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Design of Evaporator Tube Sheet used in the Sugar Industry

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Abstract: *The evaporator is one type of heat exchanger which is used to transfer the heat from hot fluid to cold fluid efficiently and it is made up of various parts. Tube sheet are one of the major component of a shell and tube heat exchanger from structural and cost price. The design of tube sheet is need to be established and pattern of holes calculated to spread them evenly over the tube sheet surface. In tube sheet pattern, vapour spacing is provided for proper circulation of steam in tube sheet. Arrangement of tube sheet pattern are of various types namely, triangular, square, rectangular but most preferable pattern is triangular which achieve high turbulence and high heat transfer coefficient also distance between two tubes i.e. tube pitch varies the distance from one tube to another and angle of the tube relative to each other and direction of flow. So design the tube sheet by using various parameters like pattern should be symmetric, vapour circulate throughout calandria, easy to maintain and assembly. In this paper appropriate tube sheet pattern is selected to achieve an efficient flow of steam to supply all over calandria tubes.*
Keywords: *Calandria, Evaporator, Tube sheet, Vapour line.*

I. Introduction

A tube sheet is a plate which is utilized to fortify the tubes in a shell and tube heat exchanger. The tubes are aligned in a parallel way in vertical/horizontal directions which are fortified and held in a place by placing the tube sheets. The tube sheet is a circular shape plate which drills groups of holes so that the tubes can fit through the hole (as shown in fig.1). Tubes are fortified on either end by sheets which are drilled in a predetermined pattern to sanction the tube ends to pass through the sheets [1]. The cessations of the tubes which perforate the sheet are expanded to lock them in place and form a seal. The tube aperture pattern or pitch varies the distance from one tube to the other and angle of the tubes relative to each other and to the direction of flow. This sanctions control of fluid velocities and pressure drop and provides the maximum amount of turbulence for efficacious heat transfer [2].

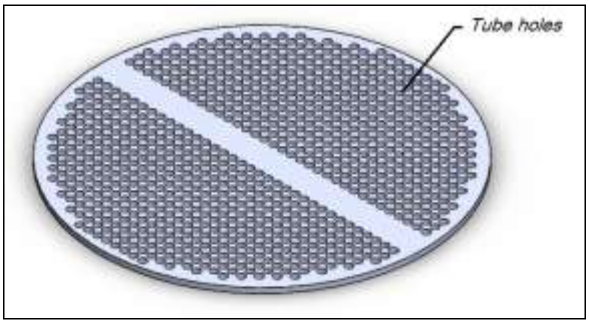


Fig. 1 Tube sheet

The design of the tube sheets is a fairly precise and involute process, that exact number of tubes needs to be established and a pattern of apertures calculated to spread them evenly over the tubes sheet surface. Astronomically immense exchanger may have several thousand tubes running through them arranged into precisely calculated groups. Tube layout arrangements are designed so as to include as many tubes as possible within the shell to achieve maximum heat transfer area. Opportune design of a tube sheet is consequential for the safety and reliability of the heat exchanger. It is withal consequential for the congruous flow of vapour steam should be passed equipollently to all tubes. Tube sheet sanctions for differential thermal expansion between the shell and the tube bundle [3].

II. Literature Review

Kulbir Singh, S. Jalaldeen, P. Chellapandi, S. C. Chetal, Presented paper on Assessment of simplified tube sheet analysis based on three dimensional finite element simulation [1], according to this paper, the steam generator is an important component in power plant, so in the steam generator, there are two tube sheet, steam side(top)tube sheet and waterside bottom(tube sheet). Waterside tube sheet of the prototype fast breeder reactor is used to carry out the study purpose. Analysis of the tube sheet is carried out by a different method to find geometry, loading condition, pressure loading at room temperature without considering thermal load and transient.Somankar Vikas, Tembhare G.U, Patil V.G., Presented paper on Optimization of tube sheet thickness of triple concentric pipe heat exchanger using ASME code [2], this paper regarding the tube sheet safety, so that main purpose of this paper to analyzing the temperature and stress variation in tube sheet and optimizing its thickness. So they achieved an optimized thickness of tube sheet and stress and validated by ansys software. So that thickness of tube sheet achieved and safety of Heat exchanger tube take place.S. Murali, Y. Bhaskar Rao, Presented paper on A Simple Tube sheet Layout Program for Heat Exchangers [3], In this paper sorting procedure, is used to approximately place the tubes according to the tube distance to the shell centre. Generally, in the industrial heat exchanger, different types of standard tube layout are used, but the largest heat transfer surface within a given shell can be obtained by the 30-degree layout. In 30-degree layout, 85% heat surface area is achieved.

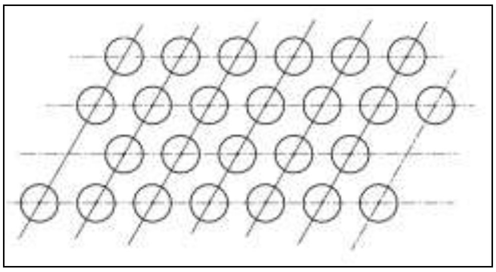
III. Methodology

Design of tube sheet depends on a number of tubes, for the design of a tube sheet first need to be a calculating number of the tube. Number of tube depends on the heating surface. After calculating a number of tubes, overall dimensions of tube sheet such as tube sheet diameter, tube sheet thickness etc. are finding out. By arranging hole on the tube sheet with vapour line spacing, design of tube sheet is done by some guideline [4].

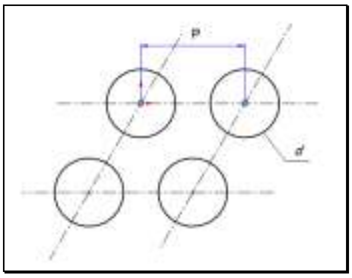
IV. Design Of Tube Sheet Pattern

4.1 Tube Sheet Pattern

The layout of the tubes in the tube plates generally follows a staggered arrangement (Fig.2a). This arrangement permits the greatest number of tubes to be accommodated per unit area of the plates, for a given distance between the tubes.



(a) Arrangement of tubes



(b) Tubes of staggered arrangement

Fig, 2 (a)(b) Tube arrangement

The distance between the centers of two adjacent is called the 'pitch' (p) of the tubes (Fig. 2b). The steam or vapour is admitted to calandria by one, two or more inlets. Tubes are arranged in triangular, square or rotated-square pitch. Triangular tube-layout results in better shell side heat transfer coefficients and provide more surface area in a given shell diameter[4].

4.2 Vapour Line

In order to facilitate access of vapour of the furthest portion of the calandria steam lines are often provided between the tubes; these are obtained by simply leaving out rows of tubes over part of their length. Shell and tube heat exchangers are complex and more expensive than ordinary pressure vessels [4].

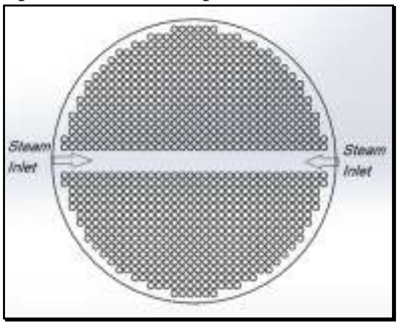
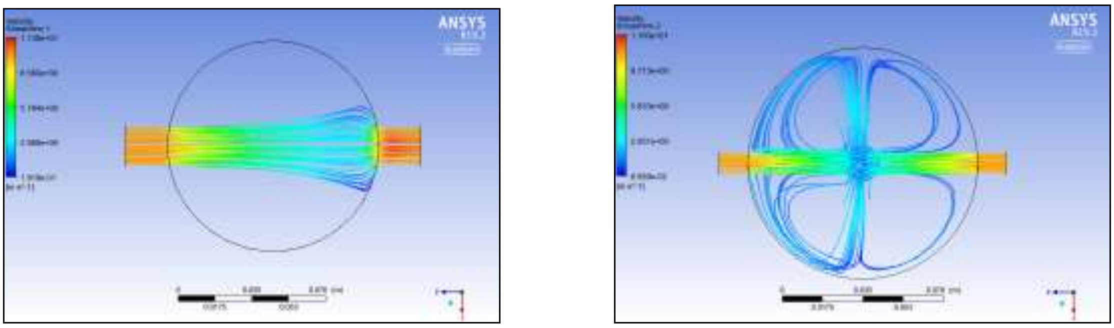


Fig. 3 Tube sheet without vapour lines

Fig.3 shows the tube sheet without vapour line in that steam is flow but it is not circulated all over passage its need to provide some vapour line. To understand the vapour line concept some simulation of the steam flow shown in fig.4 (a) & (b). This flow simulation is carried out in Ansys Fluid flow (CFX)



(a)Flow of steam without guidelines (b) Flow of steam with guide line

Fig. 4 (a)(b) Flow simulaton

In fig. 4(a) when steam enters in evaporator its try to exit directly without flow all around surface, because of the absence of any guideline. But in fig. 4(b) there are some guidelines provide so steam tries to flow in the passage and circulate in passage and exit. From the above figures it's concluded the importance of the presence of vapour in the tube sheet. Generally, only one vapour inlet is used in vessels of less than 3m diameter; two are provided for vessels of 3m or more diameter; sometimes four for very large vessels, in such a way as to supply effectively all the tubes; some would otherwise be too far away from a single entry. Also, the strength calculation is more difficult. Part of the design process includes the determination of the number 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 makes the calculation by hand for the tubes difficult. The number of tubes and the dimensions is required to execute the calculation for the tube sheet [4].

4.3 Calculations Of Tube Sheet Dimensions

Given Parameters:-
Heating Surface= 400m^2
Tube Outer Diameter= 45mm
Tube Thickness= 1.22mm
Tube length= 2000mm
Tube Expansion allowance= 5mm
Proportional factor (β) = 0.9
Downtake diameter = 620mm

1) Number of Tubes(N):-

a) Mean diameter of the tube(D_{am})=Tube Outer diameter – Tube Thickness (1)
=45-1.22
=43.78mm=0.04378mm

b) Effective length of the tube(L)=Tube length–2*(tube plate thickness)–2*(tube Expansion allowance) (2)
=2000-2*(32)-2*(5)
=1926mm=1.926m

c) Number of tubes=Heating Surface/($\pi D_m L$) (3)
N=400/(π*0.04378*1.926)
N=1510.003933=1510

2) Tube sheet plate diameter:-

a) Tube pitch (p)=O.D + Ligament + Tube Clearance + Hole Clearance (4)
=45+10+0.3+0.1
=55.4mm=0.0554mm

b) Tube plate area required for tubes only(A) =(0.866*p^2*N)*(20%extra)/β (5)

$= (0.866*0.0554^2*1510*1.2)/0.9$
$=5.35m^2$

c) Tube plate diameter required for tubes only= $\sqrt{[A*4/\pi]}$ (6)
$= \sqrt{[5.35*4/\pi]}$
$=2.6099485m=2609.94mm$

d) Final diameter of tube plate= Tube plate diameter required for tubes only (7)
= 2609.94- (2609.94*.3) =1826.958
= 2000mm

e) Tube Plate Thickness:-

- Max. Allowable pressure = 2.728kg/cm^2=2.67*10^{5}Pa
- Allowable Stress =1400kg/cm^2 = 1.37293*10^{8}Pa
- Modulus Factor for M.S Sheet =210000
- Corrosion Allowance = 1.5mm

Tube plate Thickness
= {[(Modulus factor)*(Calandria thickness)]*[(O.D. of Calandria) – (Thickness of shell)] /
[(No. of tubes*Modulus Factor*Tube Thickness)*(O.D. of tube – thickness of tube)]} (8)
= [(210000*12)*(5952-12)] / [(7550 * 210000 *1.22) – (45-1.22)]
=7.7385mm=8mm
No. of plates =4
Total tube thickness=8mm*4 =32mm

4.4 Tube Sheet Design

The design of tube sheets is a fairly precise and involute process; the exact number of tubes needs to be established and a pattern of apertures calculated to spreads them evenly over the tube sheet surface. Astronomically immense exchangers may have several thousand tubes running through them arranged into precisely calculated groups or bundles. Sheet design and engenderment is largely automated these days with computer software (like CAD) performing the calculations and the tube sheet drilling done on computer numerical control (CNC) machines. Vapour line is a consequential part of the tube sheet pattern. In tube sheet pattern give the space for vapour line because of steam is circulated congruously in tube sheet pattern and steam is passed to all calendars tubes. There are different patterns and different ways of vapour line [5].
At the time of tube sheet design some point should be considered which are as follows:

- Tube sheet aperture pattern should symmetric to half portion
- Vapour circulate throughout calandria
- All tube must be arranged
- Easy to maintain
- Easy to assemble

In tube sheet first need to find vapour line space
Vapour line space= Pitch*2 - Tube diameter (9)
= (55.4*2) - 45
= 65.8mm
With consideration of above points and dimension, design of tube sheet carried out

1. Pitch distance

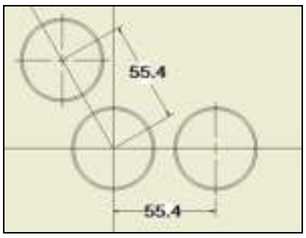


Fig.5 Tube sheet hole pitch

2. Tube Layout

Triangular tube-layout results in better shell side heat transfer coefficients and provide more surface area in a given shell diameter. We construct tube hole as triangular tube layout.

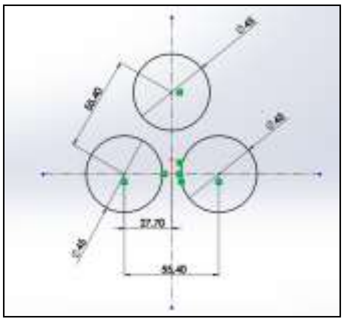


Fig.6 Tube layout

3. Vapour line pattern

We use tube sheet patern which normally used in sugar industry evaporator

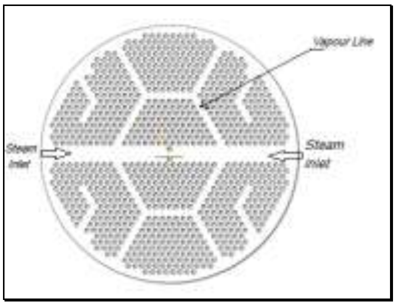


Fig.7 Selected vapour line pattern for tube sheet

4. Vapour line space

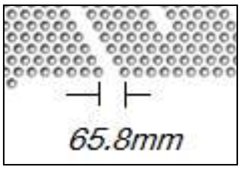


Fig.8 Vapour line space

5. Generate CAD Model

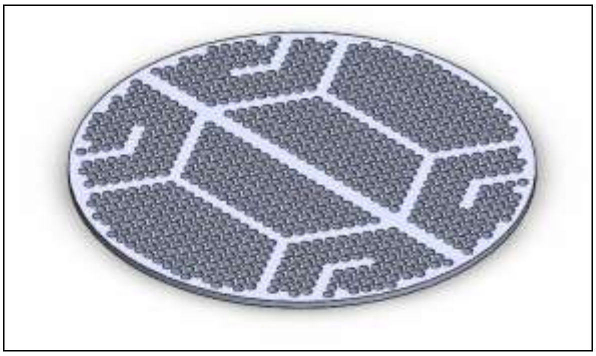


Fig. **9 Tube sheet CAD Model**

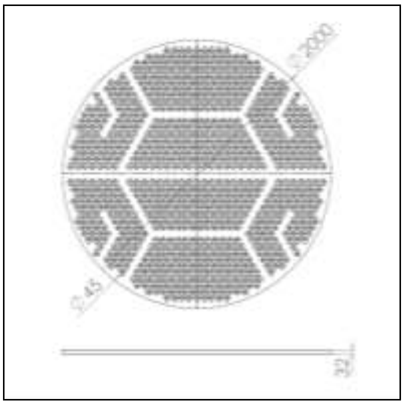


Fig.10 Drafting of tube sheet

In tube sheet pattern with the vapour line, all tubes are arranged properly as shown in the cad model. Steam is entered in the steam inlet and steam pass through all tubes so the heat transfer rate is improved. Also, maintenance and assembly are easy. All objectives are achieved in the tube sheet pattern with the vapour line. In the tube sheet pattern, vapour line is important so it needs to provide vapour line.

V. Conclusion

In tube sheet pattern without vapour line steam is not circulated throughout the tubes because there is the absence of vapour line but in tube sheet pattern with vapour line steam is circulated through the tubes, so the heat transfer rate is amended. Vapour lines are paramount to provide supplemental safety and security when carrying liquid. The design of the tube sheet is predicated on all the objectives verbally expressed above in paper. The congruous design of a tube sheet pattern is paramount for the safety and reliability of heat exchanger. For achieving maximum heat transfer area the layout of tube sheet pattern is predicated on sundry parameters like pitch distance, vapour line pattern, arrangement of tubes. Four types of layouts are their which are triangular, square and rotated square. A triangular pattern is utilized to sanction more tubes than square pattern. The tube pitch is the shortest center to center distance between tubes. Tube sheet design and engenderment these days is largely computerized by utilizing computer software's like CAD. By the help of flow simulation software circulation of steam easily find out.

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Conflict of interest: the authors declare that there is no conflict of interests regarding the publication of this paper.

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