RESEARCH ARTICLE OPEN ACCESS

ANALYSIS OF HEAT TRANSFER IN CHANNEL WITH ARRAY OF DIMPLED RECTANGULAR FINS

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ABSTRACT: Combined convection heat transfer through rectangular dimpled fin array is done to determine the Gr/Re^2□ 1 at the different velocities & power output. It also studies the effect of different velocities on combine convective heat transfer coefficients. It is therefore decided to build fin arrays with hot surface with inverted T shape channel. Dimpled fins with aluminium having small thickness are used, which gives high thermal conductivity. The horizontal & vertical ducts are made up of acrylic. The heat transfer by radiation is neglected. The temperature of finned system decreases with increase in air velocity, as expected. The specimen temperatures are increasing in al fins when compared. The observed value of Gr/Re^2 within the prescribed zone i.e. 1 to 10 which is the combined convection effect. Heat transfer coefficient increases with increase in air velocity for given heat input. Reynolds Number increases with increasing in air velocity. The Nusselt Number for rectangular fin array increases with increasing the Grashof Number. Hence the fin performance found increased due to dimples on fins.

Keywords: dimpled fins, heat transfer, combined convection.

INTRODUCTION: The objective of this work on combined convection heat transfer through rectangular dimpled fin array is done to determine the Gr/Re^2□ 1 at the different velocities & power output. It also studies the effect of different velocities on combine convective heat transfer coefficients. It is therefore decided to build fin arrays with hot surface with inverted T shape channel. The fin array was constituted by three geometrical parameters fin length 'L', fin height 'H' & fin spacing 'S'. It is decided to use cartridge type heater. Which is inserted at the base of fin arrays. Thus the fins & spacer pieces made of aluminum having small thickness are used, which gives high thermal conductivity. The horizontal & vertical ducts are made up of acrylic. The heat transfer by radiation is neglected.

OBJECTIVES:

To find Reynolds Number (Re), To find Nusselt Number (Nu), To find Coefficient of Heat Transfer (h), To draw a Plot of friction factor vs. Reynolds Number as well as Reynolds Number, Nusselt Number. To draw a Plot of Reynolds Number Vs Nusselt Number. To compare heat transfer performance.

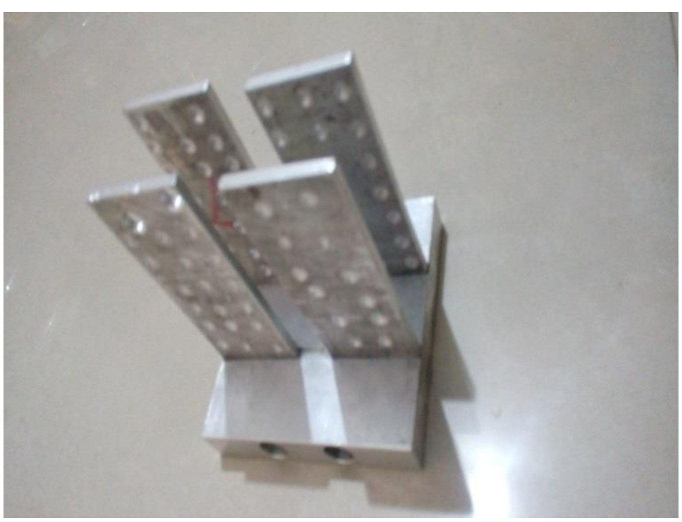


Fig:1. Dimpled fins 2x2 array fixed on heater base

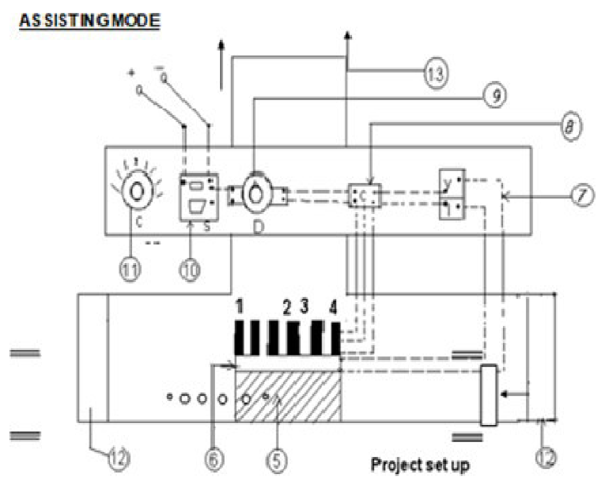
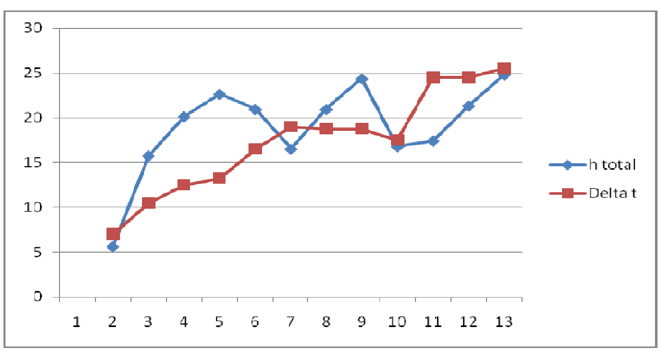


Fig:2.Experimental setup schematic diagram.-1,2,3,4- Thermocouples **5.**-fin 6**.**-Insulating material **7.**-Voltmeter & Ammeter.**8.**-Temprature indicator **9-**Dimmer stat 10**.**-Switch 11**.**-fan Controller **12.**-fan

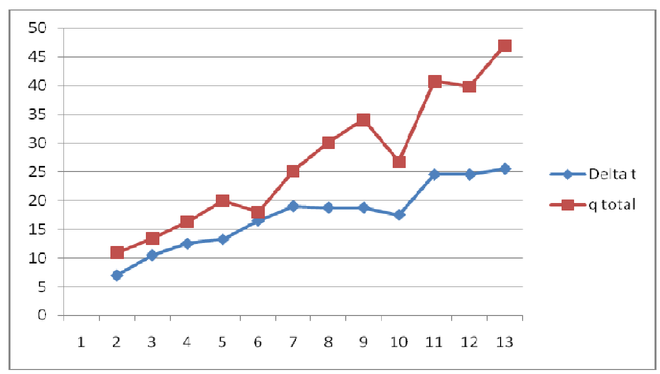
Fig:3 Experimental Set up

Result Table: 1 for Plane Fins

SN	Coeff. of vol. exp.	h total	Delta (t)	Grashof's no.		Nusselt No.		
	B			Gr	Gr Pr	Nun	hn	Qn
1	0.00321	5.616027	7	232658.1	162628	11.84816	5.616027	6.005218
2	0.003265	15.73721	10.5	164229.9	115125.2	10.86787	4.999222	3.301736
3	0.003255	20.13534	12.5	154298.6	108009	10.69589	4.984286	3.291872
4	0.003251	22.62563	13.25	165118.4	115582.9	10.87866	5.069455	3.587273
5	0.003162	20.94021	16.5	337445.4	235874.3	13.00236	6.241133	10.40303
6	0.003201	16.51133	19	260029.7	181760.7	12.18224	5.77438	6.900962
7	0.003212	20.94021	18.75	256711.2	179441.1	12.14318	5.755868	6.788327
8	0.003212	24.35281	18.75	256711.2	179441.1	12.14318	5.755868	6.788327
9	0.003118	16.78063	17.5	470817.7	328630.7	14.12632	6.780634	15.99382
10	0.003157	17.41133	24.5	420503.9	294352.7	13.7426	6.513994	12.08704
11	0.003182	21.32414	24.5	332367.2	232324.7	12.95316	6.139799	9.461738
12	0.003177	24.79599	25.5	345383.6	241423.2	13.07816	6.199049	9.942965



Graph: 1. Plots of (h_{total} Vs ΔT) br



Graph: 2. Plots of (qtotal Vs ΔT) br

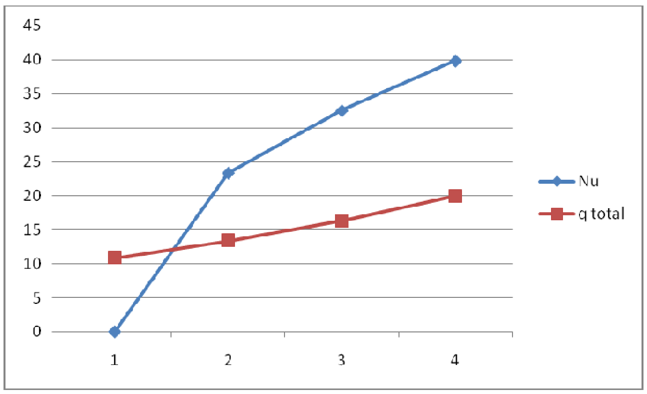
Remark: Heat transfer coefficient increases as the increase in temperature difference.

Remark: Heat transfer rate increases as the increase in temperature difference.

Result Table 2: For plane fins

Reading No.	Reynolds No Re	Nu	Hf	qf	qr	q total	Gr/RexRe
1	0	0	0	0	4.8503448	10.85556	-
2	1562.5	23.34345	10.73799	7.091903	2.9958012	13.38944	6.726857
3	3033.981	32.51298	15.15105	10.00651	2.9958012	16.29418	1.676241
4	4550.971	39.82011	18.55617	13.13081	3.209787	19.92787	1.397237
5	0	0	0	0	7.5608316	17.96386	-
6	1474.057	22.6518	10.73695	12.83173	5.4209736	25.15367	3.96726

7	2948.113	32.03448	15.18434	17.90803	5.349645	30.04601	2.953633
8	4422.17	39.23406	18.59694	21.93277	5.349645	34.07074	1.312726
9	0	0	0	0	10.69929	26.69311	-
10	1516.99	22.99015	10.89733	20.22054	8.4167748	40.72436	5.27277
11	2948.113	32.03448	15.18434	23.39983	6.9902028	39.85177	3.824105
12	4422.17	39.23406	18.59694	29.82857	7.2755172	47.04705	1.766164

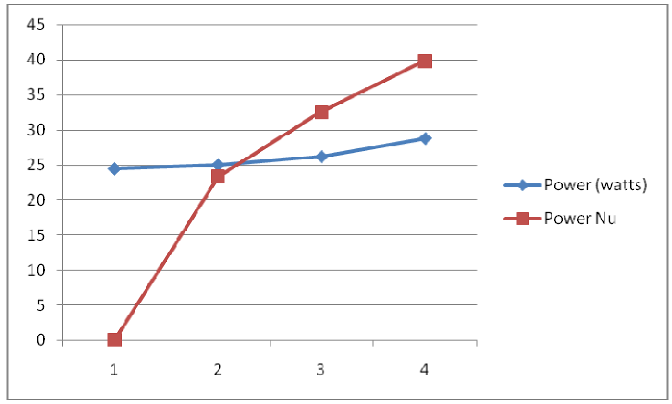


Graph: 3. Plots of (Nu_n Vs q_{watts}) br

Remark: Nusselt numbers increases as the rate of heat transfer increases.

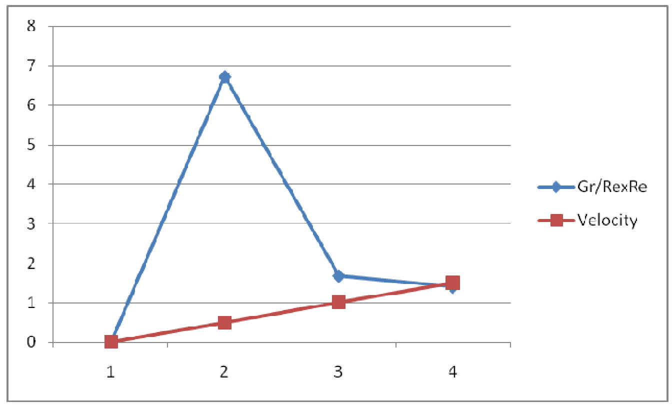
Result Table: 3. for Dimpled Fins

Reading	h total	Delta (t)	Coef. of Vol. exp.	Grashoffs No.		Nusselt No.		
			B	Gr	Gr Pr	Nun	hn	Qn
1	15.69914	18	0.003215	246739.9	172471.2	12.02351	5.69914	6.452569
2	16.12123	14.25	0.003235	220810.5	154788.2	11.70271	5.38324	4.825139
3	18.01415	13.5	0.00326	139831.1	97881.74	10.43584	4.86310	2.905946
4	22.28784	12.5	0.003265	125316.3	87721.38	10.15379	4.73166	2.529786
5	21.95806	10.25	0.003256	134399.3	93945.08	10.32929	4.95806	3.196585
6	16.66983	18.25	0.003199	289776.1	202553.5	12.51662	5.93287	7.930031
7	19.78467	16.75	0.003222	230067.6	160817.2	11.81504	5.60032	5.900366
8	20.9809	14.25	0.003235	196520.6	137367.9	11.35856	5.38395	4.825776
9	16.69883	15.5	0.003137	448504	313055.8	13.95589	6.69882	14.95814
10	17.39812	19.25	0.003158	417104.9	291973.4	13.71475	6.50079	11.96032



Graph: 4. Plots of (Nu_f Vs qs) br

Remark: Power (watt) rises as Power Nu

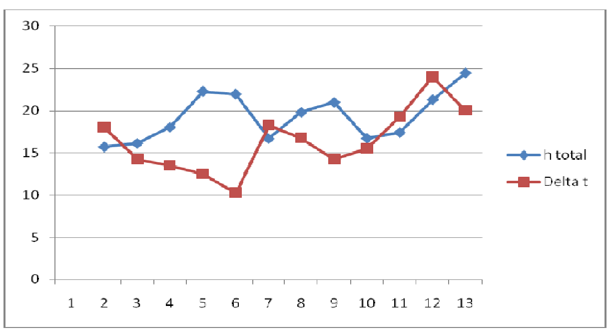


Graph: 5. Plots of (velocity Vs Gr/ Re2) br,
Remark: Gr/ RexRe increases as air flow velocity on dimpled fins increases.

11	21.29379	24	0.003185	325843.4	227764.5	12.88913	6.10944	9.222821
12	24.45291	20	0.003226	275039.9	192252.9	12.35436	5.85596	7.366805

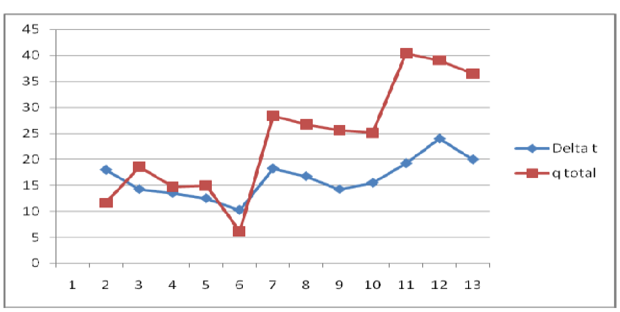
Result Table: 4. for Dimpled Fins

Reading No.	Reynolds No Re	Nu	Hf	qf	Qr	q total	Gr/RexRe
1	0	0	0	0	5.1356592	11.58823	-
2	1562.5	23.34345	10.73799	9.624726	4.0657302	18.5156	9.0444
3	3033.981	32.51298	15.15105	9.05351	2.7104868	14.66994	1.519071
4	4550.971	39.82011	18.55617	9.921057	2.4251724	14.87602	1.605061
5	0	0	0	0	2.9244726	6.121058	-
6	1474.057	22.6518	10.73695	14.35128	6.062931	28.34424	3.33627
7	2948.113	32.03448	15.18434	15.99784	4.7790162	26.67723	2.64708
8	4422.17	39.23406	18.59694	16.66891	4.0657302	25.56041	1.004933
9	0	0	0	0	10.1286612	25.0868	-
10	1516.99	22.99015	10.89733	20.04918	8.3454462	40.35495	5.12507
11	2948.113	32.03448	15.18434	22.92228	6.8475456	38.99265	3.749045
12	4422.17	39.23406	18.59694	23.39496	5.706288	36.46805	1.406452



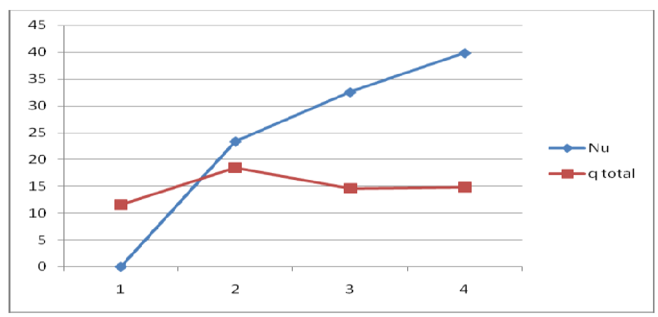
Graph: 6. Plots of (h_{total} Vs ΔT) al

Remark: Heat transfer coefficient increases as the increase in temperature difference.



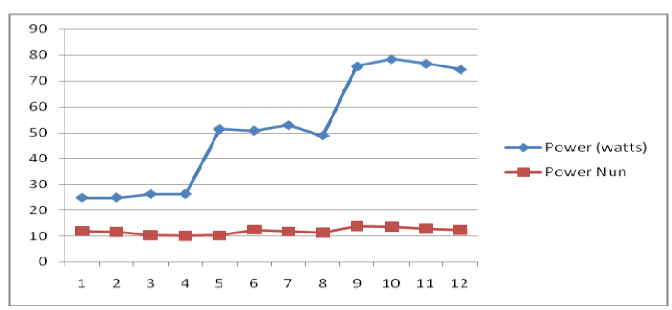
Graph: 7. Plots of (qtotal Vs ΔT) al

Remark: Heat transfer rate increases as the increase in temperature difference.



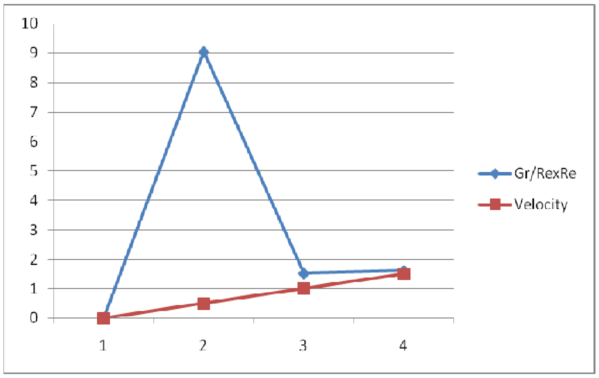
Graph: 8. Plots of (Nu_n Vs q_{watts}) br

Remark: Nusalt Number increases as the rate of heat transfer increases.



Graph: 9. Plots of (Nu_f Vs qs) al

Remark: Power (watt) rises as Power Nu



Graph: 10. Plots of (velocity Vs Gr / R_e^2) al
Remark: Gr/ RexRe increases as air flow velocity on dimpled fins increases.

DISCUSSION ON COMBINED CONVECTION:

The most important parameter of combined convection is Gr/Re^2, numerator represents the natural convections effect. While the denominator represents the forced convection effect. The relative magnitude of Gr/Re^2 will indicate which convection is predominant. In case of dominant natural convection, the forced convection effect will be small, resulting in large values of Gr/Re^2. If the forced convection is dominating factor, then the Gr/Re^2 assume a small value. Reynolds number 13,500–42,000, the clearance ratio (C/H) 0, 0.33 and 1, the inter-fin spacing ratio (Sy/D) 1.208, 1.524, 1.944 and 3.417. [1].

The combined convection region is that region, where both the convections are of similar magnitude the range of Gr/Re^2 from about 1 to 10 is a zone of combined convection.

It is observed that the parameter Gr/Re^2 assumes the values of in the range from 1 to 10. With increase of velocity 'Re' increases, resulting in the decrease of the parameter Gr/Re^2 With increase of heater input Gr increases. The effect of flow direction and the effect of tube inclination on the surface temperature, local and average Nusselt numbers with Reynolds number ranged from 400 to 1600 and Grashof number from 2.0 to 6.2 [2]. The effects of the resistance parameters and of the Prandtl numbers on heat transfer characteristics are investigated. [3]. Thermal insulation of the cavity can be achieved through the use of high horizontal velocity flow. Various results for the streamlines, isotherms and the heat transfer rates in terms of the average Nusselt number are presented and discussed for different parametric values. [4]

EXPERIMENTATION:

The present experimental work was concerned with combined convection studies from horizontal rectangular fin array. From the literature it is seen that combined convection as topic of research for a few geometries only such as vertical plate with rectangular and circular cross section fins. Study of mixed convection flow inside a rectangular ventilated cavity in the presence of a heat conducting square cylinder at the center has been carried out [5].However there are only a few studies reported on combined convection from other geometries such as fin arrays. Horizontal rectangular fin arrays are used for cooling of electronics components in the form of Heat sink, in many situation a fan is mounted to increase the heat dissipation rate and thus there exist a problem of combined convection of horizontal rectangular fin array with this idea in mind the experiment setup was developed to work in the region of combined convection. With this limited objective the present work can be viewed as a starting step for carrying out for further research. The dimpled fins will be interest as a topic of research; however this requires very careful observation and adequate control on the parameter. Pulling Fins are extended surfaces employed to enhance the convective heat transfer from a surface for increasing heat dissipation Fins with various geometries [6]. The problem of natural convection heat transfer from fin arrays with inclination is studied experimentally and theoretically to find the effect of inclination of the base of the fin array on heat transfer rate [7]. Dimples play a very important role in heat transfer enhancement of electronic cooling systems, heat exchangers etc. [8]. Experimental study had been carried out to investigate the buoyancy-opposed mixed convection from an upward flow of hot air to a vertical pipe with a cooled surface [9]. Experiments were carried out in the range of $2 < Pe < 2200$ and $700 < Ra < 1500$[10].Novel split-dimple interrupted fin configuration for heat transfer augmentation [11]. forced convection heat transfer analysis through dimpled surfaces with different arrangements**,** Dimples play a very important role in heat transfer enhancement of electronic cooling systems, heat exchangers etc.[12]. The experiments were carried out in the range of 2 < Pe < 2200 and 700 < Ra < 1500[13]. For circular and oval dimples, heat transfer enhancements (relative to a flat plate) were observed for Reynolds number range from 600 to 2000 (Reynolds number based on channel height) [14]. Experimental and numerical analysis on heat transfer characteristics of shoe brush-shaped fins [15].

WORKING:

Rectangular pipes are made of acrylic sheets of size 150x150mm with inverted 'T' section of 500mm horizontal and 500mm vertical. 12 volt DC fans controlled by dimmer knob are fixed at the base pipes left and right ends to force the air to come out from top end of vertical pipe.2x2 array of dimpled aluminum fins 5x30x80mm fitted vertically on al base & heated by two pencil heating rods 10mm diameter 80mm length controlled by separate dimmer knob. Four thermocouples brazed to one of 4 fins with equal gaps to get average temperature of any fin. Input and output temperatures are measured by two more thermocouples. This way 6 temperatures are noted by digital thermometer. The observations, results & discussions made in previously enables one to predict, the heat transfer rate from rectangular fin array, losing by combined convection. In this experiment we use the velocity of air in between 0 m/s to 1.5 m/s for the combined convection. Rectangular fin array have been investigated experimentally & the results are obtained. Since the fin array has a major portion of vertical plates then let us, use the correlation for the vertical plates, $Gr.Pr\ 10^4 < Gr.Pr < 10^9$.

$$Nu_n = 0.59\ (Gr.Pr)^{0.25}$$

$$\mathbf{h_n = Nu_n * K/ L}$$

$q_{nat} = h_{n\,*}\, A * \otimes T$

$Re < 5X10^5$ Hence flow is Laminar flow. Correlation for flat plate is used

$Nu = 0.664\ (Ré)^{0.5}\ (Pr\ )^{0.33}$

$h_f = Nu_f * K/L$

$q_f = h_f\, A\ \otimes T$

$q_{\ rad} =\ 6\ A \nabla\ (T^4\text{-}T^4_{amb})$

CONCLUSION:

The temperature of finned system decreases with increase in air velocity, as expected. The specimen temperature are increasing in Al fins when compared. The observed value of Gr/Re^2 within the prescribed zone i.e. 1 to 10 which is the combined convection effect. From graph, it is clear that the value of heat transfer coefficient increases with increase in air velocity for given heat input. It seen that value of Reynolds Number increases with increasing in air velocity. The Nusselt Number for rectangular fin array increases with increasing the Grashof Number. Hence the fin performance found increased due to dimples on fins.

FUTURE SCOPE:

1) Heat transfer by radiation is also a factor of consideration. This can be studied by surfaces of the fin arrays made of polished & dull by providing a black coating etc.
2) The work was concerned with the combined convection heat transfer from rectangular fin array. It is worthwhile to carry out the work on vertical rectangular fin array under forced and Natural convection condition also
3) It may also be possible to change the specimen material from aluminum to its alloy, cast iron etc. because the heat transfer rate & the thermal conductivity for different material is different.
4) In future the similar experiment may be studied for the various cross sectional specimen such as Circular, Rectangular, triangular trapezoidal etc. by using different materials of the specimen & using different working fluids.

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