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Verification of Computer Generated Design of Heat Exchangers

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Abstract - *The purpose of this paper is to obtain satisfactory design of shell and tube heat exchangers from software which can be implemented for specific oil under actual operating conditions. In this project, for validation of the thermal design of shell and tube heat exchangers given by the software, testing of heat exchangers is performed under different operating conditions. The geometric parameters of the heat exchanger like tube diameter, tube length, shell types, baffle spacing etc are all standardized. Testing of shell and tube heat exchanger usually involves a trial and error procedure where for a certain combination of design variables, particular results are obtained. The testing is done by varying parameters of heat load, oil flow rate and water flow rate. Heat exchanger is tested under actual operating conditions for a certain combination of design parameters and then another combination is tested to obtain required results. Software output about design of shell and tube heat exchangers is obtained after providing the software with basic exchanger parameters as input. The testing results are obtained in accordance with software output which validates the design given by the software. Percentage of over design for given heat transfer is obtained while pressure drops and fouling is within required limits.*

Key Words: Shell and Tube Heat Exchanger, Oil Cooler, Thermal Design, Oil- (ISO VG 46), Test Rig

1. INTRODUCTION

Lube oil systems are used for cooling & filtering turbine oil which lubricates the bearing of very large compressors, turbines & pumps. It comprises of pumps, motors, reservoirs, pressure relief valves, pressure control valves, oil cooler, oil filter and instruments like gauges, transmitters. Oil cooler is a key component of this system. The oil cooler is a shell & tube type heat exchanger.

Due to differences in the thermal design of shell and tube heat exchangers used for manufacture for actual use and the design obtained from the software, the reliability of the software needs to be validated for actual working conditions. Therefore, the research is undertaken to find the relation between the computer generated and the actual thermal design. This is done by experimental analysis of shell and tube heat exchangers (oil coolers) by manufacture of test skid in accordance with actual parameters.

The test rig was setup to test the shell and tube heat exchanger performance under actual operating conditions. The heat transfer process was between oil (ISO VG 46) and water which was used as the cooling medium. Thermal design of the heat exchanger under specific operating conditions was given by the software. The test results were compared to the thermal design given by the software for validation.

2. SETUP AND WORKING OF TEST RIG

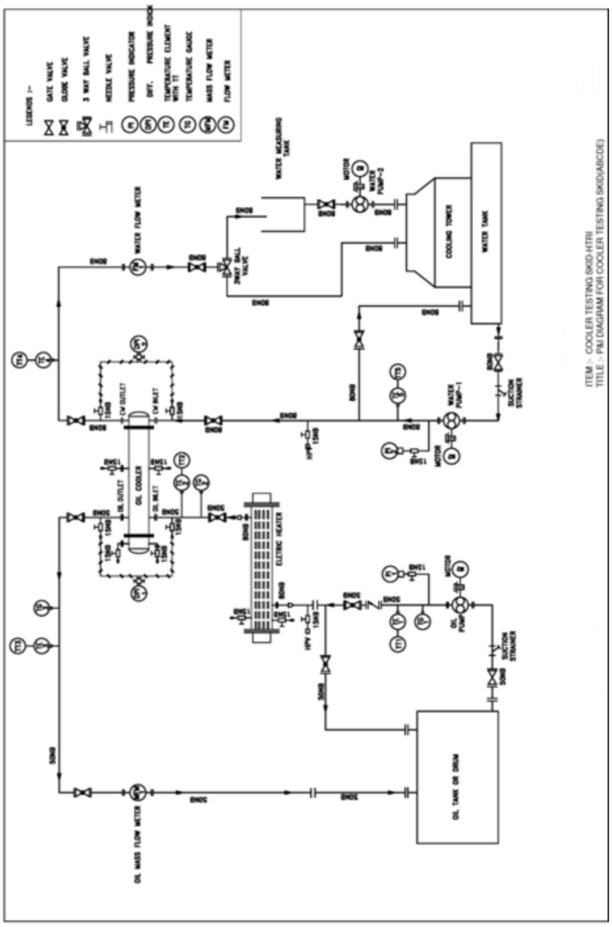

Fig -1: Line Diagram of Test Rig

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The test rig is divided into two parts: Water Side and Oil Side

1. Water side:

The direction of water flow is as follows:

Water Tank → Water Pump 1 → Heat Exchanger → Flow Meter → Measuring Tank → Water Pump 2 → Cooling Tower → Water Tank.

2. Oil side:

The oil used in the system is ISO VG 46. The direction of oil flow is as follows:

Oil Tank → Oil Pump → Heater → Heat Exchanger → Mass Flow Meter → Oil Tank.

The test rig included temperature and pressure indicators, mass flow meters, pressure drop indicators for measuring various parameters during testing.

The oil flow rate, water flow rate and heat duty (input to heater) were the main parameters which were varied during testing. Heat exchanger was tested for a specific combination of these three parameters and its performance was analyzed.

3. OBSERVATIONS, CALCULATIONS AND RESULTS

For Test: Heat Duty= 95 kW, Oil Flow= 190 lpm, Water Flow= 460lpm

Table -1: Observations for 95 kW Test

SR NO.	TIME	KW	OIL FLOW	WATER FLOW	HEATER INLET TEMP.	COOLER INLET TEMP.	COOLER OUTLET TEMP.	COOLING WATER INLET	COOLING WATER OUTLET	PRESSURE DROP (kgf/cm2)	
			(KG/ MIN)	ACTUAL (GPM)	TE1 (°C)	TE2 (°C)	TE3 (°C)	TE5 (°C)	TE4 (°C)	OIL SIDE	WATER SIDE
1	1:00	93.81	161.98	121	49.947	67.995	51.368	42.354	45.216	0.408	0.365
2	1:15	93.76	161.96	121	49.936	67.989	51.354	42.219	45.080	0.409	0.366
3	1:30	95.05	162.76	121	50.54	68.852	52.222	42.891	45.753	0.4155	0.362
4	1:45	94.83	162.44	121	50.204	68.673	52.045	42.283	45.141	0.412	0.368
5	2:00	94.12	162.17	121	50.001	68.566	51.937	42.145	45.008	0.415	0.367
6	2:15	93.20	161.86	121	49.653	68.01	51.399	42.187	45.054	0.411	0.371
7	2:30	93.70	161.96	121	49.826	68.10	51.471	42.216	45.072	0.412	0.372
8	2:45	95.10	162.9	121	49.81	68.899	52.279	43.114	45.973	0.410	0.374
9	3:00	94.20	162.02	121	50.021	68.071	51.466	42.003	45.112	0.413	0.366
10	3:15	94.0	162.21	121	50.799	68.414	51.784	42.254	45.115	0.411	0.371
11	3:30	94.60	162.32	121	49.862	68.562	51.942	42.873	45.737	0.425	0.373
12	3:45	93.5	161.94	121	50.081	68.027	51.396	42.171	45.052	0.415	0.371
13	4:00	93.42	161.63	121	50.332	67.984	51.354	42.002	44.843	0.412	0.372
14	4:15	93.0	161.54	121	50.198	67.826	51.177	41.898	44.759	0.401	0.377
15	4:30	94.5	162.02	121	50.482	68.201	51.581	42.516	45.374	0.414	0.371

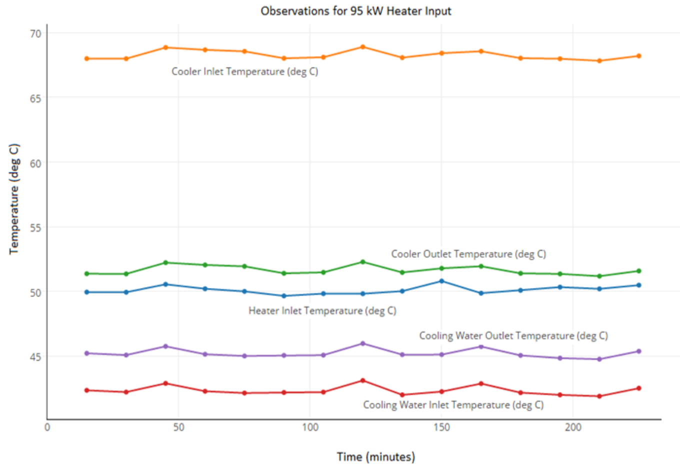


Chart -1: Observations of 95 kW Test

Calculations are done for steady state conditions of temperatures and flow rate.

Table -2: Calculations for 95 kW Test

		DATE 19.02.16	
Sr. No.	Description	Value	Unit
1)	Average Power	93.8	KW
2)	Avg. Oil Inlet temp.	68.12	°C
3)	Avg. Oil Outlet temp.	51.490	°C
4)	Avg. Water Inlet Temp.	42.292	°C
s)	Avg. Water Outlet Temp.	45.153	°C
6)	Avg. Specific heat of oil (Cp)	2.0507	KJ/kg°C
7)	Avg. Specific heat of water (Cp)	4.1805	KJ/kg°C
8)	Avg. Flow of oil (m)	9713.58	kg/hr
	190 lpm	2.698	kg/sec
9)	Avg. Flow of water (m)	27600	kg/hr
	460 lpm	7.667	kg/sec

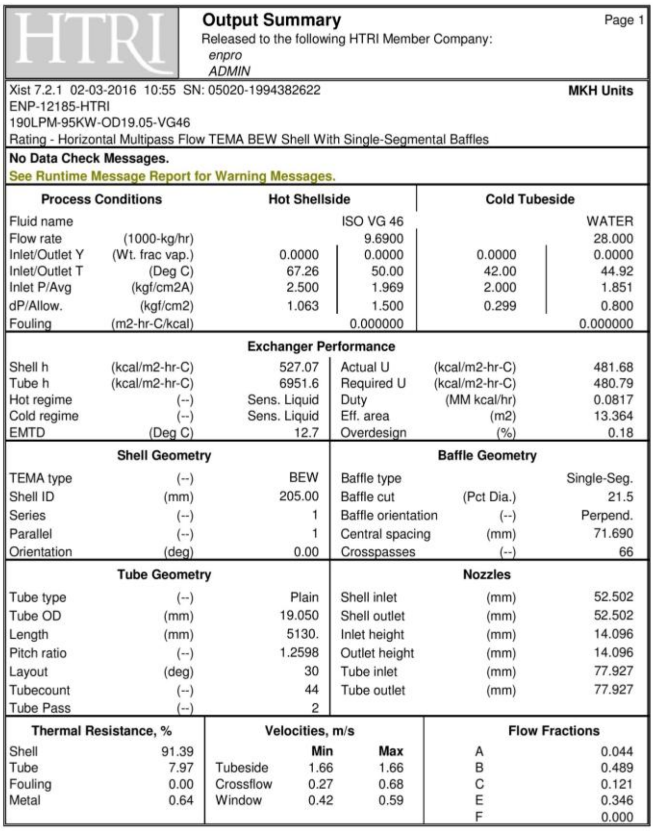
HEAT BALANCE:

1) WATER = m x Cp x Δt 91.696 kW

2) OIL = m x Cp x Δt 92.018 kW

3) Provided Power = 95 kW

These calculation results are compared with the software output for heat exchanger performance analysis for validation purpose.



HTRI

Output Summary Page 1
Released to the following HTRI Member Company:
enpro
ADMIN

Xist 7.2.1 02-03-2016 10:55 SN: 05020-1994382622 **MKH Units**
ENP-12185-HTRI
190LPM-95KW-OD19.05-VG46
Rating - Horizontal Multipass Flow TEMA BEW Shell With Single-Segmental Baffles

No Data Check Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name			ISO VG 46		WATER
Flow rate	(1000-kg/hr)		9.6900		28.000
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	0.0000	0.0000
Inlet/Outlet T	(Deg C)	67.26	50.00	42.00	44.92
Inlet P/Avg	(kgf/cm2A)	2.500	1.969	2.000	1.851
dP/Allow.	(kgf/cm2)	1.063	1.500	0.299	0.800
Fouling	(m2-hr-C/kcal)		0.000000		0.000000

Exchanger Performance					
Shell h	(kcal/m2-hr-C)	527.07	Actual U	(kcal/m2-hr-C)	481.68
Tube h	(kcal/m2-hr-C)	6951.6	Required U	(kcal/m2-hr-C)	480.79
Hot regime	(--)	Sens. Liquid	Duty	(MM kcal/hr)	0.0817
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	13.364
EMTD	(Deg C)	12.7	Overdesign	(%)	0.18

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEW	Baffle type		Single-Seg.
Shell ID	(mm)	205.00	Baffle cut	(Pct Dia.)	21.5
Series	(--)	1	Baffle orientation	(--)	Perpend.
Parallel	(--)	1	Central spacing	(mm)	71.690
Orientation	(deg)	0.00	Crosspasses	(--)	66

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	52.502
Tube OD	(mm)	19.050	Shell outlet	(mm)	52.502
Length	(mm)	5130.	Inlet height	(mm)	14.096
Pitch ratio	(--)	1.2598	Outlet height	(mm)	14.096
Layout	(deg)	30	Tube inlet	(mm)	77.927
Tubecount	(--)	44	Tube outlet	(mm)	77.927
Tube Pass	(--)	2			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	91.39				A	0.044
Tube	7.97	Tubeside	1.66	1.66	B	0.489
Fouling	0.00	Crossflow	0.27	0.68	C	0.121
Metal	0.64	Window	0.42	0.59	E	0.346
					F	0.000

Fig -2: Software Output of 95 kW Test.

4. SUMMARY

Table -3: Summary of Tests

Tube Dia: 19.05mm		SUMMARY OF TESTS								Date: 29/02/2016	
Sr. No.	HEATER	OIL SIDE					WATER SIDE				
	ACTUAL	ACTUAL FLOW		INLET TEMP.	OUTLET TEMP.	CALCULATED	ACTUAL FLOW		INLET TEMP.	OUTLET TEMP.	CALCULATED
	kW	Kg/hr	lpm	°C	°C	kW	Kg/hr	lpm	°C	°C	kW
1.	72.821	11220	220	61.91	50.645	71.409	27600	460	45.125	47.432	71.07
2.	93.8	9713.6	191.86	68.12	51.49	92.018	27600	460	42.292	45.153	91.70
3.	118.96	14028	278	76.21	61.98	115.967	35100	585	52.23	55.05	115.03

5. CONCLUSIONS

1. Appreciable results were obtained from testing which validates software output. The heat transfer area suggested by the software is sufficient for the heat transfer in the shell and tube heat exchanger. Thus, the overall performance of the heat exchanger will be satisfactory if designed by using the software.

2. Software provided a small degree of overdesign. Overdesign percentage of 0.04 - 0.18 was obtained from testing analysis.

3. Pressure drops, flow velocities and fouling were within limits for the shell and tube heat exchanger used.

6. FUTURE SCOPE

The test rig can be used for carrying further testing of different heat exchangers for different operating conditions, different fluids. Thus, large amount of results will be obtained which can be then implemented during actual design and manufacture of lube oil systems.

Results obtained from the project can be utilized for improvements in the software. That includes performance of oil ISO VG 46 under actual operating conditions rather than ideal lab conditions.

ACKNOWLEDGEMENT

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