CHEN 3600 Computer-Aided Engineering
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**MEMORANDUM**

**Date:** February 13, 2012

**To:** Dr. Timothy Placek, Ph.D., Chemical Engineer

**Subject:** Lab 3 – Interim Report 1

**Executive Summary** – Temperature and time readings were provided for analysis and commentary. After graphing the data, it was observed that the placement of thermocouples and the type of run demonstrated varying temperatures. There are three sections to each graph, the first section is the period of candling that is similar to a preheat setting, followed by a linear increase in temperature for the heating, and a parabolic curve for the cooling process. However, for the fast glaze cone 06 firing the candling period have been omitted.

Additionally, there are six temperature recordings taken from: the top section exterior, bottom section exterior, lid, floor, top section interior, and bottom section interior. By observing the difference between top and bottom exterior thermocouple sensors, the rate at which the fast run reaches thermodynamic equilibrium is faster than the slow run. Likewise, the temperature differences between the top and bottom interior sensors are cooling at a rate to reach thermodynamic equilibrium.

The venting system and the AC system cause the variations in the temperature differences between top and bottom. However, there are general trends and similarities for all data sets. In parallel with slight differences for the two types of firings that result from understanding all the complexities of firing clay structures in a kiln.

**Purpose** – Data of temperature and time readings were recorded and presented in a CVS file. Based on location of sensors and type of run, temperature and time data sets varied. The types of runs include the Fast Glaze Cone 06 run and the Slow Bisque Cone 05 run. Throughout the duration of the report the Fast Glaze Cone 06 run, will be referred to as the fast run, while the Slow Bisque Cone 05 run will be referred to as the slow run. The temperature recordings are taken from the top section exterior, bottom section exterior, lid, floor, top section interior, and bottom section interior. Organizing the data sets with MATLAB informative graphs are developed to interpret the temperature recordings.

**Results & Discussion-** Regardless of the position of thermocouple sensor or run type, all temperature plots displayed a modified bell-shape curvature for the heating and cooling process. In reference to the modified bell-shape curve there are three distinct regions: linear candling, linear heating, and parabolic cooling. A period of candling is a practice of removing water from the objects to be fired in order to prevent cracks and other defects by holding a low temperature, about 200°F (Figure 1 – Interior Temperature Data (Slow)). The heating rate decreases with time due to the $∆T$ driving force getting smaller as the kiln heats up (Figure 2 - Heating Rate with Respect to Time). The following equation gives an approximate model of the overall linear trend,$y=-0.64\*x+5.3$ where x is the time in hours and y is the heating rate in °F per hour. After candling, the temperature increases linearly with time until the end of the run and while the kiln is cooling the temperature is related to the time of the run in a parabolic nature (Figure 1 – Interior Temperature Data (Slow), Figure 3 – Exterior Temperatures Compared to Kiln Interior (Slow), and Figure 4 – Lid & Floor Temperatures Compared to Kiln Interior (Slow), Figure 5 – Interior Temperature Data (Fast), Figure 6 – Exterior Temperatures Compared to Kiln Interior (Fast), and Figure 7 – Lid & Floor Temperatures Compared to Kiln Interior (Fast), respectively). All graphs for all runs display this curvature and relation to time, however it should be noted that the exterior, lid, and floor temperatures continue to increase while the kiln is cooling(Figure 4 –Lid & Floor Temperatures Compared to Kiln Interior (Slow)).

Figure 1 – Interior Temperature Data (Slow)

 Figure 2 – Heating Rate with Respect to Time
Figure 3 – Exterior Temperatures Compared to Kiln Interior (Slow)



Figure 4 – Lid & Floor Temperatures Compared to Kiln Interior (Slow)

Also, it is important to note that, for the fast run, there is no period of candling (See Attachment 1). The differences between top and bottom sensors tend to fluctuate a great deal during both the fast and the slow run. This variation is, however, rather insignificant compared to the total heat of the kiln, but it is still worth investigating because it reveals several things about the nature of the heat distribution in the kiln. For example, by observing the curvature of the differences plotted against the run time and then comparing the slow and fast runs one would notice that, while cooling, the fast run reaches thermodynamic equilibrium (when the sensors are within five degrees of each other) faster than the slow run, in which the fast run takes 15 hours to cool and the slow run requires 20 hours to cool (Figure 1 – Interior Temperature Data (Slow) and Figure 5 – Interior Temperature Data (Fast)).

In order to explain the trends within the data, which are displayed through the graphs, a deeper understanding of what is going on with the kiln and the room for the duration of the firing is necessary. The kiln is equipped with a venting system to remove fumes and organics as the firing progresses, this venting system pulls air through any openings the kiln has in it through to the bottom of the kiln and out through an exhaust tube. The main gaps in the kiln are the slight opening between the lid and the top of the kiln and also in the middle of the kiln between exterior panels. For the room, there is a wall mounted AC system that attempts to cool the room, but this system has a built in controller causing it to turn on and off at regular intervals in order to prevent the cooling coils from freezing. The on and off cooling of the AC causes a slight temperature fluctuation both in the room and in the kiln dueto room air entering the kiln via the venting. This explains the variations in the sensors that are seen throughout the firing while the kiln is being heated (See Figure 5 – Room Temperature Data).



Figure 5 – Room Temperature Data

Now it is important to note that as the kiln reaches high temperatures and as these temperatures are maintained longer, the variations become much less**,** this is due to the kiln itself heating up which causes any room air pulled into the kiln to become preheated and it reduces the $∆T$ between the kiln air and the room air, thereby reducing the driving force for heat transfer.

Furthermore, inside the kiln, during cooling, the temperature differences between the top and bottom interior sensors are similar to a PID plot, for both runs (See Figure 6 – Comparison of Interior $∆T$ Between Slow Runs and PID). The reason why the data displays this characteristic is due to the system attempting to come to a thermodynamic equilibrium in which both temperatures are about the same. The temperature differences on the exterior also display this fluctuation as the Kiln cools.

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Figure 6 – Comparison of Interior $∆T$ Between Slow Runs and PID



Figure 7 – Comparison of Interior $∆T$ Between Fast and Slow Runs

There are several differences between the two runs, especially in regards to the temperature differences between the top and bottom sensors, but both runs follow the general idea of having plot similar to a generic proportional-integral-derivate (PID) plot. It is not necessarily the specifics of the data when compared that matter but more the overall trends and patterns that are most important upon review. An example of the discrepancies in the specifics of the data is best displayed in a comparison of the temperature differences between the top and bottom inside the kiln for the fast and slow runs. The two plots look to be reversed but they follow a similar heating and cooling trend (See Figure 7 – Comparison of Interior $∆T$ Between Fast and Slow Runs). These discrepancies could be caused by the differences in the nature of the two runs in which one heats very quickly and the other is a more gradual heating.

**Conclusions –** While heating, the Kiln exhibits a linear relationship to the run time and while cooling the relationship is parabolic. Also, fluctuations in the temperature differences between top and bottom sensors are caused by a combination of the venting system and the AC system. Last, while there are discrepancies between the two runs, the data all follows a general rule in regards to what happens during heating and what happens during the cooling. Some possible sources of some error could be the nature in which the kiln is loaded. Overall, the results found for the two runs of the kiln represent significant trends, similarities, and differences for the two types of firing that can aide in understanding all the complexities of firing clay structures in a kiln.

**Attachment –**

Attachment 1 – Interior Temperature Data (Fast)

Attachment 2 – Exterior Temperatures Compared to Kiln Interior (Fast)

Attachment 3 – Lid & Floor Temperatures Compared to Kiln Interior (Fast)

Attachment 4 – Code