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Performance Evaluation of a Domestic Refrigerator with a Thermal Storage arrangement Using Propane as a Refrigerant

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Abstract

In developing countries like India, a general problem relates to frequent power breakdown , which gives augment to the spoiling of unpreserved items such as medicine and foodstuff due to lack of a passive cold retention system. Moreover, the rural India is subjected to maximum isolation due to power cuts for many hours and even days. The paper has an attempt to tackle this problem by developing a domestic refrigerator system capable of maintaining the cooling effect for more than 15 hours without energy input and being compact as well as cost-effective. The second objective was to reduce the global warming potential caused by HCFC refrigerant. Taking into account the very needs of an average rural household in India, the required cooling load is estimated. The system was designed and analyzed using R290 (Propane) as a refrigerant by replacing R134a. The theoretical and experimental analysis of 45 liter domestic refrigerators using R290 as a refrigerant is carried out. The R290 is a replacement for R134a and R22 refrigerants. The Phase change material (PCM) is located in the newly designed evaporator in order to improve its efficiency and provide a storage capacity allowing a number of hours of refrigeration without energy supply. The system has been tested with Ethylene Glycol as a PCM with and without thermal load. Results show that the refrigerant R290 have a slightly lower coefficient of performance than R134a for the condensation temperature of 35°C to 43°C and evaporating temperatures range between −5°C to 5°C. Depending on the load in the refrigerator with PCM the average compressor running time per cycle is reduced significantly and it is in the range of 17% to 20% as compared with refrigerator without PCM. The coefficient of performance of refrigeration systems with R290 as refrigerant is comparable with R134a as a refrigerant and starting torque of compressor reduces which leads to improvement in a life span of the compressor.

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Keywords: Domestic Refrigerator, Evaporator, Phase change Material,Propane

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1. Introduction

Conquering execution of the different components of the Montreal protocols and Kyoto protocols will express to the effectual phase-out of Ozone Depletion Potential and Global Warming Potential substances if appropriate long term alternative refrigerants are identified. 1,1,1,2-tetrafluoroethane (HFC-134a) was identified as an alternate refrigerant to Chlorodifluoromethane **(**R22). The problems associated with ozone depletion and climate change are technically, theoretically and monetarily interconnected. Ozone depletion and global climate change are linked through physical and chemical processes in the atmosphere. The industries in the field of HVAC have grown extensively over the past few decades and will continue to do so all over the globe for the forth coming year. Ozone Depletion Potential and Global Warming Potential values are very less for the Hydro carbon group of refrigerants, but these refrigerants are limited in use for safety reasons. The energy efficiency of refrigerator is improved using thermal energy storage material . The cooling capacity stored in the PCM is used to stabilize the temperature in the compartment, also reduces the effects of peak loads and cooling losses during periods when the door is open [4]. Refrigerator has previously tested a with 5 mm and 10 mm ice slabs as a PCM. The results showed that the refrigerator autonomy increased from 5 to 9 hours depending on the thermal load [9]. In order to simulate the cycle, all components are interconnected with each other to form the complete system and the thermodynamic properties of R134a and R290 refrigerants are compared with the help of the REFPROP 9.1 software.

2. Phase Change Material(PCM)

Phase Change Material is a substance who has high heat of fusion. During melting and solidifying at a certain temperature large amount of energy get stored or release by PCM . The experiments be carried on refrigerator to evaluate the energy performance and the cool storage capacity of the refrigerator with and without PCM. The use of phase change materials (PCMs) to accumulate thermal energy in domestic refrigerators is a new solution. The cooling capacity stored in the PCM can be used to stabilize the temperature in the compartment.

Gobin D *et al* [5] have previously tested a domestic refrigerator with 5mm and 10 mm ice slabs in get in touch with with the evaporator. Their result shows that the refrigerator autonomy increased from 5 to 10 hours depending on the thermal load. It was observed that the ice slab of 10 mm slab was never completely freeze, probably because of low thermal conductivity of the PCM and low cooling capacity of the 5×10^{-6} m^3 (i.e. 5 cm^3) swept volume compressor employed. During experimentation in domestic refrigerator Ethylene glycol was used as a PCM [6].

3. Experimental Setup

A household refrigerator is incredibly common for the storage of perishable food items, medicines, cold drinks. These refrigerators are available in various capacities such as 45 litres to 300 litres, etc. These consume electrical energy at the rate of about 100W to 300W. The Largest population in India is staying in the villages. Almost these villages do not get electricity for more than 10 hrs per day. The major heat load comes from the outside environment of the storage space through insulated walls. Moreover, door openings bring warm and moist air into the cold storage space, raising the temperature. The refrigerator capacity is estimated based on the needs of a rural family for domestic use. The cooling load is predicted based on heat ingress into the refrigerator through walls, door openings, and product load. Theoretical and Experimental analysis of the refrigerator using propane (R290) as a refrigerant is carried out to maintain the required temperature of the refrigerator during power failure for fifteen hours. PCM is lagged in the modular chamber of the refrigerator.

The domestic refrigerator is designed, fabricated and tested with R290 as an eco-friendly refrigerant. To begin with, refrigerator performance is simulated using simulation software at different cooling capacities and in experimentation, the real world effect was simulated by door openings and by electrical breakdown. Thermocouples are bonded to the tube surface at compressor discharge, condenser discharge, and capillary