

A Review on Fabrication of Combined Refrigerator cum Air Conditioning cum Water Heater Unit by VCRS

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ABSTRACT: The objective of this project was to determine the energy savings associated with improved utilization of waste heat from a domestic refrigerator. The continual operation of this equipment accounts more electrical energy consumption. Furthermore, a significant amount of waste heat is rejected by the condenser of refrigerator. The heat rejected by condenser is of low quality, meaning temperature is low. Thus, practical uses of waste heat from the domestic refrigerators are typically limited to space heating and water heating.

The refrigeration cum air-conditioning cum water heater system works on basic cooling cycle - Vapour compression refrigeration cycle(VCRS). The system operates on a single compressor and performs both the refrigeration and air conditioning functions. It is an energy efficient system as it offers the triple benefits. This can be used for the commercial as well as domestic purposes.

The idea of this project explores the possibility of combining three units i.e. Refrigerator, Air-Conditioner and water heater into a single unit, such that the device saves energy and the lot of space. The name of the device is termed as Refrigerator cum Air-Conditioner cum water heater where all are working on the cost of only Refrigerator. This is how we can try to make the environment and a common man comfortable. This project is about attempt to merge domestic Refrigerator and Air conditioner into a combined system. In all metropolitan cities, environment degradation due to automobile & other factors is on the rise, therefore the requirement of air-conditioner has already been felt.

Normal refrigerator works on VCRS, extract heat from substance to be cooled and exert that heat to the atmosphere through the device called condenser. That refrigerator which is been previously made to exert a lot of heat through condenser is modified to overcome this wastage of heat. It saves a lot of space as 3 machines are combined in a single unit.

KEYWORDS: Combining three units, Refrigerator cum Air-Conditioner cum water heater, Vapour compression refrigeration cycle.

I. INTRODUCTION

The **refrigeration cum air-conditioning cum water heater system** works on basic cooling cycle - **Vapour compression refrigeration cycle(VCRS)**. The system operates on a single compressor and performs both the refrigeration and air conditioning functions. It is an energy efficient system as it offers the triple benefits. This can be used for the commercial as well as domestic purposes.

The idea of this project explores the possibility of combining three units i.e. Refrigerator, Air-Conditioner and water heater into a single unit, such that the device saves energy and the lot of space. The name of the device is termed as Refrigerator cum Air-Conditioner cum water heater where all are working on the cost of only Refrigerator. This is how we can try to make the environment and a common man comfortable. This project is about attempt to merge domestic Refrigerator and Air conditioner into a combined system. In all metropolitan cities, environment degradation due to automobile & other factors is on the rise, therefore the requirement of air-conditioner has already been felt. The motivation for the project comes from rising energy demands and hence its cost. As we all know that we are lacking of

power resources, so this product will help us in tackling this problem as we are trying to make a personalized cooling system which will run at a very low cost that can be afforded by a common man. In minimum construction, maintenance and running cost, this attempt is quite useful for domestic purpose so that our ultimate aim of the project that is those who cannot afford an Air Conditioner can have the comfort of Air Conditioner could be completed. Since all energy cost are on a rise, therefore this project is a way forward in realizing the economic as well as environmental demands. As it is said “the energy saved is the energy produced”. On the other hand the common man can have the comfort of Air conditioner. Domestic refrigerator consumes significant amount of energy in buildings like hospitals, hotels, multifamily buildings. By recovering part of energy for air conditioning effect energy can be saved. Since variation of outdoor air temperature is small in tropical countries, cooling is needed year round. This is the best condition to perform combined effect of refrigerator and air conditioners for energy saving. A prototype combined air-conditioning cum refrigeration cum water heater is designed and built.

Normal refrigerator works on VCRS, extract heat from substance to be cooled and exert that heat to the atmosphere through the device called condenser. That refrigerator which is been previously made to exert a lot of heat through condenser is modified to overcome this wastage of heat. For recovery of that waste heat we decide to develop a machine which utilizes that waste heat for heating water with the use of water heater. The main important thing in our model is, it does not require any kind of additional power supply for its working operation. As the energy saving plays vital role in development, our model has lot of importance from that particular point of view. Another interesting thing in this project is that it performs operation without disturbing original refrigerator working. The refrigerator that we use in our daily routine release lot of heat which goes waste but as per the accessories that attached we have used i.e. Hot water tank used above heat and fulfill the purpose. After the attachment of water heater the efficiency of refrigerator is not affected. The machine fabricated has good utilization in hotels, dairy, industry and also useful for domestic purpose. The serving cooling and heating both the purpose. The wasted heat from condenser utilized for the water heating. This can be used for the commercial as well as domestic purposes. This machine is made by the combination of an air conditioner with refrigerator and water heater System. It can be used in as air conditioner or water heater and a refrigerator. The heat absorbed by the AC can be used in the vaporization of refrigerant and in condenser waste heat eject from the condenser utilised for water heating purpose. It saves a lot of space as 3 machines are combined in a single unit. A unique feature about this is at any time you can switch to start the system. Also it conserves water as the water released by Air Conditioner System can be used for heating water. If you want to drink cool water, you can use the refrigerator box. This is designed for middle class family mainly. For saving energy 1st we can start refrigerator and ac in the room then waste heat from Condenser heat the water.

Waste heat recovery depends upon the various sources of application and temperature range. It broadly classified as given in table 1 below,

Sr. No.	Type of heat Recovery	Remark
1	High Temperature Heat Recovery (650-1650°C)	These type of heat recovery results from direct fuel fired processes of industrial process equipment in the high temperature range.
2	Medium Temperature Heat Recovery (230-650°C)	Most of the waste heat in this temperature range comes from the exhaust of directly fired process units in medium temperature range.

3	Low Temperature Heat Recovery (27-230°C)	These type of heat recovery results from bearings, welding machines, injection molding machine, Annealing furnaces, forming dies, Air compressor, pumps, Internal combustionengine, Air conditioning and refrigeration condensers, Drying, baking and curing ovens, Hot processed solid or liquid etc.
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A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators.

Heat can be recovered by using the water-cooled condenser and the system can work as a waste heat recovery unit. The recovered heat from the condenser can be used for bathing, cleaning, laundry, dish washing etc. Typical waste heat temperature for Air conditioning and refrigeration condensers are 32 to 43°C. Low temperature waste heat may be useful in a supplementary way for preheating purposes. Keeping this in mind, a technique for condensing heat of the refrigeration system is proposed in this paper. The proposed system employs a combined air and water-cooling (desuperheating) technique for condensing heat of refrigeration system. This new system provides not only the refrigeration effect, but also hot water.

II. RELATED WORK

Many Scientist and Engineers have done the research on the concept of possibility of combining two units i.e. Refrigerator and Air-Conditioner into a single unit and Waste heat recovery. Here is the review of some researcher regarding their research in the field of refrigeration cum air-conditioning cum water heater system.

In a paper published by Mr. V.D.Navle, Prof.J.N.Yadav titled as "Design, Construction of Combined Airconditioning and Refrigeration Unit" et al.^[1] in which by recovering part of energy for air conditioning effect energy can be saved. Since variation of outdoor air temperature is small in tropical countries, cooling is needed year round. This is the best condition to perform combined effect of refrigerator and air conditioners for energy saving. A prototype combined air-conditioning and refrigeration is designed and built.

Refrigeration system using CO₂ was commonly applied in marine sector. At that time, this machine was operated as subcritical cycle. There had been operating problem with this system when the ship was passing through hot water temperature where its cooling capacity drops rapidly (Lorentzen, 1995)^[2]. To increase the cooling capacity, some additional CO₂ had to be charged into the system and then discharged when air temperature has decreased, which of course was not a good practice from operational practice point of view. This problem has been solved by the invention of Prof. Gustav Lorentzen who suggest transcritical cycle in place of subcritical cycle which make possible to operate the transcritical cycle like subcritical cycle without a need of charging and discharging CO₂ manually.

Experiments on mobile air-conditioning system have been performed and they showed the performance of CO₂ system was higher at low ambient temperature (below 35°C) but lower at higher ambient temperature (above 35°C) compared to R134a system (Furuya, 1999)^[3].

Another research paper titled as "Heat utilization from refrigerator condenser using water heater and hot box" et al.^[4] that, it heat water up to 55-60 degree in water heater and maintain temperature up to 45-50degree in Hot Box. The refrigerator that we use in our daily routine release lot of heat which goes waste but as per the accessories that attached we have used i.e. Hot Box and Hot water tank used above heat and fulfill the purpose. After the attachment of Hot Box and water heater the efficiency of refrigerator is not affected. The machine fabricated has good utilization in hotels, dairy, industry and also useful for domestic purpose.

In one article by Sreejit k published journal papers on "Experimental Investigation of A Domestic Refrigerator Having Water-Cooled Condenser Using Various Compressor Oils"^[5] stating that condenser coils can be used for floor heater. Household refrigerator is common appliance that consists of thermally insulated compartment and which transfers heat from inside compartment to its external environment so that the condenser coil gets heated and can be used as a floor

heater by simply forming a floor by adjusting the coil to the floor. So the floor heater can be used for heating water and many other purposes.

S.C. Kaushik^[6] et al. presents an investigation of the feasibility of heat recovery from the condenser of a vapour compression refrigeration (VCR) system through a Canopus heat exchanger (CHE) between the compressor and condenser components. The presence of the CHE makes it possible to recover the superheat of the discharged vapour and utilize it for increasing the temperature of the external fluid (water) removing heat from the condenser. The effects of the operating temperatures in the condenser and evaporator for different inlet water temperatures and mass flow rates on the heat recovery output and its distribution over the condenser and CHE (the fraction of the condenser heat available through the CHE), available outlet water temperature and heat recovery factor have all been studied and optimum operating parameters for feasible heat recovery have been ascertained. The parametric results obtained for different working fluids, such as R-22, R-12, R-717 and R-500, have been presented. It is found that, in general, a heat recovery factor of the order of 2.0 and 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions.

Dr.M.S.Tandale^[7] et al. presented a case study on Super Heat Recovery Water Heater At Worli, Dairy. They used R717 Kirloskar Reciprocating Compressor having refrigeration system capacity of 270 TR (950KW). The Inlet & Outlet temperature of Refrigerant are 115 & 60°C. The Inlet & Outlet temperatures of Water are 25 & 70°C. They installed super heat recovery water heater in counter current mode. The hot water flow rate is 70000 L/day. In this system fuel saving is about 390 l FO/day. The annual saving is near about Rs.23 Lac/year. Also the reduction in CO₂ emissions is 330 ton/year.

Romdhane ben slama^[8] developed a system that can recover heat from the condenser of the refrigerator. In this work air-cooled conventional condenser is replaced by another heat exchanger to heat water. The results show that water at a temperature of 60°C was produced by the system. This paper also analysed the economic importance of the waste heat recovery system from the energy saving point of view.

Sheng shan Bi et al^[9] experimentally investigate the performance of a domestic refrigerator using TiO₂-R600a nano-refrigerants. The test results shows that refrigerator performance was better than the pure R600a system ,with 9.6% less energy used with 0.5 g/L TiO₂-R600a nano-refrigerant.

S.S. Hu, B.J. Huang et al^[10] conducted an experimental investigation on a split air-conditioner having water cooled condensers. They developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operations. The experimental investigation verified that the water cooled condenser and cooling tower results in decreasing the power consumption of the compressor.

H.I. Abu- Mulaweh^[11] designed and developed a thermosyphon heat recovery system which can recover heat from a window air conditioner. They design two types of heat exchangers, concentric type heat exchanger & coiled heat exchanger and then it is retrofitted in to the air conditioning system. They analysed the performance of the system with these two types of heat exchangers. The circulation of water through the heat exchanger is done with the thermosyphon effect which completely eliminates the need of pump. For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the super-heated refrigerant the hot water flow upward through the connecting pipe into the top of the storage tank and at the same time the cold water from the bottom of the tank will flow into the heat exchanger. The test result show that the concentric heat exchanger produce hot water at a temperature of 45°C and the coil type produced hot water having 40°C.

Sheng-shan Bi et al^[12] experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and TiO₂ nanoparticles in the working fluid. The result indicated that the energy consumption of the HFC134a refrigerant using SUNISO 3GS mineral oil and 0.06% mass fraction of TiO₂ nanoparticle mixture as lubricant reduced the energy consumption by 21.2% when compared to that of HFC134a and POE oil system.

Mukuna and Kilfoil^[13] investigated the technical feasibility of combined refrigerator/heat exchanger and geyser system. It was concluded that 0.8 % of the total input energy in the geyser was saved in cycling mode of the refrigerator and continuous mode of the geyser. However, the refrigerator's effectiveness was reduced because the refrigerant was not cool enough.

Patil and Dange^[14] modified a domestic 190 liter refrigerator to recover the waste heat by installing a water tank containing the condenser coils of refrigerator. Experiment showed that maximum temperature increment was up to 40 degree centigrade. But major drawback with this type of arrangement was that it had no mobility and cannot be used for domestic purposes.

Sreejith ^[15] investigated the effect of different types of compressor oil in a domestic refrigerator with water cooled condenser. The experiments were done using HFC134a as the refrigerant, Polyester oil (POE) oil and SUNISO 3GS mineral oil. It was concluded that the HFC134a/SUNISO 3GS mineral oil system worked normally and efficiently in the household refrigerator with water-cooled condenser and the energy consumption of the HFC134a refrigerator using SUNISO 3GS mineral oil as the lubricant reduced the energy consumption of the household refrigerator between 8% and 11% for different loads.

Momin et al. ^[16] recovered waste heat from condenser unit of a household refrigerator to improve the performance of the system by using a thermosyphon. It was found that after recovering heat from the condenser of the conventional refrigerator, its performance was improved than conventional refrigerator. It was concluded that the theoretical COP of the system was more than the system running with air cooled condenser.

M. M. Rahman et al. ^[17] developed a heat recovery system which can recover heat from a split air conditioning system. In this case, 60 litre heating tank is designed in a way that the copper tube conveying refrigerant is not submerged in water. The heating recovery tank consists of two cylindrical chambers, the inner chamber, is filled with water, is coiled with the hot refrigerant carrying tube at the outer surfaces. It was found that this heat recovery system improved the compressor efficiency and at the same time continuously supplied warm water for domestic purpose. This system rejected less heat to the environment so it is safer in environmental aspects.

R.A Clark *et al.* ^[18] described the design, construction, and testing of an integrated heat recovery system which was designed both to enhance the performance of a residential refrigerator and simultaneously to provide preheated water for an electric hot water heater. The particular opportunity investigated in that study was to preheat the supply water for a hot water system using refrigerator condenser waste heat. An economic analysis revealed that a savings of 18.3 % on the water heater operating cost was possible. The R-12 used in that project was not friendly to the ozone layer. The time to increase the temperature of water of 30 °C in the no use test was five days. Thus the apparatus developed in this experimental study did not heat water quickly enough.

Sanmati Mirji ^[19] presented a multipurpose warming apparatus utilizing the waste heat of domestic refrigerator. The multipurpose apparatus was constructed as an additional part of the refrigerator. It uses the waste heat generated by the refrigerator and has several possible household uses like food warming, domestic fermentation purpose such as curd making, fermentation for Indian food. The maximum temperature of the chamber got as high as 50°C and the average temperature was around 40 °C. The main advantage of the invention was to keep cooked food warm for a sufficiently long duration before consumption as well as warming the food removed from the refrigerator before consumption. It makes use of the waste heat generated by the domestic refrigerator and does not need any additional power supply. Crown et al. ^[20] discussed the findings of 'An experimental study designed to show the effect of changing refrigerants on the performance of a refrigeration system'. It was concluded that COP and cooling capacity of R-134a proved to exceed that of R12 for the majority of test conditions. The values of COP and capacity of R134a were maximum of 5.4% and 6.8% higher than that of R-12, respectively.

Reviewing all above papers published by researchers I am going to study the concept of possibility of combining two units i.e. Refrigerator and Air-Conditioner into a single unit and Waste heat recovery.

III. CONCLUSION

This paper undertook a review based study into COP Enhancement of a Domestic Air Cooled Refrigerator by recovering heat from Condenser in terms of its background, originality, current status, and researches. This all work has great significant for developing new technologies relates to heat recovery from a domestic refrigerator, in order to get cooling at low energy cost, no harmful effect to environment and also having low initial cost. So more attention is required in this area and lot of work has to be done. Domestic refrigerator consumes significant amount of energy in buildings like hospitals, hotels, multifamily buildings. By recovering part of energy for air conditioning effect energy can be saved. Since variation of outdoor air temperature is small in tropical countries, cooling is needed year round. This is the best condition to perform combined effect of refrigerator and air conditioners for energy saving. A prototype combined air-conditioning and refrigeration is designed and built. It is evident from above investigation that the machine called as "Refrigerator with Hot Box And water Heater" performs the best result and heat water up to 55-60 degree in water heater and maintain temperature up to 45-50 degree in Hot Box. The refrigerator that we use in our daily routine release lot of heat which goes waste but as per the accessories that attached we have used i.e. Hot Box and Hot water tank used above heat and fulfill the purpose. After the

attachment of Hot Box and water heater the efficiency of refrigerator is not affected. The machine fabricated has good utilization in hotels, dairy, industry and also useful for domestic purpose. The serving cooling and heating both the purpose.

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