CO_2 Calculation Tool Version 1.52

All pressures are absolute values

2017-11-03 / All data subject to change

Project name	20170928				
System	Booster (LT and MT)	Net supply	50 Hz	/	400 V

Low temperature

Refrigerant	R744				
Evaporator capacity	62,5	kW			
Number of compressors	2				
Evaporating temperature	-33,0	°C	12,9	bar	
Evaporator superheat	6,0	K			
Suction line superheat	4,0	K			
Int. heat exch. superh.	0,0	K			
Tot. superh./suct. g. temp.	10,0	K	/	-23,0	°C
	Two stage expansion				
Condensing temperature	-7,0	°C	28,8	bar	
Int. heat exch. subc.	0,0	K			
External subcooling	0,0	K			
Tot. subc. / liquid temp.	0,0	K	/	3,3	°C
Desuperheater temp.	35,0	°C			

Medium temperature

Refrigerant	R744					
Evaporator capacity	735	kW				
Number of compressors	5					
Evaporating temperature	-7,0	°C	28,8			
Evaporator superheat	6,0	K				
Suction line superheat	4,0	K				
Tot. superh./suct. g. temp.	0,0	12,3	K	/	5,3	°C
	Transcritical				Flash gas bypass	
High pressure (manually)	80,0	bar			○ FG - Bypass	
Gas cooler outlet temp.	32	°C			◉ FG - Parallel	
Int. heat exch. subc.	0,5	K				
Tot. subc. / fluid temp.	0,5	K			31,5	°C
Interstage pressure (ip)	38	bar	/		3,3	°C
External subcooling (ip)	0,0	K				
Tot. subc. / liquid temp. (ip)	0,0	K	/		3,3	°C

Low temperature

Compressors	4ESL-9K	4ESL-9K					Total
Motor code	40S (Δ)	40S (Y)					
Variable speed drive	65 Hz	No					
Cooling cap. compressor	36,42 kW	27,79 kW					64,21 kW
Evaporator capacity	35,78 kW	27,30 kW					**63,08 kW**
Power input	8,34 kW	6,19 kW					14,53 kW
Current (400 V)	---	11,58 A					---
Max. current	33,70 A	18,90 A					52,60 A
COP/EER compressor	4,37	4,49					4,42
Mass flow	548 kg/h	419 kg/h					967 kg/h
Discharge gas temp.	49 °C	47 °C					48 °C
Ratio to system capacity	57 %	43 %					100 %
Ratio to design capacity	57 %	44 %					**101 %**
VARIPACK Model (70Hz)	FEU+24						

Medium temperature

Compressors	6CTE-50K	6CTE-50K	6CTE-50K	6CTE-50K	6CTE-50K		Total
Motor code	40S (Δ)	40S (Y)	40S (Y)	40S (Y)	40S (Y)		
Variable speed drive	70 Hz	No	No	No	No		
Motor version	Motor 2	Motor 2	Motor 2	Motor 2	Motor 2		
Cooling cap. compressor	139,14 kW	95,26 kW	95,26 kW	95,26 kW	95,26 kW		520,16 kW
Evaporator capacity	193,50 kW	132,47 kW	132,47 kW	132,47 kW	132,47 kW		**723,39 kW**
Power input	60,75 kW	42,50 kW	42,50 kW	42,50 kW	42,50 kW		230,74 kW
Current (400 V)	---	81,20 A	81,20 A	81,20 A	81,20 A		---
Max. current	172,00 A	106,00 A	106,00 A	106,00 A	106,00 A		596,00 A
Gas cooler capacity (Total)	199,89 kW	137,75 kW	137,75 kW	137,75 kW	137,75 kW		1 107,54 kW
COP/EER compressor	2,29	2,24	2,24	2,24	2,24		2,25
Mass flow compressor	3 223 kg/h	2 206 kg/h	2 206 kg/h	2 206 kg/h	2 206 kg/h		12 048 kg/h
Discharge gas temp.	100 °C	101 °C	101 °C	101 °C	101 °C		101 °C
Ratio to system capacity	27 %	18 %	18 %	18 %	18 %		100 %
Ratio to design capacity	26 %	18 %	18 %	18 %	18 %		**98 %**
VARIPACK Model (70Hz)	FKU+180						

(Please consider also the informations on page 2, 3 and 5!)

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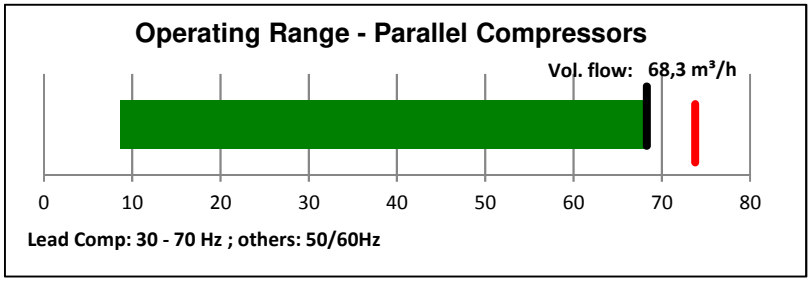
Parallel Compressors + Air Conditioning					
Number of compressors	3		to (AC)	3,3	°C
Evaporator capacity(AC)	-	kW	toh (AC)	1	K

HX Parallel:	fl. g. <-> gas cooler	Int. heat exch. superh.	5	K

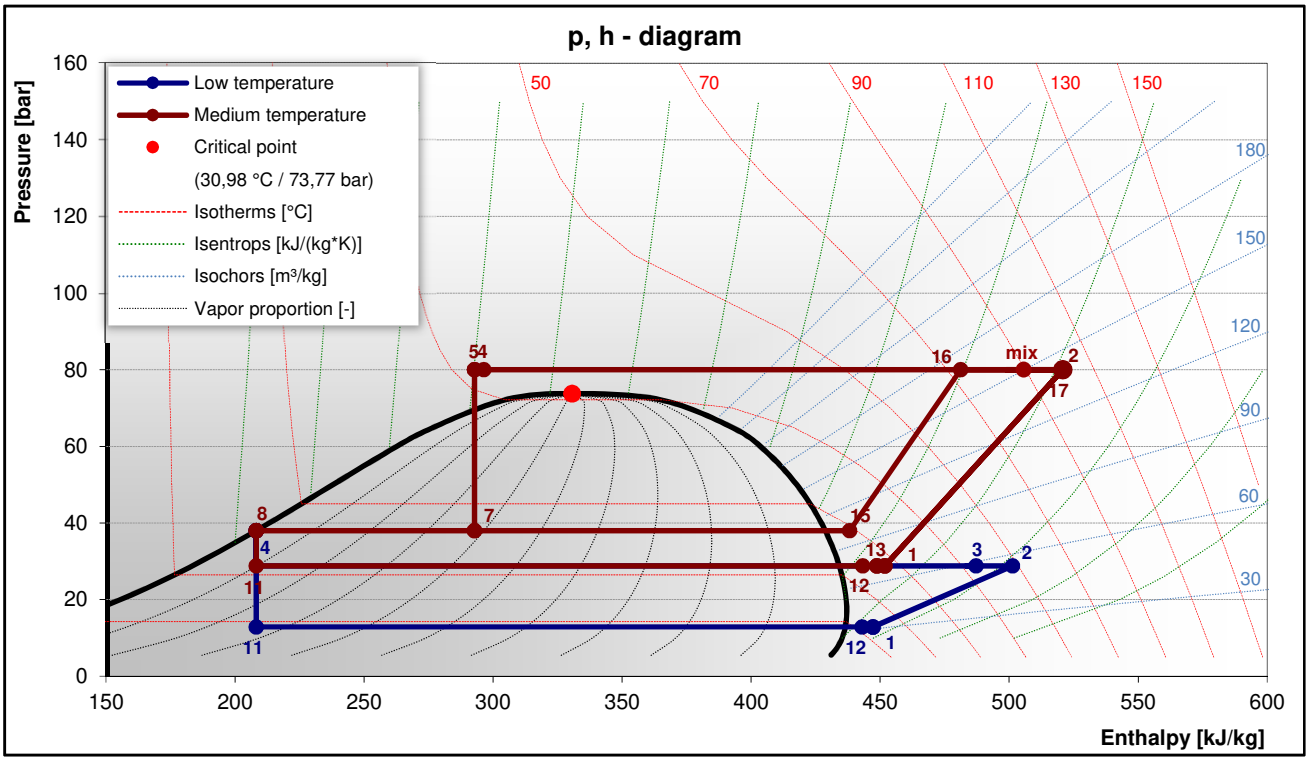
	LEAD Compressor	t_Discharge gas LT (cooled):		35,0 °C	
Compressors	4FTC-30K	6FTE-50K	6FTE-50K		Total
Motor code (Manual)	40S (Δ) 70 Hz	40S (Y) No	40S (Y) No		
Motor version	Motor 1	Motor 1	Motor 1		
Power input (Parallel)	27,05 kW	28,02 kW	28,02 kW		83,10 kW
Current (400 V) (Parallel)	---	64,17 A	64,17 A		---
Max. current (Parallel)	102,00 A	95,90 A	95,90 A		293,80 A
	118,22 kW				
COP/EER compressor	3,35	3,26	3,26		3,29
Mass flow compressor	2 304 kg/h	2 323 kg/h	2 323 kg/h		6 949 kg/h
Discharge gas temp.	73 °C	73 °C	73 °C		73 °C
	--	--	--		
Ratio to design capacity	**31 %**	**31 %**	**31 %**		**93 %**
VARIPACK Model	FHU+73				

Gas cooler capacity (Total)	1107,5 kW
Gascooler inlet temperature	89,6 °C
Gascooler outlet temperature	32 °C
Mass flow Total (@100%)	19550,5 kg/h

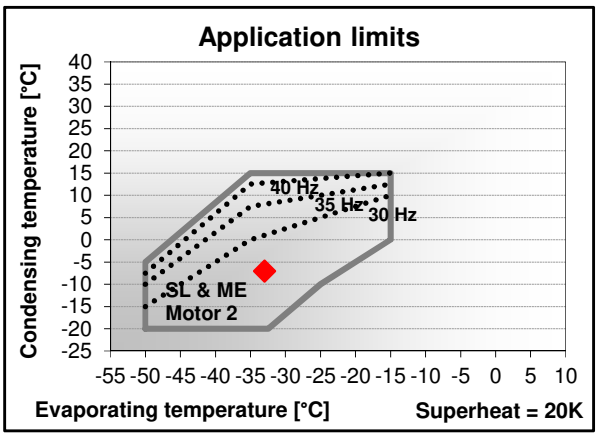


(Please consider also the informations on page 3 and 5!)

Project name: 20170928

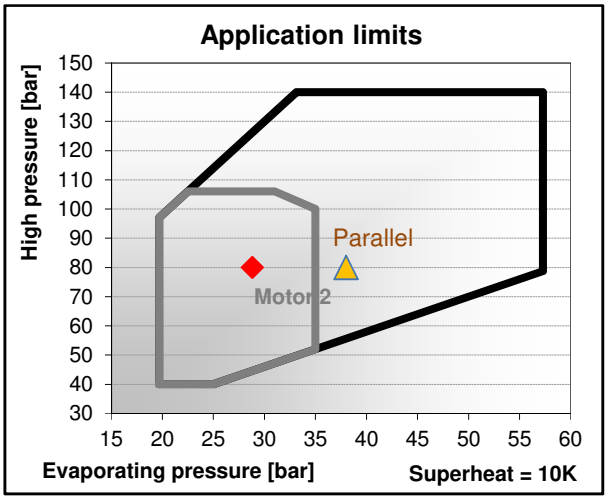


Low temperature



Mass flow		967 kg/h
Int. heat exch. ΔTlog / cap.	0,0 K	0,00 kW
External subcooling cap.		0,00 kW
Desuperheater cap.		3,79 kW
COP/EER LT Stage		
COP/EER evap.		1,68

Medium temperature

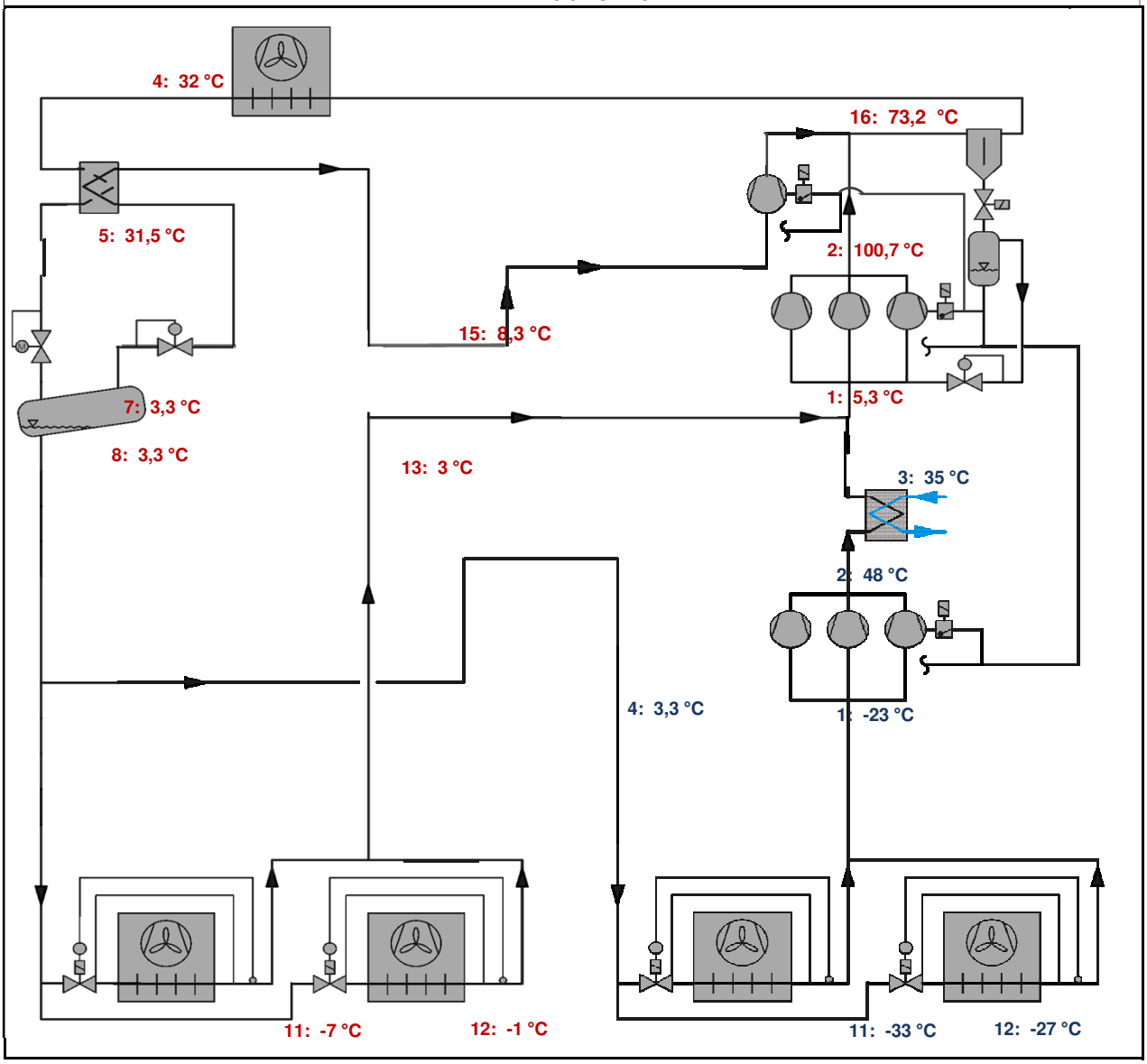


Mass flow Parallel:		7 502 kg/h
Mass flow compressor		12 048 kg/h
Mass flow liquid		12 048 kg/h
Mass flow evaporator		11 081 kg/h
Int. heat exch. ΔTlog / cap.(Parallel)	0,0 K	19,53 kW
External subcooling cap.		0,00 kW
COP/EER MT Stage		
COP/EER evap. (+AC)		2,43
COP/EER Total		
COP/EER evap. total (+AC)		2,35

(Please consider also the informations on page 3 and 5!)

Project name: 20170928

Schematic piping diagram



(Please find legend to the operating points on page 3)

Project name: 20170928

Fluid properties at stated conditions

	1	2	3	4	11	12
Pressure [bar]	12,89	28,82	28,82	38,00	12,89	12,89
Temperature [°C]	-23,00	47,95	35,00	3,30	-33,00	-27,00
Enthalpy [kJ/kg]	447,22	501,32	487,21	208,19	208,19	443,01
Density [kg/m³]	31,29	54,03	57,67	907,02		32,11
Entropy [kJ/(kg*K)]	2,06	2,11	2,07	1,03		2,04
Vapor proport. [%]					26,19	

Medium temperature

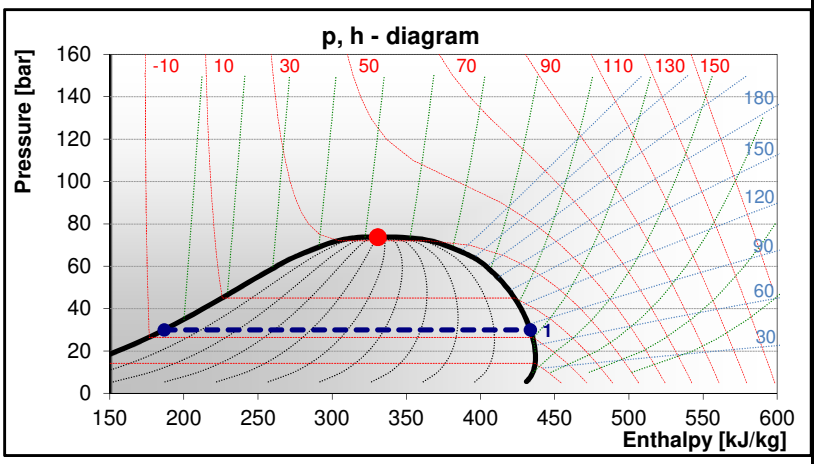
	1	2	4	5	7	8
Pressure [bar]	28,82	80,00	80,00	80,00	38,00	38,00
Temperature [°C]	5,31	100,67	32,00	31,50	3,30	3,30
Enthalpy [kJ/kg]	451,84	520,79	296,42	292,83	292,83	208,19
Density [kg/m³]	69,82	140,75	652,12	666,94		907,02
Entropy [kJ/(kg*K)]	1,95	2,01	1,31	1,30		1,03
Vapor proport. [%]					38,37	

	11	12	13	15	16	17
Pressure [bar]	28,82	28,82	28,82	38,00	80,00	80,00
Temperature [°C]	-7,00	-1,00	3,00	8,30	73,22	100,67
Enthalpy [kJ/kg]	208,19	443,20	448,76	438,13	481,18	520,79
Density [kg/m³]		73,70	71,16	101,67		140,75
Entropy [kJ/(kg*K)]		1,92	1,94	1,86		2,01
Vapor proport. [%]	9,89				-366,32	

Individual fluid properties calculation

Bubble and dew line

	1	2
Pressure [bar]	30,00	
Temperature [°C]	-5,55	
Bubble line		
Enthalpy [kJ/kg]	186,75	
Density [kg/m³]	959,25	
Entropy [kJ/(kg*K)]	0,95	
Dew line		
Enthalpy [kJ/kg]	433,63	
Density [kg/m³]	81,91	
Entropy [kJ/(kg*K)]	1,88	
Wet vapor area		
Enthalpy [kJ/kg]		
Vapor proport. [%]		



Vapor and liquid area

	3	4	5	6	7	8	9	10
Pressure [bar]								
Temperature [°C]								
Enthalpy [kJ/kg]								
Density [kg/m³]								
Entropy [kJ/(kg*K)]								
Dyn. viscosity [*10^-6 Pa*s]								
Therm. conductivity [mW/(m*K)]								
Vapor proportion [%]								

Project name: 20170928

Remarks

- In case of a compressor failure, the decision on a potential warranty claim remains reserved to a diagnosis and examination of the compressor at the BITZER factory. Design, operation, and monitoring of the system is in the responsibility of the designer or executing company.

- The heat exchangers are calculated theoretic. Heat losses or heat influence from the surrounding is not considered.
- The optimum high pressure is calculated iterative. Depending on the selection, COP or cooling capacity will be maximized.
- The cooling cap. compressor is calculated by multiplying the mass flow compressor with the enthalpie difference between state point 1 and 4.
- External variable speed drive: Inverter losses are considered
- All pressure values are absolut pressures.

- More information about subcritical compressors see leaflet KP-120 and operating instruction KB-120.
- More information about transcritical compressors see leaflets KP-130, KP-132 and operating instruction KB-130.

- Selection of the parallel compressors is based on the calculated amount of flash gas and further consumers (e. g. air conditioning)

- Please consider the additional information provided. Especially, the fact, that without the parallel compression, a significant lack of capacity will occur, e. g. under nominal full load conditions. Possible back-up solutions might be: Ground water heat exchanger or mechanical subcooling downstream the primary gas cooler, installation of larger displacement compressors or additional compressors in the MT stage.

- Please consider the change over from parallel compression to the application of flash gas bypass during operation with lower head pressures without heat reclaim. Possible limitations are: Minimum frequency of a single parallel compressor, application limit of the parallel compressor(s), minimum discharge temperature.

- Application of an internal heat exchanger upstream of the parallel compressor(s) is recommended.

- In contrast to the application with flash gas bypass, the return gas temperature of the MT-stage compressors is typically on a higher level compared to operation with parallel compression. The outlet temperature of an de-superheater in the LT stage has a great influence on the reliable operation of the system. For the case that the chosen temperature at the outlet of the de-superheater is on a low level, the lack of this particular heat rejection may cause intolerable operating conditions for the compressors in the MT stage.

Status messages

Warning messages

Low temperature:

- CME and TE - Compressors : All data subject to change

Medium temperature:

- Extended application range based on the following calculations:

4CTC-30KC:	6CTC-50KC:
U > 360 V	U > 340 V
f = 30..60 Hz	f = 30..70 Hz
dtoh > 10 K	dtoh > 10 K

- Reduced voltage range for 50ps motors:
  - 380..400/3/50
  - 440..460/3/60

Additional notes

CO_2 Calculation Tool Version 1.52

All pressures are absolute values

2017-11-03 / All data subject to change

Project name	20170928		
System	Booster (LT and MT)	Net supply	50 Hz / 400 V

Low temperature

Refrigerant	R744			
Evaporator capacity	62,5	kW		
Number of compressors	2			
Evaporating temperature	-33,0	°C	12,9	bar
Evaporator superheat	6,0	K		
Suction line superheat	4,0	K		
Int. heat exch. superh.	0,0	K		
Tot. superh./suct. g. temp.	10,0	K /	-23,0	°C
	Two stage expansion			
Condensing temperature	-7,0	°C	28,8	bar
Int. heat exch. subc.	0,0	K		
External subcooling	0,0	K		
Tot. subc. / liquid temp.	0,0	K /	3,3	°C
Desuperheater temp.	35,0	°C		

Medium temperature

Refrigerant	R744				
Evaporator capacity	735	kW			
Number of compressors	5				
Evaporating temperature	-7,0	°C	28,8		
Evaporator superheat	6,0	K			
Suction line superheat	4,0	K			
Tot. superh./suct. g. temp.	0,0	12,1 K /	5,1	°C	
	Transcritical		Flash gas bypass		
High pressure (manually)	80,0	bar	○ FG - Bypass		
Gas cooler outlet temp.	32	°C	◉ FG - Parallel		
Int. heat exch. subc.	0,5	K			
Tot. subc. / fluid temp.	0,5	K	31,5	°C	
Interstage pressure (ip)	38	bar /	3,3	°C	
External subcooling (ip)	0,0	K			
Tot. subc. / liquid temp. (ip)	0,0	K /	3,3	°C	

Low temperature

Compressors	4ESL-9K	4ESL-9K					Total
Motor code	40S (Δ)	40S (Y)					
Variable speed drive	65 Hz	No					
Cooling cap. compressor	36,42 kW	27,79 kW					64,21 kW
Evaporator capacity	35,78 kW	27,30 kW					**63,08 kW**
Power input	8,34 kW	6,19 kW					14,53 kW
Current (400 V)	---	11,58 A					---
Max. current	33,70 A	18,90 A					52,60 A
COP/EER compressor	4,37	4,49					4,42
Mass flow	548 kg/h	419 kg/h					967 kg/h
Discharge gas temp.	49 °C	47 °C					48 °C
Ratio to system capacity	57 %	43 %					100 %
Ratio to design capacity	57 %	44 %					**101 %**
VARIPACK Model (70Hz)	FEU+24						

Medium temperature

Compressors	6CTE-50K	6CTE-50K	6CTE-50K	6CTE-50K	6CTE-50K		Total
Motor code	40S (Δ)	40S (Δ)	40S (Y)	40S (Y)	40S (Y)		
Variable speed drive	70 Hz	70 Hz	No	No	No		
Motor version	Motor 2	Motor 2	Motor 2	Motor 2	Motor 2		
Cooling cap. compressor	139,12 kW	139,12 kW	95,25 kW	95,25 kW	95,25 kW		563,99 kW
Evaporator capacity	195,12 kW	195,12 kW	133,58 kW	133,58 kW	133,58 kW		**790,97 kW**
Power input	60,75 kW	60,75 kW	42,50 kW	42,50 kW	42,50 kW		249,00 kW
Current (400 V)	---	---	81,20 A	81,20 A	81,20 A		---
Max. current	172,00 A	172,00 A	106,00 A	106,00 A	106,00 A		662,00 A
Gas cooler capacity (Total)	199,88 kW	199,88 kW	137,75 kW	137,75 kW	137,75 kW		1 225,51 kW
COP/EER compressor	2,29	2,29	2,24	2,24	2,24		2,27
Mass flow compressor	3 227 kg/h	3 227 kg/h	2 210 kg/h	2 210 kg/h	2 210 kg/h		13 084 kg/h
Discharge gas temp.	100 °C	100 °C	101 °C	101 °C	101 °C		100 °C
Ratio to system capacity	25 %	25 %	17 %	17 %	17 %		100 %
Ratio to design capacity	27 %	27 %	18 %	18 %	18 %		**108 %**
VARIPACK Model (70Hz)	FKU+180	FKU+180					

(Please consider also the informations on page 2, 3 and 5!)

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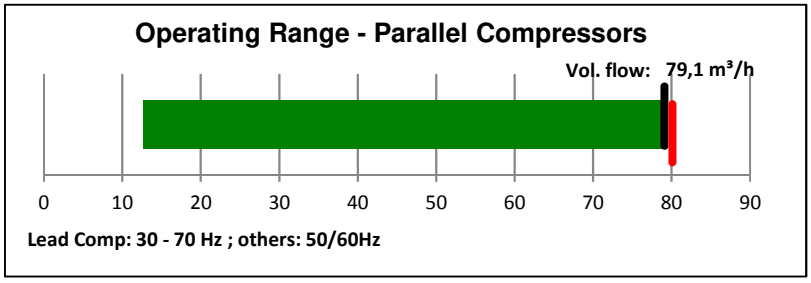
Parallel Compressors + Air Conditioning					
Number of compressors	3		to (AC)	3,3	°C
Evaporator capacity(AC)	-	kW	toh (AC)	1	K

HX Parallel:	fl. g. <-> gas cooler	Int. heat exch. superh.	5	K

	LEAD Compressor	t_Discharge gas LT (cooled):	35,0	°C

Compressors	6FTE-50K	6FTE-50K	6FTE-50K		Total
Motor code (Manual)	40S (Δ) 70 Hz	40S (Y) No	40S (Y) No		
Motor version	Motor 1	Motor 1	Motor 1		
Power input (Parallel)	40,06 kW	28,02 kW	28,02 kW		96,11 kW
Current (400 V) (Parallel)	---	64,17 A	64,17 A		---
Max. current (Parallel)	167,00 A	95,90 A	95,90 A		358,80 A
	174,11 kW				
COP/EER compressor	3,33	3,26	3,26		3,29
Mass flow compressor	3 393 kg/h	2 323 kg/h	2 323 kg/h		8 038 kg/h
Discharge gas temp.	73 °C	73 °C	73 °C		73 °C
	--	--	--		
Ratio to design capacity	**42 %**	**29 %**	**29 %**		**99 %**
VARIPACK Model	FJU+145				

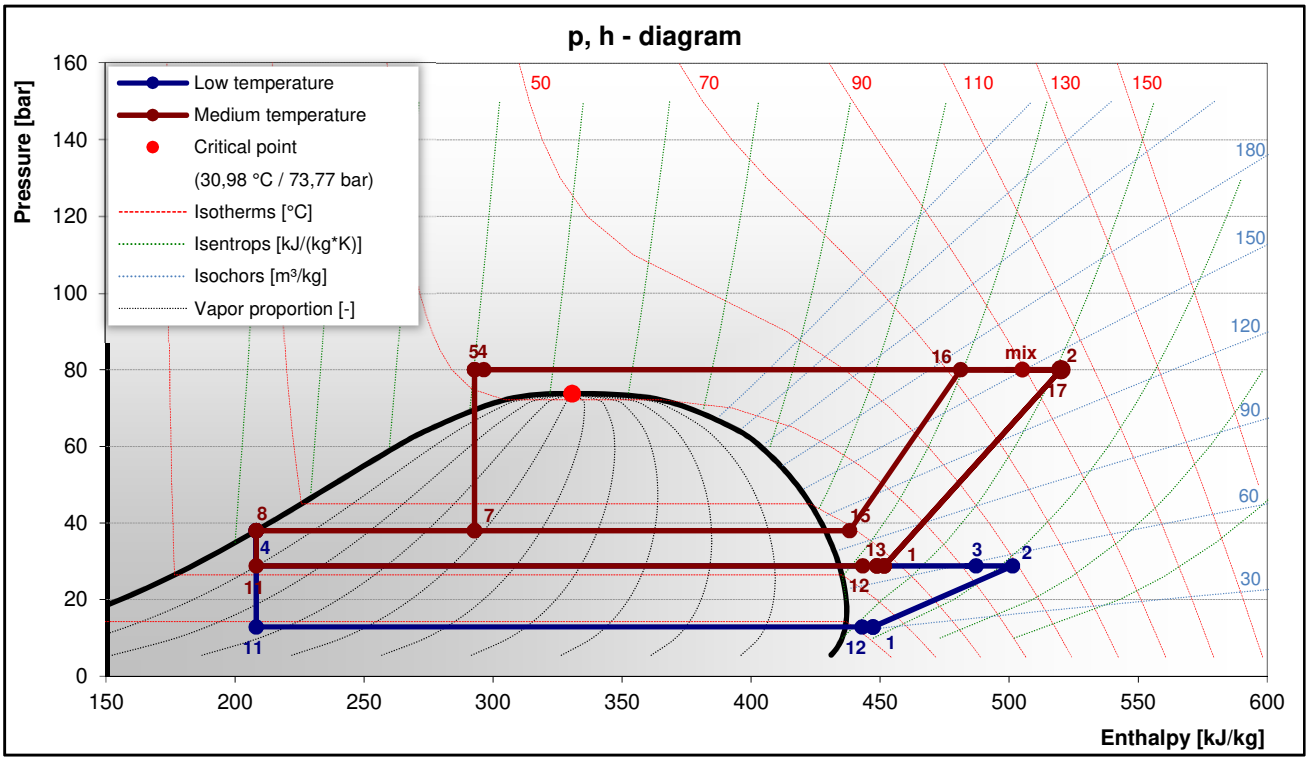
Gas cooler capacity (Total)	1225,5 kW
Gascooler inlet temperature	89,3 °C
Gascooler outlet temperature	32 °C
Mass flow Total (@100%)	21230,4 kg/h



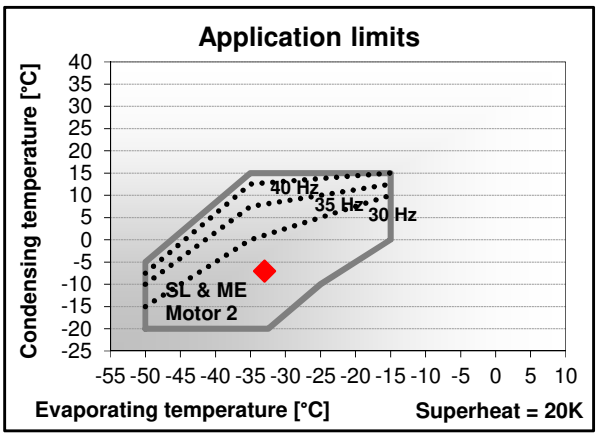
(Please consider also the informations on page 3 and 5!)

CO_2 Calculation Tool Version 1.52

Project name: 20170928

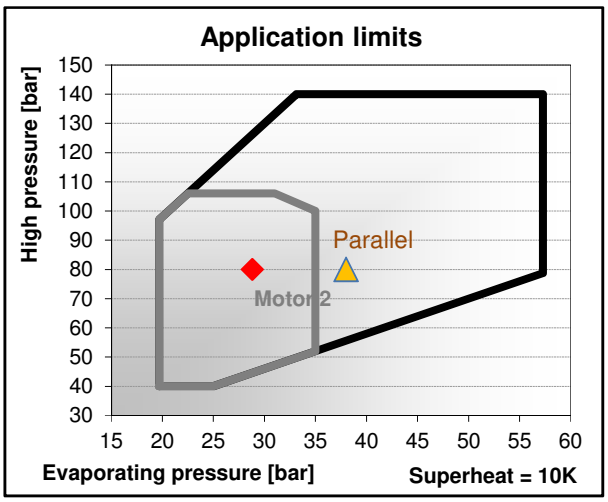


Low temperature



Mass flow		967 kg/h
Int. heat exch. ΔTlog / cap.	0,0 K	0,00 kW
External subcooling cap.		0,00 kW
Desuperheater cap.		3,79 kW
COP/EER LT Stage		
COP/EER evap.		1,69

Medium temperature

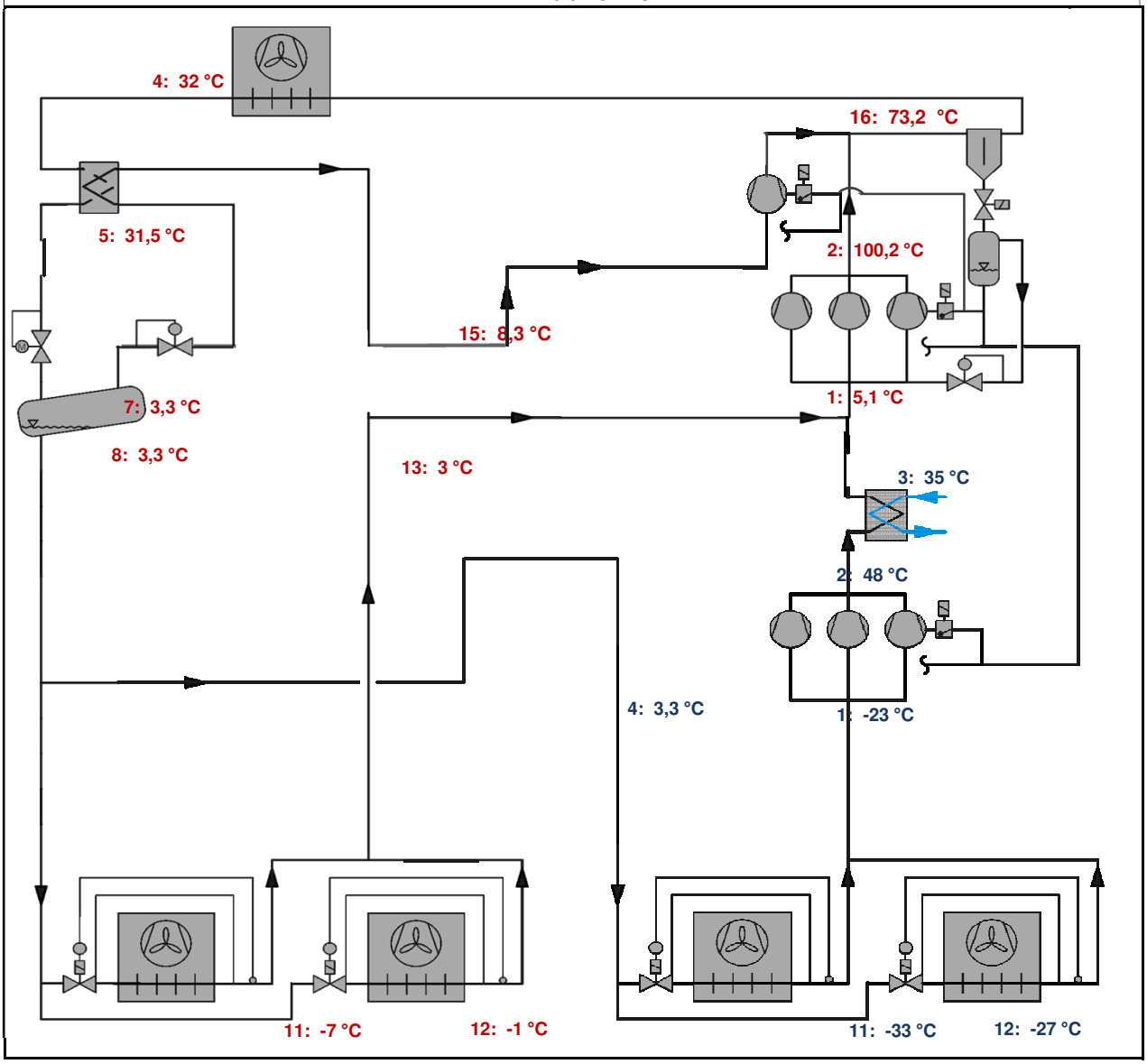


Mass flow Parallel:		8 147 kg/h
Mass flow compressor		13 084 kg/h
Mass flow liquid		13 084 kg/h
Mass flow evaporator		12 117 kg/h
Int. heat exch. ΔTlog / cap.(Parallel)	0,0 K	21,21 kW
External subcooling cap.		0,00 kW
COP/EER MT Stage		
COP/EER evap. (+AC)		2,44
COP/EER Total		
COP/EER evap. total (+AC)		2,37

(Please consider also the informations on page 3 and 5!)

Project name: 20170928

Schematic piping diagram



(Please find legend to the operating points on page 3)

Project name: 20170928

Fluid properties at stated conditions

	1	2	3	4	11	12
Pressure [bar]	12,89	28,82	28,82	38,00	12,89	12,89
Temperature [°C]	-23,00	47,95	35,00	3,30	-33,00	-27,00
Enthalpy [kJ/kg]	447,22	501,32	487,21	208,19	208,19	443,01
Density [kg/m³]	31,29	54,03	57,67	907,02		32,11
Entropy [kJ/(kg*K)]	2,06	2,11	2,07	1,03		2,04
Vapor proport. [%]					26,19	

Medium temperature

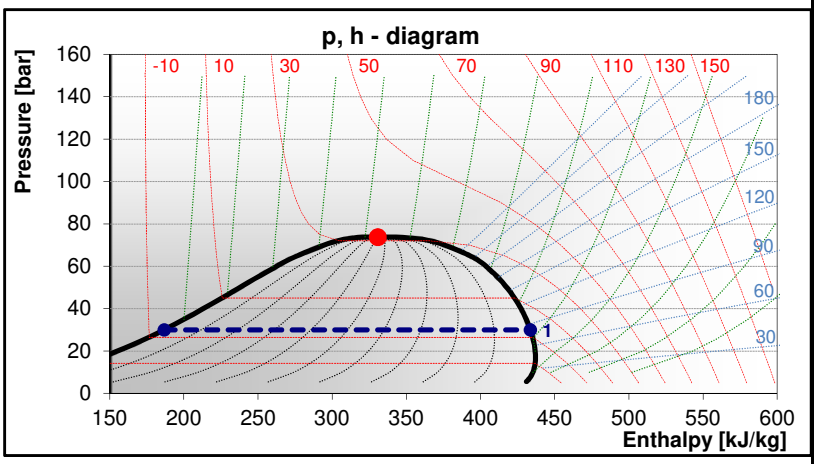
	1	2	4	5	7	8
Pressure [bar]	28,82	80,00	80,00	80,00	38,00	38,00
Temperature [°C]	5,13	100,17	32,00	31,50	3,30	3,30
Enthalpy [kJ/kg]	451,61	520,12	296,42	292,83	292,83	208,19
Density [kg/m³]	69,92	141,14	652,12	666,94		907,02
Entropy [kJ/(kg*K)]	1,95	2,01	1,31	1,30		1,03
Vapor proport. [%]					38,37	

	11	12	13	15	16	17
Pressure [bar]	28,82	28,82	28,82	38,00	80,00	80,00
Temperature [°C]	-7,00	-1,00	3,00	8,30	73,22	100,17
Enthalpy [kJ/kg]	208,19	443,20	448,76	438,13	481,17	520,12
Density [kg/m³]		73,70	71,16	101,67		141,14
Entropy [kJ/(kg*K)]		1,92	1,94	1,86		2,01
Vapor proport. [%]	9,89				-366,30	

Individual fluid properties calculation

Bubble and dew line

	1	2
Pressure [bar]	30,00	
Temperature [°C]	-5,55	
Bubble line		
Enthalpy [kJ/kg]	186,75	
Density [kg/m³]	959,25	
Entropy [kJ/(kg*K)]	0,95	
Dew line		
Enthalpy [kJ/kg]	433,63	
Density [kg/m³]	81,91	
Entropy [kJ/(kg*K)]	1,88	
Wet vapor area		
Enthalpy [kJ/kg]		
Vapor proport. [%]		



Vapor and liquid area

	3	4	5	6	7	8	9	10
Pressure [bar]								
Temperature [°C]								
Enthalpy [kJ/kg]								
Density [kg/m³]								
Entropy [kJ/(kg*K)]								
Dyn. viscosity [*10^-6 Pa*s]								
Therm. conductivity [mW/(m*K)]								
Vapor proportion [%]								

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Remarks

- In case of a compressor failure, the decision on a potential warranty claim remains reserved to a diagnosis and examination of the compressor at the BITZER factory. Design, operation, and monitoring of the system is in the responsibility of the designer or executing company.

- The heat exchangers are calculated theoretic. Heat losses or heat influence from the surrounding is not considered.
- The optimum high pressure is calculated iterative. Depending on the selection, COP or cooling capacity will be maximized.
- The cooling cap. compressor is calculated by multiplying the mass flow compressor with the enthalpie difference between state point 1 and 4.
- External variable speed drive: Inverter losses are considered
- All pressure values are absolut pressures.

- More information about subcritical compressors see leaflet KP-120 and operating instruction KB-120.
- More information about transcritical compressors see leaflets KP-130, KP-132 and operating instruction KB-130.

- Selection of the parallel compressors is based on the calculated amount of flash gas and further consumers (e. g. air conditioning)

- Please consider the additional information provided. Especially, the fact, that without the parallel compression, a significant lack of capacity will occur, e. g. under nominal full load conditions. Possible back-up solutions might be: Ground water heat exchanger or mechanical subcooling downstream the primary gas cooler, installation of larger displacement compressors or additional compressors in the MT stage.

- Please consider the change over from parallel compression to the application of flash gas bypass during operation with lower head pressures without heat reclaim. Possible limitations are: Minimum frequency of a single parallel compressor, application limit of the parallel compressor(s), minimum discharge temperature.

- Application of an internal heat exchanger upstream of the parallel compressor(s) is recommended.

- In contrast to the application with flash gas bypass, the return gas temperature of the MT-stage compressors is typically on a higher level compared to operation with parallel compression. The outlet temperature of an de-superheater in the LT stage has a great influence on the reliable operation of the system. For the case that the chosen temperature at the outlet of the de-superheater is on a low level, the lack of this particular heat rejection may cause intolerable operating conditions for the compressors in the MT stage.

Status messages

Warning messages

Low temperature:

- CME and TE - Compressors : All data subject to change

Medium temperature:

- Extended application range based on the following calculations:

4CTC-30KC:	6CTC-50KC:
U > 360 V	U > 340 V
f = 30..60 Hz	f = 30..70 Hz
dtoh > 10 K	dtoh > 10 K

- Reduced voltage range for 50ps motors:
  - 380..400/3/50
  - 440..460/3/60

Additional notes