CHAPTER 3
Calculations

1. General

Quantitative measurements of the products entering and leaving the factory are required for the purpose of factory control, whilst those relating to cane, mixed juice, final bagasse and where applicable press water mud, are also required for cane payment.

2. Rules for rounding off

Wherever a decimal place to be discarded is represented by a number less than five, the preceding digit (that is the last to be recorded) shall remain as it stands; but where the number to be discarded is greater than five, one shall be added to the preceding digit. Where the number to be discarded is exactly five, the preceding digit shall be unaltered if it is an even number, but if it is an odd number one shall be added to it.

3. Cane payment requirements

3.1 Mill balance and direct analysis of cane

In the South African Sugar Industry cane is analysed in parallel at every factory by two methods:

(a) the mill balance which entails the determination of Brix, pol and fibre from the analysis of mixed juice and final bagasse and where applicable, diffuser press water muds and recycled clarifier muds, and

(b) the direct analysis of individual cane consignments for Brix, pol and fibre content.

These methods are independent of one another except that the final bagasse mass determination in the mill balance does depend on the quantity of fibre in cane as determined by Direct Analysis of Cane (DAC).

- See section 4 for standard methods of calculation.

3.2 Distribution of mill balance tonnages

The mill balance tonnages of pol, Brix and fibre are normally determined for a weekly period at a mill and the respective weekly tonnages are then distributed among the individual cane suppliers pro rata to their individual cane consignment tonnages of pol, Brix and fibre as determined by DAC. Distribution periods are set in terms of clause 142 of the Sugar Industry Agreement, 2000.

3.3 Factors for pol, Brix and fibre

The distribution of the mill balance tonnage is effected by determining a factor for the week, which in the case of pol is determined as follows:

$$\text{Factor (pol)} = \frac{\text{total tons pol for all cane by mill balance for week}}{\text{total tons pol for all cane by DAC for the week}}$$

The individual cane consignment tonnages of DAC pol are then multiplied by the factor to give the adjusted pol tonnages for each consignment; similarly for brix and fibre.

3.4 Conversion of adjusted pol tonnages to sucrose tonnages

Composite samples of mixed juice are collected over the week at each factory. These weekly samples are stored and transported under freeze preservation to the Sugar Milling Research Institute (SMRI) where they are analysed for pol and for sucrose by gas chromatography and the pol/sucrose ratio so determined is applied to the corresponding pol tonnage in mixed juice as determined at the mill, to convert it to sucrose (see 4.1.18). All individual consignment adjusted pol tonnages are converted to sucrose tonnages by correcting for the change from pol to sucrose in mixed juice.

3.5 Calculation of recoverable value % cane

Having determined individual consignment tonnages of sucrose, brix and fibre as shown above, the corresponding consignment percentages are readily calculated. For calculating recoverable value % cane, the sucrose % cane, non-sucrose % cane and fibre % cane are required and non-sucrose % cane is calculated as follows:

non-sucrose % cane = Brix % cane – sucrose % cane

Recoverable value % cane is then calculated according to 4.2.35 and tons recoverable value according to 4.2.36.

4. Standard methods of calculation

It is often possible to calculate certain primary data in more than one way. Due to small errors in the different primary data used, very small differences in the results obtained will be found. Hence it is necessary to standardise methods of calculation as far as possible. The recommended procedures are listed below but alternatives are sometimes imperative due to procedural differences in different factories. However for cane payment purposes the relevant procedures listed below shall apply.

4.1 Masses

4.1.1 Tons Brix in cane by mill balance

tons Brix in mixed juice + tons Brix in bagasse

Where press water clarifier mud is not returned to the mixed juice it is necessary to include tons Brix in press water mud in the above calculation, and where clarifier mud is returned to the diffuser, tons Brix must be subtracted in the above calculations.

4.1.2 Tons Brix in cane by DAC

$$\frac{\text{tons cane} \times \text{DAC Brix \% cane}}{100}$$

4.1.3 Tons pol in cane by mill balance

tons pol in mixed juice + tons pol in bagasse

Where press water clarifier mud is not returned to the mixed juice it is necessary to include tons pol in press water mud in the above calculation, and where clarifier mud is returned to the diffuser, tons pol must be subtracted in the above calculations.

4.1.4 Tons pol in cane by DAC

$$\frac{\text{tons cane} \times \text{DAC pol \% cane}}{100}$$

4.1.5 Tons fibre in cane

$$\frac{\text{tons cane} \times \text{DAC fibre \% cane}}{100}$$

4.1.6 Tons cane per hour

tons cane crushed divided by hours actual milling

4.1.7 Tons fibre per hour

tons fibre in bagasse divided by hours actual milling

4.1.8 Tons Bagasse

$$\frac{\text{Tons fibre in bagasse}}{\text{fibre \% bagasse}} \times 100$$

4.1.9 Tons Brix in bagasse

$$\frac{\text{tons bagasse} \times \text{arithmetic average of Brix \% bagasse analyses}}{100}$$

As accurate hourly bagasse mass data are not available, arithmetic averages of the analyses are used for calculating daily data; daily data are, however, combined on a weighted basis.

4.1.10 Tons pol in bagasse

$$\frac{\text{tons bagasse} \times \text{arithmetic average of pol \% bagasse analyses}}{100}$$

As accurate hourly bagasse mass data are not available, arithmetic averages of the analyses are used for calculating daily data; daily data are, however, combined on a weighted basis.

4.1.11 Tons moisture in bagasse

$$\frac{\text{Tons bagasse} \times \text{arithmetic average of moisture \% bagasse analyses}}{100}$$

As accurate hourly bagasse mass data are not available, arithmetic averages of the analyses are used for calculating daily data; daily data are, however, combined on a weighted basis.

4.1.12 Tons fibre in bagasse

tons fibre in cane - tons insoluble solids in mixed juice

Where press water clarifier mud is not returned to the mixed juice it is necessary to subtract the tons insoluble solids in press water mud in addition to the tons insoluble solids in mixed juice.

4.1.13 Tons insoluble solids in mixed juice

$$\frac{\text{tons mixed juice} \times \text{insoluble solids \% mixed juice}}{100}$$

4.1.14 Tons uncorrected Brix in mixed juice*

$$\frac{\text{tons mixed juice from scale reading} \times \text{Brix \% mixed juice}}{100}$$

4.1.15 Tons Brix in mixed juice

$$\frac{\text{tons uncorrected * Brix in mixed juice x (100 - insoluble solids \% MJ)}}{100}$$

4.1.16 Tons uncorrected pol in mixed juice*

$$\frac{\text{tons mixed juice from scale reading} \times \text{pol \% mixed juice}}{100}$$

4.1.17 Tons pol in mixed juice

$$\frac{\text{tons uncorrected * pol in mixed juice x (100 - insoluble solids \% MJ)}}{100}$$

4.1.18 Tons sucrose in mixed juice

$$\frac{\text{tons pol in mixed juice}}{\text{pol / sucrose ratio}}$$

where the pol/sucrose ratio is the ratio of pol % mixed juice to sucrose % mixed juice as determined on the composite mixed juice sample by the SMRI laboratory.

4.1.19 Tons Brix in press water mud

$$\frac{\text{tons press water mud} \times \text{Brix \% press water mud}}{100}$$

4.1.20 Tons pol in press water mud

$$\frac{\text{tons press water mud} \times \text{pol \% press water mud}}{100}$$

4.1.21 Tons insoluble solids in press water mud

$$\frac{\text{tons press water mud} \times \text{insoluble solids \% press water mud}}{100}$$

4.1.22 Tons sucrose in cane

tons sucrose in mixed juice + tons pol in bagasse

where clarifier mud is returned to the diffuser, tons sucrose in clarifier mud must be subtracted from above calculation.

** Uncorrected here refers to insoluble solids and not temperature.*

4.1.23 Tons cane per ton sugar

tons cane crushed divided by tons sugar made and estimated from that cane

4.1.24 Tons final molasses at 85°Brix

$$\frac{\text{tons final molasses} \times \text{Brix \% final molasses}}{85}$$

4.1.25 Tons pol in final molasses

$$\frac{\text{tons final molasses} \times \text{pol \% final molasses}}{100}$$

4.1.26 Tons sucrose in final molasses

$$\frac{\text{tons pol in final molasses}}{\text{pol / sucrose ratio}}$$

where pol/sucrose ratio is the ratio of pol % final molasses to sucrose % final molasses as determined on the composite final molasses sample by the SMRI laboratory.

4.1.27 Tons undetermined loss of pol

tons pol in cane - tons pol in bagasse - tons pol in filter cake - tons pol in final molasses - tons pol in sugar

4.1.28 Tons undetermined loss of sucrose

tons sucrose in cane - tons pol in bagasse - tons pol in filter cake - tons sucrose in final molasses - tons pol in sugar

4.1.29 Tons pol in clarifier mud

$$\frac{\text{tons mud} \times \text{pol \% mud}}{100}$$

4.1.30 Tons Brix in clarifier mud

$$\frac{\text{tons mud} \times \text{Brix \% mud}}{100}$$

4.1.31 Adjustment to mill balance for clarifier mud pol and Brix

(i) Adjustment to tons mixed juice

adjusted tons mixed juice = tons mixed juice massed - tons mud (1 – 0.01 insoluble solids % mud)

(ii) Adjustment to tons pol and Brix in mixed juice

adjusted tons pol = recorded tons pol – tons pol in mud

adjusted tons Brix = recorded tons Brix – tons brix in mud

4.1.32 Final bagasse mass

(i) For total and continuous re-routing of clarifier mud the determination is as follows:

As the insoluble solids leaving the extraction unit in the mixed juice are being returned via the clarifier mud and then removed via the bagasse bed, the mass of fibre in bagasse can be taken as being equal to the mass of fibre in cane determined by DAC. Thus there is no need for the DAC fibre to be corrected for the insoluble solids in mixed juice when calculating the fibre in final bagasse.

Therefore, in the case of clarifier mud being recycled to the diffuser:

$$\text{tons final bagasse} = \frac{\text{tons fibre in cane}}{\text{fibre \% bagasse}} \times 100$$

(ii) Where re-routing of clarifier mud is partial or intermittent (within a week) the final bagasse mass determination is as follows:

$$\text{tons final bagasse} = \frac{\text{tons fibre in bagasse}}{\text{fibre \% bagasse}} \times 100$$

Where

tons fibre in bagasse = tons fibre in cane – tons insoluble solids in mixed juice + tons insoluble solids in clarifier mud

4.2 Percentages and ratios

4.2.1 Brix % cane

$$\frac{\text{tons Brix in cane}}{\text{tons cane}} \times 100$$

4.2.2 Brix % cane (DAC)

$$\text{Brix \% cane} = \frac{b}{100} \times \left(100 \times \frac{C + W}{C} - 1.25 \times F\right)$$

where b ≡ Brix % extract
C ≡ mass of cane sample (g) put into the cold digester bowl
W ≡ mass of water (g) added to the cold digester bowl
F ≡ fibre % cane

Routine procedure is to take 1 000 g cane and 2000 g water and hence the formula reduces to:

$$\text{Brix \% cane} = b \times (3 - 0.0125 \times F)$$

The above analysis is normally carried out separately for each consignment of cane. In determining the average Brix % cane for a period it is necessary to weight the individual analyses according to their respective consignment masses.

4.2.3 Brix % extract (cane)

In the case of manual precision refractometers, the refractometer reading is converted to Brix percent extract by means of the appropriate tables provided with each refractometer. Automatic refractometers give a direct read out of Brix % extract.

4.2.4 Pol % cane

$$\frac{\text{tons pol in cane}}{\text{tons cane}} \times 100$$

4.2.5 Pol % cane (DAC)

$$\text{pol \% cane} = \frac{p}{100} \times \left(100 \times \frac{C+W}{C} - 1.25 \times F\right)$$

where	p	≡	pol % extract
	C	≡	mass of cane sample (g) put into the cold digester bowl
	W	≡	mass of water (g) added to the cold digester bowl
	F	≡	fibre % cane

Routine procedure is to take 1 000 g cane and 2 000 g water and hence the formula reduces to

$$\text{pol \% cane} = p \times (3 - 0.0125 \times F)$$

The above analysis is normally carried out separately for each consignment of cane. In determining the average pol % cane for a period it is necessary to weight the individual analyses according to their respective consignment masses.

4.2.6 Pol % extract (cane)

The pol % extract is obtained from the saccharimeter reading and the Brix value of the extract. The basic formula for the calculation is as follows:

$$\text{pol \% extract} = \frac{\text{normal mass} \times \text{saccharimeter reading}}{\text{mass in g of 100 cm}^3 \text{ of solution}}$$

where

(i) normal mass = 26.000 g when the saccharimeter calibrated according to the International Sugar Scale

(ii) mass in g of 100 cm^3 of solution is equal to 100 × apparent density at 20°C. Values of apparent density at 20°C for corresponding Brix values are available from Table 3 in the Appendix

In practice the pol is found from the Schmitz's Table or formula.

4.2.7 Fibre % cane

$$\frac{\text{tons fibre in cane}}{\text{tons cane}} \times 100$$

4.2.8 Fibre % cane (DAC)

$$\text{Fibre \% cane} = \frac{100 \times C - C \times M - (C+W) \times b}{C \times (1 - 0.0125 \times b)}$$

where	C	≡	mass of cane sample (g) put into the cold digester bowl
	M	≡	moisture % cane
	W	≡	mass of water (g) added to the cold digester bowl
	b	≡	Brix % cane extract

When C = 1000 g and W = 2000 g the formula simplifies to

$$\text{fibre \% cane} = \frac{100 - M - 3 \times b}{1 - 0.0125 \times b}$$

4.2.9 Moisture % cane (DAC)

$$\text{moisture \% cane} = \frac{(M_2 - M_3)}{(M_2 - M_1)} \times 100$$

where M_1 ≡ mass of empty oven tray (g)
M_2 ≡ mass of tray with original cane sample (g)
M_3 ≡ mass of tray with dried sample (g)

4.2.10 Brix % mixed juice

$$\frac{\text{tons Brix in mixed juice}}{\text{tons mixed juice}} \times 100$$

4.2.11 Pol % mixed juice

$$\frac{\text{tons pol in mixed juice}}{\text{tons mixed juice}} \times 100$$

4.2.12 Sucrose % mixed juice

$$\frac{\text{tons pol in mixed juice}}{\text{tons mixed juice} \times \text{pol / sucrose ratio}} \times 100$$

where the pol/sucrose ratio is the ratio of the pol % mixed juice to sucrose % mixed juice as determined on the composite mixed juice sample by the SMRI laboratory.

4.2.13 Insoluble solids % mixed juice

$$\text{insoluble solids \% mixed juice} = \frac{(M_3 - M_1)}{(M_2 - M_1)} \times 100$$

where M_1 ≡ mass of beakers, filter paper and filter aid prior to addition of mixed juice (g)
M_2 ≡ M_1 + mass of mixed juice sample (g)
M_3 ≡ M_1 + mass of insoluble solids in mixed juice sample (g)

4.2.14 Brix % bagasse

$$\text{Brix \% bagasse} = \frac{b}{100} \times \left(100 \times \frac{B + W}{B} - 1.25 \times F\right)$$

where b ≡ Brix % bagasse extract
B ≡ mass of bagasse sample (g) put into the cold digester bowl
W ≡ mass of water (g) added to the bagasse sample in the cold digester bowl
F ≡ fibre % bagasse

In the case of final bagasse the quantities of bagasse and water taken are as follows:

B = 350 g

W = 2541 g

Therefore the above formula reduces to:

$$\text{Brix \% bagasse} = b \times (8.26 - 0.0125 \times F)$$

For routine purposes Brix % final bagasse is calculated with sufficient accuracy using the formula:

$$\text{Brix \% bagasse} = 7.7 \times \text{Brix \% extract}$$

Final bagasse samples are taken and analysed once per hour. As an accurate hourly bagasse mass is not readily available, arithmetic averages of the analyses are used for calculating daily data. Daily data are combined on a weighted basis.

4.2.15 *Brix % extract (bagasse)*

As for 4.2.3.

4.2.16 Pol % bagasse

$$\text{pol \% bagasse} = \frac{p}{100} \times \left(100 \times \frac{B + W}{B} - 1.25 \times F\right)$$

where p ≡ pol % bagasse extract
B ≡ mass of bagasse sample (g) put into the cold digester bowl
W ≡ mass of water (g) added to the bagasse sample in the cold digester bowl
F ≡ fibre % bagasse

In the case of final bagasse the quantities of bagasse and water taken (350 g and 2541 g respectively) are such as to give a solution very close to half normal. Thus when using a 200 mm saccharimeter tube, the saccharimeter reading multiplied by 2 gives the pol % bagasse directly.

Final bagasse samples are taken and analysed once per hour. As an accurate hourly bagasse mass is not readily available arithmetic averages of the analyses are used for calculating daily data. Daily data are combined on a weighted basis.

4.2.17 Pol % extract (final bagasse)

The pol % extract is obtained from the saccharimeter reading and the Brix value of the extract using the following formula:

$$\frac{\text{normal mass} \times \text{saccharimeter reading}}{\text{mass in g of 100 cm}^3 \text{ of solution}}$$

where

(i) normal mass 26.000 g for saccharimeters calibrated according to the International Sugar Scale

(ii) mass in g of 100 cm^3 of solution is equal to 100 × apparent density at 20°C. Values of apparent density at 20°C for corresponding Brix values are available from Table 3 in the Appendix

Bagasse extract concentrations usually fall outside the range covered by Schmitz's Table hence the Table cannot be applied in these instances.

4.2.18 Fibre % bagasse

(a) $$\text{fibre \% bagasse} = \frac{100 \times B - B \times M - (B + W) \times b}{B \times (1 - 0.0125 \times b)}$$

where B ≡ mass of bagasse (g) put into the cold digester bowl
M ≡ moisture % bagasse
W ≡ mass of water (g) added to the cold digester bowl
b ≡ Brix % bagasse extract

In the case of final bagasse with B = 350 g and W = 2541 g the formula simplifies to:

$$\text{fibre \% bagasse} = \frac{100 - M - 8.26 \times b}{1 - 0.0125 \times b}$$

(b) daily fibre % bagasse = 100 arithmetic average of moisture % bagasse analyses
- arithmetic average of Brix % bagasse analyses

(c) $$\text{weekly fibre \% bagasse} = \frac{\text{tons fibre in bagasse for the week}}{\text{tons bagasse for the week}} \times 100$$

where tons fibre in bagasse for the week are calculated as shown in 4.1.12

4.2.19 Moisture % bagasse

$$\text{moisture \% bagasse} = \frac{(M_2 - M_3)}{(M_2 - M_1)} \times 100$$

where M_1 ≡ mass of the empty tray (g)
M_2 ≡ mass of the tray with original bagasse sample (g)
M_3 ≡ mass of the tray with dried sample (g)

Final bagasse samples are taken and analysed once per hour. As an accurate hourly bagasse mass is not readily available, arithmetic averages of the analyses are used for calculating daily data. Daily data are combined on a weighted basis.

4.2.20 Brix % press water mud

The press water mud is assumed to have the same purity as the press water. Brix % press water mud is calculated as follows:

$$\frac{\text{pol \% press water mud}}{\text{purity of press water}} \times 100$$

4.2.21 Pol % press water mud

The sample is prepared as a normal solution and therefore the pol result is obtained directly from the saccharimeter reading.

4.2.22 Insoluble solids % press water mud

The calculation is carried out in the same manner as in 4.2.13.

4.2.23 Brix % press water

The result is obtained in the same manner as in 4.2.3.

4.2.24 Pol % press water

The result is obtained in the same manner as in 4.2.6.

4.2.25 Pol factor

$$\frac{\text{tons pol in cane by mill balance}}{\text{tons DAC pol in cane}} \times 100$$

4.2.26 Brix factor

$$\frac{\text{tons Brix in cane by mill balance}}{\text{tons DAC Brix in cane}} \times 100$$

4.2.27 Mixed juice pol/sucrose ratio

$$\frac{\text{pol \% mixed juice (SMRI laboratory analysis)}}{\text{sucrose \% mixed juice (SMRI laboratory analysis)}}$$

4.2.28 Bagasse % cane

$$\frac{\text{tons bagasse}}{\text{tons cane}} \times 100$$

4.2.29 Imbibition % cane

$$\frac{\text{tons imbibition}}{\text{tons cane}} \times 100$$

4.2.30 Imbibition % fibre

$$\frac{\text{tons imbibition}}{\text{tons fibre in bagasse}} \times 100$$

4.2.31 Mixed juice % cane

$$\frac{\text{tons mixed juice (from scale reading)}}{\text{tons cane}} \times 100$$

4.2.32 Purity of cane juice

$$\frac{\text{pol \% extract}}{\text{Brix \% extract}} \times 100$$

4.2.33 Reducing sugars/pol ratio

$$\frac{\text{reducing sugars \% product}}{\text{pol \% product}} \times 100$$

4.2.34 Reducing sugars/ash ratio

$$\frac{\text{reducing sugars \% product}}{\text{ash \% product}} \times 100$$

4.2.35 Recoverable value % cane (RV % cane)

(i) RV = S - dN - cF

where S ≡ sucrose % cane
N ≡ non-sucrose % cane
F ≡ fibre % cane
d ≡ the relative value of sucrose which each unit of non-sucrose diverts from sugar production to molasses.
C ≡ the loss of sucrose from sugar production per unit of fibre

(ii) Calculation of the d factor

The factor d represents the quantity of sucrose lost to molasses per unit of non-sucrose, but with a credit for the value of the molasses recovered per unit of non-sucrose, and is calculated as follows:

$$d = \left(1 - \frac{m \times Pm}{Rs/es \times b \times Ps}\right) \times b$$

where m ≡ industry average molasses yield per unit of N delivered
Pm ≡ industry average realisation per ton of molasses as calculated by SASA
Rs/es ≡ industry average unit recovery of saleable sugar (S) from the estimated sugar (ES). See item (iv) for calculation of ES
Ps ≡ industry average realisation per ton of saleable sugar as calculated by SASA

$$b = \frac{\text{tons non - sucrose in molasses and sugar}}{\text{tons non - sucrose in cane}} \times \frac{\text{tons sucrose in molasses}}{\text{tons non - sucrose in molasses}}$$

(iii) Calculation of the c factor

$$c = \frac{\text{tons sucrose in bagasse}}{\text{tons fibre in cane}}$$

(iv) The factors m, b, c and Rs/es used in the above formulae are rolling three season weighted averages determined for the immediately preceding three seasons.

In the case of Rs/es the ES delivered is determined as follows:

ES = S – bN – cF

Where S, N and F are the industry average sucrose %, non-sucrose % and fibre % cane for the season concerned and the factors b and c are again rolling three seasons weighted averages calculated as above.

(v) Pm and Ps will at the start of the season be the SASA pre-season estimates with adjustments made each month by SASA on basis of the latest available data with final adjustment at the end of the season to actual data for the season.

4.2.36 *Tons recoverable value (RV) in a cane consignment*

$$\frac{\text{Tons cane} \times \text{RV \% cane}}{100}$$