

TPS Hot Plate Characterization

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4/23/2009



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DOCUMENT TITLE: TPS Hot Plate Characterization

DOCUMENT NUMBER: SP2009-LI-001

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4/23/2009

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Purpose

This document describes the operation and functional performance of the new Torrey Pines Scientific (TPS) Digital Hot Plates installed in the exhaust enclosure in Bay 2 (Lithography) of the UTD Clean Room Labs.

Description

The new digital hot plates are multifunctional and have a solid ceramic heater top which will withstand aggressive chemical attack, however please do not test this aspect of the spec. The hotplate will attain high temperatures, but the UTD Cleanroom recommended max is limited to 200 C in the exhaust enclosure. The hotplate is designed for 1% temperature accuracy over their entire range and will maintain a set temperature to +/- 1 C. The heater uses 600 Watts of electrical power and the temperature is controlled by a Platinum RTD sensor under the plate surface which feeds a PID control loop set for the specific heater top being used. The LCD display shows the plate target and actual temperature as well as the temperature ramp value and count-down timer with alarm and user settable Auto-Off. The hot plates also feature an electronic calibration that was set at the factory and can be traced to NIST. There is no stirring capability on these hot plates, so no heating of beakers of liquid is allowed.

Operation

The hotplate power switch is located on the back at the point of entry of the power cord. Hotplate commands are entered via function and arrow icon buttons on the front panel. Basically, the operation technique is to press a function icon and then push the arrow buttons until the desired value of the icon function appears in the LCD window. Figure 1 shows the keyboard with function labels.

Since the power switches are on the back of the units, we have decided to leave the hotplates on all the time. To conserve power, we will turn the temperature to room temperature at the end of the day. The hot plates heat up quite rapidly so the rule will be to turn them on only when required.



Figure 1. TPS Hotplate with Ceramic heating platen and function controls.

Operation Details

- 1. *Basic Hotplate Bake* – Standard hotplate operation.
 - a. Turn on the Power switch at rear
 - b. Press the “Heat Off” key to clear previous programming.



Heat Off button to clear previous program.

- c. Press Plate Temperature icon.



Plate Temperature icon

- d. Tap arrow keys until your desired temperature appears in the LCD window.
 - e. Oven will start max ramp to attain set temperature after 5 second delay.

- f. Note that the Temperature readout continuously toggles between “Target” and “Actual” temperatures.
- 2. **Thermal Ramp-Up** – Increase the temperature at a predetermined rate.
 - a. Press the “Heat Off” key to clear previous programming.
 - b. To set a ramp value, press the ramp icon.



i. Thermal Ramp icon

- c. Then press the arrow keys until the ramp rate value (deg C per hr) appears in the LCD window.
- d. Then set the desired temperature
 - i. Press the Plate Temperature icon
 - ii. Press arrow keys until desired temperature appears in the LCD window.
- e. After a 5 sec delay the hotplate will ramp at the desired rate until it reaches the set-point temperature.
- 3. **Thermal Ramp-Down** – Cool the sample at a predetermined rate (slower than its natural cooling rate).
 - a. Press the “Heat Off” key to clear previous programming.
 - b. Press the ramp icon (at any temperature)
 - c. Then tap the arrow keys until the desired (lower) temperature appears in the LCD window.
 - d. After a 5 sec delay, the hotplate will ramp at the desired rate until it reaches the new temperature.
- 4. **Timed Bake** – heat a sample for a specified time and sound an alarm when complete.
 - a. TIMED BAKE: Bake a sample for a given time at some temperature and alarm.
 - i. Press the “Heat Off” key to clear previous programming.
 - ii. Establish the desired temperature as noted in step 1. - Basic hot plate bake.
 - iii. Then press the Time icon.



Time icon

- iv. Tap arrow keys to set seconds
- v. Re-press the Time icon
- vi. Tap arrow keys to set minutes
- vii. Re-press the Time icon

- viii. Tap arrow keys to set hours
 - ix. Note, if only minutes are desired, just press the timer icon until the minutes flash in the LCD display, then tap the timer icon until all numeral blinking ceases and the timer will start.
 - x. When the time expires, an alarm will sound. The temperature remains at the set point.
- b. AUTO-OFF: Bake a sample for a set time and have the hotplate turn off and alarm.
- i. Establish the desired temperature as noted in step 1. – Basic Hot Plate bake.
 - ii. Then press the Time icon and tap the arrow keys to set the time as outlined above.
 - iii. Press the “Auto-Off” button.



Auto-Off button

NOTE 1: The hot plate Red LED labeled “Hot Plate” illuminates when the temperature exceeds 50 C, warning users that the plate is “HOT.”

NOTE 2: If the temperature goes higher than 455 C, the “Over Temp Alarm” will illuminate, sound an alarm, and turn off the heater for safety protection.

Characterization

The following discussion describes the initial operating characteristics of the new hotplates. Parameters such as heating and cooling rates and controlled cooling characteristics as well as hotplate temperature uniformity are measured and reported in the following sections.

1. Heating and Cooling Cycles

To characterize the hotplate performance, the first parameters to note are the heating and cooling rates. We are setting a rule that these hotplates be used at temperatures no higher than 200 C. So I collected temperature vs. time data between room temperature and the max 200 C. These curves are shown in Figure 2.

All the hotplates follow the same heating curve to a high precision. The time taken to reach the setpoint of 200 C is a little over 6 minutes, but stability is achieved only after another 5 minutes of recovering from a 2 or 3 degree overshoot – which at 1% error, may not be significant.

The natural cooling curve shows that in the current enclosure, the temperature will fall exponentially to room temperature in less than an hour. This is the maximum cooling rate and a programmed cooling rate must therefore be less than this.

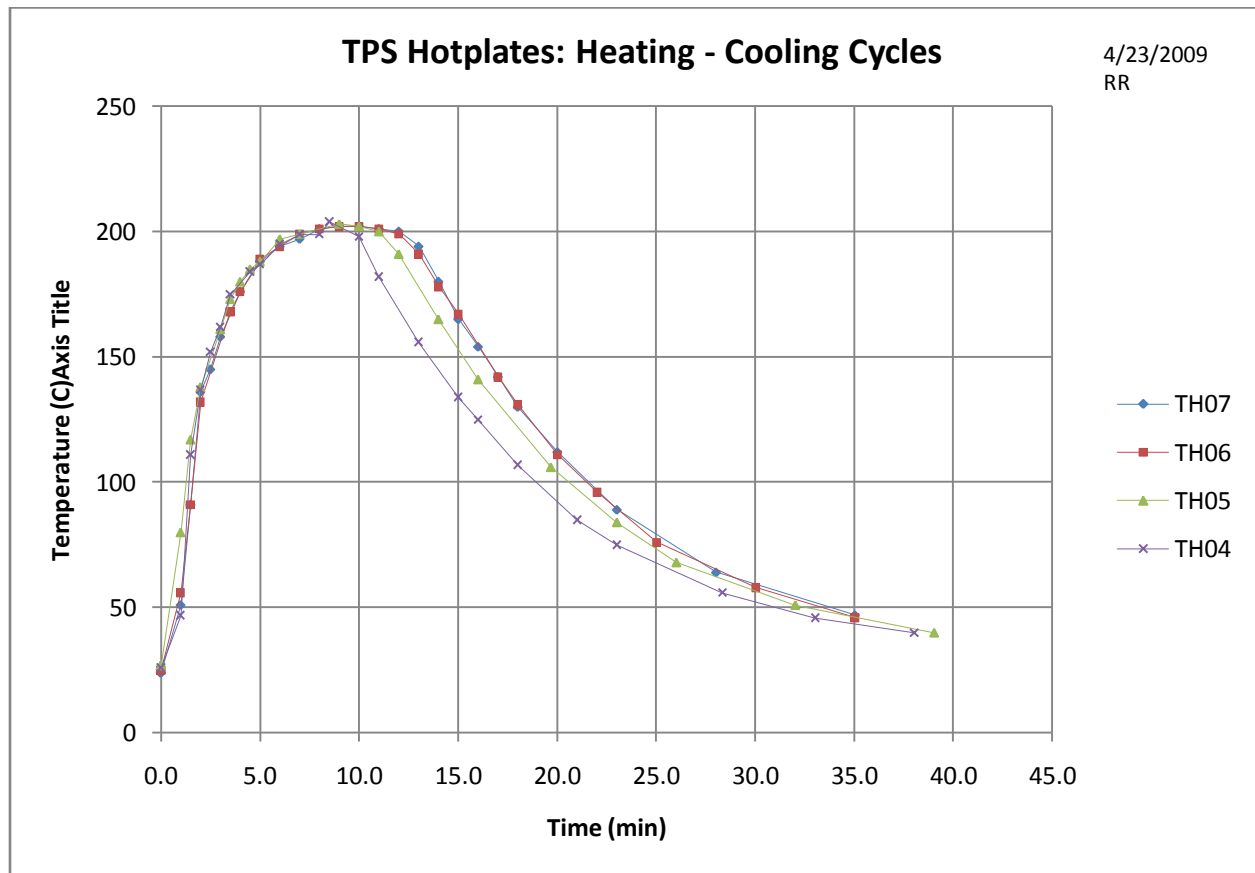


Figure 2. Heating and cooling curves for the four Torrey Pines Scientific (TPS) hotplates in the exhausted enclosure in the UTD Clean Room Bay 2.

2. Programmed Cooling Curve

Figure 3 shows a sample cooling curve set by using the Cooling Ramp program mentioned in the Thermal Down-Ramp section of the operation section above. This cooling curve was set for a 60 deg C per hour cooling rate as an example. Shown in the same graph is the natural maximum cooling rate. The cooling rate is nicely linear until it approaches room temperature where it fades into the exponential shape in Figure 2.

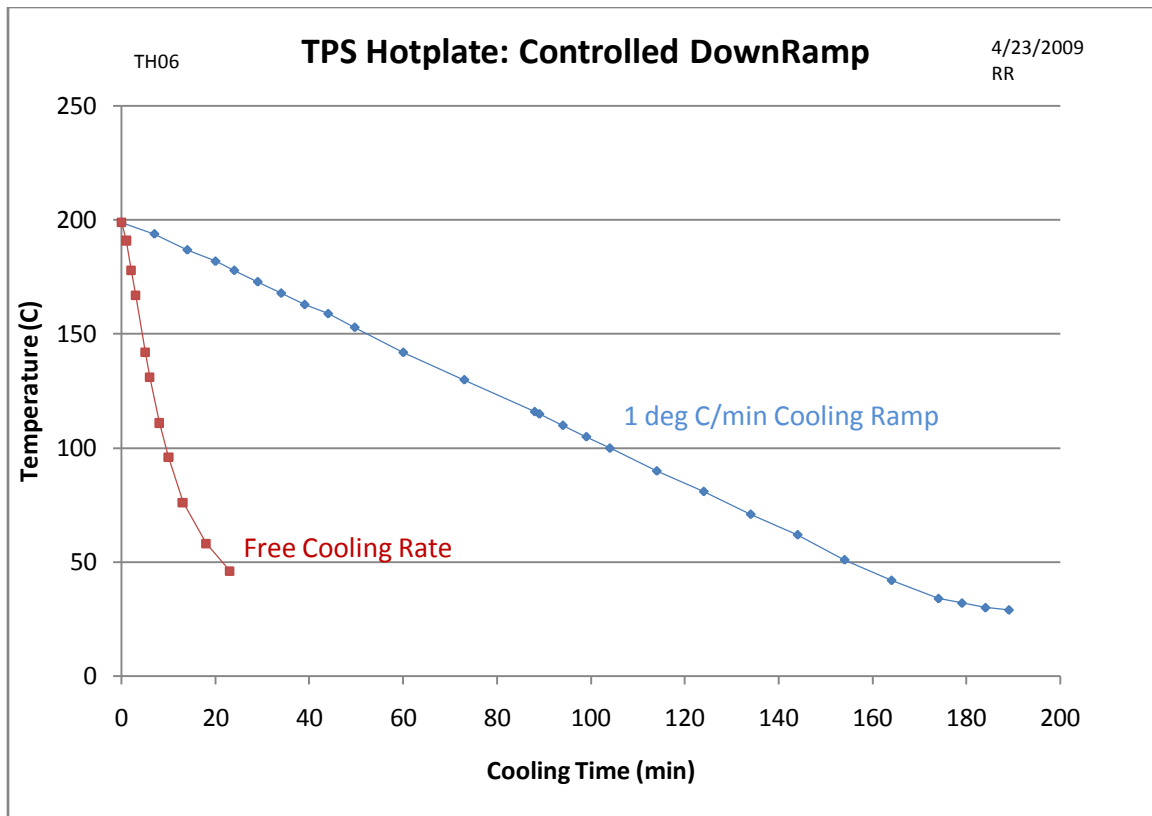


Figure 3. Programmed and Natural (Free Cooling Rate) example for the TPS Hotplates.

3. Programmed Heating Curve

The programmed heating (Example shown in Figure 4) curve is normally used to gently raise the temperature of a sample to prevent such things as bubbling resulting from releasing internal solvent too-fast from a film. A slower temperature rise will allow solvent to migrate through the material and escape through the surface without expanding into bubbles in the bulk of the film.

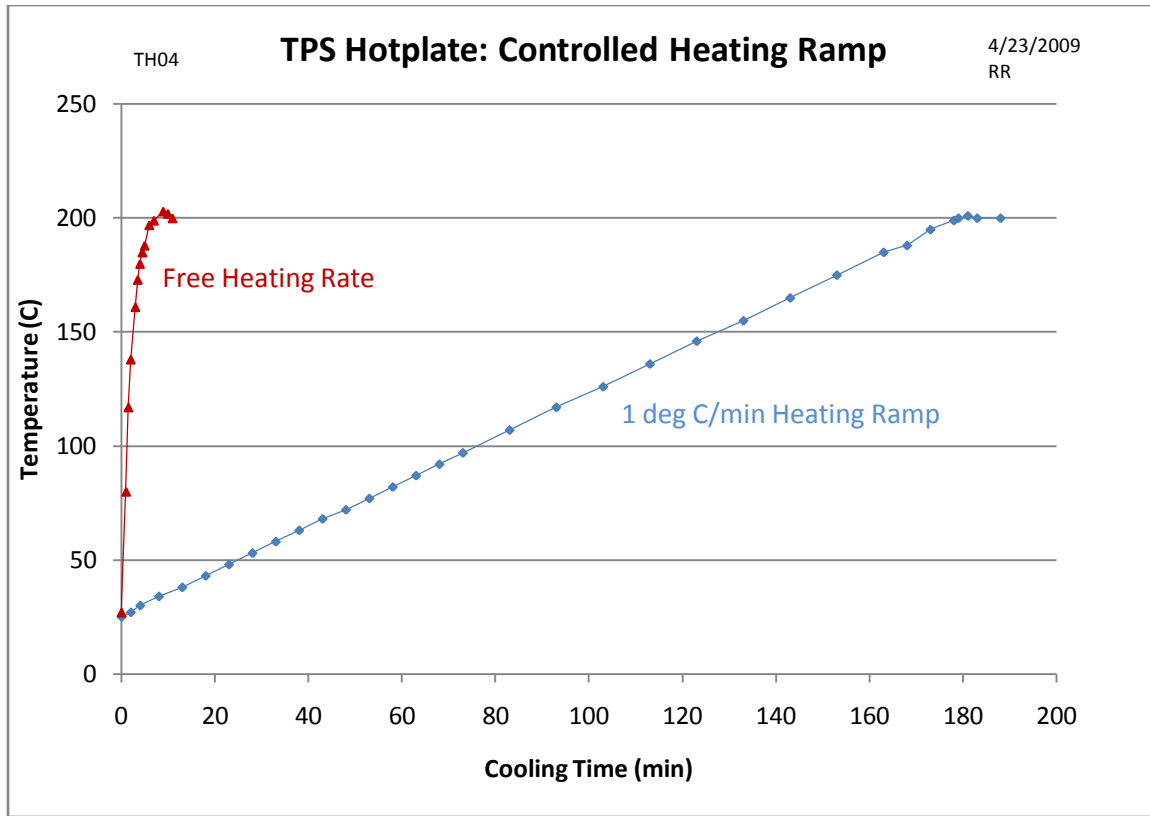


Figure 4. Example heating ramp compared to the maximum heating rate (with no ramp value set).

4. Hotplate Surface Temperature Uniformity

The uniformity of the temperature on the surface of the hotplate is a critical parameter which helps determine how to utilize the hotplate. For example if you attempt to use one hotplate for a multitude of samples, you might obtain a significant discrepancy in process performance due to unrealized temperature difference based on their position on the surface of the hotplate. This measurement was made by setting the hotplate to a given temperature and then measuring the surface temperature at selected locations with an IR non-contact thermometer. Measurements were taken on the diagonal and across the plate on a bisector line from left to right. At high temperature, the uniformity is poor (36%) and at low temperature, the uniformity is better (22%). Figures 5 and 6 show the measured results.

Therefore take note of this uniformity and for multiple samples on the same plate, at least keep them inside a circle of about 10 cm diameter in the middle of the hotplate.

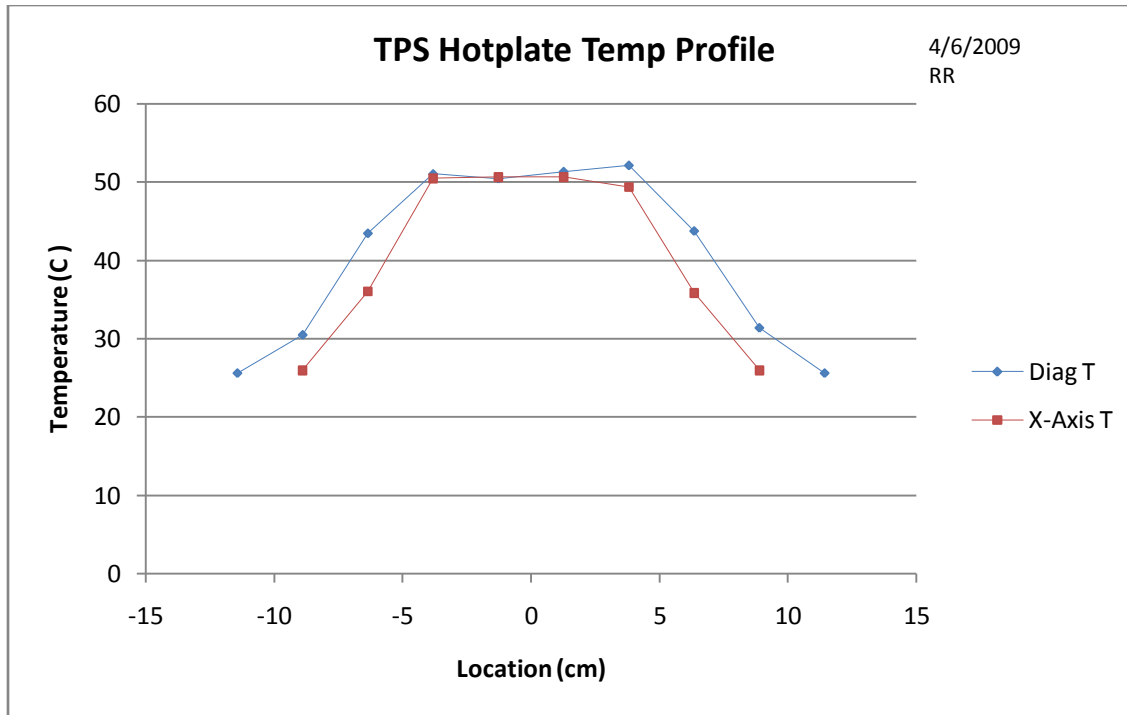


Figure 5. Temperature uniformity with a set temperature of 50 C along the X-axis and a diagonal.

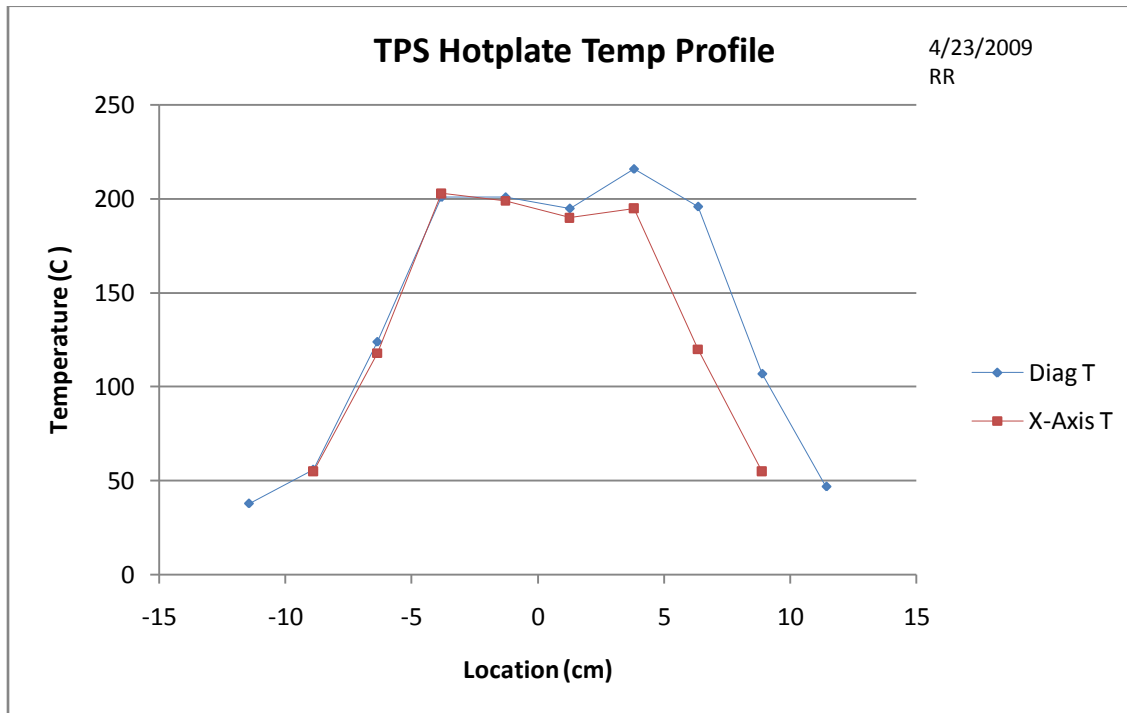


Figure 6. Temperature uniformity with a set temperature of 200 C along the X-axis and a diagonal.

5. Exhaust Flow

The hotplate exhaust enclosure (Figure 7) shows the layout of the hotplates in the exhaust enclosure along with a schematic containing numerical boxes where airflow measurements were taken. Table 1 records the actual airflow measured at the locations specified in the schematic.



Figure 7. Hotplate exhausted enclosure. Photo on left and schematic on right show the locations of airflow measurements. Boxed 1 and 4 denote the measurement location for the front face airflow just behind the center of the front plane of the enclosure opening. Boxed numbers 2, 3, 4, and 5 represent the airflow about 2 inches above the center of each corresponding hotplate.

Table 1

Airflow Measurements (ft/min)

Location	Exhaust Flow
1	60
2	75
3	75
4	31
5	33
6	32

The concept of this design is to waft any vapor emitted from samples baked on these hotplates into the exhaust away from users in the Cleanroom. The design is to have just enough airflow to entrain the vapors in the exhaust flow but not to have so much airflow that the sample heating would be affected.

Conclusion

This document has briefly outlined the operation procedures, and characterized the hotplate performance. Key results of the characterization are 1) the hotplate is highly accurate in temperature set point and ramp performance, 2) the heating table on the hotplate is ceramic and the temperature uniformity is poor – thus keep your samples at the center inside a 10 mm circle.

There can be some confusion in programming the hotplate unless you clear the old programming with the “Heat Off” key before adding new programming.

These hotplates are mounted inside an exhaust enclosure to capture any vapors emitted during the bake.