A PROJECT REPORT ON HEAT EXCHANGERS

DRISHTI
A Revolutionary Concept

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Aim

To study the different types of heat exchangers and to design and maufacture the working model of **DOUBLE PIPE HEAT EXCHANGER** due to its simple design and better feasibility at laboratory scale.

Abstract

A double-pipe heat exchanger is a widely used equipment for transferring heat from one fluid to another in the industry. It consists of two concentrically arranged pipes or tubes, with one fluid flowing inside the inner pipe and the other in the annular region between the pipes. Special end fittings are used to get the fluids into and out of their respective flow channels and keep them from leaking into the atmosphere. The operation of a DPHE is enhanced by using auxiliary equipment like valves, pumps, meters, switches, and controllers.Operations are carried out per the requirements taking into consideration safety regulations.

This project aims to design and develop the best possible Heat Exchanger with the minimal expenditure.The project involved manufacturing and testing of a Double pipe Heat Exchanger at a laboratory scale.The final model was prepared in accordance with the calculations and design developed throughout the project duration.

Contents

1 Basics of Heat Exchangers

1.1 What Are Heat Exchangers??

Heat exchangers are devices which are used mainly to transfer heat from one fluid to another fluid. These media may be a gas, liquid, or a combination of both. The media may be separated by a solid wall to prevent mixing or may be in direct contact. Most exchangers consist of coiled pipes (which is generally made up material with high thermal conductivity) passing through a chamber which is generally whose outer coating is generally made up of insulating material to prevent heat loss.

The actual design of heat exchangers is a complicated task as it involves much more parameters along with heat transfer coefficients. One of the most common strategies to design heat exchanger at industry level Bell-Delaware method which considers the variation of heat transfer coefficient with baffle configuration and the occurring baffles phenomena such as leakage, pass partition bypass and many more.

The classic example of a heat exchanger is found in an internal combustion engine in which an engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. In power engineering, common applications of heat exchangers include steam generators, fan coolers, cooling water heat exchangers, and condensers. For example, steam generator is used to convert feed water into steam from heat produced in a nuclear reactor core. The steam produced drives the turbine.

1.2 Working of Heat Exchanger

It is a device that allows heat from one liquid (liquid or gas) to be transferred to another liquid or gas without the two-liquids mixing or coming into direct contact. They are used for cooling components featuring water to air, liquid-cooled, closed-loop systems.

1.3 Classification Of Heat Exchangers

1.3.1 On The Basis Of Operation

- **Recuperative Heat Exchanger/Recuperators**

  In a recuperative type of heat exchanger, cold and hot fluid flow through the unit without mixing with each other. Such heat exchangers have separate flow paths for each fluid and fluids flow simultaneously through the exchanger exchanging heat across the wall separating the flow paths. Most recuperators operate as counter-flow heat exchangers. Examples of recuperative heat exchangers are boilers, heaters, coolers, vaporizers, condensers etc.

- **Regenerative heat exchanger/regenerators/capacitive heat exchanger**

  Regenerative type of heat exchanger with the same heating surface is alternately exposed to hot and cold fluid. Heat associated with hot fluid is stored or absorbed by picking for solids.The hot fluid supply is then shut off and cold fluid is passed over pickings or solids to regenerate the heat.Examples of such types of heat exchangers are re generators of open hearth furnaces, glass melting furnaces etc.

  Recuperative and regenerative units can also be called surface condensers.

- **Direct Contact**

  In direct contact type of heat exchangers hot and cold fluids are in direct contact and mixing Occurs among them during the process of heat transfer.Mass transfer also occurs simultaneously. Examples of direct contact type of heat exchangers are spray columns, cooling towers, scrubbers etc.

1.3.2 On The Basis Of Flow

- **Co-current flow**

  In this type of flow both the fluids flow in the same direction. It is also known as parallel flow. This type of flow is used to get higher temperature difference and in this type of flow the temperature of outlet of cold fluid never exceeds the outlet temperature of hot fluid. In a parallel flow arrangement, the cold inlet and hot inlet are interacting with each other. At that entry point, the temperature difference is wide, and heat transfers quickly.

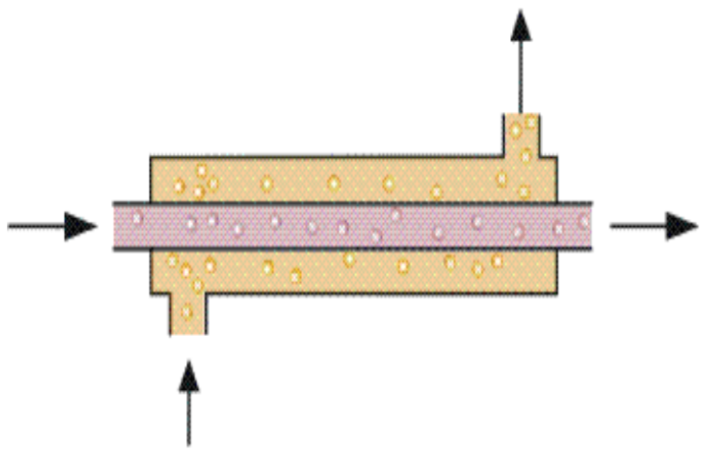

Figure 1: Co-current flow

As the streams pass through the parallel-flow exchanger, they start to approach each other's temperature. The heat transfer rate drops in line with the reduction in temperature difference.

- **Counter-current flow**

  In this type of flow the fluids can flow in opposite directions. In this flow the temperature distribution is constant through the length. In this type of flow the outlet temperature of cold fluid can exceed the outlet temperature of hot fluid.This type of flow is generally preferred when we want constant temperature distribution over the length of pipe.

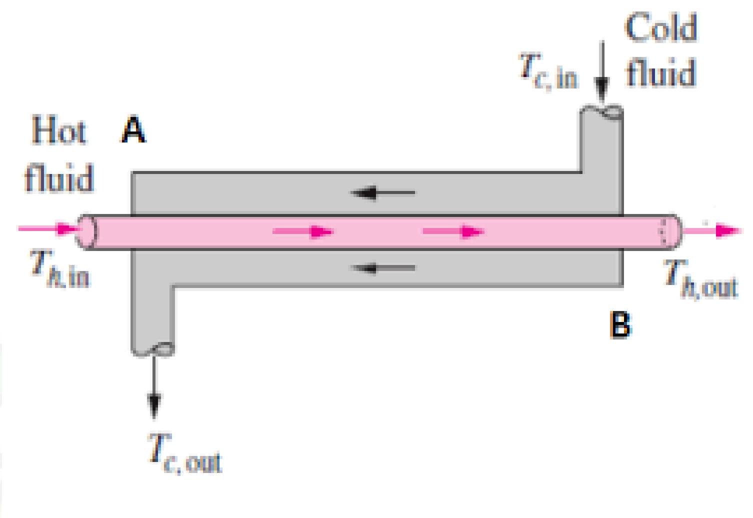

Figure 2: Coumter-current flow

- **Cross flow**

  In this type of flow the fluids flow in the perpendicular direction of each other. When one of the fluids undergoes a phase change, a cross-flow arrangement is suitable. In order to change the phase of a fluid, a large amount of heat is required because phase change operation involves latent and sensible heat, and along with that, we have to maintain a pressure drop across the tube. This can be achieved with cross flow, as it provides good thermal efficiency with reasonably compact construction.

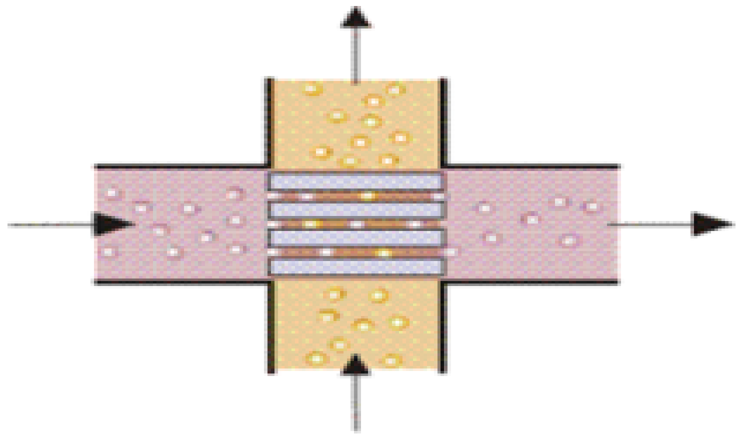

Figure 3: Cross flow

For a given flow rate and at the given inlet and outlet temperatures, a parallel flow heat exchanger requires a maximum flow area, whereas a cross flow heat exchanger, requires a minimum flow area, and a counter flow heat exchanger area lies between two extreme limits.

Application

1)The crossflow heat exchangers are used in refrigerators

2)They are also used in the cooling industries.

1.3.3 On The Basis Of Construction

- **Shell and Tube Heat Exchangers**

  These heat exchangers consist of a chamber which is known as shell and a pipe with small diameter is coiled in this chamber and this pipe is known as tubes.

  Basic components of shell and tube heat exchangers are:

  1)Tube bundles

  2)Tube Sheet

  3)Shell and Shell Side Nozzle

  4)Tube side channels and nozzles

  5)Tube Pitch

  6)Channel cover

  7)Fins

  8)Baffles

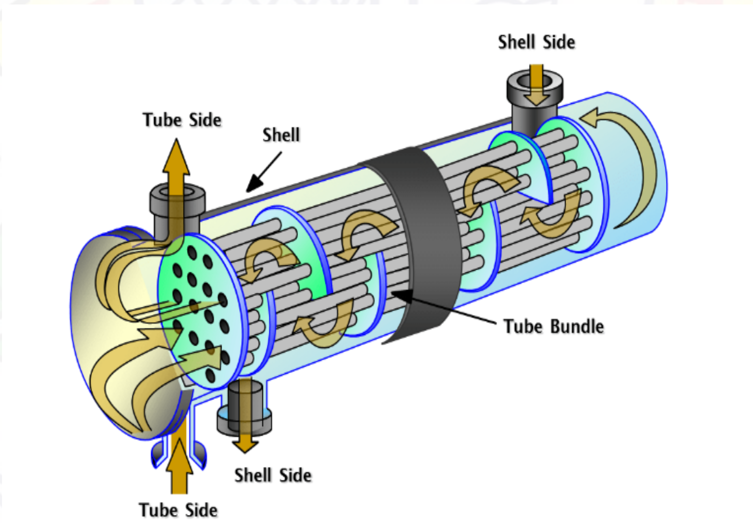

Figure 4: Shell and tube heat exchanger

The fluid flowing through the tubes will be decided majorly on ease of operation, frictional effects and purpose whether it is to be cooled or heated up. For example, in Gas +liquid heat exchanger it is difficult to push steam through the tubes and hence liquid is made as tube side fluid. In liquid +Liquid type the one which is having low viscosity is generally the tube fluid. And finally hot fluid is chosen as shell side fluid for effective heat transfer and of course it varies from one application to another

Heat exchangers have to be able to handle a wide range of temperatures, varying by application. Their ability to deal with extreme temperatures helps maintain production and keep operations moving. Shell and tube heat exchangers have a high temperature working capacity and can be adapted to fit any conditions

Applications

Shell and Tube heat exchangers are used for a variety of applications and meet the needs of an assortment of industries. Since they are available in different configurations, they can be adapted to the requirements of any manufacturing or production operation.

Why Shell and Tube is not feasible?

It is economically not feasible to manufacture at lab scale.
The designing part is complex and cumbersome to perform. A large sheet has to be rolled to create a shell hence leading to chances of leakage.

- **Flat Plate Heat Exchanger**

  Flat Plate Heat Exchanger consists of a series of metal plates, which are either welded together or brazed together or separated by gaskets. These plates are then compacted by placing them in a rigid frame in such a manner that the hot and cold fluids flow in alternate channels.Many Plate Heat Exchangers are made of corrugated plates on a frame. This creates high turbulence and high wall shear stress, resulting in a high heat transfer and a high fouling resistance.Plate Heat Exchangers utilize counter-current flow, where one fluid flows in the opposite direction of the other. Parallel flow is where both fluids move in the same direction, but this regime is uncommon in plate designs as plates work best in counter flow configuration.To withstand high pressure and temperature flat plate heat exchangers are made up of steel tubes (carbon, stainless, super alloys, etc.) rather than copper ones, as well as thicker gauges of aluminium fin material or different fin material, such as copper, carbon steel, and stainless steel to manufacture cost effective plate heat exchangers.

Flow Distribution

The simplest type of plate heat exchanger arrangement is that in which both fluids have only one passage, so no change occurs in the direction of the fluid flows.A notable advantage of the single-pass arrangement is that the inlets and outlets of the fluids can be mounted on the fixed plate, which makes it easy to maintain and clean the equipment without interrupting the work of the pipe. This design is known as the U-arrangement and is the most common single-pass design.

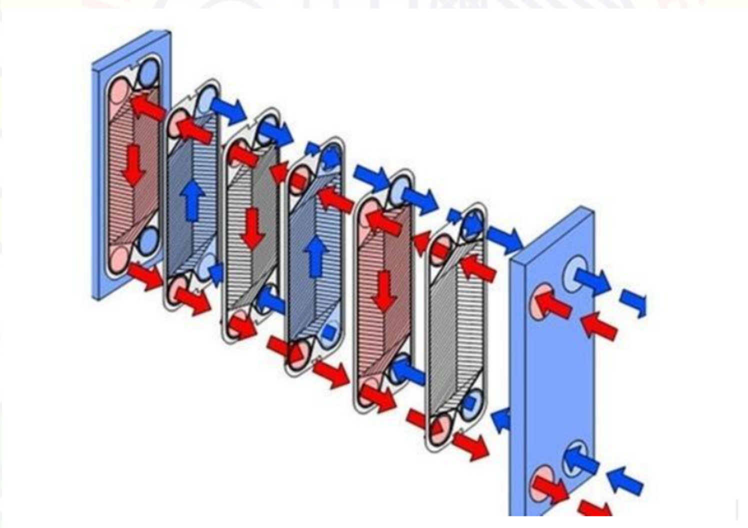

Figure 5: Flat plate heat exchangers

Types of Flat Plate heat exchangers

1)Brazed plate heat exchangers:

2)Gasketed plate heat exchanger:

3)Welded plate heat exchangers:

4)Semi-welded plate heat exchanger:

Applications Due to its compact and light-weight nature it is widely used in aircraft, aerospace,cryogenic industries etc

Why Flat Plate is not feasible?

The Flat Plate heat exchanger is very compact in size, so its manufacturing requires highly specialised instruments and extreme manufacturing conditions.To obtain a highly efficient heat exchanger we should ensure that the plates are sealed in an efficient manner

Due to considerations of such issues, it has been concluded that Flat Plate heat exchangers are not feasible at laboratory scale

- **Double Pipe Heat Exchanger**

It is the simplest type of heat exchanger consisting of two concentric pipes of different diameters.The double pipe heat exchanger is also known as **'pipe in pipe'**and**'tube in tube'** heat exchangers.

This type of heat exchanger is known as hairpin, jacketed pipe, jacketed u-tube, and pipe in pipe exchanger. They can contain one pipe or pipe bundle (less than 30), and the outer pipe must have a diameter of less than 200mm. In some cases, to increase the rate of heat transfer between working fluids, there are longitudinal fins in the inner tube.

The fin material need not be the same as the pipe material; for example, carbon steel fins can be attached to stainless steel pipes. Combinations of this type are used when a corrosion resistant alloy is needed for the inner fluid but not for the fluid in the annulus.

When heat is beginning to be transferred, this changes the temperature of the fluids. Until these temperatures reach a steady state, their behaviour is dependent on time.

The determination of the overall heat-transfer coefficient is necessary in order to determine the heat transferred from the inner pipe to the outer pipe. This coefficient takes into account all of the conductive and convective resistances (k and h, respectively) between fluids separated by the inner pipe, and also takes into account thermal resistances caused by fouling (rust, scaling, i.e.) on both sides of the inner pipe.

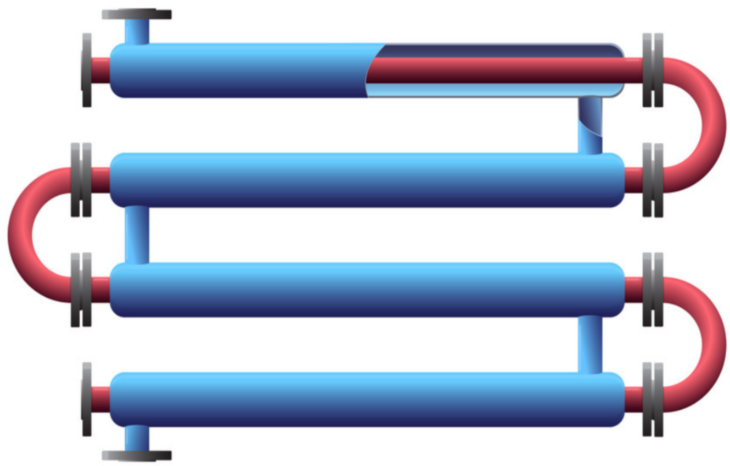

Figure 6: Double pipe heat exchangers

Construction Depending on the pipe configuration, double-pipe heat exchangers are classified into straight coiled pipes and helical coiled pipes . Helical coiled double-pipe heat exchangers are considered the most applicable type of heat exchangers in various industries including cooling applications because of their high performance, high heat transfer rate, and compact volume.In a double-pipe heat exchanger the inner pipe is made of a conductive metal and is thin.

Components The hotter flow is traversing the inner tube, while the outer shell contains the cold flow (note that this is not always the case). The double pipe heat exchanger works via conduction, where the heat from one flow is transferred through the inner pipe wall, which is made of a conductive material such as steel or aluminum.

Four Types of Flow in DPHE:-

1)Counter flow In this type of flow the fluid flows in opposite directions of each other.Cold side temperature at the outlet (T2out) can obtain temperatures close to the T1in, and as we know, this temperature is greater than T1out. In this type, the clod fluid temperature can reach more than the hot side outlet, while in the parallel one, it is impossible.

2)Parallel flow: In this type of flow both the fluid flows in the same direction of each other.

3)Cross flow: Both fluids flow at right angles to each other.

4)Hybrid: A novel hybrid shell and double pipe heat exchanger was fabricated and applied for intensification of heat transfer process. The heat transfer surface was increased using double pipes instead of simple tubes.

Feasibility of Double Pipe Double pipe heat exchangers are the simplest type of heat exchanger.It can be used to show the flow of heat in the most efficient way at lab scale.It is the most economical heat exchanger. Maintenance and operations of double pipe heat exchangers can be carried out in most efficient way.

Hairpins

Hairpin heat exchanger designs can increase heat transfer coefficients in single-pass process streams with high temperature differentials. A Hairpin Heat Exchanger and Double Pipe / Multi Tube Heat Exchanger can be described as a single pass shell and tube unit that has been folded in half to give it a hairpin appearance.

Hairpins lead to a pressure drop across the pipe and it's equivalent to half the length of straight pipe to maintain the same flow rate throughout the setup.

Figure 7: Hairpins

1.4 Why Double Pipe Heat Exchanger?

This type of exchanger has some unique advantages over other complicated heat exchangers.Some of them are as follows:

- The parts of double pipe heat exchangers are standardized.
- The maintainancce and repairing work of double pipe heat exchanger is quite easy.
- The double pipe heat exchnager have simple and flexible design such that addition and removal of parts can be done easily.
- Double pipe heat exchanger can withstand high pressure and high temperature.
- The design allows large thermal expansion without any expansion joint.

2 Terminologies

2.1 Fouling

Fouling is defined as the scaling, deposition of unwanted materials such as insoluble salts or even the growth of fungi on internal surfaces of heat exchangers. It results in changing the heat transfer surface and reducing the overall heat transfer rate through that surface. During fouling, the surface of a heat exchanger wall develops another layer of solid material.Types of Fouling are as follow:

1)Chemical Fouling
2)Biological Fouling
3)Deposition Fouling
4)Corrosion Fouling

Fouling Factor: The fouling factor represents the theoretical resistance to heat flow due to the build-up of a fouling layer on the tube surfaces of the heat exchanger.

The fouling factor is a mathematical value (usually referred to as Rf or Rd) that represents the thermal resistance of the deposit and is effectively a ratio between the transfer coefficient of a clean heat exchanger and the same unit after fouling.

2.2 Prandtl number

The Prandtl number is a dimensionless number.The Prandtl number is defined as the ratio of momentum diffusivity to thermal diffusivity.

$$Pr = \frac{c_p \mu}{k} = \frac{\nu}{\alpha}$$

Small values of the Prandtl number, Pr << 1 , means the thermal diffusivity dominates. Whereas with large values, Pr >> 1, the momentum diffusivity dominates the behavior.Prandtl number is dependent solely on the fluid and the fluid state. For a Prandtl number of unity, the momentum diffusivity equals the thermal diffusivity and the mechanism and rate of heat transfer are similar to those for momentum transfer. For many fluids, Pr lies in the range from 1 to 10. For gases, Pr is generally about 0.7.

2.3 Reynolds number

Reynolds number is a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. Reynolds number is defined by the ratio of inertial forces to that of viscous forces.

Inner pipe: $\operatorname{Re} i = \frac{4\dot{m}_i}{\pi Di,i\mu_i}$

Annulus between pipes: $\operatorname{Re} o = \frac{4\dot{m}_o}{\pi(Do,i+D_{i,o})\mu_o} = \frac{D_{\text{eq}}\dot{m}_o}{\mu_o S}$

If the Reynolds number calculated is high (greater than 4000), then the flow through the pipe is said to be turbulent. If Reynolds number is low (less than 2300), the flow is said to be laminar.If Reynolds number lies in the range of (2300 < Re < 4000),then flow is said to be transition flow.For fully developed turbulent flow reynolds number should be greater than 10000.

2.4 Conduction

Heat conduction is the transfer of heat by direct contact of particles of matter.It determines the total internal energy of the heat transfer system and drives the system to reach a heat energy balance.The rate of heat conduction is given by **fourier's law** which is given as:

$$q_s'' = -\, k_f \frac{\partial T}{\partial y}\bigg|_{y=0}$$

2.5 LMTD

LMTD is the logarithmic mean of temperature difference of the fluids at both the sides of the heat exchangers,which is used to determine the temperature driving force for heat transfer in heat exchangers.

$$\Delta T_{\text{lm}} = \frac{(T_s - T_i) - (T_s - T_o)}{\ln\left(\frac{T_s - T_i}{T_s - T_o}\right)}$$

It is used in the calculation of heat exchanger because the rate of cooling or the temperature change in the heat exchanger is not linear and thus follow an exponential curve.

2.5.1 LMTD Correction factor

Double Pipe Heat Exchanger Series/Parallel Configurations of Hairpins To account for the departure from true counter-flow in series-parallel configurations, the counter-flow logarithmic mean temperature difference (LMTD) is multiplied by a correction factor, F, given by the following equations:

$$F = \left[\frac{(R-x)}{x(R-1)}\right] \frac{\ln[(1-P)/(1-PR)]}{\ln\left[\frac{(R-x)}{R(1-PR)^{1/x}} + \frac{x}{R}\right]} \quad (R \neq 1) \quad F = \frac{P(1-x)}{x(1-P)\ln\left[\frac{(1-x)}{(1-P)^{1/x}} + x\right]} \quad (R = 1)$$

where P is given by

$$P = (t_b - t_a) / (T_a - t_a)$$

x = number of parallel branches $R = (T_a - T_b) / (t_b - t_a)$
T_a $\mathrm{T_b}$ = inlet and outlet temperatures of series stream
$t_a\mathrm{t_b}$ = inlet and outlet temperatures of parallel stream

Heat Flow equation is given by $Q = FUALMTD$ where F is interpreted as a geometric correction factor,that when applied to the LMTD of a counter flow heat exchanger, provides the effective temperature difference of the heat exchanger under consideration. The correction factor is a measure of the heat exchanger's departure from the ideal behavior of a counter flow heat exchanger having the same terminal temperatures. The F-LMTD method is widely used in heat exchanger analysis, particularly for heat exchanger selection.

2.6 Nusselt number

The Nusselt number is the ratio of convective to conductive heat transfer across a boundary.It is an important parameter in heat exchanger device and is dependant on Reynolds and Prandlt Number. Here h_i is given by:

For turbulent flow ($Re \geq 10^4$), the Seider-Tate equation is used in the form:

$$\mathrm{Nu} = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3}\left(\frac{\mu}{\mu_{\mathrm{wall}}}\right)^{0.14}$$

For the transition region ($2100 < Re < 10^4$), the Hausen equation is used:

$$Nu = 0.116\left[R^{2/3} - 125\right]\mathrm{Pr}^{1/3}\,(\mu/\mu_w)^{0.14}\left[1 + (D_i/L)^{2/3}\right]$$

For laminar flow ($Re \leq 2100$) in pipes, the Sieder-Tate equation is used:

$$Nu = 1.86\,[\mathrm{Re}\,\mathrm{Pr}\,D_i/L]^{1/3}\,(\mu/\mu_w)^{0.14}$$

2.7 Heat transfer coefficient

Heat transfer coefficient is a quantitative characteristic of convective heat transfer between a fluid medium a fluid and the surface wall flowed over by the fluid. The formula for DPHE is given by:

Individual Heat Transfer Coefficients are given by-

$$h_o = \frac{k}{D_e} \times 0.116 \left[R^{2/3} - 125\right] \mathrm{Pr}^{1/3}$$

Hydraulic Mean Diameter is often used to calculate the heat transfer coefficient

$$D_e = 4r_h = \frac{4 \times \text{ flow area}}{\text{wetted perimeter}} = \frac{4\pi\left(D_2^2 - D_1^2\right)}{4\pi D_1} = \frac{D_2^2 - D_1^2}{D_1}$$

$$D_9' = \frac{4 \times \text{ flow area}}{\text{frictional wetted perimeter}} = \frac{4\pi\left(D_2^2 - D_1^2\right)}{4\pi\left(D_2 + D_1\right)} = D_2 - D_1$$

The mean wall temperature of the inner pipe is given by:

$$T_w = \frac{h_i t_{ave} + h_o\left(D_o/D_i\right) T_{ave}}{h_i + h_o\left(D_o/D_i\right)}$$

The overall heat transfer coefficient is necessary in order to determine the heat transferred from the inner pipe to the outer pipe. The coefficient takes into account all of the conductive and convective resistances between fluids separated by the inner pipe and also takes into account thermal resistances caused by fouling (rust, scaling, etc) on both sides of the inner pipe.

We can calculate overall heat transfer coefficient by considering dirt factor:

$$U_D = \left[\frac{D_o}{h_i D_i} + \frac{D_o \ln\left(D_o/D_i\right)}{2k} + \frac{1}{h_0} + \frac{(R_{Di} D_0}{D_i} + R_D\right]^{-1}$$

For a DPHE the required surface area and number of hairpins is given by:

$$q = U_D A \Delta T_{\ln} \quad ; A = \frac{q}{U_D \Delta T_{\ln}}$$

Length of of Hairpin (L) can be calculated as:

$$L = \frac{A}{circumference}$$

We observe a Pressure drop across the height of the Heat Exchanger due to variable flow rate at the two ends of the Heat exchanger. Hence pressure drop Pressure drop in straight section of pipe is given by:

$$\Delta P_f = \frac{(f)LG^2}{7.50 \times 10^{12} D_i s \phi}$$

$\Delta P_r = 1.6 \times 10^{-13} \left(2N_{HP} - 1\right) G^2/s$ (turbulent flow)
$\Delta P_r = 2.0 \times 10^{-13} \left(2N_{HP} - 1\right) G^2/s$ (laminar flow, $Re \geq 500$)

No. of hairpins= $L/2^{*}lengthofhairpin$

2.8 Fanning friction factor

Fanning Friction Factor there are two common friction factors in use, the Darcy and the Fanning friction factors. The Fanning friction factor, named after John Thomas Fanning, is a dimensionless number, that is one-fourth of the Darcy friction factor, so attention must be paid to note which one of these is used as the friction factor.

For laminar flow in the inner pipe $f = 64/Re$

For turbulent flow $f = 0.3673Re^{-0.2314}$

3 Designing

3.1 Design Calculations

Our Aim is to calculate the Length of the pipe required for the best efficient heat transfer conditions

Step 1 : We consider the inlet and outlet temperature of both the Hot and Cold Fluids passing through the Heat Exchanger.

Calculate the physical properties of fluid at average temperature of hot and cold liquids.for example viscosity,specific heat,density and thermal conductivity.

$$\mu = f(T)$$
$$C_p = f(T)$$
$$K = f(T)$$
$$\rho = f(T)$$

Step 2: Here we calculate logarithmic mean temperature difference (LMTD):

$$\Delta T_1 = T_{hi} - T_{ci} \tag{1}$$
$$\Delta T_2 = T_{ho} - T_{co} \tag{2}$$
$$LMTD = \frac{(\Delta T_1 - \Delta T_2)}{log\frac{(\Delta T_1}{\Delta T_2)}} \tag{3}$$

Step 3: calculate h_i (heat transfer coefficient inside the tube)
For a flow through circular tube:

For turbulent flow- Sieder tate equation :

$$Nu = 0.023Re^{0.8}Pr^{1/3}(\frac{\mu}{\mu_w})^{0.14}$$

For transition region- Hausen equation:

$$Nu = 3.66 + \frac{0.068(R_eP_r\frac{D}{L})}{1+0.04(R_eP_r\frac{D}{L})^{2/3}}$$

For laminar flow- Dittus-boelter equation :

$$Nu = 0.023RePr(\frac{\mu}{\mu_w})^{0.14}(\frac{D_i}{L})^{0.14}$$

where D_i is the inside diameter of inner pipe we've used a 2.5 inch outer pipe and a schedule 40s inner pipe

Step 4: To calculate the heat transfer coefficient h_o the heat transfer coefficient of outside of inner pipe:

$$h_0 = (0.116)(\frac{K}{D_{eq}})(Re^{2/3} - 125)Pr^{1/3}$$

$$D_{eq} = D_1 - D_2$$

Step 5: Compute pipe wall temperature to caculate the viscosity of the fluid flowing inside:

$$T_w = \frac{h_i t_{avg} + h_o}{h_i + h_o(\frac{D_o}{D_i})}$$

Step 6: Calculate the viscosity correction factors for turbulent flow :

$$(\frac{\mu}{\mu_w})^{0.14}$$

Calculate the viscosity correction factors for laminar flow :

$$(\frac{\mu}{\mu_w})^{0.25}$$

Step 7: calculate the overall heat transfer coefficient with the consideration of dirt factor compute:

$$U_o = [\frac{D_o}{h_i D_i} + \frac{D_o ln(\frac{D_o}{D_i})}{2k} + \frac{1}{h_o} + \frac{R_i D_o}{D_i} + R_o]^{-1}$$

Step 8: Calculate the required surface area and no of hairpins:

$$q = U_o A \Delta T_{lm}$$

$$Area(A) = \frac{q}{U_o \Delta T_{lm}}$$

The required length of heat exchanger will be:

$$Length(L) = \frac{A}{Circumference}$$

Step 9: Pressure drop in a double pipe heat exchanger will be given as:

$$\Delta P_f = \frac{(fLG^2)}{(7.5)(10)^{12} D_i S\phi)}$$

3.2 Materials Required:

On the basis above performed calculations, we chose the most efficient and economical material design as follows.

3.2.1 Inner Pipe

The inner pipe material is made up Mild Steel (MS) which has a thermal conductivity of 45 W/m K.It was chosen considering economic as well as the efficiency factors.The diameter of MS pipe is 1.5 inch 40 Schedule Number and the heat transfer length is 2.74m through which the hot fluid flows.

3.2.2 Outer Pipe

The outer pipe is made of PVC of grade 3 Schedule No. 40 with 2.5 inch diameter providing an insulation to the atmosphere due to its Thermal Conductivity of just 0.18 W/m K.The cold fluid flowing in the Annular region transfers heat to the outer pipe which gets minimised due to PVC.

3.2.3 Elbows

Two 90 degree Galvanised Iron (G.I.) elbows of are utilised for creating a structure similar to U-bend Hairpins.They are threaded on both ends for proper fittings with the inner pipe of 1.5 inches.

3.2.4 Coupling

Couplings are important for connecting two two elbows to create a Hairpin and four such to connect the elbows with the inner pipe for smooth flow,These fittings have sockets at both ends which are fastened with the pipes.

3.2.5 Rubber Corks

A rubber cork of 2.5 inch was utilised as a stopper at both ends of the three pipes for blocking the flow of the cold fluid in annular region. A concentric hole of 1.5 inch is created in each of Six corks for allowing the inner MS pipe to pass through it.

3.2.6 Pipe Joints

Tee-Joints of PVC of 2.5 inch dia were used to connect two parallel outer pipes fot the smooth flow of cold flow.It is assembled in such a way that least amount of dead zone as well as least pressure drop is created.

3.2.7 Reducers

Reducers of various fittings were required for connecting the Pipes of the DPHE with the reservoirs and the pump.PVC reducers were broadly used because of economic constraints.

3.2.8 Miscellaneous

M-seal,Plumbing Glue and Silicon tapes were utilised for keeping all the leaks in check. An inclined stand was created for the whole Heat Exchanger to rest upon. It is built of waterproof Plywood along with supports attached to support the setup.

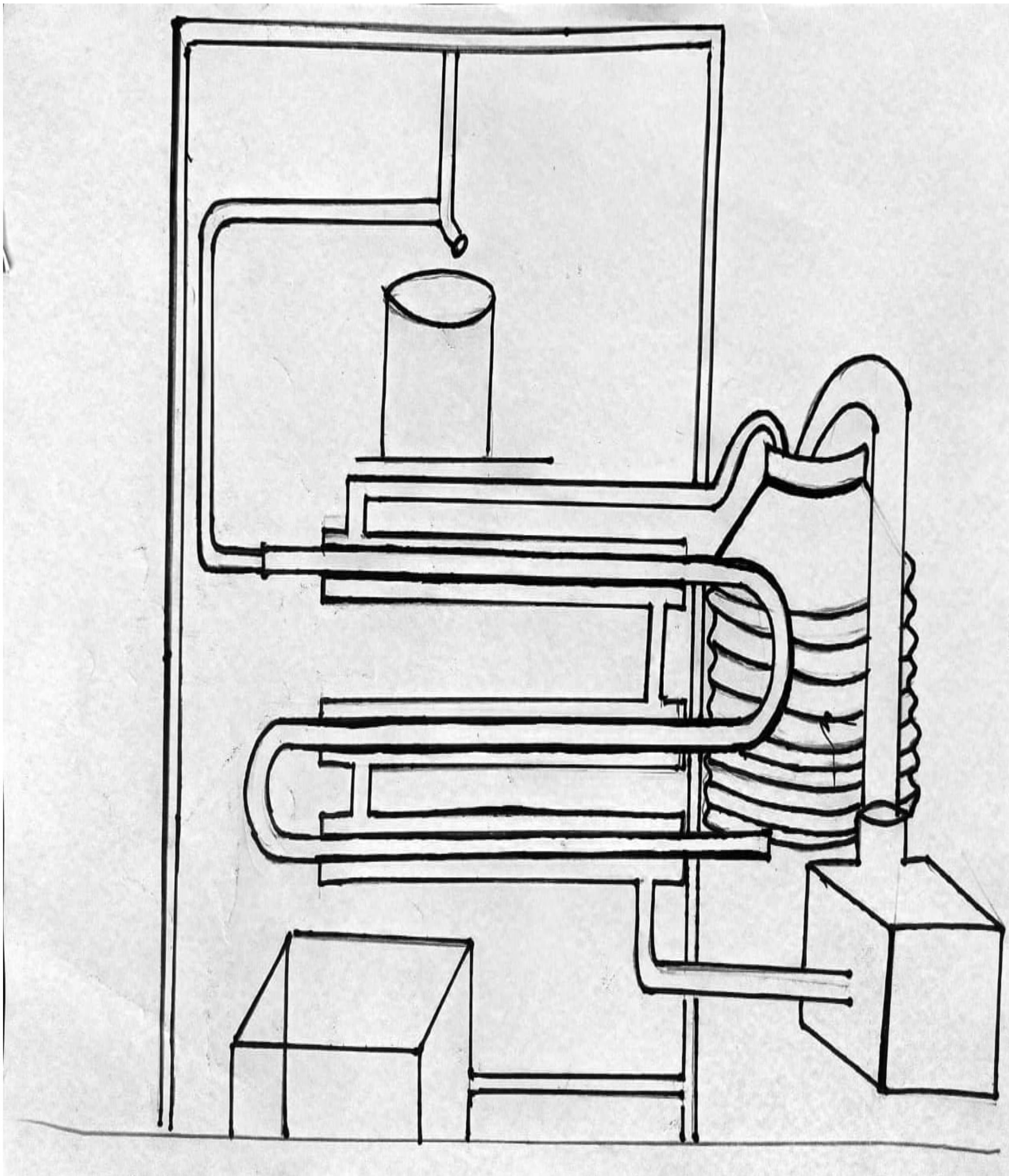

Figure 8: Final design of our model

4 Observations

OBSERVATION TABLE 1:

Reading									
Sr.No	Set	Qh	Qc	m_h	m_c	Th,i	Th,o	Tc,i	Tc,o
1.		73.33	198.4	0.07186	0.197	63.5	58.5	27	32
2.		73.33	198.41	0.07201	0.1976	62	55.5	27	32
3.	I	73.33	198.41	0.07204	0.1976	62	54.4	27	32
4.		73.33	198.41	0.0722	0.19757	60	51	27	31.5
1.		66	185.41	0.065	0.186	58.5	53	27	32.5
2.		66	185.41	0.06504	0.7	58	51	27	32.50
3.	II	66	185.41	0.06506	0.1846	57	50.5	27	32
4.		66	185.41	0.06512	0.1846	56	49.5	27	32
1.		66	128.73	0.0648	0.1284	60.7	56	27	36
2.		66	128.73	0.0648	0.1284	60.7	56	27	35.5
3.	III	66	128.73	0.0649	0.1286	60.7	56	27	36
4.		66	128.73	0.06501	0.1288	58	53	27	36
5.		66	128.73	0.06503	0.1305	57	52.5	27	36.25

Table 1: Table showing Experimental Parameters

OBSERVATION TABLE 2:

Reading							
Sr. No.	Set	$T_{h,m}$	$T_{c,m}$	LMTD	q_h	q_c	U_i
1.	I	61	29.5	31.5	1505.47	4129.84	106.53
2.		58.75	29.5	29.2435	1961.9	4129.84	149.49
3.		57.7	29.5	28.1924	1992.19	4129.84	157.52
4.		55.5	29.25	26.1856	2722.66	3716.29	231.78
1.	II	55.75	29.625	26.1248	1497.92	4264.25	127.81
2.		54.5	29.75	25.7492	1903.07	4246.53	164.75
3.		53.75	29.5	25.6843	2039.63	3858.14	177.02
4.		52.75	29.5	23.2419	1769.31	3858.14	169.69
1.	III	58.35	31.5	26.7925	1276.11	4830.41	106.173
2.		58.35	31.25	27.055	1276.5	4562.052	105.19
3.		56.75	31.5	25.209	1495.62	4837.93	132.25
4.		55.5	31.5	23.944	1361.95	4845.46	126.79
5.		54.75	31.625	23.043	1223.21	5045.78	118.33

Table 2: Table showing Calculated Parameters

5 Corrections And Inferences

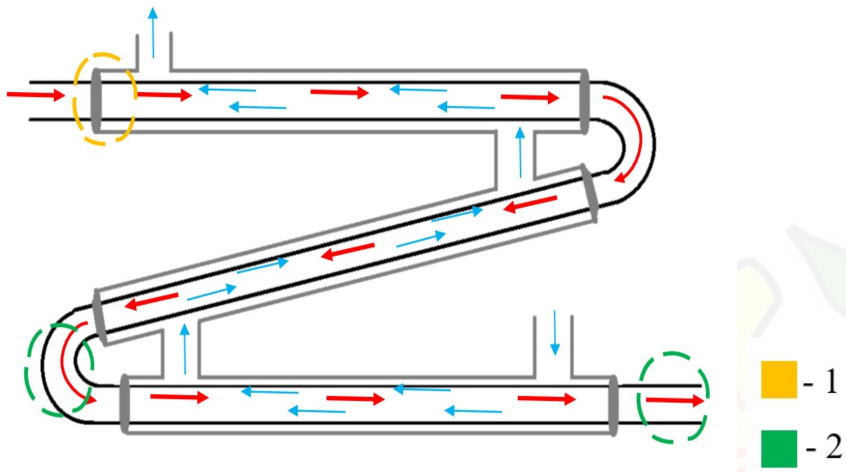

Figure 9: Corrections And Inferences

1 - Rubber corks attached to the ends of PVC pipes produce a dampened zone where fluid remains stagnant; this increases the fluid's retention time with the metal pipe, forcing it to absorb more energy than the energy released by hot fluid. Consequently, this error is reflected in the outlet temperatures of both fluids.

2 - At the bends of metal pipes and areas where they are exposed to the atmosphere, additional heat loss occurs, increasing the temperature difference between the inlet and outlet of a hot fluid.

PVC pipe has a Thermal Conductivity of 0.25W/mK . This amount, though minor, contributes for a significant energy loss from the PVC pipe to the environment due to the larger length of pipe; hence, the estimated values for the net effective heat transfer to the cold fluid vary from the theoretical values.

6 Result

The Average values of LMTD, Heat Flow rate and Overall Heat transfer Coefficient for Hot fluid is found to be
LMTD = 24.428 °C
Heat Flow Rate = 1572.975 W,
Overall Heat Transfer Coefficient = 133.87 W/m^2 °C.

The rate of heat transfer is largely affected by the flow rate of both the fluids,dead zones,insulation provided and the length of the pipes.

7 Outlook of the Project

Figure 10: Initial phase of project

Figure 11: Working phase of project

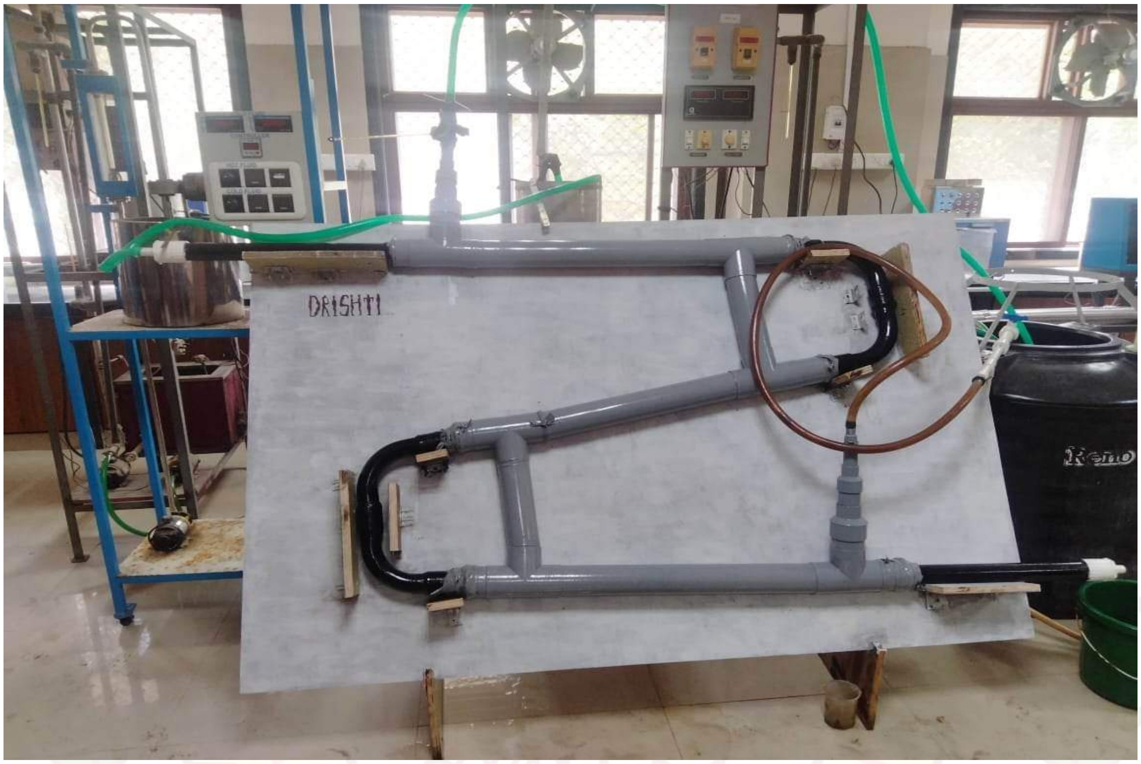

Figure 12: Final Outlook of project

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8 Industrial Applications of DPHE

Features of double pipe heat exchanger like high efficiency,international quality standards,low maintenance cost,quick heat transfer make it appropriate for many industrial uses:-

- Double pipe heat exchangers are used in many industrial processes, cooling technology, refrigeration device, sustainable energy applications and another field.
- They have a simple, compact and robust design and hence are a great choice in the industries if the heat transfer area required is low.
- Double tube heat exchangers are used in compressors and boilers due to their extremely high pressure and temperature.
- They are found in fields ranging from petroleum refining to refrigeration to sewage treatment to space heating, so it is clear that the possibilities are endless with such a useful, elegant design.
- Double Pipe Heat exchangers (DPHE) are extensively used in high voltage and air conditioning, bioprocessing industries etc.

9 Conclusion

Hence the above designed Double Pipe Heat Exchanger is one of the most effective comprehensive working model under given economic constraints.While designing the heat exchanger, we had many discussions to finalize the materials of construction, the dimensions of DPHE, the number of passes, and the type of flow to arrive at an optimum design. After finalizing the model and manufacturing it, we conducted experiments to study the effects of mass flow rate and terminal temperatures on the amount of heat transfer and log mean temperature difference.

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[6] Working and Design parameters
[7] Log Mean Temperature Difference
[8] Comprehensive Design of a DPHE