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CONCENTRIC TUBE HEAT EXCHANGER EFFECTIVENESS ENHANCEMENT

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Abstract: Heat transfer fluids carry heat from heat collectors to the heat storage tanks in heating (and cooling) systems. The fluids most commonly used are water, propylene glycol, ethylene glycol and air. Less common fluids are synthetic hydrocarbons, paraffin hydrocarbons, aromatic refined mineral oils, refrigerants, and silicones. While selecting a heat transfer fluid, we consider the following criteria the coefficient of expansion, viscosity, thermal capacity; freezing point, boiling point, and flash point are considered. For example, in a cold climate, solar systems require fluids with low freezing points. Fluids exposed to high temperatures, as in a desert climate, should have a high boiling point. Viscosity and thermal capacity determine the amount of pumping energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help determine the effectiveness of a fluid is its corrosiveness and stability.
In the present work an attempt was made to arrive at the best combination which would give the best heat transfer rate and how the porosity effected the heat transfer rate in the system.

***Index Terms* – Heat transfer, Concentric tubes, Heat flux, Effectiveness, Propylene glycol.**

I. INTRODUCTION

A heat exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat exchangers are useful in many engineering processes like those in refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors and space or aeronautical applications.
Heat exchangers may be classified in several ways. One Classification is according to the fluid flow arrangement or the relative direction of the hot and cold fluids. The fluids flow may be separated by a plane wall but more commonly by a concentric tube (double pipe) arrangement. If both the fluids move in the same direction, then the flow is called a parallel flow type. In the counter flow arrangement, the fluids move in parallel but opposite directions. In a double pipe heat exchanger, either the hot or cold fluid occupies the annular space, or the other fluid moves through the inner pipe. Since both fluid streams traverse the exchanger only once, this arrangement is called a single pass heat exchanger.

II. EXPERIMENTAL SETUP

The experimental setup consists of following list of equipment's mainly:

- Concentric tube heat exchanger
- Geyser
- Electric pump
- Tube attachments
- Roto meter

2.1 Construction of concentric tube heat exchanger:

It consists of inner copper tube with internal diameter 10.36 mm and external diameter 12.54 mm. External tube is stainless steel tube with internal diameter 22.88mm and external diameter 25.4 mm. The length of heat exchanger is 1 meter. The outer surface of stainless steel is covered with asbestos rope of 6 mm diameter. We used fallowing materials for the construction of concentric tube heat exchanger:

2.2 Geyser

A storage water heater is a domestic water heating appliance that uses a hot water storage tank to maximize heating capacity and provide instantaneous delivery of hot water. Conventional storage water heaters use a variety of fuels, including natural gas, propane, fuel oil, and electricity. Less conventional water heating technologies, such as heat pump water heaters and solar water heaters, can also be categorized as storage water heaters. Conventional storage water heaters are the most common water heating type used in the United States. Most electric water heaters use electric resistance elements to heat the water in the storage tank using two electric resistance elements, which are located at the bottom and top of the storage tank. Each element is controlled by an independent thermostat. In two element tanks the lower element provides recovery from standby losses and the upper element provides heating during periods of large hot water use. Some resistance water heaters contain only a lower element.

Water heaters that have residual hot water storage in a vessel /container heat, electrical water heaters can be a good match for an intelligent electrical power distribution system, heating when the electrical grid load is low and turning off when the load is high. This could be implemented by allowing the power supplier to send load shedding requests, or by the use of real-time energy pricing. Heat pump water heaters use an air source heat pump to transfer thermal energy from the air around the unit into the storage tank. Electric resistance element(s) are typically included to provide backup heating if the heat pump cannot provide enough heating capacity

Fig :1 Geyser

Fig :2 Stainless steel tube

Fig 3. Copper tube

Fig 4. Inlet and outlet pipes

Temperature measuring devices
1.thermometer
2.digital temperature indicator

Fig 5 Temperature measuring device-thermometer

Insulating material:
1.Asbestas rope
2.Rubber sheet

Fig 6 (a). Asbestos rope

Fig 6(b). Rubber sheet

Some other materials we used are :

1. M-SEAL (ANTI leakage substance)
2. NUT -BOLT
3. CLIPS

Fig 7. M-seal

Fig 8.Nut and bolts

Fig 9. clips

Water flow rate measurement device:

1.rotometer

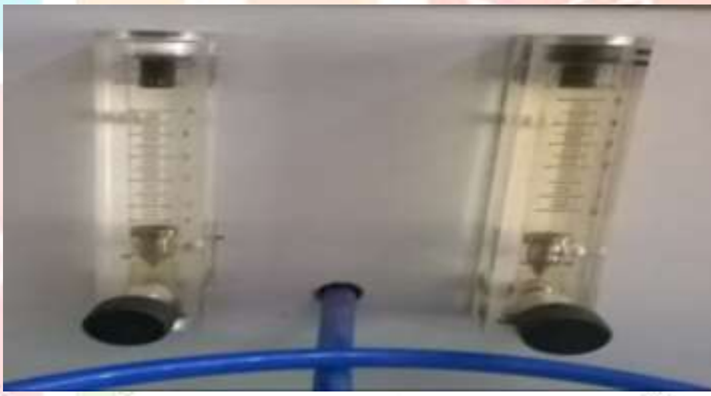

Fig 10. Rota meter

Temperature measuring device-thermocouple:

Fig 11. Thermocouple

2.3 Concentric tube heat exchanger and its experimental calculations:

In nearly every engineering operation there usually exists a large array of heat exchangers. They are used to change the temperatures of a fluid stream by passing another fluid close to the desired temperature. The simplest design is a concentric tube heat exchanger (CTHE). It consists of a small inner tube surrounded by larger outer tube. The construction of the CTHE allows the rapid exchange of heat by keeping the two fluids separated by a relatively thin conductive metal tube.

The primary advantage of a concentric configuration, as opposed to a plate or shell and tube heat exchanger, is the simplicity of their design. As such, the insides of both surfaces are easy to clean and maintain, making it ideal for fluids that cause. Additionally, their robust build means that they can withstand high pressure operations. They also produce turbulent conditions at low flow rates, increasing the heat transfer coefficient, and hence the rate of heat transfer.[4] There are significant disadvantages however, the two most noticeable being their high cost in proportion to heat transfer area; and the impractical lengths required for high heat duties. They also suffer from comparatively high heat losses via their large, outer shells.

The simplest form is composed of straight sections of tubing encased within the outer shell, however alternatives such as corrugated or curved tubing conserve space while maximising heat transfer area per unit volume. They can be arranged in series or in parallel depending on the heating requirements. Typically constructed from stainless steel, spacers are inserted to retain concentricity, while the tubes are sealed with O-rings, packing, or welded depending on the operating pressures.

While both co and counter configurations are possible, the counter current method is more common. The preference is to pass the hot fluid through the inner tube to reduce heat losses, while the annulus is reserved for the high viscosity stream to limit the pressure drop. Beyond double stream heat exchangers, designs involving triple (or more) streams are common; alternating between hot and cool streams, thus heating/cooling the product from both sides.

Here we have made a concentric tube heat exchanger using the above specifications. And we conducted experiment on parallel flow and counter flow of concentric tube heat exchanger for the determination of effectiveness of heat exchanger.
First, we conducted experiment for determination of effectiveness in original heat exchanger equipment in heat transfer laboratory.

Table 1. Observation for parallel and counter flow of original lab equipment

TYPE	**WATER FLOW RATE Cold Hot**	**T ci (○C)**	**T co (○C)**	**T hi (○C)**	**T ho (○C)**
Parallel	2/60 1/60	31	36.2	58.8	51.9
Parallel	3/60 2/60	32.9	30.8	47.9	45
Parallel	4/60 2/60	32.5	30.9	47.3	44.2
Counter	2/60 1/60	29.4	34.2	62.3	52.6
counter	3/60 2/60	30.1	32.7	46.7	43.6
counter	2/60 3/60	30.3	32.7	41.7	40.3

Fig 12. Original heat exchanger equipment set up

Table 2. Calculation for parallel flow in original heat exchanger

Type	$Q_h = M_h * C_{ph} * [T_{hi} - T_{ho}]$	$Q_c = M_c * C_{pc} * [T_{co} - T_{ci}]$	$Q = [Q_h + Q_c]/2$	$\Theta 1 = T_{hi} - T_{ci}$	$\Theta 2 = T_{ho} - T_{co}$	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= $[T_{hi} - T_{ho}]/[T_{hi} - T_{ci}]$	$Q_{max} = Q/X$
PARALLEL									
$T_{ci=31}$ $T_{co=36.2}$ $T_{hi=58.8}$ $T_{ho=51.9}$	481.56 watts	725.02 watts	603.29 watts	27.8	15.7	21.176	330.1 watts/m^{2}K	0.2482	2430.63 watts

Table 3. Calculation for counter flow in original heat exchanger

Type	$Q_h = M_h * C_{ph} * [T_{hi} - T_{ho}]$	$Q_c = M_c * C_{pc} * [T_{co} - T_{ci}]$	$Q = [Q_h + Q_c]/2$	$\Theta 1 = T_{ho} - T_{ci}$	$\Theta 2 = T_{hi} - T_{co}$	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= $[T_{hi} - T_{ho}]/[T_{hi} - T_{ci}]$	$Q_{max} = Q/X$
COUNTER									
$T_{ci=29.4}$ $T_{co=34.2}$ $T_{hi=62.3}$ $T_{ho=52.6}$	676.89 watts	669.92 watts	673.40 watts	23.2	28.1	25.271	308.76 watts/m^{2}K	0.2948	2284.0370 watts

From the above we can conclude that effectiveness value is more in case of counter flow.

In Similar manner we conducted second experiment for determination of effectiveness in our heat exchanger equipment using water as the working media in both parallel and counter flow arrangement in heat transfer laboratory.

Fig 13. Our concentric tube heat exchanger prototype with conjunction with original lab equipment

Table 4: Observations for our concentric tube heat exchanger

TYPE	WATER FLOW RATE Cold Hot	T ci (○C)	T co (○C)	T hi (○C)	T ho (○C)
Parallel	2/60 2/60	28.8	32.2	47.6	44.5
Parallel	3/60 2/60	30.8	32.4	47.9	45
Parallel	4/60 3/60	30	32.6	47.3	41.7
Counter	2/60 1/60	29.4	34.2	62.3	52.6
Counter	3/60 2/60	30.1	32.7	46.7	43.6
Counter	4/60 2/60	30.3	32.2	47.3	40.3

Table 5. Calculations for parallel flow in our CTHE

Type	$Q_h = M_h * C_{ph} * [T_{hi} - T_{ho}]$	$Q_c = M_c * C_{pc} * [T_{co} - T_{ci}]$	$Q = [Q_h + Q_c]/2$	$\Theta 1 = T_{hi} - T_{ci}$	$\Theta 2 = T_{ho} - T_{co}$	LMTD= $[\theta 2 - \theta 1]/\ln(\theta 2/\theta 1)$	U0=Q/(area*LMTD)	Effectiveness (X)= $[T_{hi} - T_{ho}]/[T_{hi} - T_{ci}]$	Q_{max}= Q/X
PARALLEL									
$T_{ci=30.8}$ $T_{co=32.9}$ $T_{hi=47.9}$ $T_{ho=45}$	404.74 watts	439.63 watts	422.18 watts	17.1	12.1	14.45	417.38 watts/m²K	0.1695	2490.73 watts

Table 6. Calculations for counter flow in our CTHE

Type	$Q_h = M_h * C_{ph} * [T_{hi} - T_{ho}]$	$Q_c = M_c * C_{pc} * [T_{co} - T_{ci}]$	$Q = [Q_h + Q_c]/2$	$\Theta 1 = T_{ho} - T_{ci}$	$\Theta 2 = T_{hi} - T_{co}$	LMTD= $[\theta 2 - \theta 1]/\ln(\theta 2/\theta 1)$	U0=Q/(area*LMTD)	Effectiveness (X)= $[T_{hi} - T_{ho}]/[T_{hi} - T_{ci}]$	Q_{max}= Q/X
COUNTER									
$T_{ci=30.1}$ $T_{co=32.7}$ $T_{hi=46.7}$ $T_{ho=43.6}$	432.65 watts	544031 watts	488.48 watts	13.5	14	13.74	507.88watts/m²K	0.1867	2613.3 watts

From the above we can conclude that effectiveness value is more in case of counter flow.

In Similar manner we conducted third experiment for determination of effectiveness in our heat exchanger equipment using water+stone as the working media in both parallel and counter flow arrangement in heat transfer laboratory.

Fig 14. Stones between the annular space of the heat exchanger

Table 7: Observations for water+stone working medium in CTHE

TYPE	WATER FLOW RATE Cold Hot	**T ci (○C)**	**T co (○C)**	**T hi (○C)**	**T ho (○C)**
Parallel	4/60 2/60	29	31.2	47.3	42
Parallel	3/60 2/60	29	31.2	46.2	41.5
Parallel	4/60 3/60	29	31.1	47.1	39.6
Counter	3/60 2/60	29	32.6	46.7	43.3
Counter	4/60 2/60	29.2	32.6	46.7	43.4
Counter	2/60 3/60	30.3	32.7	46.1	40.6

Table 8. Calculations for water+stone working medium in parallel flow CTHE

Type	Q_h= M_h* C_{ph}*[T_{hi}-T_{ho}]	Q_c= M_c* C_{pc}* [T_{co}-T_{ci}]	Q= [Q_h+Q_c]/2	Θ1= T_{hi}-T_{ci}	Θ2= T_{ho}-T_{co}	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= [T_{hi}-T_{ho}]/[T_{hi}-T_{ci}]	Q_{max} = Q/X
PARALLEL									
$T_{ci=30.8}$ $T_{co=32.9}$ $T_{hi=47.9}$ $T_{ho=45}$	655.96 watts	460.57 watts	558.26 watts	17.1	10.3	13.45	592.95watts/m^{2}K	0.2732	2043.43 watts

Table 9: calculations for water+stone working medium in counter flow CTHE

Type	Q_h= M_h* C_{ph}*[T_{hi}-T_{ho}]	Q_c= M_c* C_{pc}* [T_{co}-T_{ci}]	Q= [Q_h+Q_c]/2	Θ1= T_{ho}-T_{ci}	Θ2= T_{hi}-T_{co}	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= [T_{hi}-T_{ho}]/[T_{hi}-T_{ci}]	Q_{max}= Q/X
COUNTER									
$T_{ci=29}$ $T_{co=32.7}$ $T_{hi=46.7}$ $T_{ho=43.3}$	474.524watts	774.59 watts	624.55 watts	14.3	14	14.149	630.98 watts/m^{2}K	0.192	3252.8watts

Addition of small stones to water inside the concentric tube, there is a creation of turbulence motion inside the system. So, effectiveness of the system decreases and transfer of heat from the system increases.

In Similar manner we conducted third experiment for determination of effectiveness in our heat exchanger equipment using water+wiremesh as the working media in both parallel and counter flow arrangement in heat transfer laboratory.

Table 11: observations for water+wire mesh working medium in CTHE

Type	Q_h= M_h* C_{ph}*[T_{hi}-T_{ho}]	Q_c= M_c* C_{pc}* [T_{co}-T_{ci}]	Q= [Q_h+Q_c]/2	Θ1= T_{hi}-T_{ci}	Θ2= T_{ho}-T_{co}	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= [T_{hi}-T_{ho}]/[T_{hi}-T_{ci}]	Q_{max}= Q/X
PARALLEL									
$T_{ci=29}$ $T_{co=32.8}$ $T_{hi=47.9}$ $T_{ho=43.8}$	572.23 watts	795.537 watts	683.876 watts	18.9	11	14.59	669.61watts/m^{2}K	0.2169	3152.95 watts

Table 12: Observations for water+wire mesh working medium in CTHE

With this we are going to conclude that addition of wire mesh to water transfer of heat from the system reduces.

Type	Q_h= M_h* C_{ph}*[T_{hi}-T_{ho}]	Q_c= M_c* C_{pc}* [T_{co}-T_{ci}]	Q= [Q_h+Q_c]/2	Θ1= T_{ho}-T_{ci}	Θ2= T_{hi}-T_{co}	LMTD= [θ2-θ1]/ln(θ2/θ1)	U0=Q/(area*LMTD)	Effectiveness (X)= [T_{hi}-T_{ho}]/[T_{hi}-T_{ci}]	Q_{max}= Q/X
COUNTER									
$T_{ci=29}$ $T_{co=32.2}$ $T_{hi=46.7}$ $T_{ho=42.5}$	586.18 watts	669.92 watts	628.05 watts	13.5	14.5	13.99	641.325 watts/m^{2}K	0.2372	2647.76watts

III. EXPERIMENTAL FOR DETERMINATION OF OVERALL HEAT TRANSFER COEFFICIENT USING PROPYLENE GLYCOL

In this experiment we have tried to find out the overall heat transfer coefficients of the mixtures having different percentages of propylene glycol by mass. These various aqueous solutions are passed to absorb the heat from the hot water coming out of the geyser having a temperature range between (50-70) degrees celsius.

Table13. Variation of propylene glycol by Weight %

S.no	%by weight of Propylene glycol	Mh (lt/sec)	T_{hi}	T_{ho}	Mc (lt/sec)	T_{ci}	T_{co}
1	10	0.019	77	63	0.0384	45	52
2	30	0.026	75	61	0.038	43	51
3	40	0.033	52	42	0.0667	32	37
4	50	0.033	52	44	0.0667	34	38
5	60	0.033	54	48	0.0667	34	38
6	70	0.033	52	44	0.0667	35	39
7	80	0.033	51	43	0.0667	34	38
8	90	0.033	55	47	0.0667	37	41

Table 14. Determination of over heat transfer coefficient for propylene glycol by 10%weight

S.no	%by weight of Propylene glycol	M_h (lt/sec)	T_{hi}	T_{ho}	M_c (lt/sec)	T_{ci}	T_{co}
1	10	0.0192	77	63	0.0384	45	52

$Q_c=M_c*C_{pc}*[T_{co}-T_{ci}]$

$=0.0384*4.0192*[52-45] = 1.08272KW$

$Q_h=M_h*C_{ph}*[T_{hi}-T_{ho}] = 2.1607KW$

$Q=[Q_h+Q_c]/2 = 1.6213KW$

LMTD = 66.6525

$Uo=231.4W/m^2K$

Table 15: Overall heat transfer coefficient for weight % of propylene glycol

S.no	% of propylene glycol by weight	Cp(kj/kg'c)	Uo Watt/m^2K
1	10	4.772	231.4
2	30	3.6837	291.44
3	50	3.3484	475.93
4	60	3.1807	663.45
5	70	3.01304	525.35

From the above table we find that composition having 60% of propylene glycol and 40% water is best suited for heat transfer application.

IV. CONCLUSIONS

- Addition of small stones to water inside the concentric tube, there is a creation of turbulence motion inside the system. so, effectiveness of the system decreases and transfer of heat from the system increases.
- Addition of wire mesh to water inside the concentric tube, there is a decrease in space inside the system. so, effectiveness of the system increases and transfer of heat from the system reduces.
- Propylene glycol has more specific heat value compared to water. So, it has more capacity to transfer heat.

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