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Performance & Design Analysis of forced Draft counter to cross flow Air cooled heat exchanger at extremely low ambient temperature i.e. at - 28^{o}C

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ABSTRACT: There are several sites, in the world as well as in India, where the ambient temperature reaches below 0°C to -28°C, at this temperature the fluid in heat exchanger freezes. If the fluid Freezes in Heat Exchanger, the heat exchanger ceases and it would damage the heat exchanger also. In extremely cold environments, overcooling of the process fluid may cause freezing. This may lead to tube burst, and hence protection from freezing is required to prevent plugging or damaging the tubes [2]. Heat Exchanger is designed on the basis of hot fluid temperature, cold fluid temperature & ambient temperature, but in practical sense, the ambient temperature changes throughout the year. Here we are analyzing the effect of extreme low ambient temperature on Forced Draft Counter to Cross flow Air Cooled Heat Exchanger. Here, we have taken the temperature of surrounding air, as -28^{o}C. Here, we are studying the performance & design analysis of Air Cooled heat exchanger at extremely low ambient temperature. In this we are doing the thermal design of forced draft counters to cross flow Air Cooled heat exchanger at extremely low ambient temperature i.e. at -28^{o}C. The most important parameter, while taking into consideration of designing Air Cooled Heat Exchanger is permissible /minimum tube skin temperature. There are various fluids such as Diethanolamine or Lean DEA which are used in various industries like oil Refinery, the temperature at which this fluid starts freezes is 9°C. So, as to protect the fluid from freezing, we need an equipment which maintains the temperature of ambient air & fluid according to their pour point & freezing temperature. For this, we can use the steam coil to raise the temperature of ambient air & fluid. If the fluid Freezes in Heat Exchanger, the heat exchanger ceases and it will damage the heat exchanger also. For this reason, we use the steam coil.

Keywords: Thermal Design, counter to cross flow heat exchanger, permissible/minimum tube skin temperature, lean dea, extremely low ambient temperature

I. INTRODUCTION

Heat Exchanger is designed on the basis of hot fluid temperature, cold fluid temperature & ambient temperature, but in practical sense, the ambient temperature changes throughout the year. There are several sites, in India as well as in world, where the ambient temperature reaches below 0^{o}C, that is freezing temperature. We know that in extreme low ambient temperature the fluid in the Air cooled heat exchanger freezes & this may lead to the tube burst & fluid freeze. At low ambient temperature the fluid in heat exchanger freezes. If the fluid Freezes in Heat Exchanger, the heat exchanger ceases and it would damage the heat exchanger also. In extremely cold environments, overcooling of the process fluid may cause freezing. There are various fluids such as Diethanolamine or Lean DEA are used in Refinery, the temperature at which this fluid starts freezes is 9°C. So, as to protect the fluid from freezing

The process parameters/boundary conditions for thermal design of Air Cooled heat Exchanger are-

Flow rate of hot & cold fluid
Inlet & outlet temperature of hot & cold fluid
Inlet temperature of cold fluid
Allowable pressure drop **[1]**

II. OBJECTIVES

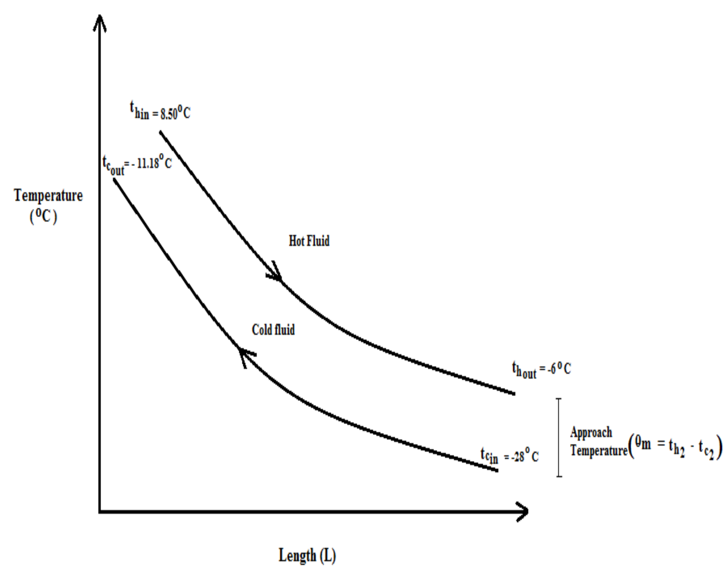
1. The main objective of this master thesis is to give the idea for thermal design of Forced Draft Counter to Cross Flow Air Cooled Heat Exchanger at extremely low ambient temperature, as there are lots of problems associated, while designing an Air Cooled Heat Exchanger.
2. In this research paper we will analyze the effect of ambient temperature on Forced Draft Counter to Cross flow Air Cooled Heat Exchanger. Here, we have taken the temperature of surrounding air, as -28°C. Here, we are studying the performance & design analysis of Air Cooled heat exchanger at extremely low ambient temperature.
3. To give the thermal design & procedure of Air cooled heat exchanger counter to cross flow at extremely low ambient temperature.
4. To discuss the various challenges while designing the Counter to Cross Flow Heat Exchanger.

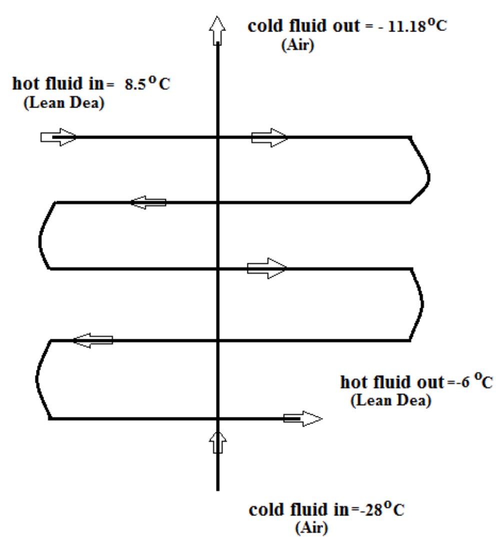
Thermal Design of forced draft counter to cross flow heat exchanger for extremely low ambient condition, i.e. -28°C-

In this we are doing & analyzing the thermal design of forced draft counters to cross flow Air Cooled heat exchanger at extremely low ambient temperature i.e at -28°C. The most important parameter, while taking into consideration of designing Air Cooled Heat Exchanger is permissible /minimum tube skin temperature At this, the temperature of surrounding air, i.e. temperature of cold fluid (air) is -28°C. Here we have gone to extremely low ambient temperature i.e -28°C, By previous records of temperature on some particular locations, we have come to the conclusion that in extreme cases, the temperature of these locations falls to -28°C. In this we have done the thermal design & performance analysis of forced draft counter to cross flow air heat exchanger at extremely low ambient conditions, so we have taken -28°C temperature for designing & performance analysis of Air Cooled Heat Exchanger. The most important parameter ,while taking into consideration of designing Air Cooled Heat Exchanger is permissible /minimum tube skin temperature .In this forced draft counter to cross flow air cooled heat exchanger, the process fluid is lean dea. The pour point of any fluid can be defined as that point, when fluid ceases to flow i.e. fluid start freezing at this temperature

For extremely low atmospheric conditions, i.e. extremely low ambient temperature is- 28°C, the process parameters are-

a). Flow rate of hot fluid (lean dea) = 94.526 (1000-kg/h)
b). Flow rate of cold fluid (air) = 300.262 (1000-kg/h)
c). Inlet temperature of hot fluid = 8.5°C
d). Outlet temperature of hot fluid= - 6°C
e). Inlet temperature of cold fluid (air)= -28°C
f). Allowbale pressure drop of hot fluid =0.710kgf/cm^2
g). Inlet pressure of hot fluid = 2.133kgf/cm^2
h). Altitude





Nomenclature:

Hot fluid (lean dea) enters in Air Cooled Heat Exchanger =t_{hin} =8.5°C
Hot fluid (lean dea) leaves the Air Cooled Heat Exchanger = t_{hout} = -6°C
Cold fluid (air) enters in Air Cooled Heat Exchanger = t_{cin} = -28°C
Cold fluid (air) leaves the Air Cooled Heat Exchanger = t_{cout} =-11.18°C

Change in hot fluid(lean dea) temperature $\Delta t_h = t_{hin} - t_{hout}$ =8.5ºC -(-6 ºC)=14.5 ºC
Change in cold fluid (air) temperature $\Delta t_c = t_{cout} - t_{cin}$ = -11.18 – (-28) =16.82ºC
Approach Temperature = $\theta m_1 = t_{hout} - t_{cin}$ = -6 ºC –(-28 ºC) = 22 ºC
Approach Temperature = $\theta m_2 = t_{hin} - t_{cout}$ =8.5ºC – (-11.18 ºC) =19.68 ºC
There are two different approach temperatures, but in counter to cross flow heat exchanger, we consider the
Approach Temperature = $\theta m_1 = t_{hout} - t_{cin}$
= -6 ºC – (-28 ºC)
= 22 ºC
Only this approach temperature is important, while designing the forced draft counter to cross flow heat exchanger.

The most important parameter, while taking into consideration of designing of Air Cooled Heat Exchanger is Tube skin temperature. In this Forced draft counter to cross flow Air Cooled heat exchanger the process fluid is lean dea. We know that, the pour point of lean dea is 8ºC and as per API 661 guidelines of heat exchanger design,
The permissible tube skin temperature = pour point of fluid + 9 ºC
= 8 ºC + 9 ºC
=17ºC
So, permissible tube skin temperature of Air Cooled Heat Exchanger is 17ºC, but in this case it goes to -12.73ºC, in such condition fluid in the heat exchanger ceases resulting in exchanger failure & tube bursts .So, this design of Air Cooled Heat Exchanger is Unsafe & Fail.

By using thermal design software we found the following properties of hot fluid (lean dea) & cold fluid (Air)-

Stream properties of hot fluid side fluid (lean dea) –

Stream Properties

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow — **MKH Units**

Hot Tubeside Fluid		**Inlet**	**Outlet**
Fluid name		Lean DEA	
Temperature	(C)	8.50	-6.00
Pressure	(kgf/cm2A)	2.133	1.318
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(kcal/hr-m-C)	--	--
Heat capacity	(kcal/kg-C)	--	--
Molecular weight	(--)	--	--
Liquid Properties			
Density	(kg/m3)	1044.53	1053.83
Viscosity	(cP)	4.1136	6.6665
Conductivity	(kcal/hr-m-C)	0.4019	0.3929
Heat capacity	(kcal/kg-C)	0.8877	0.8817
Molecular weight	(--)	0	0
Latent heat	(kcal/kg)	--	--
Surface tension	(dyne/cm)	0.0000	0.0000

Molar Composition	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 [New User-Defined]	--	--	--	--	--	--

Stream properties of cold outside fluid (Air)

Stream Properties

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow — **MKH Units**

Cold Outside Fluid		**Inlet**	**Outlet**
Fluid name			
Temperature	(C)	-28.00	-11.18
Pressure	(kgf/cm2A)	1.031	1.030
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Density	(kg/m3)	1.4373	1.3450
Viscosity	(cP)	0.0158	0.0166
Conductivity	(kcal/hr-m-C)	0.0189	0.0200
Heat capacity	(kcal/kg-C)	0.2401	0.2401
Molecular weight	(--)	28.96	28.96
Liquid Properties			
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(kcal/hr-m-C)	--	--
Heat capacity	(kcal/kg-C)	--	--
Molecular weight	(--)	--	--
Latent heat	(kcal/kg)	--	--
Surface tension	(dyne/cm)	--	--

Molar Composition	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**

Physical properties of hot tube side (lean dea) at various sections of forced draft counters to cross flow Air Cooled heat exchanger at normal ambient temperature

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Hot Tubeside (Lean DEA)

Reference pressure, (kgf/cm2A) (P1= 2.133)

	(P)	1	2	3	4	5	6	7	8	9	10
Temperature, (C)	1	8.50	8.00	7.50	7.00	6.50	6.00	5.50	5.00	4.50	4.00
Heat duty/flow rate, (kcal/kg)	1	0.0000	0.4438	0.8875	1.3311	1.7745	2.2179	2.6612	3.1044	3.5474	3.9904
Weight fraction vapor	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Liquid Properties											
Density, (kg/m3)	1	1044.53	1044.85	1045.17	1045.49	1045.81	1046.13	1046.46	1046.78	1047.10	1047.42
Viscosity, (cP)	1	4.1136	4.1792	4.2460	4.3142	4.3838	4.4547	4.5270	4.6007	4.6760	4.7527
Thermal conductivity, (kcal/hr-m-C)	1	0.4019	0.4016	0.4012	0.4009	0.4006	0.4003	0.4000	0.3997	0.3994	0.3991
Enthalpy, (kcal/kg)	1	0.0000	-0.4438	-0.8875	-1.3311	-1.7745	-2.2179	-2.6612	-3.1044	-3.5474	-3.9904
Specific heat, (kcal/kg-C)	1	0.8877	0.8875	0.8873	0.8871	0.8869	0.8867	0.8864	0.8862	0.8860	0.8858
Surface tension, (dyne/cm)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Critical pressure, (kgf/cm2A)	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Latent heat, (kcal/kg)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Hot Tubeside (Lean DEA)

Reference pressure, (kgf/cm2A) (P1= 2.133)

	(P)	11	12	13	14	15	16	17	18	19	20
Temperature, (C)	1	3.50	3.00	2.50	2.00	1.50	1.00	0.50	1.184e-3	-0.50	-1.00
Heat duty/flow rate, (kcal/kg)	1	4.4332	4.8760	5.3187	5.7612	6.2036	6.6460	7.0882	7.5304	7.9724	8.4143
Weight fraction vapor	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Liquid Properties											
Density, (kg/m3)	1	1047.74	1048.06	1048.38	1048.70	1049.02	1049.34	1049.66	1049.98	1050.30	1050.62
Viscosity, (cP)	1	4.8310	4.9109	4.9924	5.0755	5.1603	5.2469	5.3352	5.4254	5.5174	5.6114
Thermal conductivity, (kcal/hr-m-C)	1	0.3988	0.3985	0.3981	0.3978	0.3975	0.3972	0.3969	0.3966	0.3963	0.3960
Enthalpy, (kcal/kg)	1	-4.4332	-4.8760	-5.3187	-5.7612	-6.2036	-6.6460	-7.0882	-7.5304	-7.9724	-8.4143
Specific heat, (kcal/kg-C)	1	0.8856	0.8854	0.8852	0.8850	0.8848	0.8846	0.8844	0.8842	0.8840	0.8838
Surface tension, (dyne/cm)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Critical pressure, (kgf/cm2A)	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Latent heat, (kcal/kg)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Hot Tubeside (Lean DEA)

Reference pressure, (kgf/cm2A) (P1= 2.133)

	(P)	21	22	23	24	25	26	27	28	29	30
Temperature, (C)	1	-1.50	-2.00	-2.50	-3.00	-3.50	-4.00	-4.50	-5.00	-5.50	-6.00
Heat duty/flow rate, (kcal/kg)	1	8.8561	9.2979	9.7395	10.1810	10.6224	11.0637	11.5049	11.9460	12.3870	12.8280
Weight fraction vapor	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Liquid Properties											
Density, (kg/m3)	1	1050.94	1051.27	1051.59	1051.91	1052.23	1052.55	1052.87	1053.19	1053.51	1053.83
Viscosity, (cP)	1	5.7073	5.8051	5.9051	6.0071	6.1113	6.2177	6.3264	6.4373	6.5507	6.6665
Thermal conductivity, (kcal/hr-m-C)	1	0.3957	0.3953	0.3950	0.3947	0.3944	0.3941	0.3938	0.3935	0.3932	0.3929
Enthalpy, (kcal/kg)	1	-8.8561	-9.2979	-9.7395	-10.181	-10.622	-11.064	-11.505	-11.946	-12.387	-12.828
Specific heat, (kcal/kg-C)	1	0.8836	0.8833	0.8831	0.8829	0.8827	0.8825	0.8823	0.8821	0.8819	0.8817
Surface tension, (dyne/cm)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Critical pressure, (kgf/cm2A)	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Latent heat, (kcal/kg)	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Physical properties of cold outside tube (Air) at various sections of forced draft counters to cross flow Air Cooled heat exchanger at normal ambient temperature

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Cold Outside

Reference pressure, (kgf/cm2A)	(P1= 1.031)										
	(P)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Temperature, (C)	1	-11.18	-11.76	-12.34	-12.92	-13.50	-14.08	-14.66	-15.24	-15.82	-16.40
Heat duty/flow rate, (kcal/kg)	1	4.0384	3.8991	3.7599	3.6206	3.4814	3.3421	3.2029	3.0636	2.9244	2.7851
Weight fraction vapor	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Vapor Properties											
Density, (kg/m3)	1	1.3450	1.3480	1.3510	1.3540	1.3570	1.3600	1.3631	1.3662	1.3692	1.3723
Viscosity, (cP)	1	0.0166	0.0166	0.0166	0.0165	0.0165	0.0165	0.0164	0.0164	0.0164	0.0163
Thermal conductivity, (kcal/hr-m-C)	1	0.0200	0.0200	0.0200	0.0199	0.0199	0.0198	0.0198	0.0198	0.0197	0.0197
Enthalpy, (kcal/kg)	1	0.0000	-0.1393	-0.2785	-0.4178	-0.5570	-0.6963	-0.8355	-0.9748	-1.1141	-1.2533
Specific heat, (kcal/kg-C)	1	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Cold Outside

Reference pressure, (kgf/cm2A)	(P1= 1.031)										
	(P)	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Temperature, (C)	1	-16.98	-17.56	-18.14	-18.72	-19.30	-19.88	-20.46	-21.04	-21.62	-22.20
Heat duty/flow rate, (kcal/kg)	1	2.6458	2.5066	2.3673	2.2281	2.0888	1.9496	1.8103	1.6711	1.5318	1.3926
Weight fraction vapor	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Vapor Properties											
Density, (kg/m3)	1	1.3754	1.3786	1.3817	1.3848	1.3880	1.3912	1.3944	1.3976	1.4008	1.4040
Viscosity, (cP)	1	0.0163	0.0163	0.0163	0.0162	0.0162	0.0162	0.0161	0.0161	0.0161	0.0161
Thermal conductivity, (kcal/hr-m-C)	1	0.0196	0.0196	0.0196	0.0195	0.0195	0.0194	0.0194	0.0193	0.0193	0.0193
Enthalpy, (kcal/kg)	1	-1.3926	-1.5318	-1.6711	-1.8103	-1.9496	-2.0888	-2.2281	-2.3673	-2.5066	-2.6459
Specific heat, (kcal/kg-C)	1	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401

Properties Profile Monitor

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Physical Properties Profile: Cold Outside

Reference pressure, (kgf/cm2A)	(P1= 1.031)										
	(P)	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Temperature, (C)	1	-22.78	-23.36	-23.94	-24.52	-25.10	-25.68	-26.26	-26.84	-27.42	-28.00
Heat duty/flow rate, (kcal/kg)	1	1.2533	1.1140	0.9748	0.8355	0.6963	0.5570	0.4178	0.2785	0.1393	0.0000
Weight fraction vapor	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Vapor Properties											
Density, (kg/m3)	1	1.4073	1.4106	1.4138	1.4171	1.4205	1.4238	1.4271	1.4305	1.4339	1.4373
Viscosity, (cP)	1	0.0160	0.0160	0.0160	0.0159	0.0159	0.0159	0.0158	0.0158	0.0158	0.0158
Thermal conductivity, (kcal/hr-m-C)	1	0.0192	0.0192	0.0191	0.0191	0.0191	0.0190	0.0190	0.0189	0.0189	0.0189
Enthalpy, (kcal/kg)	1	-2.7851	-2.9244	-3.0636	-3.2029	-3.3421	-3.4814	-3.6206	-3.7599	-3.8991	-4.0384
Specific heat, (kcal/kg-C)	1	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401	0.2401

III. RESULTS

Output Summary

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Process Conditions		Outside		Tubeside	
Fluid name				Lean DEA	
Fluid condition			Sens. Gas		Sens. Liquid
Total flow rate	(1000-kg/hr)		300.262		94.526
Weight fraction vapor, In/Out		1.000	1.000	0.000	0.000
Temperature, In/Out	(Deg C)	-28.00	-11.18	8.50	-6.00
Skin temperature, Min/Max	(Deg C)	-17.74	-1.89	-12.73	3.55
Pressure, Inlet/Outlet	(kgf/cm2A)	1.031	1.030	2.133	1.318
Pressure drop, Total/Allow	(mmH2O) | (kgf/cm2)	10.840	0.000	0.815	0.710
Midpoint velocity	(m/s)		5.42		1.42
- In/Out	(m/s)			1.43	1.47
Heat transfer safety factor	(--)		1		1
Fouling	(m2-hr-C/kcal)		0.000000		0.000500

Exchanger Performance

Outside film coef	(kcal/m2-hr-C)	37.33
Tubeside film coef	(kcal/m2-hr-C)	1702.55
Clean coef	(kcal/m2-hr-C)	22.743
Hot regime		Sens. Liquid
Cold regime		Sens. Gas
EMTD	(Deg C)	20.7
Duty	(MM kcal/hr)	1.212

Actual U	(kcal/m2-hr-C)	17.339
Required U	(kcal/m2-hr-C)	20.850
Area	(m2)	2811.99
Overdesign	(%)	-16.84

Unit Geometry

Bays in parallel per unit			1
Bundles parallel per bay			2
Extended area	(m2)		2811.99
Bare area	(m2)		123.118
Bundle width	(mm)		1276.
Nozzle		**Inlet**	**Outlet**
Number	(--)	1	1
Diameter	(mm)	131.750	131.750
Velocity	(m/s)	0.92	0.91
R-V-SQ	(kg/m-s2)	887.83	879.99
Pressure drop	(kgf/cm2)	4.980e-3	3.141e-3

Tube Geometry

Tube type		High-finned
Tube OD	(mm)	25.400
Tube ID	(mm)	21.184
Length	(mm)	7999.903
Area ratio(out/in)	(--)	27.3853
Layout		Staggered
Trans pitch	(mm)	75.000
Long pitch	(mm)	64.950
Number of passes	(--)	4
Number of rows	(--)	6
Tubecount	(--)	99
Tubecount Odd/Even	(--)	17 / 16
Tube material		Carbon steel

Fan Geometry

No/bay	(--)	2
Fan ring type		30 deg
Diameter	(mm)	2286.
Ratio, Fan/bundle face area	(--)	0.40
Driver power	(kW)	6.34
Tip clearance	(mm)	11.430
Efficiency	(%)	65

Fin Geometry

Type		Plain round
Fins/length	fin/meter	433.0
Fin root	mm	27.000
Height	mm	15.075
Base thickness	mm	0.400
Over fin	mm	57.150
Efficiency	(%)	81.5
Area ratio (fin/bare)	(--)	22.8398
Material		Aluminum 1060 - H14

Airside Velocities		**Actual**	**Standard**
Face	(m/s)	2.84	3.40
Maximum	(m/s)	5.27	6.31
Flow	(100 m3/min)	34.818	41.654
Velocity pressure	(mmH2O)	3.670	
Bundle pressure drop	(mmH2O)	9.263	
Bundle flow fraction	(--)	1.000	

Thermal Resistance, %

Air	46.45
Tube	27.89
Fouling	23.76
Metal	1.90
Bond	0.00

Airside Pressure Drop, %

Bundle	85.45			Louvers	6.03
Ground clearance	0.00	Fan guard	0.55	Hail screen	0.00
Fan ring	2.03	Fan area blockage	5.94	Steam coil	0.00

Final Results

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

		Process Data	Airside		Tubeside	
Fluid name					Lean DEA	
Fluid condition				Sens. Gas		Sens. Liquid
Total flow rate	(1000-kg/hr)			300.262		94.526
Weight fraction vapor, In/Out	(--)		1.000	1.000	0.000	0.000
Temperature, In/Out	(Deg C)		-28.00	-11.18	8.50	-6.00
Skin temperature, Min/Max	(Deg C)		-17.74	-1.89	-12.73	3.55
Wall temperature, Min/Max	(Deg C)		-17.74	-1.89	-12.89	3.36
Pressure, In/Out	(kgf/cm2A)		1.031	1.030	2.133	1.318
Pressure drop, Total/Allowed	(mmH2O) | (kgf/cm2)		10.840	0.000	0.815	0.710
Pressure Drop, A-frame reflux section	(kgf/cm2)					
Velocity - Midpoint	(m/s)		5.42		1.42	
- In/Out	(m/s)				1.43	1.47
Film coefficient, Bare/Extended	(kcal/m2-hr-C)		852.58	37.33	1702.55	
Mole fraction inert	(--)					
Heat transfer safety factor	(--)			1		1
Fouling resistance	(m2-hr-C/kcal)			0.000000		0.000500
Overall Performance Data						
Overall coef, Design/Clean/Actual	(kcal/m2-hr-C)		20.850 /	22.743 /	17.339	
Heat duty, Calculated/Specified	(MM kcal/hr)		1.2118 /	0.0000		
Effective mean temperature difference	(Deg C)		20.67			

Unit and Bundle Construction Information

Bays in parallel/unit	(--)		1	Bundles in parallel/bay		2
Extended area/unit	(m2)		2811.99	Bare area/unit	(m2)	123.118
Extended area/bundle	(m2)		1405.99	Bare area/bundle	(m2)	61.559
Tubepasses/Tuberows	(--)	4 /	6	Number of tubes/bundle	(--)	99
Tubecount, Odd rows/Even rows	(--)	17 /	16	Edge seals	(--)	Yes
Bundle width	(mm)		1276.	Fan guard	(--)	Yes
Clearance	(mm)		9.525	Louvers	(--)	Yes
Header depth	(mm)		101.600	Steam coil	(--)	No
Header Box				Hail screen	(--)	No
- Plate thickness	(mm)		25.400	*Tube support information*		
- Tubesheet thickness	(mm)		34.925	- Number	(--)	4
Plenum type			Tapered	- Width	(mm)	25.400
Weight/Bundle	(kg)		3649	Orientation (from horiz.)	(deg)	0.00
Structure weight	(kg)		3347	Tubeside volume	(L)	386.5
Total weight, Dry / Wet	(kg)		13165 /	13937		
Ladder/walkway weight	(kg)		2520	Cost Factor	(--)	47.3566

Tube Information

Straight length	(mm)	8000.	Tube type		High-finned
Unfinned length	(mm)	36.000	Unheated length	(mm)	171.450
Layout	(--)	Staggered	Area ratio (fin/bare)	(--)	22.8398
Transverse pitch	(mm)	75.000	Fins per unit length	(fin/meter)	433.0
Longitudinal pitch	(mm)	64.950	Fin root diameter	(mm)	27.000
Tube form	(--)	Straight	Fin height	(mm)	15.075
Outside diameter	(mm)	25.400	Fin thickness at base	(mm)	0.400
Inside diameter	(mm)	21.184	Fin thickness at tip	(mm)	0.189
Area ratio (out/in)	(--)	27.3853	Fin type	(--)	Plain round
Over fin diameter	(mm)	57.150	Fin efficiency	(%)	81.5
Tube material		Carbon steel	Internal tube type		None
Fin material		Aluminum 1060 - H14			

Final Results

MKH Units

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

Inlet Airside Velocities		Actual	Standard
Face velocity	(m/s)	2.84	3.40
Maximum velocity	(m/s)	5.27	6.31
Volumetric flow	(100 m3/min)	34.818	41.654
Maximum mass velocity	(kg/s-m2)	7.575	
Air humidity	(%)		
Volumetric flow per fan at fan inlet	(100 m3/min)	17.409	
Velocity at fan inlet	(m/s)	7.07	

Fan Description and Fan Power			
Number of fans per bay	(--)		2
Diameter	(mm)		2286.
Tip clearance	(mm)		11.430
Ratio, fan area to bay face area	(--)		0.40
Fan ring type	(--)		30 deg
Percent open area - in fan guard	(%)		95
- in hail screen	(%)		0
Ratio, ground clearance to fan diameter	(--)		
Percent blockage, other obstruction	(%)		5
Bundle pressure drop/ Velocity pressure	(mmH2O)	9.263 /	3.670
Fan and drive efficiency	(%)		65
Motor power per fan-design air temperature	(kW)		6.34
Motor power per fan-minimum air temperature	(kW)		0.00
Ambient temperature, maximum / minimum	(Deg C)	-17.78 /	-17.78

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F
Bundle flow fraction	(--)	1.000		

Heat Transfer and Pressure Drop Parameters			Tubeside	Outside
Midpoint j-factor		(--)		0.0058
Heat transfer	Wall Correction	(--)	0.9680	0.9856
	Row Correction	(--)		1.0000
Midpoint f-factor		(--)	0.0105	0.1866
Pressure drop	Wall Correction	(--)	1.0488	1.0093
	Row Correction	(--)		1.0008
Reynolds number	Inlet	(--)	7670	12980
	Midpoint	(--)	5686	12683
	Outlet	(--)	4930	11593
Fouling layer thickness		(mm)	0.000	0.000
Input minimum velocity		(m/s)		
Input maximum velocity		(m/s)		
Input minimum wall temperature		(Deg C)		
Input maximum wall temperature		(Deg C)		

Thermal Resistance (Percent)					Over Design
Air	Tube	Fouling	Metal	Bond	
46.45	27.89	23.76	1.90	0.00	-16.84

Airside Pressure Drop (Percent)			
Across bundle	85.45	Other obstruction	5.94
Fan ring	2.03	Steam coil	0.00
Fan guard	0.55	Louvers	6.03
Ground clearance	0.00		

Tube Nozzle (Perpendicular)		Inlet	Outlet
Number of nozzles	(--)	1	1
Diameter	(mm)	131.750	131.750
Velocity	(m/s)	0.92	0.91
Nozzle R-V-SQ	(kg/m-s2)	887.83	879.99
Pressure drop	(kgf/cm2)	4.980e-3	3.141e-3

IV. CONCLUSION AND OUTCOME

The most important parameter, while taking into consideration for designing the Forced Draft Counter to cross flow Air Cooled Heat Exchanger is tube skin temperature. In this Forced Draft Counter to cross flow Air Cooled Heat Exchanger, the process fluid is lean dea. Here, the air acts as a cold fluid & lean dea acts as a hot fluid. The hot fluid lea dea loses its heat from 8.5ºC to - 6ºC & cold fluid air gains the heat from -28ºC to -11.18ºC, during heat exchanging process. By studying the various properties of lean dea, we come to know that ,the pour point of lean dea is 8ºC & by studying API 661 guidelines for designing of Air Cooled Heat Exchanger , the minimum tube skin temperature is equal to the pour pint of fluid +9ºC API Margin.

i.e. Permissible/minimum tube skin temperature = pour point of fluid (lean dea) +9ºC (API Margin)

= 8ºC +9ºC = 17 ºC

By studying the properties of lean dea we come to know that the tube skin temperature at -28 ºC is -12.73 ºC. At- 28ºC the permissible tube skin temperature is -12.73 ºC, which is far below than the permissible tube skin temperature(17ºC). So, the design & performance of Forced Draft Counter to Cross Flow Air Cooled Heat Exchanger is unsafe & fail & this will lead to freezing of fluid & tube burst in the Air Cooled Heat Exchanger . So, for this reason a equipment or a method is needed for heating the process fluid and to maintain the temperature of tube skin as per API guidelines. In these ambient conditions, there is a need of steam coil because at this temperature, the fluid in the heat exchanger freezes, hence there is a problem in this design. So, we require a steam coil for heating the fluid, so that tube skin temperature is maintained at 17 ºC.

V. FUTURE SCOPE

For extremely low ambient temperature the fluid in the heat exchanger freezes for this A steam coil is required for heating the fluid, so that the tube skin temperature is maintained at 17ºC. So we have to design a steam coil to prevent the fluid from freezing without affecting the performance of Air Cooled Counter to cross flow heat exchanger. And there arises a question that at what temperature we start the steam coil for heating the fluid to achieve maximum auxiliary power saving, energy saving & lower use of steam? In case if the fluid is already freeze, than the fan, motor, pumps do the extra work for heating the fluid. This will lead to more power, more energy & more steam consumption.

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