Research Inventy: International Journal of Engineering And Science
Vol.6, Issue 4 (April 2016), PP -19-23
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Experimental Investigation of Waste Heat Recovery System for Household Refrigerator

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ABSTRACT :- *Household refrigerator generally use air-cooled condenser. Most of the time the heat from the condenser side is dissipated to room air. If this heat is not utilised, it simply becomes waste heat. By retrofitting a waste heat recovery system this waste heat can be recovered and can be utilised for water heating purpose. The hot water thereby produced can be used for several residential and commercial usages. The hot water can also be stored in an insulated tank for later use. In our main project, we had designed, fabricated and experimentally analysed a waste heat recovery system for domestic refrigerator. We had analysed the system at various load conditions (No load, 40 W load and 100W load). We also carried out the techno-economic analysis by comparing the waste heat recovery system with the conventional geyser. From our obtained test results, we found that the waste heat recovery system performs well along with the household refrigerator. Hot water of moderate temperature can be obtained from it. This modification made the household refrigerator to be work as both refrigerator and water heater. Considerable amount of hot water at a significant temperature can be collected from the waste heat recovery system.*
KEYWORDS: - *Household refrigerator, waste heat recovery system, effectiveness, techno-economic analysis*

I. INTRODUCTION

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. In most cases, household refrigerator uses air-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air- conditioners and are using POE oil as the conventional lubricant. Generally, heat from the condenser side is dissipated to room air. If this heat is not utilised, it simply becomes waste heat. By retrofitting a waste heat recovery system this waste heat can be recovered and can be utilised for water heating purpose. The hot water thereby produced can be used for several residential and commercial usages. The hot water can also be stored in a tank for later use. The modified system results in energy saving due to non-usage of electricity for heating the water and cost saving by combining both utilities (refrigeration and heating) in one system. The hot water which was obtained from the water-cooled condenser can be utilised for household applications like cleaning, dish washing, laundry, bathing etc.

II. EXPERIMENTAL SETUP

II.1. Experimental System

The refrigerator was of 165L capacity, single door, manufactured by Godrej. The system was retrofitted with a Waste Heat Recovery System (WHRS). WHRS is a single tube heat exchanger coiled around and over the air-cooled condenser and compressor and having an inlet for the cooling water and an exit for collecting the hot water. The modified household refrigerator was properly instrumented with digital thermometer, pressure gauges and digital energymeter.

The temperature at various points was noted using digital thermometer. Evaporator and condenser pressure are noted using calibrated pressure gauges. The power consumption of the domestic refrigerator was measured by using a digital energymeter. Figure 1. shows the experimental test rig. The retrofitted WHRS can also been seen. The refrigerator specifications are given in TableI.

The waste heat recovery system is suitably attached over the air-cooled condenser and compressor. The cold water is then passed from one end and hot water is collected from the other end. PVC valves are provided to control the flow of water through the waste heat recovery system. Measuring instruments are used to measure various parameters.

Figure 1: Experimental Test Rig

Table I: Refrigerator Specifications

Gross capacity	165 L
Refrigerant	HFC134a
Charged mass	140 g
Compressor type	Hermetic

II.2. Experimental Procedure

Schematic diagram of the experimental apparatus is shown in Figure 2. After the integration of the components, the valves were adjusted to maintain the required volume flow rate through the WHRS. At each load conditions (No Load, 40W load and 100W load) temperature and pressure at salient points were noted down before and after attaining the steady state condition in the evaporator. The energy consumption of the system is measured using a digital energymeter. The temperature of the water at inlet and exit of WHRS was also measured.

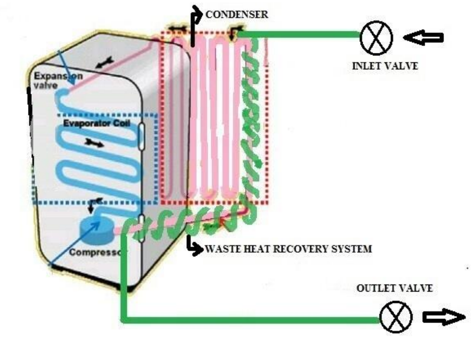

Figure 2: Schematic diagram of the experimental test rig

Techno economic analysis was done by comparing the waste heat recovery system with the conventional geyser (water heater). The geyser selected is the most sold type in India. The capacity of geyser is 10L and the power rating of it is 3000W.

III. RESULTS AND DISCUSSIONS

Figure 3 gives the comparison of the work done by the compressor on various load conditions. From the result it is found that when the pressure difference increases, the work done by the compressor also increases.

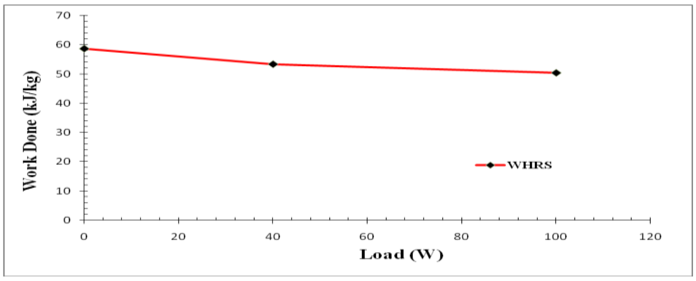

Figure 3: Work done vs Load

Figure 4 shows the COP variation of the system on various load conditions. From the result it is found that when the load increases the C.O.P also gets increased.

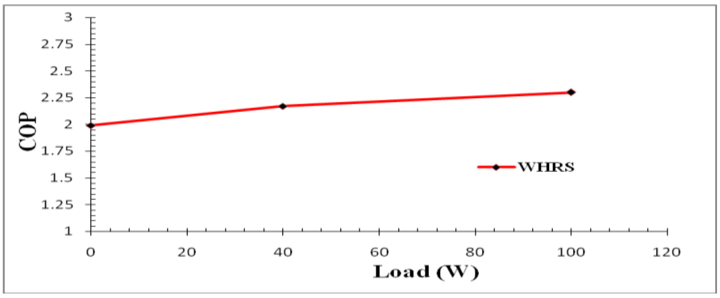

Figure 4: COP vs Load

Figure 5 shows the exit water temperature on various load conditions. From the experimental test results, it was found that the exit water temperature get as the load increases.

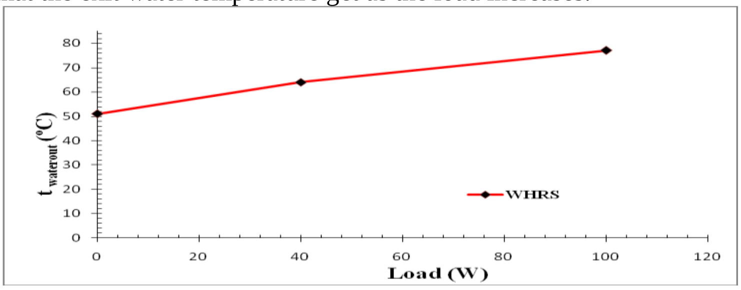

Figure 5: Exit water temperature vs Load

Table II

Experimental performance of WHRS

	WHRS		
	NO LOAD	**40W**	**100W**
P (W)	109	120	195
W (kJ/kg)	58.62	53.37	50.45
Q_e (kJ/kg)	116.80	116	115.86
COP	1.99	2.17	2.30
Q_w (W)	721.93	1215.88	1709.83

Table III

Comparison between geyser and waste heat recovery system

	Geyser	**Waste heat recovery system**
Cost	□6120	□2300
Capacity	10 litres	-
Time taken in minutes to collect 10L of hot water	10	19
Energy consumed in (W) for producing 10L of hot water	30000	741
Cost of collecting 10L of hot water	□0.0504	□0.0066
Power consumed in (kW) in one day	4320	57
Cost of 24hr operation	□7.26	□0.50
Water collected in (L) in one day	1440	758

IV. CONCLUSIONS

Experimental studies have been conducted to evaluate the performance parameters of a domestic refrigerator with WHRS. The main conclusions are listed below:

1) The waste heat recovery system performs well along with the household refrigerator.

2) The household refrigerator with waste heat recovery system was experimentally investigated at various load conditions (No load, 40W and 100W) and the performance parameters were found out on each load conditions and were compared.

3) About 758 litres of hot water at a temperature of about 77ºC over a day can be collected from the outlet of water cooled condenser and this modification made the household refrigerator to be work as both refrigerator and water heater. It also reduces the amount of green house gases by eliminating the use of fossil fuels to heat water and the system will save considerable amount of energy by avoiding the use of water heaters. The hot water which was obtained from the WHRS can be utilised for household applications like cleaning, dish washing, laundry, bathing etc.

4) Techno economic analysis was done by comparing the WHRS with the conventional geyser and it was found that the installation cost and running cost of the waste heat recovery system in 24 hours of operation is much lower than the geyser. However the water collected in one day is less compared to a geyser but this amount is enough for the hot water requirement of a small family.

V. ACKNOWLEDGEMENT

This study was supported by the UG section, Department of Mechanical Engineering, Jyothi Engineering College, Thrissur-679 531, Kerala, India.

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