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STUDIES ON THE USE OF THERMOELECTRIC ELEMENTS FOR IMPROVING THERMAL CONFORT IN AUTOMOBILE

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Abstract: *In the last years, the automobile manufacturers put more and more accent on thermal comfort into cars. At the moment, the thermal comfort into passenger compartment is obtained through the system of cooling and air conditioning (HVAC) which use a refrigerant charge. According to the Kyoto Protocol is desired to eliminate agents that influence global warming (see* $R134_a$*) and finding other solutions to obtain an optimum temperature in passenger compartment. A solution is to use Peltier effect, which is based on a thermoelectric module used to cool the air inside the car. In this paper is shows the current state of research that uses thermoelectric modules for cooling one or more parts of a car.*

Keywords: thermal comfort, thermoelectric cooler devices, air-conditioning, Peltier effect.

INTRODUCTION

In the last years, in automobile industry many research activities have been developed relating to decrease of environment pollution. Especially when the Kyoto treat (see references) was created, because using HFC's like refrigerant for air conditioning devices in the cars it was forbidden (see **Directive 2006/40/CE)**. Refrigerant HFC's is highly bad for the Ozone layer. The effect of 100 gm of HFC's (hydro fluorocarbons) can destroy 0.5 tons of O3 molecules. These HFC's once destroy O3-layer; it takes lack of years to recover its thickness as it is formed by complex reactions. This is because as HFC's comes in environment they remain in atmosphere for 18 years.[1],[2] Since then, it was starting to appear a lot of innovative systems who can replace air conditioning. One of these innovative systems is thermoelectric cooler device based upon Peltier effect [3].

THE DESCRIPTION OF A THERMOELECTIC MODULE

A CLASSIC THERMOELECTRIC MODULE ASSEMBLY

A thermoelectric cooler has analogous parts. At the cold junction, energy (heat) is absorbed by electrons as they pass from p-type (low energy) semiconductor element, to the n-type semiconductor (high energy). The power supply provides the energy to move the electrons. [18],[19] At the hot junction, energy is expelled to a heat sink as electrons move from an n-type to a p-type. Figure 1 shows an illustration on the assembly of a Thermoelectric cooler. [2],[10],[20]
When an engineer wants to start designing a thermoelectric cooling device he must take into consideration a few aspects:

- the temperature of the object that is to be cooled must be kept constant;
- the heat from the cooled object must be removed;
- after the power is applied at thermoelectric device it is required a time for attain the cooling;

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- must take into consideration the ambient temperature;
- if is necessary , must control the temperature of the cooled object [12].

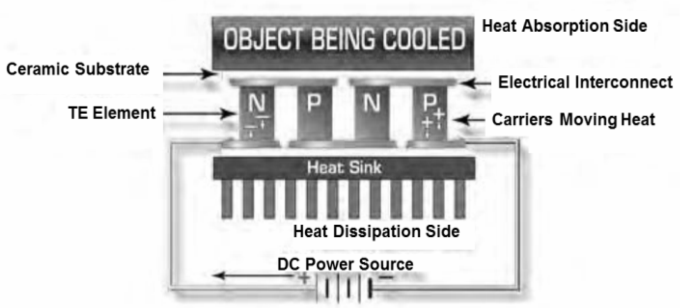

Figure 1. A Classic Thermoelectric Module Assembly

PARAMETERS OF A THERMOELECTRIC MODULE

After it is decided that thermoelectric cooler is to be considered for cooling system, the next step is to select a thermoelectric module that can satisfy a particular set of requirements. Modules are available in many varieties of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity [12]. The minimum specifications for finding an appropriate thermoelectric module by the designer must be based on the parameters script below. The construction of a thermoelectric module is shown in Figure2.

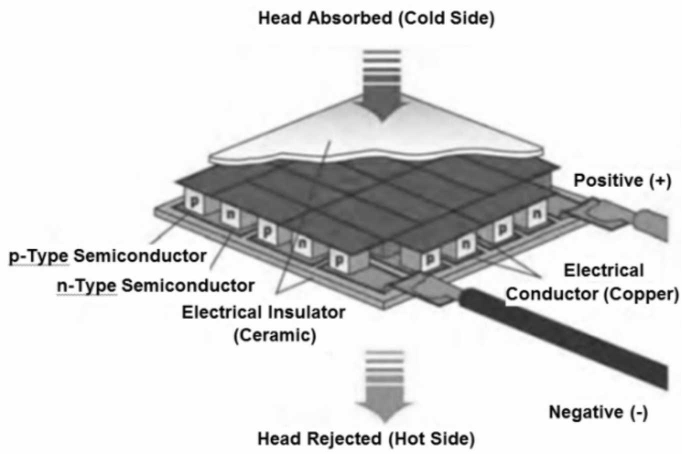

Figure 2. The Construction of a Thermoelectric Module

Parameters:

- T_c - cold side temperature;
- T_h - hot side temperature;
- ΔT -temperature difference (the temperature difference between T_h and T_c ;
- Q_c - heat to be absorbed by the cold side of Thermoelectric cooler;
- Operating current[13]

TEMPERATURE DIFFERENCE

In a cooling system are two temperature differences - ΔT. First ΔT is the temperature difference between the hot and cold side of thermoelectric cooler. Second ΔT is the temperature difference between the ambient temperature and temperature of the object to be cooled. *Figure 3* illustrates a relationship of a classic temperature summary across a thermoelectric system. [2],[10]

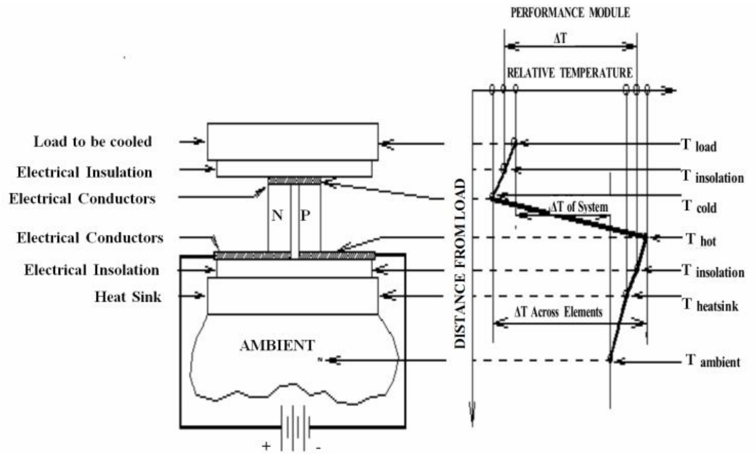

Figure 3. Characteristics temperature of relationship in a thermoelectric cooler

The allowances for ΔT at the hot side heat sink of a thermoelectric cooler are:
- 10 to 15 °*C* for a forced air cooling system with fins.- Forced convection which is shown below (*Figure 4)*.

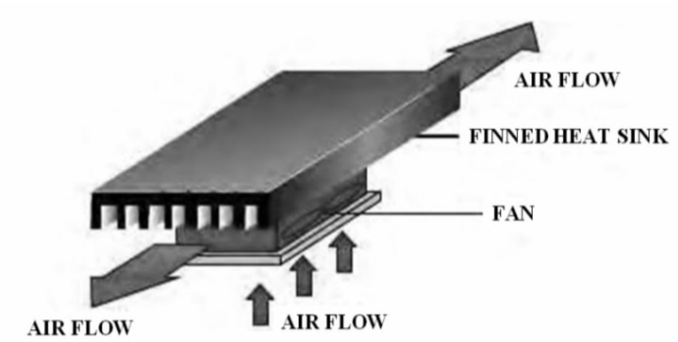

Figure 4. Forced convection heat sink system

- 20 to 40 °*C* for cooling using free convection - Natural convection.
- 2 to 5 °*C* for cooling using liquid heat exchangers - Liquid cooled [2],[9]

The main heat sink parameter for the selection process is its thermal resistance. Heat sink resistance can be termed as the measure of the capability of the sink to dissipate the applied heat. Most of the thermoelectric cooling requires forced convection or water cooled heat sinks [2],[13].

COMPARISON AMONG THERMO-ELECTRIC, MAGNETIC AND ADSORPTION REFRIGERATION

All these refrigeration devices are eco-friendly technologies which are received more attention when environments problems occur. This also have a huge role in preserve energy with great applicability. In [4] it was made a comparison between thermo- electric, magnetic and adsorption refrigeration. There are obvious differences in physical principle, applicability, thermodynamic and economical characteristic among these three technologies, which are exposed in Table 1, 2, 3.

Table 1. Comparison among thermoelectric refrigeration

Refrigerating manner		Thermoelectric refrigeration
Work medium (Energy flow carrier)	Work medium	Electron
	Entropy density	Low
Physical principle	Outfield	Electric field
	equipment	PN electric idol couple
	Energy conversion	Electron transplant

Refrigerating manner		Thermoelectric refrigeration
Applicability, economical characteristic, development status	Low temperature region (< 15 K)	Inapplicable
	Middle temperature region (15-77 K)	Difficult to applicable
	High temperature region (>77 K)	Good applicability, special superiority
	Near room temperature region	Good applicability, special superiority

Table 2 .Comparison among magnetic refrigeration

Refrigerating manner		Magnetic refrigeration
Work medium (Energy flow carrier)	Work medium	Magnetic material
	Entropy density	High
Physical principle	Outfield	Magnetic field
	Equipment	magnet
	Energy conversion	Excitation, de-magnetization
Applicability, economical characteristic, development status	Low temperature region (< 15 K)	Technically mature
	Middle temperature region (15-77 K)	Small applicable scope
	High temperature region (>77 K)	Applicable, Technically immature
	Near room temperature region	Without applicable technique and economical characteristic

Table 3. Comparison among adsorption refrigeration

Refrigerating manner		Adsorption refrigeration
Work medium (Energy flow carrier)	Work medium	Work medium couple
	Entropy density	Low
Physical principle	Outfield	Pressure
	equipment	adsorption bed
	Energy conversion	Adsorption, desorption
Applicability, economical characteristic, development status	Low temperature region (< 15 K)	Inapplicable
	Middle temperature region (15-77 K)	inapplicable
	High temperature region (>77 K)	Inapplicable
	Near room temperature region	Applicable, without applicable technique and economical characteristic

In conclusion, thermoelectric refrigeration possesses following advantages: longer development period; more technically mature; widest application field; larger refrigerating capacity; good economical trait when in small refrigerating capacity; in some application field, it has special superiority which can not be replaced by others; more and more importance are attached to the application of low-grade energy source and the recycle of waste heat [4],[11]. Magnetic refrigeration with relative short development period has been applied in low temperature region due to perfect technique, while in middle temperature region, the application technique is imperfect, especially in high temperature region there is no applicable technique up till now [4],[11]. Adsorption refrigeration with a short study period can be used only in the condition of near room temperature. Compared with compression refrigeration, its advantage is the utilization in the fields to which that compression refrigeration is inapplicable, such as the use of solar energy, geothermy energy, and the recycle of waste and exhaust heat. For adsorbing refrigeration, however, there are three disadvantages: technically inapplicable, cost ineffective and without competition superiority.[4],[11].

THE INTEGRATION OF THERMOELECTRIC COOLER IN CAR ARCHITECTURE

In this chapter, a few termoelectric cooling system are present. First termoelectric cooling system was designed, developed and tested by Manoj S. Raut and Dr.P. V. Walke from "G.H.Raisoni College Of Engg", Nagpur, India reference [2]. They started by develop a block system analysis of the project. The block diagram is shown in Figure 5.

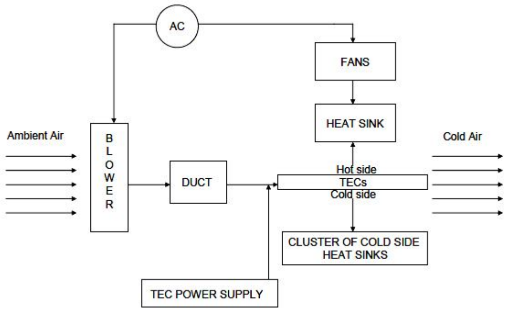

Figure 5. Block diagram of the thermoelectric cooled cooling fan.

For this thermoelectric cooling devices was used six thermoelectric cooler (TEC) who are sandwiched between cold and hot heat sinks, a duct which conveys the air from the blower to cluster of aluminum cold heat sinks, one long heat sinks is fitted to the hot side of TEC to absorb heat, four aluminum heat sinks that are attached to the cold side, an DC source which is used to power the fans and blower (car battery) and an DC power supply is used to drive the TECs who was a simple on/off temperature controller.

Second thermoelectric cooling system was develop and simulated by C.S. junior, N.C. Strupp, N.C. Lemke and J. Koehler from "Institut fuer Thermodynamik, TU Braunschweig, Braunschweig", Germany [5], [15]. They developed a thermoelectric cooler system with the help of some simulator programs. In Figure 6 is sown a sketch of the simulation model.[14].

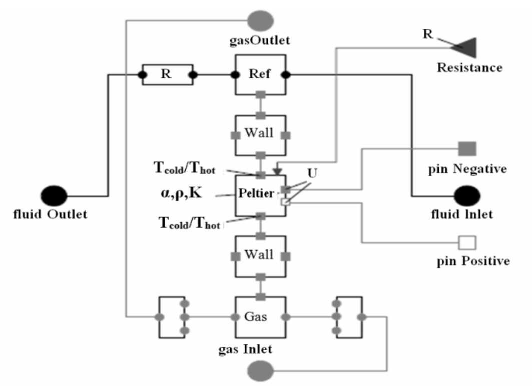

Figure 6. Flow diagram of the simulation model.

Next thermoelectric cooling system was develop and patented by Gilles Elliot, Vincent Feuillard, David Roy from France [6]. The subject of the invention is a system for heating or air-conditioning a vehicle cabin. In their paper this termoelectric cooling system is implemented on the car roof, but the termoelectric cooling system can be implemented also in other parts of the car. In *Figure 7* is shown the thermoelectric cooling system implemented in car architecture. This invention has many conveniences. Some of these conveniences are:

- the general organization is simple;
- the number of components and their size are small;

- the module has a small dependence on the use of other vehicle equipment;
- the supply of electrical energy and the control of its operation are simple and efficient;
- the module is able to thermally treat specific cabin areas independently by selecting a choice of module operating mode.[16],[17].

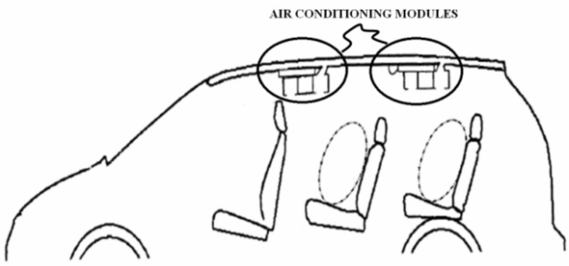

Figure 7. Schematic sectional view of a vehicle cabin equipped with two ventilating, heating and/or air conditioning modules.

Another thermoelectric system is named Amerigon's Peltier module and has been developed by Courtesy of Amerigon Corporation. This thermoelectric system works as follows: the vehicle cabin air is drawn into the cushion and back TE modules and, based on inputs from individual seat controls and from temperature sensors, the unit will either add heat or remove heat to the air flow. The basis of the system is the Peltier circuit. The Peltier circuit, heatsink (heat exchanger) and fan assembly are mounted as one module. Air is used as a medium to move heat around the seat through the perforated seat layers. Conditioned air is ported to the top surface of the foam through channels which evenly distribute the conditioned air over the surface. Breathable trim covers allow the conditioned air to pass through to the occupant. When the Peltier device is cooling, heat is generated on the opposite side of the device which must be removed to allow the temperature differential to exist. This heat is pumped into the cabin space and is labeled on *Figure 8* as 'waste heat'. This will create an extra load on the A/C system if being operated to cool the interior space. [7]
When voltage is applied to the Peltier module in one direction one side of the Peltier device will be hot and the other cool due to the direction of the charge carriers creating a ΔT across the Peltier device. Switching polarity of the circuit creates the opposite effect. Amerigon's Peltier module proprietary CCS system allows occupants to select seat temperatures to promote comfort and reduce driver fatigue through the use of a solid-state heat pump combined with an active, microprocessor controlled temperature management system to vary heating and cooling capacity. Amerigon states that it is the first to have successfully packaged this technology for use in automotive seating applications [7].

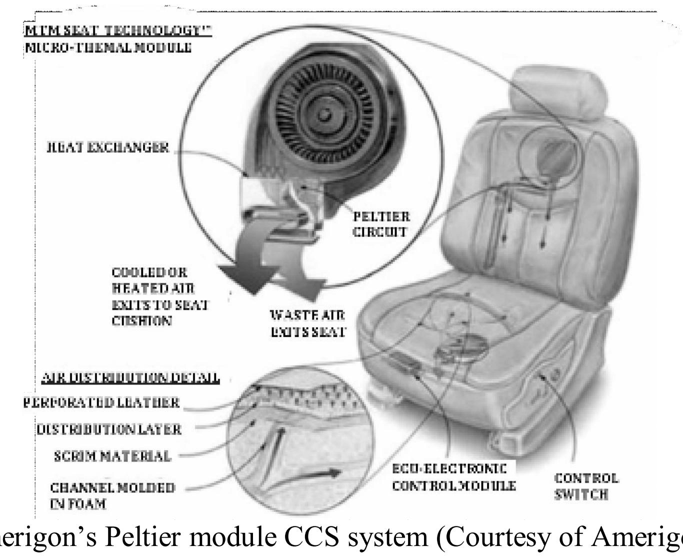

Figure 8. Amerigon's Peltier module CCS system (Courtesy of Amerigon Corporation)

The last thermoelectric system presented in this paper is accomplished by Clay Wesley Maranville, James George Gebbie and Kenneth J. Jackson.

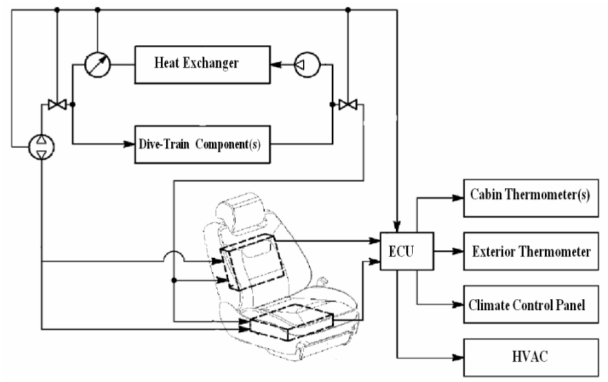

Figure 9. Schematic system diagram of a thermoelectric comfort control system

The present invention relates to a comfort control system for a vehicle that includes a thermoelectric heat pump (thermoelectric device) having a fluid temperature control loop, and specifically to such a system in which energy efficiency is improved by the exchange of heat energy between the temperature control loop and a second fluid temperature control loop that controls the temperature of a drive train component.

The object of the invention is to improve the overall energy efficiency of a motor vehicle, in particular an electric vehicle, by reducing or eliminating the need to use electric power to run a conventional heater or air conditioning unit to achieve a comfortable cabin temperature [8].

CONCLUSIONS

Because of the high number of patents and research activities which are based on the utilization of thermoelectric cooler systems, the automobile industry shows a big interest to implement this technology. The small dimension of the thermoelectric cooler system allows it to be integrated in almost every place inside de car. The conveniences of the thermoelectric cooler devices are: the small price of the components; the big number of the contractors who produce thermoelectric modules; the long life and increasing reliability of thermoelectric modules; maintenance with low costs and easy to accomplish. The thermoelectric cooler devices are still in stage of development and optimization which make this domain to have good expectation for the future.

REFERENCES

[1]. Mariana IVANESCU, Ion TABACU – Confortabilitate si ergonomie, Editura Universitatii Pitesti, 2007;

[2]. Manoj S. Raut and P. V. Walke. - Thermoelectric Air Cooling For Cars, 2012

[3]. Eckhard Müller, Steven Walczak, and Wolfgang Seifert. Optimization strategies for segmented Peltier coolers, Germany, 2006

[4]. Chunfang Tanga, Qinghai Luob, Xiangmei Lib, Xiaojuan Zhua - Comparison of Several Eco-friendly Refrigeration Technologies, 2006

[5]. C.S. junior, N.C. Strupp, N.C. Lemke and J. Koehler - Modeling a Thermoelectric HVAC System for Automobiles, Germany.

[6]. Gilles Elliot, Vincent Feuillard, David Roy - Patent US20070000255 - Autonomous air-conditioning module intended particularly for the thermal treatment of an area of a vehicle cabin

[7]. Steven Daly - Automotive Air-conditioning and Climate Control Systems,

[8]. Clay Wesley Maranville, James George Gebbie and Kenneth J. Jackson - Patent US 2012/0079837 A1 - Thermoelectric comfort control system for motor vehicle, US.

[9]. Pérez-Aparicio, R. Taylor, D. Gavela, Finite element analysis of nonlinear fully coupled thermoelectric materials, Comput. Mech, 2007

[10]. Yu-Wei Chang, Chih-Chung Chang, Ming-Tsun Ke, Sih-Li Chen. Thermoelectric air-cooling module for electronic devices, Taiwan, 2009
[11]. Christian J.L. Hermes, Jader R. Barbosa Jr. Thermodynamic comparison of Peltier, Stirling, and vapor compression portable coolers, Brazil, 2012
[12]. Payá, J., Corberán, J.M., Torregrosa-Jaime, B., Vasile-Müller, C., Innovative air-conditioning systems for conventional and electric vehicles, Spain and France
[13]. Vladimir Dudnik, Ph.D, Axel Rapp. Production and exploitation of thermoelectric air conditioning systems for vehicles
[14]. Lakhi N. Goenka, Douglas T. Crane, Lon E. Bell -Patent US7246496 - Thermoelectric based heating and cooling system for a hybrid-electric vehicle, US, 2007
[15]. Peter R. Gawthrop - Patent US7380586 - Climate control system for hybrid vehicles using thermoelectric devices, US, 2008
[16]. Prasad Shripad Kadle, Edward Wolfe IV, Joseph Pierre Heremans, Donald T. Morelli - Patent US20050257531 - Thermally conditioned container for a vehicle, US, 2005
[17]. Lon E. Bell, John LaGrandeur - Patent US20100052374 - System and method for climate control within a passenger compartment of a vehicle[18]. Ioffe, A.F. (1957). *Semiconductor Thermoelements and Thermoelectric Cooling*. Infosearch Limited.
[19]. Thomson, William (1851). "On a mechanical theory of thermoelectric currents". *Proc.Roy.Soc.Edinburgh*: 91–98.
[20]. http://www.heatsink-guide.com/peltier.htm