Defrosting at the heat pump injection evaporator

The required heating capacity of an air-to-water heat pump for a **medium-sized single-family house** is about **10 kW**, if you want to heat with it and produce hot water of 57°C.

Due to the limit service life of the refrigerant compressor, the duty cycle must be kept as short as possible. A colleague had to **replace the refrigerant compressor every 5 years**, although guidelines state that all system-relevant components must be designed for a service life of 15 years.

In addition, the storage tank for heating and hot water was also much too small, which meant, that the **heat pump ran almost constantly**.

For environmental reasons, the **refrigerant R290 (Propane) should be used at a GWP of 3** at a condensation temperature of 60°C and an evaporation temperature of -17°C in winter, assuming that the air can never get colder than -11°C.

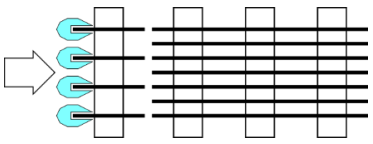
With this large temperature spread, a two-stage refrigeration circuit or, in the case of single-stage operation, a coaxial heat exchanger would actually be appropriate, which supercool the condensate and superheat the suction gas. **For cost reasons, neither is used**, which is why far too large a refrigerant circulation quantity is required.

Also, for cost reasons, **an oil separator was dispensed with**, which means, that far too much oil is in circulation and has to be replenished again and again according to the oil level indicator message, which switches off the compressor. It goes without saying, that **the heating capacity of the air-to-water heat pump drops drastically in the process**.

Again and again, it has to be found, that in winter the defrosting times on the heat pump injection evaporators **are far too long and the defrosting intervals are far too short**, which makes the availability of the heat pump ad absurdum. There are several reasons for this, which we have listed above and below.

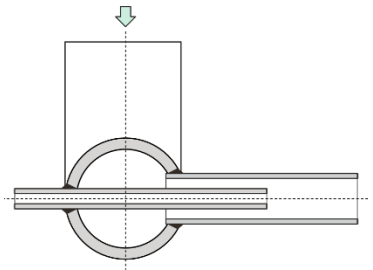
The fin pitch is much too small, which is why **tulip-like ice plugs form on the leading edge within far too short a time** and drastically reduce the air inlet cross-section. We therefore recommend, that the first two rows of tubes be designed with double fin spacing. In most cases, the heat exchanger area is much too small, which is why the frost thickness on the fins increases quickly and the **air flow rate decreases**.

Optimal execution



The best defrosting option would be the one with electric defrost heating rods. The second-best defrosting option would be the one with refrigerant hot gases via a second collector, but this would require a changeover valve. Both variants are out of the question for cost reasons, which is why only the **worst defrosting variant** is used, the one with **refrigerant hot gases via the capillary**. As a result of the high pressure drop, only a fraction of the nominal refrigerant circulation, which leads to unacceptable defrosting times and far too short defrosting intervals. If you did everything correctly, **you would never be competitive with other energy systems**.

Optimal execution

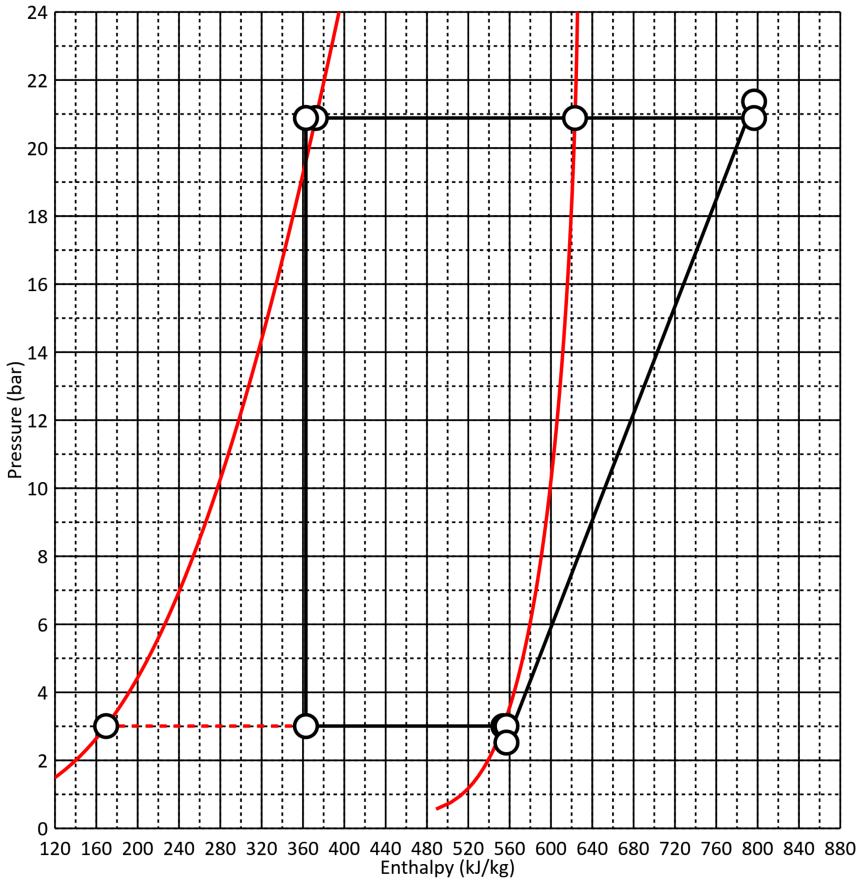


So, if you want to use an air-to-water heat pump for your single-family home without all these defects, you can't avoid going to a specialist with a detailed list of requirements and planning for **30,000 Swiss francs instead of 15,000**.

Subsequently, a reasonable defrosting interval of 6 hours was calculated.

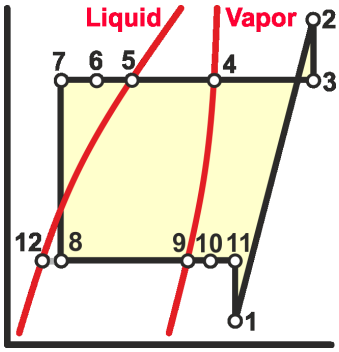
Page 2: Single-stage refrigeration circuit of R290 (software AHH-REF).
Page 3: Injection evaporator with **electric defrost heating rods** (software HEH), **defrost time 5.4 minutes**.
Page 4: R290 single-stage refrigeration circuit (CAP software).
Page 5: **Hot gas defrosting via a 2nd collector** (software CAP), **defrosting time 10.6 minutes**.
Page 6: **Hot gas defrosting via the capillaries** (CAP software), **defrosting time 28.2 minutes**.

Refrigerant **R290 (Propane)**



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=Evaporator' (Liquid)



$$T^n p^{(1-n)} = const$$

$$x = \frac{n}{1-n} = \frac{ln(p_2/p_1)}{ln(T_1/T_2)}$$

$$n = \frac{x}{1+x}$$

Refrig. compressor	bar	°C	kJ/kg	kW	kg/h	(n)	
1=Refrig. compressor	2.220	-16.416	558.820				
2=Refrig. compressor	21.667	134.318	806.456				
Difference			247.637	5.558	80.794		
Polytrophic exponent (n)						1.254	
Condenser	bar	°C	kJ/kg	kW	kg/h	COP	
3=Hot gas Condenser	21.167	133.932	806.456				
4=Condensation'' (Vapor)	21.167	60.000	627.355				
5=Condensation' (Liquid)	21.167	60.000	368.141				
6=Subcooling Condenser	21.167	57.000	358.309				
Difference			448.147	10.058	80.794	1.810	
Subcooling additional	bar	°C	kJ/kg	kW	kg/h		
6=Subcooling Condenser	21.167	57.000	358.309				
7=Subcooling additional	21.167	57.000	358.309				
Difference			0.000	0.000	80.794		
Evaporator	bar	°C	kJ/kg	kW	kg/h	COP	Flashgas
12=Evaporator' (Liquid)	2.720	-17.000	158.493				
8=Evaporator Injection point	2.720	-17.000	358.309				0.503
9=Evaporator'' (Vapor)	2.720	-17.000	555.615				
10=Evaporator Superheating	2.720	-15.000	558.820				
Difference			200.511	4.500	80.794	0.810	
Superheating additional	bar	°C	kJ/kg	kW	kg/h		
10=Superheating Evaporator	2.720	-15.000	558.820				
11=Superheating additional	2.720	-15.000	558.820				
Difference			0.000	0.000	80.794		
Pressure drop	bar	°C	kJ/kg				
2-3=Pressure drop	0.500						
11-1=Pressure drop	0.500						

Connections	p	V	c max	di min	di eff	da eff	Ø eff
----	kg/m³	m³/h	m/s	m	mm	mm	---
Condensation'' (Vapor)	49.406	1.635	7.039	0.009	14.000	16.000	3/8"
Condensation' (Liquid)	427.990	0.189	1.852	0.006	14.000	16.000	3/8"
Evaporator' (Liquid)	550.714	0.147	1.123	0.007	14.000	16.000	3/8"
Evaporator'' (Vapor)	6.089	13.268	11.699	0.020	25.000	28.000	1"

DX evaporator: 35/35/12-12R-16T-630A-3.1PA-8C-Cu/Al/AISI 304 Software by www.zcs.ch

Capacity	kW	4.500	------ sensible:	3.666
Surface reserve	%	1.562	latent:	0.726
Present surface	m2	81.490	frost:	0.108
Required surface	m2	80.237	2.0 % Oil ISO VG46	
k-coeff.	W/m2K	17.044		
Average temp. diff. (100.00 %)	K	3.290		

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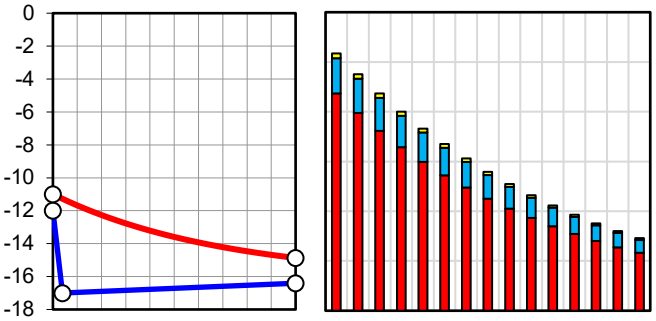
Plant
Object
Position

Air humid (ff=0.00005 m2K/W)		Inlet	Outlet	Definition
Height over sea level	m			540.000
Pressure	hPa			949.653
Temp.	°C	-11.000	-14.869	-10.000
Rel. humidity	%	90.000	99.636	100.000
Abs. humidity	g/kg	1.394	1.082	1.695
Density humid	kg/m3	1.261	1.280	1.256
Enthalpy humid	kJ/kg	-7.610	-12.282	-5.854
Volume flow humid	m3/h	2688.441	2647.443	2700.000
Mass flow dry	kg/h	3384.499	3384.499	3384.499
Condensate flow	kg/h		1.053	
Surface temperature	°C	-13.595	-15.559	
Velocity	m/s	2.117	2.084	2.126
Pressure drop (dry 112 Pa)	Pa		118.713	

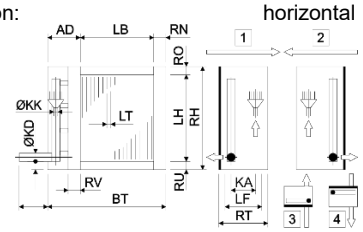
R290 (Propane) Evaporation 2.720 bar (ff=0.00005 m2K/W)		
Condensate''	°C	60.000
Condensate'	°C	60.000
Subcooling	°C	57.000
Evaporation''	°C	-17.000
Superheating	°C	-12.000
Mass flow	kg/h	80.456
Volume flow	m3/h	13.213
Velocity	m/s	4.534
Pressure drop Evaporation	K	0.589
Pressure drop Capillary	bar	4.761

Part of steam on the inject point 50.32 %



Defr. capacity 7.2 kW - Frost energy 0.65 kWh - Frost thickness 0.19 mm - Defr. cycle 6.00 h - Defr. time 0.09 h - Availability 98.50 %

Tubes total		Piece	192	Tubes:	ribbed	Cu
Tubes blank		Piece	0	Tubes:		in line
Tube rows on the depth		Piece	12	Collectors:		Cu
Tube rows on the height		Piece	16	Connections:		Cu
Tube coupling in series		Piece	24	Fins:	ribbed	Al
Number of circuits (NC)		Piece	8	Frame:	2.0 mm	AISI 304
Volume		l	16	Circulations:	1	Default
Weight		kg	71	Capillary:	4.00 x 1.00 x 700.00 mm	
Cond. connection	KK	mm	12	Protection:		without
Steam connection	KD	mm	22	Protection:		---
Frame height	RH	mm	620	Air flow direction:		horizontal
Frame width	BT	mm	776			
Frame depth	RT	mm	440			
Finned height	LH	mm	560			
Finned width	LB	mm	630			
Finned depth	LF	mm	420			
Frame on top	RO	mm	30			
Frame on bottom	RU	mm	30			
Frame in front	RV	mm	30			
Frame on back (~53mm)	RN	mm	53			
Collector covering	AD	mm	93			
Collector distance	KA	mm	385			
Fin spacing	LT	mm	3.130			
Fin thickness	LD	mm	0.200	Delivery:		5-6 weeks
Tube diameter	DA	mm	12.400	Validity:		12 weeks
Tube thickness	S	mm	0.400	Condit.:		net, prepaid address
Tube interval on the height	S1	mm	35.000	Payment:		30 days net
Tube interval on the depth	S2	mm	35.000	**Price net:**	**With el. rods**	**EUR 2275.00**



El. heat rods:18 x ø 12 x 700 mm à 400 W
Frost thickness: 0.186 mm
Fin spacing: 1x6.0+11x3.0 mm
Both end plates perforated for el.heat rods

Pressure drop capillaries

Software by www.zcs.ch

Number of circuits (NC)	Piece	8.000
Length	mm	700.000
Outside diam.	mm	4.000
Thickness	mm	1.000
Inside diam.	mm	2.000
Roughness	mm	0.002
Mass flow	kg/h	80.456
Type of cooling oil	---	Oil ISO VG46
Part of cooling oil	%	2.000

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R290 (Propane)		°C	kJ/kg	---
Hot gas	thg	134.000	806.638	
Condensate	tc"	60.000	627.355	
Condensate	tc'	60.000	368.141	
Subcooling	tsc	57.000	358.309	
Evaporation	to'	-17.000	158.493	
Evaporation	tox	-17.000	358.309	
Evaporation	to"	-17.000	555.615	
Superheating	tsh	-12.000	563.643	
Flashgas	x			0.503

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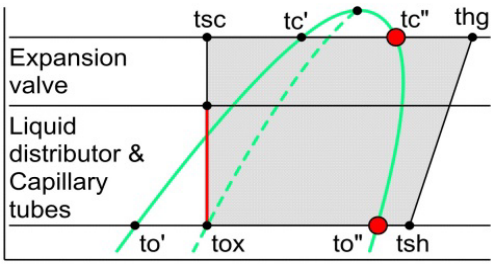
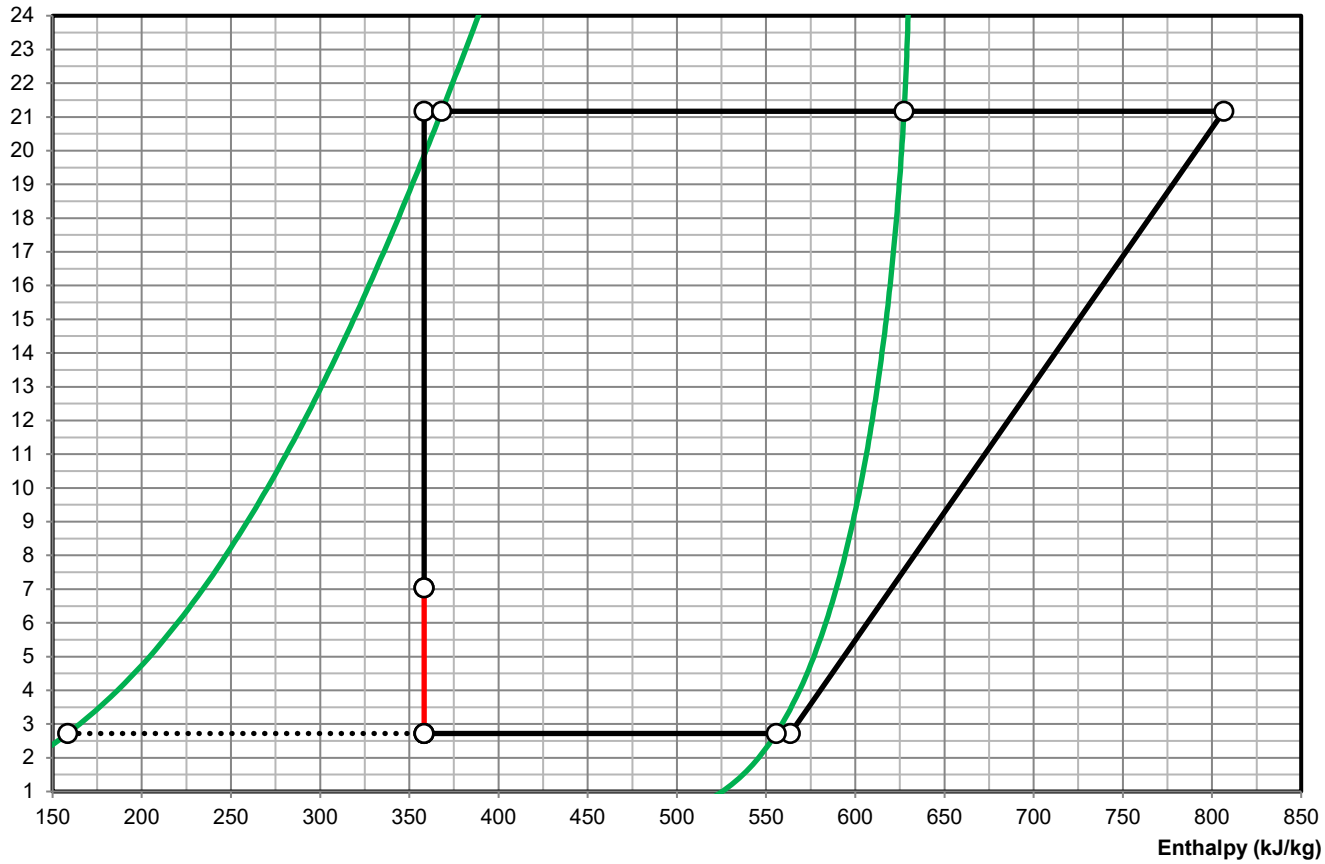
Plant
Object
Position

Pressure / Capacity		bar	kW
Condenser	pc	21.167	10.020
Evaporator	po	2.720	4.589
Refrig. compressor	dp	18.447	5.431

Pressure drop	bar	%
Pressure drop expansion valve	14.127	76.580
Pressure drop capillaries	4.320	23.420
Total	18.447	100.000



Pressure (bar)



Hot gas defrosting Software by www.zcs.ch

Number of circuits (NC)	Piece	8.000
Length	mm	700.000
Outside diam.	mm	4.000
Thickness	mm	1.000
Inside diam.	mm	2.000
Roughness	mm	0.002
Mass flow	kg/h	80.456
Type of cooling oil	---	Oil ISO VG46
Part of cooling oil	%	2.000

R290 (Propane)

Hot gas	t1	°C	134.000
Hot gas	h1	kJ/kg	806.638
Condensate"	tc1	°C	60.000
Pressure	p1	bar	21.167
Hot gas	t2	°C	133.441
Hot gas	h2	kJ/kg	806.638
Condensate"	tc2	°C	58.372
Pressure	p2	bar	20.467
Refrig. compressor	Qc	kW	3.693
Hot gas	h3	kJ/kg	641.401
Hot gas	t3	°C	63.907
Pressure drop collectors	dp	bar	0.200
Pressure drop valves, pipes	dp	bar	0.500
Pressure drop total	dp	bar	0.700
Frost energy		kWh	0.650
Defr. time		h	0.176
Defr. time		min	10.561

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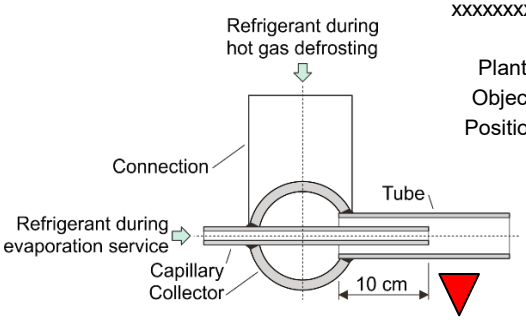
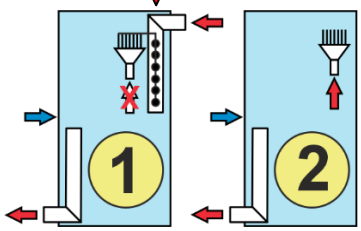
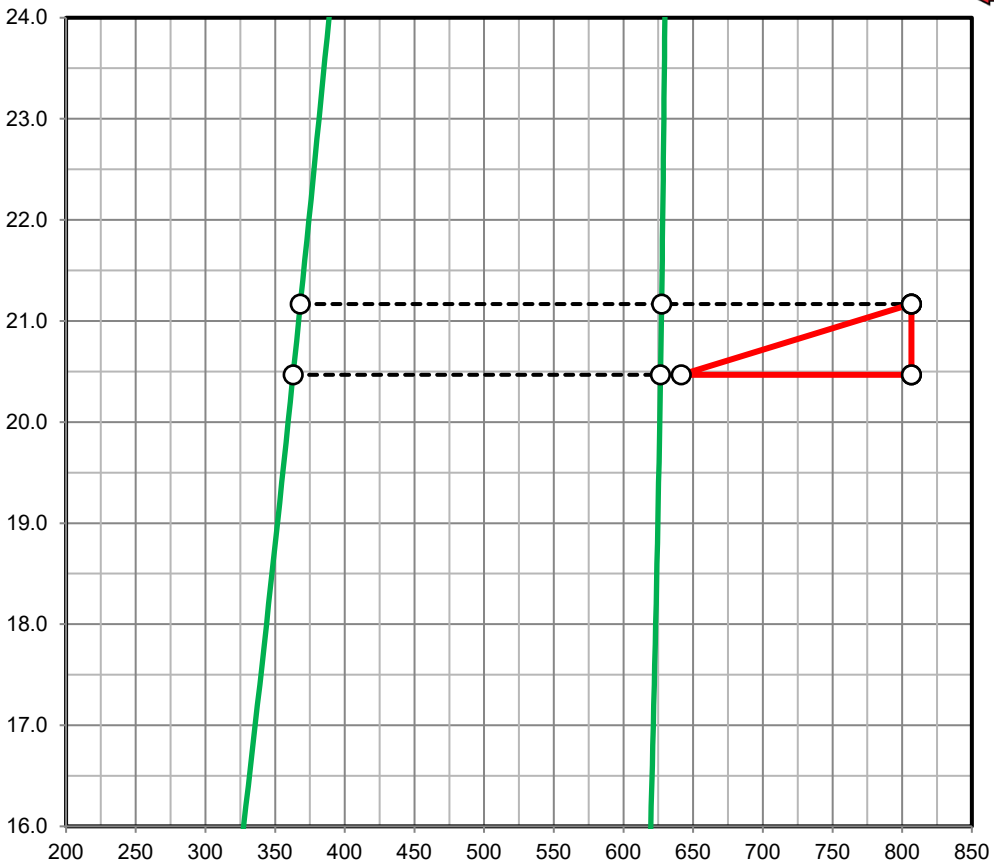
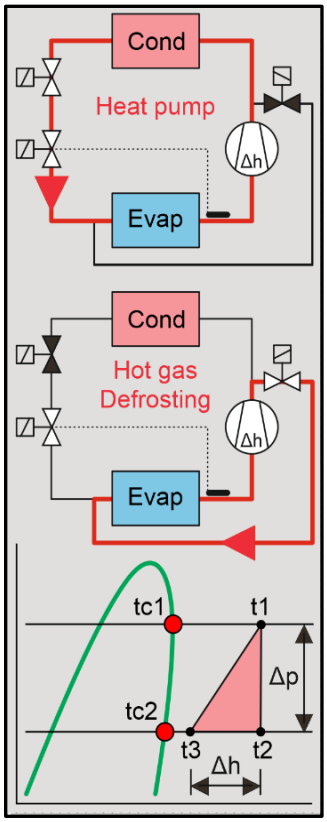




Selection = 1 !!!

Pressure (bar)





Hot gas defrosting

Hot gas defrosting Software by www.zcs.ch

Number of circuits (NC)	Piece	8.000
Length	mm	700.000
Outside diam.	mm	4.000
Thickness	mm	1.000
Inside diam.	mm	2.000
Roughness	mm	0.002
Mass flow	kg/h	30.000
Type of cooling oil	---	Oil ISO VG46
Part of cooling oil	%	2.000

R290 (Propane)

Hot gas	t1	°C	134.000
Hot gas	h1	kJ/kg	806.638
Condensate"	tc1	°C	60.000
Pressure	p1	bar	21.167
Hot gas	t2	°C	133.109
Hot gas	h2	kJ/kg	806.638
Condensate"	tc2	°C	57.398
Pressure	p2	bar	20.056
Refrig. compressor	Qc	kW	1.385
Hot gas	h3	kJ/kg	640.460
Hot gas	t3	°C	62.819
Pressure drop capillaries	dp	bar	0.611
Pressure drop valves, pipes	dp	bar	0.500
Pressure drop total	dp	bar	1.111
Frost energy		kWh	0.650
Defr. time		h	0.469
Defr. time		min	28.163

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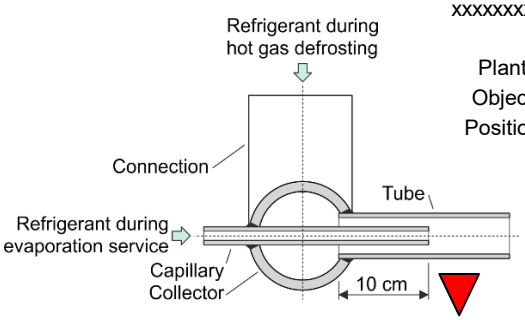
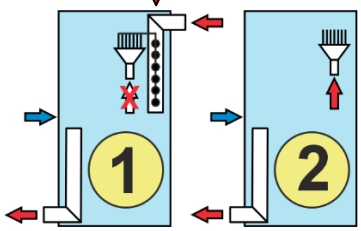
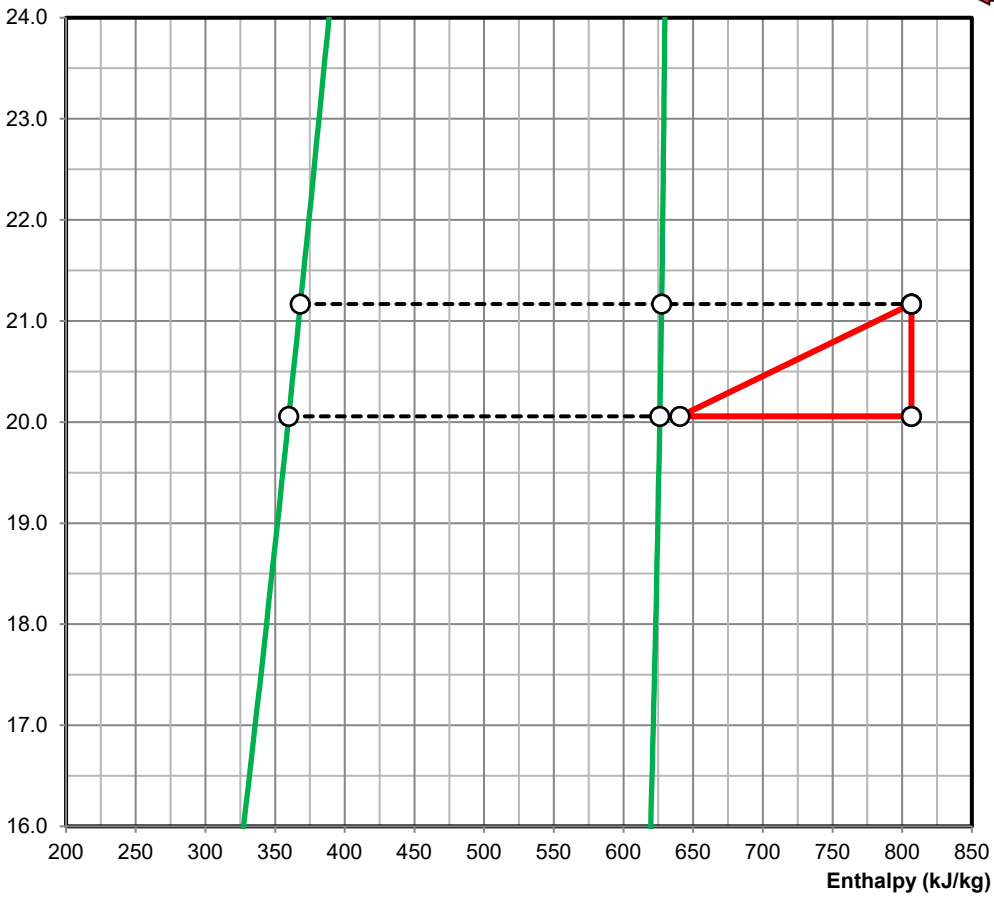
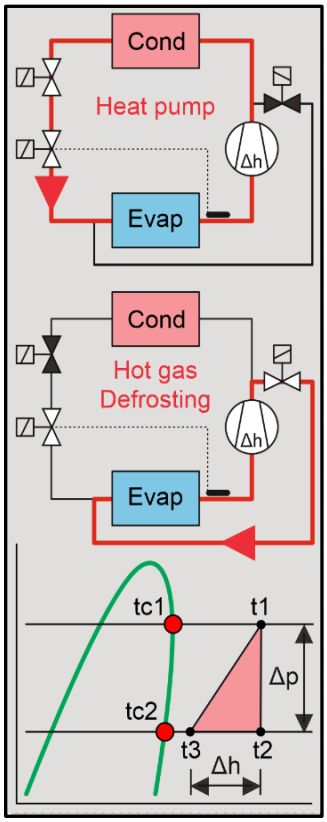




Selection = 2 !!!

Pressure (bar)





Hot gas defrosting