To Study and Do Theoretical Analysis of Compact Heat Exchangers

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Definition:-

- Heat exchanger:

  It is a device that provides exchange of thermal energy between two or more fluids at different temperature.

- Types of heat exchanger:-

  1. Double-Pipe heat exchangers
  2. Shell and tube Heat Exchangers
  3. Compact heat exchanger
  4. Gasketed Plate heat exchanger
  5. Condenser and evaporator

Compact Heat exchanger

- Types:-
  1. Plate fin and tube fin
  2. Tube boundle with small dia.

A heat exchanger having a surface area density greater than about 700 m^2/m^3 is quite arbitrarily to as a compact heat exchanger.

Fin and Tube Heat Exchanger : A Compact Heat Exchanger

Applications

- Vehicular heat exchanger
- Condenser and evaporaters
- Refrigeration industry
- Aircraft oil coolers
- Automative radiators
- Oil coolers
- Intercoolers of compressors
- Other industries

INTRODUCTION

- This proposed scheme analyzes the heat transfer process involved in the operation of an automotive radiator. The analysis of a radiator encompasses nearly all of the fundamentals discussed in a heat transfer class, including the internal and external fluid flow through a heat exchanger and the design and analysis of heat sinks and exchangers.

- The theoretical heat exchanger investigation begins with analyzing the internal fluid flow through the radiator’s circular or noncircular tubes, yielding the convective heat transfer coefficient for water.

- The external fluid flowing across the radiator tubes and fins is then analyzed to find the convective heat transfer coefficient for the air.

- The heat sink design of the radiator must then be analyzed using the Effectiveness method to find the theoretical effectiveness

- This topic is specifically selected to integrate the numerous areas from the subject of heat transfer. Through the many challenges and successes met during this project.

- The convective heat transfer between a wall and the fluid is given by

$$Q = hA(T_w - T_f)$$

Or

$$Q = (hA)_p (T_w - T_f)$$

- Enhancement ratio:

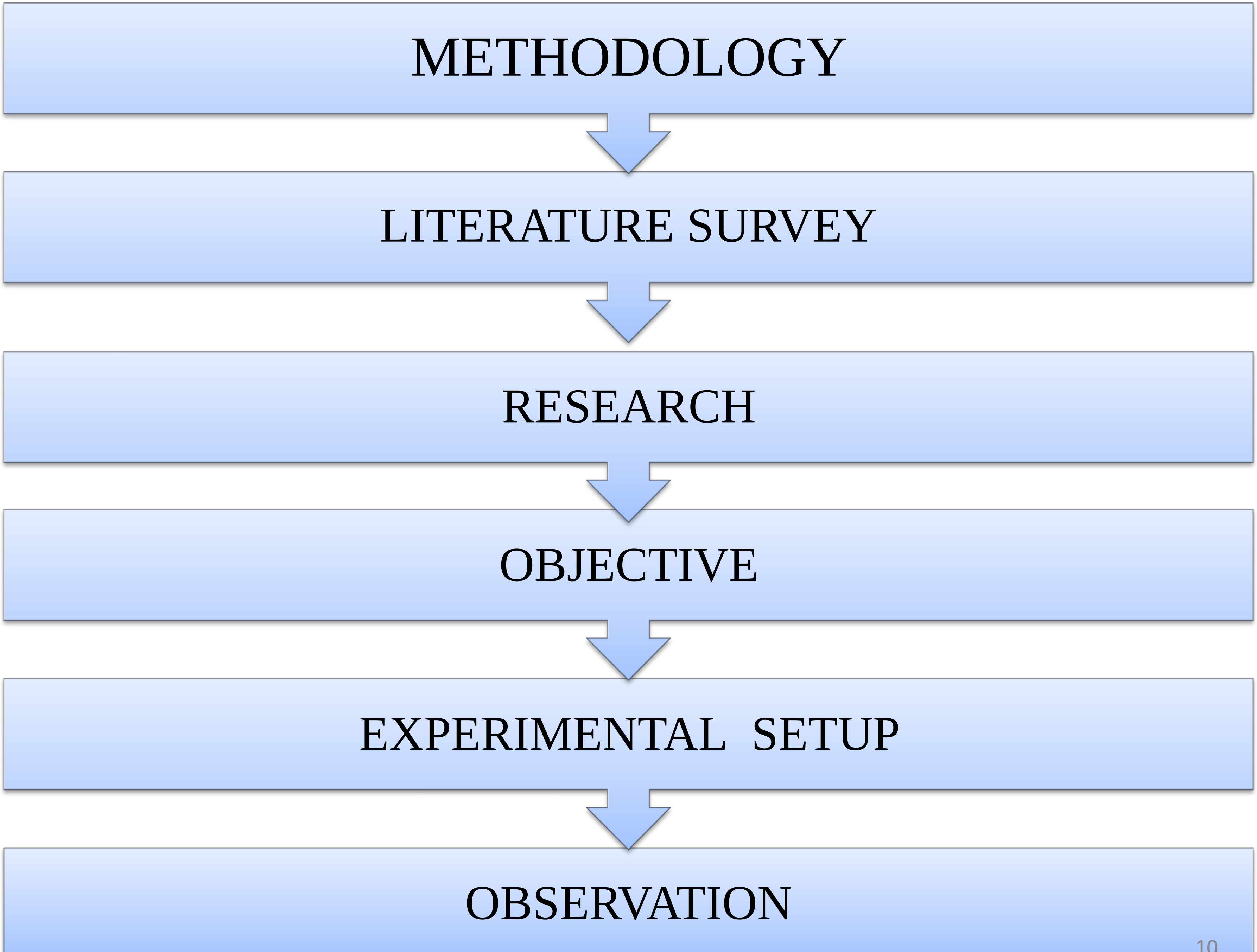
$$E = hA/(hA)_p$$

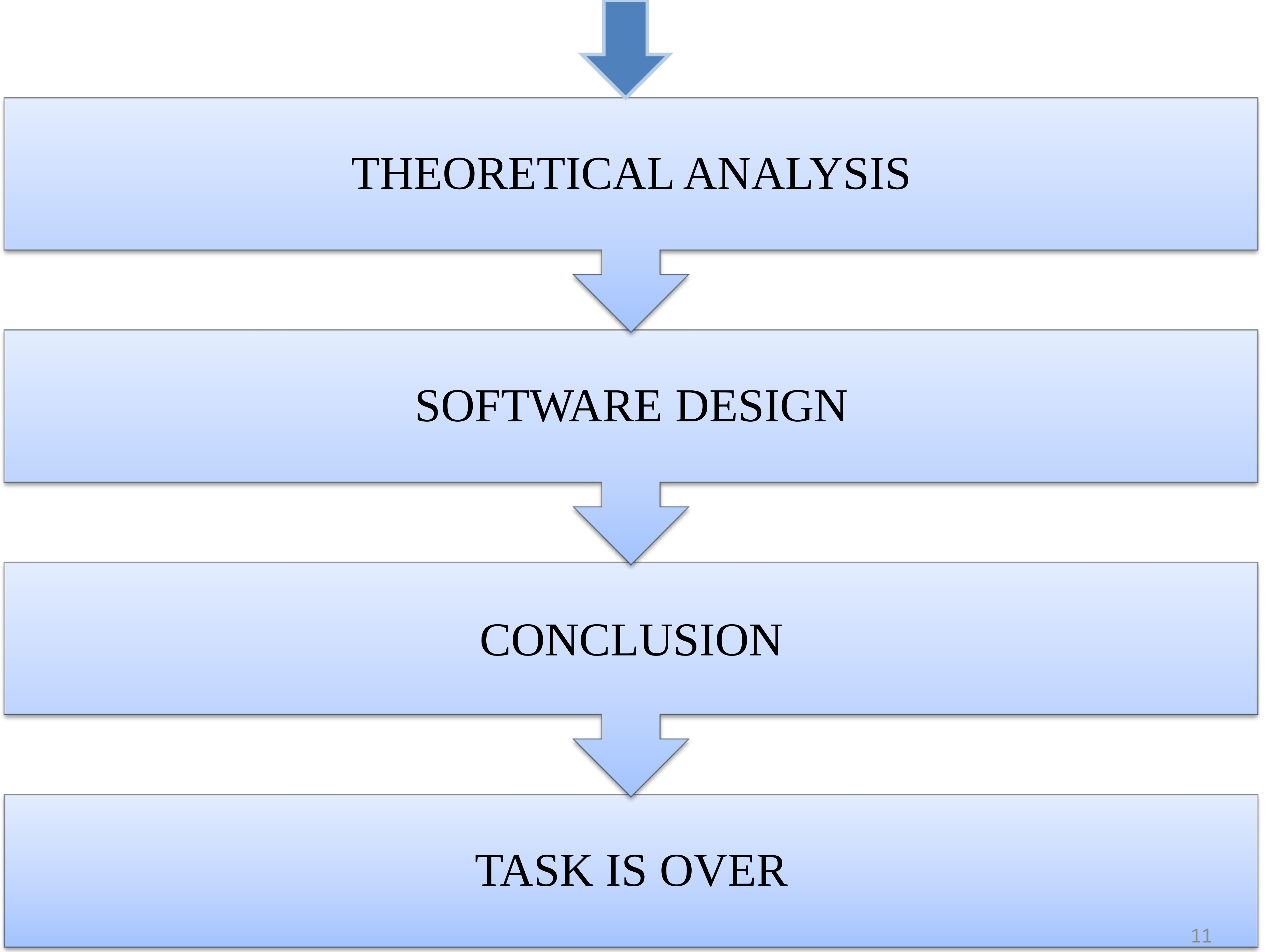
- There are several methods to increase the hA value:

- The heat transfer coefficient can be increased without an appreciable increase in surface area.

- The surface area can be increased without appreciable changes in the heat transfer co-efficient.

- Both the heat transfer coefficient and the surface area can be increased.


METHODOLOGY
LITERATURE SURVEY
RESEARCH
OBJECTIVE
EXPERIMENTAL SETUP
OBSERVATION


THEORETICAL ANALYSIS
SOFTWARE DESIGN
CONCLUSION
TASK IS OVER

➢ RESEARCH

- The first step of this project was to gather information on existing radiator designs and general heat exchangers. After gathering information, we gained a thorough understanding of how a radiator works and the disadvantages of the current radiator designs. This included a general patent search, using Google Scholar, and technical journal search, using different books, that related to radiators. Once we choose our design, we must research a general testing method to use as a basis for our comparison of our new design and the current designs.
- Current radiator designs of maruti 800 are extremely limited. The main problem is that current radiators experience a large resistance to heat transfer caused by air flowing over the radiator. Current radiators also experiences head resistance, are very bulky, and impose limitations on the design of the vehicle.

OBJECTIVES

- To study the design of radiator for given duty and find enhancement in the performance of it by doing systematic analysis.

- The main objective of compact heat exchangers is to produce more efficient heat exchange equipment for minimizing cost, which is to produce the physical size of a heat exchanger for a given duty.

- To optimization high heat transfer rates under the specified conditions.

EXPERIMENT

System Configuration

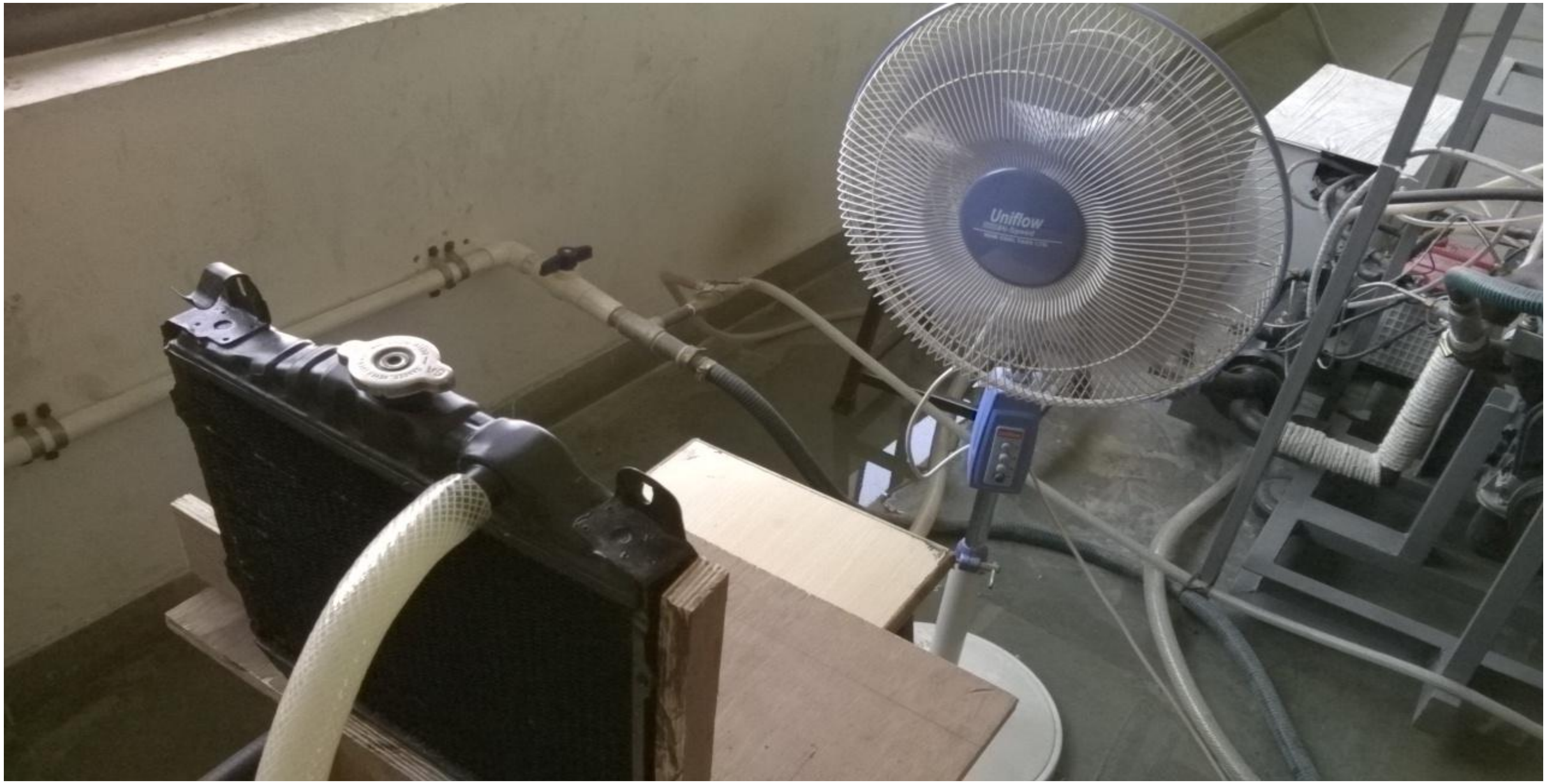


Figure 1: New radiator designed setup

Figure 2: Old radiator designed setup

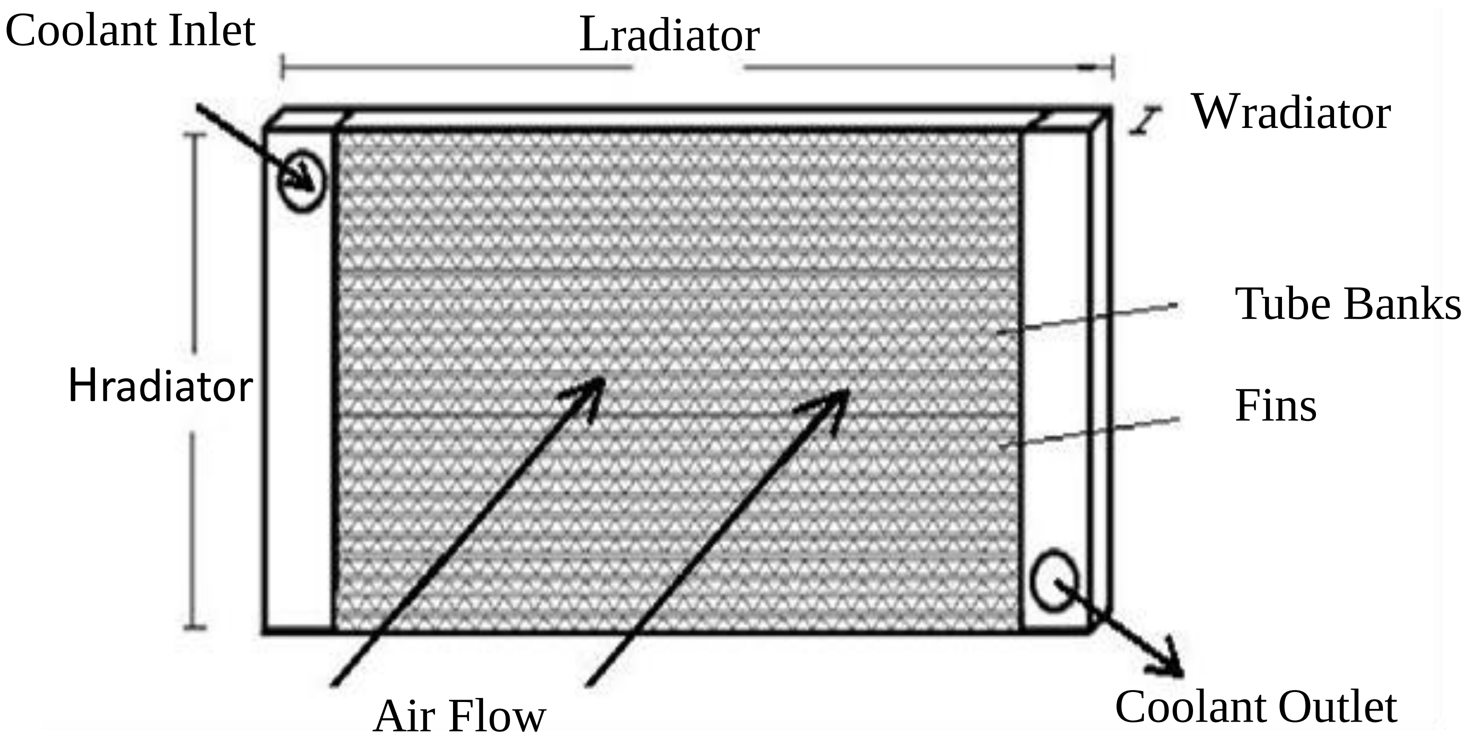


Figure 2: Schematic of radiator

- The coolant fluid (water) that passes through the engine block enters on the high side of the radiator as the hot fluid. From here, this hot fluid fills the tube banks of the radiator and makes a single pass across the radiator.

- Cool air is then forced across the radiator’s core, by a fan and by using air produced by the motion of the vehicle, to absorb and remove the heat from the coolant. During the entire process two main forms of heat transfer occur:
- (1) convection due to the internal flow of fluid passing through circular or non-circular tubes.
- (2) convection due to the external flow of air across the tube bank.

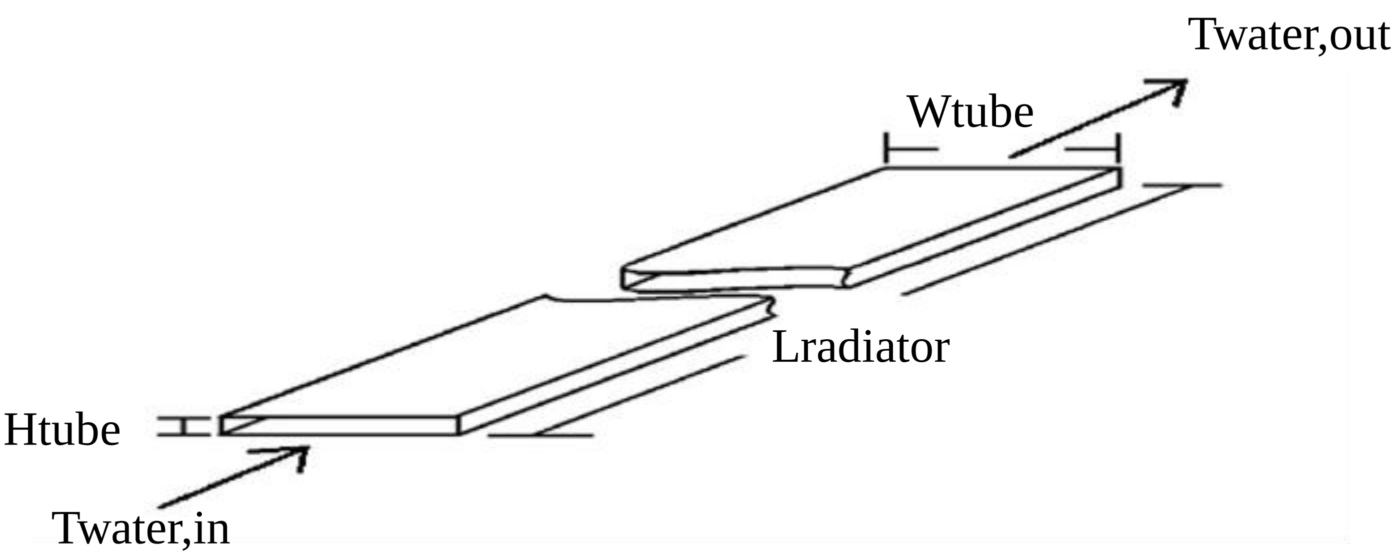


Figure 3: Schematic of single tube

➢SETUP

- An copper stock radiator of maruti800 will be tested with an engine at idle conditions. The coolant used in the radiator is pure water. The inlet and outlet temperatures for both the water and the air will be measured using a thermocouple and multi thermometer.

- For the water, a probe can be inserted in the tube right before the fluid enters the radiator and right after it exits. The inlet and outlet temperature of air will be measure with multi thermometer.
- Inlet mass flow rate of water will be measure with Rotometer. And inlet velocity of air can be measure with Anemometer.

➢PROCEDURE

- The engine run with predefine mass flow rate of water. Mass flow rate set at different value by rotometer. Once the engine reached this temperature, the fan in front of the radiator will be turned on to begin cooling the radiator. The radiator, along with the fan, then cooled the radiator until the temperatures reached steady state.

- The inlet and outlet temperatures and the for air and water will be then record. Air velocity also be record by anemometor.

- This experimental process will repeated four times in order to give a range of results to compare with one another.

- Find the Heat Transfer Rate of different value by equation .

$$Q_w = m_w \quad ϱ_w \quad c_w \quad (T_{win} - T_{wout})$$

Where,

Q_w = Heat transfer rate in KW,

m_w = Water flow rate in LPM,

$ϱ_w$ = Water density 1.0 kg/L,

c_w = Specific heat of water 4.186 KJ/kg/^{0}c

- SPECIFICATION

SPECIFICATION	NEW RADIATOR	OLD RADIATOR
MATERIAL	COPPER	COPPER
NO. OF TUBES	118	56
NO OF ROW OF TUBES	3	2
FIN GEOMETRY	PLATE TYPE	ZIG ZAG TYPE

- # RESULT

❖ New Radiator

	Tw in ˙C	Tw out ˙C	Ta in ˙C	Ta out ˙C	Air velocity m/s	Mass flow rate LPH	Heat transfer KW
1	53	50.7	30.5	30.8	0	250	0.668
2	53	50	30.7	34	5.3		0.871
3	53	49.1	31.1	36.6	5.9		1.133
4	53	48.5	32	37	6.5		1.307
5	50	47.5	31.2	31.5	0	275	0.798
6	50	46.4	31.4	36.9	5.3		1.150
7	50	45.8	31.8	37.3	5.9		1.342
8	50	45	32	37.6	6.5		1.597

	Tw in ˙C	Tw out ˙C	Ta in ˙C	Ta out ˙C	Air velocity m/s	Mass flow rate LPH	Heat transfer KW
9	46	44	32.5	33	0	500	1.162
10	46	43.6	31.9	36.7	5.3		1.395
11	46	42.7	30.5	33.5	5.9		1.918
12	46	42	29.6	31.8	6.5		2.325
13	42	40.4	32.5	33	0	1000	1.860
14	42	40	31.5	34.3	5.3		2.324
15	42	39.1	30	33.3	5.9		3.370
16	42	38.4	29	31.8	6.5		4.184

❖ Old radiator

	Tw in ˙C	Tw out ˙C	Ta in ˙C	Ta out ˙C	Air velocity m/s	Mass flow rate LPH	Heat transfer KW
1	53	51.6	32	32.3	0	250	0.407
2	53	50.8	31.1	34	5.3		0.639
3	53	49.9	31.6	36.1	5.9		0.900
4	53	49	32.5	36.8	6.5		1.162
5	50	48	32.4	32.7	0	275	0.639
6	50	47.5	36	36.5	5.3		0.798
7	50	46.7	32.7	36.5	5.9		1.054
8	50	45.7	33.4	37.1	6.5		1.380

	Tw in ˙C	Tw out ˙C	Ta in ˙C	Ta out ˙C	Air velocity m/s	Mass flow rate LPH	Heat transfer KW
9	46	44.5	33.5	34	0	500	0.871
10	46	44	32.7	35.5	5.3		1.162
11	46	43	31.5	33	5.9		1.743
12	46	42.1	30	31.6	6.5		2.267
13	42	40.9	33.5	34.1	0	1000	1.278
14	42	40.3	31.6	33.3	5.3		1.975
15	42	39.3	30.5	33	5.9		3.138
16	42	38.8	29.8	30.8	6.5		3.720

- Effectiveness of new radiator

Q= 4.184 KW

$T_{h\ in}$ =42 $T_{c\ in}$ =29

$T_{h\ out}$=38.4 $T_{c\ out}$ =30.6

$$T_{c\ mean} = \frac{30.6+29}{2}$$

$$= 29.8$$

C_{pc} = 1.005 KJ/kg K

Q = m Cp ΔT

4.184 = m 1.005 1.6

m = 2.60 kg/s

$$T_{h\,min} = \frac{42 + 38.4}{2}$$

$$= 40.2$$

C_{ph} = 4.174KJ/kgK

$Q = m \;\; Cp \;\; \Delta T$

$4.184 = m \;\; 4.174 \;\; 3.6$

m_h=0.278 kg/s

$m_h \, c_{ph}$ =0.278 4.174

= 1.160 KW/K

$m_c \, c_{pc}$ = 2.60 1.005

= 2.613 KW/K

$$\varepsilon = \frac{Q_{actual}}{Q_{max}}$$

$$= \frac{m_c\, c_{ph}(T_{h\,in} - T_{h\,out})}{C_{min}\,(T_{hin} - T_{cin})} = \frac{1.160(42-38.4)}{1.160(42-29)} = 0.2761 = 27\%$$

- Effectiveness of old radiator

$Q = 3.720$ KW

$T_{h\ in} = 42$ $T_{c\ in} = 29.8$

$T_{h\ out} = 39.8$ $T_{c\ out} = 30.8$

$$T_{c\ mean} = \frac{29.8 + 30.8}{2}$$

$= 30.3$

$C_{pc} = 1.005$ KJ/kg K

$Q = m\ \ Cp\ \ \Delta T$

$3.720 = m\ \ 1.005\ \ 1$

$m = 3.70$ kg/s

$$T_{h\,min} = \frac{42 + 39.8}{2}$$

$= 40.9$

$C_{ph} = 4.175 KJ/kgK$

$Q = m \; Cp \; \Delta T$

$3.720 = m \; 4.175 \; 2.2$

$m_h = 0.405 \; kg/s$

$m_h \, c_{ph} = 0.405 \; 4.175$

$= 1.690 \; KW/K$

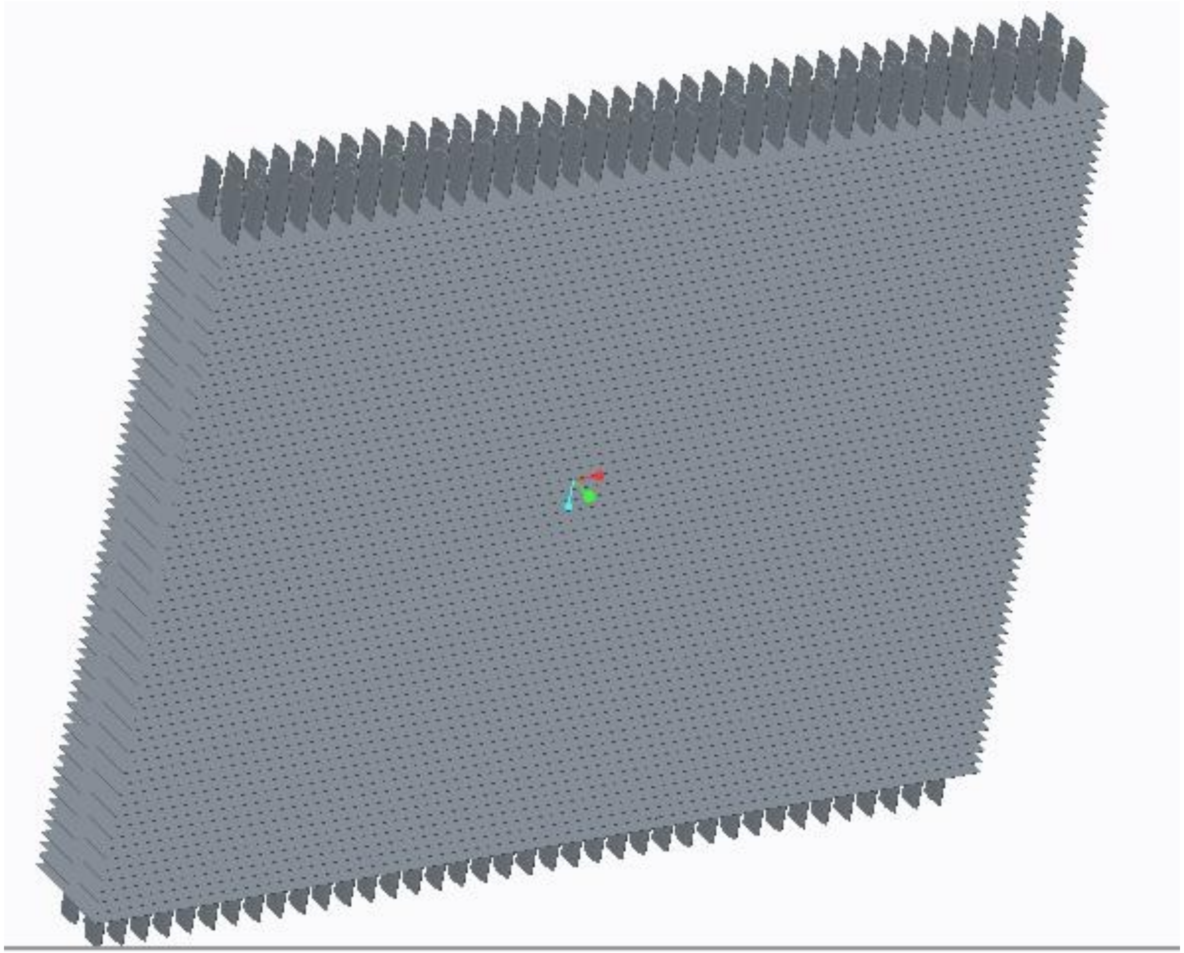
$m_c \, c_{pc} = 3.70 \; 1.005$

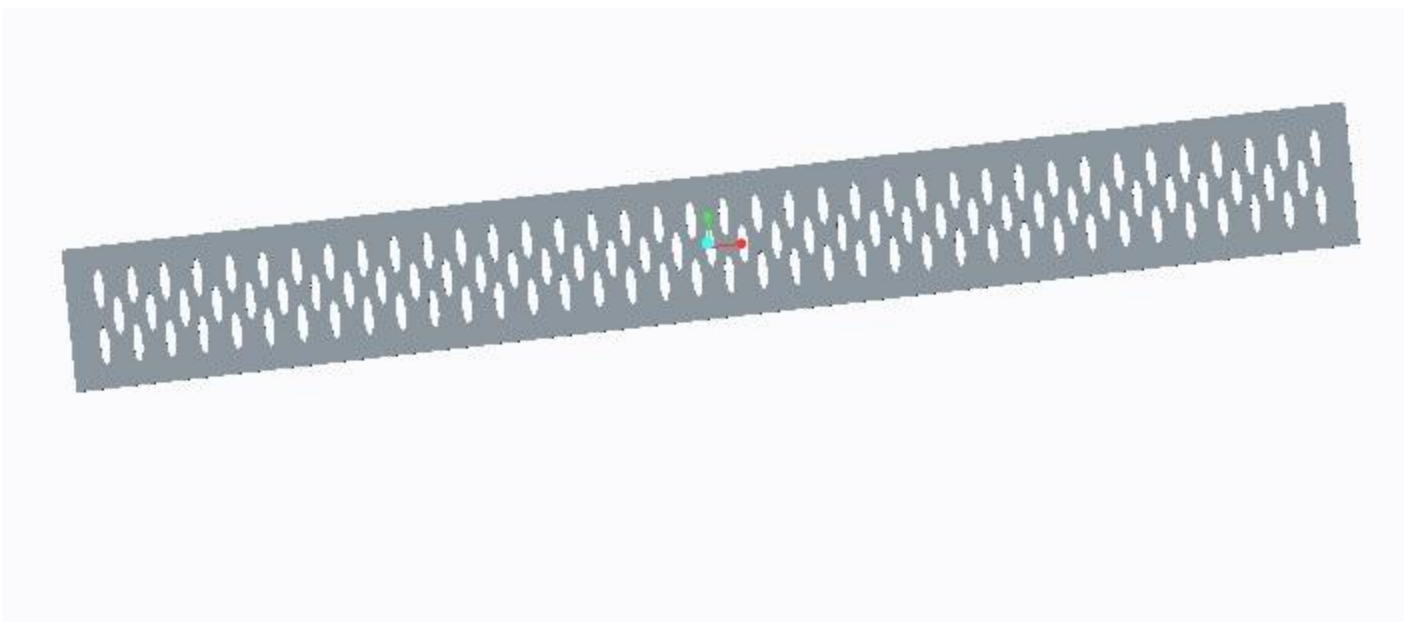
$= 3.7185 \; KW/K$

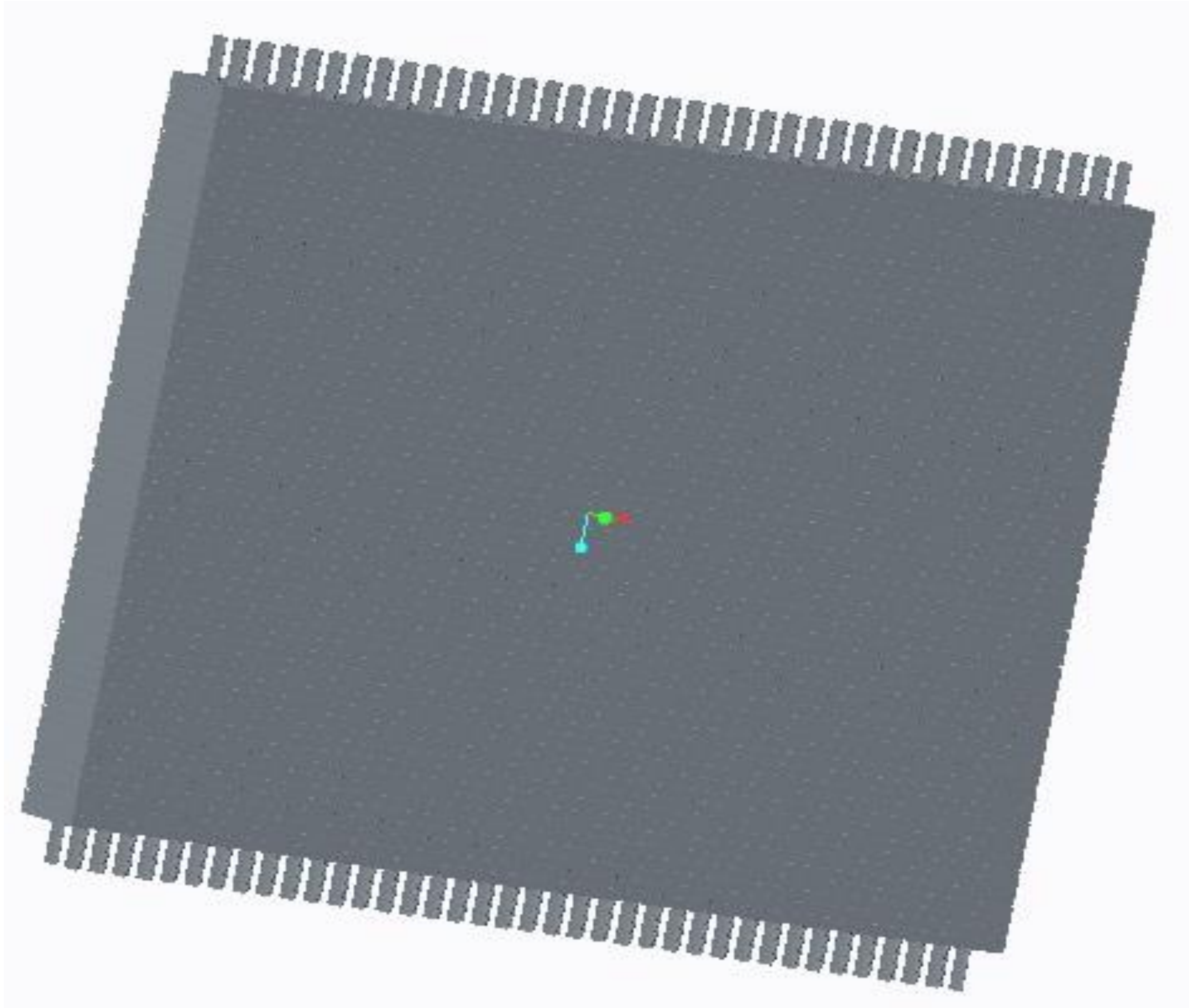
$$\varepsilon = \frac{Q_{actual}}{Q_{max}}$$

$$= \frac{m_c\, c_{ph}(T_{h\ in} - T_{h\ out})}{C_{min}\,(T_{hin} - T_{cin})} = \frac{1.160(42-39.8)}{1.160(42-29.8)} = 0.180 = 18\%$$

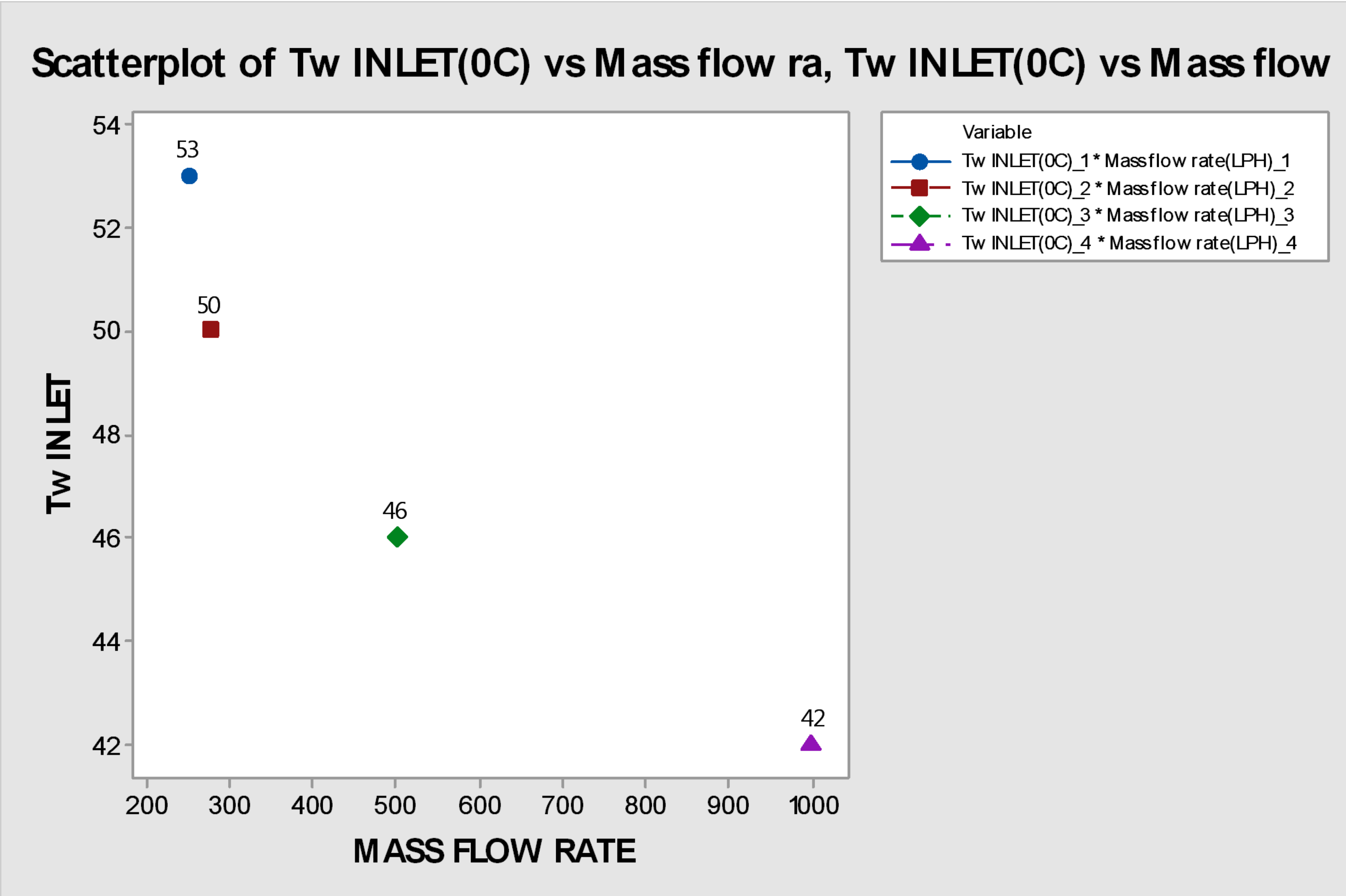
SOFTWARE DESIGN



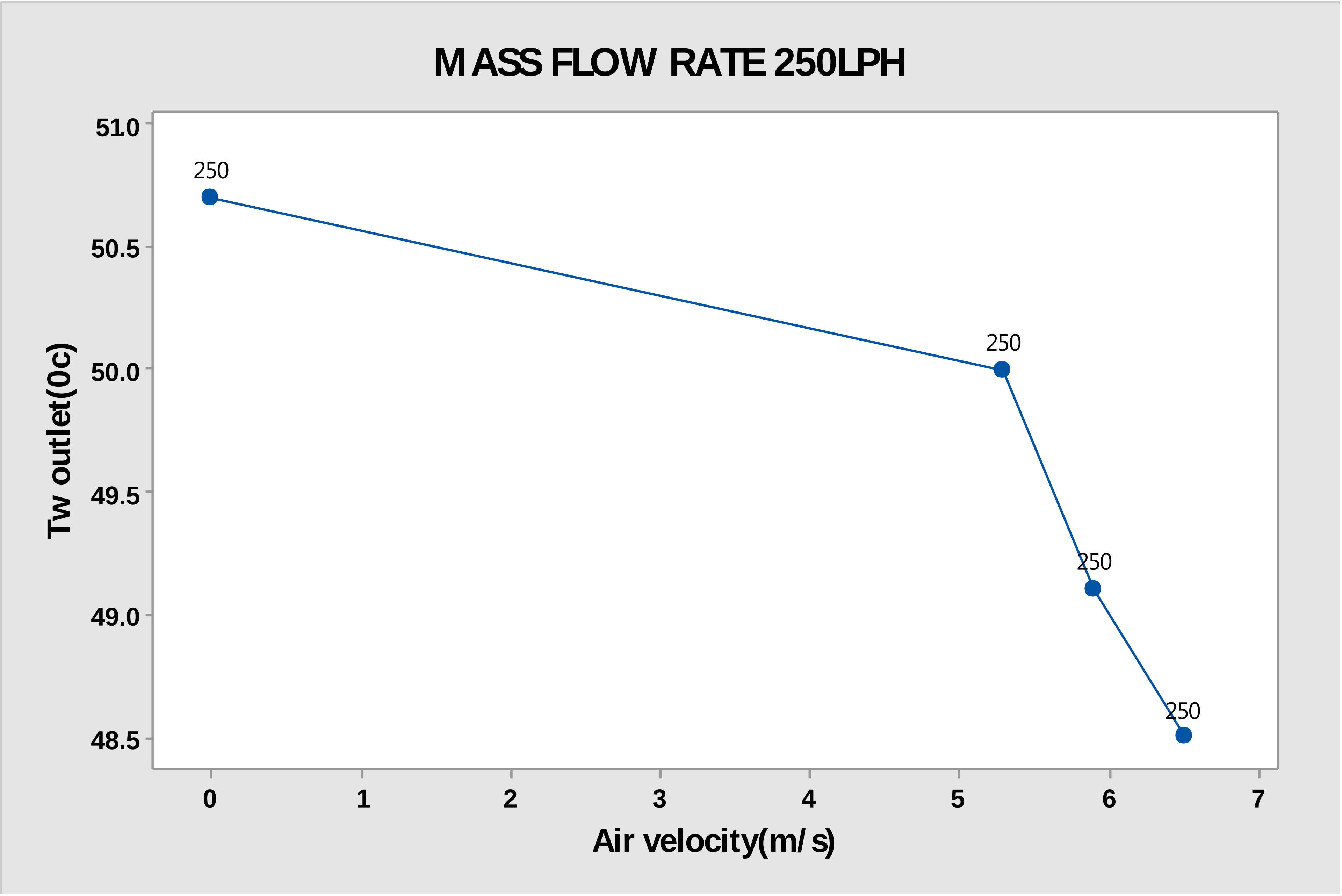




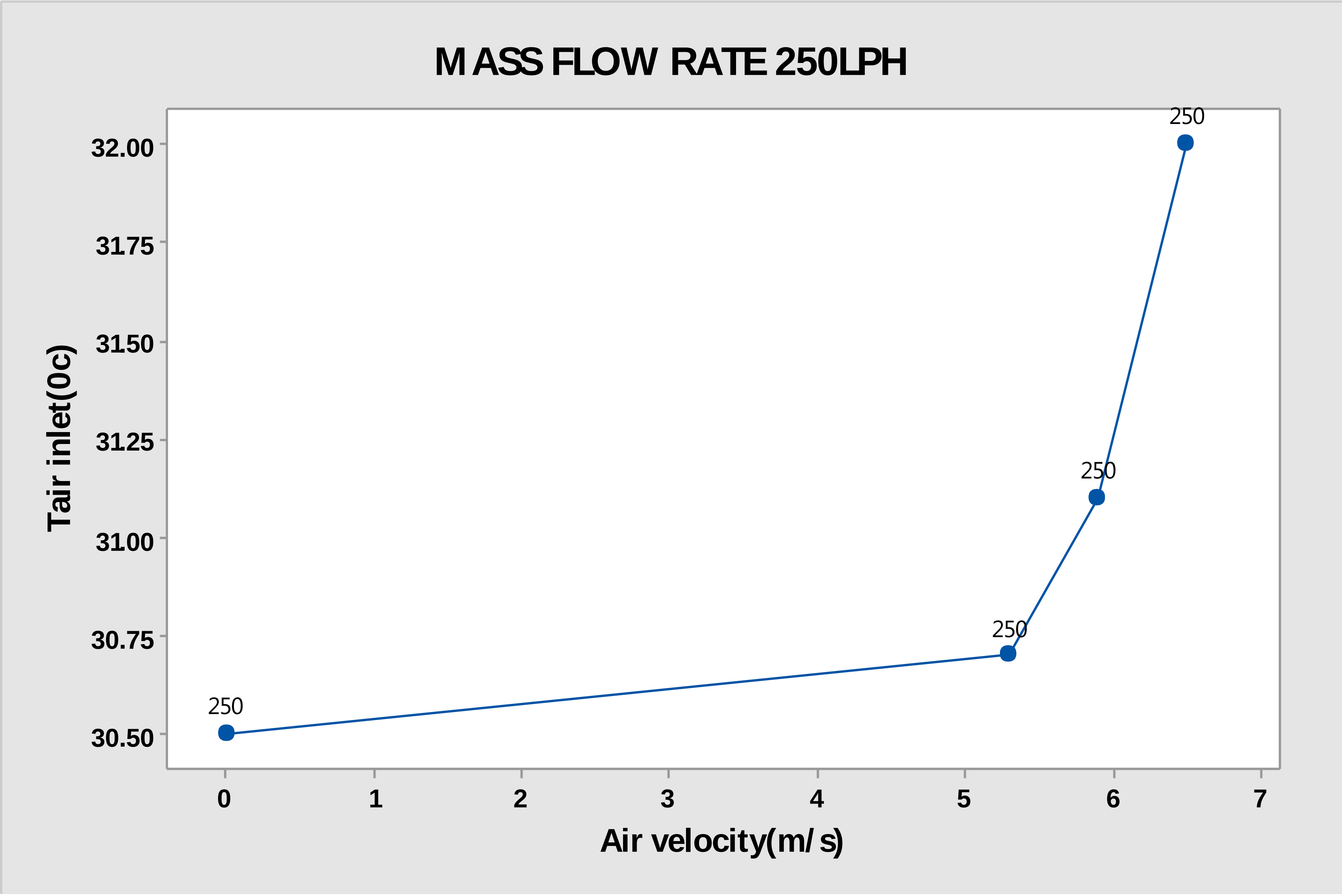
NEW RADIATOR



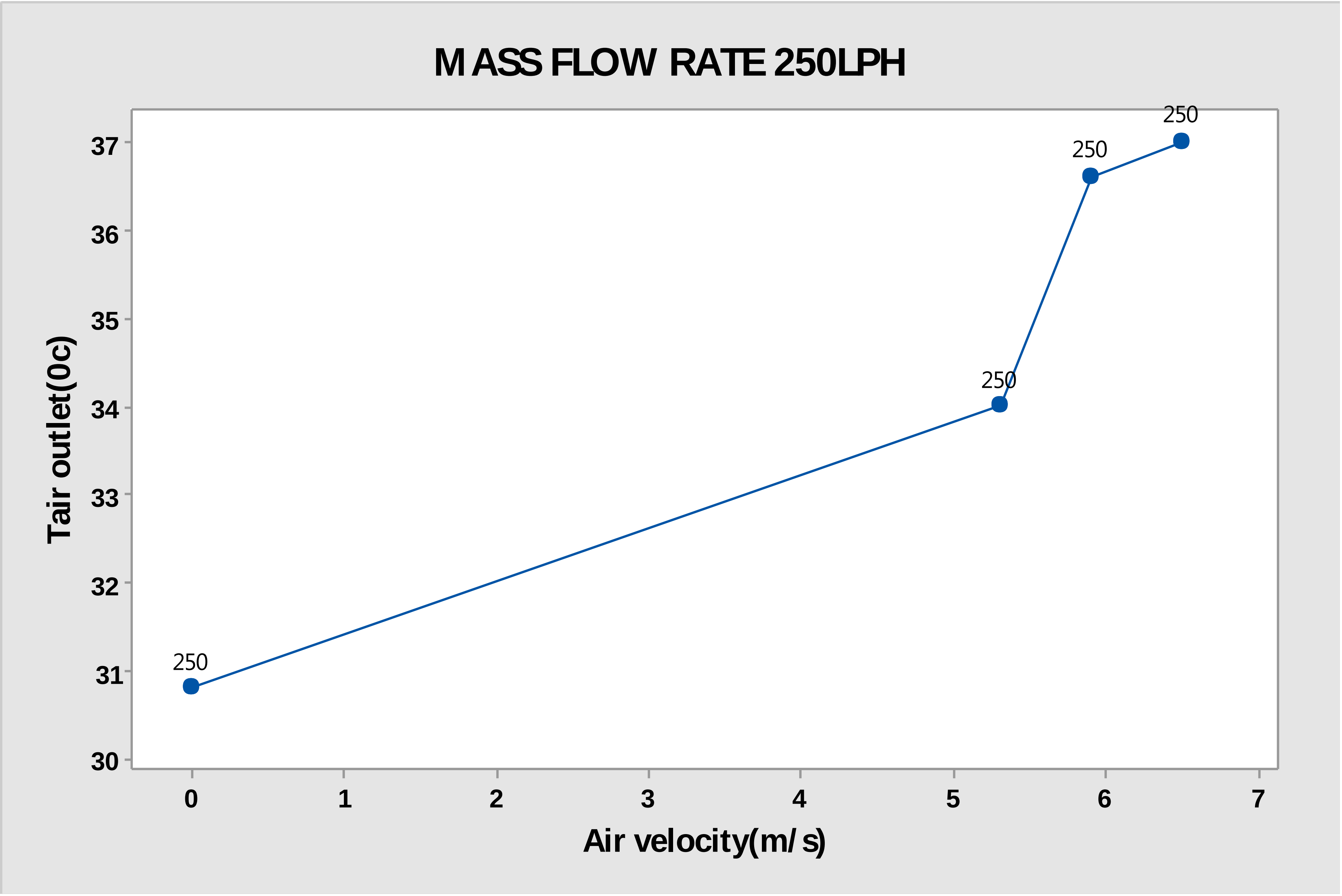
NEW RADIATOR



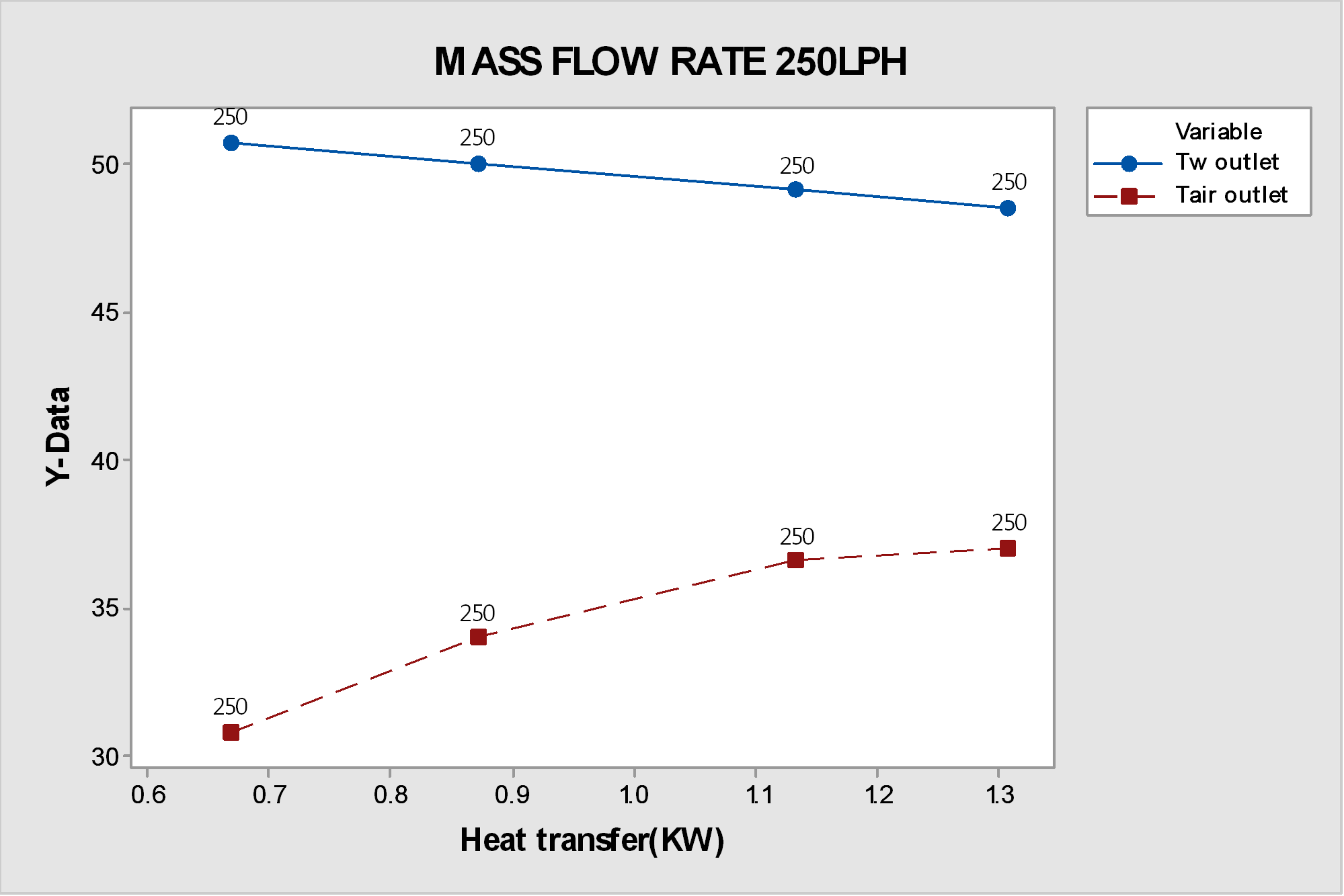
NEW RADIATOR



NEW RADIATOR



NEW RADIATOR



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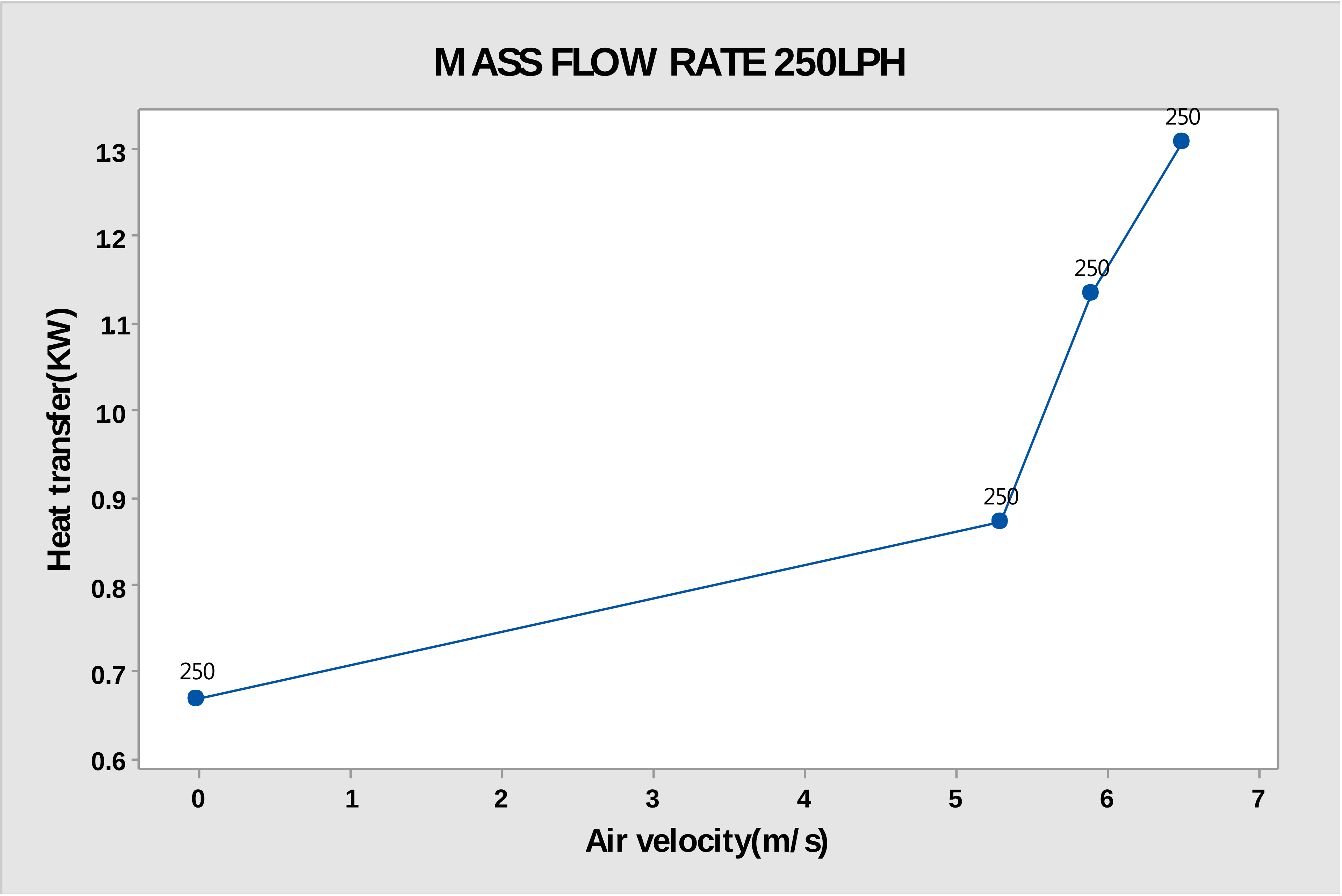

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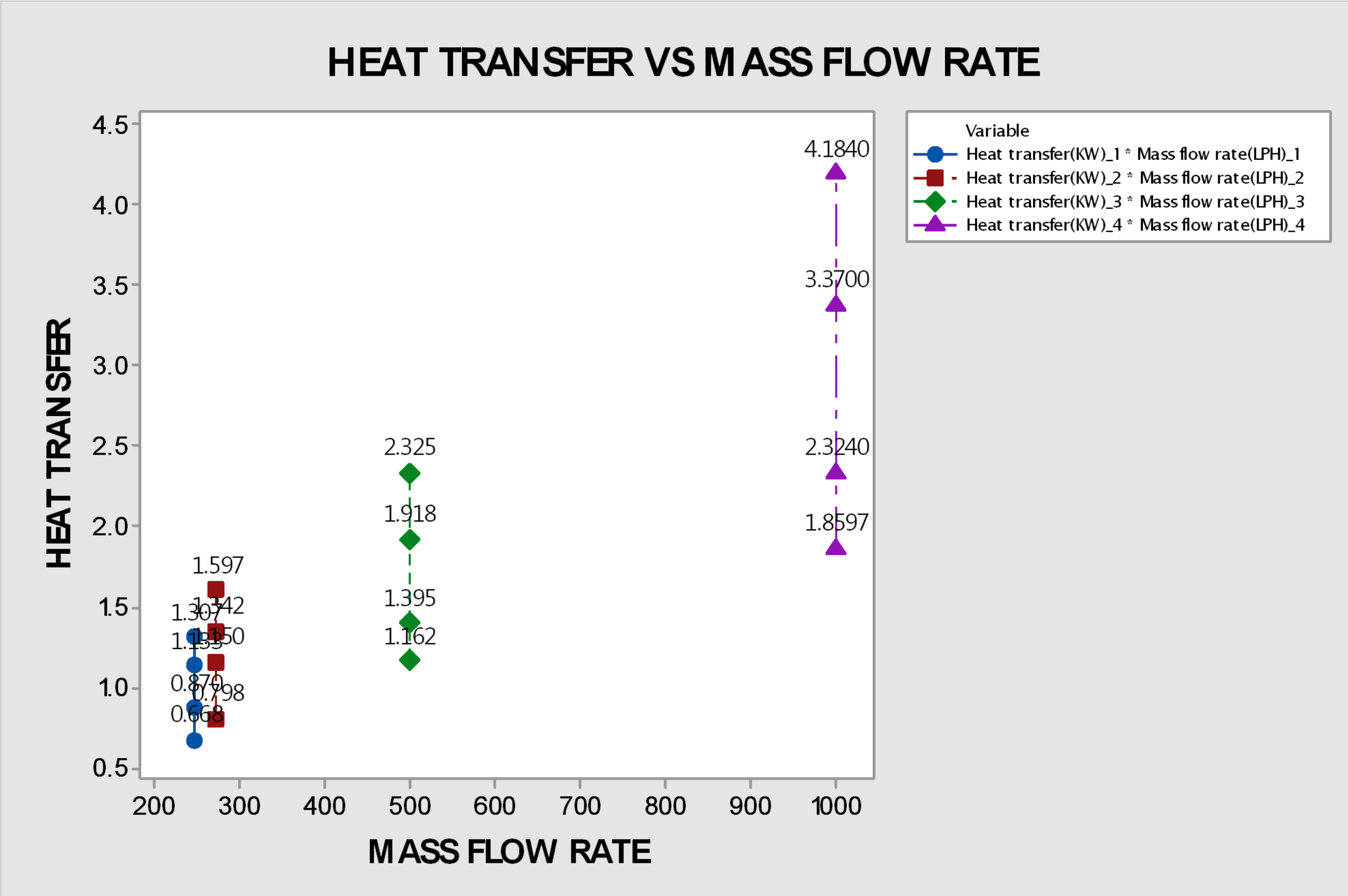

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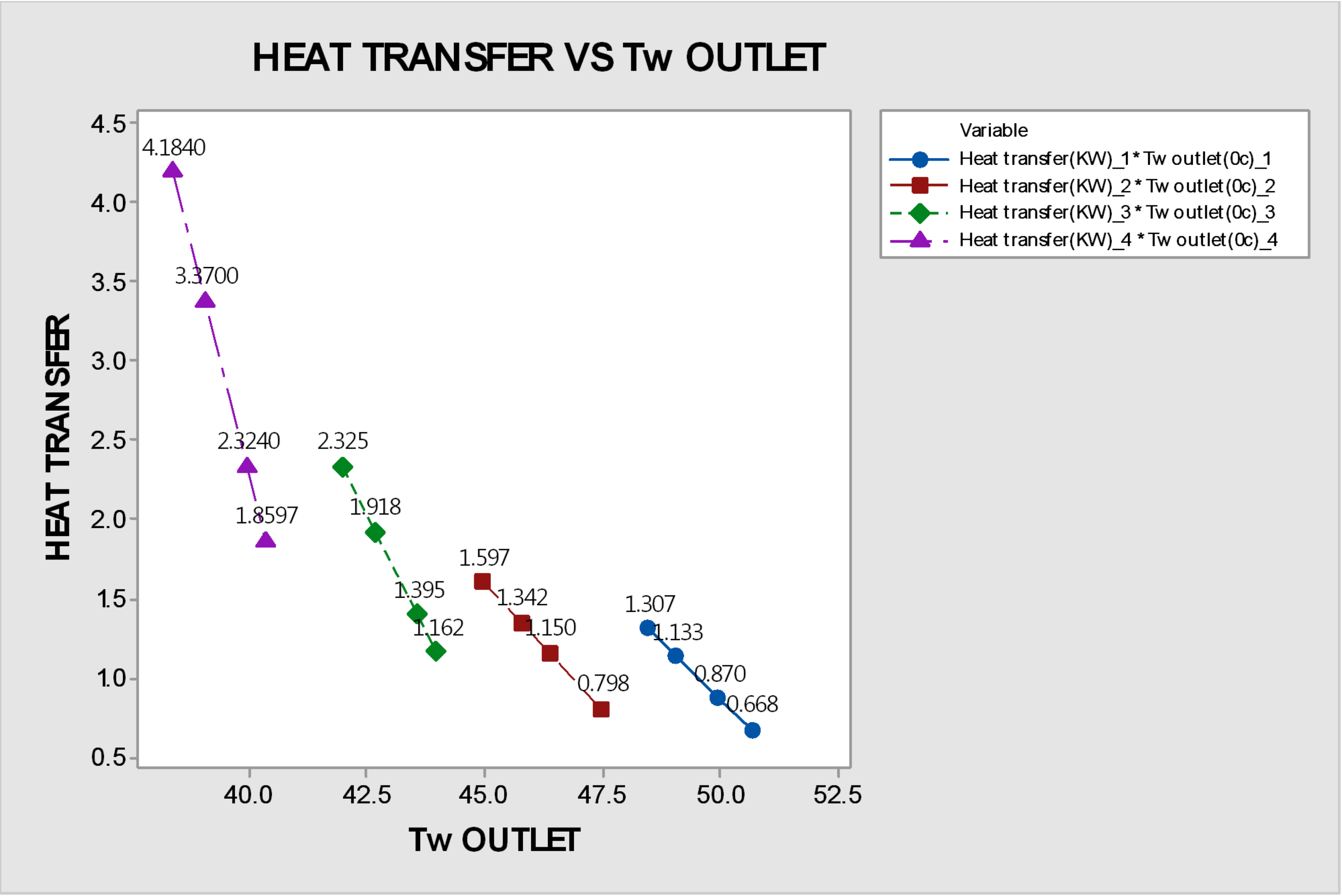

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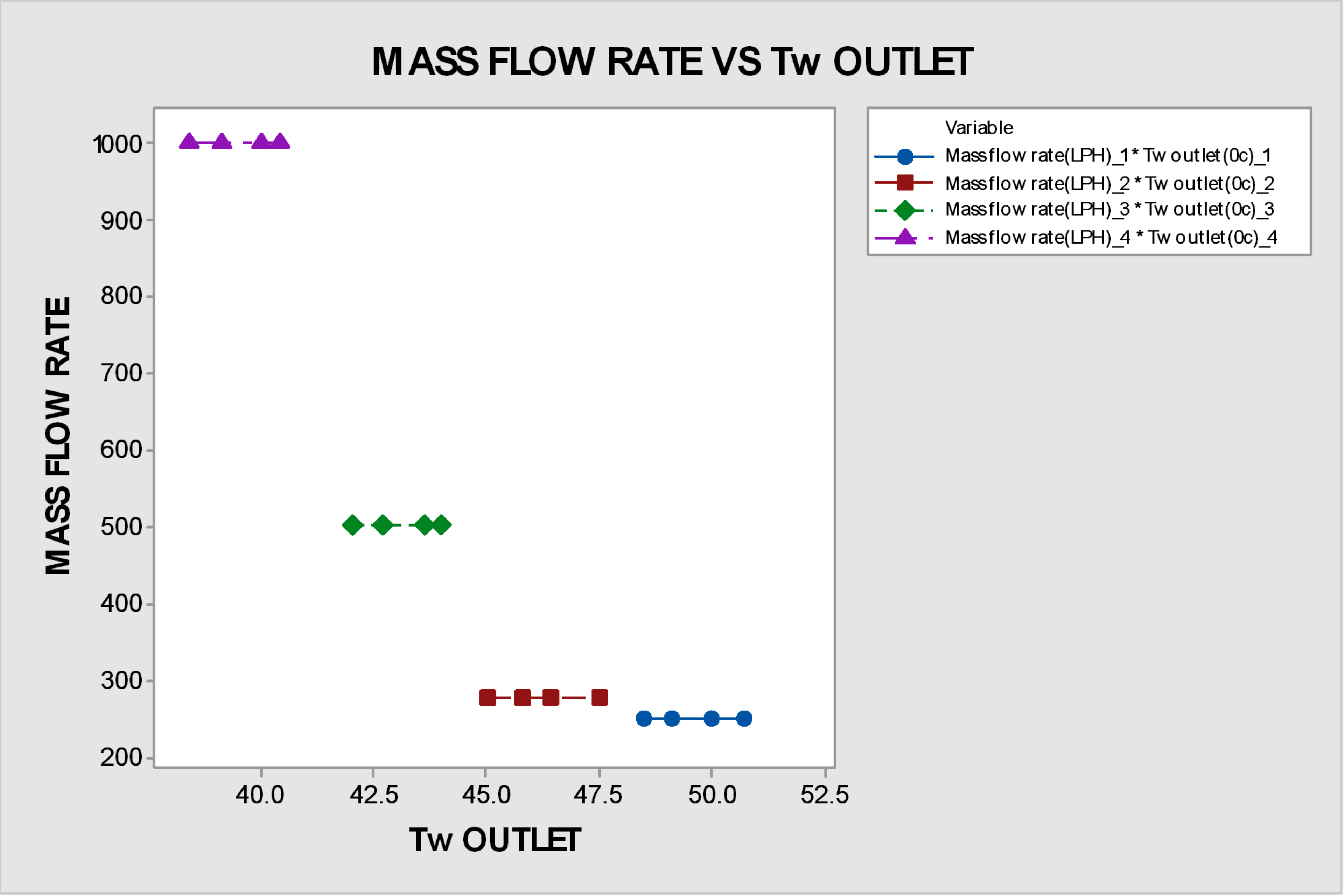

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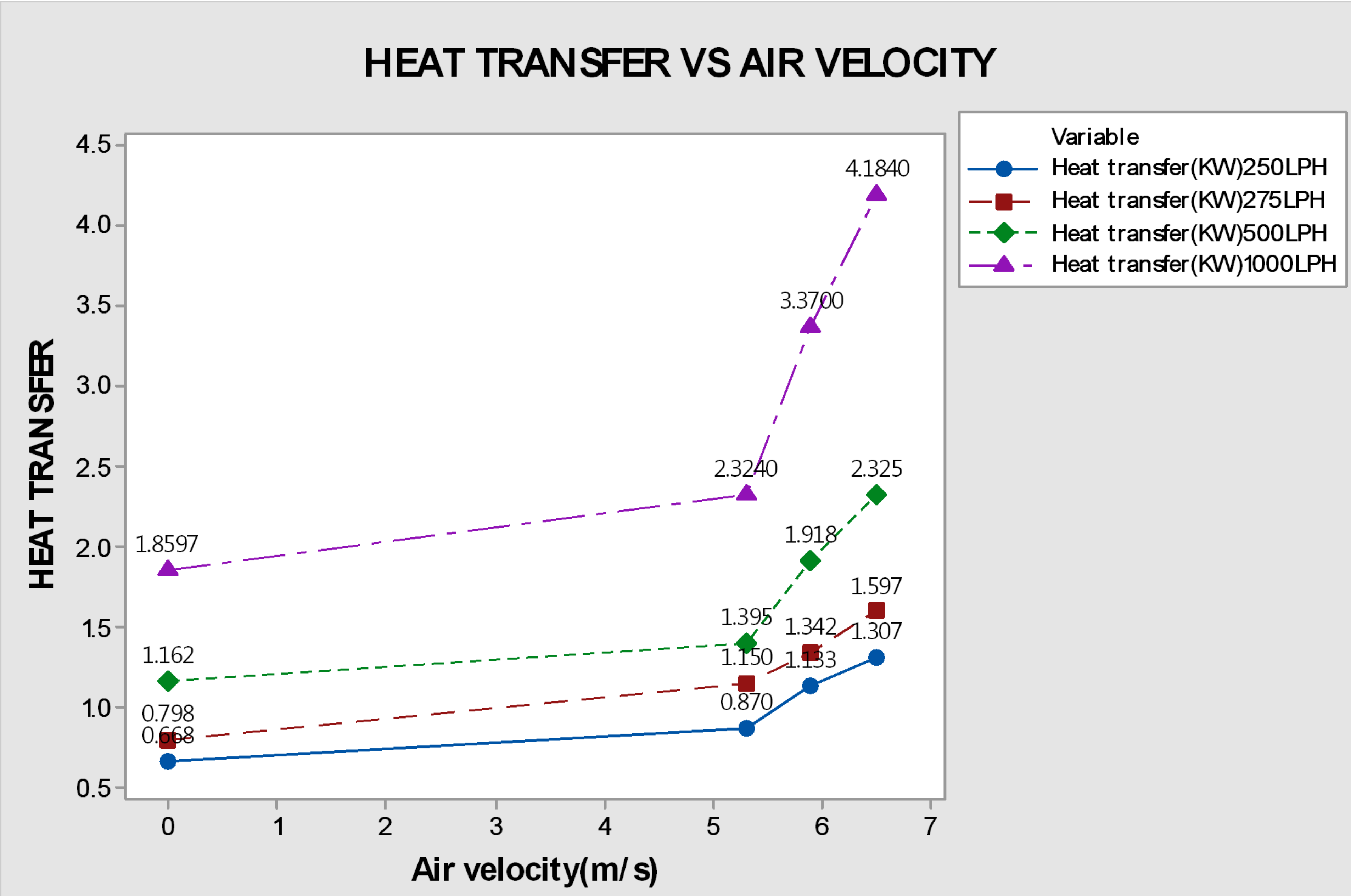
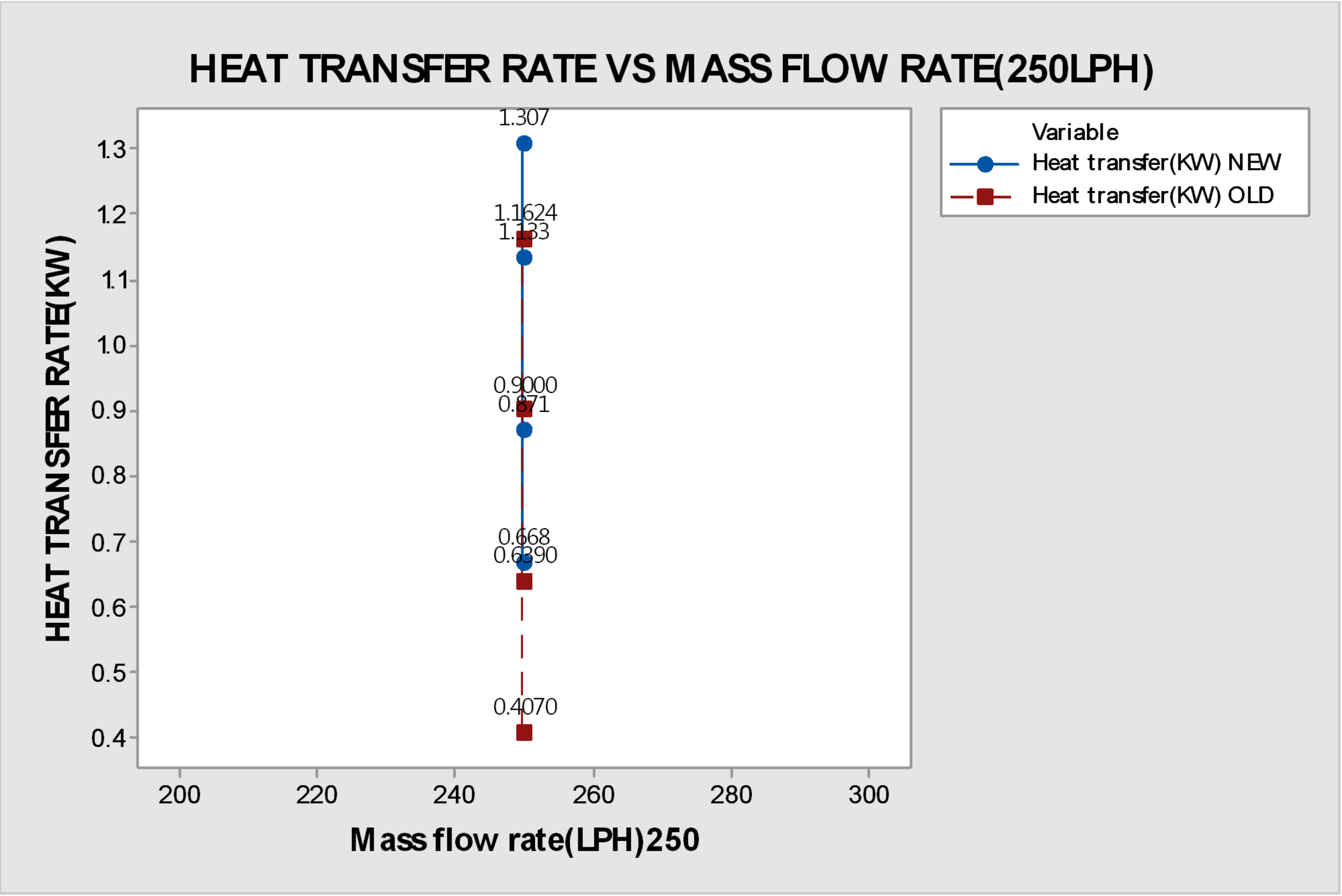
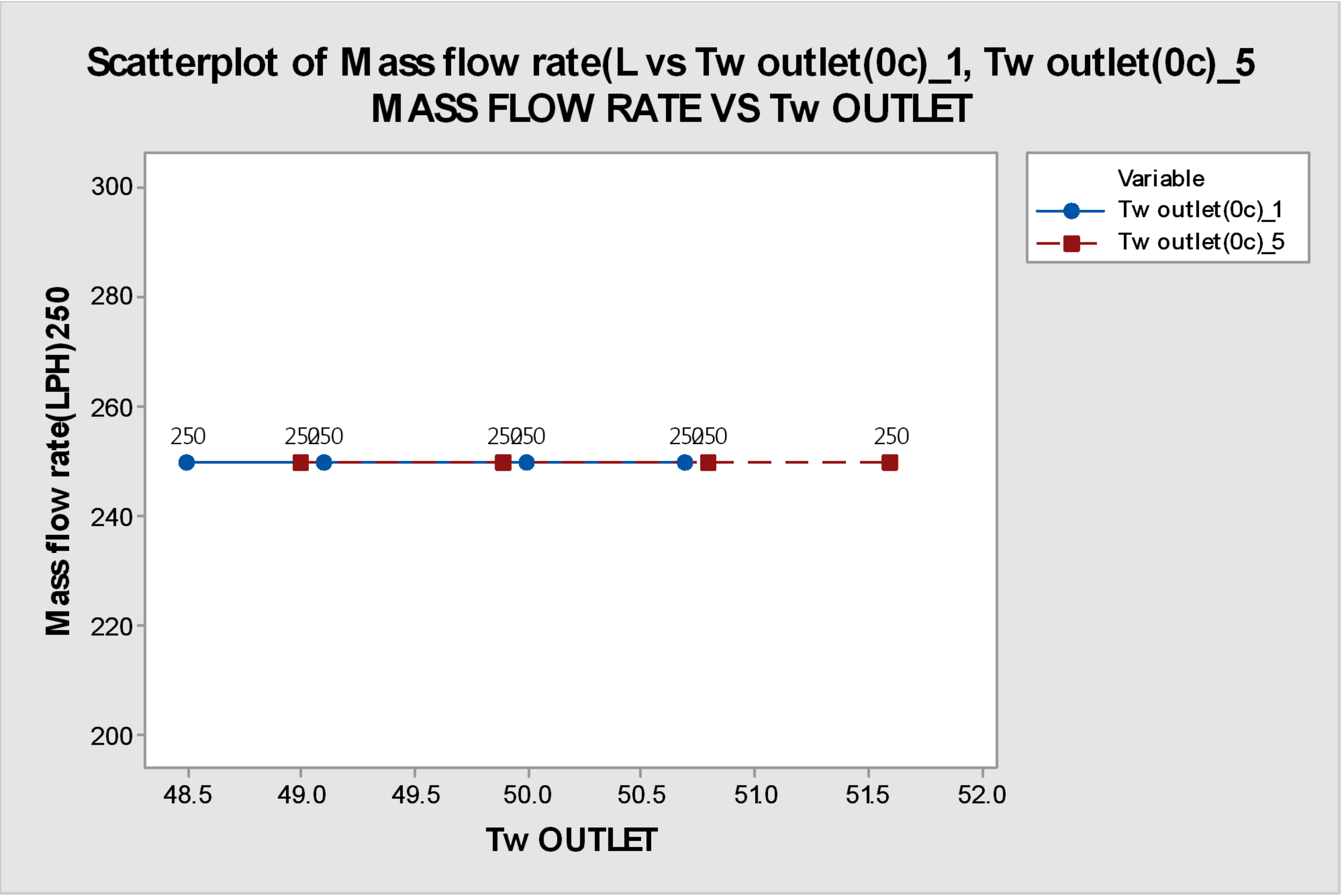


NEW RADIATOR AND OLD RADIATOR



NEW RADIATOR AND OLD RADIATOR



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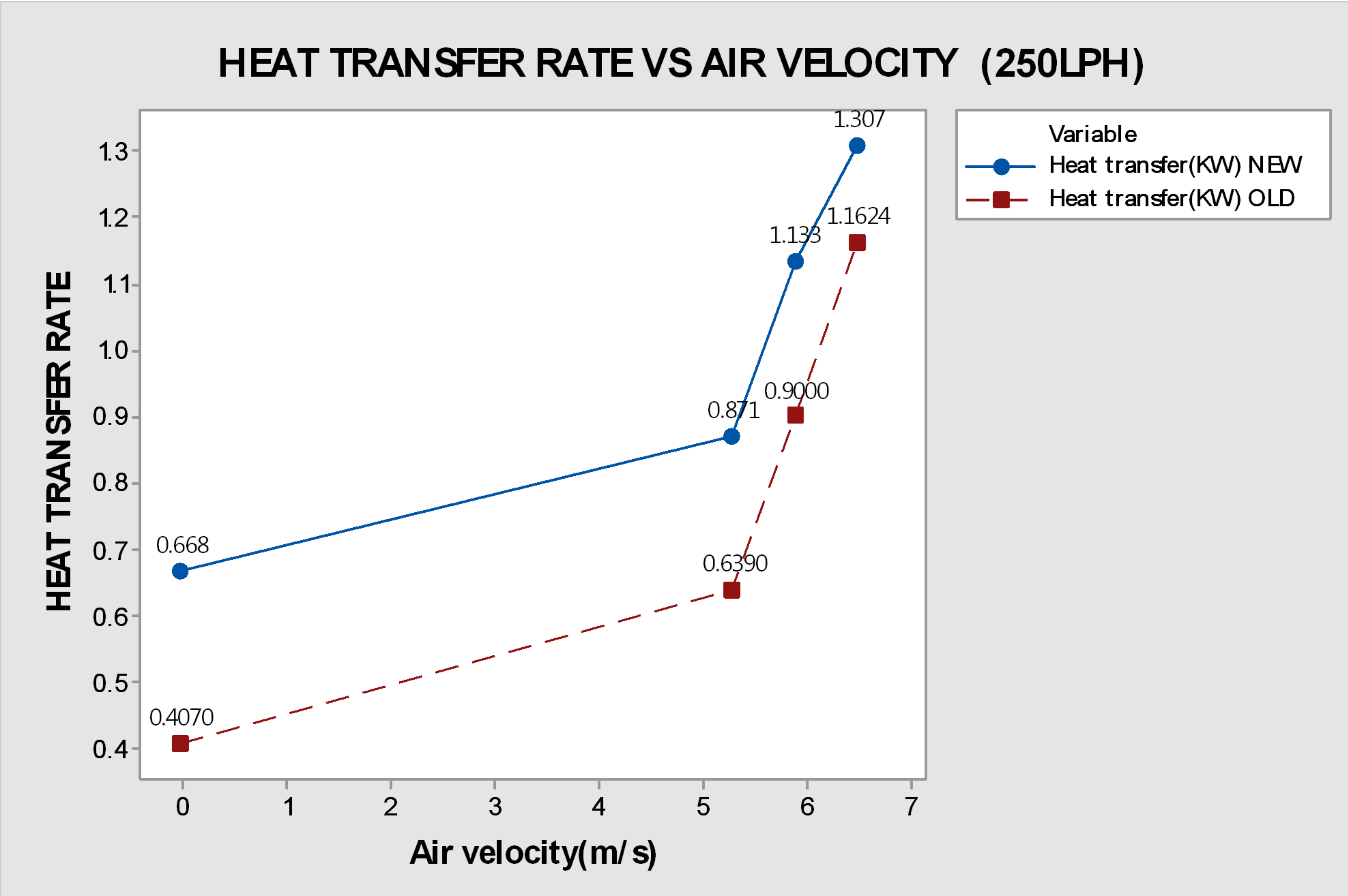

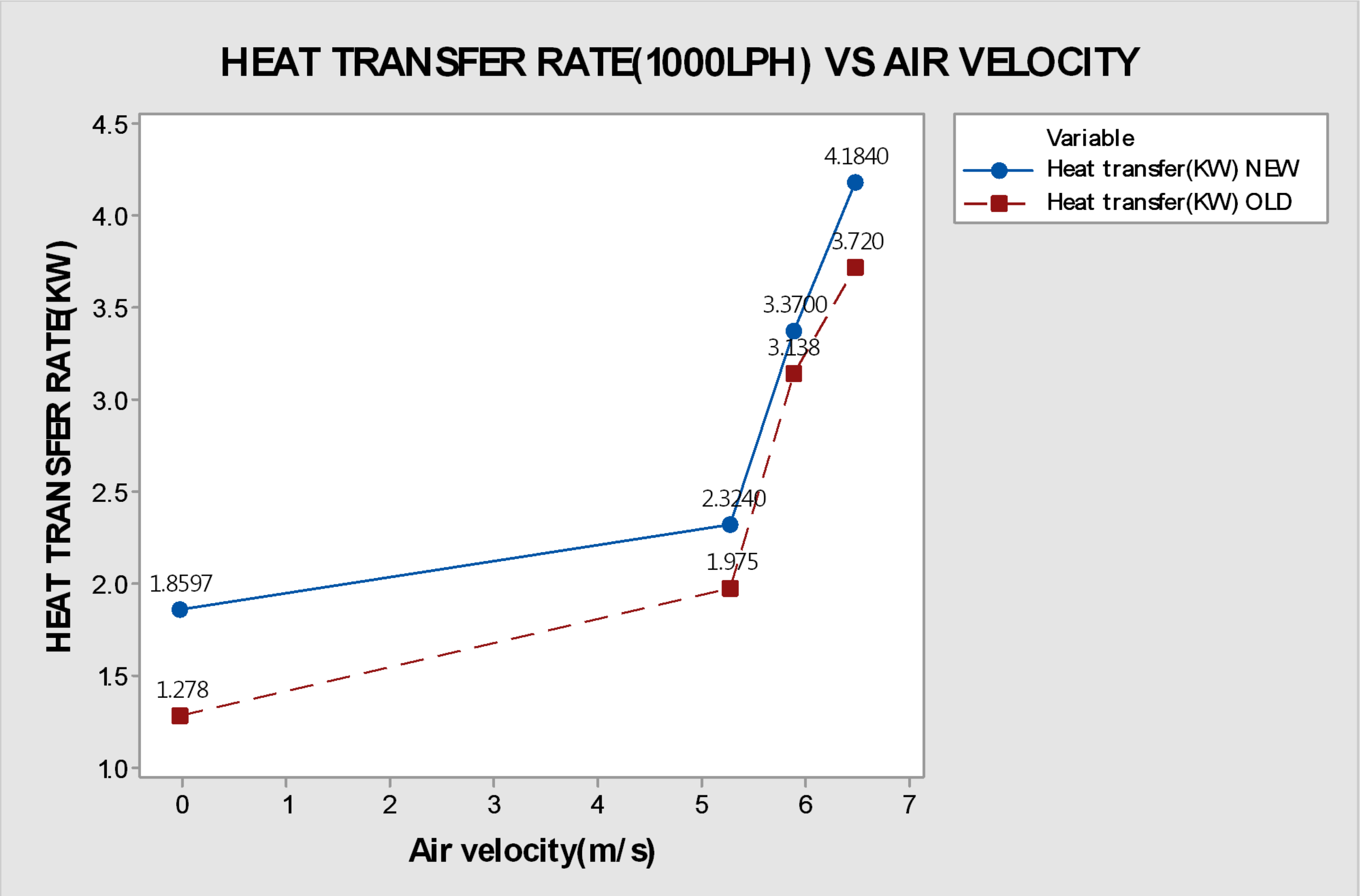
HEAT TRANSFER RATE(1000LPH) VS AIR VELOCITY
HEAT TRANSFER RATE(KW)
Air velocity(m/s)
Variable
Heat transfer(KW) NEW
Heat transfer(KW) OLD
4.1840
3.720
3.3700
3.138
2.3240
1.975
1.8597
1.278
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
1
2
3
4
5
6
7

- CONCLUSION

	Mass flow rate	Air velocity	Tw out	Ta out	No. of tubes
Heat transfer rate	Increase	Increase	Decrease	Increase	Increase

	Heat transfer rate	Mass flow rate	Air velocity	Tw out	Ta out	No. of tubes	Effectiveness
New radiator	More	Constant	Constant	Less	More	More	27%
Old radiator	Less	Constant	Constant	More	Less	Less	18%

- The heat transfer processes for the radiator are analyzed in a real life situation. The objectives of the project, to find the inlet and outlet temperatures of the fluids in the radiator, were accomplished successfully. There were numerous assumptions that were necessary to complete the theoretical calculations. Although these assumptions changed the final values for the theoretical heat transfer rate, the differences are expected. When first analyzing the radiator, there were many challenges and obstacles that hindered the advancement of the project. These challenges presented with opportunities to learn from mistakes and link concepts into an integrated whole. This project provided an in depth understanding of the theoretical knowledge learned in heat transfer and offered a chance to use this information to solve real world problems.

- Future Work

- SOFTWARE ANALYSIS

LITERATURE SURVEY

Matthew Carl et al[1] The heat transfer processes for the radiator are analyzed in a real life situation. The objectives of the project, to find and compare the inlet and outlet temperatures of the fluids in the radiator. There were numerous assumptions that were necessary to complete the theoretical calculations. Although these assumptions changed the final values for the theoretical outlet temperatures and heat transfer rate, the differences are expected. The theoretical values are good approximations of the real values found experimentally.

Brandon Fell et al[2] Our task was to design a new concept for an automotive radiator. It was required to reject an increased amount of heat (5%) from current radiator designs while lowering the fluid inlet temperature (10%). Our task is to design an automotive radiator to work in conjunction with advanced nanofluids. The new radiator design will be used in new General Motors hybrid vehicles. These hybrid vehicles have multiple cooling systems for the internal combustion engine, electric engine, and batteries.

Q. Yuet al[3] showed that one way to decrease the thermal resistance associated with the air is to change the type of fin material used. Instead of using aluminum fins, fins constructed of carbon-foam were used. The fins were constructed out carbon-foam that had a porosity of 70%, a thickness of 0.762 mm, and a height of 8.725 mm. The fin density was set to 748 fins/m.

- Fin Dimensions and Efficiency

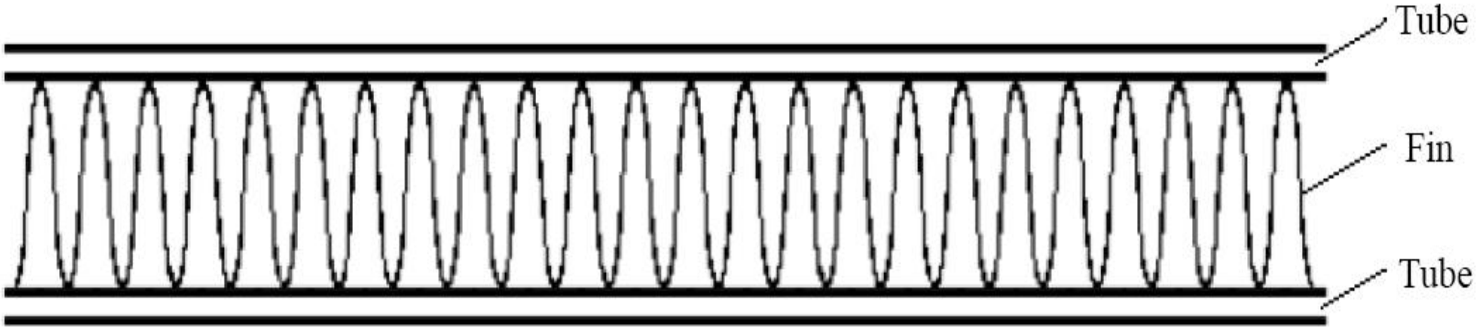

Figure: 6.7. Actual fin geometry

The geometry of the fins on the radiator is sinusoidal. The troughs of the fins touch the lower adjacent tube and the peaks of the fins touch the upper adjacent tube. The heat from the tubes emanates through the fins. The fins and tubes are then cooled by the air from the fan, which is traveling across the radiator. To simplify the geometry for the ease of calculations, the fins are assumed to be straight instead of sinusoidal. This is a minor transition in geometry since the shape and position of the actual fins are so close to the straight configuration. The following formulas are given below to calculate the fin efficiency. The fin efficiency equation takes into account the geometry of the fin and its dimensions to find the efficiency the fin will have.

- Joardar et al[4] The use of vortex generators was the technique used to improve the current radiator design. These incorporated wings on the fins which produced vortices that helped to increase the turbulence of the air. By increasing air turbulence, the convective coefficient associated with the air is increased. An increase in this value causes the thermal resistance associated with the air to be reduced.
- Some parameters that affected the performance of the vortex generators were angle of attack, and the ratio of vortex generator area to heat transfer area. With the use of the vortex generators, there was an increase in the convective heat transfer coefficient. Since the air-side resistance is directly related to this value, an increase in this value will decrease the thermal resistance due to the air. Therefore, this configuration would be more beneficial than current radiator designs.

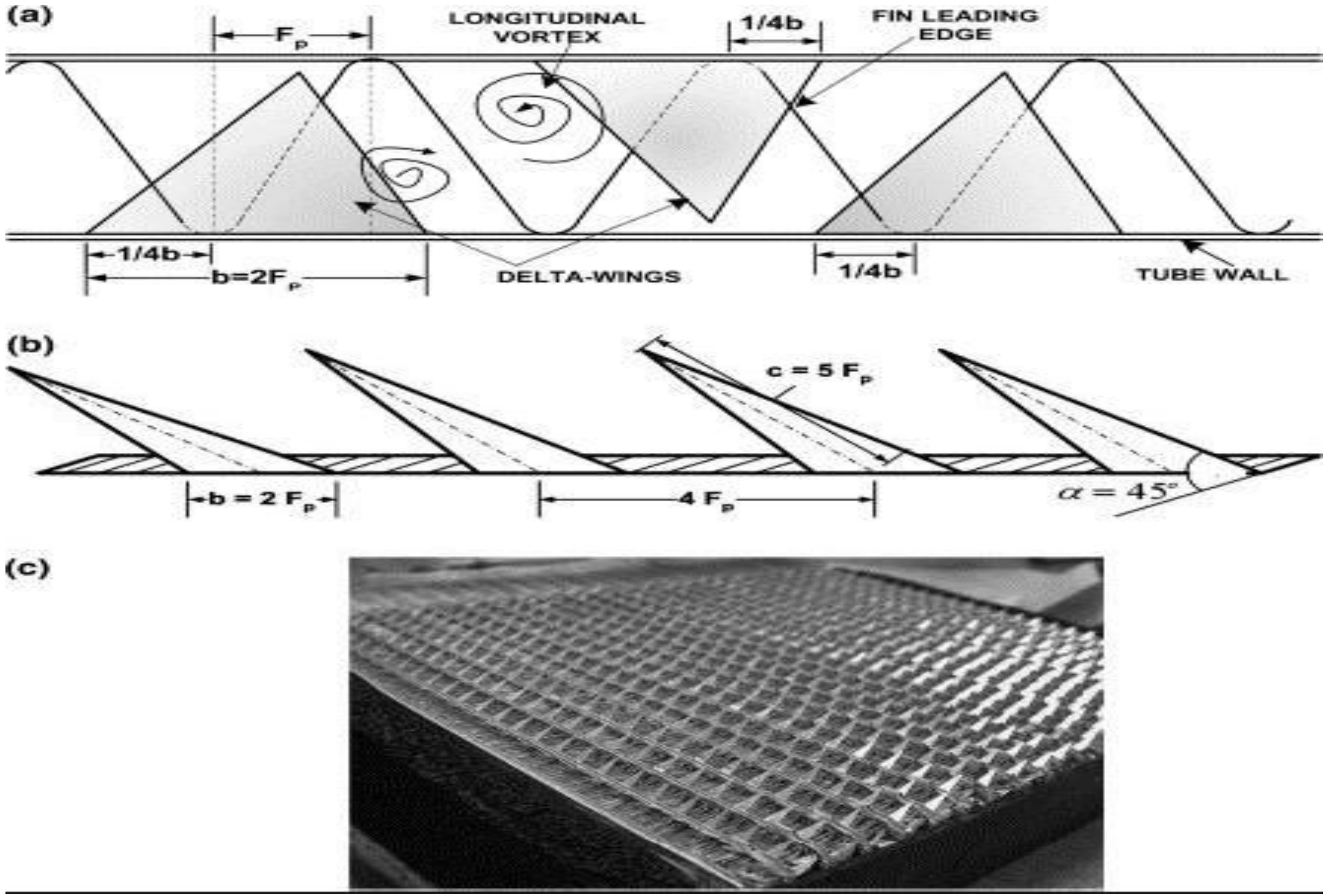

Figure: 4.3. Vortex generators increase convective heat transfer

C. Harris et al[5] possible improvement to the automobile radiator was seen through the analysis of micro heat exchangers. These heat exchangers incorporated the use of micro-channels and were fabricated from plastic, ceramic, or aluminum. One area was on a heat transfer rate to volume basis in which the micro heat exchanger was better by more than 300%. These improvements were achieved by limiting the flow to smaller channels which increased the surface area/volume ratio and reduced the convective thermal resistance associated with the solid/fluid interface.

Prof. D. K. Chavan[6]The Heat Exchangers or Radiators used in automobiles/IC Engines are either rectangular or square in shape, but the air blown/sucked by means of the fan is in circular in area, developing low velocity zones in the corners-hence it is proposed to eliminate corners and develop circular radiators. The object of work is to have a circular radiator which is compact-made with minimum material-less costly-more efficient-that will work with minimum power consumption of fan and maximum utilization of air flow.

JP Yadav et al[7]In the testing, a comparative analysis between different coolants has also been shown. Here, one of the coolants is used as water and other as mixture of water in propylene glycol in a ratio of 40:60. Here a big difference in the cooling capacity of the radiator is seen when the flowing coolant from water is changed to mixture. This is on the account of a very high value of specific heat of water in comparison to the mixture. It therefore can be concluded that the water is still the best coolant but its limitation are that it is corrosive and contains dissolved salts that degrade the coolant flow passage. By making a mixture with ethylene glycol its specific heat is decreased but its other properties are enhanced.

S. R. Patil et al[8] Automotive radiator is key component of engine cooling system. Radiator size depends on heat load as well packaging space availability. Heat load depends on heat rejection required to keep engine surface at optimum temperature. Generally LMTD or ε- NTU method is used to do heat transfer calculations of radiator. Both methods have its own advantages and preferred according to data availability. When radiator inlet and outlet temperature are known LMTD gives faster solution. When any of the temperature is unknown LMTD method undergoes iterations to find solution. In this case ε-NTU is better.

Patankar and Prakash[9] presented a two dimensional anyalysis for the flow and heat transfer in an interrupted plate passage which is an idealization of the offset stripe fins heat exchanger. The main aim of study is investi-gating the effect of plate thickness on heat transfer and pressure drop in offset strip fins channels.

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Thank You




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