PERFORMANCE OF RADIATOR BY PARAMETRIC EVALUATION

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Abstract*—Automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Radiators are used for cooling internal combustion engines, mainly in automobiles but also in other places where such engines are used. An attempt has been made to carry out rigorous testing on thermal performance evaluation of radiator. This research work leads development for performance evaluation of various parameters including mass flow rate of coolant, inlet coolant temperature, air velocity, environment condition, etc. are varied and to study the force and natural convection of heat transfer on coolant as a water. Main objective of the said work is to increase the efficiency with high performance of automobile during daily life.

***Index Terms*— Radiator, mass flow rate, inlet coolant temperature, heat transfer rate, effectiveness, forced convection**

I. INTRODUCTION

The radiator plays a very important role in an automobile. It dissipates the waste heat generated after the combustion process and useful work has been done. The effectiveness with which waste heat is transferred from the engine walls to the surrounding is crucial in preserving the material integrity of the engine and enhancing the performance of the engine.[1] The radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engine aircraft, railway locomotives, motorcycles, stationary generating plants[2] and other places where such engines are used. Problem of using the radiator is that it gives not right amount of efficiency by using old or present technology. For better performance of radiator a working medium like water and working parameters like heat flow rate and effectiveness should be taken care. Generally, heat flow rate and effectiveness are thermal parameters depended on water temperatures, air temperatures and mass flow rate.[3,5] Here the main focus is to perform evaluation for performing the radiator, a task in modern technology by using the right performance parameter and component. However, to increase the cooling capacity of radiator by heat transfer, a geometrical arrangement of flow and specific heat of coolant play important role [6], this will decrease the temperature of engine. There will be increase in the performance of engine and increase the life of engine and protect to overheating in engine. This will be occurring through changing parameter. The variable parameters in associated with radiators are measured in set upby different instruments.[4]

II. ACQUAINTANCE TO TOOLING AND MEASURING INSTRUMENTS

(1) Radiator:

Radiators are heat exchanger used to transfer heat from one medium to another for the purpose of cooling. It is the cooling system of engine which is used to cool down the engine. By the flow of fluid from radiator to the engine and engine to radiator the cooling take place in engine

Figure 1: Radiator

(2) Radiator Fan:

Radiator fan is use to blow the air towards the radiator and to take away the hot air through the radiator fins and it is also used to suck the air from engine cabin. A fan is a part of cooling system and its design helps to keep a temperature down in the engine.

Figure 2: Fan

(3) Pipe (Rubber):

Pipes are used to connect the radiator and engine. They are made from rubber.

- Internal Pipe diameter is: 35mm
- External pipe diameter is: 44mm

Figure 3: Pipe

(4) Motor:

Motor is used to convert electric energy into mechanical energy by which the fluid will force to move, circulate and to lift the fluid.

Figure 4: Electric motor

(5) Tank:

It is used to collect water and to use tank in place of circulation of water in engine.

Figure 5: Tank

(6) Heater:

A heater increases the temperature of fluid. An adjustable heater is used for the adjustment of temperature. Heater is used in place of engine to increase the temperature of fluid.

Figure 6: Heater

(7) Over flow tank:

In radiator over flow tank is used to collect the fluid which is hot fluid. So it becomes pressurize fluid and puses the cap valve up and flow takes place towards the tank of over flow tank. After decrease in the temperature of fluid some fluid continuously automatically come back in radiator till the valve comes to its original place

- Internal Pipe diameter is: 9mm
- External pipe diameter is: 14mm

Figure 7: Overflow tank

(8) Power supply unit:

It will be used for give input 12V power to run radiator fan. It will be used for variable power supply through change velocity of fan.

Figure 8: Power supply

(9) Thermometer:

Digital infrared thermometer is used to measure the temperature of the fluid in the pipe and also to find out inlet and outlet temperature of radiator and engine.

Figure 9: Thermometer

(10) Flow meter:

Digital flow meter is used to measure the flow rate in pipe by observing in screen.

Figure 10: Flow meter

(11) Anemometer:

It is used for measuring air velocity.

Figure11: Anemometer

(12) Fluid:

Here water is used as radiator fluid but it will reduce life of radiator. It does not provide lubrication, corrosion resistance and inhabitation.

- Water (60%) + coolant (40%): ethylene glycol, polyethylene glycol use as a coolant. It is mixed with water so it will increase heat transfer rate.

Figure 12: Fluid

III. METHODOLOGY FOR EXPERIMENTS

An experiment is done with a radiator having running and without running fan in order to check the performance in the said force convection system. The parameters like mass flow rate, LMTD, effectiveness and rate of heat transfer are prior important to determine.

In experiment, temperatures are measured at different locations for working medium like water and air. This is in order to find amount of heat transfer from water to air and hence how a radiator works efficiently. A valve is used to vary the mass flow rate by operating at different angles. The setup is run for 2 to 3 hrs to take readings as required.

ASSUMPTIONS:

The following assumptions are taken in experimental procedure.

a) There are no phase changes (condensation or boiling) in all fluid streams.
b) The temperature of each fluid is uniform over every flow cross section, so that a single bulk temperature applies to each stream at a given cross section.
c) The thermal conductivity of the tube material is constant in the axial direction.
d) Room temperature is 33°C.

Figure 13: Radiator setup for experiment

Figure 14: Temperature Measurement

IV. EXPERIMENTAL PERFORMANCE AND CALCULATIONS

[A] EXPERIMENT WITH RUNNING FAN:

A fan is used along with radiator to create force convection heat transfer during experimental performance. Here for changing different position of valve, mass flow rate is found.

Table 1: Calculation of Water Flow rate

Valve Angle	**90°**	**67.5°**	**45°**	**22.5°**
TIME (sec) for 500 ml	4.51	4.98	6.00	14.92
	4.35	4.82	5.95	15.62
	4.26	4.83	5.98	15.82
	4.31	4.94	5.96	16.00
	4.23	4.96	5.90	15.42
Time for 1 lit	4.31×2 = 8.62	4.94×2 = 9.88	5.95×2 = 11.9	15.62×2 = 37.24
Lit/ min	6.96 lit ≈ 7 lit	6.07 lit ≈ 6 lit	5.04 lit ≈ 5 lit	1.61 lit ≈ 2 lit

Table 2: Observation readings with running fan Duration of Experiment: 2 hr 30 minutes

Angle of valve	Ambient temperature T1	Flow rate (L/min)	Tank temperature		Time min	Temperature after running of radiator cooling fan		Air Temperature T2	Fan running time hrs
			Inlet	Outlet		Inlet t1	Outlet t2		
90	31.6	7	77.8	76.6	43:20	72.5	66.7	47.7	1:25
67.5	33.0	6	77	76	37:05	73.9	65.2	48.7	1:40
45	33.3	5	75.7	74.5	36:06	71.9	62.9	54.1	1:22
22.5	33.8	2	74.3	73.5	31:44	69.7	60.6	55	1:47

Note: Air velocity = 6.10 m/s

Calculation:

(1) LMTD and Effectiveness:

- LMTD for counter flow is calculated by using temperature values of hot and cold fluids.

$$\text{LMTDCF} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}}$$

$$\text{Effectiveness } \varepsilon = \frac{T_{\text{outlet air}} - T_{\text{inlet air}}}{T_{\text{in water}} - T_{\text{inlet air}}}$$

When valve is open at 90°

$T_{hi} = t1 = 72.5^{o}C$,

$T_{ho} = t2 = 66.7^{o}C$

$T_{ci} = T1 = 31.6^{o}C$

$T_{co} = T2 = 47.7^{o}C$

$$\text{LMTDCF} = \frac{(72.5-47.7)-(66.7-31.6)}{\ln\frac{72.5-47.7}{66.7-31.6}} = \frac{-10.3}{-0.3473} = 29.657^{o}C$$

$$\text{Effectiveness } \varepsilon = \frac{47.7-31.6}{72.5-31.6} = 0.3936$$

- LMTD for radiator:

It is calculated by considering correction factor from standard chart. A chart is depended on the geometry of heat exchanger and the inlet and outlet temp of the hot and cold fluids.

$LMTD_{R} = LMTD_{CF} * F$

Table 3: Calculation of LMTD and Effectiveness

SR NO	$LMTD_{CF}$	Correction factor F	$LMTD_{R}$	Effectiveness ε
1	29.657	0.985	29.212	0.3936
2	28.571	0.97	27.714	0.3839
3	23.182	0.96	22.254	0.5389
4	20.133	0.94	18.925	0.5905

(2) Heat transfer rate:

It is calculated by using mass flow rate and temperature difference of water.

$Q = \mathring{m}\, Cp\, \Lambda T$

Where,

Q = rate of heat transfer, KJ / sec

ΛT = temperature difference in water (T_i-T_o), °C

Cp=4.187 KJ/Kg k

Tabl e 4: Calculation of heat flow rate

$\mathring{m}$(L/min)	$\mathring{m}$(kg/s)	T_i (°C)	T_o(°C)	Q (KW)
7	0.12	77.8	76.6	0.60
6	0.10	77	76	0.42
5	0.08	75.7	74.5	0.40
2	0.03	74.3	73.5	0.10

[B] EXPERIMENT WITHOUT RUNNING FAN:

Table 5: Observation readings without running fan Duration of Experiment: 2 hr 30 minutes

Angle of valve	**Ambient temperature T1**	**Flow rate (L/min)**	**Tank temperature**		**Time min**	**Temperature after running of radiator cooling fan**		**Air Temperature T2**	**Fan running time hrs**
			Inlet	**Outlet**		**Inlet t1**	**Outlet t2**		
90	35.8	7	78.5	77.4	28:16	76.2	65.2	48.6	1:25
67.5	36.0	6	77	76	27:05	73.9	65.2	48.7	1:40
45	36.3	5	77	75.9	18:48	74	64.2	51.8	1:34
22.5	36.8	2	76	75	17:36	75	61.0	55.0	2:28

Note: Air Velocity: 5.30 m/s

Calculation:

(1) LMTD and Effectiveness:

$$\text{LMTDCF} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}}$$

$$\text{Effectiveness } \varepsilon = \frac{T_{\text{outlet air}} - T_{\text{inlet air}}}{T_{\text{in water}} - T_{\text{inlet air}}}$$

When valve is open at 90°

$T_{hi} = t1 = 76.2^oC$,
$T_{ho} = t2 = 65.2^oC$
$T_{ci} = T1 = 35.8^oC$
$T_{co} = T2 = 48.6^oC$

$$\text{LMTD CF} = \frac{(76.2-48.6)-(65.2-35.8)}{\ln\frac{76.2-48.6}{65.2-35.8}} = \frac{-1.8}{-0.0632} = 28.481^OC$$

$$\text{Effectiveness } \varepsilon = \frac{48.6-35.8}{76.2-35.8} = 0.3168$$

$LMTD_R = LMTD_{CF} * F$

Table 6: Calculation of LMTD and Effectiveness

SR NO	**LMTD $_{CF}$**	**Correction factor F**	**LMTD $_R$**	**Effectiveness ε**
1	28.481	0.97	27.627	0.3168
2	27.210	0.98	26.666	0.335
3	25.0	0.96	24.0	0.411
4	21.989	0.94	20.669	0.476

Tabl e 7: Calculation of heat flow rate

$\mathring{m}$(L/min)	**$\mathring{m}$(kg/s)**	**T_i (°C)**	**T_o(°C)**	**Q (KW)**
7	0.12	78.5	77.4	0.55
6	0.10	77	76	0.42
5	0.08	77	75.9	0.36
2	0.03	76	75	0.03

V. RESULTS AND DISCUSSION

(1) Water flow rate v/s Water temperature:

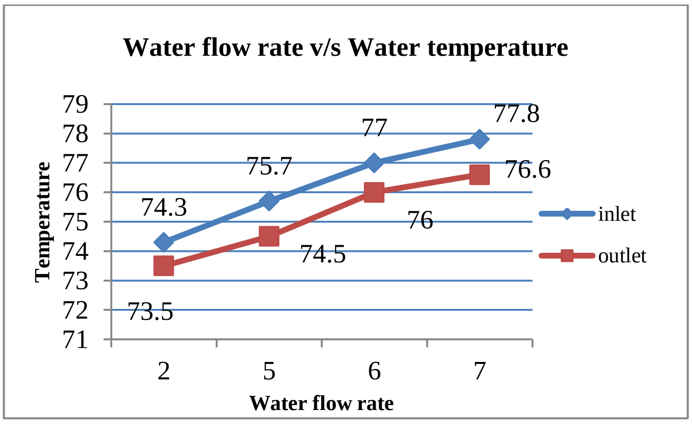


Figure 15: Water flow rate v/s Water temp (With fan)

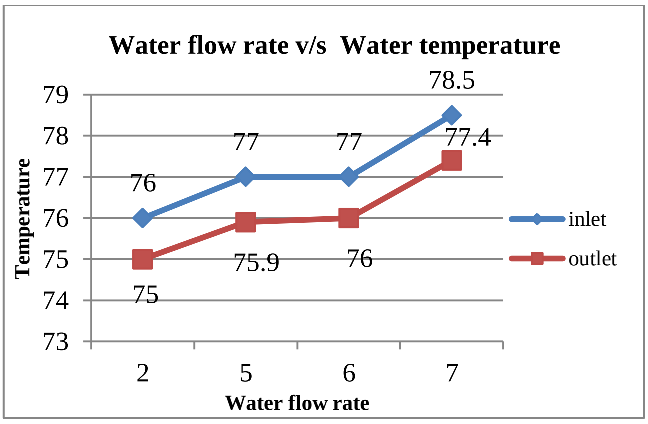


Figure 16: Water flow rate v/s Water temp (W/o fan)

As the water flow rate increases, it keeps lower down the outlet temperature as compared to inlet temperature of tank. Also in presence of fan, a temperature drop at outlet of water is also decreased. It shows that by increasing water flow rate, the temperature of engine can be decreased.

(2) Water flow rate v/s Effectiveness:

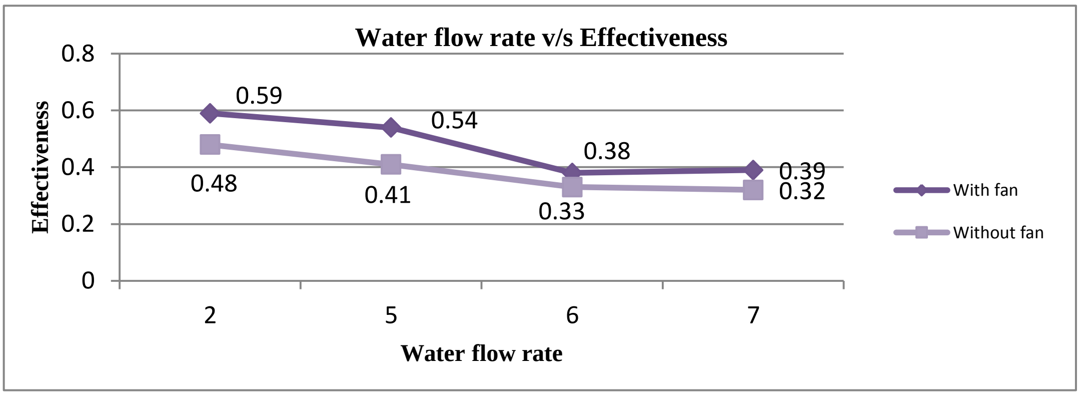


Figure 17: Water flow rate v/s Effectiveness

In case of with fan, effectiveness is higher as compared to without fan with increasing the flow rate. This is due to heat absorbed by air as an auxiliary medium.

(3) Water flow rate v/s Heat transfer rate:

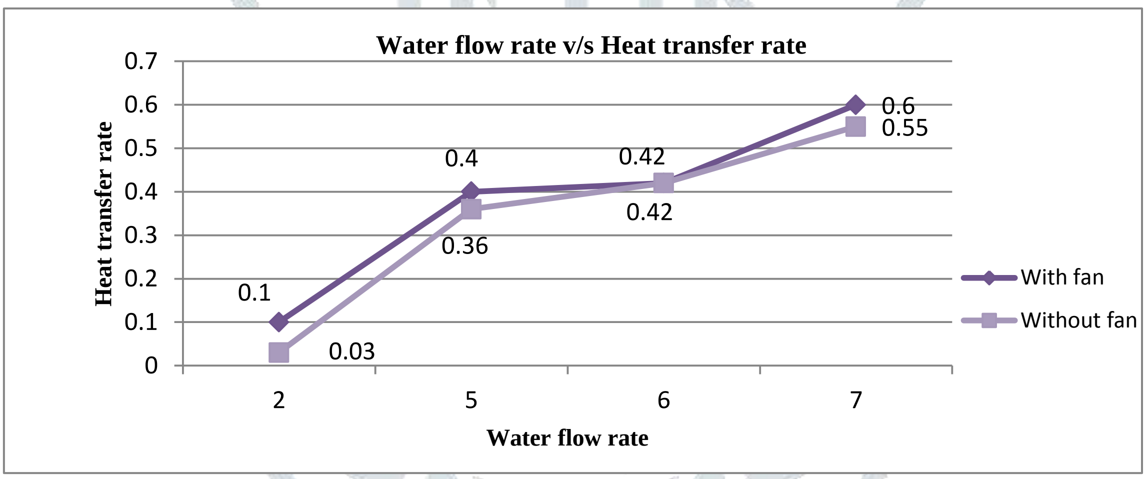


Figure 18: Water flow rate v/s Heat transfer rate

Here, with increment of waterflow rate, heat transfer rate is also increased. In presence of fan, heat transfer rate increment becomes more effective.

(4) Water flow rate v/s Time to rise temperature:

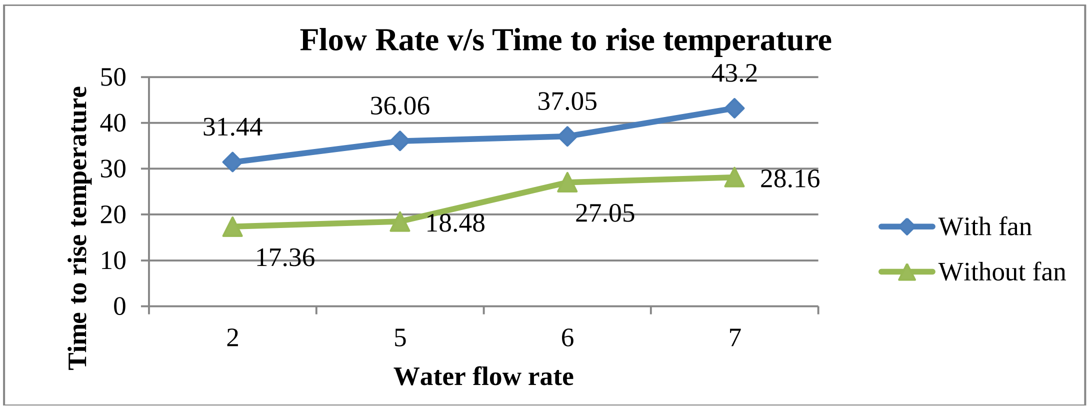


Figure 19: Water flow rate v/s Time to rise temperature

As the flow rate increases to lower the temperature, time also increases. Because of which radiator cooling fan starts many times to decrease the temperature.

(5) Inlet temperature of water v/s Effectiveness:

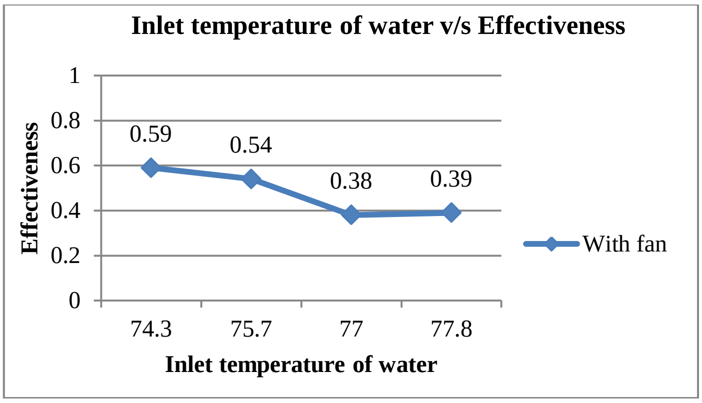


Figure 20: Inlet temp of water v/s Effectiveness (With fan)

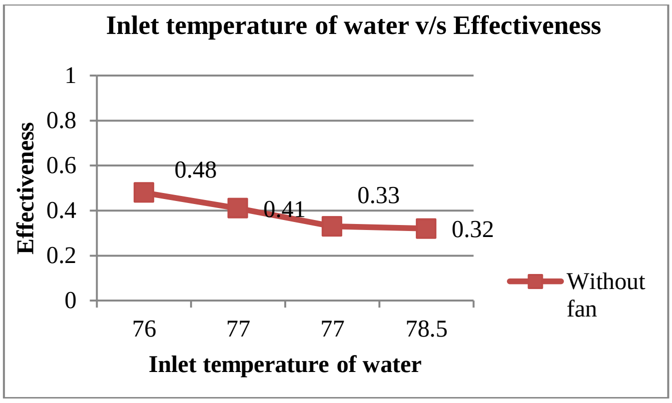
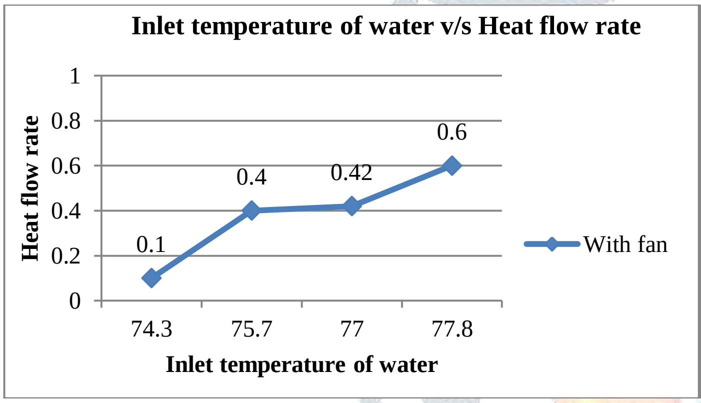


Figure 21: Inlet temp of water v/s Effectiveness(W/o fan)

If inlet temperature of water increases, it reduces the effectiveness while due to working of fan, value of effectiveness does not fall in great amount.

(6) Inlet temperature of water v/s Heat flow rate:



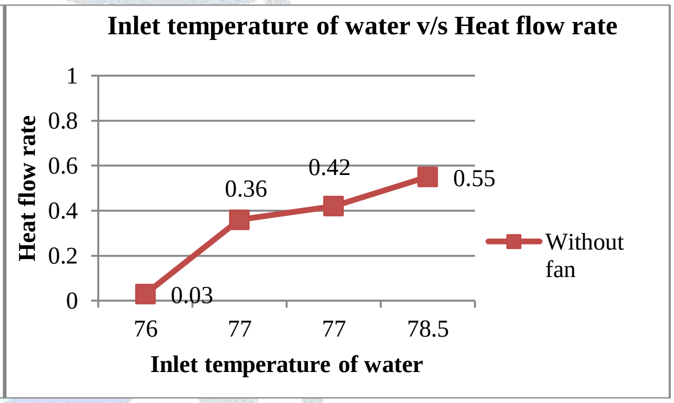


Figure 22: Inlet temp of water v/s Heat flow rate (With fan)

Figure 23: Inlet temp of water v/s (W/o fan)

When inlet temperature of water increases, heat flow rate also increases. Also, with the fan heat transfer takes place more as compared to without fan condition.

CONCLUSION

A radiator has significant role in automobile; however it is a part of cooling system for IC engine. Basically, a testing of radiator reveals how various parameters perform well those are associated with it. An efficient cooling system provides healthy life of engine. So for better working of engine, concerned parameters for radiator should behave properly. The plotting of various graphs focus on interrelation between parameters in context with working medium and auxiliary medium of fluid and hence performance of radiator.

A water flow rate is one of the variable parameter which keeps water temperature low with increased rate. Also with proper functioning of fan, it imparts more effect on cooling. Likewise, an inlet temperature of fluid has significant role that affect effectiveness and rate of heat transfer. For higher value of inlet temperature, an effectiveness of radiator is reduced. So it is necessary to keep this temperature in within limit. A radiator fan keep value of effectiveness up rather than dropping further.

i.e. For 77.8^{o} C inlet temperature of water, effectiveness comes 0.39 in force convection while for 78.5^{o} C inlet temperature of water, effectiveness comes 0.32 in natural convection. That shows utility of force draft fan in radiator. However radiator fan causes effect of air for heat absorption and hence increase the rate of heat transfer. i.e. For 77.8^{o} C inlet temperature of water, heat transfer rate comes 0.6 in force convection while for 78.5^{o} C inlet temperature of water, heat transfer rate comes 0.55 in natural convection.

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