TEMPERATURE PATTERNS WITHIN AN OIL-FIRED MAPLE EVAPORATOR

Mark Isselhardt, Abby van den Berg and Timothy Perkins
University of Vermont Proctor Maple Research Center

INTRODUCTION

Knowing the temperature in the evaporator is an essential part to making quality pure maple syrup. The temperature of the liquid near the draw off is of particular interest to the sugarmaker. When a simple evaporator is operating, sap (~ 2% sugar) enters the back of the evaporator and boiling hot syrup (~ 66 % sugar) exits the front. In between these points, temperature and density gradients develop. That is to say, the sugar in the sap becomes more concentrated the closer it is to the draw off. A day of boiling is marked by the periodic drawing off of syrup. If the system is running smoothly, the time interval for draw offs tends to be fairly regular. This article will describe how temperature varied within an evaporator during the 2006 season. This article will discuss observations of temperature in each partition and how the front and back pans temperatures are influenced by the draw off events.

MATERIALS AND METHODS

A new CDL-Dallaire 3'x 10' oil-fired, raised flue, cross-flow evaporator was used for the 2006 sugaring season.

The evaporator was installed in the University of Vermont, Proctor Maple Research Center's Maple Production Research Facility in Underhill Center, Vermont. The facility sits at approximately 1400' in elevation. The evaporator was equipped with steam hoods over both the front and back pans. The burner was rated for approximately 10.4 gallons of fuel consumption per hour and had been tuned prior to the season for optimal draft and combustion. Sap for the experiment was produced at the Proctor Maple Research Center. The sap was filtered and pumped into a 1,200 gal stainless, welded storage tank which fed the evaporator during boiling. Sap entering the evaporator was not concentrated using reverse osmosis or pre-heated and had a seasonal average brix of 1.9°. The air temperature in the building did fluctuate depending on ambient weather each day and how long the evaporator had been in operation.

A divider separates the back pan into two compartments. A small opening in the divider allows sap to move between the two compartments. The partition connected to the raw sap source will be referred to as Partition 1. Sap flowed into Partition 1 through a pipe which terminated close to the rear-most front pan. Partition 2 will describe the other half of the back pan. Sap flowed from Partition 1 to 2 via a small opening in the rear of the back pan. The front pan is made up of two 18" x 36" cross-flow style pans connected in series. Each of the two pans is further divided into two compartments, resulting in a total of four partitions in the front of the evaporator. These partitions were sequentially numbered, with Partition 3 being closest to the back pan and Partition 6 is the last partition of the front pan, also referred to as the draw-off partition. Sap is supplied to the Partition 1 from the sap storage tank via glass milk-tubing. The flow of incoming sap is regulated by a mechanical float box. Because the entire volume of sap in a raised flue evaporator's back pan is above the arch rails, a depth control mechanism is necessary between back pan and front pan. The mechanism is similar to the float box for sap entering the back pan. The float box allows the depth in both pans to be controlled independently. The depth of sap in the back pan of a raised flue evaporator must be sufficient to cover the top of the raised flues. The evaporator was operated using a depth of 9" in the back pan (1" above the top of the flues) and 1.5" (from the pan bottom) in the front pan.

Partition 6 in the front pan was equipped with a CDL "Thermo" automatic draw off. This device includes a valve, a digital display and a temperature probe. The valve is made up of a weighted metal plug and a solenoid. When the temperature being measured at the probe matches a preset temperature on the display the solenoid is energized and opens, lifting the weighted plug, allowing liquid to flow out until the temperature at the probe falls below the preset temperature. This device is designed to simulate a sugarmaker watching a thermometer placed near the draw off and regulating the flow of syrup out of the evaporator.

Temperature measurements were made using thermocouples imbedded in ¼" stainless steel tubing and connected to a recording thermocouple scanner (Digi-

Sense model 92801-10). Recording began with the initial firing of the evaporator and continued until the evaporator was shut down. Temperature measurements were taken from the same six fixed locations throughout the season; both compartments in the back pan and all four compartments in the front pan (see Figure 1). A position in the center of each partition was chosen to represent the temperature of the entire partition. The end of the probes were placed at a height ½" from the bottom of the pan. The end of each probe was completely covered with boiling sap at all times. Temperature was measured in all 6 locations simultaneously and recorded at 30 second intervals for the entire duration of each individual boiling session.

Figure 1: 3'x 10' oil-fired, raised flue, cross-flow evaporator with partition labels.

RESULTS

The evaporator was operated on nine separate days in March to April of the 2006 season (3/15, 3/25, 3/29, 3/31, 4/3, 4/5, 4/10 and 4/12). Average daily boiling time was 3.5 hours. On March 15th the boiling point of water at Proctor Maple Research Center was measured at 210° F. The evaporator was flooded and boiled with raw sap on March 15th. The first boil lasted six and a half hours. A longer then average boiling time was needed to establish the density gradient ("sweetening the pans"). This process was done once during the season. The remaining eight days of boiling began with "sweetened pans". Pan sections were divided by plugs between boils.

The lowest average temperature in any partition was partition 1, at 208.6° F. This is the partition nearest the sap source. Partition 2 of the back pan had the next highest average temperature, 210.1° F. Partitions 3 and 4 make up the first pan of the front pan and had an average temperature of 210.9 and 212.5° F respectively. Partitions 5 and 6 make up the second and last pan of the syrup pan. The average temperatures for partitions 5 and 6 were 213.3 and 215.9° F. The standard error (SE) for each partition describes how much each partitions average temperature varied over the nine days. Small SE's were observed in partitions 1 and 2. This indicates that the average temperature in these partitions did not fluctuate greatly during the season (+/- 0.1 degrees F). Partitions 3-5 had standard errors of 0.4, 0.5 and 0.6 degrees F respectively. The largest standard error was observed in partition 6 (+/- 1.2 degrees F). Looking at the 30 second temperature measurements over time shows the fluctuations in temperature associated with the draw off and reveals some noticeable patterns.

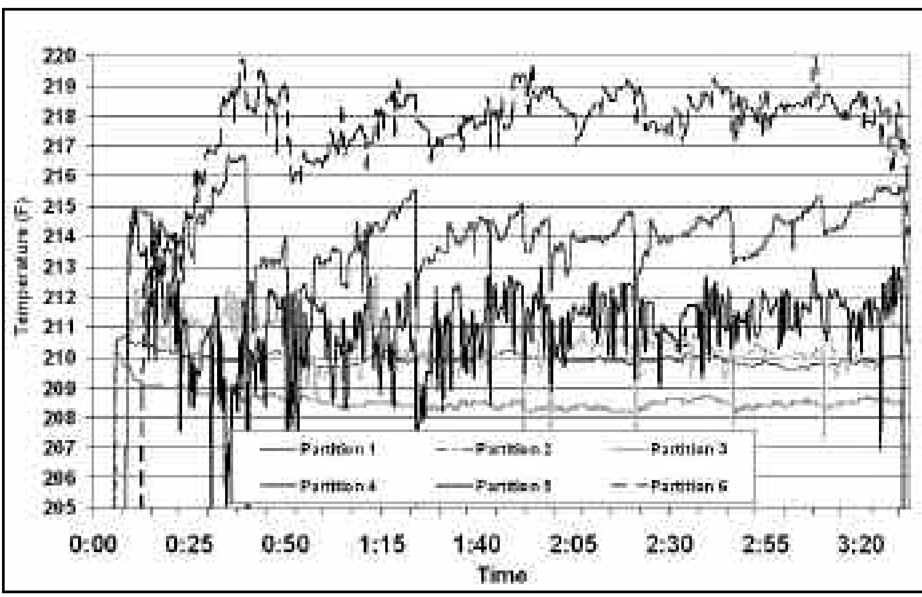

Figure 2: Partition temperatures recorded at 30 second intervals for an entire +3.5 hour boil.

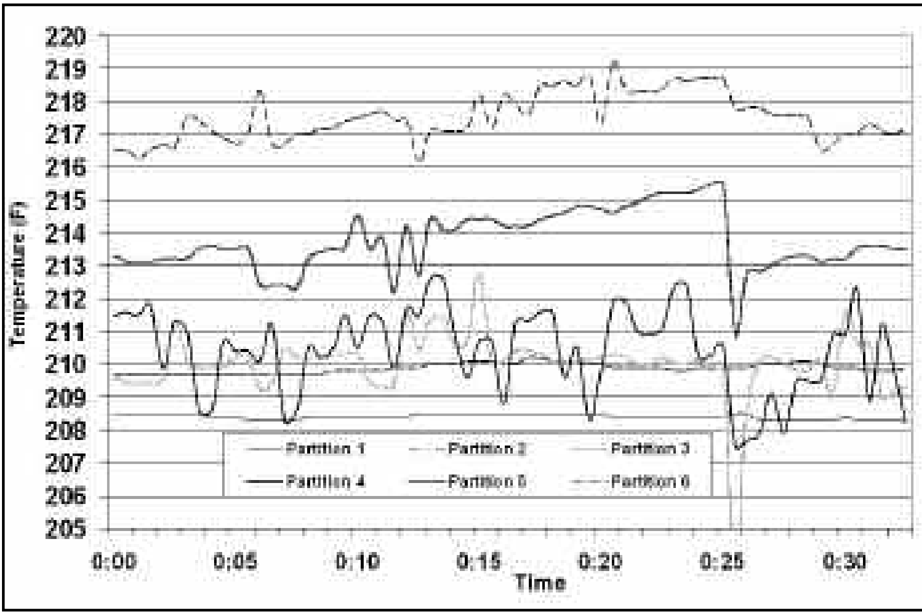

Figure 3: Partition temperatures taken from a 30 minute segment of one days boiling.

Figure 2 shows the temperatures in the front pan as a pattern of steadily rising temperatures followed by a sharp, but brief drop in temperature. The drop in temperature is brief given the large amount of heat under the pans. The time needed to bring the temperature back to the point before the draw off was around 1 minute.

The temperature fluctuations in the front pan generally range 1-2° F with an exception being the draw off event. During a draw off event the temperature in a partition will drop anywhere from 2-6° F.

Temperatures in the back pan appear relatively steady. Generally the temperature in Partitions 1 and 2 did not fluctuate more then 0.1 degrees F over the course of a days boiling. Figure 3 highlights one draw off interval. The automatic draw off opened at around minute 25.

March 15th was the first day of boiling. The average temperature in the evaporator was lower on this day then at any other time during the season. This is likely related to the process of developing the density gradient. Compared to March 15th, the remaining eight days results did not vary more then 2° F.

DISCUSSION

Temperature is commonly used to estimate the density of boiling sap in the evaporator. Therefore, knowing the temperature throughout an evaporator is a key to making a quality product.

A cycle of rising and falling temperatures was observed during the operation of a 3' x 10' evaporator which had been equipped with an automatic draw off.

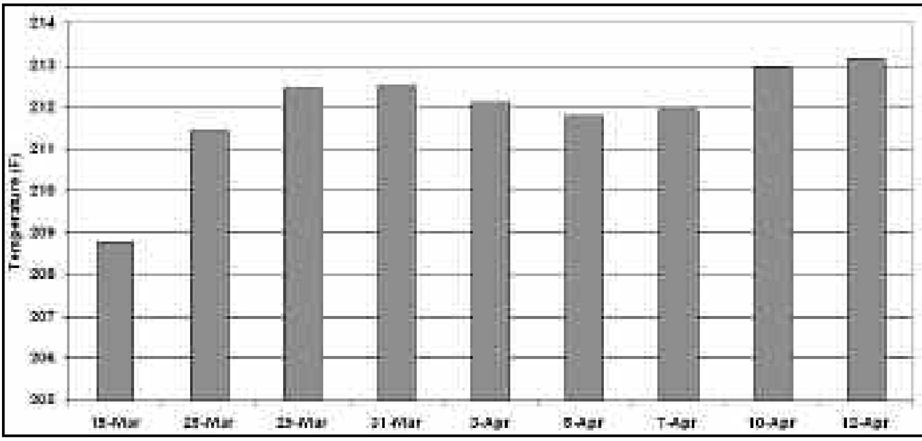

Figure 4: Average evaporator temperature in a 3' x 10' oil fired evaporator over the days of the 2006 season.

This cycle is associated with the periodic draw off of syrup in the front pan. The draw off begins when the liquid at the draw off reaches a preset temperature. As syrup exits the evaporator, the depth in the draw off partition is lowered. The lower depth is only temporary since the partially boiled syrup remaining in front pan partitions flows in to take its place. This in turn decreases the level in the float box between the front and back pans. The valve in the float box opens to accept additional sap from the back pan. When the temperature at the draw off probe falls below the preset level, the valve closes. The temperatures then immediately begin to climb. This cycle has been described as the evaporator's steady state of boiling.

The sudden opening and closing of the automatic valve may not accurately imitate the way in which a sugarmaker would choose to draw off syrup. The valve may cause unwanted mixing of partially boiled sap.

Compared to the front pan, the back pan temperature is not greatly influenced by the draw off cycle. The relatively steady temperatures in the back pan are likely a result of the comparatively large volume of liquid compared that are found in the back pan and because this is were the majority of the burners' heat is focused.

Future observations will focus how partition temperature fluctuations are different when sap concentrated with membranes is used instead of raw sap.