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Comparative Experimental Study on Effect of Copper Wire Helical Wound Steel Tube with 2.5" Full Length Insert on Performance of Double Pipe Steel Tube Heat Exchanger

Udit Seryam[1], Aseem C Tiwari[2], Jeetendra Kushwaha[3]
Department of Mechanical Engineering, UIT RGPV Bhopal, MP

Abstract: A comparative experimental study was conducted to explore the hydrothermal behavior of a double tube heat exchanger with copper wire helical wound steel tubes and plane steel tubes with and without twisted tap inserts of pitch length 2.5 inches. In comparison to helical tubes, corrugated tubes, and many other more compact tube type heat exchangers, straight tube heat exchangers offer advantages since the construction of the heat exchanger tubes is easier. In the current work, the fluid-to-fluid heat exchange is considered, with a flow rate ranging from 15 to 75 liters/hour. Constant wall temperature or constant heat flux ideas are used in the majority of investigations on heat transfer coefficients. The efficiency, overall heat transfer coefficient, and impact of hot water flow rate with constant cold water flow rate for straight steel tube and copper wire helical wrapped steel tube heat exchangers in parallel flow and counter flow configurations were investigated and compared. Utilizing a 2.5" full length clockwise twisted tape insert, both layouts were created. The measurements were carried out in a constant state. When the hot water flow rate is increased while maintaining the cold water flow rate constant, the efficiency of the heat exchanger drops for both the straight steel and the copper wire helical wound steel tube. Compared to a plane steel tube heat exchanger, the copper wire helical wound steel tube heat exchanger has a better efficiency. The test findings demonstrate that inserting inserts causes pressure drop. With 2.5" clockwise twisted tape inserts wrapped in helical copper wire, steel tube was able to transmit heat more quickly than other arrangements.
Keywords: Effectiveness, LMTD, heat transfer coefficient, double tube heat exchanger, and twisted tape insert.

I. INTRODUCTION

The world's energy needs have significantly increased over the past ten years, which has led to much research on the best ways to use energy to address this problem [1]. Along with the rise in energy conservation, there has been a consistent and generous expansion in HE research and innovation, and many qualified professionals are still looking for ways to improve design and performance [2]. HE is frequently utilized in the industrial setting to transfer heat across various streams and temperatures. The most popular and often utilized HE in industry is concentrated-tube HE [3]. Twin tube heat exchangers, which can be utilized in a range of products, must be made more effective, efficient, and compact [4].

For single-phase and phase change heat transfer in a variety of applications, double tube heat exchangers are often used in power plants, the chemical industry, waste heat recovery systems, refrigeration and air conditioning systems, automotive, and process industries. The The hydro thermal properties of double tube heat exchangers have improved significantly. There are many active and passive strategies to improve the thermal performance of the double tube heat exchanger. In the active technique, additional power from outside sources, such as impinging jets, electrostatic fields, surface vibrations, etc., is required to accelerate the rate of heat transfer. In addition to not requiring any additional energy, passive technologies are also easy to make and inexpensive to use. As a result, heat exchangers are increasingly using the passive approach as a heating method [5].

In experimental and numerical investigations to assess the efficacy of tubular heat exchangers, the passive technique known as the enhancer is widely used [6–14]. The use of wire coil (WC) and twisted tape (TT) inserts as tabulators is one of the best methods for generating swirl flows in tubes and decreasing boundary layer thickness while boosting turbulent intensity [16]. The rate of heat transmission via the heat exchanger may be accelerated by employing inserts.

II. LITERATURE SURVEY

A. Methodology

In this section, formulas for calculating the heat transfer coefficient are provided. Below are calculations and graphs for copper wire helical wrapped steel tubes with and without inserts, as well as planar steel tubes flowing parallel and counter..

B. Effectiveness

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

Where,

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

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

In order to conduct experiments and gather data for a comparison of planar steel tubes with and without insert heat exchangers, the experimental setup depicted in Fig. 1 below was constructed. Adjusting different parameters within predetermined ranges produce sufficient data.

Fig1: Experimental Setup of Heat Exchanger

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Effective length of 2.5” full length clock wise twisted tape insert has been used.

Fig. 2 Twisted tape insert and tube

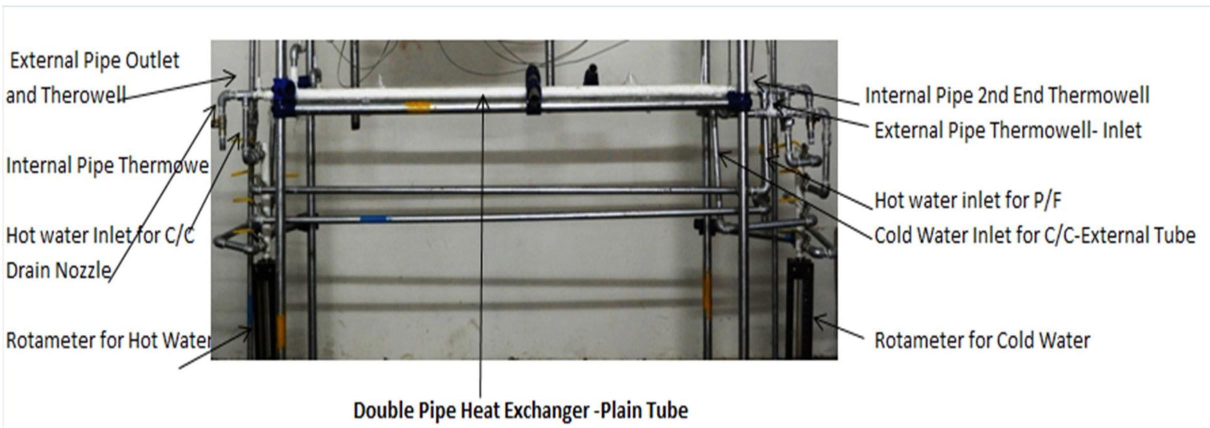


Fig 3 Double Pipe Heat Exchanger –Plain tube

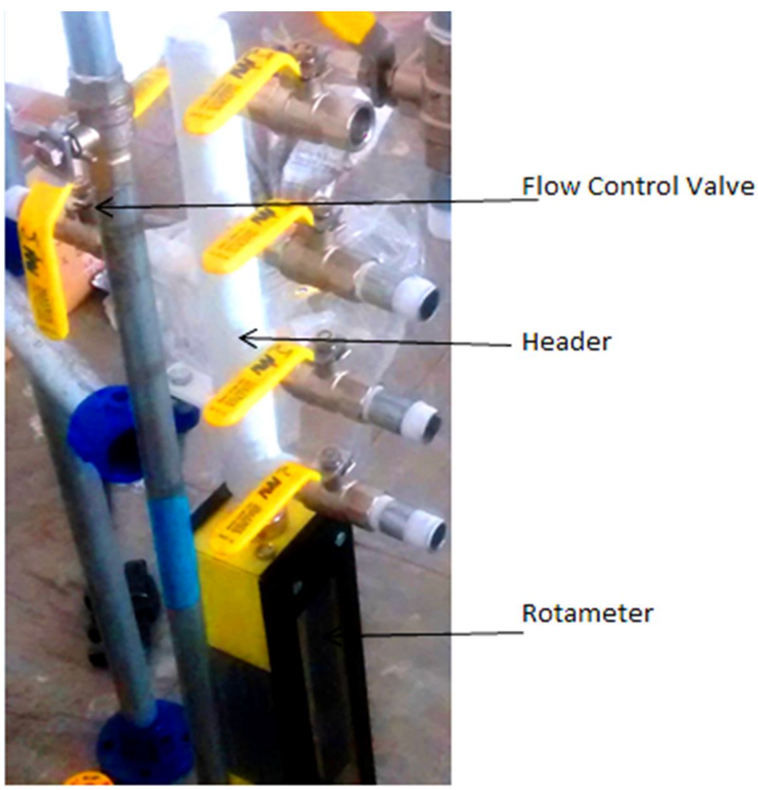


Fig 4 Rota meter and Header Loop

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.

Technical Data Sheet

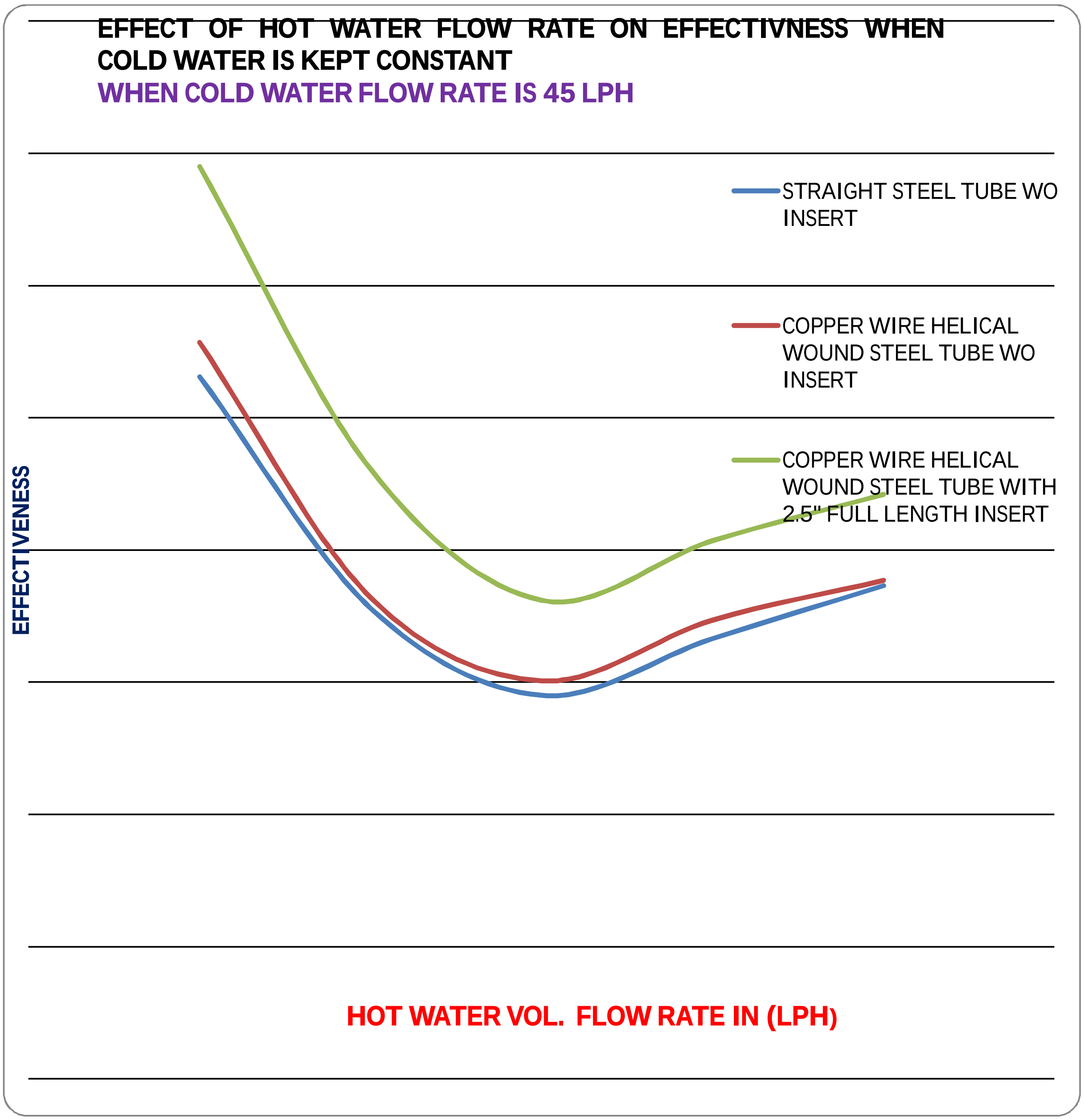
TYPE OF H.W.B. Type	: Vertical Stationary Package
MODEL	: ELEAQUA (BL-EA-10)
DESIGN COAD	: standard
MAX. HEAT OUT PUT	: 9 K.W.
MAX. OUTPUT TEMPERATURE	: 90 *C
FUEL	: ELECTRICAL HEATER,
THERMAL EFFICIENCY (GCV)	: 99 %±0. 2
CIRCULATION WATER PUMP	: 0.5 H.P.
MODEL	: ELE-9
TYPE	: IMMERSION
MOC	: SS-304
ONE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

IV. RESULTS AND DISCUSSION

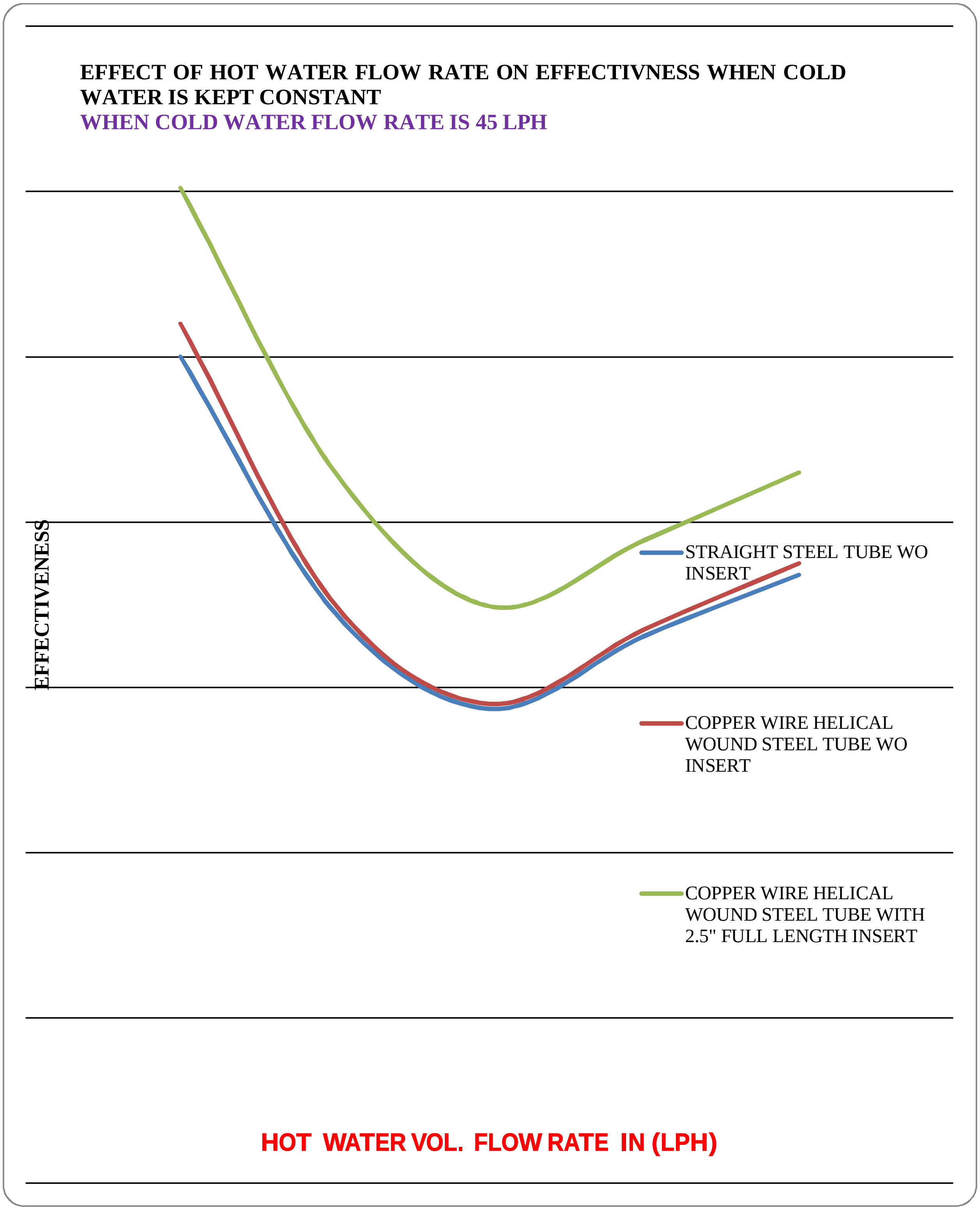
This section contains the efficacy, logarithmic mean temperature difference, overall heat transfer coefficient, and volatility due to the mass flow rates of the hot and cold fluids.

A. Graphical Presentation of Data

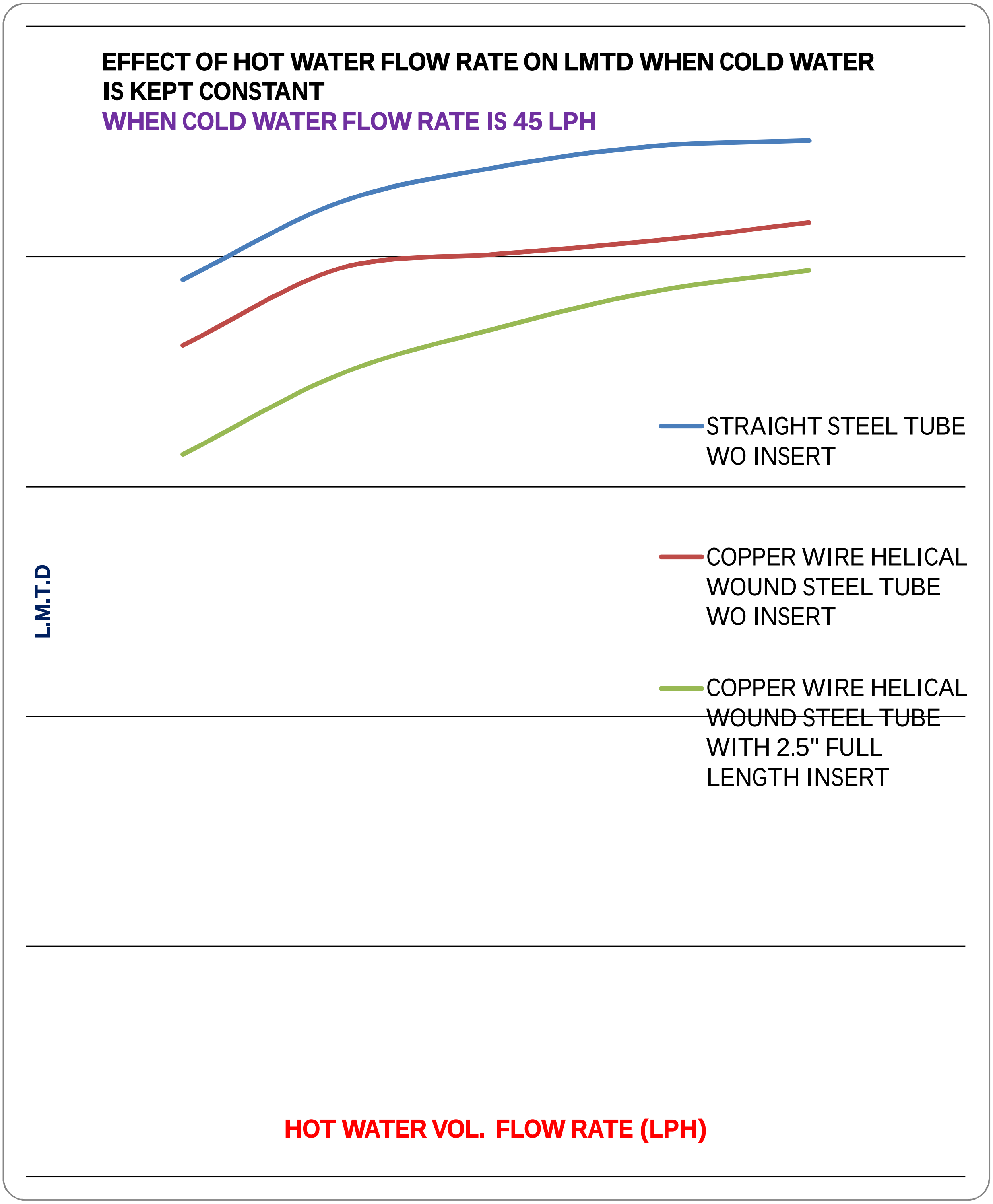
1) Graph 1, The present study aims to compare the effectiveness of straight steel tube, copper wire helical wound steel tube without inserts, and copper wire helical wound steel tube DPHE with 2.5" full length inserts in counter flow arrangement while cold water is kept constant at 45 LPH.



2) Graph 2, an evaluation of the relative efficacy of straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in parallel flow configurations under continuous cold water flow conditions of 45 LPH.



3) Graph 3, Comparison of LMTD for straight steel tube, copper wire helical wound steel tube without inserts, and copper wire helical wound steel tube DPHE with 2.5" full length inserts in counter flow arrangement when cold water is constant at 45 LPH.



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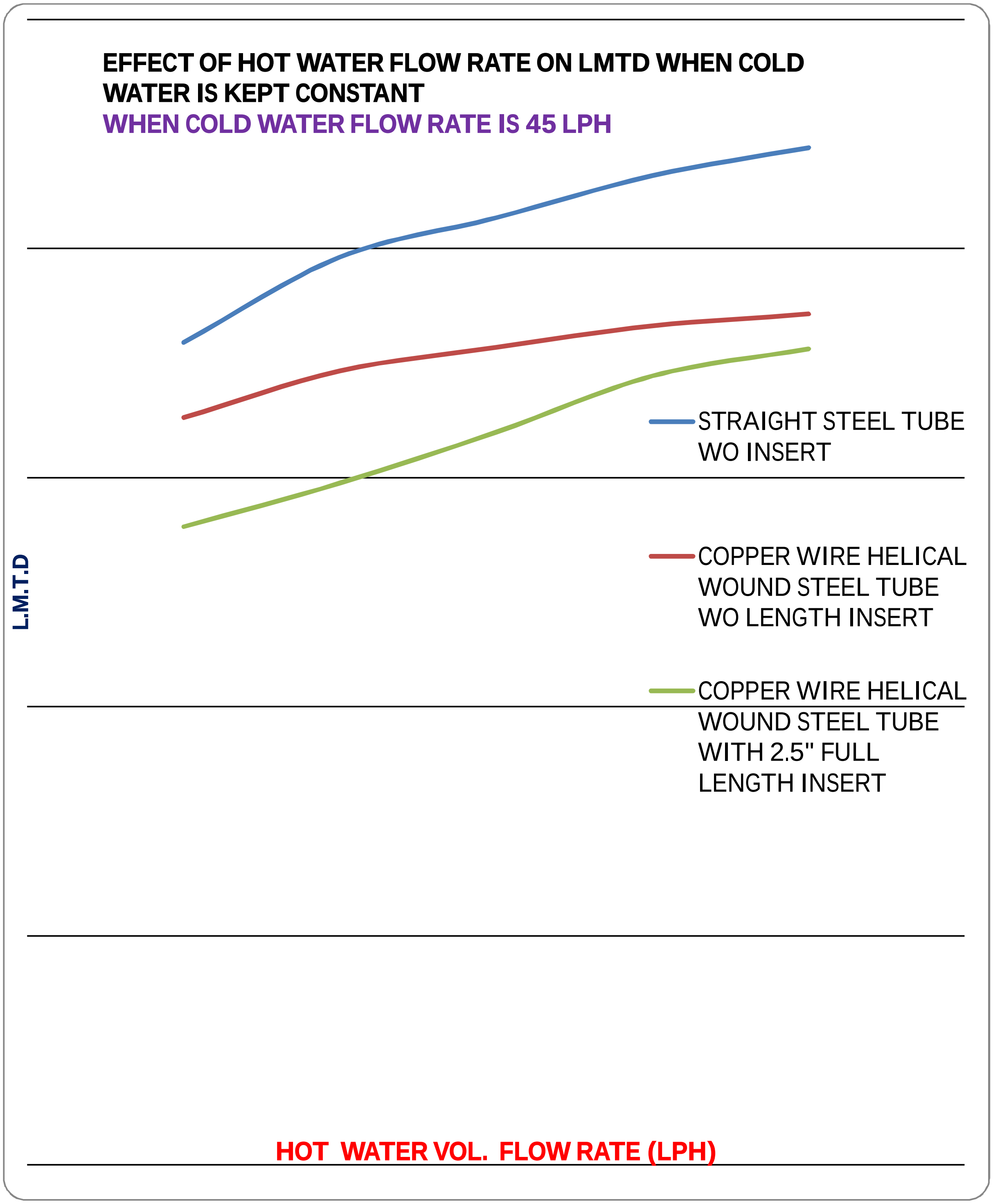
4) Graph 4, Comparison of the LMTD for straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a parallel flow arrangement where the flow of cold water is constant at 45 LPH.



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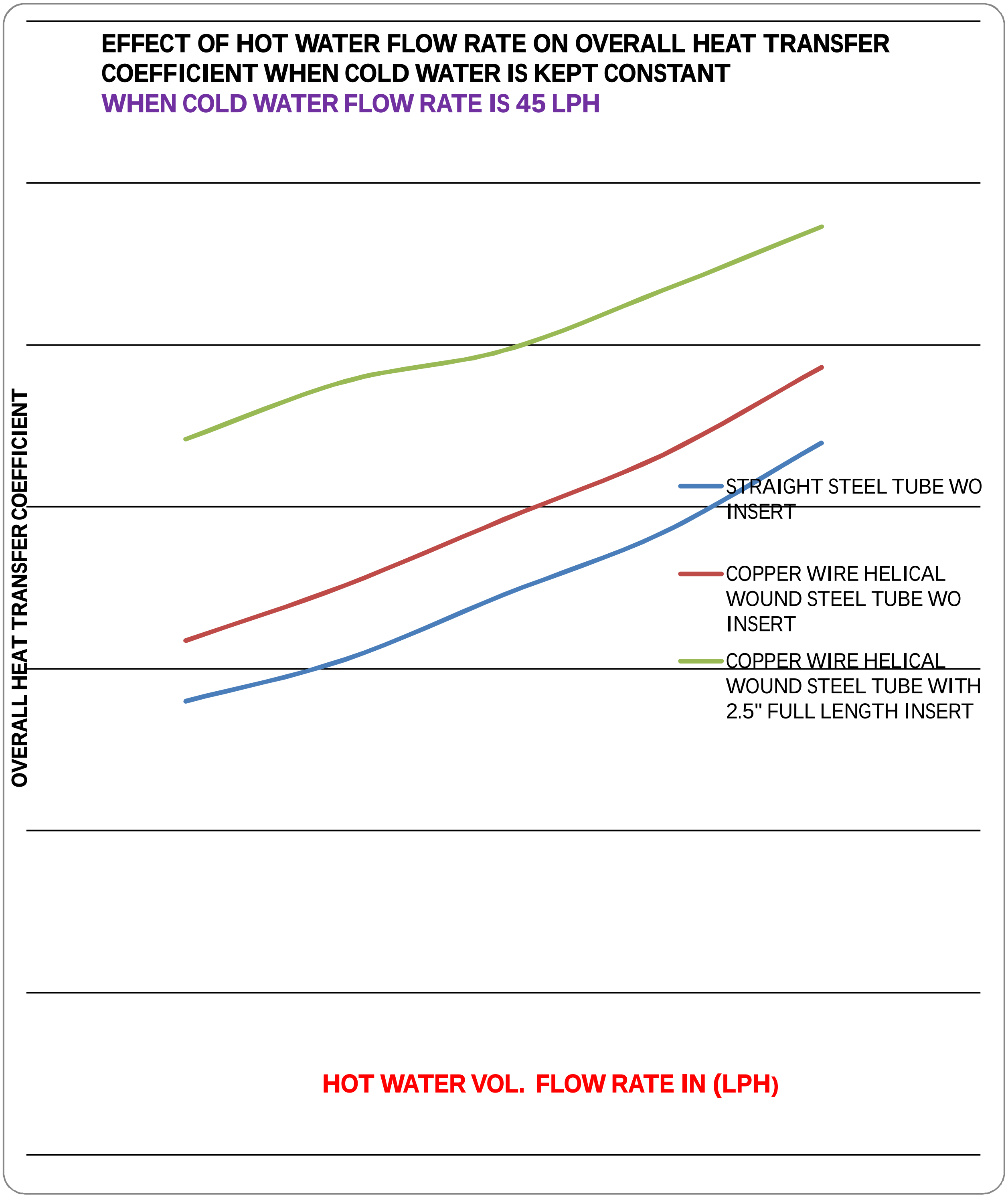
5) Graph5, analysis of overall heat transmission in comparison Coefficient for straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a counter flow arrangement when cold water is kept constant at 45 LPH.



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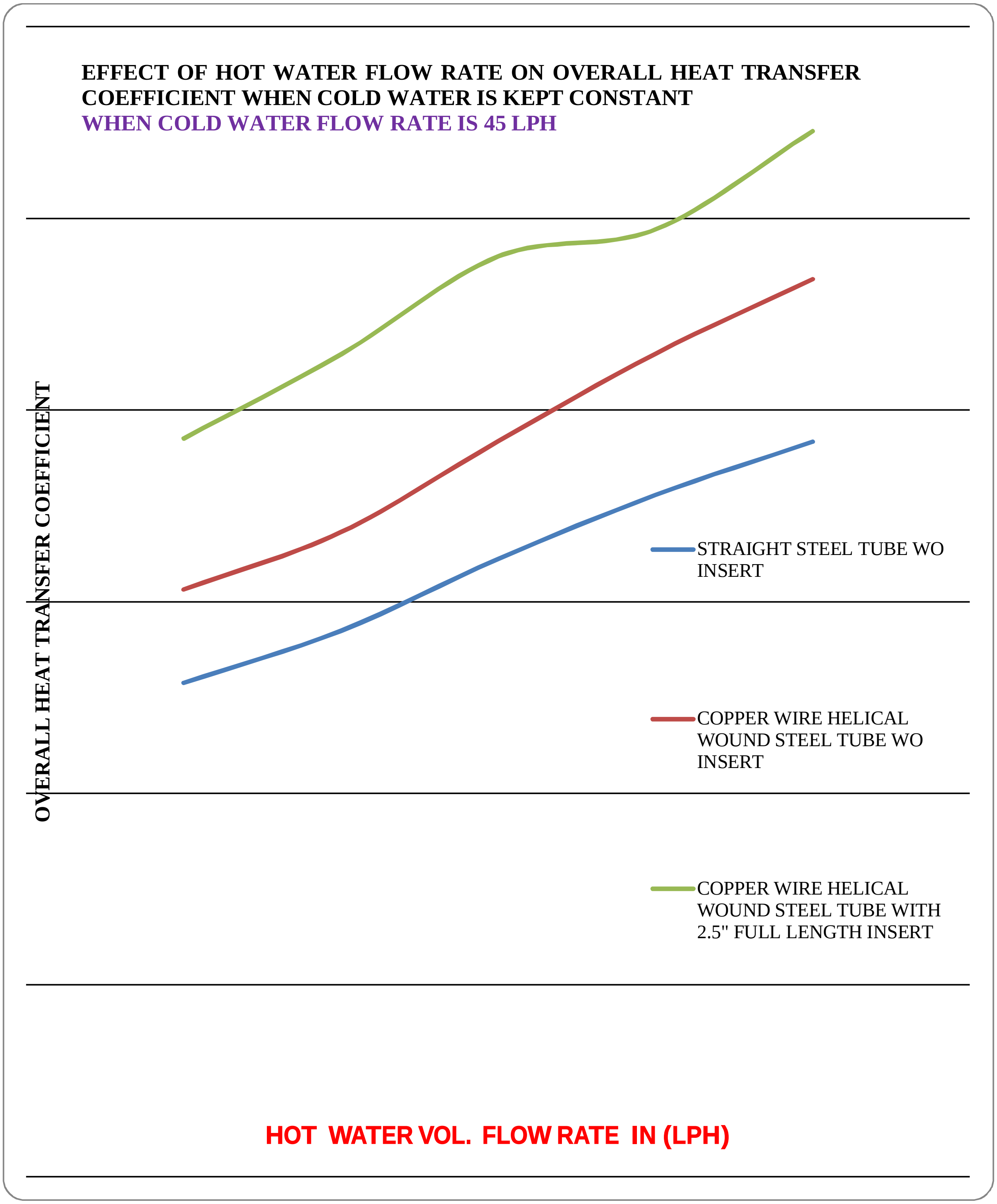
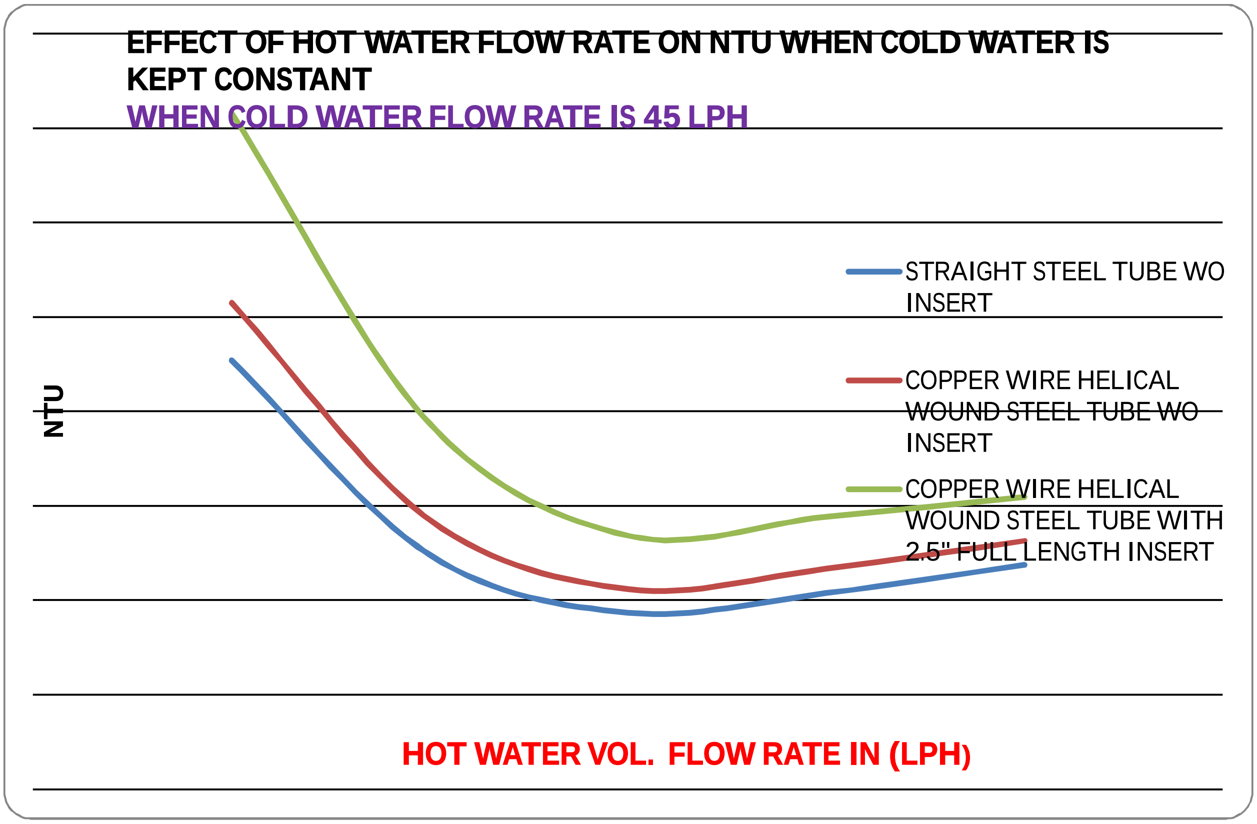
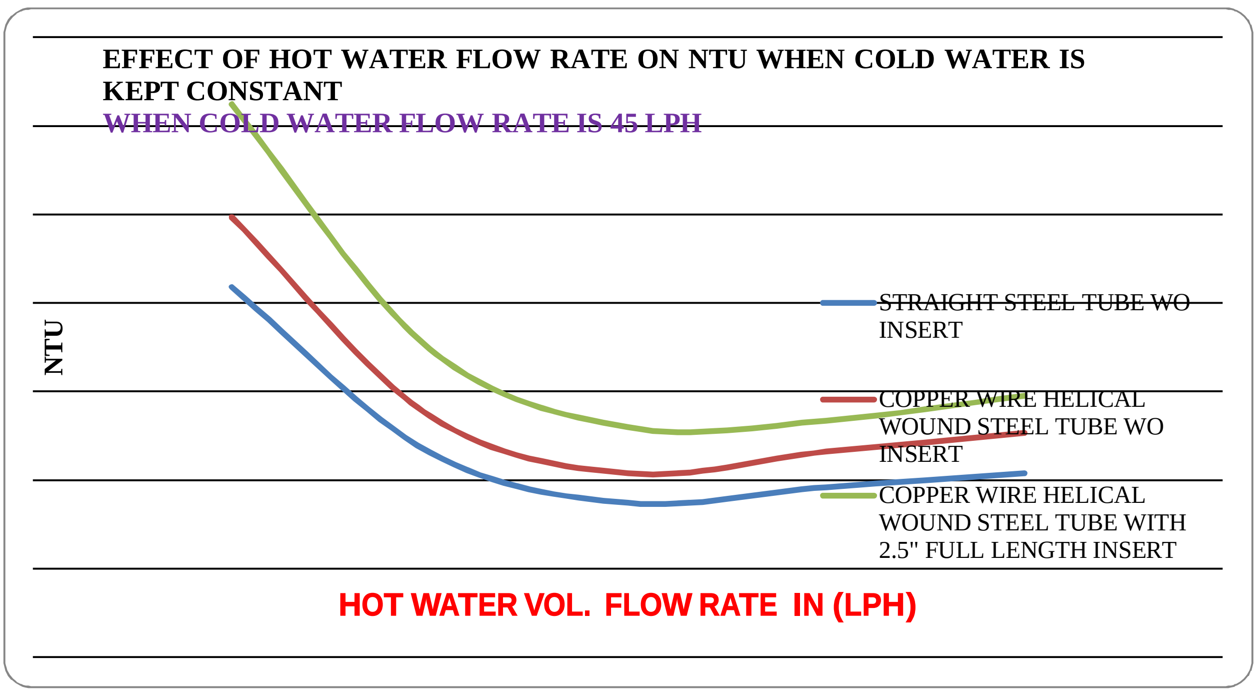
6) Graph 6, analysis of overall heat transmission in comparison Coefficient for straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a parallel flow arrangement when cold water is kept constant at 45 LPH.



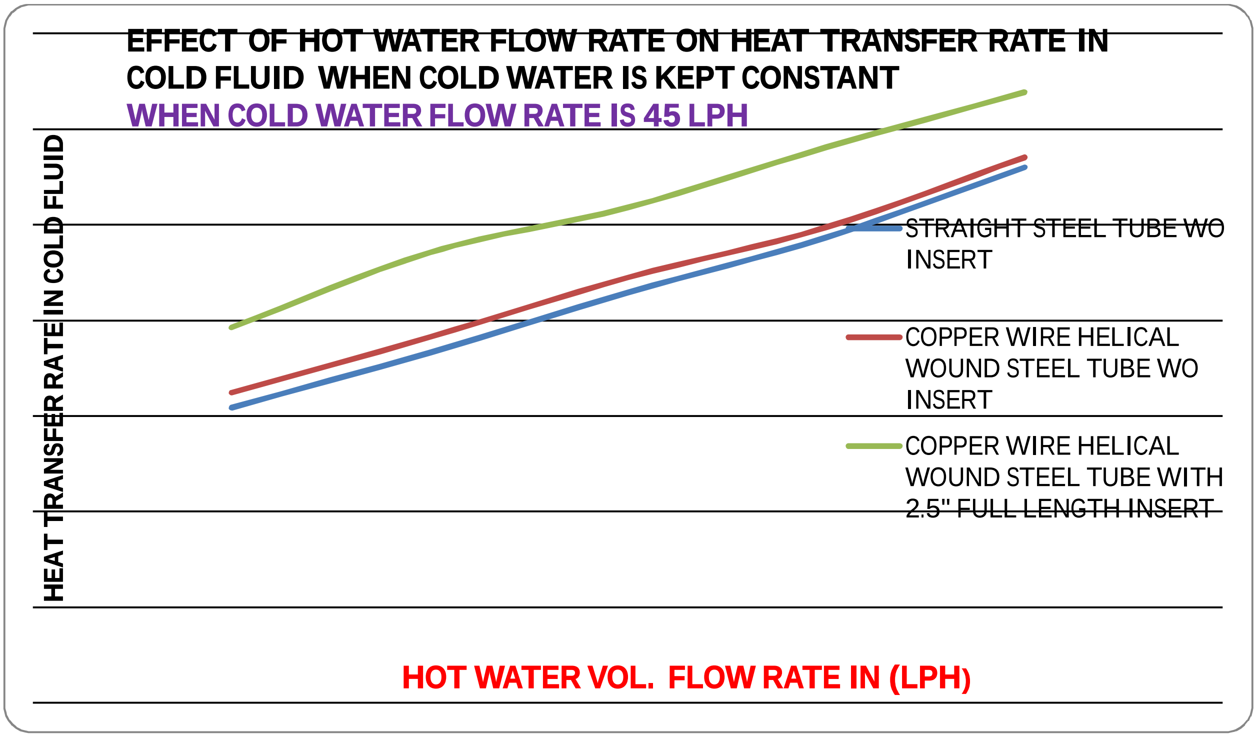
7) Graph7, NTU comparison for straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a counter flow setup while cold water is kept constant at 45 LPH.



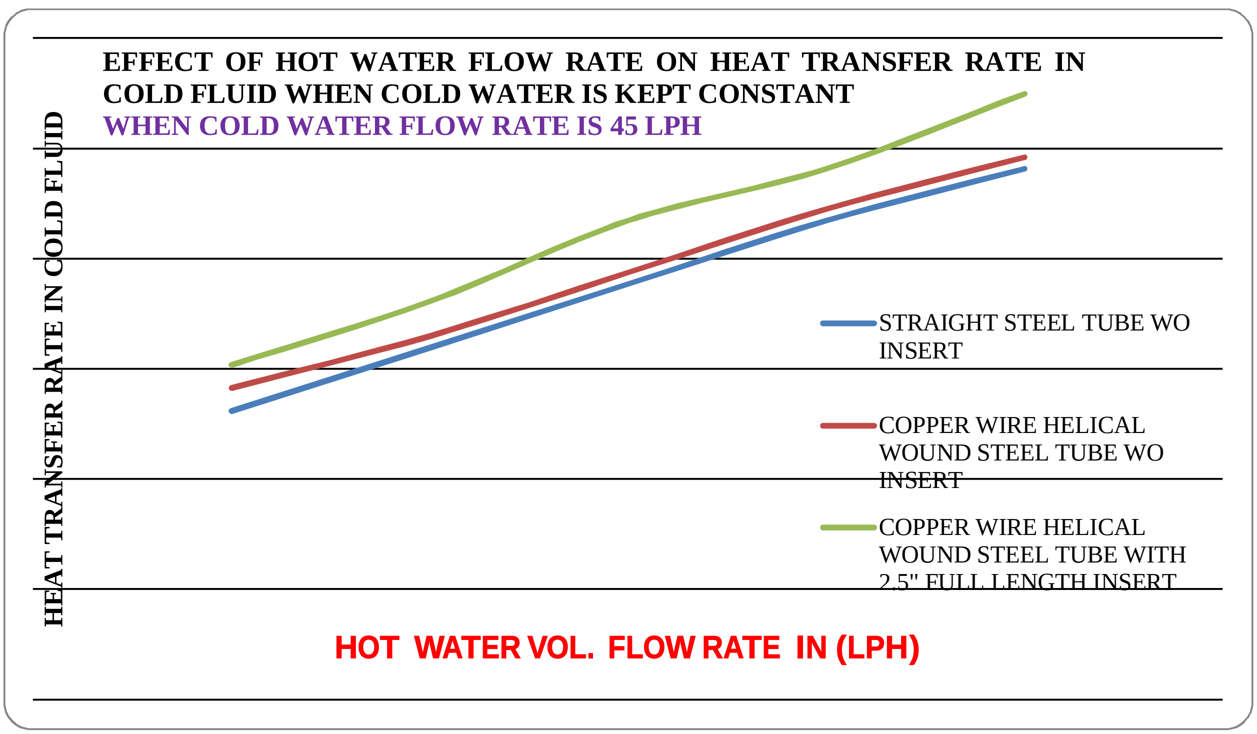
8) Graph 8, Comparison of NTU for straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a parallel flow arrangement while cold water is kept constant at 45 LPH.



9) Graph 9, Comparison of the heat transfer rates in straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a counter flow arrangement while the temperature of the cold fluid is constant at 45 LPH.



10) Graph10, Comparison of the heat transfer rates in straight steel tubes, copper wire helical wound steel tubes without inserts, and copper wire helical wound steel tubes DPHE with 2.5" full length inserts in a parallel flow configuration where the temperature of the cold fluid is constant at 45 LPH.



V. COMMENTS AND CONCLUSIONS

The mass flow rates inside and outside of straight steel and straight copper tube heat exchangers were adjusted in the heat and mass transfer lab during an experimental examination using parallel and counter flow configurations.

1) The efficiency of the heat exchanger is significantly impacted by both the hot and cold water flow rates.
2) Efficiency continuously declines when the mass flow rate of hot water is raised while the mass flow rate of cold water is kept at 45 LPH.
3) In all flow orientations, straight steel tube is more efficient and less effective in parallel flow.
4) The overall heat transfer coefficient rises as the mass flow rate of hot water does.
5) According to reports, the highest total heat transfer occurs at a hot water mass flow rate of 75 LPH at counter flow in a straight steel tube.
6) When the hot water flow rate varies while the cold water flow rate remains constant at 45 LPH in a straight steel tube with parallel flow, the LMTD is at least 15 LPH.
7) In this experimental arrangement, the heat exchanger tube is inexpensive and straight.
8) In this experimental arrangement, the heat exchanger tube is inexpensive and straight.

It was discovered that the heat transfer rate increases with the volume flow rate of hot water in both the parallel and the counter flow examples, with the counter flow case displaying a higher heat transfer rate than the parallel flow case. The insert with a 2.5-inch pitch length was found to transmit heat more quickly than the other designs in both cases. The maximum rate of heat transfer, which was 638.52 Watt, was measured in a counter-flow configuration with a 2.5-inch insert. This rate is 24.58% higher than that of parallel flow in a steel tube enclosed by a helical copper coil and 22.99% higher than that of parallel flow in a parallel configuration with no insert. It denotes the volume flow rate variation of hot fluid, the pitch length of the twisted tape, and the rate of heat transfer on the relative direction of fluid motion.

The counter flow configuration with a 2.5 inch clockwise insert was found to have the maximum effectiveness, measuring 0.690. This figure is greater by 19.27% and 23.04% than the highest effectiveness in counter flow arrangements for, respectively, plane steel tubes without inserts and helical bounded coil steel tubes without inserts.

The greatest overall heat transfer coefficient for a 2.5-inch insert in a copper-bounded helical coil straight tube was determined to be 573.00 W/m2K, which is 33.07% and 18.28% greater than the maximum values for those two designs, respectively, in a parallel flow arrangement. It was discovered that when the volume flow rate of hot fluid increases, so does the value of the overall heat transfer coefficient.

At 22.52 C, the plane steel tube in counter flow was found to have the highest value of LMTD, which was 17.53% higher than the value for the copper-bounded helical coil straight tube without insert and 20.91% higher than the value for the copper-bounded helical coil straight tube with 2.5" insert in the parallel flow arrangement, respectively. It was discovered that as the volume flow rate of hot fluid increases, so does the value of LMTD.

The lowest value of NTU was found in the case of no insert, where it was 1.433, which is 28.12% and 36.63% higher than the values discovered in 2.5 inch wise twist tape insert and copper-bounded helical coil straight tube without insert in parallel flow, respectively. The initial value of NTU was found to decrease with an increase in the volume flow rate of hot fluid.

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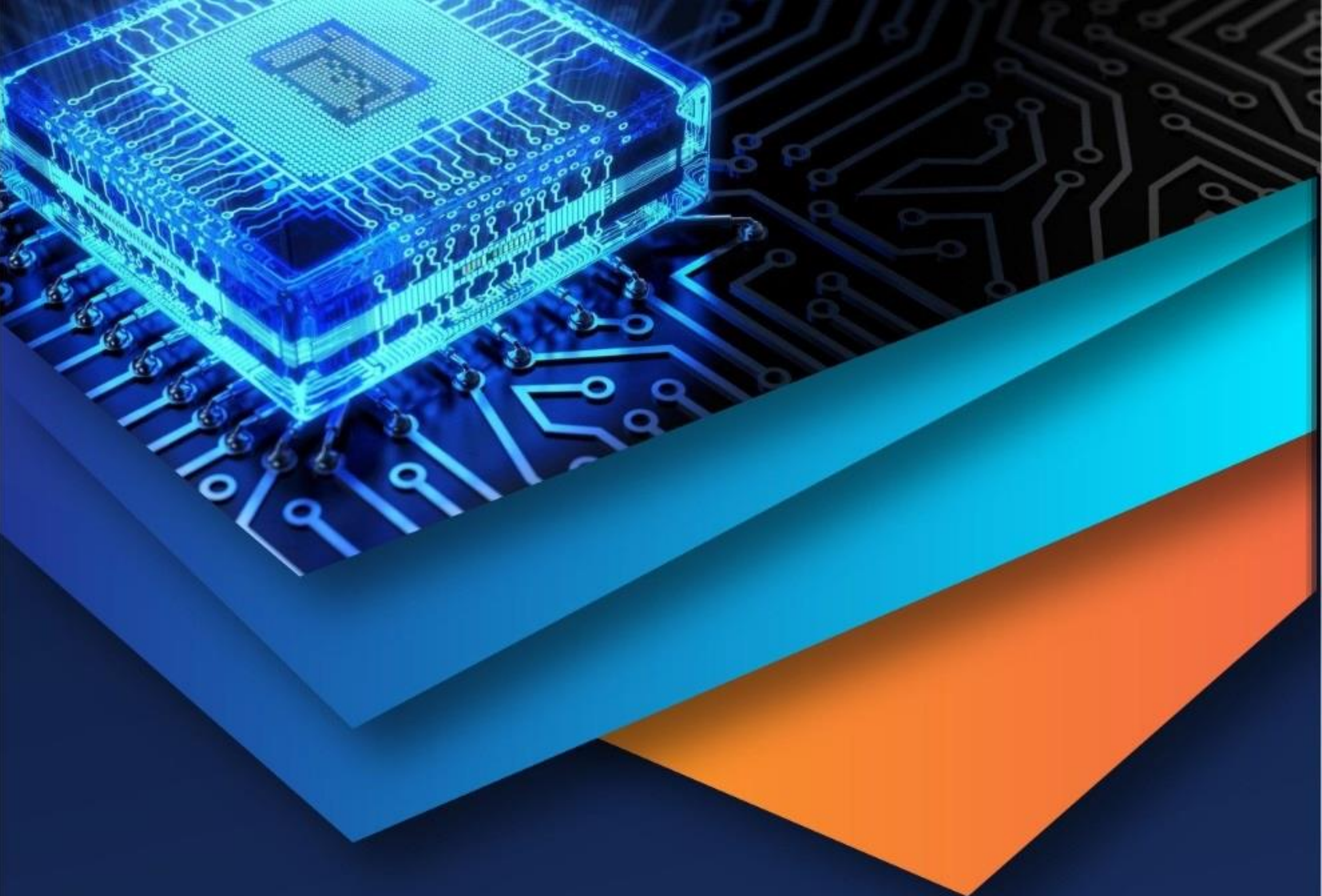

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