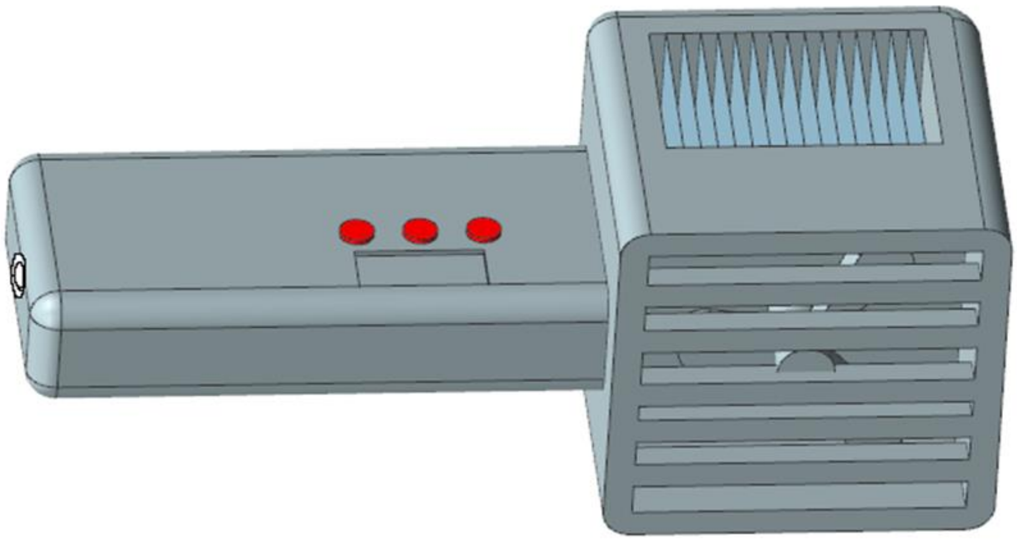
Technical Report:
Designing and patterning a thermotherapy device for inflammation and pain



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Abstract

This technical report will present the experimental approaches to realize a thermotherapy device for inflammation and pain. The objective is to develop a device for cool therapy. Peltier battery is chosen for cooling. Aluminum plates are used for transferring heat.

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1 Introduction

Thermotherapy is a physiotherapy method that uses heat-causing agents for healing purposes, which is especially helpful in treating osteoarthritis pain. Thermotherapy is divided into two categories: cold (cryotherapy) and hot. This report presents a model of a cold thermal device for inflammation and pain.

2 Components of the cold thermal device

2.1. Block diagram of the cold thermal device

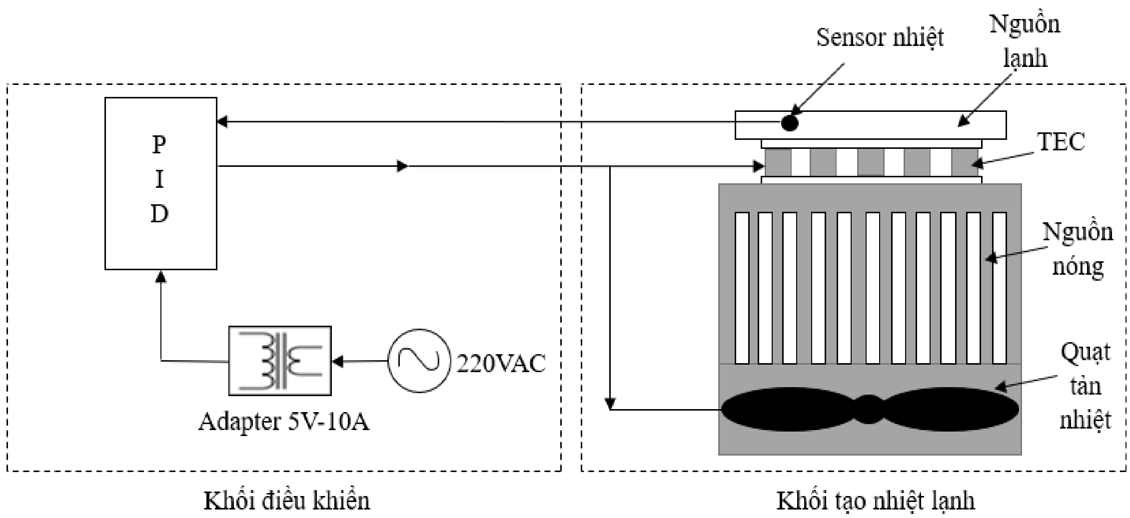

Figure 1. Block diagram of the cold thermal device

Figure 1 shows the block diagram of the device. The PID temperature-control module is powered by a DC 5V-10A adapter. Two output pins (OUT) of the PID circuit are connected to the Pelttier battery and the cooling fan. The cold side of the Peltier battery is placed on the cold side of the device while the hot side is placed on the aluminum plate of the cooling system. The signal pin of the PID circuit is connected to an NTC thermistor (10K-5%) that has been attached to the cold source. The temperature on the cold source is displayed on the 7-bar LED screen by reading the temperature signal from the thermistor.

2.2. PID temperature-control module for the cold thermal device

PID - W1209 module is a temperature-control circuit that helps us stabilize the temperature of the device.

a) b)

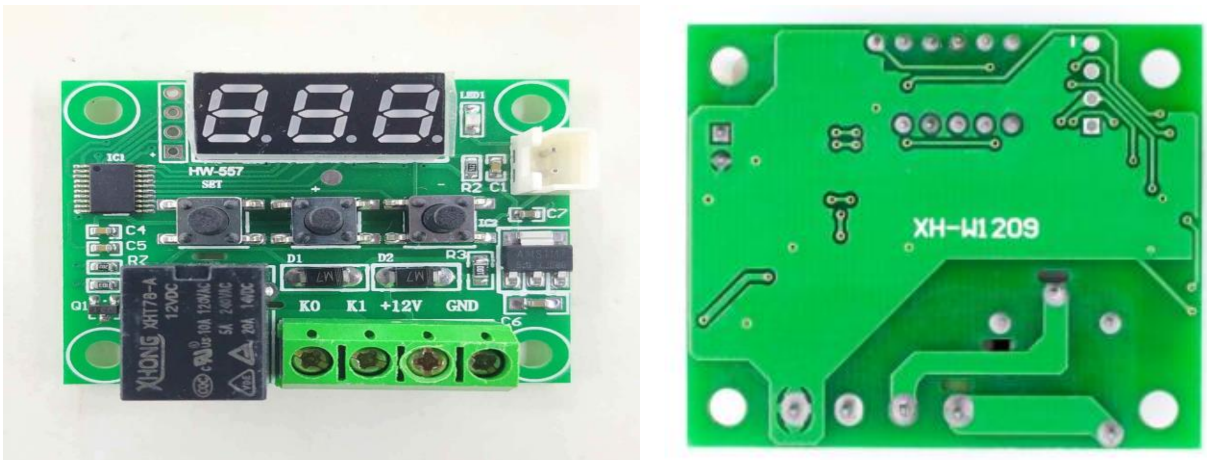

Figure 1. PID - W1209 temperature-control module : a) front side and b) back side

The device operates based on a thermal sensor to control the working environment temperature according to the initial set value showing on the 7-bar LED display. PID temperature control module has accuracy up to 0.1°C, with temperature range from 0-110°C. The device consists of 3 buttons: SET, UP (+) and DOWN (-).

The circuit has 2 input pins (IN) for power supply and 2 output pins for the Peltier battery and the cooling fan. The circuit uses a STM8 chip and a temperature sensor (thermistor) NTC (10K 0.5%). The input (IN) is sourced from the DC5V adapter and the output (OUT) is connected to the heating device. LED screen displays the temperature in real time. One can press the SET button once to set the temperature limit; the engine will stop working if exceeding that temperature. One can press and hold the SET button for 5 seconds to enter internal function settings.

Specifications of PID-W1209 temperature-control circuit:

+ Temperature control range: -50°C to 110°C
+ Accuracy temperature control: 0.5°C
+ Control mode: PID
+ Refresh rate: 4 times per second
+ Input source: DC-5V

+ Output current: MAX 10A
+ Maximum power: 5V = 120W
+ Input measurement: NTC thermistor (10K 0.5%), waterproof sensor
+ Operating temperature: -10ºC to 80ºC
+ Size: 48x40mm
+ Static current: less than 35mA, operating current: less than 65mA

2.3. The Peltier battery for the cool thermal device

The device uses the Peltier TEC1-12703 battery, a compact device with high performance. The device can work continuously, no pollution, no noise, and no vibration. The Peltier TEC1-12703-30W battery uses 5V ~ 12V voltage to create one hot side and one cold side. Specifications for the Peltier TEC1-12703-30W are operating voltage 5V ~ 12V, max current 5A, maximum temperature difference 60ºC and dimension 30x30x3.2mm.

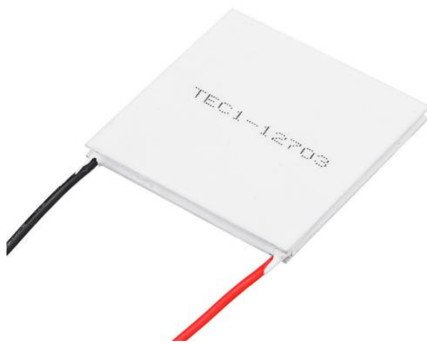

Figure 3. An image of Peltier TEC1-12703

2.4. Cooling system for the cool thermal device

Aluminum sheets are aluminum alloy in the form of sheets in different sizes and thicknesses. Using aluminum plates as a heat transfer medium is a good choice. This device uses A6061 and A7075 aluminum plates for heat dissipation. Aluminum' s outstanding features are high thermal conductivity (166 W / mK), good heat resistance with melting point of about 650ºC and low thermal expansion coefficient of about $23.4 \times 10^{-6}\ K^{-1}$. Aluminum plates are relatively flat, glossy and beautiful surface that is aesthetically pleasing, high strength, good moisture resistance and extremely high corrosion resistance, easy to process, relatively light with density of $2.72\ g/cm^{-3}$.

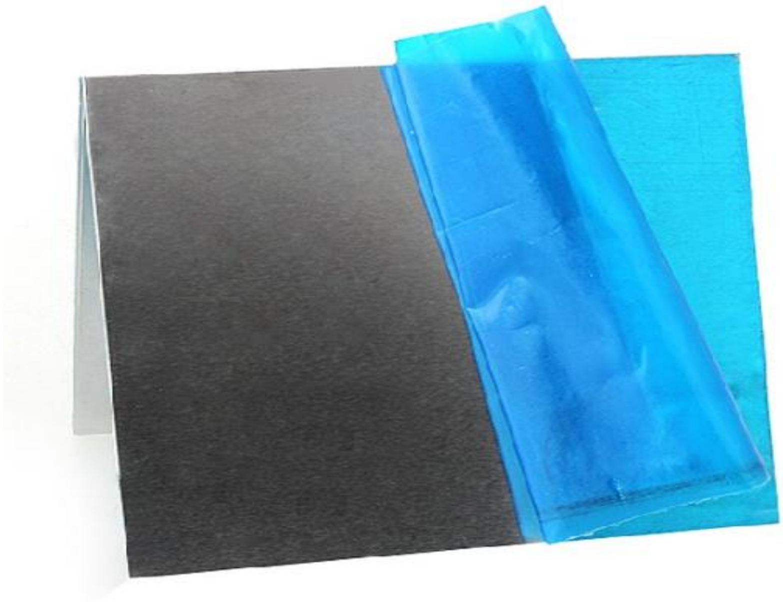

Figure 4. An A6061 aluminum sheet used for heat dissipation

We have to design a heat sink placed next to the hot side of the Peltier battery so that it can operate properly at maximum capacity with longevity. In this device, the cooling system consists of an aluminum sheet, heatsink, fitted with a cooling fan.

Figure 5. Combination of an aluminum sheet and a fan for cooling system

2.6 Power supply for the cool thermal device

The power source for the PID circuit and the battery has to supply a constant current and a voltage consistent with the aluminume sheet’s specification. A DC voltage of 5V with a maximum withstand current of 10A is suitable for the device.

Figure 6. A DC 5V-10A power supply

This power supply has overcurrent and short-circuit protection functions, automatically stabilizes the output current, and is safe for the device. Some specifications of the power supply are: input voltage: AC 100 - 240V (50-60HZ, 1.5A), output voltage: DC 5V - 10A, power: 50W, dimension: 15.2cmx8cmx4.2cm, jack: DC 5.5x2.5mm.

3 Model of the cool thermal device

The images of the device are shown below as in simulation and in pattern making.

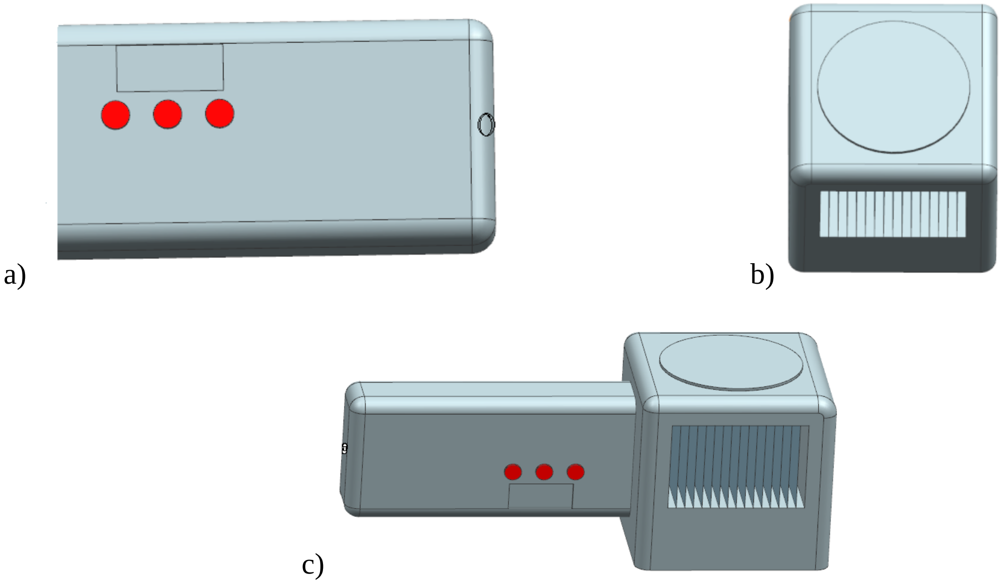

Figure 7: Images of the device in simulation: a) the handle b) the block of the Peltier battery and the cooling system c) front-view of the device

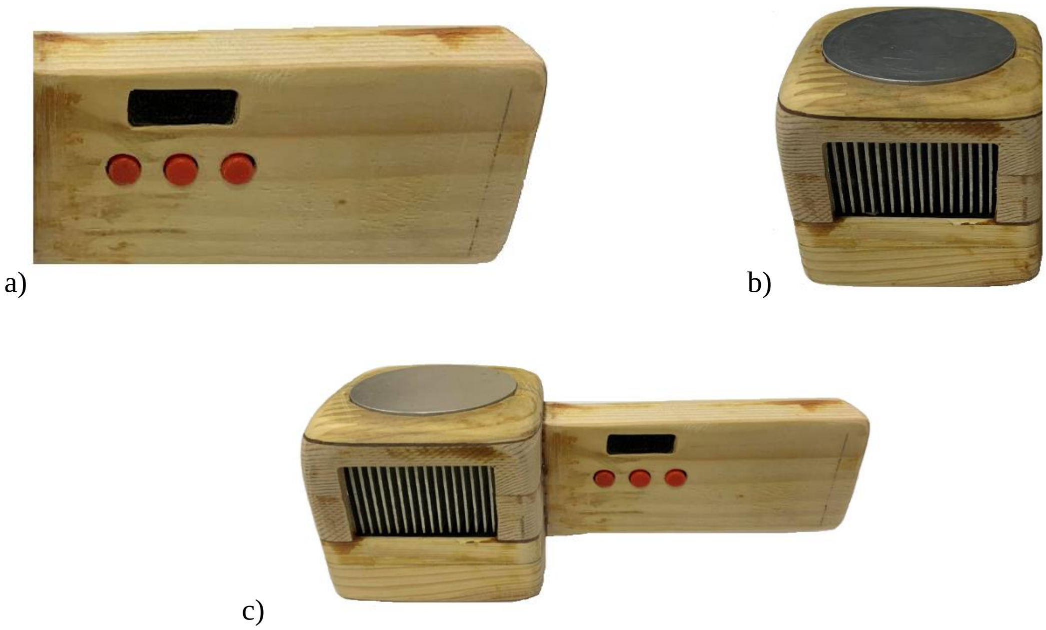

Figure 8. Images of the device in pattern making: a) the handle b) the block of the Peltier battery and the cooling system c) front-view of the device

4 Performance of the cool thermal device

The characteristics of I - V between the current flowing through the Peltier battery and the voltage placed on the Peltier battery were recorded when changing the supply voltage from 0.25V to 10V. The result is shown in Figure 9.

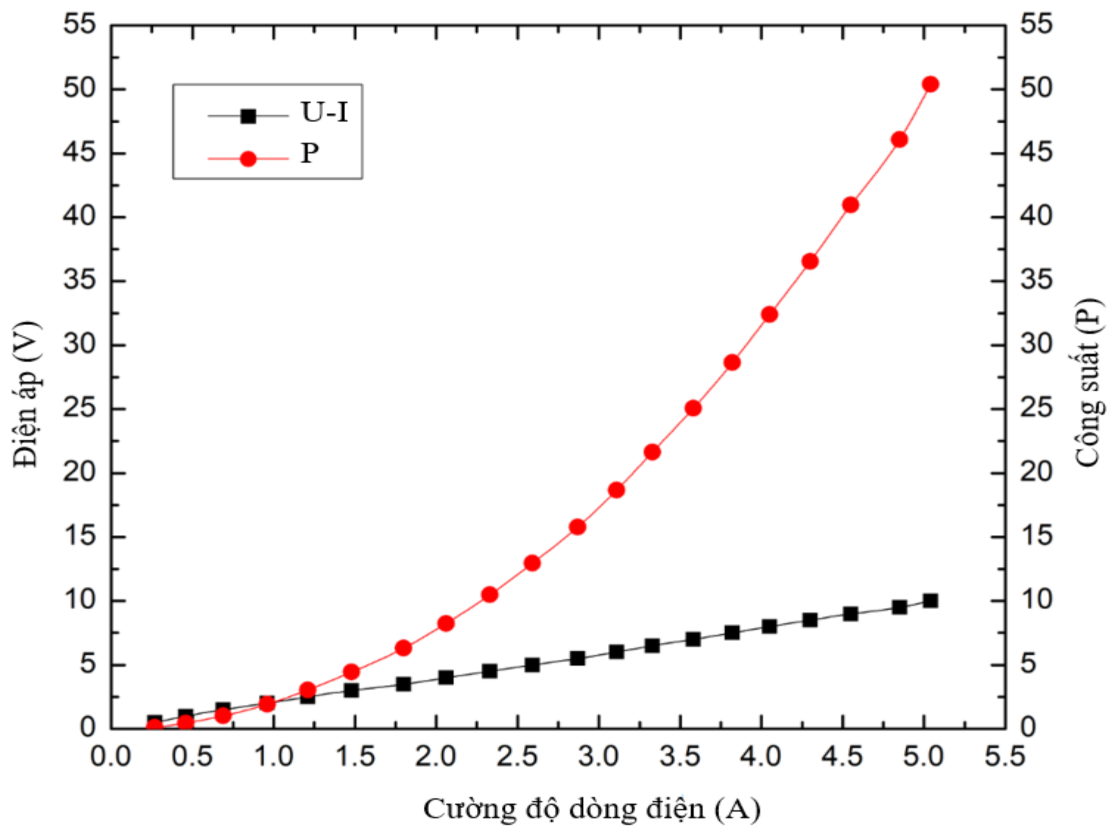

Figure 9. Graphs of the current versus the voltage and the power of the Peltier battery

The graphs show that when changing the voltage of the Peltier battery from 0.5V to 10V, the current varies from 0.27A to 5.04A. The U-I characteristic is a linear straight line. The power of the Peltier battery operates from 0.135W to 50.4W.

To study the stability of the temperature of the device over time we record the temperature of the device when there is no load and when in contact with the human body (with a load) at a temperature of SET = 7^{o}C, during the operation of 15 minutes with a room temperature of 25^{o}C.

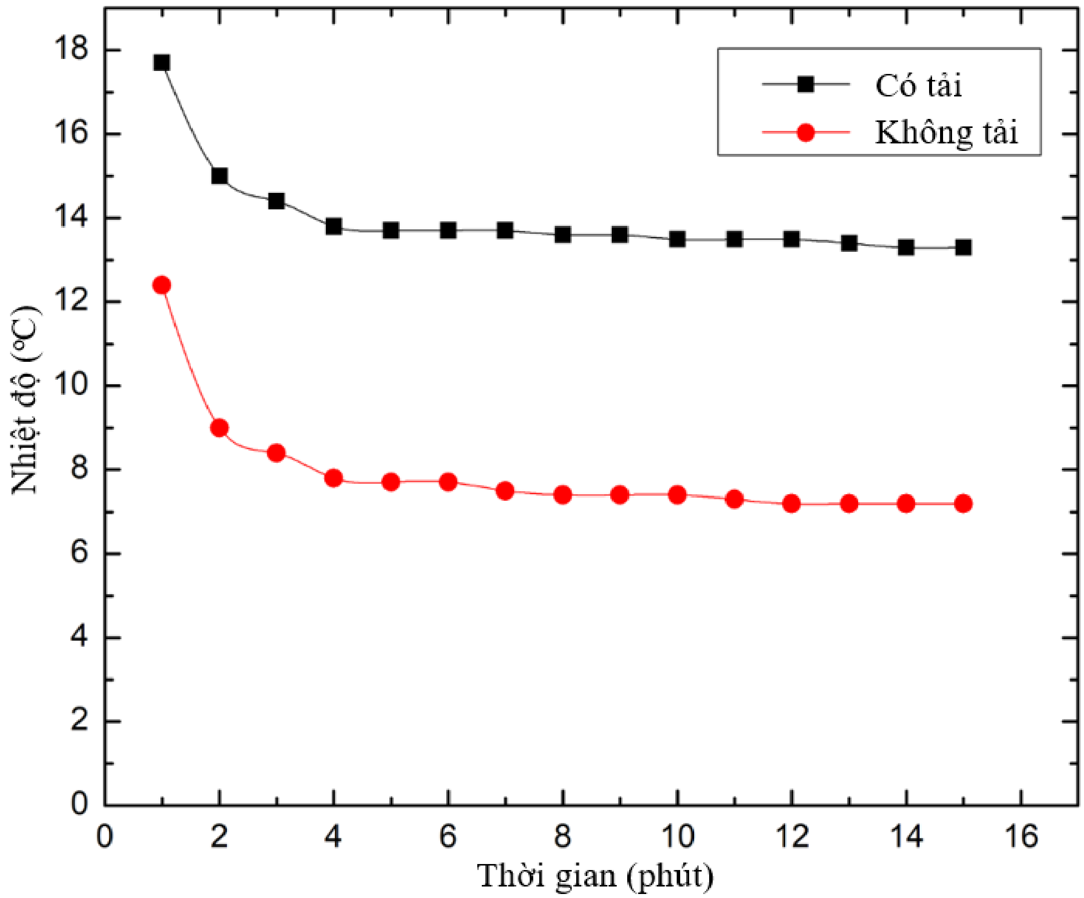

Figure 10. Graph of the temperature versus time with the SET temperature of 7°C

The graph shows that the temperature of the device without a load is reduced quickly after 3 minutes to Tc = 8°C compared to the SET temperature of 7°C and almost reaches saturation after 12 minutes Tc = 7°C. Temperature with the load reaches saturation after 7 minutes to Ttx = 13.7°C.

Besides, we study the temperature of the hot and cold sides of the device at room temperature of 25°C with a SET temperature of 8°C when there is no load.

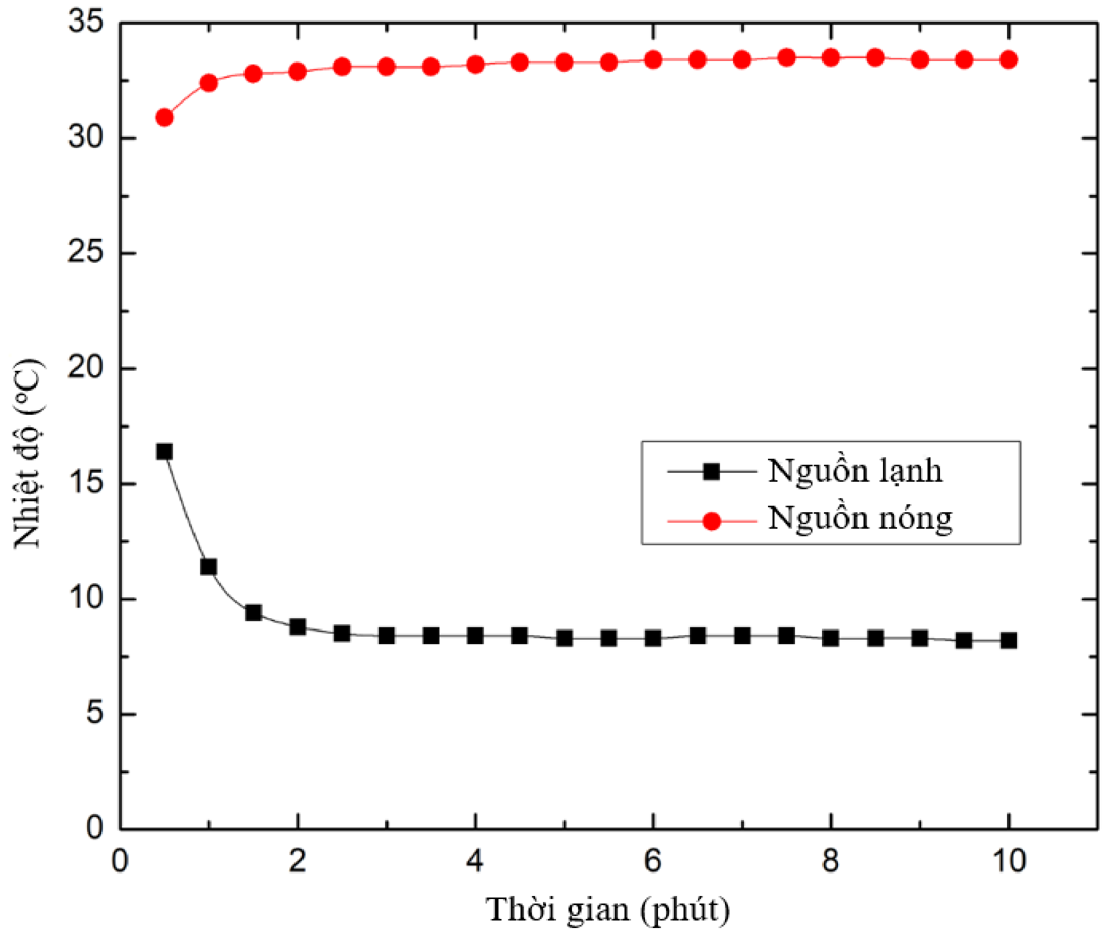

Figure 11. Graph of the temperature of the hot and cold sides of the device with the SET temperator of 8°C and at the room temperature of 25°C

The temperature of the hot side increases from 25°C to 32.4°C after 1 minute and reaches saturation at 33.4°C after 10 minutes. The temperature of the cold side decreases from 25°C to 8.8°C after 2 minutes and reaches saturation at 8.3°C after 10 minutes. The temperature difference between the hot and cold sides is 24.6°C when saturated. Cooling efficiency of the device is about 8%.

5 Conclusions and recommendations

This report presents a cool thermal device for the treatment of pain, swelling and inflammation. The device responds quickly, the power can reach 10W when supplying 5V-10A. Cooling efficiency of the device is about 8%. The temperature difference between the Peltier battery and the cold side for treatment is about 0.1-0.2°C. The temperature of the device when there is no load can drop to somewhere between 6°C-7°C.

The temperature of the device with a load compared to the case without a load varies from 5°C to 10°C when the temperature is saturated. The above results show that the device is highly effective and precisely temperature-control. The device is compact, convenient, easy to use, and effective in the treatment for pain and inflammation.

6 Acknowledgements

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7 References

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