A PELTIER CELLS RESEARCH - (FIRST PART)

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Abstract: The study presents is focused on a new method of generation of energy utilizing the thermoelectric phenomenon that deepens on the Peltier Cells. In the mathematical model it utilizes the phenomena worn-out for Seebeck, Peltier, Thomson, Joule or Fourier, the aforementioned Cells predecessors.

Keywords: Thermo electricity, MCEP, Peltier Cells.

1. INTRODUCCION

A thermoelectric module or Peltier Cell is an electronic component based on a semiconductor that works like a little heat pump. Applying it a low voltage direct current [2] [3], heat will be moved through the module of a side to the other, that is, a face of the module will be cooled while the other will be heated simultaneously [1]. It is important to stand out that this phenomenon is reversible, changing it the polarity of the source. As a result, a Peltier Cell can be used to heat up or to get cold, with a great precision in desired temperature. In this article, the first part is about the thermoelectric component phenomenon because it innovates in generation's method of energy. In the second part it fixes the Peltier effect which is the center of study and finally the Peltier encounters the mathematical model that utilizes the cell.

2. THERMOELECTRIC EFFECT

The Thermoelectricity is considered like the branch of thermodynamics superimposed to electricity where they study the phenomena in the ones that interfere with the heat and the electricity, the phenomenon but the acquaintance is the one with generated electricity for the application of heat to the union of two different materials [4]. If two wires of distinct material stick for both particulars (this circuit names thermocouple), and one of unions keeps to a superior temperature to the other, a tensile difference that makes to flow from an electric current among hot and cold unions happens .

In 1834, Jean Peltier, a French watchmaker and enthusiastic scientist, discovered than an electric current's passage through a junction A of two similar drivers X and the Y in a certain direction produces cooling, Tc. There are a heating, Th, very distinct for the purpose Joule, when the current goes by the junction B, as you can see in the fig. 1.

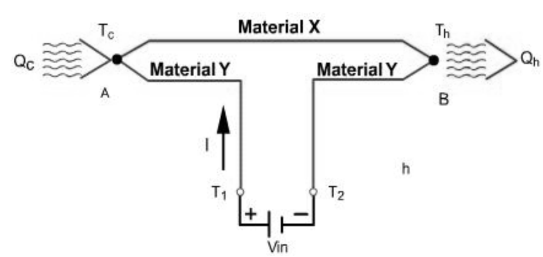

Fig. 1: Circuit with Peltier Effect.

Peltier's experiments were followed to the ones belonging to Thomas Seebeck, who in 1821 discovered than an electromotive force V0 can be produced by heating to a temperature Th of a junction B among two metals, X and Y. 2 can be appreciated in the figure 2.

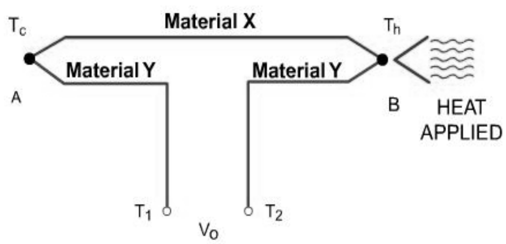

Fig. 2: Circuit with Seebeck Effect.

It is pertinent to stand out than William Thompson (later Lord Kelvin) in 1855, derive a relation among effects with thermodynamic arguments above-cited.

Let's suppose first than a difference of temperature ?T = $T_h - T_c$ is established among points B and To I dress in the figure 1-2, then an electromotive force V0 is developed among T1 and T2. The coefficient Seebeck, or thermoelectric power becomes of the following manner:

$$a_{XY} = \frac{V_0}{\Delta T} \qquad (1)$$

Now, Lets suppose that junctions are taken at the same temperature and, inserting a battery among T1 and T2, a current I makes to flow from itself for the circuit as you see in the figure 1. If the result is a velocity of heating Qh at the junction B, Qc it has to be cooled to the same velocity Qc in the other junction A. Peltier's coefficient is:

$$p_{XY} = \frac{Q}{I} \qquad (2)$$

Defining the coefficient Thompson for drivers's one, we imagine than, in addition to the ordinary I, there is an atmospheric pressure differential of temperature has dT/dx that leads on to a velocity of heating or cooling dQ/dx for unit of length. Then:

$$t = \frac{dQ/dx}{I\,dT/dx} \qquad (3)$$

Thompson obtained two equations, which connect three thermoelectric coefficients applying the first and second law of thermodynamics in a simple thermoelectric circuit, assuming that it is a reversible system. The validity of this approximation is questionable, because the thermoelectric phenomenon is always accompanied for the effect Joule that he is irreversible. However, the more reasonable application of the theory of irreversible thermodynamics is the following relation in this case:

$$p_{XY} = a_{XY} T \qquad (4)$$

And

$$t_X - t_Y = T \frac{da_{XY}}{dT} \qquad (5)$$

The equation (4) becomes of particular importance in thermoelectric refrigeration because the velocity of cooling can be expressed in terms of the coefficient Seebeck, that it is easier measuring the Peltier Thompson coefficient.

While the coefficient has been defined for a driver, coefficients Seebeck and Peltier refer to a junction among two materials themselves. It would be best if one may assign coefficients Seebeck and Peltier absolute and for each material, with the coefficients of junction given by $\alpha_X - \alpha_Y$ and $\pi_X - \pi_Y$. Then, if we assumed this the equation (5) can be rewrite of the following form:

$$t = T \frac{da}{dT} \qquad (5a)$$

The equation (4) can be also rewrite for a driver in terms of absolute coefficients

$$p = aT \qquad (4a)$$

Seebeck is easy to see that quantitatively a good thermoelectric material must have a tall coefficient, a tall electric conductivity to minimize the effect Joule, and a low thermal conductivity to reduce the heat transferred among the origin of heat and the squanderer. That called attention the fact is that semiconductors have a coefficient Seebeck a lot of principal than metals.

2.1 Thermoelectric Pumping

In this case disappear all the movable parts of conventional bombs being the electric power directly the one that develops the work on the system. The shows of the atoms of the gas, that really accomplish the transportation of heat are, the charging bearers accomplish electric of a semiconductor: Electrons and holes.

This exchange rate of temperature through a tension has not been applied even in a few years for the scarce performance obtained among the unions of metals. With the development of technology in semiconductors, has appeared Teleniuro's crystal of Bismute [5] that possesses some particular properties for the transportation of the heat of a region to other. It has been gotten with the union of a metal to this semiconductor than electrons and or the holes are the responsible ones belonging to that transportation, behaving of similar form to the growing gas or compression of traditional bombs. In this way they get for themselves performances that permit thinking about his application industrial, seeing figure 3.

A solid-state thermo-pump analogous parts to the mechanical conventional thermo-pumps, a cold region, one hot and the transporting elements of heat, than now will be the electrons and holes of semiconductors (before the gas's atoms), definitively the fluid cold storage room has been substituted for an electric current. The fundamental advantage is the lack of movable parts and fluids, fact that bears the price reduction of systems under maintenance, and I increase in his service life.

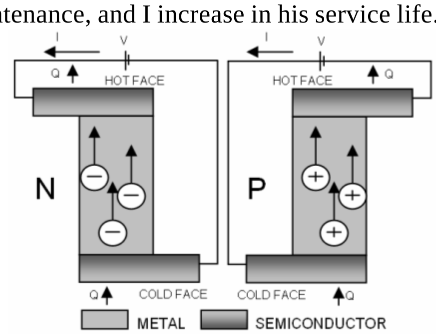

Fig. 3: Peltier Effect in Semiconductors.

Where: V is the tension of nutrition and *I* is electric current and *Q* heat transported of a zone to other.

In order to go into the functioning consider him two metallic connections joined to a material n-type semiconductor (figure 3). The applied potential does that negative bearers abandon the metallic connection at one end, flow through the material N and after penetrate into the another conductive cash producing in this process a heat absorption (cold Zone). In another terminal the electrons are impulse by applied potential pass of the semiconductor metal freeing heat (hot Zone).

Depending on the doping of semiconductors electrons or holes can be that in his movement transport the heat, the clearing is which origins that movement for an electric current; heat is absorbed when it initiate its movement through the crystal and it cede when they pass metal. Heat absorbed at the cold region is proportional to the current that the semiconductor crosses. In the figure 4 a,b,c show the energetic movements among the faces of a semiconductor and the equivalent electric and thermal circuits themselves.

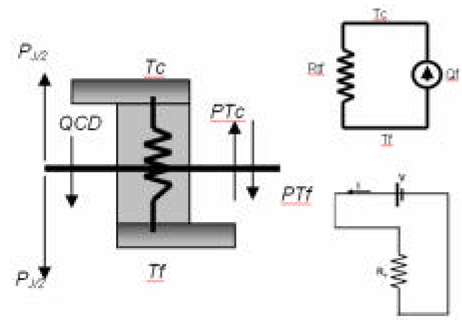

Fig. 4: Equivalent circuit.

Where:

$QP_{TF} = aIT_f$ *Cooling Equation*

$QP_{Tc} = aIT_c$ Heating Equation

$P_J = I^2 R_e$ *Lost by Joule Effect*

$Q_{CD} = \frac{T_c - T_f}{R_{th}}$ = the natural conduction natural of the heat of hot zone *at cold.*

Tf = Cold Temperature

Tc = *Hot* Temperature in hot face

The performance increases when these semiconductors stick for couples in such a way that electrically get connected serially and thermo-cycle in tandem. A same electric current accomplishes transporting twice the amount of heat. This disposition knows like ***EFFECT PELTIER CELL***, seeing figure 5. A cell of effect Peltier consists in a set of pairs of type p and n connected serially electrically (and in tandem thermo-cycler), and placed among two ceramic metallic shellacs, that they will provide him electric isolation and good thermal conduction. In the figure 6 show the equivalent electric and thermal circuits of a cell themselves.

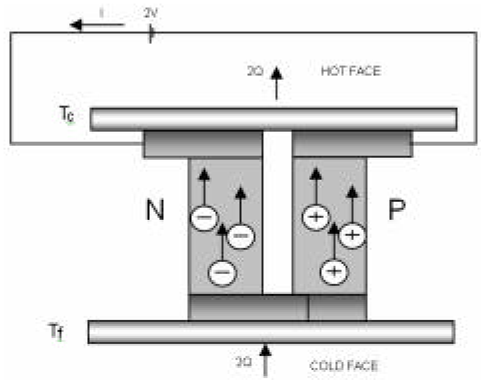

Fig. 5: Effect Peltier Cell.

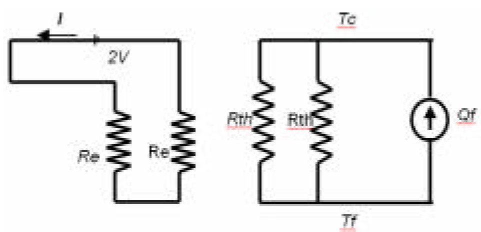

Fig. 6: Equivalent circuit.

Where:

$P_{TF} = aIT_f$ is the thermoelectric power

$P_{Tc} = aIT_c$ is the thermoelectric power heated

$P_J = I^2R_e$ are the lost by Joule Effect

$Q_{CD} = 2\dfrac{T_c - T_f}{R_{th}} =$ is the natural condition of hot in hot zone at cold.

The performance can increase still more if several connected cells push forward to a module electrically serially and thermal in tandem (m cells 2n semiconductor), ***the PELTIER*** knows this disposition itself like ***EFFECT PELTIER CELL (MCEP),*** that has been added an alumina cape, insulating electric excellent grade and great thermal conductor: These alumina capes will allow to the set-up on metallic radiators without short-circuits damage in electric connections out of every an one belonging to cells (without this isolation when all cells to place a metallic object they would get connected in tandem) seeing figure 7. The MCEP is commercialize with one all kinds of sizes, currents, tensions, forms themselves and you increase the power of pumping [6], [7] and [8].

The equivalent circuits, electric and thermal are shown in figure 8.

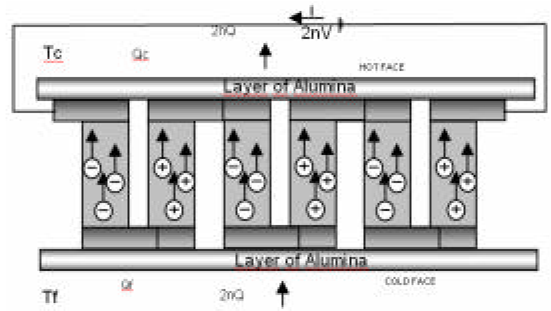

Fig. 7: Details of a Effect Peltier Cell.

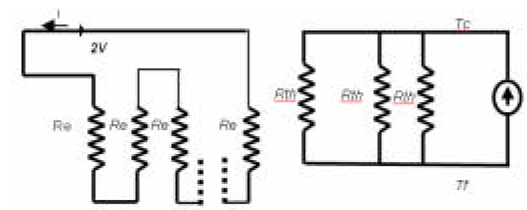

Fig. 8: Equivalent circuit.

Where:

$P_{TF} = aIT_f$ is the thermoelectric power cooling

$P_{Tc} = aIT_c$ is the thermoelectric power heating

$P_J = I^2R_e$ are the lost by Joule effect

$Q_{CD} = 2\dfrac{T_c - T_f}{R_{th}} =$ is the natural conduction of heat zone in hot zone at cool.

Habitually, face cold temperature is the variable of exit, that is to say, the thermo-pump works like refrigerator of placed objects said expensive: Passed a fixed term the object will have the temperature *Tf*. It must be remember that due to his reversibility it can work like heater, but this utilization is extended less for to exist another device that they have a great performance in the conversion of electric power to heat for effect Joule (electrical resistances).

In ideal conditions, without electric losses and with thermal infinite resistances, the pumped amount of heat in both directions names **Thermoelectric Junction** and it comes for expressions, in terms of the number of semiconductors:

$$Q_f = P_{TF} = 2nQ = 2naIT_F$$

$$Q_c = P_{TC} = 2nQ = 2naIT_C$$

The n is the number of semiconductors of the module, I is the electric current that crosses the cell, the T is the temperature in K.

MATHEMATICAL MODEL

For the correct understanding of the functioning of a Peltier cell needs to know the theoretic basics of thermoelectric phenomena and physiques that they concur in a thermo element.

A series of phenomena like the *Seebeck, Peltier, Thomson, Joule or Fourier* take place in thermoelectric chains, the existence of these phenomena is the one that permits us utilizing thermoelectric circuit like a heat pump. These mentioned effects are related among each other, which as it show the complexity of the phenomena that has place in the thermoelectric cell that our basic unit constitutes.

In a Peltier Cell, the thermoelectric elements the N and P mount themselves alternatively, connected electrically serially. If they consider only the thermoelectric elements, not taking into account the circuits of interchange of heat with cold and hot sources, they can define a Peltier Cell's theoretic coefficients. The coefficients depend on three characteristics of the thermoelectric material: Seebeck " a " in *V/ K*, electric resistivity " r " in Ω cm and thermal conductivity k in W/K cm.

Besides the aforementioned coefficients depend on the dimensions of the semiconductor thermoelectric components that form a cell, if "e" is the thickness in cm and s the section in cm ^{2} that can define the electric and thermal resistances out of every their one:

$$R_e = r\frac{e}{s}(\Omega)$$

$$R_t = \frac{1}{k}\frac{e}{s}(W/K)$$

And for each one of the cells

$$R_{eCEP} = 2R_e \qquad R_t = \frac{R_t}{2}$$

To the following explanations it is necessary to consider the Figure 5.

Other defined coefficients are:

The cooled power absorbed or pumped:

$$Q_F = m\left[aIT_F - \frac{1}{2}R_e I^2 - \frac{T_C - T_F}{R_t}\right]$$

Where: The m is the number of cells of the module, the electric current is the fact that the cell, TF is the facial cold temperature in K, cross TC is the facial hot Temperature in K.

Heating power:

$$Q_C = m\left[aIT_C + \frac{1}{2}R_e I^2 - \frac{T_C - T_F}{R_t}\right]$$

The electric power given to the module

$$P_E = Q_C - Q_F = m\left[aI(T_C - T_F) + R_e I^2\right]$$

The module's voltage at its terminals

$$V = \frac{P_E}{I} = m\left[a(T_C - T_F) + R_e I\right], V = f(I,T)$$

The terminal voltage is invariable in terms of the current that crosses it and of the T. Therefore the MCEP's resistance is variable in terms of the T and in terms I.

Expressions for QC and QF are very similar; consist of an addend that interprets the electric losses, other for thermal and another one that indicates increases the power of thermoelectric pumping developed. The difference among both rests on the term of electric losses for effect Joule right now than when totally music intends to refrigerate itself harmful, since he decreases the thermoelectric potency.

These expressions correspond basically with given for Redondo [9], if he considers despicable the Thomson effect and thesis only mean values of the transporting properties of heat. The Seebeck coefficient, the electric resistivity and thermal conductivity vary with temperature. Besides, the manufacturer of used cells, MELCOR, also uses similar expressions [10].

CONCLUSIONS

The study of the Peltier cell allows applying this element in new thermo-cycler at low cost and good quality, regarding the ones that are in the market. An application shows in the hermo-cycler PCT itself 100 located at Pamplona's University, Colombia where they accomplish tests of replication of DNA, in future publications will devote themselves to knowing the obtained results themselves.

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