Heat Transfer

What Did We Measure?

- We measured temperatures in five minute intervals through the entire burn.
    - Thermocouples on water outlet, bottom surface (½ way down the heat exchanger), 3 inches below (center of heat exchanger), and in the feed tank
    - Feed tank was maintained between “Full” and “3/4" for entire burn
    - Heat exchanger was placed on lowest rack position for entire burn
    - 1/16” flow restricting cap at heat exchanger outlet for entire burn

What Can We Do With It?

- We can import this data into Matlab and Excel and utilize previously derived equations to determine what the heat rate (Q) and the heat transfer coefficient (U) were during each five minute interval.
- $Q = m_{dot} c_p (T_{wh} - T_{wc})$ [1]
- $U = Q/(A_s(T_g - T_w)$ [2]

What Does That Tell Us?

- This data will be used to validate the values we assumed for the heat transfer coefficient and heat rate. It also helps us understand how much these values vary based on kiln and flame conditions.
- The data also shows that the rate of heat transfer drastically rose each time the heat exchanger was touching the flames from the kiln.

What Is Our Plan Moving Forward?

- With accurate values for heat transfer coefficient and heat rate, we can optimize the length and diameter of our heat exchanger pipe to accurately predict what will get the water to at least 70 °C.
- We now know that we have to design the heat exchanger where it will be engulfed in the flames a majority of the time if we want to heat the water efficiently.

Analysis Method

- Based on our expectations of constant flame interaction we use experimental data gathered when pipe was experiencing these conditions. In this instance our water increased about 19 °C while exposed to 371 W. Using our known flow rate the water was exposed to this Q for 92 s. Empirically if we need our temperature increase 55 °C (about 3x what we measured) we will need to increase our exposure time by 3x. This means we need to keep the water in the pipe for about 370s. To meet pasteurization requirements we need to maintain the water at 70 ºC for 60 s. This means our system needs to hold the water for about 430s or 7.2 min. Using this time requirement we can back out the pipe length required (using known flow rate and cross sectional area)

Fluid Dynamics

What Did We Measure?

- We measured volumetric flow rates with multiple varying parameters.
    - Flow restrictor diameters range from 1/16” to 3/4"
    - Feed tank outlet to heat exchanger inlet height difference range from 0.06” to 34.50”

What Can We Do With It?

- We can compare our max and minimum flow rates per each flow restrictor with our previously calculated minimum flow rate (46.2 L/hr) to determine what sort of flow restrictor we want on our system.
- We can use our height difference range to determine how high we want the feed tank outlet above the heat exchanger inlet.

What Does That Tell Us?

- We know that we need a minimum flow restrictor diameter of 1/8" in order to meet our minimum flow rate requirements.
    - This is a flow that we need going into the output tank.
- Head pressure makes a big difference on flow rates at smaller changes in height.
    - We will need to keep the heat exchanger as low as possible in order to achieve desired flow rates.

What Is Our Plan Moving Forward?

- We know that the thermostat needs to have a diameter of 1/8" or larger in order to produce our desired flow rate.
    - The bleed-off valve can use a 1/16” diameter valve to remove air and cold water from the system without removing too much fluid from the system (max flow rate of 19 L/hr). This water can be fed into a bucket which can then, in turn, be poured directly back into the feed tank.