A

PROJECT REPORT

ON

STANDARDIZATION OF TUBE EXPANSION SYSTEM IN SHELL & TUBE TYPE HEAT EXCHANGER

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE OF

BACHELOR OF ENGINEERING
In
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SUBMITTED BY

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DEPARTMENT OF MECHANICAL ENGINEERING

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CERTIFICATE

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will because for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

In shell and tube type Heat exchanger, tubes are generally expanded inside the shell with help of expander driven from wattage based device. In industries after every shutting down of expansion machine, they need to take the mock test in order to achieve the desired wattage required for perfect expansion for selected material and size of component. In this project we are going eliminate the mock test by standardizing the value of wattage required for expansion system by considering selected material and size. In this project we are going to select the tube and tube sheet material, expander, type of expansion process.

Chapter 1

Introduction

1.1 Introduction

A shell and tube heat exchanger is a class suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it.One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids.The set of tubes is called a tube bundles.

Expansion Joints are an integral part of many shell and tube heat exchanger designs where process conditions produce differential expansion between the shell and the tubes. Movements are in an axial direction in either compression or extension conditions. The tubes in heat exchangers are typically hotter than the shell, creating stress where the thermal expansion is generated. Depending on service conditions, the tube bundle may be a Nickel alloy and the shell a carbon or stainless steel. These materials have different expansion rates, which is part of the design movement. The design for the actual exchanger is part of Tema and or ASME codes.

An expansion joint is a specially-designed component of compact dimensions that allows differential movement between two adjacent components and maintains the pressure envelope. Sometimes a packed joint is used, but these are limited to low pressure and low severity duty. More common are the metallic *expansion bellows* used in the shell of fixed tube sheet exchangers or at the floating end of single-pass floating head exchangers of the S or T type.

Heat exchangers tubes can be attached to the tube sheet either by welding or expansion.The expansion methods include: roller expanding, explosive expanding, uniform pressure expanding and hybrid expanding. The objective of tube expanding is to create a residual interfacial pressure between the tube and surrounding tube sheet.

Roller expanding is the most common procedure for expanding heat exchangers tubes into the tube sheet holes. Tube rollers consist of a cylindrical cage with three to five (and for special cases seven) equally spaced longitudinal slots. Hardened steel rolls larger in diameter than slot width are nested in the slots and held in place by a hardened steel taper mandrel that fits inside the nest.

Current practice is to manufacture pins with a taper angle approximately opposite that of the mandrel in order to have the whole active length of the pin bear against the tube wall. The slots into which the pins fit in the cage may be parallel with the centerline or set at an angle. When the slots are parallel axial force is required to insert and withdraw the mandrel. Slots set at an angle cause rotation of the roller in one direction to screw the mandrel in or self-feed and reverse rotation to back of it.

During rolling tubes in tube sheet holes, the outer end of the mandrel is chucked into the rolling tool driver. A ball bearing thrust collar and locking nut screwed onto the cage's drive end permits the cage to rotate opposite the direction in which the rolling machine turns the mandrel. The axial position of the rolls in the tube is set by adjusting the position of the thrust collar. To perform the roller expanding process the roller expander is lubricated and inserted into the tube and a torque is applied to the mandrill. As the rolls travel up the mandrel, they cause an increasing radial force exerted at the contact point between the rolls and the tube. This increasing force moves the tube material outwards until it contacts the internal diameter of the tube sheet hole and continues until supposedly the tube sheet material is just below its yield point.

1.2 Problem Definition

- After every shutdown, during the new startup mock test is mandatory to be carried out in order to get perfect expansion.
- This leads to carry out the same expansion which was done before.
- In order to eliminate the repetition of work which is caused due to mock test there is need to do some standardization.
- The process of mock test consumes time which delays the process on daily basis.

1.3 Objective Of Work

- To eliminate mock test for every start-up.
- To save time.
- To optimize cost.
- To give standardization of tube parameters such as thickness, size & material.

Chapter 2

Literature Survey

Sr.No	Name Of The Paper	Author	Year of Publishing	Inferences taken from the paper
01	Factors Affecting Selection of Tubes of Heat Exchanger.	N. Farhami A. Bozorgian	2011	Tube Sheet material
02	Selection of Materials for Heat Exchangers	P. Rodriguez	April 1997	Properties of Material.
03	Effectively Design Shell and Tube Heat Exchanger	Chemical Engineering Progress	February 1998	Design of Shell of Heat Exchanger
04	Heat Exchanger Design	Su Thet Mon Than, Khin Aung Lin, Mi Sandar Mon.	2008	Design Considerations.
05	Expanded and Welded and Expanded Tube-to TubeSheet Joints	S Yokell	May 1992	Expanded tube to Tube sheet joints
06	Tube expansion and diffusion bonding of 316L stainless steel tube-to-tube sheet joints using a commercial roller tube expander	Nils Haneklaus Rony Reuvena, Cristian Cionea, Peter Hosemann, Per F. Petersona	2016	Tube to TubeSheet Expansion Process

Chapter 3

Selection of Material

3.1 General Criteria for Material Selection

The engineer making the materials selection must know all the aspects involved in the construction, operation and maintenance of the heat exchanger. The importance of this is illustrated with the following examples: an operator may isolate a heat exchanger with raw water for sufficient time to initiate a pitting corrosion; partial blockage of tubes, specially of small diameter, would result in stagnant conditions that 60 may cause pitting in alloys that are so prone; fouling may result in operating the heat exchangers in throttled/part load condition. A general procedure that could be used for identifying the most appropriate material for a specific heat exchanger application would consist of the following steps.

1. Define the heat exchanger requirements
2. Establish a strategy for evaluating candidate materials
3. Identify candidate materials
4. Evaluate materials in depth
5. Select the optimum material

For the first step, the engineer must consider the normal operating parameters (e.g.: nature of the fluids on both the tube and shell side, flow rate, temperature and pressure), startup and shutdown conditions, upset conditions, special conditions like product purity requirements, hazardous effects of intermixing of shell and tube side fluids, radioactivity and associated maintenance, etc. The applicable codes and safety regulations must also be considered. The heat exchanger designer would also identify the tube attachment method as this also affects the material selection. If the material selection is being done by someone other than the heat exchanger designer, there must be close consultation between these individuals.

While establishing the strategy for evaluating candidate materials, the main factors to be considered are cost and reliability. The minimum cost strategy would mean use of less expensive materials and rectifying the problems as they show up. Maximum reliability strategy would mean going for the most reliable material regardless of its cost. Both strategies have to be weighed against initial cost, loss due to possible shutdowns, repair costs, indirect loss to other industries etc.

In identifying candidate materials, it is desirable to narrow the field to a comparatively small number of materials for more extensive evaluation. There is no hard and fast rule as to how many candidate materials should be selected for detailed study. The initial identification and selection procedure, if done properly, will eliminate those materials which are unsuitable and those which are excessively expensive. This calls for use of operating experience, use of handbook data and literature on advanced materials under development, and judgment. Special considerations which affect materials selection include:

Physical Properties

- High heat transfer coefficient (requiring high thermal conductivity for tube material)
- Thermal expansion coefficient to be low and as compatible as possible with those of the materials used for tube sheet, tube support and shell to provide resistance to thermal cycling.

Mechanical Properties

- Good tensile and creep properties (High creep rupture strength at the highest temperature of operation and adequate creep ductility to accommodate localized strain at notches are important).
- Good fatigue, corrosion fatigue and creep-fatigue behavior.
- High fracture toughness and impact strength to avoid fast fracture.

Corrosion Resistance

- Low corrosion rate to minimize the corrosion allowance (and also radioactivity control in heat exchangers for nuclear industry)
- Resistance to corrosion from off normal chemistry resulting from leak in upstream heat exchanger or failure in the chemistry control
- Tolerance to chemistry resulting from mix up of shell and tube fluids.

Manufacture

Ease of fabrication is an important aspect for selection of materials. The usual manufacturing steps involved for heat exchangers are bending of tubes, joining of tube to tube sheet by rolling, welding or rolling and welding, forming of shell geometry and welding of shell plates and shell to nozzle and the heat treatments associated with the welding steps.

Operating Experience

A great deal of knowledge is gained by the operating experience of similar units. Lessons learnt from the failures of others is an important consideration in materials selection.

After narrowing down the list of candidate materials (for tube, tube sheet, shell), the next step is to perform the design of heat exchanger with candidate materials so as to establish the initial cost. Also the failure probability with each design needs to be established so as to establish the outage cost.

Criteria for making the final selection will include an assessment of each of the following: - initial cost - maintenance cost, including consideration of how frequently the equipment will need to be inspected for corrosion - cost of loss in production - consequences of failure. Is failure likely to create unsafe conditions or cause discharge of an undesirable chemical into the environment or serious repercussions to an emerging technology?

Generally materials selection is based on qualitative comparisons of the candidate materials. However, it is worthwhile to make the assessment based on financial parameters.

3.2 Selection of Material for Tubes

Heat exchangers with shell diameters of 10 inches to more than 100 are typically manufactured to industry standards. Commonly, 0.625 to 1.5" tubing used in exchangers is made from low carbon steel, Admiralty, copper, copper-nickel, and stainless steel, Hastelloy, Inconel, or Titanium.

Tubes can be drawn and thus seamless, or welded. High quality electro resistance welded tubes display good grain structure at the weld joints. Extruded tubes with fins and interior rifling are sometimes specified for certain heat transfer applications. Often, surface enhancements are added to increase the available surface or aid in fluid turbulence, thereby increasing the operative heat transfer rate. Finned tubes are recommended when the shell-side fluid have a considerably lower heat transfer coefficient than the tube-side fluid. Note, the diameter of the finned tube is slightly smaller than the un-finned areas thus allowing the tubes to be installed easily through the baffles and tube supports during assembly while minimizing fluid bypass.

A U-tube design finds itself in applications when the thermal difference between the fluid flows would otherwise result in excessive thermal expansion of the tubes. Typical U-tube bundles contain less tube surface area as traditional straight tube bundles due to the bended end radius, on the curved ends and thus cannot be cleaned easily. Furthermore, the interior tubes on a U-tube design are difficult to replace and often requiring the removal of additional tubes on the outer layer; typical solutions to this are to simply plug the failed tubes.

3.3 Selection of Tube sheet Material

Tube sheets usually constructed from a round, flattened sheet of metal. Holes for the tube ends are teen drilled for the tube ends in a pattern relative to each other. Tube sheets are typically manufactured from the same material as tubes, and attached with a pneumatic or hydraulic pressure roller to the tube sheet. At this point, tube holes can both be drilled and reamed, or they are machined grooved.

The tube sheet comes in contact with both fluids in the exchanger, therefore it must be constructed of corrosion resistant materials or allowances appropriate for the fluids and velocities. A layer of alloy metal bonded to the surface of a low carbon steel tube sheet would provide an effective corrosion resistance without the expense of manufacturing from a solid alloy.

The tube-hole pattern, often called ‘pitch’, varies the distance between tubes as well as the angle relative to each other allowing the pressure drop and fluid velocities to be manipulated in order to provide max turbulence and tube surface contact for effective heat transfer.

Tube and tube sheet materials are joined with weld-able metals, and often further strengthened by applying strength or seal weld to the joint. Typically in a strength weld, a tube is recessed slightly inside the tube hole or slightly beyond the tube sheet whereas the weld adds metal to the resulting edge. Seal welds are specified when intermixing of tube liquids is needed, this is accomplished whereas the tube is level with the tube sheet surface. The weld fuses the two materials together, adding no metal in the process. When it becomes critical to avoid the intermixing of fluid, a second tube sheet is designed in. In this case, the outer tube sheet becomes the outside the shell path, and the inner tube sheet is vented to atmosphere, so that a fluid leak can be detected easily effectively eliminating any chance of cross contamination.

Tubes of heat exchangers are connected to two sheets called tube sheets at the two ends or in other words they are hold by these two sheets. Tubes are either welded or get clinched to these two sheets. Thus, it is important to choose an appropriate material for tube sheet which does not cause polarization. Carbon steel, copper alloy, Metal Munoz (61 to 58 percent copper, 1 percent lead on the rest zinc), Admiral Brass and bronze aluminum are anode against copper tubes. Galvanic protection of this type of tube against tubes made of copper alloy does not remove corrosion at the inlet and outlet of tubes, but it is on an acceptable level. Carbon stainless steel is rarely used with a tube made of copper alloy. Since stainless steel acts cathodic against copper alloy, if tube sheet is made of copper alloy and tubes are of stainless steel or titanium, corrosion occurs quickly. Since stainless steel acts cathodic against copper alloy, if tube sheet is made of copper alloy and tubes are of stainless steel or titanium, they will get polarized easily, so that the entire level inside the tube, which is cathodic, will be located against anode which is copper alloy. Cathodic protection flow should be established on the tube sheet of the copper alloy to prevent from or improve such a situation, i.e. the issue of anode – cathode.

3.4 Conclusion for Material Selection

- Heat exchangers with shell diameters of 10 inches to more than 100 are typically manufactured to industry standards.
- Commonly, 0.625 to 1.5" tubing used in exchangers is made from low carbon steel, Admiralty, copper, copper-nickel, stainless steel, Hastelloy, Inconel, or titanium.
- The shell is constructed either from pipe or rolled plate metal.

- Mild steel is a very popular metal and one of the cheapest types of steel available. Since it's relatively inexpensive, mild steel is useful for most projects requiring huge amounts of steel.
- Stainless steel is a hard and strong substance, it is not a good conductor of heat and electricity, it is ductile, magnetic, retains its strength and cutting edge regardless of temperature.

COMPONENT	MATERIAL
Shell	**Mild Steel**
Tube	**Stainless Steel**

Table 3.4 Material Selection

Chapter 4

Design of Shell

4.1 Criteria for Design

Shell and tube heat exchangers are complex and more expensive than ordinary pressure vessels. Also the strength calculation is more difficult. Part of the design process includes the determination of the amount of tubes to be used in the heat exchanger. The number and length of the tubes create the area through which the heat is transferred from one process medium to the other. The outside of the shell and tube heat exchanger is mostly a cylindrical form which make the calculation by hand for the amount of tubes difficult. The number of tubes and the dimensions are required to execute the calculation for the tube sheet.

The Tube Sheet Lay-out page facilitates the calculation of the amount of tubes. The calculation can be done for four (4) pitch patterns (how the tubes are laid out) and for ten (10) types of passes (tube compartments).

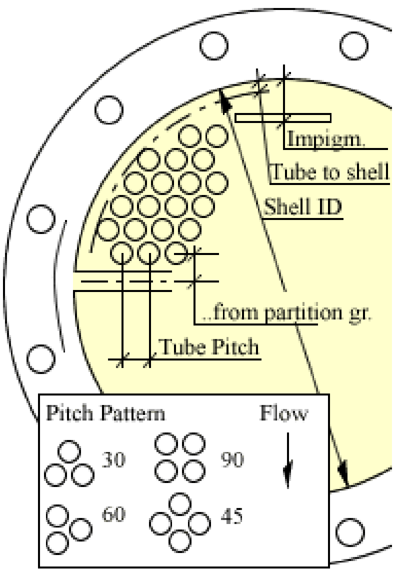

Fig. TubeSheet Layout

4.2 Tube Arrangement

4.2.1 Tube Layout

Tube layout arrangements are designed so as to include as many tubes as possible within the shell to achieve maximum heat transfer area. There are four tube layout patterns, as shown in Figure 6: triangular (30°), rotated triangular (60°), square (90°), and rotated square (45°).

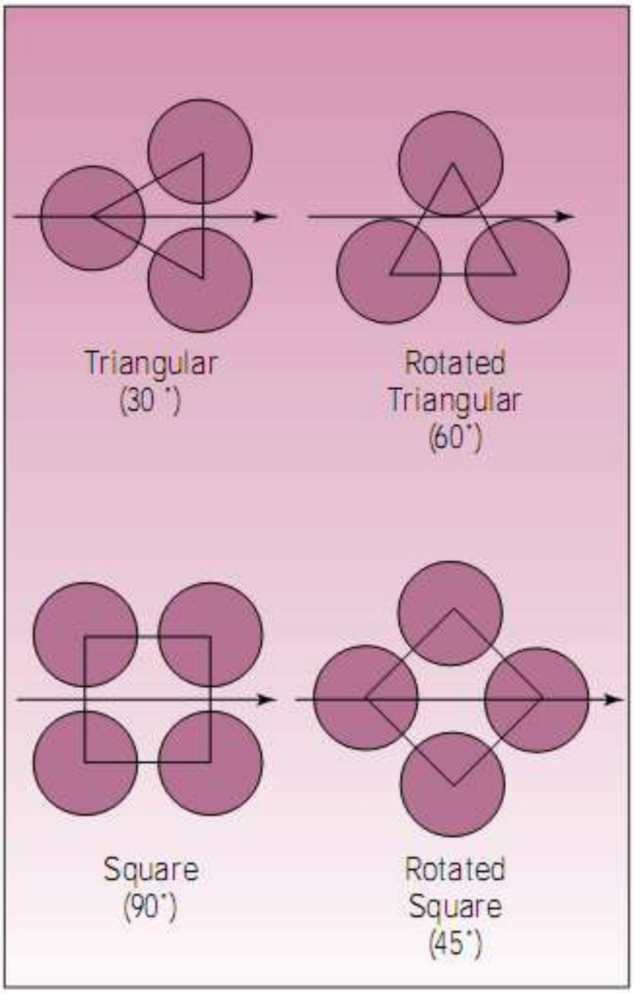

Fig. Tube Layout

A triangular (or rotated triangular) pattern will accommodate more tubes than a square (or rotated square) pat- tern. Furthermore, a triangular pattern produces high turbulence and therefore a high heat-transfer coefficient. However, at the typical tube pitch of 1.25 times the tube O.D., it does not permit mechanical cleaning of tubes, since access lanes are not available.

Consequently, a triangular layout is limited to clean shell side services. For services that require mechanical cleaning on the shell side, square patterns must be used.

Chemical cleaning does not require access lanes, so a triangular layout may be used for dirty shell side services provided chemical cleaning is suitable and effective. A rotated triangular pattern seldom offers any advantages over a triangular pattern, and its use is consequently not very popular. For dirty shell side services, a square layout is typically employed. However, since this is an in-line pattern, it produces lower turbulence. Thus, when the shell side Reynolds number is low (< 2,000),it is usually advantageous to employ a rotated square pattern because this produces much higher turbulence, which results in a higher efficiency of conversion of pressure drop to heat transfer.

As noted earlier, fixed-tube sheet construction is usually employed for clean services on the shell side, U-tube construction for clean services on the tube side, and floating-head construction for dirty services on both the shell side and tube side. (For clean services on both shell side and tube side, either fixed-tube sheet or U-tube construction may be used, although U-tube is preferable since it permits differential expansion between the shell and the tubes.)

Hence, a triangular tube pattern may be used for fixed-tube sheet exchangers and a square (or rotated square) pattern for floating-head exchangers. For U-tube exchangers, a triangular pattern may be used provided the shell side stream is clean and a square (or rotated square) pattern if it is dirty.

4.2.2 Tube Pitch

Tube pitch is defined as the shortest distance between two adjacent tubes. For a triangular pattern, TEMA specifies a minimum tube pitch of 1.25 times the tube O.D. Thus, a 25-mm tube pitch is usually employed for 20-mm O.D. tubes. For square patterns, TEMA additionally recommends a minimum cleaning lane of 4 in. (or 6 mm) between adjacent tubes. Thus, the minimum tube pitch for square patterns is either 1.25 times the tube O.D. or the tube O.D. plus 6 mm, whichever is larger. For example, 20-mm tubes should be laid on a 26-mm (20 mm +6 mm) square pitch, but 25-mm tubes should be laid on a 31.25-mm (25mm × 1.25) square pitch. Designers prefer to employ the minimum recommended tube pitch, because it leads to the smallest shell diameter for a given number of tubes. However, in exceptional circumstances, the tube pitch may be increased to a higher value, for example, to reduce shell side pressure drop. This is particularly true in the case of a cross-flow shell.

The selection of tube pitch is a compromise between a close pitch for increased shell-side heat transfer and surface compactness, and a larger pitch for decreased shell-side pressure drop and fouling, and ease in cleaning. In most shell and tube exchangers, the minimum ratio of tube pitch to tube outside diameter (pitch ratio) is 1.25. The minimum value is restricted to 1.25 because the tube-sheet ligament (a ligament is the portion of material between two neighboring tube holes) may become too weak for proper rolling of the tubes into the tube sheet. The ligament width is defined as the tube pitch minus the tube hole diameter; this is shown in Fig

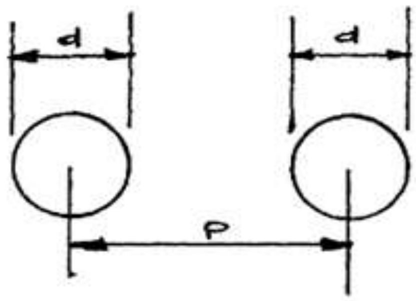

Fig. Tube Pitch

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4.2.3 Tube sheet

A tube sheet is an important component of a heat exchanger. It is the principal barrier between the shell-side and tube-side fluids. Proper design of a tube sheet is important for safety and reliability of the heat exchanger. Tube sheets are mostly circular with uniform pattern of drilled holes. Tube sheets of surface condensers are rectangular shape. Tube sheets are connected to the shell and the channels either by welds (integral) or with bolts (gasketed joints) or with a combination thereof. Tube-sheet connection with the shell and channel for fixed tube-sheet exchanger can be categorized into two types:

1. Both sides integral construction,
2. Shell-side integral and tube-side gasketed construction

Tube-sheet connection with the shell and channel for floating heat exchanger and U-tube heat exchangers can be categorized into three types:

1. Both sides integral construction
2. One side integral and the other side gasketed construction
3. Both sides gasketed construction

4.2.4 Pass Arrangements for Flow through Tubes

The simplest flow pattern through the tubes is for the fluid to enter at one end and exit at the other. This is a single-pass tube arrangement. To improve the heat-transfer rate, higher velocities are preferred. This is achieved by increasing the number of tube-side passes. The number of tube passes depends upon the available pressure drop, since higher velocity in the tube results in higher heat-transfer coefficient, at the cost of increased pressure drop. Larowski et al. suggests the following guidelines for tube-side passes:

1. Two-phase flow on the tube side, whether condensing or boiling, is best kept in a single straight tube run or in a U-tube.
2. If the shell-side heat-transfer coefficient is significantly lower than on the tube side, it is not advisable to increase the film coefficient on the tube side at the cost of higher tube-side pressure drop, since this situation will lead to a marginal improvement in overall heat transfer coefficient.

4.2.5 Number of Tube Passes

The number of tube-side passes generally ranges from one to eight. The standard design has one, two, or four tube passes. The practical upper limit is 16. Maximum number of tube side passes is limited by workers' abilities to fit the pass partitions into the available space and the bolting and flange design to avoid interpass leakages on the tube side. In multipass designs, an even number of passes is generally used; odd numbers of passes are uncommon, and may result in mechanical and thermal problems in fabrication and operation. Partitions built into heads known as partition plates control tube-side passes. The pass partitions may be straight or wavy rib design. There are some limitations on how the different types of heat exchangers can be partitioned to provide various numbers of passes.

They are summarized here.

1. Fixed tube-sheet exchanger-any practical number of passes, odd or even. For multipass arrangements, partitions are built into both front and rear heads.
2. U-tube exchanger-minimum two passes; any practical even number of tube passes can be obtained by building partition plates in the front head.

3. Floating head exchangers: With pull through floating head (T head) type and split backing ring exchanger (S head); any practical even number of passes is possible. For single-pass operation, however, a packed joint must be installed on the floating head. With outside packed floating head type (P head), the number of passes is limited to one or two. With externally sealed floating tube sheet (W head), no practical tube pass limitation.

4. Two-phase flow on the tube side, whether condensing or boiling, is best kept within a single pass or in U-tubes to avoid uneven distribution and hence uneven heat transfer.

4.2.6 Tube to Header Plate Connection

Tubes are arranged in a bundle and held in place by header plate (tube sheet).The number of tubes that can be placed within a shell depends on Tube layout, tube outside diameter, pitch, number of passes and the shell diameter. When the tubes are too close to each other, the header plate becomes too weak.

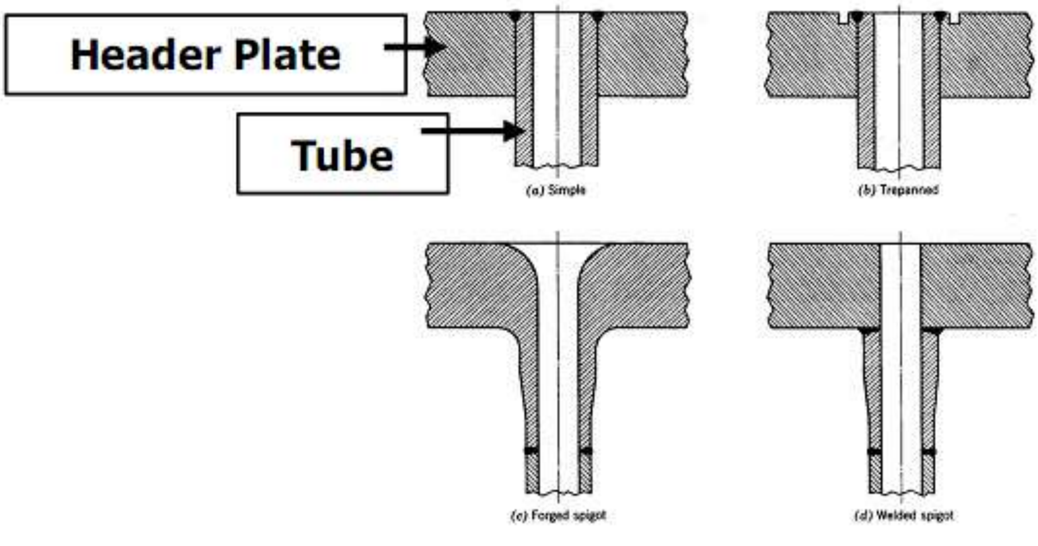

Fig. Tube to Header Plate Connection

4.2.7 Design of Shell

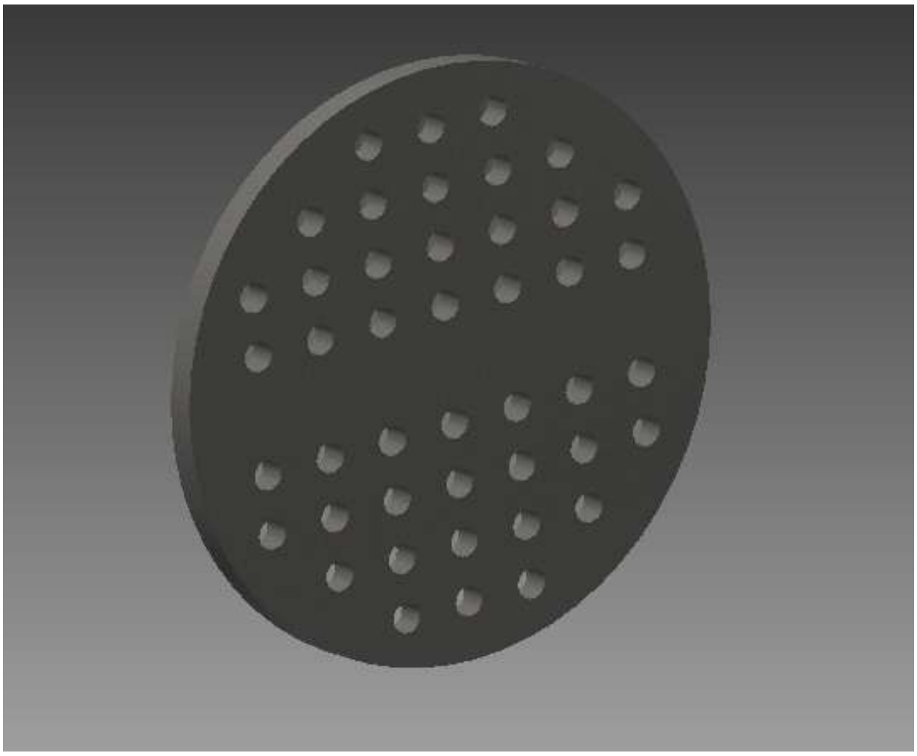

Fig. TubeSheet Design

Chapter 5

Methodology

5.1 Expansion

Elimination of diameter difference between the two pipe ends to be joined. Joining tubes to tubesheets and steam drums by mechanically expanding them to create an artificial shrink fit between the tubes and surrounding tube sheet or drum material has been a successful process since the 19th century. In this process, after the tube is inserted into the tube sheet or drum holes, the tube is first enlarged until it contacts the hole surfaces. Enlargement continues with the initial tube distortion elastic and further distortion plastic. After contact with the hole surface, the outside of the tube presses against the inside of the hole and distorts the surrounding metal. The distortion of the surrounding metal may be fully elastic or plastic near the tube and elastic farther out.

Fig.Expansion

Upon release of expanding force, the tube and surrounding metal recover. Recovery is elastic but not to the original dimensions. If the tube and surrounding metal have substantially identical properties, after relaxation, there will be a residual stress field with zero magnitude at the tube I.D. and increasing magnitude to a maximum at some radius in the tube-hole structure, diminishing to zero magnitude farther out. The residual stress at the interface between the tube and hole is the equilibrium stress between the parts equal to an interfacial pressure.

If the tube sheet or drum has twice the yield stress of the tubes, distortion of the tube sheet or drum remains elastic throughout the process. If the tubes have a yield stress higher than the tube sheet or drum, the position of maximum residual stress shifts depending upon the tube diameter and thickness. The equilibrium stress at the interface of tube and hole surfaces is lower than for constructions of equal tube-tube sheet or drum yield stresses or in which the tube or drum yield stress is higher that of the tube yield stress.

The axial shear strength of the expanded joint is approximately equal to the product of the tube-hole contact area, the interfacial pressure and the coefficient of static friction for the metal pair.

Although, most expanded joints have historically been made by roller expanding, most investigations of tube expanding have used the concept of uniformly applied pressure inside a capsulated length of tubing in contact with the tube sheet or drum. This simplifies the analysis by eliminating a many variables that define the roller expanding process.

5.2 Expansion Limit

- In expansion process first the clearance between the tube and tube sheet is removed to maintain the metal to metal contact, and at this stage there will be no reduction in wall thickness.
- This stage is called "'metal to metal contact". Still by the end of this first stage expansion in the tube it is not leak proof.
- Now to increase the expansion and reach the point where the material is deformed, further rolling is required which results into the deformation of wall thickness. This creates tension because of the compression between the tube and tube sheet.

- A leak proof expansion is assured if the pressure tension is greater than the service pressure which arises from the heating, the lengthening and finally the tension of the medium. The difference of expansion between the ‘contact’ and the final expansion is called ‘expansion limit’.
- This ‘expansion limit’ must never cause a rupture in the cohesion of the molecules of the tube material by an exaggerated deformation of the material. If this were the case the tube material could become damaged – it could crack or break – and this would create the danger of explosions etc. when the tube comes under high pressure.
- From the literature review in an article “modeling the effect of initial tube clearance, wall reduction and the material strain hardening” it has been observed that the
- Recommended expansion range:
    - Metal to Metal contact : about 3-5% of tube wall thickness
    - Expansion limit : about 10-15% of tube wall thickness

5.3 Percentage Wall Reduction

Tube Expanding is the art of reducing a tube wall by compressing the O.D. of the tube against a fixed container such as rolling tubes into tube sheets, drums, ferrules or flanges. To assure a proper tube joint, the tube wall must be reduced by a predetermined percentage.

Percentage wall reduction is the most frequently used procedure to obtain the optimal mechanical joint between a tube and tube sheet. In order to calculate this reduction we must take into account the variances between the tube OD, tube wall thickness and tube sheet hole diameter. We must also consider the differening types of materials being used for both tube and tube sheet, however as a general rule percentage wall reduction ranges between 4% to 10%

The table illustrates the applicable percentage tube wall reduction according to the differing materials commonly used for both tubes and tubesheets:

Tube Sheet Material	Tube Material	Tube Wall Reduction
Stainless Steel	Stainless Steel	4-5%
Steel	Stainless Steel	4-5%
Steel	Steel	7%
Steel	Copper	5%
Copper	Copper	10%

Table 5.3 Tube Wall Reduction

For boiler tube wall reduction ranges between 8% to 16%.

5.4 Procedure to Calculate Percentage of Expansion

- Step 01: Major tube bore
- Step 02: Major tube outer diameter
- Step 03: Calculate play between tube sheet and tube
- Step 04: Major tube internal diameter
- Step 05: Select the expander which will give optimal percentage of expansion
- Step 06: Expand the tube with Electrical Expander
- Step 07: Measure the expanded tube internal diameter
- Step 08: Calculate percentage of expansion

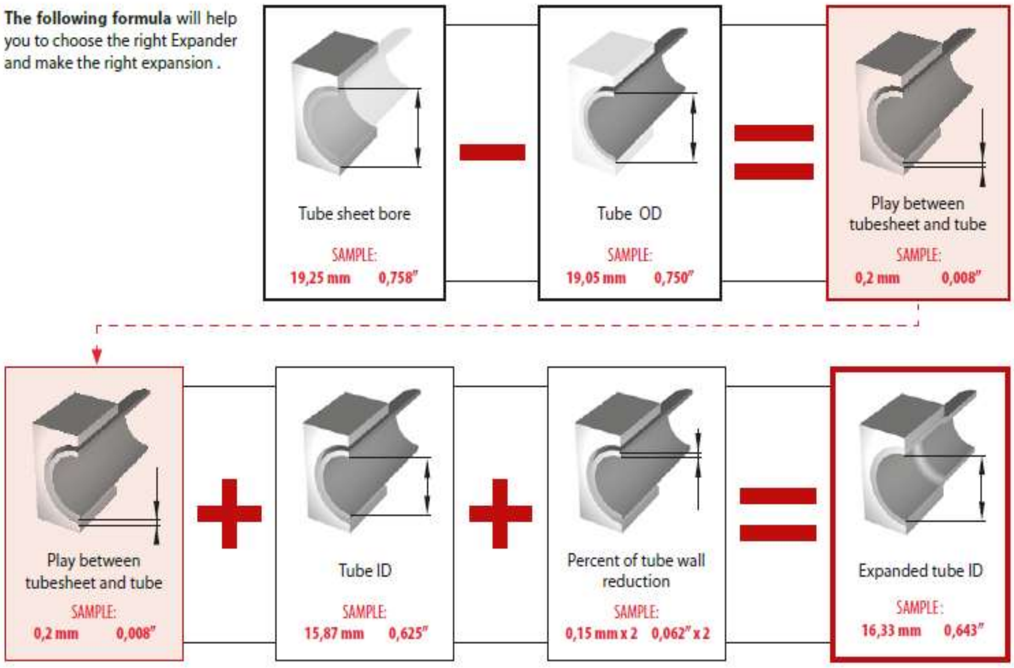

Fig. Calculation for Expanded Tube ID

5.5 Calculations

1) Tube sheet bore – Tube OD = Play between tube sheet and tube

$\therefore$ 13 - 12.70 = 0.3mm

2) Now,

Expanded Tube ID = Play between tube sheet and tube + Tube ID + Percent of tube wall reduction

$\therefore$ Expanded Tube ID = 0.3+10.8+0.07

$\therefore$ Expanded Tube ID = 11.17 mm

3) Calculation of tube thickness reduction rate

$W_t = (D - d_0) – (H – d_1) / (D - d_0) * 100$

where,

W_t = tube thickness reduction rate (%)

H = sheet hole diameter before expansion (mm)

D = outer diameter of tube before tube expansion (mm)

d_0 = inner diameter of tube before expansion (mm)

d_1 = inner diameter of tube after expansion (mm)

$W_t = (12.70 – 10.8) – (13 – 11.17) /(12.70 – 10.8) *100$

$W_t = 3.68\ \%$

4) Calculation of tube inner diameter growth rate:

$W_d = d_1 – (d_0 + C) / (d_0 + C) * 100$

$= 11.7 – (10.8 + 0.3) / (10.8 + 0.3) * 100$

$= 0.63\ \%$

In general , it is estimated that W_d is between 1 and 1.2 %

5.6 Torque Calculation

The torque calculation is done to select the type of expansion to be used for carrying out the expansion process.

- There are basically 3 methods of Tube Expansion:

1. Electrical Expansion (Wattage variation)
2. Pneumatic Expansion (Pressure variation)
3. Hydraulic Expansion (Pressure variation)

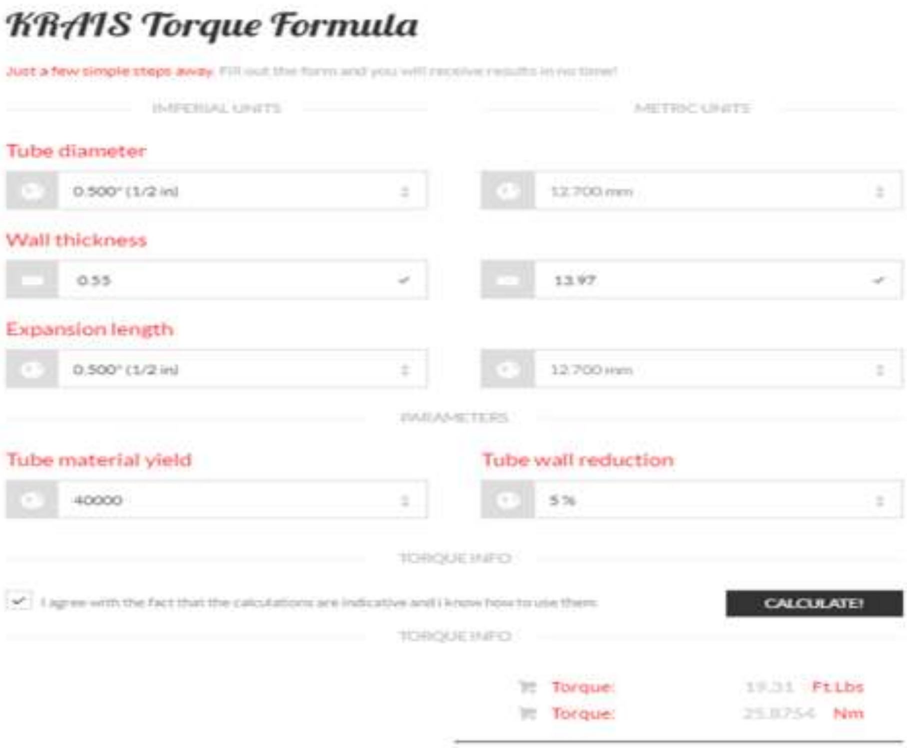

Fig. Torque Calculation

According to the torque calculated for carrying out the expansion process we are selecting **Electrical Expansion** as the value of torque is low.

5.7 Selection of Expander

5.7.1 Structure of Tube Expanders

- ✓ Roller: This component is for plastic deformation of the internal surface of the tube with counter pressure. It has a reverse taper that conforms to the taper of the mandrel and it is designed so that the internal surface of the tube when expanded will always be perfectly circular. In addition, the ends of the rollers have a smooth R that avoids stress concentration after tube expansion and that prevents sharp angles in the internal surface of the tube.
- ✓ Mandrel: This component is for rotation of the rollers via contact friction. Like the rollers, it has a tapered shape. The rollers and mandrel use a special steel for the required resistance to pressure and friction; they have been processed with precise heat treatment and precision grinding and finishing.

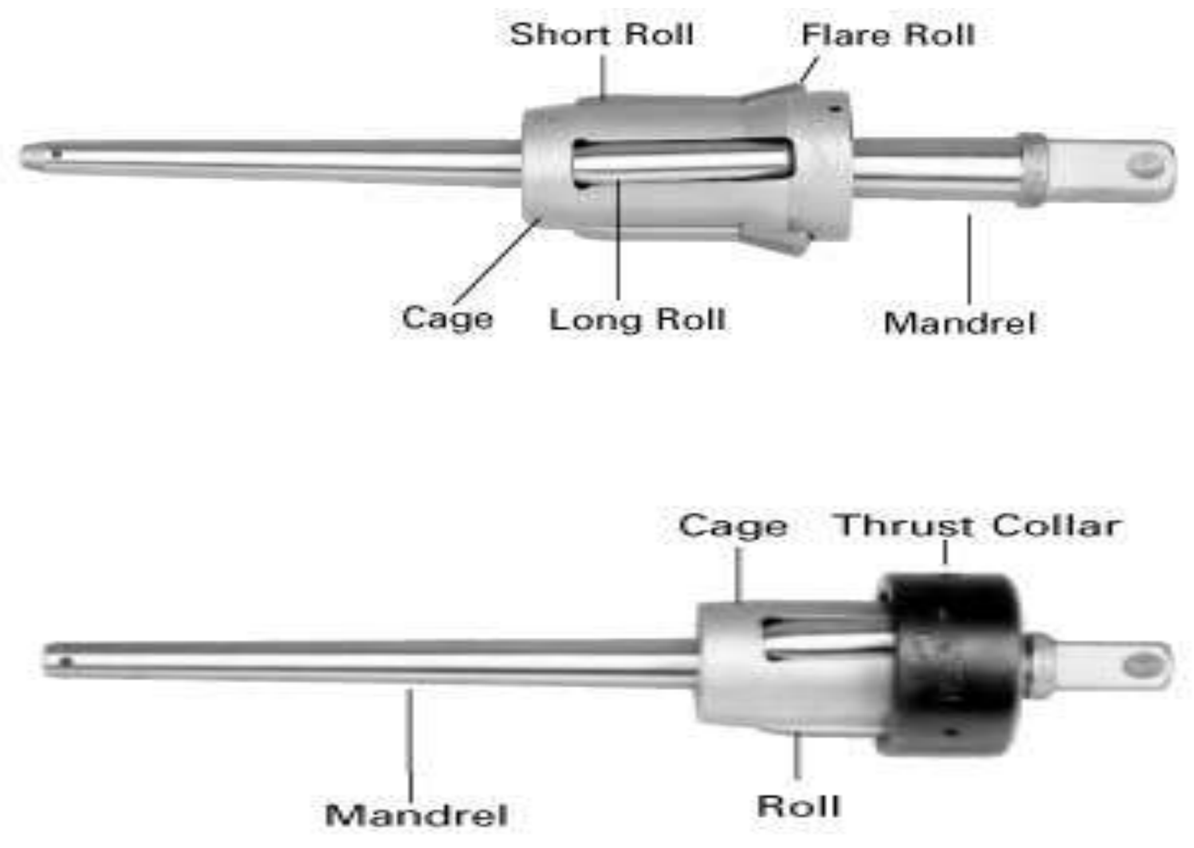

Fig. Structure of Tube Expander

- ✓ Frame: This component is for holding 3-7 rollers at equal intervals and for prevention of roller drop. There is a feed angle in the roller groove; the mandrel is self-propelled with rotation of the tool to the right, forming a structure that automatically expands the tube.
- ✓ Bearing Collar: A bearing collar that prevents damage to end of tubes and tube sheets by reducing thrust during tube expansion is attached to all of the tube expanders except the BK type. The effective roller length and reach length can be adjusted as desired by adjusting the position of the bearing collar forward and backward.

Fig. Tube Expander

5.7.2 Selection of Tube Expander

The tube expanders comes in standard size according to the size of the pipe. Selection of tube expander is done on the basis tube outer diameter, tube thickness and tube inside diameter.

FOR TUBES INTERNAL DIAMETER
FROM (3.8 mm) .152" TO (8.4 mm) .331"

TUBE EXPANDERS FITTED WITH ROLLER LENGTH	FOR TUBE SHEET ADJUSTABLE RANGE	
	MINIMUM A	MAXIMUM B
(38.1mm) 1.1/2"	(12.7mm) 1/2"	(38.1mm)1.1/2"
(57.1mm) 2.1/4"	(31.7mm)1.1/4"	(57.7mm)2.1/4 "

Table 5.7.2.1 Roller Length

■ SPECIFICATIONS

Tube O.D.	TubeThickness			Tube I.D		Minimum I.D. Tool Enters		Maximum Expansion Tool		Tube sheet thickness 1/2" to 1-1/2" (12.7 mm to 38.1 mm)			Tube sheet thickness 1-1/4" to 2-1/4" (31.7 mm to 57.1 mm)		
(mm) inch	bwg	mm	Inch	mm	Inch	mm	Inch	mm	Inch	Complete Tool No.	Mandrel No.	Rollers No.	Complete Tool No.	Mandrel No.	Rollers No.
(12.7 mm) 1/2"	14	2.10	.083	8.4	.334	8.2	.324	9.5	.374	797	797	797	-	-	-
	15	1.82	.072	9.0	.356	8.8	.348	10.1	.398	799	799	R-1	-	-	-
	16	1.65	.065	9.4	.370	9.1	.360	10.4	.410	801	M-1	R-1	-	-	-
	17	1.47	.058	9.7	.384	9.5	.374	10.7	.424	803	M-1	R-2	-	-	-
	18	1.24	.049	10.2	.402	9.9	.392	11.3	.447	805	M-2	R-3	-	-	-
	20	0.88	0.35	10.9	.430	10.3	.406	11.7	.461	805 S	M-3	R-3	-	-	-

Table 5.7.2.2 Expander Selection Table

According to the specification of the tube we are selecting 805S tube expander for carrying out the expansion process.

5.8 Working Process

- After all the calculations and selection of material we started the mock test in the beginning of 8th semester.
- After carrying out mock test on more than 1000 tubes by varying wattage.
- By changing the wattage, we observed that in the range of 835watts to 850watts we reached the expected expansion limit.
- We carried out leak detection test by JTK after tube expansion

Fig. Torque Controller

Fig. Tube Expander 805S

Fig. Electric Drive

Fig. Expansion Process

Chapter 6

Conclusion

And

Future Scope

Conclusion

- Material used for tube sheet is **Mild Steel.**
- Material used for tube is **Stainless Steel.**
- Tube sheet bore = 13mm
- Tube OD = 12.7mm
- Tube ID = 10.8mm
- Bwg = 18.
- Many trials were carried between the range of 835watts to 850watts.
- The range was used to expand almost 1000 tubes.
- After all the trials we got 836watts as a standard wattage for expansion.

Future Scope

For the time being we have the standardization for the one material and by using this theory standardization of all other materials can also be done.

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