Summary of Executive Summaries

***Executive Summary1***

This technical memo will “make sense” out of the data provided by the CN7800 Microprocessor Controller located on the L&L E23S JH series crystalline glaze 12 cone kiln. The kiln is specifically design for crystalline glaze firing. The microprocessor receives data from two Type S thermocouples and four Type K thermocouples. The glazes used in the kiln are custom designed and developed recipes. Through the firing process, the glaze is affixed to the clay. The process used in the kiln calls for the clay to be heated slowly. The time varies according to the specific requirements of each run. Data is collected twice every minute. The kiln is designed to fire at a maximum temperature of 1,315°C.

**Executive Summary2:**

The following interim report was composed from data given to Dr. Placek’s CHEN 3600 Spring 2012 Computer Aided Chemical Engineering class to be examined and interpreted. The information was imported from Excel to MATLAB for visual observation. Data was collected from a professional-grade ceramics kiln used for glaze development research and related experiments, using auto-sampling software associated with thermocouple types “S” and “K.” Different sets of data were recorded as a result of the location in the kiln and type of thermocouple.

***Executive Summary3***

This technical memo will “make sense” out of the data provided by the CN7800 Microprocessor Controller located on the L&L E23S JH series crystalline glaze 12 cone kiln. The kiln is specifically design for crystalline glaze firing. The microprocessor receives data from two Type S thermocouples and four Type K thermocouples. The glazes used in the kiln are custom designed and developed recipes. Through the firing process, the glaze is affixed to the clay. The process used in the kiln calls for the clay to be heated slowly. The time varies according to the specific requirements of each run. Data is collected twice every minute. The kiln is designed to fire at a maximum temperature of 1,315°C.

**Executive Summary4:** The research conducted involved analyzing the data from an L&L Cone 12 Kiln E23S-Jh during two different types of firings. The first set of data was from a Cone 6 fast glaze firing, and the second was from Cone 05 bisque firing. Temperatures were collected and analyzed for 6 different areas on the kiln for the duration of the firings.

Temperature data from each run was imported into MATLAB from a comma separated value file provided by the instructor. Unnecessary columns were stripped to make the data more useful, and then it was organized into plots. Plots included relationships between temperature observed and time, the rate of temperature change and time, and also the rate of temperature change versus temperature. After these plots were created, they were analyzed for any conclusions that could be made about what happens inside and outside of the kiln. This open-ended analysis was used to make conclusions about the firing process.

From the analysis of this data, it was determined that inside of the kiln, several changes of state occur within the kiln during the firing. These include changes within the clay itself and the glaze on the clay. It was also determined that once the temperature in the kiln becomes high enough, the top and bottom temperatures within the kiln no longer differ. The kiln is not at steady state during the runs, first and foremost because the properties of the air, most notably the density, change drastically.

**Executive Summary5** – A professional-grade ceramics kiln is used for glaze development research and related experiments. This kiln is computer controlled and produces a variety of data streams dealing with the measurement of temperature via thermocouples. The firing kiln data from an L&L kiln was collected though auto sampling software in multiple locations within the kiln via top and bottom thermocouples. The data sets were provided for analysis and were found to have four regions of controlled heating and one region of uncontrolled cooling for the slow-bisque cone firing and two regions of controlled heating and one region of uncontrolled cooling for the fast glaze cone firing. This was determined by the linear behavior of the controlled regions and the non-linear behavior of the uncontrolled region and the calculation of slopes for each.

**Executive Summary6** – A professional-grade ceramics kiln is used for glaze development research and related experiments. This kiln is computer controlled and produces a variety of data streams dealing with the measurement of temperature via thermocouples. The firing kiln data from an L&L kiln was collected though auto sampling software in multiple locations within the kiln via top and bottom thermocouples. The data sets were provided for analysis and were found to have four regions of controlled heating and one region of uncontrolled cooling for the slow-bisque cone firing and two regions of controlled heating and one region of uncontrolled cooling for the fast glaze cone firing. This was determined by the linear behavior of the controlled regions and the non-linear behavior of the uncontrolled region and the calculation of slopes for each.

**(NO )EXECUTIVE SUMMARY7(HEADING)**

This report shall attempt to cover the various temperature discrepancies throughout the graphs by using various MATLAB functions in order to gain a better understanding of the system. These discrepancies shall be used to attempt to explain what is occurring during the actual processes. Also in a more general manner, these processes shall be separated into stages, where major changes occur via a significant change in the rate of heating or cooling. These changes as well as any steady discrepancies throughout the processes shall be used as a basis for deconstructing what is happening within the system.

**Executive Summary8:** Interim Report I is the first in a series of reports to be delivered on the topic of L&L kiln data analysis. The kiln in question was fitted with both S and K thermocouples placed at specific interior and exterior locations to record the temperature data of each of the two firing runs to be considered. The area of the kiln is divided into two zones, an upper mid-section and lower mid-section. Two type S thermocouples are employed to record the temperature, one for each zone inside the kiln. A total of four type K thermocouples are also utilized in temperature recording. One type K thermocouple is placed on the exterior upper mid-section, a second on the exterior lower mid-section, another is placed on the exterior surface of the kiln lid, and the final is located on the floor directly beneath the kiln. The data was collected from runs corresponding to Orton Pyrometric Cone firing ramp specifications. This data was converted to XLSX format and then uploaded into the MATLAB® program. MATLAB® was used to plot and interpret the information accordingly. Upon further study, the Cone 05 data was found to fit a firing ramp of 27 F/hr and the Cone 6 data was found to be indicative of a firing ramp of 108 F/hr.

**Executive Summary9**

This report includes temperature vs. time analysis from two kiln firing runs. One set of data comes from a glaze firing run, the other from a bisque firing run. Learning how the firing time at high temperatures affects the ceramic firing process is critical to producing high quality wares.

***Executive Summary10***

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.

*Executive Summary11*

Ceramic kilns are widely used in industry and by individuals. Kilns provide high temperatures at controlled conditions to fire wares to appropriate levels. Temperature and time data were collected from a slow bisque firing and a fast glaze firing to compare and contrast the two different styles of runs. Also the data was used to analyze the effect of the kiln on the surrounding environment. MATLAB ® was used to plot time versus temperature data from various locations inside and outside of the kiln. As found there are major similarities between the two types of run as well as one distinct difference.

**Executive Summary12**

For this interim report the goal was to take a set of data obtained from two runs of the L&L CONE 12 kiln system organize the data, and analyze it for useful information about the kiln and the processes it undergoes while in operation. In this analysis the data was broken up into distinct subsets based on how it was gathered. The key foci of the analysis performed were: the general trends generated by the temperature data, the difference in temperatures between the top and bottom interior thermocouples, and the anomalies in the room temperature while the kiln was in operation. These three topics combined helped provide insight into the overall ability of the kiln to operate correctly and efficiently.

**Executive Summary13 –** The data from an L&L kiln was collected via auto sampling software in multiple, strategically placed, locations throughout the inside of the kiln. There were two different data sets to be analyzed, the data collected from a bisque kiln firing and the data collected from a glaze kiln firing. Within in the bisque data, there were three regions of controlled heating and one region of uncontrolled cooling. This was determined from analyzing the linear behavior of the controlled heating regions and the non-linear behavior of the uncontrolled cooling regions. The glaze firing was much simpler in that there was only one region of controlled heating and one region of uncontrolled cooling; this was determined by the same linear versus non linear analysis of the data. Conclusions were made after a more in depth review of the bisque firing data that the second controlled heating region had various peaks and valleys due to fluctuating temperatures.

**Executive Summary14**

On Monday, January 30, Dr. Placek’s Computer-Aided Chemical Engineering class was given the task of analyzing two sets of data from a kiln. The class was asked to include a detailed analysis of the data, informative plots, and basic descriptive information about the data sets, as well as technical commentary and meaningful summarizations of the data characteristics. The first set of data contained temperature values for various times for a slow bisque firing to cone 05, while the second contained similar information for a fast glaze firing to cone 6 using the same kiln.

The computer software, MATLAB, was incorporated to aid in the analysis of the various data plots of temperature and time. Numerous plots were prepared in order to depict the various trends in temperature data, such as temperature-vs.-time plots, temperature-rate-vs.-time plots, temperature-difference-vs.-time plots, and temperature-rate-vs.-temperature plots. The plots were then analyzed to determine general trends and meaningful relationships in the temperature data.

After careful analysis, it was found that the firing sections for both the slow bisque and fast glaze firings could be divided into three distinct regions with unique heating rates. Furthermore, after the kiln has been turned off, one can see a characteristic exponential decay in temperature for both types of firings. Interestingly, the temperatures within the kiln were not as uniform as one would expect. Instead, the temperature differences varied over time, depending on the firing of the kiln. It was also determined that the exterior surface of the kiln, as well as the floor beneath the kiln and the air within the room, were greatly affected by the processes that took place within the kiln. It seems that every element within the room was ‘aware’ of the kiln, but to varying degrees.

**Executive Summary15 –** We have been provided with data sets from two kiln firings, a slow bisque firing and a fast glaze firing. The data given was the temperature and time of the separate kiln firings. The data from the two separate firings were to be analyzed, which was done using MatLab. Using Matlab, the data was used to make graphs relating the temperature and time to each other. The type of kiln that was used was a L&L Cone 12 Kiln: E23S-JH for Crystalline Glaze Firing (240V-1Ph). The Digital Controller that comes with the kiln is an Omega Engineering Series CN7800 Microprocessor Based Temperature Process Controller. The data provided was recorded with the use of two types of thermocouples, a type S and type K. The first type is type S and there are two of those and they record the top and bottom zones of the kiln. The second type is type K and it records the top section exterior temperature, the bottom section exterior, the top surface lid exterior, and the temperature of the floor directly below the kiln. We were also provided with typical room temperature data during a firing. The kiln is fitted with a Vent-Sure Downdraft Kiln Vent System and a bypass box that has an orifice opening of approximately 50%. The max temperature that the kiln is capable of is cone 12 with 2400 degrees Fahrenheit or 1315 degrees Celsius. The cones used for the firings were Orton Pyrometric Cones and the kiln is made of K25 firebrick.

**Executive Summary16**

Temperature data was collected every thirty seconds from six thermocouples in various locations in and around a kiln for two different types of firings. In addition, room temperature data for a typical firing was furnished. The data was to be analyzed and explained. Relationships between the readings at each thermocouple were also determined.

MATLAB was used to process the data given and manipulate it into usable forms, as well as to graphically display selected portions of the data to evaluate. MATLAB was also used to determine the rate of change of temperature data from one of the thermocouples for evaluation. Relationships between the data from each thermocouple were determined analytically by examining the graphs produced by MATLAB. Resources depicting typical behavior for each firing were also used, and the collected data was compared to the typical behavior.

Several relationships were determined by analyzing the graphs produced from the data. In general, the graphs for the data from the thermocouples outside of the kiln reflected the same temperature changes that occurred inside the kiln, but to a much lesser degree. For example, the temperature at the lid of the kiln peaked at the same time as the temperature inside the kiln, but at a smaller temperature. In addition, the bottom portion of the kiln was consistently cooler than the top portion during heating because the shelves near the bottom acted as heat sinks and absorbed more heat; at the start of cooling, the bottom portion was warmer than the top portion because the shelves had more heat to disperse. The data that was collected also closely correlates the typical behavior for each firing profile.

**Executive Summary17** – 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.

**Executive Summary18**

In an effort to fulfill the requirements for this project, research was conducted for the preparation of analyzing the given kiln firing data. Such preparation included studying how the kiln operates, the physical environment of the kiln, the kiln parts, the kiln firing schedules, heat transfer principles, graphical representations of kiln firing data, cone variations in temperatures, definitions and location of S and K thermocouples, and Dr. Timothy Placek’s protocol for kiln firing.

Upon considering these elements for understanding of the kiln firing data, MATLAB was employed to manipulate the kiln firing data and formulate corresponding graphs, find slopes at certain points on the graphs, zoom in on relevant points on the graphs, and estimate the maximum temperatures on the graphs. Correlations between maximum and minimum temperatures were also formed in addition to a pictorial diagram of the kiln’s internal and external surroundings.

Close observations of several relevant graphs formed enabled creation of technical interpretations for each. Heat transfer principles, familiarity with the surroundings of the kiln, and the operations of the kiln were employed to better attain understanding of the unique graphical behaviors. Additionally, other cooling devices in the room were also considered, such as the air conditioner, exhaust fan, and downdraft venting system, which collectively worked to cause temperature changes at varying times in the kiln firing process.

After analyzing the graphical information of the kiln firing data, the graphs made it evident that the temperature increased when the air conditioner turns off and no longer provides air to keep the room cool, and it decreases when the air conditioner turns back on. Furthermore, the heat movement begins from the inside of the kiln to its external body, to its lid, to the floor and then to its surroundings.

**Executive Summary19** – This is an examination and analysis of data from an L&L Kiln. The data represents temperature readings from seven (7) different thermocouples relaying values to a computer for recording. Examining temperature versus time for thermocouple sampling data sets allows for certain conclusions to be drawn about the firing of such a kiln. The data was collected for a Slow Bisque Cone 05 Firing and a Fast Glaze Cone 6 Firing. The data were used to analyze the different stages in the firing process for a kiln and compare data from a Cone 5 and a Cone 6 firing.The findings for the difference in maximum temperature and the existence of a holding period between a fast glaze and slow bisque firing were consistent with what was expected. The rates of change for temperature with respect to time for slow bisque firing were also consistent with what was expected. One unexpected phenomenon was noticed in the analysis of the data, the existence of a constant oscillation in the temperature and in the difference between temperature values of the upper and lower interiors of the kiln. The holding time for the slow bisque firing was the most significant point of analysis due to the variations of the interior temperature of the kiln and the interior and exterior thermocouple temperatures of the kiln during this time. The cause in variation for the temperatures during the holding period was attributed to the shutting on and off of the heating coils and the downdraft ventilation set up of the kiln.

**Executive Summary20**

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MATLAB was used to make sense of the data provided. This included graphical illustrations, mathematical expressions, and locating important points of data. These tools allowed for an accurate and precise comparison of data.

These areas of focus were chosen due to the fact that each revealed distinct indications about the operation of the kiln. The general trends were analyzed because they provided information about the control scheme of the kiln. The difference in temperatures illustrated the regions that exist within the kiln and the distinct phenomena that cause these regions. The room temperature data points out the fact that heat is constantly leaking from the kiln while it is in operation.

**Executive Summary21**

Data was provided for an L&L cone 12 ceramics kiln; the data was gathered using 6 thermocouples. Two, type S, thermocouples are located within the kiln, one in the upper and one in the lower section. Four, type K, thermocouples were used outside the kiln to record the exterior upper and lower section temperatures as well as the lid and floor temperatures. The thermocouples were used to monitor temperature conditions to assure proper firing and maintain a safe environment.

Two data sets were provided, one for a cone 5 slow bisque firing and the other for a cone 6 fast glaze firing. Both data sets were reconstructed in Excel and saved to the MATLAB directory. A program was designed to save each data collection to an appropriate variable name, so that comparative plots could be created. The plots allowed for temperature and time values to be examined. The values determined included but were not limited to initial, maximal, and final temperature.

The plots created helped to determine that the majority of external heat transfer resulted from convection. The movement of air outside the kiln was due mostly to the fan and air conditioning unit nearby. This resulted in temperature fluctuations found in the data. The internal kiln temperature conditions gave a basis for external data.