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RESEARCH ARTICLE

COMPUTATIONAL THERMAL DESIGN OF FORCED DRAFT COUNTER TO CROSS FLOW AIR COOLED HEAT EXCHANGER AT NORMAL AMBIENT TEMPERATURE I.E. AT 38 ^{O}C

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ABSTRACT

Heat exchangers are equipment that transfers heat from one medium to another. An air cooled heat exchanger, or ACHE, is simply a pressure vessel which cools a circulating fluid within finned tubes by forcing ambient air over the exterior of the tubes. In cross flow exchangers, the hot and cold fluids move perpendicular to each other. Some actual heat exchangers are a mixture of cross flow and counter flow (Known as Counter to Cross Flow Heat Exchangers) due to design features (Parag Mishra and Dr Manoj Arya, 2016). The proper design, operation and maintenance of heat exchangers will make the process energy efficient and minimize energy losses. Heat exchanger performance can deteriorate with time, off design operations and other interferences such as fouling, scaling etc. It is necessary to assess periodically the heat exchanger performance in order to maintain them at a high efficiency level. This section comprises certain proven techniques of monitoring the performance of heat exchangers, coolers and condensers from observed operating data of the equipment. In this we are doing the thermal design of forced draft counters to cross flow Air Cooled heat exchanger at normal ambient temperature i.e at 38 ^{o}C. The most important parameter, while taking into consideration of designing Air Cooled Heat Exchanger is permissible /minimum tube skin temperature. A major problem constantly faced by heat exchanger designers is to predict accurately the performance of a given heat exchanger or a system of heat exchangers for a given set of service conditions. The problem is complicated by the fact that uncertainties exist in most of the design parameters and in the design procedures themselves. The design parameters that are used in the basic thermal design calculations of a heat exchanger include process parameters, heat-transfer coefficients, tube dimensions (e.g., tube diameter, wall thickness), thermal conductivity of the tube material, and thermo physical properties of the fluids. Nominal or mean values of these parameters are used in the design calculations. However, uncertainties in these parameters prevent us from predicting the exact performance of the unit. The effect of the uncertainties is mostly in the performance degradation in service. Hence, there is an imperative need to consider all the uncertainties and to critically evaluate them and correctly predict the thermal performance of a heat exchanger. This is particularly true for critical applications. In thermal design of heat exchangers there are presently many stages in which assumptions in mathematical solution of the design problem are being made. Accumulation of these assumptions (e.g. use of mean values) may introduce variations in design as large as the uncertainties introduced in heat-transfer and flow friction correlations. The designer needs to understand where these inaccuracies may arise, and strive to eliminate as many sources of error as possible by choosing design configurations that avoid such problems at source. Heat Exchanger Thermal Design Problem referred to as the rating and sizing problems (Parag Mishra and Dr Manoj Arya, 2016)

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INTRODUCTION

Heat exchangers are equipment that transfers heat from one medium to another. An air cooled heat exchanger, or ACHE, is simply a pressure vessel which cools a circulating fluid within finned tubes by forcing ambient air over the exterior of the tubes (CFD, 2015).

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A heat exchanger is a heat-transfer devise that is used for transfer of internal thermal energy between two or more fluids available at different temperatures.

In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak.

Types of draft in air cooled heat exchangers

There are many similar configurations by different manufacturers; however most of these are a derivative of one of these types. The most common type of air cooler is the horizontal coil with horizontal fan and vertical air flow. This type is typically driven by an electric motor drive attached to the fan through v-belts to allow for speed reduction between the motor and the fan. The normal application for these models are in plants or refineries where electric power is available, and where the cooler is installed away from other equipment to allow adequate air flow around the air cooler. This model is built in both induced draft and forced draft configurations (Parag Mishra, 2015).

Forced Draft ACHE

The most economical and most common style of air cooler is the forced draft ACHE, uses axial fans to force air across the fin tube bundle. The fans are positioned below the bundle thus not exposing the mechanical sections to the hot exhaust airflow. The forced draft air cooler also simplifies future plant expansion by providing direct access to bundle for replacement. Structural disassembly is not required**.** Forced Draft – fans are positioned below the tube bundle and force air across the fin tubes (Parag Mishra, 2015). A subset of the forced draft unit is called a "Winterized" unit. Here, a forced draft unit is outfitted with one or more methods to control the process fluid temperature leaving the ACHE. This type of unit is typically found in colder climates but is also used in hotter climates for process fluids with high viscosities and/or high pour points (Parag Mishra, 2015).

Induced Draft ACHE

The second most economical and most common style air cooler is the induced draft ACHE. This design uses axial fans to pull air across the fin tube bundle. The fans are positioned above the bundle thus offering greater control of the process fluid and bundle protection due to the additional structure. Lower noise levels at grade are another benefit. The induced draft air cooler does require some structural disassembly if bundle replacement is required. Induced Draft – fans are positioned above the bundle and pull across the fin tubes. Induced draft coolers offer improved air distribution and protection of the tube bundle from the elements (Parag Mishra, 2015).

Problems with Heat Exchangers in Low-Temperature Environments

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. In that case, the fluid in heat exchanger freezes. In extremely cold environments, overcooling of the process fluid may cause freezing. This may lead to tube burst, and hence freeze protection is required to prevent plugging or damage to the tubes. For this, we can use steam coil in Heat Exchanger for heating the working fluid (Parag Mishra, 2016).

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

Dimensions of Air Cooled Heat Exchanger

Dimension of Air Cooled Heat Exchanger is based on plot area or land area. Important dimensions of Air Cooled Heat Exchanger includes-

- Total Plot area
- Bays in parallel per unit
- Bundles parallel per bay
- Bundle width
- Length of tube
- Number of rows
- Number of fan/bay
- Fan Diameter

Computational Software for Using Thermal Design of Air Cooled Heat Exchanger

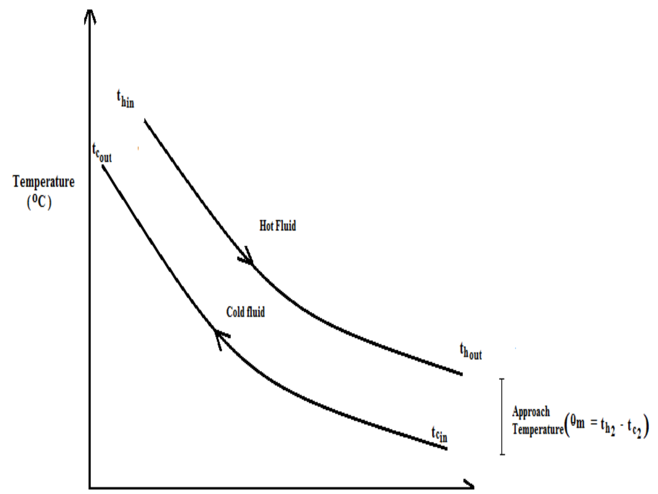
Reflecting the growing trend of using computers for design and teaching, recent heat transfer texts incorporate computer software for the design and optimization of heat exchangers. These software are written to reinforce fundamental concepts and ideas and allow design calculations for generic configurations with no reference to design codes and standards used in the heat exchanger industry. For actual engineering applications, most heat exchangers are designed using commercially available software such as those developed by co-operative research organizations such as Heat Transfer and Fluid Flow Service (HTFS) and Heat Transfer Research Inc. (HTRI) and by computer service companies such as B-JAC International. These programs offer design and cost analysis for all primary heat exchanger types and incorporate multiple design codes and standards from the American Society of Mechanical Engineers (ASME), Tubular Exchangers Manufacturers Association (TEMA) and the International Standards Organization (ISO). These are user-friendly computer software developed for the thermal and hydraulic design of heat exchangers. (LEONG and TOH, 1998)

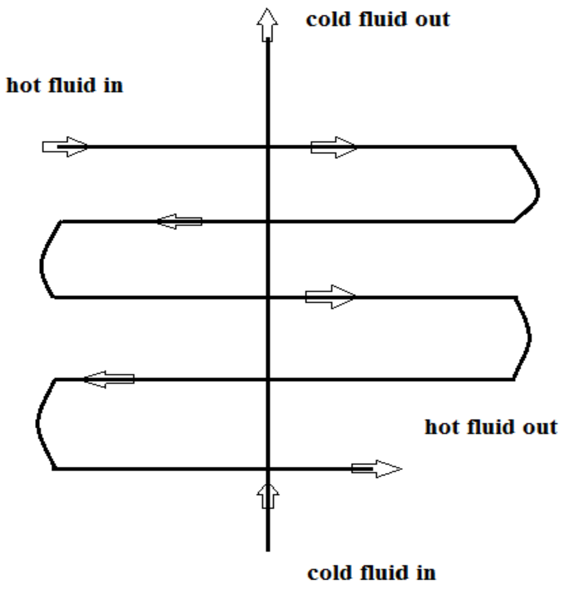
Approach Temperatures The approach temperatures are the difference between the Outlet Temperature of one stream and the Inlet Temperature of the other stream. Although each application will have two approach temperatures, typically it is obvious which one is important from a design standpoint. (Parag Mishra and Dr manoj Arya, 2016)

Objectives

- 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 normal ambient temperature, as there are lots of problems associated, while designing an Air Cooled Heat Exchanger

- In this research paper we 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 38°C. Here, we are studying the performance & design analysis of Air Cooled heat exchanger at normal ambient temperature.
- To give the thermal design & procedure of Air cooled heat exchanger counter to cross flow at normal ambient temperature
- To discuss the various challenges while designing the Counter to Cross Flow Heat Exchanger.



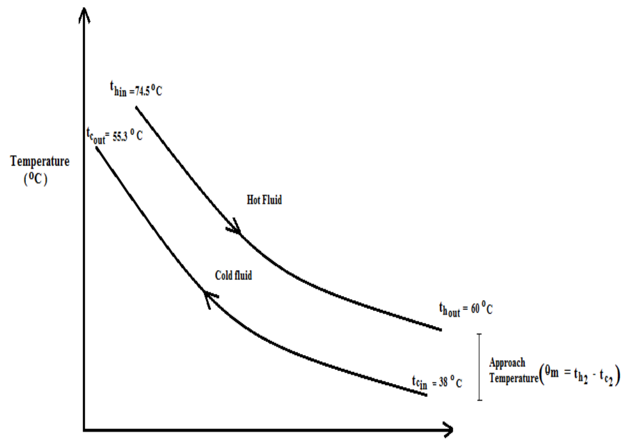


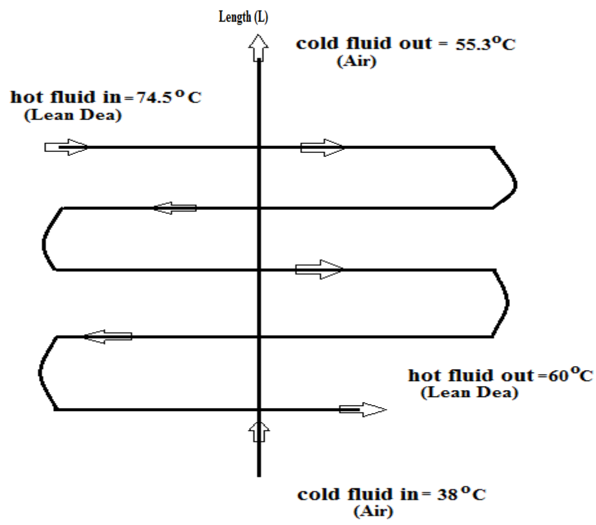
Thermal Design of forced draft counter to cross flow heat exchanger for normal ambient condition, i.e. 38⁰C

In this we have done the thermal design & performance analysis of forced draft counter to cross flow cooled air heat exchanger at normal ambient conditions, so we have taken 38⁰C 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 freeze on this temperature In this case, the hot fluid lean dea enters in the Air Cooled Heat Exchanger &the hot fluid is cooled by passing the ambient air with the help of fans, which directs the air in tube bundles & fluid cools down.

For normal atmospheric conditions, i.e. ambient temperature is 38°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 = 74.5°C d) Outlet temperature of hot fluid = 60 °C
e)Inlet temperature of cold fluid (air) = 38 °C
f)Allowable 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 $= t_{hin} = 74.5°C$
Hot fluid (lean dea) leaves the Air Cooled Heat Exchanger $= t_{hout} = 60 °C$
Cold fluid (air) enters in Air Cooled Heat Exchanger $= t_{cin} = 38 °C$

Cold fluid (air) leaves the Air Cooled Heat Exchanger = t_{cout} =55.3 ^{o}C
Change in hot fluid (lean dea) temperature Δt_h = t_{hin}- t_{hout} =74.5^{o}C-60 ^{o}C=14.5 ^{o}C
Change in cold fluid (air) temperature Δt_c = t_{cout}- t_{cin} =55.3 ^{o}C-38 ^{o}C =17.3 ^{o}C
Approach Temperature= m1 = t_{hout} - t_{cin} = 60 ^{o}C -38 ^{o}C = 22 ^{o}C
Approach Temperature= m_2 = t_{hin} - t_{cout} =74.5^{o}C - 55.3 ^{o}C =19.2 ^{o}C

There are two different approach temperatures, but in counter to cross flow heat exchanger, we consider the Approach Temperature = m_l = t_{hout} - t_{cin}
= 60 ^{o}C -38 ^{o}C
= 22 ^{o}C

Only this approach temperature is important, while designing the forced draft counter to cross flow heat exchanger.

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

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

Hot Tubeside Fluid		Inlet			Outlet		
Fluid name		Lean DEA					
Temperature	(C)	74.50			60.00		
Pressure	(kgf/cm2A)	2.133			1.559		
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)	1002.20			1011.50		
Viscosity	(cP)	0.7600			1.0400		
Conductivity	(kcal/hr-m-C)	0.4428			0.4338		
Heat capacity	(kcal/kg-C)	0.9150			0.9090		
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

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

Cold Outside Fluid		Inlet			Outlet		
Fluid name							
Temperature	(C)	38.00			55.31		
Pressure	(kgf/cm2A)	1.031			1.030		
Weight fraction vapor	(--)	1.0000			1.0000		
Vapor Properties							
Density	(kg/m3)	1.1324			1.0727		
Viscosity	(cP)	0.0190			0.0197		
Conductivity	(kcal/hr-m-C)	0.0234			0.0245		
Heat capacity	(kcal/kg-C)	0.2404			0.2407		
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	74.50	74.00	73.50	73.00	72.50	72.00	71.50	71.00	70.50	70.00
Heat duty/flow rate, (kcal/kg)	1	0.0000	0.4575	0.9148	1.3721	1.8292	2.2863	2.7432	3.2001	3.6568	4.1134
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	1002.20	1002.52	1002.84	1003.16	1003.48	1003.80	1004.12	1004.44	1004.77	1005.09
Viscosity, (cP)	1	0.7600	0.7679	0.7760	0.7841	0.7924	0.8007	0.8092	0.8178	0.8265	0.8353
Thermal conductivity, (kcal/hr-m-C)	1	0.4428	0.4425	0.4422	0.4419	0.4416	0.4413	0.4410	0.4406	0.4403	0.4400
Enthalpy, (kcal/kg)	1	0.0000	-0.4575	-0.9148	-1.3721	-1.8292	-2.2863	-2.7432	-3.2001	-3.6568	-4.1134
Specific heat, (kcal/kg-C)	1	0.9150	0.9148	0.9146	0.9144	0.9142	0.9140	0.9138	0.9136	0.9133	0.9131
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	69.50	69.00	68.50	68.00	67.50	67.00	66.50	66.00	65.50	65.00
Heat duty/flow rate, (kcal/kg)	1	4.5700	5.0264	5.4827	5.9389	6.3950	6.8510	7.3070	7.7628	8.2185	8.6741
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	1005.41	1005.73	1006.05	1006.37	1006.69	1007.01	1007.33	1007.65	1007.97	1008.29
Viscosity, (cP)	1	0.8443	0.8533	0.8625	0.8719	0.8813	0.8909	0.9006	0.9104	0.9204	0.9306
Thermal conductivity, (kcal/hr-m-C)	1	0.4397	0.4394	0.4391	0.4388	0.4385	0.4382	0.4378	0.4375	0.4372	0.4369
Enthalpy, (kcal/kg)	1	-4.5700	-5.0264	-5.4827	-5.9389	-6.3950	-6.8510	-7.3070	-7.7628	-8.2185	-8.6741
Specific heat, (kcal/kg-C)	1	0.9129	0.9127	0.9125	0.9123	0.9121	0.9119	0.9117	0.9115	0.9113	0.9111
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

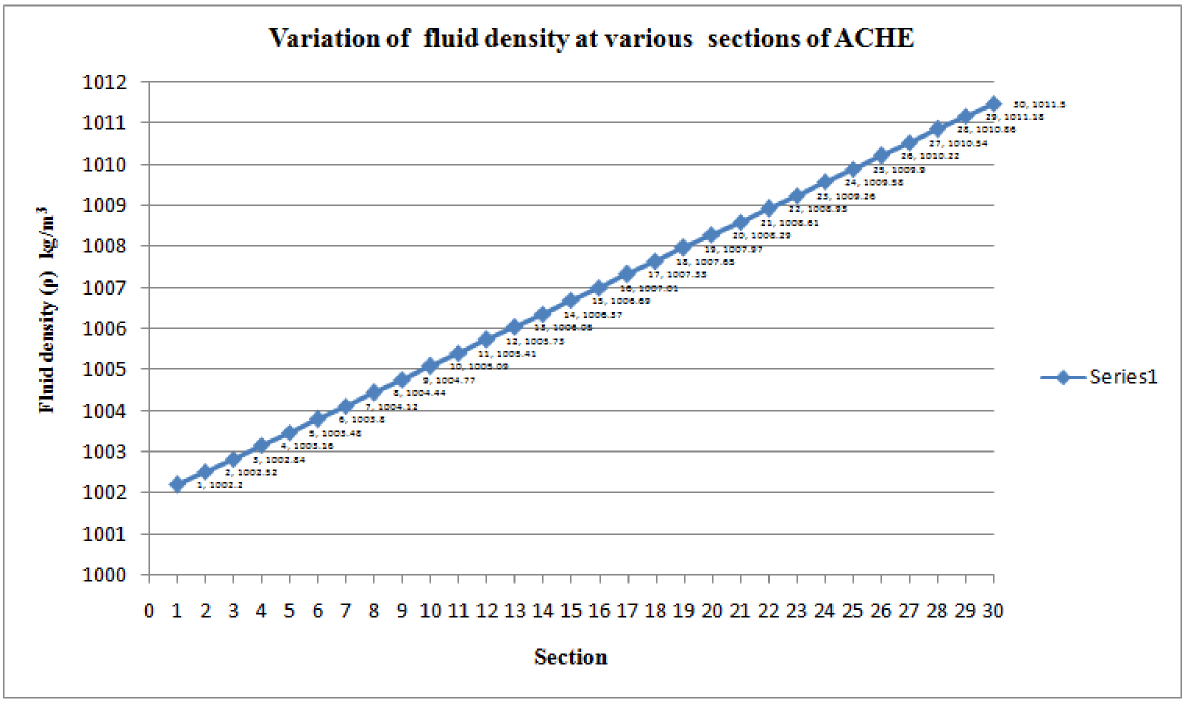
MKH Units

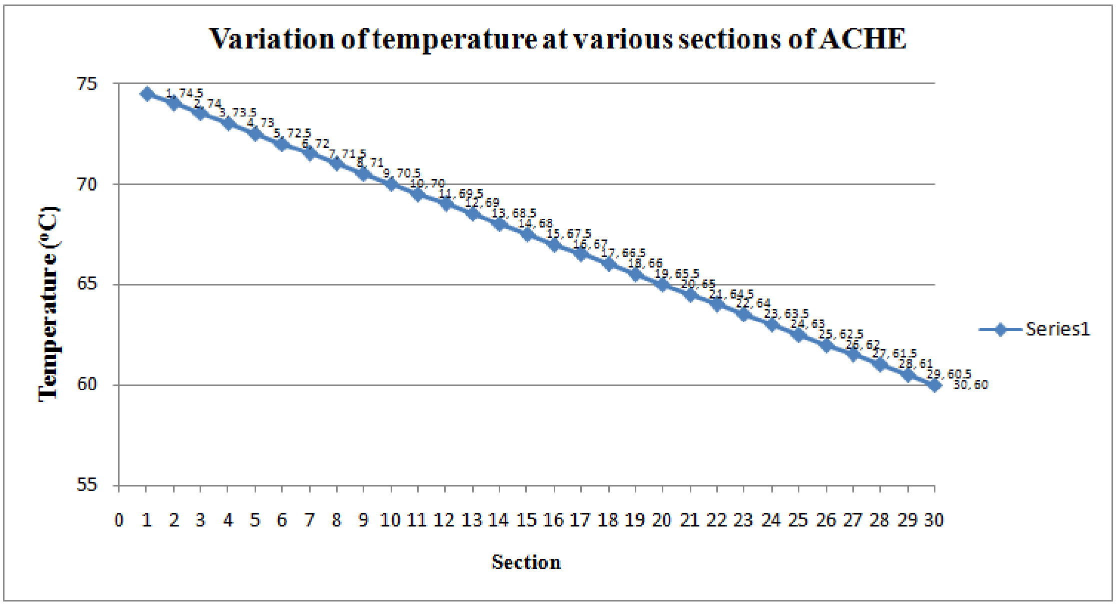
Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow

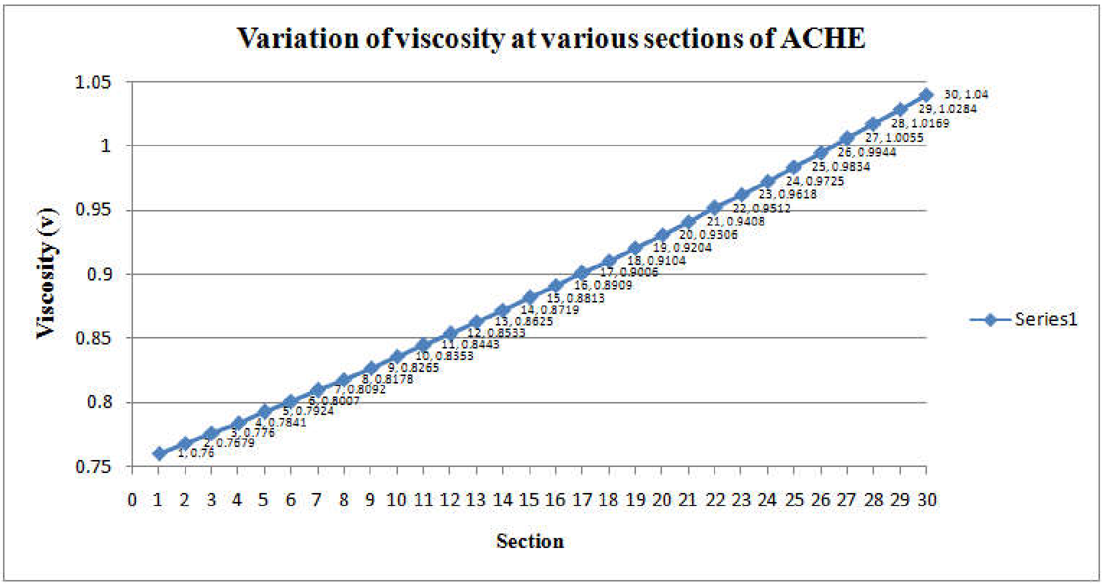
Physical Properties Profile: Hot Tubeside (Lean DEA)

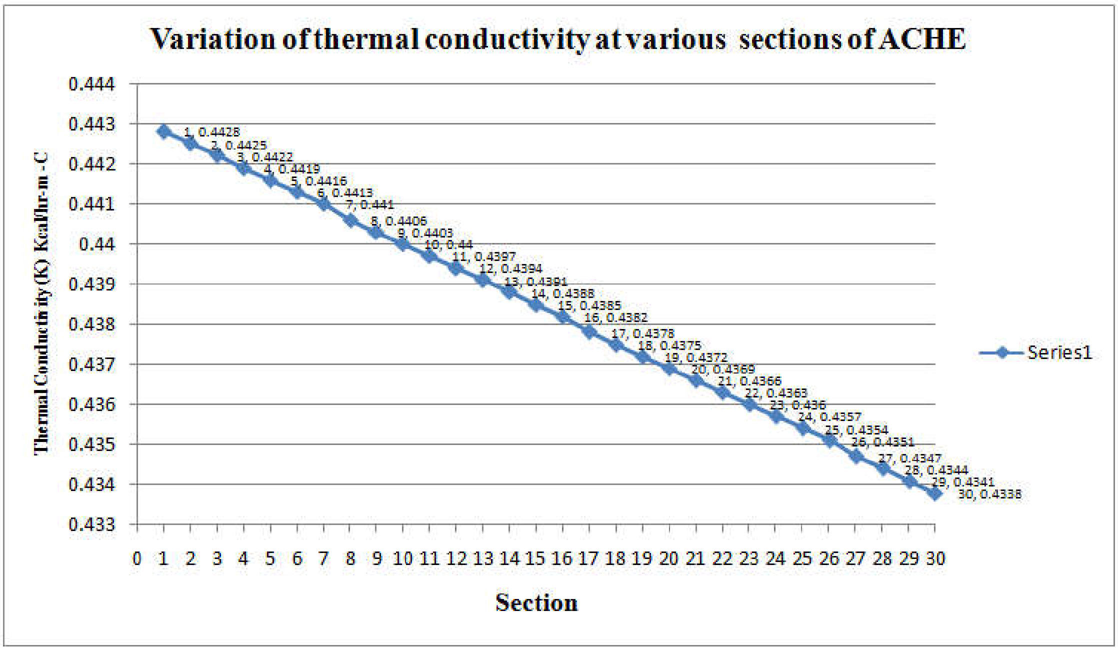
Reference pressure, (kgf/cm2A) (P1= 2.133)

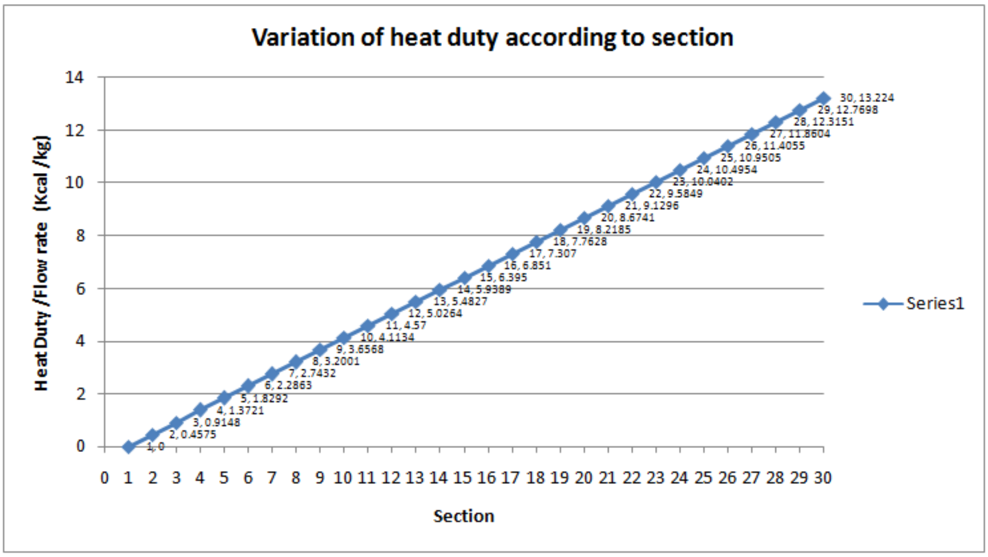
	(P)	21	22	23	24	25	26	27	28	29	30
Temperature, (C)	1	64.50	64.00	63.50	63.00	62.50	62.00	61.50	61.00	60.50	60.00
Heat duty/flow rate, (kcal/kg)	1	9.1296	9.5849	10.0402	10.4954	10.9505	11.4055	11.8604	12.3151	12.7698	13.2240
Weight fraction vapor	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Liquid Properties											
Density, (kg/m3)	1	1008.61	1008.93	1009.26	1009.58	1009.90	1010.22	1010.54	1010.86	1011.18	1011.50
Viscosity, (cP)	1	0.9408	0.9512	0.9618	0.9725	0.9834	0.9944	1.0055	1.0169	1.0284	1.0400
Thermal conductivity, (kcal/hr-m-C)	1	0.4366	0.4363	0.4360	0.4357	0.4354	0.4351	0.4347	0.4344	0.4341	0.4338
Enthalpy, (kcal/kg)	1	-9.1296	-9.5849	-10.040	-10.495	-10.951	-11.406	-11.860	-12.315	-12.770	-13.224
Specific heat, (kcal/kg-C)	1	0.9109	0.9107	0.9104	0.9102	0.9100	0.9098	0.9096	0.9094	0.9092	0.9090
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




Variation of temperature at various sections of ACHE
Temperature (°C)
75
70
65
60
55
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Section
Series1
1, 74.5
2, 74
3, 73.5
4, 73
5, 72.5
6, 72
7, 71.5
8, 71
9, 70.5
10, 70
11, 69.5
12, 69
13, 68.5
14, 68
15, 67.5
16, 67
17, 66.5
18, 66
19, 65.5
20, 65
21, 64.5
22, 64
23, 63.5
24, 63
25, 62.5
26, 62
27, 61.5
28, 61
29, 60.5
30, 60


Variation of viscosity at various sections of ACHE
Viscosity (v)
1.05
1
0.95
0.9
0.85
0.8
0.75
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Section
Series1
1, 0.76
2, 0.7679
3, 0.776
4, 0.7841
5, 0.7924
6, 0.8007
7, 0.8092
8, 0.8178
9, 0.8265
10, 0.8353
11, 0.8443
12, 0.8533
13, 0.8625
14, 0.8719
15, 0.8813
16, 0.8909
17, 0.9006
18, 0.9104
19, 0.9204
20, 0.9306
21, 0.9408
22, 0.9512
23, 0.9618
24, 0.9725
25, 0.9834
26, 0.9944
27, 1.0055
28, 1.0169
29, 1.0284
30, 1.04


Variation of thermal conductivity at various sections of ACHE
Thermal Conductivity (K) Kcal/hr-m-C
0.444
0.443
0.442
0.441
0.44
0.439
0.438
0.437
0.436
0.435
0.434
0.433
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Section
Series1
1, 0.4428
2, 0.4425
3, 0.4422
4, 0.4419
5, 0.4416
6, 0.4413
7, 0.441
8, 0.4406
9, 0.4403
10, 0.44
11, 0.4397
12, 0.4394
13, 0.4391
14, 0.4388
15, 0.4385
16, 0.4382
17, 0.4378
18, 0.4375
19, 0.4372
20, 0.4369
21, 0.4366
22, 0.4363
23, 0.436
24, 0.4357
25, 0.4354
26, 0.4351
27, 0.4347
28, 0.4344
29, 0.4341
30, 0.4338



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)	38.00	55.31	74.50	60.00
Skin temperature, Min/Max	(Deg C)	50.49	65.43	57.16	71.83
Pressure, Inlet/Outlet	(kgf/cm2A)	1.031	1.030	2.133	1.559
Pressure drop, Total/Allow	(mmH2O) | (kgf/cm2)	14.141	0.000	0.575	0.710
Midpoint velocity	(m/s)		6.85		1.48
- In/Out	(m/s)			1.49	1.53
Heat transfer safety factor	(--)		1		1
Fouling	(m2-hr-C/kcal)		0.000000		0.000500

Exchanger Performance					
Outside film coef	(kcal/m2-hr-C)	40.11	Actual U	(kcal/m2-hr-C)	21.814
Tubeside film coef	(kcal/m2-hr-C)	4508.25	Required U	(kcal/m2-hr-C)	21.768
Clean coef	(kcal/m2-hr-C)	31.113	Area	(m2)	2811.99
Hot regime		Sens. Liquid	Overdesign	(%)	0.21
Cold regime		Sens. Gas			
EMTD	(Deg C)	20.4			
Duty	(MM kcal/hr)	1.249			

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)	0.96	0.95
R-V-SQ	(kg/m-s2)	925.32	916.81
Pressure drop	(kgf/cm2)	5.190e-3	3.273e-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)	10.42
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	(%)	79.6
Area ratio (fin/bare)	(--)	22.8398
Material		Aluminum 1060 - H14

Airside Velocities		Actual	Standard
Face	(m/s)	3.61	3.40
Maximum	(m/s)	6.69	6.31
Flow	(100 m3/min)	44.192	41.654
Velocity pressure	(mmH2O)	4.658	
Bundle pressure drop	(mmH2O)	12.306	
Bundle flow fraction	(--)	1.000	

Thermal Resistance, %	
Air	54.39
Tube	13.25
Fouling	29.89
Metal	2.47
Bond	0.00

Airside Pressure Drop, %					
Bundle	87.02			Louvers	4.63
Ground clearance	0.00	Fan guard	0.53	Hail screen	0.00
Fan ring	1.97	Fan area blockage	5.85	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)	38.00	55.31	74.50	60.00
Skin temperature, Min/Max	(Deg C)	50.49	65.43	57.16	71.83
Wall temperature, Min/Max	(Deg C)	50.49	65.43	56.94	71.62
Pressure, In/Out	(kgf/cm2A)	1.031	1.030	2.133	1.559
Pressure drop, Total/Allowed	(mmH2O) | (kgf/cm2)	14.141	0.000	0.575	0.710
Pressure Drop, A-frame reflux section	(kgf/cm2)				
Velocity - Midpoint	(m/s)	6.85		1.48	
- In/Out	(m/s)			1.49	1.53
Film coefficient, Bare/Extended	(kcal/m2-hr-C)	916.06	40.11	4508.25	
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)	21.768 /	31.113 /	21.814
Heat duty, Calculated/Specified	(MM kcal/hr)	1.2492 /	1.2500	
Effective mean temperature difference	(Deg C)	20.41		

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)		3640	Orientation (from horiz.)	(deg)	0.00
Structure weight	(kg)		3438	Tubeside volume	(L)	386.5
Total weight, Dry / Wet	(kg)		13238 /	14011		
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	(%)	79.6
Tube material		Carbon steel	Internal tube type		None
Fin material		Aluminum 1060 - H14			

Final Results

Rating-Horizontal air-cooled heat exchanger forced draft countercurrent to crossflow			MKH Units
Inlet Airside Velocities		**Actual**	**Standard**
Face velocity	(m/s)	3.61	3.40
Maximum velocity	(m/s)	6.69	6.31
Volumetric flow	(100 m3/min)	44.192	41.654
Maximum mass velocity	(kg/s-m2)	7.575	
Air humidity	(%)		
Volumetric flow per fan at fan inlet	(100 m3/min)	22.096	
Velocity at fan inlet	(m/s)	8.97	

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)	12.306 /	4.658
Fan and drive efficiency		(%)		65
Motor power per fan-design air temperature		(kW)		10.42
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		(--)		0.0062
Heat transfer	Wall Correction	(--)	0.9912	0.9865
	Row Correction	(--)		1.0000
Midpoint f-factor		(--)	0.0068	0.1973
Pressure drop	Wall Correction	(--)	1.0079	1.0091
	Row Correction	(--)		1.0012
Reynolds number	Inlet	(--)	41514	10787
	Midpoint	(--)	34313	10591
	Outlet	(--)	31602	9749
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	
54.39	13.25	29.89	2.47	0.00	0.21

Airside Pressure Drop (Percent)			
Across bundle	87.02	Other obstruction	5.85
Fan ring	1.97	Steam coil	0.00
Fan guard	0.53	Louvers	4.63
Ground clearance	0.00		

Tube Nozzle (Perpendicular)		Inlet	Outlet
Number of nozzles	(--)	1	1
Diameter	(mm)	131.750	131.750
Velocity	(m/s)	0.96	0.95
Nozzle R-V-SQ	(kg/m-s2)	925.32	916.81
Pressure drop	(kgf/cm2)	5.190e-3	3.273e-3

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 74.5°C to 60°C& cold fluid air gains the heat from 38°Cto 58.31°C,during heat exchanging process. By studying the various properties of lean dea, we come to know that, the pour point of lean dea is 8°C & 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 +9°C API Margin. i.e. Permissible/ minimum tube skin temperature = pour point of fluid (lean dea) +9 °C (API Margin) = 8°C +9°C = 17 °C By studying the properties of lean dea we come to know that the tube skin temperature at 38

^{o}C is 57.16 ^{o}C . At 38 ^{o}C the permissible tube skin temperature is 57.16 ^{o}C, which is far greater than the permissible tube skin temperature (17^{o}C), So, the design & performance of Forced Draft Counter to Cross Flow Air Cooled Heat Exchanger is safe. In this ambient conditions, there is no need of steam coil because at this temperature, the fluid in the heat exchanger does not freeze, hence there is not a problem.

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