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EXPERIMENTAL STUDY OF A NEW HYDROCARBON MIXTURE FOR DOMESTIC REFRIGERATOR TO REPLACE R134A

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ABSTRACT

In a domestic refrigerator with 4.49cc displacement compressors, the performance of R290 (48 by mass percent) and R600a (52 by mass percent) was examined experimentally. In our research, we employed a 210-litre refrigerator that was designed to run on R12 and had a longer capillary. The amount of energy utilised, as well as the pressure and temperature at crucial locations on the various refrigerated compartments and refrigerator circuit, are all monitored. With R290/R600a, we performed a scroll-down test and ice-making test. According to our findings, R290/R600a is the best contenders for re-placing R134a in terms of energy conservation. Because the amount of refrigerant utilised is so small, the flammability fac-tor can be overlooked.

I. INTRODUCTION

Food preservation and life-saving drugs, as well as indi-vidual health and safety, rely on refrigeration technology. The refrigeration technology is also use to provide well-being in industrial process and air conditioning system. The risk of CFCs, as well as the Montreal and Kyoto Pro-tocols, must be considered while evaluating future refrig-erants. Natural refrigerants and hydrogenated chloro-fluorocarbons (HCFCs) are suitable substitutes.

CFC-12 was outmoded when it was initially developed to the refrigerator pursuit and it was subsequently replaced by HFC-134a, an average refrigerant. HFC-134a on the other hand, must be phased out by 2020; it is critical to evaluate HFC-134a's prospects and upgrade. Mineral lu-bricating oil with 0% ODP and a low GWP is suitable with hydrocarbon refrigerants. The most significant disad-vantages of these refrigerants they are inconsistent flam-mable. The hydrocarbon refrigerants have a higher latent heat vaporization then R12 and less density makes them desirable low load applications in defiance of their flam-mability.

Hydrocarbons have been recommended as a replacement for conventional refrigerants in residential freezers by a number of scientists. Propane's performance in small resi-dential refrigerators was investigated by [1],[2]. the findings revealed that Propane is a suita-ble alternative to R12 that does not require any modifica-tions [1]. Investigated a household refrigerator that ran on Propane and found that Propane performed better than R12. Experiments with isobutene and propane these mixtures were conducted in home refrigerator and the results showed the attained. Co-efficient of performance was more than that of R12. For [3], studied the use of propane in a 239 liter refrigerator, and it is found that the refrigerator uti-lised the least amount of energy per day while using Pro-pane. To replace Propane, a compressor with a smaller displacement is required due to the higher volumetric re-frigeration capability. In prior work [4], used SRK EoS to look at the properties of an HC, and therefore the results are well within permissible limits. Computer modelling was wont to estimate the perfor-mance of hydrocarbons as alternative refrigerants to ex-change R12 in average size residential freezers. The R270 and DME R270 and DME, also as R290 R1270 with a re-duced displacement compressor, were found to be suita-ble drop-in choices. Parashurama S et al. conducted a the-oretical and experimental evaluation of the refrigerant R 290, which is a substitute for R12 with a smaller dis-placement compressor [5].

Propane does not require any changes to the refrigera-tor's structure. Normal oil is miscible with all hydrocar-bons and has good lubricating qualities. Another ad-vantage of hydro-carbons is that no damp air is intro-duced because to the favorable evaporator pressure. According to [6]. The hydrocarbons in gas-eous and liquid phases in on heat transfer properties, these phases are much higher than R12 and R134a. As a result from a heat transfer standpoint, R290 is a viable al-ternative. R134a is presently as an alternative to R12. It has a low energy efficiency, a high GWP, and is incompat-ible with mineral oil. As a result, the issue remains un-solved, and it must be changed in compliance with F-gas regulations. [7],[8], used SRK EOS to estimate the thermodynamic characteristics of Fluroethers, HFs and HFCs and screened and offered R270 and R152a as a alternatives to R134a an equivalent compressor, also as R290, R161 and R1270 with lower displacement com-pressor, also as R290, R161, and R1270 with lower com-pressor displacement, also as R290, R161, and R1270 with lower compressor displacement. They also project-ed the thermodynamic properties of several binary mixes of HFs and HFCs using the SRK PSRK AND EOS mixing rules, performed thermodynamic analysis, and offered them as alter-natives to R134a [8]. In the present paper a new mixture R290 (48%)/R600a (52%) is tested with a 4.49 cc hermetic compressor in an unaltered refrigerator used for R12,

Table 1: Property data of HC and R290 for Te = -25^{O}C & T_k=55^{O}C.

Refrigerant	HC	R290
NBP (^{O}C)	-	-42.07
ODP	0	0.000
GWP	20	3
Evaporator pressure (bar)	1.4	2.02
Critical temperature (K)	389.61	369.8
Critical pressure (bar)	139.33	42.5
Condenser pressure (bar)	14.22	19.07
Pressure ratio	13.29	10.71
Latent heat (kJ/kg)	390.13	404.99
Specific volume (m^3/kg)	0.4142	0.2913

Source: Authors, (2024).

Table 1 shows the computed refrigerant properties for the refrigerator design settings. Using the prediction method described in Reference [8], the thermodynamic character-istics of the R290/R600a mixture are calculated. The study's findings are summarised in Table 2. For the R290/R600a (HC) system, simulation was utilised to cal-culate features including refrigeration effect, pressure ra-tio, condenser heat rejection, mass flow rate, compressor exit temperature, starting torque, and COP. R290 operates better-quality with a higher coefficient of performance value and requires a smaller compressor and a lower mo-tor rating, according to the simulation results.

Table 2**:** Results of Thermodynamic Analysis.

Refrigerant	R290	HC
Mass flow rate (kg/sec) (x10^4)	0.289	0.386
Compressor power input (W)	40.32	43.94
Condenser duty (W)	137.83	139.88
Piston displacement (cc)	2.43	4.6
Starting torque (N-m)	2.16	2.83
COP	1.84	1.99
Discharge temperature (ºC)	125	133
Isentropic index	1.124	1.137
Capillary bore, d (m)	0.00066	0.00079
Capillary length, L (m)	4.178	4.3

Source: Authors, (2024).

II. EXPERIMENTAL SETUP

The testing chamber has a small wooden chamber for air circulation. Temperature sensors, steam injecting nozzles, heater coils, and relative humidity sensor connected to a steam raiser outside the chamber and split air conditioner to replicate the needed weather conditions with the help of condenser heat rejection to the testing chamber are also included. The experimental setup that was developed is depicted in Figure

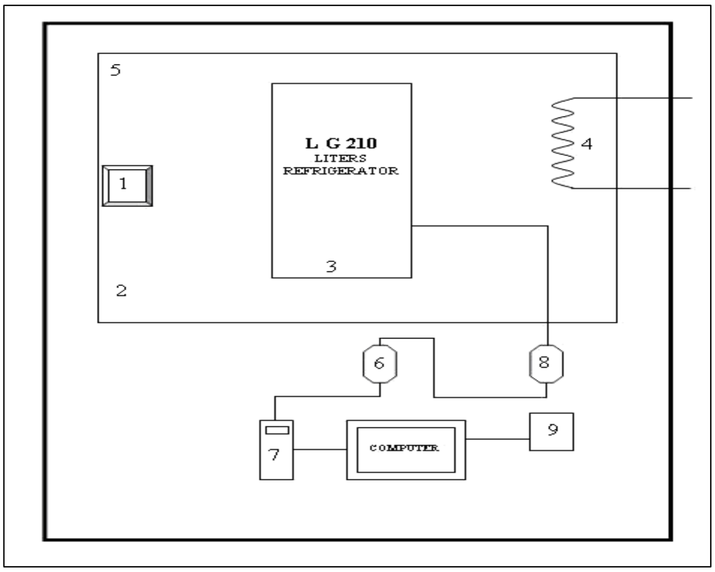

Figure 1: Experimental Setup and Simulation Room Layout.
Source: Authors, (2024).

1. Air condition unit
2. Humidification sensor
3. LG Refrigerator
4. Heater
5. Testing room temperature
6. Thermocouple
7. ADAM Module
8. Analog to digital converter
9. Power supply

Table 3: Details of Instrumentation.

Instrument	Range	Uncertainty
Pressure gauges	0 to 10.34	± 0.345bar
	0 to 20.69 bar	5 Psi
Thermocouple	-	± 0.1ºC
Digital thermometer	-50 to 500ºC	± 0.1 ºC
Clamp meter	0 to 10 amps	±0.1 amps
	0 to 1000 V	± 1V

Source: Authors, (2024).

II.1 EXPERIMENTATION AND PERFORMANCE ANALYSIS

Leakage tests, ice making test, Scroll-Down tests, and Power Consumption tests are all administered in compliance with IS regulations [9]. As results of setting the thermostatic knob to optimize the mean compartment temperature to 7ºC, power outage, failure to take care of the condition as stated in Indian standards, and other factors, certain findings are destroyed. The discharge pressure, Temperatures is recorded using thermocouples at the condenser outlet, freezer compartment, compressor inlet, evaporator outlet, and evaporator inlet. The second and third compartment. The electrical energy consumption of the compressor was measured using a clamp on watt meter with a 0.01 KWh resolution. Nitrogen and soap bubbles were used to conduct leakage tests. 65g of Refrigerant HC has been charged into the system. R290/R600a tests were carried out with a 4.49cc displacement compressor with a 4.29m capillary length. After the Scroll-Down phase, the system will run up 6 hours then placed within the refrigerator for the zero load performance test. After the Scroll-Down time, the system was run ice making tests for up to three hours. After it had been pulled down, the ice making test for HC with a length of 4.29 meter was extended for an additional 3 hours. Ex-pediments are run until steady-state conditions are reached. The refrigerator it will run three months to verify the results and for up to 6 hours after it had been pulled right down to achieve its steady state conditions.

Table 4: Results of Experimentation.

Refrigerant	R290 [5]	HC
Capillary length (m)	5.95	3.0
Suction pressure	2.895	1.768
Discharge pressure	15.855	13.840
Discharge temperature (oC)	66.4	68.2
Pull down time (min)	111	110
Pull down energy Consumption (kWh/day)	0.1369	0.1833
Energy consumption (kWh/day)	1.329	1.4854
Ice making time (min)	160	151
COP_{act}	1.74	1.72
η_{ref}	55.81	41.2
I (W)	56.14	38.42
$Q_{ext.}$	4.883	3.946
Q	5.82	35.94

Source: Authors, (2024).

III. RESULTS AND DISCUSSION

Equations from Reference 4 are used to analyse and compare performance parameters the table 2 lists the value of performance parameters for HC and R290. R290 appears to have a lower pressure ratio than R290/R600a, hinting that a lower displacement com-pressor is required. The more boiling refrigerants R290 necessitates a smaller motor rating than R290/R600a, as shown in Table 2.

Table 2 shows due to the high pressure ratio the volu-metric efficiency of HC is slightly lower than that of R290. Using the aforesaid volumetric efficiencies, the displacement volumes of R290/R600a and R290 are de-termined. R290 requires less displacement than R290/R600a due to its larger volumetric refrigeration capacity. As shown in Table 2, R290 requires less dis-placement than R290/R600a. R290's discharge tempera-tures are lower than R290/ R600a's. The winding tem-perature rises as the discharge temperature rises. Be-cause certain charge is required for the hydrocarbon is very small and it is well under safety regulations, specif-ically 55g there is no risk of fire. As a result, the R290 compressor runs smoothly [10].

According to the theoretical research, R290 has a greater COP than R290/R600a. Furthermore, the condenser's heat released rate is lower than that of R290/R600a, im-plying that the condenser does not need to be a larger. The mass flow rate of R290 is much lower than R290/R600a, while the pressure ratio is much larger. As a result, the capillary must be lengthened. If an R12 compressor is used to compress R290, there is no diffi-culty with starting torque [11]. R290/R600a is evaluated under the identical operating conditions in this experi-ment utilizing a household refrigerator built.to.work with.R12.Table 3 shows that the Scroll-Downtime for R290 is essentially comparable to R290/R600a, but the ice making time is 5.96 percent longer, energy usage is 10.53 percent lower, and the average discharge tempera-ture is 1.20C lower in compressor. Scroll down test, ice making test and temperature profiles demonstrate that the refrigerator of R290 has roughly identical capacity to the R290/R600a refrigerator, as illustrated in Figures 2 to 7. The temperature differences in the freezer com-partment, first compartment, and second compartment are shown in Figures 2 to 7.

Because the refrigerator volumes are nearly identical, Wong wises et al. [3] and Rasti et al. [12] can be com-pared to our work. Table 5 demonstrates that when com-pared to R134a, the refrigerant R290 (48)/R600a (52) used the least amount of energy. The usage of a reduced displacement compressor in our test resulted in a higher level of electricity savings.

Table 5: Comparison of present study with literature.

Refrigerant	[3]		[12]		Present Study
	R134a	R290(60)/R600a	R134a	R290(56)/ R600a	R290(48)/R600a
Temperature(°C)	25	25	32	32	43
Capacity(c)	239	-	238	-	-
Charge(g)	120	60	-	105	65
Energy consumpt ion (kW hr/day)	1.43	1.41	1.628	1.541	1.485

Source: Authors, (2024).

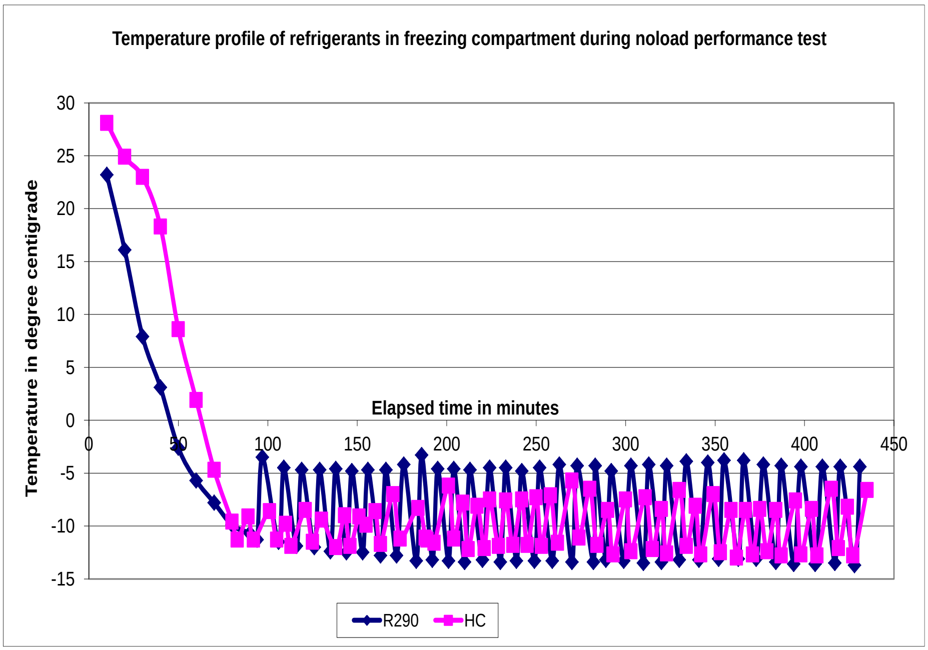

Figure 2: Variation in Temperatures of Freezer Compartment in Scroll-Down test.
Source: Authors, (2024).

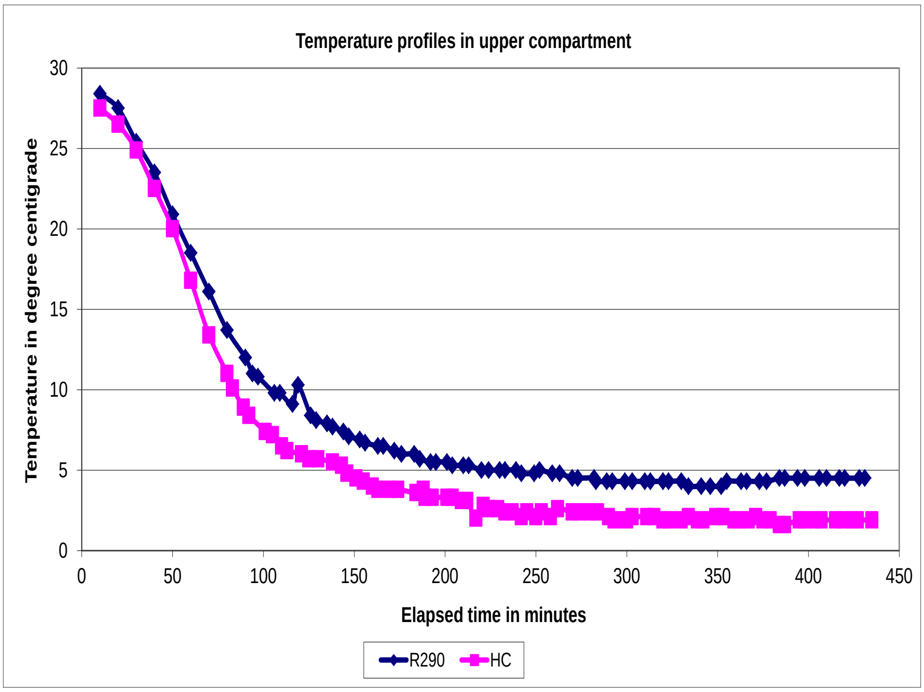

Figure 3: Variation in Temperatures of Upper Compart-ment in Scroll-Down test.

Source: Authors, (2024).

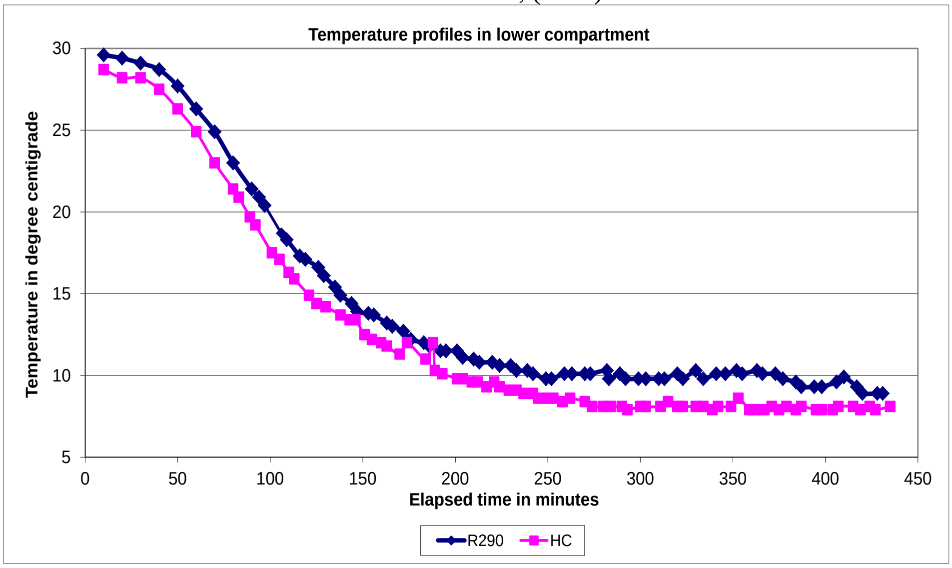

Figure 4: Variation in Temperatures of Lower Com-partment in Scroll-Down test.
Source: Authors, (2024).

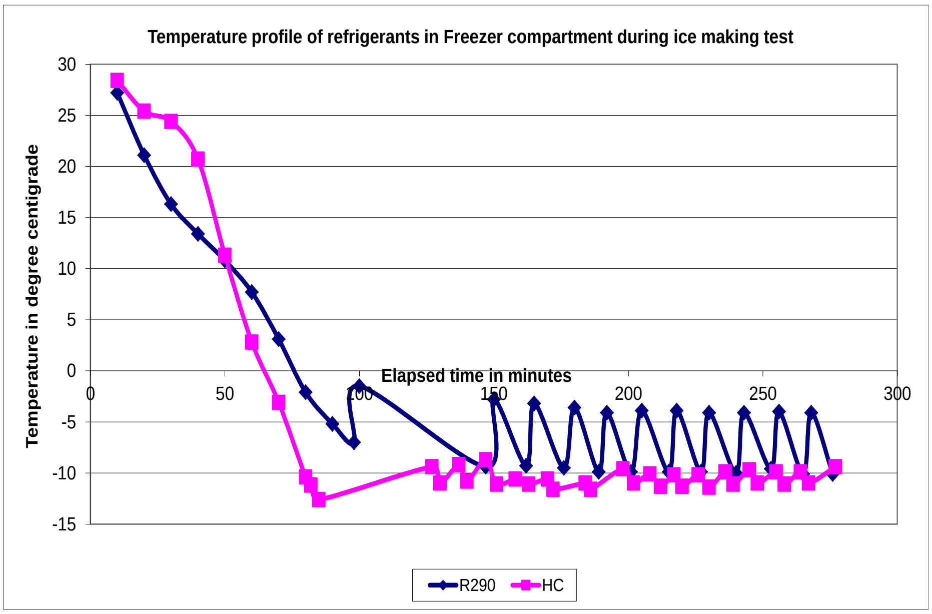

Figure 5: Variation in Temperatures of Freezer Com-partment in Ice making test.
Source: Authors, (2024).

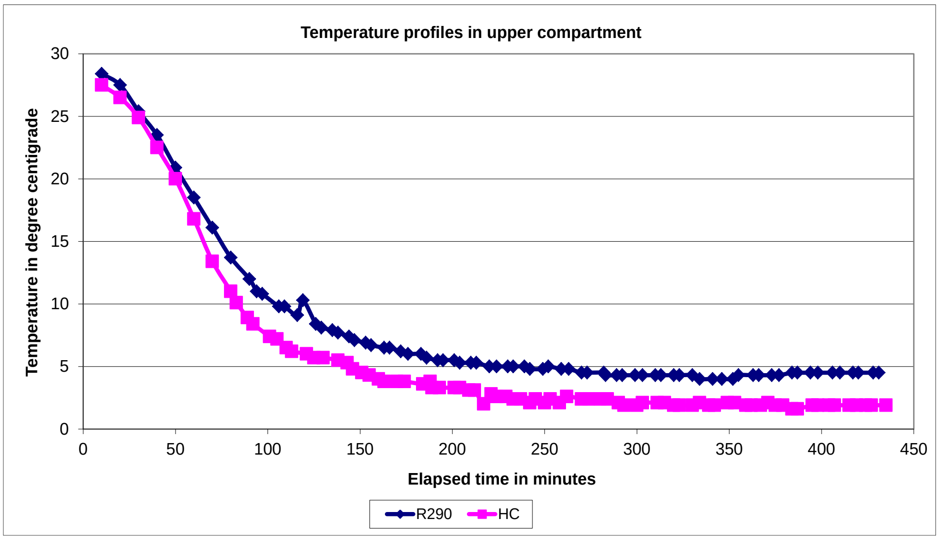

Figure 6: Variation in Temperatures of Upper Compart-ment in Ice making test.

Source: Authors, (2024).

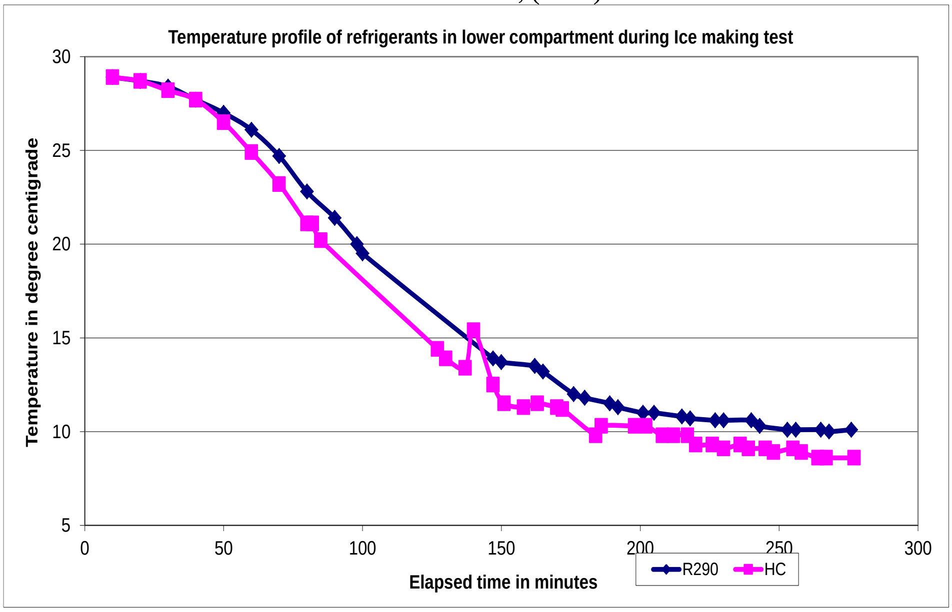

Figure 7: Variation in Temperatures of Lower Com-partment in Ice making test.
Source: Authors, (2024).

IV. CONCLUSIONS

According to the theoretical research, R290 has a greater COP than R290/R600a. In the case of R290, the heat re-jected in the condenser is slightly lower, but the conden-ser size remains the same. R290 has a lower mass flow rate than R290/R600a, but a higher pressure ratio. As a result, the capillary length must be raised. When com-pared to R290/R600a, propane consumed 10.53 percent less energy. Propane's charge has decreased by 16.38 percent, making it more cost effective to use. The capil-lary length used in this study was 6 meters. Propane has a lower compressor exit temperature than R290/R600a, which is a favorable thing. As a result, the compressor's life may be extended. R290 has equivalent capacities to R290/R600a, according to pull-down and ice-making experiments.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Parashurama S and Anjappa S B.
Methodology: Parashurama S and Anjappa S B.
Investigation: Parashurama S and Anjappa S B**.**
Discussion of results: Parashurama S and Anjappa S B.
Writing – Original Draft: Parashurama S and Anjappa S B**.**
Writing – Review and Editing: Parashurama S and Anjappa S B.
Resources: Parashurama S and Anjappa S B.
Supervision: Parashurama S and Anjappa S B.
Approval of the final text: Parashurama S and Anjappa S B.

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