

# 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.
- 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	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



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







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       g/kg       20.000       12.579       2.000         Abs. humidity 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       Phone: xxxxxx         Velocity       m/s       1.386       1.271       1.278       Phone: xxxxxxx         Pressure drop       Pa       81.659       149.694       70.910       E-Mail         Homepage       40       30       40       30       City, 4.11.202       With the complime         Pressure       bar       1.000       30       30       Co1 = 44.326 %       Co2 = 55.674 %       City, 4.11.202         With the complime       30       30       30       Action of the complime       Bepresentativ	City xxx xx 4 ents of g
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Pressure bar 1.000 Temp. °C 20.000 30 Rel humidity % 40.000	re re 1
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Supply air kg/h 6000.000 20 Direct dialing	
Temper -20 Co1 / He 10	
Temp. in °C -2.000 Plant	
Temp. out °C 28.050 0 Object	
Volume flow m3/b 2 289	
Pressure drop total kPa 337 100 10	
Temper 20	
Temper -30 Coz	
Temp. in °C -26.000 -20	
Temp. out °C -20.000	
Volume flow m3/h 15.872 -30 Software by www.z	zcs.ch
Pressure drop kPa 39.076	
Technical data Co1 Co2 He Wire mesh droplet eliminator	(Demister)
Tubes blank Piece 0 0 0 Drop eliminator: Pressure drop >	100 Pa ?!?
Int yent /drains Piece 7 0 7 Condensate flow 108	001 ka/h !!!
Tube revealed by the depth Biogo 16 20 16	501 Ng/11
Tube rows on the beight Field 10 20 10 21 22 000 %C 766 %C 17 700 %C	25 000 %C
	25.000 °C
Number of circuits (NC) Piece 4 30 4 40.582 % 99.060 % 100.000 %	6.344 %
Volume I 87 113 87 20.000 g/kg 12.579 g/kg 2.000 g/kg	2.000 g/kg
Weight         kg         249         340         266	1
Connections G 1" 2 ½" 1"	
Frame height RH 1020 1020 1020 Co1 Co2 H	
Frame width BT 1300 1300 1300	<b>_</b> ↓ ▲ Ľ
Frame depth RT 580 760 580	
Figned beight I H 960 960 960 -20 000 / 26 000 °C	
Frame on top RO 30 30 30 -2.000 °C	
Frame on bottom RU 30 30 30	
Frame in front         RV         30         30         30         28.050 °C	
Frame on back (~69/69/69) RN 69 69 .	
Collector covering AD 149 167 149 Yes!	
Fin spacing LT 3.000 3.000 2.500 If the temperature and I	humidity at
Fin thickness LD 0.200 0.200 0.200 the outlet are not main	tained, the
Tube diameter DA 16 400 16 400 16 400	be checked
for sufficient pressu	re drop!
Tube informed on the bainty C1 10,000 10,000 10,000 AD LB RN	
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I ube interval on the depth S2 $34.641$ $34.641$ $34.641$ $\frac{1}{1}$	
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Tubes staggered staggered staggered <u>ØK   </u>	
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	3 41,
Fine Aliviyo Aliviyo Aliviyo Aliviyo	V
Fins smooth smooth smooth	
Frame AISI 316 AISI 316 AISI 316 Delivery:	5-6 weeks
Protection without without Validity:	12 weeks
Protection Condit.: net, prep	aid address
Price EUR 6840.00 11749.00 7067.00 Payment:	20 dava ant

#### 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.



Company Branch Street Country / ZIP / City

Phone: xxxxxxxxx Fax: xxxxxxxxx E-Mail Homepage

City, 4.11.2024 With the compliments of

> Representative Direct dialing xxxxxxxxx

> > Plant Object Position

Software by www.zcs.ch



Capacity (---)



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-10	82A-3.0P	A-12C-AISI	316/AIMg3/AISI 31	6 Software	by www.zcs.ch	
Capacity		F/V1	160 095	sonsiblo:	85 <i>1</i> 70	
Surface reserve		r. V V 0/.	100.900	latont:	72 025	
Prosont surface		/0 m2	4.050	froct:	1 570	Company
Required surface		m2	456 281	11031.	1.575	Branch
k-coeff		W/m2K	11 742	ffi	5.000E-05	Street
Average temp. diff		K K	28 505	ffa:	5.000E-05	Country / ZIP / City
Average temp. um.		K	20.000	na.	5.000L 05	oountry / Zii / Oity
Air with 0.05 Acetone / 0.95	Water		Inlet	Outlet	Average	Phone: xxxxxxxxx Fax: xxxxxxxxxx
Proceuro		bor	1 000			Homenade
Tomp		bar °C	1.000	17 700	7 610	Homepage
Pol humidity		C %	40 582	-17.700	101 959	City 4 11 2024
Abs humidity		/0 a/ka	20.000	2 000	12 067	With the compliments of
Density humid		y/ky ka/m3	20.000	2.000	1 235	What the compliments of
Enthology humid		kj/lii3	92 509	12 125	26 920	
Volume flow humid		m2/h	5424 460	-13.133	4019 061	Representative
Mass flow dry		ka/h	6000 000	6000 000	4910.001	Direct dialing
Condensate flow		kg/li	0000.000	108 001	0000.000	
Surface temperature		kg/II °C	22 022	20.475		*******
Volocity		m/s	23.932	-30.475		Software by www.zcs.ch
Pressure drop (dry 105 Pa)		III/S Pa	1.451	120 472		
Flessure drop (dry 105 Fa)		Гd		129.472		n=1 n=2 >>> n=15
Temper -55				40		
				30 0		
Temp. in		°C	-53.326	20		two
Temp. out		°C	7.610	10		
Density		kg/m3	1259.791	0		tw <sub>x</sub>
Spec. heat		kJ/kgK	2.775	-10		tw a
Heat cond.		W/mK	0.406	-20	Ϋ́	tw, tt, tt,
Viscosity		Pas	1.883E-02	-30		tr <sub>x</sub> - x
Volume flow		m3/h	2.721	-40		tr <sub>1</sub>
Velocity		m/s	0.347	-50		Rel Humidity = 100 %
Pressure drop		kPa	57.294	-60		
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 AIMq3
Tube rows on the height		Piece	24		Circulations:	1 Defaul
Tube coupling in series		Piece	44		Frame:	2.00 mm AISI 316
Number of circuits (NC)		Piece	12		Protection:	withou
Volume		I	119		Protection:	
Weight		kg	336	Ai	r flow direction:	horizonta
Connections	G		1"			RN
Frame height	RH	mm	1020		***	
Frame width	вт	mm	1300	→		
Frame depth	RT	mm	790			╡╇╓││╓╺╋┢
Finned height	LH	mm	960	ØK		
Finned width	LB	mm	1082	<u>ں</u>		
Finned depth	LF	mm	762			
Frame on top	RO	mm	30			
Frame on bottom	RU	mm	30			
Frame in front	RV	mm	30	I	4	
Frame on back (~69mm)	RN	mm	69			
Collector-Diameter	к	mm	34	E	I. heat rods: with	out
Collector covering	AD	mm	149	<b>⊢_</b> Fi	rost thickness: 0.	113 mm
Collector distance	KA	mm	729	Fi	in spacing: 22x3.0	) mm
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 ne
Tube interval on the depth	S2	mm	34.641	Price net: N	on el. rods	EUR 9361.00

Heater: 40/35/16-10R-24T-1	082A-3.0P	A-6C-AISI 3	16/AIMg3/AISI 316	Software	by www.zcs.ch	
Capacity		L\\/	71 007			
Surface reserve		r. V V 07	5 /10			
Present surface		70	0.410 016 700			Company
Required surface		m2	210./99			Branch
k-coeff		111Z \//m2l4	204.700 02 020	<i>tt</i> ;.		Stract
		vv/1112K	23.U3Z	•••••		
Average temp. diff.		К	i5.∠68	rra:	3.000E-05	Country / ZIF / OILY
Air with 0.05 Acetone / 0.95	5 Water		Inlet	Outlet	Average	Phone: xxxxxxxxx Fax: xxxxxxxxxx
Pressure		bar	1.000			E-Mail
Temp.		°C	-17.780	25.000	3.610	Homepage
Rel. humidity		%	100.000	6.344	21.896	
Abs. humidity		g/kg	2.000	2.000	2.000	City, 4.11.2024
Density humid		kg/m3	1.364	1.168	1.258	With the compliments of
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	Representative
Velocity		m/s	1.179	1.377		Direct dialing
Pressure drop		Pa	-	38.054		xxxxxxxxx
Temper -55			<u> </u>	40	<u></u>	Software by www.zcs.ch
				30		
Temp. in		°C	33.891			
Temp. out		°C	7.610	20		1
Density		kg/m3	1239.543	10		Ļ
Spec. heat		kJ/kgK	2.877		<b>\</b>     <b>\</b>	۲
Heat cond.		W/mK	0.446	0		1
Viscosity		Pas	2.878E-03	-10	+++	
Volume flow		m3/h	2.765	20		5
Velocity		m/s	0.706	-20		ſ
Pressure drop		kPa	60.117	-30		1
Technical data						
<b>T</b>						
rupes total		Piece	240		Tubes:	AISI 316
i upes 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:	AIMg3
Tube coupling in series		Piece	40		Fins:	smooth
Number of circuits (NC)		Piece	6		Circulations:	1 Default
					Frame:	2.00 mm AISI 316
Volume		I	55		Protection:	without
Weight		kg	162		Protection:	
Connections	G		1"	Aiı	r flow direction:	horizontal
Frame height	RH	mm	1020			
Frame width	BT	mm	1300	<b>4</b>		RN 1 2
Frame depth	RT	mm	380		<b>↓</b>   <b>→</b>	
Finned height	LH	mm	960			
Finned width	LB	mm	1082	-	ן "יייווון נווך"	TT         Tt*
Finned depth	LF	mm	346	ØK	<b>╆╢</b> ╃╢╵ <u>_</u> ╢╻┰╶╎	그  군
Frame on top	RO	mm	30	۵		
Frame on bottom	RU	mm	30 30		╤┅┽┟╴╴╷╢╢║║╢	」 <sub>─</sub> ↓ ┃╙ ₩¦≈=\$₩ ╙┃
Frame in front	R\/	mm	30 20	+	   _  RV	
Frame on back (~69mm)	RN	mm	60 50		_ <del>→ i i i i</del> BT	_ "  [F] 🗐 🚍
Collector-Diameter	ĸ	mm	34			
Collector covering		mm	140			
Collector distance	KV KV	mm	212			
Fin spacing		mm	<b>3 000</b>	Delivery		5-6 wooko
Fin thickness		mm	0.000	Validity:		12 WOOKO
Tube diameter		mm	16 400	Condit		net prepaid address
Tube thickness	с С	11111 mm	0.400	Pavmont		not, prepaiu duuress
Tube interval on the height	े २१	uilli mm	40.000	, ayment.		ou days net
Tube interval on the death	े। <u>२</u> २	mm	40.000 34 641	Price net:		FUR 1300.00
. allo interval on the depth	52	11111	J4.04 I			LUN 4300.00

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 reco	overy)	without	with
Heat exchanger	EUR	13741.00	25656.00

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

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.



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