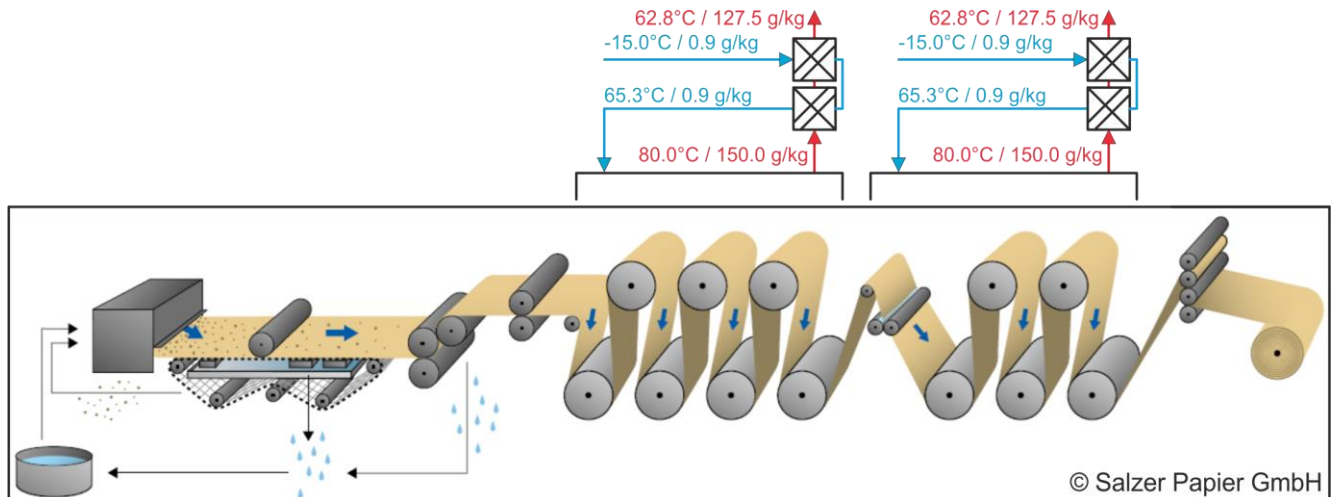




Heat recovery with Smooth-tube heat exchanger

Smooth-tube heat exchangers (Smooth-tube-HE) are used, for example, in paper and cardboard production, where contaminated warm air of around 80°C with 150 g/kg moisture is extracted above the dryer section and with it the cold fresh air of -15°C in winter and 30°C in summer. The contamination is paper particles, which is why the contaminated exhaust air is routed through heat exchanger tubes with a diameter of at least 30 mm. These must be cleaned periodically, which is done, for example, with saturated steam or mechanically. Another area of application is generally the entire process engineering, where contaminated warm air is to be used for heat recovery.

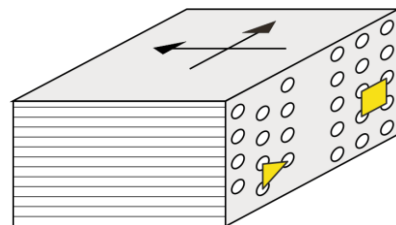


The **smooth-tube heat exchanger** is usually designed with a 1-stage cross-flow, whereby the design with a 2-stage cross-flow naturally has a higher heat recovery and is still amortized within a very short time.

Example with 1-stage cross-flow on 1.01325 bar
Temperature efficiency 71.211%
Heat recovery 947.628 kW

Description	Unit	Supply air	Exhaust air
Air mass flow dry	kg/h	50'000.000	50'000.000
Inlet temperature	°C	-15.000	80.000
Inlet humidity	g/kg	0.905	150.000
Outlet temperature	°C	52.650	69.000
Outlet humidity	g/kg	0.905	129.434
Pressure drop	Pa	180.223	188.657

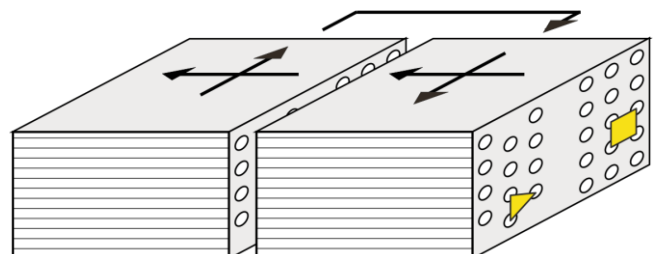
1-stage cross-flow
Temperature efficiency 71%



Example with 2-stage cross-flow on 1.01325 bar
Temperature efficiency 84.534%
Heat recovery 1125.154 kW

Description	Unit	Supply air	Exhaust air
Air mass flow dry	kg/h	50'000.000	50'000.000
Inlet temperature	°C	-15.000	80.000
Inlet humidity	g/kg	0.905	150.000
Outlet temperature	°C	65.298	62.829
Outlet humidity	g/kg	0.905	127.496
Pressure drop	Pa	384.909	336.613

2-stage cross-flow
Temperature efficiency 85%



Following pages

Page 2: **Smooth-tube heat exchanger, 1-stage cross-flow**: Temperature efficiency 71%, heat recovery 948 kW
 Page 3: **Smooth-tube heat exchanger, 1-stage cross-flow**: Process representation in the Mollier-TX-Diagram

Page 4: **Smooth-tube heat exchanger, 2-stage cross-flow**: Temperature efficiency 85%, heat recovery 1,125 kW
 Page 5: **Smooth-tube heat exchanger, 2-stage cross-flow**: Process representation in the Mollier-TX-Diagram

Page 6: **Smooth-tube heat exchanger, 2-stage cross-flow, HE1**: Temperature efficiency 76%, heat recovery 897 kW

Page 7: **Smooth-tube heat exchanger, 2-stage cross flow, HE2**: Temperature efficiency 52%, heat recovery 228 kW

Heat exchanger		Cold air	Hot air	Definition
Height over sea level	m			0.000
Pressure	bar			1.013
Efficiency	%	71.211	11.579	
Capacity sensible	kW	947.628	191.331	
Capacity latent	kW		756.641	
Capacity frost	kW		0.000	
Fouling factor	m2K/W	1.000E-04	1.000E-04	
Present surface	m2			570.199
k-coeff.	W/m2K			35.386
Average temp. diff. (93.03 %)	K			46.965



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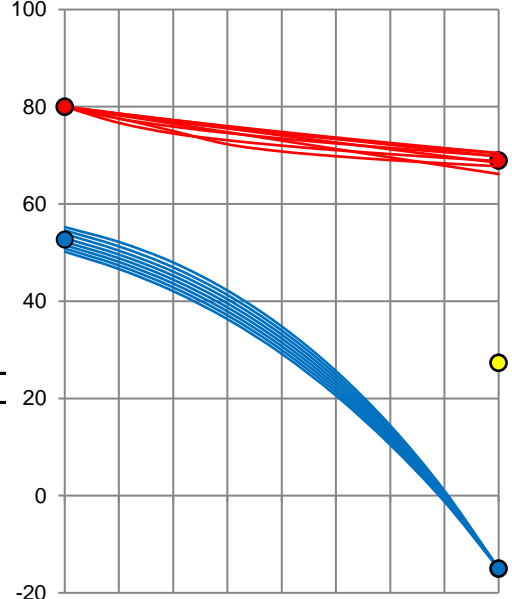
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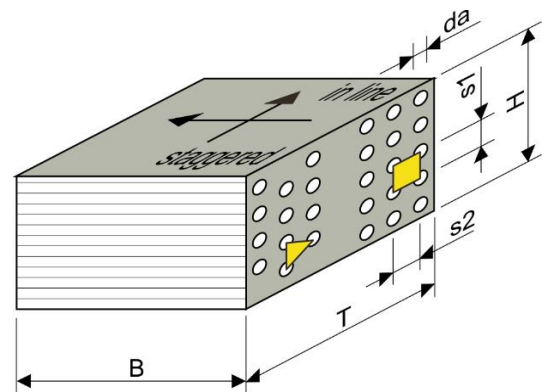
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Cold air around the tubes		Inlet	Outlet
Temp.	°C	-15.000	52.650
Rel. humidity	%	90.000	1.052
Abs. humidity	g/kg	0.905	0.905
Density humid	kg/m3	1.366	1.083
Enthalpy humid	kJ/kg	-12.852	55.377
Volume flow humid	m3/h	36627.444	46225.578
Mass flow dry	kg/h	50000.000	50000.000
Maximal velocity	m/s	1.779	2.245
Pressure drop	Pa		180.223

Hot air in the tubes		Inlet	Outlet
Temp.	°C	80.000	69.000
Rel. humidity	%	41.726	58.740
Abs. humidity	g/kg	150.000	129.434
Density humid	kg/m3	0.926	0.964
Enthalpy humid	kJ/kg	477.974	409.720
Volume flow humid	m3/h	62094.411	58558.193
Mass flow dry	kg/h	50000.000	50000.000
Surface temperature	°C	51.488	45.392
Condensate flow	kg/h		1028.307
Velocity	m/s	8.633	8.141
Pressure drop dry	Pa		111.255
Pressure drop wet	Pa		188.657



Technical data			
Cold corner - Surface temperature	°C		27.373
Cold air - Outlet - Min.	°C		50.201
Cold air - Outlet - Max.	°C		55.246
Hot air - Outlet - Min.	°C		66.171
Hot air - Outlet - Max.	°C		67.757
Tubes - Material			AISI 316
Frame - Material			AISI 316
Frame width	B	mm	2000
Frame height	H	mm	2860
Frame depth	T	mm	2860
Weight		kg	3009
Tube arrangement			in line
Tube rows on the height		Piece	55
Tube rows on the depth		Piece	55
Tubes total		Piece	3025
Tube interval on the height	s1	mm	52.000
Tube interval on the depth	s2	mm	52.000
Tube diameter	da	mm	30.000
Tube thickness	s	mm	0.500



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Heat exchanger (Unit 1 & Unit 2)		Cold air	Hot air	Definition
Height over sea level	m			0.000
Pressure	bar			1.013
Efficiency	%	84.524	18.075	
Capacity sensible	kW	1125.154	303.865	
Capacity latent	kW		821.787	
Capacity frost	kW		0.000	
Fouling factor	m2K/W	1.000E-04	1.000E-04	
Present surface	m2			1140.398
k-coeff.	W/m2K			31.965
Average temp. diff. (81.49 %)	K			30.866



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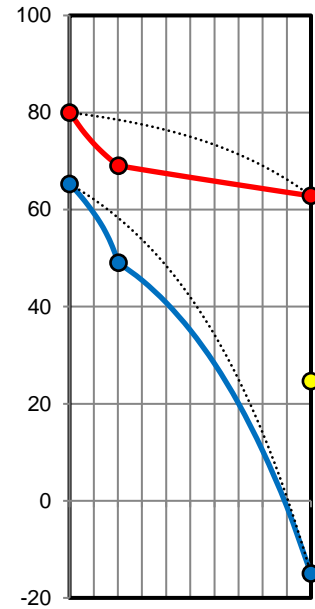
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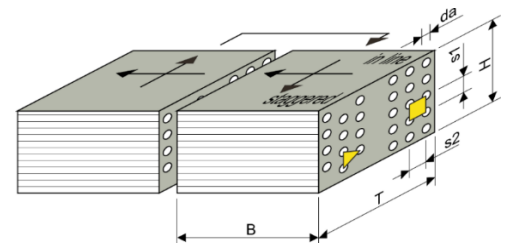
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Cold air around the tubes		Inlet	Average	Outlet
Temp.	°C	-15.000	49.064	65.298
Rel. humidity	%	90.000	1.256	0.584
Abs. humidity	g/kg	0.905	0.905	0.905
Density humid	kg/m3	1.366	1.095	1.042
Enthalpy humid	kJ/kg	-12.852	51.755	68.159
Volume flow humid	m3/h	36627.444	45716.781	48019.973
Mass flow dry	kg/h	50000.000	50000.000	50000.000
Maximal velocity	m/s	1.779	2.220	2.332
Pressure drop	Pa			384.909

Hot air in the tubes		Inlet	Average	Outlet
Temp.	°C	80.000	69.048	62.829
Rel. humidity	%	41.726	65.816	76.336
Abs. humidity	g/kg	150.000	149.138	127.496
Density humid	kg/m3	0.926	0.956	0.983
Enthalpy humid	kJ/kg	477.974	461.570	396.927
Volume flow humid	m3/h	62094.411	60101.597	57353.780
Mass flow dry	kg/h	50000.000	50000.000	50000.000
Surface temperature	°C	65.810	46.517	41.965
Condensate flow	kg/h		43.118	1082.098
Velocity	m/s	8.633	8.355	7.973
Pressure drop dry	Pa			221.500
Pressure drop wet	Pa			336.613



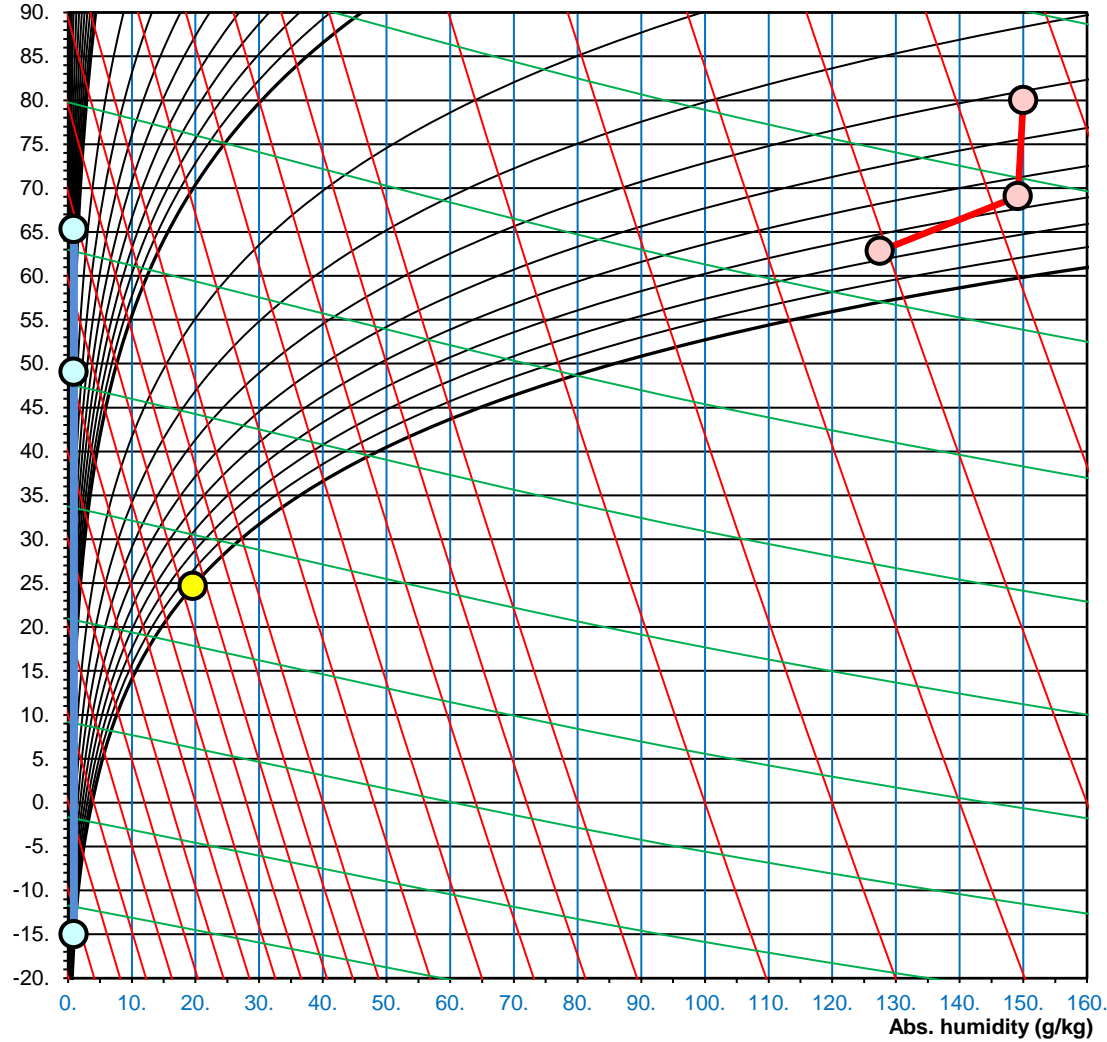
Technical data		Unit 1	Unit 2
Cold corner - Surface temperature	°C	24.666	57.742
Cold air - Outlet - Min.	°C	47.158	62.900
Cold air - Outlet - Max.	°C	51.026	68.154
Hot air - Outlet - Min.	°C	58.339	69.171
Hot air - Outlet - Max.	°C	64.785	71.579
Tubes - Material		AISI 316	AISI 316
Frame - Material		AISI 316	AISI 316
Frame width	B mm	2000	2000
Frame height	H mm	2860	2860
Frame depth	T mm	2860	2860
Weight	kg	3009	3009
Tube arrangement	---	in line	in line
Tube rows on the height	Piece	55	55
Tube rows on the depth	Piece	55	55
Tubes total	Piece	3025	3025
Tube interval on the height	s1 mm	52.000	52.000
Tube interval on the depth	s2 mm	52.000	52.000
Tube diameter	da mm	30.000	30.000
Tube thickness	s mm	0.500	0.500



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Temp. (°C)



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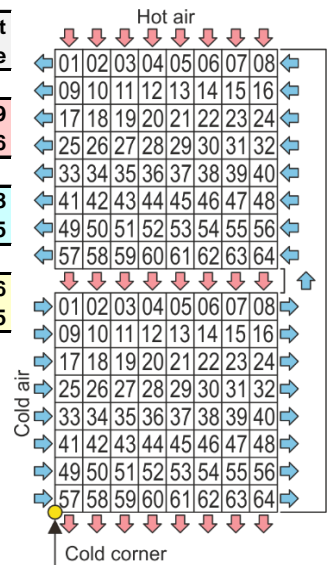
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Temperature lines: Black
Abs. Humidity lines: Blue
Rel. Humidity curves: Black
Enthalpy curves: Red
Density curves: Green

Heat exchanger		Inlet	Average	Outlet	
		---	---	Average	
Hot air in the tubes	t	°C	80.000	69.048	62.829
	x	g/kg	150.000	149.138	127.496
Cold air around the tubes	t	°C	-15.000	49.064	65.298
	x	g/kg	0.905	0.905	0.905
Cold corner	t	°C			24.666
	x	g/kg			19.615



Heat exchanger - Unit 1		Cold air	Hot air	Definition
Height over sea level	m			0.000
Pressure	bar			1.013
Efficiency	%	76.223	7.399	
Capacity sensible	kW	897.319	107.756	
Capacity latent	kW		790.060	
Capacity frost	kW		0.000	
Fouling factor	m2K/W	1.000E-04	1.000E-04	
Present surface	m2			570.199
k-coeff.	W/m2K			38.156
Average temp. diff. (96.94 %)	K			41.243



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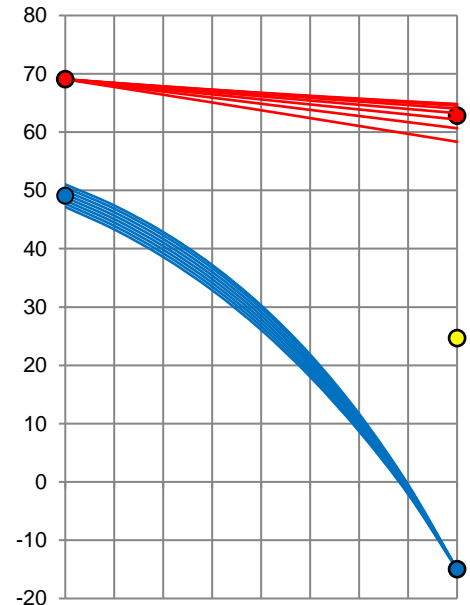
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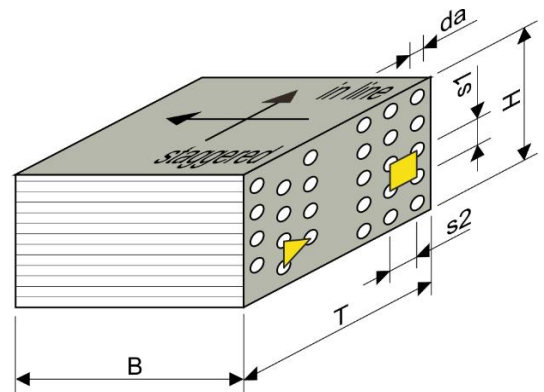
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Cold air around the tubes		Inlet	Outlet
Temp.	°C	-15.000	49.064
Rel. humidity	%	90.000	1.256
Abs. humidity	g/kg	0.905	0.905
Density humid	kg/m3	1.366	1.095
Enthalpy humid	kJ/kg	-12.852	51.755
Volume flow humid	m3/h	36627.444	45716.781
Mass flow dry	kg/h	50000.000	50000.000
Maximal velocity	m/s	1.779	2.220
Pressure drop	Pa		179.025

Hot air in the tubes		Inlet	Outlet
Temp.	°C	69.048	62.829
Rel. humidity	%	65.816	76.336
Abs. humidity	g/kg	149.138	127.496
Density humid	kg/m3	0.956	0.983
Enthalpy humid	kJ/kg	461.570	396.927
Volume flow humid	m3/h	60101.597	57353.780
Mass flow dry	kg/h	50000.000	50000.000
Surface temperature	°C	46.517	41.965
Condensate flow	kg/h		1082.098
Velocity	m/s	8.355	7.973
Pressure drop dry	Pa		107.948
Pressure drop wet	Pa		217.299



Technical data			
Cold corner - Surface temperature	°C		24.666
Cold air - Outlet - Min.	°C		47.158
Cold air - Outlet - Max.	°C		51.026
Hot air - Outlet - Min.	°C		58.339
Hot air - Outlet - Max.	°C		64.785
Tubes - Material		AISI 316	
Frame - Material		AISI 316	
Frame width	B	mm	2000
Frame height	H	mm	2860
Frame depth	T	mm	2860
Weight		kg	3009
Tube arrangement		---	in line
Tube rows on the height		Piece	55
Tube rows on the depth		Piece	55
Tubes total		Piece	3025
Tube interval on the height	s1	mm	52.000
Tube interval on the depth	s2	mm	52.000
Tube diameter	da	mm	30.000
Tube thickness	s	mm	0.500



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Heat exchanger - Unit 2		Cold air	Hot air	Definition
Height over sea level	m			0.000
Pressure	bar			1.013
Efficiency	%	52.475	35.402	
Capacity sensible	kW	227.835	196.109	
Capacity latent	kW		31.727	
Capacity frost	kW		0.000	
Fouling factor	m2K/W	1.000E-04	1.000E-04	
Present surface	m2			570.199
k-coeff.	W/m2K			25.773
Average temp. diff. (90.09 %)	K			15.504



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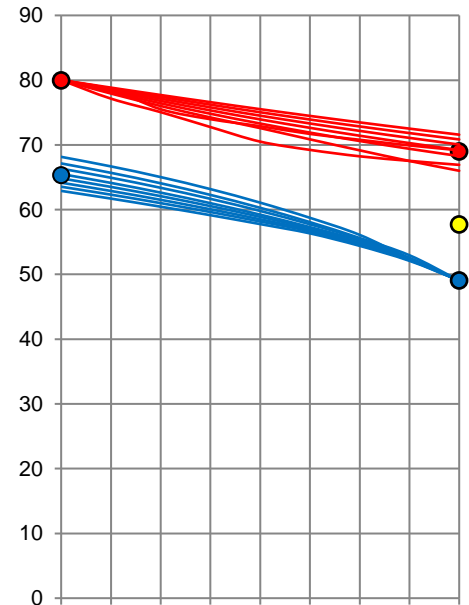
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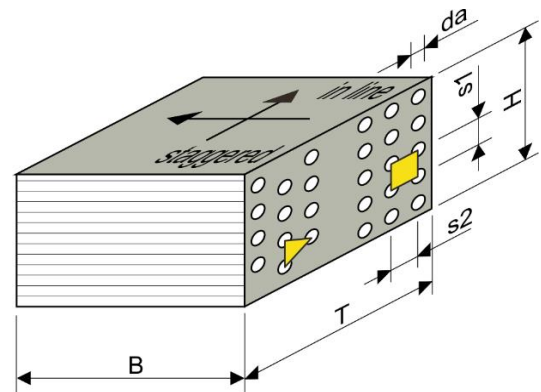
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Cold air around the tubes		Inlet	Outlet
Temp.	°C	49.064	65.298
Rel. humidity	%	1.256	0.584
Abs. humidity	g/kg	0.905	0.905
Density humid	kg/m3	1.095	1.042
Enthalpy humid	kJ/kg	51.755	68.159
Volume flow humid	m3/h	45716.777	48019.973
Mass flow dry	kg/h	50000.000	50000.000
Maximal velocity	m/s	2.220	2.332
Pressure drop	Pa		205.884

Hot air in the tubes		Inlet	Outlet
Temp.	°C	80.000	69.048
Rel. humidity	%	41.726	65.816
Abs. humidity	g/kg	150.000	149.138
Density humid	kg/m3	0.926	0.956
Enthalpy humid	kJ/kg	477.974	461.570
Volume flow humid	m3/h	62094.411	60101.597
Mass flow dry	kg/h	50000.000	50000.000
Surface temperature	°C	65.810	61.291
Condensate flow	kg/h		43.118
Velocity	m/s	8.633	8.355
Pressure drop dry	Pa		113.553
Pressure drop wet	Pa		119.313



Technical data			
Cold corner - Surface temperature	°C		57.742
Cold air - Outlet - Min.	°C		62.900
Cold air - Outlet - Max.	°C		68.154
Hot air - Outlet - Min.	°C		69.171
Hot air - Outlet - Max.	°C		71.579
Tubes - Material		AISI 316	
Frame - Material		AISI 316	
Frame width	B	mm	2000
Frame height	H	mm	2860
Frame depth	T	mm	2860
Weight		kg	3009
Tube arrangement	---		in line
Tube rows on the height		Piece	55
Tube rows on the depth		Piece	55
Tubes total		Piece	3025
Tube interval on the height	s1	mm	52.000
Tube interval on the depth	s2	mm	52.000
Tube diameter	da	mm	30.000
Tube thickness	s	mm	0.500



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