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**MEMORANDUM**

**Date:** February 13, 2012

**To:** Dr. Timothy Placek, Associate Professor

**Subject:** Lab 3: Kiln Firing

***Executive Summary***

Batch temperature with corresponding time data has been acquired from high-fire electric kiln. Two different thermocouples, S and K, were used in the kilns and data has been collected for each of the thermo couples at different places within the kiln.The kiln firing data was recorded on two separate dates.The temperature versus time data of each run was plotted to graphically demonstrate the heating and cooling process of each firing.The temperature versus time data of each run was plotted to graphically demonstrate the heating and cooling process of each firing. By analysis of the given data it was found that the highest temperatures were found by thermocouples placed within the top and bottom interior of the kiln. The next set of temperatures, data taken from the top and bottom of the sides of the kiln, also exceeded that taken to the outside of the kiln. The temperatures taken from the top of the lid and the bottom outside of the kiln had the greatest temperature difference and this could possibly be explained by the insulation of the kiln and the placement of the thermocouple. The max temperature from the fast glaze data inside the kiln was collected at 2220.5 °F and the minimum temperature from outside the bottom of the kiln was 129.1°F. The data collected can be used to determine a heatwork term in which the unit of necessary pseudo energy to deform the original shape of a pyrometric cone is calculated.

***Purpose***

The provided temperature versus time batch data information for a high-fire electric kiln is to be analyzed to show the how the temperature is influenced by the time. The data is also used to compare the K and S thermocouples at different locations in the kiln and observe any differences between them. Data with prefix “001” and “002” represent thermocoupleson the top and bottom of the inside of the kiln, respectively. Data with prefix “003” and “005” represent thermocoupleson the side of the kiln interior. Data with prefix “006” and “007” represent the top and bottom of the outside of the kiln. Runs were performed and recorded on two separate dates.

***Theory and Analysis***

A thermocouple is device that is made up of two different wires joint at a junction at the end. The temperature difference between the junction and the tail end creates a voltage difference that is proportional to a relative temperature. Type S thermocouples use platinum based wires and operate to high pressures; however, the voltage output is lower than type K and they are less sensitive. (Cambridge). Thermocouples are differentiated by type according to the metal alloys that they consist of. A type S thermocouple uses platinum for each conductor and is among the more stable types, but with a lower sensitivity. Type K thermocouple is a combination of alloys and is a more general choice with less stability than type S, yet a higher sensitivity. **Absolute accuracy** relates to how closely the thermocouple derived temperature mimics the actual temperature. The major errors usually arise from the thermocouple materials themselves (Microlink).The type and placement of the thermocouple can cause an inconsistency in the data. This inconsistency is a small difference seen in the following graphs.

Type S thermocouples are constructed using one wire of 90% Platinum and 10% Rhodium and a second wire of 100% platinum. Type S thermocouples are used up to 1600°C, or 2912°F.Type K thermocouples are the most general purpose thermocouple. They are relatively inexpensive, physically rugged, and can handle most of the temperatures of a kiln. The consistency of Type K thermocouples are about 90% nickel and 10% chromium. Because type S and K have differences, graphs comparing them are shown and analyzed throughout the report. Plots of temperature versus time data were constructed to better understand the heating and cooling process of the kiln. What occurs between each data point is known since approximately six data points were collected every minute, thus the data is over specified and can be plotted using a line.

The “run” of a high-fire electric kiln refers to the comprehensive cycle of heating from room temperature to a maximum temperature and then cooling back to room temperature. Data is collected at approximately 30 second time intervals and the temperature is plotted versus the time to give a representation of a complete cycle. Temperatures were recorded by use of a thermocouple within the kiln and a developed program.

***Results and Discussion***

There were two separate days that kiln data was recorded. The “Fast Glaze Cone 6 Firing” data occurred on January 19, 2012. The “Slow Bisque Cone Firing” data was recorded on January 14, 2012. Both days include thermocouple data point from various places on the kiln, as mentioned above. Each temperature reading was taken at 30 second intervals.



**Figure 1**Temperature verses Time for “001” and “002” data.

Figure 1 shows data of thermocouple “001” and “002” which is the top and the bottom of the kiln for the slow bisque. There is very little variation between the two lines.



**Figure 2** Maximum temperature data for “001” and “002” slow bisque



**Figure 3** Temperature data for “001” and “002” fast glaze

From Figure 2, it can be seen that thermocouple “001”, located at the top of the kiln, reaches maximum temperature of 1851 °F whereas thermocouple “002”, located at the bottom of the thermocouple, reached a maximum temperature of 1856 °F. Figure 3 shows the temperature and time relationship for the “001” and “002” thermocouples for the fast glaze data. The maximum temperature for “001” fast glaze thermocouple at the top of the kiln is 2220.5 °F. The maximum temperature is 2225.3 °F for “002” fast glaze data. When comparing the “001” data of the slow bisque and fast glaze, the fast glaze reaches a maximum temperature 369.5 °F higher than the slow bisque. This is almost the exact same temperature difference when comparing the “002” data. The fast glaze has a maximum temperature 368.3 °F higher than slow bisque at the bottom of the kiln.

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**Figure 4** Temperature and Time data of thermocouples “006” and “007” slow bisque

Figure 4 shows the temperature change over time for thermocouples measuring data on the outside of the kiln. Thermocouple“006”, which measures the kiln data at the top of the kiln reached a maximum temperature of 313.3°F. Thermocouple “007” measures the temperature at the bottom of the kiln and reached a maximum temperature of 122.5°F. There is a 190.8°F temperature difference between the top and bottom of the outside of the kiln.



**Figure 5**Temperature data for “006” and “007” fast glaze

Figure 5 gives the time and temperature relationship for the fast glaze thermocouples “006” and “007”. Both of these were also outside of the kiln. The maximum temperature for the top of the kiln,”006” thermocouple, is 345°F. The maximum temperature for the bottom of the kiln during the slow bisque is 129.1°F. There is a 216°F difference between the top and the bottom. By comparing Fig. 4 and Fig. 5, it can be seen that the fast glaze reaches a higher temperature for both “006” and “007” thermocouple. It also takes much longer for the fast glaze temperatures to cool after the maximum temperature has been reached. The slow bisque data for “006” and “007” stays a fairly steady temperature ranging around 85°F for a while and then the change of temperature increases quickly and decreases at about the same rate.

***Conclusion and Recommendation***

The data illustrates the differences and comparisons between type S and type K thermocouples, as well as, between placement at the top, bottom, sides, and outside of the kiln. The differences between the data collected during the fast glaze and data collected during the slow bisque can be explained through the difference of data points collected. With more points collected during the slow bisque, higher maximum temperatures for the run were collected. The data collected characterized the complete cycle of a firing kiln and allow calculation of a rate of heating through representing a visualization of all inflection points within the cycle. With data collected inside and outside the kiln, a heat transfer term of the insulation of the kiln may all be calculated. Data collected from the fast glaze does not include a stable starting temperature as the slow bisque does, but by use of the heating data, a heatwork term can still be calculated for this run. By analyzing different sections of the data a calculation of an approximate stable temperature at the beginning of the run, a linear calculation of the heating curve, and a calculation for the cooling curve at the end of the run can also be determined.

***References***

Microlink.<http://www.microlink.co.uk/tctable.html>

 Cambridge. <http://www.msm.cam.ac.uk/utc/thermocouple/pages/ThermocouplesOperatingPrinciples.html>

Sheffield

< http://www.sheffield-pottery.com/L-L-CONE-12-KILN-JD18-JH-for-Crystalline-Glaze-Fi-p/lkjd18jh.htm>

***Attachments***

Attachment 1 – MATLAB ® code