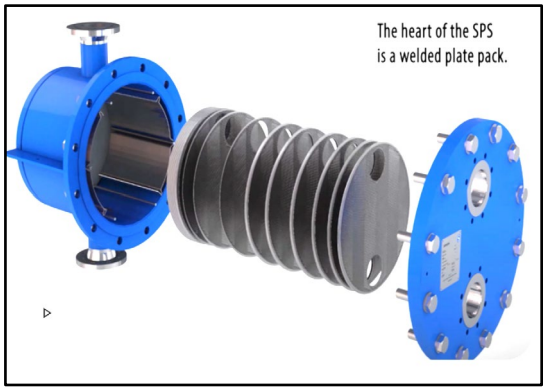
R290-Heat pump 2-stage

Air-to-water R290 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 R290 heat pump is recommended, i.e. with the natural refrigerant R290 with a GWP = 0 (Global Warming Potential), best for greater capacity 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 increases the efficiency in the heat exchangers due to the lack of oil films.



Alternatives to R290 (Propane)

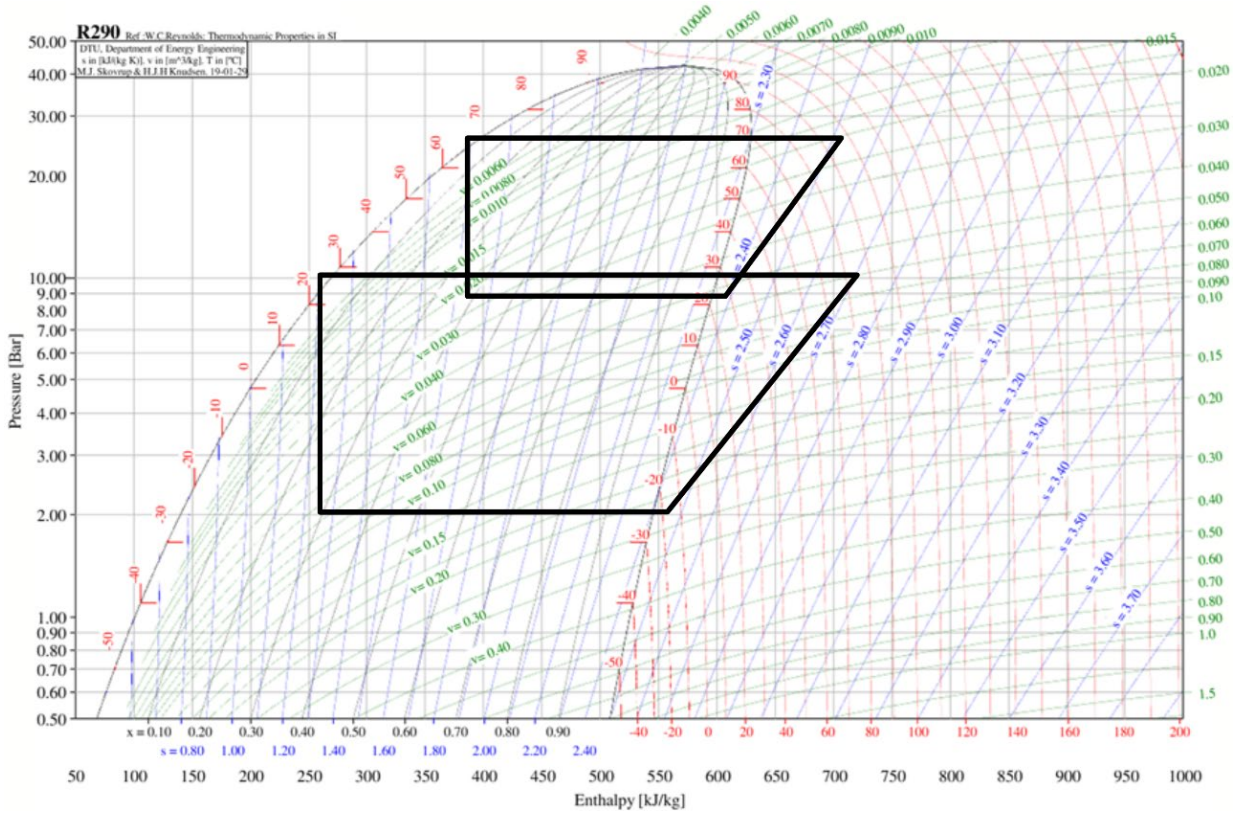
The refrigerant R717 (NH3) is often used at high capacities, although it is toxic. In the second stage, the refrigerant R744 (CO2) has supercritical pressures of up to 110 bar on the cooler, which makes the heat exchangers unnecessarily expensive.

Low Pressure Stage 1

For optimal regulation, 2 turbo compressors compress the R290 refrigerant to a modest 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

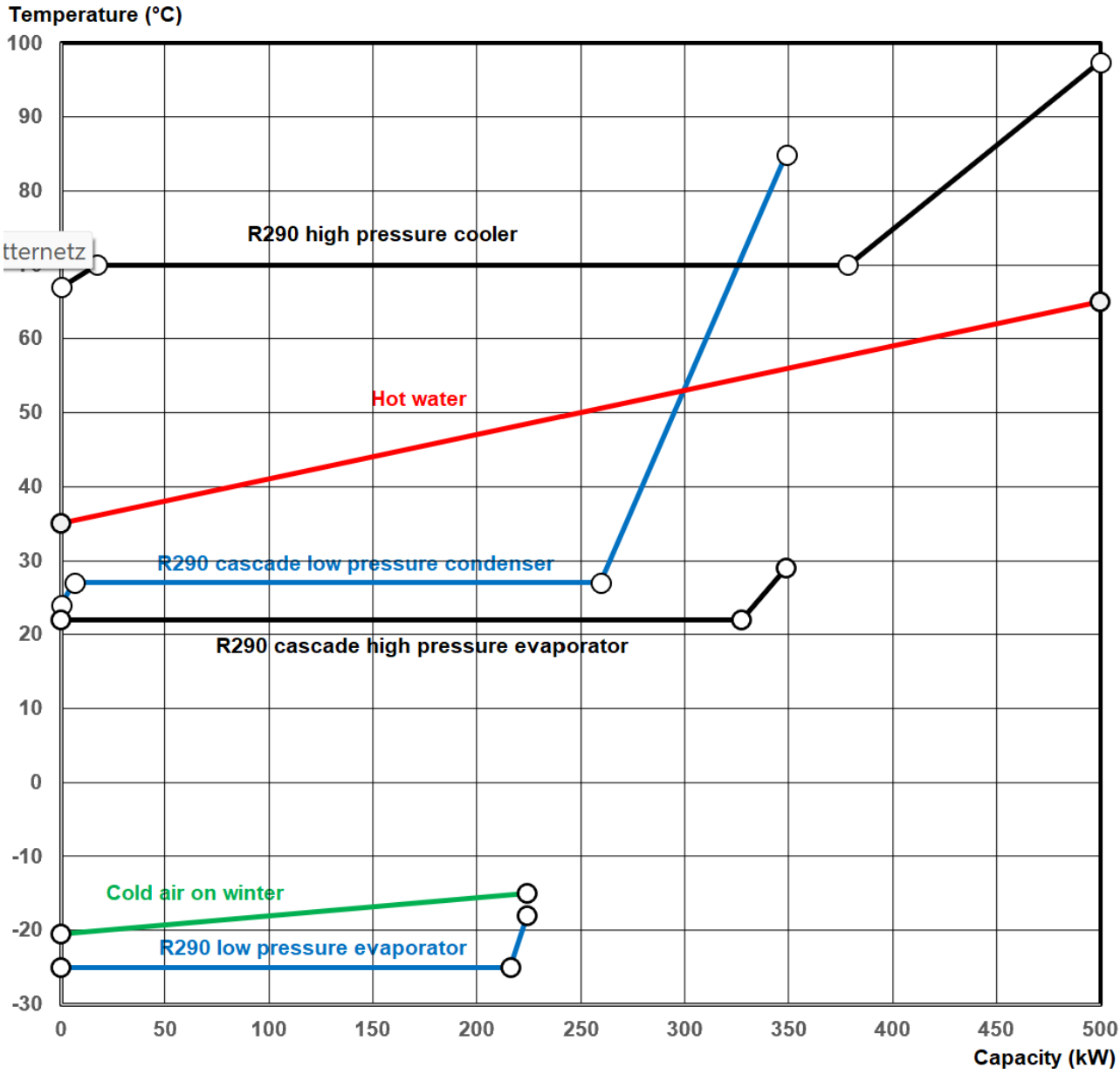
For optimal regulation, 2 turbo compressors compress the R290 refrigerant to an acceptable pressure and temperature level. This results in a high usable heat of 65°C for hot and heating water. The condenser is ideally a welded plate heat exchanger. The evaporator is ideally a welded plate heat exchanger, which is connected to the low-pressure stage in a cascade connection.



Example

Subsequently, an air-to-water R290 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 auf 65	500.000
R290 high pressure cooler	25.868	5689.587	65.000	500.000
R290 cascade low pressure condenser	10.015	2743.296	27.000	348.931
R290 cascade high pressure evaporator	8.814	5689.587	10.000	348.931
R290 low pressure evaporator	2.034	2743.296	-25.000	224.612
Cold air on winter		119278.084	-15 auf -20.6	224.612



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 meter, the temperature rises by about 3°C per 100 metres due to the geothermal gradient.

Page 3 Software Changeover refrigerants: Injection evaporator, freezing capacity 5,260 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: 40/35/15-6R-64T-5000A-4.0PA-96C-Cu/Al/AISI 304

Software by www.zcs.ch

Capacity	kW	224.612	------ sensible:	185.530
Surface reserve	%	0.235	latent:	33.822
Present surface	m2	1253.432	frost:	5.260
Required surface	m2	1250.491		
k-coeff.	W/m2K	28.651		
Average temp. diff. (100.00 %)	K	6.269		

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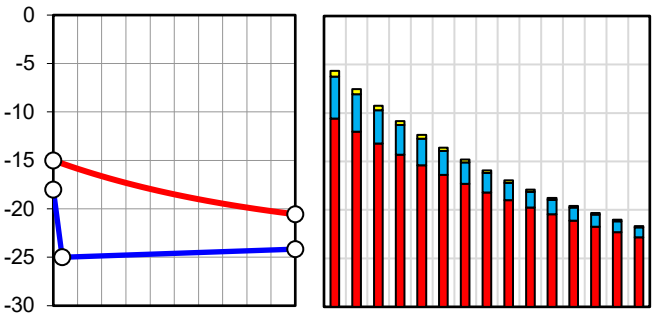
Plant
Object
Position

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	-20.560	20.000
Rel. humidity	%	100.000	100.000	40.000
Abs. humidity	g/kg	1.006	0.593	5.783
Density humid	kg/m3	1.366	1.397	1.200
Enthalpy humid	kJ/kg	-12.603	-19.224	34.801
Volume flow humid	m3/h	87391.154	85452.235	100000.000
Mass flow dry	kg/h	119278.084	119278.084	119278.084
Condensate flow	kg/h		49.235	
Surface temperature	°C	-21.144	-22.835	
Velocity	m/s	1.897	1.854	2.170
Pressure drop (dry 39 Pa)	Pa		41.177	

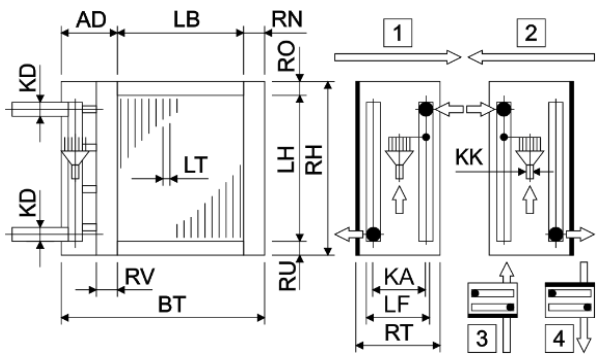
R290 (Propane) Evaporation 2.034 bar (ff=0.00005 m2K/W)		
Condensate"	°C	27.000
Condensate'	°C	27.000
Subcooling	°C	24.000
Evaporation"	°C	-25.000
Superheating	°C	-18.000
Mass flow	kg/h	2743.296
Volume flow	m3/h	591.462
Velocity	m/s	10.223
Pressure drop Evaporation	K	0.833
Pressure drop Capillary	bar	2.747

Part of steam on the inject point 30.20 %



Technical data

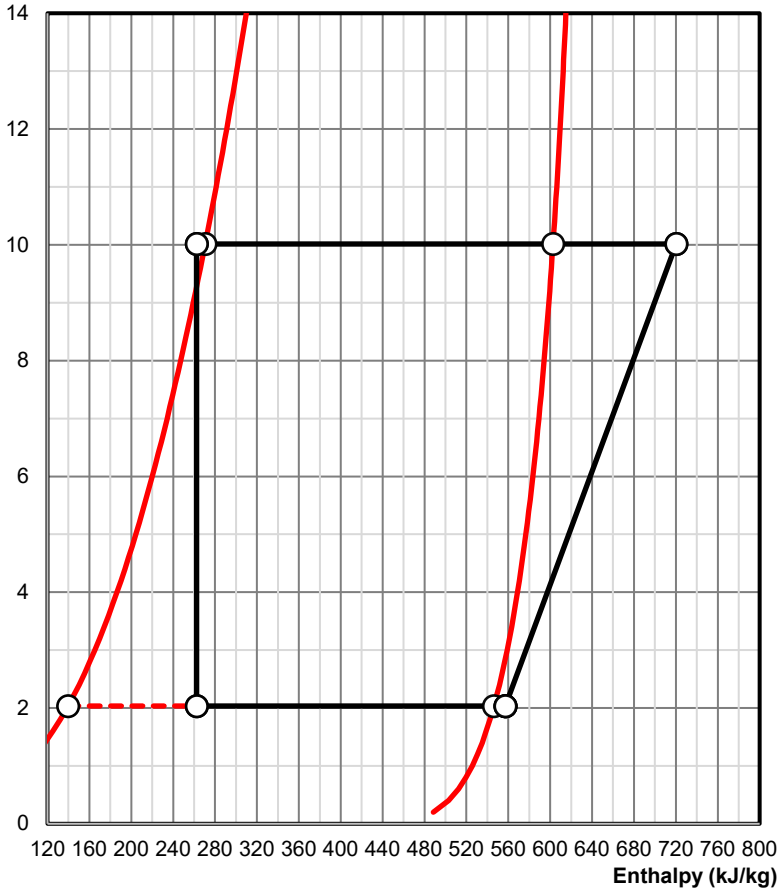
				Capillary:	6.00 x 1.00 x 2760.00 mm	
Tubes total		Piece	384	Tubes:	smooth	Cu
Tubes blank		Piece	0	Tubes:		staggered
Tube rows on the depth		Piece	6	Collectors:		Cu
Tube rows on the height		Piece	64	Connections:		Cu
Tube coupling in series		Piece	4	Fins:	smooth	Al
Number of circuits (NC)		Piece	96	Frame:	2.0 mm	AISI 304
Volume		l	383	Circulations:	1	Default
Weight		kg	917	Protection:		without
Cond. connection	KK	mm	54	Protection:		---
Steam connection	KD	mm	168	Air flow direction:		horizontal
Frame height	RH	mm	2640			
Frame width	BT	mm	5319			
Frame depth	RT	mm	390			
Finned height	LH	mm	2560			
Finned width	LB	mm	5000			
Finned depth	LF	mm	210			
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 (~254mm)	AD	mm	254			
Collector distance	KA	mm	189			
Fin spacing	LT	mm	4.000			
Fin thickness	LD	mm	0.200			
Tube diameter	DA	mm	15.400			
Tube thickness	S	mm	0.400			
Tube interval on the height	S1	mm	40.000			
Tube interval on the depth	S2	mm	35.000			



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.

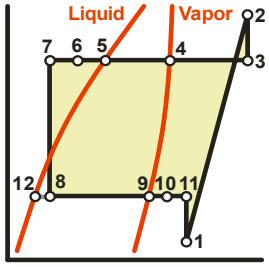
Refrigerant R290 (Propane) Software by www.zcs.ch

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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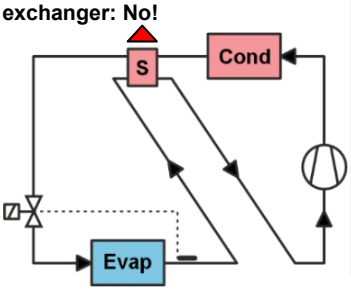
Plant
Object
Position

Heat exchanger: No!



Refrig. compressor	bar	°C	kJ/kg	kW	kg/h	(n)	
1 = Refrig. compressor	2.034	-18.000	557.154				
2 = Refrig. compressor	10.015	84.933	720.296				
Difference			163.142	124.319	2743.296		
Polytrophic exponent (n)						1.270	
Condenser	bar	°C	kJ/kg	kW	kg/h	COP	
3 = Hot gas Condenser	10.015	84.933	720.296				
4 =Condensation'' (Vapor)	10.015	27.000	602.741				
5 =Condensation' (Liquid)	10.015	27.000	270.567				
6 = Subcooling Condenser	10.015	24.000	262.397				
Difference			457.898	348.931	2743.296	2.807	
Subcooling additional	bar	°C	kJ/kg	kW	kg/h		
6 = Subcooling Condenser	10.015	24.000	262.397				
7 = Subcooling additional	10.015	24.000	262.397				
Difference			0.000	0.000	2743.296		
Evaporator	bar	°C	kJ/kg	kW	kg/h	COP	Flashgas
12 =Evaporation' (Liquid)	2.034	-25.000	139.600				
8 = Evaporator Injection point	2.034	-25.000	262.397				0.302
9 = Evaporator'' (Vapor)	2.034	-25.000	546.279				
10 = Evaporator Superheating	2.034	-18.000	557.154				
Difference			294.756	224.612	2743.296	1.807	
Superheating additional	bar	°C	kJ/kg	kW	kg/h		
10 = Superheating Evaporator	2.034	-18.000	557.154				
11 = Superheating additional	2.034	-18.000	557.154				
Difference			0.000	0.000	2743.296		
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)	21.706	126.385	9.721	0.068	72.100	76.100	2 ½"
Condensation' (Liquid)	489.220	5.607	1.612	0.035	39.000	42.000	1 ½"
Evaporation' (Liquid)	560.614	4.893	0.930	0.043	51.000	54.000	2"
Evaporation'' (Vapor)	4.638	591.462	10.697	0.140	159.300	168.300	NW 150

Pressure drop capillaries			Software by www.zcs.ch
Number of circuits (NC)	Piece	96.000	
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	2743.296	
Type of cooling oil	---	Oil ISO VG32	
Part of cooling oil	%	0.500	

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R290 (Propane)		°C	kJ/kg	---
Hot gas	thg	84.933	720.296	
Condensate	tc"	27.000	602.741	
Condensate	tc'	27.000	270.567	
Subcooling	tsc	24.000	262.397	
Evaporation	to'	-25.000	139.600	
Evaporation	tox	-25.000	262.397	
Evaporation	to"	-25.000	546.279	
Superheating	tsh	-18.000	557.154	
Flashgas	x			0.302

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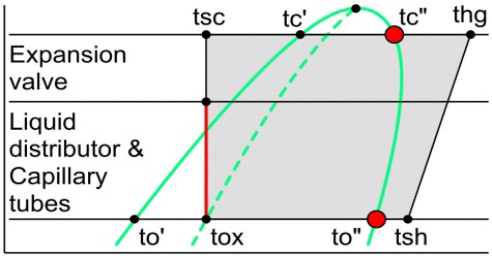
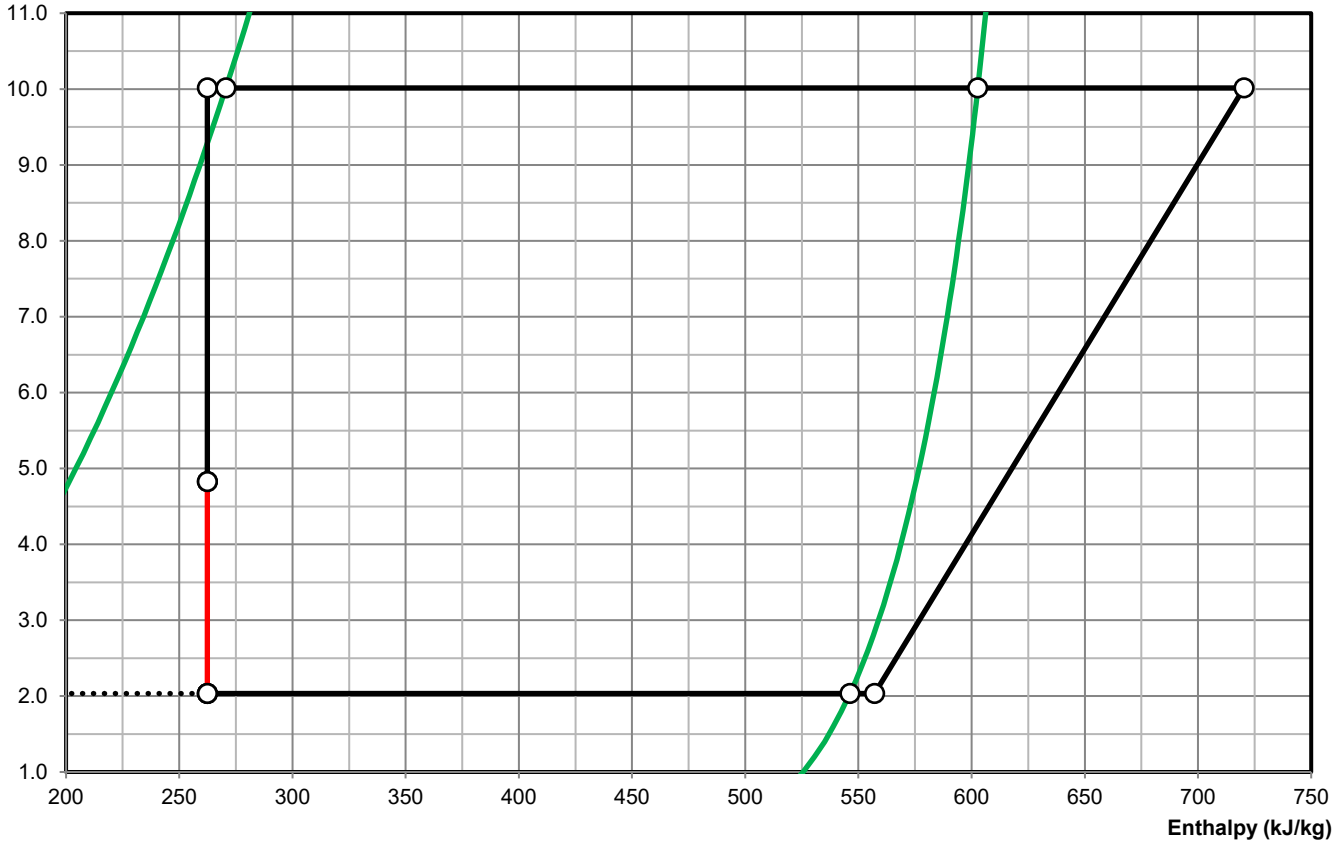
Plant
Object
Position

Pressure / Capacity		bar	kW
Condenser	pc	10.015	348.931
Evaporator	po	2.034	224.612
Refrig. compressor	---	7.980	124.319

Pressure drop	bar	%
Pressure drop expansion valve	5.187	64.999
Pressure drop capillaries	2.793	35.001
Total	7.980	100.000



Pressure (bar)



Hot gas defrosting (Collector)

Software by www.zcs.ch

Number of circuits (NC)	Piece	96.000	
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	2743.296	(100.00%)
Type of cooling oil	---	Oil ISO VG32	
Part of cooling oil	%	0.500	

R290 (Propane)

Hot gas	t1	°C	84.933	
Hot gas	h1	kJ/kg	720.296	
Condensate"	tc1	°C	27.000	
Pressure	p1	bar	10.015	
Hot gas	t2	°C	84.300	
Hot gas	h2	kJ/kg	720.296	
Condensate"	tc2	°C	24.560	
Pressure	p2	bar	9.415	
Refrig. compressor	Qc	kW	83.542	(67.20%)
Hot gas	h3	kJ/kg	610.664	
Hot gas	t3	°C	29.685	

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	5.260
Defr. cycle		h	12.000
Frost energy		kWh	63.120
Defr. time		h	0.756
Defr. time		min	45.333

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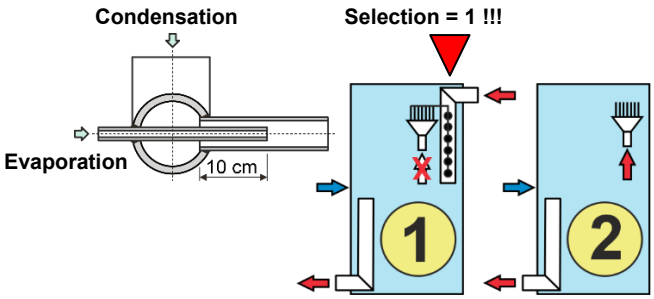
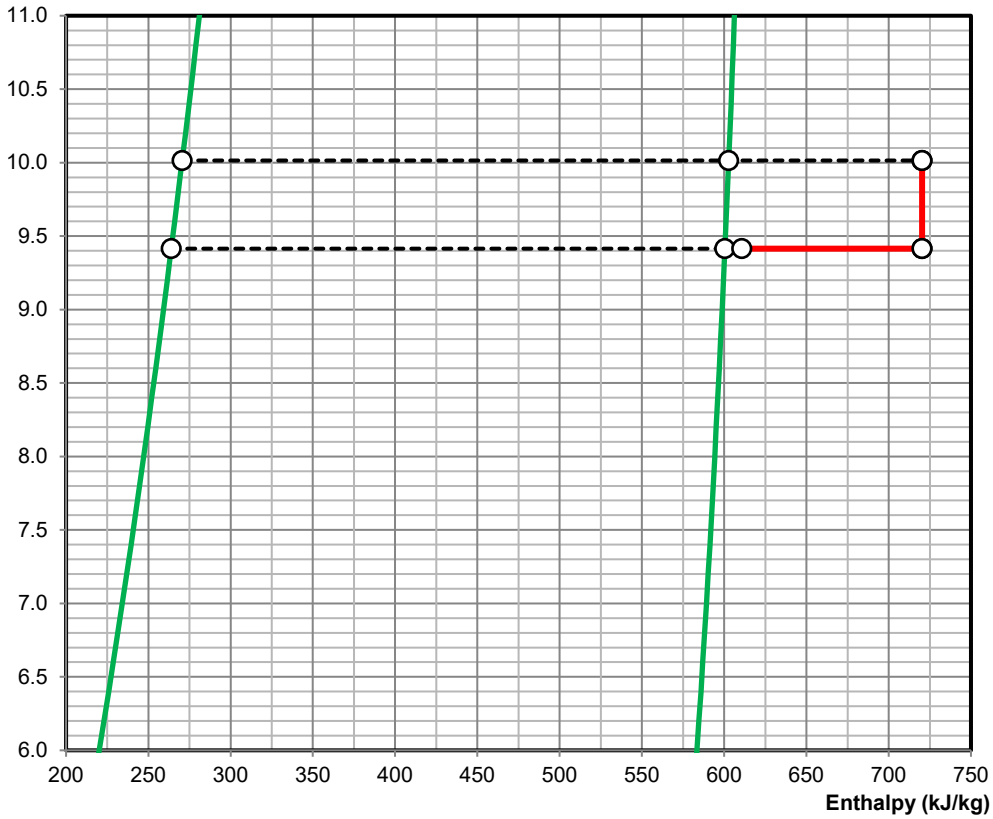
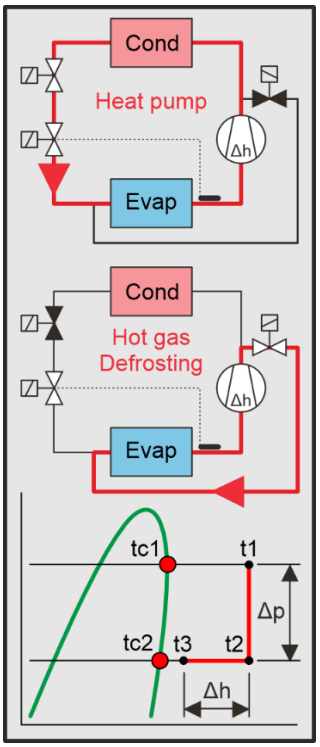


Pressure (bar)





Hot gas defrosting

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

Number of circuits (NC)	Piece	96.000	
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	1008.161	(36.75%)
Type of cooling oil	---	Oil ISO VG32	
Part of cooling oil	%	0.500	

R290 (Propane)

Hot gas	t1	°C	84.933	
Hot gas	h1	kJ/kg	720.296	
Condensate"	tc1	°C	27.000	
Pressure	p1	bar	10.015	
Hot gas	t2	°C	81.455	
Hot gas	h2	kJ/kg	720.296	
Condensate"	tc2	°C	11.936	
Pressure	p2	bar	6.722	
Refrig. compressor	Qc	kW	34.436	(27.70%)
Hot gas	h3	kJ/kg	597.329	
Hot gas	t3	°C	17.134	

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop capillaries	dp	bar	2.793
Pressure drop total	dp	bar	3.293
Frost capacity		kW	5.260
Defr. cycle		h	12.000
Frost energy		kWh	63.120
Defr. time		h	1.833
Defr. time		min	109.977

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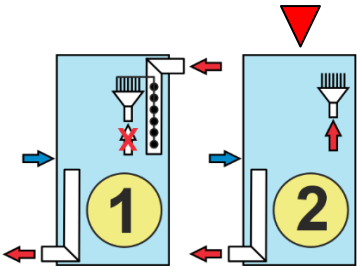
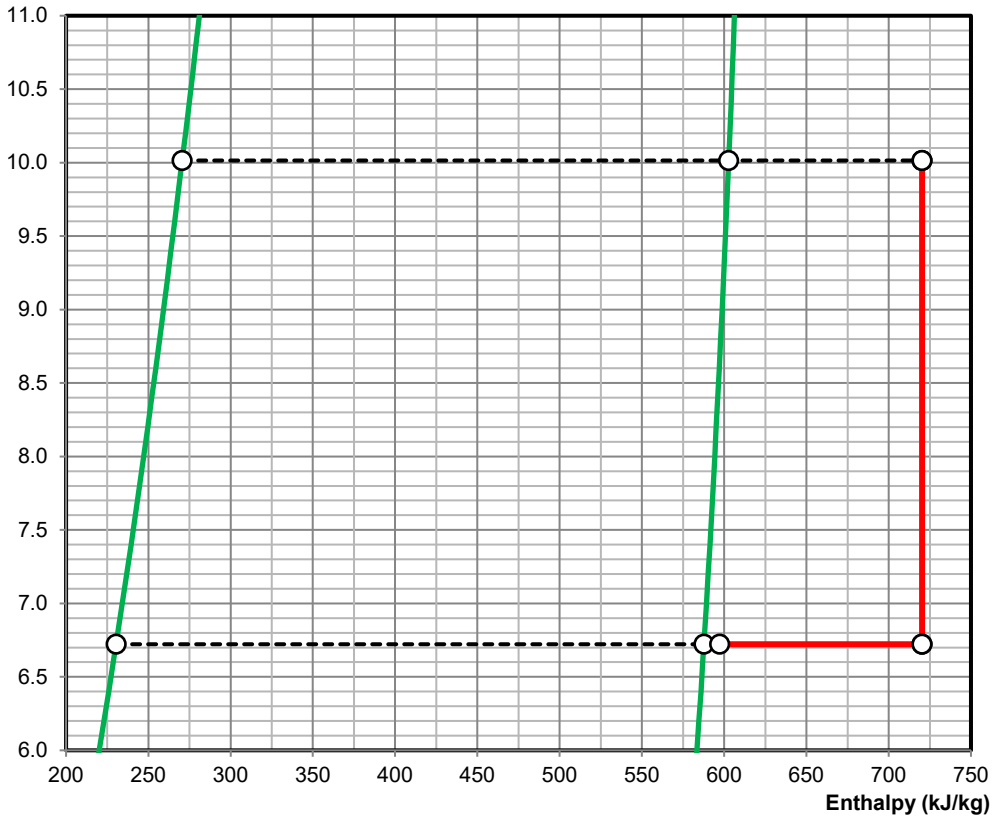
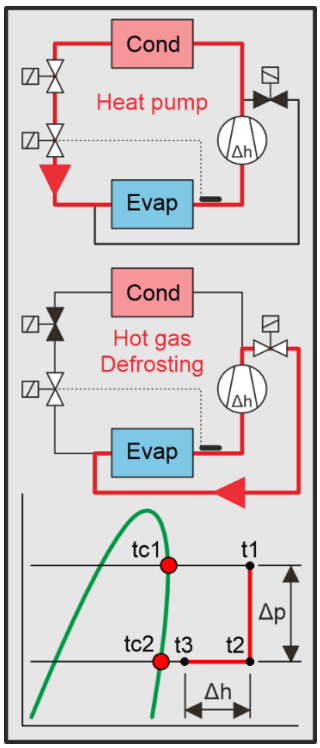
Plant
Object
Position

Selection = 2 !!!



Pressure (bar)



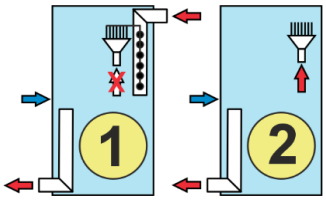


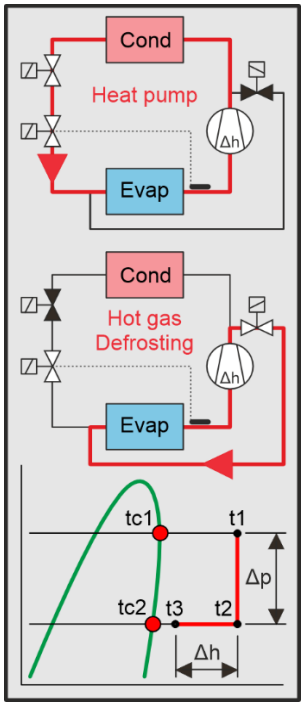
Hot gas defrosting

Evaporator

Number of circuits (NC)	Piece	96.00
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	2743.30
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.50

Selection = 1 !!!





R290 (Propane)

Hot gas	thg	°C	84.933
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	---	0.302

Pressure / Capacity		**bar**	**kW**
Condenser	pc	10.015	348.931
Evaporator	Po	2.034	224.612
Refrig. compressor	---	7.980	124.319

Pressure drop	**bar**	**%**
Pressure drop expansion valve	5.187	64.999
Pressure drop capillaries	2.793	35.001
Total	7.980	100.000

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Object
Position

Software by www.zcs.ch

Hot gas defrosting (Collector)			**Selection = 1 !!!**	**Selection = 2 !!!**
Refrig. compressor	---	kW	83.542	34.436
Pressure	p2	bar	9.415	6.722
Hot gas	t2	°C	84.300	81.455
Hot gas	t3	°C	29.685	17.134
Condensate"	tc2	°C	24.560	11.936
Pressure drop total	dp	bar	0.600	3.293
Frost capacity	---	kW	5.260	5.260
Defr. cycle	---	h	12.000	12.000
Frost energy	---	kWh	63.120	63.120
Defr. time	**---**	**h**	**0.756**	**1.833**
Availability	**---**	**%**	**93.704**	**84.725**

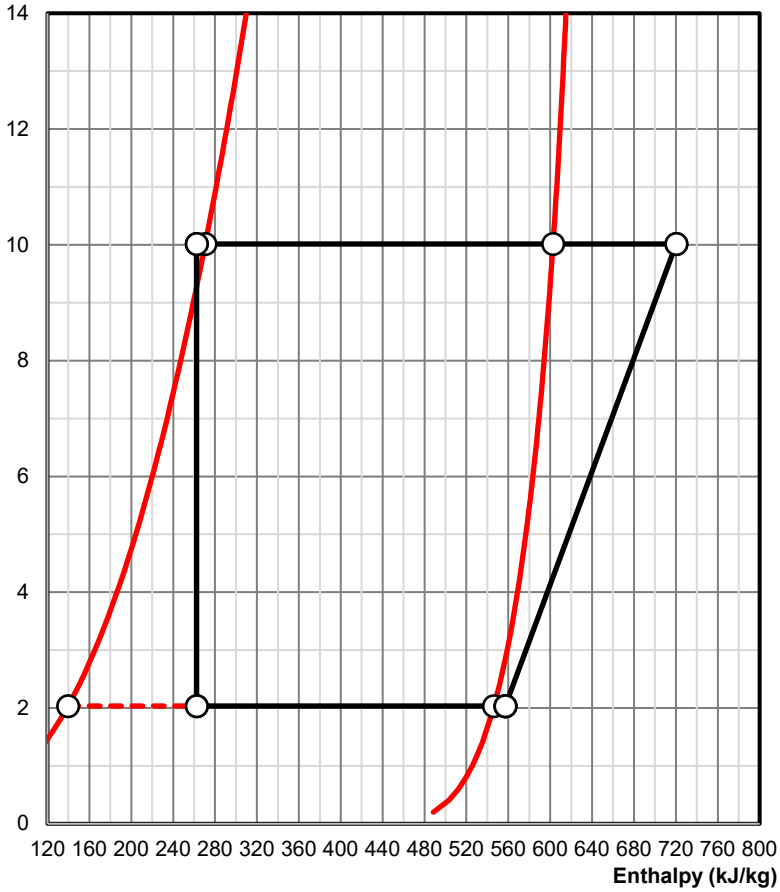
Changeover operation			**Selection = 1 !!!**	**Selection = 2 !!!**
Condenser	**---**	**kW**	**348.931**	**139.352**
Evaporator	**---**	**kW**	**224.612**	**93.665**
Refrig. compressor	**---**	**kW**	**124.319**	**45.687**

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.

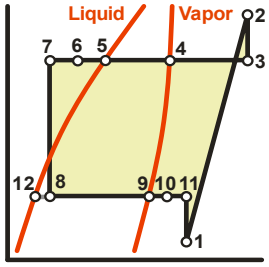
Refrigerant R290 (Propane) Software by www.zcs.ch

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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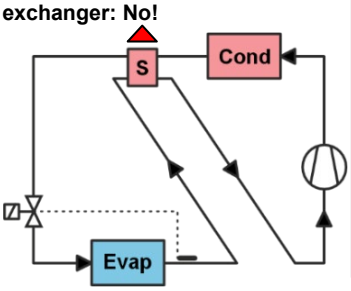
Plant
Object
Position

Heat exchanger: No!



Refrig. compressor	bar	°C	kJ/kg	kW	kg/h	(n)	
1 = Refrig. compressor	2.034	-18.000	557.154				
2 = Refrig. compressor	10.015	84.933	720.296				
Difference			163.142	124.319	2743.296		
Polytrophic exponent (n)						1.270	
Condenser	bar	°C	kJ/kg	kW	kg/h	COP	
3 = Hot gas Condenser	10.015	84.933	720.296				
4 =Condensation'' (Vapor)	10.015	27.000	602.741				
5 =Condensation' (Liquid)	10.015	27.000	270.567				
6 = Subcooling Condenser	10.015	24.000	262.397				
Difference			457.898	348.931	2743.296	2.807	
Subcooling additional	bar	°C	kJ/kg	kW	kg/h		
6 = Subcooling Condenser	10.015	24.000	262.397				
7 = Subcooling additional	10.015	24.000	262.397				
Difference			0.000	0.000	2743.296		
Evaporator	bar	°C	kJ/kg	kW	kg/h	COP	Flashgas
12 =Evaporation' (Liquid)	2.034	-25.000	139.600				
8 = Evaporator Injection point	2.034	-25.000	262.397				0.302
9 = Evaporator'' (Vapor)	2.034	-25.000	546.279				
10 = Evaporator Superheating	2.034	-18.000	557.154				
Difference			294.756	224.612	2743.296	1.807	
Superheating additional	bar	°C	kJ/kg	kW	kg/h		
10 = Superheating Evaporator	2.034	-18.000	557.154				
11 = Superheating additional	2.034	-18.000	557.154				
Difference			0.000	0.000	2743.296		
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)	21.706	126.385	9.721	0.068	72.100	76.100	2 ½"
Condensation' (Liquid)	489.220	5.607	1.612	0.035	39.000	42.000	1 ½"
Evaporation' (Liquid)	560.614	4.893	0.930	0.043	51.000	54.000	2"
Evaporation'' (Vapor)	4.638	591.462	10.697	0.140	159.300	168.300	NW 150

Pressure drop capillaries

Software by www.zcs.ch

Number of circuits (NC)	Piece	96.000
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	2743.296
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.000

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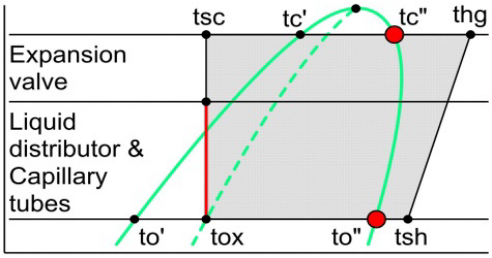
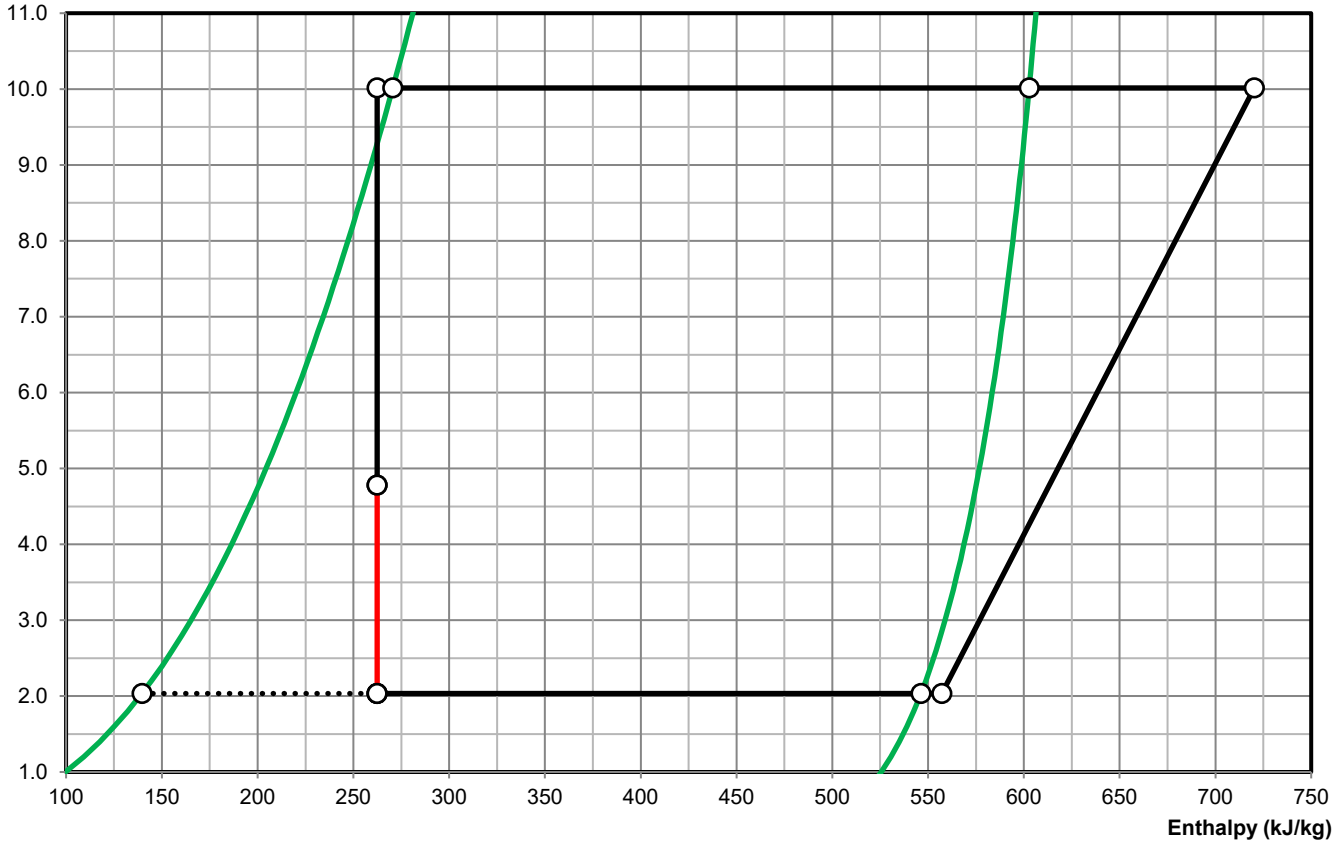
R290 (Propane)		°C	kJ/kg	---
Hot gas	thg	84.933	720.296	
Condensate	tc"	27.000	602.741	
Condensate	tc'	27.000	270.567	
Subcooling	tsc	24.000	262.397	
Evaporation	to'	-25.000	139.600	
Evaporation	tox	-25.000	262.397	
Evaporation	to"	-25.000	546.279	
Superheating	tsh	-18.000	557.154	
Flashgas	x			0.302

Pressure / Capacity		bar	kW
Condenser	pc	10.015	348.931
Evaporator	po	2.034	224.612
Refrig. compressor	---	7.980	124.319

Pressure drop	bar	%
Pressure drop expansion valve	5.233	65.577
Pressure drop capillaries	2.747	34.423
Total	7.980	100.000



Pressure (bar)



Condensation (Collector)

Software by www.zcs.ch

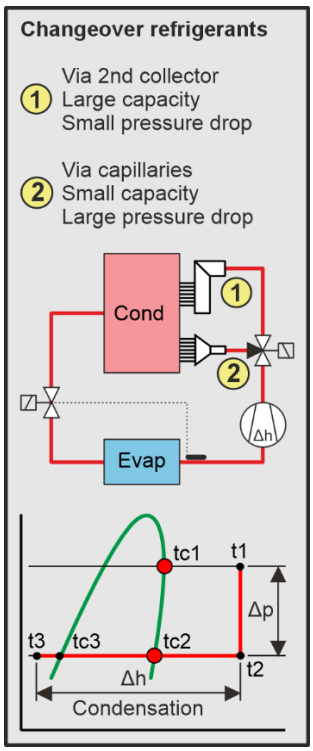
Number of circuits (NC)	Piece	96.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	2743.296
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.000

R290 (Propane)

Hot gas	t1	°C	84.933
Hot gas	h1	kJ/kg	720.296
Condensate"	tc1	°C	27.000
Pressure	p1	bar	10.015
Hot gas	t2	°C	84.300
Hot gas	h2	kJ/kg	720.296
Condensate"	tc2	°C	24.560
Pressure	p2	bar	9.415
Condensate'	tc3	°C	24.560
Subcooling	t3	°C	21.560
Subcooling	h3	kJ/kg	256.103
Condenser	Q	kW	353.727
Refrig. compressor	Q	kW	124.319
Evaporator	Q	kW	229.408

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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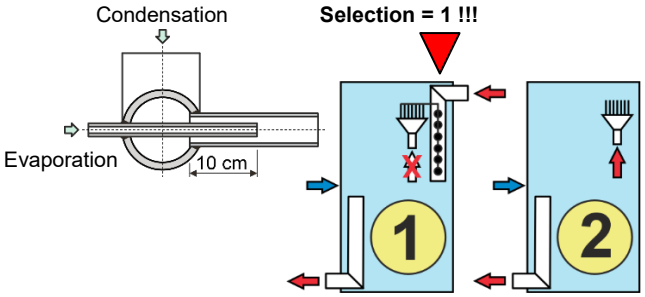
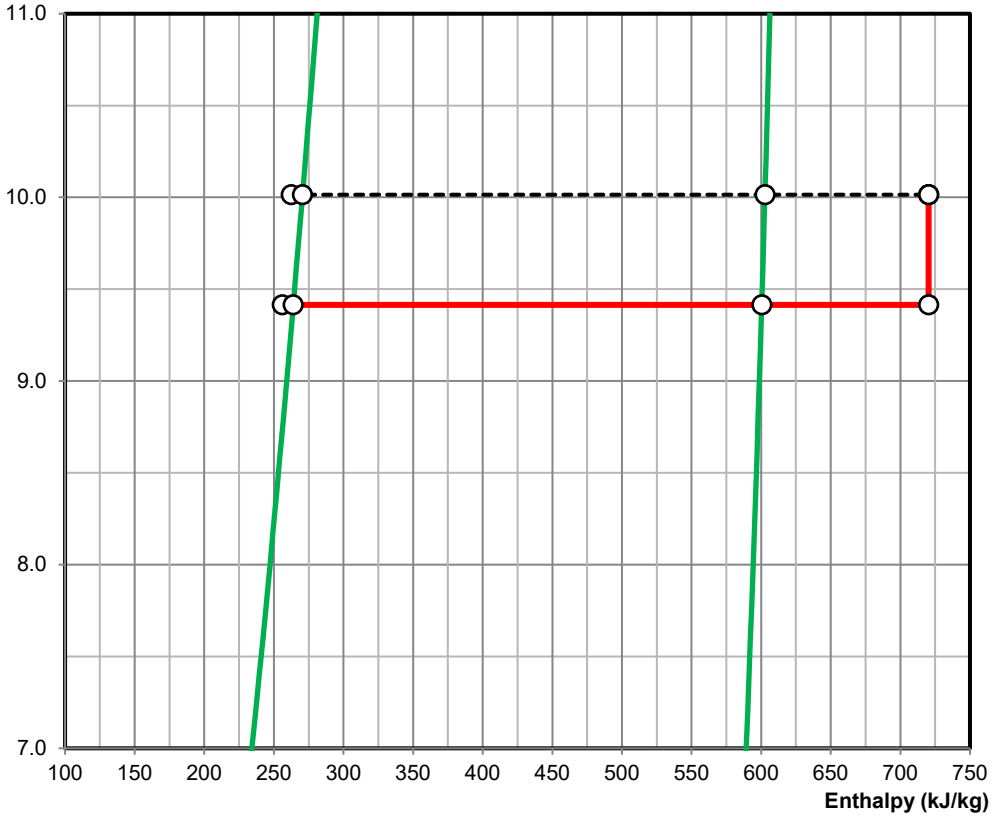
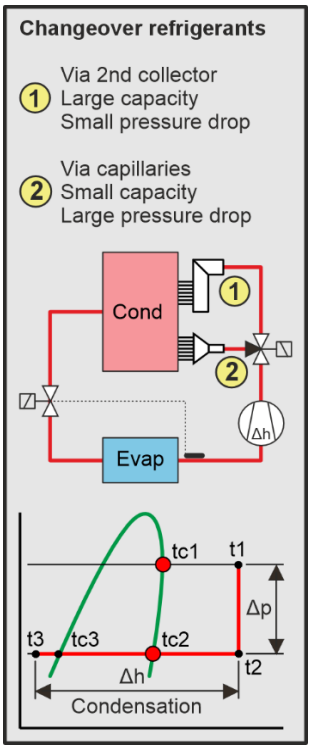


Pressure (bar)





Hot gas defrosting

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

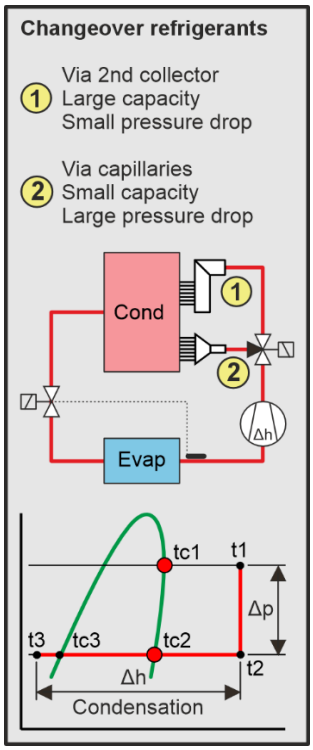
Number of circuits (NC)	Piece	96.000
Length	mm	2760.000
Outside diam.	mm	6.000
Thickness	mm	1.000
Inside diam.	mm	4.000
Roughness	mm	0.002
Mass flow	kg/h	2468.967
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.000

R290 (Propane)

Hot gas	t1	°C	84.933
Hot gas	h1	kJ/kg	720.296
Condensate"	tc1	°C	27.000
Pressure	p1	bar	10.015
Hot gas	t2	°C	82.635
Hot gas	h2	kJ/kg	720.296
Condensate"	tc2	°C	17.507
Pressure	p2	bar	7.828
Condensate'	tc3	°C	17.507
Subcooling	t3	°C	14.507
Subcooling	h3	kJ/kg	237.202
Condenser	Q	kW	331.317
Refrig. compressor	Q	kW	111.887
Evaporator	Q	kW	219.430

Pressure drop

Pressure drop valves, pipes	dp	bar	0.500
Pressure drop capillaries	dp	bar	1.686
Pressure drop total	dp	bar	2.186



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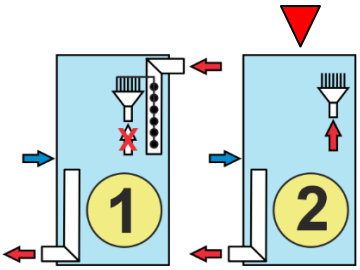
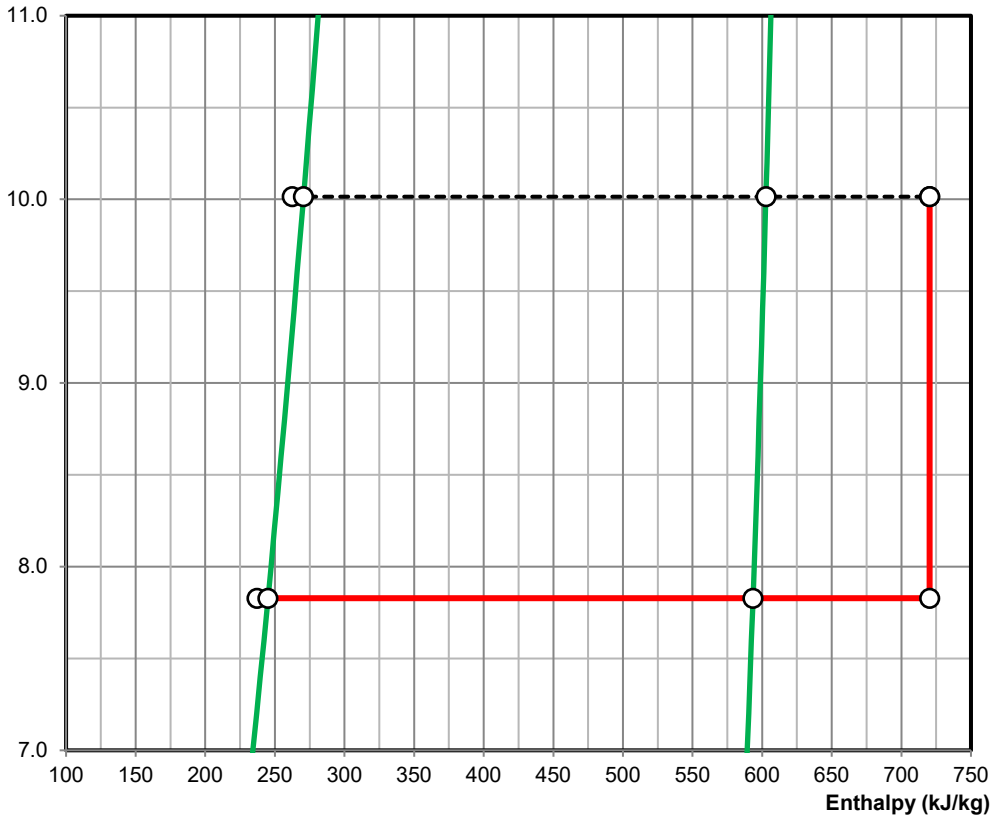
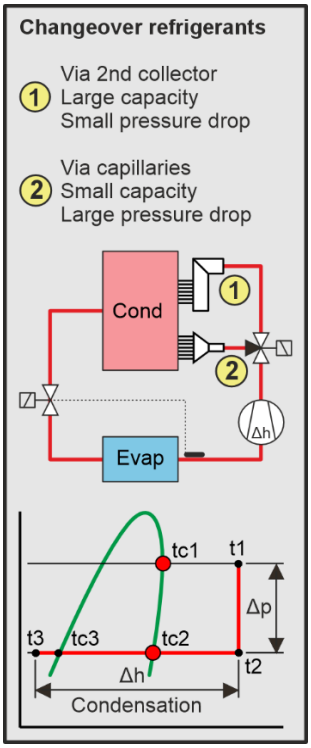
Selection = 2 !!!



Pressure (bar)



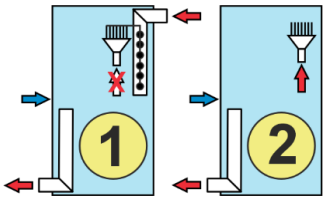


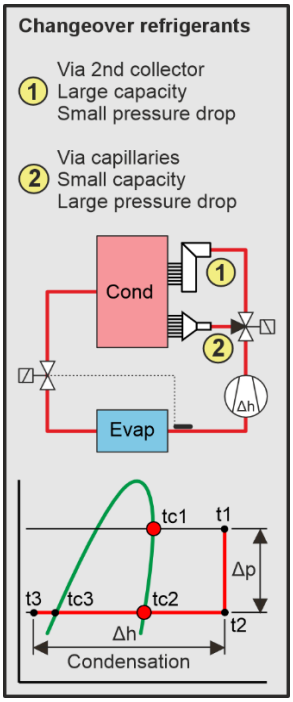
Hot gas defrosting

Evaporator

Number of circuits (NC)	Piece	96.00
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	2743.30
Type of cooling oil	---	Oil ISO VG32
Part of cooling oil	%	0.00

Selection = 1 !!!





R290 (Propane)

Hot gas	thg	°C	84.933
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	---	0.302

Pressure / Capacity		**bar**	**kW**
Condenser	pc	10.015	348.931
Evaporator	po	2.034	224.612
Refrig. compressor	---	7.980	124.319

Pressure drop	**bar**	**%**
Pressure drop expansion valve	5.233	65.577
Pressure drop capillaries	2.747	34.423
Total	7.980	100.000

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Condensation			**Selection = 1 !!!**	**Selection = 2 !!!**
Refrig. compressor	---	kW	124.319	111.887
Pressure	p2	bar	9.415	7.828
Pressure drop total	dp	bar	0.600	2.186
Hot gas	t2	°C	84.300	82.635
Condensate''	tc2	°C	24.560	17.507
Condensate'	tc3	°C	24.560	17.507
Subcooling	t3	°C	21.560	14.507

Changeover operation			**Selection = 1 !!!**	**Selection = 2 !!!**
Condenser	**---**	**kW**	**348.931**	**331.361**
Evaporator	**---**	**kW**	**224.612**	**219.474**
Refrig. compressor	**---**	**kW**	**124.319**	**111.887**

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.