Harmful vapor recovery

The **HEH-G software is used to** recover harmful vapors, **contained in gases such as air, nitrogen, etc. Any gases can be calculated with any vapors**, the majority of the vapors being **mixtures of aqueous solutions in vapor form** and for which **Raoult's** and **Dalton's** law is applied.

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 down and the harmful vapors condensed out. The partial pressure of the vapor or the vapor mixture plays a decisive role in this. 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 degreasing metallic workpieces.

The lower the partial pressure, the easier it is to condense it, which is why pure water vapor is the easiest to condense.

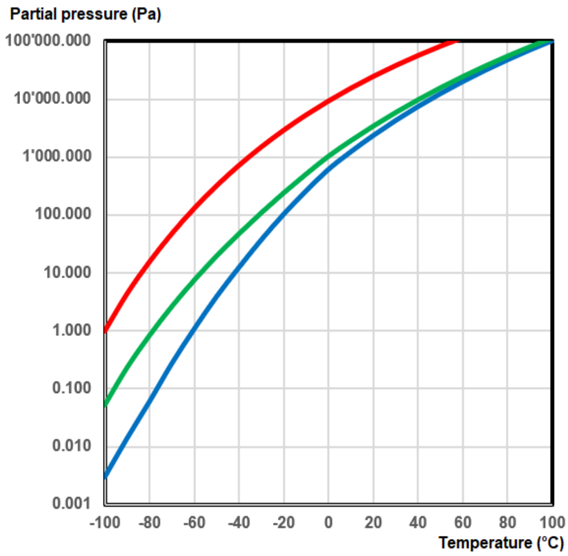
1. If you want air at 1 bar from 33°C with 20 g/kg water vapor to condense to 2 g/kg, this corresponds to an air outlet temperature of -7.4°C, which can be achieved with brines.
2. The steam mixture of 95% water and 5% acetone, also from air of 1 bar at 33°C and 20 g/kg steam mixture, is much more difficult to condense to 2 g/kg, because you have to reach an air outlet temperature of -17.8°C, which can be achieved with cooling brines.
3. However, if you want air at 1 bar from 33°C with 20 g/kg of pure acetone vapor to condense to 2 g/kg, this corresponds to an air outlet temperature of -62.8°C, which can only be achieved with cooling brines with great effort.

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 state**, which so-called engineers without process engineering training have never understood.

Returning to the example of a cabin for degreasing metallic workpieces, it is therefore absolutely advisable to continuously dehumidify the vapor mixture of water and acetone **at a high air exchange rate** in order to be able to do this with moderate coolant temperatures.

If someone comes up with the abstruse idea of recovering harmful vapors with pure external energy, he will only trigger a small investment in the heat exchanger, but will incur horrendous operating costs. If this someone has only a modest idea of economic efficiency, he will **provide a large proportion of the required cooling capacity with energy recovery.**

Steam	Name	Water	Acetone	Water 95%
Steam	Formula	H_2O	C_3H_6O	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



Recovery of harmful vapors by means of energy recovery, which can be amortised within a very short time.

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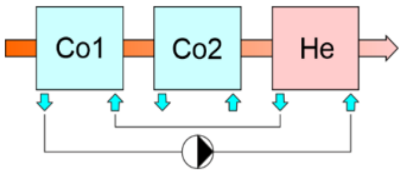

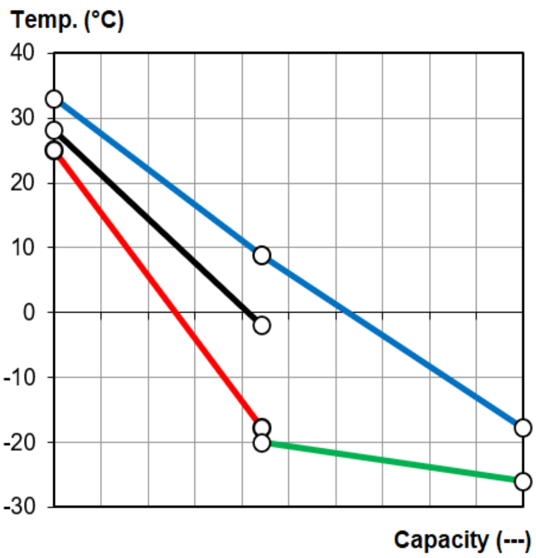

Energy recovery & Dehumidifying		Co1	Co2	He	Co1+Co2
Capacity	kW	72.085	90.538	71.987	162.623
Surface reserve	%	0.787	0.798	0.802	
Present surface	m2	345.279	424.419	410.053	
Temp. in	°C	33.000	8.766	-17.780	
Rel. humidity in	%	40.582	99.060	100.000	
Abs. humidity in	g/kg	20.000	12.579	2.000	
Temp. out	°C	8.766	-17.780	25.000	
Rel. humidity out	%	99.060	100.000	6.344	
Abs. humidity out	g/kg	12.579	2.000	2.000	
Velocity	m/s	1.386	1.271	1.278	
Pressure drop	Pa	81.659	149.694	70.910	

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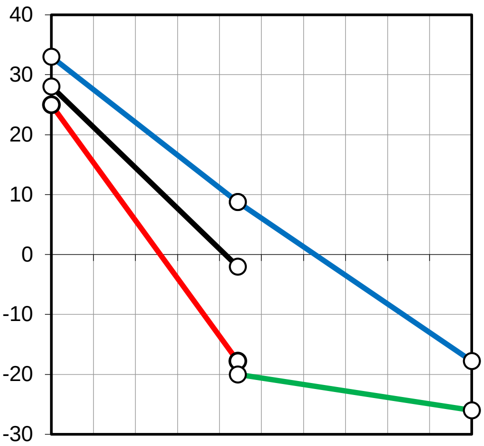
Co1 = 44.326 %   Co2 = 55.674 %

Air with 0.05 Acetone / 0.95 Water		
Pressure	bar	1.000
Temp.	°C	20.000
Rel. humidity	%	40.000
Supply air	kg/h	6000.000

Temper -20		Co1 / He
Temp. in	°C	-2.000
Temp. out	°C	28.050
Volume flow	m3/h	2.289
Pressure drop total	kPa	337.199
Temper -30		**Co2**
Temp. in	°C	-26.000
Temp. out	°C	-20.000
Volume flow	m3/h	15.872
Pressure drop	kPa	39.076



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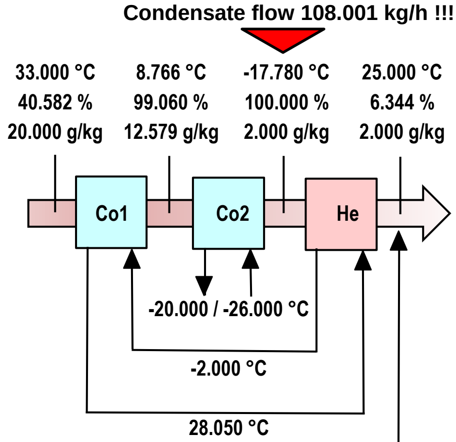
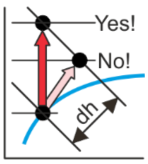
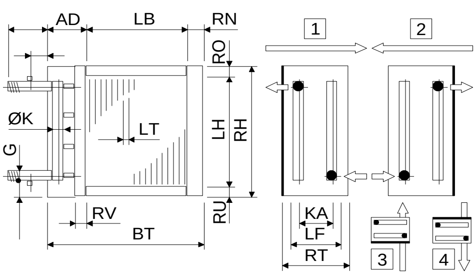
Technical data		Co1	Co2	He
Tubes blank	Piece	0	0	0
Int. vent./drains	Piece	7	0	7
Tube rows on the depth	Piece	16	20	16
Tube rows on the height	Piece	24	24	24
Number of circuits (NC)	Piece	4	30	4
Volume	l	87	113	87
Weight	kg	249	340	266
Connections	G	1"	2 ½"	1"
Frame height	RH	1020	1020	1020
Frame width	BT	1300	1300	1300
Frame depth	RT	580	760	580
Finned height	LH	960	960	960
Finned width	LB	1082	1064	1082
Frame on top	RO	30	30	30
Frame on bottom	RU	30	30	30
Frame in front	RV	30	30	30
Frame on back (~69/69/69)	RN	69	69	69
Collector covering	AD	149	167	149
Fin spacing	LT	3.000	3.000	2.500
Fin thickness	LD	0.200	0.200	0.200
Tube diameter	DA	16.400	16.400	16.400
Tube thickness	S	0.600	0.600	0.600
Tube interval on the height	S1	40.000	40.000	40.000
Tube interval on the depth	S2	34.641	34.641	34.641
Tubes	---	AISI 316	AISI 316	AISI 316
Tubes	---	staggered	staggered	staggered
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**	**6840.00**	**11749.00**	**7067.00**

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



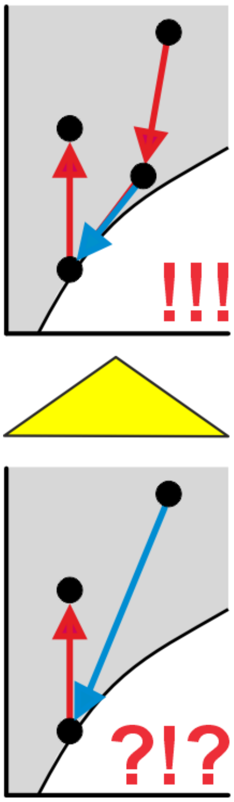


If the temperature and humidity at the outlet are not maintained, the droplet eliminator must be checked for sufficient pressure drop!



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

Variant with or without energy recovery?



In order to recover pollutants that are in a vapor state in a gas by condensation, the gas-vapor mixture must be cooled extremely low, which is why it is strongly recommended to achieve a large part of the recovery by means of energy recovery. This naturally increases the investment costs, but they can be paid back within a very short time. Anyone who wants to do without this will be faced with very high operating costs.

A typical, very common example of this is a mixture of air with an aqueous 5% solution of acetone. This solution was used to clean metal, oily workpieces. Anyone who thinks that cooling to 0°C is enough to condense most of the acetone is completely wrong. Cooling to -20°C is necessary to recover 90% of the acetone by condensation, always assuming that highly effective droplet separators are used.

Now the question automatically arises as to which brine should be used for cooling. We recommend Temper or Terminol VLT, a low-viscosity oil is the absolute leader in this regard because the Prandtl number is very low and therefore guarantees very high values for heat transfer with small pressure losses. Die-hards use glycols and are surprised when the heat exchangers become very large and thus cause the investment costs to explode.

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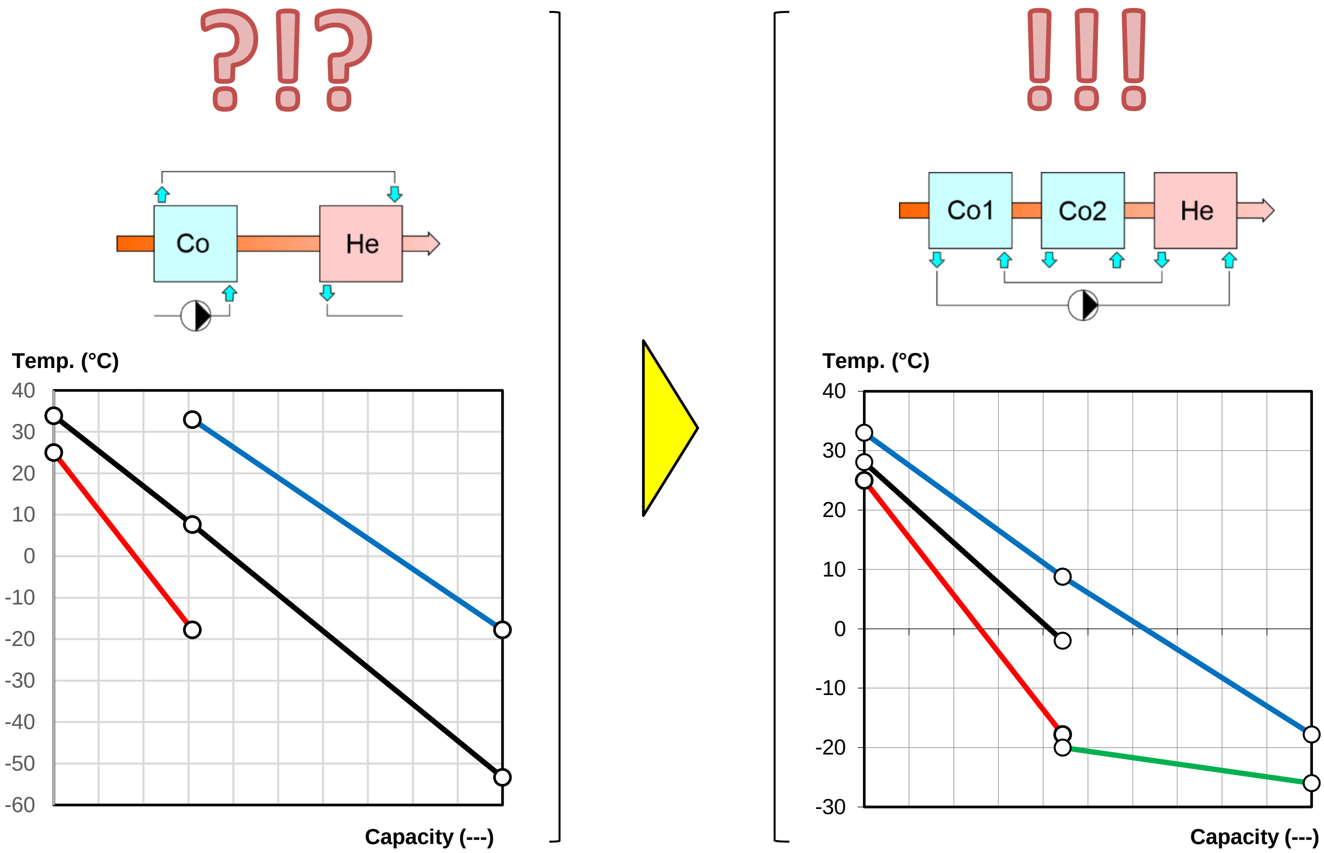

Anyone who, despite all our valid arguments, prefers a solution without energy recovery, which is absolutely incomprehensible to logically thinking engineers, should definitely make sure that, given the medium temperatures in the subsequent cooler and heater, one pump is sufficient, i.e. that it can be operated in series.

Cooler: 40/35/16-22R-24T-1082A-3.0PA-12C-AISI 316/AlMg3/AISI 316			Software by www.zcs.ch	
Capacity	kW	160.985	------ sensible:	85.470
Surface reserve	%	4.050	latent:	73.935
Present surface	m2	474.759	frost:	1.579
Required surface	m2	456.281		
k-coeff.	W/m2K	11.742	------------- ffi:	5.000E-05
Average temp. diff.	K	28.505	ffa:	5.000E-05

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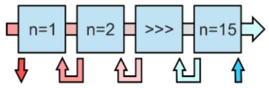
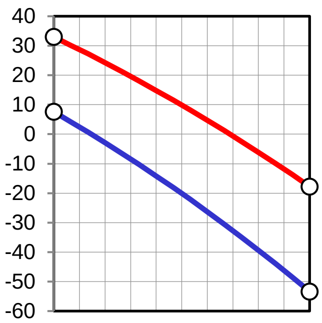
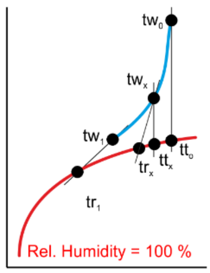
Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	33.000	-17.780	7.610
Rel. humidity	%	40.582	100.000	101.858
Abs. humidity	g/kg	20.000	2.000	12.067
Density humid	kg/m3	1.128	1.364	1.235
Enthalpy humid	kJ/kg	82.508	-13.135	36.829
Volume flow humid	m3/h	5424.460	4407.811	4918.061
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Condensate flow	kg/h		108.001	
Surface temperature	°C	23.932	-30.475	
Velocity	m/s	1.451	1.179	
Pressure drop (dry 105 Pa)	Pa		129.472	

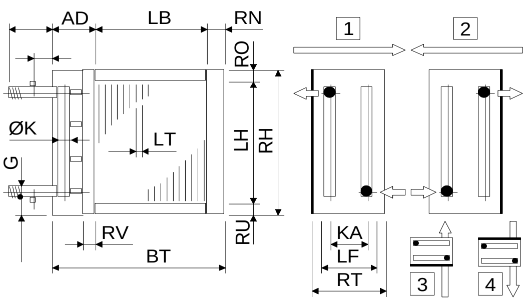


Temper -55		
Temp. in	°C	-53.326
Temp. out	°C	7.610
Density	kg/m3	1259.791
Spec. heat	kJ/kgK	2.775
Heat cond.	W/mK	0.406
Viscosity	Pas	1.883E-02
Volume flow	m3/h	2.721
Velocity	m/s	0.347
Pressure drop	kPa	57.294





Technical data						
Tubes total		Piece	528	Tubes:	smooth	AISI 316
Tubes blank		Piece	0	Tubes:		staggered
Internal venting		Piece	10	Collectors:	1.30 m/s	AISI 316
Internal drains		Piece	10	Connections:	1.30 m/s	AISI 316
Tube rows on the depth		Piece	22	Fins:	smooth	AlMg3
Tube rows on the height		Piece	24	Circulations:	1	Default
Tube coupling in series		Piece	44	Frame:	2.00 mm	AISI 316
Number of circuits (NC)		Piece	12	Protection:		without
Volume		l	119	Protection:		---
Weight		kg	336	Air flow direction:		horizontal
Connections	G	---	1"			
Frame height	RH	mm	1020			
Frame width	BT	mm	1300			
Frame depth	RT	mm	790			
Finned height	LH	mm	960			
Finned width	LB	mm	1082			
Finned depth	LF	mm	762			
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	34			
Collector covering	AD	mm	149			
Collector distance	KA	mm	729			
Fin spacing	LT	mm	3.000			
Fin thickness	LD	mm	0.200	Delivery:		5-6 weeks
Tube diameter	DA	mm	16.400	Validity:		12 weeks
Tube thickness	S	mm	0.600	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: Non el. rods**	**EUR**	**9361.00**



El. heat rods: without
Frost thickness: 0.113 mm
Fin spacing: 22x3.0 mm

Heater: 40/35/16-10R-24T-1082A-3.0PA-6C-AISI 316/AlMg3/AISI 316				Software by www.zcs.ch
Capacity	kW	71.987		
Surface reserve	%	5.418		
Present surface	m2	215.799		
Required surface	m2	204.708		
k-coeff.	W/m2K	23.032	------------- ffi:	5.000E-05
Average temp. diff.	K	15.268	ffa:	5.000E-05

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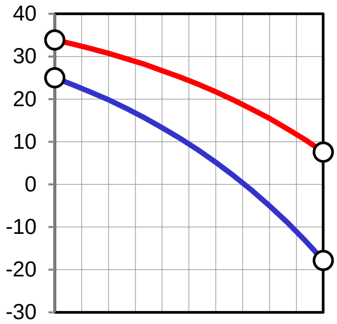
Air with 0.05 Acetone / 0.95 Water		Inlet	Outlet	Average
Pressure	bar	1.000		
Temp.	°C	-17.780	25.000	3.610
Rel. humidity	%	100.000	6.344	21.896
Abs. humidity	g/kg	2.000	2.000	2.000
Density humid	kg/m3	1.364	1.168	1.258
Enthalpy humid	kJ/kg	-13.135	30.057	8.451
Volume flow humid	m3/h	4407.811	5148.221	4778.074
Mass flow dry	kg/h	6000.000	6000.000	6000.000
Velocity	m/s	1.179	1.377	
Pressure drop	Pa		38.054	

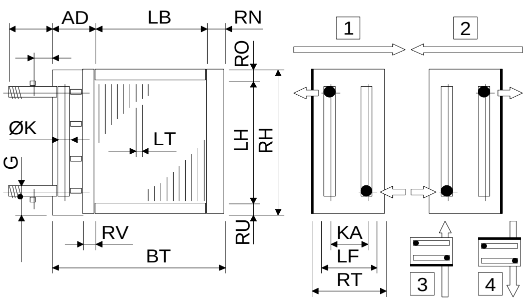
Temper -55		
Temp. in	°C	33.891
Temp. out	°C	7.610
Density	kg/m3	1239.543
Spec. heat	kJ/kgK	2.877
Heat cond.	W/mK	0.446
Viscosity	Pas	2.878E-03
Volume flow	m3/h	2.765
Velocity	m/s	0.706
Pressure drop	kPa	60.117



Technical data

Tubes total	Piece	240	Tubes:		AISI 316
Tubes blank	Piece	0	Tubes:		smooth
Internal venting	Piece	4	Tubes:		staggered
Internal drains	Piece	4	Collectors:	1.32 m/s	AISI 316
Tube rows on the depth	Piece	10	Connections:	1.32 m/s	AISI 316
Tube rows on the height	Piece	24	Fins:		AlMg3
Tube coupling in series	Piece	40	Fins:		smooth
Number of circuits (NC)	Piece	6	Circulations:	1	Default
			Frame:	2.00 mm	AISI 316
Volume	l	55	Protection:		without
Weight	kg	162	Protection:		---
Connections G	---	1"	Air flow direction:		horizontal

Frame height	RH	mm	1020
Frame width	BT	mm	1300
Frame depth	RT	mm	380
Finned height	LH	mm	960
Finned width	LB	mm	1082
Finned depth	LF	mm	346
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	34
Collector covering	AD	mm	149
Collector distance	KA	mm	313
Fin spacing	LT	mm	3.000
Fin thickness	LD	mm	0.200
Tube diameter	DA	mm	16.400
Tube thickness	S	mm	0.600
Tube interval on the height	S1	mm	40.000
Tube interval on the depth	S2	mm	34.641



Delivery:		5-6 weeks
Validity:		12 weeks
Condit.:		net, prepaid address
Payment:		30 days net
Price net:	**EUR**	**4380.00**

Economy			
Capital interest	%	1.00	
Energy increase	%	1.00	
Inflation	%	1.00	
Support costs	%	5.00	
Service	Hours/Year	2080.00	
Energy costs	EUR/MWh	80.00	Cooling
Energy costs	EUR/MWh	100.00	Current

Investment costs (Energy recovery)		without	with
Heat exchanger	EUR	13741.00	25656.00
Pump & Hydraulics (20.00%)	EUR	2748.20	5131.20
Additional costs (10%)	EUR	1374.10	2565.60
Costs total	EUR	17863.30	33352.80
Additional costs	EUR		15489.50

Overheads (Energy recovery)		without	with
Support costs	EUR	893.17	1667.64
Cooler & Heater	kW	232.97	90.54
Costs	EUR	38766.42	15065.57
Fan	kg/h	6000.00	6000.00
Density humid	kg/m3	1.25	1.24
Volume flow humid	m3/h	4813.55	4828.13
Fan efficiency	%	0.70	0.70
Pressure drop	Pa	167.53	302.26
Capacity	kW	0.32	0.58
Costs	EUR	66.56	120.46
Pump	m3/h	2.72	15.87
Pump efficiency	%	0.70	0.70
Pressure drop	bar	1.67	0.89
Capacity	kW	0.18	0.56
Costs	EUR	37.60	116.69
Pump (Energy recovery)	m3/h	---	2.29
Pump efficiency	%	---	0.80
Pressure drop	bar	---	5.37
Capacity	kW	---	0.43
Costs	EUR	---	88.82
Costs total	EUR	39763.74	17059.18

Amortization (Energy recovery)		without	with
Support costs (+)	EUR	---	774.48
Energy costs: - 58.6 %	EUR	---	22704.56
Energy recovery after 15 Years	EUR	---	380203.82
BEP (Break even point)	Years	---	1.60

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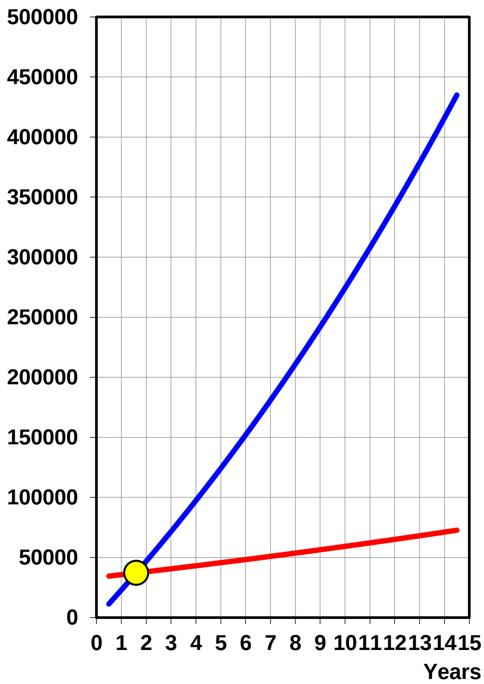
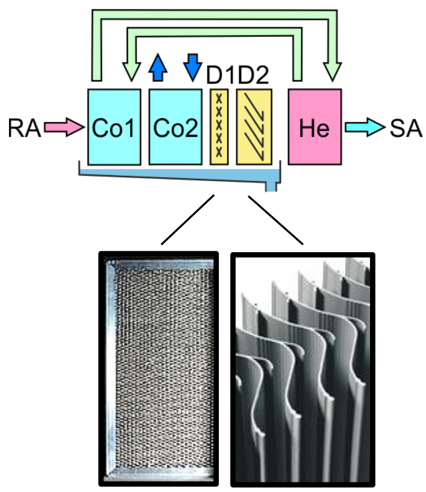


RA: Return air
SA: Supply air

Co1: Energy recovery - Cooler
He: Energy recovery - Heater

Co2: Cooler additional

D1: Wire mesh droplet eliminator (Demister)
D2: Drop eliminator: Pressure drop > 100 Pa !!!



Both coolers must have smooth fins, which allow the condensate to drain away. The thickness of the lamellas should be at least 0,2 mm in order to generate large condensate droplets. These are combined into even larger droplets in the upstream demister and separated in the downstream droplet eliminator. Droplet eliminators must have a pressure loss of at least 100 Pa in order to ensure a high degree of fractional separation.