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The design of portable automobile refrigerator powered by exhaust heat using thermoelectric

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Abstract

A cool box for passenger car refers to a kind of box which is designed and fabricated using well insulating materials in order to ensure the coolness inside the cool box is always stable. Convectional refrigeration systems use ChloroFluoro Carbons (CFCs) and Hydro-Chlorofluorocarbons (HCFCs) as heat carrier fluids. The use of such fluids has over the years raised some very serious environmental concerns which has resulted in extensive research into development of novel refrigeration technologies. Thermoelectric Refrigeration (TER) has emerged as a promising refrigeration technology as it comes with far more distinctive advantages over conventional refrigeration systems. The research and development work carried out by different researchers on TER is thoroughly reviewed in this research. Having looked on these refrigeration systems Thermoelectric Cooler (TEC) refrigeration was used in the design of a 20 litre portable automobile refrigerator. In this design a Thermoelectric Generator (TEG) waste heat recovery system was designed to meet all the TEC refrigerator power requirements. Thus an internal combustion engine TEG system designed includes a stainless steel exhaust gas heat exchanger having an interior portion defined by a stainless steel wall and an exterior surface of the stainless steel wall distal to the interior portion. The exhaust gas heat exchanger receives a pressurized exhaust gas stream from the internal combustion engine and extracts thermal energy from the exhaust gas stream. The TEG modules converts thermal energy directly into electrical energy for TEC refrigerator consumption as well as storage for later use. Thus in this design a percentage of exhaust heat that could have otherwise be rejected into the environment is used in the generation of DC power to meet the TEC electrical power requirements making this system an independent system altogether thereby reducing the number of mechanical loads on the vehicle itself.

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1. Introduction

While convectional refrigerators utilize compressors, condensers, and liquid refrigerants to lower temperature, thermoelectric cooler (TEC) is a solid-state cooling method which utilizes DC power, heat sinks, and semiconductors. A (TEC) is a small heat pump which has the advantage of no moving parts. TEC's are used in various applications where space limitations and reliability are paramount and CFC's are not desired. The coolers operate on direct current and this is achieved by moving heat from one side of the module to the other with current flow and the laws of thermodynamics. TEC modules are small and are of light weight and are capable of providing cooling below ambient temperature. They are controllable through varying the voltage/ current. The portable refrigeration unit design is going to create an alternative energy powered absorption refrigerator. The design is going to use Thermo-electric generator (TEG) to power the unit, allowing it to be completely off of the vehicle electric system. Hence in this design is going to scavenge the exhaust 1waste heat energy and feed it back into the vehicle system for powering the portable automobile refrigerator. People like doing outdoor activities such as picnic, fishing engaging in big events where there is need to serve cold beverages as well as maintaining medicine temperature when travelling and it is not convenient to bring large refrigerators. So for these events one will need to cool the beverages and medicines at home before travelling. There is therefore need to design a portable automobile refrigerator to meet all these cooling demands.

Nomenclature

COP: Coefficient of performance
DC: Direct Current.
I: Electric Current, Ampere
K: Thermal Conductance, (W/K)
$\mathbf{Q_C}$: Rate of heat absorbed at the cold junction, (Watt)
R: Electrical Resistance (Ω)
TEG: Thermoelectric Generator.
TEC: Thermoelectric Cooler.
TER: Thermoelectric Refrigerator.
TEM: Thermoelectic Module.
$\mathbf{T_H}$: Hot junction temperature, (℃)
$\mathbf{T_C}$: Cold junction temperature, (℃)
Z: Figure of Merit, K^{-1}
$\boldsymbol{\alpha_{pn}}$: Difference between the absolute Seebeck coeffient of p and n junctions, (V/K).
ρ: Thermoelectric material Electrical Resistivity, (Ω. m)
λ: Thermoelectric material Thermal Conductivity, (W/mK)

1.1 Justification

A schematic of the energy budget for a petroleum-fueled internal combustion vehicle engine is shown in figure above. The internal combustion engines (ICE) lose close about to 70% of the energy they produce, predominantly through wasted heat. Only less than 30% of the energy is transformed into mechanical work or energy. High temperatures generated by exhaust gases in automobile vehicle engines has some very great potential, thus the exhaust system therefore becomes a sweet spot for TEG in harnessing energy to power the automobile refrigerator.