A Single Strike Boiling Scheme

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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 melts 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 is 340 ICUMSA.

The product boiling scheme employs diverter valves, integral to the batch centrifuges, to segregate higher purity, lower colour [so called 'white'] run-off from lower purity, higher colour [so called 'green'] run-off. The valves switch at set points in the cycle so that the white is primarily crystal and basket washings and the green primarily mother liquor. About 75% of the run-off is sent to white and returned as pan feed for back-boiling. The remaining 25% is sent to a three boiling recovery but, given the high purity regime without affination, the 'A' sugar is melted back to fine liquor having been boiled and purged as if food quality.

The results presented in the paper show that the refinery is operating broadly as predicted, producing a refined sugar to EEC 2 standard.

Introduction

Last year in N'Orleans somebody referred to back-boiling as 'cheating'. However, it is a classic boiling system in many cane sugar mills with a back-end refinery in Central and South America. Back in 2005 at the Dubai meeting we presented a scheme based on our Russian beet factory to raw refinery conversion work and you would have heard reference to that if you were at the 2009 meeting.

We now have a stand alone refinery operational that uses this scheme. It 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 to produce fine liquor.

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 it is not difficult to envisage that one could run mini-campaigns of different products if necessary.

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 – something 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 [over the page]. It can be seen from that flow diagram that both use back-boiling with run-off segregation :

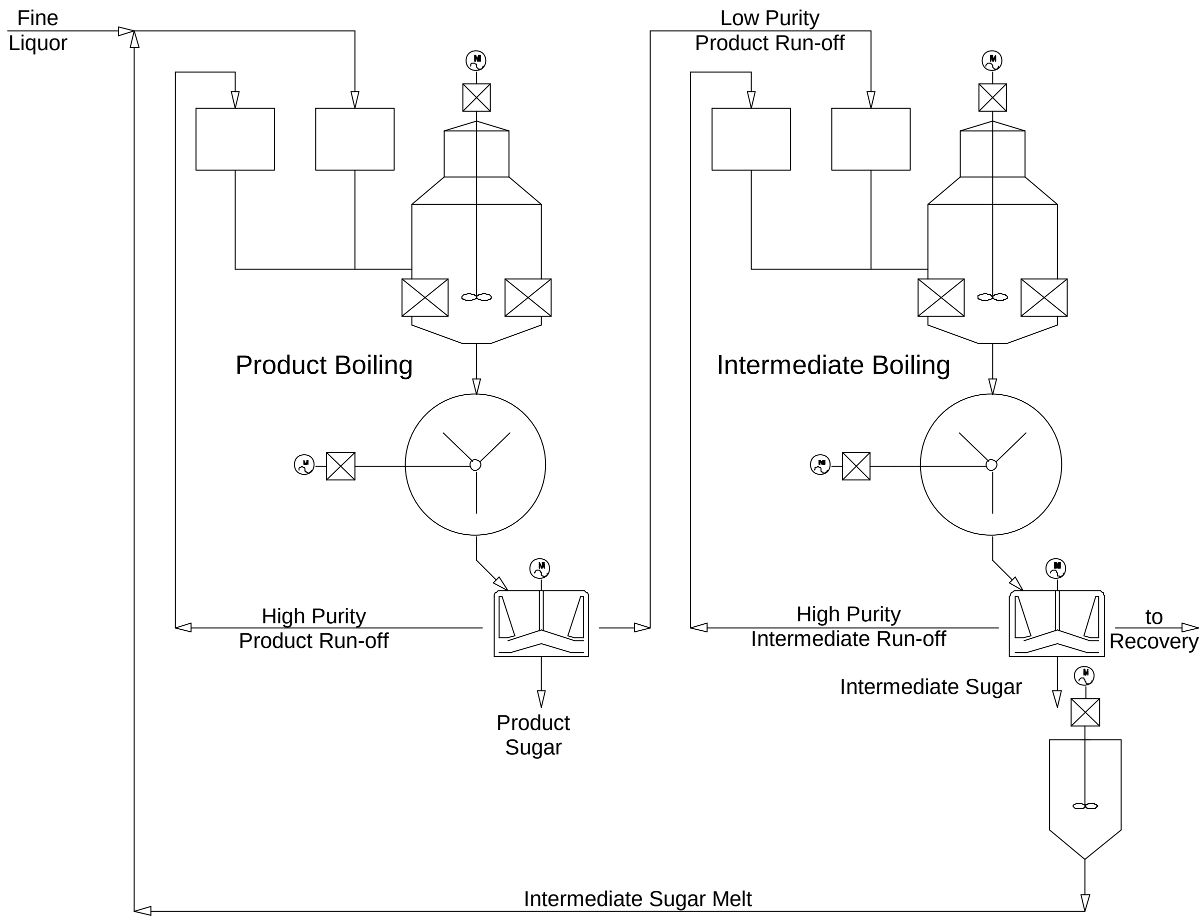

Figure 1 : The Front End Boiling Scheme

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. [In practice some of the clear liquor by-passes the evaporator and is used to melt the intermediate sugar so the fine liquor quantity is not as much as might be expected.]

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 :

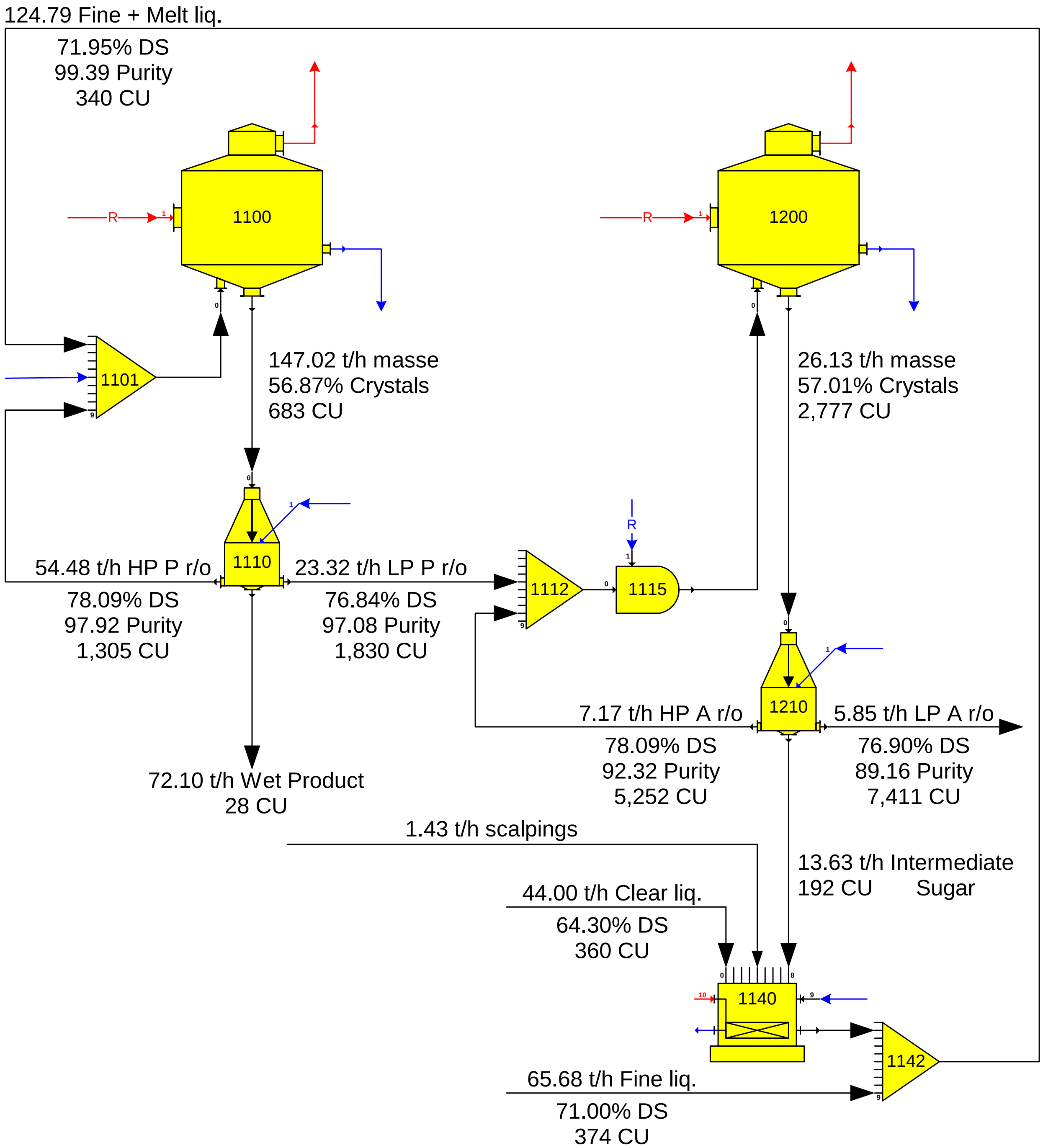

Figure 2 : Mass and Energy Balance

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 normal recovery boilings.

We should, at this point, perhaps turn to the core thesis of the 2005 paper : that colour elimination is considerably better than the rule of thumb 10:1 ratio and that crystal yields are also better than assumed provided that the refinery is run correctly. That leads naturally to the acceptance of a higher colour fine liquor as can be seen in the balance.

In fact, Sugars® calculates the feed as a single stream and arrives at an average feed liquor colour of 650 with a product colour of 28 : a colour elimination factor of 23.2 : 1. That is rather simplistic because, as explained earlier, boiling is started with the low colour [340 ICUMSA] 'fine' liquor and finished with the higher colour [1305 ICUMSA] high purity run-off from previous boilings.

Main Equipment

There are four 90 t [~60 m^3] product pans and one 90 t [~60 m^3] intermediate pan. All five are similar : BMA pans originally installed in a European beet factory. They have 455 m^2 of calandria surface area so the surface area to volume ratio is ~ 7.6 m^{-1}.

The four product pans feed into a common 140 t [~93 m^3] 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. Most of the liquor is stored on the ground floor, the small pan floor tanks being fed on a continuous basis with overflow back to the appropriate ground floor tank.

The intermediate pan also feeds a 140 t [~93 m^3] strike receiver [because it came with the pans from the beet factory] which in turn feeds a mixer above two BMA G1250 centrifuges. These have a nominal 1250 kg charge capacity. They too came from the same beet factory and are also equipped with two run-off valves each.

Results

In setting out to write this paper, it was realised that the understanding of what was going on was not going to be easy because of the mixed feedstock to the boilings. We also came up with another problem : the ash readings across the product boilings were the same for fine liquor and both run-offs with the laboratory equipment available so we felt that we couldn't use George Carter's technique for crystal yield calculation as presented at last year's meeting.

It should also be made clear that this refinery has a weekly shutdown, operating for about 136 hours a week. The shutdown and start-up clearly have an impact on the production although the length of normal time is improving with experience. None of the refinery staff had refinery experience when it was started up in late 2008, only the very small commissioning team.

The raw data for the four weeks from February 22 2010 are presented on a weekly average basis in Table 1 (over). The data is presented as reported with all of the usual anomalies of lab reports and behind it is a lot of daily, hourly and per strike information.

		Week 1	Week 2	Week 3	Week 4	
Raw Melt	Colour	1300	1400	1000	1300	ICUMSA
	Pol	99.25	99.25	99.21	99.52	%
Clear Liquor	Colour	240	270	250	330	ICUMSA
	Invert	0.1	0.1	0.2	0.1	%
Fine Liquor	Colour	250	280	250	310	ICUMSA
	Pol	99.3	99.4	99.4	99.3	%
	Invert	n/a	0.1	n/a	0.1	%
Product Sugar	Colour	39	37	38	37	ICUMSA
	Invert	<0.04	<0.04	<0.04	<0.04	%
	Ash	0.006	0.006	0.006	0.005	%
	MA	0.60	0.59	0.61	0.66	mm
	CV	36	35	36	33	%
HP Product Run-off	Colour	1100	1100	900	1400	ICUMSA
	Pol	98.3	98.3	98.5	98.1	%
	Invert	n/a	0.5	n/a	0.6	%
LP Product Run-off	Colour	1200	1000	1000	1500	ICUMSA
	Pol	98.2	98.3	98.4	98.0	%
	Invert	0.5	0.5	0.6	0.4	%
Intermediate Sugar	Colour	150	180	180	270	ICUMSA
	Pol	99.6	99.8	99.8	99.7	%
Intermediate Sugar Melt	Colour	230	300	250	350	ICUMSA
HP Intermediate Run-off	Colour	3500	3500	3700	5900	ICUMSA
	Pol	94.3	95.3	94.6	94.0	%
LP Intermediate Run-off	Colour	3500	4000	3400	5900	ICUMSA
	Pol	94.3	94.8	95.0	93.3	%

Table 1 : Raw Weekly Average Data

Some of the anomalies are interesting in their own right but the purpose of this paper is to examine the performance of the boiling scheme.

Fundamentally, the product sugar is within specification although the CV is too broad : more work is required on tighten the control of the boilings. At this stage of development there is still too much manual intervention and not enough reliance on the SCADA system.

It must be remembered that the theoretical scheme has had to be adapted for the weekend shut-down. The cycle is as follows :

- commercial sugar [< 45 ICUMSA] is produced up to the last product pan;
- every effort is made to only hold intermediate melt liquor and high purity run-off during the break;
- after the weekend it is necessary to immediately boil one or two pans with the liquor in stock as this has deteriorated somewhat over the break [higher colour and invert]. All of the run-off from these pans is treated as low purity product run-off so goes to the intermediate pan. The amount of back-boiling is then slowly increased, depending on the quality of the HP run-off, so that the product scheme is stabilised within 24hours;

Colour

The performance of the carbonatation has been good with excellent colour removal so little PAC treatment has been needed. The result is that the clear liquor colours have been low, in fact low enough to trigger a PAC reduction programme. The effect of this can start to be seen in the raw data from week 4.

Despite the low liquor colours, the 28 ICUMSA product colour predicted in the model has not yet been achieved with high feed colours. In part that is because there is no need to achieve that colour for the target market so crystal washing has been reduced accordingly and in part the higher colour pans at the start of the week distort the figures.

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 four weeks examined are presented in Table 2 together with the figures from the model :

	Model	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Mean Feed Colour	650	515	550	459	671
Product Colour	28	39	37	38	37
Colour Elimination Factor	**23.2**	**13.2**	**14.9**	**12.1**	**18.1**

Table 2 : Colour Reduction across Product Boilings

It is interesting to note the increased colour elimination factor with the higher general colours of week 4. It remains to be seen whether that is a permanent effect or an aberration within the data.

The calculated colour elimination factors are plotted against feed liquor colour in Figure 3 :

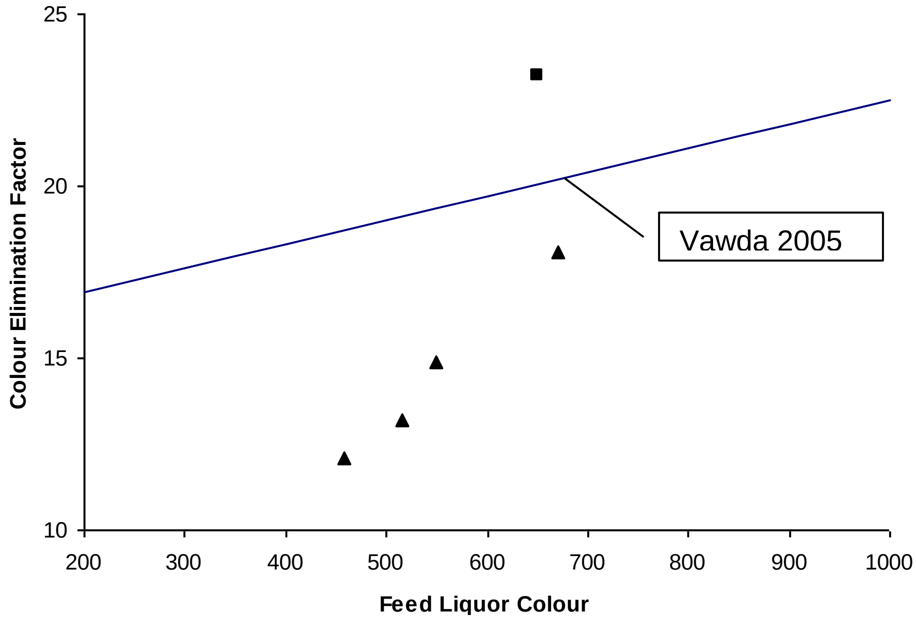

Figure 3 : Colour Elimination Factor v Feed Liquor Colour

The square is the value from the model and the triangles are the various live results. It is tempting to draw a trend line through the results but with such little data that would probably be misleading. The 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 :

Colour Elimination Factor = 15,5 + 0.007 * Feed 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 four weeks examined are presented in Table 3 together with the figures from the model :

	Model	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Mean Feed Colour	2644	1657	1494	1533	2367
Product Colour	192	150	150	180	270
Colour Elimination Factor	**13.8**	**11.0**	**10.0**	**8.5**	**8.8**

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.

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%.

We hope to present accurate sucrose yield data for this boiling scheme at a future SIT meeting.

Overall Performance

The overall performance of the refinery in its first year has been reasonable 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%.

Sugar losses in more detail are as follows as % on raw sugar :

Sugar Losses in Molasses	1,79
Sugar Losses in Mud	0,53
Undetermined Losses	0,66
Total Losses	**2,98**

Conclusions

The refinery has run reasonably well in its first full year of operation and is slowly climbing to the design performance figures as the operating team gain experience and the inevitable bottlenecks are ironed out over time.

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. Combined with modern batch centrifugals using run-off segregation, it is an efficient and robust system.

The next stage of this work, in parallel with continuing to improve the overall refinery performance, is to develop a rigorous methodology for measuring the performance of the station : no easy task given the complex nature of the pan feed.

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