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Comparative Experimental Study and Performance Intensification of Heat Exchanger by 55° Corrugated Tube and Twisted Tape Inserts of Pitch Length 1.5

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Abstract: The principal objective of this comparative experimental analysis is to determine the straight 55° corrugated steel tube heat exchanger is more beneficial to utilize than a standard straight steel tube heat exchanger. Straight tubes make heat exchanger tube fabrication easier. As a result, helical tubes and numerous other smaller tube forms of heat exchangers are inferior to straight tube heat exchangers. Most research on heat transfer coefficients is done for constant heat flow or constant wall temperature, while more recent work considers fluid-to-fluid heat exchange.

In parallel flow and counter flow arrangements of straight plain steel tube, straight 55° corrugated steel tube, straight steel tube with insert heat exchangers, and straight 55° corrugated steel tube with insert, the effectiveness, overall heat transfer coefficient, effect of hot water flow rate on effectiveness when cold water flow rate kept constant were studied and compared. At the heat exchanger's steady state, all measurements were made. The outcome is displayed graphically for the two tubes' respective efficaciousness under various flow configurations. When the cold-water flow is fixed at 45 lph and the hot water mass flow rate fluctuates at 15,30,45,60, and 75 lph the heat exchanger's effectiveness drops up to 45 lph and increases up to 75 lph for both straight steel and corrugated tube heat exchangers; the straight steel tube heat exchanger's effectiveness is better than the other tube heat exchangers. On the other hand, the heat transfer rate of the heat exchanger steadily increases when the mass flow rate of the hot water is varied and the cold water remains constant.
Keywords: Double tube heat exchanger, twisted tape insert, effectiveness, LMTD, Heat transfer coefficient.

I. INTRODUCTION

Heat transfer is a phenomena that happens when two fluids with different temperatures and a solid wall separating them exchange heat. A heat exchanger is a device that facilitates efficient heat exchange, and this phenomenon has many applications. The chemical industry, power generation, air conditioning, waste heat recovery, and chemical processing are a few examples of the precise applications of the heat transfer process. Due to its low cost and straightforward design, the double pipe heat exchanger (DPHE) is one of the most popular and straightforward heat exchangers. frequently employed in small-scale businesses such as pasteurization, reheating, preheating, food, oil, chemicals, and effluent heating processes, among others. [1] In terms of system efficiency and economy, a twin pipe heat exchanger's performance is crucial. In order to achieve sustainable energy growth, it is crucial to enhance heat transfer. Passive techniques encompass a range of tactics, such as altering the geometry of the pipe with fins, corrugation [2-4], grooves [5, 6], and dimpling [7, 8]. The use of nanoparticles to change the fluid's thermophysical characteristics is another passive technique that has been extensively studied by academics [9–13]. Turbulators with various geometries, including twisted tape [14,15], spiral wire [16], and wavy tape [17], can also be used to create spinning or radial flows. As a result, the thermal boundary layer becomes weaker and turbulence increases. Heat exchange resistance falls and the heat transfer coefficient rises as a result.

Despite their higher cost and energy consumption, active methods generally exhibit a lower pressure decrease when compared to passive alternatives. Prominent active techniques include the use of bubble injection [18–20], the recently developed electromechanical vibrator technique [21,22], the use of high voltage electric fields to stimulate dielectric fluid [23,24], ultrasound waves to stimulate fluid [25,26], and uniform and non-uniform magnetic fields to stimulate magnetic nanofluid [27–28].The aforementioned articles make it clear that both passive and aggressive strategies have disadvantages.

Passive techniques result in a significant pressure reduction in the system, but active techniques are notoriously more expensive and complex. This lab study employs a novel approach that uses corrugated tube as a turbulator to improve heat transmission in an effort to overcome the pressure drop problem.

In order to evaluate the variance of Nu and f, Naphon et al. conducted experimental research on a DPHE with and without insert. The inserts were composed of aluminum and had a thickness of 1 mm. Compared to heat exchangers without inserts, inserts significantly increased the rates of heat transfer. Twisted tape inserts also enhanced the pressure drop.

The effect of twist ratio on heat exchanger performance was examined by Noothong et al. Typical twisted tape with twist ratios of 5.0 and 7.0 was used in the studies, and its Reynolds number ranged from 2000 to 12000. Water was regarded as the working medium. Swirl flow has been shown to aid in lowering the working fluid's boundary layer thickness. It was discovered that as the twist ratio decreased, the enhancement efficiency and Nu increased. Because of the twisted tapes, a secondary flow developed, increasing the overall heat transfer coefficient. Yu et al. conducted two separate investigations to determine the effect of twisted tape inserts for oblique teeth on the fouling issue. When compared to smooth twisted strips, they found that the moment of force was raised from 75 to 101%, which boosted heat transfer and decreased fouling.

II. METHODOLOGY

The combination of active and passive methods is called as compound method.

The technique of tube inserts is frequently considered in the form of routes under the passive method. Examples of tube inserts in heat exchangers include conical rings, conical nozzles, helical springs, twisted tapes, and ribs.

Twisted tape inserts are regarded as the most popular option among all of the frequently used tube inserts, and as such, many researchers have researched them in great detail. Figure 1 shows a schematic illustration of a typical twisted tape with DPHE.

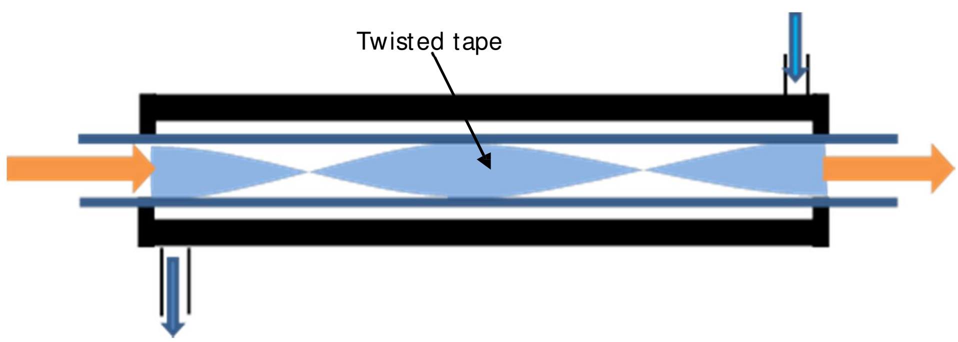


Fig.1. Structure of typical twisted tape with DPHE

This section contains the formulas needed to calculate the heat transfer coefficient. The computations and graphs for corrugated copper and steel tube, as well as flat steel and copper tube parallel and counter flow, are shown below.

A. *Effect of Conventional Twisted Tape*

The position and quantity of twisted tapes affect heat exchanger performance in addition to other geometrical factors like the twisted tape's width, length, and twist ratio. It was discovered that when the length of the twisted tape rises, NTU and LMTD rise at all heat transfer rate values. The performance of the heat exchanger is also improved by the number of twisted tapes; it has been found that while other parameters remain constant, the number of twisted tapes increases the heat transfer characteristics.

Short-length twisted tapes positioned at the tube's beginning improve the convective heat transfer coefficient and frictional losses; they work better in laminar flow than turbulent flow, and it has been shown that the twist ratio of twisted tape has an inverse relationship with f and Nu.

B. *Effectiveness*

$$\epsilon = \frac{\text{Actual heat transfer}}{\text{Maximum Possible heat transfer}} = \frac{Q}{Q_{max}}$$

Where,

$Q = m_h c_{ph}(t_{h1} - t_{h2}) = m_c c_{pc}(t_{c2} - t_{c1})$.

C. Overall Heat Transfer Coefficient

$$Q = UA\Delta T = UiAi\Delta T = UoAo\Delta T$$

Here, the subscripts 'i' and 'o' represent the inside and outside surfaces of the inner tube.

$di =$ $inner\ diameter$,

$do =$ $outter\ diameter$,

$$K = Thermal\ conductivity\ of\ the\ tube\ material,$$

$h\boldsymbol{i} =$ $inner\ heat\ transfer\ coefficient$,

$h\boldsymbol{o} =$ $outter\ heat\ transfer\ coefficient$,

If the fluids are separated by a tube wall. The overall heat transfer coefficient is given by.

Inside Surface,

$$U_i = \frac{1}{\frac{1}{h_i} + \frac{d_i}{K} ln\frac{d_o}{d_i} + \frac{d_i}{d_o} X \frac{1}{h_o}}$$

Outside Surface,

$$U_o = \frac{1}{\frac{d_o}{d_i} X \frac{1}{h_c} + \frac{d_o}{K} ln\frac{d_o}{d_i} + \frac{1}{h_o}}$$

Where,

$$UiAi = UoAo$$

$$Ai = 2\pi diL, \quad Ao = 2\pi doL$$

III. EXPERIMENTAL SETUP

Experimental equipment as illustrated in Fig 2 below was created to perform experiments to generate data for a comparison of plane steel tube and 55° corrugated steel tube with and without insert and steel tube heat exchangers.

By altering various parameters over specific ranges, enough data was generated,

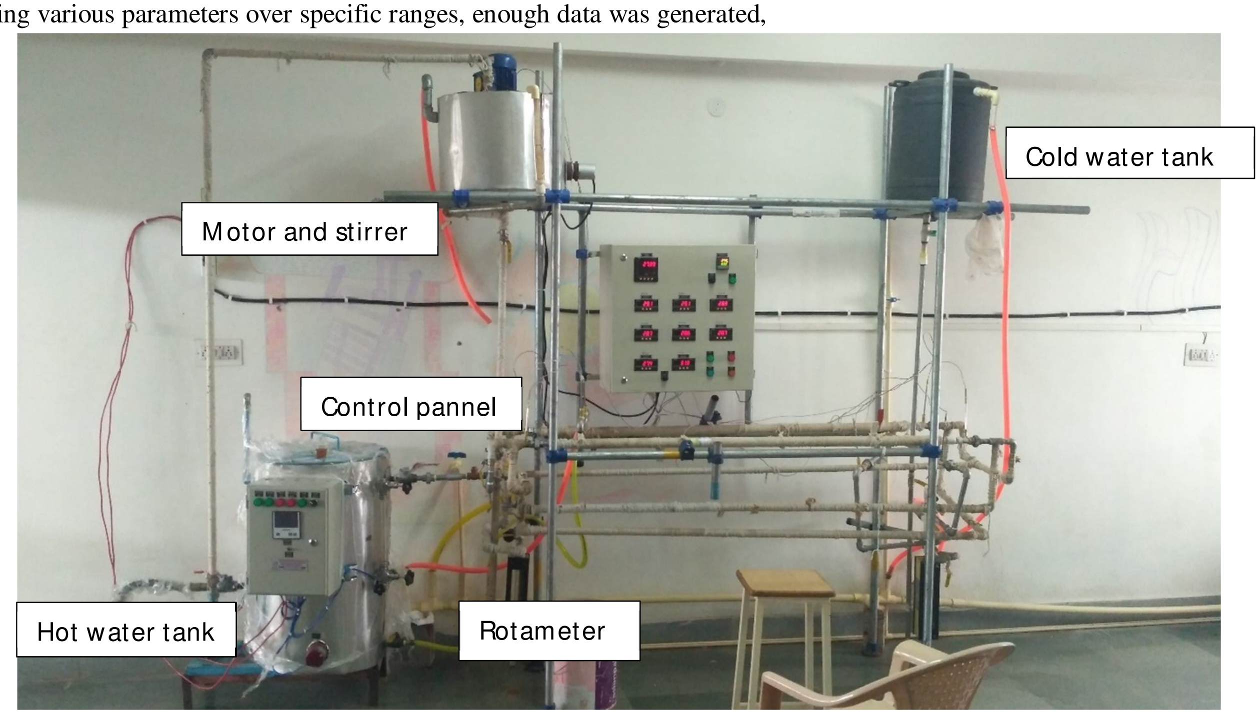


Fig2: Experimental Setup of Heat Exchanger

Fig 2: corrugated copper and steel tube

1) List of Items

Name of Article	Brief Specification
1. Plate	IS 2062 M.S. PLATE
2. Tube	TATA / TI/ MSL
3. Valve	SANT / ATAM /MAHAVIR.
4. Pump	STANDRED
5. Pr. Switch	INDFOS/ STANDRED
7. Connecters	SEIMENS/ L& T
8. Panel	Powder Coated Dust Proof
9. Relay	SEIMENS/L&T
10 Pre. Gauge	ARIHANT
11. HEATER	S.B. S
12. SAFETY VALVE	SANT / ATAM / MAHAVIR
13. ELE. MOTOR	ABB / CROMPTON.

2) Technical Data Sheet

TYPE OF H.W.B.	: VERTICAL STATIONARY PACKAGE TYPE
MODEL	: ELEAQUA (BL-EA-10)
DESIGN COAD	: STANDARD
MAX. HEAT OUT PUT	: 9 K.W.
MAX. OUTPUT TEMPERATURE	: 90 *C
FUEL	: ELECTRICAL HEATER,
THERMAL EFFICIENCY (GCV)	: 99 %±0. 2
CIRCULATION WATER PUMP	: 0.5 H.P.
MODEL	: ELE-9
TYPE	: IMMERSION
MOC	: SS-304
ONE HEATER CAPACITY.	: 9 K.W.
ELECTRIC POWER SUPPLY	: 220 V 1 PHASE N AC
TOTAL ELECTRIC LOAD	: 0.5 H.P.+ 9 K.W.

3) *Specifications Of Heat Exchanger Tube*

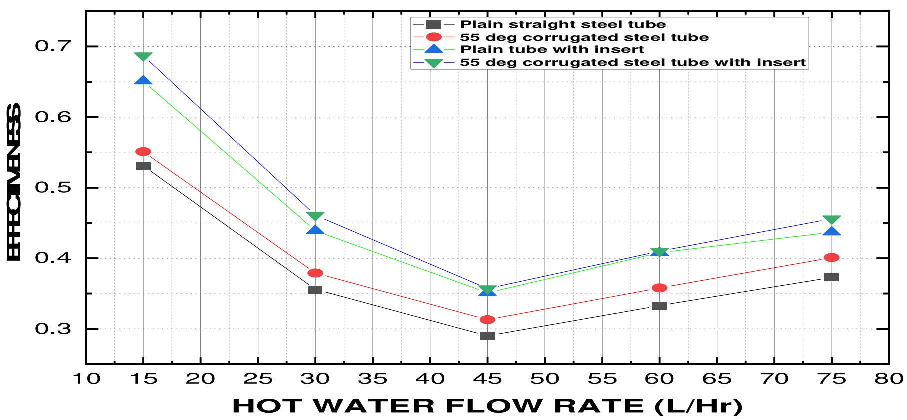
Sr. No.	Parameter	Value in mm	Value
1	Outer Diameter of Corrugated tube	12 mm	0.012 m
2	Inner Diameter of Corrugated tube	10 mm	0.010 m
3	Outer Diameter of plain steel tube	12 mm	0.012 m
4	Inner Diameter of plain steel tube	10 mm	0.010 m
5	Effective Length of cooper tube	1500mm	1.5 m
6	Effective Length of steel tube	1500mm	1.5 m
7	Effective Length of twisted tape insert	1500mm	1.5 m
8	Heat Transfer Area		0.05655 m^2

IV. RESULTS AND DISCUSSION

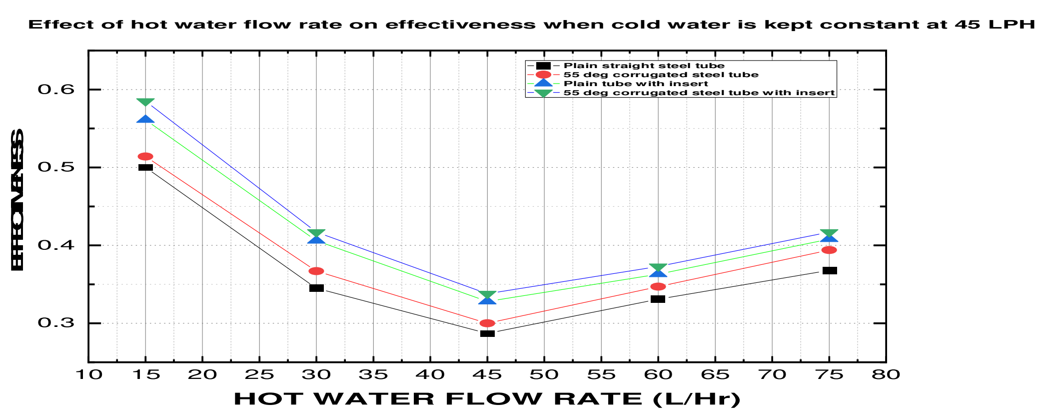
This section contains the efficacy, logarithmic mean temperature difference, overall heat transfer coefficient, and volatility due to the mass flow rates of the hot and cold fluids. As thermal conductivity of copper tube is more than steel tube then heat transfer in corrugated copper tube is maximum.

A. *Graphical Presentation of Data*

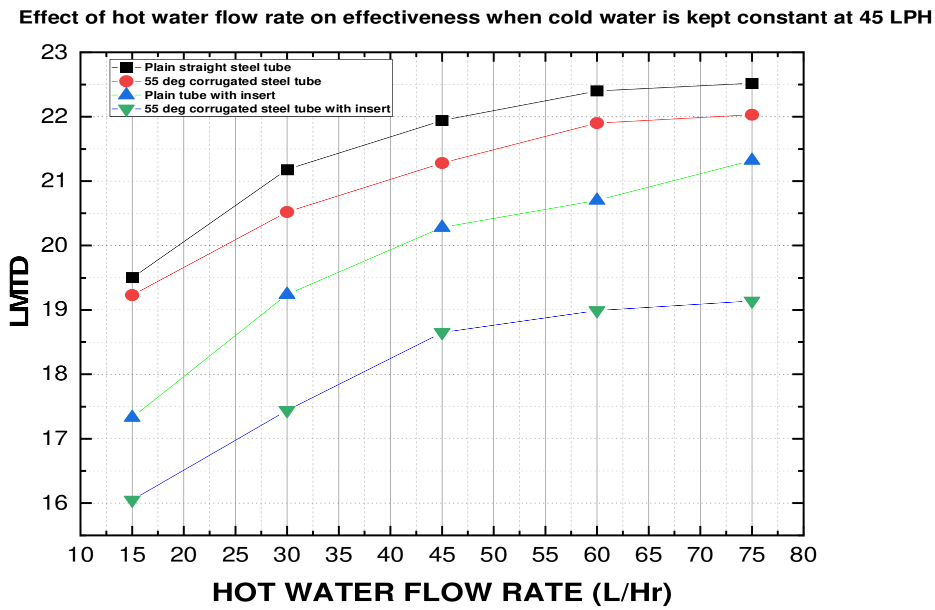
1) Graph 1, Comparative analysis of effectiveness when cold water is constant at 45 LPH plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in counter flow arrangement



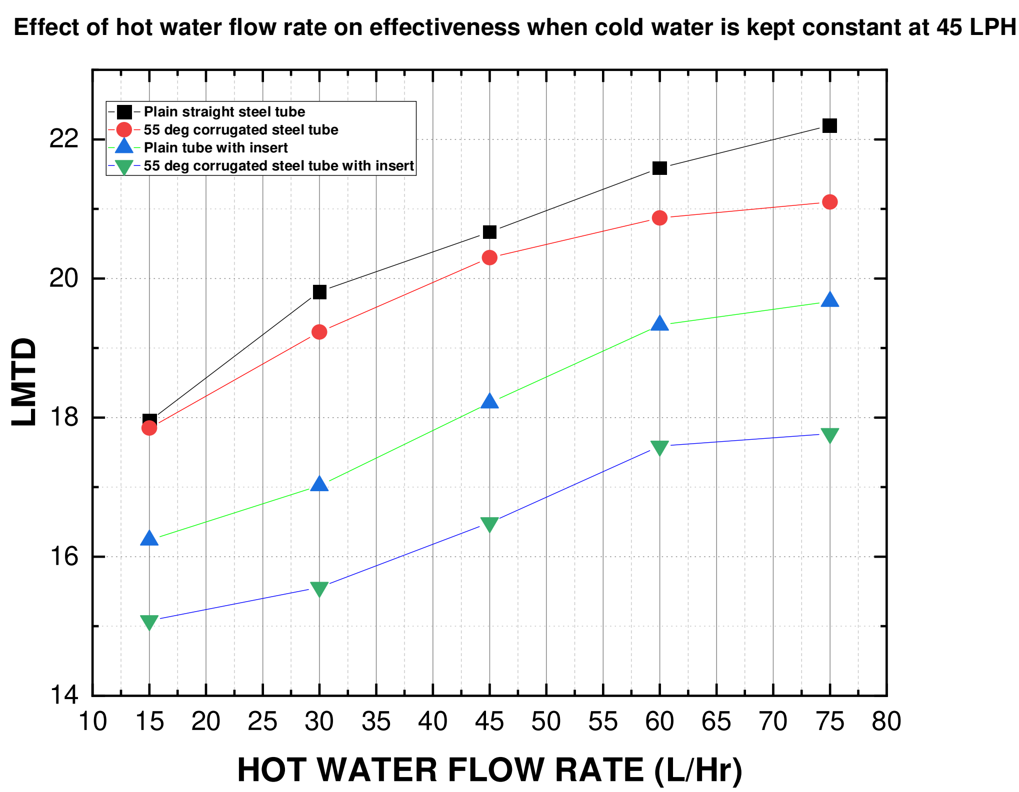
2) Graph 2, Comparative analysis of effectiveness when cold water is constant at 45 LPH plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in parallel flow arrangement



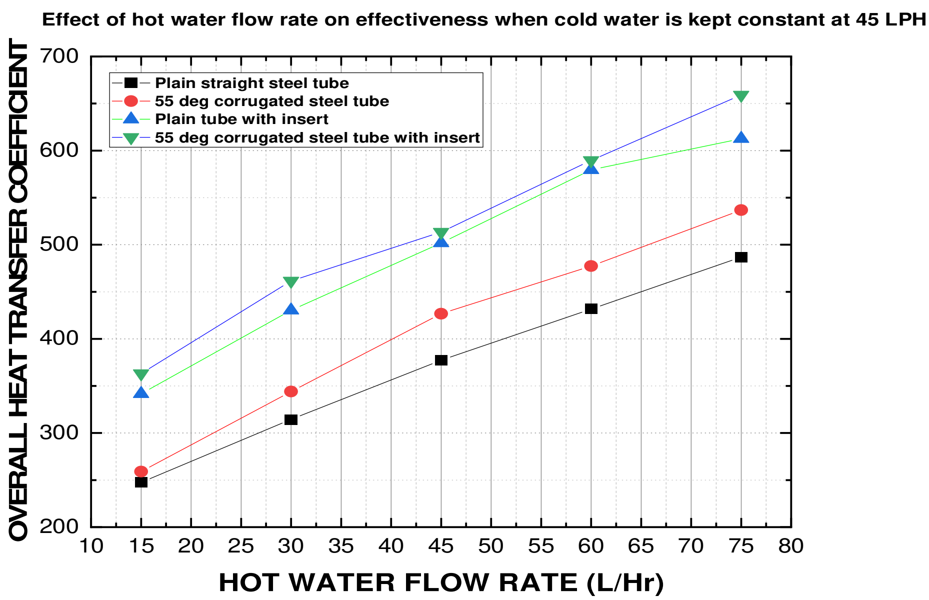
3) Graph 3, Comparative analysis of LMTD when when cold water is constant at 45 LPH plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in counter flow arrangement



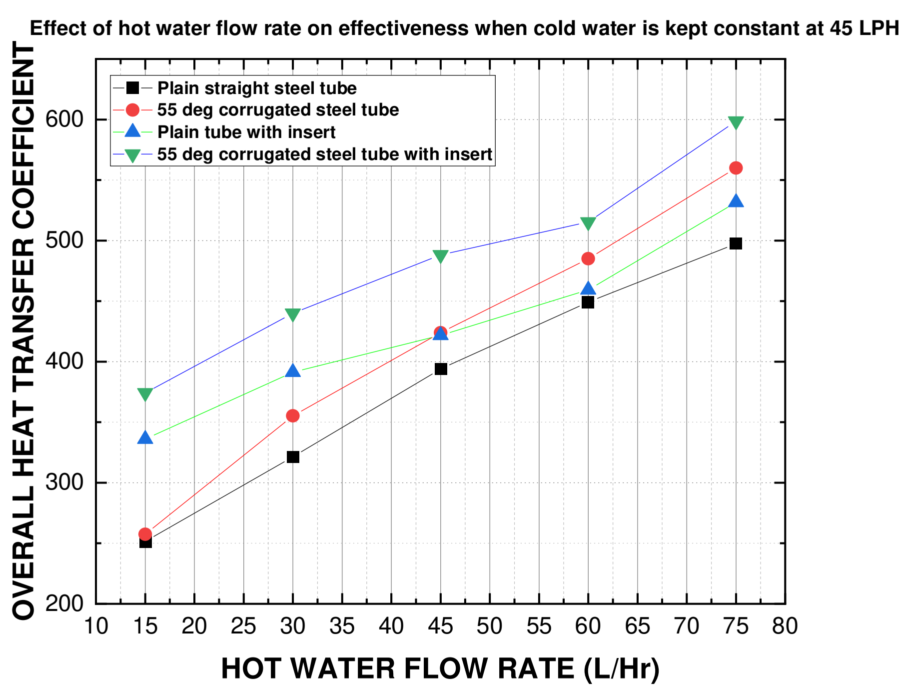
4) Graph 4, Comparative analysis of LMTD when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in parallel flow arrangement



5) Graph5, Comparative analysis of Overall heat transfer Coefficient when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in counter flow arrangement.



6) Graph 6, Comparative analysis of Overall heat transfer Coefficient when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in parallel flow arrangement.



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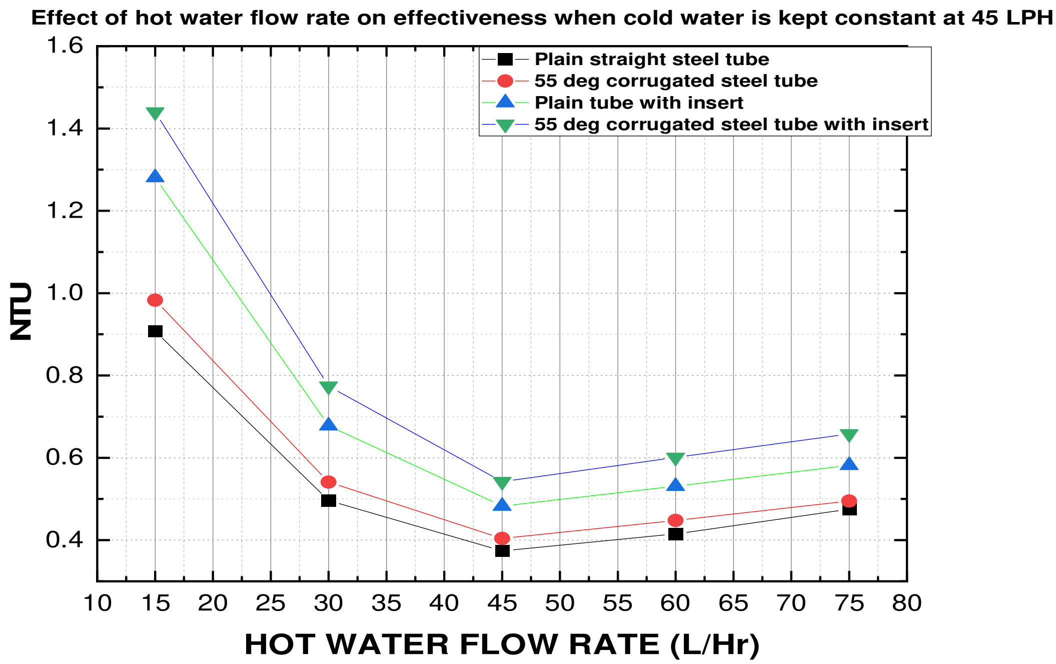
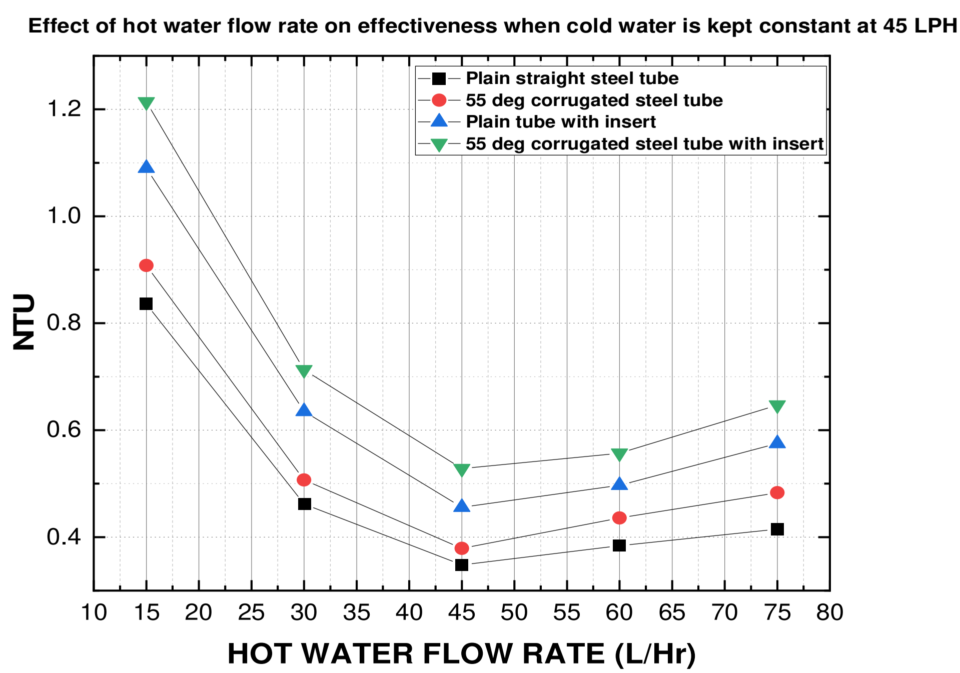
7) Graph7, Comparative analysis of NTU when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in counter flow arrangement



8) Graph 8, Comparative analysis of NTU when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in parallel flow arrangement



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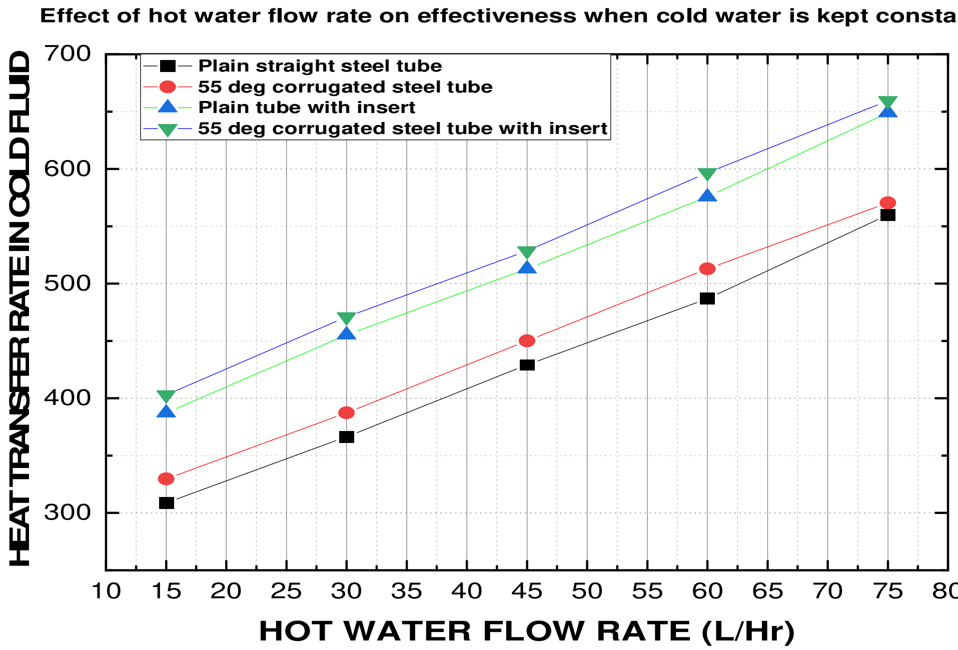
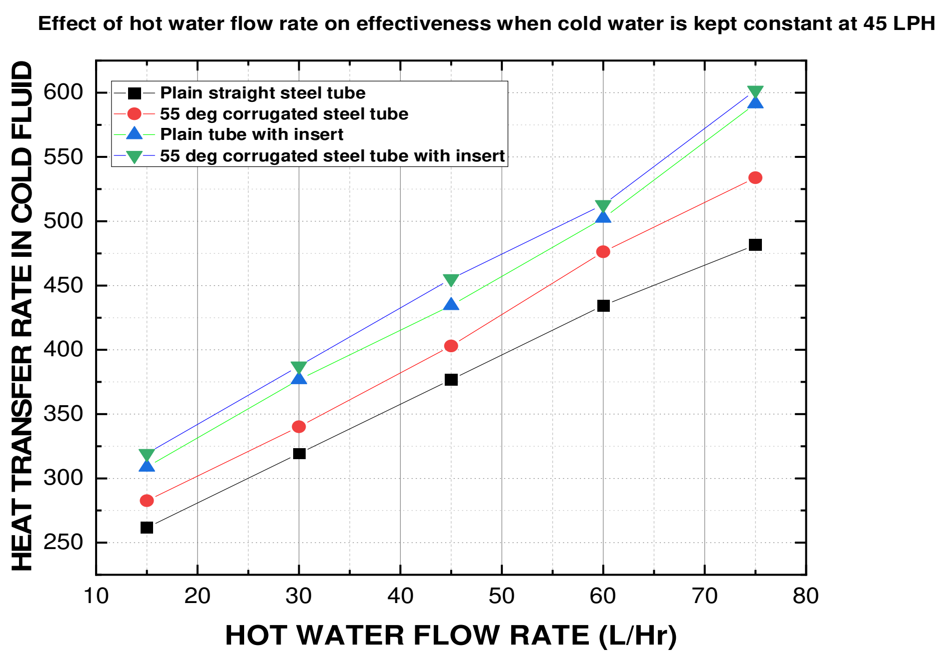
9) Graph 9, Comparative analysis of heat transfer rate in cold fluid when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in counter flow arrangement.



10) Graph10, Comparative analysis of heat transfer rate in cold fluid when cold water is constant at 45 LPH for plain straight steel tube, corrugated steel tube, plain straight steel tube with insert and corrugated Steel tube with insert DPHE in parallel flow arrangement.



V. COMMENTS AND CONCLUSIONS

A straight steel tube and 55° corrugated steel tube heat exchanger was experimentally analyzed in the heat and mass transfer lab. Using parallel and counter flow configurations with and without insert, the mass flow rates of hot fluid inside and outside the tubes were changed.

The heat exchanger's efficiency is significantly impacted by both the hot and cold-water flow rates. Efficacy gradually decreases when the mass flow rate of cold water is fixed at 45 LPH and the mass flow rate of hot water is increased. In all flow directions, straight steel tube is more effective than bent tube when used in parallel flow. The overall heat transfer coefficient rises as the mass flow rate of hot water does. It is reported that the maximum overall heat transfer occurs at a hot water mass flow rate of 75 LPH at 55° corrugated steel tube with insert counter flow. When the hot water flow rate varies and the cold-water flow rate is set at 45 LPH, the LMTD in a straight steel tube with parallel flow is at least 15 LPH. This experimental setup uses a cheap, straight heat exchanger tube. In the future, the material composition of the straight steel tube heat exchanger may alter in order to increase the heat exchanger's efficiency.

It was discovered that the heat transfer rate increases with the volume flow rate of hot water in both the parallel and counterflow cases, with the counterflow case exhibiting a larger heat transfer rate than the parallel flow case. The steel tube with 55° corrugation with insert was found to have a higher rate of heat transmission than the other variants in both cases. Maximum heat transfer rate measured in a counterflow configuration in 55° 55° corrugated steel tube with insert was 636.43 Watt; this is 21.91% higher than the rate of parallel flow in a plain steel tube in counter flow and 24.58% higher than the rate of heat transfer in a parallel configuration. It refers to the corrugation in tubes, variance in the volume flow rate of hot fluid, and the rate of heat transfer on the relative direction of fluid motion.

The counter flow configuration in a corrugated steel tube with insert was found to have the highest efficacy value 0.676. This figure is more than the highest value of efficacy in counter flow arrangements for plain steel tubes and corrugated steel tubes without insert, by 22.49% and 17.18%, respectively.

The highest total heat transfer coefficient of 571.88 W/m^2K for a corrugated steel tube with insert was found to be 17.24% and 31.13% higher in a parallel flow arrangement than the maximum values for those two designs, respectively. It was discovered that when the volume flow rate of hot fluid increases, so does the value of the overall heat transfer coefficient.

The corrugated steel tube in parallel flow arrangement with insert and the plane steel tube in with insert in parallel flow were found to have values 21.53% and 18.09% lesser than maximum respectively, the maximum value of LMTD, which was observed for the plain steel tube without insert at 22.52 C. It was discovered that when the volume flow rate of hot fluid increases, the value of LMTD also increases.

The results showed that the initial value of NTU decreased as the volume flow rate of hot fluid up to 45 lph and it again increases from 45 lph The lowest value of NTU was found to be 1.427 in the case of plane steel tube, which is 36.52% and 28.14% smaller than the values found in the corrugated steel tube with insert in parallel flow and the corrugated steel tube without insert, respectively.

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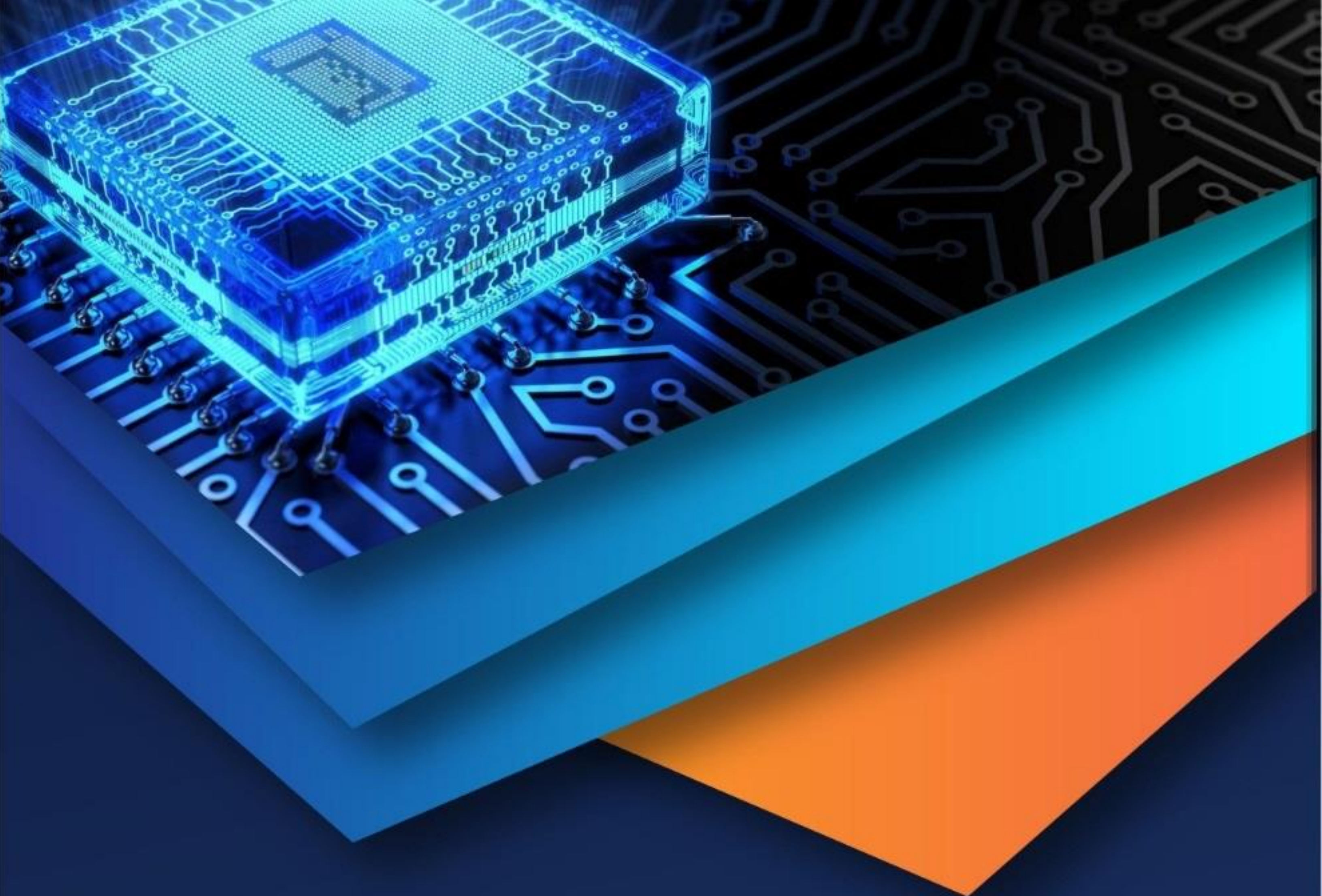

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