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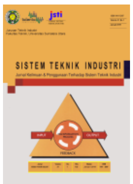

Design and Construction of the Triple-Layer Counter Flow Concentric Tube

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Abstract. A heat exchanger is a device that produces the transfer of heat from one fluid to another. The study aims to design and build a concentric three-prototype with counterflow to lower the temperature of the hot fluid. The hot fluid flows in the annular part of the second copper tube, and then the cold fluid flows into the third copper tube each through the first copper tube and the annulus. The hot fluid is water at 60ºC, a 1000-watt water heater is used to heat the fluid, and the cold fluid is air at 25ºC. The total length of the four concentric prototypes is the first 2.57-meter diameter copper tube. The diameter of the second copper pipe is 2.22 m1 inch. The copper pipe is 1.74 m long and 13/4 inches in diameter. The fluid that can be measured by a fluid thermometer in and out of the heat exchanger is the thermocouple, which is then processed by the computer through the installation of data acquisition modules and tracerdag software.

Keyword: Heat Exchanger, Copper Tube, Annulus, Water Heater

Abstrak. *Penukar panas adalah alat yang menghasilkan perpindahan panas dari satu fluida ke fluida lainnya. Penelitian ini bertujuan untuk merancang dan membangun alat penukar kalor tiga tabung konsentris dengan counterflow untuk menurunkan temperatur fluida panas. Fluida panas mengalir di bagian annular dari tabung tembaga kedua, dan kemudian fluida dingin mengalir ke dalam tabung tembaga ketiga masing-masing melalui tabung tembaga pertama dan anulus. Fluida panasnya adalah air pada 60ºC, pemanas air 1000-watt digunakan untuk memanaskan fluida, dan fluida dinginnya adalah udara pada 25ºC. Panjang total dari empat penukar panas tabung konsentris adalah tabung tembaga berdiameter 2,57-meter inci pertama. Diameter pipa tembaga kedua adalah 2,22 m 1 inci. Pipa tembaga tersebut memiliki panjang 1,74 m dan diameter $1^{3}/_{4}$ inci. Fluida yang dapat diukur oleh termometer fluida yang keluar masuk heat exchanger adalah thermocouple, yang kemudian diproses oleh komputer melalui instalasi modul akuisisi data dan software tracerdag.*

Kata Kunci: Alat Penukar Kalor, Tabung Tembaga, Annulus, Pemanas Air

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1. Introduction

In order to expand the technology based on the heat exchanger, it is necessary to develop heat exchanger technology. This completes the development of the heat exchanger. This type has

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advantages in terms of efficiency and energy efficiency of multiple prototypes of this type [1], and further development and study of this type of heat exchanger is needed. During development, heat exchangers change shape depending on their working function to increase their efficiency [2]. Heat exchangers are a viral environment in industry. For this reason, a 3-center prototype model serving as a water cooler was developed [3]. This provides an advantage as an educational method for the design process, operating mechanisms and characteristics of heat exchangers.

Although the efficiency of a heat exchanger significantly affects the performance of each regenerative cooling system, a higher efficiency of a heat exchanger does not necessarily improve system performance [4]. For this reason, THE (Three Prototype) heat exchanger technology will be developed as part of this study.

2. Literature Review

The function of a warmness exchanger is that warmness is transferred from one liquid to another, the heated liquid turns into cooled, and the cooled liquid turns into hot. Various styles of warmness exchangers had been evolved primarily based totally on one-of-a-kind programs which includes pasteurization, sterilization, region heating, AC power generation, waste heat recovery, chemical treatment, drying, evaporation, cooling and freezing [5]. Warmness exchangers can be categorized in lots of ways, e.g., warmth exchangers can be categorized in a selection of ways. primarily based on flow rules (parallel warmth exchangers, counters, and pass flows), based on extraordinary heat switch processes (direct touch and indirect contact), primarily based on geometry or creation (elongated plate tube surface), It is mainly based on the heat transfer mechanism (1- and 2-segment). [6].

The predominant shape of warmth exchanger utilized in numerous configurations is the multi-prototype. The phenomena performing in his artwork are specially primarily based totally at the switch of warmth among tubes of warm and bloodless liquids. Essential for the freezing, drying, boiling, dairy and prescription drug, food, transportation merchandise and chemical industries. To address immoderate temperature differences, it's miles vital to enhance the location of the warmth exchanger, which may be executed especially via way of means of synchronizing the warmth exchangers [7]. This take a look at permits the triple prototype (TTHE) to resolve this trouble via way of means of extending the warmth transfer role to the equal duration because the twin prototype.

(TTHE) has three concentric tubes, counting three unmistakable cabins called internal tube, profound annular and external tube [8]. By releasing the target fluid whose temperature alter is the most circumstance, it is vital to fulfill the annular computer program to make strides the utilization rate of the warm exchanger. Internal ring fingers with two warm trade surfaces (the external surface of the inward tube and the inward foot of the external tube) will increment the warm trade zone compared to a twofold tube instrument (which changes over warm more effectively than the surface). It's impossible. The rack can be swelled to uproot warm. This assist increments the capacity of the warm exchanger. This decreases the default length of the warm exchanger, guaranteeing a consistent temperature contrast compared to a two-pipe unit.

The manufacture of this warmness exchanger is used to lessen the temperature of warm water or as a coolant, designing warmness exchangers as schooling equipment for designing, production, and analyzing system and substances utilized in warmness exchangers.

3. Material and Research Method

3.1. Designing a Heat Exchanger of *Triple Tube Concentric*

When designing these heat exchangers, the capacity and purpose of the designed heat exchanger is determined from the outset, and the design of the heat exchanger is intended to dispel the opinion that pipes I and III drain water. After cooling, a new coolant flow flows through pipe II. After determining the purpose of the heat exchanger, build or design a parallel anti-float or anti-float layer suitable for the float being measured.

3.2. Designing Heat Exchanger using A Software

AutoCAD is used, for example, as software for designing buildings or structures [6] (plans, views, details, etc.). You can use a program to handle it.

3.3. Schematic of Heat Exchanger and Flow Test Scheme

Warm exchanger format, three layers of concentric counterflow tubes utilizing diverse temperature water, hot fluid 60ºC, cold fluid 25ºC. When the ball valve is open, each fluid interior the tank will stream, the fluid stream within the valve can be measured with a stream meter, and the sliding fluid will stream to the warm exchanger. The warm exchanger is associated to a information collector (ColeParmer) by means of thermocouple cables found at each conclusion of a copper tube utilized to degree the temperature of the liquid entering and clearing out the warm exchanger. The temperature estimation comes about gotten from the information securing are at that point prepared by Instacall and tracerdaq computer program on the computer.

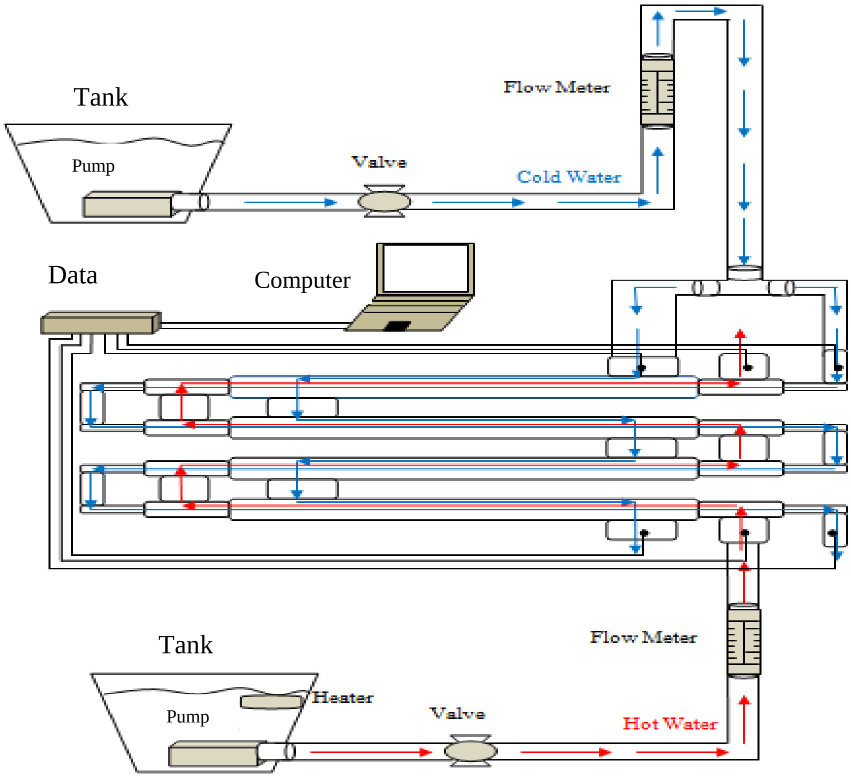

Figure 1 Schematic of heat exchanger

3.4. Schematic of Heat Exchanger Flow Test

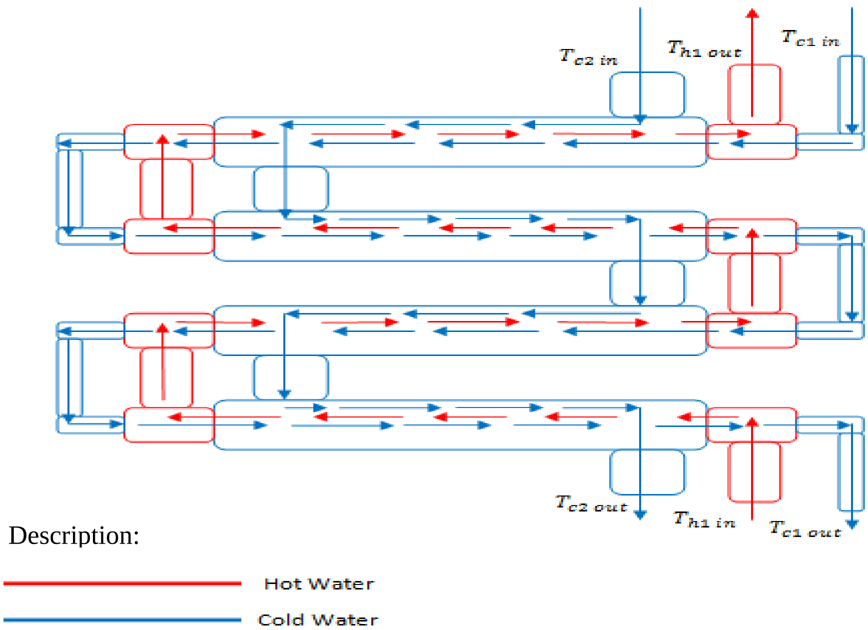

Figure 2 Schematic of counter flow heat exchanger

3.5. Flowchart of Heat Exchanger Design

Heat exchanger layouts require manufacturing process steps to provide a preferred finished product option.

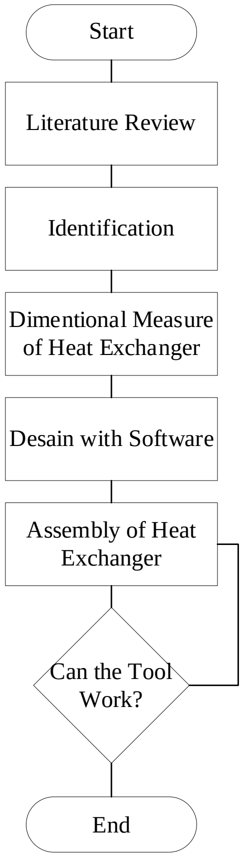

Figure 3 Flowchart of Heat Exchanger Design

4. Result and Discussion

4.1. Dimensional Design of Heat Exchanger

The pipe sizes in this warm exchanger plan are partitioned into three sorts of pipe primarily based on work. Tubes for hot fluid coasts and warm exchangers. copper pipe. Cold slip tube in expansion to the ring.

Figure 4 Copper Pipe in A Heat Exchanger

Reasons for utilizing copper and PVC channels for stream associations to warm exchangers incorporate:

1. Copper has a higher warm conductivity.
2. Connect the pipes to the heat exchanger using PVC pipes due to the low thermal conductivity

Table 1 Material Conductivity [4]

No	Name of Conductivity Material W/m.K	When Temperature (300 K)
1.	Copper	401
2.	PVC	0.19

In designing the dimensions of the heat exchanger, determine the fluid data to put in the heat exchanger and then analyze the calculations to calculate the dimensions of the designed heat exchanger. Here is the parameter data used in the design of the triple tube converters.

Table 2 Calculation Parameter Data

No	Parameter	Symbol	Value	Unit
1.	Incoming Hot Fluid Temperature	T_{Hi}	60	ºC
2.	The Temperature of the outgoing hot fluid	T_{Ho}	43	ºC
3.	The Temperature of cold fluid entering Pipe 1	$T_{C1\,in}$	25	ºC
4.	The Temperature of the cold fluid entering the pipe 2	$T_{C2\,in}$	25	ºC
5.	Hot fluid flow rate	$\dot{m}_h$	0.041	Kg/s
6.	Cold fluid flow rate 1	$\dot{m}_{c1}$	0.025	Kg/s
7.	Cold fluid flow rate 2	$\dot{m}_{c2}$	0.025	Kg/s
8.	Pipe diameter 1	d_{in1}	0.0127	m
9.	Pipe diameter 2	d_{in2}	0.0254	m
10.	Pipe Diameter 3	d_{in3}	0.04	m
11.	Thermal Conductivity of Copper	C_u	401	W/m K

To measure the common temperature of cold liquid, iteration methods are used, and assumptions are required: $T_{c1\,out}=T_{c2\,out}$ = 30.9 ºC, then the common temperature can be calculated:

A. Heat transfer coefficient in Tube I

To measure the total temperature of the cold liquid inside the pipe, I

$$T_f = \frac{T_{c\,in} + T_{c\,out}}{2} \tag{1}$$

Total cold liquid temperature in pipe I, T_f = 300.95K

Table 3 Interpolation of cold fluid (water) in Tube I

No	Parameter	Symbol	Value	Unit
1	Density	ρ_{c1}	997.008	Kg/m^3
2	Thermal conductivity	K_{c1}	613×10^{-3}	W/m k
3	Specific Heat	$C_{p\,c1}$	4179	J/kg k
4	Viscosity	μ_{c1}	855×10^{-6}	Pa.s
5	Prandtl number	Pr_{c1}	5.83	-

Then the flow velocity can be calculated in Tube I

$$V_{c1} = \frac{\dot{m}_{c1} \times 4}{\rho_{c1} \times \pi \times d^{2in}} \tag{2}$$

To measure the average temperature of cold liquid, iteration methods are used, and assumptions are required, then the average temperature can be calculated:

$$Re_{c1} = \frac{\rho_{c1} \text{ x } V_{c1} \text{ x } d_{in1}}{\mu_{c1}} \quad (3)$$

where: Re = Reynolds number, ρ = thickness (kg/m³), V = normal liquid speed (m/s), D = pipe distance across (m), μ = kinematic consistency (N.s/m²).

Instead of a Reynolds number, a formula is used to find Nusselt numbers with equations:

$$Nu_{c1} = \frac{(f/2) \text{ x } (Re_{c1} - 1000) \text{ x} Pr_{c1}}{1+1.27 \text{ x } (f/2)^{\frac{1}{2}} \text{ x } (Pr_{c1})^{\frac{2}{3}} - 1)} \quad (4)$$

calculate the coefficient of thermal flow in the inner tube, with the equation:

$$h_{c1} = \frac{Nu_{c1} \text{ x } K_{c1}}{d_{in1}} \quad (5)$$

where: 〖Nu〗_c1 = Nusselt number of inward pipe, h_c1 = convective warm exchange coefficient interior pipe (W/m² K), d_in1 = pipe breadth (m), K_c1 = warm conductivity (W/m K).

B. Heat transfer coefficient in Tube II

Measuring the average temperature of a hot liquid in a pipe II

$$T_f = \frac{T_{h\ in} + T_{h\ out}}{2} \quad (6)$$

The common temperature of the hot liquid in Tube II, Tf = 324.5 K

Table 4 Interpolation of cold fluid (water) in Tube II

No	Parameter	Symbol	Value	Unit
1	Density	ρ_{h1}	987	Kg/m^3
2	Thermal conductivity	K_{h1}	0.644	W/m k
3	Specific Heat	$C_{p\ h1}$	4181,8	J/kg k
4	Viscosity	μ_{h1}	532,9	Pa.s
5	Prandtl number	Pr_{h1}	3,455	-

Then you can calculate the flow rate in tube II

$$V_{h1} = \frac{\dot{m}_{h1} \text{ x } 4}{\rho_{h1} \text{ x } \pi \text{ x } (d_{in2} - d_{out1})^2} \quad (7)$$

me time recently calculating the Reynolds number for pipe II, the pressure driven breadth [2] was utilized concurring to the condition:

$$dh_1 = d_{in2} - d_{out1} \quad (8)$$

where: D_h = Hydraulic Diameter (m), Do = Tube Outside Diameter (m), Di = Tube Inner Diameter (m).

After finding the flow, use the following formula to find the Reynolds number for hot water pipe II:

$$Re_{h1} = \frac{\rho_{h1} \text{ x } V_{h1} \text{ x } d_{h1}}{\mu_{h1}} \tag{9}$$

where: Re = Reynolds number, ρ = thickness (kg/m³), V = normal liquid speed (m/s), D = pipe distance across (m), μ = kinematic thickness (N.s/m²)

After finding the Reynolds number, find the Nusselt number:

$$Nu_h=2,718\ Re_h^{0,597} Pr_1^{\ 1/3} \left(\frac{d_{h1}}{1,193}\right)^{2/3} \tag{10}$$

The warm stream convection coefficient of the annular pipe II at the esteem of the Nusselt number can be calculated from the condition underneath utilizing the taking after condition:

$$h_{in}= \frac{Nu_h \text{ x } K_h}{d_h} \tag{11}$$

where: 〖Nu〗_c1 = Nusselt number of inner pipe, h_c1 = convective heat transfer coefficient inside pipe (W/m² K), d_in1 = pipe diameter (m), K_c1 = thermal conductivity (W/m K).

C. Heat transfer coefficient in Tube III

To measure the overall temperature of a cold liquid tube III

$$Tf=\frac{Tc_{2in}+ Tc_{2out}}{2} \tag{12}$$

Total cold liquid temperature in pipe III, Tf = 300.95K

Table 5 Interpolation of cold fluid (water) in Tube III

No	Parameter	Symbol	Value	Unit
1	Density	ρ_{c2}	997,008	Kg/m^3
2	Thermal conductivity	K_{c2}	$613 \text{ x } 10^{-3}$	W/m k
3	Specific Heat	$C_{p\ c2}$	4179	J/kg k
4	Viscosity	μ_{c2}	$855 \text{ x } 10^{-6}$	Pa.s
5	Prandtl number	Pr_{c2}	5,83	-

Then the flow velocity can be calculated in Tube III

$$V_{c2}=\frac{\dot{m}_{c2} \text{ x } 4}{\rho_{c2} \text{ x } \pi \text{ x } (d_{in\ c2}-d_{out\ h2})^2} \tag{13}$$

Before calculating the Reynolds band for pipe III, you must first calculate the hydraulic diameter using the equation:

$$dh_2 = d_{in3} - d_{out2} \quad (14)$$

where: D_(h) = hydraulic diameter (m), Do = outer pipe diameter (m), Di = inner pipe diameter (m).

After getting the stream speeds within the third tube, find the huge Reynolds complex for cold fluid stream utilizing the condition:

$$Re_{c2} = \frac{\rho_{c2} \text{ x } V_{c2} \text{ x } d_{h2}}{\mu_{c2}} \quad (15)$$

where: Re = Reynolds number, ρ = Thickness (kg/m³), V = Liquid normal speed (m/s), D = Pipe Breadth (m), μ = Energetic Consistency (N.s/m²).

After finding the Reynolds number, discover the Nusselt number::

$$Nu_{c2} = 0{,}51\ Re_{c2}^{\ 0,5} Pr_{c2}^{\ 1/3} \text{ x } \left(\frac{Pr_{c2}}{Pr_{c2}}\right)^{0,25} \quad (16)$$

From the result of Nusselt's number, the warm flux convection coefficient of the annular tube II can be calculated by the taking after condition:

$$h_{c2} = \frac{Nu_{c2} \text{ x } K_{c2}}{d_{h2}} \quad (17)$$

where: 〖Nu〗_c1 = Nusselt number of internal pipe, h_c1 = convective warm exchange coefficient interior pipe (W/m² K), d_in1 = pipe breadth (m), K_c1 = warm conductivity (W/m K).

When calculating the full warm exchange coefficient, there are two add up to warm exchange coefficients for three concentric circles, particularly utilizing the condition:

1. The entire heat transfer coefficient [2] on the exterior and center of pipe 2 to pipe 1

$$\frac{1}{U_{01}} = \frac{d_{out1}}{d_{in1} \text{ x } h_{c1}} + \frac{d_{out1} \text{ Ln } (d_{out1}/d_{in1})}{2 \text{ x } k_{coper}} + \frac{1}{h_{in}} \quad (18)$$

2. Coefficient of overall warm exchange in pipe 2 to pipe 3

$$\frac{1}{U_{in2}} = \frac{1}{h_{in}} + \frac{d_{in2} \text{ Ln } (d_{out2}/d_{in2})}{2 \text{ x } k_{coper}} + \frac{d_{in2}}{d_{out2} \text{ x } h_{c2}} \quad (19)$$

where: U = cruel warm exchange coefficient (W/m². K), h_i = inside convective warm exchange coefficient (W/m².K), h_o = Pipa outlet convective warm exchange coefficient (W/m².K), T = Pipe thickness (m), k = warm conductivity of the fabric (W/mK)

The calculation of the logarithmic cruel temperature contrast LMTD (Logarithmic Cruel Temperature Distinction) is utilized within the upstream condition [4], i.e:

$$\Delta T_{lm}= \frac{(Thi\text{-}Tci)\text{-}(Tho\text{-}Tco)}{\ln\frac{(Thi\text{-}Tci)}{(Tho\text{-}Tco)}} \quad (20)$$

where: 〖ΔT〗_lm= Contrast in Normal Temperature Logarithm (ºC), T_hi= Gulf Hot Fluid Temperature (ºC), T_ho = Outlet Hot Liquid Temperature (ºC), T_ci= Channel Cold Liquid Temperature (ºC), T_co = Outlet Cold Liquid Temperature (ºC)

Calculate the rate of warm exchange utilizing the condition:

$$Q_h = \dot{m}_h \ . \ Cp_h \ (T_{hi} \text{-} \ T_{ho}) \quad (21)$$

where: Q = Warm Exchange Rate (W), ṁ = Mass Stream Rate of Liquid (kg/s), C_(p,h) = Particular Warm Of Hot Liquid (J/kg.K), T_(h,i) = Temperature of Channel Hot Liquid (ºC), T_(h,o) = Temperature of Outlet Hot Liquid (ºC)

Calculating the rate of warm exchange in a cold liquid

$$Q = \dot{m}_c \ . \ C_{p,c} \ (T_{c,i}\text{-}T_{c,o}) \quad (22)$$

which: Q = warmness transfer charge (W), ṁ = fluid mass flow charge (kg/s), C_(p.C) = cryogenic fluid specific warmth (J/kg.K), T_(c,i) = bloodless fluid temperature Inlet (ºC), T_(c,o) = Cold liquid outlet temperature (ºC)

Calculate the length of a heat exchanger, to locate the length of the warmth exchanger, we use equations [4]:

$$Q = U \ A \ \Delta T_{lm} \quad (23)$$

In which: Q price charge coefficient warmness transfer coefficient heat switch coefficient (W), U = total heat transfer coefficient (W/m² ºC), A = move-sectional area (m²), 〖ΔT〗_lm = Log of the suggest temperature difference (ºC) and the period of the designed pipe is 0.857 The pipe section of m is 2.57 m divided into 3, the picture of the heat exchanger can be visible in Figure 5 under:

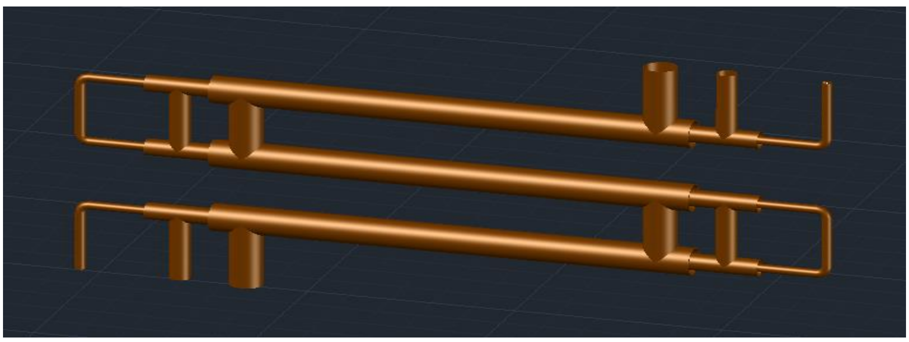

Figure 5 Design of the Heat Exchanger

Images of the built warmth exchanger and established flowmeters and the warmth exchanger's temperature sensor can be visible in Figure 6 beneath.

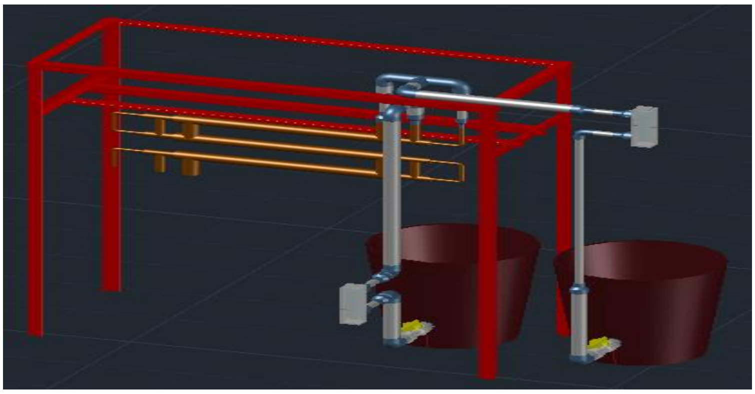

Figure 6 Heat Exchanger

4.2. Design of Heat Exchanger Frame

The framework of the heat exchanger is made of corners three mm thick. Frames are made in various sizes.:

Table 6 Frame Dimension

No	Dimension	Number of Units
1.	1200 x 33 x 33	4 mm
2.	500 x 33 x 33	4 mm
3.	1500 x 33 x 33	4 mm

on figs. 7 below shows the structure of the frame or support for the model:

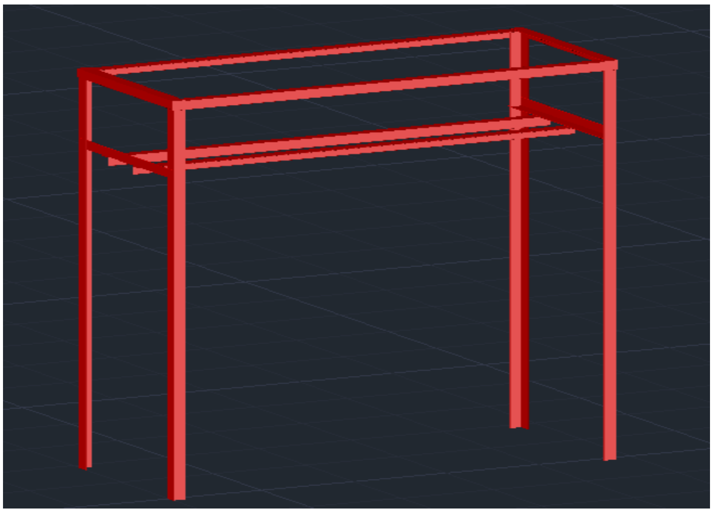

Figure 7 Frame Design

4.3. Valve Design

This layout uses a ½ inch ball valve and the primary cloth is plastic for smooth reference to PVC pipe. This ball valve become selected as it has the bottom loss element of all other valves [8] and the managing of ball valves is tons less complicated and much less exhausting than slide valves.

Table 7 Valve type and minor loss coefficient

No	Type of Valve	Coefficient of Minor Loss
1	Globe valve, fully open	10
2	Angle valve, fully open	2
3	Gate valve, fully open	0,15
4	Gate valve, ¼ closed	0,26
5	Gate valve, ½ closed	2,1
6	Gate valve, ¾closed	17
7	*Ball valve, Fully open*	*0,05*
8	Gate valve, ⅓ closed	5,5

5. Conclusion

A 3-pipe cross-flow concentric heat exchanger designed and synthetic for water cooling. The cloth used to make the warmth exchanger is copper due to the corrosive nature of water, the fabric is corrosion resistant and copper has a high electric conductivity. The warmth exchanger consists of 3 copper tubes with the identical center (concentric) alongside the whole length of every tube. Copper tube I: 2.57 m, inch diameter, 1 mm thick. Copper tube II: 2.22 m, 1 inch diameter, 1 mm thick. Copper Tube III: 1.74 m, 1¾ inch diameter, 1.25 mm thick. The frame of the warmth exchanger is designed and manufactured with a steel angle of one.2m in length, 0.5m in width, and 1.5m in height. Used liquids can harm the device**.**

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