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Experimental study of natural heat transfer from finned cylinders fixed in variable shape of duct

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Abstract

The work was an experimental study of natural heat transfer from heated cylinders fixed in variable shape air duct, made from Pyrex glass. Two finned cylinders made from mild iron, outer diameter (12) mm, inner diameter (10) mm, 22 rectangle fins with dimensions (70*40*1) mm. The angle of two walls from the duct was changed for five angles α:(0˚,3˚,5˚,10˚,15°) with vertical to make converge shape. The cylinders were fixed inside the duct at top, centre and bottom. The cylinders were heated by supply variable power of constant heat flux (88,177,390 and 680) W/m^2. The study was done with Rayleigh numbers ($15x10^3$ to $14x10^4$). The heat was carried by free convection by atmosphere air. The results of experimental work show that the Nusselt number increased with increased the angle of shape at top location until angle 15˚ ,so the Nusselt increased by 20% at q•= 680 W/ m^2 when increased the value of from 0˚ to 15˚.For centre location, the value of Nusselt number increased by 25 % at q•= 88 W/ m^2 when increased the value of angle from 0° to 3°, and increased by 21 % at q•= 680 W/ m^2 when increased the value of angle from 0° to 10°.For bottom location, the value of Nusselt number increased by 35 % at q•= 88 W/ m^2 when increased the value of angle from 0° to 3°,and increased by 30 % at q•= 680 W/ m^2 when increased the value of angle from 0° to 10°.The best location for the cylinders was at the bottom, and the best angle was 15°.

Keywords: Natural convection, Finned heat exchanger, Variable converge duct, Rectangle fins.

الخلاصة: أجريت دراسة عملية لانتقال الحرارة بالحمل الحر من اسطوانات مسخنة مثبتة داخل مجرى هوائي متغير الشكل مصنوع من البايركس.اسطوانتين مزعنفة مصنوعة من الحديد الخفيف,القطر الخارجي 12 ملم والقطر الداخلي ١٠ ملم, زعانف مستطيلة مصنوعة من الالمنيوم ابعاها ٧٠x 40 ملم. تم تغيير زوايا جدارين من المجرى إلى خمسة قيم (٠° ، ٣° ، ٥° ،١٠° و ١٥°) مع العمود ليصبح الشكل متقارب ،تم تثبيت الاسطوانات في ثلاث مواقع داخل المجرى (اعلى ، وسط و اسفل) ،وتم اختبار أربعة مستويات للفيض الحراري ٨٨، ١٧٧ ، ٣٩٠ و ٦٨٠ وات/م٢. أجريت الدراسة لمدى عدد رالي (14 x 10^4 الى ١٥ x١٠٣) باستخدام الهواء كوسط ناقل للحرارة حيث يتم انتقال الحرارة بواسطة الحمل الحراري. أظهرت النتائج العملية ,ان قيمة نسلت تزداد مع زيادة مقدار الزاويا للمجرى المتقارب حتى الزاويا ١٥°. وقيمة نسلت تزداد بمقدار ٢٠ %عند مستويات الفيض الحراري ٦٨٠ وات/م٢ وعند زيادة مقدار الزاوية من ٠° الى° ١٥ . عند الموقع الوسط فان قيمة نسلت تزداد بمقدار ٢٥ % عند مستويات الفيض الحراري ٨٨ وات/م٢ وعند زيادة مقدار الزاوية من ٠° الى° ٣ . وقيمت نسلة تزداد بمقدار ٢١ %عند مستويات الفيض الحراري ٦٨٠ وات/م٢ وعند زيادة مقدار الزاوية من ٠° الى° ١٠. عند الموقع الاعلى فان قيمت نسلت تزداد بمقدار ٣٥ % عند مستويات الفيض الحراري ٨٨ وات/م٢ وعند زيادة مقدار الزاوية من ٠° الى° ٣ . وقيمة نسلت تزداد بمقدار ٣٠ %عند مستويات الفيض الحراري ٦٨٠ وات/م٢ وعند زيادة مقدار الزاوية من ٠° الى° ١٠ . كما أظهرت النتائج العملية للأسطوانات انة افضل موقع للاسطوانات يكون في اسفل المجرى وافضل مقدار للزاوية هو ١٥°.

1. INTRODUCTION

Natural or free convection is still an important subject in engineering applications. Heat transfer from various geometries has been studied, and technicalities have been advanced to improve the heat transfer rate due to the low heat transfer coefficients. One of the problems of this division that has received concern in recent years is free convection heat transfer from a single cylinder or arrays of cylinders. The heat transfer process by free convection from the outer surface of the cylinder is very important in engineering applications, it is used in heat exchangers, boilers, air conditioning systems, heating and cooling devices, internal combustion engines, compressors, electrical appliances, and other[1]. The studying looked to the different orientations of these thermally active surfaces, such as horizontal, vertical and inclined configurations[2].The fins also have an important role in the improvement of heat transfer[3].Many researchers explored the thermal transfer mechanisms from a cylinder through free convection. Hyung et.al.[4] studied the natural convection for temperature variance between a coldish external inclined square container and a hot internal orbicular cylinder. The two-dimensional settling for free convection was acquired using the finite volume method accompanied by second-order accuracy and the immersed boundary method to dealing efficiently the inner circular cylinder within an inclined square enclosure. The investigation examined the influences of the following variables on fluid stream and heat transfer in a container. The range for Rayleigh number between 10^3 and 10^6, the range for the dimensionless cylinder radius from (0.1 to 0.3) and oblique angle of the container between 0^0 and 45^0.The results showed that the distribution of isotherms, streamlines, local and surface-averaged Nusselt numbers are determined by the combined effects of convection and the distance between the cylinder and walls of the enclosure, which are a function of the Rayleigh number, dimensionless cylinder radius and tilted angle of the enclosure. Omar.[5] investigated numerically natural convection heat transfer from horizontal circular cylinder situated in a square enclosure by using finite difference method. The work investigates the effect of Prandtl numbers on the flow and heat transfer characteristics. The study uses different Prandtl numbers (0.03, 0.7, 7, and 50), different Rayleigh numbers (10^4, 10^5, and 10^6) and different enclosure width to cylinder diameter ratios W/D (1.667, 2.5 and 5). The results showed that the Nusselt number increased with the Rayleigh number increasing for all cases. Also, the results show that the streamlines and isotherms for Pr=0.03 are unique and differ from those of other higher Prandtl numbers for all enclosure widths and $Ra \geq 10^5$.The streamlines and isotherms for $Pr \geq 0.7$ are nearly similar and independent of Prandtl number. Jnana et. al**.** [6]studied the heat transfer by free convection from a perpendicular cylinder with annular fins has been with varied the Rayleigh number (Ra) in laminar (10^4 Ra 10^8) and turbulent (10^{10} Ra 10^{12}) regions. The calculation was implemented by changing the fin to tube diameter proportion (D/d), fin spacing to tube diameter ratio (S/d) in the domain between 2 to 5 and 0.126-5.840 respectively. Optimization investigation of the accompanying heat transfer properties has been implemented to find the top fin distance for ultimate heat transfer for the turbulent stream. With the adding of fins to the heated isothermal tube surface, heat transfer drives on rising for laminar stream and turbulent stream heat transfer first rises and gets a greater value then begins to reduce and increased the Nusselt number when the Rayleigh number increased. Haneen and Hassan,[7] conducted an experimental and theoretical investigation of free convection heat transfer for three horizontal finned cylinders formed in a triangle and placed between two walls. The triangle's orientation was modified up, down, and side. Three times in each direction, the spacing between the cylinders was varied. The experiment was conducted with a constant heat flow of 1268, 660, 254, and 38 W/ m^2 with a Rayleigh number of $14x10^4$–$15x10^3$. Additionally, the cases were compared to three vertically placed finned cylinders. The results indicated that arranging the cylinders in a triangle promotes heat transmission more than arranging them vertically and that the triangle down configuration is the best for heat transfer. The results established that the number of Nusselt grows as the distance between cylinders increases. Additionally, adding Nusselt increased the number of Raleigh on all cylinders. Gi et. al.[8] investigated the free convection heat transfer from four cylinders set in container in a diamond shape numerically. The immersed boundary method (IBM) was used to capture the virtual boundary of the cylinders. The convection phenomena caused by the temperature variance between the hot cylinders surfaces and container walls were studied using various Rayleigh numbers in range between (10^3 to 10^6) and spaces between adjoining cylinders (dimensionless space between the four cylinders) from 0.30.7. The influences were investigated the variables that affect the heat transfer between the cylinder surface and walls. Nusselt number of cylinders and Nusselt number of containers have to rise with the Rayleigh number and dimensionless space between the four cylinders. With rising Rayleigh number, the geometrical configuration of the cylinders has a small influence on the heat transfer. Ghufran and Hassan.[9] investigated the effect of inclination angles for finned cylinders throw natural convection heat transfer. The free heat transfer from three cylinders finned with spiral fins and fastened between two plates was investigated experimentally and theoretically. Three finned cylinders are made from (steel iron), with an outside diameter d_o (12) mm, an inner diameter d_i (10) mm, and a fin diameter of (30) mm. The cylinders' inclination angle was modified to four different values of inclination angles for walls (0°, 30°, 60°, and 90°) ,used four values of heat flux: (121.16, 278.8, 497.9, and 792.5) W/ m^2 ,the Nusselt number for finned cylinders was greatest at a 30° angle with low heat flux and the best angle which give the maximum value of the Nusselt number was angle (60°).Hassan Abdullah and Mohammed Hassan.[10]investigated Experimental of natural heat transfer from two horizontal finned cylinders fixed in converge duct, made from Pyrex glass. The angle of the two walls of the duct was changed to five angles α : 0°, 3°, 5°,10°, and 15° with the vertical, The cylinders were fixed inside the duct at top, centre, and bottom in three locations, used constant heat flux 88,177, 390, and 680 w/ m^2 .The results of experimental found that, for top location, the value of Nusselt number increased by 7.8 % at q•= 88 W/ m^2 .For bottom location, the value of Nusselt number increased by 35 % at q•= 88 W/ m^2 when increase the value of angle from 0° to 3°.

In this study, A practical study of the rate of free convection heat transfer from the outer surface of two finned cylinders fixed in variable converge air duct, and studying effect the angle of shape and location of cylinders inside the duct for three locations: top, centre and bottom.

Nomenclature:

A: the radiation area of heat exchanger surface (m^2)
A_t: total surface area (m^2)
A_f: fin area (m^2)
A_b: bare cylinder area(m^2)
b: width of fin (m)
a: height of fin (m)
D: hydraulic diameter for fin (m)
d_o: outer diameter of cylinder (m)
d_i: inner diameter of cylinder (m)
g: gravitational acceleration (m/ s^2)
h: convection of heat transfer (w/m^2.k)
I: electric current (Ampere)
K_f: thermal conductivity for conduction at film temperature (W/m. k)
L: length of cylinder(m)
Nu: Nusselt number
N: fins number
Pr: Prandtl number

$Q_{con\ v}$: energy of transmitted by convection (W)
Q_{cond} : energy of transmitted by conduction (W)
Q_{rad}: energy of transmitted by radiation (W)
Q_g: heat generation result from electric current (W)
$Ra = Gr.Pr = \frac{g.\beta.\Delta T.D^3}{\vartheta.\alpha}$
Ta1: inlet temperature of air duct
Ta2: outlet temperature of air duct
Ts: average Temperature of pipe and fins surface (K)
T_W: $wall$ temperature (k)
T_b : air temperature (k)
t: thickness fin (m)
V: electric voltage (v)
β: thermal of expansion coefficient (1/K)
ϑ: kinematic viscosity for air (m^2/s)
ε: The emissivity of cylinders
σ: Stefan-Boltzmann constant (w/m^2 .K^4)
π: equal to 3.1415926
α: shape angle of converge duct

2. EXPERIMENTAL SETUP

The schematic diagram is shown in Fig. (1). It consists of externally two finned cylinders which fixed in variable air duct in order to change the angle to make converge or diverge with α:(0°,3°,5°,7°,10°,15°). The two cylinders are fixed in horizontal array. The air duct made from Pyrex glass the dimensions 550×140×70×5 mm height, length, width and thickness respectively open from top and bottom to surrounding by using the air as medium for heat transfer. Every cylinder with outer diameter (12) mm, inner diameter (10) mm, the length of each cylinder (160) mm, made from mild iron. 22 Rectangle fins made from aluminium with dimensions of 70 x40 mm with thickness (t) 0.5 mm, the fins fixed on the outer surface of cylinders as radially. Using voltage regulator for electrical power supply system, variac, digital multimeter, clamp meter, data logger and thermocouples, two thermocouples for each cylinder to measure pipe and fins temperature and two thermocouples for air inlet and outlet temperature of the duct. Hot wire used to measure air velocity at inlet and outlet of duct.

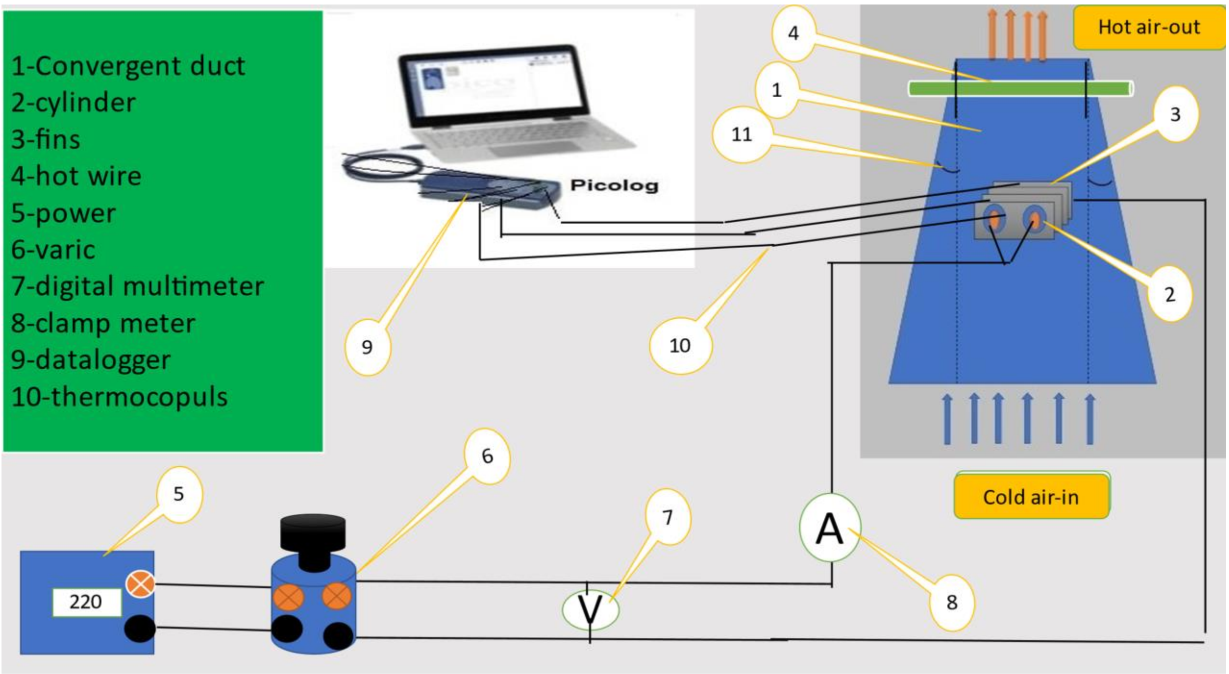

Figure 1 Schematic diagram of the experimental set

2.1. Electrical Power Supply System

The measurement devices are used in this study as Variac control the power supply to the heater, and supply a constant thermal flux to the heaters of cylinders. Digital multimeter measure the voltage supply to the cylinders. Digital clamp meter to measure the current passing through the heater. Data Logger is used to read the values of temperatures by using thermocouples and program in the computer. Hot wire used to measure air velocity at the top of air duct outlet of the duct. The measurement devices calibrated in (COSQC) as explained in appendix [A].

2.2.Thermocouples Installation and Distribution

In this study, thermocouples types K [Ni-10% (+) Cr versus Ni-5% (-) aluminium silicon] they are used to measure the temperatures of the cylinders and fins. The probe of thermocouple wire installed on the cylinder surface and fins by drilling holes (1mm) diameter and it depth about(1mm) then the thermocouples are inserted inside the holes then fixed by good type of epoxy. In the work used eight thermocouples: two thermocouples along cylinders, two thermocouples along fins, two thermocouples for air inlet and outlet of the duct, two thermocouples to measure the wall temperature of the duct to calculate the heat losses by the conduction, the thermocouple connect to datalogger by wires then the datalogger send the signal of computer by using (USB) wire and the computer read the temperature for each thermocouple by using program (picolog), as show in Fig. (3) from experimental work.

Figure 2 Photo of experiment work

3. MATHEMATIC RELATION

The main variables used in the experimental work were the angles of the walls duct from rectangle to converge, every angle of the converge duct heated four levels from thermal flux (88,177, 390 and 680) W/ m^2, and three fixed locations (top, centre and bottom), the steady state for temperature about one hours, then the temperature measured at all points of cylinders, fins and air outlet temperature.

Thermal flux can calculate from.

$$Qg = V * I \quad (1)$$

$$Qg = Qconv + Qcond + Qrad \quad \text{(for cylinders and fins)} \quad (2)$$

$$Qcond = Uwall * Awall * (Tw - Tamb) \quad (3)$$

Qcond (neglected) because it was found very small due to low thermal conductivity of Pyrex glass.

$$Qconv = h * At * (Ts - Tb) \quad (4)$$

$$Qrad = \sigma * A * \varepsilon * (Ts^4 - Tb^4) \quad (5)$$

$$Ab = \pi * d_o * (L - N * t) * 2 \quad (6)$$

$$Af = \left[(a * b) - 2\left(\frac{\pi D^2}{4}\right)\right] * 2 * N + [2(a + b) * t * N] \quad (7)$$

Nusselt number and the Rayleigh number are calculated by.

$$Nu = \frac{have * D}{K} \quad (8)$$

$$D = \frac{4A}{P} \quad (9)$$

$$have = \frac{Q_{conv}}{A_t * \Delta T} \quad (10)$$

$$Ra = Gr.Pr = \frac{g.\beta.\Delta T.D^3}{\nu_f^2} * \frac{\mu_f\ Cp_f}{K_f} = \frac{g.\beta.\Delta T.D^3}{\nu.\alpha} \quad (11)$$

$$\nu = \frac{\mu}{\rho} \quad (12)$$

$$\alpha = \frac{K}{\rho C_p} \quad (13)$$

$$T_f = \frac{T_S + T_\infty}{2} \quad (k) \quad (14)$$

$$T_S = \frac{T_P + T_f}{2} \quad (k) \quad (15)$$

$$T_b = \frac{T_{a1} + T_{a2}}{2} \quad (k) \quad (16)$$

$$\beta = \frac{1}{T_f} \qquad (\frac{1}{K}) \quad (17)$$

Table 1: The percentages values of Qconv. , Qrad. , Qcond for converge duct (Top, Centre and Bottom) at angle =15º.

Location	Qgen.(Watt)	Q conv. %	Qrad.%	Q cond.%	Nu
Top	48	96.51%	3.21%	0.28%	41.1
Center	48	96.41%	3.27%	0.32%	28.5
Bottom	48	96.825	2.9%	0.28%	49.8

4. EXPERIMENT PROCEDURE

All the tests were conducted according to the following procedure:

1- Maintaining a nearly constant laboratory ambient temperature and ensuring that the laboratory is suitable for free convection heat transfer without any external air movement above the test section, as well as controlling it continuously throughout the test.
2- Fixing two horizontal finned cylinders in a vertical array inside the variable duct at the bottom location.
3- Obtaining electric power from a reliable source to the variac, then the voltage from variac supply to the heater by wires after controlling the required heat flux (88,177,390 and 680) W/ m^2.
4- To measure the current, a digital clamp meter and used a digital multimeter to measure voltage
5- Steady state was achieved after (1) hour.
6- Using a data-logger, record the temperatures of thermocouples on the cylinder surface, the input and output temperatures of the air surrounding the cylinders, the room temperature, and the velocity of air output for the duct when reaches to the steady state.
7- After recording results, change the angle of the two walls for the variable duct five times at values 3˚,5˚, 7˚,10˚,15˚ with vertical axes to make convergent duct and the voltage has changed four times 10,20,30 and 40 volts, then repeat the above steps for another two locations (centre and top) all the cases required in this study.
8- The experiments for both cylinders in the air duct have been done for four value of heat flux (88,177,390 and 680) W/ m^2.

5. UNCENRTAINTY ANALYSIS

The method that suggested by Kline and McClintock [11] was used to measure the uncertainty of the experimental work, the uncertainty in calculating the heat transfer coefficient, Nusselt number, Rayleigh number and heat flux. The measuring devices are not quite accurate sometimes; therefore, the uncertainty in the measurements happens.

The uncertainty of the experimental present work is obtained in Table (2).

Table 2. Measurements uncertainties

Variables	X1	X2	X3	$\bar{X}$mean	σ	σ mean	X	Uncertainty Percentage
h	17.2	18.37	19.4	18.3	1.1	0.63	18.93	- 3.04 %
							17.67	3.8 %
Nu	32.3	34.45	36.4	34.35	4.2	2.42	36.77	- 6.73 %
							31.93	7.3 %
Ra	320124	335614	361431	339056.3	20867.5	12047.8	351104.1	-4.6 %
							327008.5	2.56 %

6. RESULTS AND DISCUSSIONS

The experimental tests were done for following variables: heat flux (88,177,390 and 680) W/ m^2, Rayleigh number values (15x10^3 to 14 x10^4), walls angles from the y-axis (0°-15°) and three locations for cylinders (top, centre, and bottom). Nusselt number of free convections of cylinder was calculated for each cases. Fig. (3) shows the change in the average temperature of the cylinders, fins, and outlet air temperature with the inclination shape angles at (q•=88 W/ m^2) at the top location and the air velocity at the duct exit. The average temperature for cylinders reached a maximum value at an angle (0◦), then decreased with increased the inclination shape angle of walls until reached minimum value at the angle (5◦) this mean improve in heat transfer between the air and the cylinder. Moreover, the velocity and average temperature of the outlet of the air duct will increased with the increased the inclination angle of the walls until it reached to the maximum value at an angle (5◦) because the cross-section area of the outlet of the duct decreased, hence the Nusselt number to maximum value at 5◦ and keep constant of other angles as shown in Fig. (4) at top location. For the same location top, when increased heat flux to 680 W/ m^2, the average temperature for the cylinder reached the minimum value at an angle (15◦),because the outlet velocity increased due to reduce in cross-section area, so Nusselt number will be maximum at angle (15◦) as shown in Fig.s(5) and (6),wherefore the Nusselt number will increased about 7.8 % at q•= 88 W/ m^2 for angle (5◦) and increased about 20 % at q•= 680 W/ m^2 for angle (15◦) .In Fig.s(7),also shows show the change in the average temperature of the cylinders, fins, and temperature of the outlet air with the inclination angles at (q•=88 W/ m^2) at the centre location as well as the air velocity at the duct exit. It shows that the average temperature for cylinders reached a maximum value at an angle (0◦), then decreased with the increased of the inclination angle of walls until reached minimum value at the angle (3◦) this mean improve in heat transfer between the air and the cylinder. Moreover, the velocity and average temperature of the outlet of the air duct will increased with the increased of the inclination angle of the walls until it reaches the maximum value at an angle (3◦) because the cross-section area of the outlet of the duct decreased, hence the Nusselt number to maximum value at 5◦ and keep constant of other angles as shown in Fig. (8) at the centre. For the same location centre, when increased heat flux to 680 W/ m^2, the temperature of cylinder reached the minimum value at an angle (10◦),because the outlet velocity increased due to reduce in cross section area ,so Nusselt number will be maximum at angle (10◦) as shown in Fig.s(9) and(10), wherefore the Nusselt number will increased about 25 % at q•= 88 W/ m2 for angle (3◦) and increased about 21 % at q•= 680 W/ m^2 for angle (10◦).For the bottom location for the same reason, shows the Nusselt number will increased about 35 % at q•= 88 W/ m^2 for angle (3◦) and increased about 30 % at q•= 680 W/ m^2 for angle (10◦), as shown in Fig.s (11),(12),(13)and(14).The result for q•= 177 W/ m^2 , q•= 390 W/ m^2 are in between the value of q•= 88 W/ m^2 and q•= 680 W/ m^2 .

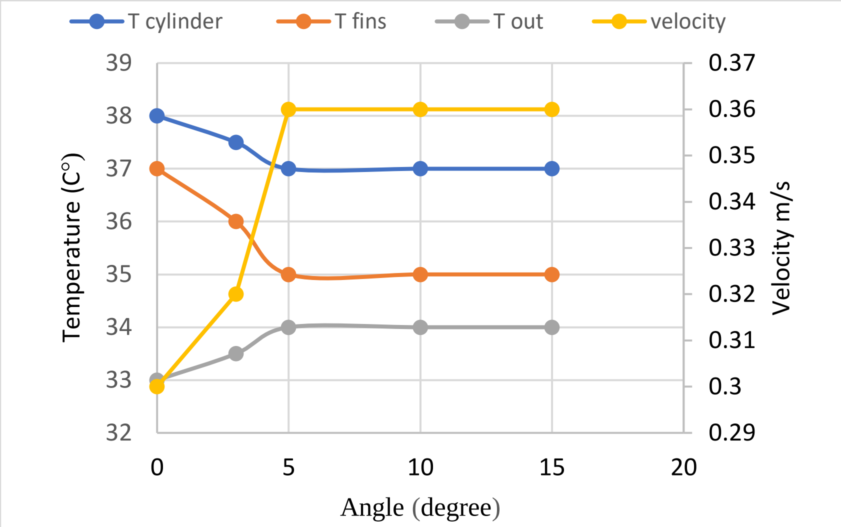

Figure 3 Temperature and velocity change with different angles for converge at top location with q=88 W/m^2

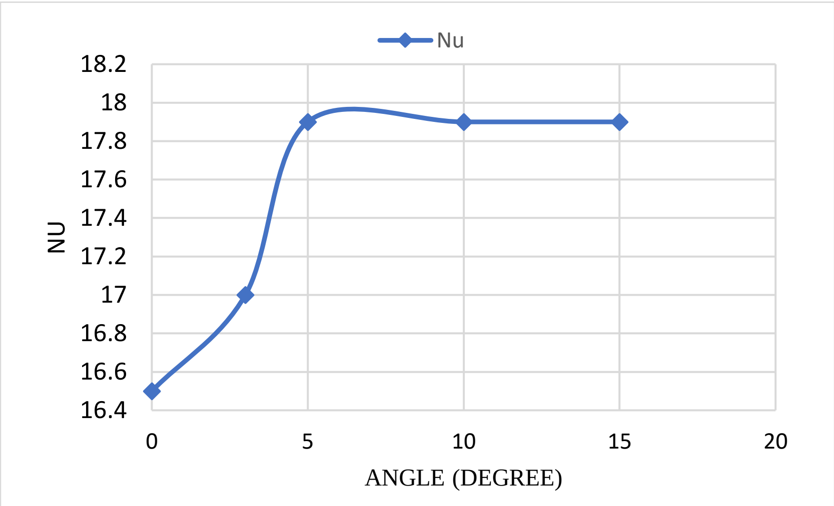

Figure 4 Nusselt number change with different angles for converge at top location with q=88 W/m^2

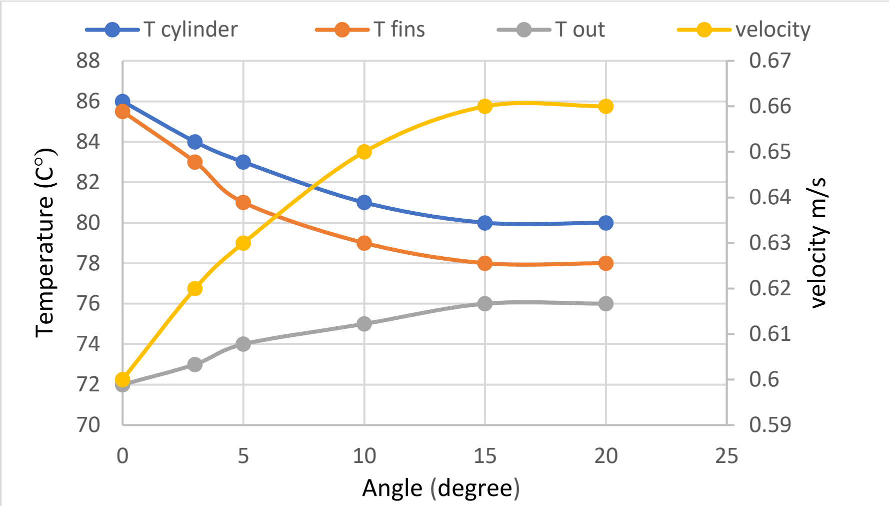

Figure 5 Temperature and velocity change with different angles for converge at top location with q=680 W/m^2

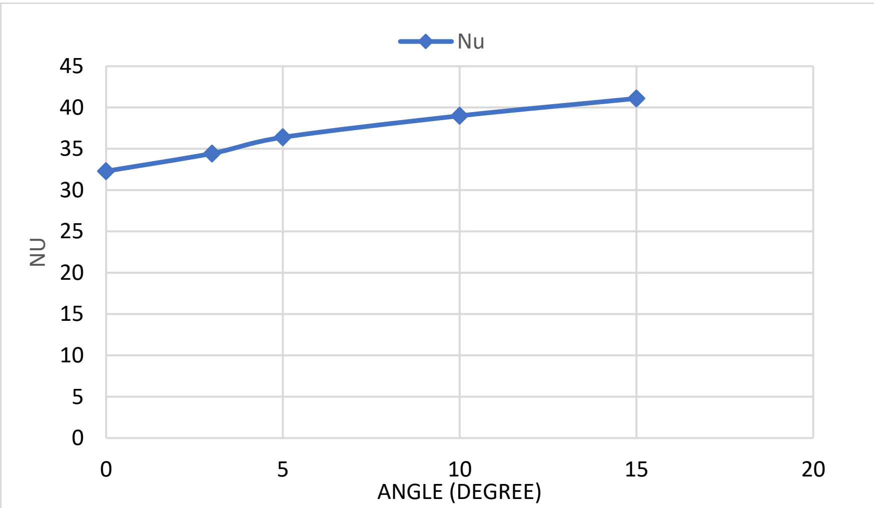

Figure 6 Nusselt number change with different angles for converge at top location with q=680 W/m^2

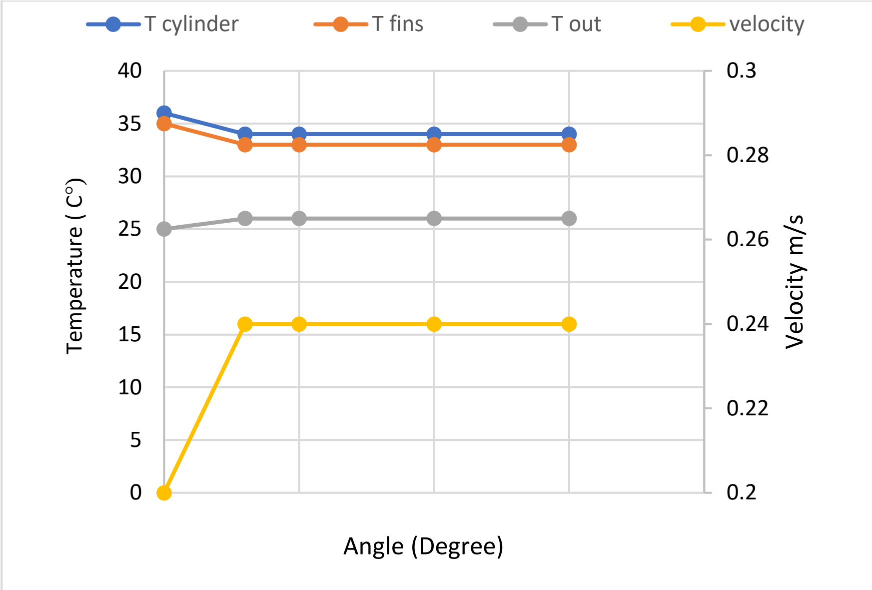

Figure 7 Temperature and velocity change with different angles for converge at centre location with q=88 W/m^2

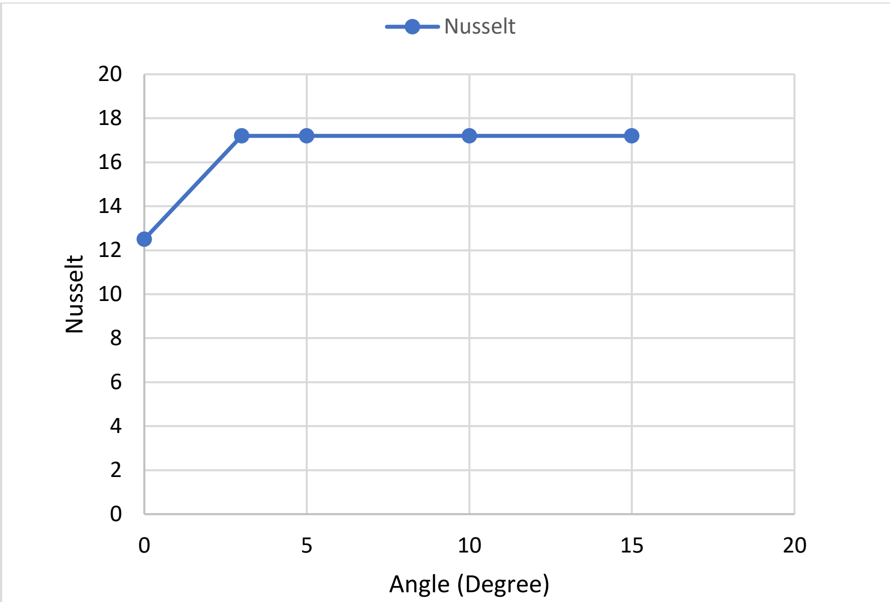

Figure 8 Nusselt number change with different angles for converge at centre location with q=88 W/m^2

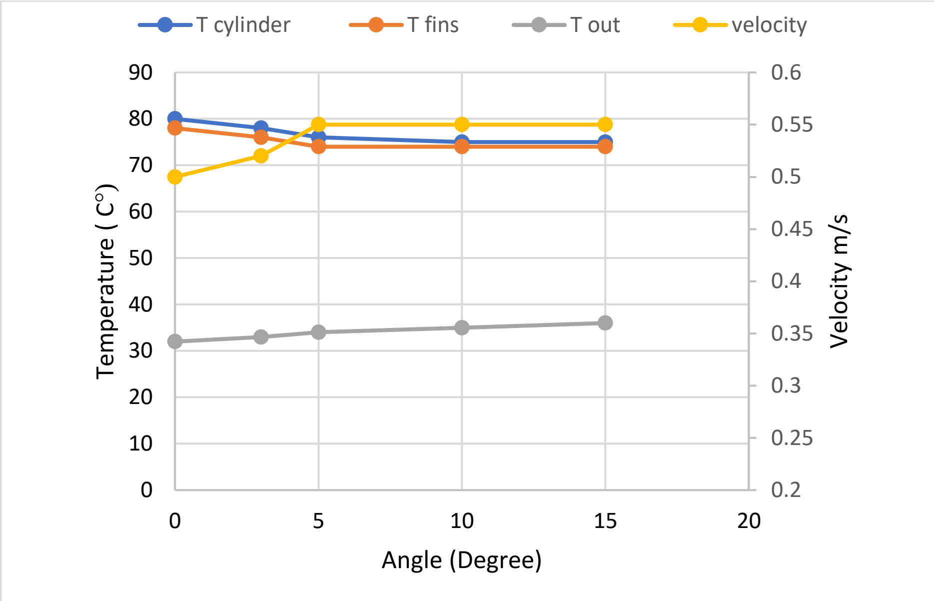

Figure 9 Temperature and velocity change with different angles for converge at centre location with q=680 W/m^2

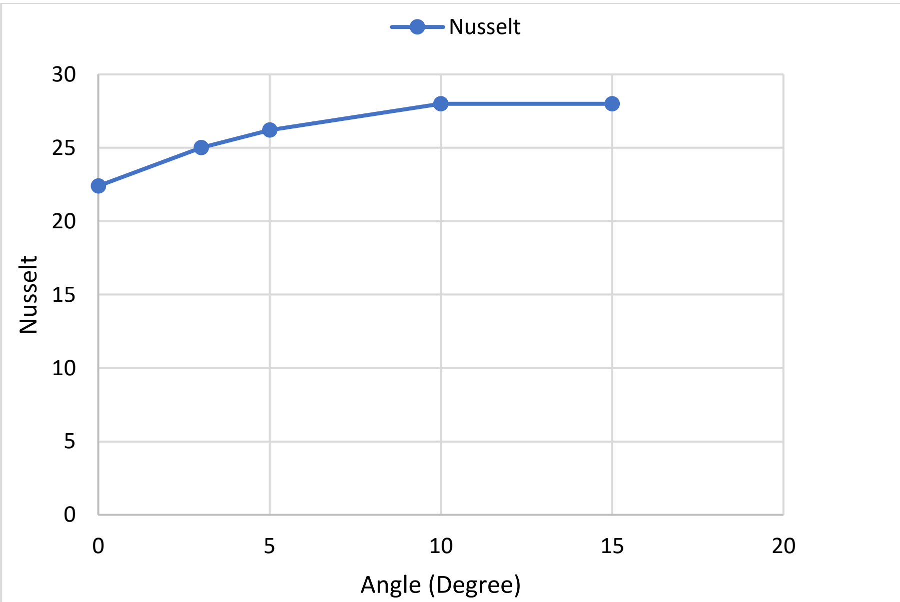

Figure 10 Nusselt number change with different angles for converge at centre location with q=680 W/m^2

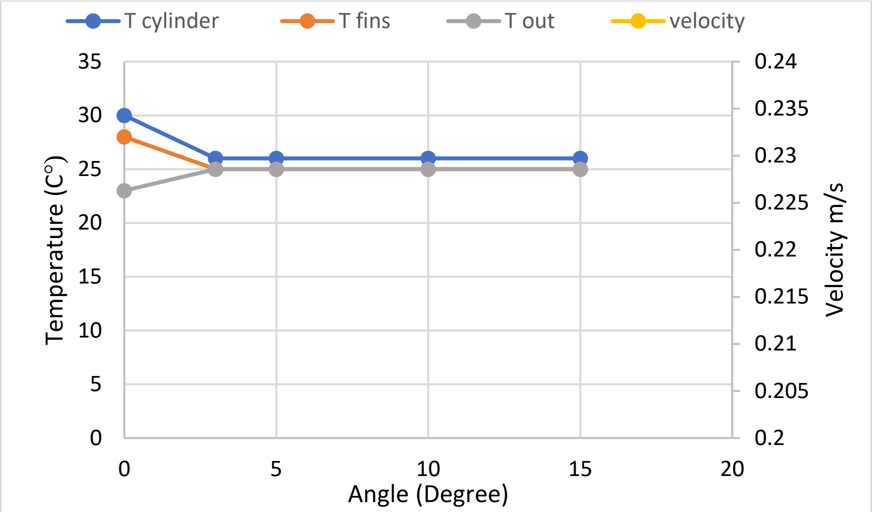

Figure 11 Temperature and velocity change with different angles for converge at bottom location with q=88 W/m^2

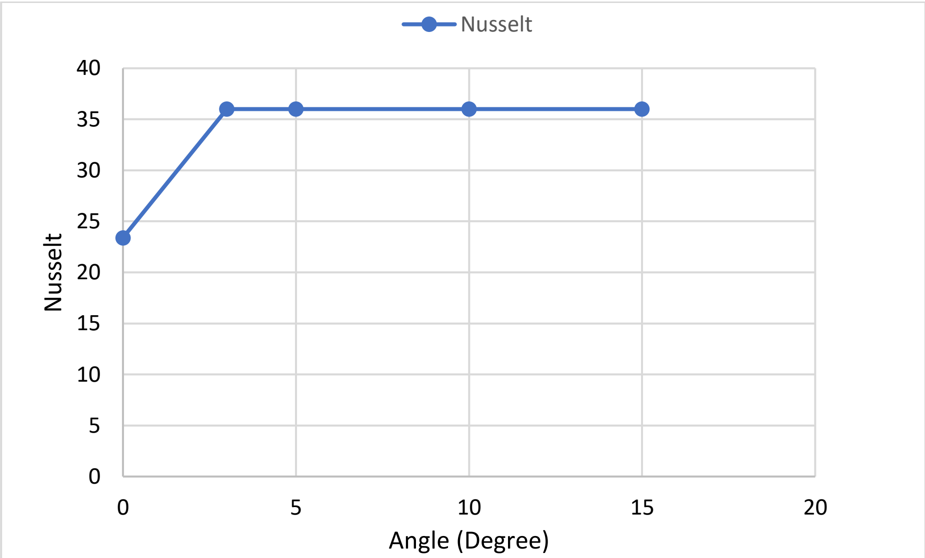

Figure 12 Nusselt number change with different angles for converge at bottom location with q=88 W/m^2

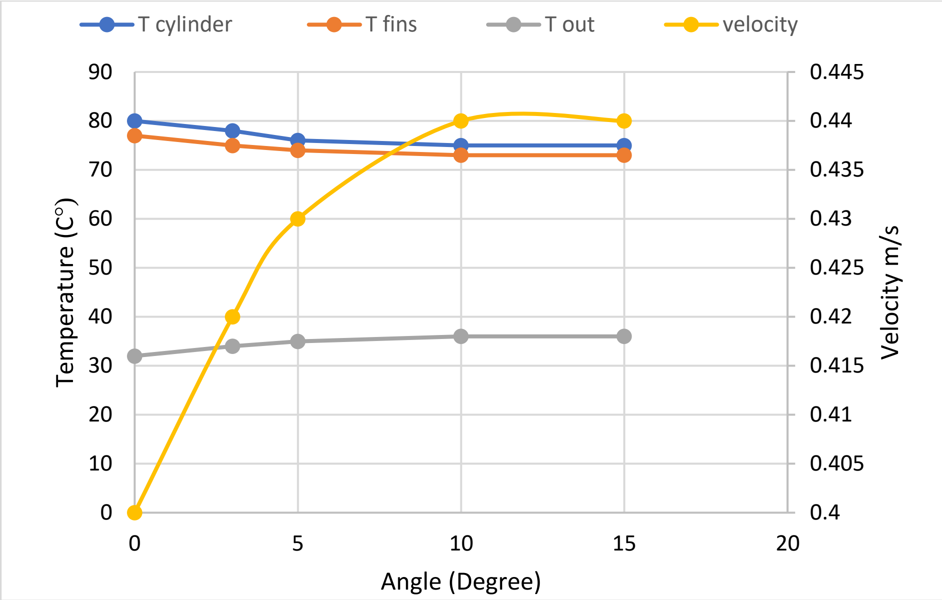

Figure 13 Temperature and velocity change with different angles for converge at bottom location with q=680 W/m^2

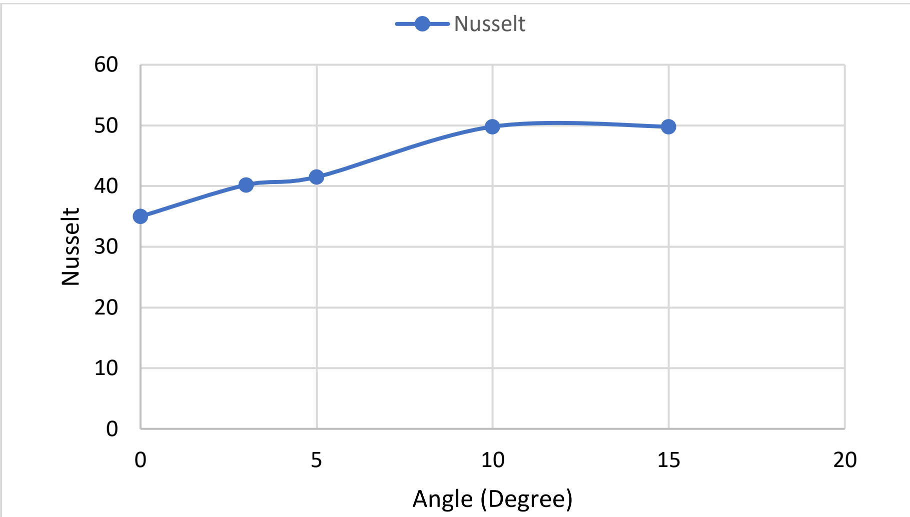

Figure 14 Nusselt number change with different angles for converge at bottom location with q=680 W/m^2

7. CONCLUSIONS

1. The Nusselt number increasing with increasing the angle of converge duct until 15°, when the cylinders at the top location of the converge duct.
2. The Nusselt number increasing with increasing the angle of converge duct until 10°, when the cylinders at the centre and bottom location of the converge duct.
3. The best location for finned cylinders inside the converge duct at bottom location.

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Appendix [A]

C.O.S.Q.C
IRAQ

PHT
440/2022
تاريخ المعايرة
2022/4/28
قسم المقاييس

Accredited Lab
IQAS

Calibration Certific[ate]
Central Organization for Standardization and [Quality Control (CO]SQC)
Metrology Department - Physics Section (FOR-TC-012)
P.O. Box13032 Aljadriya street, Baghdad , Tel:7785180 - E-Mail : cosqc@cosqc.gov.iq

Certificate No.: PHT 440/2022
Date of issue : 28/04/2022

Customer		
Name:		
Address:	العراق - واسط	
Item under calibration		
Description:	Thermocouple Thermometer With TC (K)	Res.: 0.1 °C
Manufacturer:	HTI	
Model:	HT - 9815	
Serial number:	201809027367	
Other identification:	(-200 ------- 1372) °C	
Date of reception:	Order no.: (325) , Date of Reception : 26/04/2022	
Condition of reception:	As Found	
Standard(s) used in the calibration		
Description:	Digital Nano volt / Micro Ohm meter	PT100
Manufacturer:	Agilent	——
Model:	34420A	——
Serial number:	MY42000734	(1)
Other identification:	ID : PHT-01- 17	ID : PHT-01-84

Calibration information	
Date of calibration:	28/04/2022 Due to: 28/04/2023
Place of calibration:	PH LAB. 1
Method(s) of calibration:	Calibration method using - PROC-TC-012 (C)
Calibrated quantity:	Temprature °C
Results of calibration:	Attached a complete result in Annex **1** of this certificate
Measurement uncertainty:	The reported expanded uncertainty is based on UKAS M3003 Standard and the standard Uncertainty multiplied by coverage factor k=2 to give confidence level of 95%
Metrological traceability:	The traceability of measurement results to the SI units is assured by the National standard maintained at Central Organization for standardization and Quality Control through calibration at :- UME /CER. NO (G1KS-0127)
Environmental conditions of calibration:	Temp. 23.55° C RH. 32.7%
Observations, opinions or recommendations:	The results in Annex 1 should be taken into consideration

Approved by:

Ban Omer Farooq
Head Of Physics Section
28/04/2022

1 of 2

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Ref. Proc.Tc-012

C.O.S.Q.C
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Accredited Lab
IQAS
Accreditation no.

Calibration Certificate

Central Organization for Standardization and Quality Control (COSQC)

Metrology Department - Physics Section (FOR-TC-012)

P.O. Box13032 Aljadriya street, Baghdad, Tel:7785180 - - E-Mail : cosqc@cosqc.gov.iq

Certificate No.: PHT 440/2022
Date of issue : 28/04/2022

Annex 1

Results

The results of the measurements are given on table below.

Set. Value C°	Ref. (R) (ave.) C°	UUC (M) (ave.) C°	Error (M)-(R) (approx.) C°	Uncertainty ± C°
25	25.0	24.9	-0.2	0.29
30	30.0	29.5	-0.5	0.73
35	35.8	35.1	-0.7	0.77
40	40.43	39.5	-0.9	1.08
45	45.08	44.2	-0.9	1.02

Calibrated by :
Khalid Naser + Ali Hassan
28/04/2022

Revised by :
Mustafa Omar
28/04/2022

Approved by:
Ban Omer Farooq
28/04/2022

COSQC

2 of 2

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Ref. Proc.Tc-012