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DESIGN AND DEVELOPMENT OF COMPUTER-CONTROLLED TEMPERATURE GRADIENT SYSTEM

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Abstract

In the 21. century, the job of a horticulturist is made easier with the help of a thermogradient table, with which the developmental stage of plants in different temperature conditions can be observed, this way, a plant's optimal ambient temperature can be found. The price of a thermo-gradient table is very high, it can reach thousands of euros. This is the reason why we had the idea of making our own thermo-gradient table, which is much more competitive, and can ease our institution horticulturist's work.

Keywords: *thermogradient, optimal seeding, temperature control.*

1. Introduction

Our aim is to design and construct a heat gradient table, the essence of which is to hold two ends of a relatively good heat conducting plate at a constant temperature, which results in a linear heat distribution. System users, horticultural engineers, or biologists may place plant seeds or microorganism colonies on the surface of the table that provides the same conditions except temperature [1]. By following the occasional multi-week process, we gobtain the optimal development temperature for them. The table's main piece is a 2000×1000×10 mm, 5083 type (95% Al, 4,5% Mg, 0,5% Mn) aluminium sheet. Taking in consideration the aluminum's heat conductivity, among other metals, it's considered to have a good heat conductivity, it serves well for our purpose. The aluminum's heat factor is 237 W/m×K, and taking in consideration the purchase of the purest form of aluminium, we hope that we reach linear temperature distribution. At one end of the aluminium sheet, providing the heat, we will have a row of heating resistances, that produces a ΔQ heat quantity in form of energy. We know from the law of thermodynamics, that the delivered temperature is equal to the acquired temperature. This way, we can say that the acquired temperature by the aluminium sheet can be defined as follows:

$$\Delta Q = m \cdot c \cdot \Delta t \tag{1}$$

where m is the mass of the sheet, c is the specific heat while Δt is the temperature change. At the other end of the sheet, a coolant maintained at a low temperature by a cooling device serving as a heat exchanger is supplied in copper tubes. Due to the heat conduction, heat is emitted from the sheet, which is another ΔQ, the amount of heat that is proportional to the mass and specific heat of the coolant passing through the units in unit time. [2].

Figure 1. shows the thermal imaging of the sheet, showing the temperature of the cold end +2 ° C and the hot end + 40 ° C and the linear transition. The thermal imaging shot was made with a US-made FLIR One Pro thermal imager. During the measurements, our preliminary assumption was that the reflection of the metal sheet interferes with the camera, so we intend to cover it with a light-absorbing layer.

2. Structural composition

2.1. Structure

In **Figure 2.** swe can see the complete system's block diagram.

2.2. The heating and cooling subsystem

The hot end of the table is heated using 20, 100W/piece power HTS-14 type heating (**Figure 3.**), that we powered with a self-designed phase cutting power source.

The maximum power we can reach is 2000W, but with the help of the measurements and the calculations, we concluded that we can heat the aluminium sheet with a smaller amount of power. The main piece of the power source is a PIC type microcontroller, that, with a help of a TRIAC, controls a phase splitting voltage of 230V AC.

The cooling is achieved using a Beko BPEU121 air conditioner that has a cooling capacity of 12000 BTU. The air conditioner's internal unit was split up, and the heat exchanger placed in a cooling liquid filled container, that contained about 33l of ethylene glycol. The circulation of the coolant was performed using a DAB Evotron 60/130 type circulator suction-pump. At the cold end of the table, a copper heat exchanger was placed. (**Figure 4.**). **[3]**

2.2. Temperature measuring

The transient and final state of the thermal balance is measured and visualized by a microcontroller-based sensor system and a Flir One Pro thermal imager. The thermometer system consisted of an Arduino Nano and ten DS18B20 type OneWire digital sensors. The program written at Arduino measures the temperature at predetermined intervals at ten different points, sends it to a computer on which a software written in a CVI LabWindows development environment graphically displays and stores the measured data. **[4]**

2.3. Phase cutting power supply

The diagram of the phase splitter power supply and the printed-circuit's plan were made with Eagle

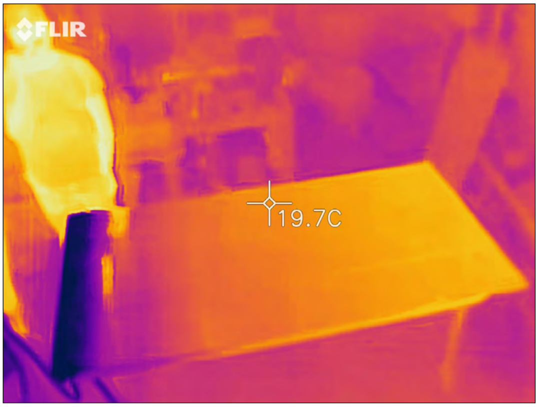

Figure 1. *Thermal image of the thermogradient table*

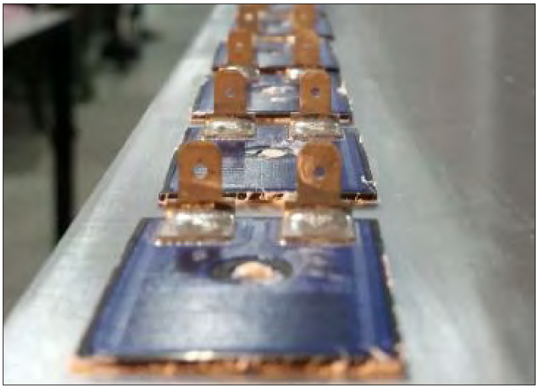

Figure 3. *Fitting the heating resistors*

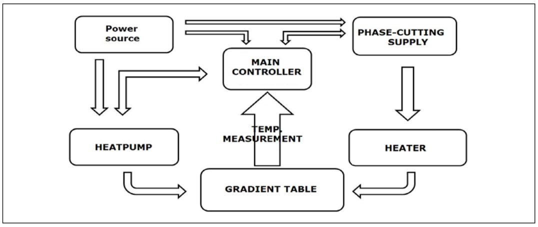

Figure 2. *System block diagram*

Figure 4. *Heat exchanger plate mounted on the bottom of the aluminum block*

software. After development, the printed-circuit was made using the photo-technical method, and the components were implemented. At the base of the power supply stands a PIC 16f684 microcontroller, that produces an analogue signal from the 0-5V range, and generates a PWM (pulse width modulated) signal at appropriate intervals based on an optocoupler to generate ignition pulses to a triac that performs the phase lock. In the illustrations below, we can see some oscilogramms while the power supply is working. In **Figure 5.** the oscilloscope's 1st channel is connected to the analogue lead voltage, on the second channel the PIC generated staringignition pulse. **[5]**

In **Figure 6.** we can observe the phase cut line power, measured on the ends of the heat resistor.

This way, if we measure the temperature at the table's warm point, it can be controlled, and the desired temperature can be set.

On the PIC microcontroller, in the mikroC PRO for PIC software, we developed a firmware, which controls the phase splitting, and a cooling fan that drains the heat from an ontriac placed on heat sink, if needed.

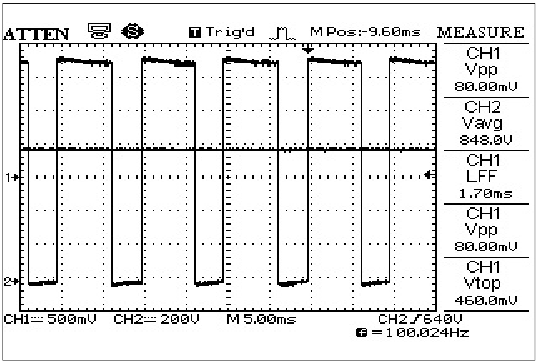

Figure 5. *Leading analog signal and ignition pulse*

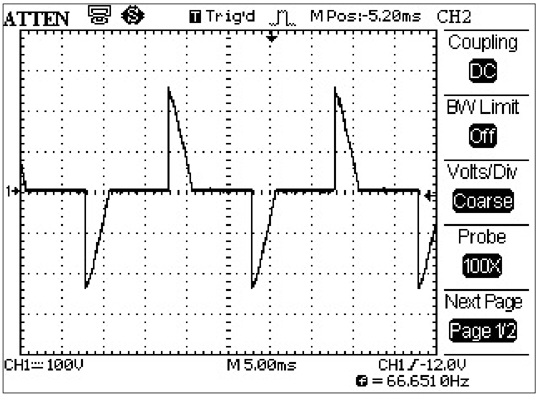

Figure 6. *The phase cutted sine signal*

3. Calculations, simulation, measurements

3.1. Calculations

The cooling and heating of the aluminium sheet can be described with the help of a mathematical equation. To use this differential equation, we need two standard physical equations. One of these equations is that temperature flows from the higher to the lower temperature place. The other one is Joseph Fourier's law, the time rate of heat transfer through a material is proportional to the negative gradient in the temperature. If we take into consideration the boundary conditions, at both ends of the aluminium sheet, the heat source and the heat detractor's presence and the starting temperature, we can write a differential equation with two variables,

$$f=\frac{du}{dt}-\frac{a\cdot d^2u}{dx^2} \tag{2}$$

which interprets the mixed task of the thermal conduction equation and allows us to calculate the temperature of a given point at a given time. In equation (2), a is the constant

$$a=\frac{k}{c\cdot g} \tag{3}$$

and h is the temperature permeability's factor, c the aluminium's specific heat, and a is the aluminium's density.

3.2. Simulation

In addition to the above equation, we proved and simulated the linear temperature distribution using the ENERGY 2D software. In the next illustrations we can observe the temperature distribution on the aluminium sheet. Taking into consideration the aluminium sheet's and the insulant's heat permeability, it is provable with the simulation that the temperature distribution is linear. (**Figure 7.** and **8.**)

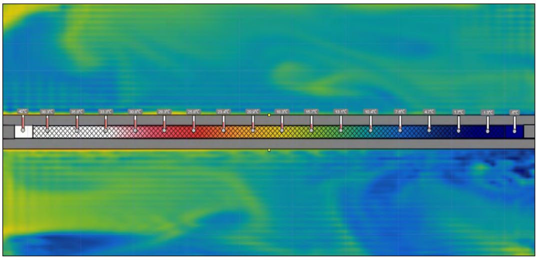

Figure 7. *Heat distribution in the aluminum block*

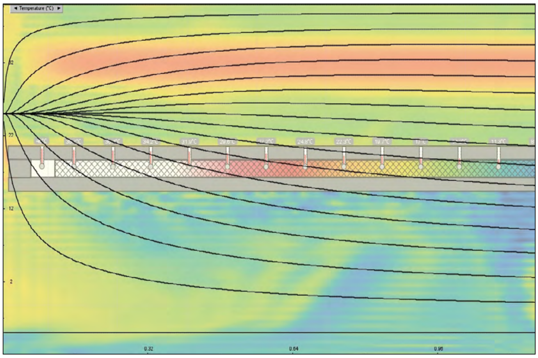

Figure 8. *Temperature change at different points*

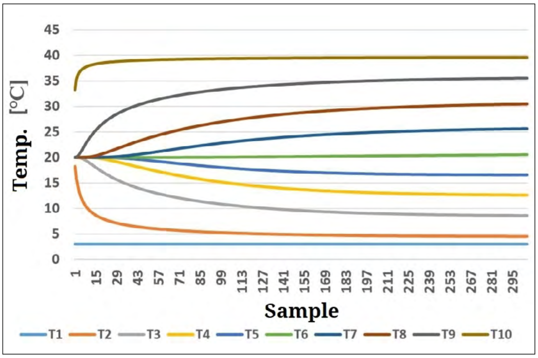

Figure 9. *The measurement graph*

3.3. Measurements

After the simulation results arrived, we could see that it confirmed our calculations. After the thermogradient table's equipment was ready, we started a test measurement with the help of a sensor system. After the termination of the measurements, we illustrated the data in a graph, and we confirmed our expectations. The temperature on the aluminium sheet spreads in a gradient form - from 40 °C to 3 °C. In the next graph (**Figure 9.**) the measurements results are shown.

The measurements provide an hoursworth of information, the program is set up to a 10 second interval for sampling, this is about 300 data samples. We can observe that the temperature distribution is nearly linear.

4. Conclusions, future plans

The thermo-gradient system's construction presented in the article was made with the help of the Horticultural Engineering tutors and students from Sapientia Hungarian University of Transylvania. Seeing the increased and immediate application of the system, as an II. year electrical engineering student, we have undertaken this work, often encountering concepts and technologies that have not yet been learned. We see these obstacles as a challenge and we intend to use a well-functioning automated system for our gardener and biologist colleagues at the end of our further student research activity.

In the future we would like to study the communication line of the heat pump in order to control the optimal heat balance. We intend to build everything that makes up the table so that it can be handled easily by the average user. We intend to provide the system with a permanent light-emitting lighting system suitable for special plants to be suitable for indoor use. In addition, we have a plan to create an interactive interface for easy setting of parameters and feedback on temperature and humidity. We consider it necessary to insulate the plate or to form a closed space to keep the biological material used for the experiment at a constant temperature using relatively little energy. Last but not least, we intend to create a design that will make the system we design marketable

Acknowledgments

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