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Research Article

Experimental Study On Performance Of Window Air Conditioner System By Optimizing Capillary Tube Configurations With Different Refrigerants

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ABSTRACT

Present work focuses on the enhancing of window air conditioning system performance by varying capillary geometry. The selection of the capillary tube is a critical factor on effecting the performance of a VCR system. An examination of the capillary tube in a basic VCR system is essential to comprehend the factors that can improve the overall system performance. In an experimental study with R32 & R407C refrigerant, capillary tubes of length 2m is investigated, with two distinct configurations i.e., helical coiled and straight with two different refrigerants. The diameter of every capillary tube is consistently held at 2mm. The examination focused on assessing how the configuration of the capillary tube affected the overall performance of the system. The results of the experimental study revealed several key findings. Initially, refrigeration effect for R32 is 5.2% high in the coiled configuration compare to straight capillary, Secondly, the COP was greatest in the helical coiled configuration with value of 3.71 compare to straight coiled configuration with same refrigerant flow rate. These findings provide valuable insights into how different capillary tube configurations such as coil diameter can influence the performance of a VCR system and 300 mm coil diameter is retrofit straight capillary.

Keywords: Capillary tube, coil diameter, R32 & R407C.

1. Introduction

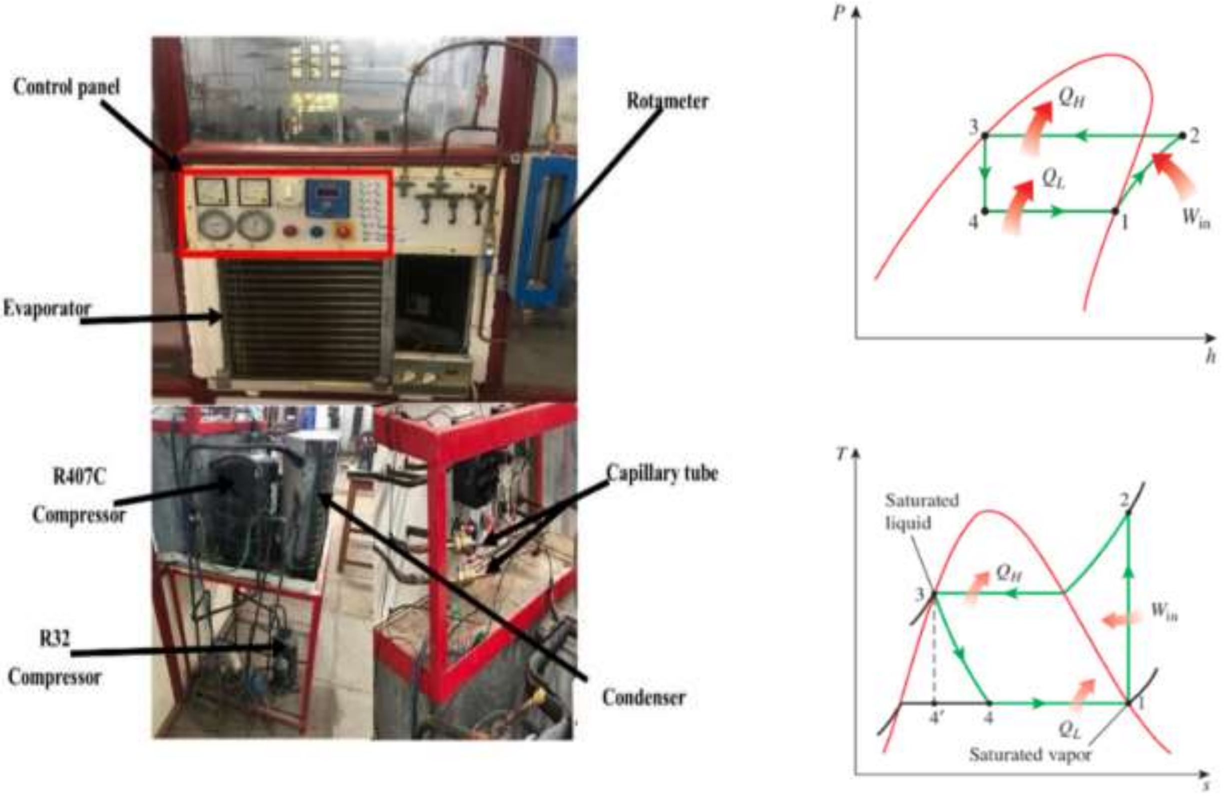
The vapor-compression process employs liquid refrigerant to absorb and remove heat from the targeted space for cooling, releasing the absorbed heat elsewhere. Flash evaporation's auto-refrigeration effect causes a temperature decrease in the liquid-vapor refrigerant mixture, lowering it below the intended refrigeration space's temperature. The air conditioning system's performance relies on the refrigerant properties and the geometry of each component. In smaller-scale systems up to 40 kW capacity, the expansion device is typically a capillary tube. The AC system's performance varies significantly based on changes in capillary configuration, including diameter and coiling patterns like helical and straight coiling. Capillary tubes, known for their simplicity, dependability, and cost-effectiveness, are widely used as expansion devices in small refrigeration and air-conditioning systems, with recent applications in larger units up to 35.2 kilowatts [1]. Past studies, both experimental and theoretical, have primarily focused on straight capillary tubes (SCT), with limited attention to the impact of coiling in practical scenarios. The use of ozone-depleting CFC and HCFC refrigerants in VCRS has led to environmental concerns, prompting regulations to curtail their production and use. This has led to a growing need for exploring alternative refrigerants with zero ODP and lower GWP for air-conditioning and heat pump applications. HFC refrigerant mixtures are now suggested as suitable replacements for phased-out refrigerants, aligning with environmental requirements.
R407C is considered a suitable substitute for R22, even though R22 exhibits a higher refrigeration effect compared to R407C, and at the same ambient temperature, the condenser temperatures for R22 are higher than those for R407C [2]. The power consumption for R32 was lower compare to R22, R410A and R407C, R32 requires less power due to its higher compression ratio, resulting in increased gas discharge temperatures [3]. The Q_{ref} increases with the coiled diameter growth; however above D_{coil} 300 mm exhibits

lower variations in system performance. When the system utilizes ACCT with D_{coil} of 40 mm has a Q_{ref} roughly 10% lower than straight capillary tubes, the essential tube length may vary for every 3.5kW capacity [4&5]. The AHCT with R407C shows 4.0% lower Q_{ref} compare to R22, it is lower by comparing to straight ones, the Q_{ref} for coiled tubes is substantially lower [6]. The capillary diameter's more impact on the Q_{ref} characteristics of R134a within AHCT is more pronounced than other factors [7]. For 1,1,1,2-Tetrafluoroethane through capillary tubes with D_{coil} with 140 mm of Q_{ref} is reduced compared to the Q_{ref} of R-407C in CCT [8]. The system's performance was enhanced through helical coiled capillary tubes with varying coil diameters, and as D_{coil} increases, the system's COP rises with R32 [9]. The optimal coil number in the refrigeration cycle has been determined by achieving the best performance with highest cooling capacity, and lowest compression power at low Q_{ref} with alternate refrigerant mixture of R134a [10]. The system's performance is impacted by system configuration and varying L_c ; maximum Q_{ref} was achieved in the infinity D_{coil} configuration, while the helical coiled configuration resulted in the lowest Q_{ref} and the COP exhibited an inverse relationship with the D_{coil} [11&12]. Under identical operating conditions, R290 maintained a higher Q_{ref} through the HCT compared to R1270, and R1270 produced a vapor-liquid mixture at the exit of the capillary tube with a lower temperature than R290 [13]. R410A, specifically with a lower P_c, demonstrated the most favourable COP for retrofitting a WAC originally designed for R22 [14]. the performance of a household refrigerator is improved by changing the D_{coil} of capillary within, constructing a setup based on the NRB33TA refrigerator model [15]. The impact of magnetic fields and various capillary tube configurations are enhancing the AC system performance. This approach was observed to elevate the refrigerant temperature in AC systems, potentially improving overall air conditioning unit efficiency [16]. The performance of air conditioning systems is influenced by pertinent parameters affecting the Q_{ref} characteristics of R134a and R-22 as they flow through AHCT along the material of the capillary tube i.e., Al and Cu [17]. Higher D_c results in a higher Q_{ref} for constant inlet pressure and fixed L_c in a partially condensed refrigeration system with R32 refrigerant [18]. Spiral coiled capillary tube reduces Q_{ref} by 5-10% with R134a, and a helical coiled capillary tube with D_{coil} 40mm gives 11% less Q_{ref} compared to a straight one [19&20]. The Q_{ref} can be reduced by nearly 35% by altering the surface characteristics of the capillary tube [21].

For more than five decades, the refrigerant R-22 has been widely used in a variety of applications. However, due to its ODP of 0.05, the need to phase out R-22 in the near future has become imperative. In response to this, efforts to find eco-friendly alternatives to R-22 have identified R-407C as the most promising substitute to date. R-407C is an environmentally safe, and it exhibits performance characteristics closely resembling those of R-22. Numerous studies reported in the literature have focused on the use of refrigerant R-407C in CCT. In line with these previous studies, the current research aims to further validate and enhance the existing body of literature by investigating different operating parameters and various geometrical parameters of the capillary tube along with R32 and R407C refrigerant for achieve good optimization conditions.

2. System configuration and details

Figure 1 displays the representation of the experimental setup and Ph & TS diagram of air conditioning system. The air conditioning unit comprises a hermetically sealed compressor for R407C and Rotary compressor for R32, an air-cooled condenser, and an evaporator with an air supply system for extracting cooling from the evaporator during point 4 to 1. Within the Experimental setup, capillary tube is made by copper is installed in between 3 to 4, enabling the refrigerant to expand from the peak-pressure side to the lower-pressure side from point 3 to 4. The refrigerant enters the evaporator via the capillary tube with diameter of 2mm, which is available in various configurations, including straight and helical coiled forms with diameters ranging from 300 mm to 400 mm. High-pressure refrigerant vapours exiting the compressor are directed to the condenser during point 1 to 2, where the superheated vapours undergo condensation in a coiled structure from point 2 to 3. The resulting peak-pressure saturated liquid refrigerant is received in a receiver to ensure a continuous supply to the capillary tube. A drier-cum-filter is positioned after the receiver to eliminate unwanted substances and humidity from the refrigerant. Prior to the capillary tube inlet, a ball-type control valve is placed to finely regulate the mass flow rate of refrigerant before the rotameter. A sight glass float-type rotameter included to visually assess the phase of the refrigerant entering the capillary tube follows the drier-cum-filter to measure the flow rate of refrigerant of the peak-pressure liquid refrigerant. Multiple hand shutoff valves are strategically situated between the main components of the experimental setup, facilitating the replacement of damaged components in the event of leakage or repairs. Temperature readings at different points within the experimental configuration are obtained through k-type thermocouples with an accuracy of 0.2°C. Pressure measurements of the refrigerant are accomplished using pressure gauges with an accuracy of ±0.25%.



a. Experimental setup b. P-h & T-S diagram [2]

Figure 1: Experimental setup

Table 1: Technical details and Range of Experimentation

Refrigerants	R32 & R407C	
Compressor	**Model**	Tecumsh Hermitically sealed compressor with model of AW1000 QAWQ5515EGE
		GMCC 1.0 for R32 refrigerant
	Oil type	Mineral
	Voltage range	180 to 264V
Evaporator	14 copper coiled Aluminium Finned type with range of -25°C to 15 °C	
Condenser	16 copper coiled Aluminium Finned type with range of 30°C to 70°C	
Refrigerant flow rate	0.01 to 0.022 kg/sec	
Capillary tube	**Length (m)**	2
	Diameter (mm)	2
	Coil diameter (mm)	∞(straight),300, 350 and 450
Cabinet dimension	10' × 10' × 10' with relative humidity 68 to 75%	
Induced air Temperature into evaporator	30°C - 32°C	
Thermo couples	K type with range of -200°C to 150 °C	
Pressure gauges	Suction 35bar	
	Discharge 55bar	

3. Experimental Procedure

To ensure purity and eliminate moisture, the system underwent a comprehensive flushing process with nitrogen gas before introducing the R407C refrigerant. Subsequently, the R407C refrigerant was charged into the system. The system reached a stable and steady-state condition after a continuous three-hour run, during which experimental data were systematically collected. The cabin temperature was consistently maintained at 32°C throughout the study. For this investigation, experiments were carried out using capillary tubes featuring internal diameters of 2 mm and a length of 2 meters. The configurations included both straight tubes and helical coils with diameters of 300 mm, 350 mm, and 400 mm, with variations in refrigerant flow ranging from 0.010 to 0.022 kg/sec. The cabin temperature was initially maintained at 32°C. Upon completing the test with R407C, the system underwent a refrigerant evacuation process using a vacuum pump and was subsequently run with nitrogen gas, following the earlier procedure. After refilling the system, the experimental procedure was repeated, this time employing R32 refrigerant, with readings diligently recorded.

4. Data Aggregation

Refrigeration effect (or) load on air conditioning system is calculated by fallowing equation

$$RE = h_1 - h_4 \quad (1)$$

Where h_1 and h_4 enthalpies of refrigerant before and after evaporative process
work done by the compressor is calculated by fallowing equation

$$W_C = h_2 - h_1 \quad (2)$$

Where h_2 and h_1 enthalpies of refrigerant before and after compression process
From equation 1 &2 Coefficient performance of Air condition system is

$$COP = \frac{\text{Refrigeration effect (or) load on air conditioning system (RE)}}{\text{work done by the compressor } (W_C)}$$

5. Results and Discussions

In this section, we can find the test results detailing the performance of different adiabatic capillary tubes configuration with respect to refrigerants R407C & R32. These results cover a range of geometric and operational conditions. The section also provides that correlates the Q_{ref} for both infinity coiled diameter and different D_{coil} capillary tubes.
As depicted in figure 2, the relationship between evaporator temperature and air conditioner performance is closely linked to fluctuations in refrigerant flow rate. Alterations in the evaporator temperature exert a significant influence on both the overall efficiency and cooling capacity of the air conditioner. By examining the figure 2, we can discern a key trend: as the system load increases, the refrigerant flow rate similarly increases, while the evaporator temperature decreases.

Table 2: variation of evaporator temperature with respect to Refrigerant flow rate

Refrigerant flow rate (kg/sec)	Evaporator Temperature (℃)							
	R407C				R32			
	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled
0.010	10.1	10	11.8	12.1	8.8	7.9	8.4	9.1
0.012	7.2	6.9	8.1	8.6	6.7	5.4	6.2	7.1
0.014	6.4	5.6	6.5	7.1	5.9	4.2	5.1	6.3
0.016	5.1	3.5	4.2	4.7	4.8	2.3	3.4	4.1
0.018	4.5	1.9	3.1	3.1	3.9	0.7	1.2	2.8
0.020	3.1	0.8	2.5	2.1	2.4	-0.9	0.8	1.9
0.022	1.8	-1.2	1.1	1.8	1.2	-1.9	-0.9	0.8

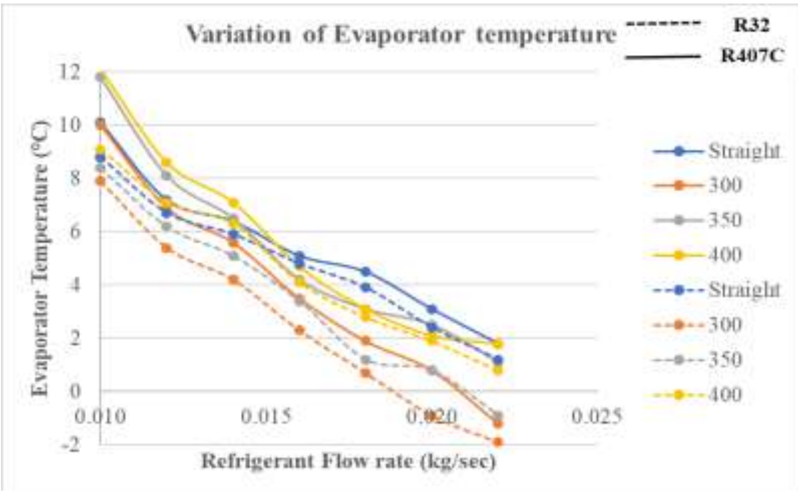


Figure 2: Variation of Evaporator Temperature

In a practical scenario, the system with R407C attains an approximate evaporator temperature of -1.2℃, similarly with R32 attains -1.9℃ when the flow rate reaches 0.022 kg/sec for a coil configuration with a 300 mm diameter [3].The value which got with the helical coiled capillary with 300 mm coil diameter is efficient

[2] and 9.8 percentage is lower. These observations lead to the conclusion that, for a coil diameter of 300 mm with R32, a lower evaporator temperature is achieved, resulting in enhanced cooling capacity.
As illustrated in figure 3, the correlation between condenser temperature and air conditioner performance is intricately linked to fluctuations in the refrigerant flow rate.

Table 3: variation of Condenser temperature with respect to refrigerant flow rate

Refrigerant flow rate (kg/sec)	Condenser Temperature (℃)							
	R407C				R32			
	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled
0.010	45.4	46.2	49.4	50.8	42.1	43.4	46.4	47.7
0.012	46.5	47.3	50.6	52.1	44.2	44.6	47.7	49.1
0.014	47.1	48.4	51.8	53.3	45.1	45.7	48.9	50.3
0.016	48.2	49.6	53.1	54.5	46.4	46.8	50.1	51.5
0.018	49.1	49.8	53.3	54.8	47.4	47.6	50.9	52.4
0.020	49.6	50.1	53.6	55.1	48.2	48.4	51.8	53.3
0.022	51.2	52.1	55.7	57.3	49.1	50.1	53.6	55.1

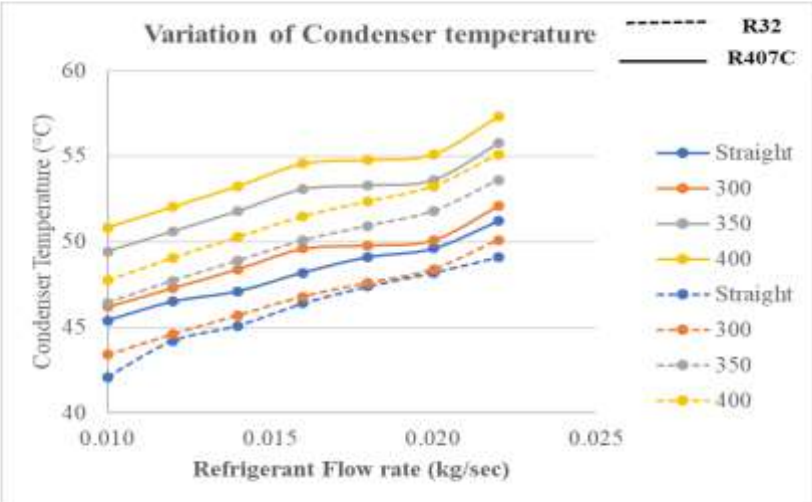


Figure 3: Variation of Condenser Temperature

Variations in condenser temperature exert a substantial impact on the overall efficiency, cooling capacity, and the external work required for refrigerant condensation in the air conditioner. Upon a closer examination of the figure 3, it becomes apparent that, with an increase in system load, the refrigerant flow rate also rises in tandem with an elevation in condenser temperature. In practical terms, the system attains a maximum condenser temperature of approximately 57°C and 50°C when utilizing a R407C and R32 for 300 mm coiled diameter capillary tube, at a flow rate of 0.022 kg/sec. These findings lead to the inference that for a smaller coil diameter, such as 300 mm with R32, a lower condenser temperature is achieved to 50.1℃ which is 8% lower is lower with same configuration of the system [2], subsequently reducing the external work required for refrigerant condensation within the air conditioning system.

Table 4: variation of refrigeration effect with respect to refrigerant flow rate

Refrigerant flow rate (kg/sec)	Refrigeration effect (kJ/kg)							
	R407C				R32			
	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled
0.010	174.0	182.7	176.2	174.4	181.0	190.05	186.25	182.45
0.012	176.0	184.8	181.2	179.6	184.0	192.15	188.31	184.47
0.014	177.0	185.9	182.8	181.2	187.0	196.35	192.42	188.49
0.016	178.0	186.9	183.6	182.4	191.0	200.55	196.54	192.53
0.018	178.2	187.1	184.2	183.2	194.1	205.45	199.73	195.65
0.020	179.1	188.1	186.1	184.6	197.6	207.48	203.33	199.18
0.022	179.4	188.4	187.2	186.2	201.5	212.10	207.34	203.11

When the evaporator temperature is lowered by increasing the refrigerant flow rate, the refrigeration effect experiences an augmentation because more cooling effect is released by the refrigerant. This relationship is elucidated in figure 4 which illustrates the variation in refrigeration effect based on different capillary tube geometry configurations. It is discernible from the figure that the refrigeration effect is notably more pronounced for capillary coil configurations with smaller diameters, surpassing that of straight capillary tubes by approximately 0.28% with R407C and 6.34% with R32 at a Q_{ref} of 0.022 kg/sec is better at same flow rate [3].

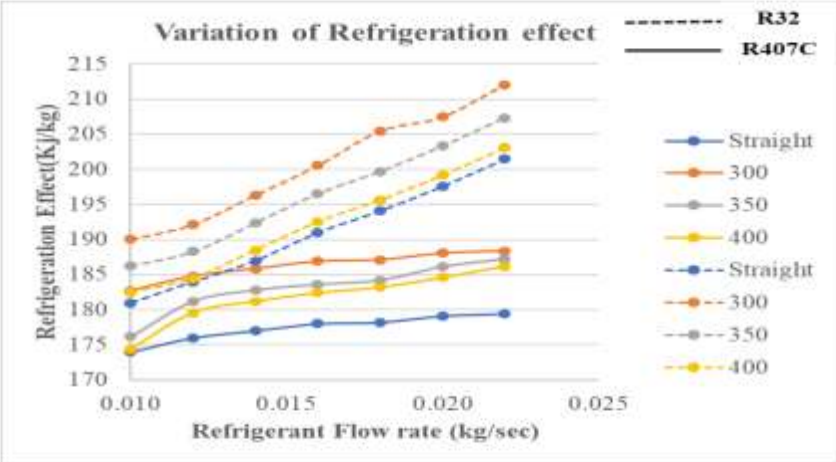


Figure 4: Variation of Refrigeration effect

The energy consumption of the compressor has been graphed across various capillary tube coil diameters and compared to straight capillary tubes under varying ambient temperatures. These observations were conducted at different ambient temperature settings.

Table 5: Variation of Compressor work with respect to Refrigerant flow rate

Refrigerant flow rate (kg/sec)	Compressor work (kW)							
	R407C				R32			
	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled
0.010	0.85	0.87	0.86	0.89	0.78	0.73	0.74	0.74
0.012	0.95	0.91	0.97	1.05	0.89	0.83	0.84	0.85
0.014	1.02	0.98	1.09	1.18	0.98	0.94	0.95	0.96
0.016	1.12	1.11	1.17	1.25	1.12	1.01	1.06	1.01
0.018	1.23	1.21	1.23	1.27	1.17	1.07	1.07	1.07
0.020	1.31	1.29	1.33	1.36	1.24	1.16	1.19	1.19
0.022	1.33	1.34	1.37	1.44	1.34	1.25	1.29	1.31

Figure 5 illustrates the changes in compressor energy consumption concerning the D_{coil}. In Figure 5, the graph displays the relationship between compressor energy consumption and different refrigerant flow rates for various capillary tube geometry configurations. It's important to note that, in all observations, the refrigeration effect remained consistent between 170 to 215 kJ. Notably, transitioning from a straight capillary tube to a 300 mm capillary coil diameter resulted in a 0.8 percent for R407C and 7.2 percent for R32 reduction in compressor work, which is 12% less [3].

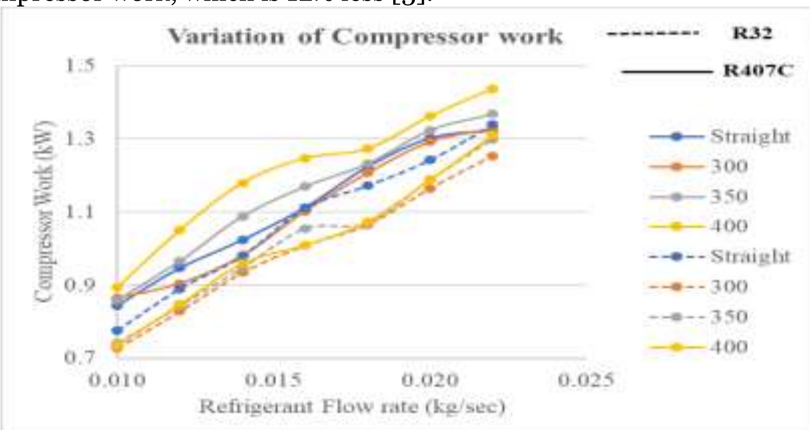


Figure 5: Variation of Compressor Work

The Coefficient of Performance (COP) has been graphically represented concerning different coil diameters and contrasted with SCT, all conducted under an T_a of 32°C. In figure 6, the variations in COP with varying capillary tube coil diameters are illustrated. It is noteworthy that during the transition from a SCT to a 300 mm coil diameter, there is a notable and substantial increase in the system's COP, R407C and R32 showing a significant rise of 3.2 and 12.4 percent. This indicates that the performance of the system experiences a noteworthy enhancement when employing a larger coil diameter in comparison to a straight capillary tube configuration with R32 refrigerant, which is 11% higher compare to the R32 straight which is 12 percentage higher [3] .

Table 6: Variation of COP with respect to Refrigerant flow rate

Refrigerant flow rate (kg/sec)	COP							
	R407C				R32			
	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled	Straight	300 mm Coiled	350 mm Coiled	400 mm coiled
0.010	2.06	2.11	2.05	1.95	2.33	2.61	2.51	2.48
0.012	2.23	2.45	2.25	2.05	2.48	2.78	2.68	2.61
0.014	2.42	2.65	2.35	2.15	2.67	2.94	2.84	2.75
0.016	2.56	2.71	2.51	2.34	2.75	3.18	2.98	3.05
0.018	2.62	2.79	2.69	2.59	2.98	3.47	3.36	3.28
0.020	2.75	2.91	2.81	2.71	3.18	3.56	3.42	3.35
0.022	2.98	3.12	3.01	2.85	3.31	3.72	3.51	3.41

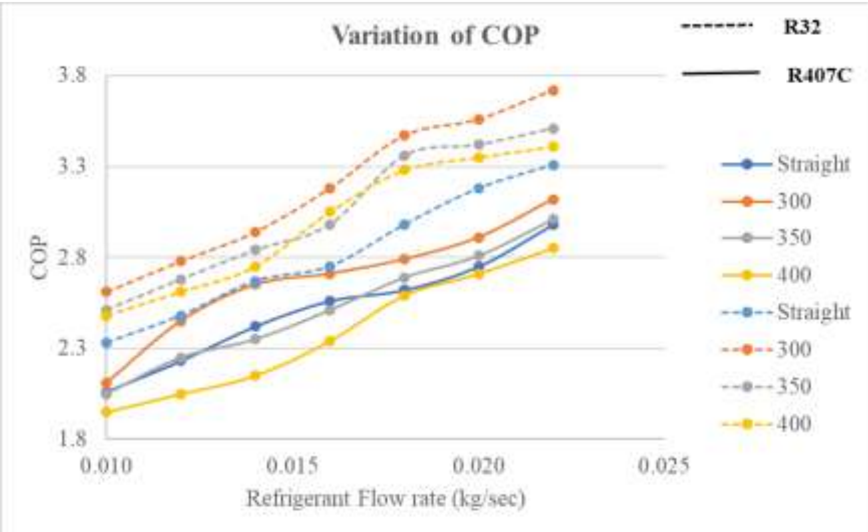


Figure 6: Variation of COP

6. Conclusions

The research presented in this study focuses on assessing the performance of R407C and R32 in a variety of capillary tube configurations, which encompass both straight and coiled geometries. The investigation delves into the influence of a fixed capillary diameter (2mm) and varying capillary coil diameters within the range of 300 mm to 400mm on the system's overall performance. The study conducts an evaluation and comparison of these different configurations. Additionally, a series of experiments were carried out to cover a range of refrigerant flow rates, spanning from 0.01 to 0.022 kg/sec. The primary aim was to analyze how alterations in ambient temperature affect the overall thermal performance of the system. The following conclusions were drawn from the study:

- Emphasizing the importance of further research is crucial for optimizing capillary tube configurations in window air conditioning systems using different refrigerants.
- As the mass flow rate refrigerant increases, the condensation temperature also increases. However, the condensation temperatures for a Coiled capillary tube are slightly higher than those for the Straight capillary tube, and these values are within acceptable levels.
- The refrigeration effect with a 300 mm Coiled capillary tube of R32 surpasses the refrigeration effect with a Straight capillary tube, and there is a maximum difference of 5% for R407C. Similarly, R32 achieves a 5.2% difference.
- The compressor work, or energy consumption, with a 300 mm Coiled capillary tube of R32 is lower than that of a Straight capillary tube when compared to R407C.

- The COP for a 300 mm Coiled capillary tube of R32 is higher than that for the system with R407C.
- Choosing R-32 with a coiled capillary tube (300 mm) appears to be the preferred option when compared to the straight capillary tube configuration.

Abbreviations and Nomenclature

WAC	Windows air conditioning system
ACT	Adiabatic capillary tube
CCT	Coiled capillary tube
SCT	Straight capillary tube
HCT	Helical coiled capillary tube
AHCT	adiabatic helical capillary tubes
CFC	Chlorofluorocarbon
HCFC	Hydrochlorofluorocarbon
VCRS	Vapor compression refrigeration systems
ODP	Ozone depletion potential
GWP	Global warming potential
L_c	Capillary length
D_c	Capillary diameter
P_c	Capillary pitch
D_{coil}	Capillary Coil diameter
Q_{ref}	Refrigerant flow rate

References

[1]. Kasuba Sainath, T. Kishen Kumar Reddy, Suresh Akella , " Optimization of capillary tube dimensions using different Refrigerants for 1.5 ton mobile air conditioner", *Case Studies in Thermal Engineering*, 100528, Vol.16, pp. 1-8, 2019.

[2]. Ibrahim F. Abdulqadir, Badran M. Salim, Omar M. Ali, "Experimental Investigation to Retrofit HCFC-22 Window Air Conditioner with R-407C", *International Conference on Advanced Science and Engineering (ICOASE) University of Zakho*, pp. 226-229,2019

[3]. Boda Hadya, A. M. K. Prasad, Suresh Akella," Performance Assessment of HFC Group Refrigerants in Window Air Conditioning System", *International Journal of Mechanical Engineering and Applications*, Vol. 3(5), pp. 81-85, 2015.

[4]. Zhou Guobing, Zhang Yufeng ," Numerical and experimental investigations on the performance of coiled adiabatic capillary tubes", *Applied Thermal Engineering*, Vol. 26, pp. 1106–1114,2001.

[5]. Wong, T.N. and K. T. Ooi," Evaluation of capillary tube performance for CFC- 12 and HFC 134a, *International Communications in Heat and Mass Transfer*, Vol. 23, pp. 993-1001, 1996.

[6]. S. G. Kim, M. S. Kim1, S. T. Ro, "Experimental investigation of the performance of R22, R407C and R410A in several capillary tubes for air-conditioners", *International Journal of Refrigeration* Vol. 25, pp. 521–531,2002.

[7]. Jatuporn kaew-on, sakarin chingulpitak, and somchai wongwises, "Experimental investigation of r134a flowing through adiabatic helically coiled capillary tubes", *International Journal of Air-Conditioning and Refrigeration*, Vol. 20, pp. 125-140, 2012.

[8]. M.K. Mittal, Ravi Kumar, Akhilesh Gupta," An experimental study of the flow of R-407C in an adiabatic helical capillary tube", *International Journal of Refrigeration*, Vol. 33, pp. 840-847,2010.

[9]. Sanjeev singh punia & Jagdev singh, "Experimental Investigation on The Performance of Coiled Adiabatic Capillary Tube with LPG As Refrigerant", *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, Vol. 2 Issue 4, ISSN 2249-6890, pp. 73-82, 2012

[10]. Ali Khalid Shaker Al-Sayyab, "An Experimental study for the effect of capillary tube diameter on Refrigerator performance with new alternative Refrigerant mixture to R134", *Kufa Journal of Engineering,* Vol. 9, No. 2, pp. 31-44, 2018.

[11]. Sunil M. Telang, Prof. Prashant Walke," An Experimental Study of the Effect of Capillary tube in Different Length and Different Configuration on the Performance of Simple Vapour Compression Refrigeration System", *International Research Journal of Engineering and Technology (IRJET)*, Volume: 06 Issue: 07 e-ISSN: 2395-0056, pp. 2336-2343, 2019.

[12]. D.V.Raghunatha Reddy, Dr P.Bhramara, Dr K.Govindarajulu, "Performance and Optimization of Capillary Tube Length In a Split Type Air Conditioning System", *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181,Vol. 1 Issue 7, pp. 1-11, 2012.

[13]. Sofen Kumar Jena, Soumik Bose, Sewan Das Patle, "Comparison of the performance of propane (R290) and propene (R1270) as alternative refrigerants for cooling during expansion in a helical

capillary tube: A CFD-based insight investigation", *International Journal of Refrigeration* Volume 146, pp. 300-313, 2023,

[14]. K. J. Samuel, K. Govindarajulu, G. Edison," An Experimental Investigation and Performance Evaluation of 1.5 TR Window Air-Conditioner by Using R22, R407C and R410A by Varying the Capillary Pitch", *World Applied Sciences Journal* 29 (11), ISSN 1818-4952, pp. 1468-1472, 2014.

[15]. M.Y.Taib, A.A.Aziz and A.B.S.Alias, "Performance analysis of a domestic refrigerator", *National Conference in Mechanical Engineering Research and Postgraduate Students*, pp. 2256-2265, 2010.

[16]. Kayser Aziz Ameen, Husam Abdulrasool hasan, Mustafa J. Al-Dulaimi,a Azher M. Abed,b and Haidar F. Al-Qrimlic, " Improving the performance of air conditioning unit by using a hybrid technique", *Methods X*, 9: 101620, pp. 1-12, 2022.

[17]. Buddha Chouhan, Poshal, Suresh Kumar," Analytical Investigation of R134a Flowing Through Adiabatic Helically Coiled Capillary Tubes", *International Advanced Research Journal in Science, Engineering and Technology,* Vol. 4, Issue 2, pp. 226-235, 2017.

[18]. Maheshbhai Vanajara, Ravi Kumar & Anil Kumar, "Experimental analysis of mass flow rate for partially condensed R-32 in an adiabatic straight capillary tube", *Experimental Heat Transfer*, vol 35, Issue 4, pp. 455-465,2021.

[19]. M. K. Khan, R. Kumar, and P. K. Sahoo, "An experimental study of the flow of R-134a inside an adiabatic spirally coiled capillary tube," *International Journal of Refrigeration*., vol. 31, no. 6, pp. 970–978, 2008.

[20]. S. Chingulpitak and S. Wongwises, "Two-phase flow model of refrigerants flowing through helically coiled capillary tubes," *Applied Thermal Engineering*, vol. 30, pp. 1927–1936, 2010.

[21]. S. K. Dubba and R. Kumar, "Flow of refrigerants through capillary tubes: a state-of-the-art," *Exp. Therm. Fluid Sci.*, vol. 81, pp. 370–381, 2017.