Middle-East Journal of Scientific Research 23 (3): 417-420, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.03.22156

Experimental Study on Energy Recovery from Condenser Unit of Small Capacity Domestic Refrigerator

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Abstract: This paper presents an investigation on heat recovery from the condenser of the Vapour Compression Refrigeration (VCR) system through hot oven and heater which is placed between the compressor and condenser components. The presence of oven makes it possible to recover the superheat of the discharge vapour and utilize it for increasing the temperature of the space inside the hot oven and increase the temperature of the water in the heater chamber. Temperature of the juice in the juice cooler chamber is also reduced by pumping the juice in a separate heat exchanger tube attached with the evaporator tube and the cooled juice is stored in the juice cooler chamber. The effectiveness of the cooler with varying working time has been studied. The effect of operating temperature in the oven and heater for varying operating time of a refrigeration system have all been studied and feasible heat recovery have been ascertained. The parametric result obtained for varying working hours have also been presented.

Key words: Waste heat recovery · Vapour compression refrigeration system · Hot oven · Water heater · Juice Cooler

INTRODUCTION

Energy saving is one of the key issues not only from the view of energy conservation but also for the aegis of global environment. Energy conservation is now faced with the challenge of applying the latest technology for facilities and improvements that can be justified on its own merits. In the present world energy spectrum and energy management plays an important role. Energy conservation is the technique to be adopted to face the energy crisis under these circumstances. Waste heat is the heat, which is generated in a process by the way of fuel combustion or chemical reaction and then "dumped" into the environment even though it could still be utilized for some useful and economic purposes. Waste heat, in most general sense, is the energy associated with the waste streams of air, gases and liquids that leave the boundaries of a plant or building and enter into the environment. Waste heat which is rejected from a process at a temperature high enough above the ambient temperature permits the recovery of energy for some useful purposes in an economic manner.

By experimenting with waste heat recovery system in refrigeration unit, Kaushik et al have found that in general, 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions [1, 2]. Sathiamurthi P et al discussed in his studies on waste heat recovery from an air conditioning unit that the energy can be recovered and utilized without sacrificing comfort level and also he has designed and developed the waste heat recovery system for air conditioning unit [3, 4]. Rahman et al investigated on the waste heat recovery equipment from split air conditioner unit. In their research, the condenser unit was replaced by a copper tube, which was sunken in a water tank in order to get warm up the water which could be used for domestic purposes. The results have shown that the temperature of the water in the tank can be increased from 25°C to 42°C and subsequently, evaporator temperature can be denied from 27°C to 18°C within 7 minutes [5]. Stalin, et al carried out the usage of waste heat from air-conditioners efficiently. The work engrossed on hot water for several applications using heat renounced by the air-conditioner system [6]. Abu-Mulaweh et al discussed that

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a thermo siphon heat recovery system in which heat is rejected from a small capacity air-conditioner by experimentation. The work was designed and constructed experimentally. According to the report, energy recovery from an AC with help of thermo siphon was astonishing for the reason which it eliminates the requirement for a circulating pump [7].

In this paper, the authors have investigated about utilisation of waste energy and conducted experiments to recover condensation heat (heat rejected) and evaporator cooling from a commercial refrigeration system of 165 litre capacity. The refrigeration unit rejects considerable amount of heat to the atmosphere through its condensing coil unit. Therefore, by suitably fitting the hot oven and heater in the refrigeration unit, hot water and heat in the oven is generated. The heat available in the oven is used to heat food particles and hot water is used for drinking purpose. By installing juice cooler with the evaporator the cooling loss due to opening and closing the door of the refrigerator is reduced and cooled juice is obtained in the tap outside the system. Thereby saves significant amount of energy.

MATERIALS AND METHODS

The proposed waste heat based hot oven and hot water system produces heat by recovering waste heat from the condenser of the conventional refrigeration system. The layout of the proposed system is shown in Fig.1.

The existing refrigeration system has air cooled condenser. A compactable hot oven and hot water chamber is inserted between the compressor discharge and condenser. Thermostat arrangement is added to control the heat in hot oven and the heater so that overheating is also avoided. Heating of food particles is done by placing it in the hot oven chamber and water line connected with the float valve in the heater chamber for inlet of normal water. The food particles and chamber water is heated from the waste heat of refrigeration system.

In addition with the hot oven and heater, juice cooler is also installed in the separate line to store the juice outside the refrigerator in cold condition. For this normal juice is pumped into the evaporator coil by means of copper tube and then it is stored in the insulated cooler chamber. From this the temperature of the juice is absorbed in the evaporator coil and cooling effect in the juice is obtained. The cooling control is done by the cooling thermostat of the refrigeration system.

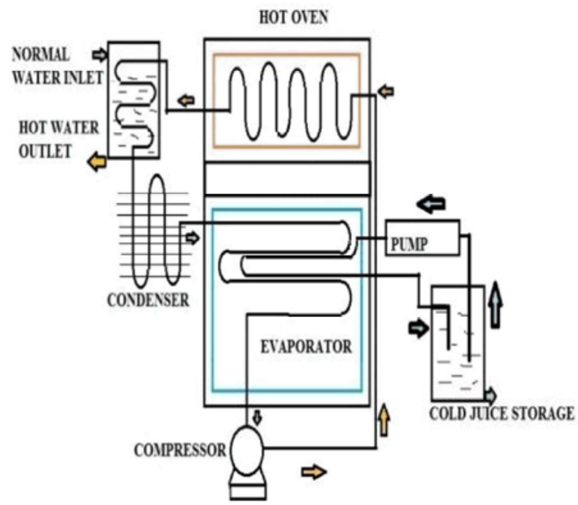

Fig. 1: Schematic layout of Refrigerator coupled with hot oven, heater and juice cooler.

The expected temperature of the respective components (Compressor, Condenser and Evaporator) is obtained due to the continuous running of refrigeration system with the thermostat control.

Experimental Setup: The following experimental facility has been created. Highly insulated hot oven box and heater vessel with 5 litre capacity is installed in the compressor outlet. The control of water inlet to the heater vessel is done by float valve attached inside the chamber. The high pressure high temperature vapour refrigerant is made to pass through the copper tube which is coiled inside the hot oven and heater chamber. The copper tube is highly insulated outside the oven and heater with asbestos rope. Oven box is also fully insulated with foam or fibre wool to prevent loss of heat to atmosphere. By this the heat of the refrigerant is emitted only inside the hot oven and heater chamber and the waste heat is recovered and utilised for useful purpose.

A juice in the juice cooler vessel is pumped through the copper tube which is coiled inside the evaporator. The temperature of the juice is reduced and it is stored in the same chamber separately outside the refrigerator. When refrigerator operates, due to the flow of refrigerant the waste heat is utilised in oven and heater chamber. Pump running along with the compressor is used to reduce the temperature of the juice in the juice cooler. The experimental setup is shown in Fig.2 (a,b)

Fig. 2(a): Front view

Fig. 2(b): Back side view

RESULTS AND DISCUSSION

After preliminary trials for few days, an experiment was carried out. Hot oven was closed and also 5 litres of water was poured in the heater chamber and thermometer was attached with oven and heater separately. 5 litres of juice was also poured in the cooler chamber and the pump was connected with the cooler chamber. The various operating parameters which have been measured during the time of experiment are tabulated below:

Various parameters of conventional refrigeration system used for experiment are:

Capacity of refrigerator:	165 litres
Type of compressor:	Reciprocating type
Capacity of compressor:	1/6 HP: 124 watts
Length of condenser coil:	30 Feet: 90 cm
Refrigerant gas used:	R 134 a
Atmospheric temperature during experiment:	29.2°C

Table 1: Compressor inlet and outlet Pressures

Parameters	Domestic Refrigerator kg/cm^2	Proposed Refrigerator kg/cm^2
p_{cd}	15.8	14
p_{ci}	0.8	0.8

Table 2: Variation of temperature on Compressor, Condenser, Evaporator and Expansion valve

Parameters	Domestic Refrigerator °C	Proposed Refrigerator °C
T_{co}	48	50
$T_{con.o}$	39	35
$T_{exp.o}$	37	34
$T_{ev.o}$	24	23.6

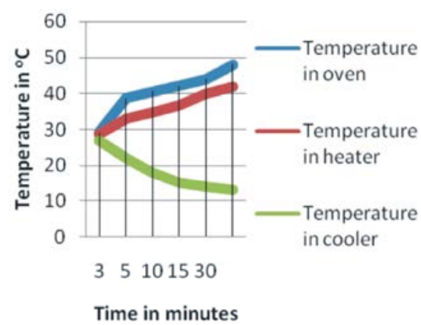

Fig. 3: Variation of temperature of influenced components with respect to time,

Pressure parameters were measured using pressure gauge and Temperature parameters were measured using digital thermometer.

Temperature variation with respect to time in the proposed system is also measured and tabulated. The graph for temperature variation in installed components is shown in Fig.3.

At the time of measurement the temperature of refrigerant entering into the oven was 45°C. After flowing through the coiled copper tube inside the oven and emitting some amount of heat inside the oven, the outlet temperature of refrigerant from the hot oven was 41°C. After nearly 4 heat emissions taking place, the temperature of refrigerant at the inlet of heater chamber was 39°C and after transferring heat to the water its temperature reduced to 36.5°C.

From this proposed system we can get the temperature up to 48 in oven and 42 in water at a time period of 30 minutes continuous running. By this we can utilise the waste heat emitted to the atmosphere for useful purpose and we can also save our power consumption for heating water and also for cooler.

ACKNOWLEDGEMENT

This study was supported by Paavai Engineering College, Pachal, Namakkal (Dist.) Tamilnadu, India

NOMENCLATURE

Acronyms

VCR - Vapour Compression Refrigeration

LPG - Liquefied Petroleum Gas

Subscripts

p_{cd} - Compressor discharge pressure, kg/cm^2

p_{ci} - Compressor inlet pressure, kg/cm^2

T_{co} - Compressor outlet temperature °C

$T_{con.o}$ - Condenser outlet temperature °C

$T_{exp.o}$ - Expansion valve outlet temperature °C

$T_{ev.o}$ - Evaporator outlet temperature °C

CONCLUSION

From the above experimental analysis, It was perceived that by installing hot oven and heater chamber in the compressor outlet, It can be utilized the maximum heat emitted to the atmosphere for heating the food particles and also for heating the drinking water. By this system the power consumption and LPG consumption in a house for heating food items and water can be reduced. Thus the waste energy emitted to the atmosphere is utilized for useful purposes and the demand for power is reduced.

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