A

PROJECT REPORT

ON

"COMPARATIVE STUDY OF THE PERFORMANCE OF R600A AND R134A IN A HEAT PUMP"

Submitted in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

GUIDED BY

DR. AMIT MANDAL
Associate Professor

SUBMITTED BY

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PRASHANT PANWAR
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RAJASTHAN TECHNICAL UNIVERSITY, KOTA

DEPARTMENT OF MECHANICAL ENGINEERING

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ISI-6, RIICO Institutional Area, Sitapura, Jaipur-302022

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DEPARTMENT CERTIFICATE

This is to certify that Mr. / Ms. / Mrs. Neeraj Yadav, Prashant Kumar, Rakesh Kumar, Shubham Yadav, Junaid Mastan, registration no. PCE18ME044, PCE18ME051, PCE18ME055, PCE18ME067, PCE19ME702 of the final year Department of Mechanical Engineering, has submitted this project report entitled "**Comparative study of the performance of R600a and R134a in a Heat Pump**" under the supervision of Dr Amit Mandal, working as Associate Professor in Department of Mechanical Engineering as per the requirements of the Bachelor of Technology program of Poornima College of Engineering, Jaipur.

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ABSTRACT

The purpose of this report is to analyse energy productivity through the investigation of execution in fume pressure cycle for assembly hall in University of Indonesia utilizing regular refrigerant R600A. The establishment of the chiller framework which is the first in Indonesia inside scholastic organization is especially pertinent considering the picking up interest and examination with respect to the execution of refrigeration framework using generally low ODP and GWP refrigerant as choice to supplant the refrigerant HCFC-22. It is discovered that the most elevated COP during 64% halfway cooling load is 4.27 at temperature water delta is 8.9°C. The most extreme COP during 75% halfway burden is 5.25 at temperature water gulf is 6,8 °C. The cooling limit are 125.93 kW and 148.39 kW during 64% and 75% burden, individually.

In this investigation, the presentation of R600A refrigerant is tentatively estimated to dissect its appropriateness for water cooler application, particularly in tropical nations. A water cooler test seat with an ostensible limit of 1.5 kW is explicitly planned and produced for R600A refrigerant. Tests are directed utilizing R600A refrigerant at a dissipating temperature of 10°C and distinctive gathering temperatures of 38°C, 43°C, 48°C and 55°C.

Gathering temperatures are set alluding to the Indian Standard (IS) rules. The exhibition of the refrigerant is investigated as far as weight proportion, cooling limit, coefficient of execution and blower release temperature. The outcomes demonstrated that the R600A framework performs well concerning the coefficient of execution and release temperature. The general exhibition of the framework indicated that R600A refrigerant is the most reasonable, energy productive and climate benevolent refrigerant.

According to IEA (2018) estimates, space cooling accounted for around 10% of total electricity demand worldwide in 2016. With business as usual, the energy demand from air conditioners will more than triple by 2050. The increase in absolute numbers of split ACs will be the most significant from just over 850 million to over 3.7 billion.

CHAPTER 1

INTRODUCTION

Aim:

The purpose of this report is to analyse energy productivity through the investigation of execution. In fume pressure cycle for assembly hall in University of Indonesia utilizing regular refrigerant R600A. The establishment of the chiller framework which is the first in Indonesia inside scholastic organization is especially pertinent considering the picking up interest and examination with respect to the execution of refrigeration framework using generally low ODP and GWP refrigerant as choice to supplant the refrigerant HCFC-22. It is discovered that the most elevated COP during 64% halfway cooling load is 4.27 at temperature water delta is 8.9°C. The most extreme COP during 75% halfway burden is 5.25 at temperature water gulf is 6,8 °C. The cooling limit are 125.93 kW and 148.39 kW during 64% and 75% burden, individually.

According to IEA (2018) estimates, space cooling accounted for around 10% of total electricity demand worldwide in 2016. With business as usual, the energy demand from air conditioners will more than triple by 2050. The increase in absolute numbers of split ACs will be the most significant from just over 850 million to over 3.7 billion.

Scope:

Minus40 hydrocarbon refrigerant is R600A, a pure refrigerant grade of isobutane. It can and is already being used in medium and low temperature refrigeration and air conditioning systems as an alternative to HCFC-R22. Its application range covers supermarket cabinets, ice-cream display cabinets, heat pumps, and air conditioning systems.

Minus 40, the natural and safe product from the Australian-based company Hy-Chill is a pure hydrocarbon refrigerant with a single molecule and no temperature glide. It is suitable for transport refrigeration and static cool room applications. The product is fully compatible with most refrigeration systems, including valves and oils, both mineral and synthetic. In addition, Minus40 produces similar performance results to ammonia and could be used as a substitute in some applications.

A major advantage of Hy Chill's hydrocarbon refrigerant is that it is an ideal natural solution, a natural replacement for HCFC-R22. Manufacturers have shown a great deal of interest in R600A, and experimentation has grown significantly in recent times in this alternative in pre-existing HCFC-R22 type technologies. The design changes required in HCFC-R22 systems is minimal and cheap to successful update designs for R600A.

Selection of Topic:

Heat pumps are generally recognized as an efficient energy-saving method and are widely used in industrial and residential applications. Due to the ratification of the Kyoto Protocol, the use of high-GWP refrigerants is gradually being restricted and they will be phased out for heat pump systems. Currently, low-GWP refrigerants, such as R718, R1234ze(Z), R600, R600a, R1233zd(E) have been evaluated for high-temperature heat pumps. However, there is still a lack of choice and research regarding low-GWP refrigerants for conventional heat pumps. Therefore, taking the system's COP, volumetric heating capacity, pressure ratio and discharge temperature into consideration, R1234ze(E) is selected for study in this paper due to its relatively excellent system performance for wider working temperature ranges. Furthermore, a water-source heat pump using R1234ze(E) as the working fluid was simulated, built, and tested. The experimental results showed that the COP of the R1234ze(E) heat pump can reach 3.5 with a heat source varying from 10 °C to 30 °C and a water outlet temperature above 60 °C. The simulation results are in good agreement with experimental data. Moreover, the component characteristics were compared between R1234ze(E) and R134a. The results show that R1234ze(E) has apparent advantages for residential use and is economically comparable with R134a.

R22 is a hydrochlorofluorocarbon (HCFC) refrigerant generally utilized in cooling. R22 is an ozone exhausting substance. Because of ozone layer exhaustion, HCFC will be eliminated in notso-distant future. R600A is hydrocarbon (HC) refrigerant is an option in contrast to R22.

This paper presents results of this relative examination. A 1-ton limit window forced air system was utilized to test. R22 was utilized for gauge refrigerant. R600A refrigerant utilizing air cooled condenser coefficient of execution (C.O.P.) brought down by 6.91%, 6.28% and 1.38% at various set point temperatures 16°C, 20°C& 25°C. The framework is improved to increment in thermodynamic execution by utilizing evaporative cooling condenser with R600A refrigerant.

C.O.P. of framework is improved by 15.84%, 18.23% and 22.92% at various set point temperature and force utilization lessens by practically half than the gauge framework. The measure of refrigerant charge of R600A refrigerant is 70% not as much as that of R22 refrigerant. Test results show that execution of the evaporative cooled air condenser by utilizing R600A refrigerant significantly affects execution improvement of window climate control system.

CHAPTER 2

LITERATURE REVIEW

Literature Review 1:

Topic: *Performance of R600A and R1270 for R22 applications with evaporator and condenser temperature variation*

Author: Ki-Jung Park & Dong Soo Jung

Year: 2008

Review:

Execution of two hydrocarbon refrigerants of R600A and R1270 was estimated trying to substitute R22. They were tried in a warmth siphon seat analyser of 1 ton limit with an airtight revolving blower. Water constantly/glycol combination were utilized as the auxiliary warmth move liquids in the test seat. All tests were directed under similar outside conditions reproducing three diverse cooling and warmth siphoning conditions. Test outcomes show that the coefficient of execution of these hydrocarbon refrigerants is up to 11.5% higher than that of R22 under all conditions.

Literature Review 2:

Topic: *Experimental Performance Analysis of Refrigerant R600A for Water Cooler Application.*

Author: Chandrakishor Choudhari, Shivalinga N Sapele

Year: 2017

Review:

In this investigation, the presentation of R600A refrigerant is tentatively estimated to dissect its appropriateness for water cooler application, particularly in tropical nations. A water cooler test seat with an ostensible limit of 1.5 kW is explicitly planned and produced for R600A refrigerant.

Tests are directed utilizing R600A refrigerant at a dissipating temperature of 10°C and distinctive gathering temperatures of 38°C, 43°C, 48°C and 55°C.

Literature Review 3:

Topic: *Performance evaluation of R600A isobutane refrigerant at existing R22 air conditioning system; Drop in case study.*

Author: Azman Hussin

Year: 2015

Review:

The hydrocarbon refrigerant, R600A isobutane which is profoundly combustible under Class A3 was proposed to sup-element HCFC 22. The framework exhibitions are assessed by estimating the voltage, current, low and high side weight and temperatures at standard encompassing rating condition. The dry bulb temperature of indoor space was set to 24°C and outside estimated information was 34°C, separately. The R600A isobutane was a flammable gases and green application which not hurtful to the ozone layer and an Earth-wide temperature boost potential. Because of it combustibility, wellbeing taking care of should be all around presented.

Literature Review 4:

Topic*:* *Chiller performance study with refrigerant R600A*

Author: Zulfa Fuadia, Ardiyansyah Yatimb, Rachmah Rizkyc, Nyayu Aisyahd, Idrus Alhamide, Budihardjo Budihardjof, and Nandy Putra

Year: 2019

Review:

The reason for this research is to analyse energy productivity through the investigation of execution in fume pressure cycle for assembly hall in University of Indonesia utilizing regular refrigerant R600A. The establishment of the chiller framework which is the first in Indonesia inside scholastic organization is especially pertinent considering the picking up interest and examination with respect to the execution of refrigeration framework using generally low ODP and GWP refrigerant as choice to supplant the refrigerant HCFC-22. It is discovered that the most elevated COP during 64% halfway cooling load is 4.27 at temperature water delta is 8.9°C. The most extreme COP during 75% halfway burden is 5.25 at temperature water gulf is 6,8 °C. The cooling limit are 125.93 kW and 148.39 kW during 64% and 75% burden, individually.

Literature Review 5:

Topic: *Experimental performance study of R600A as an alternative to R22 refrigerant in a window air conditioner.*

Author: Vishakha S. Jawale, Ashok J. Keche

Year: 2019

Review:

R22 is a hydrochlorofluorocarbon (HCFC) refrigerant broadly utilized in cooling. R22 is an ozone draining substance. Because of ozone layer consumption, HCFC will be eliminated in not-sodistant future. R600A is hydrocarbon (HC) refrigerant is an option in contrast to R22. This paper presents results of this similar examination. A 1-ton limit window climate control system was used to analyse. R22 was utilized for pattern refrigerant. R600A refrigerant utilizing air cooled condenser coefficient of execution (C.O.P.) brought down by 6.91%, 6.28% and 1.38% at various set point temperatures 16˚C, 20˚C& 25˚C. The framework is improved to increment in thermodynamic execution by utilizing evaporative cooling condenser with R600A refrigerant. C.O.P. of framework is improved by 15.84%, 18.23% and 22.92% at various set point temperature furthermore, power utilization diminishes by practically half than the pattern framework.

Literature Review 6:

Topic: *A Comparison Between Refrigerants Used in Air Conditioning.*

Author: Derya Özkan, Özden Agra and Özlem Çetin

Year: 2007

Review:

It's plainly realized that developing components of the opening on ozone layer has significant harms and consequences for living animals today. Examinations show that refrigerants that ordinarily utilized in cooling impacts affect harm of ozone layer. For this reason, explores on elective refrigerants to be utilized for cooling are still proceeding. In this examination, execution of various refrigerants like R600a, R134a, R600A, R1270, R32, R22, and R152a, in fume pressure refrigeration cycles and warmth siphons was researched. Examinations was made on the ideal fume pressure refrigeration cycle and a second cycle which was made by adding subcool and superheat areas on the first.

Literature Review 7:

Topic: *Improvement of R134a Performances by Addition of R600A*

Author: R. Camporese, B. Boldrin, M. Scattolini, G. Cortella

Year: 1992

Review:

The blend R600A·R 134a is dissected as a short-term substitute of R 12 for the retrofit of the refrigerating units where refrigerating limit assumes a fundamental job. The fume fluid equilibria and the thermodynamic properties of the combination are anticipated by the Soave condition of state. The exhibitions of this semi-azeotropic blend are determined for dissipating temperatures in the reach - 20 +0°C and are contrasted and those of the unadulterated refrigerants R 12, R 134a and R 152a.

CHAPTER 3

THEORY

Refrigerant R 600A:

R600A, also known as CARE 40, is refrigerant grade isobutane, a natural, or "not in kind", refrigerant suitable for use in a range of refrigeration and air conditioning applications. The use of R600A is increasing due to its low environmental impact and excellent thermodynamic performance. It is non-toxic with zero ODP (Ozone Depletion Potential) and very low GWP (Global Warming Potential). It is a flammable refrigerant and therefore not suitable for retrofitting existing fluorocarbon refrigerant systems.

R600A (Isobutane) is refrigerant grade isobutane, used as an alternative to R404A and R407 series refrigerants in new refrigeration and air conditioning systems. R600A (Isobutane) is a Hydrocarbon and although highly flammable it is an efficient refrigerant that has a low Global Warming Potential (GWP).

As you know, in the hospitality industry several refrigeration units are often used to keep food at the ideal temperature until the service and to comply with sanitary regulations.

However, these units have an electrical consumption and require a specific maintenance that can suppose an avoidable expense to the owners of restaurants, bars or cafeterias. Likewise, the refrigerant gases they contain to maintain the proper temperature usually report a high polluting impact. For all these reasons and in order to comply with the F-Gas Regulation, at Distort we have opted for the R600A refrigerant, the most ecological on the market.

When it comes to the maintenance required by R600A equipment, you will also find outstanding benefits. In any case, we recommend that you always contact a qualified technical service for its handling, as this refrigerant gas is very flammable. If you detect leaks in your kitchen that come from a R600A device, you must ventilate the room properly and have a fire extinguisher nearby. With these tips in mind, you will enjoy an efficient and environmentally conscious equipment.

Fig:- Heat pump test rig

Advantages of R 600A

- It has a low polluting impact.
- Tax-exempt
- Low toxicity
- Ensures efficiency and energy savings.
- Facilitates equipment profitability.
- Requires easy maintenance.
- Complies with European F-Gas Regulation

Application of R 600A

- Commercial Refrigeration
- Commercial Refrigeration: Plug-Ins & Vending Machines
- Industrial Refrigeration
- Residential & Light Air Conditioning
- Industrial / Commercial Air Conditioning DX Chillers

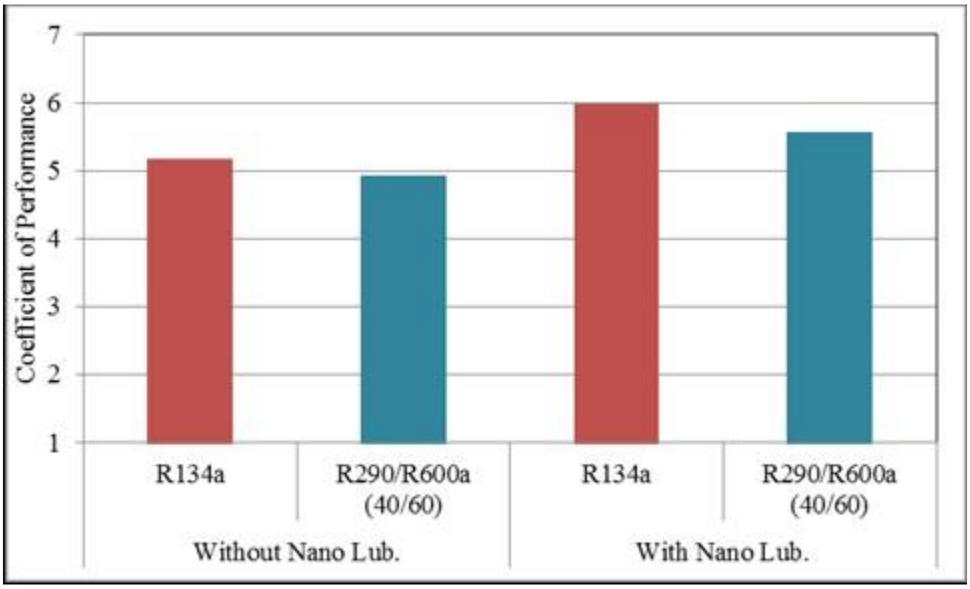


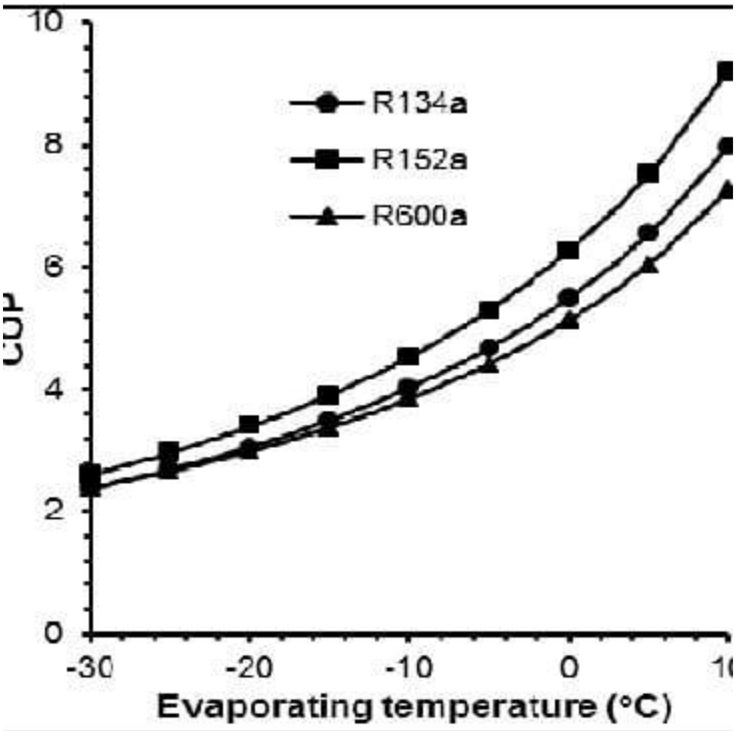
Fig.2

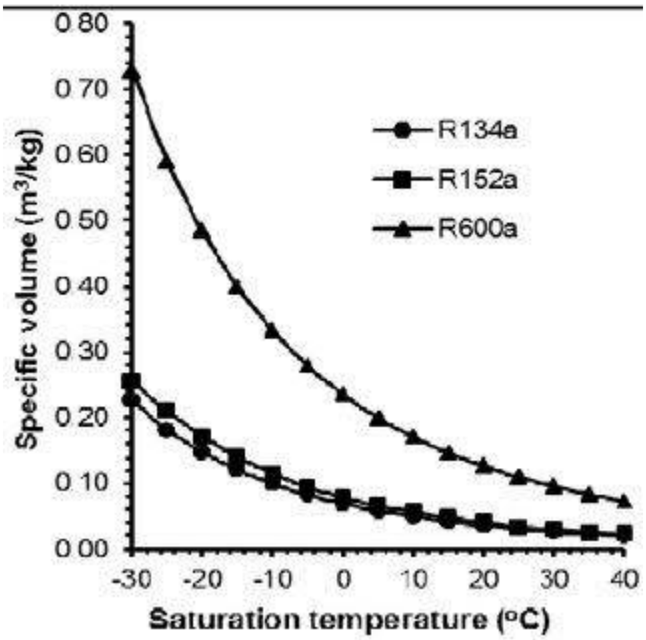
Forthcoming of R600A:

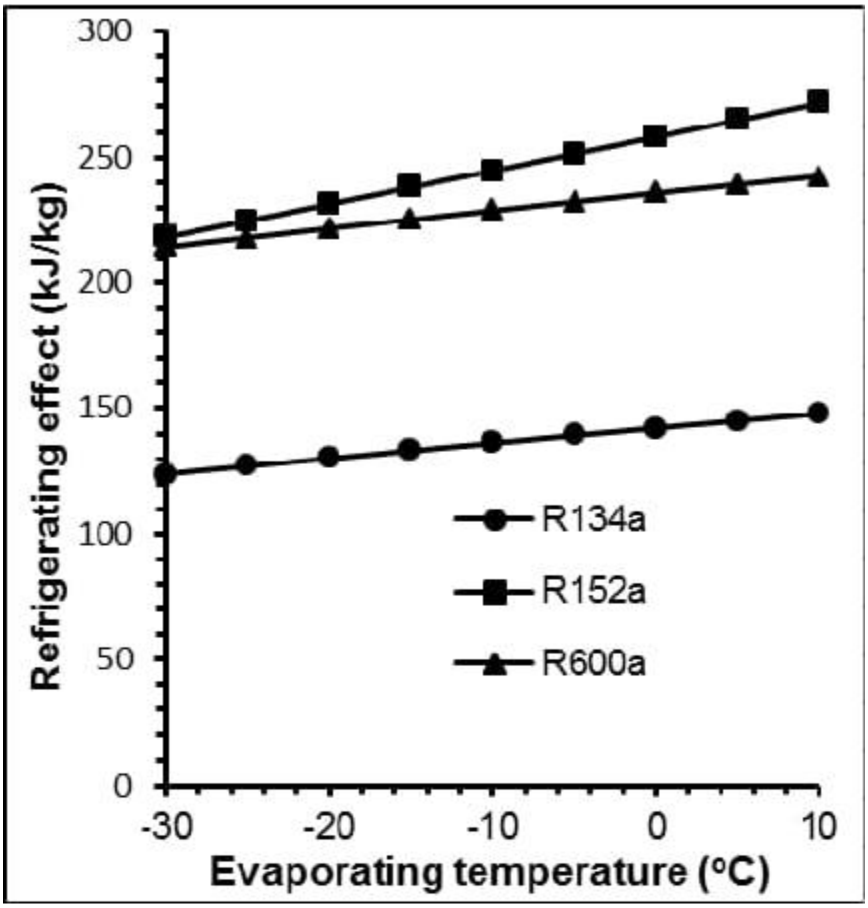
Introducing R600A refrigerant into our product offering is not a change that can be implemented overnight. The introduction requires substantial process updates, inventory and production management, and capital expenditures. Therefore, it will be a controlled rollout.

We are committed to R600A as the refrigerant of the future, due to its increased performance and eco-friendly properties. As of now, there is no phase out date set for R404a. Any future transition away from R404a will be driven environmental legislation and/or market demands, in which case, there will be ample warning and communication at that time.

In 2020, R404a units, for all Leer products, will be available from stock and/or with standard lead times. R600A units, for select products, will be available made to order and/or with extended lead times. We'll continue to update and communicate our timeline to rollout additional sizes and products.






Refrigerating effect (kJ/kg)
Evaporating temperature (°C)
R134a
R152a
R600a
300
250
200
150
100
50
0
-30
-20
-10
0
10

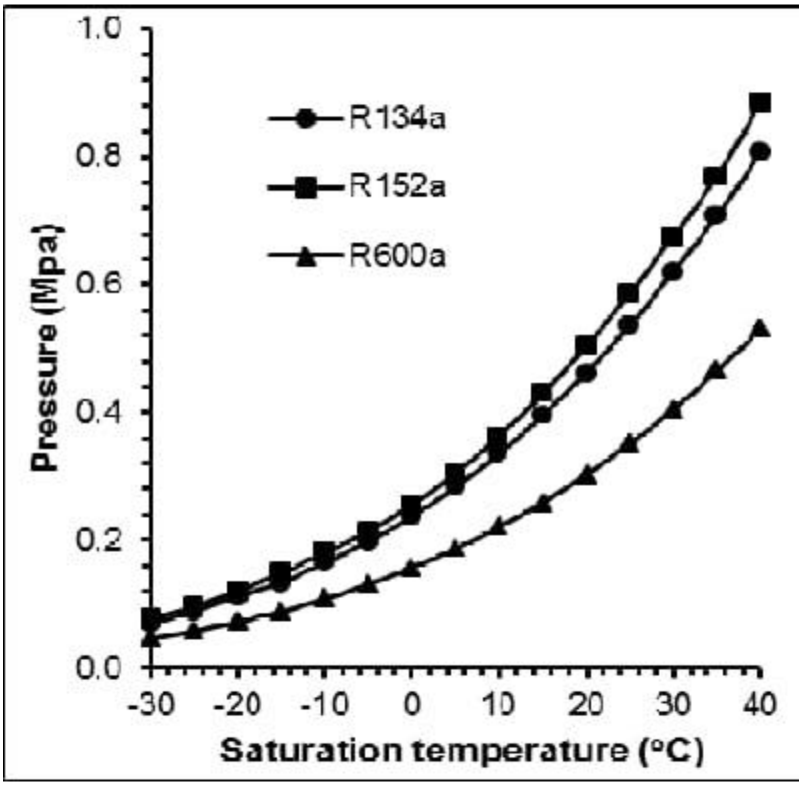

Pressure (Mpa)
Saturation temperature (°C)
R134a
R152a
R600a
1.0
0.8
0.6
0.4
0.2
0.0
-30
-20
-10
0
10
20
30
40

Fig 3

Refrigerant R 600A vs R 290

	R290	R600a
Refrigerant Charge Reduction	~40%	~45%
Global Warming Potential	3	3
Common Fluorocarbon Replacement	R22	R12
Ignition Temperature	878°F (470°C)	860°F (460°C)
Lower Flammability Limit	2.1% by volume	1.5% by Volume
Upper Flammability Limit	9.5% by volume	8.5% by volume

R600a and R290 are hydrocarbons. These refrigerants are flammable and are only allowed for use in appliances which fulfil the requirements laid down in the latest revision of EN/IEC 60335-224. (To cover potential risk originated from the use of flammable refrigerants). Consequently, R600a and R600A are only allowed to be used in household appliances designed for this refrigerant and fulfil the abovementioned standard. R600a and R600A are heavier than air and the concentration will always be highest at the floor. R600a must only be stored and transported in approved containers and must be handled according to existing guidelines.

Flammable refrigerants like R600a and R290must always be charged by weight. Charging by volume must be made with a refrigerant charging cylinder. The refrigerant R404A and all other refrigerants in the 400 series must always be charged as liquid.

If the charging amount is unknown, charging must be done gradually until the temperature distribution above the evaporator is correct. However, mostly it will be more appropriate to overcharge the system and then gradually draw off refrigerant until the correct charge has been obtained. The refrigerant charge must be made with the compressor running, the refrigerator without load, and with the door closed.

To ensure reasonable refrigeration system life, the refrigerant must have a maximum moisture content of 20 ppm (20 mg/kg). Do not fill the refrigerant from a large container into a filling bottle through several container sizes, as with every drawing-off the water content in the refrigerant is increased considerably.

Comparison performance of R600A and R134A Refrigerant on Heat pump

There have also been several studies on the modelling or optimization of air source heat pumps. A parametric model operated on refrigerant side variables was developed using a domestic air source heat pump. This model is suitable for the performance analysis of heat pumps in service because it can be established based on field data. A comprehensive model for heat pumps was developed and included the models of each component and the energy balance. With respect to the optimization conducted optimization work involving an ASHPWH using theoretical and experimental methods. The optimization objectives were the capillary tube length, filling quantity of refrigerant, and the condenser coil tube length. The operating performance of a frost-free air source heat pump was also analysed using different refrigerants (R22, R407C, and R134a) in another study by our team. The intermediate pressure is a key parameter of a two-stage air source heat pump system. we conducted a real-time optimization study that aimed to minimize the total energy consumption. Another key issue with respect to the investigation of air source heat pumps relates to refrigerants. With the increasingly stringent requirements of environmental protection, natural eco-friendly refrigerants have attracted more attention in recent years feasibility of a refrigerant mixture R744/R290 as an alternative to R22 in a heat pump water heater. . R600a is also eco-friendly refrigerants that are often used in refrigeration or heat pump systems. theoretically analysed the performance of a two-stage compression refrigeration system using a refrigerant mixture R290/R600a. The results showed that the best ratio of R290 was 40 wt% also studied the performance of R290 and R600a in a single-stage compression heat pump. The cycle performance of pure fluids R290 and R600a were experimentally investigated, as well as their mixtures. The annual performance analysis showed that the heating capacity of the air source heat pump ranged from 10-13.5 kW, and the COP ranged from 3.10-3.25. Meanwhile, developed an air source heat pump model to predict the annual performance. While more efficient and ecofriendly refrigerants need to be developed. R600a is considered eco-friendly refrigerants with low GWP and no ozone depletion potential (ODP). A new eco-friendly refrigerant mixture with good cycle performance is obtained by optimizing the ratio of the above-mentioned refrigerants in this work. The feasibility analysis of the refrigerant mixture as drop-in replacement for R134a was conducted in air source heat pumps under typical and off-design working conditions. The condensing pressure, compressor discharge temperature, compression ratio, specific heating capacity and the COP of the proposed mixture, a contrast mixture and R134a are comparatively studied. The annual performances of an ASHPWH using these refrigerants operating in Central China are also comparatively analysed.

Property	R22	R600A
	59°C(vapor)	55°C (vapor)
Pressure (MPa)	2.4275	1.9072
Density (Kg/m3)	0.00785	0.02288
Viscosity (µPa-s)	14.98	9.7
Thermal Conductivity (W/m°C)	16.36	24.65
Specific heat (KJ/Kg°C)	1.6075	1.478
Velocity of sound (m/s)	147.7	69.8

Refrigerant R600A vs R 134a

The most significant test results are shown in figs. 5,6,7,8,9, in which the refrigerating capacity, the electric power, the COP, the condensing and evaporating pressures are plotted against the temperature of the air entering the evaporator.

The replacement of R 12 with R 134a produces a decrease both in the refrigerating capacity (-8% at 0°C air entering the evaporator and -16% at -10 °C air entering the evaporator) and in the COP (-6% at 0°C air entering the evaporator and -12% at -10 °C air entering the evaporator).

These decreases are higher than the predicted values, and this is probably since the unit was designed for R 12 and not for R 134a. The original performances of the unit seem to be hardly achievable unless changes in the components of the circuit are made.

The cool down performance under varying speed and varying ambient conditions, system performance under severe accelerating conditions and bumper-to-bumper traffic conditions is studied. The test results show that the new blend can be a promising substitute for the existing R12 systems, and it can eliminate the use of hygroscopic PAG oil.

A small addition of R600A to R 134a results in an increase of the refrigerating capacity roughly proportional to the mass fraction of R600A. At the lower evaporating temperatures, the COP is unaffected by the mass fraction of R600A and, at higher evaporating temperatures, the COP decreases as the mass fraction of R600A increases.

Property	R600A	R134a
	55°C(vapor)	50°C(vapor)
Pressure (MPa)	1.9072	1.3179
Density (Kg/m3)	0.02288	0.01509
Viscosity (µPa-s)	9.7	12.88
Thermal Conductivity (W/m°C)	24.65	16.18
Specific heat (KJ/Kg°C)	1.478	1.246
Velocity of sound (m/s)	69.8	136.6

Industry Application: R600a is used in industrial refrigeration. R600a is used in vending machine and plug-ins. R600a is used in geothermal power generation. R600a also finds its application in aerosol sprays.

Chapter 4

FUTURE SCOPE

For decades, the most widely used refrigerants used in commercial applications have been R134 for refrigerator applications or R404 for freezer systems. Both have very high Global Warming Potential (GWP) that is harmful to the atmosphere. By contrast, R600A is a highly refined isobutane used as an alternative to these refrigerants.

Its capacity to absorb heat is nearly 90% higher than R134 or R404 which results in quicker temperature recovery and lower energy consumption. Also, its low ozone-depleting properties and extremely low GWP make R600A one of the most climate-friendly and cost-effective refrigerants on the market.

Eco-Friendly: R600A is a natural, non-toxic, sustainable hydrocarbon (HC) refrigerant and the top alternative to hydro monocarbene (HFC) refrigerants. R600A, has an Ozone Depletion Potential (ODP) of 0 and an ultra-low Global Warming Potential (GWP) of 3.

Isobutane containing too much propene (also called propylene) is not suited for most vehicle fuels. HD-5 is a specification that establishes a maximum concentration of 5% propene in isobutane. Isobutane and other LP gas specifications are established in ASTM D-1835. All isobutane fuels include an odorant, almost always ethanethiol, so that people can easily smell the gas in case of a leak. Isobutane as HD-5 was originally intended for use as vehicle fuel. HD-5 is currently being used in all isobutane applications.

Isobutane is also instrumental in providing off-the-grid refrigeration, usually by means of a gas absorption refrigerator. Blends of pure, dry "isobutane" (R600A) (isobutane/isobutane mixtures) have negligible ozone depletion potential and very low Global Warming Potential (having a value of 3.3 times the GWP of carbon dioxide) and can serve as a functional replacement for R-12, R22, R-134a, and other chlorofluorocarbon or hydrofluorocarbon refrigerants in conventional stationary refrigeration and air conditioning systems.

Chapter 5

Conclusion

In the present work, a new refrigerant mixture R290/R600a/R13I1 with low GWP and no ODP is proposed as an alternative to R134a in air source heat pump. A theoretical model for an ASHPWH was developed based on MABLAB linking with REFPROP. The condensing pressure, compressor discharge temperature, compression ratio, specific heating capacity and the COP of the proposed mixture, a contrast mixture and R134a are comparatively studied under typical and off-design working conditions. The aim was to verify the feasibility of substitution. The annual thermal and environmental performances of the ASHPWH using the proposed mixture, the contrast mixture and R134a operated in Central China was also comparatively Journal Preproof27 studied. The following conclusions can be drawn: The proposed mixture has better performance with lower condensing pressure and compression ratio, and higher specific heating capacity and COP. While the compressor discharge temperature of the proposed mixture is also within the safe operating temperature range of the compressor. Therefore, it is feasible to replace R134a with the proposed mixture under typical working conditions. The condensing pressure of R134a exceeded 2.5 MPa when the condensing temperature was 80 °C, while that of the proposed mixture was still below this value when the condensing temperature reached 90 °C. The COP can reach 4.0 at 70 °C and can exceed 3.8 at 90 °C, which is about 9.2% higher than that of R134a. In addition, there was little difference in the compression ratio and the compressor discharge temperature of the two refrigerants under off-design working conditions. Therefore, it is feasible to replace R134a with the proposed mixture under off-design working conditions, and the performance can be significantly improved. Both the annual thermal performance (COP) and annual environmental performance (TWEI) of the two-stage compression ASHPWH using the proposed mixture were better than the results obtained using R134a. The annual average COP of the ASHPWH can be improved by 6.2% with the proposed mixture when compared with R134a, and the TWEI can be reduced by 18.99%. In addition, the ASHPWH using the proposed mixture has obvious advantages compared with that obtained using R134a when the ambient temperature is very low in winter.

Chapter 6

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