Refinery Performance using Single Strike Boiling

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Abstract

SIT #875, presented in Dubai 2005, proposed a single strike boiling scheme model based on the way that Russian beet factory conversions operated when refining raw sugar. It suggested that it would be particularly suitable for medium size refineries up to about 2000 t/d RSO.

We now have operational a 1700 t/d RSO stand-alone refinery that uses the scheme. It was designed to melt up to 1200 colour VHP raws and runs carbonatation followed by a light dosing of PAC as necessary then double effect evaporation to produce fine liquor. Target colour for the fine liquor was 340 ICUMSA.

The product boiling scheme employs diverter valves, integral to the batch centrifuges, to segregate higher and lower purity liquors [called respectively HP run-off and LP run-off]. The valves switch at set points in the cycle so that the HP run-off is primarily crystal and basket washings and the LP run-off is primarily mother liquor. Modelling predicted about 75% of the total run-off returned as pan feed for back-boiling, the remaining 25% being sent to an Intermediate Station [A Station] which again used the same back-boiling concept before a more conventional standard B and C Recovery Station in the model.

Given the high purity regime without affination, the 'A' sugar produced from this Intermediate Station is melted back with clear liquor to produce fine liquor. 'B' and 'C' sugars are sent to the melter station.

The results presented in the paper show that the refinery is operating broadly as predicted, continuously producing 100% refined sugar to bottlers' standards.

At the recovery station, the concept of back-boiling without segregation was extended up to the B station. Like the HP run-off or HP A run-off, some B run-off is continuously sent back, this time in order to reduce molasses quantity and improving its exhaustion.

Introduction

Most cane sugar refineries use a conventional straight three or four boiling scheme but a few of them use a back-boiling system. In 2005 at the Dubai meeting, SKIL presented a scheme based on our Russian beet factory to raw refinery conversion work.

We started to use a single boiling scheme with a lot of back-boiling in a stand-alone refinery in 2010. During the SIT 2010 meeting in New Orleansl, we described the scheme and presented the first results obtained with it. After more production experience [more than 240 000 t RSO produced in 2011] we confirm in this new paper that the approach used delivers good performance.

The stand-alone refinery is a 1700 t/d RSO refinery which is designed for VHP feedstock up to 1200 colour so there is no affination, it just runs carbonatation followed by a light dosing of PAC as necessary and then a double effect evaporator.

The product is all made from a single boiling with a lot of back-boiling combined with run-off segregation. We accept that such a scheme reduces the flexibility for making multiple products but in the last 2 years we have proved that EEC2 quality sugar can be produced efficiently despite having to work on a 5½ day week basis.

Description

The scheme is not particularly novel, but equally it is not much used. There is a single product boiling followed by an intermediate boiling – not envisaged in our 2005 paper – and then a two boiling recovery house so four boilings in all. The first two boilings are shown diagrammatically in Figure 1. It can be seen from that flow diagram that both use back-boiling with run-off segregation :

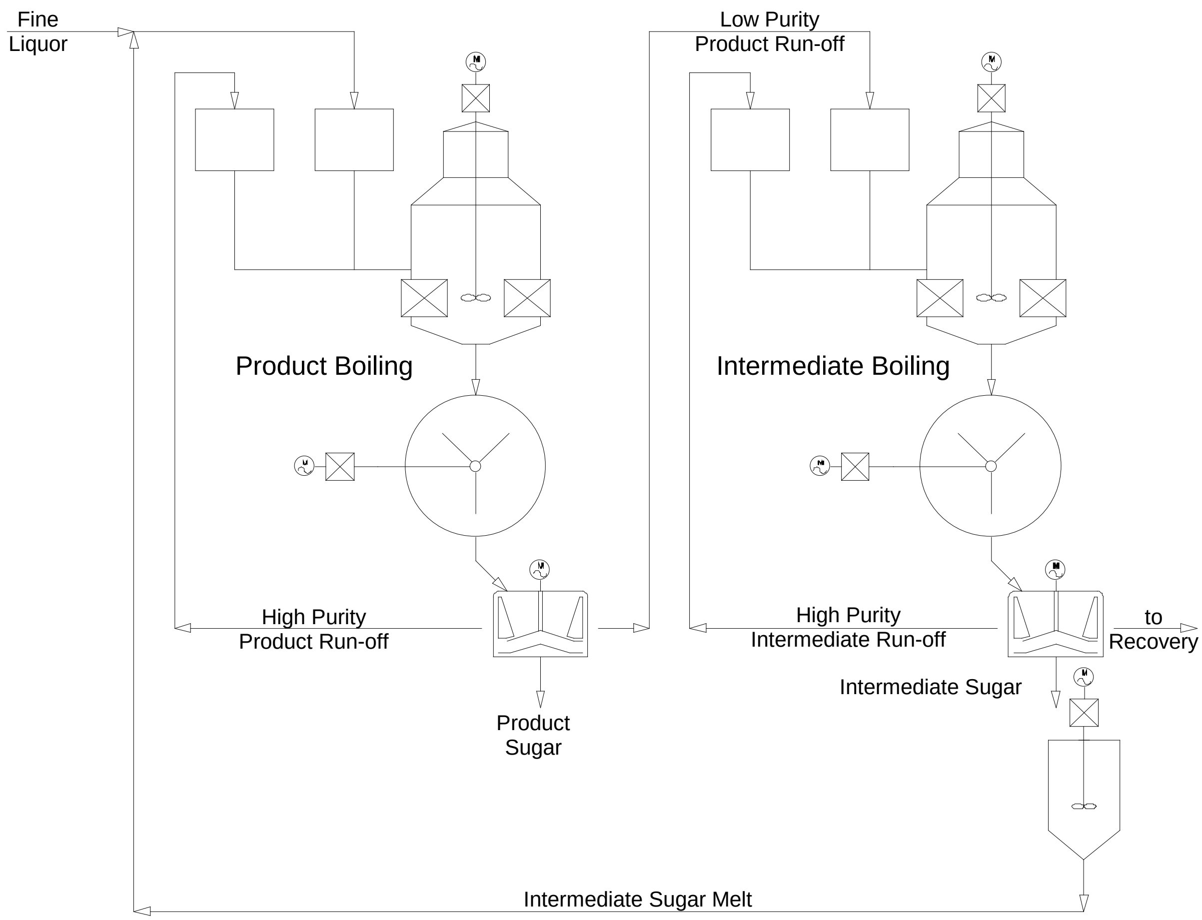

Figure 1 : The Front End Boiling Scheme

Mixed fine liquor and intermediate sugar melt are held in one pan feed system and high purity run-off from the product boilings is held in another. Both feed the product boiling but at different times.

The product boiling itself is a more or less a conventional refinery boiling with a cycle of about 2 hours to make a 0.6 mm crystal. The fine liquor / intermediate sugar melt is used in the first part of the boiling which is then finished with the HP run-off so that the core of the crystal comes from highest quality liquor.

The centrifuges are set up to divert the crystal and basket washings plus some of the mother liquor to the HP run-off gutter and most of the mother liquor to the LP run-off gutter using timers. The HP run-off returns to the product boiling feed as described and the LP run-off becomes the primary feed for the intermediate boiling. That boiling is operated in a very similar manner with the HP intermediate run-off returning as the secondary feed. Intermediate sugar is melted as described previously and the LP intermediate run-off passes to the recovery house.

Theoretical Mass Balance

The refinery Mass and Energy Balance was developed using Sugars®. An extract from the diagram for that balance is shown in Figure 2 :

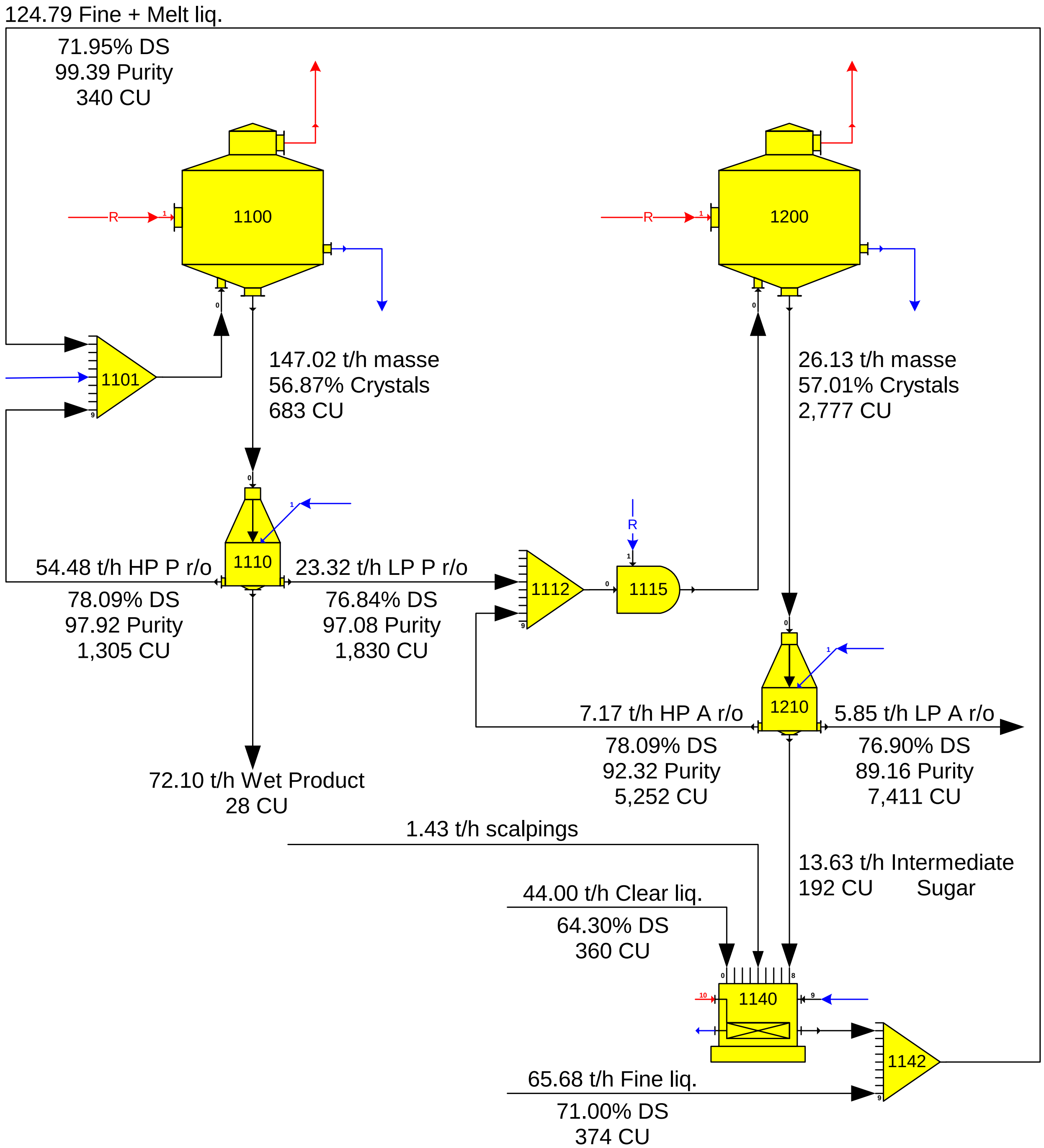

Figure 2 : Mass and Energy Balance

It can be seen that the feedstock to the product boiling is made up of the two liquor streams :

- 124.79 t/h of fine liquor plus intermediate sugar melt, 340 ICUMSA, 99.39 purity
- 54.48 t/h of high purity product run-off, 1305 ICUMSA, 97.92 purity;

Tracing back shows that 70% of the product run-off is returned to the product boiling, only 30% going forward to the intermediate boiling. The back-boiling of the intermediate strike is less adventurous with 55% of the run-off returned, 45% going forward to the recovery boilings.

Main Equipment

There are 6 pans in total and 6 batch centrifuges plus 3 continuous centrifuges.

Product Pan Station : there are four 90 t product pans, all similar [BMA pans originally installed in a European beet factory]. They feed into a common 140 t strike receiver which in turn feeds a mixer above four Broadbent C54MT centrifuges. These have a nominal 1850 kg charge capacity. As stated earlier, each machine is fitted with two run-off valves feeding one or other of the gutters under the battery of machines.

Intermediate Station : there is one 90 t intermediate sugar pan similar to and from the same origin as the product pans. It feeds another 140 t strike receiver which in turn feeds a mixer above two BMA G1250 centrifuges. These have a nominal 1250 kg charge capacity. They are also equipped with two run-off valves each.

Recovery station: there is only one 50 t recovery pan for both B & C boilings. Three 60 t receivers allow segregation of the B [one] and C [two to give a longer residence time] massecuites. The continuous centrifuges are three BMA K1300 machines.

Results

The results discussed are obtained after two years of improving experience, practice and dealing with different kinds of VHP sugars.

Table 1 [over the page] shows the yearly average data obtained so far.

We used these results for a mass balance calculation for the crystallisation house. In order to compare with the model, we assumed the same sugar production rate [72 t/hr of sugar production in both cases]. In practice, since 2011, the refinery has worked on a weekly basis mainly between 60 to 65 t/hr although some weeks were at the 70 t/hr for which the plant was designed.

To achieve good performances, the pan operator is always looking to optimise the recirculation of the run-off to the product station according to the target for the final sugar colour. We are now looking for a colour of 35 UI instead of 28 UI as in the original model.

It is interesting to note that we have never achieved a clear difference in analysis of the supposed ‘high’ and ‘low’ purity run-offs for either of the batch centrifuge stations : ash content, purity and colour are, on average, practically the same. Also on average, before the purging phase, the mother liquor purity drops ± 2.2 points below the product massecuite purity.

		2010-11	2011	2012 to date	
Raw Sugar	Colour	814	850	845	ICUMSA
	Pol	99.54	99.40	99.44	%
	Invert	0.18	0.19	0.22	%
Raw Melt	Colour	1060	1070	1110	ICUMSA
Clear Liquor	Colour	246	300	346	ICUMSA
Fine Liquor	Colour	276	320	371	ICUMSA
	Pol	99.48	99.46	99.3	%
	Invert	0.19	0.24	0.32	%
Product Sugar	Colour	34	34	42	ICUMSA
	Invert	<0.01	<0.01	<0.01	%
	Ash	0.005	0.005	0.005	%
	MA	0.62	0.62	0.62	mm
	CV	34	34	34	%
HP Product Run-off	Colour	1330	1500	1606	ICUMSA
	Pty	98.07	97.9	97.2	%
LP Product Run-off	Colour	1300	1500	1610	ICUMSA
	Pty	98.09	97.9	97.2	%
	Invert	0.88	0.96	1.4	%
Intermediate Sugar	Colour	181	185	232	ICUMSA
	Pol	99.75	99.67	99.63	%
Intermediate Sugar Melt	Colour	276	294	319	ICUMSA
HP Intermediate Run-off	Colour	6233	6296	6510	ICUMSA
	Pty	92.11	92.15	90.9	%
LP Intermediate Run-off	Colour	6280	5921	6538	ICUMSA
	Pty	92.0	92.56	91.1	%

Table 1 : Yearly Average Data

Figure 3 shows the results of the modelling with actual data. It can be seen that production is similar to the theoretical model.

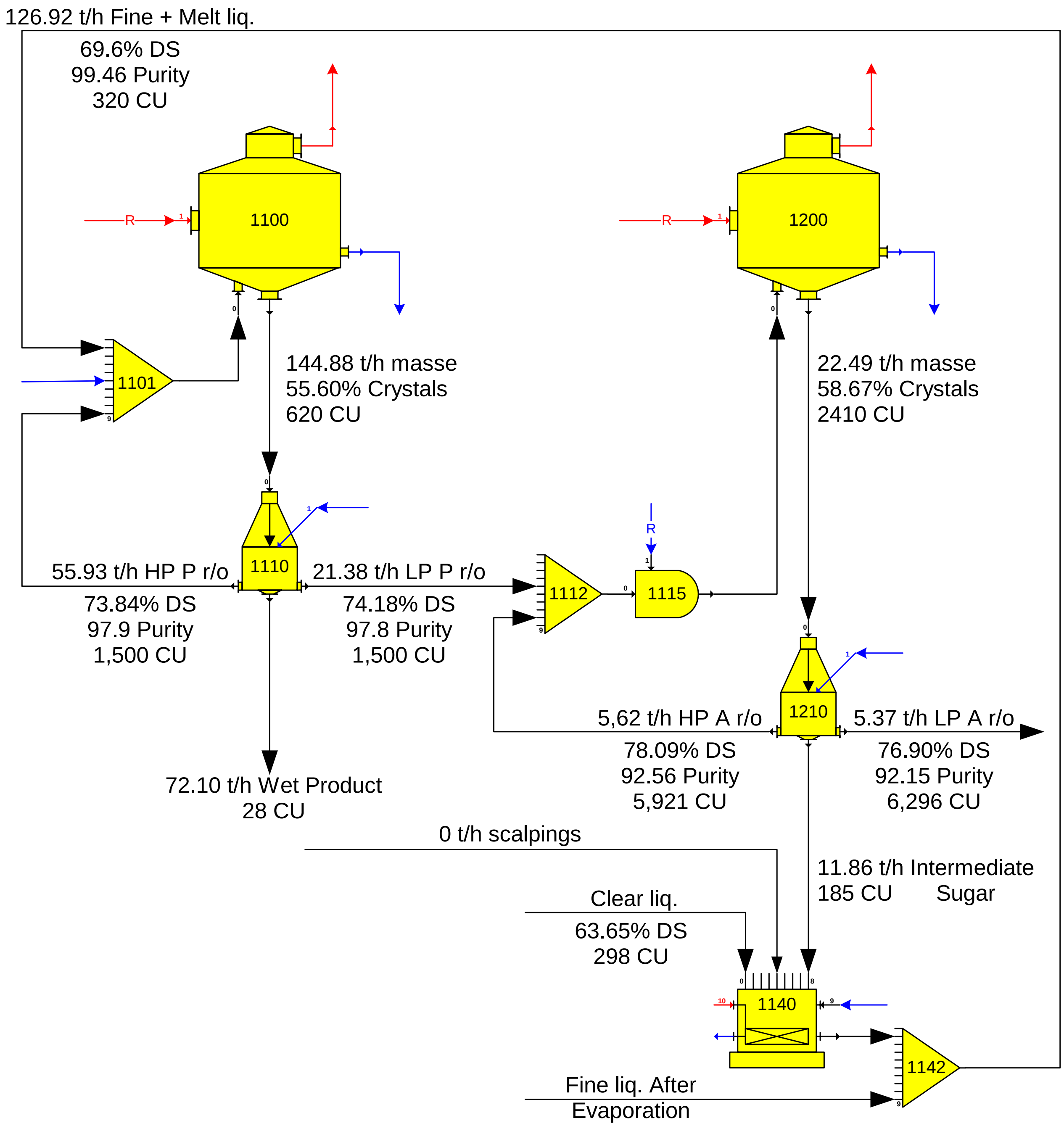

Figure 3 : Refinery Mass Balance 2011

Fundamentally, the product sugar is within specification : more work is on going on tighten the control of the boiling [adding VFD's to the pan stirrers] and clearly segregating the liquor produced during the pan steam cleaning from the massecuite discharged.

It must be remembered that the theoretical scheme has had to be adapted for the weekend shut-down. Depending on maintenance and/or commercial requirements the refinery is running 116 to 126 hours per week. The shutdown and start-up clearly have an impact on the production although with experience today, we are always able to produce sugar within specification. The key points are as follows :

- commercial sugar is produced up to the last product pan before shut down;
- every effort is made to only drop the melting, product and intermediate stations for the shut-down; low product massecuite receivers are maintained at 70% on max level;
- pH adjustment during shut-down: only in run-off vessels and B & C melter;
- during the first hours of the restart phase, the percent of HP run-off is increased progressively in order to achieve commercial sugar from the first pan onwards;

Colour

As seen on Table 1 and on the mass balance, it is always possible to return a higher colour charge with the run-off [1,500 ICUMSA instead of 1,300 ICUMSA for the model]. This result was expected as it is clear that one can work far better than the 'rule of thumb' 10:1 ratio for colour elimination. That leads naturally to the acceptance of a higher colour fine liquor as can be seen in practice. In 2012, with a higher commercial sugar colour target of 45 ICUMSA, the HP run-off was up to 1,700 ICUMSA.

The same effect is seen on the intermediate sugar station. Concerning the intermediate sugar itself, the initial target was set at 185 ICUMSA but it has been shown in practice that the colour can be increased up to 350 ICUMSA without upsetting the product station. It is this which allows the operators to maintain the sugar quality during shut-down and restart stages.

Taking the model flow rates as reasonably representative of what is actually happening, the mean colour of the feed to the pans can be calculated and the colour elimination factor determined. The values for the actual data are presented in Table 2 together with the figures from the model :

	Model	**2010/11**	**2011**	**2012**
Mean Feed Colour	650			
Product Massecuite Colour	683	567	625	628
Product Colour	28	34	34	42
Colour Elimination Factor	**24.4**	**16.7**	**18.4**	**15.0**

Table 2 : Colour Reduction across Product Boilings

The calculated colour elimination factors are plotted against massecuite colour for 2011 in Figure 4 [over the page].

The dotted line is the value from the model and the lozenges are the various actual results on a weekly average basis. The 2010 data is not used as the refinery was still in its early operational phase and, to ensure the refined sugar quality, higher decolourisation agent [PAC] doses were being used.

Concerning the 2012 data, a 45 ICUMSA commercial sugar is being produced for the early part of the year, so again it was decided not to use that either.

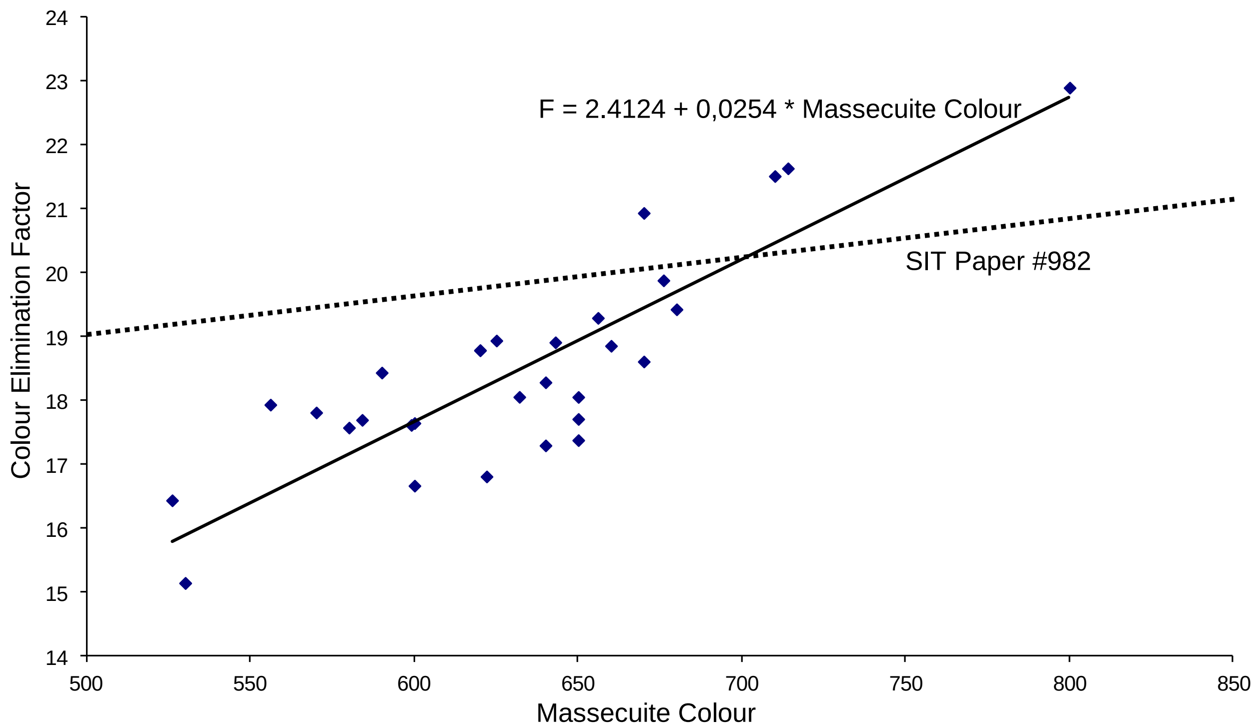

Figure 4 : Colour Elimination Factor v Massecuite Colour

The second trend line which is drawn is that from the private communication of Ahmed Vawda which was quoted in the 2005 concept paper. It is clear that the results are not yet anywhere near as good as those predicted by his formula [F = 15,5 + 0.007 * Feed Colour].

For the colour elimination factor in this paper, the massecuite colour was used rather than the feed colour as in fact, Sugars® calculates the feed as a single stream and arrives at an average feed liquor colour of 650. That is rather simplistic because, as explained earlier, boiling is started with the low colour [320 ICUMSA] 'fine' liquor and finished with the higher colour [1,615 ICUMSA] high purity run-off from previous boilings.

Colour Elimination Factor = 2.4124 + 0.0254 * Massecuite Colour

The same calculation can be made across the intermediate sugar boilings although there is a lot less data due to the reduced number of boilings [typically one boiling for five and a half product boilings]. The values for the last years are presented in Table 3 together with the figures from the model :

	Model	2010/11	2011	2012
Mean Feed Colour	2644			
Intermediate Massecuite	2777	1840	2410	2480
Intermediate Sugar Colour	192	181	185	232
Colour Elimination Factor	**13.8**	**10.2**	**13.0**	**10.7**

Table 3 : Colour Reduction across Intermediate Boilings

In order to achieve better exhaustion in the recovery house, the partition between HP and LP run-off was deliberately skewed towards HP. This was possible as the quality difference between the two was not as great as implied by the model [see Table 1]. Colour was controlled at a lower level and purity > 94 instead of 92.

On average, 200 ICUMSA colour was easily maintained on the intermediate sugar.

Purity and Invert Levels

One of the criticisms frequently levelled at the scheme is that heavy back-boiling will result in high invert levels and require the entire run-off to be dumped to recovery. What we have shown is that this is not the case and the use of a small continuous blowdown [to borrow boiler terminology] with low purity run-off from each purge cycle is adequate. This seems to be true even though there is little difference between the invert levels of the high and low purity run-offs.

Actually, the invert interactions in the process (lowering performances, increasing losses) start with the PAC usage and continue through the recovery house. The pH of the fine liquor is on average 7.3. At the crystallization station, efforts are being made to improve pH control of the HP and LP 'A' run-off in order to increase the exhaustibility of the molasses from B & C station. The invert % on B molasses can be > 10 % and with a pH below 6 sometimes, it is difficult to get a good C massecuite. This work is in progress.

What has been found is that with only one pan for B and C boilings, when working at a rate > 65 t/h, it is not possible to reduce the final molasses purity as calculated on the model. Instead of the 52 purity predicted by the model, the purity is in the 65 to 69 range.

Pan Yield

In the 2005 paper, yield is the solids yield and calculated on a mass / mass basis so the yield in the model shown in Figure 2 would be 54.3%. However, Carter (2009) defined yield more precisely than many are used to by calculating only the sucrose component of the streams. On that basis the sucrose yield of the model would be 54.9%.

In practice, pan yield expressed as kg dried sucrose / kg sucrose in feed liquor stream is equal to 55.60% on average in 2011 instead of the 54.9% calculated by the model.

Overall Performance

The overall performance of the refinery in its first year (2010) was reasonable for a start-up operation with a sugar recovery [Pol made on raw sugar] of 97.40% and a steam on RSO figure approaching 105%, showing every likelihood of reaching its targeted 90%.

In 2011, the refinery achieved a sugar recovery of 97.53%. Sugar losses in more detail are as follows :

Sugar Losses in Molasses	1.59
Sugar Losses in Mud	0.34
Undetermined Losses	0.54
Total Losses	2.47

The steam consumption target was exceeded during the same year.

Conclusions

The refinery has run reasonably well since start-up and is working near the design performance figures. Not one gram of any extra chemical aids has been used in order to maintain the sugar quality.

The single strike product boiling adapted to a stand-alone, medium capacity refinery scheme is performing well, albeit not yet at the originally modelled conditions. It does require modern batch centrifugals using run-off segregation to work though.

The next objective is to control the invert level all along the process in order to maintain maximum efficiency for the plant. In 2012, the team has started to manage raw sugar with a higher colour input [> 1800 ICUMSA] without an affination station using the same design. It is clear that the system is efficient and robust.

References

1 Thomson et al (2005), "Thoughts on Refinery Boiling Schemes", SIT Paper #875
2 Carter (2009), "Measuring and Improving White Pan Yields", SIT Paper #962
3 Inkson et al. (2010), A single strike boiling scheme", SIT Paper #982