Review on study of waste heat utilization techniques in vapour compression refrigeration system

Dhananjay Parmar[1], Neelesh Soni[2]

[1]*Research Scholar, Department of Mechanical, ITM University, Gwalior, India*
[2]*Assistant Professor, Department of Mechanical, ITM University, Gwalior, India*

Abstract - *To review the design of working research model associated with maximum utilization of waste heat via installation of water chamber in between compressor and condenser. Vapour compression refrigeration system is most typically and domestic and as well large-scale approach to generating refrigerating effect. On the process, it rejects large amount of heat which is actually dumped to environment as waste products. The rejected waste heat could possibly be utilized to run any low-grade heat required refrigerating system. The recovered hot water could be put to use for home purpose like heating water, bathing, washing in addition to large scale industrial purpose like fabricating, processing, diluting, incorporating water into product or perhaps for sterilization necessities. This paper proposes and attain optimum utilization of waste heat recovery from VCR system that has nominal constructional, renovation and operating cost, substantially useful for domestic intent. Finally, this could be surrogate for water heater and fulfils all of the applications of hot water, which furthermore, could tackle the requirement of LPG gas and thus, safer in environmental aspects.*

Key Words: Compressor, Refrigeration, VCRS cycle, Waste Heat Recovery, Water Chamber

1. INTRODUCTION

The household refrigerator is the most common household kitchen appliance, which usually includes thermally insulated inner compartment and which in turn when functions, exchanges heat from inside of the compartment to the exterior natural environment to ensure that the interior of the thermally well insulated compartment is cooled to the temperature under the environmental temperature of the room or space. High Temperature being rejected might happen straight towards the air flow in the event of a standard home refrigerator needing air-cooled condenser as well as to drinking water when it comes to a water-cooled condenser. Tetrafluoro ethane (HFC134a) refrigerant was right now broadly utilized in the majority of the home refrigerators [1].

Refrigeration systems are made to absorb temperature at a minimal temp and decline it in a greater temperature and it all perform an essential part in commercial, household, and business industries intended for air conditioning, heating system, and meals retaining uses. High temperature being rejected might happen straight towards the natural environment, just as the situation of the most standard air-cooling models, as well as to drinking water moving from an air conditioning tower system. In the fast-developing nation like India, the majority of the vapour compression-based refrigeration, air-conditioning and high temperature pumping devices continue to keep operate on halogenated refrigerants credited for their superb thermodynamic and thermo-physical properties aside from the low priced [2].

Waste heat is a heat that could be produced in a procedure through method of gas usage or chemical substance response after which "got rid of" in the environment although it can even now end up being employed for a few beneficial and financial reasons. A tough estimation of waste heat obtainable via a refrigeration and a/c (RAC) program shows the fact that regarding 3-5 kW of waste energy is usually declined to the natural environment for each kw of energy spent by air compressor. Restoration of this energy will lead to the conserving of general energy price ranges. Nevertheless, the potentiality of such energy retrieval offers not really been regarded as while developing RAC systems in the majority of the set-up models, certainly credited to partial strategies where retrieved energy might possibly become place to make use of [2,3].

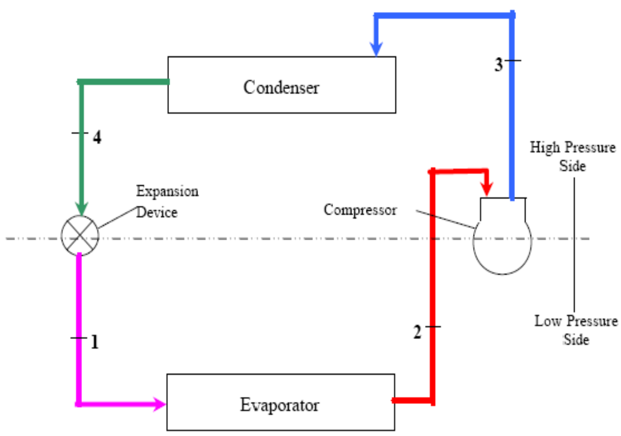

Fig. 1: vapour compression refrigeration cycle [4]

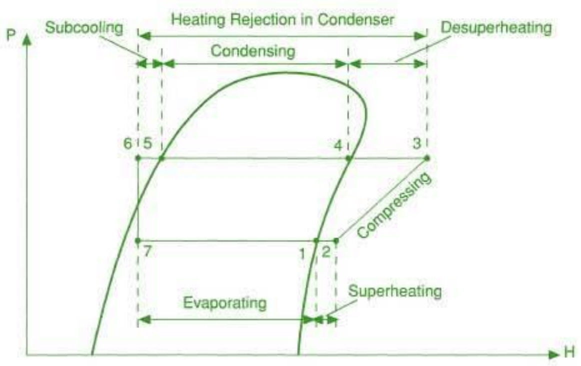

Fig. 2: P-h diagram with sub-cooling and super heating [4]

2. PARTS OF THE VCRS SYSTEM

2.1 Compressor

The compressor enhances the pressure of the refrigerant streaming from the evaporator i.e. pulling in low- pressure, low temp saturated vapour and supplying highly pressured and high temperatures towards the condenser. Due to compression put in, vapour leaves the compressor at a varied pressure as well as the excessive function used leads to superheating of the vapour. The objective of the compressor is normally to recover the vapour from the evaporator, and to increase the heat range and pressure to a stage so that it could become condensed with the obtainable condensing part.

2.2 Discharge Line

The warm gas or simply discharge line provides the highly pressured, high-temperature vapour through the excretion from the compressor to the condenser.

2.3 Condenser

The highly pressured, high-temperature vapour which goes in the condenser has heat taken out of it and consequently it is condensed back again into a liquid state. The heat transmission channel can become air or water, the necessity is that, the temp is usually lesser when compared to whatever compares to the condensing pressure. the process of condenser is same as evaporator except opposite work.

2.4 Receiver Tank

The receiver tank operates as temporary tank and it is employed to give storage for the condensed liquid to ensure that a consistent flow of liquid is available to the evaporator as needed.

2.5 Liquid Line

A liquid line carrier the liquid refrigerant from the receiver tank to the refrigerant flow control.

2.6 Expansion Valve

It is also known as refrigerant flow control valve. To lower pressure to the equal level as that of the evaporating pressure, a device has to be placed to undertake this procedure, referred to as throttling device or an expansion device.

2.7 Evaporator

Refrigerant in liquid state can absorb heat from the cold chamber leads to evaporate. When a refrigerant is permitted to increase through expansion device, heat will become used up from the encircling atmosphere and evaporation of the refrigerant will certainly happen. the evaporator offers a heat transfer surface area through which heat may move from refrigerant space in to the vaporizing refrigerant.

2.8 Suction Line

The suction line delivers the lower temperature vapour from the evaporator towards the suction inlet of the compressor [6,7].

3. REFRIGERANTS R134A

The refrigerant R134a or tetra-fluoro ethane composed of 2 atoms of carbon, 2 atoms of hydrogen and 4 atoms of fluorine. The molecular weight is 133.4 and its boiling point is 15.1-degree F. Its chemical formula is $CF_3\ CH_2\ F$.

Refrigerant R134a is a hydrofluorocarbon (HFC) which has no potential to influence the destruction of the ozone layer and have very little greenhouse effect. It is the non-flammable and nonexplosive, offers toxicity within boundaries and better chemical stability. It includes relatively great affinity for the moisture content. The complete physical and thermodynamic properties very closely imitate with that of refrigerant R12 [8].

4. LITERATURE REVIEW

Several studies have been performed on refrigeration systems meant for heat recovery, which were analyzed in greater detail.

Elumalai et al. [9] have studied about heat retrieval from the condenser in the Vapour Compression Refrigeration (VCR) system by using oven and heating unit that could be installed between compressor and condenser parts. The existence of oven enables us to retrieve the superheat from the discharge vapour and put it to use for raising the temperature of the space inside hot oven and raise the temperature of the fluids in the heater. The effectiveness of the chiller with varying operating time has were studied. The result of operating temperature inside the oven and heating unit for changing working time of a refrigeration device have been analyzed and possible heat recovery had been determined.

Fig. 3: front view [9] *Fig. 4:* back view [10]

Maurya & Awasthi [10] have studied theoretical methodology towards usage of waste heat of a vapour compression refrigeration system. The discarded heat could possibly be utilized to perform any other low-grade heat needed refrigeration system such as simple ejector refrigeration system. Based on a few analytical samples they proposed a combined cycle here. It is an appropriate method of utilization of such waste heat thus enhance the co-efficient of performance of the vapour compression refrigeration system.

Walawade et al. [11] have studied "Waste heat recuperation framework for residential refrigerator". For small price range, this framework is much valuable for residential reason. An endeavor has been discovered from condenser of refrigerator to retrieve the heat. This heat can be used for number of home and industry purposes. It is important option way to deal with enhance general effectiveness and reuse the waste heat. The review has demonstrated that such a framework is in fact technically and economically feasible.

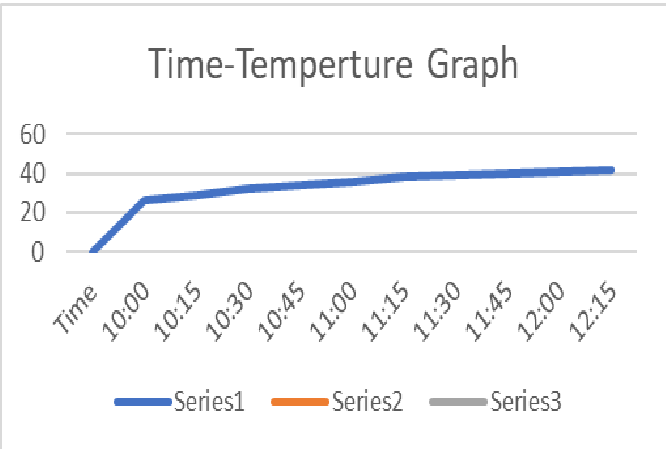

Fig. 5: Design and Development of Waste Heat Recovery System for Domestic Refrigerator [11]

Vedil et al. [12] have analyzed hypothetical method to retrieve the waste heat liberated out of vapour compression cycle, that is used to operate vapour absorption cycle. The required heat has been provided by solar powered energy. The work examined the effectiveness of combined cooling cycle.

Kaushik et al. [2] have dealt with the waste heat retrieval from the commercial refrigeration by featuring Canopus heat exchanger. There is a significant amount of low-grade heat obtainable in large-capacity systems. To recuperate this sub-standard heat, a Canopus heat exchanger is presented in between compressor and condenser elements. The device feasibility is normally studied with various working ranges and the influence on heat recovery aspects and general COP of the machine. The parametric results acquired for different eco-friendly functioning fluids have been provided. He found that, generally, overall COP of the operational system is normally improved without affecting the actual performance of the system. The potential of low-grade heat availability is elevated with increasing cooling capability.

Sreejith K. et al. [13] have analyzed experimentally the effects of water-cooled condenser in a house-hold refrigerator. The research was carried out using HFC134a as the refrigerant and Polyester oil as the lubricant. The functionality from the home refrigerator with air-cooled and water-cooled condenser was examined for many load situations. The solutions display that the refrigerator general functionality got elevated when water-cooled condenser was employed rather than air-cooled condenser on all load situations. Water-cooled condenser reduced the energy use in assessment with the air-cooled condenser meant for different load situations. There was also an improvement in coefficient of performance, when water-cooled condenser was applied rather than air-cooled condenser. The water-cooled heat exchanger was made and the system was revised using retrofitting it, the water-cooled heat exchanger was built and the functional program was modified using retrofitting it, rather than the regular air-cooled condenser by producing a bypass range and therefore the gadget can be employed as a waste heat retrieval. The warm drinking water acquired can be used for home uses like cleaning, dish washing, showering and so on. Experimental result signifies that on the subject of 200 L of warm water at a temperature around 58 Celsius more than a day could possibly be generated and then the system indicates the cost-effective importance from the energy conservation perspective.

Ambarita et al. [14] have discussed on the general performance of clothes drying chamber with the use of waste heat out of a split-type residential air-conditioner (RAC) have been performed. A drying chamber having a volume of 1m3 had been built and fabricated. The waste heat from condenser of the RAC with power of 800W was used as a heat source.

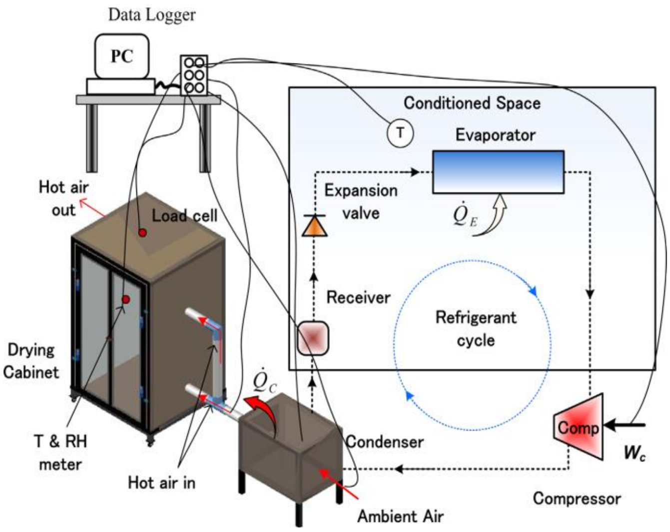

Fig. 6: RAC, experimental apparatus, and data acquisition unit. [14]

Shinde et al. [1] have determined the energy savings concerning better utilization of waste heat from a residential refrigerator. Residential refrigerators potentially perform constantly to maintain appropriate food storage condition. The constant operation of the equipment accounts considerably more electricity consumption. Further, a substantial amount of waste heat is discarded by the condensers of refrigerator. Heat discarded by condenser is of low quality, so this means temperature is low. Therefore, functional applications of waste heat from the residential refrigerators are generally restricted to space heating and water heating system. In order to more efficiently utilize waste heat, the temperature of the waste heat can be raised, to a limited degree, by increasing the condensing pressure of the refrigeration device. Even so, analyses have demonstrated the fact that increasing the condensing pressure to attain high quality waste heat utilizes even more energy than it saves.

Varghese et al. [6] have illustrated the practical feasibility of the heat recovery system to extract heat which is waste from the condenser exit of the refrigerator and use it for heating. The shown work, attempted to retrieve the waste heat out of a 210 L refrigerator, intended for residential requirements. The top chamber of the refrigerator was made as a hot chamber, by extension of the condenser coils, and the connection of the top section, towards top surface of the lower chamber of the refrigerator. Hot chamber and the cold chamber had temperature difference inside hence, was analysed considering the different variables considering the aspects of time, capacity of chamber and load. From the outcomes, it had been founded that the mentioned technique of heat recovery, could be engineered and developed for each and every domestic refrigerator, with the nominal cost. Thus, the reuse of waste heat provided method for optimum energy conservation. This kind of work could be improved by providing better insulation which in turn reduces the heat loss and increases the performance of the system..

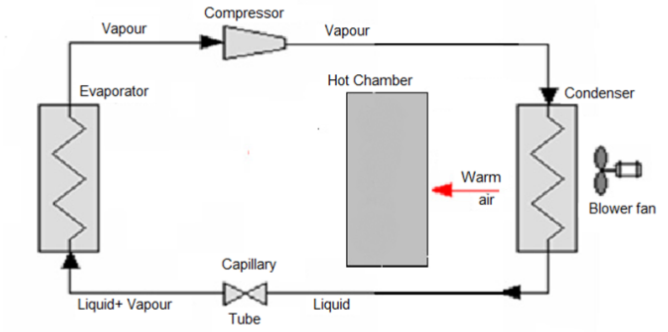

Fig. 7: Compression Refrigerator Systematic Diagram [6]

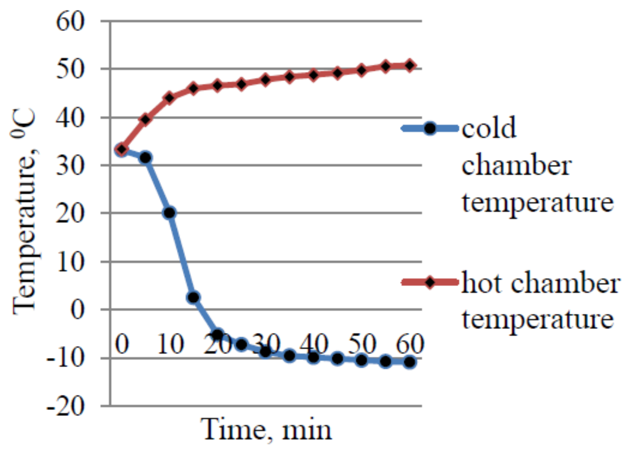

Fig. 8: Temperature-Time plot (without load) [6]

Momin et al. [15] have retrieved waste heat coming from condenser unit of the home refrigerator to enhance the overall performance of the system. Retrieval of heat is from the home refrigerator is by thermos siphon. From the experimentation, it had been noted that after heat retrieving process from the condenser of the home refrigerator its overall COP got raised when compared to conventional refrigerator.

Stalin et al. [16] have focused on the hypothetical evaluation of fabrication of domestic hot water and decline of LPG gas employing air conditioner waste heat. An effort had been taken to retrieve waste heat discarded by 1 TR air conditioning units. With this water-cooled condenser is applied as well as water is enacted by pumping till required temperature is obtained. Then hot water was collected in well insulated container for use. The end result of the paper demonstrates that the temperature of hot water, time needed for obtaining that temperature for the specified volume of water and the lowering of LPG gas by utilizing hot water is additionally discussed. Factors like supply and demand, condenser coil design are considered and hypothetically determined. At last this might be the replacement for hot water heater and so it fulfils most of the applications of hot water. Likewise, it could possibly tackle the requirement of LPG gas.

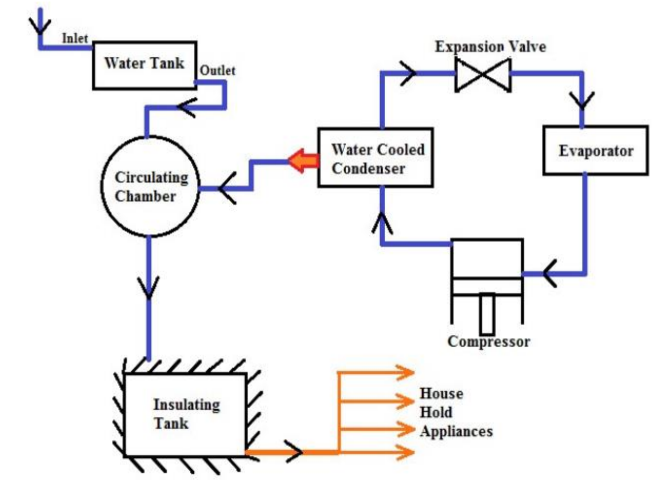

Fig. 9: Flow chart for working of AC integrated Hot water system [16]

Soni [17] have developed ways to use waste heat coming from condenser of refrigerator. This kind of heat can be employed for number of residential and commercial reasons. In minimal constructional and service cost this method is considerably useful for residential motive. It could be beneficial alternative solution to increase functionality and reuse the waste product which is in heat form. The study has unveiled that such process is practically feasible and financially feasible. This system discarded less heat to the natural environment therefore it is safer in environmental attributes.

Prasad [18] have discussed heat transfer by convection in AC by changing the refrigerants are in accordance with CFD and thermal simulation. The evaluation is out on an air-cooled tube condenser of the vapour compression refrigeration system. The components taken into consideration intended for tubes are Copper mineral and Aluminum alloys 6061 and 7075. The checking is out on an air-cooled tube around the condenser of the VCR system. The refrigerants variable can be R22, R134 and R407C. CFD simulation is performed to ascertain temperature distribution and heat transfer rates by changing the refrigerants. Heat transfer simulation is carried out on the condenser to evaluate the desirable materials. 3-dimensional modelling is carried out in CREO and evaluation is performed in ANSYS.

Slama et al. [19] have discussed about the combining of the refrigerator to a cumulus to heat up water, which, the heat yielded towards standard of the condenser of the refrigerating system. The heating up of standard water was performed consequently without energy over consumption. The amount of heat transported by water-cooled condenser is enough to improve the temperature of the latter with 60 °C by the end of 5 hours. This could fulfil entirely or partly certain requirements out of hot water of the family which could dispense its requirements out of hot water almost all day and the week. The amount of heat retrieved by water to heat, increases by four multiples the power usage by compressor. The system therefore enables to conserve energy and also to protect environmental surroundings.

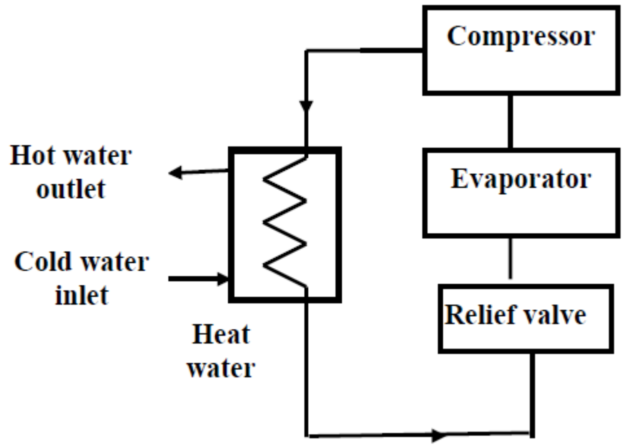

Fig. 10: Diagram of the modified refrigerating circuit to heat water [19]

Sreejith K. et al. [20] have designed, constructed and experimentally analyzed a waste heat retrieval model for residential refrigerator. They'd analyzed the system at several load conditions (No load, 40 W load and 100W load). They even performed the techno-economic evaluation by comparing the waste heat recovery system along with the standard geyser. From gathered testing outcomes, they determined that waste heat recovery system works very well with the home refrigerator. Hot water of moderate temperature can be acquired from it. This kind of changes made residential refrigerator to get work as simultaneously refrigerator and water heater. Considerable amount of hot water during an appreciable temperature could be obtained from the waste heat recovery system.

Agarwal, et al. [21] have given economical approach to raise the COP and utility of the residential refrigerator working with R-134a refrigerant. A cabin was installed on the top of a residential refrigerator with the condenser coils of refrigerator providing as heating coils inside cabin. Known amount of water was heated by condenser coils (as a result of convection currents) thus elevating the overall COP of the refrigerator. Additionally, the utility was improved as it can certainly fulfil the objective of cooking (oven), geysers and so on. Besides, refrigerator can be used as standard refrigerator keeping the cabin door open in the instance of absence of heat sink. It was determined that it is possible to improve the COP up to 11% simply by utilizing a cabin on the top of the refrigerator system. Additional rise in COP is achievable; even so improvements will involve excessive costs.

Yashwanth M. [7] have proposed waste heat retrieval in R & AC System. Using one source from compressor we acquire 3 effective results i.e. warm water, cold water and air conditioning. The refrigerant utilized in the component is usually R-290 combined with R-134a which is usually comparative to R-22. Evaporative cooler generates good cooling by merging a normal procedure water evaporation with a basic, dependable air shifting system. Evaporative cooling is considered the most cost-effective and powerful method of refrigeration and air conditioning, as its release especially in the locations where weather circumstances are warm and dried out. The energy conserving by performing so is usually preserved even more than 30 watts. It is usually known as a little size dessert cooler.

Krishna, et al. [22] have discussed condenser of the air conditioning unit which is attached with a co-axial copper pipe by means of a spiral coil and is linked to water tank via the pipes to heat up the water to be employed for residential purposes. The outcomes demonstrated for AC (air conditioner) of 1.5 TR are; temperature of the water in the heating tank could be increased via preliminary temperature of the water 28°C to 57°C within 15 to16 minutes, the temperature from the evaporator could be reduced below within short while. By using this kind of heat recovery units, compressor performance could be increased and also, hot water intended for residential purposes could be constantly acquired. The outcome is quicker cooling and long-term compressor life as well as the AC system was determined to be higher COP when compared to those of conventional AC. This system is quite simple and cheap and capable to save the water heating cost and also, safe in environmental aspects.

3. CONCLUSIONS

This paper initiated a review based research into Waste Heat Utilization of a Domestic Refrigerator by recovering heat using water heater chamber in between compressor and condenser. This work offers tremendous significant for developing new technologies pertains to heat recovery from a domestic refrigerator, in order to achieve hot water at low initial cost, no harmful effect and safer in environment aspect. So, more attention is needed in this area and lots of work has to be done based in terms of its background, originality, current status, and researches.

REFERENCES

[1] Shinde Tanaji Balawant, Dhanal Shailendra V., Mane Shirish S., Experimental Investigation of Waste Heat Recovery System for Domestic Refrigerator, International Journal of Mechanical Engineering and Technology (IJMET), Volume 5, Issue 8, 2014, 73-83

[2] Kaushik S.C., Panwar N.L. And Reddy V. Siva, Thermodynamic Evaluation of Heat Recovery Through a Canopus Heat Exchanger for Vapor Compression Refrigeration (VCR) System, J Therm Anal Calorim, 2012, 1493–1499

[3] Stinson G. E., Design principles of refrigeration waste energy recovery, Aust Refrig Aircond Heat, 1985, 25–30

[4] Tile Vijaykumar G, S. Shivashankara B., R. Raghavendra R., K Sajjan Acharya and V. Vishal Somanna K., Review on Exhaust Gas Heat Recovery for I.C. Engine Using Refrigeration Systems, International Journal on Emerging Technologies, 2016, 154-157

[5] Rajput R.K., Thermal Engineering, New Delhi: Laxmi Publications, Tenth edition,2010

[6] Varghese Reny, Raju Nithin, M. Rohit, Antony Roshan Thomas, Mathew Tom, Heat Recovery System in Domestic Refrigerator, International Journal for Research & Development in Technology, Volume 2, Issue 2, 2014, 16-20

[7] Yashwanth M., Utilization of Heat Energy in R & AC Systems, International Journal of Science and Research (IJSR), 2013, 2319-7064

[8] Dossat J. Roy, Principles of Refrigeration, Prentice Hall: Pearson Hall Education, 1997

[9] Elumalai P., Vijayan R., Ramasamy K.K. And Premkumar M., Experimental Study on Energy Recovery from Condenser Unit of Small Capacity Domestic Refrigerator, Middle-East Journal of Scientific Research 23 (3), 2015, 417-420

[10] Maurya Satish K., Awasthi Saurabh, Waste Heat Recovery: An Analytical Study of Combined Ejector and Vapour Compression Refrigeration System, International Journal of Engineering Sciences & Research Technology, 2014, 1422-1425

[11] Walawade S.C., Barve B.R. And Kulkarni P.R. Design and Development of Waste Heat Recovery System for Domestic Refrigerator, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), ISSN: 2278-1684, 28-32

[12] Vedil S.N., Kumar A. And Mahto D., Waste Heat Utilization of Vapour Compression Cycle, International Journal of Scientific and Research Publications, Volume 4, Issue 11, ISSN 2250-3153, 2014, 1-4

[13] Sreejith K., S.Sushmitha, Das Vipin, Experimental Investigation of a Household Refrigerator Using Air-Cooled and Water-Cooled Condenser, International Journal of Engineering And Science, Vol.4, Issue 6, 2014, 13-17

[14] Ambarita Himsar, Nasution Abdul Halim, Siahaan Nelson M. And Kawai Hideki, Performance of a Clothes Drying Cabinet by Utilizing Waste Heat from a Split-Type Residential Air Conditioner, Case Studies in Thermal Engineering, 2016, 105-114

[15] Momin G.G., Deshmukh S.R., Deshmukh M.T., Chavan P.T., Choudhari P.P., COP Enhancement of Domestic Refrigerator by Recovering Heat from the Condenser, International Journal of Research in Advent Technology, Vol.2, No.5, 2014, 402-406

[16] Stalin M. Joseph, Krishnan S. Mathana, Kumar G. Vinoth, Efficient Usage of Waste Heat from Air Conditioner, International Journal of Advances in Engineering & Technology, Vol. 4, Issue 1, 2012, 414-423

[17] Soni Lakshya, Kumar Pawan, Goyal Rahul, Waste Heat Recovery System from Domestic Refrigerator for Water and Air Heating, International Journal of Engineering Sciences & Research Technology, 2016, 500-507

[18] Prasad P., Improving the Heat Transfer Rate of AC Condenser by Optimizing Material, Interntional Journal of Scientific Engineering and Technology Research, Vol.06, Issue.13, 2017, 2512-2516

[19] Slama Romdhane Ben, Thermodynamic Heat Water by The Condenser of Refrigerator, Int. Symp. On Convective Heat and Mass Transfer in Sustainable Energy, 6029 Gabes Tunisia, 2009

[20] Sreejith K., T.R. Sreesastha Ram, Mossas V.J., Nidhin M.J., Nithil E.S., Sushmitha S., Experimental Investigation of Waste Heat Recovery System for Household Refrigerator, International Journal of Engineering and Science, Vol.6, Issue 4, 2016, 19-23

[21] Agarwal Tarang, Kumar Manoj, Gautam Praveen Kumar, Cost-Effective COP Enhancement of a Domestic Air Cooled Refrigertor Using R-134a Refrigerant, International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 11, 2014, 300-305

[22] Krishna A. Vamshi, Reddy M. Venkateshwara, Gowd A.E. Rana, Experimental Investigation on Recovery of Waste Heat from Window Air Conditioner, International Journal of Core Engineering & Management, 2017, 218-233

BIOGRAPHIES

Dhananjay Parmar
Research Scholar, Department of Mechanical, ITM University, Gwalior, India

Neelesh Soni
Assistant Professor, Department of Mechanical, ITM University, Gwalior, India