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Design, Analysis and Fabrication of Shell and Tube Heat Exchanger

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Abstract: *A heat exchanger is an equipment used for transferring heat from one medium to another. There is a wide application of coiled heat exchanger in field of cryogenics and other industrial applications for its enhanced heat transfer characteristics and compact structure. Lots of researches are going on to improve the heat transfer rate of the heat exchanger. Here, We have fabricated the shell and tube heat exchanger with selecting the materials on the primary objective of enhancing the transfer effectiveness. We casted the tube in the spiral shape with the helical angle of 30 degree. Then we intended to perform calculation on the heat transfer effectiveness. We are intended to show the merits of spiral coiled heat exchanger to that of the conventional parallel type heat exchanger.*

I. Introduction

The Heat exchanger is a mechanical device which is used for the purpose of exchange of heats between two fluids at different temperatures. There are various types of heat exchangers available in the industry, however the Shell and Tube type heat exchanger is probably the most used and widespread type of the heat exchanger's classification. It is used most widely in various fields such as oil refineries, thermal power plants, chemical industries and many more. This high degree of acceptance is due to the comparatively large ratio of heat transfer area to volume and weight, easy cleaning methods, easily replaceable parts etc. Shell and tube type heat exchanger consists of a number of tubes through which one fluid flows. Another fluid flows through the shell which encloses the tubes and other supporting items like baffles, tube header sheets, gaskets etc. The heat exchange between the two fluids takes through the wall of the tubes.

Heat exchanger is nothing but a device which transfers the energy from a hot fluid medium to a cold fluid medium with maximum rate, minimum investment and low running costs. The heat transfer in a heat exchanger involves convection on each side of fluid and conduction taking place through the wall which is separating the two fluids. In a heat exchanger, the temperature of fluid keeps on changing as it passes through the tube sand also the temperature of the dividing wall located between the fluids varies along the length of heat exchanger. Examples:

- Boilers, super heaters, re-heaters, air-preheaters.
- Radiators of an automobile.
- Oil coolers of heat engine.
- Refrigeration of gas turbine power plant.
- In waste heat recovery system. Types:

1. Direct contact type of heat exchanger
2. Non-contact type of heat exchanger

Direction of motion of fluid:

- Parallel flow,
- Counter flow
- Mixed flow.

Shell and tube heat exchangers are most versatile type of heat exchanger; they are used in process industries, in conventional and nuclear power station as condenser, in steam generators in pressurized water reactor power plants, in feed water heaters and in some air conditioning refrigeration systems. Shell and tube heat exchanger provide relatively large ratio of heat transfer area to volume and weight and they can be easily cleaned. Shell and tube heat exchanger offer great flexibility to meet almost any service requirement. Shell and tube heat exchanger can be designed for high pressure relative to the environment and high pressure difference between the fluid streams. Heat exchangers are used in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air-conditioning, refrigeration, space applications, petrochemical industries etc.

OPERATING PRINCIPLE OF SHELL AND TUBE HEAT EXCHANGER

There are three principle means of achieving heat transfer, conduction, convection, and radiation. Heat exchangers run on the principles of convective and conductive heat transfer.

Radiation does occur in any process. However, in most heat exchangers the amount of contribution from radiation is miniscule in comparison to that of convection and conduction. Conduction occurs as the heat from the hot fluid passes through the inner pipe wall. To maximize the heat transfer, the inner-pipe wall should be thin and very conductive.

However, the biggest contribution to heat transfer is made through convection. There are two forms of convection; these are natural and forced convection. Natural convection is based on the driving force of density, which is a slight function of temperature. As the temperature of most fluids is increased, the density decreases slightly. Hot fluids therefore have a tendency to rise, displacing the colder fluid surrounding it. This creates the natural "convection currents" which drive everything from the weather to boiling water on the stove. Forced convection uses a driving force based on an outside source such as gravity, pumps, or fans. Forced convection is much more efficient, as forced convection flows are often turbulent. Turbulent flows undergo a great deal of mixing which allow the heat to be transferred more quickly. In this particular apparatus, water is used as both the hot and cold fluid. The purpose of this heat exchanger is to cool a hot stream. Cooling water flows through the outer pipe (the shell), and hot water flows through the inner pipe (actually 28 tubes) on the inside. Heat transfer occurs in both directions; the hot water is cooled, and the cooling water is heated. This arrangement is called a "shell-and-tube" heat exchanger. There are many other forms of heat exchangers; most notably, the double-pipe heat exchanger. In this arrangement a cold fluid flows through a pipe in the center of the apparatus and is heated by a hot fluid on the outside of that pipe. The hot water used in the shell-and-tube heat exchanger is produced by means of a double-pipe heat exchanger. The discharge from the shell of the shell-and-tube heat exchanger is circulated through the inner pipe of the double pipe heat exchanger. Low-pressure steam condenses on the outside of the pipe, heating the water before it enters the tubes of the shell-and- tube heat exchanger.

CONSTRUCTION

The shell-and-tube heat exchanger is named for its two major components –round tubes mounted inside a cylindrical shell. The shell cylinder can be fabricated from rolled plate or from piping (up to 24 inch diameters).The tubes are thin-walled tubing produced specifically for use in heat exchangers. Other components include: the channels (heads), tube sheets, baffles, tie rods & spacers, pass partition plates and expansion joint (when required).Shell & tube heat exchanger designs and constructions are governed by the TEMA and ASME codes.

fig :- Construction of STHE

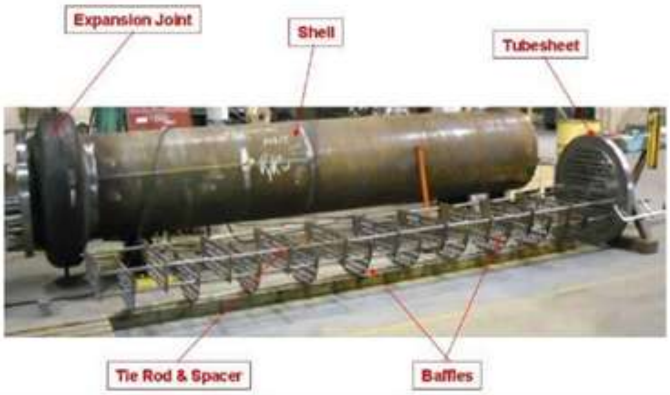


fig :- Component of STHE Tubes

Tubing may be seamless or welded. Seamless tubing is produced in an extrusion process; welded tubing is produced by rolling a strip into a cylinder and welding the seam. Welded tubing is usually more economical. Normal tube diameters are 5/8 inch, 3/4 inch and 1 inch. Tubes of smaller diameter can be used but they are more difficult to clean mechanically. Tubes of larger diameter are sometimes used either to facilitate mechanical cleaning or to achieve lower pressure drop. The normal tube wall thickness ranges from 12 to 16 BWG (from 0.109 inches to 0.065 inches thick).Tubes with thinner walls (18 to 20 BWG) are used when the tubing material is relatively expensive such as titanium. Tubing may be finned to provide more heat transfer surface; finning is more common on the outside of the tubes, but is also available on the inside of the tubes. High flux tubes are tubing with special surface to enhance heat transfer on either or both sides of the tube wall. Inserts such as twisted tapes can be installed inside tubes to improve heat transfer especially when handling viscous fluids in laminar flow conditions. Twisted tubes are also available. These tubes can provide enhanced heat transfer in certain applications.

THERMAL DESIGN CONSIDERATIONS

The flow rates of both hot and cold streams, their terminal temperatures and fluid properties are the primary inputs of thermal design of heat exchangers.

Thermal design of a shell and tube heat exchanger typically includes the determination of heat transfer area, number of tubes, tube length and diameter, tube layout, number of shell and tube passes, type of heat exchanger (fixed tube sheet, removable tube bundle etc), tube pitch, number of baffles, its type and size, shell and tube side pressure drop etc.

Shell

Shell is the container for the shell fluid and the tube bundle is placed inside the shell. Shell diameter should be selected in such a way to give a close fit of the tube bundle. The clearance between the tube bundle and inner shell wall depends on the type of exchanger. Shells are usually fabricated from standard steel pipe with satisfactory corrosion allowance. The shell thickness of 3/8 inch for the shell ID of 12-24 inch can be satisfactorily used up to 300 psi of operating pressure.

Tube

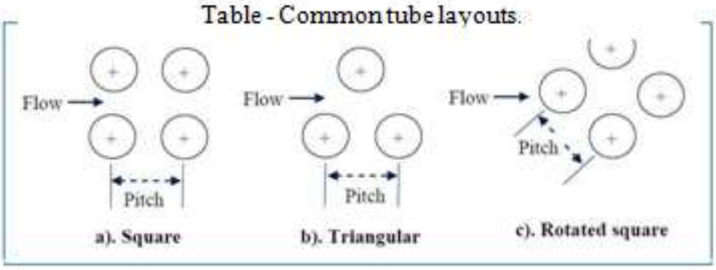
Tube OD of ¾ and 1"" are very common to design a compact heat exchanger. The most efficient condition for heat transfer is to have the maximum number of tubes in the shell to increase turbulence. The tube thickness should be enough to withstand the internal pressure along with the adequate corrosion allowance. The tube thickness is expressed in terms of BWG (Birmingham Wire Gauge) and true outside diameter (OD). The tube length of 6, 8, 12, 16, 20 and 24 fts are preferably used. Longer tube reduces shell diameter at the expense of higher shell pressure drop. Finned tubes are also used when fluid with low heat transfer coefficient flows in the shell side. Stainless steel, admiralty brass, copper, bronze and alloys of copper-nickel are the commonly used tube materials:

Tube pitch, tube-layout and tube-count

Tube pitch is the shortest centre to centre distance between the adjacent tubes. The tubes are generally placed in square or triangular patterns (pitch). The widely used tube layouts are illustrated in **Table** The number of tubes that can be accommodated in a given shell ID is called tube count. The tube count depends on the factors like shell ID, OD of tube, tube pitch, tube layout number of tube passes type of heat exchanger and design pressure.

Tube OD, in	Pitch type	Tube pitch, in
3/4	Square	1
1		$1\frac{1}{4}$
3/4	Triangular	$\frac{15}{16}$
3/4		1

Table - Common tube layouts.



Tube passes

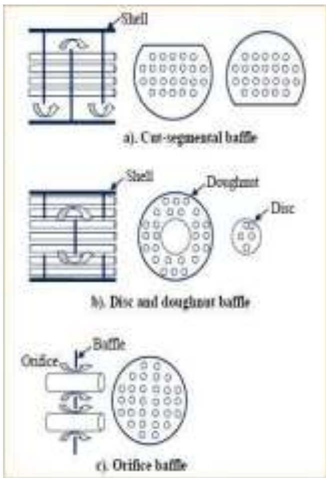
The number of passes is chosen to get the required tube side fluid velocity to obtain greater heat transfer co-efficient and also to reduce scale formation. The tube passes vary from 1 to 16. The tube passes of 1, 2 and 4 are common in application. The partition built into exchanger head known as partition plate (also called pass partition) is used to direct the tube side flow.

Tube sheet

The tubes are fixed with tube sheet that form the barrier between the tube and shell fluids. The tubes can be fixed with the tube sheet using ferrule and a soft metal packing ring. The tubes are attached to tube sheet with two or more grooves in the tube sheet wall by „tube rolling". The tube metal is forced to move into the grooves forming an excellent tight seal. This is the most common type of fixing arrangement in large industrial exchangers. The tube sheet thickness should be greater than the tube outside diameter to make a good seal. The recommended standards (TEMA) should be followed to select the minimum tube sheet thickness.

Baffles

Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer co- efficient. The distance between adjacent baffles is called baffle-spacing. The baffle spacing of 0.2 to 1 times of the inside shell diameter is commonly used. Baffles are held in positioned by means of baffle spacers. Closer baffle spacing gives greater transfer co-efficient by inducing higher turbulence. The pressure drop is more with closer baffle spacing. The various types of baffles are shown in **Figure** In case of cut-segmental baffle, a segment (called baffle cut) is removed to form the baffle expressed as a percentage of the baffle diameter. Baffle cuts from 15 to 45% are normally used. A baffle cut of 20 to 25% provide a good heat-transfer with the reasonable pressure drop. The % cut for segmental baffle refers to the cut away height from its diameter. **Figure** also shows two other types of baffles.



Semi-circular Cut-segmental baffle

Different type of heat exchanger baffle Fouling Considerations

The most of the process fluids in the exchanger foul the heat transfer surface. The material deposited reduces the effective heat transfer rate due to relatively low thermal conductivity. Therefore, net heat transfer with clean surface should be higher to compensate the reduction in performance during operation. Fouling of exchanger increases the cost of construction due to oversizing, additional energy due to poor exchanger performance and cleaning to remove deposited materials. A spare exchanger may be considered in design for uninterrupted services to allow cleaning of exchanger. The effect of fouling is considered in heat exchanger design by including the tube side and shell side fouling resistances. Typical values for the fouling coefficients and resistances are summarized in **Table.** The fouling resistance (fouling factor) for petroleum fractions are given below –

Fluid	Coefficient (W.m^{-2}.°C^{-1})	Resistance (m^2.°C.W^{-1})
River water	3000-12,000	0.0003-0.0001
Sea water	1000-3000	0.001-0.0003
Cooling water (towers)	3000-6000	0.0003-0.00017
Towns water (soft)	3000-5000	0.0003-0.0002
Towns water (hard)	1000-2000	0.001-0.0005
Steam condensate	1500-5000	0.00067-0.0002
Steam (oil free)	4000- 10,000	0.0025-0.0001
Steam (oil traces)	2000-5000	0.0005-0.0002
Refrigerated brine	3000-5000	0.0003-0.0002
Air and industrial gases	5000-10,000	0.0002-0.000-1
Flue gases	2000-5000	0.0005-0.0002
Organic vapors	5000	0.0002
Organic liquids	5000	0.0002
Light hydrocarbons	5000	0.0002
Heavy hydrocarbons	2000	0.0005
Boiling organics	2500	0.0004
Condensing organics	5000	0.0002
Heat transfer fluids	5000	0.0002
Aqueous salt solutions	3000-5000	0.0003-0.0002

Table :- Typical values of fouling coefficients and resistances

Selection of fluids for tube and the shell side

The routing of the shell side and tube side fluids has considerable effects on the heat exchanger design. Some **general guidelines** for positioning the fluids are given in **Table** It should be understood that these guidelines are not ironclad rules and the optimal fluid placement depends on many factors that are service specific.and number. The baffle spacing is usually chosen to be within

Ds to Ds.

Step 10. Determine the tube side film heat transfer coefficient (h i) using the suitable form of Sider-Tate equation in laminar and turbulent flow regimes.
Estimate the shell-side film heat transfer coefficient (h o) from

Tube-side fluid	*Shell-side fluid*
Corrosive fluid	Condensing vapor (unless corrosive)
Cooling water	Fluid with large temperature difference (>40°C)
Fouling fluid	
Less viscous fluid	
High-pressure steam	
Hotter fluid	

Table :- Guidelines for placing the fluid in order of priority

THERMAL DESIGN PROCEDURE

Select the outside tube (shell side) dirt factor ( ) and inside tube (tube side) dirt factor (R_{di}).
Calculate overall heat transfer coefficient (Uo, cal) based on the outside tube area (you may neglect the tube-wall resistance) including dirt factors:
Shell and tube heat exchanger is designed by trial and error
( )
calculations. The main steps of design following the **Kern method** are summarized as follows:

Step 1. Obtain the required thermos-physical properties of hot and cold fluids at the **caloric temperature or arithmetic mean temperature**. Calculate these properties at the caloric temperature if the variation of viscosity with temperature is large.

Step 2. Perform energy balance and find out the heat duty (Q) of the exchanger.

Step 3. Assume a reasonable value of overall heat transfer coefficient (Uo). The value of Uo, with respect to the process hot and cold fluids can be taken from the books.

Step 4. Decide tentative number of shell and tube passes (P_n). Determine the LMTD and the correction factor FT normally should be greater than 0.75 for the steady operation of the exchangers. Otherwise it is required to increase the number of passes to obtain higher FT values.

Step 5. Calculate heat transfer area (A) ~~required:~~

Step 6. Select tube material, decide the tube diameter (ID= d i, OD = d o), its wall thickness (in terms of BWG or SWG) and tube length (L). Calculate the number of tubes ( ) required to
provide the heat transfer area (A): n=

Calculate tube side fluid velocity, u=

If u <1 m/s, fix p n ~~so that,~~

Where m, ρ and μ are mass flow rate, density and viscosity of tube side fluid. However, this is subject to allowable pressure drop in the tube side of the heat exchanger.

Step 7. Decide type of shell and tube exchanger (fixed tube sheet, U-tube etc.). Select the tube pitch (PT), determine inside shell diameter (D_s) that can accommodate the calculated number of tubes (n t). Use the standard tube counts table for this purpose.

Step 8. Assign fluid to shell side or tube side (a general guideline for placing the fluids is summarized in **Table**). Select the type of baffle (segmental, doughnut etc.), its size (i.e. percentage cut, 25% baffles are widely used), spacing (B)

Step 11. If 0< <30%, go the next **step12**.

Otherwise go to **step 5**, calculate heat transfer area (A) required using Uo, cal and repeat the calculations starting from **step #5**.

If the calculated shell side heat transfer coefficient (h o) is too low, assume closer baffle spacing (B) close to 0.2 D sand recalculate shell side heat transfer coefficient. However, this is subject to allowable pressure drop across the heat exchanger.

Step 12. Calculate % overdesign. Overdesign represents extra surface area provided beyond that required to compensate for fouling. Typical value of 10% or less is acceptable.

% Overdesign =-×100

A = design area of heat transfer in the exchanger; A_{reqd} =
required heat transfer area.

Step 13. Calculate the tube-side pressure drop ( )**:**

(i) pressure drop in the straight section of the tube (frictional loss) (ΔP t) and
(ii) return loss (ΔPrt) due to change of direction of fluid in a "multi-pass exchanger".

Total tube side pressure drop: ΔP T = ΔPt + ΔPrt

Step #14. Calculate shell side pressure drop ( )**:**
(i) pressure drop for flow across the tube bundle (frictional loss) (ΔPs) and
(ii) Return loss (Prs) due to change of direction of fluid.

Total shell side pressure drop: Ps= Ps+ Prs

If the tube-side pressure drop exceeds the allowable pressure drop for the process system, decrease the number of tube passes or increase number of tubes per pass. Go back to **step6** and repeat the calculations steps. If the shell-side pressure drop exceeds the allowable pressure drop, go back to **step #7**and repeat the calculations steps.

CHARACTERISTICS OF MATERIAL

Many industrial and chemical processes involve heating and cooling. Since heat represents money, heat exchanger is an extremely vital part of the process equipment.

Following materials are used in heat exchanger

❖ **STAINLESS STEEL**

The amount of stainless steel utilized in heat exchanger equipment is increasing as industry strives toward greater efficiency and reduced costly shutdown in its operation and higher product purity. As will be shown, stainless steel is sometimes the only material that can be used in other situations it is the most economical when cost of installation, maintenance and production stoppages are considered.

Following are ten good reasons for using stainless steels in heat exchange equipment:

1. Resistance to corrosion in virtually all cooling waters and many chemical environments.
2. High temperature resistance to oxidation and scaling.
3. Good strength characteristic in low and high temperature service.
4. Maintains excellent heat transfer properties in service.
5. Resistance to fouling due to corrosion.
6. No contamination of product or process by corrosion.
7. Easy to mechanical chemical.
8. Fabric ability.
9. Availability in a variety of compositions as –
   - Seamless &welded tubing for shell and tube heat exchangers.
   - Thin flat rolled sheet & strip for plate exchangers.
   - Plate for tube sheets
   - Bar and wire for mechanical fasteners
10. Economical in terms of Initial cost and long term service.

Choosing the right stainless steel

Selection of the right stainless steel from the many types available requires an evolution based upon four important criteria. Listed in order of descending importance, they are:

Corrosion resistance – The primary reason for specifying stainless steel. The specified needs to know the nature of the environment and degree of corrosion resistance required.

Cost performance – To put everything into proper perspective, a total value analysis is appropriate. How much is it going to cost spread over the entire service life? This considers first cost plus saving in maintenance and replacement.

Fabric ability – how the product is to be made is a third-level consideration. These include ability to be welded, formed etc.

Mechanical Properties –With particular emphasis on heat transfer characteristics and on strength at ambient. Elevated or

low temperature. Generally speaking, the combination of corrosion resistance and strength is the basis of selection.

Corrosion resistance -Corrosion has always been an important and costly problem facing the process engineer. The decision as to whether a chemical process is practical or not intimately related to the corrosivity of the process. Not only must equipment damage and repair under corrosion attack and subsequent repair be considered, but the danger of product loss or contamination must be eliminated.

❖ COPPER

Copper has many desirable properties for thermally efficient and durable heat exchangers. First and foremost, copper is an excellent conductor of heat. This means that copper's high thermal conductivity allows heat to pass through it quickly. Other desirable properties of copper in heat exchangers include its corrosion resistance, bio fouling resistance, maximum allowable stress and internal pressure, creep rapture strength, fatigue strength, hardness, thermal expansion, specific heat, antimicrobial properties, tensile strength, yield strength, high melting point, alloy-ability, ease of fabrication and ease of joining.

The combination of these properties enable copper to be specified for heat exchangers in industrial facilities, HVAC systems, vehicular coolers and radiators and heat sinks to cool computers, disk drives, television, computer monitors and other electronics equipment . Copper is also incorporated into the bottoms of high quality cookware because the metal conducts heat quickly and distributes it evenly.

Non-copper based heat exchangers are also available. Some alternative materials include aluminium, carbon steel, stainless steel, nickel alloys, and titanium.

WORKING

The two fluids that flow through the shell and tube heat exchanger will typically begin at different temperatures. One fluid will flow through the tube side while the other fluid will flow outside of the tubes on the shell side. Fluids may be either gases or liquids. In order to ensure that heat is transferred efficiently, the heat transfer area should be large. This makes it possible for any heat waste to be utilized, thus conserving energy.

Heat exchangers may feature only one phase, either gas or liquid, on each side. In this instance, they are known as single- phase or one-phase heat exchangers. In a two-phase heat exchanger, a liquid can be heated to the point that it is boiled into a gas or it may be used for the purpose of cooling a vapour, so that it can then be condensed into a liquid. Such phase changes typically take place on the shell side of the shell and tube heat exchanger. This type of heat exchanger may be used in a variety of different applications based on the specific needs of that industry. The shell and tube design can also include a variety of variations based on specific industrial needs. For instance, the tubes inside the exchanger may be U- shaped or they may be straight.

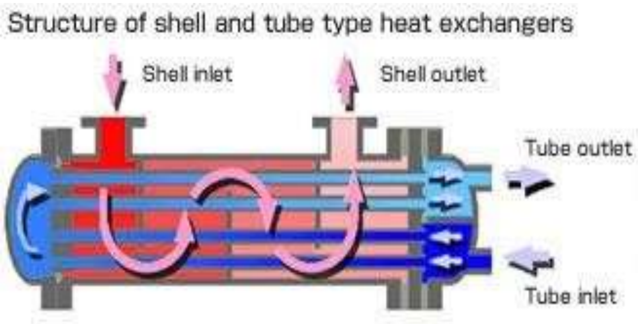


Figure :– Working of STHE

II. FABRICATION WORK

❖ CUTTING THIN STEEL SHEET

When cutting steel 1/8 inch or less in thickness, use the smallest cutting tip available. In addition, point the tip in the direction the torch is traveling. By tilting the tip, you give the preheating flames a chance to heat the metal ahead of the oxygen jet, as shown in figure 4-20. If you hold the tip perpendicular to the surface, you decrease the amount of preheated metal and the adjacent metal could cool the cut enough to prevent smooth cutting action. Many Steelworkers actually rest the edge of the tip on the metal during this process. If you use this method, be careful to keep the end of the preheating flame inner cone just above the metal.

❖ ROLLING

In metalworking, rolling is a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform. The concept is similar to the rolling of dough. Rolling is classified according to the temperature of the metal rolled. If the temperature of the metal is above its recrystallization temperature, then the process is known as hot rolling. If the temperature of the metal is below its recrystallization temperature, the process is known as cold rolling. In terms of usage, hot rolling processes more tonnage than any other manufacturing process, and cold rolling processes the most tonnage out of all cold working processes. Roll stands holding pairs of rolls are grouped together into rolling mills that can quickly process metal, typically steel, into products such as structural steel (I-beams, angle stock, channel stock, and so on), bar stock, and rails. Most steel mills have rolling mill divisions that convert the semi-finished casting products into finished products.

- **SURFACE GRINDING**

Surface grinding uses a rotating abrasive wheel to remove material, creating a flat surface. The tolerances that are normally achieved with grinding are ± 2 × 10−4 inches for grinding a flat material, and ± 3 × 10−4 inches for a parallel surface (in metric units: 5 μm for flat material and 8 μm for parallel surface).The surface grinder is composed of an abrasive wheel, a work holding device known as a chuck, either electromagnetic or vacuum, and a reciprocating table.

Grinding is commonly used on cast iron and various types of steel. These materials lend themselves to grinding because they can be held by the magnetic chuck commonly used on grinding machines, and they do not melt into the wheel, clogging it and preventing it from cutting. Materials that are less commonly ground are Aluminum, stainless steel, brass & plastics. These all tend to clog the cutting wheel more than steel & cast iron, but with special techniques it is possible to grind them.

- **DRILLING**

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips (swarf) from the hole as it is drilled.

- **GAS METAL ARC WELDING**

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt and join.

Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations.

Problem Description and Nomenclature

The thermal performance of a heat exchanger depends upon so many factors. Some of them are thermal conductivities of involved fluids and materials, velocity of flow, turbulence, quality and quantity of the insulation provided, ambient conditions flow conditions etc. To make any exact prediction about the performance of heat exchanger under a set of loading conditions is always a tough job. However by certain testing and experience predictions up to a certain level can be made. The present paper is also an attempt of analysing the performance of shell and tube type heat exchanger under certain specified loading conditions.

Nomenclature

m mass flow rate of fluid (kg/second)
specific heat of fluid (J/kg-)
C capacity rate of fluid (W/)
t temperature of fluid as used in designing (
)
t' experimental value of temperature of the fluid ( )
LMTD (or ΔT) Logarithmic Mean Temperature Difference (
)
Q amount of heat transfer taking place (watts) U or overall heat transfer coefficient (w/)
A area of heat exchanger ( )
ID inner diameter
OD outer diameter
l length of heat exchanger (m)

N number of tubes
tube bundle diameter (mm)
d diameter of tubes (mm)
D diameter of shell (mm)
B baffle spacing (mm)
Prandtl number
Reynold's number
Nu Nusselt number
h heat transfer coefficient (w/ °c)

Subscripts
I inner surface parameter
o outer surface parameter
t tube side parameter
s shell side parameter
w wall temperature parameter
h hot fluid parameter
c cold fluid parameter
1, 2 for inlet and outlet respectively

iii. Our next step is to calculate the area required of the heat exchanger (on the basis of assumed), number of tubes, tube bundle diameter, diameter of shell and its thickness with the help of following expressions:

iv. Then by the values obtained by the above equation we calculate the actual value of heat transfer coefficient and check whether the actual value is greater than the assumed one or not.
After rigorous mathematical calculations we have found out following values of interest:

0.25 ⁄

72

A = 1.235

12 mm

10 mm

12

= 300 mm

max maximum amount of the quantity

= 306

Constants
, constants depending on the pitch and type of pass

Manual Designing Using Kern's Method
Shell and tube heat exchangers are designed normally by using either Kern's method or Bell-Delaware method. Kern's method is mostly used for the preliminary design and provides conservative results whereas; the Bell-Delaware method is more accurate method and can provide detailed results. It can predict and estimate pressure drop and heat transfer coefficient with better accuracy. In this paper we have designed a simple counter flow shell and tube type heat exchanger to cool the water from 55 to 45 by using water at room temperature by using Kern's method. The steps of designing are described as follows:

i. First we consider the energy balance to find out the values of some unknown temperature values.

Certainly some inputs like hot fluid inlet and outlet temperatures, cold fluid inlet temperature, mass flow rate of the two fluids are needed to serve the purpose. The energy balance equation may be given as:

ii. Then we consider the LMTD expression to find its value:
Number of semi-circular baffles = 5 Diameter of semi-circular baffles = 300 mm
U = 850 – 1170 w/ (For water to water)
Practical Recordings under Counter Flow condition
Hot water flowing in tubes and cold water flowing in the shell

 = 72
= 55 (actual)
= 30
= 54
Where, and

Figure :-Logarithmic Mean Temperature Difference For Counter Flow
Heat balance equation
Heat loss by hot fluid = heat gain by cold fluid
………………………(1)

7. Tube coolers may be preferred for lubricating oil cooling because of the pressure differential
8. Condensation or boiling heat transfer can be accommodated in either the tubes or the shell, and the orientation can be horizontal or vertical. You may want to check out the orientation of the heat exchanger in our laboratory. Of course, single phases can be handled as well.
Q =
9. Thermal stresses can be accommodated inexpensively.

Q = 0.25 × 4.187 × (54-30) Q = 25.122 KW

Q =

25.122 = 0.25 × 4.187 × (72 -)

= 47.91 (Theoretically by heat balance equation)

The LMTD expression is

10. There is substantial flexibility regarding materials of construction to accommodate corrosion and other concerns. The shell and the tubes can be made of different materials.
11. Cleaning and repair are relatively straightforward, because the equipment can be dismantled for this purpose.

DISADVANTAGES

1. Heat transfer efficiency is less compared to plate type cooler
2. Cleaning and maintenance is difficult since a tube cooler requires enough clearance at one end to remove the tube nest

3. Capacity of tube cooler cannot be increased.

Where, and
LMTD =
LMTD = 20.34

Hear transfer area is given by

A = 1.235

ADVANTAGES
Here are the main advantages of shell-and-tube heat exchangers –

1. Less expensive as compared to Plate type coolers.
2. Can be used in systems with higher operating temperatures and pressures
3. Pressure drop across a tube cooler is less
4. Tube leaks are easily located and plugged since pressure test is comparatively easy
5. Tubular coolers in refrigeration system can act as receiver also.
6. Using sacrificial anodes protects the whole cooling system against corrosion

4. Requires more space in comparison to plate coolers

III. Conclusion

On the basis of above study it is clear that a lot of factors affect the performance of the heat exchanger and the effectiveness obtained by the formulas depicts the cumulative effect of all the factors over the performance of the heat exchanger. It may be said that the insulation is a good tool to increase the rate of heat transfer if used properly well below the level of critical thickness. Amongst the used materials the cotton wool and the tape have given the best values of effectiveness. Moreover the effectiveness of the heat exchanger also depends upon the value of turbulence provided. However it is also seen that there does not exists direct relation between the turbulence and effectiveness and effectiveness attains its peak at some intermediate value. The ambient conditions for which the heat exchanger was tested do not show any significant effect over the heat exchanger's performance.

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