Harmful vapor recovery

When **recovering harmful vapors** contained in gases such as air, 3 software applications (cooler, injection evaporator and pump circulation evaporator) are used:

1. **HEH-G** (Finned heat exchangers)
2. **HEH-SR-G** (Spiral rib heat exchangers)

Any gas with any vapor can be calculated, most **vapors being mixtures of aqueous solutions** in vapor form, using the **Raoult** and **Dalton** laws.

https://de.wikipedia.org/wiki/Raoultsches_Gesetz

$$x_A + x_B = 1 \rightarrow p = x_A p_A + x_B p_B$$

The gas is cooled and the noxious vapors are condensed out. The partial pressure of the steam or the steam mixture plays a decisive role here. The diagram on the right shows the partial pressure of water, acetone and a mixture consisting of 95% water and 5% acetone.

Acetone is very often used industrially as a solvent for greasy and oily surfaces. The lower the partial pressure, the easier it is to condense, which is why pure water vapor is the easiest to condense.

If you want to condense air at 1 bar from 33°C with 20 g/kg water vapor to 2 g/kg, this corresponds to an air outlet temperature of -7.4°C, which can be achieved with brines.

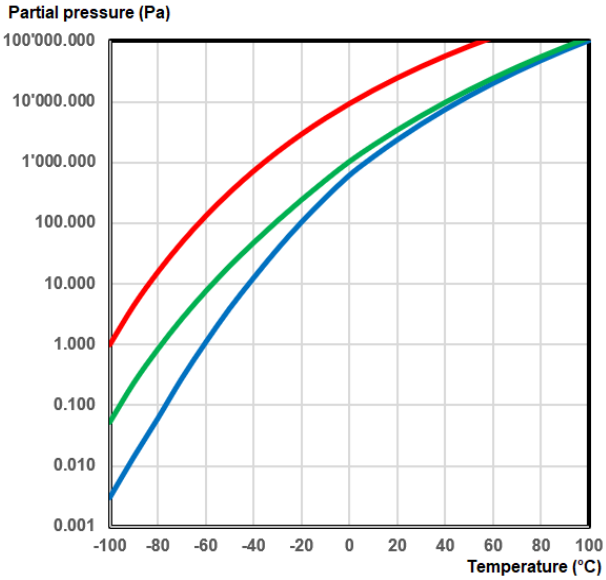
The vapor mixture of 95% water and 5% acetone, also from air at 1 bar at 33°C and 20 g/kg vapor mixture is much more difficult to condense to 2 g/kg because the air outlet temperature is given by -17.8°C has to achieve what one can achieve with brines, see the special Mollier TX diagram on the right.

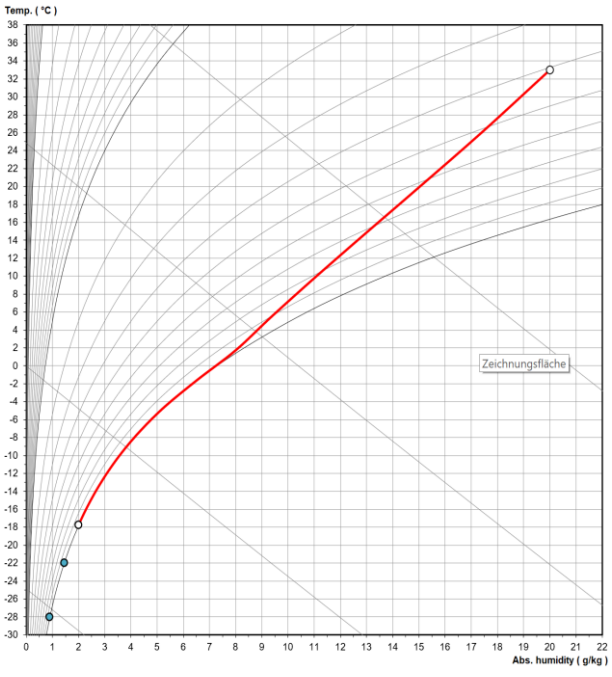
However, if you want to condense air at 1 bar from 33°C with 20 g/kg of pure acetone vapor to 2 g/kg, this corresponds to an air outlet temperature of -62.8°C, which can only be achieved with great effort with brines.

It should also be noted that in the 3 examples, an absolute humidity of 20 g/kg was calculated at the inlet. However, **the relative humidity at the inlet is very different for this condition**, which unfortunately many so-called experts can neither understand nor want.

Coming back to the industrial example of a cabin for degreasing the surfaces of various products, it is therefore absolutely advisable to **continuously dehumidify the vapor mixture of water and acetone with a high number of air changes** in order to be able to do this with moderate coolant temperatures.

Steam	Name	Water	Acetone	Water 95%
Steam	Formula	H2O	C3H6O	Acetone 5%
Steam	CAS	7732-18-5	67-64-1	---
Molecular weight	kg/kMol	18.015	58.079	20.018
Triple point temperature	°C	0.010	-94.650	-4.723
Evaporation-Energy (0°C)	J/kg	2500900.000	558870.000	2403798.500
Frost energy	J/kg	335000.000	96300.000	323065.000





Should someone come up with the abstruse idea of carrying out this cooling with pure external energy, it will only trigger a small investment for the heat exchanger at 12,851 euros, but horrendous operating costs for a cooling capacity of 161.4 kW (80 euros/MWh, 52 x 5 x 8 = 2,080 h/year, 26,857 euros/year), see page 2. If this someone has only a modest idea of economy, he will carry out a large proportion of the required cooling capacity with energy recovery. In this case, 3 heat exchangers are required for a total of 35,116 euros. On the other hand, the operating costs are reduced because only a cooling capacity of 90.6 kW (80 euros/MWh, 52 x 5 x 8 = 2,080 h/year, 15,076 euros/year) is required, see page 3 and the following. **If interest is not taken into account, the payback period is 2 years!**

Cooler: 40/35/16-24R-26T-1064A-4.5PA-52C-AISI 316/AlMg3/AISI 316 Software by www.zcs.ch

Capacity	kW	161.391	------ sensible:	85.470
Surface reserve	%	0.784	latent:	73.935
Present surface	m2	362.032	frost:	1.986
Required surface	m2	359.215		
k-coeff.	W/m2K	16.894	---------- ffi:	5.000E-05
Average temp. diff.	K	26.595	ffa:	5.000E-05

LOGO

Company
Branch
Street
Country / ZIP / City

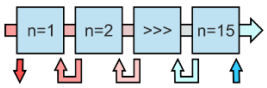
Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

City, 11.11.2022
With the compliments of

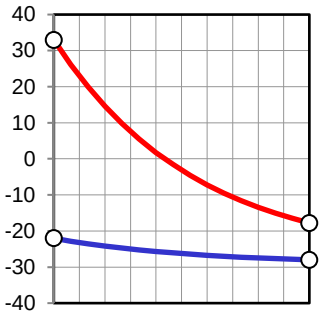
Representative
Direct dialing
xxxxxxxxxx

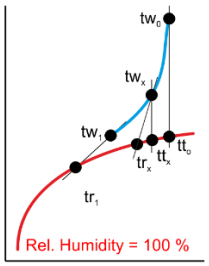
Software by www.zcs.ch

Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	33.000	-17.780	7.610
Rel. humidity	%	40.582	100.000	49.232
Abs. humidity	g/kg	20.000	2.000	5.780
Density humid	kg/m3	1.128	1.364	1.238
Enthalpy humid	kJ/kg	82.508	-13.135	21.629
Volume flow humid	m3/h	5424.460	4407.811	4874.091
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Condensate flow	kg/h		108.001	
Surface temperature	°C	6.621	-22.682	
Velocity	m/s	1.362	1.106	
Pressure drop (dry 82 Pa)	Pa		100.919	

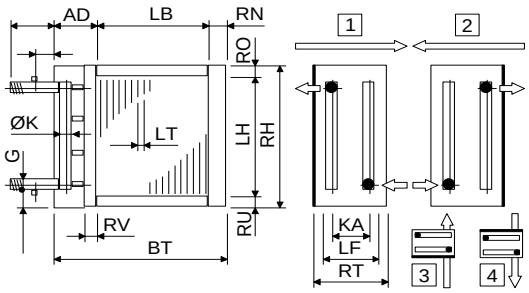


Temper -30		
Temp. in	°C	-28.000
Temp. out	°C	-22.000
Density	kg/m3	1190.705
Spec. heat	kJ/kgK	2.867
Heat cond.	W/mK	0.429
Viscosity	Pas	1.317E-02
Volume flow	m3/h	28.366
Velocity	m/s	0.930
Pressure drop	kPa	39.037





Technical data			rost energy 1.99 kWh - Frost thickness 0.19 mm - Defr. cycle 1.00 h - Defr. time 0.06 h - Availability 93.70 %			
Tubes total		Piece	624	Tubes:	smooth	AISI 316
Tubes blank		Piece	0	Tubes:		staggered
Internal venting		Piece	0	Collectors:	1.06 m/s	AISI 316
Internal drains		Piece	0	Connections:	1.06 m/s	AISI 316
Tube rows on the depth		Piece	24	Fins:	smooth	AlMg3
Tube rows on the height		Piece	26	Circulations:	2	Parallel
Tube coupling in series		Piece	12	Frame:	2.00 mm	AISI 316
Number of circuits (NC)		Piece	52	Protection:		without
Volume		l	132	Protection:		---
Weight		kg	487	Air flow direction:		horizontal
Connections	G	---	2 ½"			
Frame height	RH	mm	1100			
Frame width	BT	mm	1300			
Frame depth	RT	mm	900			
Finned height	LH	mm	1040			
Finned width	LB	mm	1064			
Finned depth	LF	mm	831			
Frame on top	RO	mm	30			
Frame on bottom	RU	mm	30			
Frame in front	RV	mm	30			
Frame on back (~69mm)	RN	mm	69			
Collector-Diameter	K	mm	76			
Collector covering	AD	mm	167			
Collector distance	KA	mm	797			
Fin spacing	LT	mm	4.500			
Fin thickness	LD	mm	0.200	Delivery:		5-6 weeks
Tube diameter	DA	mm	16.400	Validity:		12 weeks
Tube thickness	S	mm	1.000	Condit.:		net, prepaid address
Tube interval on the height	S1	mm	40.000	Payment:		30 days net
Tube interval on the depth	S2	mm	34.641	**Price net:**	**With el. rods**	**EUR 12851.00**



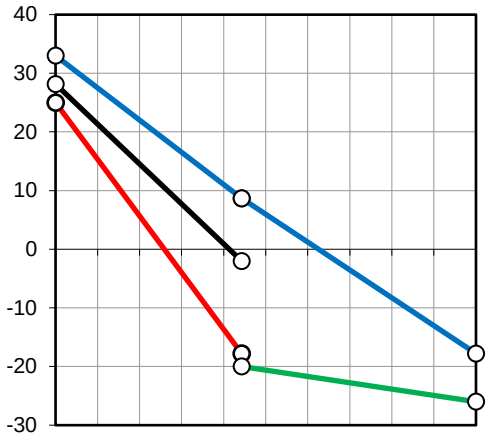
El. heat rods:42 x ø 8.4 x 1200 mm à 750 W
Frost thickness: 0.187 mm
Fin spacing: 24x4.5 mm

Energy recovery & Dehumidifying		Co1	Co2	He	Co1+Co2
Capacity	kW	71.987	90.641	71.987	**162.628**
Surface reserve	%	3.738	2.665	2.267	
Present surface	m2	567.755	362.032	611.103	
Temp. in	°C	33.000	8.689	-17.780	
Rel. humidity in	%	40.582	99.960	100.000	
Abs. humidity in	g/kg	20.000	12.636	2.000	
Temp. out	°C	8.689	-17.780	25.000	
Rel. humidity out	%	99.960	100.000	6.344	
Abs. humidity out	g/kg	12.636	2.000	2.000	
Velocity	m/s	1.237	1.173	1.141	
Pressure drop	Pa	65.556	113.327	53.383	

Definition		
Pressure	bar	1.000
Temp.	°C	20.000
Rel. humidity	%	40.000
Supply air	kg/h	6000.000

Temper -40		Co1 / He
Temp. in	°C	-2.000
Temp. out	°C	28.150
Volume flow	m3/h	2.368
Pressure drop total	kPa	290.642
Temper -40		**Co2**
Temp. in	°C	-26.000
Temp. out	°C	-20.000
Volume flow	m3/h	15.311
Pressure drop	kPa	36.832

Co1 = 44.265 % **Co2 = 55.735 %**



LOGO

Company
Branch
Street
Country / ZIP / City

Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

City, 11.11.2022
With the compliments of

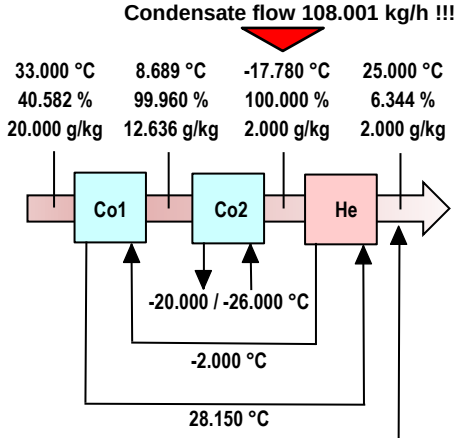
Representative
Direct dialing
xxxxxxxxxx

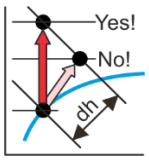
Plant
Object
Position

Software by www.zcs.ch

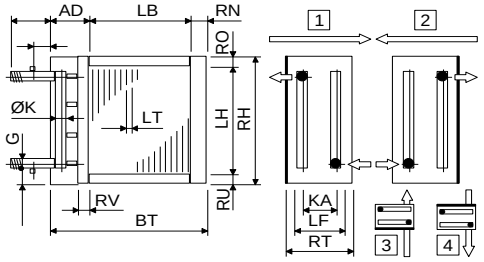
Technical data		Co1	Co2	He
Tubes blank	Piece	0	0	0
Int. vent./drains	Piece	9	0	9
Tube rows on the depth	Piece	20	24	20
Tube rows on the height	Piece	30	26	30
Number of circuits (NC)	Piece	10	39	10
Volume	l	65	132	65
Weight	kg	420	487	432
Connections	G	1"	2 ½"	1"
Frame height	RH	1100	1100	1100
Frame width	BT	1300	1300	1300
Frame depth	RT	730	900	730
Finned height	LH	1050	1040	1050
Finned width	LB	1108	1064	1108
Frame on top	RO	25	30	25
Frame on bottom	RU	25	30	25
Frame in front	RV	30	30	30
Frame on back (~53/69/53)	RN	69	69	69
Collector covering	AD	123	167	123
Fin spacing	LT	2.700	4.500	2.500
Fin thickness	LD	0.200	0.200	0.200
Tube diameter	DA	12.400	16.400	12.400
Tube thickness	S	1.000	1.000	1.000
Tube interval on the height	S1	35.000	40.000	35.000
Tube interval on the depth	S2	35.000	34.641	35.000
Tubes	---	AISI 316	AISI 316	AISI 316
Tubes	---	in line	staggered	in line
Tubes	---	smooth	smooth	smooth
Collector	---	AISI 316	AISI 316	AISI 316
Connections	---	AISI 316	AISI 316	AISI 316
Fins	---	AlMg3	AlMg3	AlMg3
Fins	---	smooth	smooth	smooth
Frame	---	AISI 316	AISI 316	AISI 316
Protection	---	without	without	without
Protection	---	---	---	---
Price	**EUR**	**10227.00**	**14545.00**	**10344.00**

Wire mesh droplet eliminator (Demister)
Drop eliminator: Pressure drop > 100 Pa ?!?
Condensate flow 108.001 kg/h !!!





If the temperature and humidity at the outlet are not maintained, the droplet eliminator must be checked for sufficient pressure drop!



Delivery:	5-6 weeks
Validity:	12 weeks
Condit.:	net, prepaid address
Payment:	30 days net

Cooler: 35/35/12-20R-30T-1108A-2.7PA-10C-AISI 316/AlMg3/AISI 316 Software by www.zcs.ch

Capacity	kW	71.987	------ sensible:	41.741
Surface reserve	%	3.738	latent:	30.246
Present surface	m2	567.755	frost:	0.000
Required surface	m2	547.296		
k-coeff.	W/m2K	18.186	---------- ffi:	5.000E-05
Average temp. diff.	K	3.289	ffa:	5.000E-05

LOGO

Company
Branch
Street
Country / ZIP / City

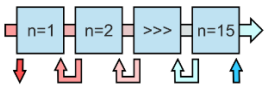
Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

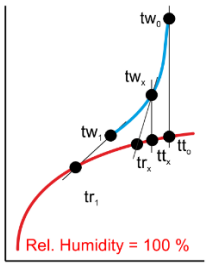
City, 11.11.2022
With the compliments of

Representative
Direct dialing
xxxxxxxxxx

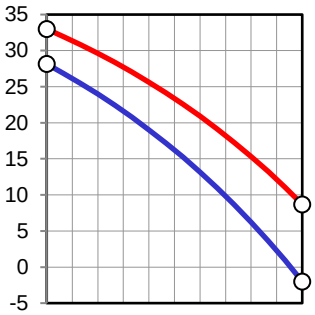
Software by www.zcs.ch

Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	33.000	8.689	20.844
Rel. humidity	%	40.582	99.960	77.653
Abs. humidity	g/kg	20.000	12.636	20.000
Density humid	kg/m3	1.128	1.230	1.175
Enthalpy humid	kJ/kg	82.508	39.316	69.814
Volume flow humid	m3/h	5424.460	4941.086	5208.768
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Condensate flow	kg/h		44.182	
Surface temperature	°C	30.049	2.185	
Velocity	m/s	1.295	1.180	
Pressure drop (dry 55 Pa)	Pa		65.556	



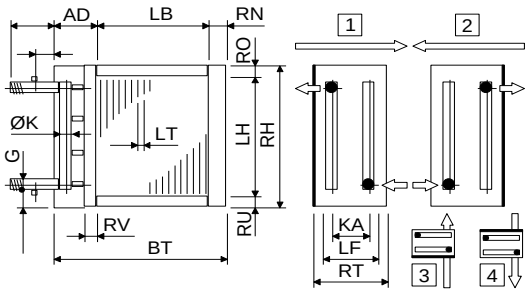


Temper -40		
Temp. in	°C	-2.000
Temp. out	°C	28.150
Density	kg/m3	1209.746
Spec. heat	kJ/kgK	3001.071
Heat cond.	W/mK	0.458
Viscosity	Pas	3.316E-03
Volume flow	m3/h	2.368
Velocity	m/s	0.774
Pressure drop	kPa	145.321



Technical data

Tubes total		Piece	600	Tubes:	smooth	AISI 316
Tubes blank		Piece	0	Tubes:		in line
Internal venting		Piece	9	Collectors:	1.13 m/s	AISI 316
Internal drains		Piece	9	Connections:	1.13 m/s	AISI 316
Tube rows on the depth		Piece	20	Fins:	smooth	AlMg3
Tube rows on the height		Piece	30	Circulations:	1	Default
Tube coupling in series		Piece	60	Frame:	2.00 mm	AISI 316
Number of circuits (NC)		Piece	10	Protection:		without
Volume		l	65	Protection:		---
Weight		kg	420	Air flow direction:		horizontal
Connections	G	---	1"			
Frame height	RH	mm	1100			
Frame width	BT	mm	1300			
Frame depth	RT	mm	730			
Finned height	LH	mm	1050			
Finned width	LB	mm	1108			
Finned depth	LF	mm	700			
Frame on top	RO	mm	25			
Frame on bottom	RU	mm	25			
Frame in front	RV	mm	30			
Frame on back (~53mm)	RN	mm	69			
Collector-Diameter	K	mm	34			
Collector covering	AD	mm	123			
Collector distance	KA	mm	665			
Fin spacing	LT	mm	2.700			
Fin thickness	LD	mm	0.200	Delivery:		5-6 weeks
Tube diameter	DA	mm	12.400	Validity:		12 weeks
Tube thickness	S	mm	1.000	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:**	**Non el. rods**	**EUR** **10227.00**



El. heat rods: without
Frost thickness: 0.000 mm
Fin spacing: 20x2.7 mm

Cooler: 40/35/16-24R-26T-1064A-4.5PA-39C-AISI 316/AlMg3/AISI 316 Software by www.zcs.ch

Capacity	kW	90.641	------ sensible:	44.523
Surface reserve	%	2.665	latent:	42.895
Present surface	m2	362.032	frost:	3.223
Required surface	m2	352.636		
k-coeff.	W/m2K	15.705	---------- ffi:	5.000E-05
Average temp. diff.	K	16.367	ffa:	5.000E-05

LOGO

Company
Branch
Street
Country / ZIP / City

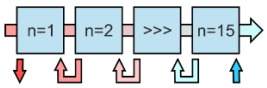
Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

City, 11.11.2022
With the compliments of

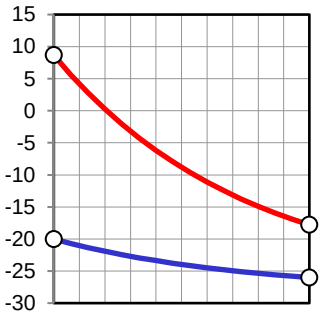
Representative
Direct dialing
xxxxxxxxxx

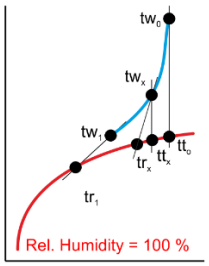
Software by www.zcs.ch

Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	8.689	-17.780	-4.546
Rel. humidity	%	99.960	100.000	74.574
Abs. humidity	g/kg	12.636	2.000	3.945
Density humid	kg/m3	1.230	1.364	1.295
Enthalpy humid	kJ/kg	39.316	-13.135	4.880
Volume flow humid	m3/h	4941.086	4407.811	4650.397
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Condensate flow	kg/h		63.819	
Surface temperature	°C	-0.702	-20.471	
Velocity	m/s	1.240	1.106	
Pressure drop (dry 91 Pa)	Pa		113.327	



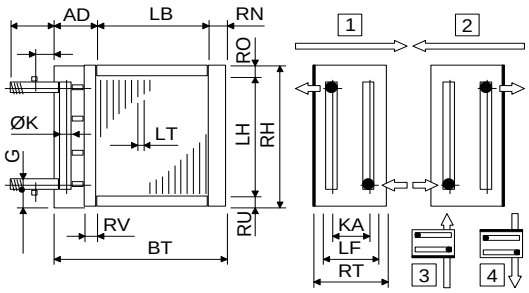
Temper -40		
Temp. in	°C	-26.000
Temp. out	°C	-20.000
Density	kg/m3	1222.755
Spec. heat	kJ/kgK	2904.956
Heat cond.	W/mK	0.418
Viscosity	Pas	1.512E-02
Volume flow	m3/h	15.311
Velocity	m/s	0.670
Pressure drop	kPa	36.832





Technical data rost energy 3.22 kWh - Frost thickness 0.30 mm - Defr. cycle 1.00 h - Defr. time 0.10 h - Availability 89.77 %

Tubes total		Piece	624	Tubes:	smooth	AISI 316
Tubes blank		Piece	0	Tubes:		staggered
Internal venting		Piece	0	Collectors:	1.14 m/s	AISI 316
Internal drains		Piece	0	Connections:	1.14 m/s	AISI 316
Tube rows on the depth		Piece	24	Fins:	smooth	AlMg3
Tube rows on the height		Piece	26	Circulations:	1	Default
Tube coupling in series		Piece	16	Frame:	2.00 mm	AISI 316
Number of circuits (NC)		Piece	39	Protection:		without
Volume		l	132	Protection:		---
Weight		kg	487	Air flow direction:		horizontal
Connections	G	---	2 ½"			
Frame height	RH	mm	1100			
Frame width	BT	mm	1300			
Frame depth	RT	mm	900			
Finned height	LH	mm	1040			
Finned width	LB	mm	1064			
Finned depth	LF	mm	831			
Frame on top	RO	mm	30			
Frame on bottom	RU	mm	30			
Frame in front	RV	mm	30			
Frame on back (~69mm)	RN	mm	69			
Collector-Diameter	K	mm	76			
Collector covering	AD	mm	167			
Collector distance	KA	mm	797			
Fin spacing	LT	mm	4.500			
Fin thickness	LD	mm	0.200	Delivery:		5-6 weeks
Tube diameter	DA	mm	16.400	Validity:		12 weeks
Tube thickness	S	mm	1.000	Condit.:		net, prepaid address
Tube interval on the height	S1	mm	40.000	Payment:		30 days net
Tube interval on the depth	S2	mm	34.641	**Price net:**	**With el. rods**	**EUR** **14545.00**



El. heat rods:42 x ø 8.4 x 1200 mm à 750 W
Frost thickness: 0.303 mm
Fin spacing: 24x4.5 mm

Heater: 35/35/12-20R-30T-1108A-2.5PA-10C-AISI 316/AlMg3/AISI 316 Software by www.zcs.ch

Capacity	kW	71.987			
Surface reserve	%	2.267			
Present surface	m2	611.103			
Required surface	m2	597.560			
k-coeff.	W/m2K	15.896	---------- ffi:	5.000E-05	
Average temp. diff.	K	7.579	ffa:	5.000E-05	

LOGO

Company
Branch
Street
Country / ZIP / City

Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

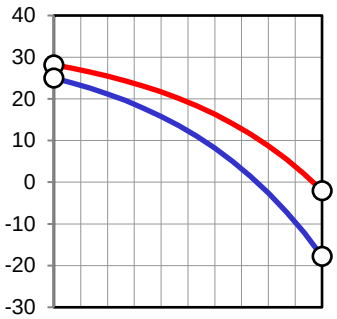
City, 11.11.2022
With the compliments of

Representative
Direct dialing
xxxxxxxxxx

Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	-17.780	25.000	3.610
Rel. humidity	%	100.000	6.344	21.896
Abs. humidity	g/kg	2.000	2.000	2.000
Density humid	kg/m3	1.364	1.168	1.258
Enthalpy humid	kJ/kg	-13.135	30.057	8.451
Volume flow humid	m3/h	4407.811	5148.221	4778.074
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Velocity	m/s	1.052	1.229	
Pressure drop	Pa		53.383	

Software by www.zcs.ch

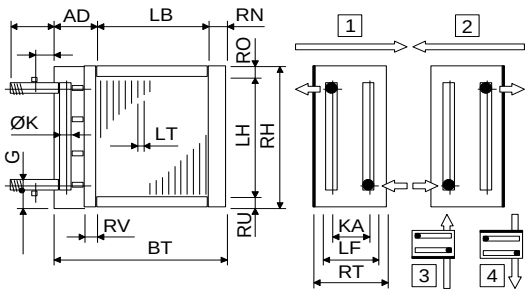
Temper -40		
Temp. in	°C	28.150
Temp. out	°C	-2.000
Density	kg/m3	1209.746
Spec. heat	kJ/kgK	3001.071
Heat cond.	W/mK	0.458
Viscosity	Pas	3.316E-03
Volume flow	m3/h	2.368
Velocity	m/s	0.774
Pressure drop	kPa	145.321



Technical data

Tubes total		Piece	600	Tubes:		AISI 316
Tubes blank		Piece	0	Tubes:		smooth
Internal venting		Piece	9	Tubes:		in line
Internal drains		Piece	9	Collectors:	1.13 m/s	AISI 316
Tube rows on the depth		Piece	20	Connections:	1.13 m/s	AISI 316
Tube rows on the height		Piece	30	Fins:		AlMg3
Tube coupling in series		Piece	60	Fins:		smooth
Number of circuits (NC)		Piece	10	Circulations:	1	Default
				Frame:	2.00 mm	AISI 316
Volume		l	65	Protection:		without
Weight		kg	432	Protection:		---
Connections	G	---	1"	Air flow direction:		horizontal

Frame height	RH	mm	1100
Frame width	BT	mm	1300
Frame depth	RT	mm	730
Finned height	LH	mm	1050
Finned width	LB	mm	1108
Finned depth	LF	mm	700
Frame on top	RO	mm	25
Frame on bottom	RU	mm	25
Frame in front	RV	mm	30
Frame on back (~53mm)	RN	mm	69
Collector-Diameter	K	mm	34
Collector covering	AD	mm	123
Collector distance	KA	mm	665
Fin spacing	LT	mm	2.500
Fin thickness	LD	mm	0.200
Tube diameter	DA	mm	12.400
Tube thickness	S	mm	1.000
Tube interval on the height	S1	mm	35.000
Tube interval on the depth	S2	mm	35.000



Delivery:		5-6 weeks
Validity:		12 weeks
Condit.:		net, prepaid address
Payment:		30 days net
Price net:	**EUR**	**10344.00**

Mollier TX chart for: Air with 0.05 Acetone / 0.95 Water		Gas	Steam
Pressure 1.000 bar	Name	Air	Mix
	Formula	N2+Ar+O2	---
	CAS	132259-10-0	---
Molecular weight	kg/kMol	28.965	20.018
Triple point temperature	°C	-213.400	-4.723
Evaporation-Enthalpy (0.000 °C)	J/kg		2403798.500

Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet
Temp.	°C	33.000	25.000
Rel. humidity	%	40.582	6.344
Abs. humidity	**g/kg**	**20.000**	**2.000**

Capacity	kW	Drawing
Energy recovery	71.987	
Recooler	90.641	

Range restrictions
0.5 / 20.0 bar
-100 / 300 °C
0 / 1000 g/kg

Reduce the polutants by recovering, recooling and an optimal separation with 90.00%!

LOGO

Company
Branch
Street
Country / ZIP / City

Phone: xxxxxxxxxx
Fax: xxxxxxxxxx
E-Mail
Homepage

City, 11.11.2022
With the compliments of

Representative
Direct dialing
xxxxxxxxxx

Software by www.zcs.ch