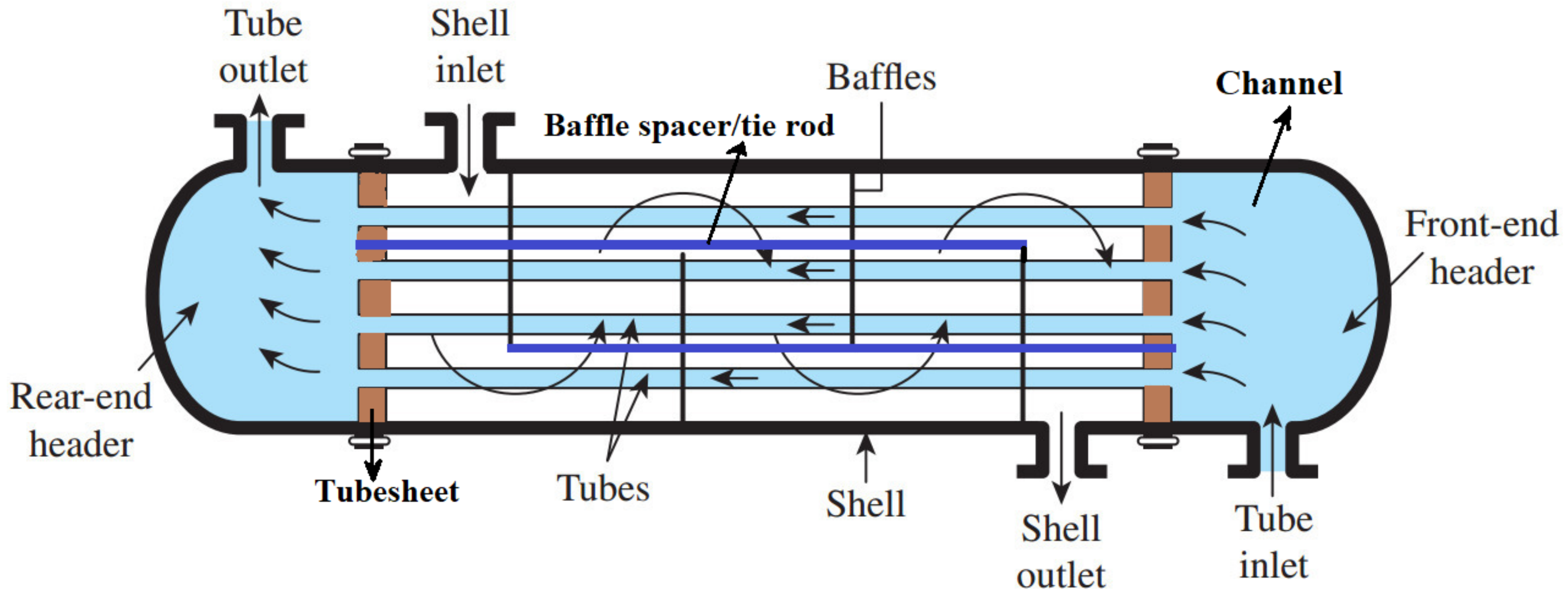
Heat Exchangers

Shell and tube heat exchanger

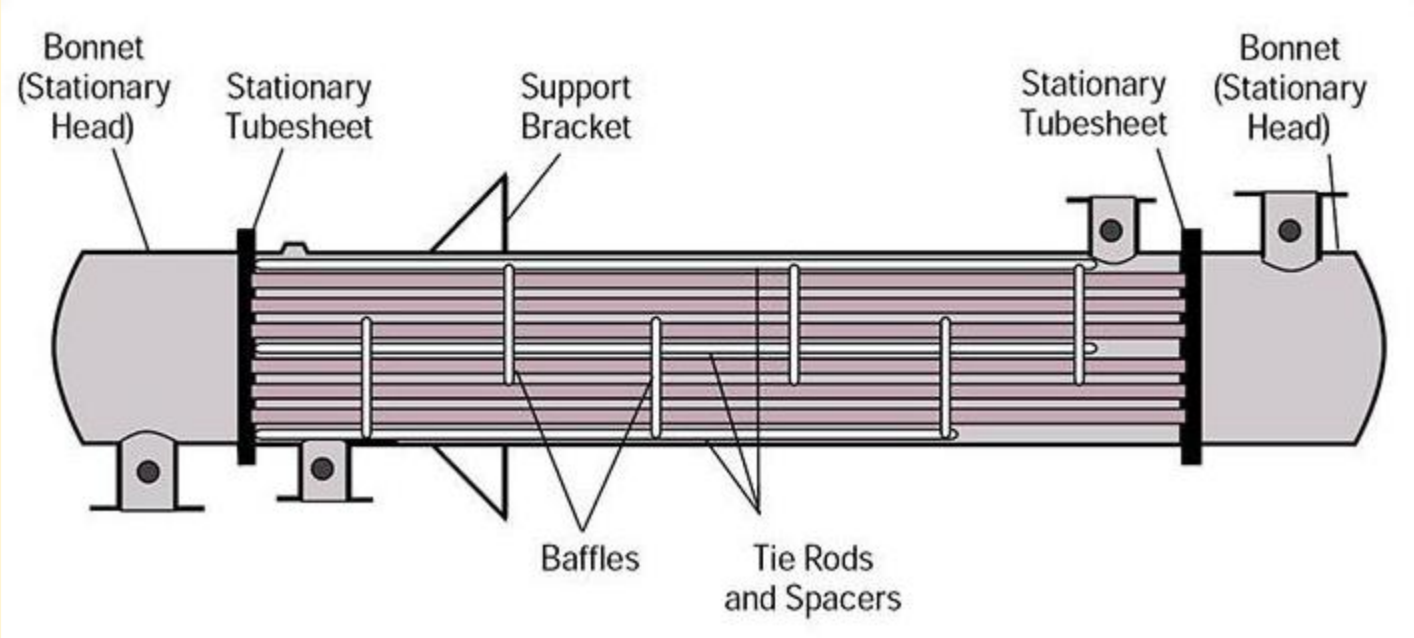
- A shell and tube heat exchanger is the most widely used heat exchange equipment
- This is an extension of the double pipe exchanger where the single inner tube is replaced by a large number of tubes fixed into a tube sheet
- The outer pipe of the double pipe exchanger is replaced by a shell which covers all the inner tubes
- One fluid flow through the inner tubes while the other through the shell
- Use of a large number of tubes greatly enhances the heat transfer area

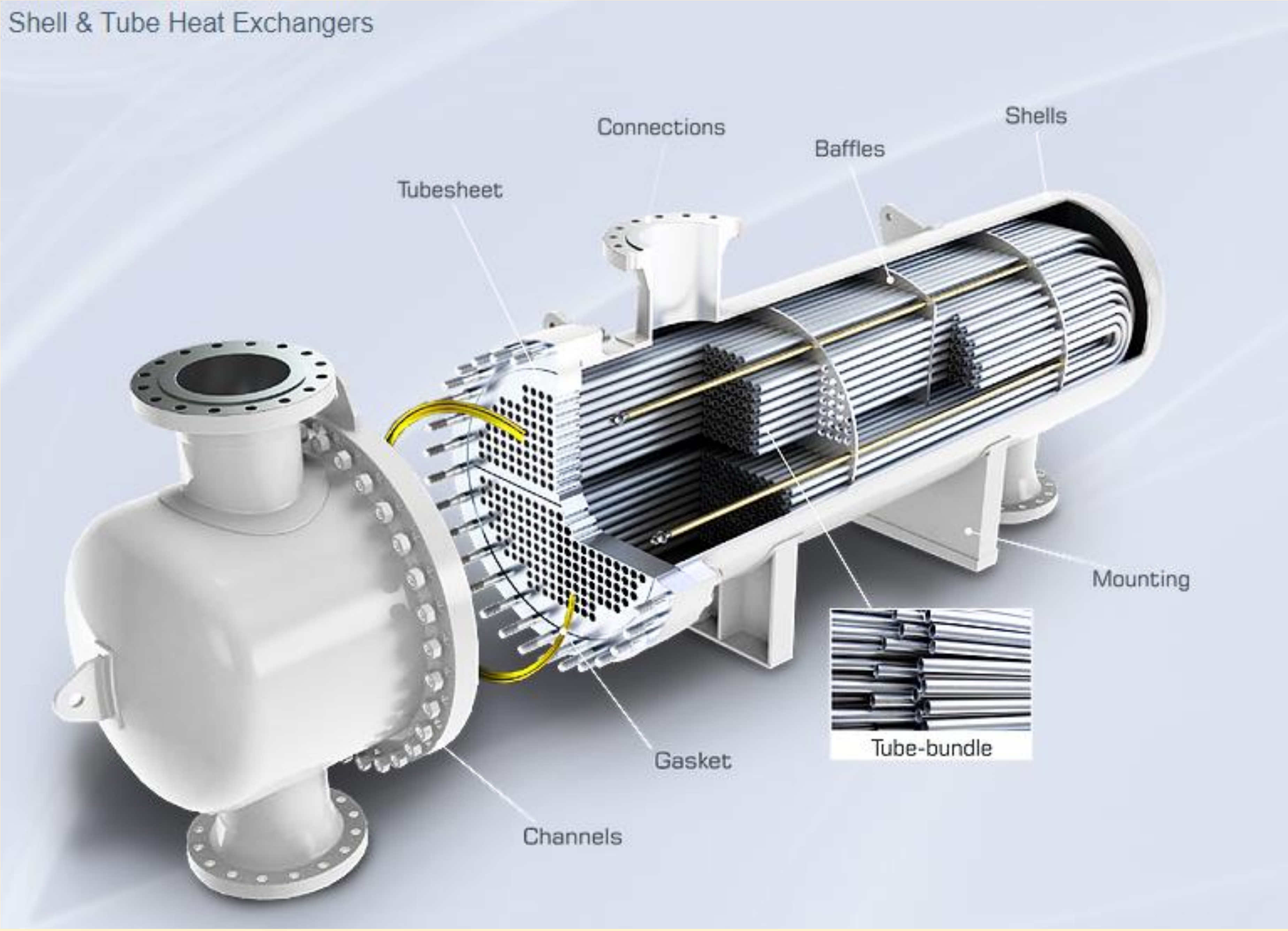


The basic structure of the shell and tube heat exchanger is shown here

This is a 1-1 pass shell and tube heat exchanger

- The exchanger consists of a shell to which the tube sheets are welded, one at each end
- The heat exchanger tubes are fixed to the tube sheets by either expanding a tube or by attaching them by ferrules
- The channels are attached to the two ends along with the channel covers/ headers by flanges
- The nozzles on the tube and shell sides are present for the inlet and outlet of the two fluids
- The baffles are present inside the shell in order to increase the turbulence of the shell side fluid – this helps in improving the heat transfer coefficient
- The shell side fluid flows at right angles to the axis of the tubes due to the presence of these baffles
- Baffle spacers/tie rods are used to maintain the baffles in position




Shell & Tube Heat Exchangers
Connections
Shells
Baffles
Tubesheet
Mounting
Tube-bundle
Gasket
Channels

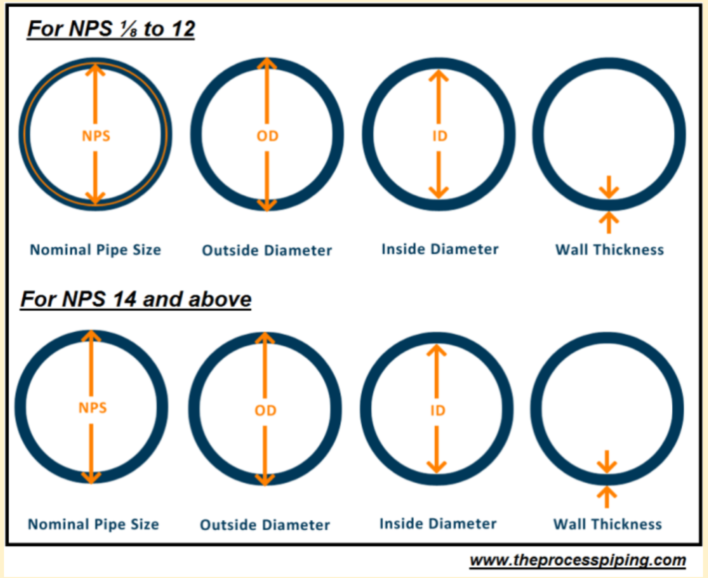
Shell

- The shell is the enclosure through which the shell side fluid flows
- It has a circular cross-section and is constructed either *from a pipe* (up to 24 inches) or *rolled and welded plate metal*
- For shells above 24 inch diameter, a metal sheet of suitable dimension is rolled into a cylinder and welded along the length
- Sections of pipe of suitable thickness is used as a shell for diameters up to 24 inches – for diameter up to 12 inch steel pipes with nominal IPS are used, for diameters above 12 inch and up to 24 inch, the nominal diameter is the is the actual outside diameter
    - Steel pipes are denoted by the IPS (iron pipe size) or NPS (nominal pipe size)
    - Nominal diameter does not correspond to either inner diameter or outer diameter for steel pipes upto 12”
    - For pipes above 12”, the nominal diameter corresponds to the outer diameter
    - If there is a copper pipe denoted by 2” IPS, it means that it is a copper pipe having the same outer diameter as a standard 2” steel pipe
    - The thickness of the pipe can be increased by changing the Schedule No, keeping the outer diameter the same
    - The higher the Schedule No, the thicker is the pipe
- The thickness of the shell depends on the shell-side operating pressure – for operating pressure up to 300 psi (20 atm), shell thickness of 3/8 “ (~ 1 cm) can be used for shells between 12-24”; greater wall thickness is used for higher pressure

- The selection of the material for the shell depends on the corrosiveness of the fluid and the working temperature and pressure with the most common material being low carbon steel

PIPE SCHEDULES & WEIGHTS

NOMINAL PIPE SIZE	OUTSIDE DIAMETER	SCHEDULE 40 Wall Thick.	SCHEDULE 40 Wt. Per Ft.	SCHEDULE 80 Wall Thick.	SCHEDULE 80 Weight Per Ft.
1/8	0.405	0.068	0.245	0.095	0.315
1/4	0.540	0.088	0.425	0.119	0.535
3/8	0.675	0.091	0.568	0.126	0.739
1/2	0.840	0.109	0.851	0.147	1.088
3/4	1.050	0.113	1.131	0.154	1.474
1	1.315	0.133	1.679	0.179	2.172
1-1/4	1.660	0.140	2.273	0.191	2.997
1-1/2	1.900	0.145	2.718	0.200	3.631
2	2.375	0.154	3.653	0.218	5.022
2-1/2	2.875	0.203	5.793	0.275	7.661
3	3.500	0.216	7.576	0.300	10.250
3-1/2	4.000	0.226	9.109	0.318	12.510
4	4.500	0.237	10.790	0.337	14.980
5	5.563	0.258	14.620	0.375	20.780
6	6.625	0.280	18.970	0.432	28.570
8	8.625	0.322	28.550	0.500	43.390
10	10.750	0.365	40.480	0.500	54.740
12	12.750	0.375	49.560	0.500	65.420



Nominal size [inches]	Outside diameter [inches]	Outside diameter [mm]	Wall thickness [inches]	Wall thickness [mm]	Weight [lb/ft]	Weight [kg/m]
1/8	0.405	10.3	0.068	1.73	0.24	0.37
1/4	0.540	13.7	0.088	2.24	0.42	0.84
1/2	0.840	21.3	0.109	2.77	0.85	1.27
3/4	1.050	26.7	0.113	2.87	1.13	1.69
1	1.315	33.4	0.133	3.38	1.68	2.50
1 1/4	1.660	42.2	0.140	3.56	2.27	3.39
1 1/2	1.900	48.3	0.145	3.68	2.72	4.05
2	2.375	60.3	0.154	3.91	3.65	5.44
2 1/2	2.875	73.0	0.203	5.16	5.79	8.63
3	3.500	88.9	0.216	5.49	7.58	11.29
3 1/2	4.000	101.6	0.226	5.74	9.11	13.57
4	4.500	114.3	0.237	6.02	10.79	16.07
5	5.563	141.3	0.258	6.55	14.62	21.77
6	6.625	168.3	0.280	7.11	18.97	28.26
8	8.625	219.1	0.322	8.18	28.55	42.55
10	10.750	273.0	0.365	9.27	40.48	60.31
12	12.750	323.8	0.406	10.31	53.52	79.73
14	14	355.6	0.375	11.13	54.57	94.55
16	16	406.4	0.500	12.70	82.77	123.30
18	18	457.0	0.562	14.27	104.67	155.80
20	20	508.0	0.594	15.09	123.11	183.42
24	24	610.0	0.688	17.48	171.29	255.41
32	32	813.0	0.688	17.48	230.08	342.91

This chart gives dimensional - size data for American National Standard Schedule 40 Welded and Seamless Steel Pipe.

Tubes

- The tubes provide the heat transfer area in the shell and tube heat exchanger - the two fluids are brought in thermal contact through the tube wall
- Heat exchanger tubes may be both seamless and welded
- Heat exchanger tubes are available in a wide variety of materials such as low carbon steel, stainless steel, cupronickel, copper, brass, aluminium etc – the choice of material depends on the fluid used
- Though tubes are available in sizes varying from ¼ "to 1½", the most commonly used tubes are ¾ " (19 mm) and 1" (25 mm)
- Narrower tubes are used for cleaner fluids and to design compact heat exchangers
- BWG (Birmingham Wire Gauge) is used to denote the wall thickness for heat exchangers and condensers tubes
- The outer diameter of heat exchanger tubes is the actual outside diameter in inches within a very strict tolerance
- Tube thickness should be maintained to withstand:

    1) Pressure on the inside and outside of the tube

    2) The temperature on both the sides

    3) Thermal stress due to the differential expansion of the shell and the tube bundle

    4) Corrosive nature of both the shell-side and the tube-side fluid

- The tubes are available in various wall thickness defined by BWG (Birmingham Wire Gauge)

  Eg: ½" OD tube, BWG 12, Wall thickness = 0.109"

  ½" OD tube, BWG 16, Wall thickness = 0.065"

Thickness of wall in Birmingham Wire Gauge (BWG)

OUTSIDE TUBE DIAMETER

B.W.G.	00	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
Wall Thickness	.380	.340	.300	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049	.042	.035	0.32	.028	.025	.022
Inside Tube Diameter																										
1/4"														0.32	.060	.084	.106	.120	.134	.152	.166	.180	.186	.194	.200	.206
3/8"										.045	.079	.107	.135	.157	.185	.209	.231	.245	.259	.277	.291	.305	.311	.319	.335	.331
1/2"						.024	.060	.094	.140	.170	.204	.232	.260	.282	.310	.334	.356	.370	.384	.402	.416	.430	.436	.444	.450	.456
5/8"			.025	.057	.107	.149	.185	.219	.265	.295	.329	.357	.385	.407	.435	.459	.481	.495	.509	.527	.541	.555	.561	.569	.575	.581
3/4"		.070	.150	.182	.232	.274	.310	.344	.390	.420	.454	.482	.510	.532	.560	.584	.606	.620	.634	.652	.666	.680	.686	.694	.700	.706
7/8"	.115	.195	.275	.307	.357	.399	.435	.469	.515	.545	.579	.607	.635	.657	.685	.709	.731	.745	.759	.777	.791	.805	.811	.819	.825	.831
1"	.240	.320	.400	.432	.482	.524	.560	.594	.640	.670	.704	.732	.760	.782	..810	.834.	.856	.870	.884	.902	.916	.930	.936	.944	.950	.956
1-1/4"	.490	.570	.650	.682	.732	.744	.810	.844	.890	.920	.954	.982	1.010	1.032	1.060	1.084	1.106	1.120	1.134	1.152	1.166	1.180	1.186	1.194	1.200	1.206
1-1/2"	.740	.820	.900	.932	.982	1.024	1.060	1.094	1.140	1.170	1.204	1.232	1.260	1.282	1.310	1.334	1.356	1.370	1.384	1.402	1.416	1.430	1.436	1.444	1.450	1.456
1-3/4"	.990	1.070	1.150	1.182	1.232	1.274	1.310	1.344	1.390	1.420	1.454	1.482	1.510	1.532	1.560	1.584	1.606	1.620	1.634	1.652	1.666	1.680	1.686	1.694	1.700	1.706
2"	1.240	1.320	1.400	1.432	1.482	1.524	1.560	1.594	1.640	1.670	1.704	1.732	1.760	1.782	1.810	1.834	1.856	1.870	1.884	1.902	1.916	1.930	1.935	1.944	1.950	1.956
2-1/4"	1.490	1.570	1.650	1.682	1.732	1.774	1.810	1.844	1.890	1.920	1.954	1.982	2.010	2.032	2.060	2.084	2.106	2.120	2.134	2.152						
2-1/2"	1.740	1.820	1.900	1.932	1.982	2.024	2.050	2.094	2.140	2.170	2.204	2.232	2.260	2.282	2.310	2.334	2.356	2.370	2.384	2.402						
2-3/4"	1.990	2.070	2.150	2.182	2.232	2.274	2.310	2.344	2.390	2.420	2.454	2.482	2.510	2.532	2.560	2.584	2.606	2.620	2.634	2.652						
3'	2.240	2.320	2.400	2.432	2.482	2.524	2.560	2.594	2.640	2.670	2.704	2.732	2.760	2.782	2.810	2.834	2.856	2.870	2.884	2.902						
3-1/4"	2.490	2.570	2.650	2.682	2.732	2.774	2.810	2.844	2.890	2.920	2.954	2.982	3.010	3.032	3.060	3.084	3.106	3.120	3.134	3.152						
3-1/2"	2.470	2.820	2.900	2.932	2.982	3.024	3.060	3.094	3.140	3.170	3.204	3.232	3.260	3.282	3.310	3.334	3.356	3.370	3.384	3.402						
3-3/4"	2.990	3.070	3.150	3.182	3.232	3.274	3.310	3.344	3.390	3.420	3.454	3.482	3.510	3.532	3.560	3.584	3.606	3.620	3.634	3.652						
4"	3.240	3.320	3.400	3.432	3.482	3.524	3.560	3.594	3.640	3.670	3.704	3.732	3.760	3.782	3.810	3.834	3.856	3.870	3.884	3.902						
4-1/4"	3.490	3.570	3.650	3.682	3.732	3.744	3.810	3.844	3.890	3.920	3.954	3.982	.4.010	4.032	4.060	4.084	4.106	4.120	4.134	4.152						
4-1/2"	3.740	3.820	3.900	3.932	3.982	4.024	4.060	4.094	4.140	4.170	4.204	4.232	4.260	4.282	4.310	4.344	4.356	4.370	4.384	4.402						

- The length of the tube is chosen based on the heat load and the space available for installation
- Tube lengths of 6, 8, 12, 16, 20, and 24 feet are commonly used
- Longer tube reduces shell diameter at the expense of higher shell pressure drop
- Use of smaller diameter tubes and longer tubes makes the exchanger compact and therefore cheaper
- Tubes of larger diameter are sometimes used either to facilitate mechanical cleaning or to achieve lower pressure drop
- Larger diameter tubes are selected for heavily fouling fluids
- A maximum number of tubes in the shell increase turbulence, which increases the heat transfer rate
- The optimum *tube length to shell diameter* usually fall in the range of *5 to 10*

- Finned tubes are also used when fluid with low heat transfer coefficient flows in the shell side - fin efficiency up to 90% may be attained