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# Influence of Pressure Drop, Reynolds Number and Temperature in the Design of Double Pipe Heat Exchanger on Cold Fluid Side in Outer Pipe

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***Abstract:*** *Heat exchanger is a heat transfer device that is used for transfer of internal thermal energy between two or more fluids available at different temperatures. Heat exchanger is one of the important devices in cooling and heating process in the process, power, petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, building, and others. In the present study, heat transfer from hot lubricant oil to cold water by double pipe heat exchanger which consist concentric tube for experimental setup, fabrication criteria are given. The length and diameter of the outer tube where cold water is flowing is very important design criteria apart from other parameters. Optimum values for various parameters for the design of the heat exchanger also taken, based on several calculations which are presented in this paper. The inlet and outlet temperatures are measured by using thermocouples at various locations. A feature of heat exchanger design is the process of specifying a design, Heat transfer area, pressure drop, Reynolds number and Temperature are checking whether the assumed design satisfies all requirement or not. The idea of this paper is how to design the double pipe heat exchanger which is the majority type of liquid –to- liquid heat exchanger. General design consideration and design processes are also illustrated in this paper. Also the main components of heat exchanger are shown in drawing and its detail discussion is given.*

***Keywords:*** *Coefficient of heat transfer, Double pipe Heat Exchanger, length and diameter, overall heat transfer coefficient*

## I. Introduction:

Heat exchanger is a special equipment type because when heat exchanger indirectly fired by a combustion process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger make a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, boiler, condenser etc. Heat exchanger may be designed for chemical reactions or energy-generation processes which become an integral part of reaction system such as a nuclear reactor, catalytic reactor or polymer. Normally, heat exchanger is used only for the transfer and useful elimination or recovery of heat without changing in phase. The fluids on either side of the barrier usually liquids but they can be gasses such as steam, air and hydrocarbon vapor or can be liquid metals such as sodium or mercury. In some application, heat exchanger fluids may use fused salts.

Horizontal double pipe heat exchanger uses various inserts inside tube so as to enhance heat transfer and hence increase heat transfer coefficient. These types of heat exchangers found their applications in heat recovery processes, air conditioning and refrigeration systems, chemical reactors, and food and dairy processes. The double pipe heat exchanger would normally be used for many continuous systems having small to medium duties. This double pipe heat exchanger is a device which transferred the heat from hot medium to cold medium without mixed both of medium since both mediums are separated with a solid wall generally. There are many types of heat exchanger that used based on the application. For example, double pipe heat exchanger is used in chemical process like condensing the vapor to the liquid. For this type of heat exchanger, the outlet temperature for both hot and cold fluids that produced is estimated by using the best design.

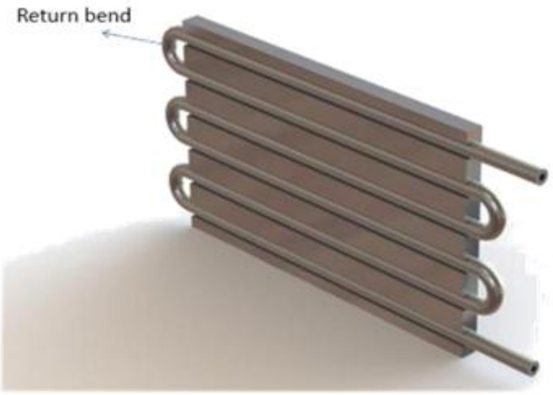


**Fig1:** Double pipe Heat Exchanger

The double pipe heat exchanger is used in industry such as condenser for chemical process and cooling fluid process. This double pipe heat exchanger is designed in a large size for large application in industry. For this research, the small heat exchanger of double pipe type is constructed which wants to make it practicality in such in cooling the hot lubricant oil from engine or any other machine. There are three modes of heat transfer conduction, convection and radiation. In heat exchanger compared with conduction and convection, radiation doesn't make major role. Conduction occurs due to heat transfer from higher temperature and passes through the solid wall. For maximum heat transfer, the wall should be thin and made with a very high conductive material. A double pipe heat exchanger are commonly used in where lower flow rates and high temperatures or pressures. Other advantages include low installation cost, ease of maintenance, and flexibility.

Jiangfeng Guo et al [1] given a new shell-and-tube heat exchanger optimization design approach is developed, wherein the dimensionless entropy generation rate obtained by scaling the entropy generation on the ratio of the heat transfer rate to the inlet temperature of cold fluid is employed as the objective function, some geometrical parameters of the shell-and-tube heat exchanger are taken as the design variables and the genetic algorithm is applied to solve the associated optimization problem. It is shown that for the case that the heat duty is given, not only can the optimization design increase the heat exchanger effectiveness significantly, but also decrease the pumping power dramatically. In the case that the heat transfer area is fixed, the benefit from the increase of the heat exchanger effectiveness is much more than the increasing cost of the pumping power. O.N. Sara et al [2] the available objective functions for heat exchanger optimization designs may be classified into two groups, one is based on the first law of thermodynamics and another is based on the combination of the first and second law of thermodynamics. In recent decades the second group has aroused widespread interest, which includes the entropy and exergy. Based on the concept of entropy, several heat exchanger performance criteria were developed; these criteria have their own characteristics and constraints, but also are interrelated as described. Among them the entropy generation number is the most frequently applied one proposed by Bejan [3–5], and entropy generation minimization (EGM) has been widely applied to the optimization design of heat exchangers. Bejan [4] demonstrated that EGM may be used by itself in the preliminary stages of design, in order to identify trends and the existence of optimization opportunities. Vargas et al. [6] presented an approach to determine the internal geometric configuration of a tube bank by optimizing the global performance of the installation that uses the cross flow heat exchanger. Based on the EGM, Ogˇulatu et al. [7] analytically carried out an optimization design of a cross flow plate heat exchanger, and examined the optimum result by the experimental data.

From our knowledge the applications related to the EGM are mainly based on the dimensionless entropy generation defined by scaling the entropy generation rate on the heat capacity rate. However it was found that the entropy generation number (EGN) defined in such a manner exhibits the so-called 'entropy generation paradox [8,9]. In order to avoid this paradox the ratio of heat transfer rate to the cold fluid inlet temperature can be employed to non-dimensionalise the entropy generation rate [8]. The obtained dimensionless entropy generation number is called as the modified entropy generation number in the following discussion and employed as the objective function in our heat exchanger optimization design approach. Usually the heat exchanger optimization design with multiple design variables is more practicable, and its global optimum solution is more desirable. The genetic algorithm is a powerful tool to address the multi-variable optimization problems. Recently the application of genetic algorithm on thermal engineering has received much attention [10–12]. In order to get the shell side pressure drop, it needs to calculate the ideal pressure drops in cross flow section and window section, correct them by the effective correction factors, and finally sum all the components to give the total shell pressure drop [13, 14].

**Selection Criteria:**

The primary criteria are type of fluids to be handled, operating pressures and temperatures, flow rates, and cost etc. the fluids involved in heat transfer can be characterized by temperature, pressure, phase, physical properties, toxicity, corrosivity etc. operating conditions for heat exchangers vary over a very wide range, and a broad spectrum of demands is imposed for their design and performance. All of these must be considered when assessing the type of unit to be used. The following parameters are very important for while selecting a particular exchanger.

1. Materials of construction
2. Operating pressure
3. Operating temperature
4. Temperature driving force
5. Flow rates
6. Flow arrangements
7. Performance parameters-thermal effectiveness and pressure drops
8. Fouling tendencies
9. Types and phases of fluids
10. Maintenance, inspection, cleaning, extension, and repair possibilities
11. Overall economy
12. Fabrication techniques

**1. Materials of construction:**

For reliable and continuous use, the material plays very important role in heat exchangers. The material should exhibit strength to withstand the operating temperature and pressure, corrosion. And the materials also should be easily pressed or welded.

**2. Operating pressure**

The operating pressure is very important to design, fabricate to operate heat exchanger. Which plays role in selecting the thickness, generally as the higher the pressure, the greater the required thickness and vice versa.

**3. Operating temperature**

This parameter is important as it indicates whether a material at the design temperature can withstand the operating temperature and various loads imposed on the component. For low-temperature and cryogenic applications, toughness is a prime requirement, and for high temperature applications the material has to exhibit creep resistance.

**4. Temperature driving force**

The effective temperature driving force is a measure of the actual potential for heat transfer that exists at the design conditions. With a counter flow arrangement, the effective temperature difference is defined the log mean temperature difference (LMTD). For other flow arrangements LMTD must be corrected by a correction factor, F.

**5. Flow rate**

It determines the flow area, higher the flow rate, higher will be the flow area. Higher flow area is required to limit the flow velocity. Sometimes, a minimum flow velocity is necessary to improve heat transfer to eliminate stagnant areas and to minimize fouling.

**6. Flow arrangement**

The choice of a particular flow arrangement is dependent upon the required exchanger effectiveness, exchanger construction type, upstream and downstream ducting, packaging envelope, and other design criteria.

**7. Performance parameters: thermal effectiveness and pressure drops**

**Thermal effectiveness:** for high performance service requiring high thermal effectiveness, use brazed plate-fin exchangers and regenerators and for slightly less thermal effectiveness use tube-fin exchangers and for low-thermal effectiveness service use shell and tube units.

**Pressure drop:** it is also very important parameter in heat exchanger design. Limitations may be imposed either by pumping cost or by process or both. The heat exchanger should be designed to avoid pressure drop to the maximum extent in areas like inlet and outlet bends, nozzles, and manifolds.

**8. Fouling tendencies**

Fouling is defined as the formation of undesirable deposits that impede the heat transfer and increase the resistance to fluid flow, resulting in higher pressure drop etc in a heat exchanger. The growth of these deposits causes the thermo hydraulic performance of heat exchanger to decline with time. It effects on energy consumption and extra material is required to provide extra heat transfer surface to compensate this effect.

**9. Types and phases of fluids**

Various combinations of fluid phases in heat exchangers are liquid-liquid, liquid-gas, and gas-gas. But generally the liquid phase fluids are simplest to deal with. The high density and the favorable values of many transport properties allow high heat transfer coefficients to be obtained at relatively low-pressure drops.

**10. Maintenance, inspection, cleaning, repair, and extension aspects:**

The above aspects are very important while selecting a heat exchanger. Some of the heat exchanger types offer great variations in design; hence care must be taken while designing so.

**11. Overall economy:**

While designing a heat exchanger two major costs are to be considering viz., the manufacturing cost and the operating cost, including maintenance costs. Obviously, less the heat transfer surface area and less the complexity of the design, the lower is the manufacturing cost. Majorly the operating cost is the pumping cost such as fans, blowers and pumps. And the maintenance cost includes the costs of spares that require frequent renewal due to corrosion/fouling prevention and control. Hence, the heat exchanger design requires a proper balance between thermal sizing and pressure drop.

**12. Fabrication Techniques**

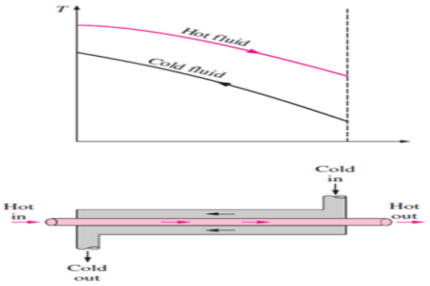
Fabrication techniques are likely to be the determining factor in the selection of a heat transfer surface matrix or core. For instance, shell and tube units are mostly fabricated by welding, plate-fin heat exchangers and automobile aluminum radiators by brazing, copper-brass radiators by soldering, most of the circular tube-fin exchangers by mechanical assembling etc.

## II. Experimental Set Up:

**Fig 2:** experimental set up

The important parts of experimental set-up are the test section containing horizontal concentric copper pipes, hot lubricating oil tank and cold water tank, Rota meters, pumps, sensors etc. All these instruments are selected as per the requirements depending upon their measuring range, accuracy and availability in the market. The test section is made up of copper tubes as it has higher thermal conductivity.

To achieve a particular engineering objective, it is very important to apply certain principles so that the product development is done economically. This economic is important for the design and selection of good heat transfer equipment. The heat exchangers are manufactured in different types, however the simplest form of the heat exchanger consist of two concentric pipes of different diameters known as double pipe heat exchanger. In this type of heat exchanger, one fluid flows through the small pipe and another fluid flows through the space between both the pipes. The flows of these two different fluids, one is at higher temperature called hot fluid and another is at lower temperature called cold fluid, can be in same or in opposite directions. If the flows are in same direction then the heat exchanger is called as parallel flow heat exchanger and if the flows are in opposite direction then the heat exchanger is called as counter flow heat exchanger. As the counter flow heat exchanger is more effective than parallel flow, hence counter flow heat exchanger is taken into consideration for the present study. The same was shown in fig 3.



**Calculations To Select Suitable Parameters**:

Let$D_i$= pipe inner diameter in m
$m_{hot}$=hot fluid flow rate in LPM
$m_{cold}$=cold fluid flow rate in LPM
L = length of the inner pipe in m
Vfluid =volume of fluid in ml
U= overall heat transfer coefficient in kW/$m^2$C
$C_{pc}$ = specific heat of cold fluid in KJ/kg K
$C_{ph}$ =specific heat of hot fluid in KJ/kg K
Th,in= hot fluid inlet temperature in °C
Tc,in= cold fluid inlet temperature in °C
$m_c$ =cold fluid in kg/sec
$m_h$=hot fluid in kg/sec
As = Surface Area in m²
Cc =Heat capacity of cold fluid in kW
Ch =Heat capacity of hot fluid in kW
Cmin= Minimum heat capacity in kW
Cmax= Maximum heat capacity in kW
C =Capacity Ratio = Cmin/Cmax
Qmax = maximum heat transfer in kW
Q actual= actual heat transfer in kW
NTU= number of transfer units
ε = Effectiveness
Th,out= hot fluid outlet temperature in °C
Tc,out= cold fluid outlet temperature in °C
Thi-Tho= hot fluid temperature difference in °C
Tco-Tci= cold fluid temperature difference in °C
LMTD= log mean temperature difference
$\varrho$=density of oil, kg/m3
$\nu$=kinematic viscosity, m2/s
Q= discharge, m3/s
$A_c$=cross sectional area, m2
V=velocity, m/s
Re=reynolds number
f=friction factor

| s.no | Constant parameters | values |
|---|---|---|
| 1 | $m_{cold}$ | 2 |
| 2 | $m_{hot}$ | 3 |
| 3 | U | 0.2 |
| 4 | Cpc | 4.178 |
| 5 | Cph | 2.219 |
| 6 | Th,in | 100 |
| 7 | Tc,in | 30 |
| 8 | Mc | 0.0333 |
| 9 | Mh | 0.042 |

| s.no | parameter | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | $D_0$ | 0.018 | | | |
| 1 | L | 1 | 1.5 | 2 | 2.5 |
| 2 | $V_{fluid}$ | 254.3400 | 381.5100 | 508.6800 | 635.8500 |
| 3 | As | 0.0565 | 0.0848 | 0.1130 | 0.1413 |
| 4 | Q actual | 0.7185 | 1.0302 | 1.3155 | 1.5776 |
| 5 | NTU | 0.1213 | 0.1819 | 0.2426 | 0.3032 |
| 6 | ε | 0.1101 | 0.1579 | 0.2016 | 0.2418 |
| 7 | Th,out | 92.2911 | 88.9463 | 85.8847 | 83.0723 |
| 8 | Tc,out | 35.1588 | 37.3972 | 39.4460 | 41.3281 |
| 9 | Re | 3535.460522 | | | |
| 10 | $h_f$ | 0.000134 | 0.000201 | 0.000268 | 0.000335 |
| 11 | Thi-Tho | 7.7089 | 11.0537 | 14.1153 | 16.9277 |
| 12 | Tco-Tci | 5.1588 | 7.3972 | 9.4460 | 11.3281 |
| 13 | LMTD | 63.5576 | 60.7562 | 58.1881 | 55.8253 |

| s.no | parameter | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | $D_0$ | 0.024 | | | |
| 1 | L | 1 | 1.5 | 2 | 2.5 |
| 2 | $V_{fluid}$ | 452.1600 | 678.2400 | 904.3200 | 1130.4000 |
| 3 | As | 0.0754 | 0.1130 | 0.1507 | 0.1884 |
| 4 | Q actual | 0.9294 | 1.3155 | 1.6603 | 1.9699 |
| 5 | NTU | 0.1617 | 0.2426 | 0.3234 | 0.4043 |
| 6 | ε | 0.1425 | 0.2016 | 0.2545 | 0.3020 |
| 7 | Th,out | 90.0279 | 85.8847 | 82.1852 | 78.8628 |
| 8 | Tc,out | 36.6734 | 39.4460 | 41.9218 | 44.1451 |
| 9 | Re | 2393.801395 | | | |
| 10 | $h_f$ | 0.000038 | 0.000057 | 0.000077 | 0.000096 |
| 11 | Thi-Tho | 9.9721 | 14.1153 | 17.8148 | 21.1372 |
| 12 | Tco-Tci | 6.6734 | 9.4460 | 11.9218 | 14.1451 |
| 13 | LMTD | 61.6626 | 58.1881 | 55.0792 | 52.2809 |

| s.no | parameter | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | $D_0$ | 0.03 | | | |
| 1 | L | 1 | 1.5 | 2 | 2.5 |
| 2 | $V_{fluid}$ | 706.5000 | 1059.7500 | 1413.0000 | 1766.2500 |
| 3 | As | 0.0942 | 0.1413 | 0.1884 | 0.2355 |
| 4 | Q actual | 1.1281 | 1.5776 | 1.9699 | 2.3151 |
| 5 | NTU | 0.2022 | 0.3032 | 0.4043 | 0.5054 |
| 6 | ε | 0.1729 | 0.2418 | 0.3020 | 0.3549 |
| 7 | Th,out | 87.8961 | 83.0723 | 78.8628 | 75.1591 |
| 8 | Tc,out | 38.1000 | 41.3281 | 44.1451 | 46.6237 |
| 9 | Re | 1832.575231 | | | |
| 10 | $h_f$ | 0.000015 | 0.000023 | 0.000030 | 0.000038 |
| 11 | Thi-Tho | 12.1039 | 16.9277 | 21.1372 | 24.8409 |
| 12 | Tco-Tci | 8.1000 | 11.3281 | 14.1451 | 16.6237 |
| 13 | LMTD | 59.8757 | 55.8253 | 52.2809 | 49.1533 |

# III. Results And Discussion:

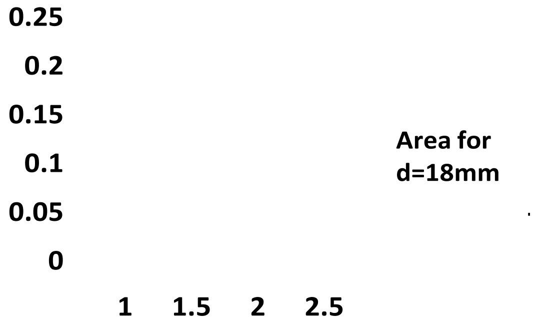
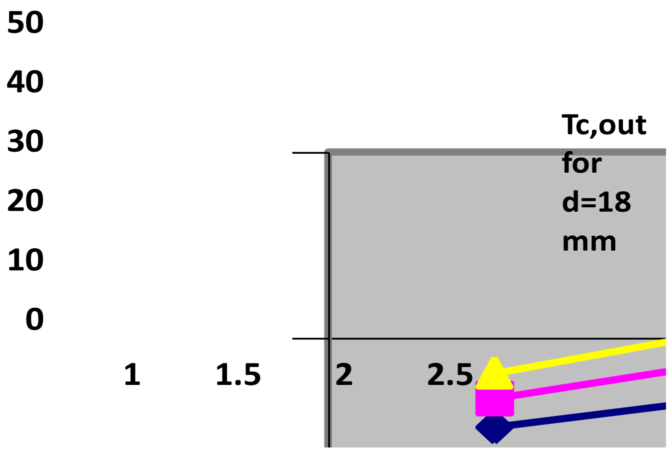


**Fig:**Variation of As along the length

From the above diagram, we can observe that as the diameter of pipe increses the area also because of proporationality, but there is much deviation in this area as the length of pipe increases, thus at 2.5m length the deviation of areas is much higher compared to the length of 1m.



The above diagram shows that as the diameter increases with respect to length, their will be more temperature change in the cold fluid of the pipe. Hence, it is advisable to have large diameter for better temperature distribution, to increase heat transfer rate. In above selection it is preferrable to have diameter 30mm for cold fluid pipe.

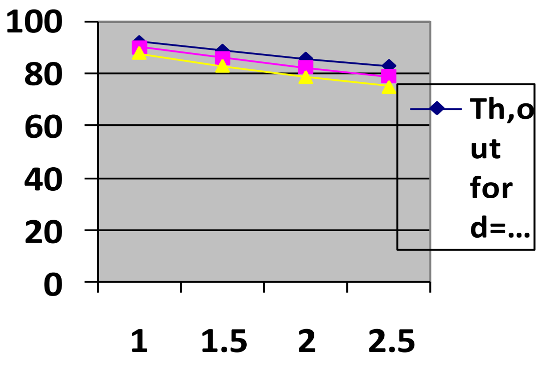


**Fig:** Variation of Th,out along the length

from above diagram we can observe that as the diameter increases with respect to length, their will be less heat transfer in the hot fluid of the pipe. Hence, it is advisable to have less diameter for better heat exchange, to increase the temperature rate. from above diagram it is preferrable to have diameter 18mm for cold fluid pipe.

from above diagram we can understand that as the diameter increases with respect to length, their will be more heat transfer in the cold fluid of the pipe. Hence, it is advisable to have large diameter for better heat exchange, to increase heat transfer rate. from above diagram it is preferrable to have diameter 30mm for cold fluid pipe.

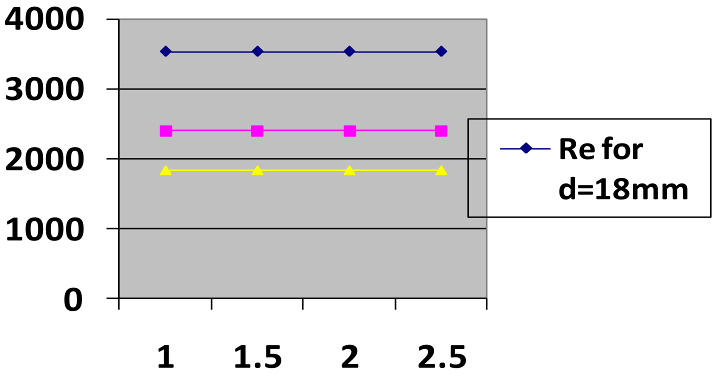


**Fig:** Variation of Qactual along the length

from above diagram we can understand that as the diameter increases with respect to length, their will be more heat transfer in the cold fluid of the pipe. Hence, it is advisable to have large diameter for better heat exchange, to increase heat transfer rate. from above diagram it is preferrable to have diameter 30mm for cold 30mm for cold fluid pipe.

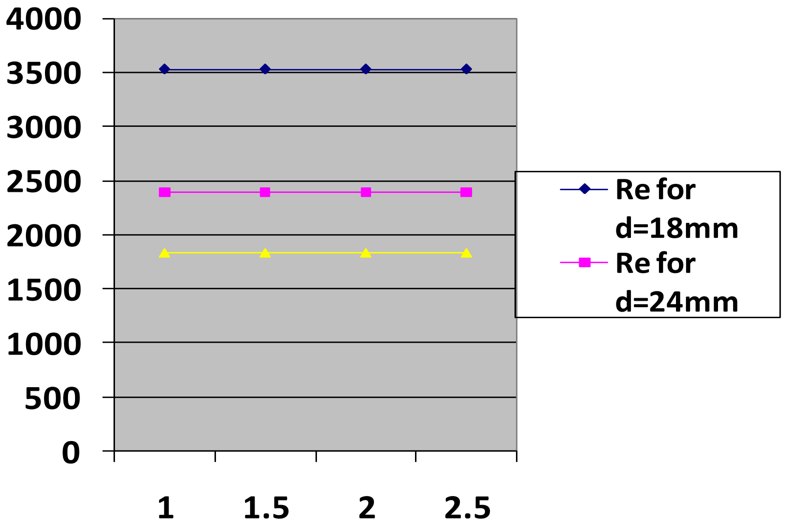


**Fig:** Variation of Re along the length

The above figure shows that as the diameter increases there will be low reynolds number, causes the flow lower laminar side. If the diameter is more and more, the flow is moving much into laminar side, may be at point the obstruction of flow may occur. And it will be serious problem for more viscous fluids. Hence, from the observations it is prefferble to have low diameter of pipe.

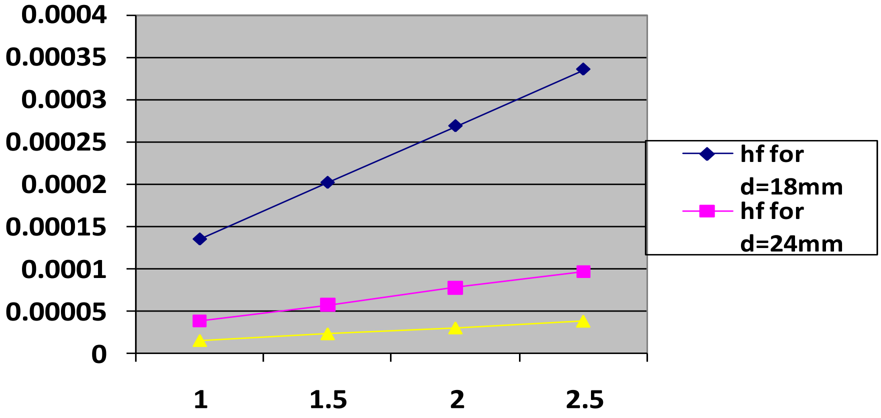


**Fig:** Variation of hf along the length

The above figure shows that as the diameter increases there will be less friction. If the diameter is more and more, friction will be less. So, it is better is have more diameter for the pipe.

## IV. Conclusion

from above diagrams and discussion, it was concluded that the length of the pipe is 2m, diameter of the pipe is 24mm, $m_{hot}$=3 LPM, $m_{cold}$=2 LPM.

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