A FINANCIAL EVALUATION APPLIED TO SELECTION OF A CENTRIFUGALS

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Abstract

Replacement A sugar centrifugals were required for the Maidstone Factory for installation in 1988. Sugar quality constraints determined that automatic batch machines be used; and other considerations reduced the final tender adjudication to an evaluation of three models, each with different features. Methods used to assess the cost effectiveness of the differences between the three machines are described. The most significant factors in the adjudication were curing capacity, ploughing efficiency and drive characteristics. The evaluation was specific to Maidstone's circumstances and included some subjectivity, but the methodology could be applied to other factories and to selection of other equipment.

Introduction

The Maidstone Mill processes up to 9 500 tcpd, with raw sugar production of 45 tons per hour (90 tons A massecuite per hour). Maidstone's sugar is despatched either to the Hulett Refinery or for export, both of which require VHP sugar at an average pol of 99,4°.

Maidstone's cane supplies are now the Industry's worst affected by Eldana borer. For agronomic reasons, most of the non-Eldana cane is not burned, giving an overall 60% trashed cane. Approximately 60% of the Mill's cane is processed through a diffuser and 40% through a milling tandem.

The cane supplies are primarily natural rain fed, although approximately 10% is under supplementary irrigation. The cane is thus subject from time to time to severe drought stress.

Eldana, drought stress and the combination of trash cane and diffusion, result in high intrinsic sugar colour levels and from time to time in viscous, gummy massecuites.

Poor massecuites and high sugar quality specifications make the A centrifugals an important station at Maidstone. In 1987, the station comprised two relatively modern 1 250 kg BMA Variant and seven 25 year old 450 kg ASEA machines. The ASEA machines had become unreliable, costly to maintain and poor in performance due to general deterioration and lack of power. It was therefore decided to purchase two large centrifuges to replace the curing normally done by the ASEA machines.

Preliminary requirements

Initially, general tenders were requested. These tender results were not revealed, but used by Maidstone to clarify technical preferences and to select final tenderers. Preliminary decisions covered the following items:

Batch versus Continuous Machines

Stringent sugar quality specifications determined that batch machines would be required despite the considerable mechanical and initial price appeal of the continuous option. Excessive washing and hence purity rise, would have been required on continuous machines to attain a polarisation consistently above 99,3°, sugar colour of less than 1 350 ICUMSA units (with affinated colour sometimes as high as 900) and less than 30% fines with a mean crystal size of only 0,75 mm. Even then, South African data reported by Lamusse *et al*[1,2] and Bruijn[3] indicated that continuous machines would not normally achieve the specifications on Maidstone massecuites.

Capacity

As the new machines would be added to an existing station and four of the present ASEA machines would initially be retained for emergency standby, the question of providing N + 1 machines (the "1" being standby) did not arise. The largest available certrifuge would not have substituted entirely for the seven ASEAS and, with future planning in mind, it was decided to order two large machines. From all suppliers, the best capacity/cost ratio was provided by their largest model and final tenders were therefore confined to these. One of the final tenderers could have achieved some commonality with the two existing DC driven 1 250 kg machines, but the advantages of their larger machine were considered to outweigh any benefits of commonality.

Drive

The Maidstone factory exports electricity, bagasse and steam, which requires supplementary coal burning. Power efficiency was therefore an important consideration so that either DC or AC frequency converter drives were strongly perferred to pole-changing motors.

Table 1
Features of electronically controlled centrifugal drives

Characteristics	Drive type		
	DC Drive	AC Current source inverter	AC PWM inverter
Approximate relative cost	1	1,02	1,15
Reactive current drawn from mains (also total current)	High	High	Low
Power factor (rated speed)	0,90	0,90	0,98
(50% speed)	0,44	0,44	0,99
(10% speed)	0,09	0,09	0,94
Harmonics to mains (rated speed)	1	1	0,9
(50% speed)	1	1	0,5
Inverter efficiency (rated speed)	97%	95%	97%
Overall efficiency (rated speed)	92%	90%	92%
(50% speed)	83%	81%	85%
Motor maintenance	Brushes etc	None	None
Electronic complexity	Low	Low	Medium
Environmental tolerance	Moderate	High	High
Overall reliability/availability	Moderate	High	High

The infinitely variable speed settings, savings on brake maintenance and mechanically smoother operation were also factors taken into account in this decision.

The question of DC or AC converter drive was less clear cut. Three types of AC converters are now commonly available:

(a) with current source inverter, electronically the simplest;

(b) with voltage source inverter (limited to about 20 kW maximum, so not suitable for centrifugal drives); and

(c) with pulse width modulated (PWM) inverter, the most advanced.

The characteristics relevant to centrifugal drives of DC, current source converter and PWM converter are contrasted in Table 1.

While AC converter drives are more costly than DC drives, they are now widely preferred in the European beet industry where large numbers of both are installed. The main advantage of the AC drive lies in its simple, low maintenance motor with no sliprings and, with pulse width modulated (PWM) converters, better power factor and cleaner mains supply (less reactive current and harmonics). These electrical advantages of the PWM drive are illustrated in figures 1, 2 and 3. Final tenders were consequently required to incorporate AC frequency converter drives, either current source or PWM controlled.

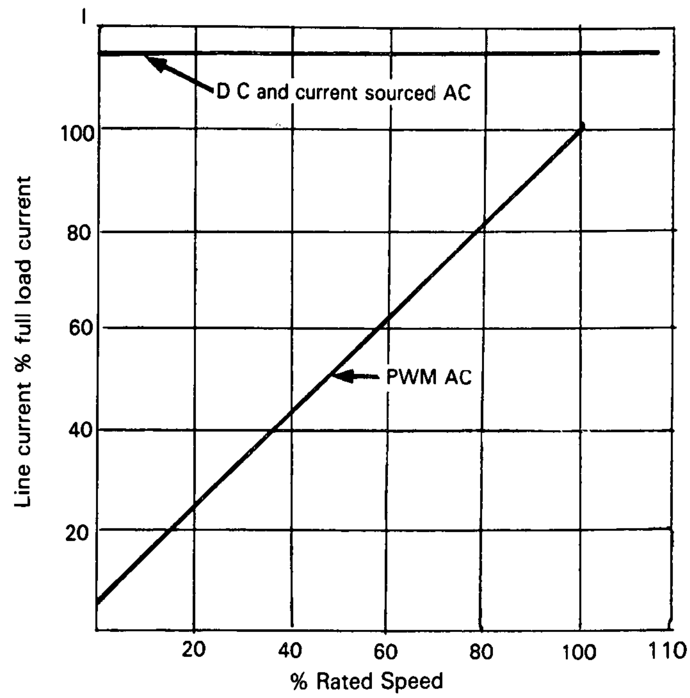

FIGURE 2 Line current versus speed.

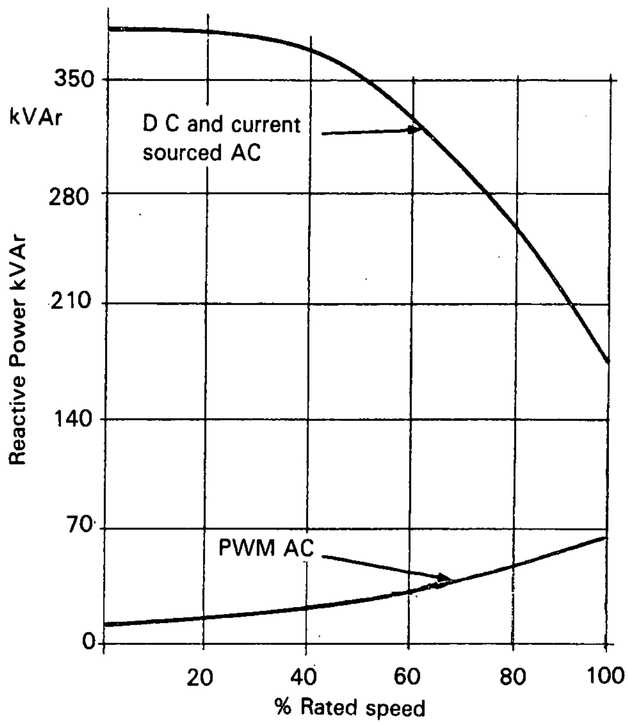

FIGURE 1 Reactive power versus rated speed for a 315 kW drive.

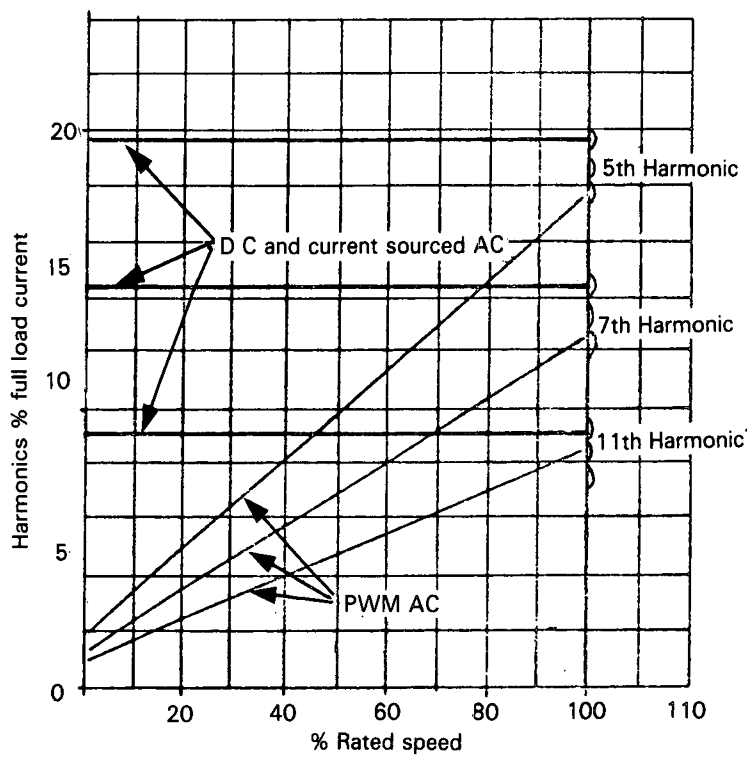

FIGURE 3 Harmonics versus speed.

Local support

Although only machines expected to be mechanically, electrically and electronically reliable would be considered, competent local service and spares support after commissioning is essential. If a local representative could not guarantee to carry common spares, the cost of these would be added to the basic tender for adjudication purposes. The local representative should also be competent to provide operational advice (plough setting, electronic maintenance, etc).

Country of Origin

It is unfortunately important in South Africa in the 1980's to ensure that equipment with specialised components is procured from a country that is expected to continue to service the South African market. The suppliers under final consideration were from Germany and Britain which were considered to be amongst the most reliable countries in this regard.

Final Tenders

From these considerations, three suppliers were invited to submit final detailed tenders with a limited number of optional alternatives. All three had cause to be particularly anxious to secure this order which resulted in competitive and close tender prices. To decide the relative merits of the three tenders, a technique used previously at Maidstone for the adjudication of both boiler and turbo-alternator tenders, was invoked.

An estimate was made of the annual savings or additional costs to be expected from the different features of each machine (e g differences in power consumption, exhaustion, steam consumption, maintenance costs, etc). These annual savings were converted to a capital or present value (PV) assuming an appropriate interest rate (R% p.a.) and amortization life for the equipment (t years).

This calculation of the PV is readily made by multiplying the annual savings by the factor K derived from Figure 4.

For the centrifugal evaluation, the values assumed were R = 12% p.a. and $t = 12$ years, this giving a multiple K = 6,2. For example, power savings of R10 000 p.a. would be assessed at a PV = 6,2 × R10 000 = R62 000. (Note: this is equivalent to a simple capitalisation rate of 100/6,2 = 16,1% p.a.)

The difference in taxation effects between capital and operating expenditure was not calculated but was partially allowed for by selecting a slightly lower R than actually anticipated.

Each optional extra offered was similarly evaluated and was included in that supplier's basic tender provided the PV of that item exceeded its cost - in which case it obviously was worth having and enhanced that tender.

Tender adjudication was then completed by noting equivalent basic tender prices of the machines from each supplier, delivered, installed and commissioned at Maidstone, including all shipping, duties and taxes and options selected as worth purchasing. From these basic prices were subtracted the PV's of their special features to arrive at "comparable" final tender prices.

Although the final evaluation was provided to all three tenderers and is not confidential, to avoid any impression of a "commercial" paper, the three tenders will be referred to here simply as X, Y and Z.

Technical specifications

Technical specifications of the three machines are compared in Table 2.

Table 2

Comparison of technical specifications

Machines on offer	X	Y	Z
Basket diameter (mm)	1 600	1 372	1 600
Basket height (mm)	1 100	1 067	1 000
Maximum sugar wall thickness (mm)	230	200	200
Charge with 200 mm wall (m³)	0,968	0,786	0,879
Recommended spin speed (rpm)	1 000	1 200	1 000
Maximum speed obtainable (rpm)	1 100	1 400	1 000
Speed required to obtain 900 G-factor	1 004	1 085	1 004
G-factor at spin speed	900	1 100	900
G-factor at maximum speed	1 080	1 498	900
Quoted cycle time, adjusted for equivalent sugar quality (sec):			
Cycle time to charge speed	2	7	7
Charging	14	15	12
Acceleration to 900 G-factor	46	35	39
High speed spin	15,8	18,0	17,2
Deceleration	40	27	39
Ploughing	40	25	42,5
Basket wash	*Done on acceleration to charge speed*		
TOTAL	157,8	127,0	156,7
Hence: cycles/h	22,8	28,4	23,0
∴ Capacity with 200 mm wall (m³/h)	22,1	22,3	20,2
Basket design features:	Hooped	Hooped	Plain
Material	S/S	S/S	S/S
Drilling	Full	Full	Full
Number of drainage holes	715	3 360	504
Size of drainage holes (mm dia)	6	5	6
No of hoops	6	23	Nil
Screens (all S/S):			
backing	Pressed & slotted	No 4 mesh	58% drilled
secondary	—	No 7 mesh	—
sugar	0,4 mm slot	0,55 mmØ	0,5 mmØ
open area	24%	23%	24%
Plough geometry	Leading; Spring Loaded	Trailing; Fixed Stop; Soft tip	Trailing; Fixed Stop + clutch + air jet
Cleanliness of screens (assessed from operating machines)	Good	V Good	Excellent
Motor and drive (all AC frequency converter)			
Inverter source	Current	PWM	Current
Motor KW	315	335	315
Power used kWh/ton massecuite	1,15	1,03	1,15

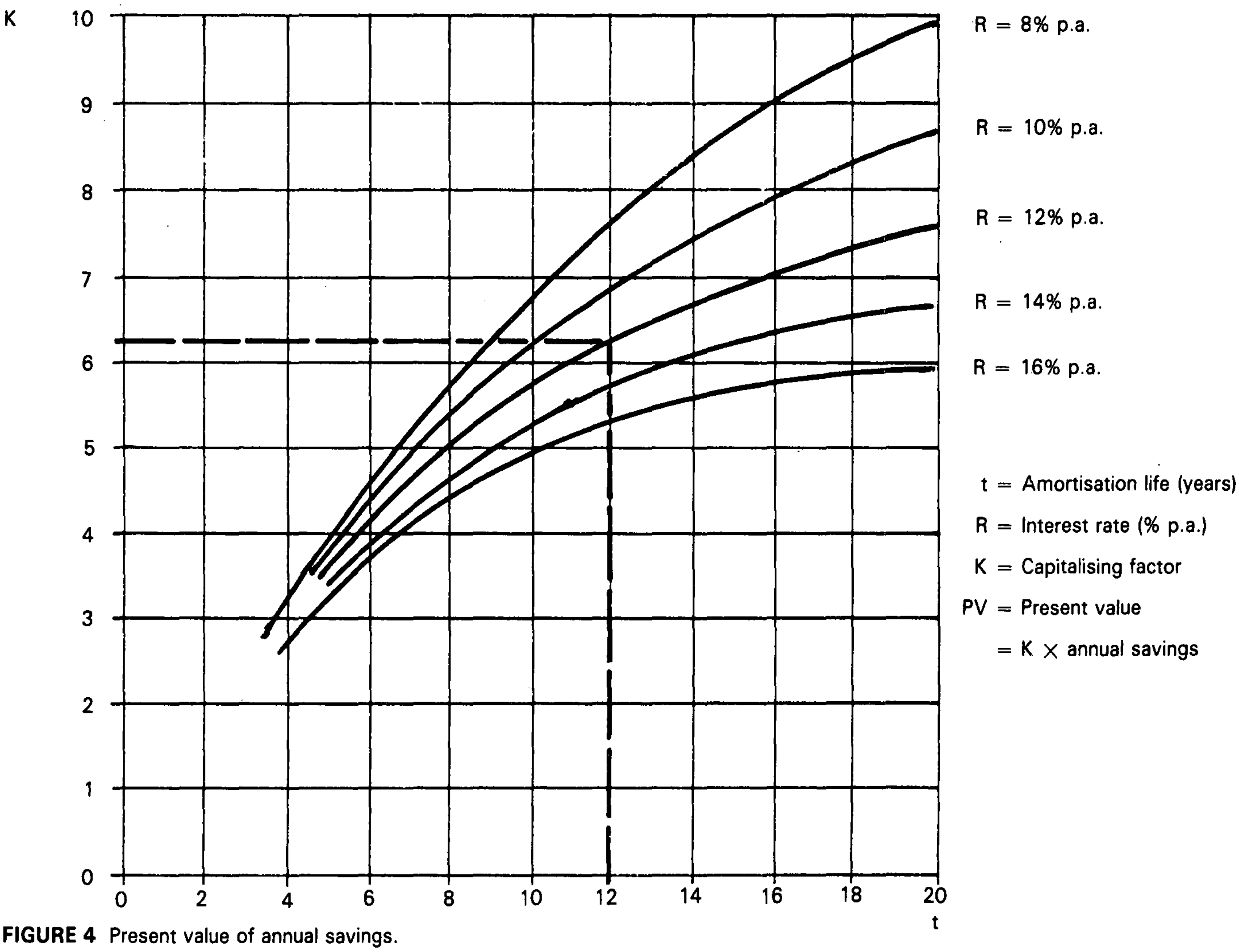

FIGURE 4 Present value of annual savings.

Tender Adjudication

A preliminary cost comparison was made for two machines, delivered, installed and commissioned, including all duties and taxes plus options which would be selected on common terms of payment. This is shown in Table 3.

Table 3

Preliminary cost comparison

	X	Y	Z
Basic price, 2 machines	R815 728	R902 958	R874 936
Monitor casing in S/S	34 484	16 632	36 440
Discharge valve	Incl.	Incl.	23 576
Hooped basket	16 710	Incl.	No offer
Air blast on plough	No offer	No offer	1 456
Total commissioned cost	R866 922	R919 590	R936 408

These costs were then adjusted for perceived values of technical differences.

Evaluation of technical differences

Present values (PVs) were assessed for technical differences as follows:

1. *Relative Capacity*

- For equivalent sugar quality, all machine cycle times were taken for a G-factor at spin of 900 i.e. 'Y' adjusted to a spin speed of 1 085 rpm.
- In order to compare the various tenders fairly, the last 20% (time) of acceleration to full speed was considered to be part of the "curing" spin time. This was necessary due to the different acceleration rates of the machines under consideration. The total curing time was set at 25 sec.

  Hence: high-speed spin required = 25 − 20% of acceleration time (secs). This was used to set comparable cycle times and hence comparable capacities.
- The value of capacity difference was assessed as follows:

	X	Y	Z
Comparable capacities (m^3/h)	22,1	22,3	20,2
Difference from average of 21,53m^3/h	+ 0,57	+ 0,77	− 1,33

Given the approximate cost of two machines as R900 000, average "capacity value" is R900 000/21,53 = R41 800/m^3/h. This was discounted by 30% to R29 260/m^3/h as maximum capacity is not always required/utilised. This gave:

	X	Y	Z
Value Adjustments	+R16 678	+R22 530	−R38 915

'X' can accept a 230 mm sugar wall. This gives further capacity but for comparable sugar quality under these conditions, a longer spin time would be required. Therefore additional capacity provided by this was calculated as above, but discounted by 50% instead of 30%.

Value Adjustments	+R40 985	0	0

2. *G-Factor*

At the start and finish of each season poor quality massecuites are encountered and result in pol/colour penalties. Additional G-Factor will reduce these penalties and a scale of R0–R4 000 p.a. was used as being an estimated one-third of penalties presently incurred which might be avoided by operating at the highest G-Factor of machine Y. Capitalised by a PV multiplier of 6,2 as above:

PV Adjustments	+R7 464	+R24 800	0

A high G-Factor could also provide extra capacity with poor massecuites – this was not evaluated.

3. *Power Consumption*

Only two types of drive were finally considered and the difference in quoted power between the two is 0,12 kWh/ton massecuite.

As Maidstone both buys and sells electrical power, this was an important factor.

Calculation: 0,12 kWh/ton × 30 tons/h/machine × 2 machines × 5 500 hrs/season × R0,0304 unit cost/kWh = R1 200 p.a.

The related maximum demand charge for these units would be R1 000 p.a. Total = R2 200 p.a.

As this is an annual cost, it must be capitalised as above:

PV Adjustments	0	+R13 640	0

4. *Inverter Source Philosophy*

Benefits of R650 p.a. per machine were assessed for a PWM inverter versus a current sourced unit, due to its better power factor and reduced harmonics:

PV Adjustments	0	+ R8 000	0

5. *Subjective Reliability & Maintenance Assessments*

While all three machines offered were highly regarded, subjective values were placed on perceived general differences as follows:

Motor and drive	0	+ R5 000	0
Mechanicals/maintenance	0	+ R4 000	+ R8 000
Suspension/ploughing mechanics	0	+ R2 000	+ R6 000
Local technical support	+ R2 000	+ R2 000	0

6. *Ploughing Efficiency*

The three ploughing systems differed widely in principle and in observed effectiveness in operating machines. Supplier X offered a deep plough, conventionally pivotted with the tip leading ahead of the fulcrum so that the plough would dig into the screen if snagged. For finer settings, three individually adjustable spring-loaded tips were provided. In practice, the performance of this plough was observed to be moderate.

Plough Y was pivotted with a trailing configuration and provided with a soft tip. This enabled safe setting of the plough to touch the screen. Performance was very good.

Plough Z was also pivotted with trailing geometry and had a slip-clutch to yield should the plough snag strongly. Z also was provided with a device enabling fine setting and the basket was exactly centralised during ploughing. As an option, a small air jet was provided behind the plough tip in this unit. In practice, this plough achieved an exceptionally clean basket.

Given Maidstone pan house capacity limitations, ploughing efficiency was the single most important process consideration. Sugar left in the basket after ploughing is transferred into the molasses during the basket wash. This has at least four adverse effects:

(a) Recycling of the sugar through process uses up pan, crystalliser and centrifugal capacity and Maidstone is short of this capacity.

(b) Recycling with more boiling increases colour formation - also a serious problem at Maidstone, with high intrinsic colour levels in juices.

(c) Recycling with additional boilings causes increased "undetermined loss" of sugar. Tongaat-Hulett's Technical Management Department uses an approximate relationship that one unit of purity rise on A-curing will reduce A-exhaustion by 1,5 units and this in turn will lead to an increase in % undetermined loss of approximately 0,15 units.

(d) Recycling requires considerable extra process steam.

Of these four effects, only (c) and (d) above were evaluated:

6.1 *Effect of undetermined loss*

Tongaat-Hulett Sugar's experience and tests previously conducted indicate expected benefits from ploughing efficiency characterised as follows:

Given normal plough maintenance and attention (ie less than perfect), it was guesstimated that the plough of X would leave 0,5 kg more sugar per cycle than the Z plough, and this sugar would be washed into the molasses. On 750 kg of 68° purity molasses per cycle, this represents an increase in purity rise of 0,1°. This would increase % undetermined loss by 0,015 units. With overall recovery of 85% and 160 000 tons sugar processed by two machines per season, and at R550 per ton sugar; the sugar loss would be

$$\frac{0,015}{85} \times 160\,000 \times 550 = R15\,529 \text{ p.a.}$$

Capitalised as above PV = R96 280

The Y plough efficiency was assessed midway between those of X and Z.

PV Adjustments	0	+R48 140	+R96 280

6.2 *Effect of steam demand*

The reduction in Maidstone's process steam demand due to reduced A, B & C boilings was evaluated using the "Boiling house Operations Overall Balance" programme of Hoekstra.[4,5]

This showed that the estimated difference in purity rise of 0,1 unit between X and Z (see above) would lead to an additional 0,187 ton/h pan floor vapour use. As this is Vapour I from a quintuple-effect evaporator station, the increase in exhaust steam use would be 0,8 × 0,187 tph × 5 500 hrs per season or 823 tons steam/season.

At 7,5 tons steam/ton coal and R65 per ton coal, this would cost R7 133 p.a.

However, the Maidstone factory steam balance is only exhaust-steam dependent at times of low electrical load (10,00 p.m. to 6,00 a.m. and weekends) - about 52% of total time. Hence savings would only be

R7 133 × 0,52 = R3 709 p.a.

Capitalised as above, PV = R22 995.
With Y ploughing efficiency midway between X and Z:

PV Adjustments	0	+R11 498	+R22 995

Table 4

Comparative tender prices

	X	Y	Z
Basic price, installed & commissioned	866 922	919 590	936 408
Adjustments for Technical features:			
Capacity	−16 678	−22 530	+38 915
+ 230 mm Wall	−40 985	0	0
G-Factor	− 7 464	−24 800	0
Power consumption	0	−13 640	0
Inverter philosophy	0	− 8 000	0
Reliability/maintenance:			
- Motor and drive	0	− 5 000	0
- Mechanicals	0	− 4 000	− 8 000
- Suspension/Ploughing	0	− 2 000	− 6 000
- Local Technical support	− 2 000	− 2 000	0
Ploughing efficiency; undetermined loss	0	−48 140	−96 280
Ploughing efficiency; steam saving	0	−11 498	−22 995
COMPARATIVE TENDER PRICES	R799 795	R777 982	R842 048

Final Tender Comparison

Comparative tender prices were derived by subtracting the positive values ascribed to technical features from the basic tender price, as shown in Table 4.

Conclusion

Despite supplier X having tendered the lowest basic price, supplier Y was successful after the detailed tender evaluation. Although the capacity advantage of the large X machine was important, the perceived better ploughing efficiency and superior drive characteristics of Y proved decisive in securing this order.

The methodology of this tender adjudication may be applied to any major capital plant under consideration in any industry.

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