CLEAR JUICE TURBIDITY MONITORING FOR SUGAR QUALITY

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Abstract

A considerable amount of South African raw sugar is sold to export markets. Consistently good filterability of this sugar is important for satisfying the requirements of customers. To the refiner, the filterability of raw melt is important as this affects refinery throughput. Analysis of filtration-impeding impurities in raw sugar has shown that, among other things, poor juice clarification could be related to poor filtering sugars. To this end, a South African Sugar Association sponsored investigation into sources of high turbidity in clarified juices and their relation to poor filtering sugars was begun.

Results from the 2002 season show that both process variables and cane quality were causes of high juice turbidities. In particular, flow disturbances, poor pH control, and poor and frequent start-up and shutdown incidents were major process variable contributors to poor turbidities. Some of the worst start-up and shutdown incidents would have resulted in carryover. Poor cane quality consistently resulted in high juice turbidity. While cane quality is largely a field issue, evidence suggests that slowing down of the factory does improve juice turbidity. This strategy would be particularly beneficial when employed to minimise the frequency of the shutdown and start-up often associated with poor cane supply. It is planned to correlate juice turbidity to sugar filterability and to relate these to various aspects of cane quality. Filterability of raw sugar is generally only measured at the Sugar Terminal and then only on composited samples. More frequent measurements are needed for process monitoring and, to this end, filterability test equipment is being manufactured for use at mills.

Keywords: cane quality, clarification, turbidity, suspended solids, sugar quality, filterability

Introduction

An increasingly competitive global market has resulted in a need for the South African sugar industry to refocus on sugar quality, especially the filtering quality of raw sugar.

Considerable work has been done in South Africa to address this issue of sugar quality. Some of the work that has been done includes an industry wide survey of flash tank capacity (Naidoo, 2000) and an investigation of a wide range of fundamentals of mixed juice clarification (Sahadeo, 2001). Other work included clarifier modelling to improve clarifier design.

Simpson (1999), Simpson and Davis (1998) and Lionnet and Ramsumer (2002) studied filtration problems in raw sugar. They found that one of the main reasons for the problems was suspended solids and turbidity, a conclusion supported by Donovan and Lee (Donovan and Lee, 1994; Lee and Donovan, 1995) in their work on sugars from various sources around the world. These findings suggested that poor juice clarification could be the primary source of the problem.

To this end, an investigation funded by the South African Sugar Association, was initiated to assist the mills in identifying incidents of high clear juice turbidities and carryover of suspended solids, and to link these to causes. This paper presents the findings from the work that was done in the 2002 season.

Methodology

It was decided to select a few mills that would be representative of the South African sugar industry. Three mills were selected; two diffuser mills (Eston and Maidstone mills) and the third (Noodsberg mill) was a milling tandem. Other mills made various smaller contributions of their experiences at some time during the season.

Turbidity of clear juice was measured and logged together with key clarification process data. Logging of data was done using the factories' control and database systems. In one case where this was not possible, the Sugar Milling Research Institute (SMRI) data logger was installed to capture the data. Logging was done at one minute time intervals to help distinguish accurately cause and effect. Other data which were not available electronically were extracted from process daily log sheets. Additionally, input from factory personnel was sought and specifically a record book was used by factory staff to comment on high juice turbidities and possible causes.

Juice turbidity measurement in these factories is done using on-line turbidity meters designed by the SMRI to detect mud break-throughs in clear juice. The SMRI turbidity meter measures optical absorbance of a juice stream, in this case clear juice. The measurements are expressed in absorbance units and the scale for clear juice is zero to two units. A good clear juice should have an absorbance well below one unit. As the juice becomes more turbid, its optical absorbance increases. Absorbance closer to two units indicates carryover of suspended solids. Zero is the reference turbidity which is established by calibration with clean water. The instruments have a self-calibration feature to zero them regularly to compensate for cell fouling.

Of the three factories surveyed, Maidstone and Eston use the older version instrument with a red light source at 640 nm wavelength, whereas Noodsberg uses the latest version instrument with an infrared light source at a wavelength of 880 nm. There would be a slight interference from juice colour with the lower wavelength units (640 nm), but in the worst case this is expected to be no more than 10%. The signal from the 880 nm meters should be practically independent of colour ([1]personal communication). Older version instruments also need routine cleaning of the cell, whereas newer versions are self-cleaning.

Baseline turbidity was established when good quality cane was being processed and process conditions were stable, which is typically early on in the season. Logging began about June 2002, with the intention of continuing through the season so that seasonal changes could be captured. Data were retrieved periodically for in-depth analysis, when deviations from the baseline were noted and causes investigated. Problems with data logging and storage and computer failures left some gaps in the data. However, it is believed that a representative scenario was obtained.

Results

The base case

Early season data suggests that the baseline for Eston mill was between 0.30 to 0.35 units and for Noodsberg mill was 0.34 to 0.49 units. Both mills considered 0.50 as the upper limit for turbidity, above which causes were investigated and logged.

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Although Maidstone did not normally use turbidity meter data directly for control, this was logged as with the other mills. Juice quality was inspected routinely, especially when throughput was being increased. Throughput was increased gradually, especially closer to design capacity and if carryover was experienced, throughput would be reduced to the previous level. Turbidity data showed that the Maidstone baseline was between 0.21 and 0.34 absorbance units.

Flow control

As expected, large flow disturbances caused surges in juice turbidity. The disturbances in flow appear to have been from forced changes as opposed to routine setpoint changes. Figure 1 shows an example of juice flow, with a sudden loss in flow. There were a number of these incidents, which were more frequent towards the end of the season. The typical impact to juice turbidity is illustrated in Figure 2, which shows turbidity rise to about one unit.

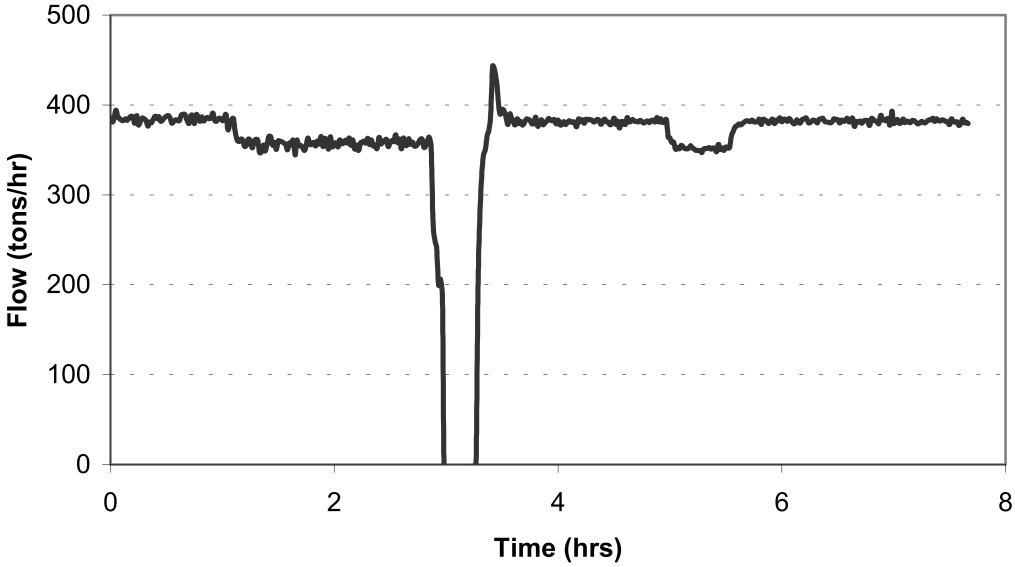

Figure 1. Trend in juice flow, showing a typical flow loss.

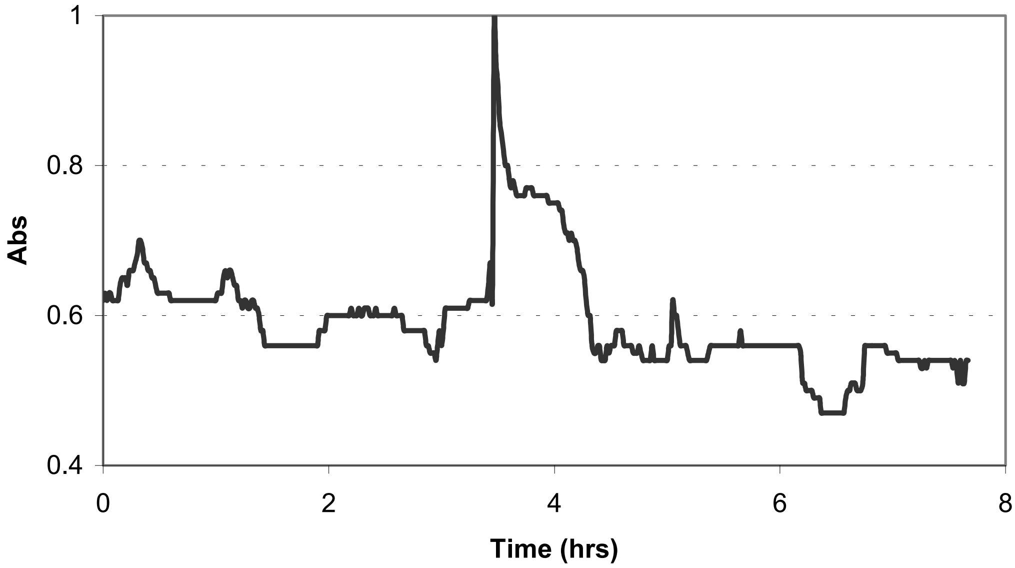

Figure 2. Trend in juice turbidity, showing the effect of juice flow upset.

There were also reports from other mills that operate more than one clarifier in parallel, of selective carryover, which indicates possible maldistribution.

pH control

Overliming of mixed juice was also found to cause high juice turbidity. Analysis of these incidents showed that high juice turbidity would last at least 20 minutes, and in most cases turbidity persisted for nearly three hours. Causes of poor pH control were reportedly pH probe failure, poor lime quality, lime preparation problems and lime dosing pump problems. Typical incidents are illustrated in Figures 3 and 4. Figure 3 shows the limed juice pH deviation incidents, while Figure 4 shows the resulting juice turbidity.

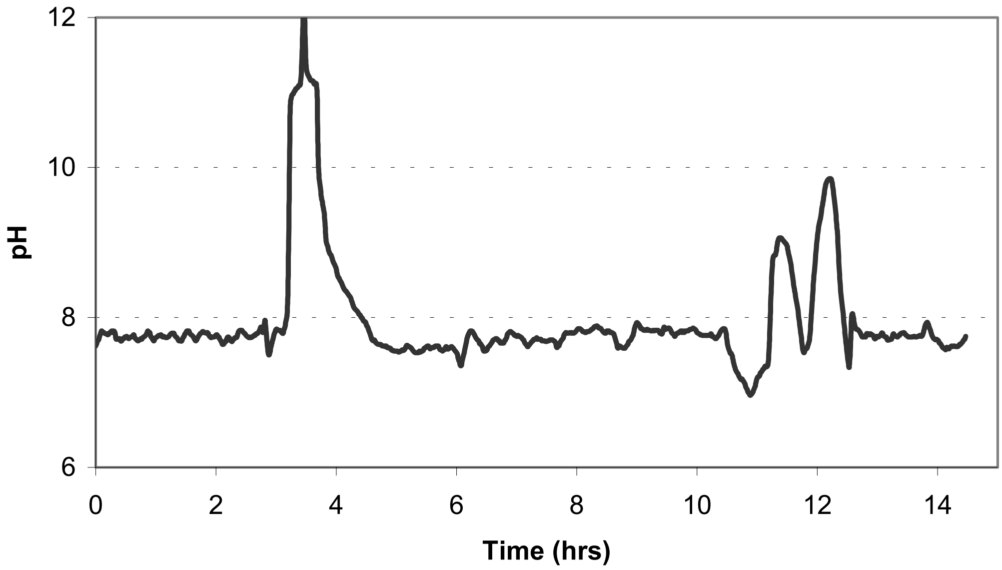

Figure 3. Trend in limed juice pH, showing pH upsets.

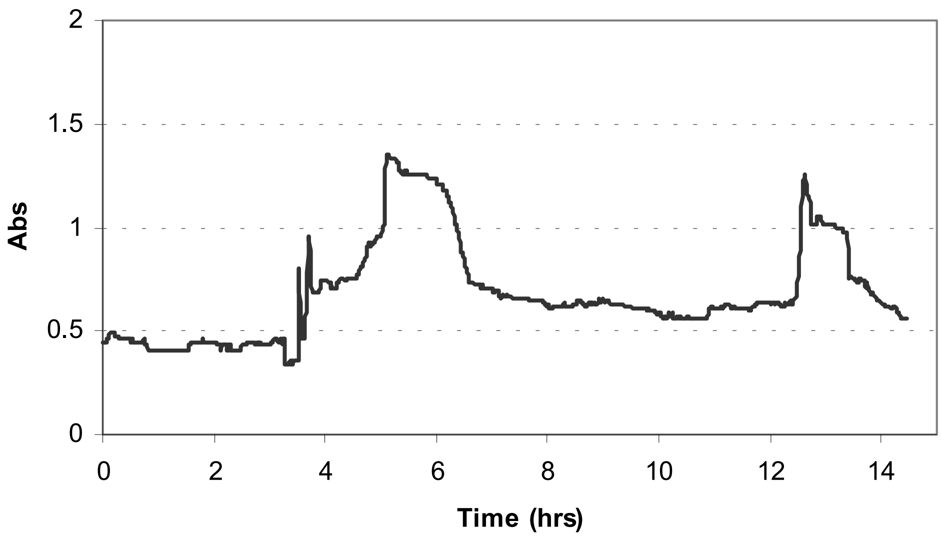

Figure 4. Trend in juice turbidity, showing the effects of high pH.

Start-up and shutdown

Start-up and shutdown were identified as other areas that had an impact on juice quality. As can be expected, the unsteady conditions at start-up will often result in peaks in juice turbidity. It was nevertheless found that juice turbidity start-up profiles varied widely. In particular, juice turbidity would at times rise close to two units during a start-up, and this would persist for hours. This level of turbidity indicates possible carryover. Figure 5 highlights this observation.

As would be expected, the frequency of start-up and shutdown increased towards the end of the season.

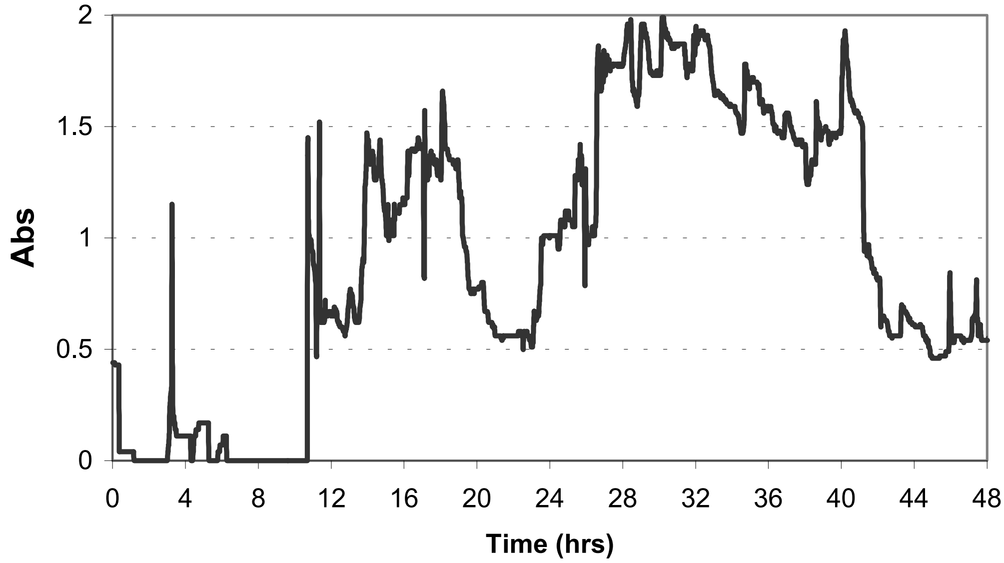

Figure 5. Trend in juice turbidity, showing the effect of start-up.

Cane quality/effect of rainfall

The measurement of clear juice turbidity seemed to track the impact of cane quality changes reasonably well. The effect of cane quality on juice turbidity was observed by comparing data from the period before the rains to data shortly after the rains, excluding changes due to process variables. At all three mills data showed a marked rise in average juice turbidity. When June and July data were analysed in this way, it was found that the average juice turbidity rose by about 50% at Maidstone, 25-45% at Eston and about 65% at Noodsberg following the rains. This effect is probably due to a combination of increased loading of the clarifier with colloids from wet soil adhering to the cane, interference with flocculation caused by deterioration products in the cane and unsteady operation due to intermittent cane supply.

Overall, juice turbidity was more variable when poor cane was being processed. Furthermore, disturbances in process variables during this time had an even more marked effect on juice turbidity.

Juice turbidity optimisation

When analysing data from Maidstone mill, it was found that, when juice throughput was reduced, juice turbidity improved. Data from July showed a benefit of about 42% in average juice turbidity for an approximately 38% reduction in throughput. Figure 6 shows juice turbidity against juice flow, with an improved juice turbidity as throughput is lowered.

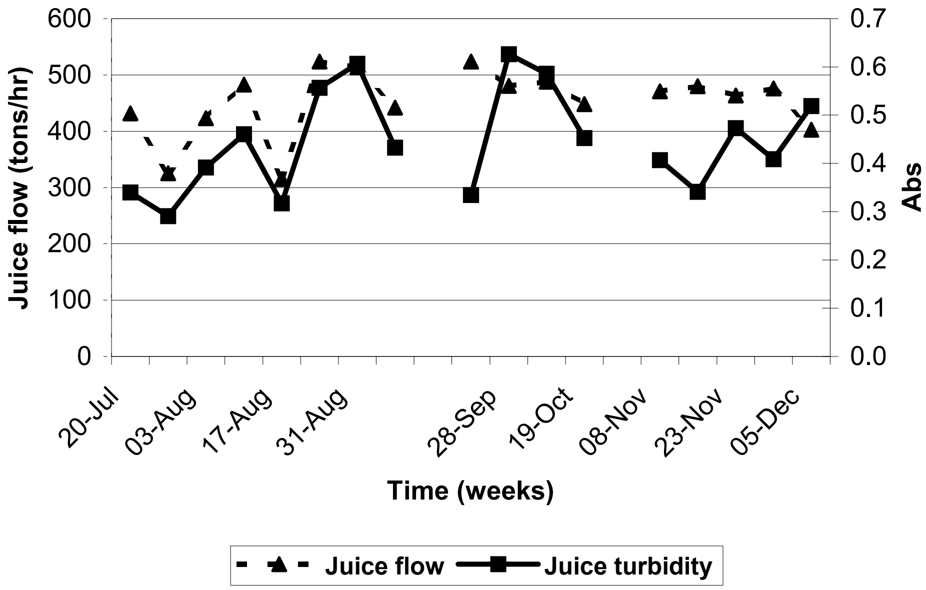

Figure 6. Trend in juice flow against turbidity at Maidstone in the 2002 season.

Phosphate control

It is difficult to measure the influence of this variable on juice turbidity because it is controlled manually. But it is understood that mills still experience problems with accurate analysis of available phosphates in juice and the level of phosphates required for good clarification. This would have led to a situation where dosing of additional phosphates was sub-optimal.

Mud level control

Vigilance around mud level control was very high. The different mechanisms being employed to regulate mud level in clarifiers seemed satisfactory. The few incidents of high mud levels related to operational problems in the mud filter station. As would be expected, these incidents caused mud carryovers, as mud levels in the clarifier increased. The incidents were quickly brought under control.

Temperature control

The minimum pre-flash temperature was not always kept due to normal variations in mixed juice temperature. The impact of this cannot be measured directly from data since the turbidity meters often cannot detect bagacillo carryovers if they are not visible to the naked eye.

Composition of components causing turbidity and poor filterability

Lionnet and Ramsumer (2002) reported on the comparison between poor turbidity juice and poor filtering sugar. The suspended matter from a poor filtering raw sugar and sludge from poor turbidity clear juice were analysed by X-ray fluorescence. The results showed that suspended solids in the poor filtering sugar were chemically similar to the turbidity causing material filtered from the turbid clear juice, which in turn has a composition similar to clay i.e. high amounts of aluminium and silica. Table 1 gives an analysis of the inorganic fraction in the sludges.

Table 1. Analysis of ashed sludges from clear juice and from raw sugar.

Component (% m/m)	Clear juice	Poor filtering sugar
Silica as SiO_2	20.8	50.8
Aluminium as Al_2O_3	13.0	14.2
Magnesium as MgO	2.4	1.6
Calcium as CaO	43.4	13.4
Phosphorous as P_2O_5	10.4	9.8
Iron as Fe_2O_3	7.1	7.8
Total	97.1	97.6

Discussion

Turbidity measurement can be used with a high degree of confidence to measure the efficiency of clarification and to identify incidents of carryover. Targets for juice turbidity set by the mills were found to be effective in commanding a response from the operating staff. Problems began when poor cane was being processed, since the target limits were no longer realistic, being sometimes lower than the average prevailing turbidity. Under these conditions factory staff lose control of turbidity.

The troubleshooting of high turbidities needs improvement. For instance, there were a number of cases where the factories attributed high juice turbidities to bagacillo carryovers. The corresponding temperature data did not support this. Moreover, bagacillo carryovers are often not detectable by the naked eye, nor can they be detected by turbidity meters. The inferences to bagacillo carryover causing high turbidity are unlikely to have been correct. There was at least one genuine case where a high amount of bagacillo was found in sugar and positively identified as originating from juice carryover. This incidence raised questions about control of pre-flash temperature. The minimum operating pre-flash temperature has often been set at the absolute minimum. Operating limits should be set slightly higher to allow for the typical variations in juice temperature and prevent it from dropping below the critical level.

The considerable recycling which takes place in a sugar factory prevents close linkage between a short term turbidity excursion and the filterability of the resulting sugar. The short term excursions affect a considerable amount of sugar to a small extent. The longer term high juice turbidity associated with rainy periods is generally reflected as a distinct lowering of filterability of all the sugar produced.

It is well known that available phosphates in juice have an important bearing on clarification efficiency.

Insufficient phosphates lead to poor clarification. The analysis of available phosphates continues to be a problem in the mills. This leads to poor control of phosphates in juice. As a guide, when there is uncertainty about the accuracy of phosphate levels in juice, a batch-settling test with varying phosphate levels can be performed, and the dosage level that gives the acceptable juice turbidity can be used in the factory. However, this will need to be done regularly, as phosphates in juice vary with cane quality.

While it is understandable that conditions at start-up and shutdown are not steady, wide variations in the start-up profiles show a need for better control. Frequent start-ups and shutdowns are also not good for juice quality. This is particularly important to note since during the rainy periods there are usually frequent start-ups and shutdowns. Cane quality being poor during this time, the impact on juice quality can be very bad and the potential for carryover is high.

Although the impact of cane quality on juice turbidity was noted, there are limited options to deal with it, other than perhaps slowing down. The strategy of slowing down to control juice quality appears to have been beneficial for the Maidstone mill. The highest benefits were obtained at the end of season when poor quality cane was being processed. This approach should also reduce the incidents of start-up and shutdown, which have been shown to be detrimental to juice quality. This strategy of slowing down seems to be an accepted practice in some sugar industries abroad ([2]personal communication), and needs to be investigated by other factories, as it will result in smoother operations.

There would, however, be limits to how far a factory could slow down before losses become unacceptable. Apart from throughput, purity losses would also be a constraint. Bearing this in mind, the efforts to improve cane quality, and investigations into new technologies to improve sugar quality, should be sustained.

Conclusions and Recommendations

- On-line turbidity measurement shows that there is a need for continuous monitoring of clear juice quality, as it is highly variable.
- The process control problems need to be addressed. This is expected to minimise sporadic poor juice quality problems.
- Poor cane quality consistently resulted in high juice turbidity. While cane quality is largely a field issue, evidence suggests that slowing down of the factory does improve juice turbidity. This strategy would be particularly beneficial when employed to minimise the frequency of shutdown and start-up often associated with poor cane supply. However, it is expected that, in the long term, new technologies would have to be employed to sustain and improve sugar quality.
- It is planned to correlate juice turbidity to sugar filterability, and to relate these to various aspects of cane quality. Filterability of raw sugar is generally only measured at the Sugar Terminal and only on composited samples. More frequent measurements are needed for process monitoring and, to this end, filterability test equipment is being manufactured for use at mills.

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[2] Simon Bower and Max Polzin

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