CO2-Heat pump 2-stage

Air-to-water CO2 heat pumps

If the outside air is to be used at low temperatures in winter, for example in Central Europe at -15°C, a 2-stage CO2 heat pump is recommended, i.e. with the natural refrigerant CO2 with a GWP = 0 (Global Warming Potential), preferably for a higher output with oil-free turbo compressors. Thanks to non-contact magnetic or gas bearings, lubricating oil is completely dispensed with. The flowing refrigerant serves as the lubricant, which prevents the oil from foaming and significantly increases the efficiency in the heat exchangers due to the lack of oil films.

Alternatives to R744 (CO2)

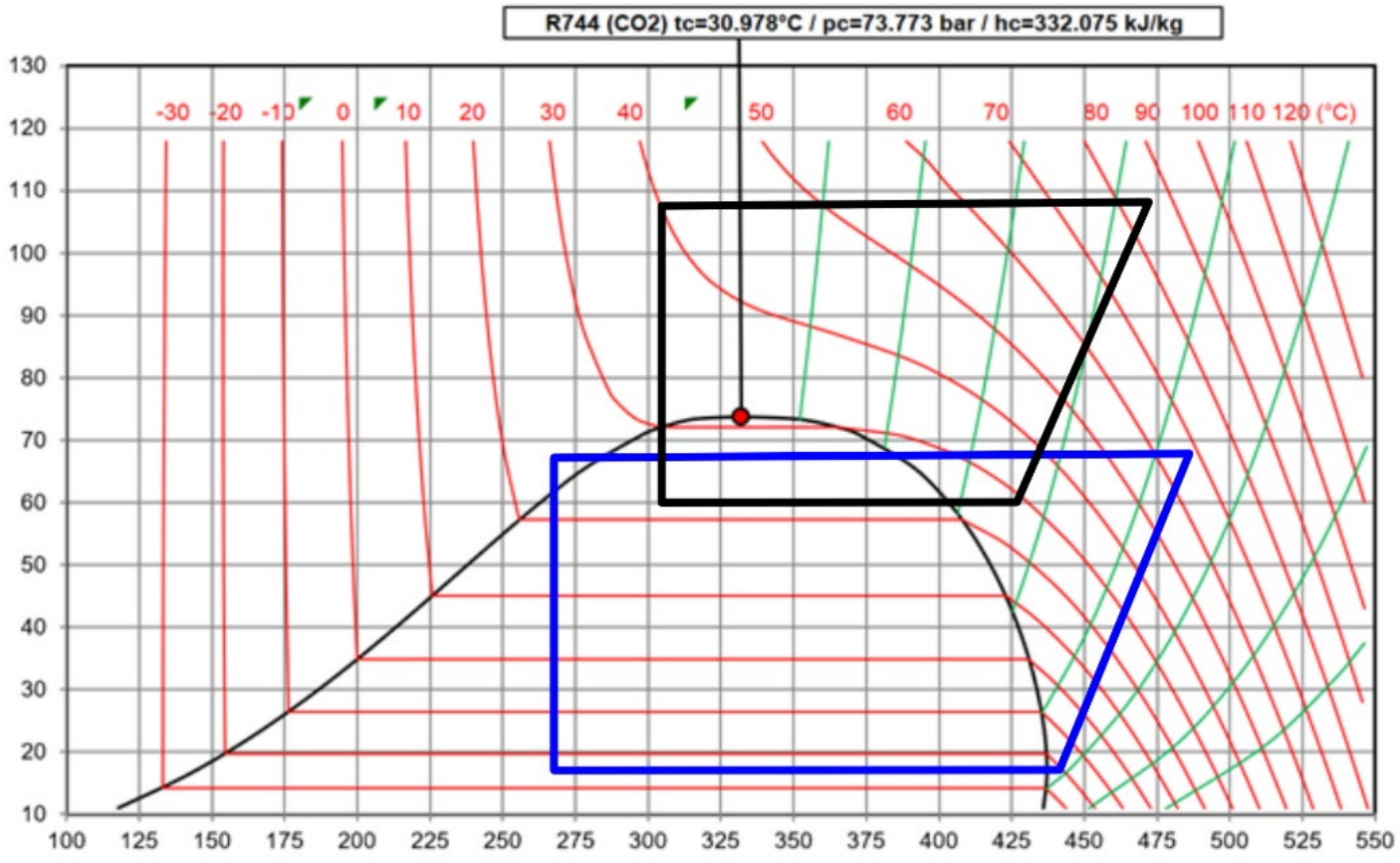
The flammable refrigerant R290 (Propane) is not used at high capacities for reasons of various strict regulations. The refrigerant R717 (NH3) is particularly suitable for high capacities, but is rarely used due to its toxicity for heat pumps.

Low Pressure Stage 1

For reasons of optimal regulation, 2 turbo compressors compress the refrigerant CO2 to a high subcritical pressure and temperature level. The evaporator is a fin coil heat exchanger, that cools the outside air and must be defrosted periodically with hot gases via a second collector in winter due to frost formation. If you wanted to defrost via the capillaries, it would take far too much time. Ideally, the condenser is a welded plate heat exchanger, which is connected to the high-pressure stage in a cascade connection.

High Pressure Level 2

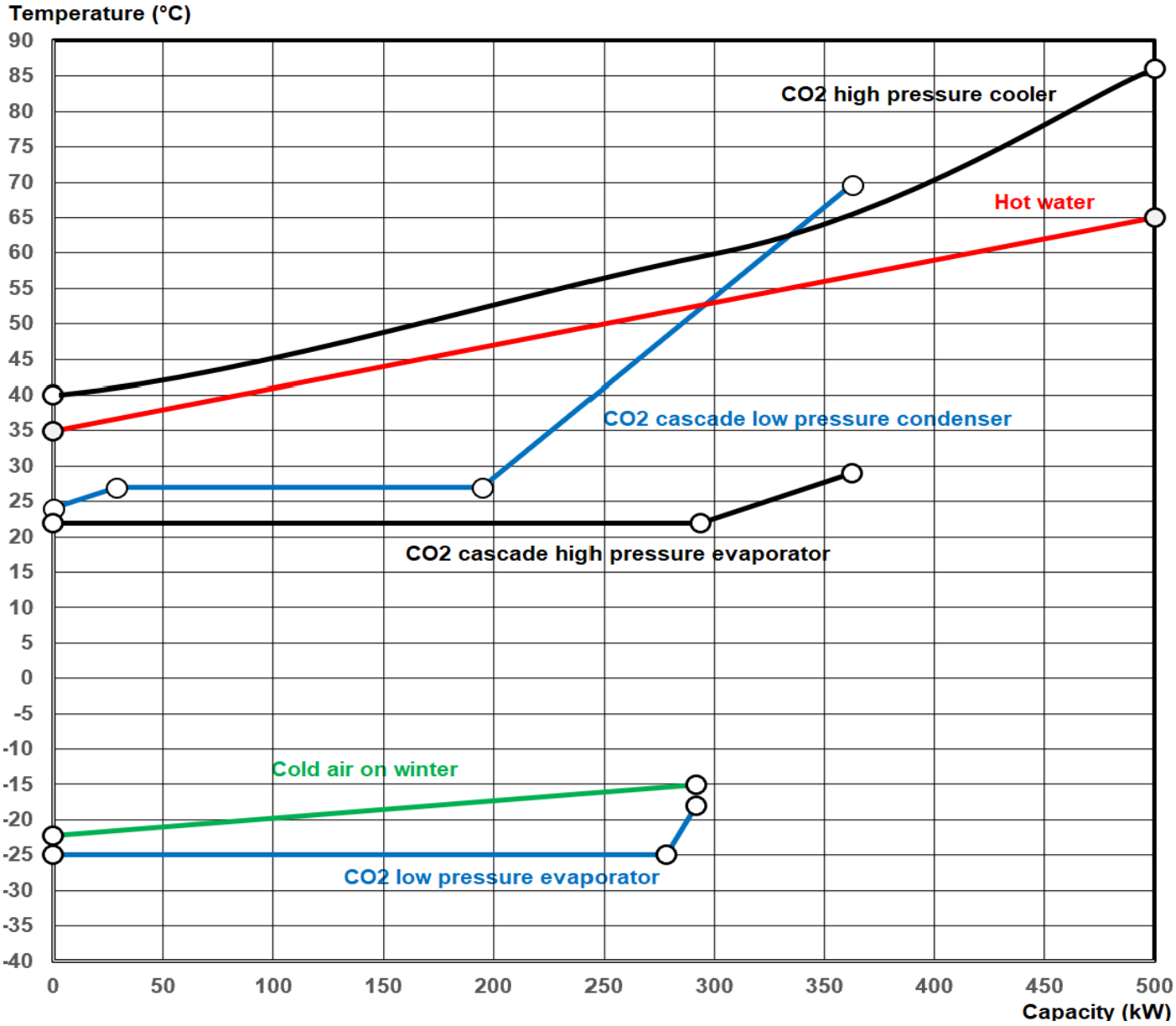
For optimal regulation, 2 turbo compressors compress the refrigerant CO2 into the transcritical range without the coolant being liquefied in the cooler. This results in a high usable heat of 65°C for hot and heating water. The cooler is ideally a welded plate heat exchanger. The evaporator is ideally a welded plate heat exchanger. Which is connected to the low-pressure stage in a cascade connection.



Example

Subsequently, an air-to-water CO2 heat pump was designed for hot and heating water of 65°C with a capacity of 500 kW. This temperature level is sufficient not only for underfloor heating, but also for heating systems with sufficiently large radiators.

Heat exchanger	Pressure bar	Mass flow kg/h	Temperature °C	Capacity kW
Hot water	1.000	14358.514	35 to 65	500.000
CO2 high pressure cooler	108.000	10622.603	86 to 40	500.000
CO2 cascade low pressure condenser	67.362	5878.095	27.000	362.692
CO2 cascade high pressure evaporator	60.026	10622.603	22.000	362.692
CO2 low pressure evaporator	16.857	5878.095	-25.000	291.549
Cold air on winter		119278.084	-15 to -22	291.549



Problem

Air-to-water heat pumps have to be defrosted periodically in winter at low outside temperatures, which requires a lot of equipment and noticeably reduces the availability of heat pump operation. This would not be the case with water-to-water heat pumps, which are operated via geothermal probes. The temperature of geothermal probes depends on the depth and the season. In the upper layers of the earth (up to approx. 15 m) it is constant all year round at about 10°C to 12°C. From a depth of 100 meters, the temperature rises by about 3°C per 100 meters due to the geothermal gradient.

Page 3 Software Changeover refrigerants: Injection evaporator, freezing capacity 6,443 kW
Page 4-8 Software CAP: Defrosting via the second collector or via the capillaries
Pages 9-13 Software COR: Reduced capacity during the defrosting process

DX evaporator: 40/35/15-8R-64T-5000A-4.0PA-64C-Cu/Al/AISI 304

Software by www.zcs.ch

Capacity	kW	291.549	------ sensible:	243.675
Surface reserve	%	2.475	latent:	41.431
Present surface	m2	1671.242	frost:	6.443
Required surface	m2	1630.871		
k-coeff.	W/m2K	33.898		
Average temp. diff. (100.00 %)	K	5.274		

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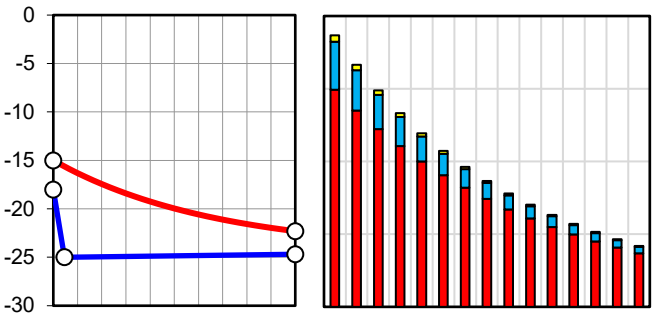
Plant
Object
Position

Air humid (ff=0.00005 m2K/W)		Inlet	Outlet	Definition
Height over sea level	m			0.000
Pressure	hPa			1013.250
Temp.	°C	-15.000	-22.304	20.000
Rel. humidity	%	100.000	100.000	40.000
Abs. humidity	g/kg	1.006	0.500	5.783
Density humid	kg/m3	1.366	1.406	1.200
Enthalpy humid	kJ/kg	-12.603	-21.208	34.801
Volume flow humid	m3/h	87391.154	84849.657	100000.000
Mass flow dry	kg/h	119278.084	119278.084	119278.084
Condensate flow	kg/h		60.311	
Surface temperature	°C	-21.916	-24.012	
Velocity	m/s	1.897	1.841	2.170
Pressure drop (dry 51 Pa)	Pa		54.127	

R744 (CO2) Evaporation 16.827 bar (ff=0.00005 m2K/W)

Condensate"	°C	27.000
Condensate'	°C	27.000
Subcooling	°C	24.000
Evaporation"	°C	-25.000
Superheating	°C	-18.000
Mass flow	kg/h	5878.087
Volume flow	m3/h	134.130
Velocity	m/s	4.128
Pressure drop Evaporation	K	0.305
Pressure drop Capillary	bar	3.499

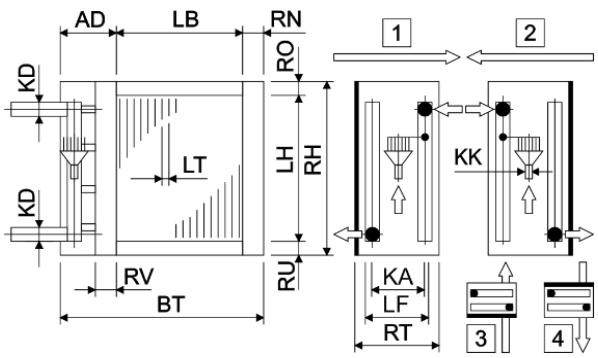
Part of steam on the inject point 41.92 %



Technical data

Tubes total		Piece	512
Tubes blank		Piece	0
Tube rows on the depth		Piece	8
Tube rows on the height		Piece	64
Tube coupling in series		Piece	8
Number of circuits (NC)		Piece	64
Volume		l	386
Weight		kg	1625
Cond. connection	KK	mm	54
Steam connection	KD	mm	89
Frame height	RH	mm	2640
Frame width	BT	mm	5240
Frame depth	RT	mm	360
Finned height	LH	mm	2560
Finned width	LB	mm	5000
Finned depth	LF	mm	280
Frame on top	RO	mm	40
Frame on bottom	RU	mm	40
Frame in front	RV	mm	30
Frame on back (~65mm)	RN	mm	65
Covering (~175mm)	AD	mm	175
Collector distance	KA	mm	245
Fin spacing	LT	mm	4.000
Fin thickness	LD	mm	0.200
Tube diameter	DA	mm	15.400
Tube thickness	S	mm	1.000
Tube interval on the height	S1	mm	40.000
Tube interval on the depth	S2	mm	35.000

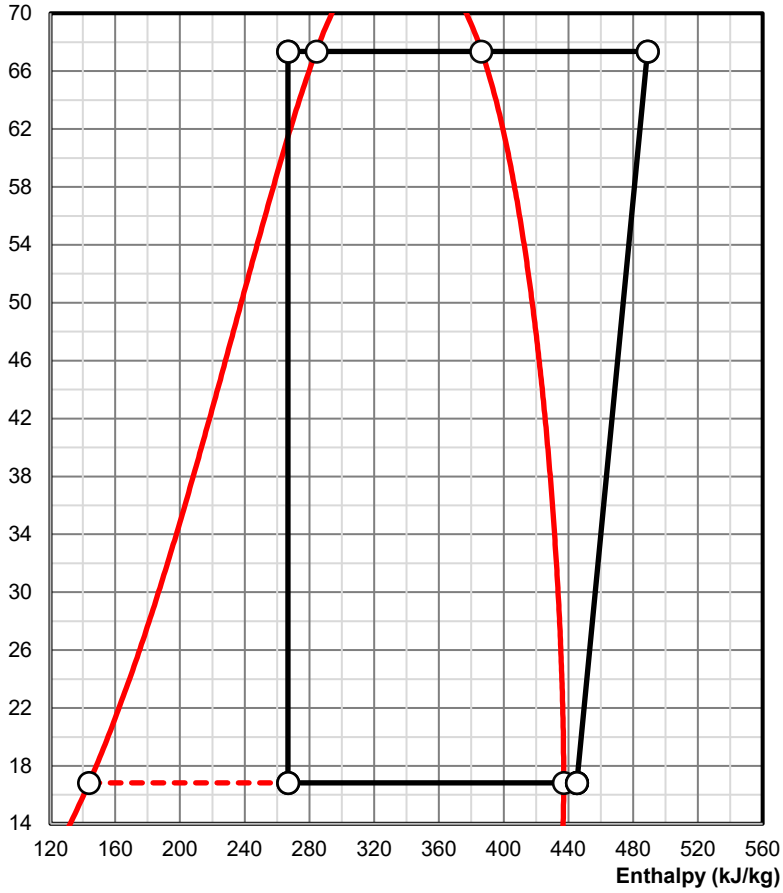
Capillary:	6.00 x 1.00 x 2760.00 mm		
Tubes:	smooth	Cu	
Tubes:		staggered	
Collectors:		Cu	
Connections:		Cu	
Fins:	smooth	Al	
Frame:	2.0 mm	AISI 304	
Circulations:	1	Default	
Protection:		without	
Protection:		---	
Air flow direction:		horizontal	



This requires 10 fans from Ziehl-Abegg, type FE80-AD.6N.V7.Y. These models use bionically shaped blades modelled on the owl's wing and are used worldwide in mechanical engineering as well as in air-conditioning, refrigeration and ventilation technology.

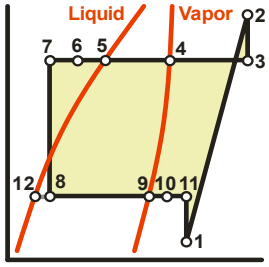
Refrigerant R744 (CO2) Software by www.zcs.ch

Pressure (bar)



Description

1 = Refrig. compressor
2 = Refrig. compressor
3 = Hot gas Condenser
4 =Condensation'' (Vapor)
5 =Condensation' (Liquid)
6 = Subcooling Condenser
7 = Subcooling additional
8 = Evaporator Injection point
9 = Evaporator'' (Vapor)
10 = Superheating Evaporator
11 = Superheating additional
12 =Evaporation' (Liquid)



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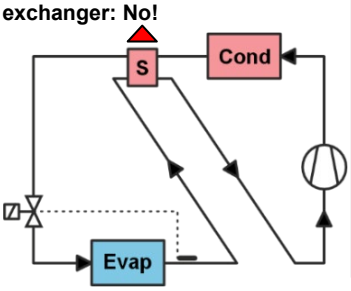
Plant
Object
Position

Heat exchanger: No!



Refrig. compressor	bar	°C	kJ/kg	kW	kg/h	(n)	
1 = Refrig. compressor	16.827	-18.000	445.272				
2 = Refrig. compressor	67.362	69.632	488.843				
Difference			43.571	71.143	5878.095		
Polytrophic exponent (n)						1.270	
Condenser	bar	°C	kJ/kg	kW	kg/h	COP	
3 = Hot gas Condenser	67.362	69.632	488.843				
4 =Condensation'' (Vapor)	67.362	27.000	386.114				
5 =Condensation' (Liquid)	67.362	27.000	284.368				
6 = Subcooling Condenser	67.362	24.000	266.715				
Difference			222.128	362.692	5878.095	5.098	
Subcooling additional	bar	°C	kJ/kg	kW	kg/h		
6 = Subcooling Condenser	67.362	24.000	266.715				
7 = Subcooling additional	67.362	24.000	266.715				
Difference			0.000	0.000	5878.095		
Evaporator	bar	°C	kJ/kg	kW	kg/h	COP	Flashgas
12 =Evaporation' (Liquid)	16.827	-25.000	143.772				
8 = Evaporator Injection point	16.827	-25.000	266.715				0.419
9 = Evaporator'' (Vapor)	16.827	-25.000	437.072				
10 = Evaporator Superheating	16.827	-18.000	445.272				
Difference			178.557	291.549	5878.095	4.098	
Superheating additional	bar	°C	kJ/kg	kW	kg/h		
10 = Superheating Evaporator	16.827	-18.000	445.272				
11 = Superheating additional	16.827	-18.000	445.272				
Difference			0.000	0.000	5878.095		
Pressure drop	bar	°C	kJ/kg				
2-3 = Pressure drop	0.000	0.000					
11-1 = Pressure drop	0.000	0.000					

Connections	ρ	$\dot{V}$	c max	di min	di eff	da eff	Ø eff
---	kg/m3	m3/h	m/s	m	mm	mm	---
Condensation'' (Vapor)	271.065	21.685	2.684	0.053	72.100	76.100	2 ½"
Condensation' (Liquid)	677.039	8.682	1.186	0.051	51.000	54.000	2"
Evaporation' (Liquid)	1053.973	5.577	0.673	0.054	72.100	76.100	2 ½"
Evaporation'' (Vapor)	43.824	134.130	7.403	0.080	84.900	88.900	3"

Pressure drop capillaries Software by www.zcs.ch

Number of circuits (NC)	Piece	64.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	5878.095
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.500

R744 (CO2)		°C	kJ/kg	---
Hot gas	thg	69.632	488.843	
Condensate	tc"	27.000	386.114	
Condensate	tc'	27.000	284.368	
Subcooling	tsc	24.000	266.715	
Evaporation	to'	-25.000	143.772	
Evaporation	tox	-25.000	266.715	
Evaporation	to"	-25.000	437.072	
Superheating	tsh	-18.000	445.272	
Flashgas	x			0.419

Pressure / Capacity		bar	kW
Condenser	pc	67.362	362.692
Evaporator	po	16.827	291.549
Refrig. compressor	---	50.534	71.143

Pressure drop	bar	%
Pressure drop expansion valve	46.996	92.998
Pressure drop capillaries	3.538	7.002
Total	50.534	100.000

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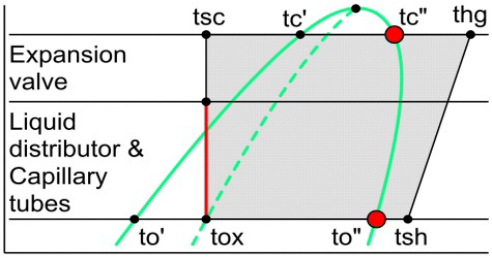
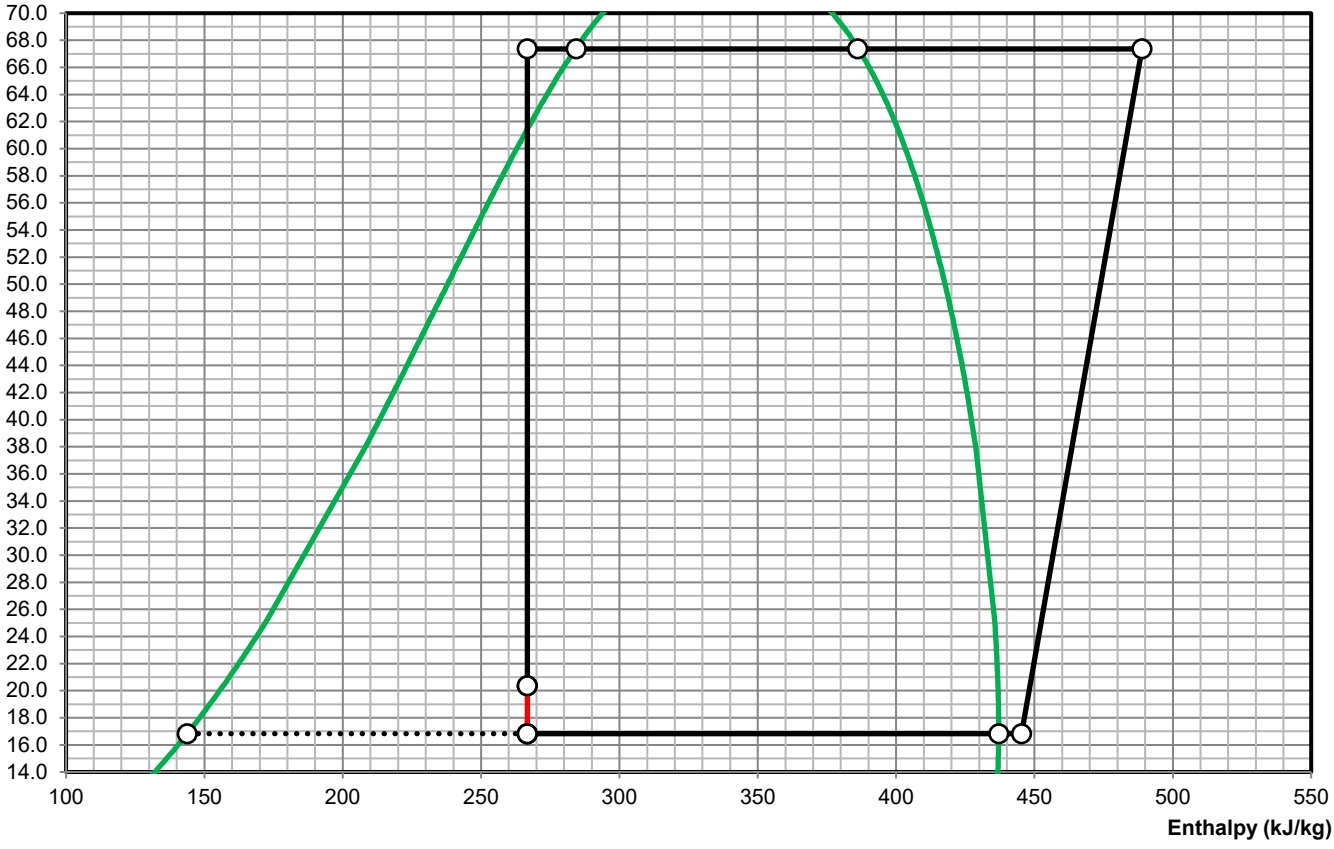


Pressure (bar)



Hot gas defrosting (Collector) Software by www.zcs.ch

Number of circuits (NC)	Piece	64.000	
Length	mm	2760.000	
Outside diam.	mm	6.000	
Thickness	mm	1.000	
Inside diam.	mm	4.000	
Roughness	mm	0.002	
Mass flow	kg/h	3526.857	(60.00%)
Type of cooling oil	---	Oil ISO VG32	
Part of cooling oil	%	0.500	

R744 (CO2)

Hot gas	t1	°C	69.632	
Hot gas	h1	kJ/kg	488.843	
Condensate"	tc1	°C	27.000	
Pressure	p1	bar	67.362	
Hot gas	t2	°C	69.173	
Hot gas	h2	kJ/kg	488.843	
Condensate"	tc2	°C	26.609	
Pressure	p2	bar	66.762	
Refrig. compressor	Qc	kW	71.143	(100.00%)
Hot gas	h3	kJ/kg	416.225	
Hot gas	t3	°C	31.804	

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop collectors	dp	bar	0.100
Pressure drop total	dp	bar	0.600
Frost capacity		kW	6.443
Defr. cycle		h	12.000
Frost energy		kWh	77.316
Defr. time		h	1.087
Defr. time		min	65.206

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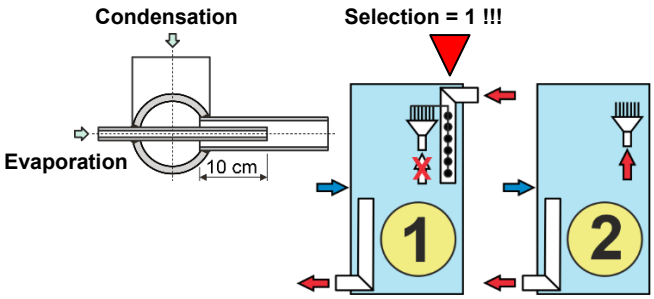

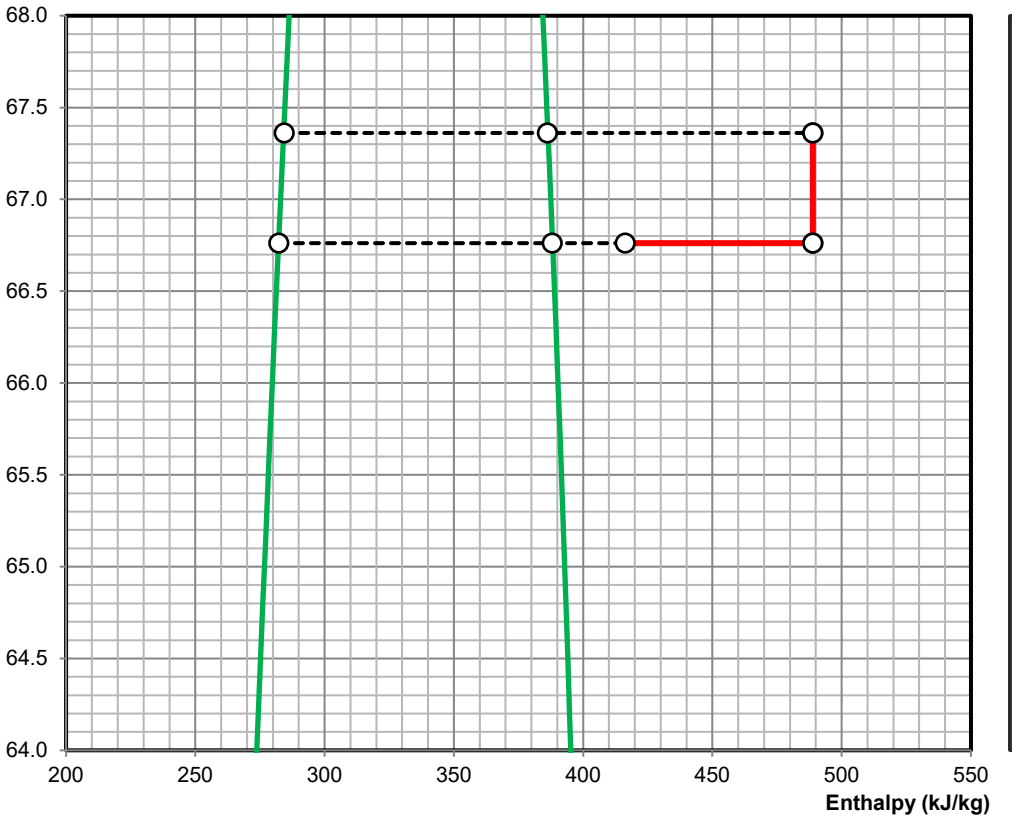

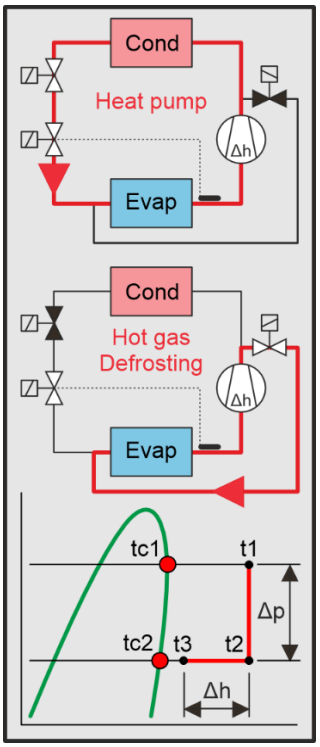

Hot gas defrosting

Hot gas defrosting (Capillary: !) Software by www.zcs.ch

Number of circuits (NC)	Piece	64.000	
Length	mm	2760.000	
Outside diam.	mm	6.000	
Thickness	mm	1.000	
Inside diam.	mm	4.000	
Roughness	mm	0.002	
Mass flow	kg/h	2939.047	(50.00%)
Type of cooling oil	---	Oil ISO VG32	
Part of cooling oil	%	0.500	

R744 (CO2)

Hot gas	t1	°C	69.632	
Hot gas	h1	kJ/kg	488.843	
Condensate"	tc1	°C	27.000	
Pressure	p1	bar	67.362	
Hot gas	t2	°C	67.548	
Hot gas	h2	kJ/kg	488.843	
Condensate"	tc2	°C	25.376	
Pressure	p2	bar	64.900	
Refrig. compressor	Qc	kW	57.626	(81.00%)
Hot gas	h3	kJ/kg	418.258	
Hot gas	t3	°C	30.506	

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop capillaries	dp	bar	1.961
Pressure drop total	dp	bar	2.461
Frost capacity		kW	6.443
Defr. cycle		h	12.000
Frost energy		kWh	77.316
Defr. time		h	1.342
Defr. time		min	80.501

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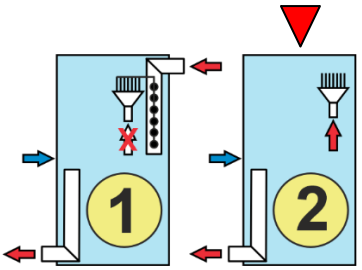
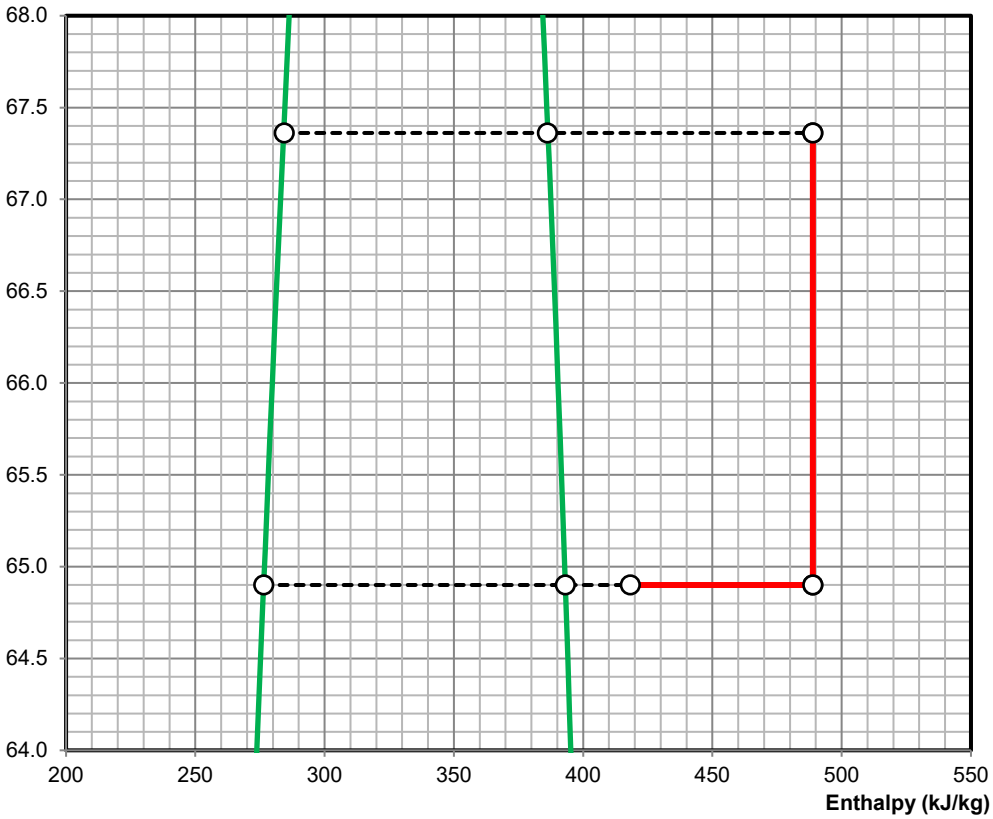
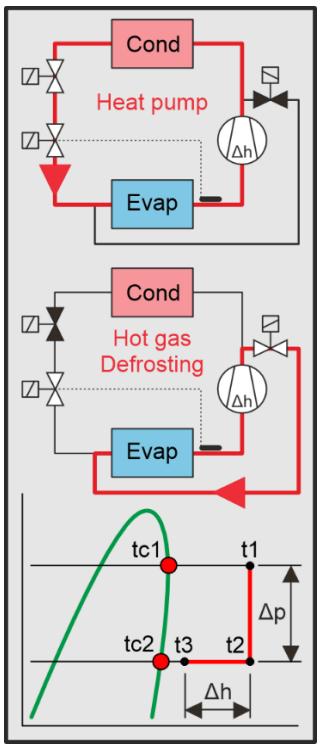
Selection = 2 !!!



Pressure (bar)



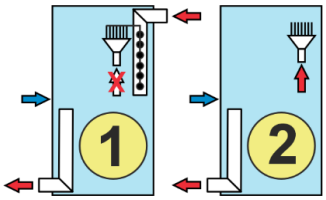


Hot gas defrosting

Evaporator

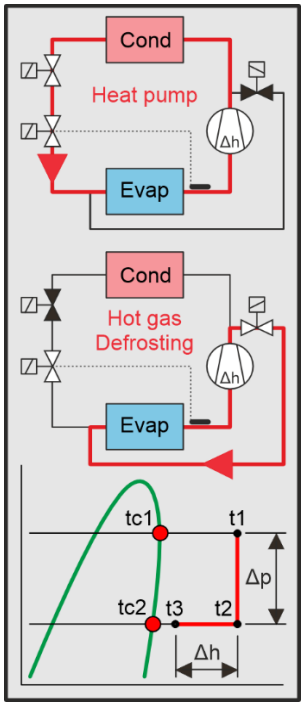
Number of circuits (NC)	Piece	64.00
Length	mm	2760.00
Outside diam.	mm	6.00
Thickness	mm	1.00
Inside diam.	mm	4.00
Roughness	mm	2.00E-03
Mass flow	kg/h	5878.09
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.50

Selection = 1 !!!



R744 (CO2)

Hot gas	thg	°C	69.632
Condensate	tc"	°C	27.000
Condensate	tc"	°C	27.000
Subcooling	tsc	°C	24.000
Evaporation	to'	°C	-25.000
Evaporation	tox	°C	-25.000
Evaporation	to"	°C	-25.000
Superheating	tsh	°C	-18.000
Flashgas	x	---	0.419



Pressure / Capacity		bar	kW
Condenser	pc	67.362	362.692
Evaporator	Po	16.827	291.549
Refrig. compressor	---	50.534	71.143

Pressure drop	bar	%
Pressure drop expansion valve	46.996	92.998
Pressure drop capillaries	3.538	7.002
Total	50.534	100.000

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Software by www.zcs.ch

Hot gas defrosting (Collector)			Selection = 1 !!!	Selection = 2 !!!
Refrig. compressor	---	kW	71.143	57.626
Pressure	p2	bar	66.762	64.900
Hot gas	t2	°C	69.173	67.548
Hot gas	t3	°C	31.804	30.506
Condensate"	tc2	°C	26.609	25.376
Pressure drop total	dp	bar	0.600	2.461
Frost capacity	---	kW	6.443	6.443
Defr. cycle	---	h	12.000	12.000
Frost energy	---	kWh	77.316	77.316
Defr. time	**---**	**h**	**1.087**	**1.342**
Availability	**---**	**%**	**90.944**	**88.819**

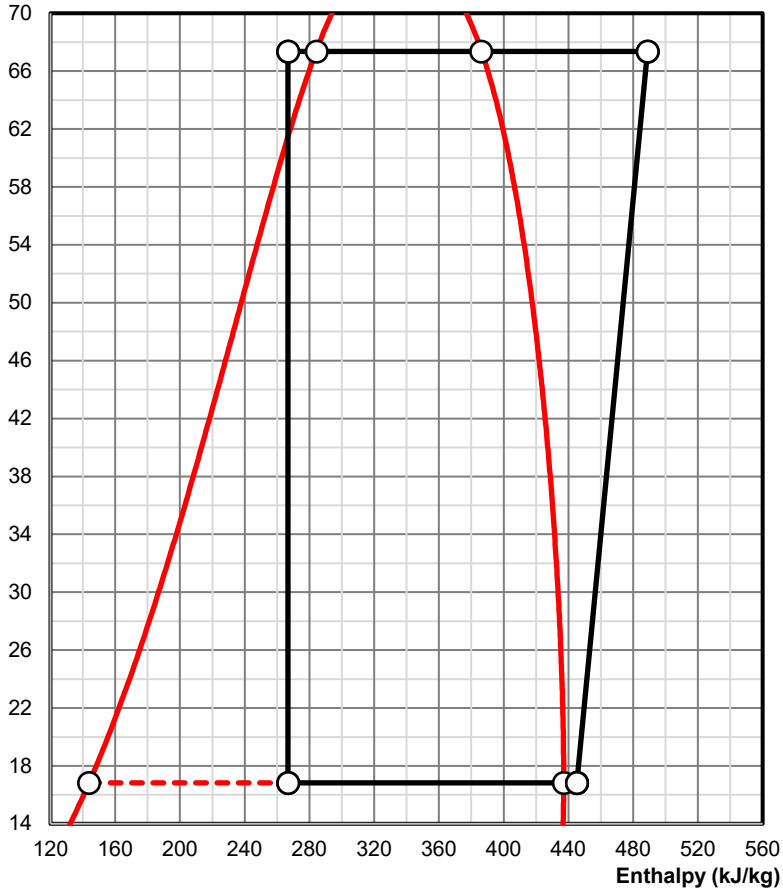
Changeover operation			Selection = 1 !!!	Selection = 2 !!!
Condenser	**---**	**kW**	**362.692**	**185.973**
Evaporator	**---**	**kW**	**291.549**	**150.401**
Refrig. compressor	**---**	**kW**	**71.143**	**35.572**

Selection = 1 !!!

Option 1: If the pressure drop in the capillaries is very high and defrosting with hot gases via the collector is desired, this is not a problem. If the condenser is expected to deliver a high capacity via the collector in changeover mode, this is also not a problem. Defrosting with hot gases via the collector takes little time, and the condenser can easily deliver its nominal capacity. Option 2: If the pressure drop in the capillaries is very high and defrosting with hot gases via the capillaries is desired, this is a problem. If the condenser is expected to deliver any capacity via the capillaries in changeover mode, this is also a problem. It is not surprising, if two highly negative consequences occur. Defrosting with hot gases via the capillaries takes far too long, and the condenser can only deliver a fraction of its nominal output.

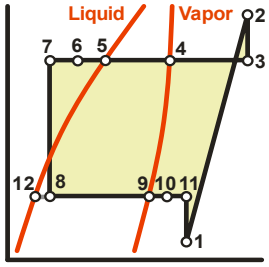
Refrigerant R744 (CO2) Software by www.zcs.ch

Pressure (bar)



Description

1 = Refrig. compressor
2 = Refrig. compressor
3 = Hot gas Condenser
4 =Condensation'' (Vapor)
5 =Condensation' (Liquid)
6 = Subcooling Condenser
7 = Subcooling additional
8 = Evaporator Injection point
9 = Evaporator'' (Vapor)
10 = Superheating Evaporator
11 = Superheating additional
12 =Evaporation' (Liquid)



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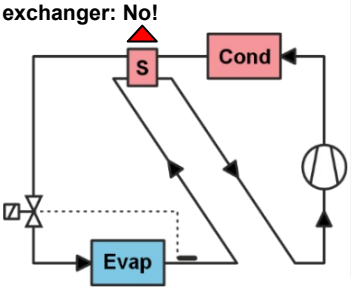
Position

Heat exchanger: No!



Refrig. compressor	bar	°C	kJ/kg	kW	kg/h	(n)	
1 = Refrig. compressor	16.827	-18.000	445.272				
2 = Refrig. compressor	67.362	69.632	488.843				
Difference			43.571	71.143	5878.095		
Polytrophic exponent (n)						1.270	
Condenser	bar	°C	kJ/kg	kW	kg/h	COP	
3 = Hot gas Condenser	67.362	69.632	488.843				
4 =Condensation'' (Vapor)	67.362	27.000	386.114				
5 =Condensation' (Liquid)	67.362	27.000	284.368				
6 = Subcooling Condenser	67.362	24.000	266.715				
Difference			222.128	362.692	5878.095	5.098	
Subcooling additional	bar	°C	kJ/kg	kW	kg/h		
6 = Subcooling Condenser	67.362	24.000	266.715				
7 = Subcooling additional	67.362	24.000	266.715				
Difference			0.000	0.000	5878.095		
Evaporator	bar	°C	kJ/kg	kW	kg/h	COP	Flashgas
12 =Evaporation' (Liquid)	16.827	-25.000	143.772				
8 = Evaporator Injection point	16.827	-25.000	266.715				0.419
9 = Evaporator'' (Vapor)	16.827	-25.000	437.072				
10 = Evaporator Superheating	16.827	-18.000	445.272				
Difference			178.557	291.549	5878.095	4.098	
Superheating additional	bar	°C	kJ/kg	kW	kg/h		
10 = Superheating Evaporator	16.827	-18.000	445.272				
11 = Superheating additional	16.827	-18.000	445.272				
Difference			0.000	0.000	5878.095		
Pressure drop	bar	°C	kJ/kg				
2-3 = Pressure drop	0.000	0.000					
11-1 = Pressure drop	0.000	0.000					

Connections	ρ	$\dot{V}$	c max	di min	di eff	da eff	Ø eff
---	kg/m3	m3/h	m/s	m	mm	mm	---
Condensation'' (Vapor)	271.065	21.685	2.684	0.053	72.100	76.100	2 ½"
Condensation' (Liquid)	677.039	8.682	1.186	0.051	51.000	54.000	2"
Evaporation' (Liquid)	1053.973	5.577	0.673	0.054	72.100	76.100	2 ½"
Evaporation'' (Vapor)	43.824	134.130	7.403	0.080	84.900	88.900	3"

Pressure drop capillaries Software by www.zcs.ch

Number of circuits (NC)	Piece	64.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	5878.095
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.500

R744 (CO2)		°C	kJ/kg	---
Hot gas	thg	69.632	488.843	
Condensate	tc"	27.000	386.114	
Condensate	tc'	27.000	284.368	
Subcooling	tsc	24.000	266.715	
Evaporation	to'	-25.000	143.772	
Evaporation	tox	-25.000	266.715	
Evaporation	to"	-25.000	437.072	
Superheating	tsh	-18.000	445.272	
Flashgas	x			0.419

Pressure / Capacity		bar	kW
Condenser	pc	67.362	362.692
Evaporator	po	16.827	291.549
Refrig. compressor	---	50.534	71.143

Pressure drop	bar	%
Pressure drop expansion valve	46.996	92.998
Pressure drop capillaries	3.538	7.002
Total	50.534	100.000

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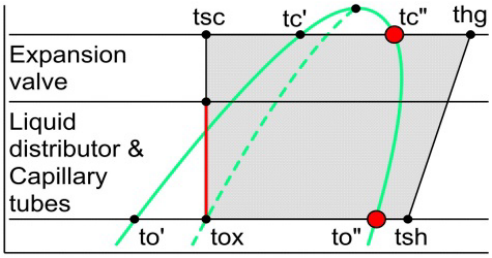
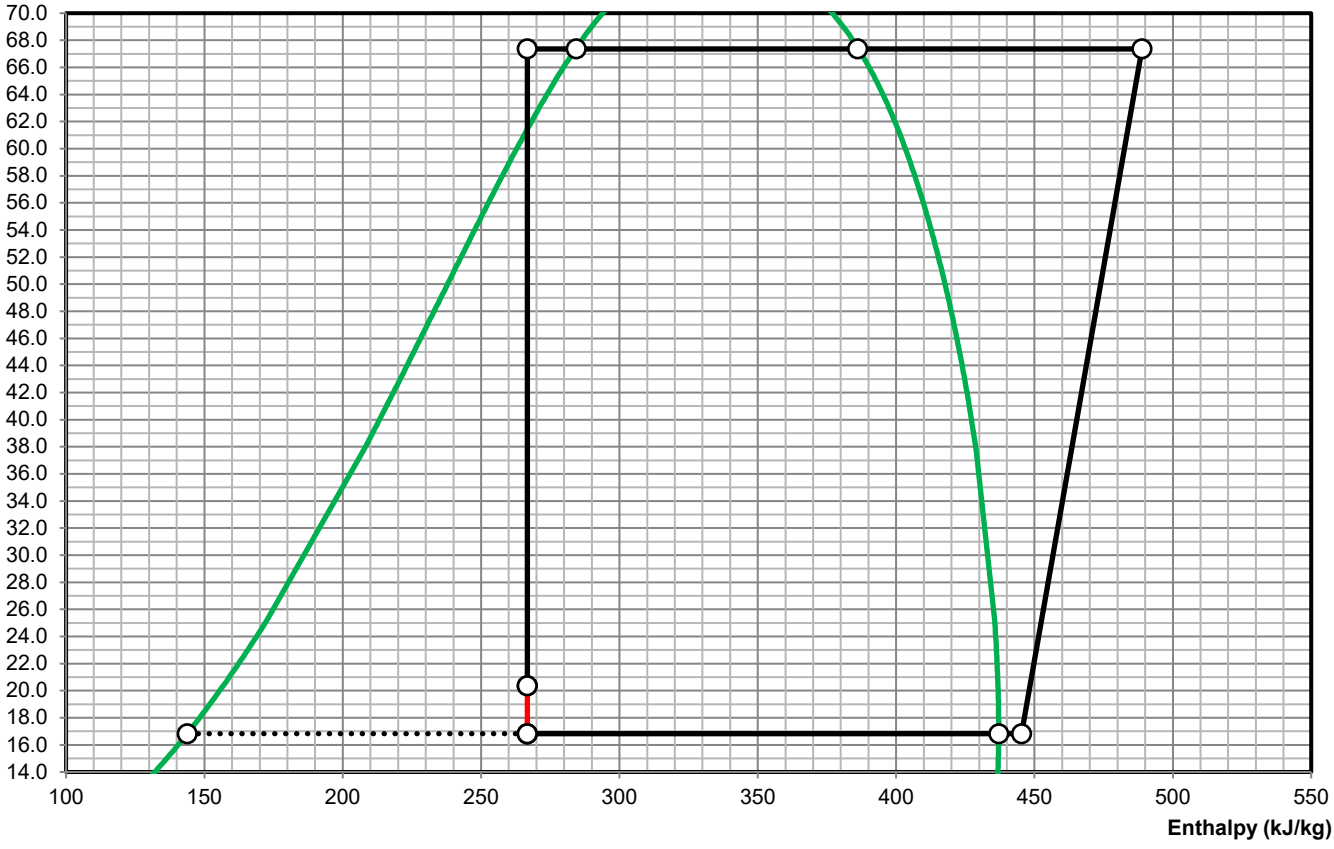


Pressure (bar)



Condensation (Collector) Software by www.zcs.ch

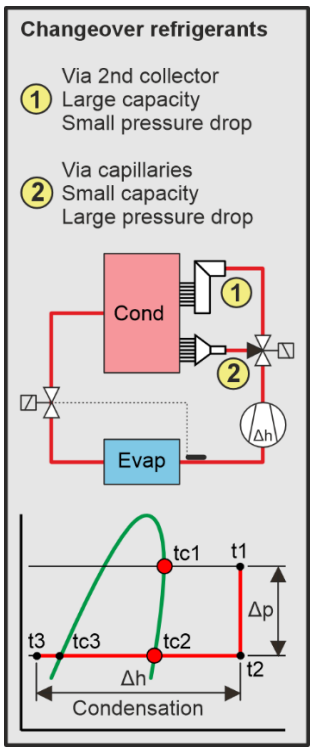
Number of circuits (NC)	Piece	64.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	5878.095
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.500

R744 (CO2)

Hot gas	t1	°C	69.632
Hot gas	h1	kJ/kg	488.843
Condensate"	tc1	°C	27.000
Pressure	p1	bar	67.362
Hot gas	t2	°C	69.173
Hot gas	h2	kJ/kg	488.843
Condensate"	tc2	°C	26.609
Pressure	p2	bar	66.762
Condensate'	tc3	°C	26.609
Subcooling	t3	°C	23.609
Subcooling	h3	kJ/kg	272.678
Condenser	Q	kW	352.955
Refrig. compressor	Q	kW	71.143
Evaporator	Q	kW	281.812

Pressure drop

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop collectors	dp	bar	0.100
Pressure drop total	dp	bar	0.600



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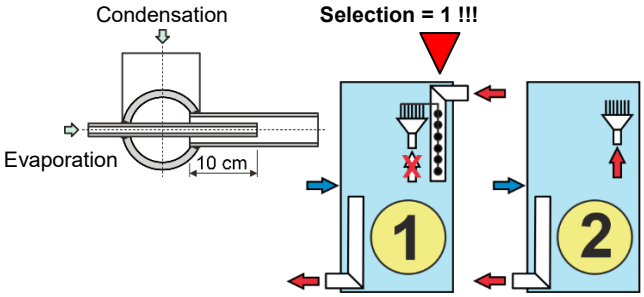
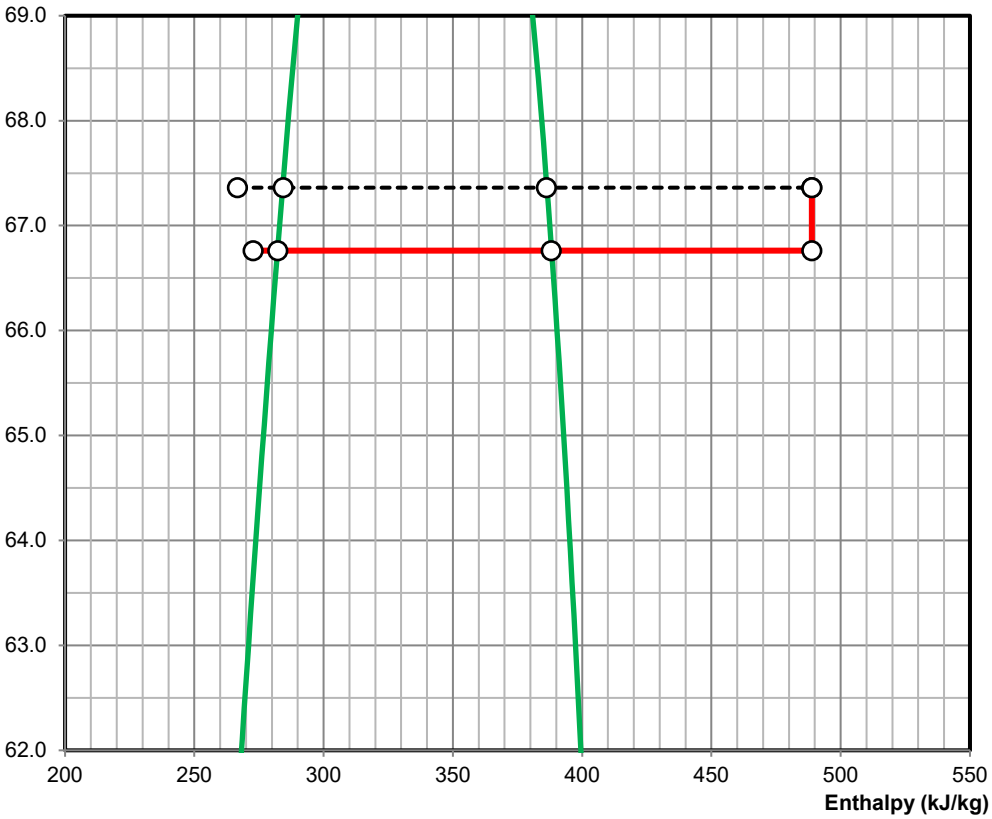
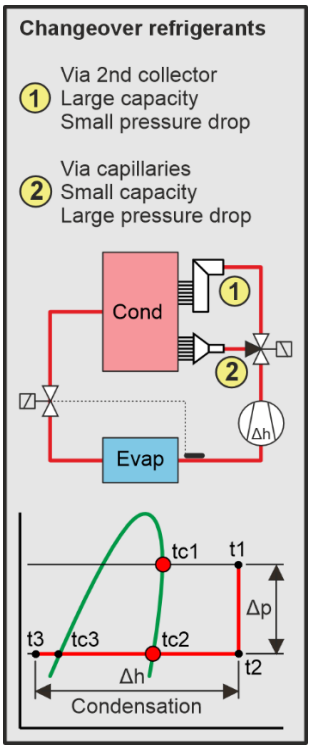


Pressure (bar)





Hot gas defrosting

Condensation (Capillary: !) Software by www.zcs.ch

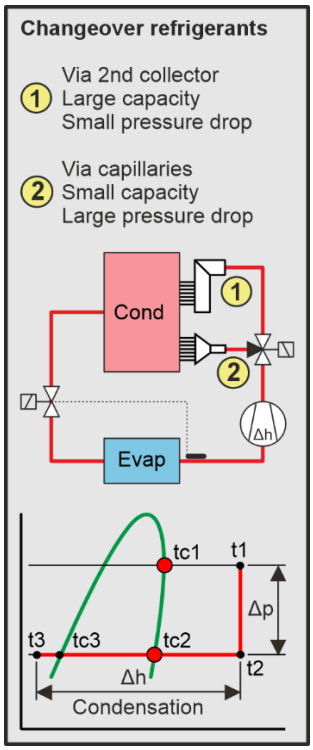
Number of circuits (NC)	Piece	64.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	4972.280
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.500

R744 (CO2)

Hot gas	t1	°C	69.632
Hot gas	h1	kJ/kg	488.843
Condensate"	tc1	°C	27.000
Pressure	p1	bar	67.362
Hot gas	t2	°C	66.438
Hot gas	h2	kJ/kg	488.843
Condensate"	tc2	°C	24.306
Pressure	p2	bar	63.323
Condensate'	tc3	°C	24.306
Subcooling	t3	°C	21.306
Subcooling	h3	kJ/kg	262.106
Condenser	Q	kW	313.167
Refrig. compressor	Q	kW	60.180
Evaporator	Q	kW	252.987

Pressure drop

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop capillaries	dp	bar	3.538
Pressure drop total	dp	bar	4.038



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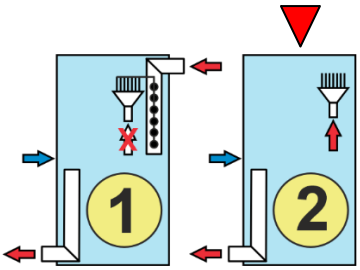
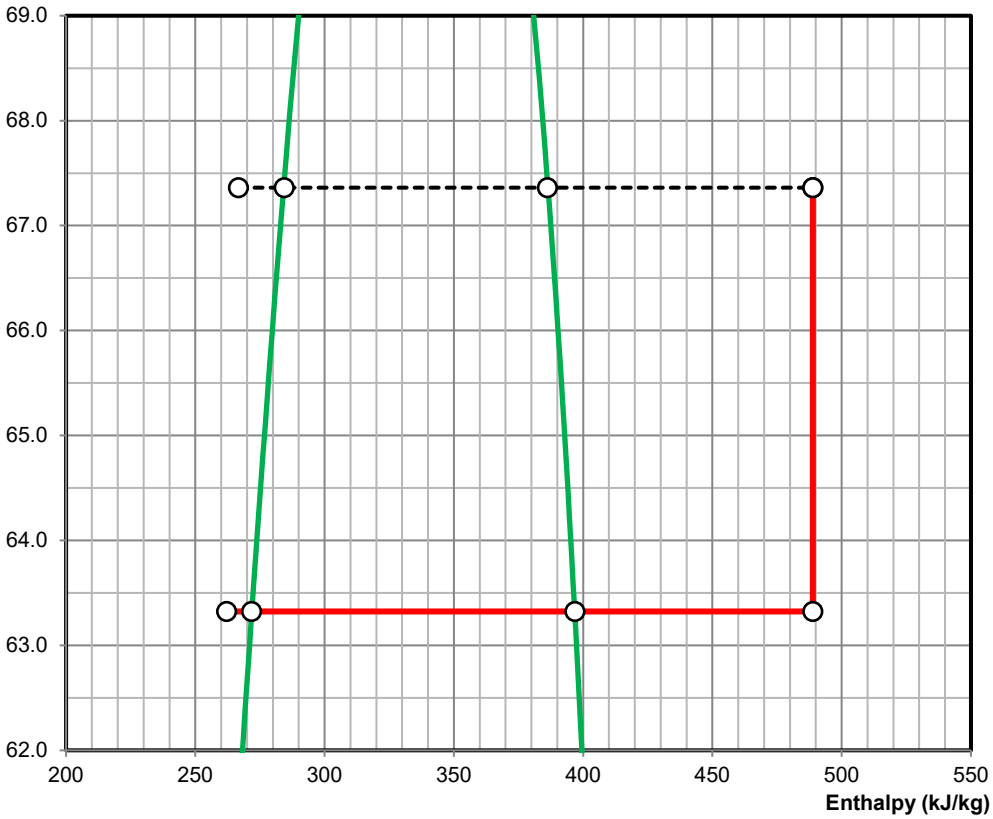
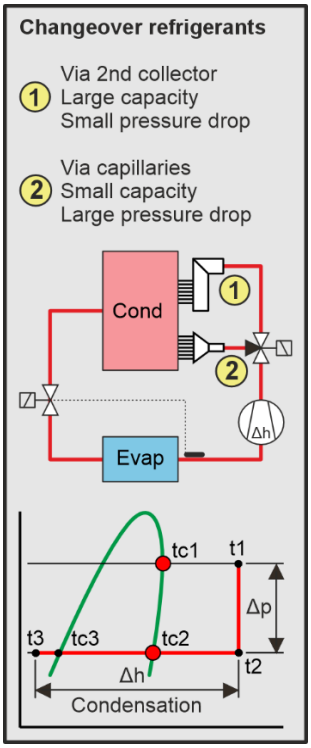
Selection = 2 !!!



Pressure (bar)



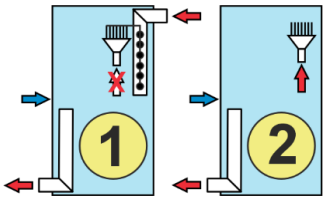


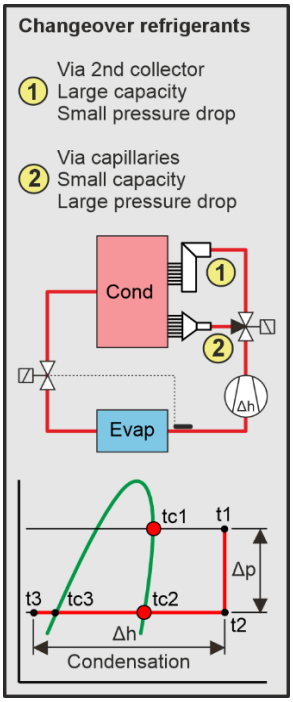
Hot gas defrosting

Evaporator

Number of circuits (NC)	Piece	64.00
Length	mm	2760.00
Outside diam.	mm	6.00
Thickness	mm	1.00
Inside diam.	mm	4.00
Roughness	mm	2.00E-03
Mass flow	kg/h	5878.09
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.50

Selection = 1 !!!





R744 (CO2)

Hot gas	thg	°C	69.632
Condensate	tc''	°C	27.000
Condensate	tc''	°C	27.000
Subcooling	tsc	°C	24.000
Evaporation	to'	°C	-25.000
Evaporation	tox	°C	-25.000
Evaporation	to''	°C	-25.000
Superheating	tsh	°C	-18.000
Flashgas	x	---	0.419

Pressure / Capacity		**bar**	**kW**
Condenser	pc	67.362	362.692
Evaporator	po	16.827	291.549
Refrig. compressor	---	50.534	71.143

Pressure drop	**bar**	**%**
Pressure drop expansion valve	46.996	92.998
Pressure drop capillaries	3.538	7.002
Total	50.534	100.000

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Selection = 1 !!!

Condensation			**Selection = 1 !!!**	**Selection = 2 !!!**
Refrig. compressor	---	kW	71.143	60.180
Pressure	p2	bar	66.762	63.323
Pressure drop total	dp	bar	0.600	4.038
Hot gas	t2	°C	69.173	66.438
Condensate''	tc2	°C	26.609	24.306
Condensate'	tc3	°C	26.609	24.306
Subcooling	t3	°C	23.609	21.306

Changeover operation			**Selection = 1 !!!**	**Selection = 2 !!!**
Condenser	**---**	**kW**	**362.692**	**319.300**
Evaporator	**---**	**kW**	**291.549**	**259.120**
Refrig. compressor	**---**	**kW**	**71.143**	**60.180**

Option 1: If the pressure drop in the capillaries is very high and defrosting with hot gases via the collector is desired, this is not a problem. If the condenser is expected to deliver a high capacity via the collector in changeover mode, this is also not a problem. Defrosting with hot gases via the collector takes little time, and the condenser can easily deliver its nominal capacity. Option 2: If the pressure drop in the capillaries is very high and defrosting with hot gases via the capillaries is desired, this is a problem. If the condenser is expected to deliver any capacity via the capillaries in changeover mode, this is also a problem. It is not surprising, if two highly negative consequences occur. Defrosting with hot gases via the capillaries takes far too long, and the condenser can only deliver a fraction of its nominal output.