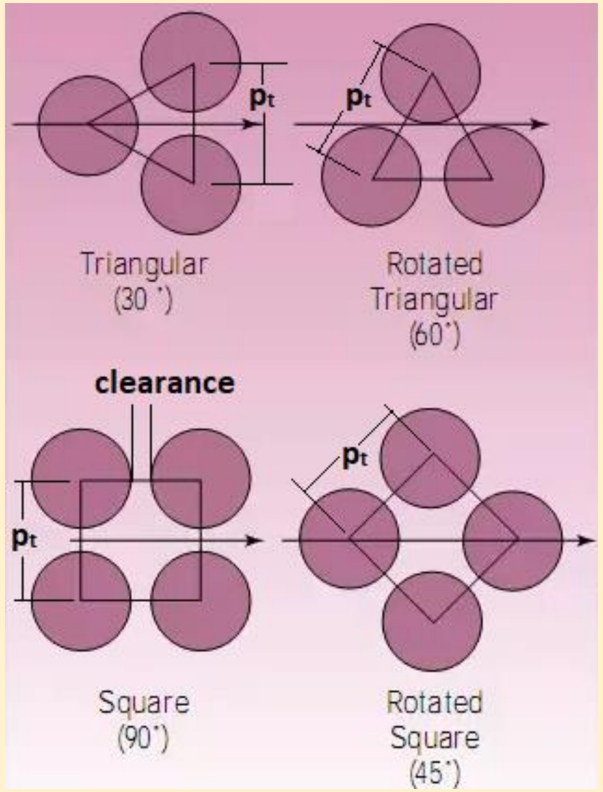
Heat Exchangers

Tube pitch

- Tube holes cannot be drilled very close together in tube sheets as it would make the tube sheet structurally weak
- The shortest distance between two adjacent tube holes is caused the *clearance*
- The shortest centre-to-centre distance between adjacent tubes is known as *tube pitch* (p_t)
- The tubes are usually arranged in a *triangular* or *square* pitch
- The tube pitch should not be less than 1.25 times the tube diameter
- Common pitch for different layouts (tube arrangements) are:

Square pitch: for ¾ " OD tube, pitch is 1"
for 1" OD tube, pitch is 1¼"

Triangular pitch: for ¾ " OD tube, pitch is 15/16 "
for 1" OD tube, pitch is 1¼ "



- A larger number of tubes in the shell increases turbulence, which increases the heat transfer rate
- The optimum *tube length to shell diameter* usually fall in the range of *5 to 10*
- For triangular and rotated triangular pitch, there is a higher heat transfer rate but at the expense of higher pressure drop
- A square or rotated square arrangement is used for heavily fouling (dirty) fluids, as this arrangement allows easier cleaning of the outer surface by brushes and also has lower pressure drop

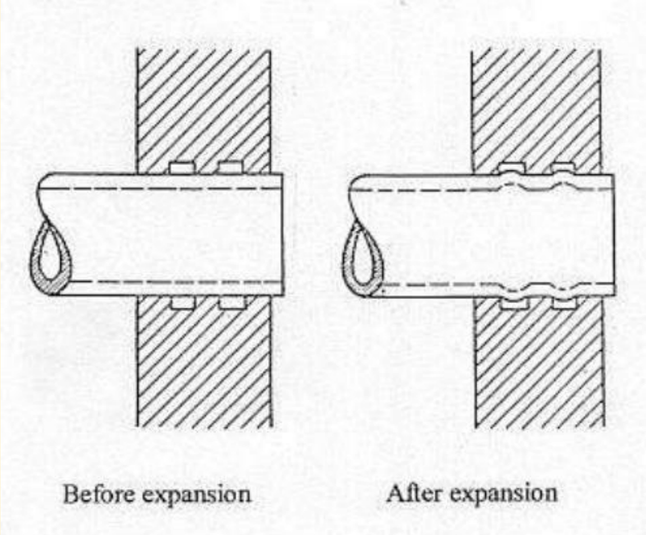

Square pitch


Triangular pitch

Tube sheet

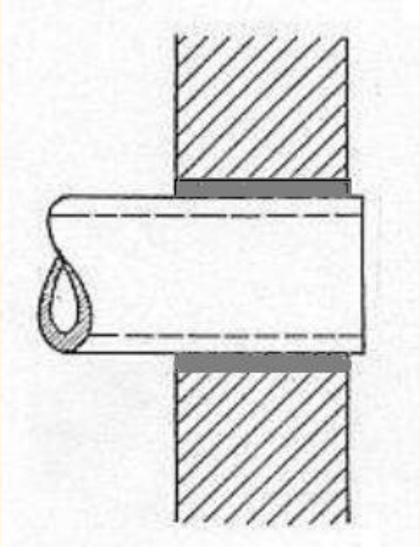
- Tube sheets are circular, thick metal plates which hold the tubes at the ends
- In the simplest case of the fixed tube heat exchanger, the tube sheet is welded to the shell
- The tube sheet keeps the tubes arranged in a regular manner inside the shell
- The tubes are inserted into the holes two tube sheets – perfect alignment of the holes is required
- The tube holes are usually drilled through the sheets fastened together

- The diameter of the tube holes is usually slightly larger than the outer diameter of the tubes
- The ends of the tube are fixed to the tube sheets by either an (i) *expanded joint* or a (ii) *welded joint*
- The *expanded joint* may be a (a) grooved or a (b) non-grooved one
  - In a grooved joint, small grooves are cut in the tube sheet along the periphery of each hole
  - The tube is introduced into the hole and special tools such as a mandrel is rotated at high speed inside the tube
  - The rollers press against the wall of the tube and the metal expands and crosses the elastic limit to fill the grooves
  - Grooved expansion joints form a strong and durable joint

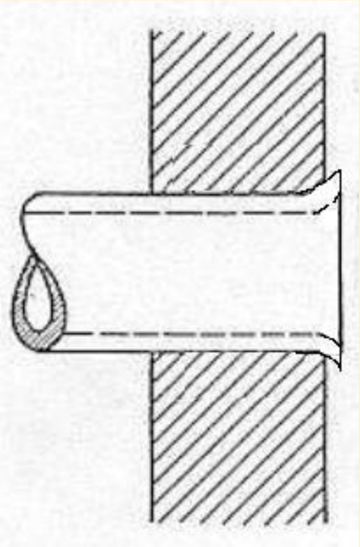


(a) Expanded

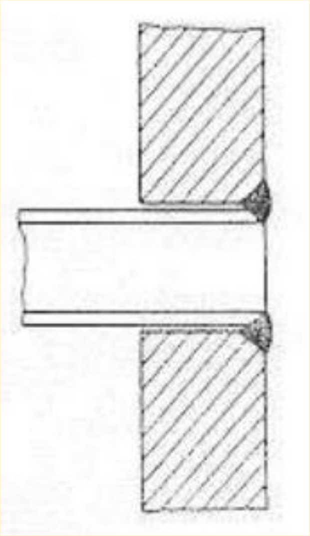
- In a non-grooved joint such as a plain joint (shown in the figure), the tube is expanded to fill the clearance between the tube and the hole in the tube sheet
- Such joints may be used for small fluid pressure differentials or low thermal stress
- Belled or beaded joint is the third type of expansion joint
- If a welded joint is used , the tubes or tube sheets should be of same or very similar material
- This provides a leak proof joint but is more expensive due to cost of welding and wider tube spacing



Plain joint



Belled or beaded joint

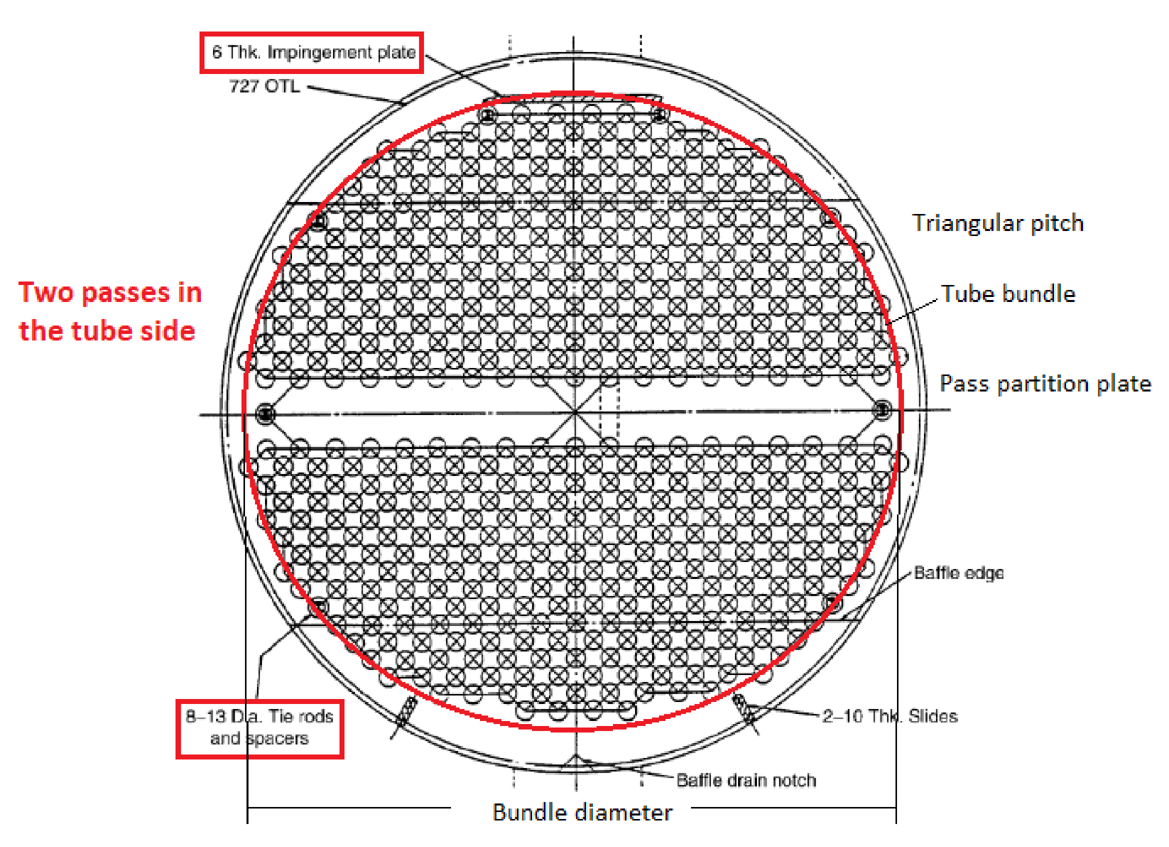


Welded joint

- Tube sheet thickness should not be less than the tube outer diameter, up to about 1” (25 mm) diameter – this is to allow sufficient thickness to seal the tubes
- The thickness of the tube sheet reduces the effective length of the tube slightly (as the two ends of the tube are fixed inside the tube sheet
- The reduced length is used to calculate the heat transfer area

- The tube sheet forms a barrier between the shell and tube fluids - for process and safety reasons it is essential that there is no mixing between the fluids due to leakage at the tube sheet joint
- For this double sheets are sometimes used with the space between them vented

- The arrangement of tubes on a tube sheet in a suitable pitch is called the *tube sheet layout*
- The tube layout is normally planned with the help of a computer program which will allow for spaces for other exchanger internals such as pass partition plates, tie rods, clearance near inlet and outlet nozzles etc
- The cluster of tubes so fixed to the tube sheets is called the *tube bundle*
- The *bundle diameter* is calculated based on the number of tubes, tube outer diameter, number of passes, tube arrangement and pitch

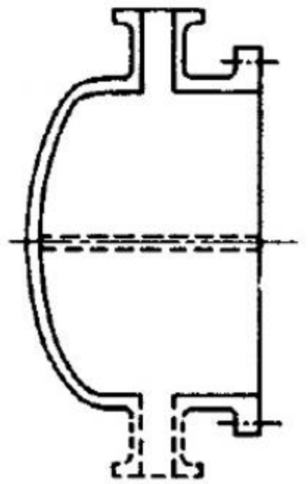


Channel or Bonnet (Tube sheet closure)

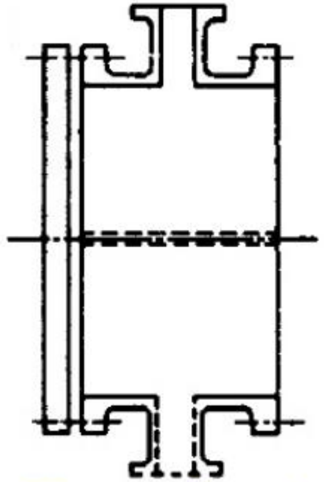
- The tube sheets at the two ends of the exchanger has a closure (cover) or head
- The space inside the closure is occupied by a tube – side fluid
- Depending on its shape and construction, a closure is either called a *bonnet* or *channel*

- A *bonnet* is an integral cover and consists of a short cylindrical section welded at one end and a flange welded at the other end
- The flange is bolted to the tube sheet after inserting a suitable gasket to make the joint leak proof
- Usually used when the tube side fluid is relatively cleaner

- A *channel type closure* has a removable cover and has a piece of cylindrical barrel with flanges bolted at both ends
- One of the flanges is bolted to the tube sheet using a gasket for sealing, and the other flange is bolted to a flat channel cover plate (like a blind flange)
- The channel cover can be unbolted to have access to the tubes
- Often used in case of dirty tube side fluid, as it has better access for cleaning

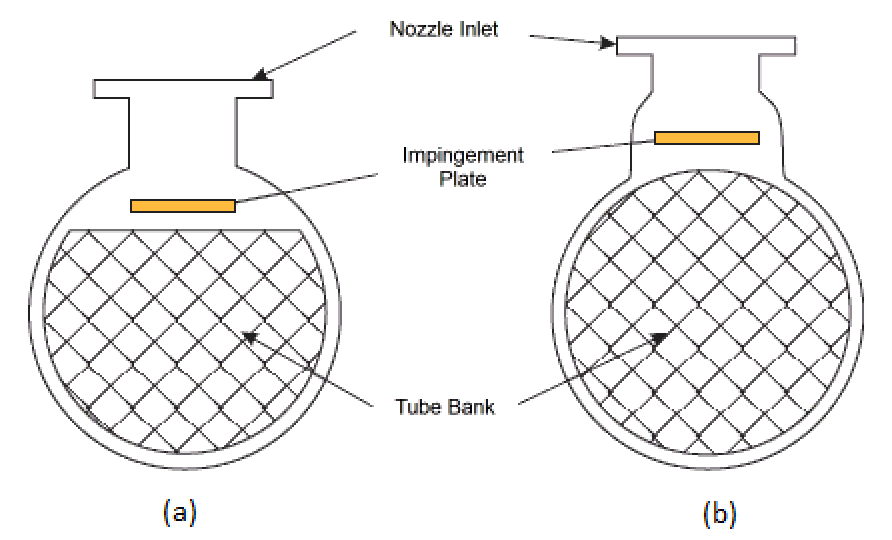


Bonnet (integral cover)

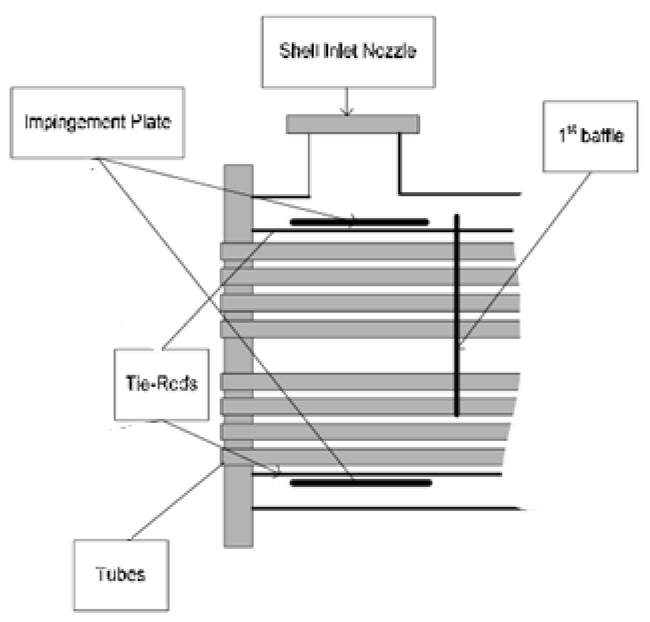


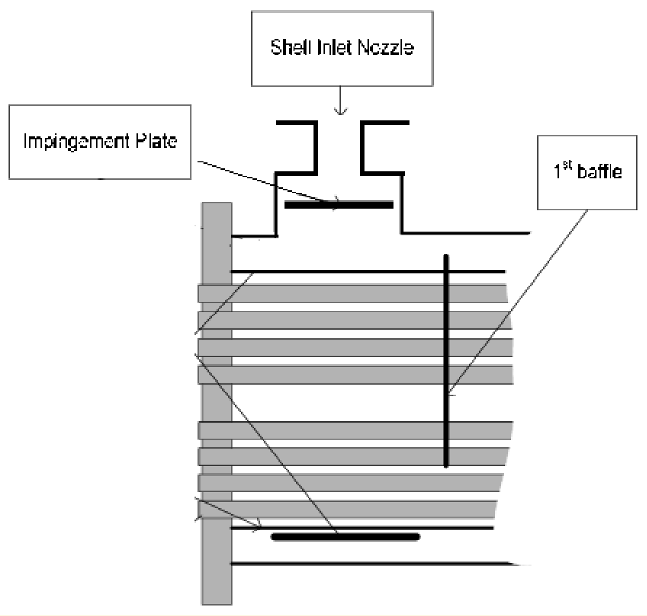
Channel and removable cover

Nozzles



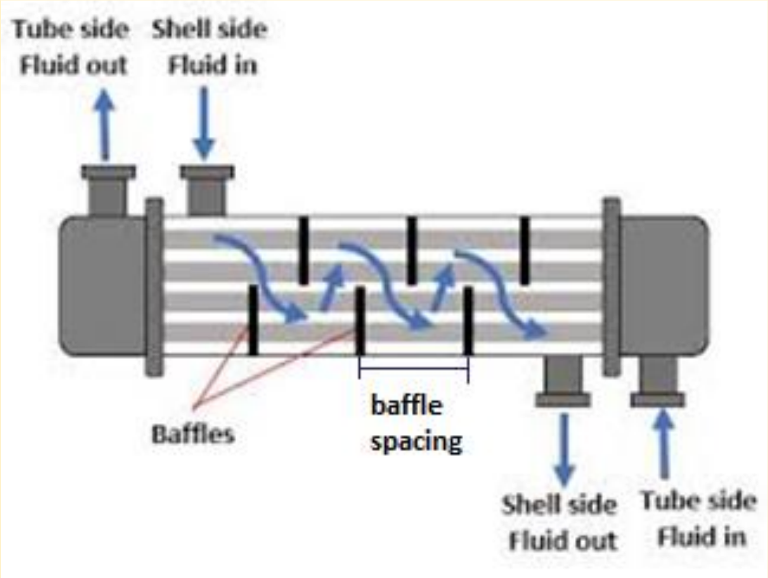
- Small sections of pipes of standard sizes are used for inlet and outlet nozzles
- They are welded to the sheet or to the channel
- Flow restrictions in the inlet and the outlet nozzles lead to excessive pressure drop and flow induced vibrations of the tube
- Some of the tube rows are omitted and the baffle spacings are increased in the baffle zone to increase the flow area
- The shell side inlet nozzle is often provided with an *impingement plate*
- This prevents the impact of the high velocity inlet fluid stream on the tube bundle
- Such impact leads to erosion and cavitation of the tubes just in front of the nozzle and can cause vibrations
- This is enhanced if the liquid or vapour streams has suspended solid and liquid droplets present in it
- The impingement plate may be fitted in the shell just (a) in front of the nozzle, or (b) inside the expanded end of a nozzle





Baffles

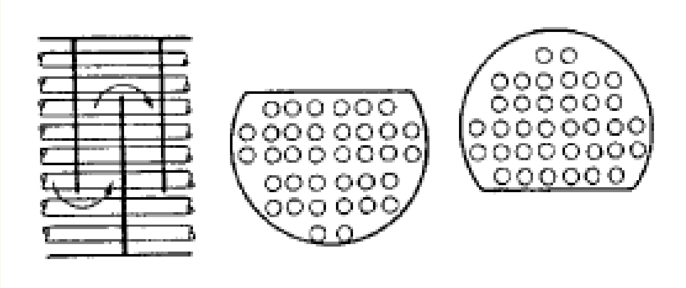
- When the liquid (fluid) in the shell side of the heat exchanger is in a state of turbulence, the heat transfer coefficient is higher and so is the rate of heat transfer
- A *baffle* is a metal plate usually in the form of a segment of a circle having holes to accommodate tubes
- Baffles are used to direct the fluid stream so that the flow pattern of the shell fluid alters between parallel and cross flow to the tube bundle
- This increases turbulence and therefore heat transfer coefficient
- Baffles are also used to support the fluid filled tubes attached to the tube sheets at the ends



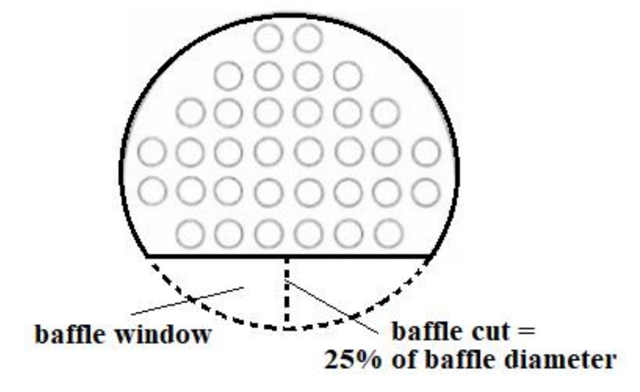
- The centre to centre distance between baffles is called the *baffle pitch* or *baffle spacing*
- A smaller baffle spacing increases turbulence, heat transfer coefficient but also pressure drop
- A baffle spacing is chosen based on the allowable shell-side pressure drop and the heat transfer coefficient desired
- The baffle spacing is usually not greater than the distance equal to shell diameter
- The minimum spacing is one-fifth of shell diameter or 5 cm which ever is larger. Optimum spacing is 0.3-0.5 times shell diameter
- The baffles are held in place by means of *baffle spacers*

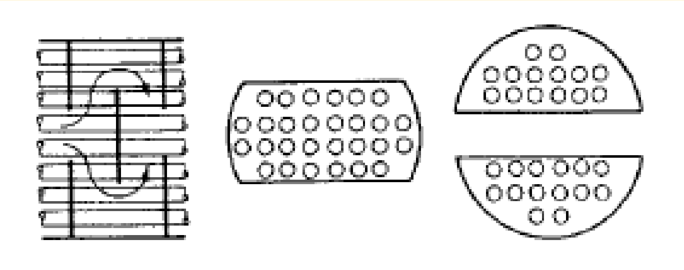
Baffles

- The most popular type of baffle is the ***segmental baffle***
- The segmental baffle may have horizontal or vertical cuts – the cut-out portion is known as the baffle window which provides the area for the flow of shell fluid
- Segmental baffles are usually denoted by their *baffle cut*
- Baffle cut is used to specify the height of the segment removed to form the baffle expressed as a percentage of the baffle diameter
- Baffle cuts from 15% to 45% are used with 20-25% baffle cuts being optimum

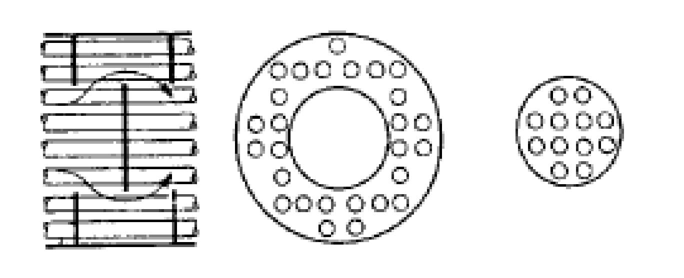


segmental baffle

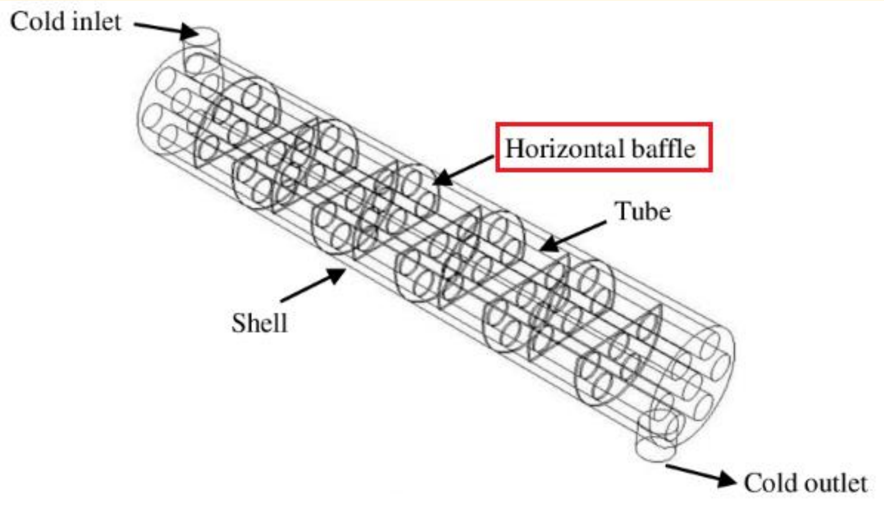


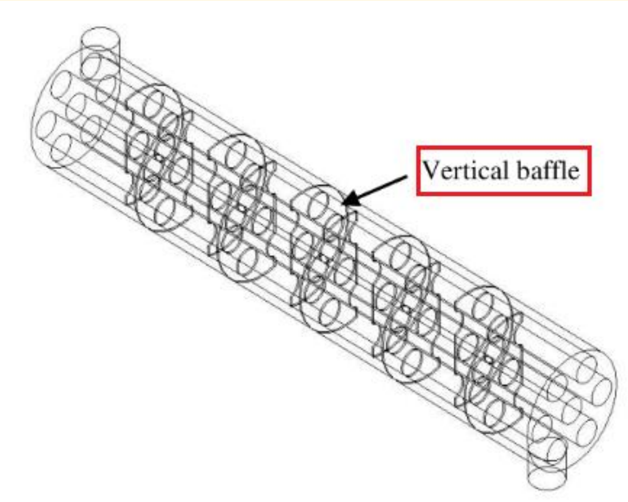


segmental and strip baffle



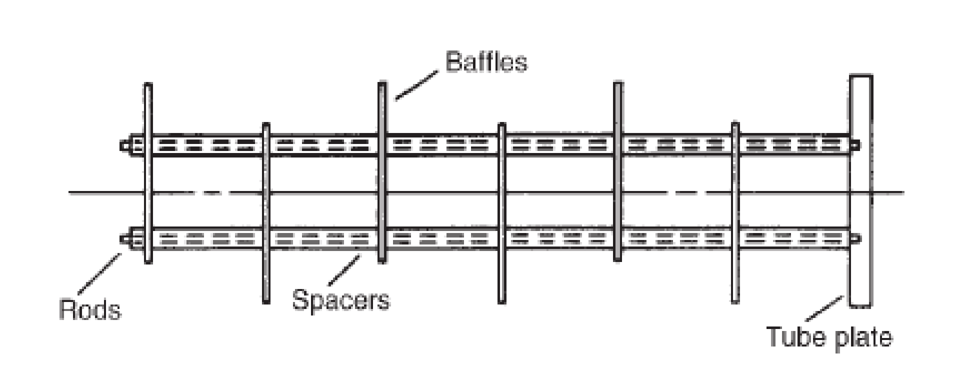
disc and doughnut baffle





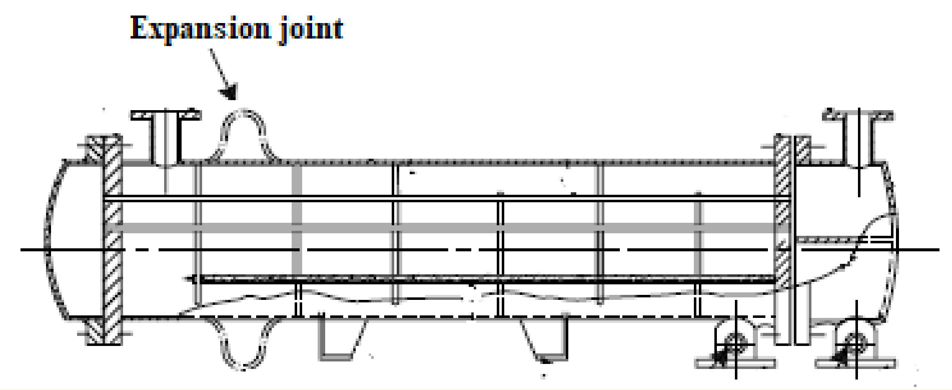
Tie Rods and Baffle Spacers

- Tie rods and baffle spacers are used to maintain the baffles in position inside the shell
- One end of a tie rod is screwed to a tube sheet
- A section of a pipe with an inner diameter slightly larger than the diameter of the tie rod is slid over it
- A baffle is then inserted followed by another section of the pipe
- These pipe sections are called baffle spacers and are used to maintain the distance between the successive baffles
- After the last baffle is inserted, lock nuts are tightened at the threaded free end of the rod



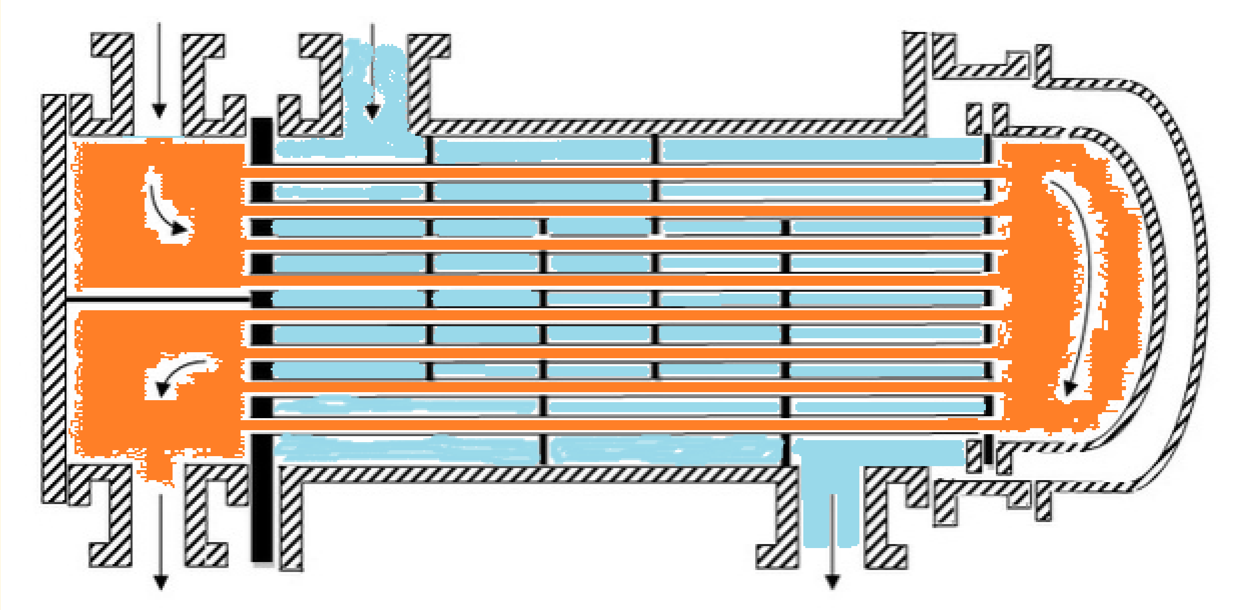
Shell expansion joint

- If there is a substantial difference in the temperature between the two fluid streams, there might be a significant difference of expansion between the shell and the tubes
- This may cause thermal stress and damage the exchanger
- An expansion joint is attached to the shell and it acts as an expansion bellow



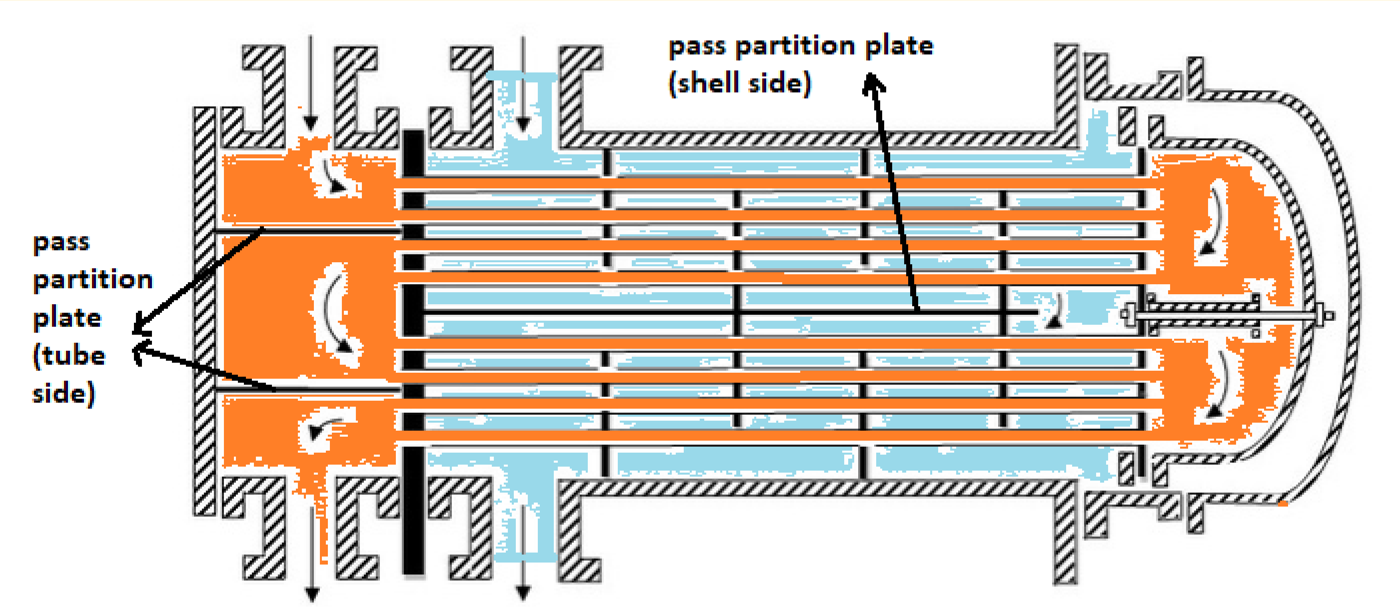
Multi-pass exchangers

- When the fluids in a heat exchanger pass each other more than once, the exchanger is called a *multi-pass exchanger*
- The *heat transfer coefficients* in the tube and shell side are a function of *Reynolds Number* (*Re*) and *Prandtl Number* (*Pr*)
- The physical properties of the fluids cannot be changed, so a convenient way of increasing heat transfer coefficient (*h*) is to increase the fluid velocity
- This can be done by providing a *partition (pass partition plate)* in the tube side or shell side so the entire fluid passes through half the tubes in one pass and then turns back to pass through the other half of the tubes in the second pass
- As the *fluid passes through only half of the tubes, the area is halved and the velocity is doubled*
- This increases the *Re*(doubled) and hence increases turbulence – which results in an increase in *Nu* and finally the heat transfer coefficient
- ***The primary reason for using a multi-pass exchanger is to increase the average fluid velocity of the tube side or the shell side***
- By convention, the number of shell side passes is always listed first (eg., 1 shell side pass – 2 tube side pass is denoted as 1:2)



1:2 pass shell and tube heat exchanger

- Enhancing the fluid velocity, however, has a negative effect on pressure drop, which also increases
- The number of passes are decided based on both the heat transfer coefficient and the allowable pressure drop
- The *pass partition plate* is used to divide the tube side or the shell side so that there are multiple passes of the fluid in either side
- In case of the tube side pass partition plate, one edge of the plate is welded to the bonnet (or channel cover) and the other edge presses against a gasket in a groove made on the tube sheet



2:4 pass shell and tube heat exchanger

- For a given number of tubes, the area available for flow of the tube side fluid is inversely proportional to the number of passes
- An even number of passes on any side is usually used (for eg., 1-2, 1-4, 2-4, 2-6 etc)
- For the shell side partition plate, a plate usually 6-13 mm thick runs axially along the shell to divide it into two semi-cylindrical halves
- The plate is either welded to the shell or fitted into ‘guide channels’ welded longitudinally along the shell wall