EFFECT OF WASHHOUSE MAKEUP AND BLOW-DOWN FLOW ON SUGAR LOSSES FOR NONFROZEN AND FROZEN SUGARBEETS

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Introduction:

The Southern Minnesota Beet Sugar Cooperative (SMBSC) factory at Renville Minnesota processes both frozen and nonfrozen sugarbeets. During the past two campaigns a detailed analysis of the sugar losses to the wash water was conducted. Significantly more sugar is lost to the wash water when processing frozen sugarbeets than when processing nonfrozen sugarbeets. For various operational reasons, the amount of water added to the wash loop varied significantly between the two campaigns. Also there were times when the added water varied significantly over a few days. This paper looks at the effect that the variation in water addition to the wash loop has on the sugar losses.

The SMBSC factory at Renville, Minnesota slices from 11,000 to 16,000 short tons per day depending on the time of year and conditions of the beets. It has an extensive wash loop that includes two rotary beet washers, rotary stone and sand catchers, screens and presses for recovery of beet materials with introduction of that material to the factory, a 1.5 million gallon settling clarifier and a pebble lime addition system. The wash loop is operated to maximize the recirculation of the water from the washhouse to the clarifier and back. The clarifier overflow is returned to the washhouse.

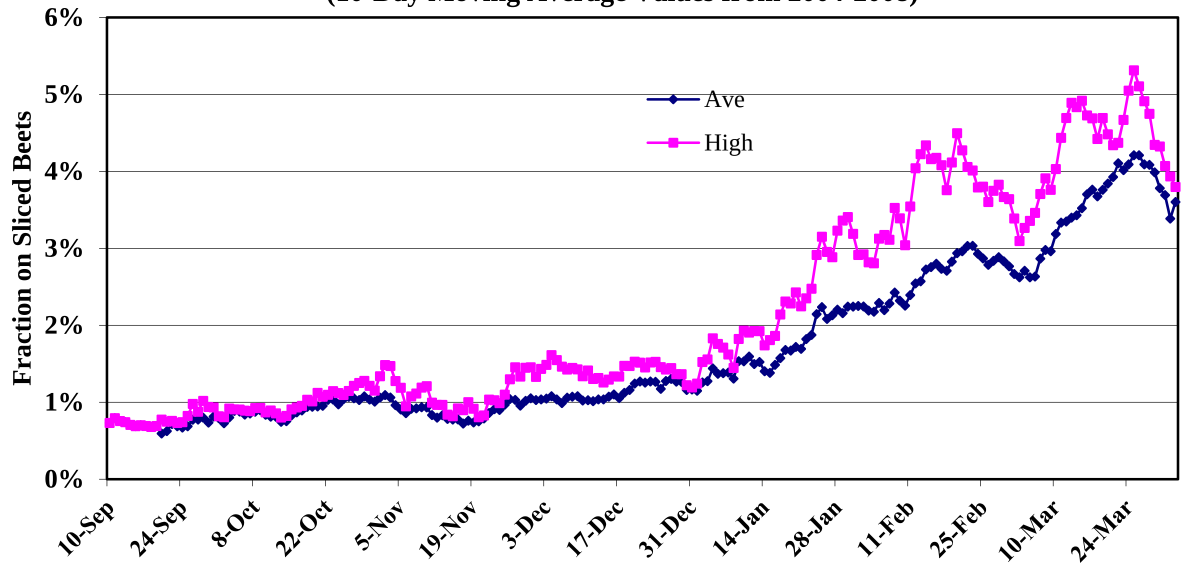
The water moves countercurrent to the beets. The makeup water is added at the end of the washing process. The water exits the washhouse just after it has been used to wash incoming beets in the first of the two rotary washers. The water added at the front of the washhouse can be water from the clarifier overflow, condensed waters from the factory or water from the ponds. Since the decanter centrate is pumped to the wastewater pond, there must be a continual makeup of water in addition to that returning from the clarifier overflow. If the water added to the washhouse exceeds the clarifier underflow, the clarifier effluent tank overflows to the factory lift station.

Sugar concentration is not a good measure of sugar lost to the wash loop because microbes in wash loop, and the ponds consume sugar and produce organic nonsugars. A relationship between the total dissolved solids (TDS) and chemical oxygen demand (COD) of the wash water and the sugar lost by the beets was established. The TDS, COD and the sugar concentration of the makeup and blow-down waters were used to calculate the amount of sugar lost during washing.

The outside temperature in Renville Minnesota drops below freezing by mid-November. At this time the beets in the outer portion of the beet storage begin to freeze. As the winter passes, the fraction of frozen beets increases in the remaining non-ventilated beets. Some of the piles are forced ventilated and frozen as soon as it is practical. During freezing, ice crystals form and rupture the cells. When washing frozen beets, the outer portion of the frozen tissue thaws and will quickly exchange its juice with the surrounding wash water. The thawed tissue is weak and much of it will abrade away during the washing process. At SMBSC, the beet pieces are screened out of the wash water and pressed. The amount of the pressed material increases dramatically with the fraction of the beets being washed.

Figure 4 shows the 10-day average amount of pressed beet pieces screened from the wash house from the 2004 through the 2008 beet slice campaigns. During these years nearly 100% of this material was weighed and trucked away. The second line on this graph shows the highest amount trucked away for the 10-day average for any single year. Until the end of November, the average amount is almost the same as the maximum amount, showing there was little variation from year-to year in the ACF produced. This suggests that during the first part of campaign the sugar contributed by the ACF will not vary much from year-to-year.

Figure 1. Pressed Beet Pieces from the Wash Water (10-Day Moving Average Values from 2004-2008)



Materials and Methods:

Grab samples of the wash water exiting the washhouse were taken every four hours and analyzed by polarimetery for sugar content. Grab samples of the wash loop clarifier influent were taken daily and analyzed for pH and TDS, and twice each week for COD.

TDS analysis: 250 mL of sample is collected and filtered under vacuum. About 10 mL of the sample is poured into a clean, dry and weighed aluminum weighing dish. The weight of the sample is taken on an analytical balance. The sample is dried in a convection oven at 110°C for two hours. The dish is placed into a desiccator to dry and reweighed when cool. The TDS weight is the difference in weight of the dried sample and the tare weight of the dish. The sample weight is the difference in weight of the original sample and the tare weight of the dish. The TDS concentration is the weight of the TDS divided by the weight of the sample.

TSS analysis: The total solids (TS) was determined by the same method as TDS without filtering the sample. The TSS was calculated by subtracting the TDS from the TS.

COD analysis: The HACH method 8000 is used on a filtered sample.

Purity of Cossettes: Cossette samples are collected every two hours from the slicers. A food processor is used to chop a sample of cossettes. 150 g of the chopped cossettes are weighed and blended with 200 mL of hot DI water for three minutes. The liquid is filtered away from the solids. The RDS is determined on this sample. 50.0 mL of the solution is combined with 10 ml of 10% zinc chloride and 10 mL of 1.7 M potassium hydroxide and enough DI water to make 100 mL of solution. After mixing the solution is filtered through a regular #415 filter paper with about one-half teaspoon of filter aid. The Brix o this solution is determined with polarimetery.

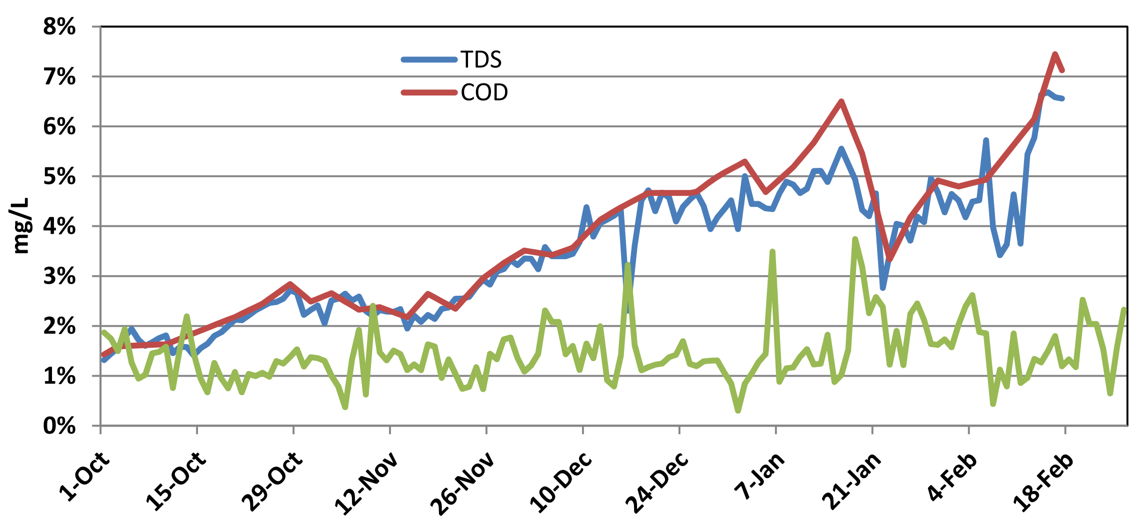
Mass of blow down: The clarifier underflow flow rate is continuously measured with a flow meter. The density of the underflow is calculated as follows: The density of the solution fraction is calculated assuming the TDS comes from beet juice and using the standard conversion1. The density value used for the solids is 1.9 mg/L. The two values are combined in the measured ratio of TSS in the underflow. The total measured flow (in gallons) is converted to pounds by multiplying it by the combined density and the conversion factor of 8.34 pounds per gallon. The volume of the clarifier tank overflow is not measured directly but calculated assuming the extra sugar seen in the lift station sample comes from the washhouse when the effluent tank is overflowing. The amount of this extra sugar is calculated based on the lift station flow and the lift station sugar concentration. The mass of wash water that contains this sugar is calculated by dividing the mass of the sugar by the sugar concentration w/w of the wash water. The total mass of the blow down is the sum of the mass of the blow down from the underflow minus the TSS in the underflow plus the mass of the wash water through the lift station.

Sugar loss calculation: The sugar lost to the wash loop was calculated by multiplying the total mass of the blow down by the TDS and by the purity of the beet juice as measured in the cossettes.

Results and Discussion:

Relation between Wash Water TDS and Sugar: Figure 2 shows the trends for the wash water TDS and the COD concentrations.

Figure 2. TDS and COD of Wash Water (2010-11 Campaign)

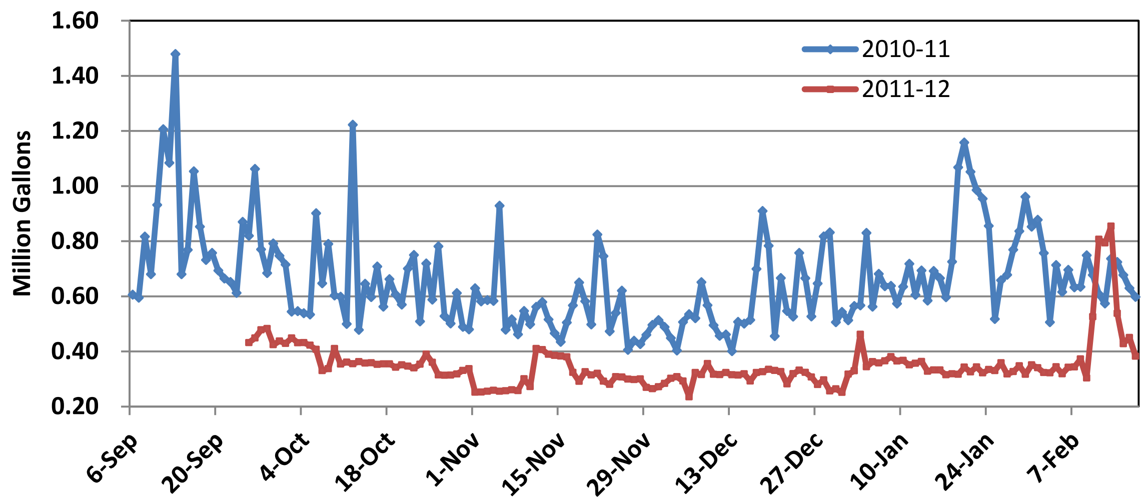


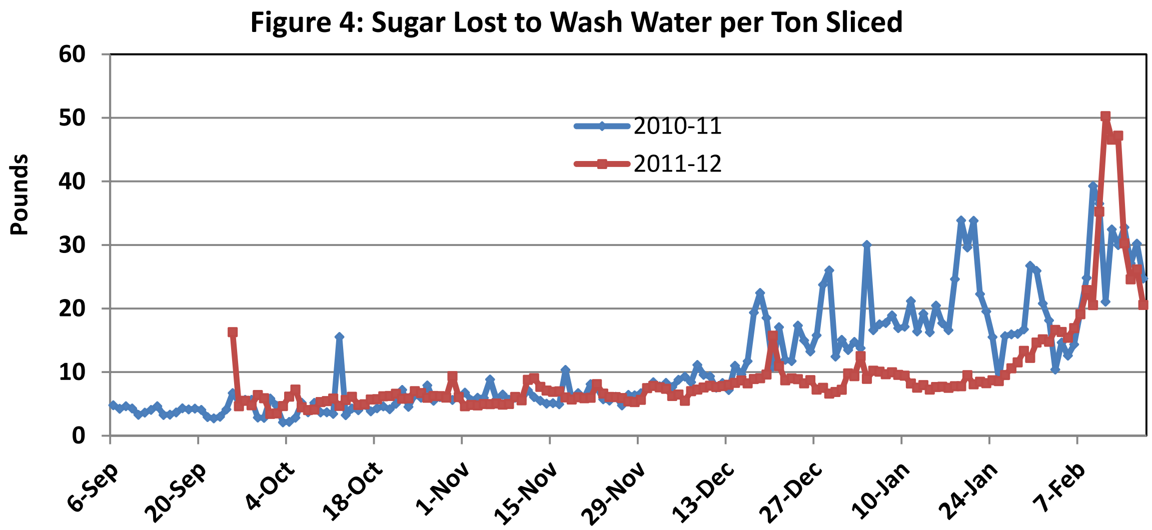
It needs to be determined what the source(s) of the TDS and COD are in the wash loop. Soluble solids can come from the beets (beet juice), from weeds or from soil. It is unlikely that very much of the soluble solids come from the soil washed from the beets. In the field the soil is continuously being washed by rain and the bulk of the soluble inorganic and organic materials are washed away. Figure 2 shows there is no correspondence between the variation in TSS and either the COD or the TDS. Both of these facts suggest that TDS is not coming from the soil.

When a least squares regression is run for COD on TDS it results with a slope 1.10 mg/L COD per mg/L TDS with an intercept of zero. The t-statistic for the correlation is 37 using a 95% confidence interval. This corresponds to the theoretical COD value of 1.12 mg per 1.00 mg of sugar. Taken together, these pieces of evidence show that the TDS in the wash water is coming from beet juice. To calculate the sugar lost from the wash loop the total TDS in the blow down from the wash loop can be multiplied by the purity of the cossettes. Any TDS in makeup water was subtracted from this amount

Daily Sugar Lost to Wash Water: Figure 3 shows the daily wash loop blow down from the start of campaign through February 17. The daily blow down during the 2010-11 campaign was almost twice that of 2011-12 campaign. In addition, there was a significant pre-pile slice. Figure 4 shows how much sugar was lost per ton sliced to the wash water blow down each day for these two campaigns.

Figure 3. Total Daily Blow Down of Water from the Wash Loop





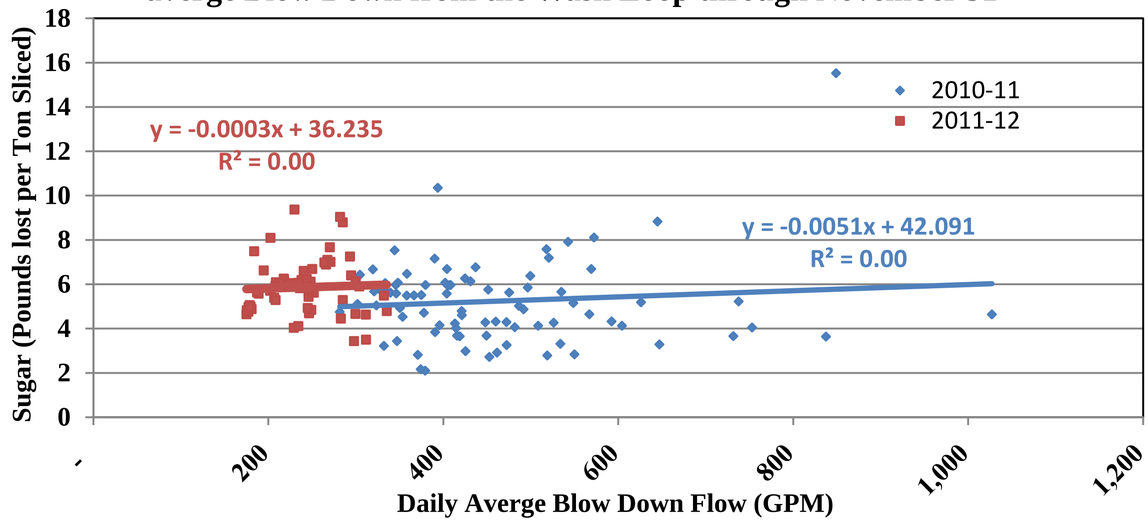
Sugar Loss in the Non-Frozen Beets: From the start of campaign through November, the daily sugar lost was about the same for both campaigns (Table I). During this period, the factory sliced non-frozen beets in good condition. The daily amount of water added to the wash loop varied both within each campaign and between the campaigns. These variations had little effect on the total amount of sugar in the wash water.

Table I: Sugar lost to Wash Loop from September 26 to November 30

	2010-11	**2011-12**
Cossette Sucrose	16.6%	16.7%
Average Daily Wash Loop Blow Down (Gallons)	610,000	340,000
Sugar Lost (Lbs./Ton Slice)	5.6	5.9
Sugar Lost % on Sugar	1.69%	1.77%

Over this period for each of the past two years when the daily sugar lost per ton sliced is correlated with the average daily water flow the determination coefficient (R^2) is nearly zero (Figure 5). A plausible explanation is as follows: Because the diffusion of sugar out of the beets is slow when the tissue is intact, the absolute concentration of the wash water relative to the sugar concentration in the beets did not change much when the blow down rate was changed. A doubling of the blow down rate only changes the sugar concentration gradient by 10-15%, providing only a small increase in the diffusion driving force.

Figure 5. Dependence of Daily Sugar Lost to Wash Water with Daily averge Blow Down from the Wash Loop through November 31



Sugar Loss and Wash Water Makeup with 100% Frozen Beets: Due to clarifier operational considerations, on February 9, 2012 the underflow flow rate was increased from 230 to over 550 GPM and maintained for five days, after which it was lowered to 250 GPM. The factory had started slicing deep-frozen sugarbeets on January 25, thirteen days before the onset of the incident. The sugar loss increased from about 50 to over 100 tons per day over the next several days as the system equilibrated to slicing frozen beets. On February 10 when the additional water was added the sugar loss went up proportionally (Figure 6).

Figure 6. Daily Clarifier Underflow

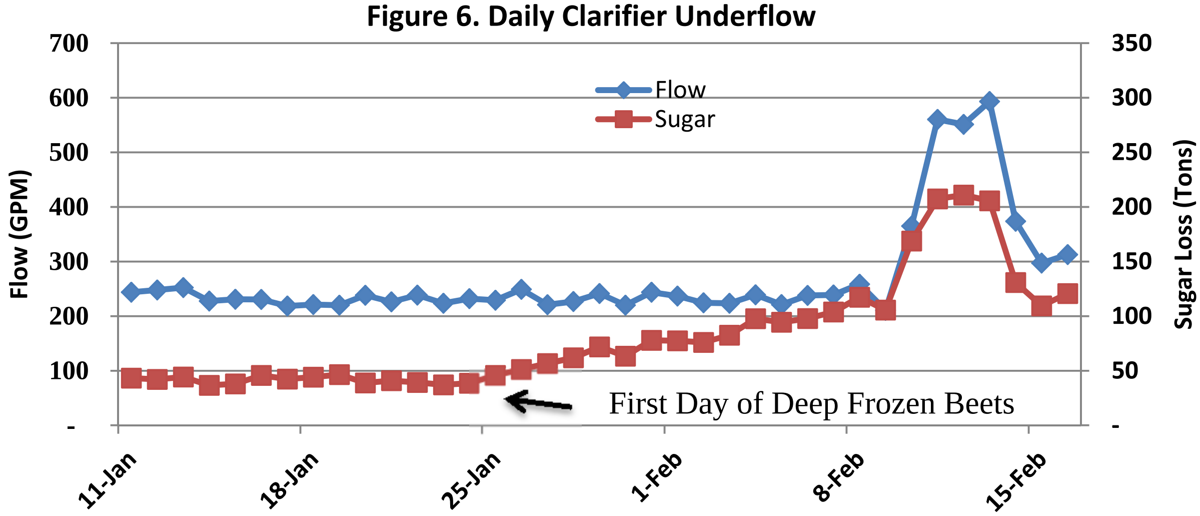
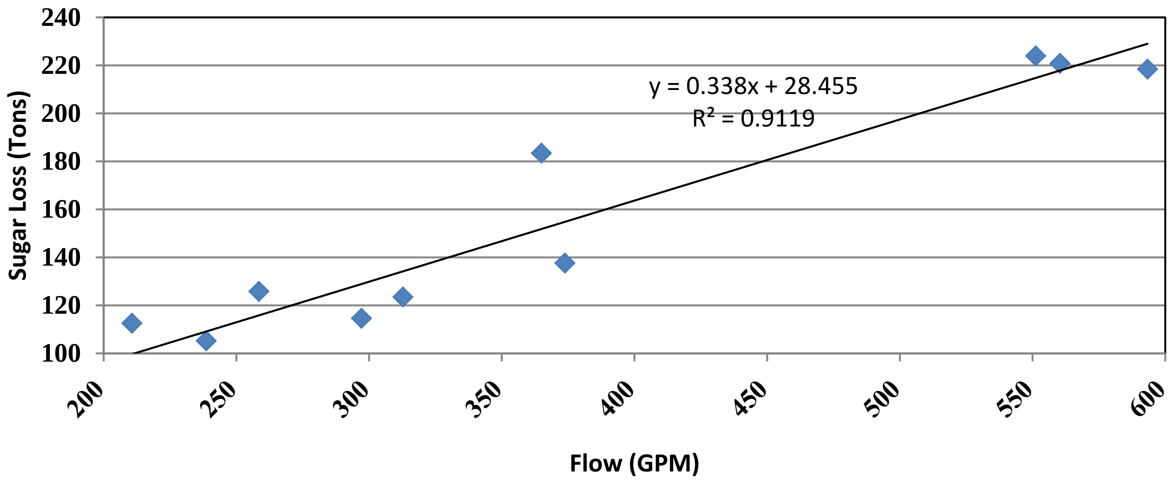


Figure 7. Dependence of Sugar Loss on Wash Water Clarifier Underflow from February 7 through 16, 2012



When the data from the last 10 days of that campaign are plotted a linear relationship between the sugar loss and the clarifier underflow flow rate is revealed (Figure 7). A least-square, best fit regression shows that for an incremental increase in 1 GPM of the underflow an additional 0.338 tons (672 Lbs.) of sugar was lost each day. If regression is forced through zero (no sugar is lost if the blow down from the clarifier is zero), this value increases to 0.407 tons (814 Lbs.) of sugar lost each day for each increase of 1 GPM in the blow down rate.

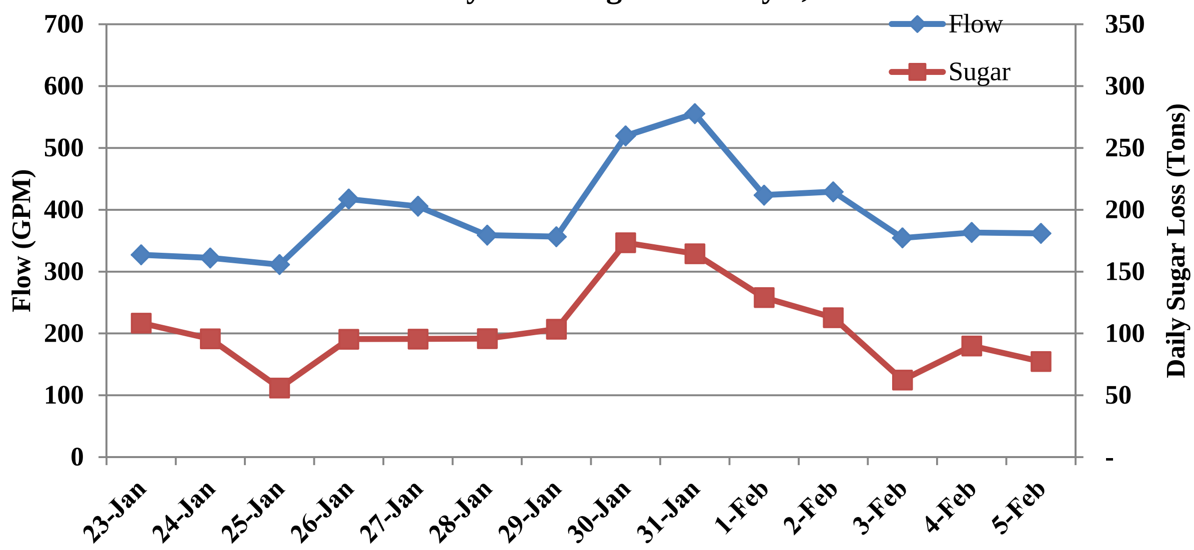
The fraction of a frozen sugar beet that will thaw in the wash water depends on the amount of heat that flows from the wash water into the beet. The water added during this time was a combination of hot condensate (95°C) and cold pond water (4°C). Assuming the average temperature was 50°C, a flow of 1 GPM will deliver 1.04 million BTU to the wash system in one day, or enough heat to thaw 3.25 tons of frozen beet tissue. At 16.6% sugar, that tissue contains about 1,100 pounds of sugar. Our finding of between 672-814 pounds of sugar lost with an increase of 1 GPM is reasonable, as some of the sugar will stay with the ACF and the thawed tissue on the beet.

Sugar Loss and Wash Water Makeup with less than 100% Frozen Beets: During the 2010-11 campaign, all the center beets from non-ventilated piles had been removed by early December leaving only the shoulders. Slicing the beets in the pile shoulders was completed by February 7. Figure 4 shows that sugar loss increased steadily through this period. This increase can be attributed to the fraction of beets that were frozen. The facts that it was a cold winter and the shoulders had a relatively large surface to volume ratio both contributed to the freezing of these beets. Estimates made from visual examination of the beets on the washed beet belt suggest that by the end of December 35% of the beets entering the factory were frozen and by the end of January that number was up to 65%.

During the 2011-12 campaign the factory had finished slicing all non-ventilated beets, including the shoulders, by early December. The factory then sliced ventilated, non-frozen sugarbeets until January 25. This was a period of mild outside temperatures. Only about 5% of the beets being sliced were frozen by the end of this period. The slight increase in sugar loss from earlier in the year, and the significant decrease in sugar loss from the previous year, shows the influence that washing frozen sugarbeets has on sugar loss to the wash water.

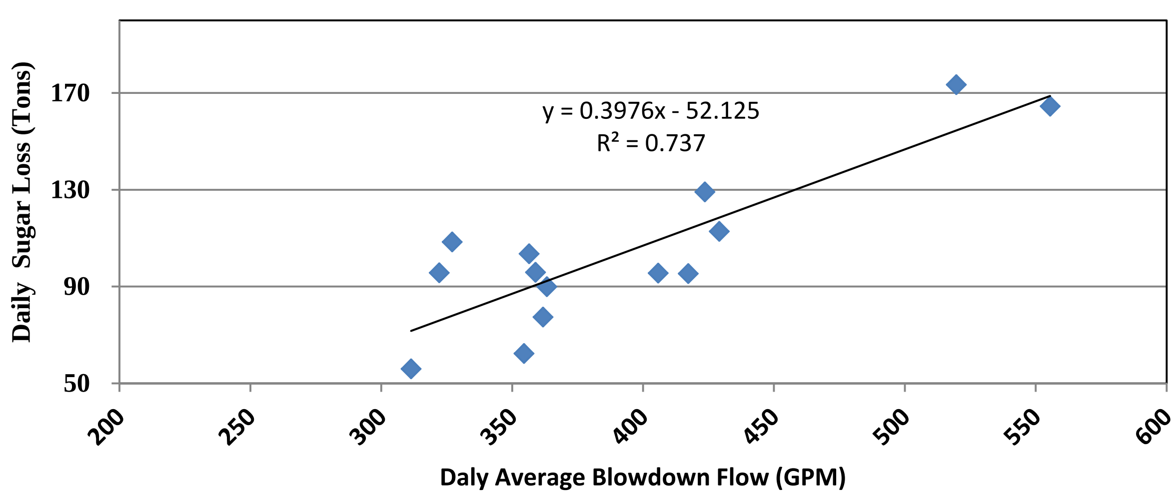
When slicing a mixture of frozen and non-frozen beets, the bulk of the heat added to the washhouse still goes into thawing the frozen beet tissue. Figure 8 shows the daily washhouse blow down and sugar loss from January 23 through February 5, 2011. This was the very end of the shoulders from the non-ventilated piles. As mentioned above about 65% of these beets were frozen. It can be seen how the sugar loss parallels the blow down flow.

Figure 8. Daily Blowdown and Sugr Loss from Washhouse from January 23 through February 5, 2011



When the daily sugar loss is plotted against the daily blow down rate a strong correlation is found (R^2=0.737). At this time for each additional gallon of blow down (and consequently make up) 0.397 tons or 796 pounds of sugar was lost each day. This is similar to what was seen in the 2011-12 example when slicing 100% frozen beets. This suggests that extra heat added to the wash water by increasing the make-up water flow will go primarily to thawing frozen beet tissue even if less than 100% of the beets are frozen.

Figure 9. Dependance of Sguar Sloss on Wash Water Clarifer Underflow from January 23 through February 5, 2011



Summary and Comments: The results showed that with other things being equal, the sugar loss to the wash loop increased between 672 and 814 pounds in 24-hours for each gallon per minute the wash water flow was increase. This increase was attributed to additional thawing of the frozen beets that resulted from adding more water to the wash loop. Data from both campaigns shows a similar relationship.

Studies at SMBSC have shown that the sliceablity of frozen beets is a function of their bulk temperature. Very cold beets (below -10°C or 15°F) become very hard and are difficult to slice. These beets are pushed in front of the knives, opening the knife doors and tripping the slicers. The knives and knife blocks are damaged and it is difficult to keep up with knife sharpening and replacement. Also, the beets freeze together in the hoppers and quit flowing, which requires hard, injury-prone work to free them up. It is a common practice to add extra hot water to the wash loop to heat up the beets.

Most of the beet juice lost to the wash water will end up in the ponds. Each pound of sugar lost creates about 1.25 pounds of COD to be processed by the wastewater treatment system. Beet juice contains about 1,000 ppm sulfate, which contributes to H_2S problems; 1,500 ppm potassium, which can cause problems passing whole effluent toxicity (WET) tests; and about 2000 ppm nitrogen containing compounds, which are turned into ammonia and/or nitrate.

The results suggest that operations personnel should prevent extraneous thawing of beets in the wash loop. If extra water ever needs to be added for any purpose besides heat, it should be the coolest water available, keeping in mind it should also be clean water. Research needs to be conducted on how to prevent extraneous thawing of sugarbeet tissue during washing. Since so much of the heat put in the washhouse goes into thawing frozen beet tissue, which is ultimately abraded away, a reduction of heat may be possible without detrimental effect on slice. SMBSC has embarked on careful management of the storage pile temperature and heat addition in the wash house with the purpose of reducing wash water sugar losses when slicing frozen beets.