Modern sugar-factory equipment for good recoveries, energy efficiency and low costs

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Abstract In recent decades, traditional sugar factory equipment has been replaced by new designs aimed at the objectives of increased sucrose recoveries, improved energy efficiency and reduced costs of capital, maintenance and operation. This paper describes some of the most important of this equipment, including novel observations on their features and benefits. Space constraints limit the amount of detail on each item, but references are quoted for more comprehensive information on the equipment:

- Diffusion extraction to avoid the use of potentially exportable power, increase recoveries and save costs;
- Direct contact juice heaters for low cost heating without an increase in process’s exhaust steam demand;
- Clarifier mud recycling, to avoid the enthalpy losses, sucrose degradation, condenser power, juice dilution, bagacillo fuel losses and costs of mud filter operations;
- 'Direct clear juice' to further reduce enthalpy and sucrose losses in clarification and save costs;
- Long tube climbing film evaporators for high capacity, low cost 1st and 2nd effects that minimise sucrose losses and avoid pumping;
- Horizontally configured vertical tube continuous pans that use low grade vapour, avoid steaming out between boilings, avoid stirrers and achieve high exhaustions that minimise reboiling of massecuites;
- Sieve plate scrubbers for high efficiency cleaning of boiler flue gases at low energy and cost.

Where appropriate, results are quoted to demonstrate that the use of these techniques and plant has enabled factories to achieve the desired objectives. Novel equipment covered includes a diffuser processing more than 20,000 t cane per day, a unique evaporator with built-in clear juice heater, and a scrubber achieving emission rates of less than 20 mg/Nm³ at a pressure drop of 600 Pa (60 mm water gauge).

Key words Energy efficiency, sucrose recovery, clarification, evaporation, CVP sugar quality, flue gas cleaning

INTRODUCTION

In recent decades, traditional sugar factory equipment has been replaced by new designs aimed at the objectives of improved energy efficiency, increased sucrose recovery and reduced costs of capital, maintenance and operation. This paper describes some of the most important of these developments, namely:

1. Diffusion extraction.
2. Direct contact juice heaters.
3. Clarifier mud recycling.
4. Direct clear juice.
5. Long tube climbing film evaporators.
7. Sieve plate scrubbers.

The descriptions include both well-known and novel observations on their features and benefits.

Space constraints limit the amount of detail on each item, but references are quoted for those seeking more comprehensive information.
EQUIPMENT OBJECTIVES

Each item is described in terms of its contribution to one or more of the following objectives:

Sucrose recovery: Sugar is the main revenue source for most factories. It is therefore an obvious objective to minimise sucrose losses in bagasse, inversion in process or in molasses (which usually sells at a price of one-tenth that of its sugar content).

Energy efficiency: Many factories now export power or steam for refining, by-products, irrigation, co-generation, etc. Energy efficiency should therefore be one of the main criteria to be considered in the design and selection of major items of sugar processing plant. The main forms of energy used in a sugar factory are electricity, high pressure (power) steam and low pressure (process heating) steam. An energy-efficient factory minimises the use of all three types.

Costs: Capital, maintenance and operating costs are all important considerations when decisions are required regarding the installation of major plant items.

The description of each item is headed by a list of the significant benefits which it contributes.

DIFFUSION EXTRACTION

Benefits: Sucrose recovery, energy efficiency, capital, maintenance and operating costs

Diffusion has long been the traditional extraction method in the beet industry, but was only successfully adopted in the cane industry following the advent of heavy duty shredders in the 1960s and 1970s. Many of the pioneering installations in southern Africa were bagasse diffusers (i.e. preceded by a milling stage), but Payne (1968) described the first commercially successful cane diffuser without an initial milling stage. His success was attributable to fine preparation from two powerful shredders in series, which enabled the effective extraction of sucrose from the cane by both the diffuser mechanisms – lixiviation (washing) and diffusion (osmosis). As heavy duty shredders with preparation indexes or % open cells greater than 90% were adopted in South Africa (Moor 1973), cane diffusers displaced bagasse diffusers. These required less power (one less milling stage) and achieved higher extractions.

Rein (1995, 2007) has described the advantages of cane diffusion over a 6-mill milling tandem. For plants of similar throughputs, these include:

- Higher extraction and overall sucrose recovery (including the effects of less filter cake and purity considerations);
- Less suspended solids in mixed juice (some diffusers use no mixed juice screening; Rein 2007);
- Energy: A diffuser plus dewatering plant uses 55% - 60% less power. The diffuser requires heating steam (usually V1 or V2), but supplies hot mixed juice requiring less downstream heating. Overall, after considering the evaporator effects, the diffuser usually uses 3-5% more exhaust (process) steam;
- Capital cost approximately 33% less (for a diffuser with two dewatering mills);
- Maintenance costs approximately 40% less; and
- Operating costs lower – generally no platform staff required for diffusers and less cleaning.

Most diffusers have either a chains and slats assembly scraping over a fixed screen deck or a moving deck supported between chains, both of which systems require a bridge structure for the returning mechanism. This bridging and the headshaft strength limit the practical width of such diffusers to a maximum of about 12 m, which in turn limits the capacity for high extractions to some 60 t fibre/h.

However, Voigt (2009) described a new type of chainless diffuser, developed by Bosch Projects, that does not suffer these mechanical constraints and can also be expanded at moderate cost if required. This design comprises a number of about 60 m long 750 mm wide screens that provide a ‘walking’ deck as the segments are sequentially pulled forwards and back by about 1 m by hydraulic cylinders. The first purpose-designed chainless cane diffuser (i.e. no preceding mill), a 12 m wide unit at Usina Noroeste (Brazil), is shown in Figure 1, with its deck and lifting screws in Figure 2. A similar 15 m wide unit at Cosan’s Jataí factory, rated for 15 000 tcd at >97% extraction, has been operated consistently at over 20 000 tcd but at lower extraction and processed a daily record 21,632 t cane on 13 June 2014. A 20 000 tcd, 16.5 m wide chainless bagasse diffuser (i.e. following a No. 1 mill) of this type has been installed at Khon Kaen Sugar (Thailand).

A design is available for a 21 m wide cane diffuser – 75% larger than the Noroeste unit. Financially, the chainless diffusers are cheaper and have lower maintenance costs than other diffuser types.
Fig. 1. 12 m wide Usina Noroeste diffuser.

Fig. 2. The Noroeste screen deck and lifting screws.

DIRECT CONTACT JUICE HEATERS

Benefits: Capital, maintenance and operating costs

Direct contact (DC) heaters operate as counter-current condensers, by spraying or cascading juice through the heating steam/vapour. The juice is heated by the enthalpy of evaporation of the condensing steam.

For many years, DC heaters were shunned by sugar technologists because the condensate of the steam dilutes the juice and increases the subsequent evaporation requirement. However, DC heaters operate at approach temperatures of 1-3°C, whereas shell-and-tube (S&T) and plate heaters are usually designed for approach temperatures of 8-20°C (Rein 2007). DC heaters can therefore operate on at least one grade of vapour lower than an equivalent S&T heater. As shown
in Figure 3, an example for a heating duty of about 22,500 MJ/h, this accommodates the extra evaporation without any increase in total exhaust steam.

Valdes (1977) presented the advantages of DC heaters to ISSCT and Wright (1979, 2000) followed up with further analysis, advocating DC heaters for optimising energy efficiency for cogeneration factories.

**Fig. 3.** Comparison of steam flows for 22 500 MJ/h heating by DC and S&T heaters. Note that each option requires the same 10 t/h of exhaust steam.

The familiar benefits of DC heaters are:
- No fouling problems to reduce heat transfer coefficient (HTC), so maintain temperature over time;
- No cleaning requirement;
- Ease of control, by either juice temperature or steam pressure;
- Can tolerate some solids in juice;
- Small footprint;
- Low radiation losses.
Less recognised benefits are:

- Evaporator HTCs are usually higher than juice heater HTCs, so less additional evaporator heating surface is needed than that saved in the heaters (200 m$^2$ vs. 300 m$^2$ in Figure 3);
- The extra evaporator tubes foul more slowly and require less frequent cleaning than juice heater tubes;
- Intermediate liming (before final heating) causes extra scaling in S&T or plate heaters, but is no problem with DC heaters.

**CLARIFIER MUD RECYCLING**

**Benefits:** Sucrose recovery, energy efficiency, capital, maintenance and operating costs

The advent of diffusion prompted the idea of recycling clarifier mud back to an appropriate position in the diffuser, rather than sending it on to rotary vacuum filters or vacuum belts for de-sweetening. Meadows *et al.* (1998) implemented this concept at Hulett’s Maidstone Mill and Jensen (2001) reported on the results achieved. The appropriate position is usually into the stage juice of similar brix that is pumped to the first lifting screws, as the screws mix the mud throughout the bed without forming any blinding layer.

Benefits include:

- Increased recovery, as filter mud losses are substituted by a lower volume of solids (no bagacillo) exiting with bagasse at a very low sucrose content;
- Elimination of the high degradation losses that usually occur in the filter station;
- Avoiding dilution by the filter wash water;
- Saving the mud conditioning bagacillo for additional fuel (usually 2-5% additional fuel);
- Eliminating the entire filter station – filters, condenser, vacuum system, condenser water and cooling, bagacillo extraction and mud mingler and filter cake disposal plant.

Disadvantages: The only concern expressed has been the effect of additional abrasive sand in bagasse causing erosion of boiler tubes. However boiler main bank tube thickness measurements at Maidstone after 15 years of mud recycling did not show any noticeable additional wear. This is possibly because:

- Diffuser bagasse anyway retains about 60% of the sand in cane, so the increase from returned mud is small; and
- The heavier, potentially more damaging particles remain on the grate with the ash.

Recycling extracted sucrose to the diffuser affects the mill balance and has implications for cane payment. It is therefore necessary to measure and analyse the recycled mud.

The mixed juice from mills contains more mud than that from diffusers, and in view of the success of mud recycling at Maidstone (and subsequently at other diffusers), Darnall and Noodsberg mills experimented with recycling on their milling tandems. However, as reported by Moor and Yeo (2001) on the Darnall trials, this was not successful. Mill slippage occurred where the high volume of hot recycled mud was returned and the rollers appeared to require more intensive welding to maintain roughness. When the mud was returned near the front of the tandem, the problem extended over more mills. When returned further back (to the 5th mill), extraction fell by 0.06% (to 97.2%). Mill management therefore decided to abandon the trials.

**DIRECT CLEAR JUICE**

**Benefits:** Sucrose recovery, energy efficiency, capital, maintenance and operating costs

Following the success of clarifier mud return to diffusers, which is now the standard practice in South Africa, the South African Sugar Milling Research Institute (SMRI) revisited the long-standing dream of eliminating the entire clarification station by clarifying in the diffuser.

After an initial successful pilot scale feasibility study in 2011, Maidstone’s 300 tch diffuser was modified in 2012 to allow full scale direct clear juice (DCJ) trials. Plant scale trials were conducted in 2013 (Jensen *et al.* 2014). Cane supply constraints in 2014 restricted throughputs to a maximum of 77% of capacity, but results to date have been extremely encouraging (Jensen *et al.* 2015).
The commercial adoption of this process clearly has potential to provide dramatic benefits of sucrose recovery, energy savings and costs. Currently, ongoing trials are planned to continue through the 2016 season and these will be reported in another paper at the 2016 ISSCT Congress (Jensen and Davis 2016).

**LONG-TUBE CLIMBING-FILM EVAPORATORS**

*Benefits:* Sucrose recovery, Energy efficiency, Capital, maintenance and operating costs

Increasing factory sizes, higher imbibition rates, the increasing demand for energy efficiency and the development of continuous pans that can operate on low pressure vapour have all created a demand for large first and second evaporator effects – often with heating surfaces of 6,000 m² to 20,000 m² per effect. Some factories have adopted multiple and large Robert type vessels, but a major concern with these is the unseen sucrose loss (manifesting as ‘undetermined’ loss) by inversion in the juice while retained at high temperature in the vessels. Schaffler (2001) using corrected pH and HPLC analysis found that the Vukov formula as widely used underestimates actual inversion losses. Rein and Love (1995) measured an average retention time by tracer tests in four small Robert 1st effect vessels (total heating surface (HS) of 1074 m²) of 27.6 minutes. At an average brix in the vessel of 18%, juice temperature of 116°C (V1 pressure 170 kPa abs) and true pH of 6.7, the calculated sucrose loss would be 0.72%. My experience (unpublished) is that retention times in other Tongaat-Hulett Robert vessels were measured at 20-28 minutes. Eggleston and Monge (2005) found average inversion losses of 0.55% sucrose in the Robert vessels at a USA factory. The SMRI has measured losses as high as 2% in vessels with throughputs reduced due to drought (Anon 2015). These constitute significant losses of sugar.

Larger vessels have larger volume/HS ratios, so probably have longer retention times. The Australian SRI and ProSuTech developed a Robert design with multiple downtakes for large vessels (Wright et al. 2003), but retention times (not quoted) are still probably at least 15 minutes. These times are much longer than the 2.4 minutes residence time in Kestners (including their separators) as measured by Rein and Love (1995). The short retention in these vessels is because they have long tubes (typically 7.3 m), which allows a small and shallow diameter base, and the apparent juice level in operation is usually 10-15% of tube height (which compares with 30-40% in Robert vessels). Compared to large Robert evaporators, inversion losses (per the Schaffler formula) in these long tube vessels are 80-85% less, HTCs are similar, and they are significantly cheaper and have a much smaller footprint. For these reasons, Kestner evaporators now constitute 90% of the total 1st effect heating surface in the South African industry. One factory has two falling film tubular evaporators and four factories still have old 1st effect Robert evaporators operating in parallel with newer Kestners.

The two falling film evaporators have not been followed by others because of their juice distribution requirements and the need for high volume recirculation pumps, neither of which are required by Kestner evaporators. With correctly sized recycle line(s), the juice level in Kestners is self-regulating, so that, unlike falling film evaporators, no instrumentation or operator intervention is required.

Bosch Projects have built on the proven advantages of the Kestner design to develop an improved long tube evaporator (LTE) (see Figure 4). Instead of the separate entrainment separator common in sugar industry Kestners, their design has a disengagement zone and chevron louver separator directly above the calandria. This enables two or more vapour exit lines in different orientations. The design includes gravity-driven recirculation to ensure an adequate tube wetting rate. Operation and HTCs are similar to conventional Kestners, but with slightly lower juice retention time due to no hold-up in a separator vessel. Bosch has supplied some of these with an effective arrangement for direct contact clear juice heating within the disengagement zone. As illustrated in Figure 4, this is achieved by spraying the incoming clear juice onto the vessel walls. The low brix juice from the walls is preferentially selected for the recycling system. The vessel stands on an extended skirt on the ground floor, so foundations are simple, no supporting steelwork is required and the footprint is small.
HORIZONTALLY-CONFIGURED VERTICAL-TUBE (HCVT) CONTINUOUS PANS

Benefits: Sucrose recovery, energy efficiency, capital, maintenance and operating costs

Most of the advantages of continuous vacuum pans (CVPs) over batch pans are obvious and widely recognised:

- Energy savings from continuous operation (no steam outs and vacuum re-establishment between boilings);
- Use of lower grade steam due to the low boiling head;
- Simplicity of control;
- Small space requirement.

However, some other significant benefits are not widely recognised and do not apply to all types of CVPs. The most important of these is sugar quality, specifically crystal quality. When the first Tongaat-Hulett CVP was commissioned as an A pan at Maidstone in 1982, the production manager, Dr Stanley Graham, reported a better CV and lower fines (20% in specification 0.7mm MA sugar) in the sugar produced by the CVP than in that from their batch pans. Kruger (1983) attributed this to excellent plug flow. This was confirmed by SMRI tracer testing, which found that the crystal residence time in the 12-compartment vertical tube T-H CVP was equivalent to 17 stirred tanks-in-series when operating on A boilings and 23 stirred tanks operating on C boilings, whereas the 14 compartment horizontal steam tube FCB CVP at the same factory and the 15-compartment FCB pan at Gledhow each tested as 9 tanks in series (Rein et al. 1985).

Moor (2007) reported results from the literature confirming that well-designed (good flow path) horizontally configured vertical tube (HCVT) CVPs can achieve the equivalent of more tanks-in-series than their actual number of compartments, indicating a measure of plug flow even within each compartment. As seen in Table 1, this was not true of horizontal steam tube CVPs.

The most common HCVT CVP types are Tongaat-Hulett (T-H), also sold as Fletcher Smith (FS) or FCB vertical tube pans, the SRI-type (or similar) and the Bosch CVP. FCB supply horizontal pans with horizontal steam tubes for heating, whereas BMA’s VKT pans comprise 3, 4 or 5 mechanically stirred stacked cylindrical pans. Measured results from unstirred pans are shown in Table 1.
Table 1. Crystal residence times – Tanks in series versus actual compartments

<table>
<thead>
<tr>
<th>Factory and duty</th>
<th>Make</th>
<th>No. compartments</th>
<th>Tanks-in-series</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical massecuite tube (HCVT) CVPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maidstone A</td>
<td>T-H / FS</td>
<td>12</td>
<td>17</td>
<td>1.4</td>
</tr>
<tr>
<td>Maidstone C</td>
<td>T-H / FS</td>
<td>12</td>
<td>23</td>
<td>1.9</td>
</tr>
<tr>
<td>Felixton A</td>
<td>T-H / FS</td>
<td>12</td>
<td>12</td>
<td>1.0</td>
</tr>
<tr>
<td>Felixton C</td>
<td>T-H / FS</td>
<td>12</td>
<td>13</td>
<td>1.1</td>
</tr>
<tr>
<td>Maryborough A</td>
<td>SRI</td>
<td>9</td>
<td>12</td>
<td>1.3</td>
</tr>
<tr>
<td>Tully B</td>
<td>Mill + SRI</td>
<td>10</td>
<td>15</td>
<td>1.5</td>
</tr>
<tr>
<td>Racecourse C</td>
<td>Mill + SRI</td>
<td>36</td>
<td>41</td>
<td>1.1</td>
</tr>
<tr>
<td>NgheAn Tate &amp; Lyle C</td>
<td>Bosch</td>
<td>8</td>
<td>18</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Horizontal steam tube CVPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maidstone C</td>
<td>FCB</td>
<td>14</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>Gledhow C</td>
<td>FCB</td>
<td>15</td>
<td>9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The superior plug flow path of the HCVT pans is clear. The BMA VKT essentially comprises 3-5 stirred mixed tanks in series. By definition, this arrangement must produce a high CV, as confirmed by Hemplemann (1996).

The crystal size variation (CV) of sugar produced by a pan from a given seed quality is a function of the crystal residence time distribution. The importance of this relationship has been stressed and analysed by Hill and Orchard (1967), Rein et al. (1985), Broadfoot (1992), Journet (1994), Hemplemann (1996), Rein and Msimanga (1999), Thelwall (2000) and Moor (2007a).

Hill and Orchard (1967) derived the theoretical relationship

\[ CV = 100 / \sqrt{(n+3)} \]

where \( n \) = number of mixed cells in series. However, this was for crystals growing at the same rate from simultaneous nucleation. Rein et al. (1985) pointed out that the seed crystal size and CV and size dispersion factors affect the final CV. In Figure 5, the Hill and Orchard formula is graphed together with a more realistic relationship for CVPs boiling 0.7 mm MA crystal from good seed at 25% of final massecuite volume.

Fig. 5. Final CV for numbers of tanks-in-series for pan boilings.
Given good seed and feed control, a narrow spread of residence times (high equivalent tanks-in-series) will produce a uniform size distribution, with minimal fines. Broadfoot (1992), Journet (1994), Thelwall (2000) and Rein (2007) have explained the importance of uniform crystals both for recoveries and to meet export specifications:

- In centrifuging, the apertures between crystals are open (not blocked by smaller crystals) and free draining, less washing is needed and fines are not dissolved or pass through the screen. This improves exhaustion, reduces losses and reduces the energy requirement of reboiling;
- Affination is easier, with less loss. This is why CV is often included in export specifications.

The effects of a poor CV are intuitively obvious from the massecuite in Figure 6 – a difficult massecuite to purge.

![Fig. 6. Massecuite from a Langreney circular CVP, Bois Rouge, Réunion.](image)

Pan characteristics alone cannot ensure a good CV, but good plug flow is essential for reasonably uniform crystals as in Figure 7. These were produced in a Bosch CVP of similar type to the NAT&L unit in Table 1 which measured a performance equivalent to 18 T-i-s. Figure 9 also exhibits reasonable plug flow with minimal fines.

![Fig. 7. 'Maui White’ sugar from 8-compartment Bosch CVP, HC&S, Hawaii (CV 28%).](image)
This contrasts with the wide range of crystal sizes in Figure 8 (shown at lower magnification) from a CVP with low tanks-in-series. Some crystals have short circuited, while others have been held up. Note that the CVs of both samples are consistent with the graph in Figure 5.

![Fig. 8. Refined sugar from a 4-cell BMA VKT, United Sugar Co, Jeddah, Saudi Arabia (CV 46%).](image)

Another advantage of HCVT CVPs is low energy usage (Moor 2014). The most energy-efficient and lowest cost boiling system is a double Einwurf (‘double magma’) or full CBA boiling system, in which the C massecuite is boiled from virgin seed, the B massecuite is boiled from C magma and the A is boiled from B magma. This minimises remelting and reboiling. However, it does require good quality uniform crystal at every stage, as size variations will be cumulative. The Khon Kaen Sugar A sugar in Figure 9 is produced by this system, using 12 compartment Bosch CVPs for all three boilings. This factory routinely achieves A-exhaustions of > 67% with crystal contents > 54%.

![Fig. 9. A sugar from 280 m³ 12-compartment Bosch CVP, Khon Kaen Sugar, Thailand.](image)

HCVT CVPs do not require energy- and maintenance-intensive mechanical stirrers. Moor (2002) has shown that, because of the calandria steam temperature / pressure necessary to overcome the boiling point elevation of solution of massecuites,
calandria incondensable gases will always be of sufficient pressure to be used as jigger steam in low head pans, thereby providing a “free” circulation aid. The feed and jigger distribution system in Bosch CVPs is particularly well suited to this. They are also able to operate for long periods between energy-wasting boil-outs (Moor 2013), especially when on-line steam outs are practised.

Horizontally configured CVPs of this type thus provide both recovery benefits and energy savings.

SIEVE-PLATE FLUE-GAS SCRUBBERS

Benefits: Energy efficiency, capital, maintenance and operating costs

Moor (2007b) described nine types of flue gas cleaning equipment for bagasse-fired boilers, concluding that the best equipment to achieve the then commonly legislated maximum emission requirements of 100 to 200 mg/Nm³ was irrigated sieve plate scrubbers. These were preferred on grounds of effectiveness, minimum energy, reliability, maintenance and cost. However, since then, several countries (including South Africa, Zambia and Colombia) and international funding agencies have demanded lower particulate emission rates of not more than 50 mg/Nm³.

To meet this target, one supplier has incorporated a simple chevron louver entrainment separator in the exit gas path from their sieve plate scrubbers. A unit of this type was installed by Wellman Company on Eastern Sugars’ 200 t/h John Thompson (Australia) boiler in Thailand. The emissions from this scrubber were measured in 2014 at 19.7 mg/Nm³, with a pressure drop across the sieve plate of <500 Pa and an estimated (not measured) pressure drop across the total scrubber system of <700 Pa (70 mm w.g.). This scrubber thus comfortably meets the most stringent of new legislation at a low energy requirement.

CONCLUSIONS

The sugar industry has a long history and orders for new plant often specify repeats of familiar traditional designs. However, the more modern equipment described in this paper can bring advantages of better recoveries, greater energy efficiency and lower costs without sacrificing simplicity of operation.

ACKNOWLEDGEMENTS

I thank the SMRI, Durban for all the crystal photographs.

REFERENCES

Les équipements modernes dans les sucreries pour de bonnes récupérations pour une meilleure efficience énergétique et de faibles coûts

Résumé. Au cours de ces dernières décennies, les équipements traditionnels dans les sucreries ont été remplacés par de nouvelles conceptions visant à augmenter le recouvrement de saccharose, à l'amélioration de l'efficacité énergétique et de la réduction des coûts du capital, d'entretien et de fonctionnement. Cet article décrit quelques-uns de ces développements les plus importants, incluant de nouvelles observations sur leurs caractéristiques et leurs avantages. Les contraintes d'espace limitent la quantité de détails sur chaque équipement. Cet article décrit quelques-uns de ces développements les plus importants, incluant de nouvelles observations sur leurs caractéristiques et leurs avantages. Les contraintes d'espace limitent la quantité de détails sur chaque équipement.

- Extraction par diffusion pour éviter l'utilisation d'énergie, potentiellement exportable, tout en augmentant le recouvrement et réduisant les coûts;
- Les réchauffeurs par contact direct pour le chauffage du jus à coût réduit sans une augmentation de la demande de vapeur d'échappement pour le procédé;
- Le recyclage de la boue provenant du clarificateur pour éviter les pertes d'enthalpie, la dégradation de saccharose, la perte de puissance du condenseur, la dilution du jus, les pertes de fibres fines (bagacillo) comme carburant et les coûts d'opérations pour le filtrage de la boue;
- ‘Jus clair direct’ pour réduire davantage les pertes d'enthalpie et de saccharose pendant la clarification et aussi des coûts;
- Evaporateurs avec de longs tubes à flot ascendant (grimpant) pour haute capacité, 1er et 2e effets qui réduisent au minimum les pertes de saccharose tout en évitant le pompage;
- Appareil à tubes vertical continues, horizontalement configurées et utilisant de la vapeur de qualité inférieure qui évite le rejet de la vapeur entre deux cuves et l'utilisation des agitateurs tout en atteignant un épuration élevée;
- Épurateurs avec tamis à plaque pour une grande efficacité dans le nettoyage des gaz de chaudières utilisant moins d'énergie au moindre coût.

Dans les cas où c'est approprié, des résultats sont cités pour démontrer que l'utilisation de ces technologies ont permis à des usines d'atteindre les objectifs souhaités. Un diffuseur traitant plus de 20,000 t de canne par jour, un évaporateur unique avec chauffage intégré de jus clair et un épurateur de gaz permettant d'atteindre des taux d'émission de moins de 20 mg/Nm² avec une chute de pression de 600 Pa (60 mm jauge d'eau) sont inclus parmi les équipements de pointe.
**Equips modernos de fàbrics de azúcar, para bons recobrats, eficiència energètica y baixos costos.**

**Resumen.** En les darreres dècades, els equips tradicionals de fàbriques d'azúcar han estat substituïts per altres de disseny nou en el fitxer de recobrir més sacarosa, millorar la eficiència energètica i costos de capital, de manteniment i de operació reduïts. El treball descriu alguns de les més importants equips, incloure obseracions novedoses de les seves perfiles i les seves avantatges. Les regulacions en la extensió limiten el nivell de detalls en cada uno de ells, però se señalen referències per una major informació sobre els equips.

- La extracció per difusió per evadir el treball de potencial energia exportable, incrementar el recobrat i reduir costos.
- Calentadors de contacte directe per baixos costos de calefacció, sin incrementar la demanda de vapor de escape.
- Recirculació del fango de les clarificadors per evitar les perdides d'enthalpxia, la degradació de sacarosa, la perdida d'energia en el condensador, dilució del jugo, perdidas de bagaç combustible i eliminar els costos de manipulació de les sals de les filtres.
- Jugo claro directo per reduir aïlava més les perdides d'enthalpxia i sacarosa en la clarificació i ahorrar costos.
- Evaporadores pel·lícula ascendente de tubs largs per altas capacitats, baixos costos, 1er i 2do efecte que minimitzan les perdides de sacarosa i evitan el bombeo.
- Tacho continu configurat horitzontalment de per alta capacitat amb tubs verticals, que utilitza vapor de escape, evita les perdides de vapor entre les cociions, evita els agitadors, que logra alto agotament minimitzant el rehervir les mases cocides.
- Depuradors de plats per alta eficiència en la limpieza de les gases efluents de calderes amb baixa energia i costos. Donde se refieren resultats apropiad per demostrar que el treball de tres techniques i instalacions han permet el que les fàbriques alcanzen els objectis desitjats. Los nous equips un difusor procesant més de 20 000 t de cana per dia, un únic evaporador amb calentador de jugo claro incorporat i un depurador que alcanza razons de emissió d'una màxima de 20 mg/Nm3 amb una caiguda de pressió de 600 Pa (60 mm de agua).

**Palavras clave:** Eficiencia energética, recobrado de sacarosa, clarificación, evaporación, calidad de azúcar CVP, limpieza de gas efluente