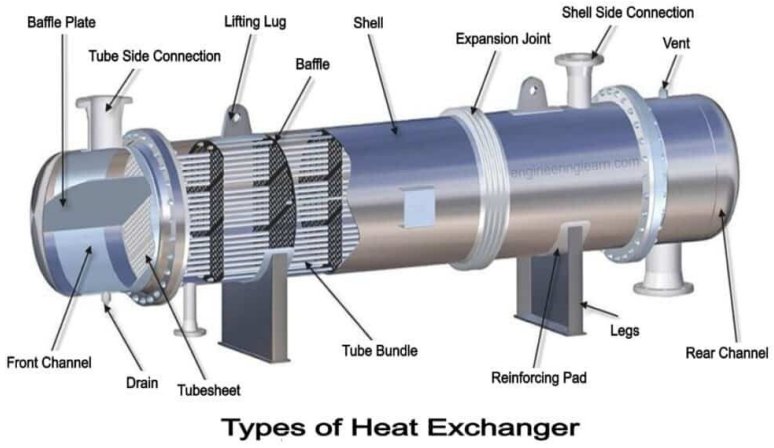
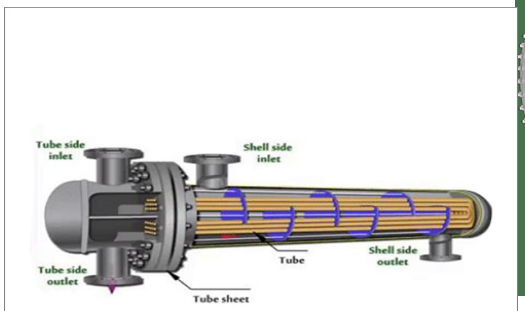
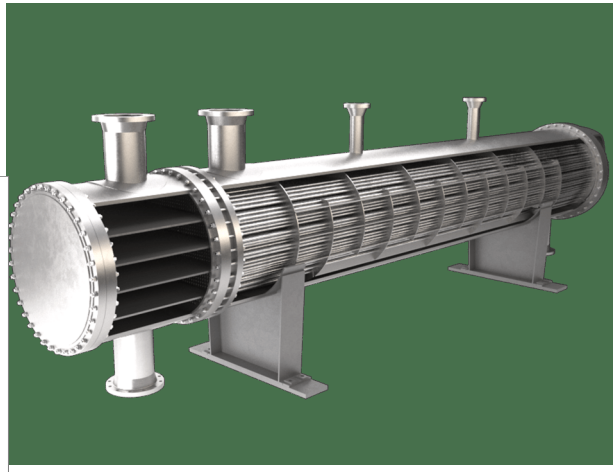
INSPECTION OF HEAT EXCHANGERS - A COMPLETE GUIDE

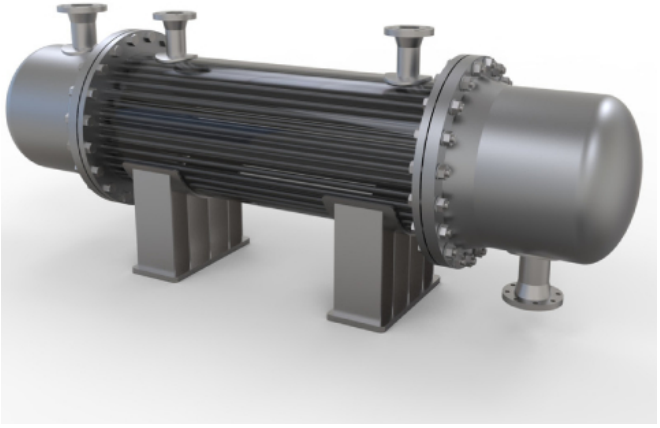


Types of Heat Exchanger





INSPECTION OF HEAT EXCHANGER DURING MANUFACTURING



HEAT EXCHANGERS

- When you deal with inspection of the heat exchangers, there are atleast two aspects.
- **By user**, wherein , he checks during shut down for damages, gasket condition ,clogging and chemical attacks.
- **By manufacturer**, wherein he carries out quality check in every component involved in manufacture.

HEAT EXCHANGERS

- We will be dealing with inspection during manufacture of the exchanger.
- Before that , let us list out various components of the heat exchanger.

HEAT EXCHANGERS

Various components of the heat exchangers.

- Main shell
- Channel shell/ bonnets
- Main cover shell
- Floating heads
- Tube sheets
- Tubes
- Bellows
- Baffles
- Support plates
- Tie rods

HEAT EXCHANGERS

-Deflector strips

-Sliding strips

-Spacers

-Impingement plates

- Jack bolts,
- Dowel pins
- Pulling Eye bolts
- Pulling eye bolt plugs
- Tie rod nuts

HEAT EXCHANGERS

To get a perfect heat exchanger all the above components need to be manufactured with good precaution and inspected for

1) Correct dimension .
2) Correct workmanship and finish.
3) Usage of correct material.

HEAT EXCHANGERS

We will not be dealing with the basics of inspection as it is expected that every organization has their own system, tooling, dimension control and inspection control points. What will be discussed is the minimum inspection requirements along with critical points which are generally overlooked.

HEAT EXCHANGERS

- Out of list of components ,we will be dealing with following components.
- Shells,
- Channels/Bonnets.
- Tube sheets.
- Baffles.
- Tubes.

HEAT EXCHANGERS

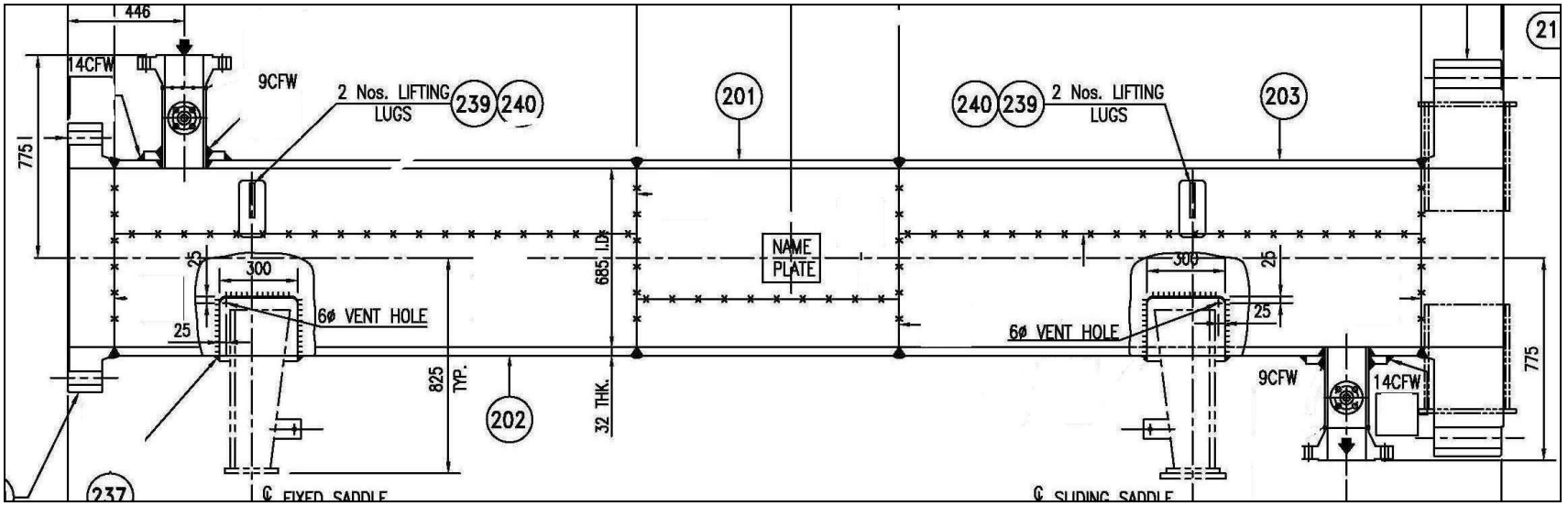
- Bellows.
- Spacers and tie rods.
- Tube bundle skeleton.
- Completed tube bundle.
- Tube to Tube sheet joints.
- Testing of heat exchangers.

HEAT EXCHANGERS

SHELLS

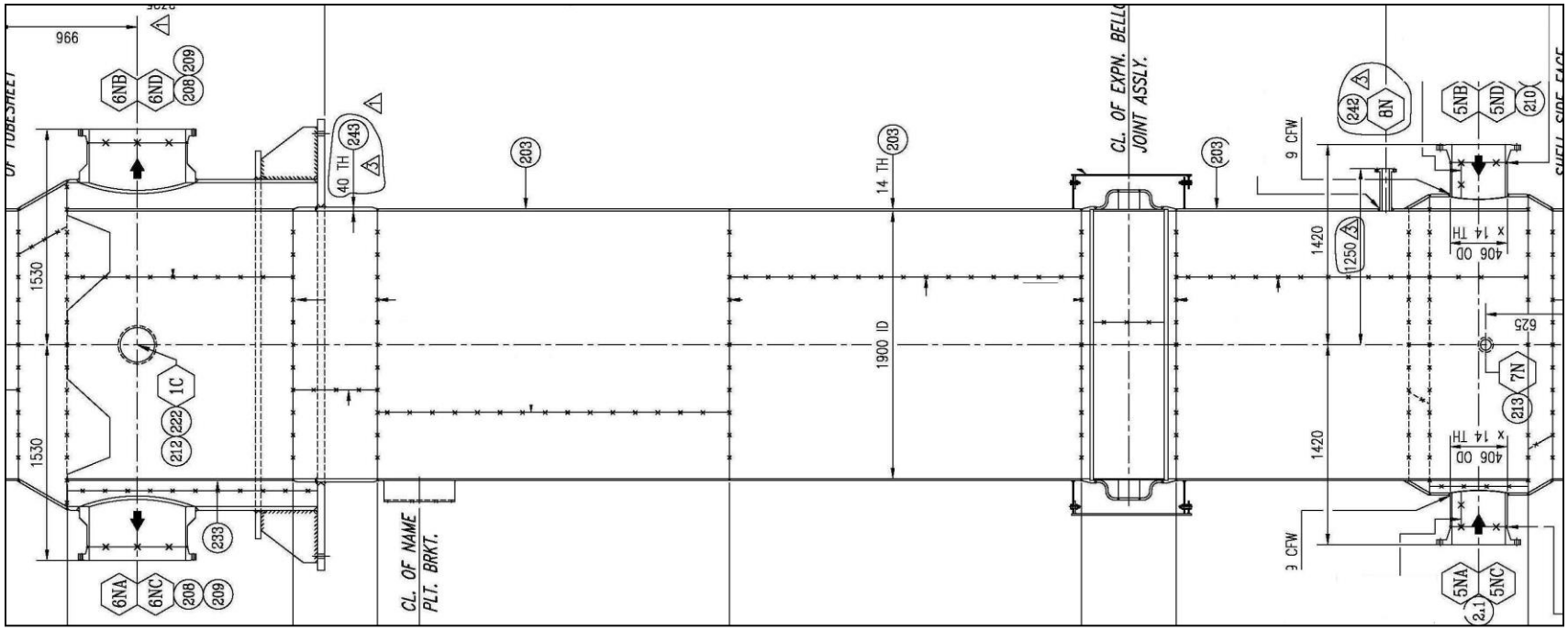
HEAT EXCHANGERS

- A simple shell with thick girth flange.



HEAT EXCHANGERS

- A typical sketch of a main shell with expansion bellow



HEAT EXCHANGERS

- Main shells
- These are designed and fabricated as per the pressure vessel design code .
- Shell is made as circular as possible controlling the ovality to less than 0.5%.
- Diameter of the main shell is generally kept on the plus side, but precaution has to be taken to ensure no excess gap around baffles, than permitted by TEMA.

HEAT EXCHANGERS

- Visual inspection of the internal of the shell should not reveal under flush welds, local depressions.
- Visual inspection need to be carried out twice, once before piston insertion and second after piston insertion .
- All NDT should have been cleared before bundle insertion. .
- Gasket face of the girth flanges should have correct finish and should be parallel to each other. This has to be ensured by measuring face to face dimension , at setup stage, after final welding and after PWHT.

HEAT EXCHANGERS

- Girth flange gasket faces should not have any distortion ,warping and the plane of the gasket face and flange as whole should be square with the central axis of the shell.
- Perfect planning should be done while procuring girth flange with additional thickness for future machining if need be, distortion control while welding and PWHT has to be ensured .
- If care is not executed properly , there can be fouling problem and girth flange over stressing problem during hydro test.

HEAT EXCHANGERS

- Channel shells / Bonnets.

The same care which is taken during the shell manufacture is to be taken in the case of channels also.

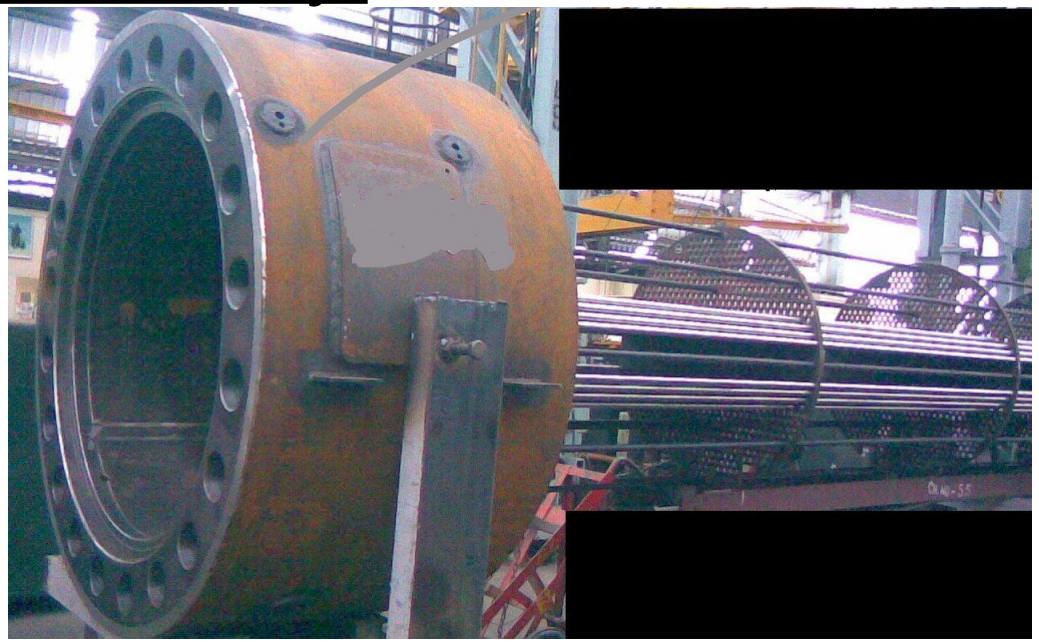
Care is taken especially during fit up of Girth flanges and dish ends. It has to be ensured that the total depth of the channel is maintained as required.

HEAT EXCHANGERS

CHANNELS / BONNETS

HEAT EXCHANGERS

- Tube bundle with integrated channel and tube sheet assembly.



HEAT EXCHANGERS

Another important aspect is partition plates.

-Partition plates are generally kept about 0.5 mm below the girth flange gasket face levels. The purpose is to ensure full mating of the girth flange gasket without any fouling .

HEAT EXCHANGERS

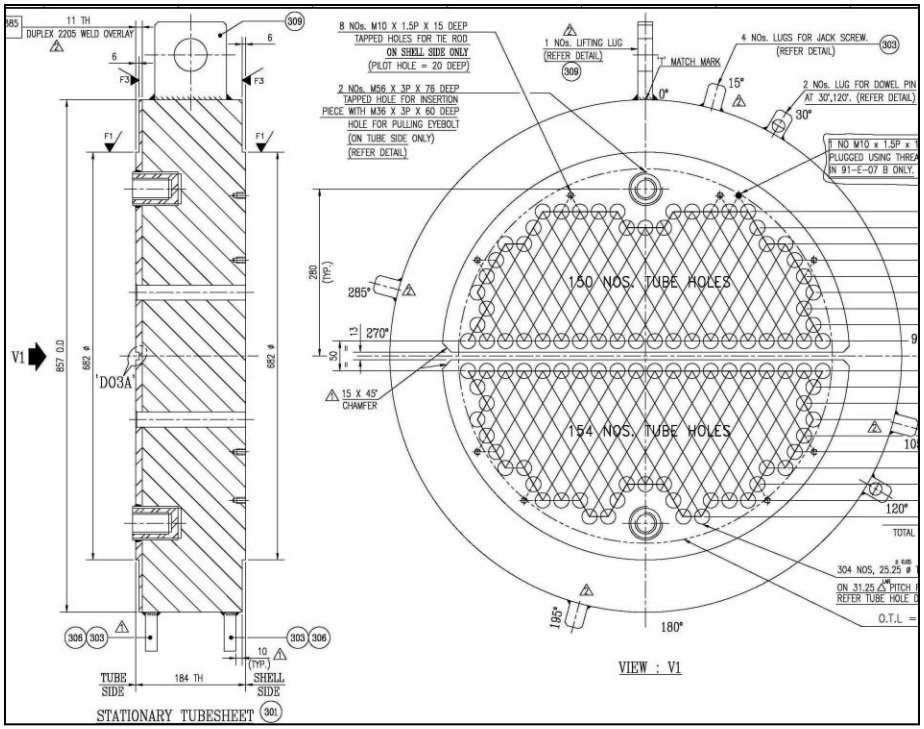
- Fillet welding of partition plates to channel ends at the open end of the partition plate near the girth flange . If left as it is the exposed end will show a small linear opening between partition plate and channel shell inside wall .This spot will be a cause of corrosion

- As a corrective measure a small groove is made on both open ends of the partition plates filled up with welding and ground smooth.

TUBE SHEETS

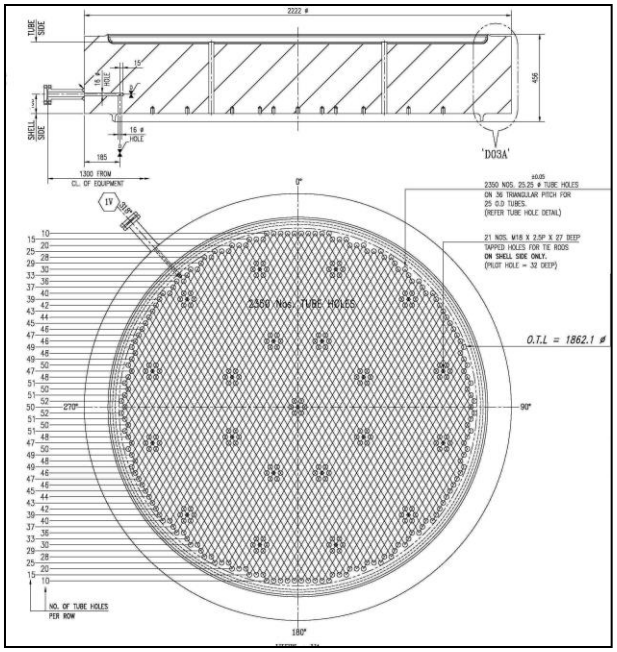
HEAT EXCHANGERS

- A typical stationary tube sheet



HEAT EXCHANGERS

- Typical tube sheet to be welded to channel.



HEAT EXCHANGERS

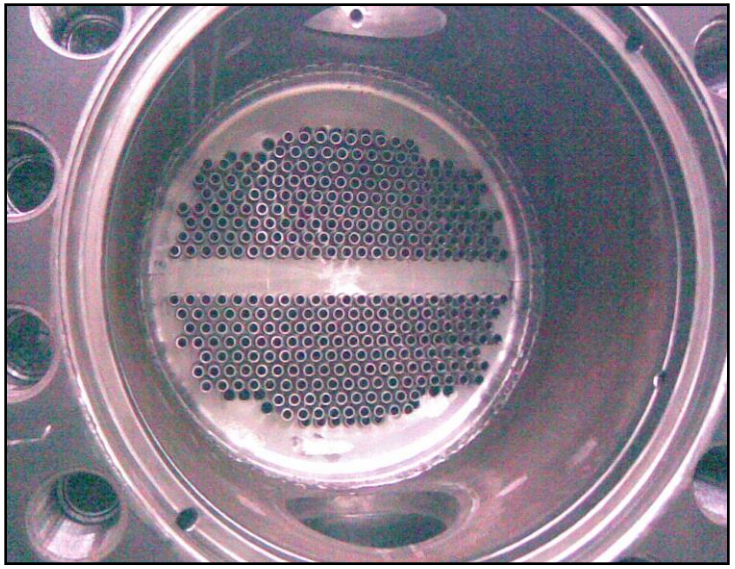
- Tube sheets

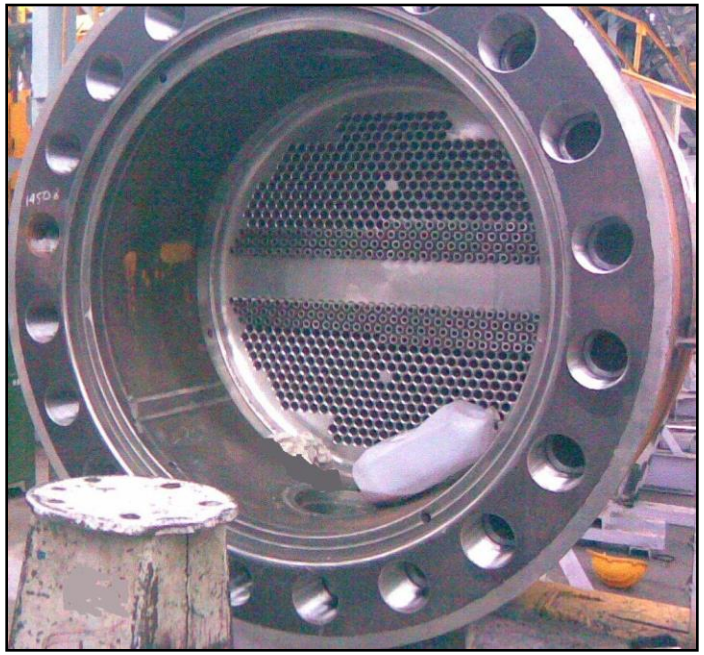
  Tube sheets are best inspected by holding it against natural light.

  This way it is very convenient have a look all around for any damages and also to verify the layout and hole finish.

HEAT EXCHANGERS

- A typical drum tube sheet





HEAT EXCHANGERS

The following points need to be looked into as a minimum

- Tube hole layout.
- Number and pitch of tube holes.
- Outer tangent line.
- Inner tangent line.

HEAT EXCHANGERS

- Hole finish.
- Hole size.
- Expansion groove pitch and dimension.
- Expansion groove finish.
- Ligaments
- Tie rod hole location.
- Tie rod hole depth.

HEAT EXCHANGERS

- Partition groove location.
- Partition groove finish.
- Partition groove dimension.
- Gasket face finish.
- Total thickness.
- Location and dimensions of dowel pin and jack bolt holes.
- Diameters and depth of various steps.

HEAT EXCHANGERS

- Ligaments can be best checked by locking the vernier to(min std ligament + 0.5mm) and using the same as a no go gauge.
- Actual dimension of the ligament is immaterial as long as the vernier does not slide into the ligament.
- Emphasis should be given for finding over sized holes with a NO GO Gauge.

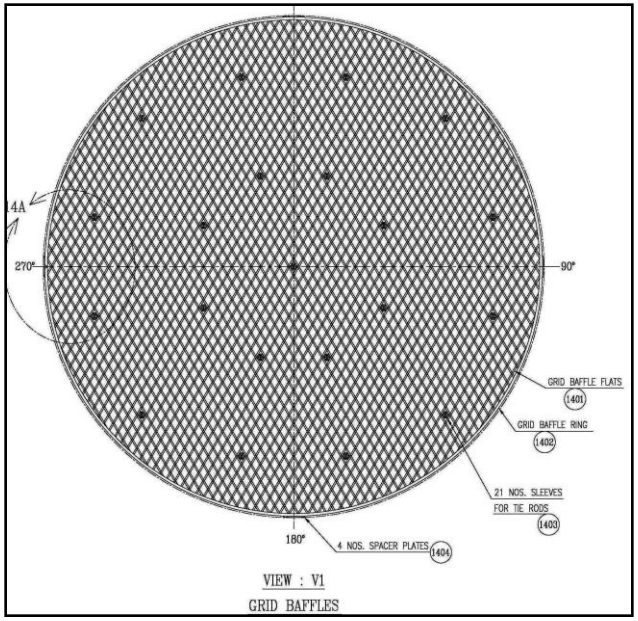
HEAT EXCHANGERS

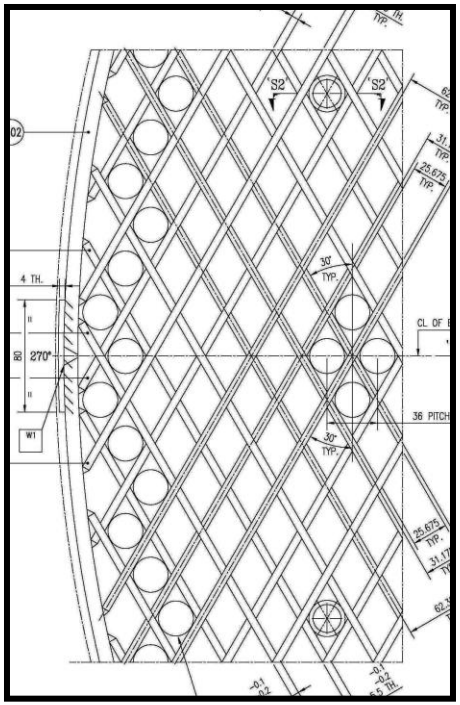
- Partition groove to gasket face junction should be checked for manufacturing damages.
- If the tube sheet is clad , then copper sulphate / feroxyl check has to be carried out on the periphery to ascertain the availability of cladding.

BAFFLES

HEAT EXCHANGERS

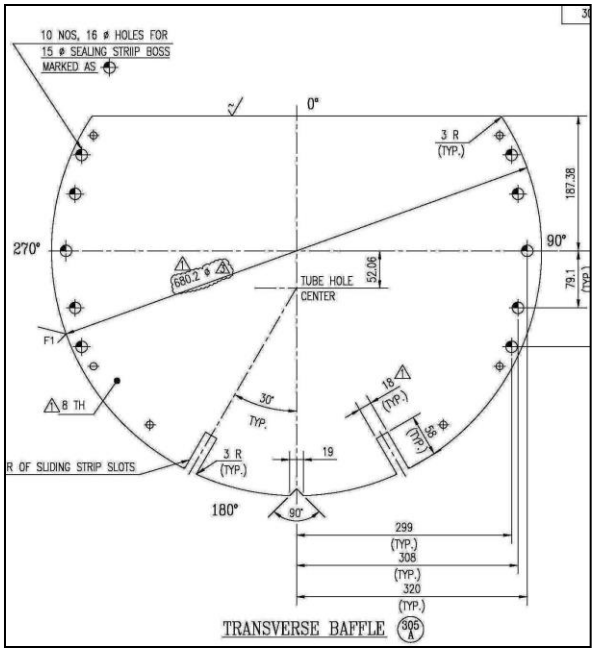
- GRID BAFFLES





HEAT EXCHANGERS

- CONVENTIONAL BAFFLES.

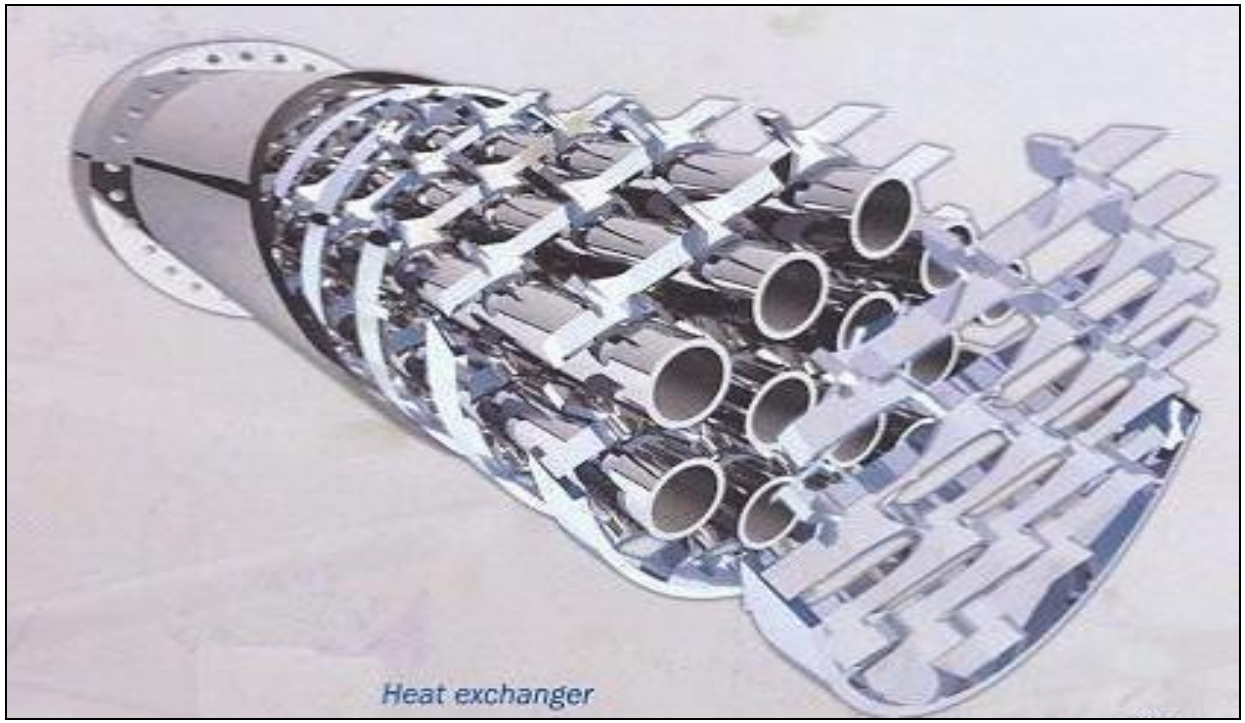


HEAT EXCHANGERS

- TUBE ASSEMBLY IN GRID BAFFLES.

HEAT EXCHANGERS

- TUBE BUNDLE WITH GRID BAFFLES.



HEAT EXCHANGERS

- Baffles
- Baffles are generally drilled using a jig plate drilled along with the tube sheet.

- Baffle OD, hole size, baffle cut , notches are important points for inspection.

HEAT EXCHANGERS

- One of the method adopted for inspection is as noted below
- Stack the baffle in proper sequence.
- Lock the stack by using four reamer bolts in the periphery .
- This way perfect alignment of holes are ensured and OD of the baffles and hole size can be checked in one go on all the baffles

HEAT EXCHANGERS

TUBES

HEAT EXCHANGERS

- TUBES

Following is basic minimum requirement of inspection for accepting a tube before insertion into bundle.

- Material grade,
- Relevant certificate ,
- Inspection authority.(Mfr or third party) ,
- Actual dimensions,
- Surface finish,
- Heat treatment condition ,
- Completion all tests as required such as eddy current, ultrasonic,hydro,IGC etc.

HEAT EXCHANGERS

- Incase of U tubes , a spare tube of lowest radius bend has to be sectioned in the middle and end of the U radius and checked for thinning and ovality.
- In addition complete visual examination to be done for check for transportation damages.

HEAT EXCHANGERS

- U tube bundle under assembly.

BELLOWS

HEAT EXCHANGERS

- BELLOWS
- Inmost of the cases this item is procured ready made from another manufacturer
- Convolute qty, convolute profile , min thickness , concentricity are important points to be checked.
- Ovality is maintained as close as possible for easy assembly with shell sections.

HEAT EXCHANGERS

- Profile and surface should be smooth without any localised flat spots and wrinkles.
- Welding should not have any reinforcement and should be smooth.
- Bellows are generally stress relieved .
- All required NDT and heat treatment should have been completed before taking into assembly.

SPACERS & TIE RODS

HEAT EXCHANGERS

- **Spacers and tie rods**
- Spacers have to be square cut and end faced.
- Length of the spacers should be based on actual thickness of the baffles.
- Tie rod should be straight and preferably in single piece.
- End threads should be of sufficient length and should not be excess.

HEAT EXCHANGERS

TUBE BUNDLE SKELETON

HEAT EXCHANGERS

- Tube bundle skeleton
- This is a very important stage of inspection.
- Salient points of inspection are as below
- Correct orientation of the tube sheet ,
- Distance and orientation of the first and last baffles .
- Pitch and number of baffles.
- Spacers has to be tight and mate with the baffles squarely.

HEAT EXCHANGERS

- Tie rod should have been fully inserted into the tube sheet .
- Excess threading of tie rod should be avoided as this can cause corrosion attack during service.
- Tie rod should have been locked by lock nut and welding

HEAT EXCHANGERS

- As a final cross check , insert few tubes in the skeleton. Then rotate them with hand. If the rotation is free ,then it can be safely presumed that the axis of the tube sheet and baffles are perfectly aligned and insertion of the balance tubes will be smooth.

COMPLETED TUBE BUNDLE

HEAT EXCHANGERS

- Completed tube bundle under insertion.

HEAT EXCHANGERS

- Tube bundle inspection
- Tube bundles are inspected after insertion of all the tubes.
- During inspection the following need to be ensured.
- Insertion of correct tubes.
- No surface damages, abrasions, end flares.
- No direct tube to tube contacts.
- No blockages inside tube.
- Tube bundles does not sag.
- Sliding strip have positive projection as per drawing.
- Sealing strips are flush with baffle OD

HEAT EXCHANGERS

TUBE TO TUBESHEET JOINT

HEAT EXCHANGERS

- Tube to tube sheet joint inspection
- Following types of tube to tube sheet joints are popular
- Tubes only expanded into tube sheets .
- Tubes fully expanded into tube sheets and seal welded
- -Tubes lightly expanded into tube sheet and strength welded.

HEAT EXCHANGERS

- Tube to tube sheet are welded / expanded to proven parameters of a qualified mock up.
- Expansion has to checked for length and percentage. The percentage has to lie within the range.
- Welding need to be checked for size, number of passes and weld defects.

HEAT EXCHANGERS

- Incase of strength weld ,it is a two pass weld , a PT check is carried out after each pass. Also a low pressure air test is carried out after both the passes.
- It must be ensured that TUBES ARE NOT EXPANDED BEFORE AIR TEST.

HEAT EXCHANGERS

TESTING OF EXCHANGERS

HEAT EXCHANGERS

- Testing of heat exchangers
- The following tests are generally carried out.
- Tube side hydro test to tube side test pressure.
- Shell side hydro test to shell side test pressure
- Exposed tube bundle hydro test to tube side pressure.
- Exposed tube bundle hydro test to shell side pressure

HEAT EXCHANGERS

- Following need to checked during hydro
- At least two calibrated pressure gauges are used.
- Gauge calibration is valid as on date.
- Pressure gauges have sufficient range, so that the test pressure is able to be read near the middle.

HEAT EXCHANGERS

- Pressurising system should have been disconnected from the equipment during hydro test.

HEAT EXCHANGERS

- Test pressure should be as required by approved drawing.
- Pressure setting on gauge dial should be as per calibration correction data.
- Caliberation correction data should be visible for scrutiny.

HEAT EXCHANGERS

It must be remembered that hydro test is the only stage in which correctness of design parameters, integrity of materials, integrity of welding is ultimately proven.

It is also the only stage in which every pressure component is in testing circuit.

Besides the welded pressure parts, unwelded pressure parts like service gaskets, service fasteners has to be in pressure test circuit.

HEAT EXCHANGERS

- Following need to checked during hydro test.
- No pressure drop .
- No leakage through the body of pressure part.
- No leakage through gasket joints.
- No leakage through tell tale holes of pads.

HEAT EXCHANGERS

- Here I would like to emphasize that there is nothing like a temporary gasket joint.
- Of course manufacturers, generally call all those joints for which he need not supply gaskets and blind flanges , as temporary joint.
- But as for hydro test is concerned there is nothing. No gasket joint should show sign of water seepage.

HEAT EXCHANGERS

- No over stressing of fasteners.
- No defects on studs and nuts.
- No damages to threads.
- Nuts should make a full face contact with the flange.
- Pressure test is perfect when the entire system holds the water under constant test pressure.

HEAT EXCHANGERS

- Holding time is as specified by the user.
- Generally a 60 min holding time is used if not specified .

HEAT EXCHANGERS

- Helium test
- This test is conducted on tube to tube sheet welding.
- ASME SEC V Code Article 10 deals with methodology to be followed .
- Test is conducted as per norms of the written procedure.

HEAT EXCHANGERS

- Unlike the hydro test , in which water is held tight in the system, Helium cannot be contained. **This gas leaks** .
- The principle behind the test is to ensure that the tube to tube sheet welding is sound enough to not to allow the gas to leak beyond a permitted rate.

HEAT EXCHANGERS

- The allowed Helium leak rate is specified by the user and this has to be monitored during test and test is considered successful if the noted Helium leak rate is lower than permitted.

HEAT EXCHANGERS

SOME OF THE PROBLEMS NOTICED DURING INSPECTION

HEAT EXCHANGERS

Following problems are generally noticed

- Non availability final approved engineering documents, like drawings, procedures, QAPs etc during final inspection stage.
- Girth flange distortion.
- Tube sheet distortion.

HEAT EXCHANGERS

- Fouling of partition plates.
- Fouling of dowel pins.
- Fouling of jack bolt hole threads.
- Fouling of jack bolts with bonnet nozzle
- Nozzle flange tilts.
- Nozzle gusset fillet welding unwelded in the ends.

HEAT EXCHANGERS

- Excess penetration inside nozzle to flange welds.
- Nozzle flange ratings incorrect.
- Distortion of support base plate.
- Incorrect sliding support holes.
- Chatter marks inside tube sheet holes.
- Handling damages in tube sheet gasket face.

HEAT EXCHANGERS

- Sliding strips flush with baffle OD.
- Tie rod end nuts not tacked.
- Loosening spacers due to mishandling.
- Loosening of spacers due to welding of impingement plate.

HEAT EXCHANGERS

- Expansion of tubes before pneumatic test.
- Insufficient tube projection .
- Tube end cut due to excess current

HEAT EXCHANGERS

- Leakages from temporary joints during hydro test.
- Hydraulic testing pump not disconnected.
- ALL THESE PROBLEMS CAN BE EASILY SORTED OUT WITH LITTLE BIT OF ADDITIONAL CARE AND PLANNING.

HEAT EXCHANGERS

PHOTOGRAPHS OF THE OBSERVED ISSUES

HEAT EXCHANGERS

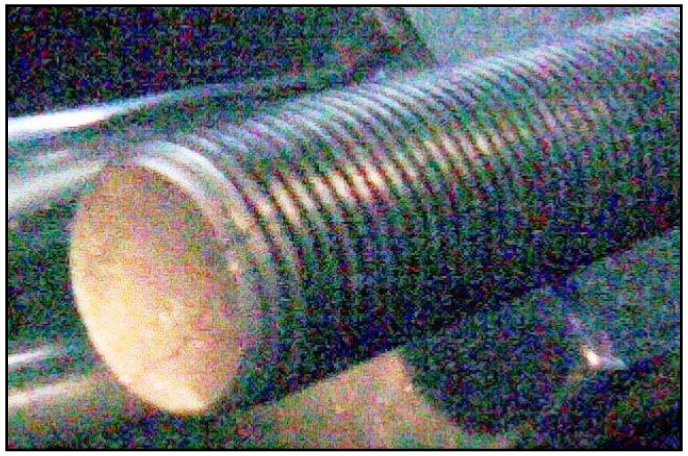
- Sagging tube bundle

HEAT EXCHANGERS

- Flange damage by nut

HEAT EXCHANGERS

- Cracked stud.



HEAT EXCHANGERS

- Stud length short.