

TEMPERATURE CALIBRATOR WITH TEC MODULE

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A TEC is a small device that operates like a heat pump when it is powered from source. When it is utilized to provide power it is called thermoelectric generator (Seebeck effect) and it is marked TEG. When it is utilized as a heat pump it is called thermoelectric module (Peltier effect) and it is marked TEC.

A TEC contains a number of junctions p-n, electrically connected in series, made sandwich between two ceramic plates. When they are connected to a continuous power source, because of the electric current, the head moves from one side of the TEC to another. In a natural way, this creates a hot side and a cold side for the TEC. A typical application is putting the cold side in contact with an object that needs to be cooled, and the hot side in contact with a radiator that will disperse the heat in the environment. To improve rated capacity the heating shifter can be cooled with air or liquid.

If the electric current's polarity is changed, we will observe that the hot side will switch places with the cold one. The maximum heat quantity a TEC can pump is 125W, when the temperature difference between the cold and the hot side is not in excess of 67°C. To increase the heat quantity the TECs can be arranged in a multilayer or in a cascade way.

Structure and function

A conventional cooling system contains three fundamental parts - the evaporator, compressor and condenser. The evaporator or cold section is the part where the pressurized refrigerant is allowed to expand, boil and evaporate. During this change of state from liquid to gas, energy (heat) is absorbed. The compressor acts as the refrigerant pump and recompresses the gas to a liquid. The condenser expels the heat absorbed at the evaporator plus the heat produced during compression, into the environment or ambient.

A thermoelectric has analogous parts. At the cold junction, energy (heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type).

Thermoelectric Coolers are heat pumps, solid state devices without moving parts, fluids or gasses. The basic laws of thermodynamics apply to these devices just as they do to conventional heat pumps, absorption refrigerators and other devices involving the transfer of heat energy.

In practical use, couples are combined in a module(fig.1) where they are connected electrically in series, and thermally in parallel.

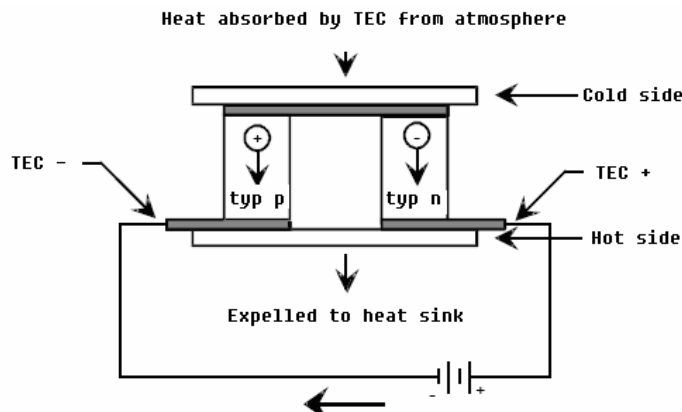


Fig.1

Single stage thermoelectric devices are capable of producing a "no load" temperature differential of approximately 67°C. This practice is often referred to as Cascading. The design of a cascaded device is much more complex than that of a single stage device, and is beyond the scope of these notes.(fig.2)

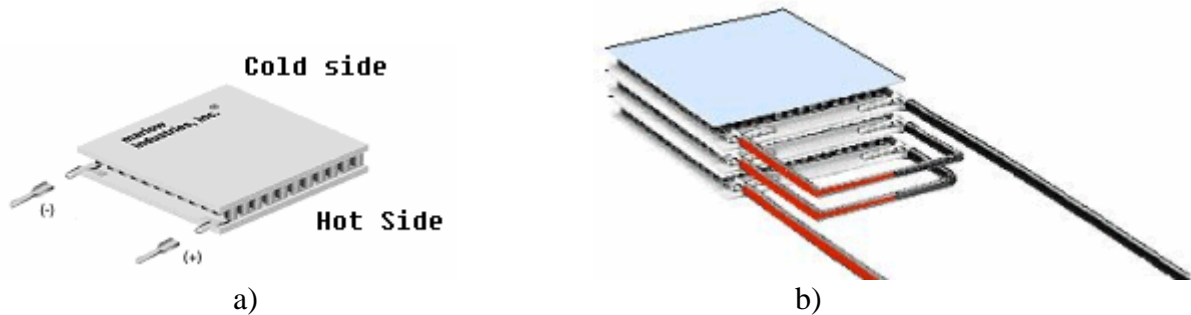


Fig.2
a)- single module variant; b)- cascade module variant

Modules are available in a great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The present trend, however, is toward a larger number of couples operating at lower currents.

Once it has been decided that thermoelectrics are to be considered, the next problem is to select the thermoelectric(s) that will satisfy the particular set of requirements. Three specific system parameters must be determined before device selection can begin. These are:

- Tc- Cold Surface Temperature
- Th- Hot Surface Temperature
- Qc- The amount of heat to be absorbed at the Cold Surface of the TEC

In most cases the cold surface temperature is usually given as part of the problem - that is to say that some object(s) is to be cooled to some temperature. Generally, if the object to be cooled is in direct intimate contact with the cold surface of the thermoelectric, the desired temperature of the object can be considered the temperature of the cold surface of the TEC (Tc).

The Hot Surface Temperature is defined by two major parameters:

- 1) The temperature of the ambient environment to which the heat is being rejected.
- 2) The efficiency of the heat exchanger that is between the hot surface of the TEC and the ambient.

These two temperatures (Tc & Th) and the difference between them (ΔT) are very important parameters and therefore must be accurately determined if the design is to operate as desired. Figure 1 represents a typical temperature profile across a thermoelectric system.

The third and often most difficult parameter to accurately quantify is the amount of heat to be removed or absorbed by the cold surface of the TEC. All thermal loads to the TEC must be considered (i.e. electrical leads, insulation, air or gas surrounding objects, mechanical fasteners, etc.). In some cases radiant heat effects must also be considered.

Once the three basic parameters have been quantified, the selection process for a particular module or group of modules may begin.

Power supply and temperature control are additional items that must be considered for a successful T.E. system. A thermoelectric device is a DC device. Any AC component on the DC is detrimental. Degradation due to ripple can be approximated by:

$$\Delta T / \Delta T_{max} = 1 / (1+N^2), \text{ where } N \text{ is } \% \text{ current ripple.}$$

In a typical TEC system, current flow through the TEC pumps heat from one plate surface to the other. Based on the Peltier effect, this makes one plate cold and the other hot. If current direction is reversed, the hot and cold **sides** also reverse. The TEC is mounted between the heat sink and the device being cooled with a sensor to monitor temperature. The controller uses the temperature sensor feedback to adjust the current flow through the TEC to maintain the device at the desired temperature.

Building a stand with thermoelectric modules for calibrating thermo-manometers between -20°C and 100°C has the following parts:

- measurement box on which there are two thermoelectric modules, the radiators, the temperature sensor and the ventilators. The calculations for dimensioning and determining the functional parameters were made with the help of software, and are presented in Annex 1.

- controller
- display
- power source

Usage of the device: (fig.3)

The thermo-electric modules **(1)** are powered from a constant source **(7)** through a controller **(6)**. The controller **(6)** is subordinated to the temperature sensor **(3)** placed in the measurement box and adjusts the polarity of the thermoelectric modules **(1)** so that the inside temperature would stabilize at the arranged value, viewed on the display **(8)**. Meanwhile the display shows the temperature from the box while it is stabilizing. The temperature adjustment is made with the keyboard on the display.

The heat transfer between the box and exterior is uniformed with the help of the radiators **(2)** permanently ventilated by four coolers **(5)**. The thermic transfer with the outside is improved by introducing an isolator **(4)** between the box and the radiators.

The controller contains an integrated "H" bridge that accomplishes a bi-directional control (warming and cooling) for more thermoelectric modules. The "H" bridge control is conceived to accomplish a continuous transition between warming and cooling. The controller utilizes a modulation in the impulse duration (PWM) for controlling the power level at 1 KHz frequency. This controller operates an algorithm (PI) to provide a precise control. The proportional function interval is adjustable from 1°C to 16°C and the integration mark adjustable from 0 to 2.55 repetitions per minute. The thermic system achieved can allow a control of $\pm 0.1^{\circ}\text{C}$.

Due to these performances was possible developing a high dimension box that allows checking thermo-manometers with bulb until 250 mm.

In the following sections, each component is reviewed in detail.

Temperature controller:

This controller is an economical, open board temperature especially designed to operate thermoelectric (Peltier effect) modules. This controller will provide temperature control of thermoelectric modules up to 350 watts.

The controller contains a solid state "H" bridge. This provides BI-directional (heating and cooling) control for one or more independent TEC modules. The control of the "H" bridge is designed to provide a seamless transition between heating and cooling. (no dead spot in the control function during transition between heating and cooling) The controller utilizes Pulse Width Modulation (PWM) to control the power level in the thermoelectric module. The base frequency is 1 kHz. The output power resolution is one of ± 250 steps in the load circuit control.

The controller provides an indication of the heat or cool operation mode. A Green LED is used to indicate a heating mode. A Blue LED is used to indicate a cooling mode. Both the Green and Blue LED being on indicate an open sensor. The controller load circuit is off for an open sensor.

This controller was designed with a proportional / integral control algorithm to provide the most precise control at the most economical cost. The proportional bandwidth is adjustable from 1.0°C to 16°C and the integral rate is adjustable from 0 to 2.55 repeats per minute. These adjustments permit optimizing individual thermal systems. In a well designed thermal system end point control can be $\pm 0.1^{\circ}\text{C}$.

The controller will accept a TS67 sensor (-20°C to $+100^{\circ}\text{C}$) or will accept a TS104 sensor (0°C to $+150^{\circ}\text{C}$). The sensor selection is made via a PCB mounted dip switch. The controller is capable of providing up to 12.5 amps of current for modules rated 3 through 28 volts dc with an ambient temperature of 0°C to $+50^{\circ}\text{C}$.

The controller will operate with a single power supply over the range of 6vdc to 28vdc. If the TEC operation demands lower tensions, two power supplies are required: one for 3...28 Vdc and one for 6...28 Vdc, for control circuit (which will draw less than 100 mA).

The controller electronics have a set point stability of $< \pm 0.1^{\circ}\text{C}$ after one hour of stabilization @ 25°C ambient.

The controller has a temperature resolution of 0.1°C . This will provide an end point control of up to $\pm 0.1^{\circ}\text{C}$. To achieve this control requires that the thermal system be well designed, the sensor must be in proper location and the system well tuned. Minimum delay in the temperature sensor seeing the temperature change in the TE Module temperature is preferred.

The controller must be located in a well ventilated place. Any displacement of the air over controller will improve thermal ambience of the controller.

Display

The display indicates the temperature of the control sensor. If this is off-line, the display indicates -21°C. If the sensor is shorted, the indication will be 160°C.

The readout may be set to indicate in °C or °F. An LED on the front panel indicates this selection. To change this selection: depress both the up and down button and then apply power to the controller. The display will indicate -S-. The up button will toggle °C & °F. The LED will indicate which is selected. To store this selection depress the down button. The display will return to normal operation, and the selected mode, °C or °F, will be indicated. You must confirm set temperature in new selected mode.

To display the set temperature, depress either the up or down button. The display will indicate the set temperature. Release the button and depress again to increment to a new set temperature. Release the button when the desired set temperature is observed. In a second or two the controller will accept the new set temperature and the controller will move to attain the new set temperature. The default reading is the actual temperature.

Power supply

If you are working with a commercial TEC based "cooler" it will have its own power supply. Be careful that you determine the operating voltage and the I_{max} (max current draw) and that these values match your temperature controller's capability.

Technical data

Operativ range : -20°C to +100°C (ambient temperature = 18 °C);
 Stability: 0,1 °C;
 Regulation and reading probe: TS67 sensor;
 Reading: °C or °F;
 Standard bolck: Ø 25x250;
 Voltage: 230V 50 Hz.

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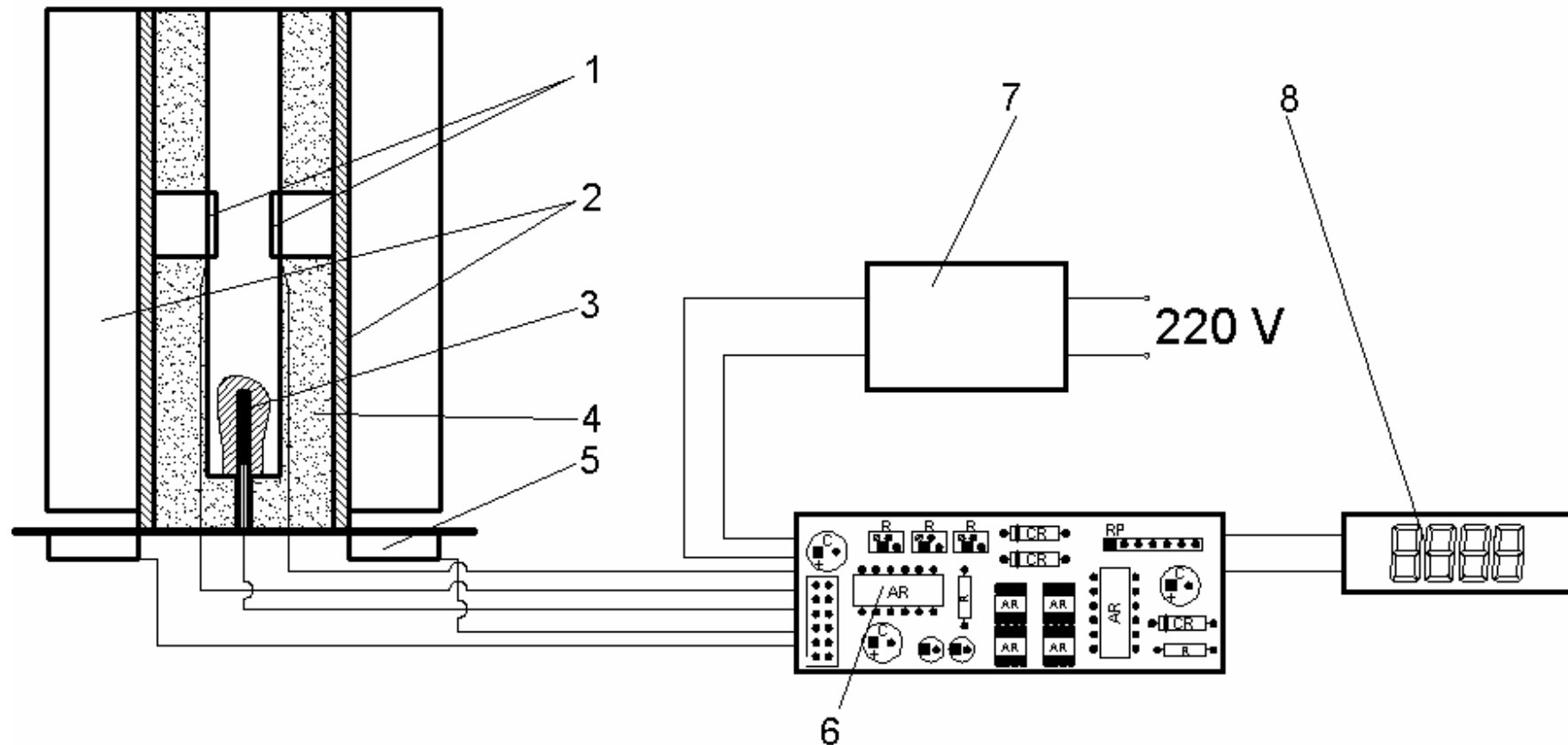
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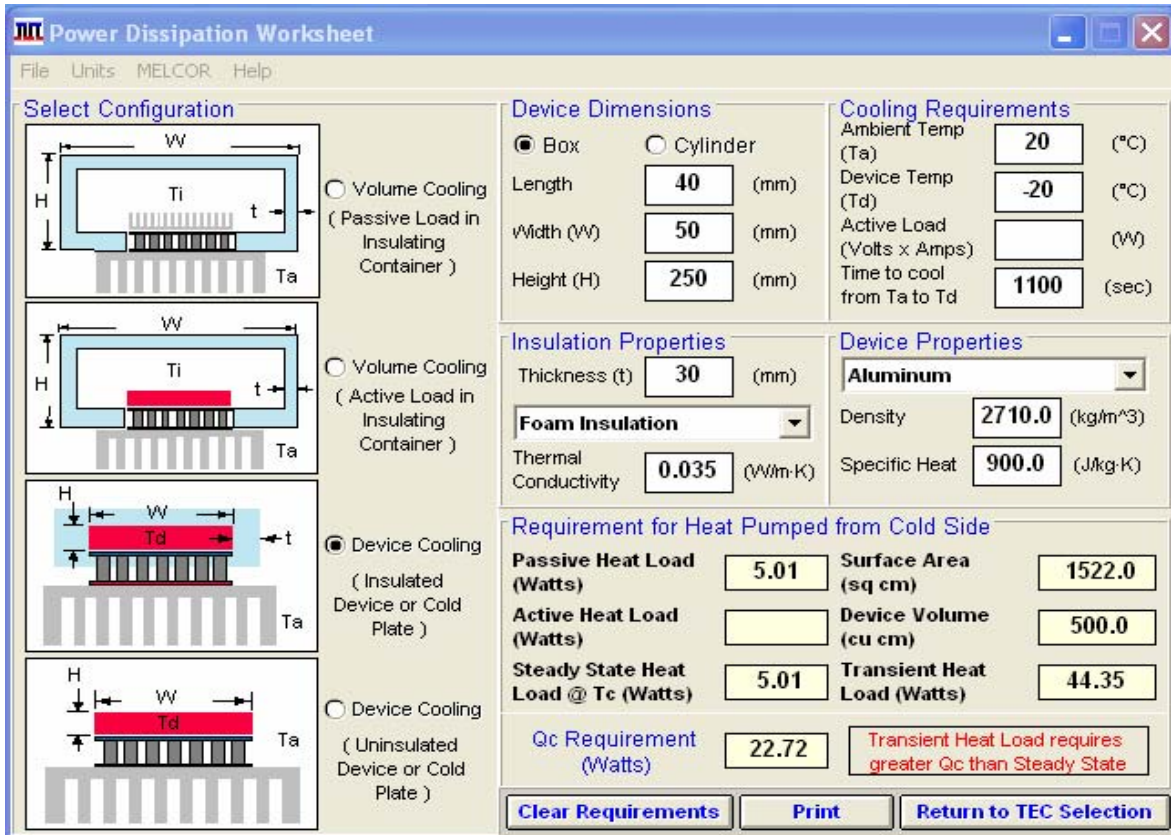
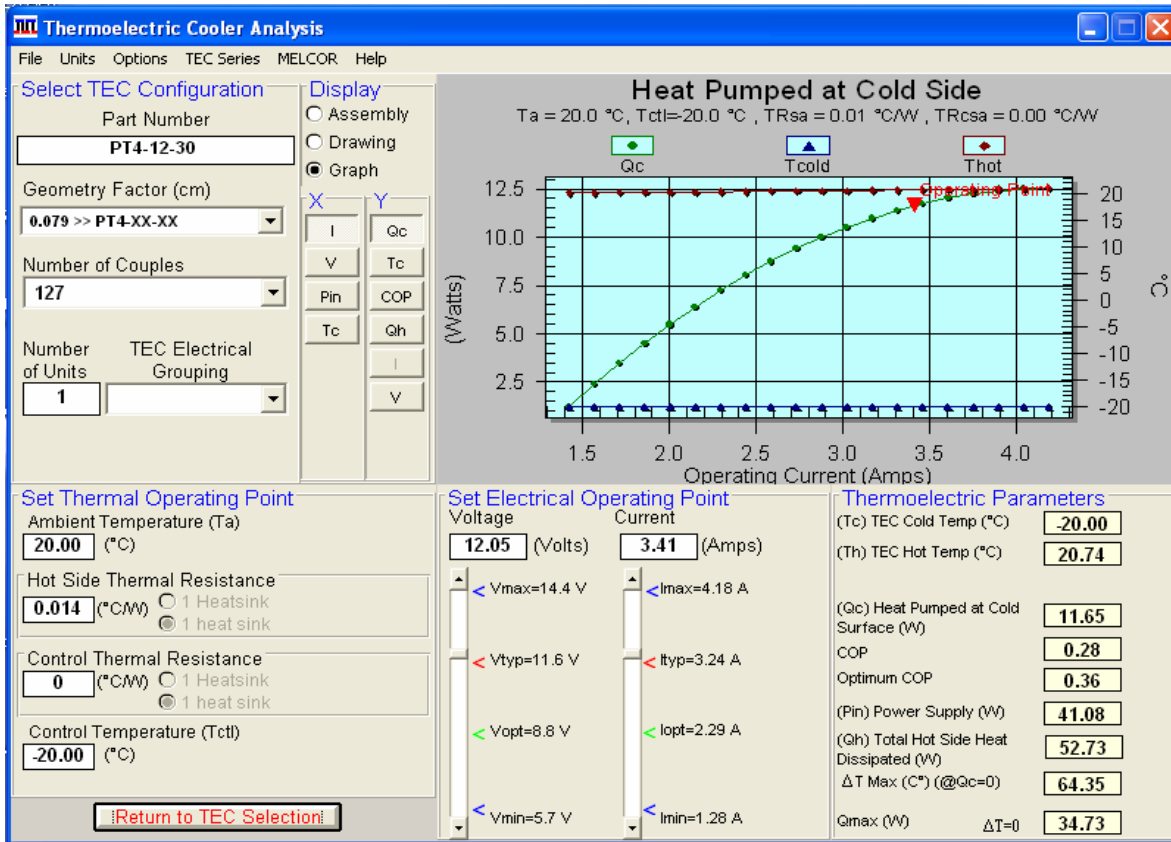
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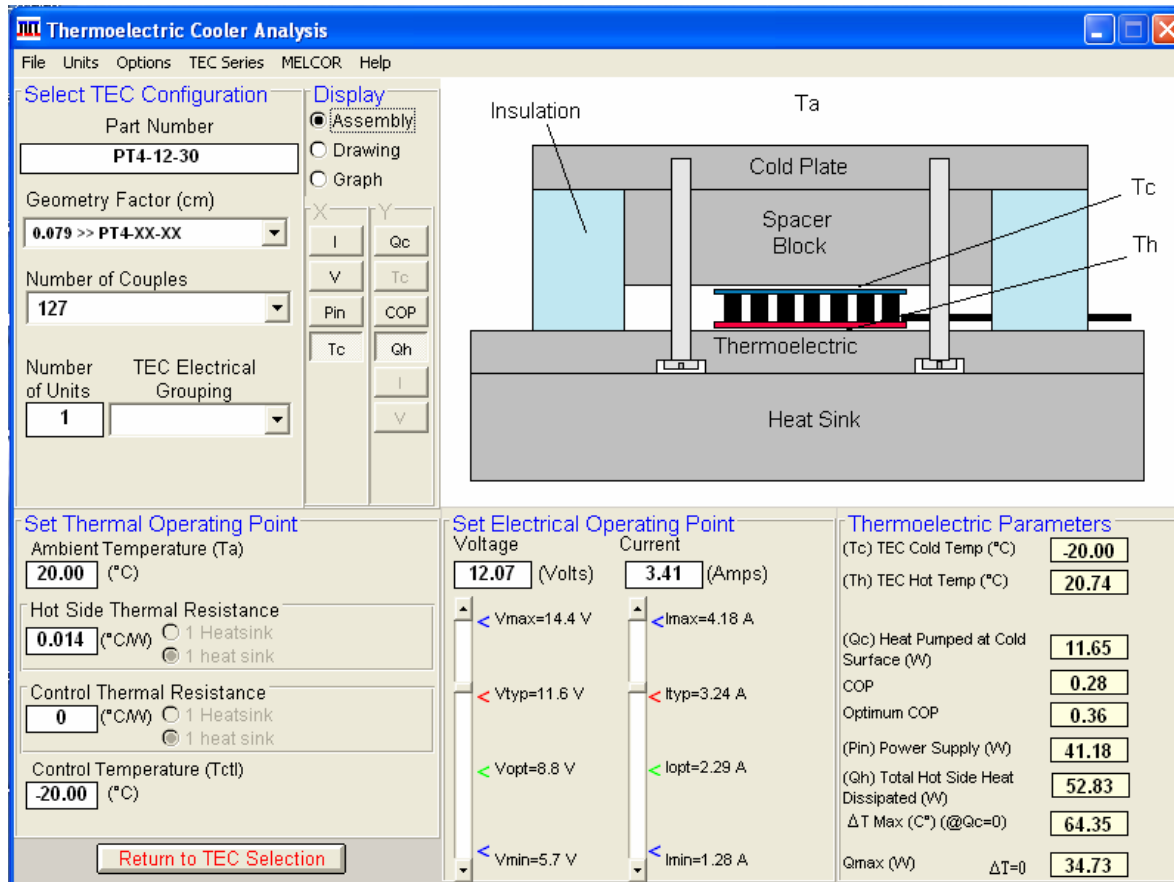
SCHEMATIC DIAGRAM



1 – TEC; 2 – Heat skins; 3 – Temperature sensor; 4 – foam insulation; 5 – Fans; 6 – Controller; 7 – Power supply; 8 – Display.

Fig.3





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Thermoelectric Cooling PT4-12-30 (2 in parallel)

Cooling Requirements	Values
Ambient Temperature (Ta) (°C)	20,00
Hot Side Thermal Resistance (°C/W)	0,069
Control Thermal Resistance (°C/W)	0
Control Temperature (Tctl) (°C)	-20,00
Voltage (Volts)	11,73
Current (Amps)	6,29

Thermoelectric Parameters	Values
Geometry Factor (cm)	0,079
Number of Couples	127
(Tc) TEC Cold Temp (°C)	-20,00
(Th) TEC Hot Temp (°C)	26,34
(Qc) Heat Pumped at Cold Surface (W)	18,17
COP	0,25
Optimum COP	0,30
(Pin) Power Supply (W)	73,77
(Qh) Total Hot Side Heat Dissipated (W)	91,93
ΔT Max (C°) (@Qc=0)	66,44
Qmax (W) $\Delta T=0$	69,30

