Project survey

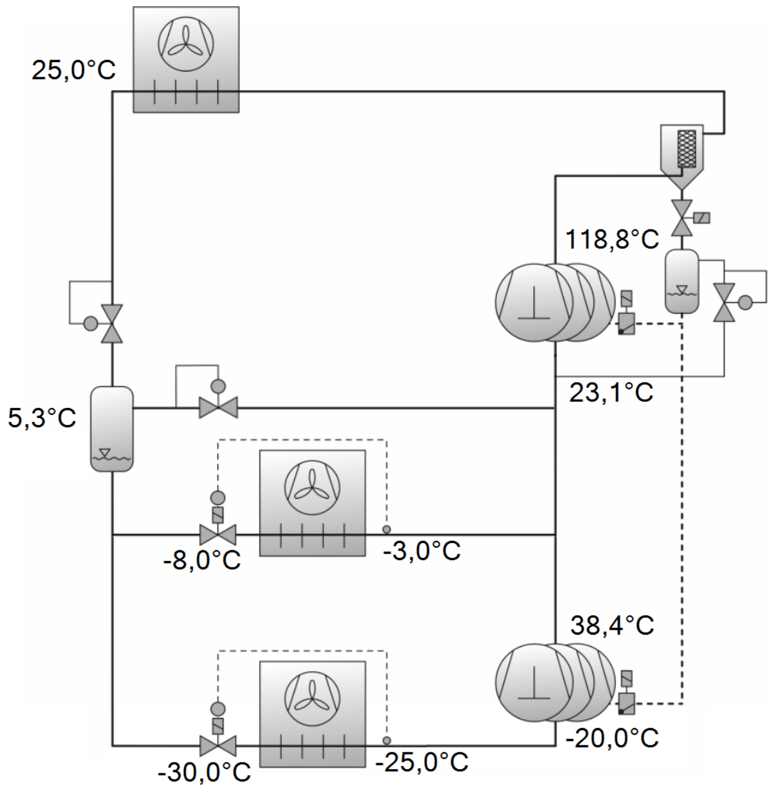
Selected compressors

CO2 Systems	3x	4DSL-10K
	2x	4FTE-30K
	1x	4HTE-20K

Selection: CO2 Systems

COP/EER Evaporator: 1,66

Input Values	LT-Stage	MT-Stage
System		Flashgas
Series	Standard	Standard
Operating mode	Subcritical	Transcritical
Number compressors	3	3
Evaporating SST	-30,00 °C	-8,00 °C
Evaporator superheat	5,00 K	5,00 K
Suction line superheat	5,00 K	5,00 K
High pressure		Auto
Gas cooler outlet		25,0 °C
Intermed. pressure		40,0 bar(a) / 5,30 °C
Power frequency	50Hz	
Power voltage	400V	



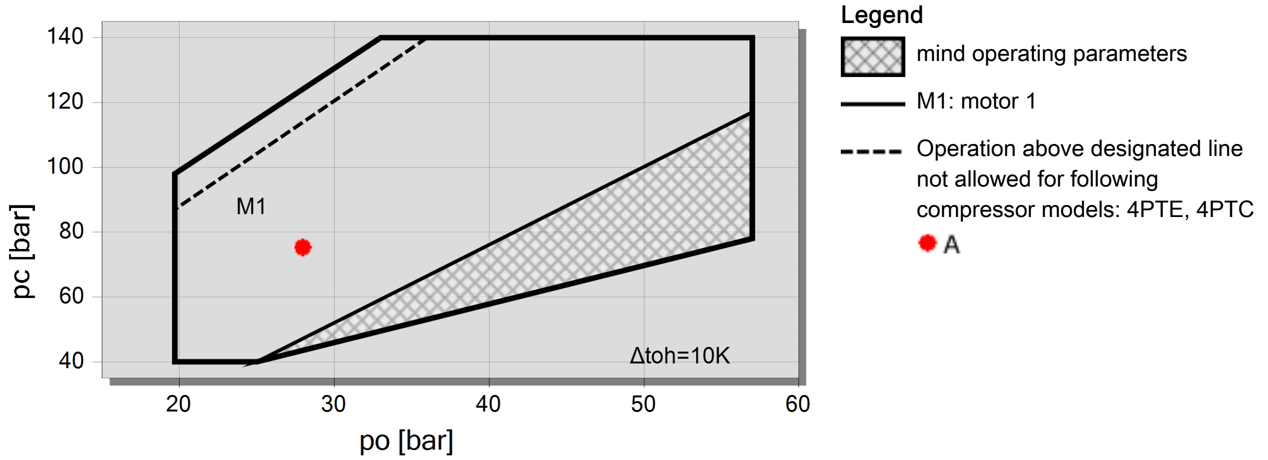
Result

Compressor	LT-Stage	4DSL-10K	4DSL-10K	4DSL-10K
Frequency compressor	--	50,0 Hz	--	--
Evaporator capacity	108,6 kW	36,1 kW	36,2 kW	36,2 kW
Ratio	--	33,2 %	33,4 %	33,4 %
Power input	20,8 kW	6,96 kW	6,93 kW	6,93 kW
Current	37,8 A	12,73 A	12,54 A	12,54 A
Voltage range	--	380-420V	380-420V	380-420V
Mass flow	1705 kg/h	567 kg/h	569 kg/h	569 kg/h
Total superheat	9,90 K	9,90 K	9,90 K	9,90 K
Discharge gas temp. w/o cooling	38,4 °C	38,6 °C	38,2 °C	38,2 °C

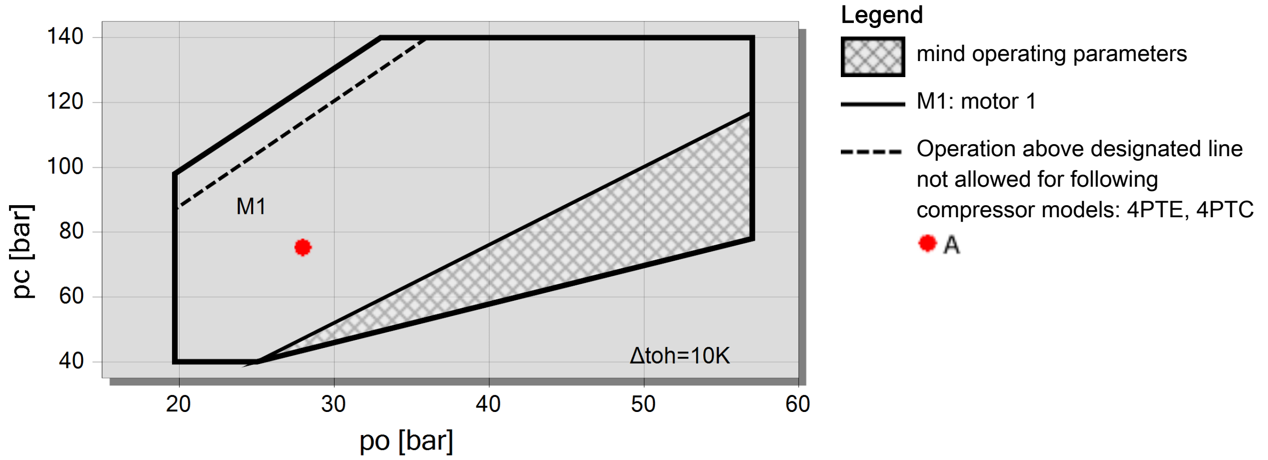
Compressor	MT-Stage	4FTE-30K	4FTE-30K	4HTE-20K
Frequency compressor	--	50,0 Hz	--	--
Evaporator capacity	4,39 kW	1,65 kW	1,65 kW	1,09 kW
Ratio	--	37,5 %	37,6 %	24,9 %
Gas cooler capacity	183,7 kW	69,0 kW	69,0 kW	45,8 kW
Power input	47,3 kW	17,76 kW	17,67 kW	11,88 kW
Current	85,7 A	32,2 A	32,5 A	21,0 A
Voltage range	--	380-420V	380-420V	380-420V
Mass flow	2348 kg/h	881 kg/h	882 kg/h	585 kg/h
Flashgas mass flow	573 kg/h	--	--	--
Total superheat	31,1 K	31,1 K	31,1 K	31,1 K
Discharge gas temp. w/o cooling	118,8 °C	118,8 °C	118,5 °C	119,3 °C
optimal high pressure	75,0 bar(a)	--	--	--

LT-Stage: Tentative Data.
LT-Stage: Discharge gas temperature at least 50°C (122°F)
LT-Stage: Power consumption at compressor inlet.
LT-Stage: Total superheat smaller than 10K / 18°F.
MT-Stage: Tentative Data.
MT-Stage: Power consumption at compressor inlet.

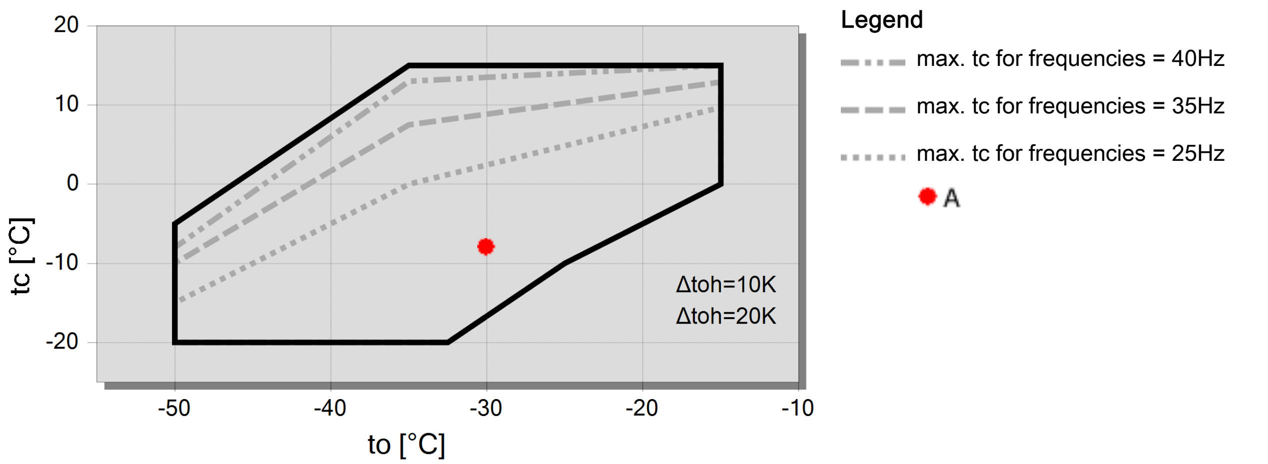
Application Limits 100%



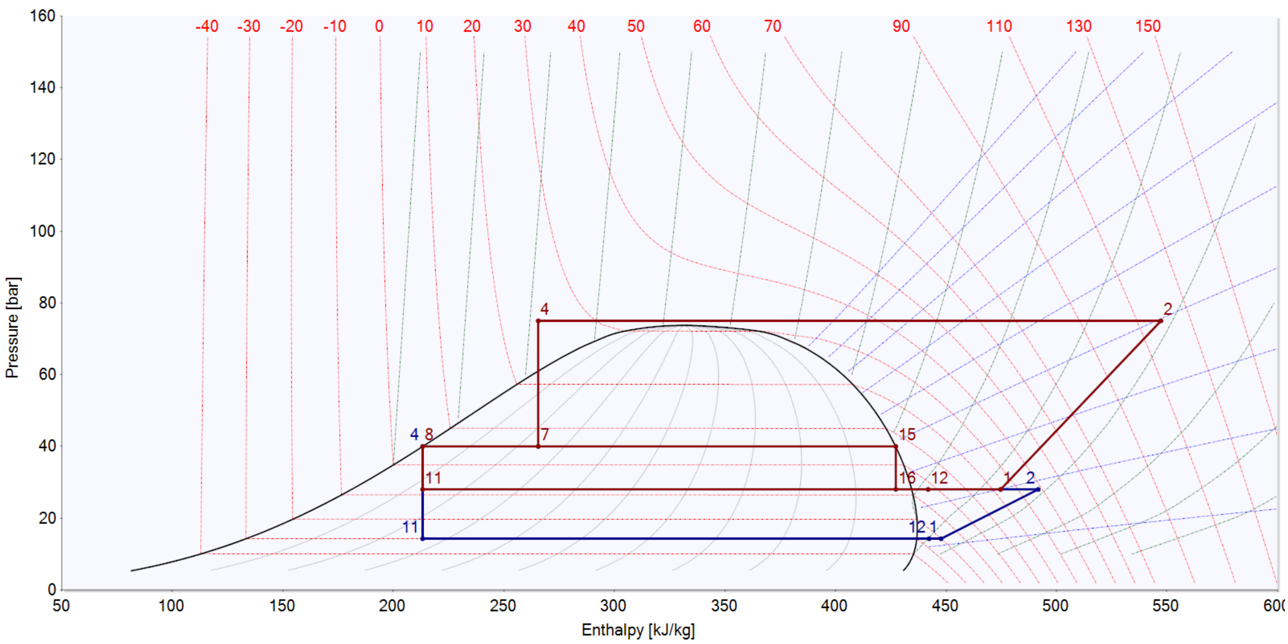
Application Limits 100%



Application Limits 4DSL-10K



p,h Diagram



LT-Stage

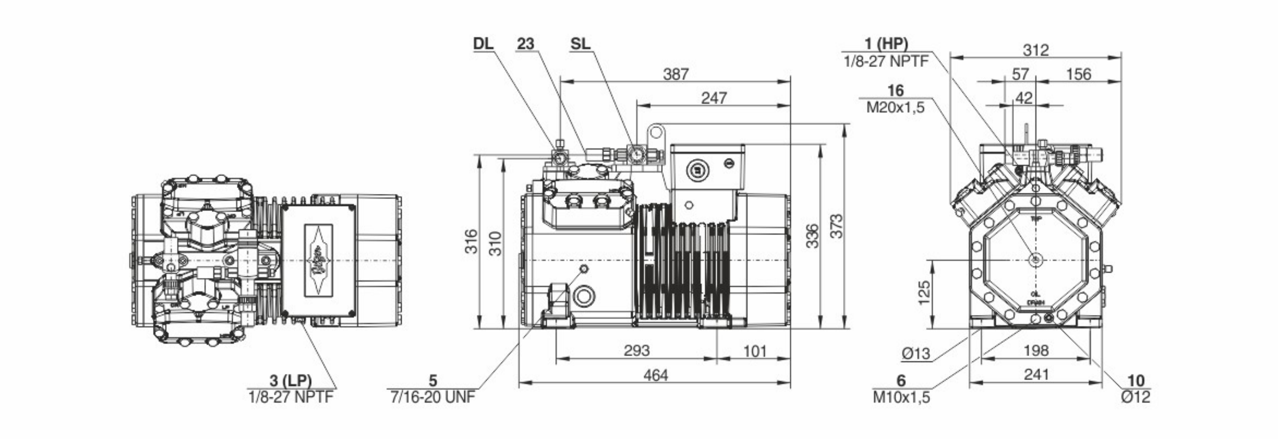
1 - 2 Compression
4 - 11 Expansion
11 - 12 Evaporation
12 - 1 Superheat suction line

MT-Stage

1 - 2 Compression
2 - 4 Gas cooling/Condensation
4 - 7 Expansion to intermediate pressure
7 - 8 Intermediate receiver: liquid outlet
8 - 11 Expansion to evaporation pressure
11 - 12 Evaporation
12 - 1 Total superheat
7 - 15 Intermediate receiver: gas outlet
15 - 16 Expansion to evaporation pressure

Technical Data: 4DSL-10K

Dimensions and Connections

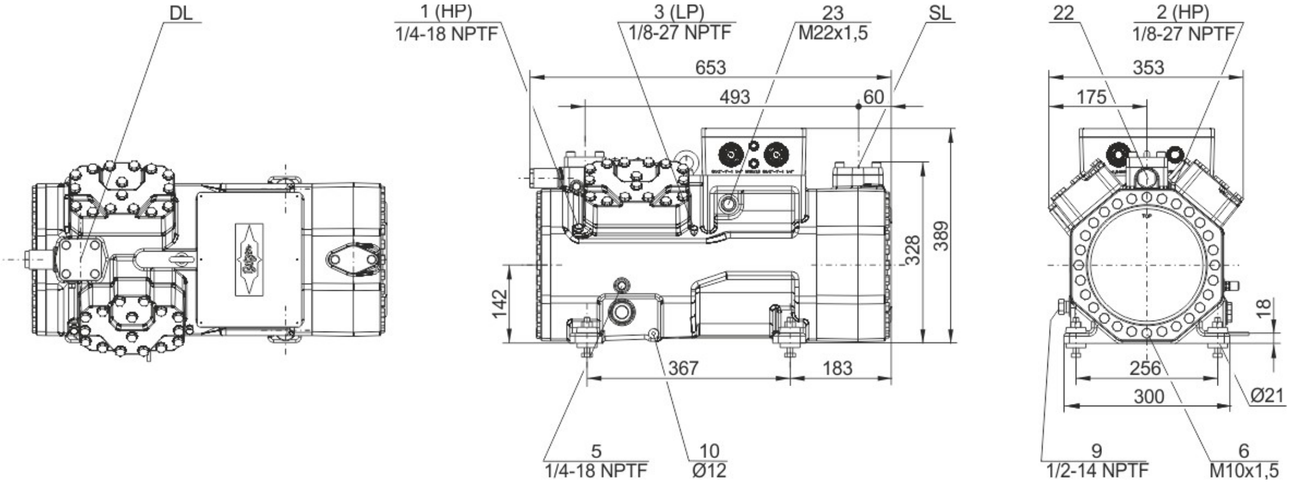


Technical Data

Technical Data	
Displacement (1450 RPM 50Hz)	18,4 m3/h
Displacement (1750 RPM 60Hz)	22,3 m3/h
No. of cylinder x bore x stroke	4 x 50 mm x 27 mm
Weight	94,5 kg
Max. pressure (LP/HP)	30 / 53 bar
Connection suction line	28 mm - 1 1/8''
Connection discharge line	22 mm - 7/8''
Oil type R744 (CO2)	BSE60K (Standard) BSE85K, BSG68K (Option)
Motor data	
Motor version	1
Motor voltage (more on request)	380-420V Y-3-50Hz
Max operating current	22.0 A
Starting current (Rotor locked)	97.0 A
Extent of delivery (Standard)	
Motor protection	SE-B3(Standard), SE-B2(Option)
Enclosure class	IP65
Vibration dampers	Standard
Oil charge	2,00 dm³
Available Options	
Crankcase heater	0..120 W PTC (Option)
Sound measurement	

Technical Data: 4FTE-30K

Dimensions and Connections

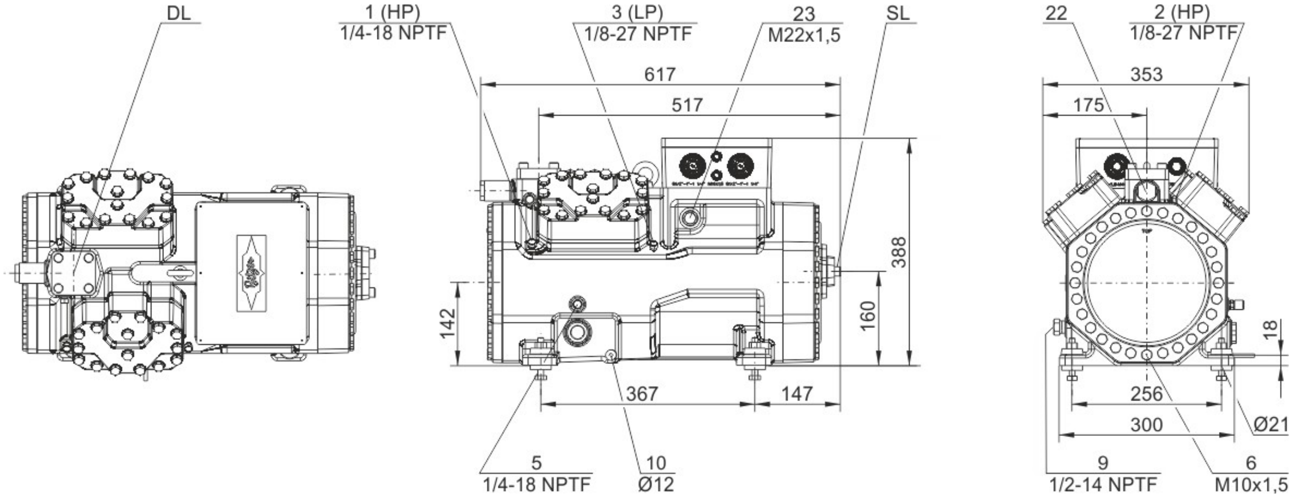


Technical Data

Technical Data	
Displacement (1450 RPM 50Hz)	17,5 m3/h
Displacement (1750 RPM 60Hz)	21,1 m3/h
No. of cylinder x bore x stroke	4 x 41mm x 38mm
Weight	211 kg
Max. pressure (LP/HP)	100/160 bar
Connection suction line	28 mm - 1 1/8"
Connection discharge line	18 mm - 3/4"
Oil type R744 (CO2)	BSE85K (Standard), BSG68K (Option)
Motor data	
Motor version	1
Motor voltage (more on request)	380-420V PW-3-50Hz
Max operating current	59.6 A
Winding ratio	50/50
Starting current (Rotor locked)	135.0 A Y / 220.0 A YY
Extent of delivery (Standard)	
Motor protection	SE-B3(Standard), SE-B2(Option)
Enclosure class	IP65
Vibration dampers	Standard
Oil charge	2,80 dm³
Crankcase heater	0..140 W PTC (Standard)
Available Options	
Connection suction line	Option
Discharge shut-off valve	Option
Oil level monitoring	OLC-K1 (Option)
Sound measurement	
Sound power level (-10°C / 90bar)	81 dB(A) @ 50Hz
Sound pressure level @ 1m (-10°C / 90bar)	73 dB(A) @ 50Hz

Technical Data: 4HTE-20K

Dimensions and Connections



Technical Data

Technical Data	
Displacement (1450 RPM 50Hz)	12,0 m3/h
Displacement (1750 RPM 60Hz)	14,5 m3/h
No. of cylinder x bore x stroke	4 x 34mm x 38mm
Weight	187 kg
Max. pressure (LP/HP)	100/160 bar
Connection suction line	28 mm - 1 1/8"
Connection discharge line	18 mm - 3/4"
Oil type R744 (CO_2)	BSE85K (Standard), BSG68K (Option)
Motor data	
Motor version	1
Motor voltage (more on request)	380-420V PW-3-50Hz
Max operating current	39.6 A
Winding ratio	50/50
Starting current (Rotor locked)	97.0 A Y / 158.0 A YY
Extent of delivery (Standard)	
Motor protection	SE-B3(Standard), SE-B2(Option)
Enclosure class	IP65
Vibration dampers	Standard
Oil charge	2,60 dm³
Crankcase heater	0..140 W PTC (Standard)
Available Options	
Connection suction line	Option
Discharge shut-off valve	Option
Oil level monitoring	OLC-K1 (Option)
Sound measurement	
Sound power level (-10°C / 90bar)	79 dB(A) @ 50Hz
Sound pressure level @ 1m (-10°C / 90bar)	71 dB(A) @ 50Hz

Design remarks of CO2 Booster Systems

The design of CO2 booster systems is influenced by many factors. Different system configurations and the operating conditions especially at part load are the main factors that influence the system performance and determine the adequate amount and size of the compressors. In the following, the most important remarks regarding the design of such a system are listed.

Flash Gas Bypass Booster System

In a CO2 booster system, the refrigerant is expanded by means of a high pressure control valve into a liquid receiver on an intermediate pressure level. The liquid receiver mainly acts as a phase separator and buffer. The saturated liquid refrigerant from the liquid receiver is used to supply the medium- and low-temperature evaporators. The, ideally saturated, flash gas is further expanded to MT-stage pressure level by means of a back pressure control valve and routed to the MT compressors. This flash gas bypass operation reduces both the operating pressure inside the receiver and adjacent components in the liquid line plus the mass flow rate from the intermediate pressure vessel to the evaporators.

Flash gas Bypass

The flash gas that is generated during the expansion process in the intermediate receiver has to be bypassed to the MT suction line in order to maintain the liquid receiver on a constant pressure level. Depending on the pressure difference of the intermediate receiver to the MT stage, a certain amount of liquid is generated while bypassing the saturated flash gas to a lower pressure level.

Attention: Liquid operation can occur!

In order to minimize the risk of liquid slugging, it is recommended to use a flash gas bypass heat exchanger in order to evaporate the generated liquid during expansion of the flash gas. This heat exchanger can exchange heat between any other refrigerant stream that contains warmer fluid with a sufficient heating capacity (e.g. liquid refrigerant out of the intermediate receiver or gas cooler outlet – Attention: Patents have to be considered).

Mixing Point

In the suction line of the MT compressors, three different refrigerant streams are mixed to one MT suction mass flow

* Bypassed flash gas out of the liquid receiver
* Discharge gas from the LT stage compressor(s)
* Superheated gas from the MT evaporators

Mixing those streams can result in either insufficient or excessive suction gas superheat, depending on the load ratio of the system (MT-Load / LT-Load), the ambient temperature (amount of produced flash gas) and the intermediate pressure level (amount of liquefied flash gas). Therefore, it is mandatory to also check the worst case scenarios in part load of both, the LT and MT stage as well as the operation at low ambient temperatures.

Scenario 1: Low load at MT stage, high load at LT stage, low ambient temperatures

* Low ambient temperature: Low amount of flash gas– less “cold” flash gas at mixing point
* Low MT load: Less “cold” gas from MT evaporators
* High LT load: More “hot” discharge gas from LT compressors

→ Tendency for higher suction gas superheat
→ Motor cooling can be insufficient! It has to be ensured that the suction gas superheat is within the limits (max. 40K resulting superheat, VARISPEED: 20K). A discharge gas desuperheater downstream of the LT compressors reduces the total suction gas superheat in the MT stage.

Scenario 2: High load at MT stage, low load at LT stage, high ambient temperatures

* High ambient temperature: Large amount of flash gas– more “cold” or even liquid flash gas at mixing point – liquid refrigerant has to be evaporated before mixing point.
* High MT load: More “cold” gas from MT evaporators
* Low LT load: Less “hot” discharge gas from LT compressors

→ Lower suction gas superheat, liquid slugging can occur
→ Liquid operation will harm the compressors (low oil temperature, reduction of oil viscosity, foaming, liquid hammer, oil washout). It has to be ensured that the suction gas superheat is within the limits (min. 10K). Flash gas superheating via internal heat exchanger is recommended.

Scenario 3: Low load at MT stage, low load at LT stage, low ambient temperatures (winter operation)

* Low overall load (night time, winter)

→ On / off cycling reduces system stability and compressor lifetime due to less effective lubrication.
→ Compressor selection has to be made for the lowest possible load ratio in order to ideally operate at least one compressor per stage continuously.

Compressor selection

Compressors can be selected manually or automatically by the software. Generally, the first compressor (lead compressor) is operated with a frequency inverter (selection of VARIPACK or VARISPEED) to ensure a stable operation point. For smooth operation and stepless capacity control, it is recommended that the displacement of the lead compressor within its approved frequency range is comparable to the displacement of the next fixed speed compressor. When switching off the fixed speed compressor, this capacity gap should be compensated by the lead compressor. Also a combination of uneven compressor displacements will help to adapt the cooling capacity as good as possible. It is recommended to choose a proper amount of compressors in order to reach the lowest cooling capacity possible without excessive cycling of the compressors.

Please keep in mind, that the application limits shown in the BITZER Software are valid for a fixed superheat of 20K for LT compressors and 10K for MT compressors. The total superheat at each stage should be in between the allowed limits (10K – 40K, VARISPEED 20K). Too high superheat or the use of a frequency inverter can restrain the application limits. Possible frequency inverter limitations can be observed in the VARIPACK selection in the accessories menu.

Due to the generally low pressure ratio of the LT compressors, it is highly recommended to use an internal suction gas heat exchanger in order to maintain a proper superheat to increase the discharge- and oil temperatures. This is also a measure to protect the compressors against liquid operation at high load fluctuations, hot gas defrost or malfunctioning expansion valves.

Oil management

Compound systems are typically equipped with an active oil management system. This consists of a high pressure oil separator, low pressure oil reservoir, and oil level regulators on the individual compressors in order to ensure a reliable compressor operation.

Please mind oil supply and oil distribution challenges in systems with more than 6 compressors per stage. Important is to carefully dimension the oil return pipe. Especially, excessive pressure drop in the oil return line has to be avoided as otherwise degassing effects due to pressure reduction can adversely affect the oil supply to the compressors. Furthermore, the suction collector has to be installed perfectly horizontal. Consultation with BITZER is recommended.

More information regarding the safe and reliable operation of CO2 systems can be found in the documentation KB-130, KP-130 and the publications: Designing, calculation and simulation of booster refrigeration systems with CO2 and Operating behavior of CO2 booster systems. Furthermore, BITZER offers trainings for designing and operating sub- and transcritical CO2 systems.