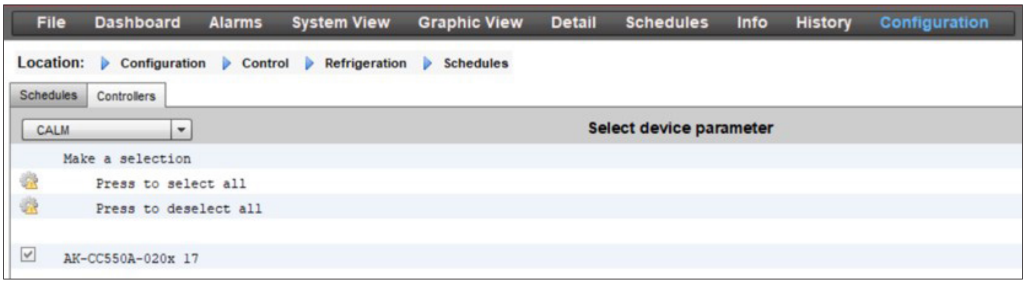
2. Configure Custom Schedule under menu Control → Refrigeration → Schedules in following way



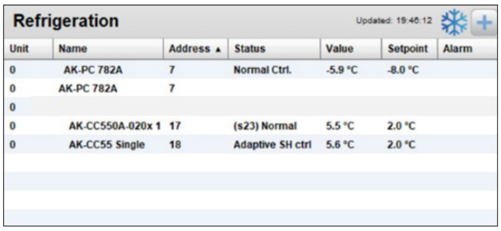
3. Select device parameter in the evaporator controller:

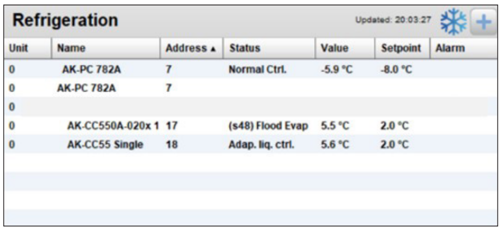


4. Select the controllers that should receive "ALC MC Liq.ctrl" command:

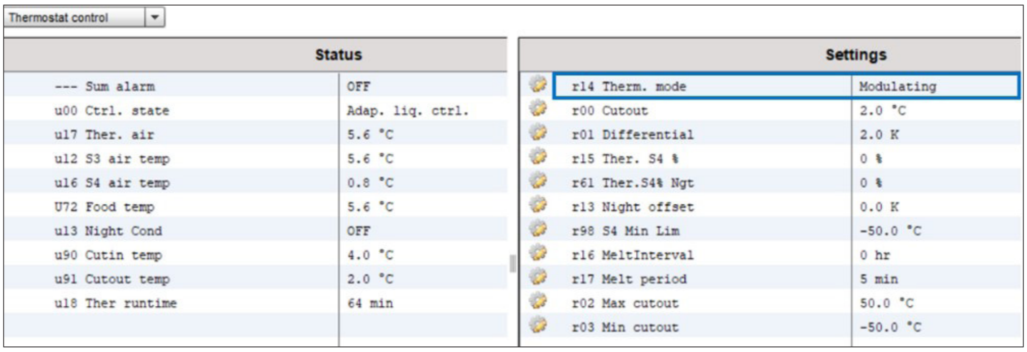


5. Evaporator controllers' status for AK-CC 550A and AK-CC55, depending on SH control mode:

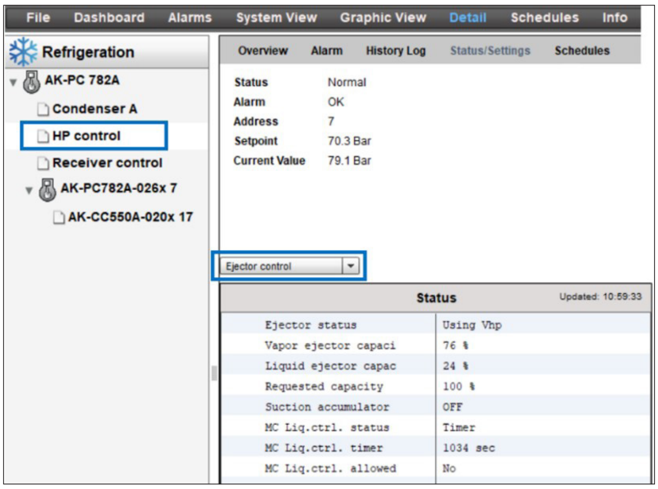


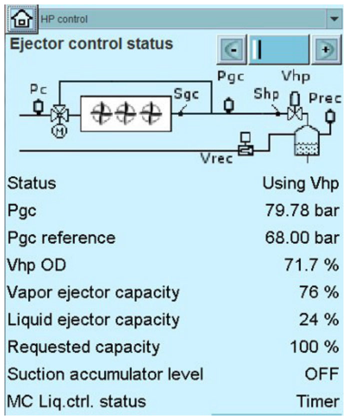


6. Setup "Thermostat mode" on the MT evaporators to "Modulating"



7. In AK-SM 8xx you can observe the ejector operation under Detail menu → HP control and drill down the menu Ejector control. When using the Service tool, the second tab under "HP control" shows the same measurements / statuses.

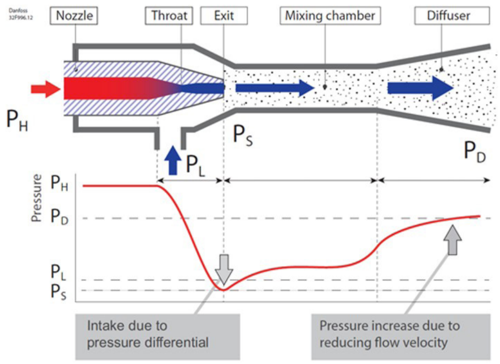




5. What is an ejector, and how does it work?

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 on the right, is driven by the high CO_2 pressure 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, CO_2 is at a higher pressure (PD) than the suction pressure (PL).



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 suction 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.

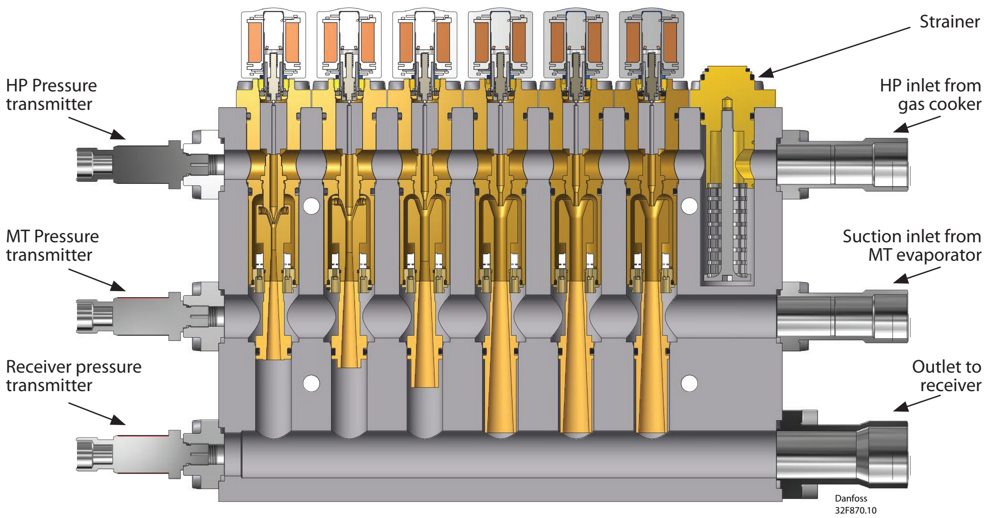
The Multi Ejectors High Pressure and Combi are delivered with three pressure transmitters, used for pressure control in the pack controller.

Each block has a variable number of ejectors of different sizes mounted vertically.

Multi Ejectors HP are available with 4 to 6 high pressure ejectors. Liquid Ejectors is available with 1 to 2 liquid ejectors. But Multi Ejectors Combi are available with 4 to 5 high pressure ejectors and 1 to 2 liquid 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.

Coils adv. (230 V DIN and 120 V UL all 50 – 60 Hz)



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

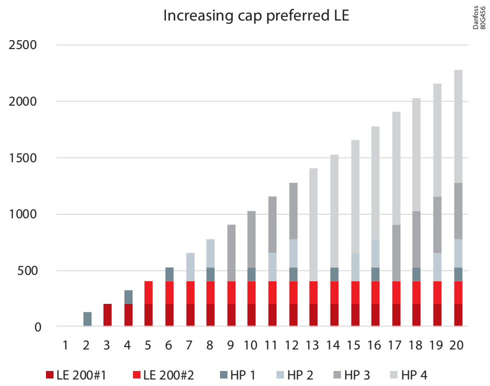
Multi Ejector Capacity Control

Multi Ejector capacity control is achieved through a binary coupling of various capacities of a number of ejectors. The Multi Ejector Combi, for example, comes in three versions. The version with four high-pressure ejectors and two liquid ejectors has high-pressure ejectors providing 125 kg/h, 250 kg/h, 500 kg/h, 1000 kg/h and two liquid ejectors each providing 200 kg/h of motive mass flow.

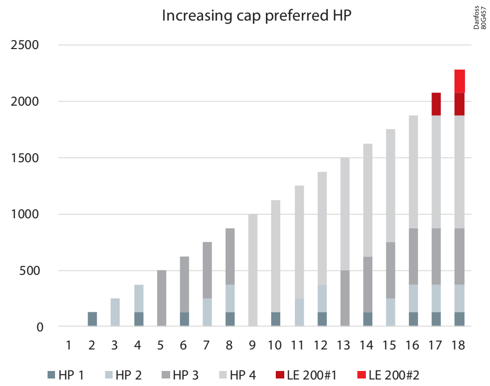
There are also two versions with five high-pressure ejectors and one liquid ejector. Both versions provide the same high-pressure capacity which consists of ejectors giving 125 kg/h, 250 kg/h, 500 kg/h, 2 x 1000 kg/h of motive mass flow, but depending on the version there are two sizes of liquid ejectors providing 200 kg/h or 400 kg/h of motive mass flow.

This allows to modulate high pressure capacity in 18 steps between 0 and 2875 kg/h in 125 kg/g steps and liquid capacity in two steps between 0 and 400 kg/h in 200 kg/h steps. But if more capacity is required, a second Multi Ejector can be added which will be controlled parallel to the first one.

Liquid ejectors are activated when there's some liquid in MT suction accumulator. They might operate alone when high-pressure ejectors are not activated or in parallel to the high-pressure ejectors. One line is used to supply liquid and gas from suction accumulator to low-pressure inlet of Multi Ejector. The liquid ejectors take in the liquid, whereas the gas is taken by high-pressure ejectors.



Capacity regulation with four HP ejectors and two LE ejectors where LE are preferred.



Capacity regulation with four HP ejectors and two LE where HP ejectors are preferred.

Multi Ejector High Pressure

Type	Code no.	Product name	Ejector 1	Ejector 2	Ejector 3	Ejector 4	Ejector 5	Ejector 6
CTM 6	032F5673	CTM Multi Ejector HP 1875	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	Blank ejector	Blank ejector
CTM 6	032F5698	CTM Multi Ejector HP 2875	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	CTM EHP 1000	Blank ejector
CTM 6	032F5674	CTM Multi Ejector HP 3875	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	CTM EHP 1000	CTM EHP 1000

Multi Ejector Liquid Ejector

Type	Code no.	Product name	Ejector 1	Ejector 2
CTM 1	032F5683	CTM Multi Ejector LE 200	CTM ELE 200	-
CTM 1	032F5684	CTM Multi Ejector LE 400	CTM ELE 400	-
CTM 2	032F5694	CTM Multi Ejector LE 400	CTM ELE 200	CTM ELE 200
CTM 2	032F5685	CTM Multi Ejector LE 600	CTM ELE 200	CTM ELE 400
CTM 2	032F5695	CTM Multi Ejector LE 800	CTM ELE 400	CTM ELE 400

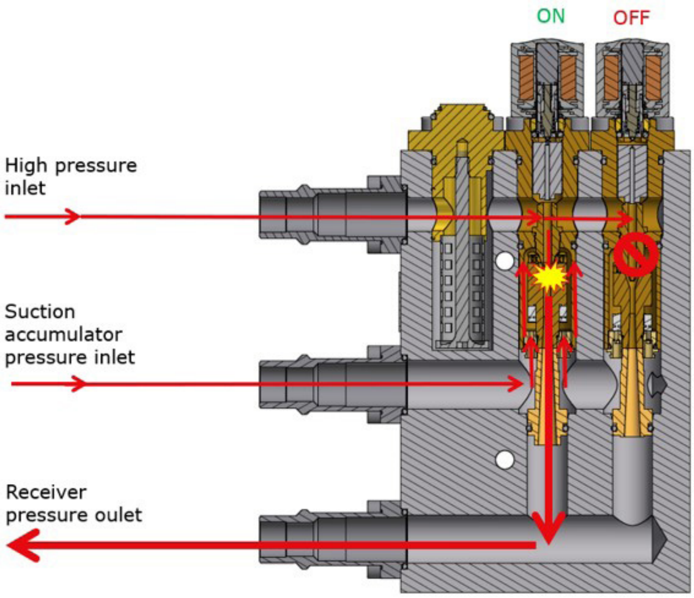
Multi Ejector Combi

Type	Code no.	Product name	Ejector 1	Ejector 2	Ejector 3	Ejector 4	Ejector 5	Ejector 6
CTM 6	032F5675	CTM Combi HP 1875 LE 400	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	CTM ELE 200	CTM ELE 200
	032F5676	CTM Combi HP 2875 LE 200	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	CTM EHP 1000	CTM ELE 200
	032F5677	CTM Combi HP 2875 LE 400	CTM EHP 125	CTM EHP 250	CTM EHP 500	CTM EHP 1000	CTM EHP 1000	CTM ELE 400

The liquid ejectors and/or largest ejectors are placed closest to the connectors.

How does the Multi Ejector solution work?

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.

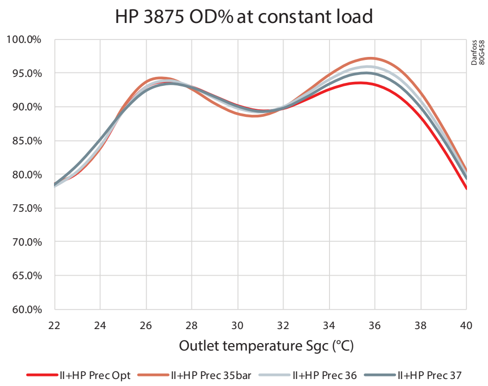


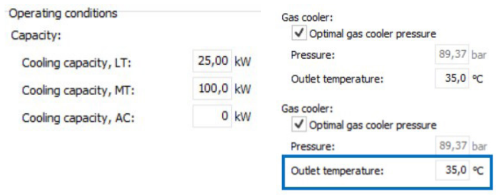
6. Coolselector®2 Selecting components

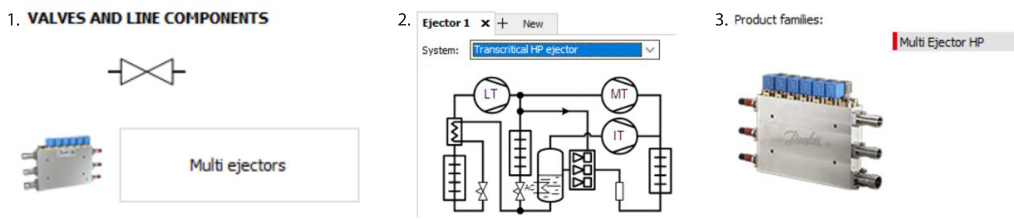
6.1 HP ejector selection

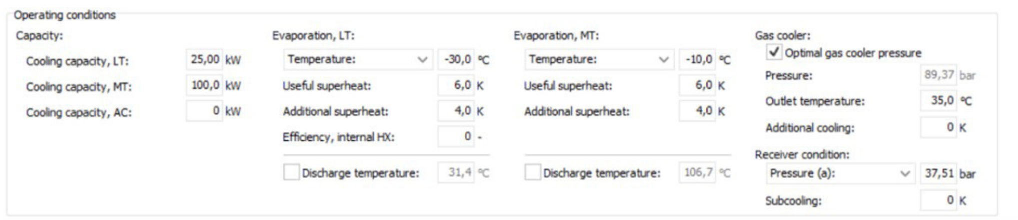
On the diagram to the right there is an example of how the HP ejector Opening Degree (OD%) changes by keeping constant cooling evaporators' load at different Gas cooler Outlet temperatures (Sgc). Notice two peeks around 26 – 27 °C and 35 – 36 °C. There is also a dependency in how it is controlled pressure in the receiver. By keeping the pressure in the receiver constantly at 35 bar(a), the peak load for the HP ejector is at 36 °C. If the pressure is controlled with the "IT Optimize" feature, the load peeks are at 27 °C and 35 °C.

By using a Gas cooler Outlet temperature at 35 °C and an Optimal gas cooler pressure around 90 bar(a) is a good starting point for selecting HP ejectors.









Selection: Multi Ejector HP 3875

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_comp_IT [kg/h]	m_motive [kg/h]	m_suction [kg/h]	Entrainment ratio
○	Multi Ejector HP 1875	2	88	380,7	1521	1118	2292	3410	784,2	0,23
○	Multi Ejector HP 2875	2	58	380,7	1521	1078	2338	3416	823,6	0,24
◉	Multi Ejector HP 3875	1	87	380,7	1521	1059	2360	3419	843,2	0,25

m_motive : Gas Cooler / motive mass flow

m_suction : Ejector suction mass flow

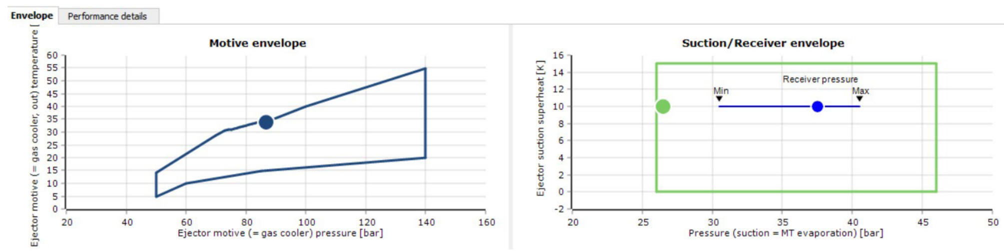
m_comp_MT : MT compressors' mass flow

m_comp_IT : IT compressors' mass flow

er : entrainment ratio

$$er = \frac{m_{suction}}{m_{motive}} = \frac{843}{3419} = 0.25$$

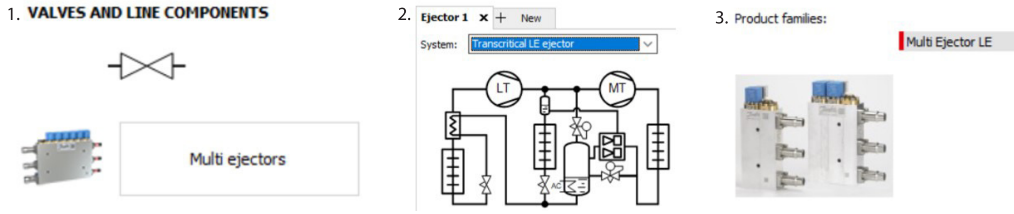
Operating envelope:



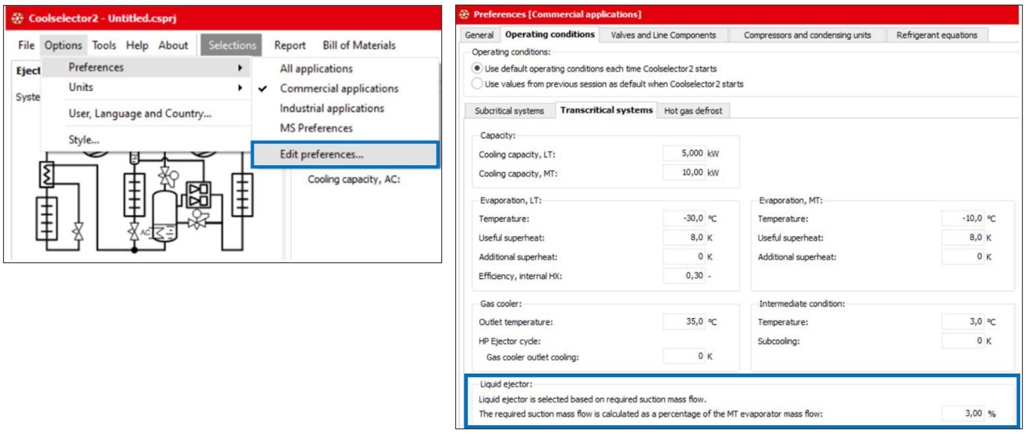
6.2 LE ejector selection

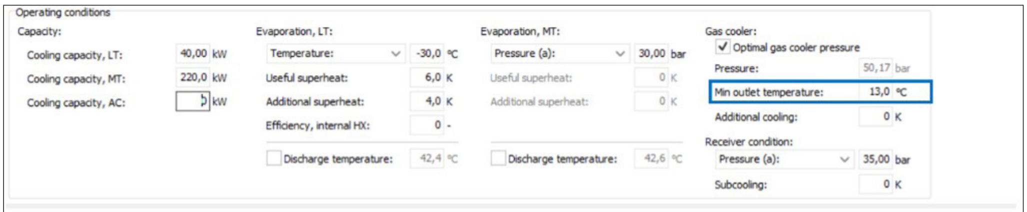
In section 2.1 "System design with Liquid ejector (LE)", there is an explanation about the amount of returned liquid from the MT evaporators depending on the application. In a typical supermarket application with more than 10 evaporators we can assume that the amount of liquid returned is 3% of the total MT evaporators' mass flow. The default value in Coolselector®2 is 3%. If the application is different, it is necessary to change this value in following preferences.

For LE the most critical condition is cold ambient and related to this minimum pressure in the gas cooler. The most critical condition is minimum gas cooler outlet temperature and related optimum pressure in the gas cooler. If the gas cooler pressure is kept at e.g. 50 bar and the temperature out of the gas cooler is lowered, then the LE will have even better performance than on optimal COP curve.



The required suction mass flow calculated as percentage of the MT evaporator mass flow:





Selection: CTM 2 LE 600

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_BP [kg/h]	m_motive [kg/h]	m_suction [kg/h]	m_suction_required [kg/h]	Entrainment ratio
◉	CTM 2 LE 600	1	61	592,9	3394	4651	664,3	630,6	167,7	101,8	0,27
○	CTM 2 LE 800	1	33	592,9	3394	4651	664,3	827,6	311,2	101,8	0,38

m_motive : motive mass flow though Liquid ejector

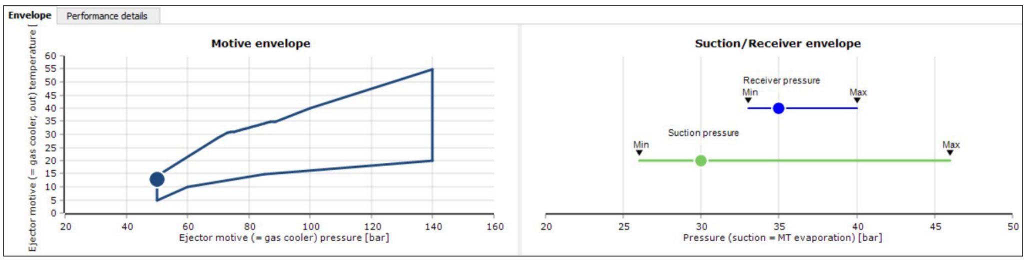
m_suction : Ejector liquid suction mass flow

m_suction_required : calculation based on assumption of 3% of m_evap_MT mass flow

er : entrainment ratio

$$er = \frac{m_{suction}}{m_{motive}} = \frac{168}{631} = 0.27$$

Operating envelope:

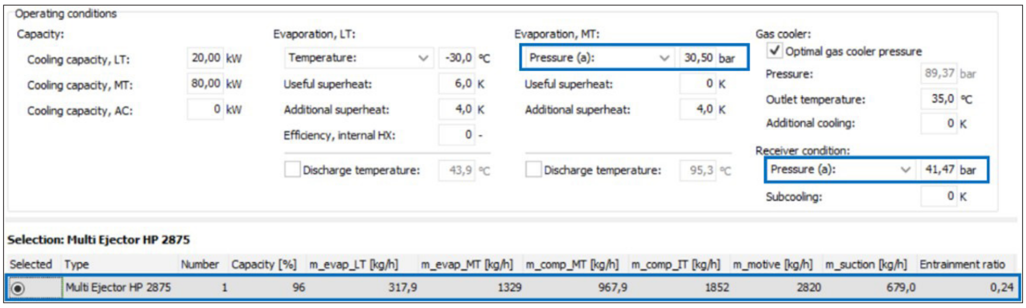


6.3 Combi ejector selection (HP+LE)

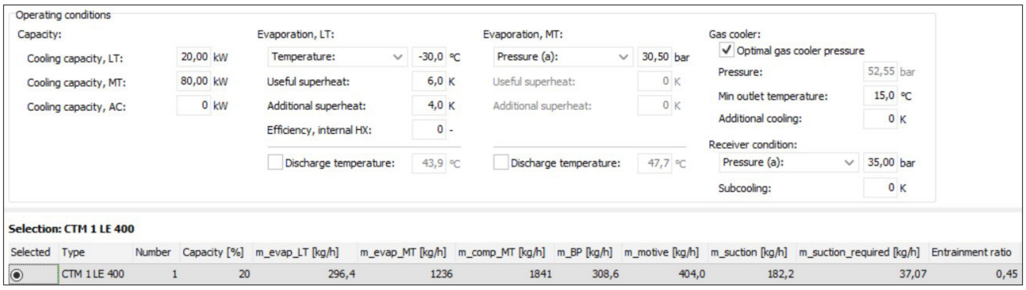
As in Coolselector®2 there is no direct selection for Combi ejector. The selection will be done separately using an HP and LE module. The below example shows a selection for Combi HP2875 LE400 consisting of 5 x HP ejectors and one LE 400.

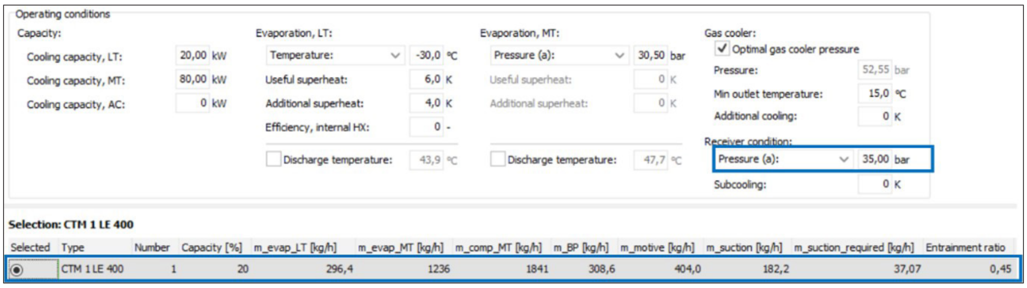
Product name	Ejector #1 kg/h	Ejector #2 kg/h	Ejector #3 kg/h	Ejector #4 kg/h	Ejector #5 kg/h	Ejector #6 kg/h
CTM Combi HP 2875 LE 400	125	250	500	1000	1000	400

The MT evaporating pressure will be higher because of ALC and CALM leading to 0 K Useful superheat. The receiver pressure level is optimized for the best system efficiency. The HP ejector should fulfill the necessary motive flow for the given capacity load and gas cooler conditions at high ambient conditions.



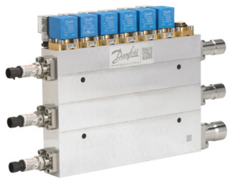
Liquid ejectors should be capable to lift liquid in cold ambient conditions, but with lower receiver pressure.



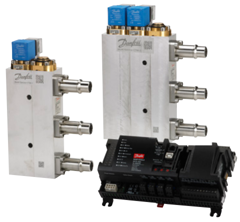


7. Multi Ejector Solution™

Danfoss offers a wide range of market leading Multi Ejectors. Including 3 MBS 8250 sensors and additional coils and LED plugs are needed.

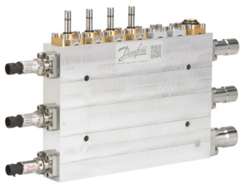


CTM Multi Ejector - High Pressure (optimizing parallel compression systems):
- Energy consumption reductions up to 9% annually in warm climates compared to parallel compression, and by up to 17% compared to booster systems.
- Available ejector types: HP 1874 (4 ejectors), HP 2875 (5 ejectors), HP 3875 (6 ejectors).
- It is recommended for stores with a refrigeration load in the range of 35 – 140 kW.

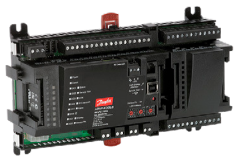


CTM Multi Ejector - Liquid Ejector (optimal evaporator utilization and efficient compressor protection):
- Energy consumption can be lowered by 2 – 12% annually in any climate compared to regular booster systems.
- Available ejector types: LE 200 (1 ejector), LE 400 (1 ejector), LE 400 (2 ejectors), LE 600 (2 ejectors), LE 800 (3 ejectors).
- It is recommended for stores with a refrigeration load in the range of 25 – 480 kW.

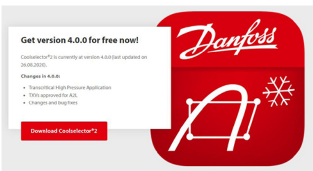
CTM Multi Ejector - Combi HP/LE (optimizing parallel compression systems and evaporator utilization and efficient compressor protection):
- Enables 15 – 35 % savings on compressor swept volume, compared to booster systems.
- Available ejector types: Combi HP 1875 LE 400 (6 ejectors), Combi HP 2875 LE 200 (6 ejectors), Combi HP 2875 LE 400 (6 ejectors).
- It is recommended for stores with a refrigeration load in the range of 35 – 120 kW.



CTM Multi Ejector - Low Pressure (optimizing booster system energy consumption):
- Energy consumption can be lowered by up to 15% compared to a booster system.
- Available ejector types: LP 935 (4 ejectors), LP 1435 (5 ejectors), LP 1935 (6 ejectors).
- It is recommended for stores with a refrigeration load in the range of 18 – 72 kW.



Pack 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 pack controls, the AK-PC 782A offers the highest possible efficiency with the Multi Ejector.



Coolselector®2 - Transcritical High Pressure Application
Helps you optimize energy consumption and increase efficiency in any system. Run unbiased calculations based on a set of operating conditions — such as cooling capacity, refrigerant, evaporation, and condensation temperature — and then select the best components for your design.
Check out the new Transcritical High Pressure Application area.