Ejector sulphitation of juice and syrup at a cane-sugar factory

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Abstract Sulphitation has been widely used in India, China and other countries to produce direct white crystal sugar. The conventional sulphitation system uses a sulphur melter, receiver, tray-type sulphur burner, cooler, scrubber, air compressor/blower and a reaction tank with a stirrer. In this system, sulphur is burnt in a burner to produce sulphur dioxide that is bubbled through juice or syrup in the reaction tank for 8 minutes. For a 6,000 tonnes of cane per day (tcd) factory, this system uses 2 t of steam at 500-700 kPa gauge pressure, 105 kW power and occupies 200 m² of floor area. After consideration of different available sulphitation systems, such as the film-type burner, the sulphitation tower and the rotary furnace with an ejector, it was decided to proceed with the ejector sulphitation system. This is of a more compact design, needs no steam and uses lower power, thus being more energy efficient. This system that was installed and improved at our factory has a rotary sulphur burner that uses induced draft air, thus eliminating the air blower and air compressor. As sulphur melts by its own heat of combustion, there is no need for medium pressure steam. The sulphur dioxide reacts with juice/syrup in the ejector, eliminating the large reaction tank. This system uses no steam and 30 kW of power and occupies 90 m² of floor area for a 6,000 tcd factory.

Key words Sulphitation, design, energy, efficiency, costs

INTRODUCTION

Sulphitation is extensively dealt with in literature. It was investigated in 1865 in Mauritius (Maxwell 1916) and was used at a cane sugar factory from the mid-1930s (Spencer and Meade 1945). It is now widely used at cane sugar plants in Brazil, India, China and other countries.

In the cane sugar manufacturing process, juice from the extraction station is sent to the clarification station where it is subjected to liming, sulphitation, heating and settling. The sulphitation process (Getaz and Bachan 1989) produces a clear juice by removing dissolved impurities, thus reducing color and turbidity. Losses due to inversion during heating and sulphiting are controlled by adding lime after heating and then sulphiting. The pH is adjusted to a set point and the juice heated again; it is then sent to the clarification station. This method has other advantages like the provision of additional calcium ions to maximize precipitation of sulphites and phosphates as calcium salts, reducing scaling of the juice heaters. A final pH adjustment of the juice, after sulphitation is extremely important to obtain a better quality clear juice that facilitates production of high quality sugar.

CONVENTIONAL SULPHITATION SYSTEM

In the conventional sulphur system sulphur is melted in a melting tank using steam. The molten sulphur then goes into a melt supply tank from where it is supplied continuously to the sulphur burner to produce sulphur dioxide gas. Air required for the combustion of sulphur is supplied by an air blower. Sulphur dioxide is bubbled through juice in a reaction tank for about eight minutes. A 6000 tonnes of cane per day (tcd) sugar plant requires 105 kW power, 2 t/h steam at 700 kPa and 200 m² of floor area. Figure 1 is a schematic diagram of a conventional system. The juice flow is shown in Figure 2; both figures are based on what is being used at our Unit 3 plant.

To improve our sulphitation system some of the available sulphitation systems we considered were the film-type burner, sulphitation towers and a rotary furnace with an ejector. It was decided to try the ejector sulphitation system which is ecofriendly, is of a compact design, requires no steam, and has a low power consumption. Equipment to sulphite the juice using an ejector system was installed at our sugar Unit 3 and tests and modifications were carried out. The results presented here are all based on the working of the optimized equipment and layout which has been in use at our Unit 3 for the past few seasons.
**Fig. 1.** A conventional sulphitation system.

**Fig. 2.** Flow diagram of the conventional juice sulphitation process.
OPERATION OF THE EJECTOR SULPHITATION SYSTEM

Sulphur furnace

Combustion air enters the rotary sulphur furnace by means of an induced draft caused by the juice ejectors. Sulphur melts by its own heat of combustion in a rotary cylinder, presenting a large surface for combustion as the interior surface of the furnace is wetted by molten sulphur. Air is drawn in through an adjustable neck ring and an anti-sublimation sleeve that is installed at the connection between the rotary furnace and the combustion chamber. A brick-lined compartment with baffles is used to continue sulphur oxidation and mixing with diluting air that is conducted to the cooling system. Gaseous SO$_2$ free of sulphuric acid is delivered to the sulphitation apparatus gas inlet through a sublimation chamber and a cooling system. The furnace temperature is about 320 to 350°C. After the cooler, the gas temperature drops to around 70°C.

Juice flow control

It is very important to maintain a good juice flow control. A steady flow of juice (Getaz and Bachan 1989) provides significant benefits for the downstream processes of pH control, juice heating (temperature control), flow control to the sulphitation ejector and speed of the screw feeder to the rotary furnace. Good performance of the sulphitation system depends on the steady flow of juice as sudden variations in feed rate disrupt the juice flow of the sulphitation system. Short-term variations of more than 5% per minute must be eliminated.

To achieve a juice flow control the essential components are:
- a buffer tank with a capacity to store 8-10 minutes of juice;
- a level transmitter fitted to the buffer tank;
- a flow controller;
- a juice pump fitted with a variable frequency drive; and
- a flow meter to monitor the juice flow.

Ejector

The ejector is a sulphitation apparatus for SO$_2$ aspiration and for mixing the gas with the juice. The juice pump produces a draft, thus sucking all of the SO$_2$ gas into the ejector. The ejector is designed with 11 nozzles, on the usual principle of an ejector and produces an aspiration of the SO$_2$ gas. Sulphitation takes place by contact and mixing in the vertical column, directing the juice/syrup to the seal tank. The nitrogen and oxygen accompanying the SO$_2$ are vented to the atmosphere by a vent pipe at the top of the seal tank. The ejector requires juice/syrup at a low pressure of around 140 kPa absolute. There are no moving parts, thus reducing maintenance. Operating experience at our Unit 3 has shown that the plant is simple, easy to operate, requires less area and has a low installation cost. General layouts of the ejector sulphitation system are shown in Figures 3 and 4.
PERFORMANCE OF THE EJECTOR SULPHITATION SYSTEM WITH JUICE

The system as installed at our Unit 3 was investigated and a number of analyses done to measure and improve its performance. The work done with juice sulphitation, described schematically in Figure 4, is discussed. Tests were done to investigate pH, colour and turbidity in draft, treated and clear juices; in addition to sugar colours that were obtained. Figures 5 and 6 show the results obtained from these tests.
The pH values shown in Figure 5 for the shock liming (draft juice treated with lime saccharate to pH 9.0 ± 0.2 for 8-10 s), clear juice and the juice after sulphitation are remarkably steady at the required values - these need to be determined under actual operating conditions (Honig 1953).

The results indicate a very steady, controlled performance of the plant, a requirement for optimum operation (Moodley et al. 1997).

Figure 6 shows that the clear juice colours follow those of the draft juice but with lower values; on average a relatively steady decolourisation of 26% (min: 19, max: 34) was achieved. Final sugar colours were low and steady, averaging 47 IU (min: 42, max: 52).

The process lowered average turbidity at 420 nm from 19,925 in draft juice to 1,680 in clear juice with a 0.051 sulphur % cane. A 91% removal of turbidity was achieved.

These results are compared to those obtained by the conventional sulphitation system, used previously at Unit 3, in Table 1 showing clearly that the ejector system results in better colours, particularly for sugar (19% decolourisation) and turbidity removals, while using approximately the same amount of sulphur.
**Table 1.** Comparison of the data for juice sulphitation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional system</th>
<th>Ejector system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft juice pH</td>
<td>5.71</td>
<td>5.61</td>
</tr>
<tr>
<td>Shock liming pH</td>
<td>8.89</td>
<td>9.24</td>
</tr>
<tr>
<td>Final pH</td>
<td>7.13</td>
<td>7.21</td>
</tr>
<tr>
<td>Clear juice pH</td>
<td>7.05</td>
<td>6.99</td>
</tr>
<tr>
<td>Clear juice transmittance % @ 560nm</td>
<td>41.0</td>
<td>45.3</td>
</tr>
<tr>
<td>Color reduction % @ 420 nm (from draft juice to clear juice)</td>
<td>22.7</td>
<td>26.4</td>
</tr>
<tr>
<td>Turbidity reduction % @ 420 nm (from draft juice to clear juice)</td>
<td>90.1</td>
<td>91.6</td>
</tr>
<tr>
<td>Sulphur consumption % on cane</td>
<td>0.052</td>
<td>0.051</td>
</tr>
<tr>
<td>Sugar color (ICUMSA GS2 / 3-10 method)</td>
<td>58</td>
<td>47</td>
</tr>
</tbody>
</table>

**PERFORMANCES OF THE EJECTOR SULPHITATION SYSTEM WITH SYRUP**

After installing the ejector system equipment for juice sulphitation, testing and optimising it and using it satisfactorily for one season the results and other relevant information were sent to the technology supplier to be used for designing an ejector system with syrup. This equipment was built in-house at our workshop, installed and optimised following the procedures used with juice.

All fabrication drawings and equipment for both juice and syrup sulphitation were developed and built in-house, based on information supplied by the technology supplier.

All the results given in this paper were obtained during normal operation with the optimised equipment at our Unit 3. We are the only factory using the ejector system with syrup.

The system shown in Figure 7 was tested with syrup (Getaz and Bachan 1989) at our Unit 3. Tests were carried out following an approach similar to that used with juice. The results are shown in Figures 8 and 9.

![Fig. 7. Ejector sulphitation system with syrup.](image-url)
The sulphitation process decreased the clarified syrup pH from an average of 5.9 to 4.5 in the sulphited syrup which then goes to the pan floor. Again the pH trends are very steady. There is some variation in the syrup colours but the range is narrow. The sulphitation process decreased the colour from an average of 14,869 to 13,770 IU, a decolourisation of 7%. In total, sulphitation resulted in a decolourisation of 33%; this value fits into the range of 30-40% given by Getaz and Bachan (1989). The sugar colours are within the range required; the color transfers (sugar colour divided by sulphited syrup colour) are very low. A low transfer is expected with sulphitation, but the very low values achieved here indicate that the colour bodies present in the syrup have a very small affinity for the crystal (Lionnet 1990).

The sulphitation process lowered average turbidity at 420 nm from 1446 to 1290 with a 0.024 sulphur % cane. A 91% removal of turbidity was achieved in total.
The results are compared in Table 2 to those obtained by the conventional system previously used at Unit 3. The results in Table 2 follow similar trends to those found with juice, except that the syrup pH values are lower than in the conventional system.

Table 2. Comparison of the data with syrup sulphitation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional system</th>
<th>Ejector system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear syrup pH</td>
<td>6.15</td>
<td>5.88</td>
</tr>
<tr>
<td>Sulphited syrup pH</td>
<td>4.89</td>
<td>4.52</td>
</tr>
<tr>
<td>Recirculation Syrup flow (m³/h)</td>
<td>-</td>
<td>98</td>
</tr>
<tr>
<td>Color reduction % @ 420 nm (clarified syrup to sulphited syrup)</td>
<td>5.7</td>
<td>7.4</td>
</tr>
<tr>
<td>Turbidity reduction % @ 420 nm (clarified syrup to sulphited syrup)</td>
<td>8.3</td>
<td>10.8</td>
</tr>
<tr>
<td>Sulphur consumption % on cane</td>
<td>0.027</td>
<td>0.024</td>
</tr>
<tr>
<td>Sugar color (GS2 / 3-10 method)</td>
<td>58</td>
<td>47</td>
</tr>
</tbody>
</table>

ADVANTAGES OF THE EJECTOR SYSTEM

With this system 2 t/h of steam, 75 kW and 110 m² of floor area are saved. At a 6000 tcd plant operating for 180 days there would be a saving of US$100,000 in operating and maintenance costs. This system offers a clean and healthy environment as it is operated under sub-atmospheric pressure. Operating this compact system is simple.

Apart from an improvement in sugar color, other advantages found with the ejector sulphitation process at our Unit 3 were:

- Rapid mud settling resulting in improved capacity of the clarifiers.
- Less viscous massecuites which boiled faster, resulting in a reduced final molasses loss.
- A gain in the capacity of the centrifugals.

Proper designing of the heat exchangers minimized fouling of the heating surface in heaters and evaporators by maintaining the required juice velocity to enhance the heat transfer (Getaz and Bachan 1989). Using direct contact heaters wherever possible may be considered without affecting the steam economy. Direct contact heaters eliminate the need for cleaning. Scaling in the evaporators can be mitigated by providing the required quantity of juice per tube in Robert evaporators and by providing proper wetting factors in falling-film evaporators.

At our Unit 3 where the ejector system is in use, a partition plate has been installed in the Robert evaporators to maintain the required juice volume per tube to achieve the required wetting factors in all the effects. The evaporators are operating without any problem.

In a conventional sulphitation system juice and syrup are sulphited for about eight minutes in a sulphitor. In the ejector sulphitation system juice and syrup are sulphited for a few seconds in the ejector.

The quality of the direct white plantation sugar produced using sulphitation was investigated extensively from 2001 to 2007. Samples were sent to recognized laboratories in Australia, Germany and India to be analysed according to industrial specifications.

All the results, including conventional ones such as pol, colour, ash and species such as Cl⁻, Ca++, SO₄²⁻, were compliant; so were those concerning microbiological parameters. Serious contaminants, such as SO₂ (Moodley et al. 1997) and heavy metals, were either well below the limits or were at undetectable levels.

CONCLUSIONS

Sulphur burners working under sub atmospheric pressure have the advantages of the absence of leaks, better regulation of feed, efficient control of combustion and lower power consumption.

The rotary furnace with an ejector does not require a separate reaction tank along with its auxiliaries. The ejector sulphitation system is more conducive to automatic pH control.

There seems to be an apprehension in the cane sugar industry that the use of sulphitation results in residual SO₂ in the sugar. The numerous certified analyses done of our sugar show that this is certainly not the case.
All the equipment used in the manufacture of raw sugar is the same as in the manufacture of direct white plantation sugar, except for the ejector sulphitation system. The colour of the raw sugar is normally around 800 to 1000 IU, while with the sulphitation system 40 to 50 IU color sugar is being produced.

Apart from lower sugar colour, the sulphitation sugar produced at our plant clearly met USP, EC-2 and Pepsico specifications.

Sulphitation could surely be considered to produce low colour sugar at a raw sugar plant.

ACKNOWLEDGEMENTS

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REFERENCES


Sulfitation du jus et du sirop par éjecteur dans une sucrerie de canne

Résumé. La sulfitation est employée couramment en Inde, Chine et autres pays pour produire du sucre blanc directement. Le système conventionnel de sulfitation utilise un récepteur, un brûleur de soufre du type plateau, un refroidisseur, un laveur de gaz, une soufflerie / compresseur d’air et un bac de réaction avec un agitateur. Dans ce système, le soufre est brûlé dans le brûleur pour produire du dioxyde de soufre qui est distribué dans le jus ou sirop dans le bac de réaction pendant 8 minutes. Pour 6 000 tonnes de canne par jour (tcd), ce système utilise 2 t de vapeur à 500-700 kPa de pression manométrique, 105 kW de puissance et occupe 200 m² de surface. Après l’examen de différents systèmes de sulfitation, tels que le brûleur type film, la tour de sulfitation et le four rotatif avec un éjecteur, il a été décidé d’utiliser la sulfitation avec éjecteurs. C’est un design plus compact, ne nécessitant pas de vapeur et très économique en énergie. Ce système qui a été installé et amélioré dans notre usine possède un brûleur de soufre rotatif qui utilise un tirage aspiré éliminant ainsi le ventilateur et le compresseur d’air. Comme le soufre fond par sa propre chaleur de combustion, il n’y a aucun besoin de vapeur. Le dioxyde de soufre réagit avec le jus ou sirop dans l’éjecteur, éliminant ainsi le bac de réaction. Ce système n’utilise pas de vapeur, se sert de 30 kW de puissance et occupe 90 m² de surface pour une usine de 6 000 tcd.

Mots clés: sulfitation, coûts, efficacité, énergie, conception

Sulfitación por eyector de jugos y siropes de una fábrica de azúcar

Resumen. La sulfitación ha sido empleada ampliamente en India, China y otros países para producir azúcar blanco directo cristalino. El sistema convencional de sulfitación emplea un fundidor de azufre, un receptor, un quemador de azufre de tipo de bandeja, un enfriador, un depurador, compresor/soplador de aire y un tanque de reacción agitado. En el sistema el azufre se combina para producir dióxido de azufre, que se burbujea a través del jugo o el sirope en un tanque de reacción por 8 minutos. Para una fábrica de capacidad de 6000 t de caña por día, este sistema emplea 2 t de vapor de 500-700 kPa manométrica de presión, 105 kW de potencia y ocupa 200 m² de área. Después de considerar varios sistemas de sulfitación disponibles, tales como el quemador de película, la torre de sulfitación y el horno rotatorio con un eyector, se decidió proceder con el sistema de eyector sulfurador. Es de un diseño más compacto, no requiere vapor y emplea menor potencia, por lo que es más eficiente energéticamente. Este sistema que fue instalado y perfeccionado en nuestra fábrica, emplea un quemador de azufre que emplea una corriente de aire inducida, por lo que elimina el soplador y compresor de aire. Como el azufre se funde por su propio calor de combustión, no se requiere vapor de presión media. El óxido de azufre reacciona con el jugo/sirope en el eyector, eliminando el voluminoso tanque de reacción. Este sistema no emplea vapor y 30 kW de energía y ocupa un área de 90 m² para un fábrica de 6000 t de caña por día.

Palabras clave: Sulfitación, diseño, energía, eficiencia, costos