ENGINEERING SELECTION

STEP 1: Calculate the heat load

The heat load in BTU/HR or (Q) can be derived by using several methods. To simplify things, we will consider general specifications for hydraulic system oils and other fluids that are commonly used with shell & tube heat exchangers.

Terms

GPM	=	Gallons Per Minute
CN	=	Constant Number for a given fluid
ΔT	=	Temperature differential across the potential
PSI	=	Pounds per Square Inch (pressure) of the operating side of the system
MHP	=	Horsepower of the electric motor driving the hydraulic pump
Kw	=	Kilowatt (watts x 1000)
T_{in}	=	Hot fluid entering temperature in °F
T_{out}	=	Hot fluid exiting temperature in °F
t_{in}	=	Cold fluid temperature entering in °F
t_{out}	=	Cold fluid temperature exiting in °F
Q	=	BTU / HR

For example purposes, a hydraulic system has a 125 HP (93Kw) electric motor installed coupled to a pump that produces a flow of 80 GPM @ 2500 PSIG. The temperature differential of the oil entering the pump *vs* exiting the system is about 5.3°F. Even though our return line pressure operates below 100 psi, we must calculate the system heat load potential (Q) based upon the prime movers (pump) capability. We can use one of the following equations to accomplish this:

To derive the required heat load (Q) to be removed by the heat exchanger, apply ONE of the following. Note: The calculated heat loads may differ slightly from one formula to the next. This is due to assumptions made when estimating heat removal requirements. The factor *(v)* represents the percentage of the overall input energy to be rejected by the heat exchanger. The *(v)* factor is generally about 30% for most hydraulic systems, however it can range from 20%-70% depending upon the installed system components and heat being generated (ie. servo valves, proportional valves, etc…will increase the percentage required).

Formula	Example
A) Q = GPM x CN x actual ΔT	A) Q = 80 x 210 x 5.3°F = 89,040 BTU/HR
B) Q = [(PSI x GPM) / 1714] x (*v*) x 2545	B) Q = [(2500x80)/1714] x .30 x 2545 = 89,090 BTU/HR
C) Q = MHP x (*v*) x 2545	C) Q = 125 x .30 x 2545 = 95,347 BTU/HR
D) Q = Kw to be removed x 3415	D) Q = 28 x 3415 = 95,620 BTU/HR
E) Q = HP to be removed x 2545	E) Q = 37.5 x 2545 = 95,437 BTU/HR

Constant for a given fluid (CN)

1) Oil	CN = 210
2) Water	CN = 500
3) 50% E. Glycol	CN = 450

STEP 2: Calculate the Mean Temperature Difference

When calculating the MTD you will be required to choose a liquid flow rate to derive the cold side ΔT. If your water flow is unknown you may need to assume a number based on what is available. As a normal rule of thumb, for oil to water cooling a 2:1 oil to water ratio is used. For applications of water to water or 50 % Ethylene Glycol to water, a 1:1 ratio is common.

Formula

HOT FLUID ΔT Oil $= \dfrac{Q}{CN \times GPM}$

COLD FLUID Δt Water $= \dfrac{BTU / hr}{CN \times GPM}$

Example

$$\Delta T = \frac{89{,}090 \text{ BTU/hr (from step 1, item B)}}{210 \text{ CN} \times 80\text{GPM}} = 5.3°F = \Delta T \text{ Rejected}$$

$$\Delta t = \frac{89{,}090 \text{ BTU/hr}}{500 \text{ CN} \times 40\text{GPM (for a 2:1 ratio)}} = 4.45°F = \Delta T \text{ Absorbed}$$

T_{in}	= Hot Fluid entering temperature in degrees F	T_{in}	= 125.3 °F
T_{out}	= Hot Fluid exiting temperature in degrees F	T_{out}	= 120.0 °F
t_{in}	= Cold Fluid entering temperature in degrees F	t_{in}	= 70.0 °F
t_{out}	= Cold Fluid exiting temperature in degrees F	t_{out}	= 74.5 °F

$$\frac{T_{out} - t_{in}}{T_{in} - t_{out}} = \frac{\textbf{S}\text{[smaller temperature difference]}}{\textbf{L}\text{ [larger temperature difference]}} = \left(\frac{S}{L}\right)$$

$$\frac{120.0°F - 70.0°F = 50.0°F}{125.3°F - 74.5°F = 50.8°F} = \frac{50.0°F}{50.8°F} = .984$$

STEP 3: Calculate Log Mean Temperature Difference (LMTD)

To calculate the LMTD please use the following method;

L = Larger temperature difference from step 2.
M =Natural log for the S/L number (LOCATED IN TABLE A). *Note: If your calculator has the "natural log" function you may use it.*

$LMTD_i$ = L x M

$LMTD_i$ = 50.8 x .992 (FROM TABLE A) = 50.39

To correct the $LMTD_i$ for a multipass heat exchangers calculate **R** & **K** as follows:

Formula

$$\textbf{R} = \frac{T_{in} - T_{out}}{t_{out} - t_{in}}$$

$$\textbf{K} = \frac{t_{out} - t_{in}}{T_{in} - t_{in}}$$

Example

$$\textbf{R} = \frac{125.3°F - 120°F}{74.5°F - 70°F} = \frac{5.3°F}{4.5°F} = \mathbf{\{1.17=R\}}$$

$$\textbf{K} = \frac{74.5°F - 70°F}{124.5°F - 70°F} = \frac{4.5°F}{55.4°F} = \mathbf{\{0.081=K\}}$$

Locate the correction factor CF_B (FROM TABLE B)
$LMTD_c = LMTD_i \times CF_B$
$LMTD_c$ = 50.39 x 1 = **50.39**

STEP 4: Calculate the area required

Required Area sq.ft. = $\dfrac{Q\ (BTU / HR)}{LMTD_c \times U\ (\text{FROM TABLE C})}$ $\qquad \dfrac{89{,}090}{50.39 \times 100}$ = **17.68 sq.ft.**

STEP 5: Selection

a) From TABLE E choose the correct series size, baffle spacing, and number of passes that best fits your flow rates for both shell and tube side. Note that the tables suggest minimum and maximum information. Try to stay within the 20-80 percent range of the indicated numbers.

Example

Oil Flow Rate = 80 GPM = Series Required from Table E = **1200 Series**
Baffle Spacing from Table E = **4**
Water Flow Rate = 40 GPM = Passes required in 1200 series = **4 (FP)**

b) From TABLE D choose the heat exchanger model size based upon the sq.ft. or surface area in the series size that will accommodate your flow rate.

Example

Required Area = 17.68sq.ft Closest model required based upon sq.ft. & series = **CS - 1224 - 4 - 6 - FP**

If you require a computer generated data sheet for the application, or if the information that you are trying to apply does not match the corresponding information, please contact our engineering services department for further assistance.

TABLE A- FACTOR M/LMTD = L x M

S/L	M	S/L	M	S/L	M	S/L	M
		.25	.541	.50	.721	.75	.870
.01	.215	.26	.549	.51	.728	.76	.864
.02	.251	.27	.558	.52	.734	.77	.879
.03	.277	.28	.566	.53	.740	.78	.886
.04	.298	.29	.574	.54	.746	.79	.890
.05	.317	.30	.582	.55	.753	.80	.896
.06	.334	.31	.589	.56	.759	.81	.902
.07	.350	.32	.597	.57	.765	.82	.907
.08	.364	.33	.604	.58	.771	.83	.913
.09	.378	.34	.612	.59	.777	.84	.918
.10	.391	.35	.619	.60	.783	.85	.923
.11	.403	.36	.626	.61	.789	.86	.928
.12	.415	.37	.634	.62	.795	.87	.934
.13	.427	.38	.641	.63	.801	.88	.939
.14	.438	.39	.648	.64	.806	.89	.944
.15	.448	.40	.655	.65	.813	.90	.949
.16	.458	.41	.662	.66	.818	.91	.955
.17	.469	.42	.669	.67	.823	.92	.959
.18	.478	.43	.675	.68	.829	.93	.964
.19	.488	.44	.682	.69	.836	.94	.970
.20	.497	.45	.689	.70	.840	.95	.975
.21	.506	.46	.695	.71	.848	.96	.979
.22	.515	.47	.702	.72	.852	.97	.986
.23	.524	.48	.709	.73	.658	.98	.991
.24	.533	.49	.715	.74	.864	.99	.995

TABLE D- Surface Area

Model Number	Surface Area in Sq.ft. 1 / 4" O.D Tubing CODE 4	3 / 8" O.D Tubing CODE 6	5 / 8 O.D Tubing CODE 10	Model Number	Surface Area in Sq.ft. 1 / 4" O.D Tubing CODE 4	3 / 8" O.D Tubing CODE 6	5 / 8 O.D Tubing CODE 10
CS-614	4.6	–	–	CS-1236	–	35.3	17.7
CS-624	7.9	–	–	CS-1248	–	47.1	23.6
CS-636		–	–	CS-1260	–	58.9	29.5
				CS-1272	–	70.6	35.4
CS-814	8.3	–	–	CS-1284	–	82.3	41.3
CS-824	14.1	–	–	CS-1296	–	94.0	47.2
CS-836	21.2	–	–				
CS-848	28.3	–	–	CS-1724	–	40.1	23.6
				CS-1736	–	60.1	35.3
CS-1014	–	8.7	4.6	CS-1748	–	80.1	47.1
CS-1024	–	14.9	7.8	CS-1760	–	100.1	58.9
CS-1036	–	22.4	11.8	CS-1772	–	120.2	70.7
CS-1048	–	29.9	15.8	CS-1784	–	140.2	82.5
CS-1060	–	37.4	19.8	CS-1796	–	160.2	94.3
				CS-17108	–	180.2	106.1
CS-1224	–	23.6	11.8	CS-17120	–	200.2	117.9

TABLE B- LMTD correction factor for Multipass Exchangers

R \ K	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.6	.7	.8	.9	1.0
.2	1	1	1	1	1	1	1	.999	.993	.984	.972	.942	.908	.845	.71
.4	1	1	1	1	1	1	.994	.983	.971	.959	.922	.855	.70		
.6	1	1	1	1	1	.992	.980	.965	.948	.923	.840				
.8	1	1	1	1	.995	.981	.965	.945	.916	.872					
1.0	1	1	1	1	.988	.970	.949	.918	.867	.770					
2.0	1	1	.997	.973	.940	.845	.740								
3.0	1	1	.997	.933	.835										
4.0	1	.993	.950	.850											
5.0	1	.982	.917												
6.0	1	.968	.855												
8.0	1	.930													
10.0	.996	.880													
12.0	.985	.720													
14.0	.972														
16.0	.958														
18.0	.940														
20.0	.915														

TABLE E- Flow Rate for Shell & Tube

Shell dia . Code	Max. Liquid Flow - Shell Side Baffle Spacing 1.5	2	3	4	6	Liquid Flow - Tube Side SP Min.	SP Max.	TP Min.	TP Max.	FP Min.	FP Max.
600	15	20	25	30	–	7.5	48	3.5	24	2	12
800	20	34	45	60	–	10	50	4.5	38	3	21
1000	30	36	50	65	–	20	120	10	70	5.0	37
1200	45	50	70	100	125	30	220	15	112	7.5	56
1700	50	65	100	140	220	57	300	29	180	14	90

TABLE C

U	TUBE FLUID	SHELL FLUID
400	Water	Water
350	Water	50% E. Glycol
100	Water	Oil
300	50% E. Glycol	50% E. Glycol
90	50% E. Glycol	Oil