

Dynamic Method of Brain Cooling

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Abstract—In this work we describe the construction of a non-invasive hypothermic system of descent a brain temperature used in the treatment of stroke. Thermoelectric effect is based on peltier elements. The device is used for those who offer first medical aid. It usage helps with the stabilization of the patient's state and stops any aggravations. The helmet allows local or total cooling of the head, monitorization and displays body temperature on a graphica interface.

Keywords—peltier element, hypothermia, thermoelectrical effect, cooling system.

I. INTRODUCTION

Vascular cerebral accidents are the causes of a big number of diseases of nerve cells or death in case of delayed intervention. Accidents occur after breaking of a blood vessel, in the brain zone that causes internal bleeding and subsequent blood clots. Studies show that about 70% from survivors of vascular cerebral accidents are restored and 15-30% become crippled [1]. Because the cerebral accident decreases blood flow circulation it is necessary to restore movement or treatment of bleeding. The control of bleeding is achieved by hypothermia. This procedure helps decrease oxygen consumption (about 7%/°C) and maintain low blood flow in the area where occurred the injury.

Hypothermia therapy (total or selective) is the process of the descent of the blood temperature below 35 °C. Maintaining below this value occurs until the patient's intracranial pressure returns to normal. Setting the temperature in the range of 34-36 °C is known as mild hypothermia and deep when the temperature is between 20-30 °C. Most often followed values are 32-35 °C [2]. Using of this treatment reduces mortality rate from 46.51% to 25.58% [3]. Are the two types of the methods of producing hypothermia: invasive and noninvasive. One of invasive method involves the introduction in the blood a crystalloid solution, which have a temperature of 4 °C during 30 minutes [2]. Non-invasive methods using external sources of cooling applied on the skin cold air, ice packs, cooling beds, or as in our case a special helmet for head with peltier elements. Peltier elements are devices that absorb heat due to electric current on one side and transfers it to the opposite side.

II. CIRCUITS

The peltier effect is a thermoelectric phenomenon in which the heat is generated or absorbed at intersection of two conductive materials with different properties when there is a

flowing electrical current. For real applications it is necessary a big number of such intersections for a thermic effect.

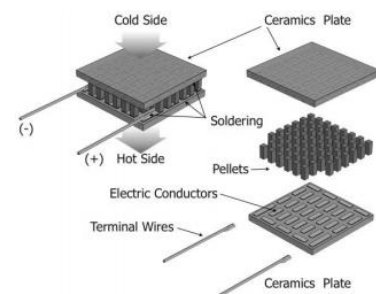


Fig. 1. Peltier element construction.

In all applications in which are used TE-Coolers it is necessary the computation of all operational parameters for device command in different cases (their usage at minimal power or maximum power) [5].

$$Q_C = Q - Q_J - Q_{\Delta T}. \quad (1)$$

$$Q = I \times \alpha \times T_C. \quad (2)$$

$$Q_J = (1/2) \times I^2 \times R. \quad (3)$$

$$Q_{\Delta T} = C \times \Delta T. \quad (4)$$

ΔT = $T_h - T_c$ - Operating temperature difference (at known ambient temperature)

Q_C - Operating cooling capacity

Q_J - Joule heat

Q - Heat pumped through the peltier effect

$Q_{\Delta T}$ - Heat flow between 2 points with different temperatures

R - Electric resistance

α - Material dependent “thermal strength”

I - electric current

C - Thermal conductance between the cold and hot side

T_C - Temperature on the cold side

The control of peltier elements is done with the help of a power block. It is made from semiconductor components capable of supporting big currents. According to the TEC12706 datasheet – the maximum current consumption is 6.4 A.

The use of peltier elements at maximum power increase their degradation. The output transistor of the power module

can support a current of 20 A. The transmitted command signal from the microcontroller is a low frequency $<100\text{Hz}$. We will not use the PWM mode because the commutation speed is big and the cooling phenomenon will not be at the expected level. The peltier elements are commanded individually which assures the localization of cooling. The overall construction can be followed in the figure below.

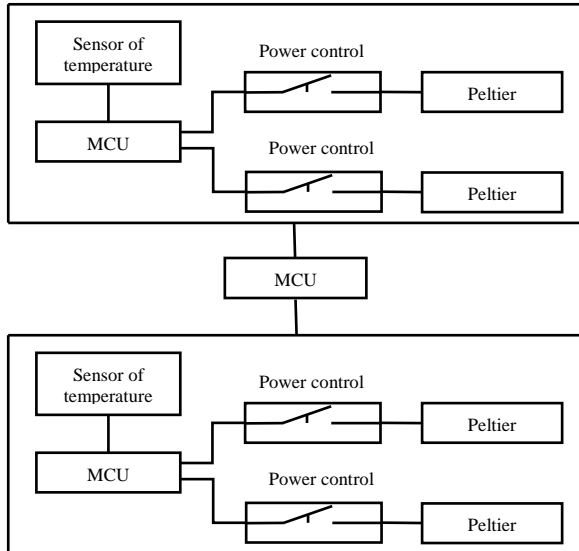


Fig. 2. Block diagram of system.

The system is made of 2 identical arms which are commanded from a microcontroller who decide the working mode of the subsystem. For a precise temperature measurement of the brain it is necessary to install the sensors in region less affected by the external factors. The ear temperature is the closest to that of the brain.

We propose to use in this device the peltier element as a hypothermic tool for cooling the selected region of the brain. The benefits of this method consist in the possibility of a manual or automatic control of temperature.

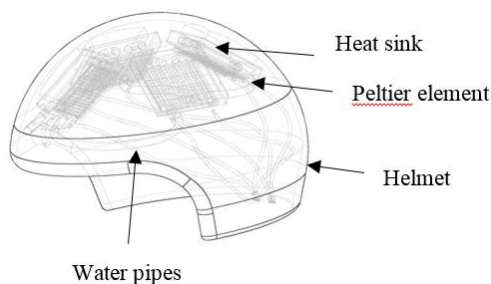


Fig. 3. Helmet construction.

The elements are deposited in a single layer with the cold side to the brain. On the other side, for heat absorption it is installed a copper radiator in which flows water as a heat elimination element. The flow of water through the radiator forms a closed circuit powered by an electric pump. The cooling efficiency is influenced directly by the water temperature from the circuit, at a lower temperature of water, the heat absorption is done with a bigger gain.

The elements are installed on the radiators which themselves are installed on a flexible helmet adaptable to the human's head size. The arrangement of elements in helmet depends very much from the regions in which the lower temperature will transfer without big losses to the brain; it must not meet strong vascularized regions which acts as a strong thermic insulator.

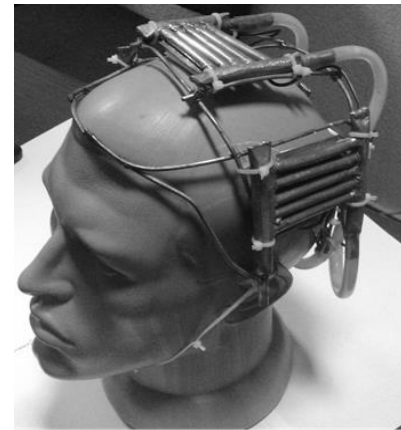


Fig. 4. Experimental set-up.

The temporal and occipital regions are strongly vascularized so we will not be able to cool this parts but the parietal and the frontal zone are good parts for cooling. It is known the fact that approximate rate of 50% of the generated excessive heat from brain is eliminated thanks to the colder blood flux from carotid arteries. Another 50% from heat is eliminated because of the brain's surface cooling through eliminating heat outside through cold blood flux at scalp skin level [6].

Because we wish a fast cooling, we will drop temperature to $5\text{ }^{\circ}\text{C}$ and this value will be the minimum. Lower temperatures mentioned above will damage the brain cells. The process of temperature lowering will be made gradually and in reprises for 15 minutes in order not to provoke a thermal shock.

III. EXPERIMENT

In order to obtain functional model of the peltier elements we performed experimental measurements at laboratory conditions to register their behavior in real different voltages and currents. The experiment was done in time, cooling capacity, ratio of the consumption power and cooling power, dissipated power, minimal temperature reaching speed and the necessary current for this temperature. The data were taken at room temperature of $20\text{ }^{\circ}\text{C}$ and in a water volume of 5 liters in evacuation system.

During measurements, established the cooling temperature till the minimum we temperature of $5\text{ }^{\circ}\text{C}$ in 1 minutes 40 seconds. To obtain this temperature, we use a power of 57.76W . The data describing temperature versus current dependency are written in the table below.

TABEL I. THE DATA DESCRIBING TEMPERATURE VERSUS CURRENT DEPENDENCY

Current ,A	Temperature, °C
0.2	18.8
0.8	16.1
1.4	14.0
2.0	12.5
2.6	10.0
3.2	8.2
3.8	5.2
4.4	3.0

Entering the data on the graphic shows a similar dependence like the graphics from the datasheet with small errors of measurement on some portions.

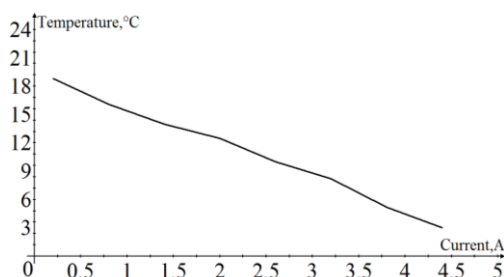


Fig. 5. Experimental set-up.

IV. CONCLUSION

The authors have built a sample device for therapeutic hypothermia used in medical needs for a controlled cooling of some tissues using peltier elements. The use of Peltier cooling elements allow elaboration of a mobile, low size device which can be used in emergency medical services which will reduce the risk of a ischemic trauma of tissues after heart failure or blockage of arteries to embolism.

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