The Fuel and Steam Balance in the Raw Sugar Factory

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The paper presents the fuel and steam balance (live and exhaust) applicable for current Louisiana raw sugar factory operating conditions as a function of the live steam conditions. The paper discusses changes that will be necessary for raw sugar factories to meet all of their energy requirements (both steam and electricity) based on current cane quality and sugar quality requirements. The effect that various evaporator configurations and sugar boiling schemes have on the steam balance will be addressed.

Operation of a Filtrate Clarification Station

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In typical sugarcane juice clarification, the filtrate juice is returned to the mixed juice that is entering the clarification station. The filtrate juice has a high suspended solids level that necessitates the need for further clarification. Using a filtrate clarification scheme eliminates the recycle of filtrate juice and increases the capacity of the clarification station. A clarifier dedicated to clarifying filtrate juice was installed, removing the suspended solids and allowing the clarified filtrate juice to be sent directly to the evaporators. The turbidity of the clear filtrate was in the 150-400 NTU range. The present research includes the experiences with the operation and performance results of a demonstration size filtrate clarification station that was operated online at a sugar mill.

2012/13 Season Investigations into Rotary Vacuum Filter Operations at Clewiston

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The sucrose losses in rotary vacuum filter cake have been slowly diminishing, season by season, since the major expansion at Clewiston in 2006. From a high of over 6% Pol% Cake in the commissioning years (2007/8) to a 3.7% in 2012/13 season, has been recorded. The medium term requirement is to be under 3% Pol in Cake. An investigation was made in the 2012/13 season to determine methods to optimize pol recovery across mud filter operations. Various factors were considered, chiefly RVF feed conditioning and operational factors. The quality, quantity, source, and handling of bagacillo added to mud feed were examined. Chemical
additions including flocculant and lime quality, quantity and dosing were also considered. Considerations were also made in regard to material handling and transport of the mud itself. These included types of facilities used for pumping the mud, mixing, and agitation at the individual filters. During the investigation, plant-scale tests were performed by making adjustments in operation for trial evaluation periods. A special pilot-scale test apparatus was also fabricated to test those factors not feasible for testing at the plant-scale level during production. For these other factors, the pilot-scale tests were used to quantitatively determine effects on the filtering characteristics of the feed material.

**Improvements of Raw Sugar Quality Using Double Purge of C-Massecuites: Performance Comparison**

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In 2013 Louisiana sugarcane crop season, three factories integrated double purge of C-magma to a three-boiling crystallization scheme corroborating (like in 2012) color improvements on raw sugar up to 50% when comparing to a factory using single centrifugation (1,400 CU compared to 2,800 CU, at pH 8.5 using 1.2 µm GF filter). New BMA k3300 centrifuges operated at 1680 rpm and 1800 rpm were applied on second centrifugation. The double purge system was run controlling purity of the first magma around 82 and purity of the affined second magma between 90 and 92. The purity of the second wash molasses ranged between 63 and 67 and, it was sent to A or B molasses tanks. Like on a three boiling scheme, A and B massecuites were seeded with footing prepared with the affined high purity magma returning a high polarization (~ 99.2°Z) and low color raw sugar (1,000 – 2,000 CU). One factory reduced color approximately on 50% while the other two factories reduced color on 36%. Double purge system and boiling house configuration and settings differ slightly among factories. Three years (2011 – 2013) boiling house indexes were compared for each factory. Indexes like C-massecuites production (ft³/ton cane), sugar lost on final molasses (pol final molasses % cane) and sugar recovery (pol sugar % cane) do not distinctly show a positive or negative effect for the integration of the double purge system. All three factories ran continuously the double purge of C-magma system almost to the end of the 2013 season.

**The Mathematical Underpinning of Sugar Industry Performance Calculations**

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The technology for conversion of sugar cane to raw sugar was initially developed before the application of analytical and material balance data became routine. The lack of data that would
have been provided by such technology based approaches led to the development of a variety of ad hoc or empirical relationships, often oversimplifying the issue but giving a simple result, useful but of limited real value. For example, statistically derived relationships are common for such activities as cane payment based on quality determination. Even with modern laboratory instrumentation and on-line process data, the classical assumptions are followed with often uncritical faith in their value. Another concern is the lack of appreciation of the inherent variability in measurements and combined with the variability in raw material (cane) quality, these lead to missing of opportunities for operational improvement resulting from better appreciation of the actual processing losses. Examples related to cane quality assessment and factory balances will be presented, including a Monte-Carlo simulation of the factory sucrose balance.

The Molasses Survey: What Is It?

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The loss of sugar in molasses is generally the largest loss suffered by a sugar mill. It is important that reliable data on molasses exhaustion be obtained. The Audubon Sugar Institute (ASI) undertook analyses of molasses samples for the mills in Louisiana from 1980-1997. It was briefly discontinued after the 1997 season and reintroduced in 2000 and is currently providing this service to the Louisiana sugar industry. A composite weekly final molasses sample is sent to the Audubon Sugar Institute for analysis. From the results, the molasses survey report is generated by the analytical laboratory and distributed to the LA sugar mills during grinding season. The report consists of Brix, calculated dry solids, Apparent Purity, True Purity, Sucrose, Glucose, Fructose, fructose to glucose ratio, Target Purity and Target Purity Difference (TPD). The difference between the true purity and the target purity is known as the target purity difference or TPD and is a chief concern for the mills. Since reintroducing the Molasses survey in 2000 the average TPD has decreased. In 2000 the average TPD was 10.2% and the average TPD for 2013 is 8.0%. The molasses survey report shows that the mills are conscious of their TPD and are continuing to improve which is an encouraging trend.

Optimization of Final Molasses Exhaustion

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The main goals of a “raw” sugarcane factory are to have an efficient, profitable operation with required sugar quality and maximum sugar recovery. Based on Louisiana sugar mills’ manufacturing report, the loss of sugar in final molasses accounts for 35% - 52% (or on average 47%) of the total sugar losses. An estimation of the average dollar amount lost for every 2 points
purity rise is over $200,000 annually for a typical grinding rate of 12,000 TCD per mill. Factors affecting the approach to molasses exhaustion are described in the fish bone diagram. These include cane quality, clarification efficiency and the low-grade station stages of the boiling house (which include the study on the ASI small crystallizer, importance of keeping supersaturation zone, crystal size and crystal content plus purity drop from pan discharge to centrifugal machines). In this study, massecuite cooling in the crystallizers was obtained at an optimum cooling time of 42 hours and cooling temperature of 96 - 110 °F to achieve zero TPD (target purity difference) before reheater and centrifuge. Recommended process parameters are given for C-massecuite purity or quantity of seed, temperature, Brix, retention time, crystal content and crystal size distribution which are necessary to improve the molasses exhaustion at each stage of the low grade station. Also discussed will be the effects of cane quality due to freezing and bad performance of each process stage prior to the pan station. A summary of general strategic steps a factory should follow to lower losses in final molasses will be included.

Managing Damaging Freeze Events in Louisiana Sugarcane

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Exposure of sugarcane to damaging frosts occurs in approximately 25% of the sugarcane producing countries of the world, but is most frequent on the mainland of the United States, especially in the state of Louisiana. The frequent winter freezes that occur in the sugarcane areas of Louisiana have forced the industry to adapt to a short growing season (about 7 months) and a short milling season (about 3 months). The nature and extent of damage to sugarcane by a freeze depends on the intensity and duration of the freeze, and the weather conditions after the freeze can control or accelerate deterioration. A series of damaging freezes occurred in Louisiana from November 26-30, 2013 where the low temperatures ranged from -2.2˚C (28˚F) in the southern area of the sugarcane belt to -4.4˚C (24˚F) in the northern area of the belt with the line of demarcation being roughly the areas north and south of the I-10 corridor. The duration of the freeze event below I-10 was approximately 6-10 hours, whereas, the duration north of I-10 was greater than 10 hours. At this point in the harvest, approximately 60% of the 14-million ton Louisiana crop had been processed by the state’s 11 factories. Immediately following the November freeze events personnel from the LSU AgCenter, the American Sugar Cane League and the USDA-ARS Sugarcane Research Unit did field inspections of the damage to the crop by the freeze. Visual ratings were taken for all commercial and some candidate varieties for both leaf and stalk cold tolerance in the field.

In the southern area there was minimal damage to the stalk with only the apical meristem or terminal bud affected. However, in the more northern areas, the freeze events affected the entire stalk. With approximately 40% of the crop still remaining in the field and to study the reaction of commercial and candidate varieties to these early freeze events, the Outfield Variety Test at
Alma Plantation, Lakeland, LA, located in the northern area above I-10 and US Highway 190, was chosen for the study. The test included the commercial varieties, HoCP96-540, L01-283, L01-299, L03-371 and HoCP04-838, and the candidate varieties, Ho07-613, L09-112, HoCP09-804 and Ho09-840. Ten-stalk samples were hand-cut at ground level but not stripped or topped from each of three replications for the first of three sampling dates, Dec. 12, 19 and 26, 2013. Another set of samples was cut on Jan. 3, 2014 but the samples were hand stripped and tops were removed approximately 30 cm (12 in) below the apical meristem (terminal bud). All samples were immediately transported, weighed and processed at the Sugar Research Station at St. Gabriel using the press method of analyses. Juice samples were analyzed for Brix by refractometer and sucrose by polarimetry and bagasse (residue) samples were analyzed for moisture (by drying). The Brix, sucrose, purity and fiber content of the cane were then calculated from these analyses after which the estimated yield of theoretical recoverable sugar per ton of cane (TRS/TC) was calculated. Juice samples were also analyzed for pH, titratable acidity, total polysaccharides, mannitol and dextran. Further, results were compared to actual factory data for daily core juice pH, crusher juice polysaccharides, syrup purities, C massecuite viscosities and sugar yield from Alma Plantation (Lakeland, LA) and syrup purities and sugar yield from the Leighton factory located at Thibodaux, LA (in the southern area below I-10).

Immediately following the field assessment, the LSU AgCenter issued best management practices (BMP) to be used in reducing the impact of the freeze events on sugar yield. Those BMPs stressed the need to deliver high quality cane to the factories free of mud, deteriorated tops and leaves and other trash. The BMP’s indicated that growers and processors should not panic as the industry had experienced freeze events of this magnitude many times before. Since areas of higher elevation tend to be warmer, the BMPs recommended that growers should harvest fields with lower elevation first. Also, growers were informed that varieties with poor stalk cold tolerance, i.e., L99-226, L99-233 and L03-371, should be harvested first. Other items discussed in the BMPs included standing vs. down cane, topping height and whether or not one should burn. It also warned of overnight sleeper loads that could lead to increased deterioration. Data from the Outfield Test at Alma indicated that most of the parameters measured for the samples with tops and leaves, i.e., pH, titratable acidity, total polysaccharides, TRS/TC, remained relatively stable (unchanged) over the sampling period although it became increasingly impossible to clarify juice samples in the lab with aluminum chloride on the Dec. 26 sampling date. The Alma factory data, however, showed that the core lab juice pH, syrup purity and sugar yield started a slow decline over the same period. On the other hand, total polysaccharides in the crusher juice and C-massecuite viscosity at Alma showed significant declines after the freeze events with the BMPs in place. For the Leighton factory operating south of I-10, syrup purities and sugar yield actually continued to rise in spite of the freeze events and a wet harvest. In general, ambient temperatures following the freeze events were cooler than normal although there was one record daily high temperature of 29°C (84°F) on Dec. 5. With the BMPs in place, the Alma factory experienced no difficulties in the boiling house without any indication of c-axis elongation of sugar crystals even with the last strike of the 2013-2014, which was processed crop on Jan. 6. It is interesting to note that on the final sampling date of the Outfield Test, Jan. 3, where tops and leaves were removed, there was no problem in clarifying juice samples in the lab at the Sugar Research Station while at the same time there was a significant reduction in juice pH and total polysaccharides and higher TRS/TC for all varieties in the test from the previous sampling date, Dec 26. All other parameters remained the same as the Dec. 26 sampling dates when all tops and leaves were not removed. These data showed that the BMPs implemented at
the time of the freeze proved to be an effective tool in mitigating the effects of the freeze events of the magnitude that occurred on Nov. 28-30 and that factories could continue to operate with minimal problems in the boiling house so long as the frozen tops and leaves were removed. Even with these BMPs in place, however, it appears that the freeze events of Nov. 28-30 reduced overall state sugar yields by approximately 5.0 kg/tonne (10 lbs/ton) and by removing the top 30 cm (10 in) of the stalk, field yields were reduced by approximately 6.75 tonnes/ha (3 tons/ac) such that the overall loss in sugar yield per hectare for the 2013-2014 crop amounted to about 33.6 kg/ha (30 lbs/ac).

**Process Systems Engineering for the Sugar Industry: Concept and Applications**

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Process Systems Engineering (PSE) is an area of chemical engineering that aims at improving process operations using primarily computer-based methodologies, using mathematical models as the core for simulation, control, optimization, planning and scheduling. Raw sugar production is a simple, yet complex process. The variability of the cane supply creates equally variable conditions that move across the plant from milling and clarification to evaporation and crystallization. Then, maintaining operating conditions at the desired level throughout the season is a challenging task. The experience of plant personnel and the installed control systems are enough to satisfy day to day operations. PSE can be used in sugar mills to achieve maximum performance, assisting plant engineers to balance steam and energy consumption in the factory, to devise control strategies that reduce variability of key variables such as chute’s height or juice pH, to obtain good quality sugar crystals, to improve molasses exhaustion, and to examine changes in equipment or operating conditions, among others. Ultimately, improved performance is reflected in reduced costs and therefore, higher profits. This paper will give general overview of PSE methodologies and present some application to the sugarcane industry.

**Gear Lubrication - Sump to Spray**

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Conversion of Cora Texas Manufacturing mill drive gears from a conventional oil float sump system to a metered, semi-atomized, direct spray application of high solids grease was commissioned for the 2013 grinding season. Incomplete lubrication coverage from a sump system contributed to soldering, powdering, metal deformation and excessive wear on both the Crown Gears and Crown Wheels. Installation of a Farval Automated Centralized Spray System included spray nozzles, controls, dual line valves, plumbing, and increased plant air capacity. The fully automated spray system insures an optimum quantity and placement of lubricant directly onto the gear face. Installation was carried out by Cora Texas Manufacturing personnel.
Design and engineering was a combined partnership between Cora Texas Manufacturing and Farval.

Scale Removal Using EDTA – Preliminary Results on 5th Effect Evaporator Scale

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Evaporator scale is a complex mixture of various chemical components that deposit on evaporator tubes and require periodic removal to ensure efficient operation. Scale composition can be highly variable from mill to mill, and also within the different effects of the evaporator set. While chemical cleaning using caustic soda (NaOH) and/or acid is widely practiced, and can in fact be considered an industry standard, calcium (Ca) based scales of sulfate and oxalate are not readily removed with these treatments. Additionally, corrosion associated with the use of acids, results in reduced equipment life and high replacement costs. Chelating agents like EDTA are known to readily dissolve such Ca based scales and have been in routine use in Australian sugar mills for over 15 years. In the U.S., there has been limited reported use or trials using EDTA as a scale management tool. This presentation describes trial results on the use of EDTA to clean evaporator vessels known to be scaled with scale containing mostly CaSO$_4$. 5th effect vessels at the U.S. Sugar facility were boiled with EDTA under vacuum at 170 – 180°F. Treatment of tubes coated with 1/8 inch thick scale with a slight excess of EDTA showed complete removal of all scale to bare metal along the entire length of the active tube surface.

On-Line Crystal Growth Monitoring and Sugar Color Measurement Using Image Processing Techniques

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Improving sugar quality comes down to improving many different factors, the main being at the crystallization level. To better characterize the crystallization process, it must be closely monitored on two fronts: (1) At the sugar boiling stage, on-line crystal growth measurement is performed using a pan microscope coupled to a high resolution digital camera mounted in front of a sight glass on the pan. A LED controlled light source illuminates the measurement area where sharp images of the crystals are taken and sent to a computer in control room. Dedicated software displays the video of the crystals moving inside the pan and applies specific algorithms to each image to calculate the coefficient of variation (CV) and the Mean Aperture (MA) in real time. The information provided helps checking that the crystals are growing homogeneously and with the correct size, therefore representing a good indicator of the expected quality of the massecuite. (2) At the centrifuges outputs, sugar color measurement is done by an on-line colorimeter, also equipped with a high resolution digital camera placed above the sugar conveyor. A controlled light source illuminates the sugar surface and the reflected light is
analyzed by dedicated software that calculates the sugar color in Icumsa units. It is used to check that the sugar color remains constant and within predefined limits, to automatically trigger alarms on non-conformities (brown lumps detection), to increase traceability with video recording or optimize maintenance and washing time for each centrifuge. The poster shows how image processing techniques are used to optimize the crystallization process while increasing production at lower costs.

**Evaluation of Harvesting and Storage Practices for Sweet Sorghum and Energy Cane**

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Two attractive potential feedstocks for biofuel production are Energy Cane and Sweet Sorghum due to the environmental adaptability, sugars concentration and yield. Evaluation and development of harvesting, transportation and storage practices is critical for bringing the production of these crops to industrial levels. Harvesting trials were conducted at St. Gabriel, LA for evaluating the feasibility of using sugarcane equipment for harvesting and for determining the effect of different harvesting/storage practices on the sugars yield and the operational efficiencies of the processes. The parameters that were varied during the trials were: billet size (6 and 8 inches length), fan speed of the extraction system (0, 900, and 1100 rpm) and the storage time (0 to 24 hours); the following operational indicators were estimated: (1) Material yield (tons/acre), (2) % Juice Yield; (3) %Brix and %Total fermentable sugars yield (TFS%); (4) Bulk Density of the material (ton/m3); (5) Plant composition before/after harvesting (% of stalk, %leaf matter and %seeds); (6) Material losses due to storage (during 24 hours of storage). The expected ethanol yield obtained from the %TFS was calculated as well as the potential profit. Statistical analyses were used for determining significant differences on the results of the variables measured in the harvesting trials. The results of the Energy Cane indicated that by harvesting with a billet length of 6 inches, processing the material in the shortest time after harvesting and by increasing the fan speed of the extractor system, the %TFS tended to increase, reaching up to 10%TFS; as a result the yield for ethanol production increased by approximately to 750(lt/acre). The results of the sweet sorghum indicated that by using a billet size of 6 inches, reducing the storage time and by increasing the fan speed of the extractor system, the TFS% tended to increase around 7.5(%TFS), however, because the material yield considerably increased by reducing the fan speed (32ton/acre), the highest ethanol yield and profit was achieved when the fan was not used, obtaining a concentration in the juice of approximately 7%TFS, 800 lt/acre of ethanol.