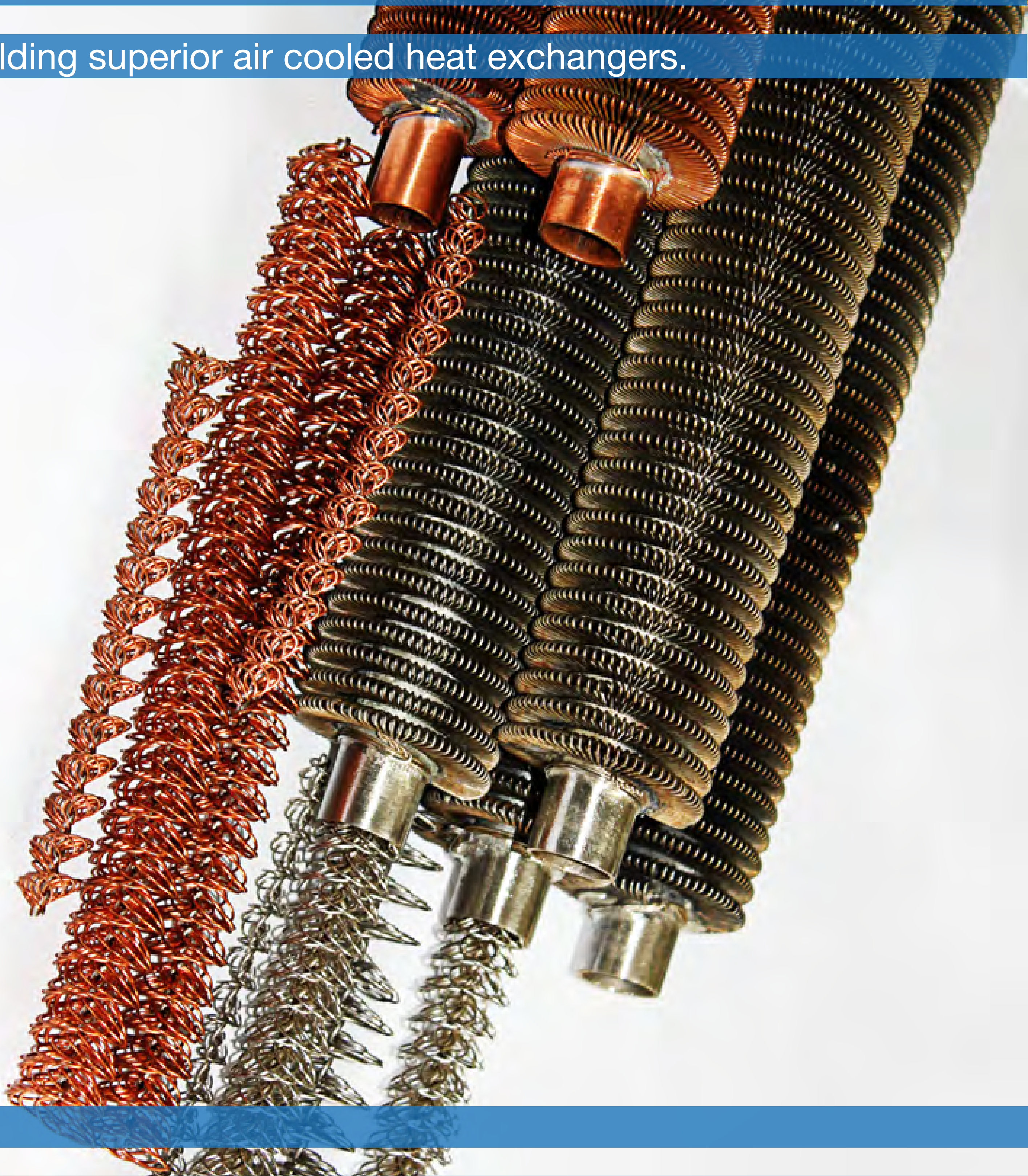
Concept Engineering International

PinFin Division

Building superior air cooled heat exchangers.



Heat Transfer Specialists

Pin Fin Division

Concept engineering makes both helical (crimp or L type) and wire wound(Pin fin) tubes and are happy to provide either one to our customers. We are happiest, however when we are able to provide an ideal solution.

Similarly for turbulators we make a very large range and are happy to offer once again what assists the customer to achieve the optimum.

Details of our complete range of Fin tubes and turbulators are given in our respective Fin tube and Turbulator Catalogs.

We have developed this presentation to help our customers size the ideal Air Cooled Heat exchanger and to select the correct tubes and turbulators to do so.

Temperature Criteria

We have limited this paper to operating temperatures below 280 degrees centigrade as above this temperature specially manufactured fin tubes should be used. For wire wound or pin fin tubes the bonding of wire fins to tube is by solder. Hence it is a very stable until the melting point of solder is reached. We use two types of solders one suitable for upto 180 degrees centigrade and another for up to 280 degrees centigrade.

Objective

Is to arrive at a solution which is

- Compact
- Durable & long lasting
- Economical to make and operate.
- Low power consumption. (linked to airside pressure drop and flow rate).
- Performs better than the standard benchmark Helical fin tube.

To establish the superiority of our Pin fin tube we have undertaken a simulation study with the traditional L fin tube.

To do this comparisons we have designed 6 panels of 1 meter by 1 meter with 3 rows of fin tubes. They have the identical number of tubes and the same tube pitch. All are based on a ¾" OD steel tube. Similarly we designed 3 other panels of 3/8", 5/8" & 1" wire fin tube.

The first Panel has 10 FPI L type fin tubes with aluminium fins. The other 3/4" tube panels has wire wound stainless steel fins of different wire winding patterns moving from S1 (the least dense) to S5 the densest. The other size tubes have only one density per tube OD.

For these Panels we have calculated the Airside Heat transfer coefficient and airside pressure drop at different air flow rates. We have also run various simulations using first steam, then hot water followed by oil. We have taken linear coefficients per feet to make comparisons easy. We have presented this data in 2 graphs and in a table overleaf. You will see that the performance on the airside of the Wire wound fin tube is significantly better.
Due to its fin geometry and efficiency the weight of the wire fin tube is very low both in absolute per meter terms and more so when the total length is adjusted for higher performance. To compare, S1 and the higher efficiency S2 and S3 stainless steel fin tubes are lower in weight than the 10 FPI Aluminum fin steel tube combination. The S4 & S5 are only slightly higher. When comparing against the stainless steel L fin tube, the S1 is 40% of the weight. The S5 stainless steel is only 2.9 kgs vs. 4.7 kgs for the stainless steel fin L tube. When you consider that the S1 is 30% more efficient and the S5 is 3 times the efficiency of the L fin tube great new possibilities open up. The weight chart given below is worth studying.

Weight of different fin configurations of fintubes

Winding	Code	Tube OD	Weight per meter (kg/mtr)				Total weight
			Tube	Fins	Tension wire	Solder wire	Kg/mtr
S1	A	3/4"	1.01	0.91	0.062	0.09	2.072
S2	B	3/4"	1.01	1.1	0.07	0.093	2.273
S3	C	3/4"	1.01	1.25	0.08	0.11	2.45
S4	D	3/4"	1.01	1.38	0.083	0.12	2.593
S5	E	3/4"	1.01	1.68	0.083	0.12	2.893
P4	F	3/8"	0.16	0.45	0.05	0.06	0.72
R2	G	5/8"	0.34	0.88	0.08	0.09	1.39
T5	H	1"	0.75	1.63	0.12	0.14	2.64
L fins SS	L 10 FPI	3/4"	1.01	3.71	–	–	4.72
L fins AL	L 10 FPI	3/4"	1.01	1.41	–	–	2.42

Pin Fin Division

Design Parameter (Tubeside steam 3 Kgs)

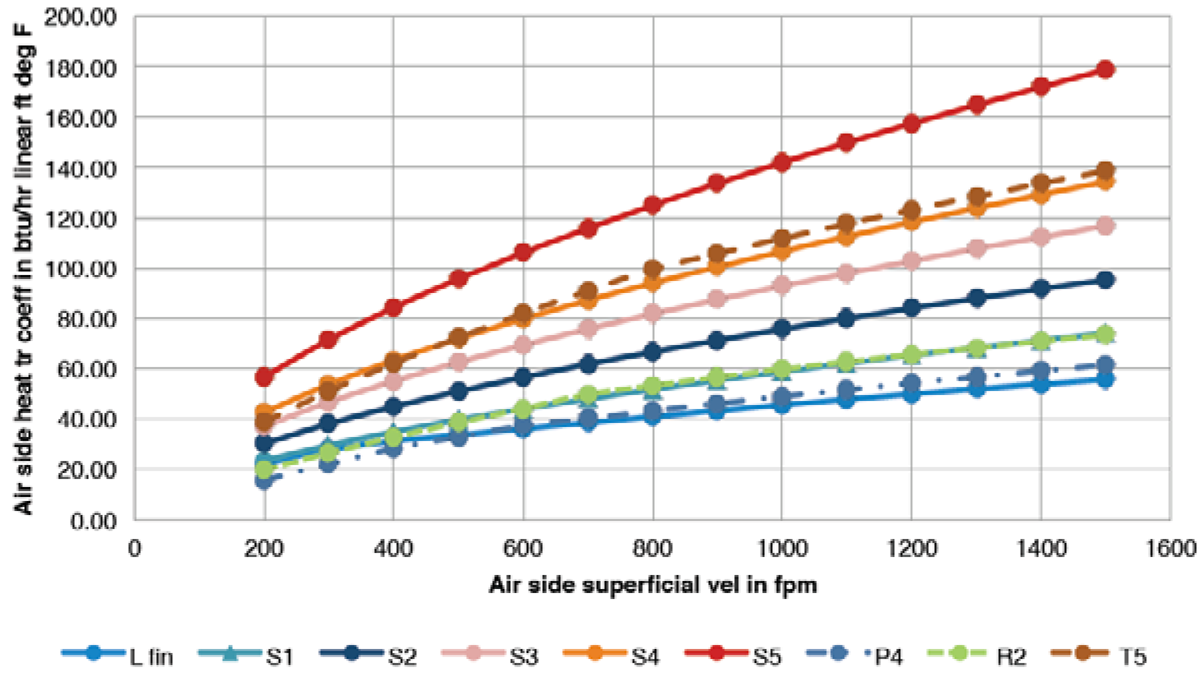
Model No		L 10, S1,S2,S3,S4,S5	T5	R2	P4
Air inlet temperature	deg C	25	25	25	25
Steam Pressure	kg/cm^2g	3	3	3	3
Heat Transfer Area (hta)	ft^2/ft	2.45	2.45	2.45	2.45
Dirt factor outside (Rdo)	hr. ft2 F/btu	0.002	0.002	0.002	0.002
Dirt factor inside (Rdi)	hr. ft2 F/btu	0.0005	0.0005	0.0005	0.0005
Face Area	M^2	1	1	1	1
		L 10, S1,S2,S3,S4,S5	T5	R2	P4
Heat Transfer Coefficient					
Tube side (hi)	btu/hr. ft^2 F	1500	1500	1500	1500
When referred to tube ID/OD (hio)	btu/hr. ft^2 F	1180	1180	1180	1180
with dirt factor (hiod)	btu/hr. ft^2 F	742	742	742	742
linear heat transfer coefficient	btu/hr. ft F	145.64	202.27	122.20	70.29
		L 10, S1,S2,S3,S4,S5	T5	R2	P4
Tube					
OD	in	0.75	1	0.625	0.375
thk	in	0.08	0.08	0.064	0.048
ID	in	0.59	0.84	0.497	0.279
No.of rows		3	3	3	3
No. of tubes		57	51	60	77
Pitch in row (pir)	mm	50.8	57.2	48	38
row pitch (Rp)	mm	38	44	36	28

Having arrived at an understanding of the airside performance of the different types of fin tubes we need to consider the tubeside performance to get the overall coefficient.

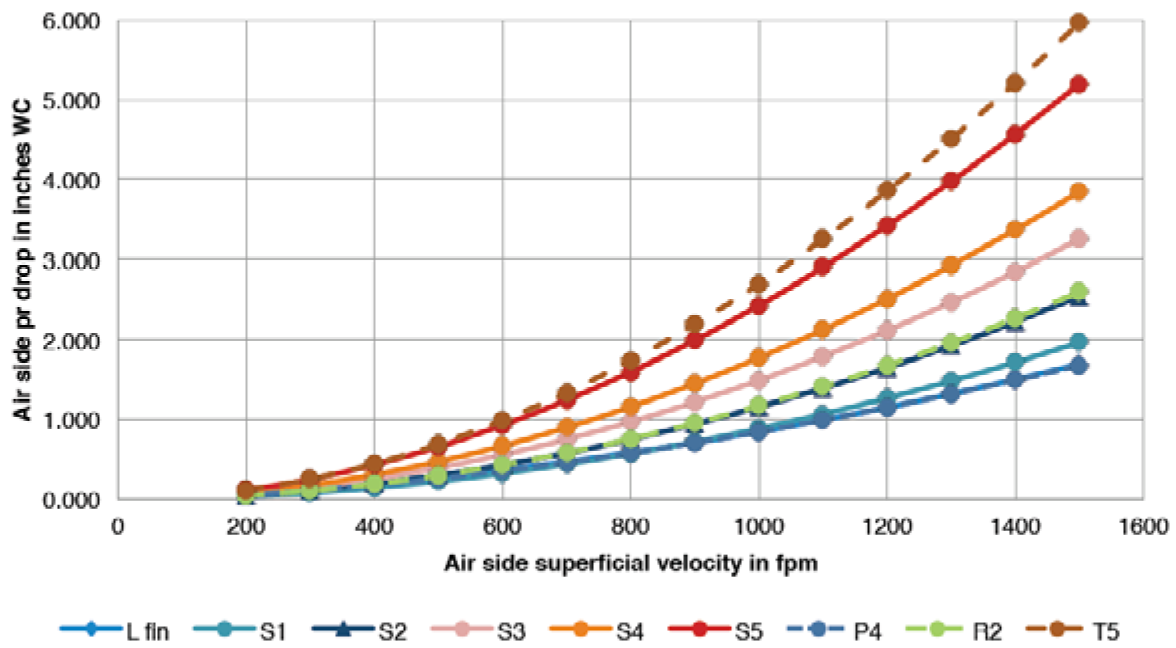
The overall coefficient depends on both the air side and tubeside coefficient and is derived by the formula:

`Ud = h’fi*h’i/h’fi+h’i

Air side heat transfer coeff linear basis at diff air velocities for diff windings



Air side pr drop in inches of WC at diff air vels for diff windings



Where:
Ud = overall heat transfer Coefficient
h'fi = Heat transfer coefficient on fin side of the tube.
h'i = Heat transfer coefficient inside the tube

Now we have the Airside coefficient we have to calculate the tubeside coefficient to get the overall coefficient.

The tubeside coefficient can be enhanced in 2 basic ways.

Increase in tube passes to increase the Reynolds number.
Introduction of turbulators in the tube to make the flow turbulent.

In both methods we experience an increase in pressure drop as well as an increase in tube side heat transfer coefficient. Our objective is to maximize the coefficient given the available pressure drop limit.

Turbulators help when the flow is laminar and when the viscosity of the fluid is high. They are very useful in oil and viscous fluids but are not warranted in water coolers/ heaters. For such fluids increasing the passes is the best option.

In steam air heaters, neither multiple passes nor turbulators are required.

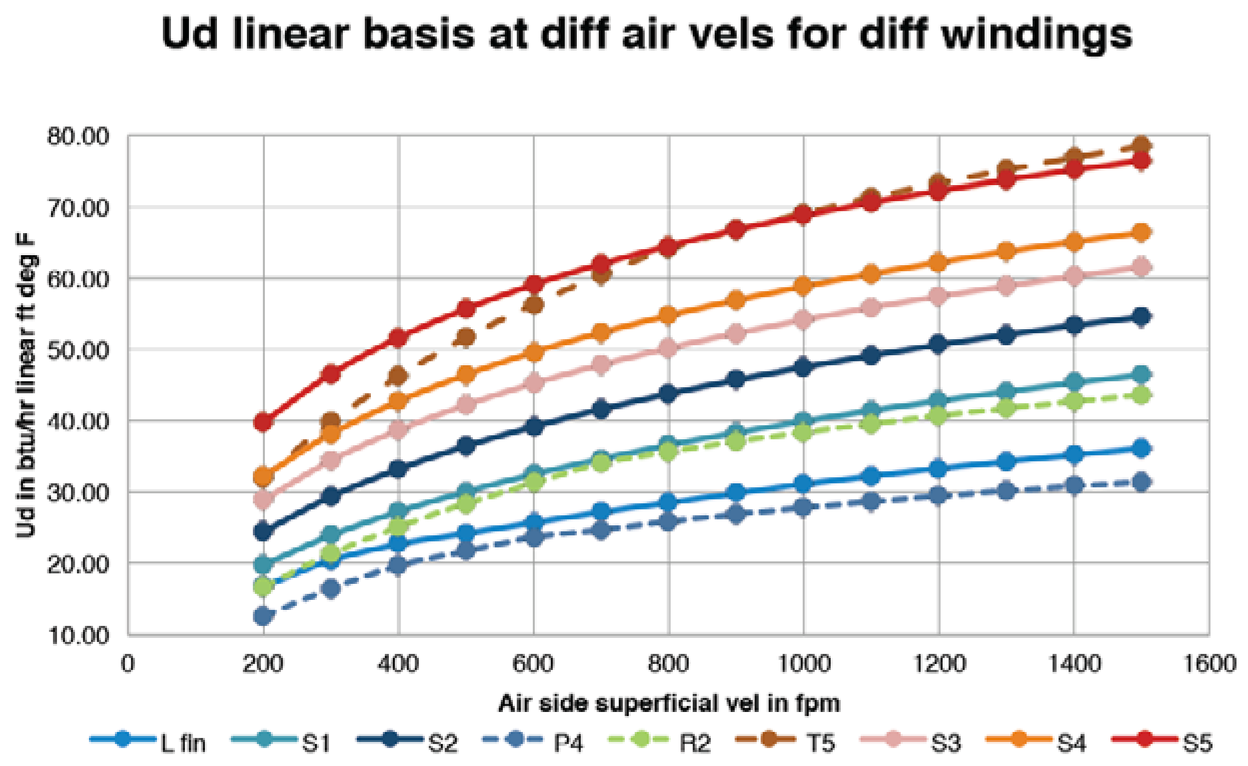
We will now do the following analysis:

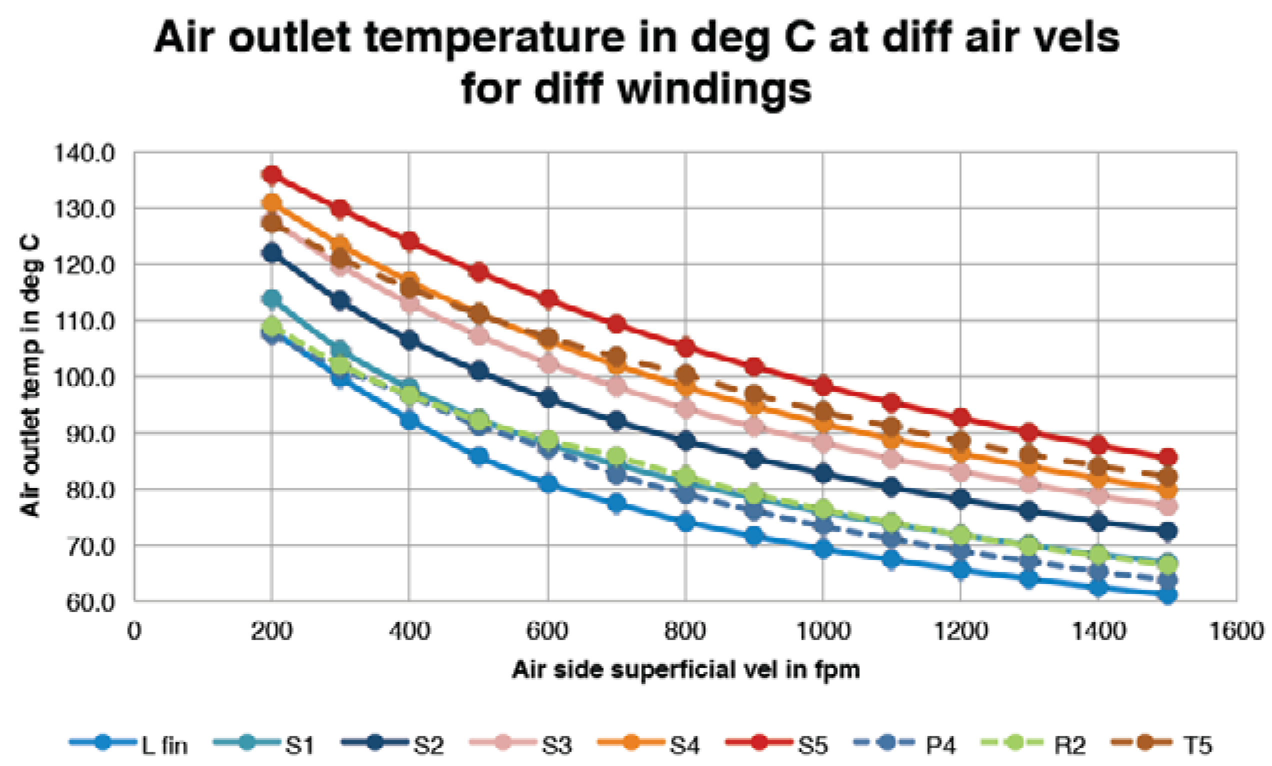
<u>The Phase change situation of Steam:</u> Given Steam's extremely high coefficient, the advantage of wire wound fin tubes is best illustrated using steam.
<u>Low viscosity liquids like water</u> at different flow rates through tubes.
<u>Medium and high viscosity fluids</u> like oil using 3 different Turbulator types.

In all these case we will use the same panels we have used to calculate the airside coefficient. However for the sake of simplicity, for the non-steam cases we will limit ourselves to the panels with ¾" OD tubes only.

Steam

All assumptions for steam, pressure, coefficient etc has been given in the design parameter chart at the beginning of this presentation.





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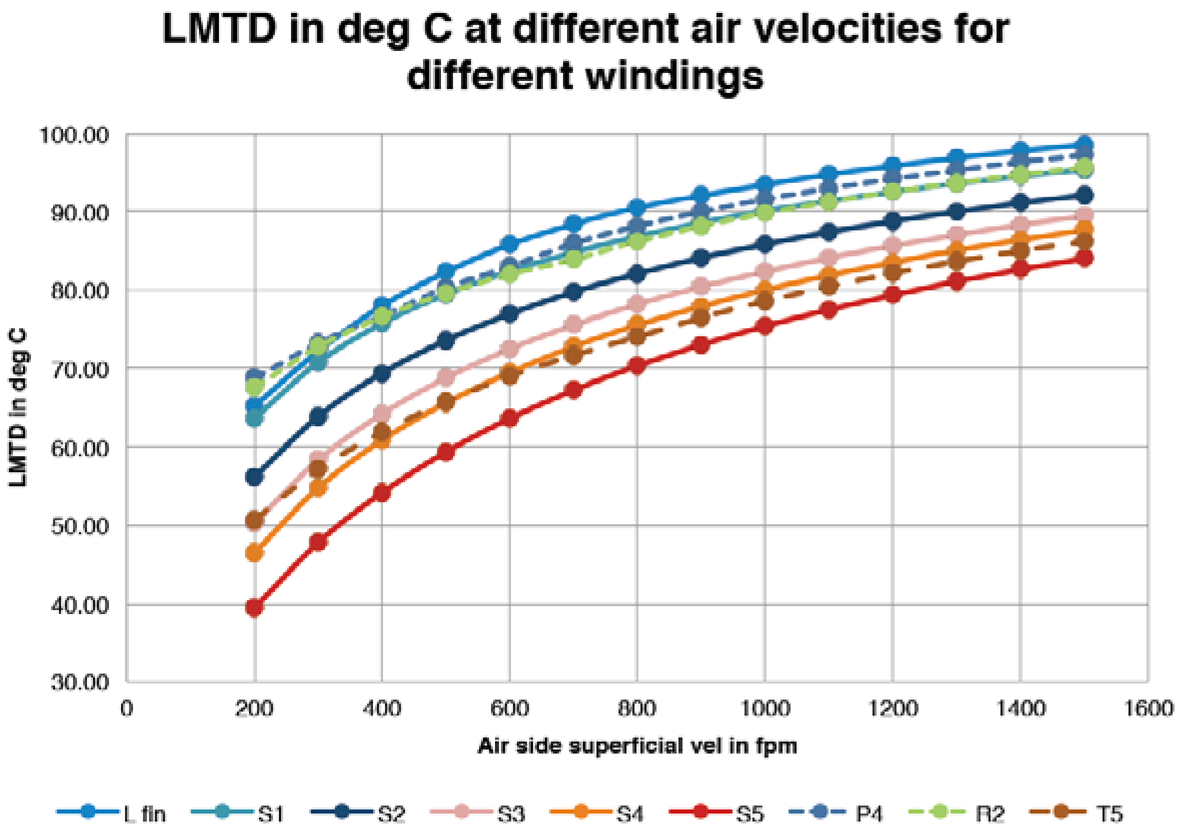

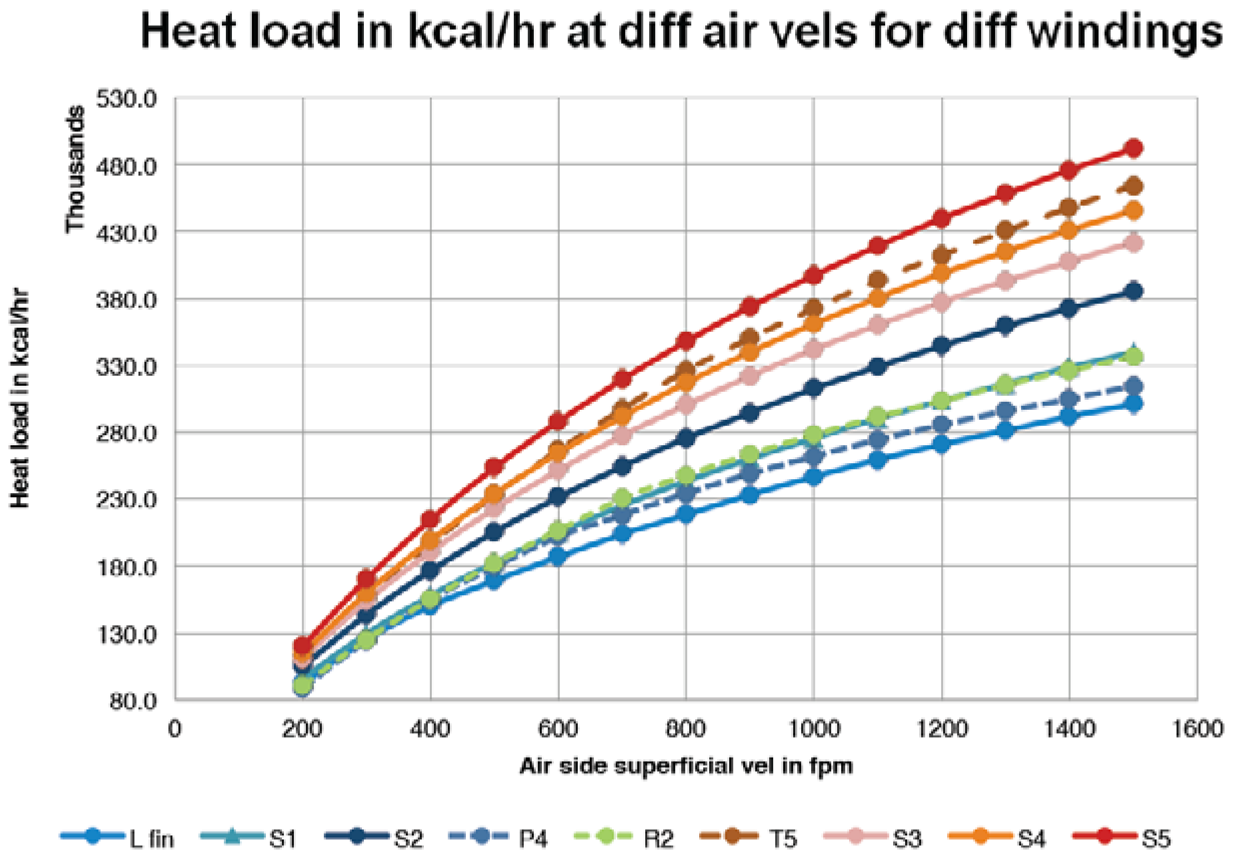

Air sup velocity fpm	Udilinear btu/hr. ft F									Air coefficient btu/hr. ft deg C								
	P4	R2	L fin	S1	S2	S3	S4	S5	T5	P4	R2	L fin	S1	S2	S3	S4	S5	T5
200	12.61	16.69	16.80	19.76	24.43	28.86	32.19	39.79	31.92	15.68	19.75	22.32	23.48	30.21	37.05	42.61	56.70	38.76
300	16.47	21.30	20.40	23.91	29.33	34.38	38.13	46.53	39.82	22.13	26.55	27.86	29.58	38.07	46.68	53.69	71.44	51.06
400	19.65	25.11	22.67	27.24	33.20	38.68	42.71	51.61	46.22	28.26	32.75	31.22	34.85	44.85	55.00	63.26	84.17	62.09
500	21.73	28.38	24.20	30.04	36.42	42.21	46.45	55.68	51.64	32.79	38.55	33.63	39.59	50.93	62.45	71.83	95.55	72.27
600	23.63	31.25	25.71	32.48	39.18	45.24	49.62	59.11	56.33	37.32	44.04	36.04	43.90	56.51	69.31	79.73	106.12	81.81
700	24.70	34.01	27.17	34.63	41.61	47.86	52.35	62.01	60.47	40.06	49.73	38.45	47.95	61.70	75.67	87.04	115.82	90.85
800	25.85	35.62	28.53	36.57	43.77	50.17	54.76	64.53	64.18	43.17	53.25	40.85	51.74	66.58	81.65	93.91	124.94	99.48
900	26.88	37.07	29.82	38.33	45.72	52.26	56.92	66.77	66.74	46.12	56.55	43.23	55.33	71.20	87.32	100.44	133.64	105.78
1000	27.81	38.38	31.09	39.94	47.50	54.15	58.86	68.79	69.11	48.92	59.67	45.56	58.75	75.61	92.73	106.68	141.96	111.85
1100	28.65	39.59	32.23	41.43	49.13	55.86	60.62	70.58	71.28	51.60	62.64	47.78	62.04	79.83	97.89	112.60	149.81	117.65
1200	29.43	40.71	33.29	42.81	50.64	57.45	62.24	72.23	73.28	54.18	65.48	49.89	65.20	83.89	102.87	118.32	157.42	123.20
1300	30.15	41.75	34.28	44.10	52.04	58.91	63.74	73.75	75.14	56.66	68.21	51.90	68.23	87.81	107.68	123.86	164.81	128.54
1400	30.82	42.72	35.20	45.31	53.35	60.27	65.12	75.13	76.87	59.06	70.84	53.82	71.18	91.60	112.32	129.20	171.90	133.69
1500	31.44	43.63	36.09	46.45	54.58	61.55	66.41	76.43	78.49	61.39	73.38	55.65	74.02	95.27	116.84	134.41	178.86	138.67

Air sup velocity fpm	Air outlet temp deg C									Heat load kcal/hr.								
	P4	R2	L fin	S1	S2	S3	S4	S5	T5	P4	R2	L fin	S1	S2	S3	S4	S5	T5
200	107.3	108.8	108.1	113.6	121.9	127.60	130.80	135.80	127.2	89234.	90860.	92400.	96065.	105064	111245	114714	120135	110811
300	101.3	101.9	99.7	104.6	113.3	119.60	123.30	129.70	120.9	124093	125069	124950	129460	143610	153856	159874	170282	155970
400	96.5	96.6	92.3	97.8	106.4	112.90	116.80	123.90	115.6	155049	155265	150150	157868	176517	190612	199070	21446	19646
500	91.2	92.2	85.7	92.4	100.8	107.20	111.20	118.50	111.0	179444	182155	169050	182697	205467	22281	23365	253445	233115
600	87.1	88.6	80.9	88.0	96.1	102.30	106.30	113.60	106.9	201997	20687	186900	204925	23127	251439	264450	28819	26640
700	82.5	85.7	77.3	84.3	92.0	98.10	101.90	109.20	103.4	21820	230350	20370	22503	254258	277407	29182	319531	29752
800	79.0	82.1	74.1	81.1	88.5	94.30	98.10	105.20	100.2	234200	247644	218400	243307	275401	30055	317037	34783	326145
900	76.0	79.0	71.5	78.3	85.4	91.00	94.70	101.60	96.8	248837	26347	233100	260059	29470	322025	34007	37374	35032
1000	73.3	76.3	69.3	75.8	82.7	88.10	91.60	98.30	93.7	261848	278112	246750	275401	312808	34208	361058	397381	372443
1100	71.0	73.9	67.3	73.7	80.2	85.40	88.80	95.30	91.0	27431	29161	25935	29041	32918	360191	38046	419228	393586
1200	68.9	71.7	65.5	71.7	78.0	83.00	86.30	92.60	88.4	285593	303809	270900	303809	344794	37732	398790	439775	412452
1300	67.0	69.8	63.9	69.9	76.0	80.80	83.90	90.00	86.1	296002	31573	281400	31644	35943	393260	415108	458099	430613
1400	65.2	68	62.4	68.3	74.1	78.70	81.80	87.70	84.0	30511	326362	29190	328639	372660	407573	431101	475881	447799
1500	63.7	66.4	61.1	66.8	72.4	76.90	79.80	85.50	82.1	314706	336662	301350	33991	385454	422048	445630	491982	464334

Pin Fin Division

Air sup velocity fpm	LMTD deg C P4	R2	L fin	S1	S2	S3	S4	S5	T5	Air side pr drop in wc P4	R2	L fin	S1	S2	S3	S4	S5	T5
200	68.71	67.54	65.2	63.63	56.15	50.24	46.46	39.43	50.68	0.055	0.049	0.07	0.038	0.051	0.067	0.081	0.115	0.113
300	73.23	72.79	72.2	70.78	63.88	58.33	54.77	47.81	57.11	0.11	0.11	0.128	0.083	0.112	0.147	0.178	0.25	0.253
400	76.66	76.59	78	75.74	69.41	64.21	60.87	54.17	61.92	0.18	0.194	0.194	0.147	0.196	0.257	0.309	0.432	0.446
500	80.29	79.61	82.3	79.48	73.59	68.79	65.61	59.34	65.78	0.262	0.301	0.273	0.227	0.302	0.394	0.473	0.66	0.692
600	83	82.02	85.8	82.41	76.94	72.5	69.49	63.63	69.02	0.357	0.43	0.368	0.325	0.43	0.56	0.671	0.93	0.99
700	85.95	83.91	88.4	84.81	79.75	75.53	72.79	67.22	71.68	0.463	0.583	0.471	0.44	0.58	0.753	0.9	1.243	1.341
800	88.14	86.21	90.5	86.84	82.08	78.18	75.53	70.33	74.03	0.58	0.758	0.587	0.572	0.751	0.973	1.161	1.598	1.743
900	89.99	88.14	92.1	88.58	84.1	80.42	77.91	73.01	76.45	0.708	0.954	0.711	0.721	0.944	1.22	1.453	1.994	2.195
1000	91.62	89.81	93.5	90.11	85.83	82.35	80.02	75.39	78.6	0.846	1.173	0.847	0.887	1.158	1.493	1.775	2.429	2.697
1100	93	91.26	94.8	91.38	87.4	84.1	81.88	77.49	80.42	0.994	1.414	0.996	1.07	1.393	1.792	2.128	2.904	3.25
1200	94.24	92.58	95.9	92.58	88.76	85.64	83.52	79.34	82.15	1.152	1.678	1.153	1.269	1.649	2.118	2.511	3.419	3.853
1300	95.35	93.71	96.9	93.65	89.99	87.02	85.06	81.09	83.65	1.319	1.963	1.323	1.485	1.927	2.47	2.926	3.974	4.506
1400	96.39	94.76	97.8	94.59	91.14	88.33	86.4	82.61	85	1.495	2.27	1.505	1.718	2.225	2.847	3.368	4.565	5.209
1500	97.25	95.7	98.6	95.46	92.16	89.44	87.65	84.04	86.21	1.681	2.6	1.695	1.968	2.544	3.25	3.842	5.196	5.963

Air sup Velocity fpm	ud/panel btu/hr panel F P4	R2	L fin	S1	S2	S3	S4	S5	T5	Air Coefficient btu/hr paneldeg C P4	R2	L fin	S1	S2	S3	S4	S5	T5
200	3185	3284	3141	3694	4568	5396	6019	7438	5339	3960	3886	4173	4390	5648	6926	7967	10600	6483
300	4161	4191	3814	4470	5483	6427	7129	8699	6661	5590	5225	5208	5531	7117	8728	10039	13357	8541
400	4962	4942	4239	5093	6207	7231	7985	9649	7732	7138	6446	5837	6516	8385	10283	11827	15737	10387
500	5489	5585	4524	5617	6808	7892	8684	10410	8638	8282	7586	6288	7401	9522	11676	13429	17864	12089
600	5969	6150	4806	6072	7325	8457	9278	11051	9423	9426	8666	6738	8208	10565	12958	14907	19839	13685
700	6239	6693	5080	6475	7779	8947	9788	11592	10116	10118	9787	7189	8964	11536	14147	16273	21653	15197
800	6529	7010	5333	6836	8184	9381	10238	12064	10736	10904	10480	7638	9674	12448	15264	17557	23360	16641
900	6789	7295	5575	7165	8548	9770	10641	12484	11165	11647	11129	8082	10345	13312	16325	18778	24986	17694
1000	7023	7554	5812	7467	8881	10123	11005	12861	11561	12355	11743	8518	10984	14136	17338	19944	26541	18711
1100	7237	7792	6026	7745	9186	10444	11333	13196	11924	13033	12328	8933	11599	14925	18302	21051	28008	19680
1200	7433	8012	6225	8004	9468	10740	11636	13504	12258	13683	12887	9327	12189	15684	19233	22121	29430	20609
1300	7614	8216	6409	8245	9730	11014	11916	13788	12569	14311	13424	9704	12757	16417	20132	23158	30814	21502
1400	7783	8407	6581	8472	9974	11269	12175	14047	12859	14917	13941	10061	13308	17125	21000	24155	32139	22363
1500	7940	8586	6748	8685	10204	11507	12417	14290	13130	15505	14441	10404	13840	17812	21845	25129	33440	23196

Conclusions about steam

The UD is about two and half times for the S5 panels compared with 10 FPI L panel. This implies a reduction to 40% in panel size for the same performance.

The outlet Air temperature achieved at different flow rates is higher for the S5 Panel by 23 to 27 degrees centigrade as we move from an air flow rate of 200 FPM to 1500 FPM. Again this implies that one can achieve the desired air temperature with a lower number of fin tube rows.

For the log mean temperature difference (LMTD) we are able to achieve an improvement of 14 -26 degrees as we move along the air flow rate curve between the 10 FPI L fin tube and S5. A tighter LMTD means a much more efficient heat exchanger.

Notwithstanding the LMTD is tight, the heat load for S5 is higher by 60-61% for S5 compared to the 10 FPI L panel.

While the difference is very large for S5 and 10 FPI L fin, it is also substantial when compared with S1, the lowest configuration. Even the P4 which is a 3/8" od tube performs very well against the L fin.

Hot Water through tubes

To demonstrate the performance in the first case we have worked out the performance of the coil using hot water. Here we have kept the air flow rate constant at 800 FPM and varied the water flow rate. The performance of all the panels with regard to all key parameters is given (Outlet water temperature, LMTD, Heat transfer coefficient, Heat Load). It can be observed that once again the Wire wound fin tube panels deliver significantly higher performance. This performance will be consistent with all other fluids and can be calculated by the customer by plugging in the required data and using the linear airside coefficient we have provided.

Assumptions:

Ambient air of 25 degrees Centigrade at mean sea level.
We have taken Hot water at 90- degrees centigrade. Air flow rate is 800 FPM.

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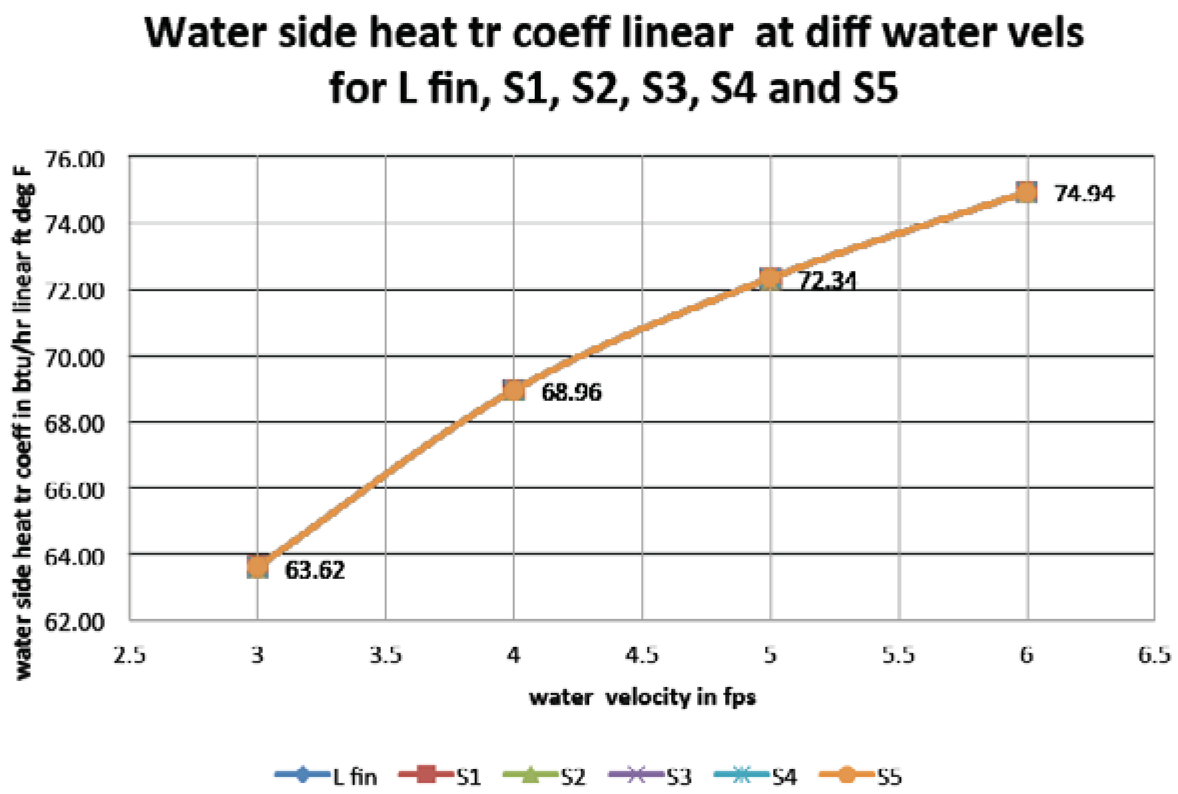

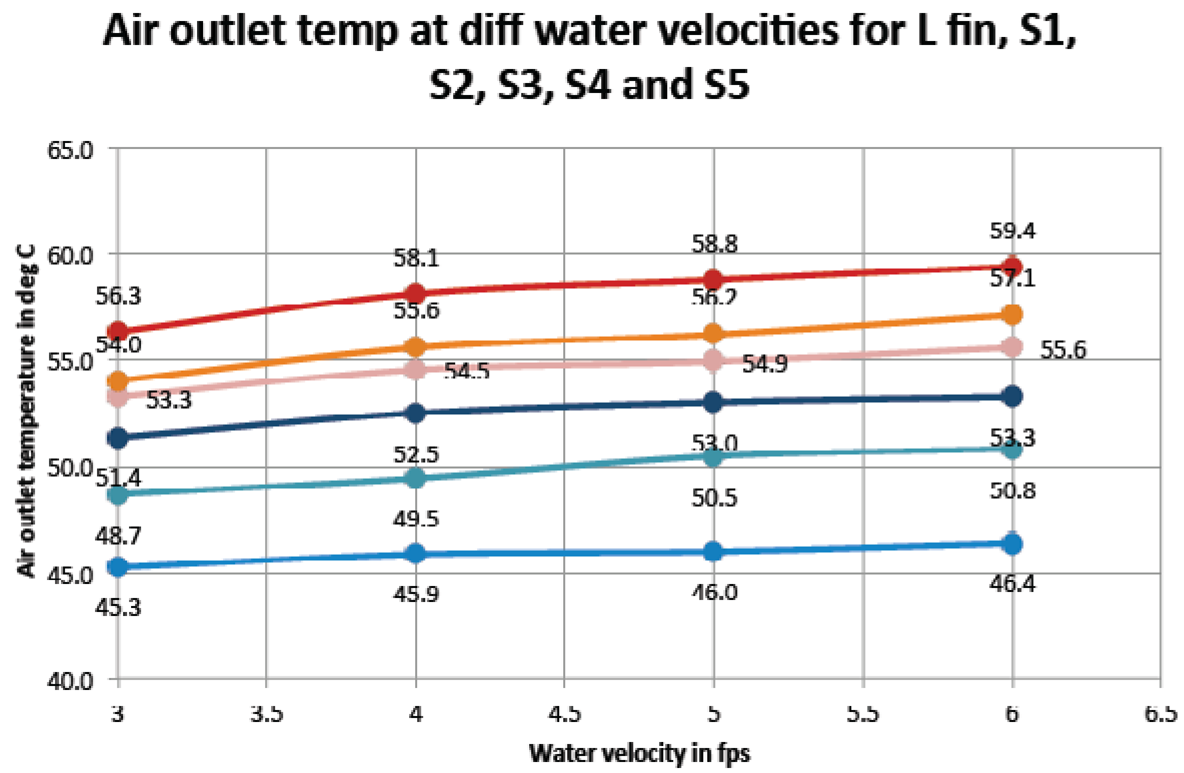

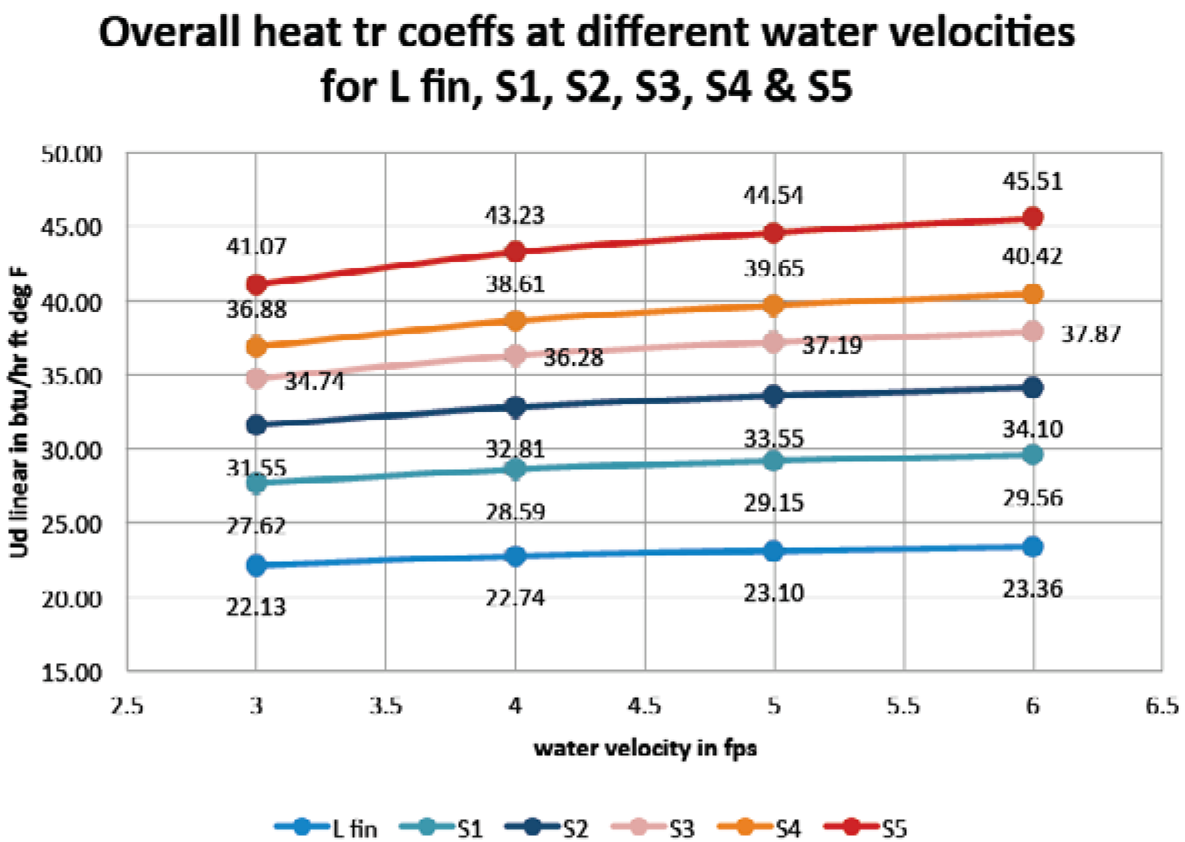

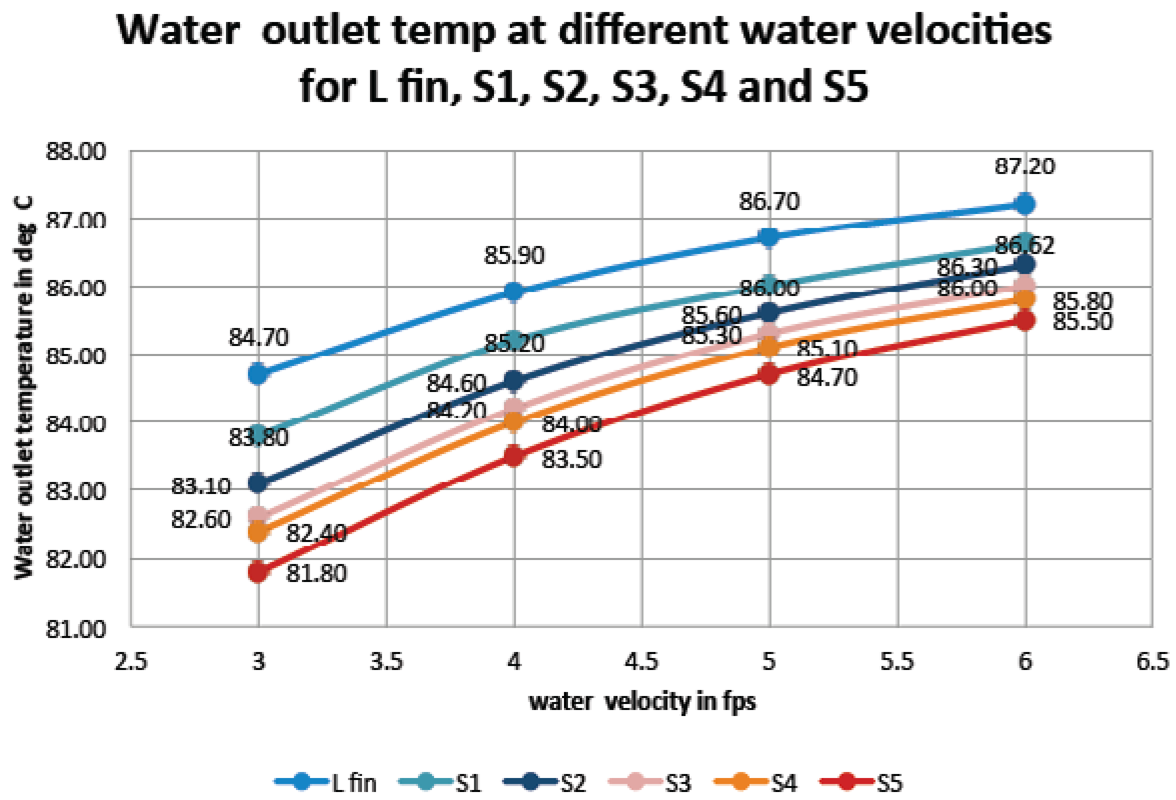

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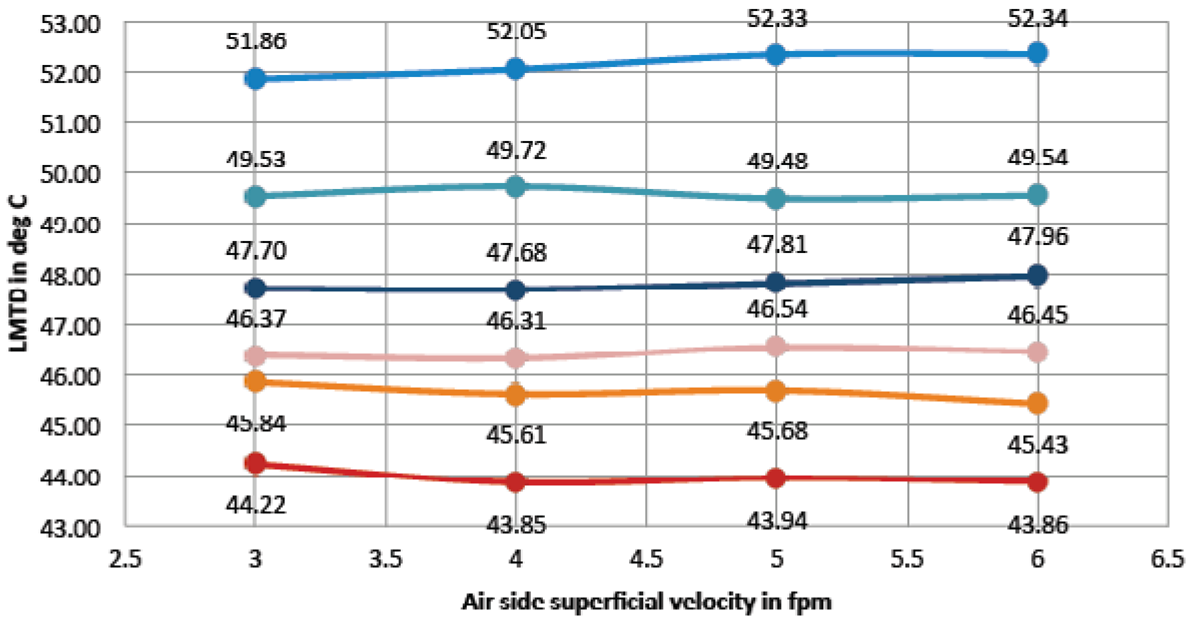
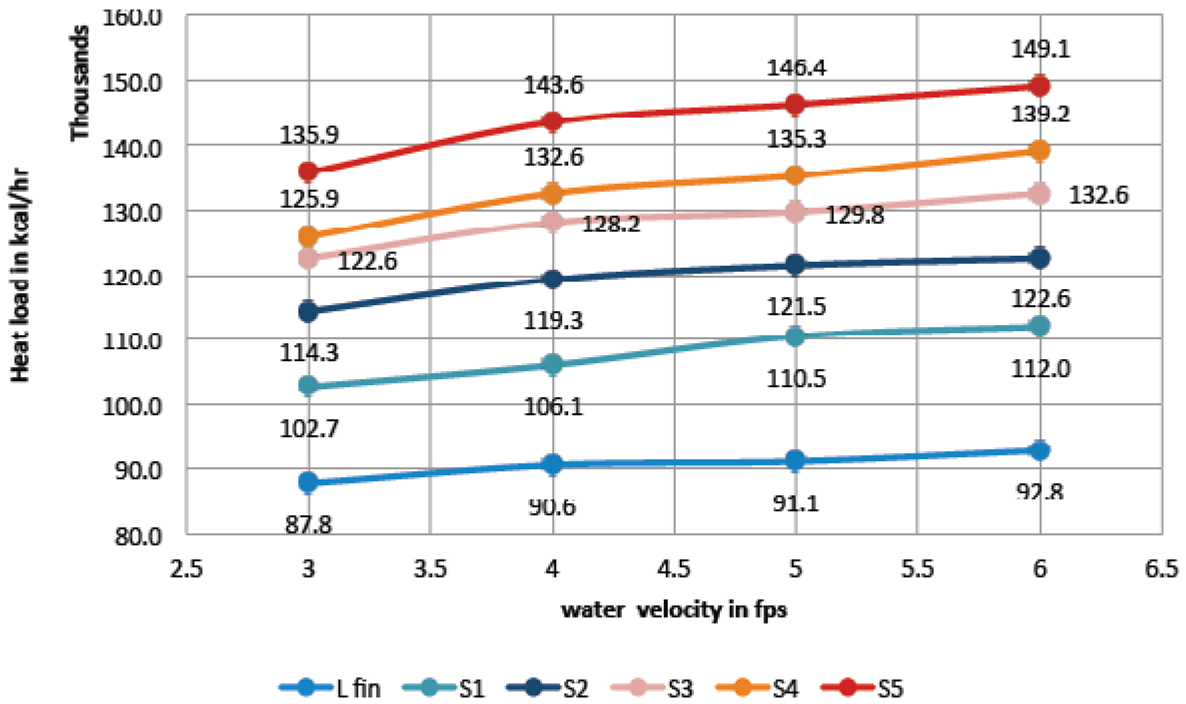
LMTD at different air velocities for L fin, S1, S2, S3, S4 and S5



Heat load at different water velocities for L fin, S1, S2, S3, S4 and S5



Air sup velocity fpm	3 fps Overall Coeff btu/hrftdeg F						4 fps Overall Coeff btu/hrftdeg F					
	L fin	S1	S2	S3	S4	S5	L fin	S1	S2	S3	S4	S5
200	14.49	16.87	20.15	23.03	25.11	29.51	14.75	17.22	20.65	23.69	25.90	30.61
300	17.09	19.80	23.36	26.42	28.58	33.06	17.45	20.29	24.05	27.30	29.61	34.45
400	18.53	22.03	25.75	28.89	31.08	35.55	18.96	22.64	26.59	29.94	32.30	37.16
500	19.51	23.83	27.65	30.82	33.02	37.43	19.98	24.54	28.61	32.03	34.40	39.22
600	20.44	25.33	29.21	32.41	34.59	38.95	20.96	26.14	30.29	33.74	36.11	40.89
700	21.33	26.63	30.54	33.73	35.90	40.19	21.90	27.52	31.72	35.18	37.54	42.25
800	22.18	27.76	31.69	34.87	37.02	41.23	22.80	28.73	32.96	36.42	38.76	43.41
900	22.99	28.76	32.70	35.87	37.99	42.14	23.65	29.80	34.06	37.50	39.83	44.42
1000	23.75	29.66	33.60	36.75	38.85	42.93	24.45	30.77	35.03	38.47	40.78	45.30
1100	24.44	30.47	34.41	37.53	39.61	43.62	25.19	31.65	35.91	39.33	41.62	46.07
1200	25.08	31.21	35.14	38.24	40.29	44.24	25.87	32.45	36.71	40.11	42.37	46.76
1300	25.67	31.89	35.81	38.89	40.92	44.81	26.50	33.18	37.44	40.82	43.06	47.40
1400	26.21	32.52	36.43	39.47	41.48	45.32	27.08	33.86	38.12	41.47	43.69	47.96
1500	26.72	33.10	36.99	40.02	42.01	45.79	27.62	34.49	38.74	42.07	44.27	48.49

Air sup velocity fpm	5 fps Overall Coeff btu/hrftdeg F						6 fps Overall Coeff btu/hrftdeg F					
	L fin	S1	S2	S3	S4	S5	L fin	S1	S2	S3	S4	S5
200	14.90	17.42	20.95	24.08	26.36	31.26	15.01	17.57	21.16	24.36	26.70	31.73
300	17.66	20.57	24.44	27.81	30.22	35.27	17.81	20.78	24.73	28.19	30.66	35.88
400	19.20	22.99	27.07	30.56	33.03	38.12	19.38	23.25	27.43	31.02	33.56	38.83
500	20.25	24.96	29.18	32.74	35.22	40.29	20.45	25.26	29.59	33.26	35.83	41.08
600	21.26	26.61	30.93	34.53	37.02	42.06	21.48	26.95	31.39	35.11	37.69	42.92
700	22.23	28.04	32.42	36.03	38.52	43.50	22.47	28.42	32.93	36.67	39.25	44.43
800	23.15	29.30	33.72	37.34	39.81	44.73	23.41	29.72	34.27	38.02	40.58	45.71
900	24.03	30.42	34.86	38.48	40.94	45.79	24.31	30.87	35.46	39.20	41.76	46.82
1000	24.87	31.42	35.89	39.50	41.94	46.73	25.17	31.90	36.52	40.26	42.80	47.80
1100	25.63	32.34	36.81	40.40	42.82	47.55	25.95	32.85	37.47	41.20	43.72	48.66
1200	26.33	33.18	37.65	41.23	43.63	48.29	26.67	33.71	38.34	42.06	44.56	49.44
1300	26.98	33.94	38.42	41.98	44.36	48.97	27.34	34.51	39.14	42.84	45.32	50.15
1400	27.58	34.66	39.13	42.67	45.02	49.58	27.95	35.24	39.88	43.56	46.02	50.78
1500	28.14	35.32	39.78	43.30	45.64	50.14	28.53	35.93	40.56	44.22	46.66	51.37

water fps	Air side pr drop at 800 fpm	Udlinear btu/hrft F				Air outlet temp deg C			
		3	4	5	6	3	4	5	6
L Fin	0.587	22.13	22.74	23.1	23.36	45.3	45.9	46	46.4
S1	0.572	27.62	28.59	29.15	29.56	48.7	49.5	50.5	50.8
S2	0.751	31.55	32.81	33.55	34.1	51.4	52.5	53	53.3
S3	0.973	34.74	36.28	37.19	37.87	53.3	54.5	54.9	55.6
S4	1.161	36.88	38.61	39.65	40.42	54	55.6	56.2	57.1
S5	1.598	41.07	43.23	44.54	45.51	56.3	58.1	58.8	59.4

water fps	Air side pr drop at 800 fpm	water outlet temp deg C				LMTD deg C			
		3	4	5	6	3	4	5	6
L Fin	0.587	84.7	85.9	86.7	87.2	51.86	52.05	52.33	52.34
S1	0.572	83.8	85.2	86	86.62	49.53	49.72	49.48	49.54
S2	0.751	83.1	84.6	85.6	86.3	47.7	47.68	47.81	47.96
S3	0.973	82.6	84.2	85.3	86	46.37	46.31	46.54	46.45
S4	1.161	82.4	84	85.1	85.8	45.84	45.61	45.68	45.43
S5	1.598	81.8	83.5	84.7	85.5	44.22	43.85	43.94	43.86

water velocity fps	Air side pr drop at 800 fpm	Heat load kcal/hr			
		3	4	5	6
L Fin	0.587	87830.5	90592.5	91144.9	92802
S1	0.572	102745.1	106059.5	110478.6	112025.3
S2	0.751	114345.4	119316.9	121526.5	122631.3
S3	0.973	122631.3	128155.2	129812.4	132574.3
S4	1.161	125945.6	132574.3	135336.3	139203.1
S5	1.598	135888.7	143622.2	146384.2	149146.1

Conclusions for Hot water Panels:

The UD is about twice for the S5 panels compared with 10 FPI L panel. This implies a 50% reduction in panel size for the same performance.

The outlet Air temperature achieved at different flow rates is higher for the S5 Panel by 11 to 13 degrees centigrade as we move from a water flow rate of 3 to 6 FPS. Again this implies that one can achieve the desired air temperature with a lower number of fin tube rows.

The log mean temperature difference we are able to achieve is an improvement of 7 -9 degrees as we move from 3-6 FPS. A tighter LMTD means a much more efficient heat exchanger.

Notwithstanding the LMTD is tight, the heat load for S5 is higher by 53-60% for S5 compared to the 10 FPI Lpanel.

While the difference is very large for S5 and 10 FPI L fin, it is also substantial when compared with S1, the lowest configuration.

Oil and viscous liquids

When dealing with Viscous Liquids the tube side coefficient becomes very important. Since we already have the Airside coefficient and pressure drop for the various panels it is easy to calculate the overall performance once we are able to optimize the tube side heat transfer.

There are two ways of doing this:

- Increasing the tubeside passes.
- Using turbulators.

General type of turbulators that can be used are as under:

- Rigid soldered turbulators.
- Rigid unsoldered turbulators.
- Flexible turbulators.
- Twisted tape turbulators.

For each class of turbulators there are various densities for every tube OD.

Generally given the very low coefficient of oil in an unturbulated tube, using a Turbulator is a huge advantage. A look at the charts on heat transfer and pressure drop provided overleaf will demonstrate the improvement provided by using different densities of Turbulator of the flexible type, Rigid soldered type and twisted tape type for oil viscosities of 5, 15 and 25 cSt.

The important thing is to choose the correct type of turbulators.

The following are some general facts about Turbulator use.

Turbulator selection will depend on the following:

- Oil Viscosity.
- Oil Velocity.
- The degree of enhancement required.
- Oil temperature.

Key elements of Good Turbulator design.

While we stand ready, and prefer to help our customers with design, we have tried to present an overview by presenting some graphical data.

To do this we have done the following:

Chosen a 3/4" OD tube as it is very widely used.

For this tube OD, we prepared the following data:

The pressure drop and heat transfer of oil of 3 viscosities, 5 cSt, 15 cSt and 25 cSt travelling through the tubes at a flow rate of 1 to 6 feet per second. This data was prepared for the following Turbulator cases:

No Turbulator.

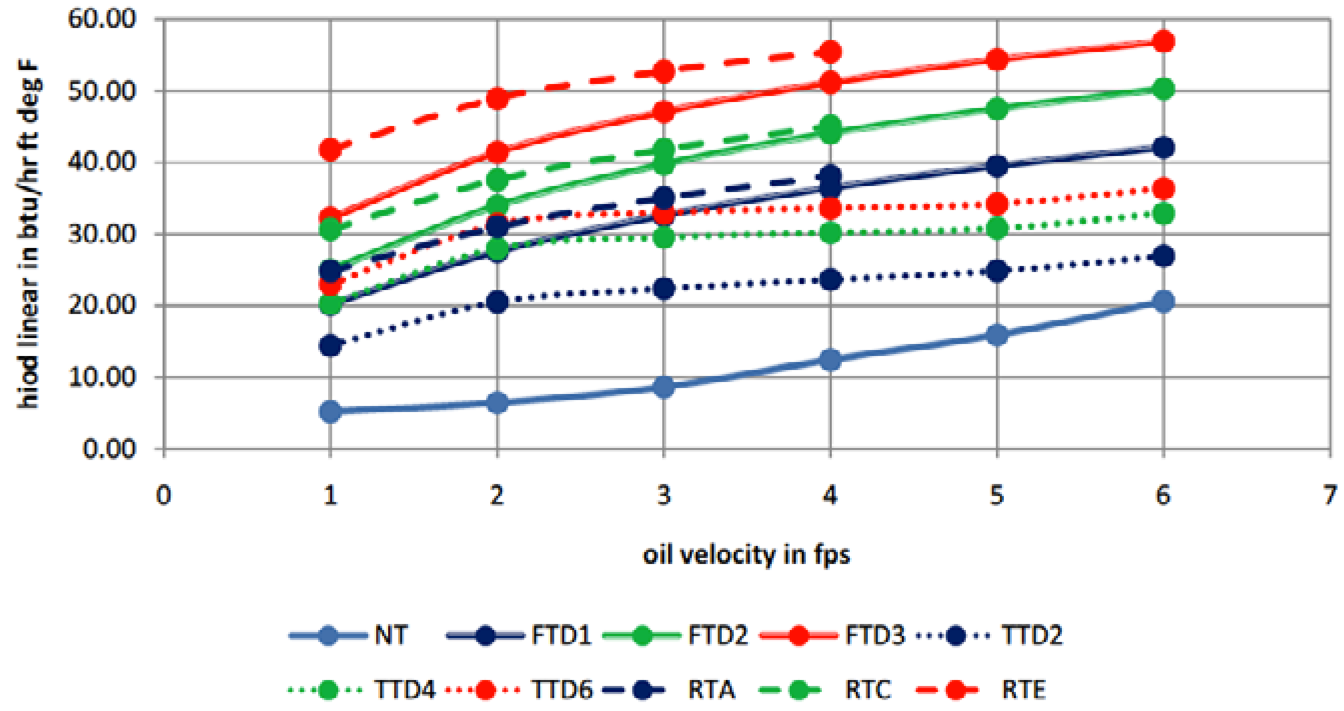
Rigid turbulators RTA, RTB & RTC. (Our standardsfor this tube size).

Flexible turbulators FTD1, FTD2 & FTD3 (Again our standard models)

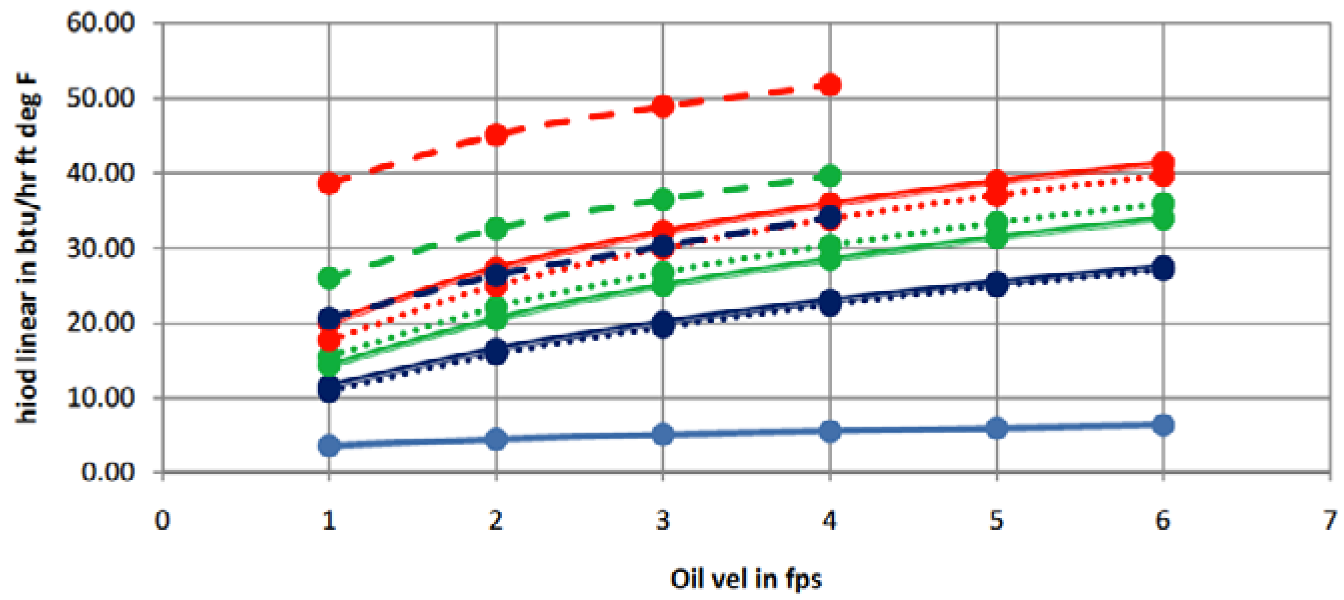
Twisted tape turbulators. Since the possibilities here are infinite for the case of better comparing the two, we selected those twisted tape turbulators that gave with a 15 cSt oil the same pressure drop at 3 FPS flow rate as the corresponding standard flexible turbulators. We must bear in mind though, that twisted tape turbulators thus selected have a very high twist ratio and are not commonly manufactured. However they were chosen for their value in comparision. Most commonly used twisted tape turbulators will have a lower performance and pressuredrop.

This data is represented graphically in the following charts/graphs.

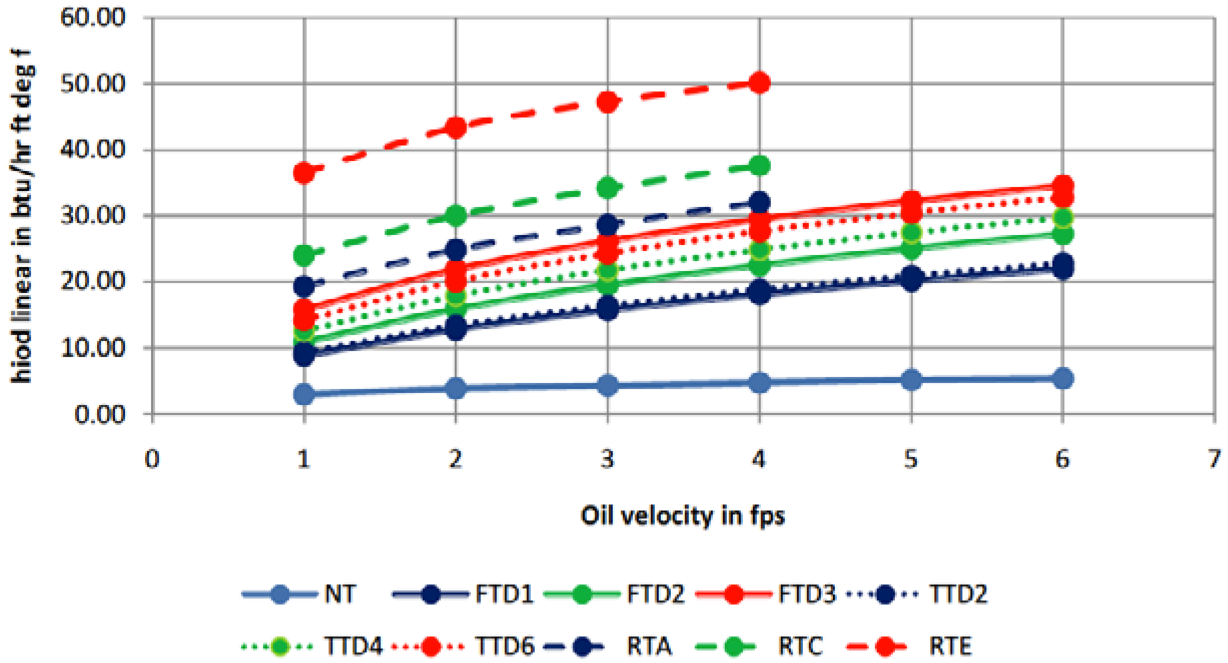
hiod linear in btu/hr for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 5 cSt oil viscosity



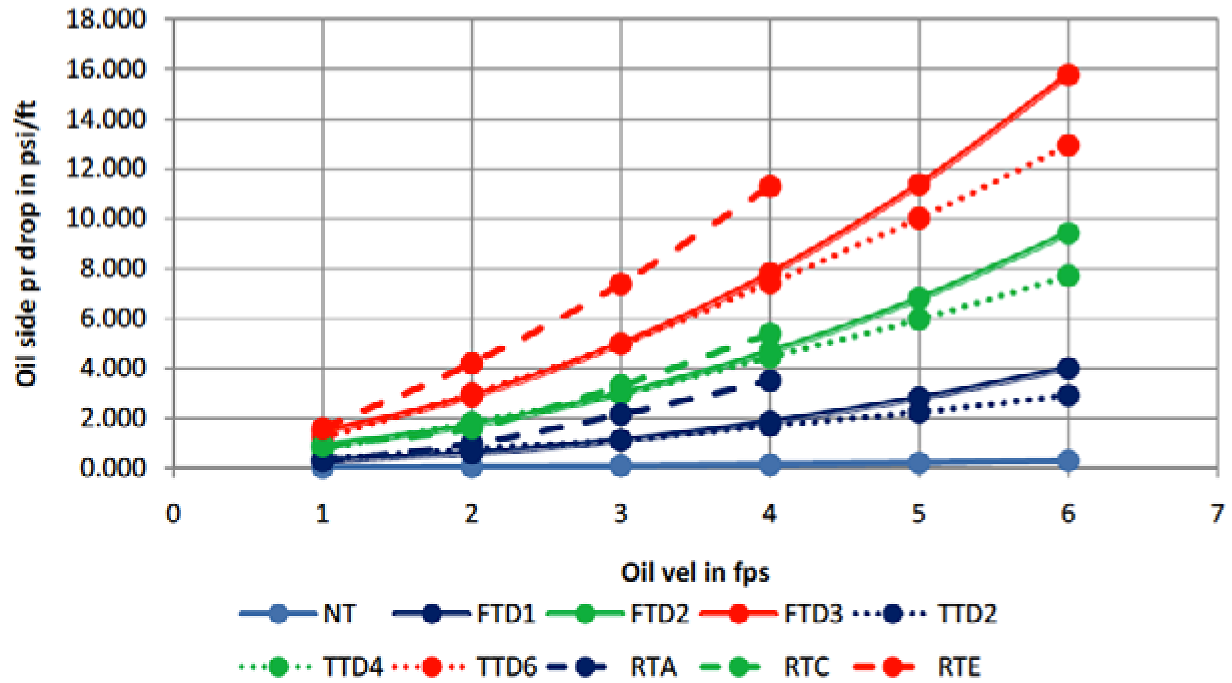
hiod linear in btu/hr for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 15 cSt oil viscosity



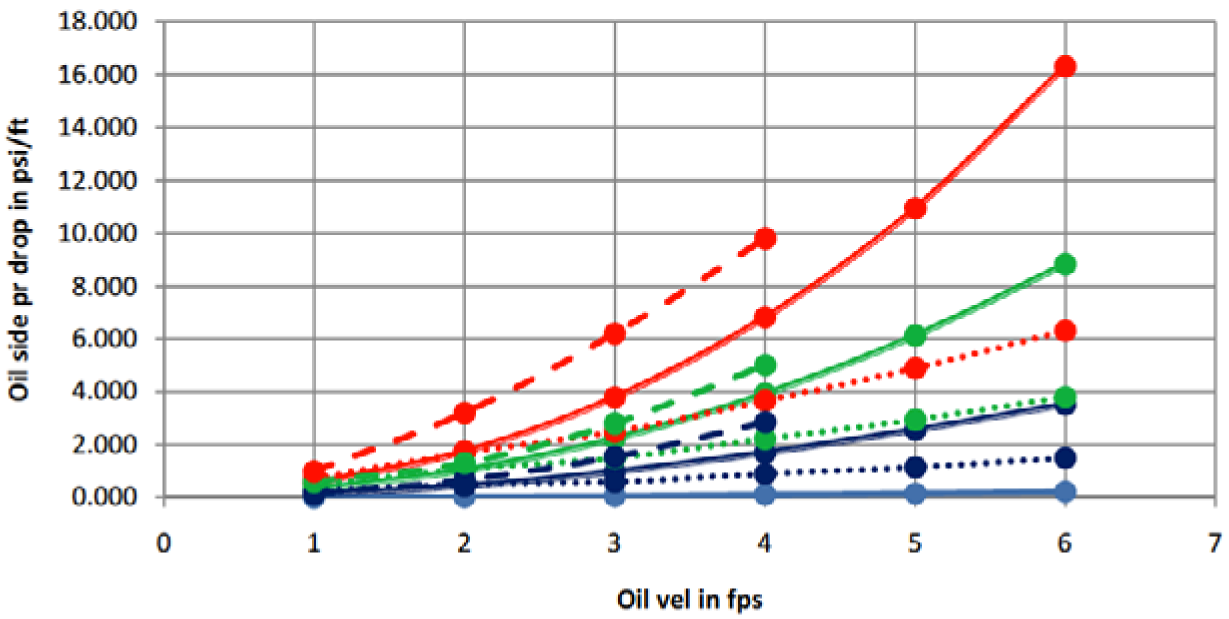
hiod linear in btu/hr for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 25 cSt oil viscosity



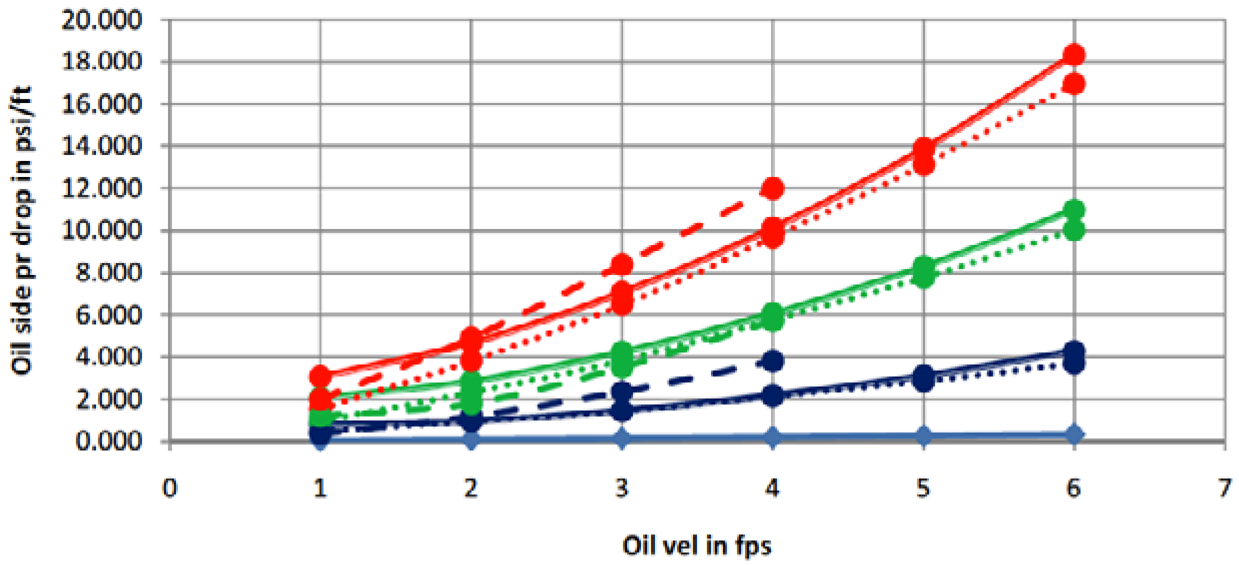
Oil side pr drop in psi/ft for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 15 cSt oil viscosity



Oil side pr drop in psi/ft for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 5 cSt oil viscosity



Oil side pr drop in psi/ft for No Turbulator, Rigid turbulator, Flexible turbulator & Twisted tape for 25 cSt oil viscosity



Pin Fin Division

From the curves, we can arrive at the following observations:

1) The rigid soldered turbulators overall give the best heat transfer and also the highest pressure drop. However as the viscosity goes up, the performance as compared to flexible turbulator goes up significantly. For example in the 5 cst case, RT6 is above FTD3, RT4 above FTD2 and RT2 above FTD1. However at 15 cst both RT6 and RT4 are above FTD 3 and RT2 is very close to FTD 3. In the case of 25 CST all the three rigid turbulators are all above the highest performing flexible turbulators.The pressure drop is also compared to performance much lower.

2) The performance of the twisted tape (even though the twisting selected is high to match the pressure drop of corresponding flexible wire turbulator) is generally lower than that of the flexible but not by much. However given that we will not have such a high degree of twisting in standard available twisted tape turbulators we can say that the flexible turbulator performs better.

3) The pressure drop increase for the two wire type turbulators with increase in fluid velocity is more than linear. The increase in performance is less than linear. This tells us that after a point it is not worth trying to purchase performance with pressure drop.

4) The performance as well as the pressure drop in the case of twisted tape turbulators are more linear.

To get another angle on this performance we worked out the following table, where we have simply divided the heat transfer coefficient by the corresponding pressure drop to get the HTPD factor (Heat transfer coefficient per unit of pressure drop). We did this for the three oil viscosities for all the Turbulator models at all the studied flow rates. We have color coded the results so that it is easier to spot the best as well as the trend.

HTPD factors for Flexible,Twisted tape & Rigid turbulators

vel fps	NT	FTD1	FTD2	FTD3	TTD2	TTD4	TTD6	RTA	RTC	RTE
1	500.5	161.5	75.2	58.0	55.2	41.3	31.2	155.3	51.1	41.8
2	195.5	62.0	32.4	23.6	40.2	25.9	18.4	45.6	28.9	15.3
3	132.3	33.2	17.8	12.4	37.2	19.7	13.3	22.6	14.9	8.5
4	112.9	21.4	11.2	7.5	26.1	13.6	9.2	13.4	9.0	5.7
5	100.8	15.4	7.8	5.0	21.5	10.5	7.0			
6	93.6	12.0	5.7	3.5	17.9	8.6	5.8		5 cSt	
vel fps	NT	FTD1	FTD2	FTD3	TTD2	TTD4	TTD6	RTA	RTC	RTE
1	119.4	37.5	15.9	13.9	29.6	20.2	14.7	72.5	28.9	24.1
2	72.2	27.3	11.9	9.5	20.5	12.1	8.4	26.9	20.4	10.7
3	53.6	17.9	8.4	6.4	17.3	9.0	6.0	14.1	11.0	6.6
4	38.1	12.4	6.1	4.6	13.2	6.8	4.6	9.8	7.3	4.6
5	27.9	9.0	4.6	3.4	11.1	5.6	3.7			
6	21.7	6.9	3.6	2.6	9.3	4.7	3.1		15 cSt	
vel fps	NT	FTD1	FTD2	FTD3	TTD2	TTD4	TTD6	RTA	RTC	RTE
1	57.9	11.1	5.2	5.2	20.1	13.0	9.2	52.2	20.0	18.2
2	39.0	13.2	5.5	4.7	13.9	7.7	5.3	20.7	16.7	8.9
3	27.8	10.7	4.6	3.7	11.4	5.7	3.8	12.2	9.8	5.6
4	23.5	8.3	3.7	2.9	8.7	4.3	2.9	8.4	6.6	4.2
5	19.3	6.5	3.0	2.3	7.3	3.5	2.3			
6	15.6	5.1	2.5	1.9	6.1	3.0	1.9		25 cSt	

Note : HTPD factor is calculated for light , medium and dense turbulators as heat transfer coefficient
hiod linear per unit pr drop at different oil viscosities and different oil velocities through tubes

Good Better Best

The following facts emerge:

1. Across all Turbulator types the HTPD factor goes down as the velocity increases.
2. Across all turbulator types the HTPD factor goes down as the winding density increases.
3. Different Turbulator types give comparatively different results under different viscosity and flow conditions.
4. We can conclude that the best Turbulator is case specific.

The following should be kept in mind:

1. The data for rigid turbulators are for rigid soldered turbulators. If the same turbulators are not soldered they perform but not as well. This is due to the better contact and so better heat transfer due to soldering.
2. Just as pressure drop is a cost we pay for performance so is the dollar cost of material and labour. The rigid soldered Turbulator while an extremely efficient Turbulator is expensive to make and install.
3. Ease of cleaning and maintenance are also key factors in Turbulator choice.
4. Since we make all types, we have nothing to loose in giving you the correct advice.

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