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Experimental Analysis of Capillary Tube and Thermostatic Expansion Valve in Domestic Refrigerator Using Eco-Friendly Refrigerant

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***Abstract*—**These work subtleties a technique to portray the presence of the capillary tube and Thermostatic expansion valve reasonable for expansion device in the domestic refrigerator just as think about the execution of various refrigerants (R134a, R290, and R600a). In this exploration work, we have investigated different refrigerants utilized in the refrigeration cycle which influence the earth, and our exertion is to diminish the impact of a dangerous atmospheric deviation by using appropriate refrigerants. R-134a is utilized in vapor compression refrigeration system having better thermodynamic properties than other refrigerants and zero ozone depletion potential (ODP), with the exception of Global Warming Potential (GWP). It has 1300 GWP every year. Hydrocarbon refrigerants (HC) for the most part propane, butane and isobutene are proposed as a domain amicable refrigerants. In this way we have utilized the mixed refrigerant of R-134a and R-290. which are ecological cordial, having low GWP, zero ODP. The trial results were contrasted and normally utilized refrigerants R-134a. In this examination work, 40 percent (200g) of R-600a is increasingly proficient on the capillary tube while the productivity is declined by 20 percent on thermostatic expansion valve. The mixed refrigerant of R-134a and R-290 give better execution on the two devices, the COP is increased by 25.8 percent on Thermostatic expansion valve and 22.5 percent on the capillary tube.

***Keywords*—** *Capillary tube, Thermostatic expansion valve GWP, ODP, Alternative refrigerant and Refrigerant Blends.*

1. INTRODUCTION

A refrigerator or a water cooler is only a warmth siphon whose work is to reject heat from a higher temperature sink to encompassing and retain heat from a lower temperature source. In the time of 1834 the main precisely created cooling framework was created in England which is celebrated as a vapor compression cycle. The vapor refrigeration cycle is the procedure that cools an encased space to a temperature lower than the encompassing temperature. Since the development of vapor compression refrigeration framework, the utilization of refrigeration has entered numerous fields which incorporate assurance of drug, nourishment, cooling for solace and modern applications. Refrigerant is an essential working liquid used to move heat from lower temperature store to higher temperature supply.

1.1 Vapour Compression Refrigeration System

The Vapor Compression Refrigeration cycle is utilized in family unit reason. Every household apparatus like water cooler, refrigerator, and air conditions are taking a shot at VCR System. This framework utilizing four noteworthy procedures like Evaporation, Compression, Condensation, and Expansion. In this framework warmth consumed by the Evaporator and warmth dismissed by the condenser.

The refrigeration framework takes a shot at the second law of thermodynamics. The underneath fig. 1 demonstrates the refrigeration framework.

The procedure begins with the compression of the refrigerant at point 1-2 at that point consolidates into the condenser at point 2-3. At that point, expansion is done into the expansion valve at point 3-4 and at long last the refrigerant go through the Evaporator and stage change happen because of stage change of refrigerant it ingests heat from lower temperature body and gets vaporized at point 1.and at last cycle finished.

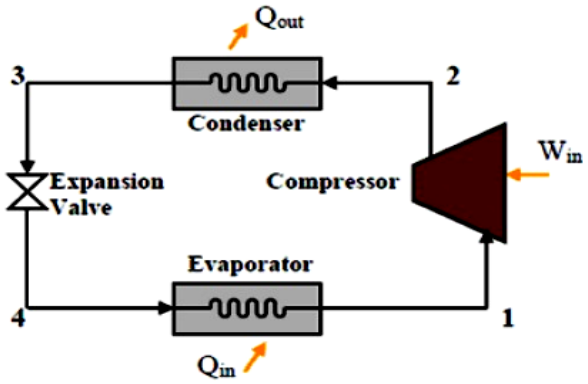

Fig.1- VCRS system

1.2 History of Refrigerants

1.2.1 Chlorofluorocarbon (CFC): They are particles made out of carbon (CO2), chlorine (Cl) and fluorine (F). It adds to the consumption of the ozone layer. These are R11, R12, R113, R500, R502 and so forth.

1.2.2 Hydro chlorofluorocarbon (HCFC): They are atoms made out of carbon, chlorine, fluorine, and hydrogen. They are less steady than CFCs, devastate ozone and to a lesser degree. These are R22, R123, R124, R401a and so on.

1.2.3 Hydro fluorocarbon (HFC): They are atoms made out of carbon, fluorine, and hydrogen. They don't contain chlorine and in this manner don't take an interest in the demolition of the ozone layer. Be that as it may, it has a high Global Warming Potential (GWP).

1.2.4 Hydrocarbons (HC): This is basically propane (R290), butane (R600) and isobutene (R600a). These fluids have great thermodynamic properties, however, they are hazardous on account of their combustibility.

During the time spent looking through new substitute, rather than utilizing single refrigerant we can accomplish better execution qualities through the mixture of at least two than two refrigerants to get an inventive working fluids with the ideal attributes which are known as a refrigerant blend. The refrigerant mixture is blends of refrigerants containing 2, 3 or 4 parts that have been detailed to give a proportional property of the refrigerants initially utilized. We can watch the different refrigerants utilizing in different ages and the sort of significance appear in table 1

Table: 1 Generation of refrigerants [1].

Importance	Generation	Type of Refrigerants
Whatever Worked	1st Generation	CO_2, NH_3, H_2O, CCL_4, etc.
Safety and Permanence	2nd Generation	CFC, HCFC's, NH_3,H_2O, etc.
Ozone depletion Potential	3rd Generation	HCFC's, HFC's, CO_2,NH_3,etc.
Global Warming Potential	4th Generation	HC, Refrigerant Blends

1.3 Need for Alternatives of R134a

R134a is an effective refrigerant and it is supplanted R12 in third era because of its ODP. Be that as it may, in current age we need a refrigerant having zero ODP and low GWP.R134a having estimated 1300 GWP. This is excessively high so there are some convention connected in the field of refrigeration and cooling

1.3.1 Montreal protocol

In the year 1987 Montreal convention set up the prerequisites that started the world – wide eliminate of Chlorofluorocarbon (CFCs.). Creation of CFCs was eliminated by the Montreal Protocol in created nations from first of January, 1996 and for creating nations was eliminated in year 2010. In the year 1992 Montreal convention set up the necessities that started the world – wide eliminate of HCFCs and complete creation of HCFCs will be eliminated by Montreal convention up to year 2030 [2].

1.3.2 Kyoto protocol

Kyoto show intends to dispose of substances that will provoke an unnatural climate change. R134a is used in the nuclear family fridge and other vapor pressure refrigeration structures it was seen as a substitution of R-12, keeping in view its zero ozone-depleting potential. R134a has 1300 GWP per multiyear, which is high. The cruising of R134a offered an explanation to AFEAS 1970-2003 is basically extending during the past two decades. The extended-release of R134a into nature are reliably growing the gathering of ozone hurting substances by methods for breaks and generally, in a meandering way, through lively execution of refrigeration plant. This will incite hostile climatic inconvenience. Therefore, R134a is one of the six manufactured substances in the "holder" that are to be organized away within the near future under Kyoto show [3].

1.3.3 Environmental concern

The essential most critical second thought is weariness of the ozone layer. The ozone layer is a layer which shields the earth from brilliant pillars starting from sun. Ozone utilization potential is evaluated on a scale that usages R-11 as a standard. The different parts rely upon how hurting to the ozone they are in association with R-11.The second huge concern is an unnatural climate change. An unnatural climate change is augmentation the earth surface temperature due to the maintenance of infrared surge on earth surface. A risky Global warming potential (GWP) is evaluated on a scale that uses CO_2 as the standard for instance CO_2 is consigned a value and various parts are diverged from CO_2 [3].

The primary requirement of the ideal refrigerant before the invention of Chlorofluorocarbons (CFCs) refrigerants was as follow: it should have a normal boiling point in the range of -40°C to 0°C. It should be steady, non-dangerous, non-combustible. None of the refrigerants accessible around then, including sulfur dioxide (So2), carbon dioxide (Co2), smelling salts (NH3), methyl chloride, and ethyl chloride, could meet any of the necessities. The Chlorofluorocarbons (CFCs) refrigerants satisfied all the essential prerequisites and proclaimed an exceptional transformation in the refrigeration and cooling industry. Today, the reiteration of the prerequisites forced on perfect refrigerants has expanded. Another essential necessity

currently incorporates zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP).

The ecological concerns identifying with Ozone exhaustion and Global warming were not longed for when Midgley and partners concocted the Chlorofluorocarbons (CFCs) refrigerants should be steady, non-dangerous, non-combustible. None of the refrigerants accessible around then, including sulfur dioxide (So2), carbon dioxide (Co2), smelling salts (NH3), methyl chloride, and ethyl chloride, could meet any of the necessities. The Chlorofluorocarbons (CFCs) refrigerants satisfied all the essential prerequisites and proclaimed an exceptional transformation in the refrigeration and cooling industry. Today, the reiteration of the prerequisites forced on perfect refrigerants has expanded. Another essential necessity currently incorporates zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP). The ecological concerns identifying with Ozone exhaustion and Global warming were not longed for when Midgley and partners concocted the Chlorofluorocarbons (CFCs) refrigerants.

Refrigerant	Chemical composition	N.B.P [°C]	Molecular weight [g/mol]	Critical Temp. [°C]	Critical pressure [MPa]	Liquid density [kg/m3]	Safety class	ODP	GWP
R134a	CH_2FCF_3	-26	102	101.1	4.059	511.9	A1	0	1300
R600 (Butane)	C_4H_{10}	-0.5	62.2	152	3.79	240.12	A3	0	20
R290 (Propane)	CH_3 -CH_2-CH_3	-42	44.096	96.675	4.247	218.5	A3	0	20
Isobutene (R600a)	CH_3-CH-CH_3	-12	58.12	134.67	3.65	224.4	A3	0	20
R290/R600a	45.2/54.8	-31	50.816	118.54	4.096	219.3	A3	0	<20
R290/R600a	50/50	-32	50.147	116.74	4.128	219.5	A3	0	<20
R290/R600a	54/46	-34	49.602	115.22	4.154	218.9	A3	0	<20
R290/R600a	56/44	-34	49.334	114.45	4.165	218.7	A3	0	<20
R290/R600a	60/40	-35	48.807	112.92	4.186	218.4	A3	0	<20
R290/R600a	68/32	-37	47.786	109.8	4.222	217.6	A3	0	<20

Fig 2- Some properties and environmental impacts of some alternative Refrigerants Sources: ASHRAE, 2001; Bitzer, 2007

1.4 Capillary Tube

A capillary tube having a long length approximately from 1.0 m to 6.0 m and narrow tube of constant diameter. Typical tube diameters of refrigerant capillary tubes range from 0.5 mm to 3 mm. In this work the inner diameter of capillary tube is 1.397 mm and coil diameter is 40 mm[3].

1.5 Thermostatic Expansion Valve

The thermostatic expansion valve (TXV) is the most flexible expansion valve and is most generally utilized in refrigeration frameworks. It is variable opening sort expansion gadget. A thermostatic expansion valve keeps up a steady level of superheat at the exit of evaporator; thus it is best for dry evaporators in counteracting the slugging of the blowers since it doesn't enable the fluid refrigerant to enter the blower. This comprises of a sensor bulb that is appended to the evaporator leave tube so it detects the temperature at the outlet of evaporator. The antenna bulb is connected to the highest point of the roars by a slender cylinder. The sensor bulb and the restricted cylinder contain some liquid that is called control liquid.

2. LITERATURE REVIEW

Air conditioners, refrigerator-freezers, and water coolers are real vitality clients in a residential domain and consequently proficiency improvement of these apparatuses can be considered as a significant advance to decrease their vitality utilization alongside the natural contamination avoidance. According to the Montreal Protocol, CFC12 (R-12) is being eliminated following a stipulated time span. The created nations have just eliminated these substances and the creating nations are to thoroughly eliminate the CFCs up to year 2030 according to the Montreal Protocol. The vast majority of the creating nations are definitely diminishing their Chlorofluorocarbons (CFCs) generation and use. This demands for a suitable substitute for CFC12 (R-12) for conceivable retrofitting of existing frameworks just as for new frameworks.

Chavan et al. have utilized residential refrigerator chipping away at vapor compression refrigeration for improvement fine cylinder with the different breadth and execution examination with refrigerant R 134a and R 600a. R 600a displayed higher blower work than R 134a, however R600a showed altogether high refrigerating impact. R 600a has the higher COP all most 23% contrast with R 134a.They found that the fine cylinder with 0.031-inch internal cylinder distance across offer best attractive necessities; it has low blower work with high refrigerating impact. It brings about higher COP contrast with other examined breadth hairlike cylinder. They investigate that in the morning, the refrigerating impact was more and blower work were less when contrasted with entire day time. According to their outcome Compressor work and power utilization was more for same refrigerating impact in evening [3].

Rao et al. his paper delineates that the vitality utilization of the thermostatic expansion valve framework was observed to be lower than that of the fine cylinder framework at higher cooling loads and at lower cooling limits. They saw that the estimation of Carnot COP > hypothetical COP > real COP which is understanding to the hypothesis [4].

Joshi et al. study the Coefficient of execution of vapor compression refrigeration framework is determined for

Thermostatic expansion valve, constant expansion valve, and capillary. Carnot, hypothetical and genuine COP of thermostatic expansion valve is more than constant expansion and capillary cylinder Thermostatic expansion valve gives most extreme effectiveness over a wide temperature and load range., it gives improved refrigerant come back to the blower henceforth guarantees better cooling at high temperatures and decreases the likelihood of fluid slugging which can be devastate the blower[5].

Dhumal et al. considered the impact of R407C refrigerant which is HFC refrigerant on vapor compression refrigeration framework with various expansion gadgets. Thermostatic expansion valve, Capillary container of distance across 0.50" with length 1.5m and 0.55" with length 1.75m. Exploratory arrangement of 1234W limit was utilized for examination reason. Thermostatic expansion valve requires half more work contribution at all loads contrast with the capillary cylinder however the normal increment in blower work with increment in load is 14%. which is a lot lesser than the capillary cylinder where it is 75%. The Thermostatic expansion valve indicates 43% low refrigerant stream rate when contrasted with capillary cylinders and it diminishes with increment of load on the framework. The capillary with dia. 0.50" indicates higher mass stream pace of refrigerant and it increments with increment of load on the framework. Capillary with dia. 0.55" demonstrates enduring increment in mass stream rate with load. The expansion in refrigerant mass stream rate in Thermostatic expansion valve is 12% where as 90% in capillary cylinder with dia. 0.50". The Thermostatic expansion valve gives higher refrigeration impact when contrasted with other two expansion gadgets and its exhibition increments by 86% at higher loads. The refrigeration impact is expanded by just half in the capillary cylinder with increment the load. The pace of warmth extraction of the Thermostatic expansion valve is vastly improved than the capillary cylinder. Thermostatic expansion valve demonstrates just 12% increment in refrigerant mass stream rate for 86% increment in refrigeration impact (RC) while capillary shows 90% expansion in refrigerant mass stream rate for half increment in refrigeration effect(RC) [6].

Amol et al. have examined and played out the trial on vapor compression refrigeration arrangement of 0.33 TR and refrigerant utilized were R-12. and utilized both expansion valve thermostatic expansion valve and Capillary cylinder for investigation with R-12. The investigation centers around Coefficient of Performance (COP) for both expansion gadgets (Capillary cylinder and Thermostatic expansion valve). The Carnot, Theoretical and Actual Coefficient of Performance of framework is increment while utilizing Thermostatic expansion valve contrast with capillary cylinder. To give vitality sparing a thermostatic expansion valve prepared VCR framework is given. Thermostatic expansion valve changes the minor weight contrast in the charged R-12 refrigerant. Capillary cylinder gives constant expansion so it doesn't have the remunerating capacity for changes in load. With Thermostatic Expansion, the returning of refrigerant into blower is improved so probability of fluid slugging is maintained a strategic distance from with better cooling at high temperature. Likewise, the work required by thermostatic expansion valve is not as much as that of the capillary cylinder[7].

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3. EXPERIMENTAL METHODOLOGY

The test arrangement was created in the refrigerating and air conditioning laboratory to the investigation the progression of refrigerant R-134a, Blend of R-134a and R-290 and R-600a through the capillary cylinder and Thermostatic expansion valve (TXV). In this test arrangement, we gather a distinctive segment of vapor compression cycle. The significant segments of this cycle is Evaporator, Compressor, Condenser, Capillary cylinder, and Thermostatic expansion valve. The analysis was brought out an adiabatic course through capillary and TXV.

The schematic Diagram of the exploratory set-up of local refrigerator has appeared in fig 3.1. The test area was a copper capillary cylinder and Thermostatic expansion valve in which the refrigerant expands from high weight side to low weight side.

The helical looped capillary cylinders and thermostatic expansion valve were placed in parallel position having In this work the inward measurement of the capillary cylinder is 1.397 mm and curl distance across is 40 mm. Hand shutoff valve was given at the finishes of the capillary cylinder. So that while supplanting the capillary cylinder with thermostatic expansion valve no loss of refrigerant happens. The refrigerant went into evaporator from capillary cylinder which comprises of copper loop twisted

on aluminum box called de-cooler; where warmth was retained from bureau. Vapor refrigerant from evaporator went into single-stage hermetically fixed 1/8 HP blower. The vitality utilization of framework was estimated with the assistance of vitality meter and voltage and current were estimated by voltmeter and ammeter which are associated over the blower.

High weight superheated vapor rising up out of blower went into condenser. The superheated vapor was consolidated in wound condenser. Warmth is dismissed by constrained convection condenser curl having wire balances. Drier-cum-channel was additionally introduced after condenser to expel undesirable strong particles and dampness. Five aligned computerized temperature sensors were appended to the outer surface of copper tube at various areas of the arrangement. The working range of temperature sensors is between - 300^0C to 800^0C. The experimental setup was instrumented with bourdon tube pressure gauges at inlet and outlet of compressor for measuring suction and discharge pressure. The systematic diagram of the experimental setup is shown in fig. 3.

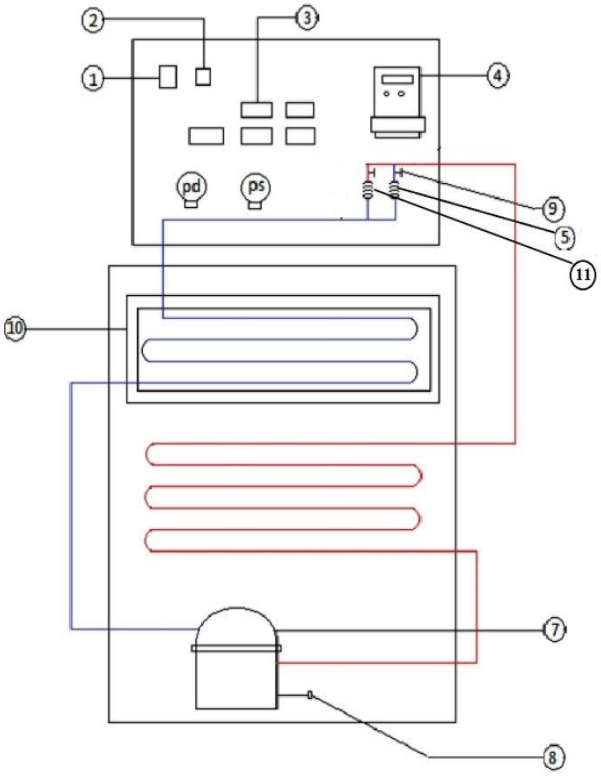

Fig 3- Schematic Diagram of Experimental Setup

1. Main Switch
2. ON/Off Switch
3. Digital Temperature Indicator
4. Energy meter
5. Capillary tube
6. Condenser
7. Compressor
8. Service line
9. Hand Setup valve
10. Evaporator
11. Thermostatic Expansion valve
12. Ps Suction Pressure

Pd Discharge Pressure

3.1 Component of the Experimental Setup

The testing office utilized in the exploratory examination appears in figure 4. Water is utilized as the working liquid and it is put away in evaporator. Right off the bat the refrigeration cycle is charged by refrigerant R-134a with accusing framework and emptied of vacuum siphon to evacuate the dampness and to make vacuum in framework. In the wake of charging refrigerants, shut off the hand-worked valve of TXV and open the valve of capillary cylinder and information were gathered in the wake of gathering information close the valve of capillary and open the valve of thermostatic expansion valve at intrigue point with same working condition. The framework achieves consistent state condition after a keep running of 30 minutes, after which test perceptions were made. The accompanying parameters were gotten to look at refrigerant like refrigerating impact, blower work, mass stream rate and coefficient of execution.

Sr. No	Parameters	Description
1	Type	Refrigeration Test Rig (Refrigeration Tutor)
2	Refrigerant	R-134a, Blend refrigerant (R-290 & R-134a 10/90 %) and R-600a
3	Capacity	0.3 TR
4	Compressor	Hermetically Sealed , single cylinder reciprocating
5	Condenser	Finned Coils , air cooled
6	Expansion device	Capillary tube and TXV
7	Evaporator	Shell & tube type evaporator

Table 2: Components in the experimental setup

At the second stage refrigeration framework is charged by refrigerant R-134a and R-290 (blend of 9:1) and cleared with vacuum siphon to evacuate the dampness and to make vacuum in framework. In the wake of charging refrigerants, all above procedure is rehashed and get all information.

At conclusive stage refrigeration framework is charged by 40 % of refrigerant R-600a and emptied with vacuum siphon to evacuate the dampness and to make a vacuum in framework. In the wake of charging refrigerants, all above procedure is rehashed and get all information.

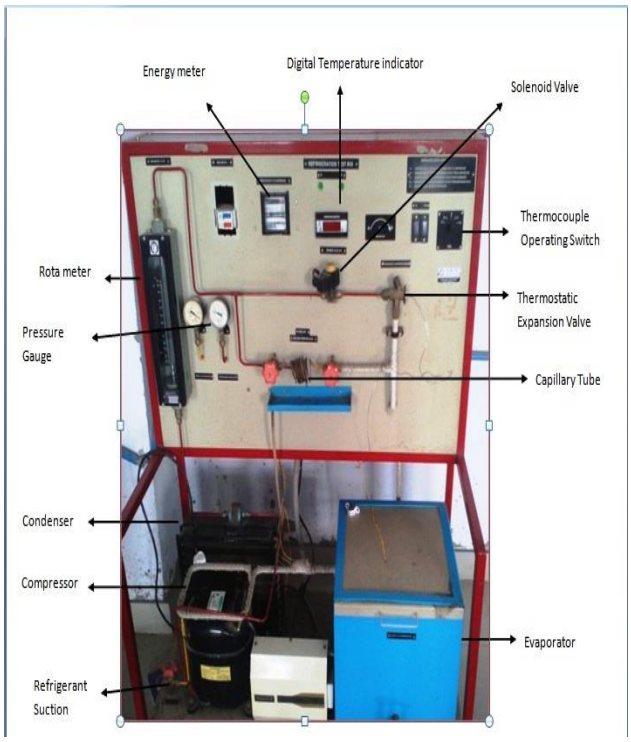

Fig 4- Photographic View of Experimental Set

4. RESULTS & DISCUSSIONS

This Chapter reports the consequence of Coefficient of execution, refrigeration impact and blower work of the framework utilizing two expansion gadgets to be a specific capillary cylinder and thermostatic expansion valve. Besides we have utilized three refrigerants R-134a, R-600a (40 % 200g) and mix of R-134a and R-290 (90/10%).

4.1 Refrigerating effect

The refrigerating impact of the framework has demonstrated the warmth retaining limit of the refrigerant into the evaporator. The warmth is consumed by the refrigerant and makes it evaporator cool. The refrigerating impact is determined with the assistance of exploratory outcome.

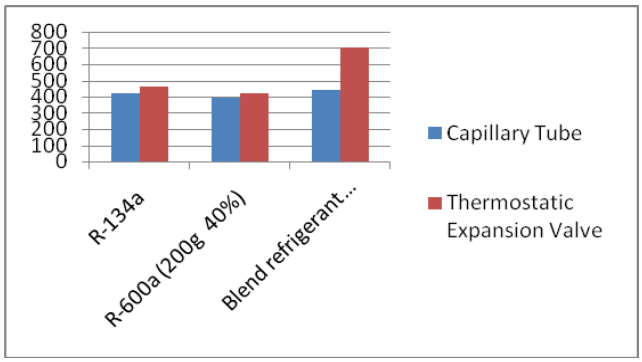

Fig 5- Refrigerating Effect for capillary tube and Thermostatic expansion valve on different refrigerant

On Capillary tube, we find when we supplant R-134a refrigerant with 40 % of R-600a the refrigerating impact is declined by 5.7%. And while we are utilizing mix of R-134a and R-290 the refrigerating impact is increment by 5%. At the point when framework chip away at thermostatic expansion valve. we find when we supplant R-134a refrigerant with 40 % of R-600a the refrigerating impact is declined by 9.6%. And while we are utilizing mix of R-134a and R-290 the refrigerating impact is increment by half. Its mean the refrigerating impact of R-600a (40%) is less nearly R-134a because of less measures of R-600a. in any case, in mix refrigerant of R-134a and R-290 give the better impact because of their mistake proportion 9:1 and substance piece of HCFC and HC.

4.2 Compressor work

The compressor work of the system is shown the power-consuming capacity of the system. The compressor compresses the refrigerant and increases the pressure and temperature of the refrigerant. The compressor work is calculated with the help of experimental result.

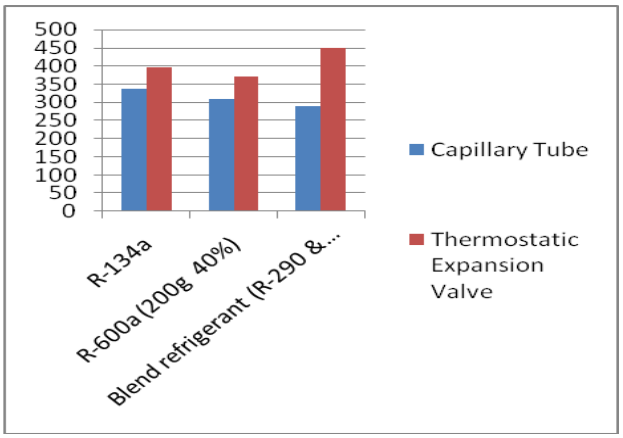

Fig 6- Compressor work for capillary tube and Thermostatic expansion valve on different refrigerant

On Capillary tube, we find when we replace R-134a refrigerant with 40 % of R-600a the compressor work is decreased by 8.3%. And while we are using blend of R-134a and R-290 the compressor work is decreased by 14.2%. When the system works on the thermostatic expansion valve. We find when we replace R-134a refrigerant with 40 % of R-600a the compressor work is decreased by 6.5%. And while we are using blend of R-134a and R-290 the compressor work is increased by 13.6%.

4.3 Coefficient of performance of the system

The coefficient of performance of the system is shown the overall efficiency of the system. The coefficient of Performance is calculated with the help of experimental result. On Capillary tube we find when we replace R-134a refrigerant with 40 % of R-600a the coefficient of Performance is increased by 2.5%. And while we are using blend of R-134a and R-290 the coefficient of Performance is increased by 22.5 %.

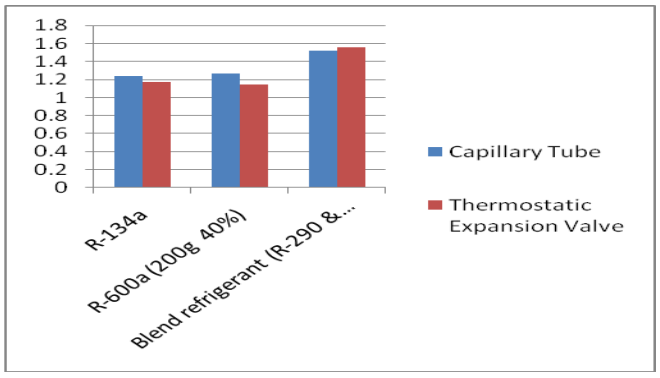

Fig 7- Coefficient of Performance for capillary tube and Thermostatic expansion valve on different refrigerant

On Thermostatic expansion valve we find when we replace R-134a refrigerant with 40 % of R-600a the coefficient of Performance is decreased by 2.5%. And while we are using blend of R-134a and R-290 the coefficient of Performance is increased by 33.3 %. It's mean the actual coefficient of Performance of R-134a is better comparatively 40 % of R-600a and blend refrigerant of R-134a and R-290 give the better COP due to their mix-up ratio 9:1 and chemical composition of HCFC and HC.

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5. CONCLUSION FUTURE SCOPE

The focus of the present work is to find out the new refrigerant which is environment-friendly as well as which enhance the efficiency of the cycle. We have also used two expansion devices with each refrigerant and hence compare the efficiency. The main outcome of my research work is listed here.

- When we are using R-134a the COP is 5.6% decrease on Thermostatic expansion valve compare to the capillary tube.
- 40% of the Refrigerant R-600a (200g) is efficient by 2.4 % on capillary tube and its COP is decreased by 20% on Thermostatic expansion valve.
- The blend refrigerant of R-134a and R-290 (90% & 10%) give better performance for both expansion device as compare to R-134a and R-600a. The COP is increased by 25.8% on Thermostatic expansion valve and 22.5% on capillary tube.
- When we are using R-134a the compressor work is 17.1% increases on Thermostatic expansion valve compare to capillary tube.
- The compressor work of R-600a (200g) decreases 8.2% on capillary tube and increase by 6.4% on Thermostatic expansion valve.
- The compressor work of blend refrigerant of R-134a and R-290 is decreased by 14.2% on capillary tube and increase by 33% on Thermostatic expansion valve.
    - When we are using R-134a the Refrigerating effect is 11% increases on Thermostatic expansion valve compare to capillary tube.
    - The Refrigerating effect of R-600a (200g) decreases 5.7% on capillary tube and approximately same on Thermostatic expansion valve.
- The Refrigerating effect of blend refrigerant of R-134a and R-290 is increase 5.23% on capillary tube and up to 67% on Thermostatic expansion valve.
- In future there may be different hydro chlorofluorocarbons (HCFC), hydrofluorocarbon (HFC) and hydrocarbon refrigerants are use for blend refrigerant.
- Many type of blend refrigerant of hydrocarbon is use in future for decrease the GWP and ODP.
- We can also use any other expansion device for improve the efficiency.
- We can also change the design of compressor, evaporator and condenser to improve the efficiency of system

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