INTERNATIONAL SUGAR JOURNAL

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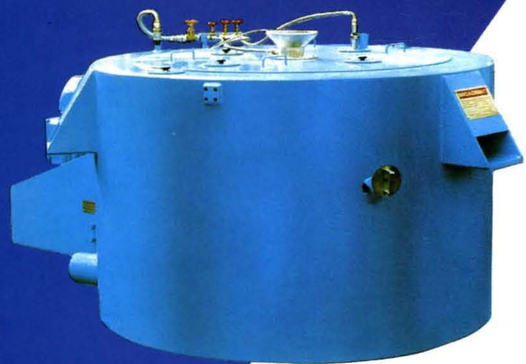

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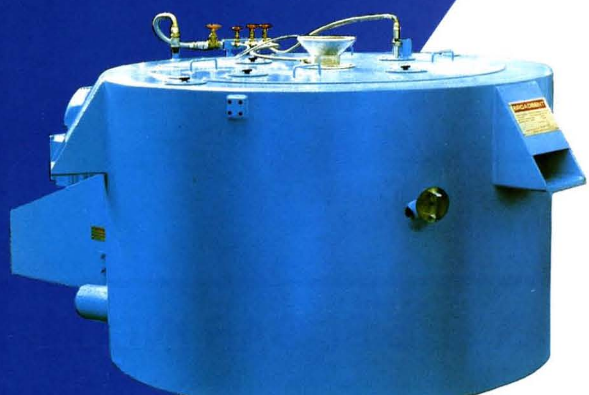

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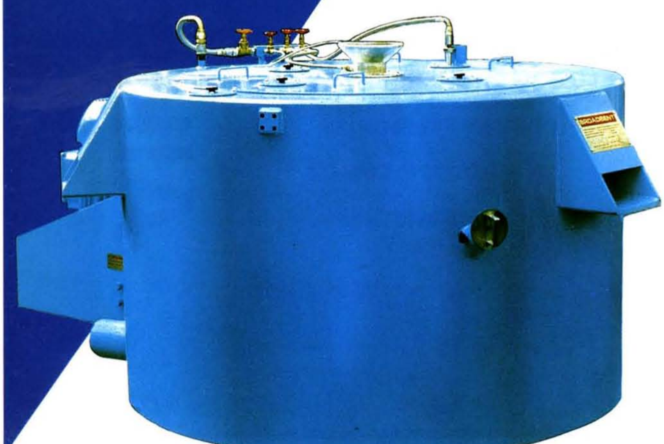

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News and views

ISJ Panel of Referees

For many years, the readers of *International Sugar Journal* have benefited from the long experience of **Dr. K. Douwes Dekker** who, after a distinguished career at the Java Sugar Experiment Station before World War II, went to South Africa, becoming Director of the Sugar Milling Research Institute. He has given us the benefit of his knowledge in the assessment of manuscripts submitted to us for publication but has now decided to pass this task on to a younger successor.

We are fortunate in obtaining the agreement to join our Panel of **Dr. Ian Sangster**, Director of the Factory Technology Division of the Sugar Industry Research Institute in Jamaica. Dr. Sangster will bring his wide experience in both research and factory operations in cane sugar manufacture to the scrutiny of submitted articles and we thank both of these gentlemen, Dr. Dowes Dekker for his great help in the past and Dr. Sangster for his help in the future.

International Sugar Organization

The Council of the ISO met on November 23, and considered a report of the Market Evaluation, Consumption and Statistics Committee. World sugar production in 1988/89 is expected to reach 108.9 million tonnes, raw value, or 350,000 tonnes less than the Committee's previous estimate, but the consumption estimate for 1989 is also set lower by 150,000 tonnes, at 108.25 million tonnes. The market is considered to be in balance, with the gap between production and consumption accounted for by the difference between crop and calendar years and by stock building. The estimated 1989 demand for imports from the free market is unchanged at 17.4 million tonnes against available supplies of 18.4 million tonnes.

During the meetings the Big Five exports (Australia, Brazil, Cuba, the EEC and Thailand) were expected to explore prospects for a new Agreement with economic provisions but no progress in this direction has been reported, perhaps because of the short interval before the GATT meetings in Montreal where sugar and other agricultural crops were expected to be discussed.

A clash at GATT

In the beginning of December representatives of the member countries of the General Agreement on Tariffs and Trade were due to meet in Montreal to review progress under the Uruguay round of negotiations to improve world trade. The scene seemed set for a clash between the US and the EEC over agricultural protection.

The US proposed a year ago that members should commit themselves to complete abolition of all subsidies by the end of the century and indicated that, in the absence of such a commitment, was not willing to consider nearer-term, intermediate measures of subsidy reduction. The EEC and a number of other member countries including a number of developing countries, considered that some measure of protection was essential to safeguard the welfare of their farming communities and were not willing to commit themselves to complete abolition.

The EEC, in particular, considers that the US is unjustified in its stance since the Montreal meeting was not to be a new negotiating meeting but one to examine progress made on the agreement reached with much difficulty in Punta del Este in 1986. In this time, the EEC has cut its subsidies appreciably and thereby reduced output. The US, by contrast, has cut its subsidies to a much smaller extent. The EEC proposed an immediate freeze on spending, to be followed by cuts in farm support to 1984 levels.

A plan had been put forward by the Cairns group of free-trading nations which incorporated aspects of both US and EEC proposals and this, it had been hoped, could be accepted as a compromise. However, this was not to be and the talks ended with no agreement. The US representatives promised to step up the use of export subsidies and the Secretary of Agriculture warned that Congress may endorse bigger funding for the Export Enhancement Program.

World sugar production, 1988/89[1]

For some time it has been obvious that world sugar production this season would show a healthy increase against last year's weather-reduced crop of 104.4 million tonnes. However, few at the beginning of 1988 would have dared to forecast a crop of more than 108 million tonnes. This is illustrated by the USDA's first forecast for 1988/89 of 103.9 million tonnes. If the USDA's first estimate had proved to be on the mark we should now be in the midst of a full boom. This level of output would have been far too low to cover requirements as there was very little surplus sugar left at the end of 1987/88.

Luckily, it appears that at least for the current season, the sugar industry will probably be spared the effects of a full boom which would have had serious long-term detrimental effects on the well-being of the industry. As F. O. Licht observe, it cannot be said often enough that another boom would only encourage the already existing tendency towards import substitution and would give a new boost to the growth of alternative sweeteners.

Licht foresees a total world production of 108,234,000 tonnes, raw value, against 104,422,000 tonnes in 1987/88 and 103,747,000 tonnes in 1986/87. Sugar from beets is expected to amount to 39.1 million tonnes or 36% of the total. This is mostly due to a favourable outlook in the EEC where beet tests show that virus yellows affecting many of the countries of the Community does not appear to have worsened sugar production prospects. Elsewhere in Western Europe, crop prospects have improved although lower forecasts have been made for Turkey and Yugoslavia.

The Soviet Union seems on course for another outstanding harvest, perhaps approaching or even exceeding the 9.8

1 F. O. Licht, *Int. Sugar Rpt.*, 1988, **120**, 509 - 518.

million tonnes of 1987/88. However, lower crops are forecast for other East European countries. In the US the beet crop has suffered from drought and production is expected to fall. This is also the case in China while Iran is also expected to produce less beet sugar.

Of the total 69 million tonnes of cane sugar expected to be produced in 1988/89, 26 million tonnes (38%) is from Asia, 18 million tonnes (26%) from North and Central America, 13 million tonnes (19%) from South America, 7 million tonnes (11%) from Africa and 4 million tonnes (6%) from Oceania. The Asian total is some 2 million tonnes higher than 1987/88, with three-quarters of this rise accounted for by India, where good monsoon rains have occurred, and China where the cane area has been increased.

Production in North and Central America is set higher by 700,000 tonnes, of which most is expected in Cuba, although the Dominican Republic crop is also expected to improve. A healthy increase is foreseen in South America this year as production in Brazil has turned out to be higher than had been expected. The serious drought which impaired the 1987/88 crop in the north/north-east region had been expected to harm the current crop but more favourable weather has improved crop prospects; elsewhere little change is expected.

African sugar production is expected to stagnate for the third year in a row, owing to reduced crops in South Africa and Mauritius, while the Oceania total is set higher because of favourable prospects in Australia. The estimate is tabulated elsewhere in this issue.

China sugar expansion problems[2]

In a bid to reverse sugar shortages, the State Council, the highest governing body in China, recently approved a plan to develop three areas of China into major sugar-producing areas. If all goes to plan, the combined output of Guangxi, Yunnan and Xinjiang will rise from 1.58 million tonnes annually to 3.6 million tonnes.

Last year total consumption was 7.3 million tonnes of which more than 2 million tonnes was imported. The gap between supply and demand widened when domestic production fell to 4,340,000 tonnes and production during the coming season is estimated to be about 5 million tonnes. The explanation lies in continued state control of sugar prices which are the same now as 25 years ago. At the same time, prices of fruit and vegetables have been allowed to rise; farmers are increasingly reluctant to grow sugar crops which are not as profitable as fish farming or growing fruits and vegetables.

The area of farmland devoted to sugar crops declined by about 100,000 hectares in 1987. Many of China's 500 sugar factories were left short of cane and in Foshan in Guangdong province four of the eleven sugar factories were closed for lack of cane. This year the local government plans to close another five. Many previously profitable factories are running at a loss of more than $200 per tonne of sugar as costs of production have mounted. In Heilongjiang province five of the 28 factories were forced to close last year and those still in production are running at half capacity.

For a long time the government put off raising the price of sugar but finally did so in July last, although not high enough to stimulate production. Expansion in the three new sugar development areas has commenced but China is looking for foreign investors and partners to assist with the program. Even so, sugar shortages are predicted for the medium term; per caput consumption is about 7kg/year, well below the world average of 20 kg. If consumption were to reach 12 kg/year by the year 2000 the then population would require double the present output of sugar.

Uncertain prospects in Brazil

C. Czarnikow Ltd. recently reported[3] their conclusions following a visit to Brazil to assess the availability of sugar, following a period in which the extent of quantities of raw and white sugar for sale from the 1988/89 crop had been of concern to the market. These concerns had been heightened by awareness that storage at the northern ports of Recife and Maceio is limited and that this might require sales for prompt shipment.

It seemed that, with production of 4.9 million tonnes, raw value, at the end of September, the crop plan target of 5.4 million tonnes for the Centre/South region was likely to be fulfilled. However, nearly all exports come from the North/North-east region and problems had arisen there. The start of the crop had been delayed for a month to allow the cane to recover as much as possible from the effects of the drought in 1987. Then production was disrupted by a cane cutters' strike in Pernambuco. The recovery from drought proved not to be complete and Czarnikow is inclined to the view that production will fall substantially short and would be surprised if the Brazilian total exceeded 8.6 million tonnes against the target of 8.9 million tonnes.

The Brazilian authorities have also shown concern for alcohol supplies and instructed southern factories with attached distilleries to cease sugar manufacture from October 25 and to make only alcohol. The National Petroleum Council is pressing for similar action with the northern crop. In all, it would seem that the overall availability of sugar is likely to be less than expected but, in view of the lack of storage, prompt sales are likely. Thus, while Brazilian sugar might exert a short-term negative impact on the market, reduced availability will probably have beneficial longer-term implications.

Barbados sugar production, 1988[4]

Sugar production in Barbados in 1988 fell 4.2% from the 1987 level of 80,000 tonnes, and marked three consecutive years of declining output.

2 F. O. Licht, *Int. Sugar Rpt.*, 1988, **120**, 549 - 550.
3 *Czarnikow Sugar Review*, 1988, (1778), 145 - 147.
4 *Latin American Commodities Rpt.*, September 15, 1988.

Pneumatic drying of bagasse

By Silvia Azucena Nebra and Isaías de Carvalho Macedo
(DE-FEC-UNICAMP, C.P. 6122, Barão Geraldo, Campinas, SP, Brazil 13081)

Industrial equipment

The industrial equipment[1] in the Barra Grande sugar factory (Lençóis Paulista, SP., Brazil), designed and built according to a project developed by the Centro de Tecnologia Copersucar, Piracicaba, SP., Brazil (Figure 1), utilizes gases that come from the boiler (a); these go through the pre-heater before entering the larger fan (b). The bagasse is fed through a conveyor and a rotary valve, entering the injector at point (c), where it is accelerated by the smaller fan through the injector. The injector throws the bagasse at high speed into the main column (d), where it is rapidly decelerated. Finally, the particles are separated from the gases in the cyclone (e) where the drying process proceeds. Dimensions of the system are indicated in Table I.

S. A. Nebra

I. de C. Macedo

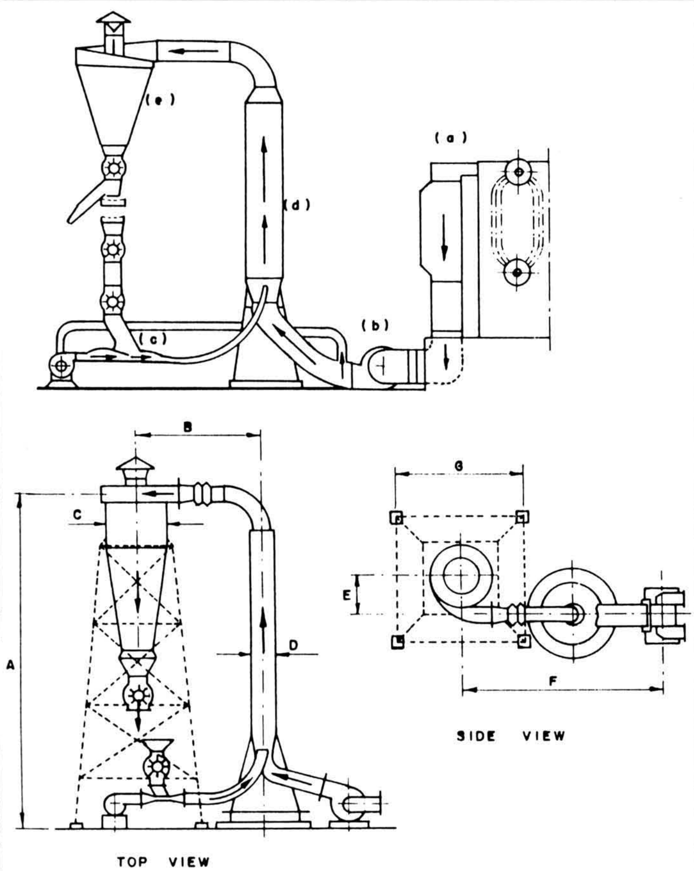

Fig. 1. Bagasse dryer[1]

Table I. Bagasse dryer dimensions[1]

A, mm	B, mm	øC, mm	øD, mm	E, mm	F, mm	øG, mm	Total weight, tonnes
25000	5200	3300	1800	1970	11000	6000	67
25000	5500	3600	2000	2170	11000	6000	70
25000	6000	4000	2200	2380	13000	6000	76

Basic equations for the injector and the column

In the pneumatic dryer we have gas of velocity v_4 carrying particles of velocity v_o. Both velocities vary along the path (y) where the drying takes place.

The fundamental hypothesis adopted in this model are:

(a) the dryer works in steady state.

(b) the particles dry according to the model of a drop of water with infinite thermal conductivity. It is predicated that the process is controlled by the heat and mass transfer at the particle surface. This hypothesis is based on the high initial moisture content of the bagasse.

(c) the particles do not interact among themselves, the single particle model being used. This hypothesis is based on the small volumetric concentration of solids, theoretically calculated as less than 1×10^{-4}.

The particles were classified in different fractions according to their shape and size; each fraction having different values of their own variables: v_{oj}, u_j, T_{oj}, ρ_{oj}, X_j, D_{pj}, f_j, α_{mj}, α_{qj}.

An experimental study was made previously[2] and the particles were divided in two main groups according to their shapes: "fibres" and "powder", within which they are sub-divided according to size. The fundamental equations for this drying process are

1 Anon: *Anais I Seminário Tecnol. Indust. Centro Tecnol. Copersucar*, 1983, 255 - 260.
2 Nebra & Macedo: *Anais VIII Brazilian Congr. Mech. Eng.*, 1985, 293 - 295.

listed below[3-6].

The mass transfer equations for fibre-shaped particles is:

$$(du/dy)_j = (-4\alpha_{mj}/D_{pj}\, V_{oj}\rho_{oj})\, [(p_{sj} - p_l)/ p(1 - p_{sj}/p)] \quad (1)$$

for powder-shaped particles the factor 4 is replaced in (1) by a factor 6.

The heat transfer equation for "fibres" is:

$$(dT_o/dy)_j = [(4\, \alpha_{aj}/D_{pj}\, V_{oj}\rho_{oj})\, (T_4 - T_{oj})/ (C_{po} + u_j C_{p2}) + (h_1 - C_{p2}T_{oj})/ (C_{po} + u_j C_{p2})] \times du/dy \quad (2)$$

Again, for "powder" particles the factor 4 must be replaced in (2) by a factor 6.

The simulation process is calculated step by step along the path (y).

The gas temperature is determined by computing the heat transfer from the beginning of the process until the point where the simulation has been conducted:

$$T_4 = \{m_4[C_{p4} + W_1C_{p1}]\, T_{4i} - m_o[C_{po}(T_o - T_{oi}) + C_{p1}(\Sigma_j x_j u_j T_{oj} - uT_{oi}) + (u_i - u)\,(h_{12} - c_{p2}T_{oi})] - Q\} / [m_4(C_{p4} + W_1C_{p1}) + (u_1 - u)m_0C_{p1}] \quad (3)$$

where:

$$u = \Sigma_j x_j u_j \quad (4)$$

$$v_o = 1/\Sigma(x_j/v_{oj}) \quad (5)$$

$$h_1 = h_{12} = C_{p1}T_4 \quad (7)$$

and Q is the heat loss in the equipment from the beginning of the run up to the point where T_4 is being computed.

The conservation of mass equation is:

$$m_o\Sigma_j x_j(du/dy)_j = -m_4(dw/dy) \quad (8)$$

The transfer of momentum equation for "fibres" is:

$$(dv_o/dy) = \pm\, g/v_{oj} - f_j\{\rho_4(1 + w)\, [v_{oj} - v_4]\, |\, v_{oj} - v_4\, |\, \}/ [v_{oj}\pi(D_{pj}/2)\, \rho_{oj}(1 + u_j)] \quad (9a)$$

and for "powder " particles is:

$$(dv_o/dy)_j = \pm\, g/v_{oj} - f_j\{3\rho_4(1 + w)\, [v_{oj} - v_4]\, |\, v_{oj} - v_4\, |\, \}/ [2v_{oj}d_{pj}\O\rho_{oj}(1 + u_j)] \quad (9b)$$

The equations (1) to (9) are a complete model for the drying in the injector and the column, considering the hypothesis made. The value adopted in (1) for the boundary layer vapour pressure, considering a boundary layer saturated, was vapour pressure at the saturation temperature (dew point) of the gases.

Specific equations for the cyclone process

Comparing the available experimental data with the results of the simulation for the injector and the column (see Figure 2) it is evident that, since an important part of the drying proceeded inside the cyclone, it was necessary to develop proper equations for this part of the process.

The flow into the cyclone may be divided into three parts: one part is the boundary layer on the external limit wall where the viscosity effects must be considered; the second is a middle part that is treated by many authors by means of a free vortex equation for an ideal fluid without viscosity; it occupies 2/5 of the external part of the radius. The third part is an internal part where the fluid flows upwards with a movement similar to a rigid body. Because of the complexity of the fluid flow and for an initial study it was decided to simplify the

3 Mendes: *Verfahrenstechnik*, 1978, **12**, (12), 791 - 794.
4 Mujumdar: *Personal communication*, 1983.
5 Macedo & Nebra: *Anais VIII Brazilian Congr.Mech. Eng.*, 1985, 295 - 288.
6 Nebra: *Doctoral Thesis* (Universidade Estadual de Campinas, SP, Brazil), 1985.

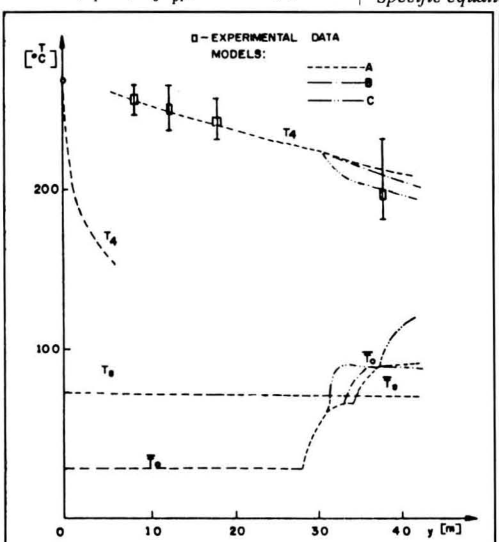

Fig. 2. Mean values of temperatures along the path for the three models of drying proposed. Inlet values, in the main column: m_4 = 76.866 kg/hr, m_o = 3.204 kg/hr; in the injector: m_4 5.163 kg/hr; T_4 = 265°C

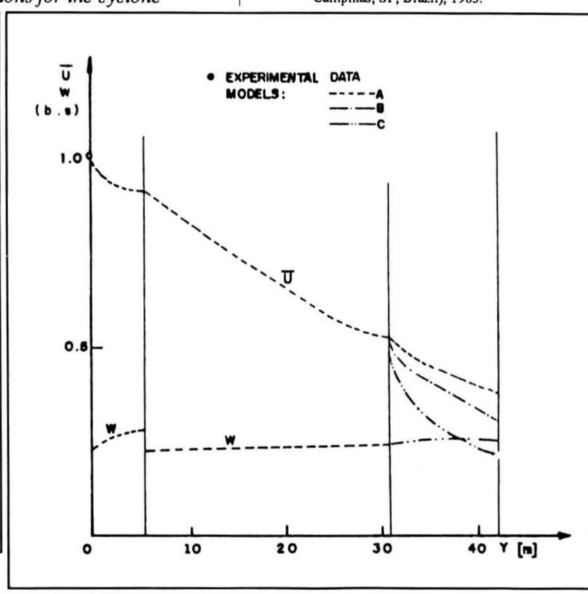

Fig. 3. Mean values of moisture along the path; the conditions are the same as in Fig. 2

problem making a model only referred to the intermediate flow region, where the particles follow the gases in their downward movement. It was considered that in this region the gases have only two components of velocity: vertical and tangential of which were adopted the mean values. Moreover, it was considered that the particles were dragged by the fluid flow with these characteristics.

For computing the mean values of the gas velocity the equations proposed by Bloor & Ingham[7,8] were used.

$$(v_4)_j = -0.5396B\sqrt{\beta}/\sqrt{Z} \qquad (10)$$

$$(v_4)_t = 1.277N/Z\beta \qquad (11)$$

where B and N are constants that depend on the gas inlet velocity, the rate of mass and the dimensions of the cyclone.

The velocity of the particles will depend on the gas velocity: in tangential direction, for "fibres":

$$d(v_o)_j/dy = -f_j \{\rho_4 (1 + w)[(v_{oj})_t - (v_4)_t] \mid (v_{oj})_t - (v_4)_t \mid \}/ [\pi(D_p/2)\, \rho_o(1 + u_j)(v_{oj})_y] \qquad (12a)$$

for "powder":

$$d(v_o)_t/dy = -f_j\, 6\rho_4 (1 + w)[(v_{oj})_t - (v_4)_t]|(v_{oj})_t - (v_4)_t|/ [4d_{pj}\, Ø\rho_o(1 + u_j)(v_{oj})_y] \qquad (12b)$$

For velocity in the vertical direction, three possibilities were considered. In the first *A* was considered the weight of the particles according to equation (9). In the second *B*, the weight of the particles was neglected. And in the third *C*, an experimental factor was introduced for adjusting the theoretical model, for "fibres":

$$d(v_{oj})_y/dy = (1/\gamma)f_j\, \rho_4 (1 + w) [(v_{oj})_y - (v_4)_y]|(v_{oj})_y - (v_4)_y|/ [\pi(D_p/2)\rho_o(1 + u_j)(v_{oj})_y] \qquad (13a)$$

for "powder"

$$d(v_{oj})_y/dy = -(1/\gamma)f_j\, 6\rho_4 (1 + w) [(v_{oj})_y - (v_4)_y]\, |(v_{oj}) - (v_4)_y|/ [4d_{pj}Ø\rho_o(1 + u_j)(v_{oj})_y] \qquad (13b)$$

The equations (1) to (8) and (10) to (12) or (13) are a complete model for the drying in the cyclone, considering the hypothesis made. The behaviour of the system may be seen in Figure 2.

Pressure drop in the system

In this type of flow system (see Mendes[3] and Mujumdar[4]), when we need to compute the properties it is usual to consider an average pressure, constant along the run, computing separately the pressure drop.

In the case of the injector and the column, the computation was made at each point of the numerical simulation, adding the terms listed below.

(a) momentum transferred from gas to particles:

$$-m_o\Sigma_j x_j(1 + u_j)/(A_1 + A_4) \times dv_{oj}/dy \qquad (14a)$$

(b) momentum transferred from the main flow of gases to the water vapour that has just left the particles at a dy:

$$-m_o\, \Sigma_j x_j/(A_1 + A_4) \times du_j/dy(v_{oj} - v_4) \qquad (14b)$$

(c) the gas supports the weight of the particles when it is rising in a vertical direction:

$$-m_o g\Sigma_j x_j/(A_1 + A_4)\times [(1 + u_j)/v_{oj}] \qquad (14c)$$

(d) the gas supports its own weight when rising in vertical direction:

$$-m_4(1 + w)g/(A_1 + A_4)/v_4 \qquad (14d)$$

Correlations used

A correlation reported by Whitaker[9] for a single infinite cylinder, was used for the heat transfer coefficient for fibres in view of the lack of data for particles with this shape. For particles with "powder" shape a correlation was adopted which has been reported by Gunn[10], who worked with data of heat and mass transfer simultaneously.

For the mass transfer coefficient, the correlations used were the same as those for the heat transfer coefficient, using the Chilton & Colburn analogy.

The γ coefficient, which corrects the vertical velocity of the particle in the cyclone, was determined with the condition that the final moisture computed by the numerical simulation was the same as the experimental value. The value obtained, in the test conditions was $\gamma = 8$.

The drag coefficient in the gas-wall friction was computed with known correlations (see, for example, Knudsen & Katz[11]), as well as the local coefficient in the bends (see, for example, Dascalescu[12]). The drag coefficient in the particle-wall friction, both in straight sections and in bends, was computed according to Mujumdar[4].

More details about other well known properties: specific heat, viscosities, diffusion coefficients, saturation temperature (dew point) in each point of the numerical simulation, can be found in Nebra's doctoral thesis[6].

Results

Figures 2 and 3 show the gas and particle temperature and moisture along the run for the conditions pointed out at the bottom of the graphs, compared with the available experimental data. The diagrams are divided in three parts that concern respectively the run in the injector, the main column and the cyclone. The coordinate y is measured along the axis of the equipment.

In case *A*, where it is a mass equation (1) which controls the process, the drying occurs from the beginning of the run and the particle does not absorb sensible heat until the drying is finished.

It can also be seen that in the injector and main column the experimental and theoretical data agree well. The same does not happen in the cyclone in cases *A* and *B*, and this was the reason why it was decided to introduce the γ factor in case *C*. The γ factor corrects essentially the residence time of the particles in the cyclone.

Figure 4 shows the theoretically predicted velocity variations along the run. It is interesting to observe the effect in the system of the injector, which gives the particles a high initial velocity.

The effect of the material size determines the functioning of this type of system and is shown in Figure 5, resulting from the simulation.

With the purpose of comparison

7 *Trans. Inst. Chem. Engrs.*, 1973, **51**, 36 - 41.
8 *Paper presented to the First European Conf. on Mixing and Centrifugal Separation*, 1974, (E6), E.95 - E.114.
9 *AIChE J.*, 1972, **18**, (2), 361 - 371.
10 *Int. J. Heat and Mass Transfer*, 1978, **21**, 467 - 476.
11 "Fluid dynamics and heat transfer" (McGraw-Hill),1958, Chap. 17.
12 "Le séchage et ses applications industrielles", (Dunod, Paris), 1969.

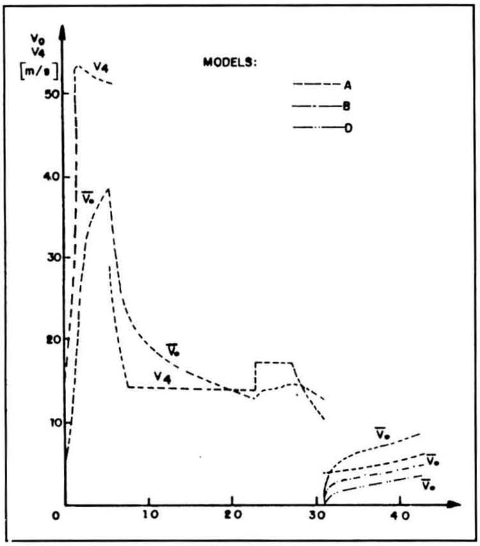

Fig. 4. Mean values of the velocities along the path; the conditions are the same as in Fig. 2

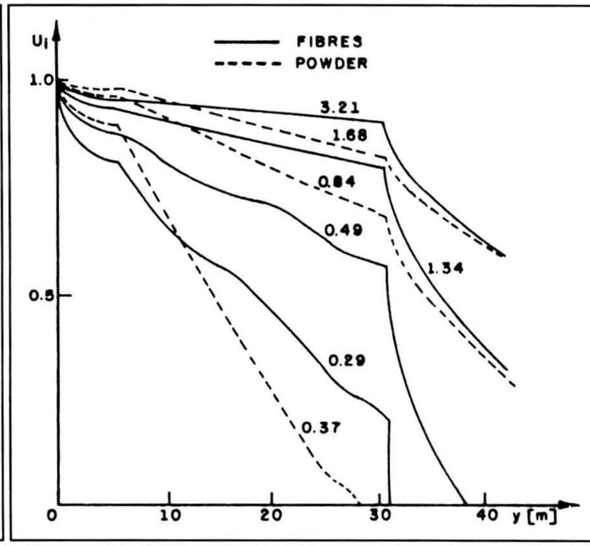

Fig. 5. Model D.– Moisture of each particle size along the path, fibres and powder type. The diameters indicated are in mm; the conditions are the same as in Fig. 2

with available experimental data, a numerical simulation was made for different bagasse rates, keeping the mass rate and inlet temperature of the gases fixed. The results are shown in Figure 6. The agreement between theory and experimental data is satisfactory, especially considering that the experimental conditions in industrial systems can not be held constant with precision.

Table II shows the comparative theoretical values of significant system variables in different places. It can be seen that the system is good even with high bagasse mass rate, with an outlet moisture of 35.8% for a bagasse mass rate of 12,000 kg/hr. The main pressure drop in the system occurs in the injector because of the feature of the equipment. It is advantageous that this main pressure drop be supplied by the small fan. The heat loss was estimated as less than 10% of the total heat transferred, and it becomes smaller when the gas outlet temperature decreases. New results and comments on other operational conditions were reported by Nebra[6].

Conclusions

Unfortunately, the only available data about the industrial system were the dimensions of the system, the size and drag coefficient of the particles[2], the mass rates, the gas composition, the gas temperatures and the initial and final bagasse moisture.

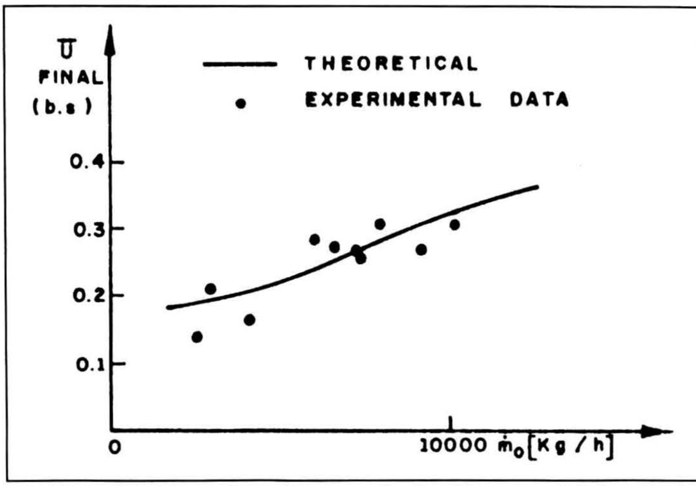

Fig. 6. Values of final mean moisture of bagasse as a function of the bagasse rate in the system; the conditions are the same as in Table II

Because of the great difficulty of measuring in industrial systems, to acquire definitive information it would be necessary to conduct more laboratory studies on bagasse drying. It would be important to measure the drying characteristics of the material, which are not well known, and the residence time of

Table II. Significant variables of the system in different places for the conditions: $(u)_i = 1.0$, $(w)_i = 0.199$; $m_4 = 86{,}400$ kg/hr; $(m_4)_i = 10{,}878$ kg/hr; $(T_4)_i = 300°C$. Injector without feed valve, with atmospheric air flowing in at a mass rate m_{air} of 9779 kg/hr

m_0, kg/hr	v_4, m/sec	v_0, m/sec	u			T_4, °C		
	In the injector outlet		In the injector outlet	In the cyclone inlet	End	In the injector outlet	In the cyclone inlet	End
2000	50.5	44.9	0.961	0.571	0.186	186	259	240
6000	49.3	44.3	0.963	0.590	0.239	171	227	180
10,000	48.2	43.8	0.965	0.621	0.319	158	201	139
12,000	47.8	43.6	0.9666	0.636	0.538	152	190	123

m_0, kg/hr	Pressure drop, kPa			t, sec	Heat loss, kW	
	In the injector	In the column	In the cyclone	Total	Total	%
2000	1.33	0.116	0.401	5.85	160	7.9
6000	3.48	0.101	0.390	6.15	123	3.1
10,000	5.77	0.087	0.380	6.43	98.2	1.8
12,000	6.94	0.080	0.376	6.56	88.7	1.5

the particles in the system.

It has been mentioned above that, in this type of system, the shape and size of the material to be dried are decisive factors. It is known that in pneumatic systems there is the problem of a short residence time of the particles. In the present case, where there is a mixture of sizes, the cyclone seems to have a decisive influence in the drying of larger particles, increasing their residence times in the system, as was mentioned by Szekely & Carr[14]. Specifically about the cyclone, it presents very interesting characteristics for the drying of larger particles.

The equations utilized in this paper for drying in the cyclone must be considered as a first model that must and can be improved, supported by a lot of new experimental data. Improvements in the flow model of the particles in the cyclone (especially when they are trapped in the boundary layer of the external wall) could bring the drying model closer to reality. Improvements in correlations for particles-gas heat and mass transfer in the cyclone would be necessary too.

Finally, it should be remembered that there is a lack of published data about drag and heat and mass transfer coefficients for particles with fibre shape.

Summary

A simulation model of drying in a pneumatic bagasse dryer was developed. This dryer comprised a particles injector, a main column and a cyclone. The equipment pressure drop and heat loss were evaluated. Theoretical equations were used to simulate the operation of an existing system and results were compared with data available from the industrial system. The influence of different parameters on the system operation (size of material, mass rate of gas and solids flow, gas inlet temperature, etc.) was analysed.

Secado neumático del bagazo

Un modelo de simulación del secado en una secadora de bagazo neumática fue desarrollado. Esta secadora comprendió un inyector de partículas, una columna principal y un ciclón. Se evaluó la caída de presión del equipo y la pérdida de calor. Se usaron ecuaciones teóricas para simular la operación de un sistema existente y los resultados fueron comparados con información disponible de los sistemas industriales. Se analizó la influencia de los diferentes parámetros sobre el sistema de operación (tamaño del material, masa promedio del flujo de gas y sólidos, temperatura del gas de entrada, etc.).

Séchage pneumatique de bagasse

On a développé un modèle de séchage dans un sécheur pneumatique de bagasse. Ce sécheur comprend un injecteur de particules, une colonne principale et un cyclone. On a évalué la perte de charge et de chaleur à travers l'équipement. On a fait usage d'équations théoriques pour simuler l'opération d'un système existant et on a comparé les résultats avec les données provenant du système industriel. On a analysé l'influence sur l'opération du système de différents paramètres (taille du matériel, débit du gaz et des solides, température du gaz à l'entrée, etc.)

NOTATION

- A: transversal area
- B: constant
- C_p: specific heat
- d_p: particle diameter, computed from sieve aperture
- D: equivalent tube diameter
- D_p: particle diameter
- f: drag coefficient
- g: gravity acceleration
- h: enthalpy
- m: mass rate
- n: fraction number of particles
- N: constant
- p: barometric pressure
- p_s: partial pressure of water vapour
- Q_y: heat loss in the running from inlet to point *y*
- t: residence time of the particles
- T: temperature
- T_s: adiabatic saturation temperature
- u: bagasse moisture content (dry weight basis)
- v: velocity
- $(V)_y$: velocity in direction *y*
- $(V)_t$: tangential velocity in the cyclone

continued on page 12

13 *Chem. Eng. Science*, 1966, **21**, 1119 - 1132.

The case for vapour compression

By U. C. Upadhiaya
(Mechanical Engineering Department, Florida International University, Miami, U.S.A.)

Introduction

The production of sugar, from either cane or beet, requires a considerable input of energy in the form of both mechanical power and thermal energy. Furthermore, to achieve the most efficient use of this total energy input, it is important to design its distribution in such a way that the quantity of steam passing through the prime movers to generate mechanical/electrical power is always less than that required for thermal energy requirements. This arrangement allows a margin for so-called make-up steam, i.e. steam which by-passes the power generating plant and goes directly to process via a pressure reducing valve and a desuperheater. This make-up steam caters for fluctuations in process steam demand.

Perk[1] has recommended that a well designed factory for cane sugar manufacture should allow for about 75% of total process steam requirements to pass through the prime movers, in order that 25% at least of total steam generation is available for by-passing power generation. Such a design arrangement would allow a margin for future factory developments, such as the installation of shredders, pollution control equipment, pan circulators, etc.

Therefore, supposing the initial design allowed for 25% make-up process steam, the future additions to factory equipment which required more mechanical/electrical power, could result in a reduction of make-up steam to, say, 15%. Such a factory would then become a good case for compressing some lower pressure vapour from, say, the 1st effect evaporator (1st vapour) to obtain a compressed vapour corresponding to the pressure of exhaust steam, and thereby achieve improved fuel economy.

In such a system, vapour from the first vessel or from the vapour cell dome is compressed to exhaust steam pressure and then returned to the calandria of the same vessel. Figure 1 is a schematic representation of this concept. In this way the vapour compression results in upgrading first vapour to exhaust

U. C. Upadhiaya

pressure, thus making the energy more readily available to do useful work at the minimum expense of energy.

The compression work can be done through a centrifugal compressor driven by an electric motor, or turbine, or through a device known as "thermo-compressor" where high pressure live steam works as motive power, passes a nozzle, converting its pressure or potential energy into kinetic energy and through surface friction or adhesion of this steam jet entrains the surrounding low pressure vapour and delivers the mixture of live steam and low pressure vapour at an intermediate pressure corresponding to exhaust pressure and temperature.

In order to improve heat economy, some eighty years ago efforts were made by the European beet sugar industry to adopt vapour compression. These trials were discontinued, partly because evaporation under pressure had been successfully carried out in the beet sugar industry and the evaporator condenser loss was either eliminated or reduced. In the cane sugar industry high exhaust pressure may provide more bleeding facilities and reduce the size of the evaporation station by reason of the increase in overall temperature difference, but simultaneously it increases the steam consumption per unit generated in turbines, which in turn reduces the margin between exhaust produced and process steam requirement.

Higher pressure boiling of juice in the first vessel in a cane sugar factory raises the temperature of the clarified juice and increases the inversion of sucrose, especially when a large quantity of vapour bleeding is required. Excessive vapour bleeding can result in the need for bigger first vessels with longer retention time which further accelerates the rate of inversion. In the beet sugar industry, owing to the absence of reducing sugars in beet juices, the clarified juice can be sent to the evaporator at a pH above 8.0, thus considerably reducing the danger of inversion. Owing to the presence of reducing sugars in cane juices, the pH of the clarified juice may be taken to only slightly above 7.0. Both inversion of sucrose and decomposition of reducing sugars are governed by the similar parameters (pH, temperature, and time). Reduction of boiling temperature, the

1 *S. African Sugar J.*, 1962, **46**, 577 - 587.

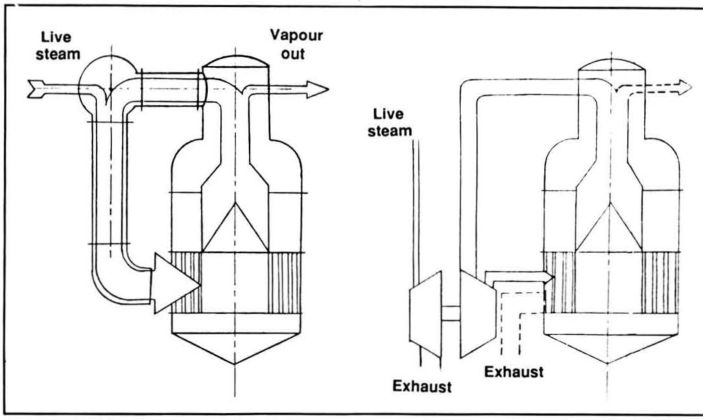

Fig. 1 (a). Evaporation with thermo-compression

Fig. 1 (b). Evaporation with mechanical vapour compression

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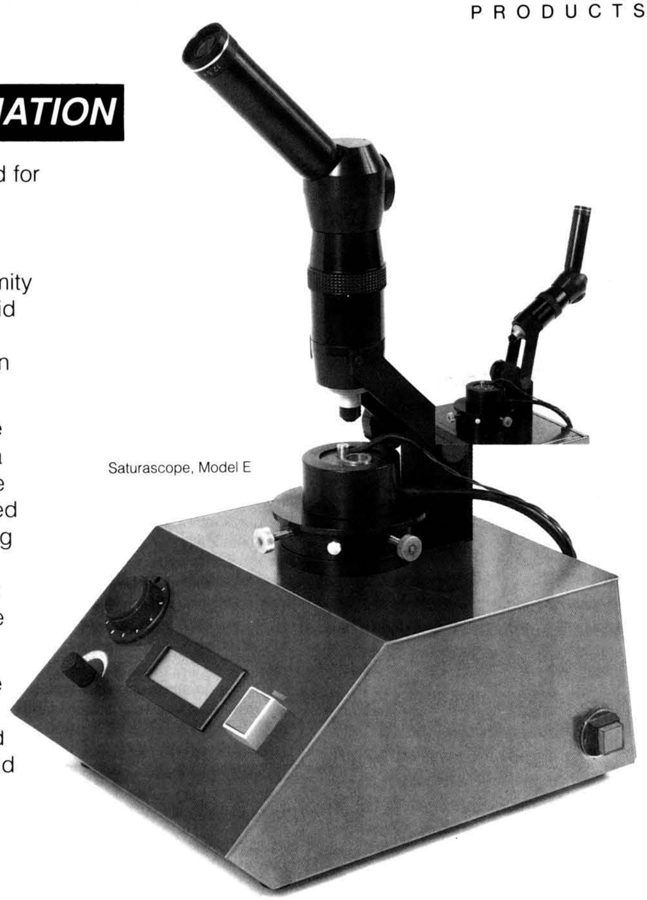

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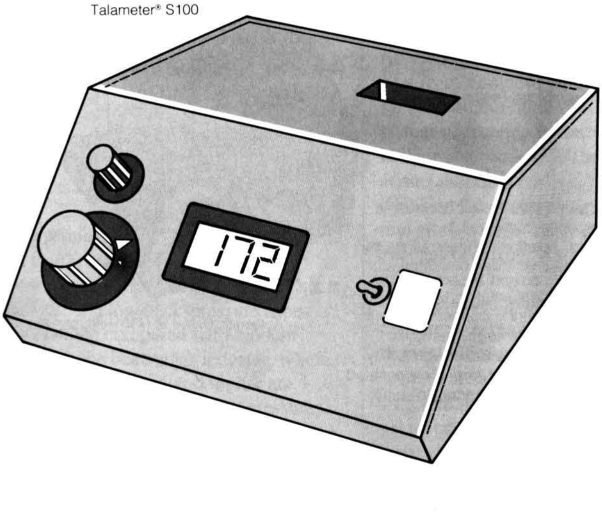

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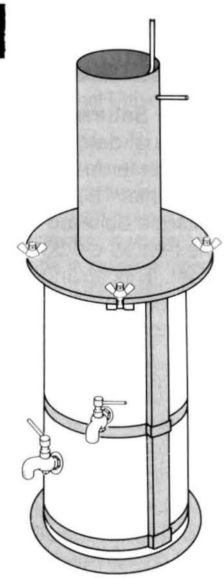

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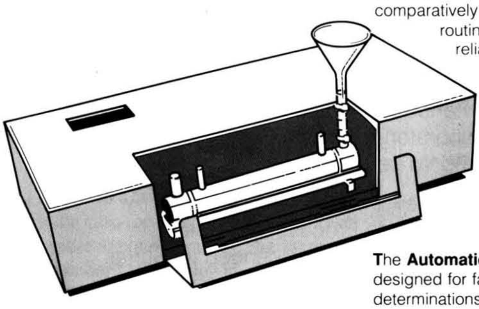
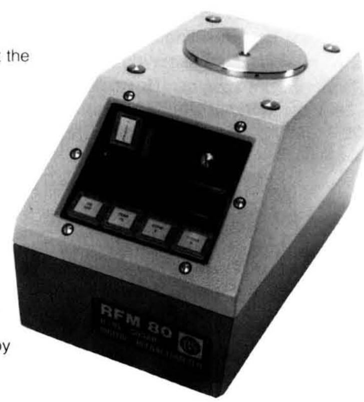


Automatic Digital Polarimeter



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retention time of the juice in the vessel, and the correct pH are all necessary in cane sugar factories to reduce the chances of inversion of sucrose and decomposition of reducing sugars[2].

In 1928 and 1929 the Java Sugar Experiment Station investigated the question of whether pressure evaporation would be suitable in the cane sugar industry for concentration of the clarified juice from defecation and sulphitation factories and confirmed that a pressure evaporator scaled more quickly than the standard evaporator. As a matter of fact the pressure evaporator scaled so quickly that the rate of flow of the clarified juice into the pilot plant had to be reduced shortly after starting a test, in order to maintain the final Brix of 50°. In the beet sugar industry the juice is normally concentrated under pressure-evaporation to about 60° Brix, the final concentration to 65/70° Brix being carried out in one or two vessels working under vacuum[3].

From the tests conducted at the Java Sugar Experiment Station, we learnt that cane juices clarified by the simple defecation or sulphitation methods caused such a heavy scaling of the heating surfaces that pressure evaporation of such juices could not be considered a worthwhile proposition. Since juices clarified by these two processes are heated to only approximately 218°F (103°C at sea level) before settling, heating to much higher temperatures in the first effect of an evaporator leads to secondary precipitation, resulting in heavy scaling of the heating surfaces of the first effect.

The trend nowadays is to order new prime movers for a back-pressure of 15 to 20 psig in preference to the previous specification of 10 psig. This is still rather a low back-pressure especially when compared with modern trends in the beet sugar industry, where pressures of 30 psig and higher are common. These higher back-pressures are required in order to operate pressure evaporators. However, the cane sugar industry is more limited in the temperatures which are allowed in the first effects of the evaporators and, because of this, back-pressures as high as those used in the beet sugar industry are not used in the cane sugar industry[4].

Although pressure evaporation is a standard practice in the beet sugar industry, many European sugar factories adopted vapour compression successfully after World War II to achieve further fuel economy. Recently, the cane sugar industry in South Africa has also successfully adopted vapour compression in pursuit of the conservation of energy.

Before discussing the theory of vapour compression it is necessary to review the first laws of thermodynamics and the Carnot Cycle, which are given as follows:–

First law of thermodynamics:–

The first law of thermodynamics can be stated as "Energy can be neither created nor destroyed, but only converted from one form to another". In essence the first law of thermodynamics may be simplified to a statement that we can convert chemical energy into heat, mechanical or into electrical energy, and that these processes are reversible.

Second law of thermodynamics:–

There are many different ways of stating the second law. One of these is the first enunciation, given by Lord Kelvin as, "it is impossible to transfer heat from a colder system to a warmer system without other simultaneous changes occurring in the two systems or in their environment". The second enunciation is that, "It is impossible to take heat from a system and to convert it into work without other simultaneous changes occurring in the system or in its environment (surroundings)."

Related to the second law are the concept of reversibility, entropy, and thermal efficiency. A reversible process is one where both the system and its surroundings can be restored exactly to a prior state; all other processes are irreversible. Strictly speaking, no real process is reversible but it is a useful concept, and many actual processes closely approximate this condition.

Scientists were long ago aware of the fact that the temperature of the heat carrying medium is much more important than the quantity available and the ratio Q:T (heat quantity divided by the absolute temperature) became known as its entropy. Entropy is actually a mathematical concept and is the name given to the quantity Q/T, which appears so frequently in the thermodynamic analysis that it seemed desirable to give a name, and is represented by letter S. There are no absolute values of entropy; we deal with difference of entropy between stated points a and b. We can only equate differences of entropy for reversible processes and for a reversible process as:–

$$S_b - S_a = \int_a^b dQ/T$$

This definition of entropy in terms of the reversible heat transfer dQ applies regardless of whether the actual process is reversible or irreversible. We note from the above equation that a reversible adiabatic process ($dQ = 0$) is isentropic (S = constant).

Cycle

If we put together a series of processes so that the beginning and the ending points are identical, the sequence is termed a cycle.

The efficiency of a cyclical process is the ratio of the net heat ouput to the total heat input. If Q_1 is the heat input and Q_2 is the heat output of a cycle, then the first law shows the thermal efficiency of the cycle is:

$\eta = 1 - Q_2/Q_1$

The maximum thermal efficiency for a reversible engine following the second thermodynamic law is $\eta = 1 - T_2/T_1$, where T_1 and T_2 are the (absolute) temperatures of the heat received and rejected, respectively, in the cyclical process.

Carnot cycle

The Carnot cycle is a reversible

2 Perk: *I.S.J.*, 1966, **68**, 361 - 363.
3 Idem: *S.M.R.I. Bull.*, 1957, (3).
4 Idem: *ibid.*, 1970, (23).

four-process cycle consisting of alternating isothermal heat transfer processes and adiabatic compression or expansion processes as shown in Figure 2. The second law shows that a reversible cycle is the most efficient of all cycles operating between two given temperature levels.

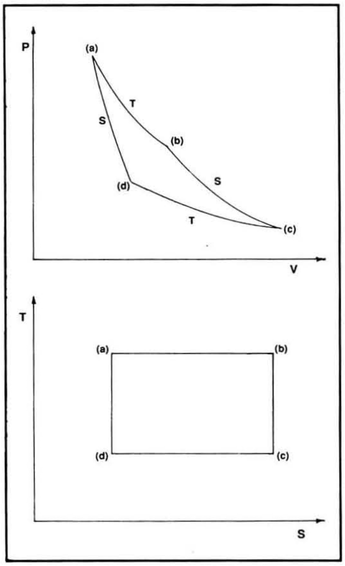

Fig. 2. Carnot reversible cycle

From Figure 2 we see that:

(1) from a to b, heat enters the engine at a constant temperature, providing a reversible isothermal expansion;

(2) from b to c, reversible adiabatic expansion occurs until the temperature drops, i.e. isentropic expansion;

(3) from c to d, heat is removed from the engine at constant temperature, corresponding to a reversible isothermal compression; and

(4) from d to a, reversible adiabatic compression occurs until the temperature rises to its initial values; i.e. isentropic compression.

The Carnot Cycle may be evaluated by working around:

at a, temperature $T_a = T_{high}$;
Entropy = S_a
at b, temperature $T_b = T_a = T_{high}$;
Entropy = S_b
at c, temperature $T_c = T_{low}$;
Entropy $S_c = S_b$
at d, temperature $T_d = T_c = T_{low}$;
Entropy $S_d = S_a$

The heat flows into and out of the system are:

$$Q_{in} = T_{high} (S_b - S_a)$$
so that $(S_b - S_a) = Q_{in}/T_{high}$
$$Q_{out} = T_{low} (S_c - S_d) = T_{low} (S_b - S_a)$$
or $(S_b - S_a) = Q_{out}/T_{low}$

The thermal efficiency of the entire cycle is:

$$\eta = (Q_{in} - Q_{out})/Q_{in} = [T_{high} (S_b - S_a) - T_{low} (S_b - S_a)]/T_{high} (S_b - S_a) = (T_{high} - T_{low})/T_{high} = 1 - T_{low}/T_{high} \quad (1)$$

where the temperatures are in absolute degrees.

We can further establish another interesting equation as follows:–

$$(S_b - S_a) = Q_{in}/T_{high} = Q_{out}/T_{low} \quad (2)$$

Theory of vapour compression

Vapour compression is based upon the theory of the Carnot Cycle. We need to modify the equations (1) and (2) to express the performance of vapour compression. As there is no heat transfer during the adiabatic (isentropic) expansion and compression, the cycle is performed between the temperature of vapour before compression, say T_b, and the temperature of compressed vapour T_e, where suffixes b and e represents the beginning and end of the performance. If Q_b represents Q_{out} and Q_e represents Q_{in}, the equation is modified as under:

$$Q_e/T_e = Q_b/T_b \quad (3)$$
or $Q_e T_b = Q_b T_e$
and thus $Q_b = (Q_e \times T_b)/T_e$

The heat energy supplied to compress the vapour being the difference between Q_e and Q_b, it follows that

$$Q_e - Q_b = Q_e - (Q_e \times T_b)/T_e = Q_e (T_e - T_b)/T_e$$

For each heat unit supplied to the cycle, i.e. $(Q_e - Q_b = 1)$

$$Q_e = T_e/(T_e - T_b) \quad (4)$$

Equation 4 indicates that the cycle will obtain highest efficiency when the temperature difference T_e - T_b is of a low value[5].

As there is a corresponding absolute pressure for an absolute temperature for saturated vapour the efficiency of compression can be expressed as an inverse function of the pressure ratio of vapour before and after compression. Therefore, it is the designer's goal in designing a vapour compression station to have the smallest pressure difference between the vapour pressure at the dome (1st vapour) and the compressed vapour pressure in the calandria of the evaporator vessel[6].

In a mechanical vapour compression, for each kWh energy expenditure the theoretical value of Q_e will thus be:

$$Q_e = 860 \times T_e/(T_e - T_b) \text{ kcal/kWh}$$
or $3413\ T_e/(T_e - T_b)$ BTU/kWh

where T_e and T_b are absolute temperatures. When vapour compression is performed in thermo-jet compressors, the heat is supplied by injecting the live steam instead of mechanical energy being converted to heat energy.

The latent heat in steam forms the bulk of the heat it carries. Table I shows the percentage of latent heat in the total heat per kg of saturated steam.

Suppose by the use of mechanical vapour compression we raise the

5 Tromp: *I.S.J.*, 1947, **49**, 289 - 292.
6 Iverson: *Sugar J.*, 1981, **44**, (1), 15 - 20.

Table I

Temperature, °C	Pressure, kPa	Total heat (T), kJ/kg	Latent heat (L), kJ/kg	Ratio L : T, %
60	19.92	2609.0	2357.9	90.37
95	84.53	2667.8	2269.8	85.08
100	101.3	2675.8	2256.7	84.34
107	129.41	2686.7	2238.1	83.3
109	138.51	2689.8	2232.7	83.0
120	198.53	2706.3	2202.5	81.38
130	270.12	2720.5	2174.2	79.92

ISJ Abstracts

Cane sugar manufacture

Design of vertical vessels and storage tanks for molasses and other liquids of the sugar industry

R. K. Behl and R. K. Vaish. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, E.55 - E.63.

A detailed study was made of the design of mild steel storage vessels for molasses and other liquids, with the aim of optimizing the strength:weight ratio. Methods used to calculate the optimum dimensions of closed and open tanks are explained and the cost benefits of optimizing shell thickness indicated.

Overall working efficiency of the factory based on non-sugars in cane and cane crushed

P. Ramaswamy and S. Kaliyamurthy. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, M.1 - M.7.

It is shown how it is preferable to optimize the crushing rate and minimize losses rather than increase the rate and incur higher losses, particularly at the time of the season when the cane non-sugars and fibre contents are greater.

Effect of depithed bagacillo on the behaviour of muddy juices in filtration

S. C. Sharma, S. K. D. Agarwal and P. C. Johary. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, M.9 - M.22.

A drop in purity from mixed to clear juice and from clear juice to Oliver filtrate was attributed to use of too fine a bagacillo; tests showed that the problem could be solved by using more fibrous bagasse material instead of pith at 5% on muddy juice.

BH molasses clarification

K. S. Jadhav. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, M.23 - M.25.

Laboratory-scale clarification of *B*-heavy molasses of 60 - 64°Bx in centrifuges raised the purity and improved the reducing sugars:ash ratio; comparable results on a factory scale would, it is suggested, reduce sugar losses and increase recovery.

Pan Anant: the Indian contipan. Basic design and performance

M. Anand. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, M.27 - M.34.

Details are given of a continuous vacuum pan designed by the author; a 7-stage prototype installed for *A*-massecuite boiling at Ponni Sugars boils 320 - 350 tonnes of massecuite per day of 0.75 - 0.80 mm crystal size from a seed footing of 030 - 0.35 mm particle size. Advantages of the pan over a conventional batch pan are indicated.

Exhaustibility increase and viscosity reduction in sugar manufacture

R. Kumar, P. Sanyal and N. P. Shukla. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, M.43 - M.48.

Tests are reported on the performances of four surfactants, designated NPR-l, NPR-2, NPR-3 and NPR-4, by comparison with Hodag CB-6 used to reduce molasses viscosity and increase crystal recovery. Tabulated data indicate that NPR-3 and NPR-2 were clearly superior to Hodag CB-6.

Bactrinol-100 - a potential and promising biocide for the sugar industry

K. C. Rao and S. Thangavelu. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, G.27 - G.33.

Bactrinol-l00 (2-bromo-2-nitro-propane-1,3-diol) inhibited bacterial growth in juice when added at 500 ppm, allowing gur to be prepared from the juice even after 48 hours' storage; however, degradation products of the bactericide caused sucrose inversion during gur manufacture. Dipping the ends of cut cane in Bactrinol-100 minimized losses associated with staleness, while the product is also considered promising in cane mill sanitation.

Some problems in chemical control

D. P. Kulkarni. *Proc. 50th Ann. Conv. Sugar Tech. Assoc. India*, 1987, C.1 - C.9.

See *I.S.J.*, 1988, **90**, 109A.

Free-turning back rolls

G. DeLaune. *Sugar J.*, 1988, **50**, (10), 14 - 17.

The effects on performance of removing the pinions from the discharge rollers[1] on all but No.1 mill in a 6-mill tandem at the author's factory are discussed. Tabulated data and graphs indicate a 2 unit fall in average bagasse moisture and a 0.41 fall in average bagasse pol as a result of the modification.

Force feeding a two-roll crusher with a rubber belt conveyor

D. Martinez. *Sugar J.*, 1988, **50**, (10), 18 - 21.

Various arrangements for forced feeding of cane to a 2-roller crusher at Raceland factory are described with the aid of diagrams. Replacement of a slat-and-chain apron conveyor (which, installed in the feed chute, had proved costly to maintain and was responsible for considerable lost time) with a rubber belt conveyor, also mounted inside the chute, resulted in the best performance of the crusher since its installation in 1961 and led to a considerably higher extraction and daily cane throughput with no maintenance or lost time problems. Even the loss of most of the cleats from the belt (because of poor vulcanization) did not seem to affect belt performance, and rubber was considered to grip prepared cane better than steel. A grooved feed roller between the bottom of the chute and the lower crusher roller prevents cane spillage into the juice pan.

Green cane harvesting - a sugar miller's view

N. Farmer. *Australian Canegrower*,

1 Anand *et al.*: *I.S.J.*, 1987, **89**, 169 - 172.

1988, **10**, (3), 26.

The disadvantages of green cane processing associated with its higher trash content are discussed on the basis of experience at Macknade sugar factory. Because it is light in weight and yet occupies space, the trash represents a substantial increase in bin and transport requirements and hence in the amount of tipping needed, so that the crushing rate may fall appreciably. Since trashy cane tends to flow in bunches rather than continuous streams, it causes problems in conveyor speed control and thereby results in overloading and spillages as well as fluctuations in the loads on a shredder. Because trash is light it can easily get caught up in awkward spots and cause chokes and mill stoppages; because it is relatively incompressible, large amounts can impose considerable strain on a mill and cause roller and/or gear breakages. Increase in mechanical stresses causes greater wear in turbines and gearboxes as well as fatigue failures. The trash is also responsible for increased bagasse losses, while dirt (present to the same degree as in burnt cane, as shown by analysis, and possibly hidden by the trash) causes boiler tube wear and reduced steam output. Benefits of green cane include a more continuous supply in wet weather, preventing mill stoppages and the use of oil as auxiliary fuel when bagasse stocks are depleted.

Processing of green cane

J. Baird. *Australian Canegrower*, 1988, **10**, (3), 26 - 27.

During 1986 and 1987, the processing of large quantities of green cane at Macknade had no major effects on sugar manufacturing rate or quality; however, much has yet to be learnt about green cane processing, and maintenance or improvement of sugar quality will depend on reduction in the amount of trash and minimizing delays between harvesting and delivery to the factory. Although there appears to be little difference between fresh clean green and burnt cane in terms of total impurity content, burnt (particularly old) cane can deteriorate much faster than green cane under hot, humid conditions and so is more likely to introduce deterioration impurities, while green cane can increase levels of impurities associated with a greater trash content.

An experimental investigation of the performance of disc pumps in transferring viscous liquids in sugar manufacture technology in Cuba

A. M. Grabovskii, O. N. Tsabiev, V. Molina M., M. I. Bortnik and E. Perez. *Rpt. Odessa Polytechn. Inst.*, 1987, 16 pp.; through *Ref. Zhurn. AN SSSR (Khim.)*, 1988, (7), Abs. 7R432.

Centrifugal pumps as used in the sugar industry are subject to rapid wear and to damage of their working parts and are of low efficiency. It was found that replacement of the impeller with a disc raised the efficiency by 25% with simultaneous increase in head and delivery when pumping media having a viscosity of 4×10^{-4} m²/sec. A method is suggested of calculating and designing disc pumps to handle molasses, for which they have a greater efficiency than centrifugal pumps.

Growth and development of centrifugal machines in the Indian sugar industry

J. S. Mehta. *Indian Sugar*, 1988, **37**, 519 - 523.

An account is given of the development of centrifugals and massecuite reheaters and of progress in their use in Indian sugar factories.

Whole reduced mill loss, reduced imbibition and performances of individual mills

P. K. More. *Indian Sugar*, 1988, **37**, 577 - 586.

The author criticizes the Noel Deerr method of calculating milling performance and sets out his own system of equations for calculating whole reduced mill loss, imbibition efficiency and mill performance.

Environmental aspects of the Florida sugar cane industry

J. R. Orsenigo and C. E. Barber. *Proc. Inter-Amer. Sugar Cane Seminar*, 1986, 67 - 72.

Analysis of the air for total suspended particulate matter in the Everglades Agricultural Area showed that it was higher during the cane season (which coincides with the dry season), although continuous monitoring for ozone and SO_2 indicated that they did not exceed permissible levels. Factory effluent and the contents of receiving ponds at seven factories revealed recoveries of six chemicals used in cane that were below normal; this was attributed to possible interference by other components in the effluent. However, a groundwater monitoring program initiated in 1984 has shown that very little of volatile organic, base/neutral and acid-extractable compounds, pesticides or herbicides (out of those tested) are transported more than a few feet from the waste water pond, whereas contents of Na, Cl, Fe, colouring matter and odoriferous compounds plus total dissolved solids in groundwater (to which they are readily transferred from effluent) have shown a significant increase; the metals Ba, Mn, Se and As occur in groundwater only in trace quantities.

Cogeneration of energy in a raw sugar factory

J. E. Lima. *Proc. Inter-Amer. Sugar Cane Seminar*, 1986, 85 - 95.

Measures that could be adopted in a hypothetical factory of 3600 tcd crushing capacity so as to increase its energy efficiency and provide excess power for sale to the public utility are set out in the form of three cases which are compared with the basic scheme and with one another to show the electricity generation levels under the different steam schemes.

Studies on the chemical composition of the ash of bagasse used as fuel in the cane sugar industry in Egypt

A. Abd-Elkader. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 200 - 210.

Despite the use of identical boilers and operation of the furnaces at the same temperatures at two sugar factories in Egypt, the ash at one factory tended to slag while at the other it was in a loose, friable state. Chemical analysis of bagasse samples from both factories revealed distinct differences, although the factories processed the same cane varieties. Analysis of bagasse samples from other Egyptian factories showed variation in their chemical composition from one area to another as a function of variety, soil and environmental conditions in the cane area. Operation of the furnace at a temperature below that at which the ash sinters (as determined by ash analysis) is necessary.

Time factor in the relation recovery/usage of energy through the agro-industrial process of the sugar cane and its products

G. L. Alemán. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 311 - 318.

The importance of the time that elapses between cane burning and/or harvesting and manufacture of the final product in regard to the optimum relationship between energy recovery and usage is discussed; as starting point, the author takes the energy in the cane and calculates the amount obtained in the form of sugar, steam and electricity obtained by burning the bagasse and various by-products such as alcohol and bagasse cellulose, and the amount of energy used and lost in process. The various processes are then examined in turn to show the effects of residence time and how efficiency may be raised; boiling schemes are compared, and a $2^1/_2$-massecuite scheme shown to be the best in terms of the time factor and energy recovery, with the advantage of requiring manipulation of only one magma. The most economical and efficient steam scheme is one in which exhaust steam from the turbines is of sufficient pressure to meet the needs of the evaporator, vacuum pans and juice heaters without any excess that could be wasted. Simultaneous production of sugar and alcohol is briefly discussed.

Sugar dust collection system

B. S. Gurumurthy. *Indian Sugar,* 1988, **37**, 641 - 645.

Types of dust separator and the bases on which they operate are surveyed and the wet system used at Ponni is described with the aid of a diagram.

Some thoughts on improving sugar mill roller shell life

S. J. Field. *S. African Sugar J.*, 1988, **72**, 181 - 182.

Cast iron is used in the manufacture of mill rollers because of its open grain structure (which is etched by juice to yield a rough surface which enables the roller to grip the cane and extract its juice) and because it is cheaper and easier to cast than steel. However, welding of shell grooving with hard-facing electrodes removes the need for roughening, while the brittleness and relative softness of cast iron lead to wear and its associated disadvantages. The author calls for an investigation to find an alternative shell material that would be suitable for welding and a welding system that could be used *in situ* to restore worn material at regular intervals, thus allowing the life of a shell to be considerably extended with a number of attendant advantages.

Plastic mill bearing liners at Breaux Bridge Co-op

K. McGrew. *Sugar J.*, 1988, **50**, (11), 17.

Successful use of nylon bearing liners on the back roller of No.1 mill at Breaux Bridge Sugars in Louisiana is reported. Details are given of their operating parameters and advantages as well as specifications of the nylon used.

Production of very low colour (VLC) crystal sugar

S. Quaiyoom and E. Rodriguez. *Sugar y Azúcar,* 1988, **83**, (7), 22, 26.

A 4-day trial at a Mexican sugar factory is reported in which 85 ppm Maztreat SDC (a product of PPG Mazer Chemicals Inc.) was added to remelt liquor of 60°Bx as it was being fed into a 6000-litre tank; when the tank was 75% full, 250 ppm phosphoric acid was added, followed by pH adjustment to 7.2 - 7.5 with lime when filling was complete. The syrup, heated to 85 - 90°C, was then transferred to a flotation clarification station where 10 ppm Mafloc 724 was added as a 0.1% solution. The treatment reduced the colour of clarified syrup, filtered syrup and final sugar by 20, 50 and 17%, respectively, by comparison with normal processing (giving a sugar colour of 0.5% on Brix), and also reduced active carbon and filter aid use by 54 and 50%, respectively.

Reverse osmosis concentration of mixed juice

D. Hsu. *Ann. Rpt. Hawaiian Sugar Planters' Assoc. Expt. Sta.*, 1987, 58 - 59.

A total of 8 runs was conducted on reverse osmosis of unlimed mixed juice at Oahu Sugar Company, with run times ranging from 3 to 21 hr. The decrease in permeate flux with time appeared to be less drastic than found previously with primary heater juice, although there was still a substantial drop in flux throughout each test, and checks with water indicated permanent fouling of the membrane tubes sufficient to cause the flux to fall far below the minimum acceptable level as specified by the membrane manufacturer; normal cleaning failed to restore the initial performance of the membrane. It is concluded that, although lime could have accelerated fouling, it was not the primary cause of the problem; a modified cleaning procedure was to be investigated.

Beet sugar manufacture

On the 1987 campaign and new technological developments

K. Buchholz and D. Schliephake. *Zuckerind.*, 1988, **113**, 361 - 379 *(German).*

A survey is presented of the 1987/88 campaign in West Germany, starting with data on beet area and yields, sugar content and quantity of beet processed, sugar production, juice analyses and molasses composition. Technological aspects are also briefly discussed as follows:

Diffusion and pulp pressing: Considerable increases in the quantities of press-water suggested that the optimum point at which to introduce it into the diffuser should be higher than hitherto, whereas a noticeable increase in the sugar content of the water suggested a lower point. However, since a change in sugar extraction at two factories (depending on which press-water parameter had altered the more) was still within the limits of analytical error, the previous recommendation of adding the water at a point about 90% of the diffuser length still stood. The average dry solids content in pressed pulp was higher at 31.26% than previously, with a range of 28.4 - 33.2%, the upper limit remaining unchanged but the lower limit being almost 4 units up on the previous campaign. New types of press are capable of giving 36% dry solids at high throughput, or only 30% but at very much greater throughputs. Further work is reported on pulp pressing aids, including investigations of the nature of the action of Ca^{++}, particularly in combination with controlled thermophilic infection in diffusion at 65 - 70°C. Experimental studies of the pulp dewatering process involving cation exchange showed that the crucial factor influencing the dry solids content achieved after 20 minutes' pressing was the rate of water discharge from the pulp tissue, and comparison between uninfected and infected diffusion indicated the positive effect of infection on both the rate of discharge and the final amount of water removed, particularly in the presence of Ca; however, there was no confirmation that cross-linkage and stabilization of the pectin structure at lower pH or the additional effects of processes triggered by microbes (e.g. cleavage of the methyl ester in the polygalacturonic acid) were the direct causes of the improvement. Electron microscopy revealed that dots in the beet cell wall were not open stretches allowing convective movement of water between adjacent cells but thin spots in the wall which acted as barriers to water transfer; it was also found that the central lamella in the cell walls (consisting primarily of pectin) became thinner as a result of mild treatment of exhausted cossettes with acetic acid, while subsequent treatment with molasses caused marked shrinkage, an indication of linkage or dewatering processes which should simultaneously improve the stability of the cell wall. Statistically significant changes were observed in the intercellular spaces that act partly as water ducts; pulp from diffusion in the presence of infection contained more free intercellular spaces, the number of which grew with molasses treatment, thus increasing the availability of paths for water discharge, although the mechanism of water flow through the cell wall remains unexplained. A diffusion scheme patented by Ponant is described which aims to increase the dry solids in pulp through the use of alkaline conditions created by pretreating the cossettes with limed thin juice at 20°C, followed by diffusion in a De Smet unit at 70°C and pH 8.5 and dewatering of the pulp in a special, very long, rotary spindle press.

Juice purification: Criteria of optimum preliming were studied in model tests which showed the need for definite pH stages; a continuing sequence of pH changes will nullify the effect of mud conditioning. Back-mixing is as important as pH for optimum preliming, but the amount involved can only be decided empirically. The relationship between back-mixing and alkalinity is affected by an apparent loss of alkalinity when the alkaline material is bound in the coagulate. In a new type of vertical carbonatation vessel as installed in the Euskirchen sugar factory of Pfeifer & Langen, the gas is distributed through directional tubes at right angles to the axis of the vessel and provided with gas discharge slots on the underside. A rotary spindle running concentrically through each tube carries spikes that jut into the slots and keep them free from incrustation through reciprocal movement. A large-diameter guide pipe above the directional tubes is installed concentrically in the vessel and serves to bring the gas and juice into contact; the mixture flows up to the top of the pipe and flows down on each side to discharge or to be recirculated up the central pipe (the design aiming at 30 - 50 recirculations). About 90% utilization of gas containing some 40% CO_2 in the new vessel compared with only 80% utilization of gas containing 33% CO_2 in a conventional vessel.

Waste water treatment: The question of waste water treatment to reduce the nitrate-N content has been examined; at one factory, a system of denitrification followed by nitrification operated satisfactorily with the ammonium-N content kept easily below the limit of 10 mg/litre and the denitrification stage reducing the nitrate-N content by about 80% at 400% recirculation. Immobilization of methane bacteria on suitable support material should allow much higher densities of active biomass in anaerobic reaction vessels and hence high performances, although the Ca^{++} content in effluents or the formation of Ca carbonate muds creates a problem. Tests with laboratory-scale fixed-bed vessels containing high biomass densities gave degradation rates of up to 130 g/litre COD per day, but Ca^{++} at the usual concentration of about 1 g/litre caused blockage. Under the same conditions, with sand as carrier, a laboratory-scale moving-bed vessel gave up to 40 g/litre/day degradation, while even with waste water of very low initial COD (about 100 mg/litre) a degradation rate of 28 g/litre/day was achieve without any problems from mud, pointing the way to use of such a scheme as supplementary treatment in the case of restricted capacity or very low discharge loads.

Factory emissions: Investigations showed that the raw juice at one factory contained 148 g per tonne of beet of nitrogen that was potentially convertible to ammonia, while at another factory the amount in beet brei was 171 g/tonne; of these quantities, 70% and 62%, respectively, could be discharged to the atmosphere. (Although beet contains hardly any ammonia, it is formed largely from glutamine, mainly during liming but also in subsequent processes.) A number of factors govern the passage of ammonia from liquid to vapour phase, but a substantial proportion of that formed during juice purification is vented to the atmosphere with carbonatation gas, while the greater part is converted to vapour in the evaporator and finally leaves the factory in waste water or is discharged to the atmosphere when condensate is cooled; only a small part is removed via the degassing system. While in theory complete cyclization of glutamine should be possible and the resultant ammonia driven off as a pre-evaporation stage, a technical solution has yet to be found. Determination of organic compounds as total organic carbon (TOC) in flue gases from pulp dryers at two factories showed an increase in the content with drum inlet temperature, whereas the proportion of acetic acid (by far the major component at 40 - 60%) fell; >80% of the TOC is removable by wet dedusting if a neutralizing medium is used, or 50 - 60% without. Various measures to reduce energy consumption also reduce emission of organic substances. The performances of a 2-stage venturi system and of a 1-stage spray system for dust separation were assessed; while both reduced N and S oxides, acetic acid and total dust contents to levels conforming to official regulations, the spray system was preferable because of a lower energy consumption.

Crystal footing preparation: The three stages in the Braunschweig Institute method of crystal footing preparation are described: (i) pretreatment of a slurry by stirring to produce a high shear (in the presence of glycerol or polypropylene glycol added to increase viscosity) so as to separate aggregates that have formed from agglomerated particles; (ii) production of a 1st crystal footing by injecting the slurry into thick juice and cooling with gentle stirring at low crystallization rates and temperatures so as to prevent agglomeration, a low temperature difference between the cooling medium and the contents of the vessel preventing the formation of fine grain; (iii) concentration by evaporative crystallization to 75°Bx. However, if the thick juice used for cooling crystallization is of sufficiently high concentration and temperature, flash evaporation can be used in (ii) to replace (iii). The final crystal size is 0.10 - 0.13 mm.

Control of the crystallization tower: Work on improving the process control of the BMA crystallization tower included development of a computer program for calculation of the major parameters and provision of means for optimizing the distribution of the charge and controlling the heat conditions in the individual compartments. A process refractometer installed experimentally below the calandria in the 2nd compartment from the top was subject to the formation of incrustation which could be removed only by normal washing. A laser diffraction spectrometer was also installed for rapid measurements of grain size distribution; initial readings showed an unusually high proportion of fine grain which could not be found microscopically, and a subsequent check using a control sample demonstrated that the spectrometer indicated the presence of considerable fine grain that in fact did not exist.

Incrustation: While incrustation is to be expected on the wall of a pan at the phase boundary level and in the spray zone above this level when higher-purity continuous boiling is carried out (lining the wall with a vibratory cladding and spreading of syrup over the wall from above can prevent this), deposits on stirrer blades or on support plate baffles (also preventable by vibratory cladding) are not to be expected because of the high relative velocities. Because of the almost constant supersaturation below the calandria in a continuous pan, deposits on colder surfaces and in dead zones around internal elements are easily explained, whereas those on lower tube entries (where the surfaces are warmer than the massecuite and there is adequate movement) are not. Research continues in order to find an explanation for these phenomena.

Syrup washing: While correct use of washing with syrup in centrifugals as a type of pre-treatment followed by washing with water reduces the quantity of water but greatly increases the crystal yield, frequent misapplication of the system leads to disappointing results; since, in the system that relies on water alone, the target effect is achieved by ensuring that the water is applied before maximum speed, it is sensible to adopt the same approach with the curtailed water wash in the combined system where both nozzle and pressure are adjusted (as a function of centrifugal cycle and massecuite quality) to ensure that the required amounts are applied within the time available.

Further experiences with continuous crystallization at Wabern sugar factory

G. Witte. *Zuckerind.*, 1988, **113**, 414 - 420 *(German, English).*

See *I.S.J.*, 1988, **90**, 14A.

Tests on increasing the amount of sugar obtained from beets in diffusion with energy saving

K. Vukov and I. Sipos. *Gaz. Cukr.*, 1988, **96**, 2 - 4 *(Polish).*

Problems associated with inadequate or excessive heating of cossettes in trough-type diffusers are outlined with mention of investigations by various authors and proposed remedies. Tests are reported with Jerusalem artichokes using a small-scale diffuser of 1.5 tonnes/hr capacity in which the scroll speed was adjusted to give a cossettes flow of 1.0 - 1.5 mm/ sec; by heating some of the extracted juice to 96°C after discharge and recycling it to 3 or 4 points in the section about one-third of the total diffuser length from the start, it was possible to raise the temperature to a required level despite unevenness in counter-current flow caused by the juice recirculation. Tests were also conducted on treatment of beet pieces and tails by a patented Hungarian process in which the material was crushed and then mixed with water (in a proportion no lower than 1:1) in a pressure tank; subjecting the mixture to a given pressure causes the beet cells to "explode" whereby they are sufficiently ruptured to allow the juice to be extracted in subsequent diffusion (the mixture being added at a point in the diffuser where it has the same Brix as the raw juice).

Corrosion control in the sugar industry

G. Trabanelli, G. Mantovani and F. Zucchi. *Sugar Tech. Rev.*, 1988, **14**, 1 - 27.

A review of the literature (140 references) is given on corrosion control in both the beet and cane sugar factory, starting with selection of materials suitable for use under conditions conducive to corrosion and a general examination of the value of protective coatings. A discussion of corrosion and its prevention in buildings and structures is followed by a detailed look at the juice parameters responsible for corrosion in the process stages up to and including evaporation. Chemical cleaning of evaporators is discussed, followed by the situation at the sugar end (with particular attention to centrifugal corrosion problems) as well as corrosion that occurs in alcohol and yeast manufacture. Boiler corrosion and means of preventing it are considered in relation to the various fuels used and plant design.

New technico-scientific achievements in the GDR sugar industry.

U. Wolff. *Lebensmittelind.*, 1988, **35**, 70 - 72 *(German)*.

After an outline of the East German sugar industry, as represented by 44 factories and one refinery plus an equipment manufacturing facility and research institute grouped under VE Kombinat Zucker, and its program of activities, the author describes beet yard equipment and storage techniques, including forced ventilation arrangements.

Underground ventilation plant for sugar beet piles

P. V. Schmidt, E. Manzke and B. Senge. *Lebensmittelind.*, 1988, **35**, 73 - 75.

Details are given of the designs, capacities and arrangements of underground beet pile ventilation systems as used in East Germany together with the materials and construction of the air ducts.

Electrical heating of low-grade massecuite

G. Kowalska. *Gaz. Cukr.*, 1988, **96**, 29 - 30 *(Polish)*.

The advantages of electrical reheating of low-grade massecuite are discussed and reference is made to a heater installed in two Polish factories that, with only about 3 minutes' retention, reduced viscosity adequately for treatment in the centrifugals; an electric heater developed by Chemadex and installed in another factory had earlier proved unsatisfactory in being too large and prolonging massecuite residence.

Disposal of by-products and waste products in the sugar industry as at Klecina sugar factory

S. Urban and H. Kmiec. *Gaz. Cukr.*, 1988, **96**, 30 - 33 *(Polish)*.

Details are given of the quantities of molasses, pulp, soil separated from beet, beet trash, filter cake, mud and stones retrieved from flume and washer, underburnt and fine particles of limestone and boiler slag and ash that occur at Klecina sugar factory. The means used for their disposal and the sales of molasses and pulp (some of the latter product being provided free of charge to beet farmers as part of their contract) are indicated and the effect of their monetary value on the unit costs of sugar production is discussed. The organization and costs of disposal and utilization of the other waste products mentioned are outlined.

Biological treatment in a deoxidation-aerobic system for cationic effluents from sugar juice demineralization plants

S. Urbinati. *Ind. Sacc. Ital.*, 1988, **81**, 53 - 56 *(Italian)*.

While the use of activated sludge and pure oxygen to treat ion exchange effluent in a single-stage system gave 90% and 94% reduction in COD and BOD, respectively, and approximately halved the total nitrogen content, the ammonia concentration doubled. A two-stage treatment process was therefore devised which included conversion of ammonia to nitrites by *Nitrosomonas* sp. followed by oxidation of the nitrite to nitrates by *Nitrobacter* sp. and subsequent denitrification by *Pseudomonas denitrificans*; this achieved the same high level of COD and BOD reduction as before but with the added benefit of almost complete removal of ammonia.

Increasing the effectiveness of chemical preparations

V. A. Knyazev, I. R. Sapozhnikova, M. L. Pel'ts and L. A. Shevtsova. *Sakhar. Svekla*, 1988, (3), 50 - 51 *(Russian)*.

Addition of dimethylsulphoxide at 0.015 - 0.06% concentration increased the effectiveness of 0.1% pyrocatechin in inhibiting fungal growth and rotting of stored beet, and considerably reduced the daily sugar losses over a period of 80 days by comparison with pyrocatechin on its own at 0.1% and 0.3% concentration. Dimethylsulphoxide also acted positively in combination with other fungicides by further reducing rotting and daily sugar losses.

Sugar refining

Coagulation and decolorization of carbonatated liquor

F. Maekawa, K. Kawasaki, M. Ishikawa, S. Sakai, F. Matsuda and S. Yoshida. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1988, **35**, 1 - 9 *(Japanese)*.

Coagulation and decolorization of carbonatation liquor with powdered ion exchange resin were studied in a pilot plant consisting primarily of a decolorization tank, a mixing tank and a coagulation tank, all of which were provided with agitators and installed between the stirred carbonatation liquor tank and a thickener. Of seven coagulants tested, the best was found to be Orfloc OX-100S, a medium acid cation exchange resin in the form of a reddish-yellow powder containing chitosan. Optimum conditions were: coagulant dosage 20 - 30 mg/litre, maximum liquor velocity 3 m/hr, a mud concentrating ratio of 10:1, and a suspended solids content in the supernatant liquor of 200 mg/litre (with Orpak inclined plates installed in the thickener). Since the specific filtration resistance of the carbonatation liquor and mud were found to be almost the same, it was calculated that mud filtration could reduce the filtration area and/or filtration time. Continuous treatment with powdered strongly basic anion exchange resin gave the same decolorization rate as batch operation under the same conditions.

Development of a panel heating-type continuous vacuum pan for refined sugar

K. Fukunaga, K. Kurokawa, T. Sakasai, M. Miyazaki, H. Amaki, T. Itami, M. Hino, T. Tsurumi and H. Iijima. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1988, **35**, 11 - 17 *(Japanese)*.

In order to develop a new type of continuous vacuum pan for high-grade refined sugar, a pilot plant was installed at Ensuiko Sugar Refining Co. Ltd. and tested. This horizontal pan is divided into 8 compartments and has a working volume of 2.32 m^3 and a heating surface of 38.4 m^2. It is provided with heating panels arranged at right angles to the direction of the massecuite stream so as to minimize residence time distribution. Tests conducted on high-grade granulated sugar to establish optimum operating conditions showed that stable production of 1.2 tonnes/hr was possible with an optimum value of sugar production rate per working volume in the range 450 - 550 kg/m^3/hr; crystal growth rate was 600 μm/hr, although 300 - 400 μm/hr was adequate. A massecuite colour rise of 40 - 60% was 20 - 30% lower than in a batch pan, although the crystal size uniformity was somewhat inferior to that in batch boiling although adequate for commercial sugar.

Energy balance of MVR system

A. Mitsui, T. Hiki, Y. Kamagami and S. Kitahara. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1988, **35**, 33 - 35 *(Japanese)*.

Mechanical vapour recompression (MVR) was adopted at Toyosu refinery in December 1984. By comparison with the previous evaporator system, it has reduced steam consumption by >93% and electricity consumption by 25%, while 95.7% of the energy consumed is re-usable by the boiling house.

Saving of water and caustic soda used in the flue gas desulphurization plant

T. Itoh, A. Suzuki, M. Hiratsuka and S. Gozawa. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1988, **35**, 45 - 57 *(Japanese)*.

The desulphurization plant described uses NaOH and yields Na sulphate as by-product. Attempts to reduce the amount of water and NaOH are described. The use of refinery waste water involved scale and microbial slime problems, but the use of an anti-scale agent and slime inhibitor plus a new type of nozzle allowed the consumption of supply (city) water to be reduced by 100 tonnes/day. The improved nozzle led to an efficient gas/liquid reaction, so that NaOH consumption fell by 20%; in addition, there was no further blockage of the nozzle, so that labour requirements were reduced. Minimization of the water supply caused a reduction in waste water which could be oxygenated for a longer period, so that both pH and COD of the treated water are stable. Less sulphuric acid is needed to neutralize the waste water.

The future of raw sugar quality

M. A. Clarke. *Proc. 1985 Meeting West Indies Sugar Tech.*, 23 - 39.

See *I.S.J.*, 1986, **88**, 72A.

Cane sugar processing at Pruszcz sugar factory

S. Lawnicki. *Gaz. Cukr.*, 1988, **96**, 61 - 64 *(Polish)*.

Refining operations in various years including 1986 are discussed. The factory used a compromise scheme based on a 4-massecuite system with no affination or evaporation of the remelt liquor. Because of a shortage of condensate in 1976, softened water had had to be used as boiler feed, resulting in considerable scaling and boiler breakdown; in 1986, the problem was overcome by isolating the 1st and 2nd evaporator effects from the rest of the evaporator station and using them to process only steam and act as a source of condensate for the boilers. This resulted in a 13.5% reduction in fuel consumption and eliminated the scale problem. A low raw sugar purity and very high colour content occasioned the need for increased lime dosages and purification of all the *C*-sugar, resulting in a low remelt liquor Brix averaging 42.3°; the future use of the 3rd and 4th evaporator effects to raise the liquor Brix to 60 - 65° is suggested. Comparison of results for 8 Polish factories refining cane raws showed that two factories operating a 3-product boiling scheme generally performed better than the others with 4-massecuite schemes, having lower molasses purities and with refined sugar outputs ranking 1st and 3rd.

Laboratory studies

A preliminary evaluation of the rapid dextran test at Millaquin mill

F. E. Bush. *Paper presented at Ann. Meeting Sugar Ind. Technol.*, 1988, 13 pp.

While dextranase is effective in reducing the dextran content in juice, it is expensive, so that a rapid method of dextran analysis and hence of determining the amount of enzyme to add would be desirable. The rapid test developed by Clarke *et al.*[1] on the basis of the Tilbury haze test was used to screen 1st expressed juice during the 1987 crushing season at Millaquin; some of the samples were also analysed by the alcohol haze method as generally used in Australia [2]. The samples analysed were taken from cane which had undergone a pre-crushing delay that exceeded a preset level. Results obtained by the rapid test for samples collected early in the season (June and July) were significantly lower (at 400 - 1400 ppm) than the values given by the other method (0 - 600 ppm) and there was poor agreement between the two techniques. However, as the weather became warmer later in the season, agreement between the two methods became much better at the higher dextran levels, but not at the lower levels, and the rapid test gave values some 400 units higher. Very much better agreement between the results when some clarified juice samples rather than 1st expressed juice were analysed suggested that clarification removed the material responsible for the elevated values given by the rapid test. A combination of wet weather and higher temperatures later in the season caused greater cane deterioration and high dextran levels; however, although wet weather in July caused a 50% increase in the burn-to-crush delay, this was not accompanied by high dextran levels, presumably because of the lower daily temperatures. Application of the rapid test to control of the addition of dextranase resulted in fewer problems in boiling than might otherwise have been encountered, while it was also of benefit in the refinery section. Dextranase activity was optimized by allowing 40 minutes' contact at 57°C prior to clarification; the dextranase was metered by a pump adjusted to add an amount proportional to the juice dextran content; the enzyme was fed into the juice return line from the laboratory to the milling train.

High molecular weight (HMW) colour in raw and refined sugars

M. A. Godshall. *Paper presented at Ann. Meeting Sugar Ind. Technol.*, 1988, 13 pp.

Gel permeation chromatography (which separates compounds on the basis of their size or molecular weight) was used to trace HMW components (colorants and polysaccharides) through a number of processes to final sugar at two refineries. So as to make the results clearer and shorten the elution times, the material was separated from 4th-strike sugar by dialysis before GPC; details are given of the procedures used in dialysis, GPC, colour and total polysaccharide measurement. Tabulated data show that the melt liquor at both refineries was of higher colour content than affined sugar. Despite a major difference in the extent of polysaccharide removal (an unusually high initial content at one refinery being easy to remove, while a lower but normal content at the other refinery was difficult to remove), neither refinery showed recycling of polysaccharides, and the clarified liquors in both cases had polysaccharide concentrations close to those of affined sugars. Sweet water and melt liquor altered the colour input from raw sugar by introducing a very high molecular weight (VHMW) component greater than 1,000,000 compared with an average raw sugar colorant molecular weight of 300,000; this VHMW component, representing recycled material, remained in the process streams and was carried over to the refined sugar crystal at both refineries, while most of the other colouring matter was removed. High temperatures, extended residence times and changes in pH caused polymerization of colorant molecules which tend to become larger; however, the VHMW component was not highly coloured, so that the 4th-strike sugar appeared to have a less-than-sparkling whiteness but was not visibly coloured. Nevertheless, the VHMW material is of concern since it does contain some colour and is associated with the polysaccharide component.

The presence of colouring matter in sucrose crystals

G. Vaccari, G. Mantovani, G. Sgualdino, D. Aquilano and M. Rubbo. *Gaz. Cukr.*, 1988, **96**, 4 - 10 *(Polish).*

The studies on colorant inclusions have continued, and photomicrographs are reproduced of inclusions at different faces of both beet and cane sugar crystals. (See also Mantovani *et al.*: *I.S.J.*, 1985, **87**, 119A; 1986, **88**, 84A; 1987, **89**, 63A, 124A.)

Microbial infection in the sugar industry

H. Essadiq. *Sucr. Maghrebine*, 1988, (34), 3 - 6 *(French).*

After discussing the major sources of bacterial infection in the beet sugar factory, cane sugar factory and refinery, the author describes direct and indirect methods of determining the presence, activity and numbers of micro-organisms.

Contact nucleation in sucrose crystallization

B. M. Liang, R. W. Hartel and K. A. Berglund. *Chem. Eng. Sci.*, 1987, **42**, (11), 2723 - 2727; through *Ref. Zhurn. AN SSSR (Khim.)*, 1988, (10), Abs. 10 R437.

Results are given of laboratory investigations on the process of contact nucleation in sucrose crystallization. The experiments were conducted in a transparent constant-temperature cell. The solution was first passed through a

1 *I.S.J.*, 1988, **90**, 31A.
2 Keniry *et al.*: *ibid.*, 1969, **71**, 230 - 233.

micro-filter of 0.45 µm pore size. After filling, the cell was cooled to a temperature needed for the start of growth of a single crystal mounted on a thin slide. The single crystal was then carefully slid along the surface of a glass plate and photomicrographed at 5 - 6 regular time intervals; the photographs were used to determine the change in size of the crystal nuclei. It was found that both normal distribution and g-distribution sufficiently described the data on growth rate distribution and that the higher the average growth rate the greater was the scatter in the growth rate of individual nuclei.

Colour precursors in sugar beet juices. I. Flavonoids

V. Maurandi. *Ind. Sacc. Ital.*, 1988, **81**, 47 - 52 *(Italian, English).*

HPLC was used to analyse press juices and the corresponding laboratory-purified juices for flavonoids; from 145 chromatograms 12 flavonoids and the characteristic groups of another 6 were identified. Examination of the list showed that the 2nd, 4th, 8th and 9th in order of frequency were also found frequently in cane juice, although the commonest flavonoid in beet juice was luteolin 7(O)-glucoside as against isoorientin 7(O),3'(O)-dimethyl ether in cane juice (which was 12th in the order of frequency in beet juice); however, it is stressed that this is only a preliminary finding. The effects of the beet flavonoids on colour formation have yet to be established, but results obtained for cane already suggest the relative colouring importance of some flavonoids.

Prediction of molasses sugar

P. Devillers. *Sucr. Franç.*, 1988, **129**, 190 - 200 *(French).*

See *I.S.J.*, 1988, **90**, 132A.

Isolation and characterization of thermophilic bacteria from Indian plantation white sugars (sulphitation and carbonatation)

R. Katiyar and K. A. Prabhu. *Taiwan Sugar*, 1988, **35**, (2), 24 - 28.

Details are given of the procedure used to isolate two thermophilic flat sour bacteria from plantation white sugars (one, C_2, from a carbonatation factory and the other, S_1, from a sulphitation factory); the morphological and physiological characteristics of each bacterium are set out in a table and the effect of different heat treatments on the viability of the S_1 culture are indicated. Isolation of the bacteria was difficult because of their heat resistance and sporulating properties, and fractional sterilization proved to be the best approach. S_1 was identified as *Bacillus stearothermophilus* and C_2 as *B. licheniformis*; both seemed to occur as secondary infections in the later stages of cane sugar manufacture.

Sugar analysis without lead - determination of the polarization of samples from a beet sugar factory without using lead salts

B. Winstrom-Olsen. *Zuckerind.*, 1988, **113**, 506 - 510.

A 0.2% solution of aluminium sulphate was used as clarifying agent instead of basic lead acetate in polarimetry of beet brei, cossettes, raw juice, beet pulp, filter cake, thin juice, thick juice, massecuite, sugar and molasses in Danish sugar factories during the 1986 campaign. The procedures used for the various types of sample are described. Comparison of the results for 925 samples of beet brei and 300 samples of raw juice using aluminium sulphate and lead acetate showed a difference less than 0.005% sugar in beet, while employing aluminium sulphate for clarification is cheaper than lead acetate.

Composition of 1987 Louisiana final molasses

M. Saska. *Sugar J.*, 1988, **50**, (12), 4 - 6.

Final molasses samples were analysed for: refractometric Brix; total dissolved solids; sucrose, glucose and fructose (determined by GLC); pol; conductimetric ash; dextran (determined by GLC); K (determined by flame photometry); and Na, Ca, Mg, Fe, Cu and P (determined by atomic absorption spectroscopy). The values found for 31 samples (usually two per factory) are tabulated and discussed.

Improvements in the design of a sugar colorimeter

J. T. Rundell. *Sugar J.*, 1988, **50**, (12), 8 - 13.

See *I.S.J.*, 1988, **90**, 19A.

Application of ion chromatography to routine analysis at a beet sugar factory

H. Inoue, Y. Senba, M. Miyoshi, Y. Saito and K. Honjo. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1988, **35**, 27 - 32 *(Japanese).*

A Dionex Qic ion chromatograph was used for the routine analysis of process juices in a beet sugar factory. For analysis of divalent cations it was necessary to use an eluent that was different from that used for monovalent cation determination. The results were calculated on a CaO basis and ion chromatography was compared with a method using ion exchange resin in terms of the total cation determination; both values agreed well in the case of thin juice but not for raw juice, and the ion chromatographic method was considered adequate. Determination of Cl^-, NO_2^-, NO_3^- and PO_4^{---} was possible with an ASA-4 column, but the SO_4^{--} peak was overlapped by organic acids; use of an AS-5 column allowed clear determination of SO_4^{--} but separation between NO_2^- and Cl^- was not good while the PO_4^{---} peak was overlapped by organic acids, so that both columns had to be used to determine all the anions in process juices. After 9 months' operation, the retention time for each ion was shorter and separation efficiency fell; however, change of the pre-column gave good separation equivalent to that of a new column.

By-products

Industrial processing of bagasse-based feeds for ruminant production

C. K. Sankat, R. H. Singh and P. Osuji. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 211 - 216.

The value of bagasse as a base for animal fodder is discussed and treatment with NaOH, ammonia and steam to enhance digestibility described. Details are then given of a process tested in Trinidad which involved NaOH treatment of bagasse of 18% moisture content that had been milled to 10 mm particles; after treatment with 5% NaOH (on dry matter), the bagasse was mixed with other feed ingredients including molasses to provide a mash which was then bagged. Preliminary trials, in which samples of the unpelleted feed (mash) were stored in polyethylene bags, showed visible growth of mould after 6 weeks, whereas treatment with 0.5% and 1.0% propionic acid (on dry matter) allowed successful storage for several months. No difficulties were experienced in experimental pelleting of the mash. A suggested industrial scheme for bagasse fodder production is outlined.

Background, production, disposal and uses of filter muds

A. L. Fors. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 230 - 239.

Problems encountered with filter cake disposal are discussed, including the high costs involved, and a flowsheet is given of the Petree process developed 60 years ago for filter cake recycling to imbibition and ultimate burning with bagasse. The quantities of organic and inorganic components found in filter cake in a number of countries are indicated, followed by a mention of wax extraction and its failure to become a commercially viable process. The use of fermented filter cake as animal fodder has also been investigated and proved totally acceptable in lamb diets. Application of filter cake to soil has proved of benefit in increasing cane yields, while compost made from filter cake and bagasse increased both plant and ratoon cane yields in trials conducted in El Salvador.

Utilization and value of filter mud in soil mixtures at Caroni Research Station, Trinidad

A. F. Donelan. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 240 - 244.

Data are presented on the composition of filter cake taken from sugar factories in Trinidad, and the beneficial effects of filter cake on the physical properties of soil indicated, including increase in the water-holding capacity and decrease in compaction. The main chemical effects on soil include increase in N (although this is insufficient for both micro-organisms and crops during the critical stages of crop growth), P, Ca, Mg, Mn and Zn and reduction in acidity. At Caroni Research Station, filter cake is allowed to weather in heaps in the open field for 8 - 9 months before being used in soil mixtures, usually with a sandy loam at 2 parts soil to l part filter cake; the mixture is placed in perforated polyethylene bags for cane cuttings or seedlings. No additional fertilizers are given, but the plants show good growth on gravel beds for 3 - 6 months before transplanting in the field. The main drawbacks of filter cake are its relatively low concentration of nutrients by comparison with other manures and its bulkiness, which makes transportation costly.

The use of alcohol distillery waste as a fertilizer

G. Samuels. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 245 - 252.

Vinasse contains N, P, K, Ca, Mg, sulphate and organic matter and is thus of value as a fertilizer when applied directly to the soil before the start of cane growth or in irrigation water. While the economics of handling it have limited its use, machines have been developed in Brazil for efficient and economical application, thus solving disposal problems and allowing cane farmers to cut fertilizer costs. The author discusses various aspects of vinasse as cane fertilizer and briefly mentions its possible fermentation to yield biogas and its limited use as animal fodder.

Non-optional by-products of Texas sugar cane production

N. Rozeff. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 253 - 262.

Non-optional by-products are those that cannot be avoided in the production of sugar and include field trash, bagasse, molasses, filter cake, wastes from cane cleaning plant and factory yards, fly ash from bagasse furnaces and other forms of furnace ash. The amounts are given of each type of material occurring in the 1985/86 season (taken as typical), methods and costs of disposal are presented, alternative uses examined and possible means of reducing the quantities and/or their handling costs discussed.

Systems and methods for slurry waste mud disposal

H. Tretter. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 263 - 269.

The application of filter cake, lime slurry, vinasse, cane wash water and factory effluent to agricultural land is discussed and the types of equipment involved are described, including mixers, pumps, irrigation plant and tank trailer distributors.

Utilizing sugar cane and its by-products for cattle production

F. M. Pate. *Proc. Inter-Amer. Sugar Cane Seminar,* 1986, 270, 273 - 275.

The value of molasses, bagasse, cane tops and whole cane as cattle fodder is discussed on the basis of results achieved in various countries.

By-products of sugar cane and a protein source for cattle rations in the tropics

J. R. Tejada and M. R. Bouscayrol.

Proc. Inter-Amer. Sugar Cane Seminar, 1986, 276 - 281, 283, 285 - 291, 293 - 299.

While increasing amounts of grain are being used to feed beef cattle in developed countries, in tropical countries beef production suffers from a poor availability of grain (which is in high demand to feed humans), from low soil fertility and productivity, fluctuations in annual rainfall, poor quality and low quantities of roughage and the lack of technological and financial resources. For these reasons, in the dry season Ingenio Tulula S.A. in Guatemala follows a feed program for fattening beef cattle that is based on chopped cane tops, molasses, urea and a protein source; results of various trials demonstrated the benefit of the ration in terms of daily live weight gain by comparison with daily losses in weight of cattle grazing on pasture. The economic advantages are discussed.

Use of cane tops in feed rations for the Peruvian walking horse

S. Leyva and R. Elías. *Proc. Inter-Amer. Sugar Cane Seminar*, 1986, 300 - 304.

In trials to compare the digestibility of different fodders fed to the Peruvian walking horse (of great value as a work animal in agriculture), fresh cane tops proved significantly better than ensilaged tops plus a small amount of molasses, ensilaged tops enriched with corn meal and ensilaged tops plus bagacillo enriched with molasses and corn meal, while the total digestible nutrients content in the fresh cane tops ration was considerably greater than in the other rations. The second best results were obtained with the ensilaged cane tops enriched with corn meal, and this ration had by far the best protein digestibility of those tested.

Influence of Ajinofer on sugar cane yields and quality

S. Saldarriaga and H. Tello A. *Proc. Inter-Amer. Sugar Cane Seminar*, 1986, 305 - 310.

A process developed by Ajinomoto Co. Inc. for the manufacture of monosodium glutamate from cane molasses at a food factory in Peru yields a liquid residue known as Ajinofer which is rich in plant nutrients. Its composition is compared with that of filter cake and trials are reported in which its application to 10-row plots of ratoon cane at 1500, 2000 and 2100 litres per plot increased cane yield by 4.7, 15.0 and 18.3%, respectively, while sugar yields rose by 2.7, 3.8 and 3.6%, respectively, compared with untreated controls. Both treated and untreated plots received urea at a rate of 223 kg/ha N; no conclusions could be drawn on the effect of Ajinofer on cane quality.

The utilization of cane trash as a source of energy and furfural production at Central Romana

P. A. López. *Proc. Inter-Amer. Sugar Cane Seminar*, 1986, 319 - 323.

Since the cane at Central Romana is harvested green, about 30% of the total weight of the aerial parts of the crop is left in the field as leaves and tops. In 1981 a feasibility study was carried out on collecting and transporting this trash for use as fuel and as raw material for the manufacture of furfural (hitherto produced from bagasse at an adjacent plant). The system adopted on the basis of the results involves the use of hay rakes to pile the trash in rows; the trash is then picked up by tractor-hauled fodder harvesters which chop it into fine pieces and dump it in trailers.

Chemical and microbial products from sucrose: recent developments

M. A. Clarke. *Paper presented to Sugar Industry Technologists*, 1988, 17pp.

Production of chemicals from sugar crops is outlined and the basic production processes for sucrose from sugar beet and sugar cane, and the by-products are briefly described. Chemicals, including sweeteners, that are in current or potential production from sucrose are reviewed. The isolation or synthesis of chemicals from the major by-products of cane and beet sugar factories are described.

Pressed sugar beet pulp in pig feed

J. P. Vandergeten. *Le Betteravier*, 1988, **22**, (230), 16 *(French)*.

Feeding trials with fattening pigs and sows have shown that rations incorporating beet pulp give weight gains almost as good as with conventional feed while being less costly; however, the pulp content should not exceed 20% on feed dry solids.

Preliminary trials on ensilage of highly pressed pulp

K. Mossakowska, E. Laskowska and K. Gozdek. *Gaz. Cukr.*, 1988, **96**, 47 - 49 *(Polish)*.

Trials showed that addition of 2.5% molasses by weight to beet pulp having a dry solids content greater than 20% greatly improved its quality as determined by two methods and stabilized its condition over a period of up to 6 months; addition of 15% beet pieces had an initial positive effect which was followed, however, by greater losses of solids, an undesirable acids composition and structural changes, while addition of 0.3% phosphoric acid had a worse effect than lack of additive.

An overview of treatment options for distillery wastes at the Caroni rum distillery

R. Biran, I. Chang-Yen and A. Mangwiro. *Proc. 1985 Meeting West Indies Sugar Tech.*, 133 - 140.

Laboratory-scale experiments are reported in which dilute blackstrap molasses samples simulating vinasse were clarified, sterilized and fermented to yield nutrients and alcohol. Results showed that the COD, BOD and total oxygen contents were still high (despite yeast removal by centrifuging) and the economics unfavourable.

pressure and temperature of vapour leaving the vessel (say at 101.3 kPa and 100°C) to a pressure and temperature prevailing in the calandria of the same vessel (say at 138.51 kPa and 109°C), only 63.37 kJ/kg of heat energy will be required by the ideal system following the Carnot Cycle. If it is assumed that the compressor and its prime mover have an overall efficiency of 70% this quantity of heat energy will be increased to about 90.53 kJ/kg. When designing a vapour compression system we should take the advice of the manufacturers of such equipment on the overall efficiency of the equipment.

Assuming that 90.53 kJ/kg of heat energy is supplied to increase the pressure of vapour leaving the vessel to a pressure corresponding to the pressure in the calandria of the same vessel, this will enable the compressed vapour to release 2232.7 kJ/kg of latent heat on condensing in the calandria. In other words, by performing a small amount of work on the vapour leaving the vessel, its latent heat can be made available to the evaporator, which is an efficient way of upgrading the energy. The power required to compress a kilogram of vapour increases as the pressure ratio increases. Aarberg sugar factory in Switzerland is the only instance known where rotary compression has been used to compress the vapour from vacuum pans where the temperature difference amounts to more than 50°C. Multi-stage rotary compressors are used, but of different design, because the specific volumes of vapours from the vacuum pans are larger on account of the low density at low absolute vapour pressure. It was possible only because hydro-electric power was amply available at a price lower than the cost of fuel for combustion[5]. A higher efficiency of mechanical vapour compression is achieved when the vapour compression cycles operate over comparatively narrow temperature ranges, 7 – 9°C being typical[7].

Although the vapour leaving the vessel is always slightly superheated, owing to the boiling point elevation, the superheat disappears owing to the heat loss by radiation. If the insulation is poor the resulting vapour leaving the vessel reaches the compressor in a slightly wet state or the compressed vapours resulting are slightly superheated. The heat energy required for compression will increase since the process of compression in such cases will involve a polytropic heat increase instead of isentropic. When the vapours leaving the vessel are slightly wet a small amount of compressed vapour must be by-passed into the incoming vapours to protect the compressor blading from erosion[8]. When part of the compressed vapours are recirculated around the compressor, the quantity of the vapours passing through the compressor needs to be estimated to determine the power required to compress the vapours by the prime mover.

Thermo- versus *mechanical vapour compression*

A thermo-compressor is an inexpensive piece of equipment; however it does not need any lubrication and there is no wear on the nozzle when pure steam is used. Its light weight makes installation easy and it may be supported from the connecting pipe lines. The design involves considerations such as live steam, vapour and intermediate delivery pressures, however, and any variation in pressures will lead to reduced efficiency. This phenomenon of reduced nozzle efficiency also arises to some extent with the nozzles of a steam turbine, but the disadvantage is of no great importance. The efficiency of a thermo-compressor is about one half that of a mechanical compressor. When a large variation in capacity is required several smaller thermo-compressors should be used, so that some can be shut off, as may be desired.

A mechanical vapour compression system requires a higher capital investment, but has about double the efficiency achieved by the thermo-compressor. Owing to its higher efficiency, when make-up steam requirement is not great, the installation of mechanical vapour compression is advisable to avoid the frequent blow-off of exhaust steam. Outside electric power can be used in conjunction with motor drive if desirable.

The steam economy in the case of vapour compression can be better understood by the following example when, say, 1 ton/hour of evaporation is required from the first vessel, for which no exhaust steam is available. This additional steam at exhaust pressure can be provided in three ways.

(a) The steam can be provided by reducing the pressure of live steam through a pressure reducing valve and desuperheater. If we neglect the increase in the quantity of steam at reduced pressure due to desuperheating, then 1 ton/hour live steam at boiler pressure will produce 1 ton/hour of steam at reduced pressure (exhaust pressure), to meet the steam demand for evaporating 1 ton/hour of water, neglecting the latent heat difference of steam in the calandria and vapour at dome pressure, i.e. a ratio of 1:1.

(b) When a thermo-compressor is used to compress 1 ton/hour of vapour, approximately 1/2 ton/hour of live steam will be required and will produced 1/2 ton/hour of steam at reduced pressure (exhaust pressure) which ultimately will produce an additional 1/2 ton/hour of vapour for bleeding, as represented in Figure No. 1 (a) – an entrainment ratio of 1:2.

(c) When a mechanical vapour compressor (e.g. a back pressure turbine as prime mover) is used to compress 1 ton/hour of vapour, it will require approximately 0.31 ton/hour of live steam to drive the turbine. The exhaust steam produced by the turbine can be gainfully utilized in the process; this is represented by Figure No. 1 (b) ratio 1:3.2.

These figures are representative of a system where live steam pressure is 3.0 MPa at 400°C, vapour pressure 146 kPa at 111.5°C, and intermediate (exhaust) pressure 196 kPa at 120°C and assuming a polytropic compression

7 Addison: *Proc. S. African Sugar Tech. Assoc..*, 1981, 56 - 58.
8 Allan *et al.*: *ibid.*, 1983, 79 - 84.

efficiency of 77%[8]. The ratios will change with changes in pressures of live vapour and exhaust steam.

If the savealls at the dome are not properly designed then there are chances of condensate being contaminated. This applies to both thermo- and mechanical vapour compression.

Control and instrumentation

Control and instrumentation should be designed to maintain calandria pressure and to prevent surge occurring. Additional protection is required in the event of the evaporator being starved of juice. The pressure control can be achieved in the case of mechanical vapour compression by varying the speed of the turbine, but when the compressor is driven by an electric motor the most effective means of pressure control is through adjustable inlet vanes.

Falling film evaporators and vapour compression

In view of the fact that a low temperature difference must be employed, special provisions have to be made in order to secure a high coefficient of heat transfer and very close vapour to liquid temperature differences. As there is no boiling point elevation due to the static head of the juice, and with a higher heat transfer coefficient, the falling film evaporator is ideally suited for the use of vapour compression. Many installations of this type are successfully in use.

Conclusions

Improvement in the thermal efficiency or steam economy of a cane sugar factory can be achieved through different approaches. One of these approaches is the gainful use of mechanical (or thermo-) vapour compression, when bagasse is to be saved for utilization or the factory has an attached refinery or distillery. The use of mechanical (or thermo-) vapour compression presents an attractive alternative to achieve steam economy where a large amount of live steam is reduced to exhaust pressure through a pressure reducing and desuperheating station to supply needed process steam. Better use of this steam can be made by using it for vapour compression, either mechanically or thermally. This steam can also provide extra power for an electric motor to drive the vapour compressor, or power can be bought from the grid to operate the electric motor. A thorough study of steam utilization needs to be made for all possible alternatives prior to adopting a vapour compression project.

A beet sugar factory depends on purchased fuel, so that, whenever a new evaporator station is needed to be installed in a beet sugar factory or some changes in the existing station are proposed, the possibility of adopting a vapour compression project to reduce the consumption of steam should be thoroughly examined.

The use of falling film evaporators of proven design with vapour compression makes an attractive case to achieve steam economy. Otherwise, with conventional evaporators, a generous heating surface needs to be provided to attain high efficiency for vapour compression, in order to operate the vapour compression process over a comparatively narrow temperature range, 7 – 9°C being typical.

Pneumatic drying of bagasse

continued from page 7

- W: gases moisture content (dry weight basis)
- x_j: particle size fraction
- y: axial coordinate (y = 0 at the inlet of the run)
- z: axial coordinate in the cyclone (z = 0 in the cone apex)
- α_m: mass transfer coefficient
- α_q: heat transfer coefficient
- β: semi cone angle in the cyclone
- γ: experimental factor
- ρ: density of *x*-component in the respective phase (mass of *x*/total volume of the phase)
- ø: shape factor

Sub-index:

- 0: solid substratum
- 1: water vapour
- 2: liquid water
- 4: dry gases
- i: inlet values
- j: size fraction

Facts and figures

Sugar cubing machinery company sale

Komori Printing Machinery Co. Ltd., in a move that establishes its first manufacturing facility outside Japan, has acquired the French firm Machines Chambon S.A. Komori, Japan's leading maker of sheet-fed and web-fed offset printing machinery, will continue to operate all of Chambon's businesses, which include package printing systems and rotary gravure presses as well as its sugar cube moulding equipment business which currently enjoys a 90% market share world-wide. The purchase of Chambon, which last year posted sales of $44 million, is valued at about $13 million and does not include responsibility for the company's debts. Chambon, whose two factories in France and one in the United Kingdom employ 540 people, filed for bankruptcy in August. Komori competed with several US and European companies before being chosen by the French government to purchase Chambon. The Japanese firm says it will invest about $60 million in Chambon over the next six years.

Jamaica sugar production, 1988

In 1988 Jamaica enjoyed its best crop in eight years as production rose by 17.4% over that of 1987. Output reached 220,803 long tons of sugar, compared with 187,966 tons in 1987, and was the best since the 1980 figure of 247,000 tons. The government hopes that the Sugar Industry Authority will be able to maintain production at the 1988 level and perhaps increase it marginally to a new annual average of between 240,000 and 250,000 tons.

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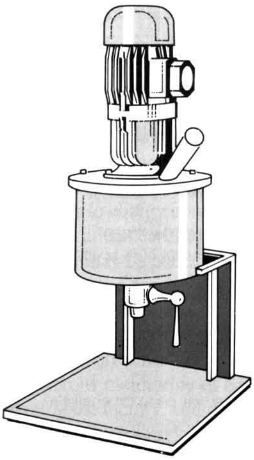

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This mill will produce after 5 hours grinding about 95% nuclei of below 10 micron.[1]

1. Report of Crystallographic Laboratory University of Utrecht, Holland.

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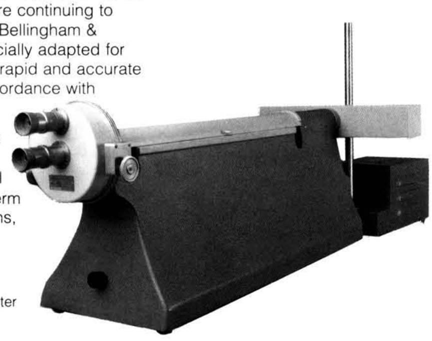

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2. E. Hugot - Handbook of Cane Sugar Engineering. 1960, p. 517

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SUMA PRODUCTS

A practical approach to energy management in a sugar factory

By G. F. Mann
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Introduction

In some way or other energy management is of concern to every sugar factory, be it because of the need to dispose of excess fuel (bagasse), or because of the need to import supplementary fuel. The proposals on a simple energy management approach which follow are applicable specifically to factories which have a bagasse fuel deficit and are required to buy-in additional fuel; but the principles applicable to energy conservation (provided adequate factory equipment is available) may be put to good use in factories where excess fuel is a concern.

When an energy management program is instituted a number of different approaches are possible. One is the rigorous monitoring of energy levels entering the factory, and monitoring the energy consumption levels at the various stages of production, with a view to being able to account for energy expenditure and so work towards reducing the overall energy account. In another, and this is the subject of this paper, attention is focused not on how much energy is expended where, but rather on minimizing energy expenditure in areas where this is under the control of the factory operators.

Both approaches have advantages and disadvantages. In the first approach the actual energy efficiency of sections of the factory is measured. This inevitably requires the measurement of numerous mass flow rates with the associated expense and manpower requirement. In the proposed approach only the controllable components of the efficiency calculation are measured – something which is easily done and most of which is part of normal routine factory control.

Setting up the energy management program

Any attempt at improving the energy efficiency of a plant such as a sugar factory requires that two interdependent aspects be afforded individual attention. The first aspect is the intrinsic energy efficiency of the individual items of equipment in the factory, and the second is the manner in which the equipment is operated.

The subject of installed energy efficiency of machinery is very broad and will not be covered here except to mention the significant impact on energy consumption of high-efficiency boilers, high efficiency prime movers, sound thermal insulation, and the extended use of vapour bleeding and vapour recompression. In general, sugar factories have equipment spanning wide ranges of energy efficiencies, and any progress made in improving on equipment efficiency tends to be capital intensive, and spans a long time period.

On the other hand decisions aimed at improving factory operating energy efficiencies tend to be inexpensive, are continually reviewed, and are made by the factory operators. Operating criteria which impact on energy efficiency can easily be identified and acted on, but not all energy-related criteria are within the control of the factory operators, and many of them have other influences of greater importance than the energy efficiency considerations. Examples are the imbibition rate and moisture % bagasse, and in these instances it is necessary either to compromise or to exclude the parameter as an energy indicator altogether.

Energy management by objective

The basis of this approach to energy management entails the isolation of the various factory operations which consume energy in any form, identifying the control criteria used which are operator influenced, and finally setting ever improving target values for the operators.

Having embarked on such a strategy one may be assured of the following:

1. Operators are aware of the need for energy conservation, and have regular tangible feed-back on their achievements in the form of frequently measured values.

2. Although absolute values of energy efficiency are not measured, where energy consumption is in the hands of operators as much as possible is being done to ensure efficient energy use.

Energy centres and the associated control parameters

Boiler station

There are a number of operating parameters under the direct control of the boiler operators which have an impact on the overall efficiency of the boiler station, but those which are considered most important are as follows:

(a) *Flue gas analysis:* The monitoring of either the carbon dioxide or the oxygen content of flue gas may be used as an assessment of combustion efficiency. High oxygen levels indicate excessive draught through the boiler with resultant high flue gas heat loss, while low oxygen levels indicate incomplete combustion with resultant high losses in ash. In the case of carbon dioxide the opposite is true, i.e. high carbon dioxide levels indicate incomplete combustion, and low levels excessive draught. In this instance a range of values considered most suited to each individual boiler installation should be given as a target to the boiler operators.

(b) *Unburnt carbon in ash:* This is a good measure of a combination of factors such as fuel-to-air ratio and grate speed/dumping frequency. A target range should be set for this value, (1 - 2% in the case of a bagasse fired boiler, and 10 - 15% in the case of coal firing). Care should be exercised not to go below the minimum value, as below this figure the gains in combustion efficiency are more than likely outweighed by the losses in excessive draught through the furnace.

In a boiler fired on coal, ash collected off the grate would give a satisfactory sample, but in the case of bagasse, it being largely burnt in suspension, the ash recovered from flue gases ought to be monitored as well,

Paper presented to the South African Sugar Technologists Association, 1988.

with a target range of 40 to 50% unburned carbon.

(c) *Boiler steaming rate*: A boiler generally operates at its highest efficiency when steaming at or near to its MCR. It is of course difficult for the boiler operators to adjust the total steam demand of a factory but, in instances where a number of steam generating units are employed, attention to this detail may allow the shutting down of one unit altogether as the load is distributed to the other units.

Power station

The efficiency of electricity generation is largely governed by the design of the equipment available and there is not much that can be done by the operators in ensuring optimum efficiency other than to operate each machine as near to its rated capacity (in terms of power output) as is practically possible.

Processing operations

In any factory where it is necessary to let-down live steam to the exhaust range the determinant of the overall steam requirement of the factory is (to all intents and purposes) the factory back-end where the principal activity is the evaporation of water. It therefore follows that significant energy conservation gains may be achieved by reducing the amount of water added to the various product streams. In many instances this water is added to improve sugar recoveries, in others it is added to improve sugar quality, and in others still it is added as a convenience to operators. Whatever the reason, all these streams should be monitored carefully, but it is not proposed that each stream be measured separately – on the contrary it is often more expedient to measure added water indirectly as product Brix, especially in instances where processing interests are in conflict with energy conservation interests.

The following measurements are considered useful in assisting in the reduction of water added to process:

Raw house

(a) *Imbibition rate.* An imbibition rate which best fits the balance between maximizing extraction and minimizing additional high pressure steam let-down should be determined according to the situation at the particular factory, and set as a fixed target for the operators.

(b) *Evaporator feed make-up.* Any make-up of water to the evaporator feed tank (clear juice tank) should be measured and reported against a target of zero. It may be argued that the volume of make-up required is a function of the number of mill stops and as such is out of the control of the evaporator operator, but there are a number of steps the pro-active operator can take to reduce the overall evaporation rate, such as reducing the steam flow to the last 2 or 3 effects, shutting off steam to the clear juice heaters, in the case of multiple vessel first-effects shutting off steam to one of the vessels, or perhaps even increasing the syrup Brix.

(c) *Syrup Brix.* Multiple effect evaporation as in a conventional evaporator station is far more efficient than single effect evaporation as in a pan, and it therefore follows that evaporator syrup Brix should be at the highest level possible. It is believed that a good target syrup Brix is 70° as this allows for a small error in over-brixing and, further, anything much above 70° Brix will generally lead to an increase in the amount of movement water required on the *A*-strike pans.

(d) *Filtrate Brix.* Measuring the volume of filter wash water, be it related to cane crush or whatever else, is not considered as good a measure of control of the use of wash water as is the Brix of filtrate. Filtrate Brix is a function of the volume of wash water added and clear juice Brix, and so a target filtrate Brix a number of units lower than the clear juice Brix may be set, or if it is assumed that the lower the clear juice Brix the less wash water is required (for a constant pol % cake) a fixed value for filtrate Brix may be preferred. Improving the efficiency of wash water application will enable higher target values for filtrate Brix to be set, while maintaining a constant pol % cake.

(e) *Pan movement water.* The use of movement water on refined, *A*-, *B*-, and *C*- pans should be monitored separately and related to the volume of massecuite produced.

(f) A- *and* B-*pan feed.* Where *A*- and *B*-molasses blow-up facilities are used, target Brix values for the two products should be set. It is believed that 70° Brix should be used in both cases as this will require minimal movement water use and, provided the molasses temperature is correct (70°C), it is safe to assume that all crystal in the molasses will have dissolved.

(g) *Remelt.* The Brix of remelt is affected by water or clear juice added to *B*- and *C*-sugars, be it for initial magma production or for melting itself. In addition it is common practice for floor washings in the vicinity of the centrifugal station to be pumped into the melter, so all water used for washings will also be measured as remelt Brix. As is the case for syrup, a Brix of 70° is considered a good target.

It is not advocated that centrifugal wash water volumes be measured because the over-riding determinant of the quantity of water used is the quality of sugar the operator wishes to produce. Also, water added at the *A*- and *B*-centrifugals will ultimately be compensated for in the blow-up process, and the quantity of water added at the *C*-centrifugal is determined more by the desired *C*-sugar quality than by energy considerations.

(h) *Sweet water.* Water used in the sugar dryer dust arrestors must be minimized. If the sweet water is not used for *B*- and *C*-sugar melting its Brix should be monitored and maintained as high as the system will permit.

Refinery

(i) *Raw sugar melt.* Raw sugar melt Brix should be maintained as high as the refining process employed permits, with the ceiling probably being 70°Brix.

(j) *Decolorized refined liquor.*

Operators should aim at minimizing the drop in Brix between melt and decolorized liquor. An initial target of 3 units is suggested.

(k) *Fine liquor.* This should be seen in the same light as syrup with similar Brix targets being set.

(l) *Evaporator feed make-up.* As is the case for the raw house evaporator supply tank, the target make-up requirement should be zero.

(m) *Refinery sweet water.* As long as all sweet water is used for melting or other process purposes and satisfactory product Brixes are achieved, there is no need to be concerned about the quantity of sweet water as far as energy management is concerned. If excessive amounts of sweet water are generated operators would do well to set ever-increasing Brix targets until such time as the sweet water excess disappears or sucrose losses in filter cake become excessive.

Measuring equipment

Flue gas carbon dioxide levels

A "Fyrite" analyser may be used to give an instantaneous reading of the CO_2 level in flue gas, but a continuous on-line measurement is preferable. Instrumentation for the continuous measurement of CO_2 tend to be far more complex than that for O_2 measurement which makes CO_2 based control less attractive than O_2 based control.

Flue gas oxygen levels

Instantaneous readings may be obtained using the "Fyrite" apparatus but, as with carbon dioxide, a continuous, on-line reading obtained using a zirconia cell is more useful. The continuous reading may be integrated and recorded, but its greatest value is to be found in the use of the oxygen measurement as a trim on the boiler air flow control, especially where more than one fuel type is used, or if the fuel quality is prone to change, such as is the case of bagasse at different moisture levels.

Carbon in boiler ash

A commercially available carbon in ash test unit which measures the electrical resistance of a ground sample of ash is best suited for this purpose. Neither sampling nor sample preparation for this determination is easy, and particular attention is required to these aspects if reliable results are to be obtained.

Water flow

There are a number of flow measuring devices on the market, varying considerably in reliability, accuracy and price, but experience has shown it worthwhile to incur the additional cost of magnetic flow meters. Whatever the case it is important that the device is correctly sized for the duty, and correctly installed.

Program monitoring

The success of a project of this nature hinges on the quality of reporting and feedback to the operators. An easy to read report, highlighting variances from targets, is required on a regular basis and should be followed up by informal discussion between supervisory staff and operators. The report should also be a discussion point for factory management on a regular basis.

A suggested lay-out of the report is shown in Appendix I but, whatever format is chosen, four essential elements need to be shown; these are: (1) the value being measured, (2) the agreed target for the value, (3) the measured value for the period, and (4) the measured value to-date.

Conclusion

Significant gains in energy conservation may be made by concentrating on the operator-controlled factory activities which have an impact on the overall energy balance. It is suggested that this is best done by involving the operators concerned in decisions made in this regard, and the management-by-objective approach is most suitable.

It must be borne in mind that other operational aspects, not under the influence of the operators, can have a significant impact on overall energy efficiency. The most noteworthy of these is the overall time efficiency – low time efficiencies are incompatible with good energy efficiencies.

Summary

Any attempt at energy management in a sugar factory is constituted of two basic aspects: the installation of suitably energy-efficient equipment in the factory, and the energy-conscious operation of the factory. The paper deals essentially with the second, i.e. the operational aspects, and proposes a strategy using the "Management by Objectives" approach to optimizing energy efficiency by minimizing unnecessary energy consumption. Wherever possible standard factory control parameters are used in monitoring the program, obviating the need for large numbers of flow measuring devices, and making report generation simple.

Un método práctico para administrar la energía en una fábrica azucarera

Cualquier intento de administrar la energía en una fábrica azucarera está constituido de dos aspectos básicos: la instalación en la fábrica de un equipo de rendimiento energético apropiado, y un funcionamiento de la fábrica conciente de la energía. Este trabajo trata esencialmente de lo segundo, esto es los aspectos operacionales, y propone una estrategia usando del método "Manejo por Objetivos" para maximizar el rendimiento energético al minimizar el consumo innecesario de energía. Donde se puede se usan parámetros standard de control de fábrica para controlar el programa, obviando la necesidad de un gran número de dispositivos medidores de flujo y haciendo que la generación de informes sea sencilla.

Une approche pratique pour la gestion de l'énergie dans une sucrerie

Toute approche de la gestion énergétique d'une sucrerie comprend

continued on page 19

Utilization of small steam turbines in the sugar industry

By Gernot Damminger
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Introduction

When planning and building or when modernizing industrial plants, the prices of raw materials and the energy cost – nowadays more than ever – play a decisive role. Optimum energy utilization is an essential prerequisite to the profitability of a plant and can only be ensured by employing adequate equipment. This applies especially to "heat-intensive" plants, i.e. to those industries in which heat is produced in the form of steam for the production process or where it is a by-product of the process. For these industries, "power/heat coupling", i.e. the coupling of steam production and generation of electrical or mechanical energy is absolutely essential.

The ideal utilization of primary input energy which results is shown in the Sankey Diagram of a "power/heat coupling" (Figure 1), compared with that of a typical large thermal power station.

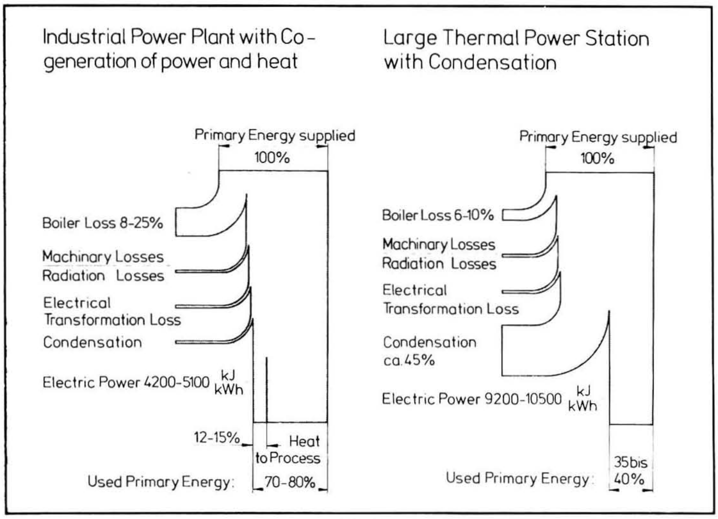


Fig. 1

Here we have an ideal application for back-pressure steam turbines. In the processing of sugar cane, there is nearly a balance between the power and heat required. Steam is produced in boilers almost exclusively fired with bagasse, at pressures and temperatures higher than required for the process.

First it is expanded in the steam turbines, producing the energy required for the electrical and mechanical drives, and then it is led into the process where the energy contained in the exhaust steam in the form of latent heat is utilized in different ways. This results in the steam being condensed into hot water which is returned to the boiler.

The increasing demand for better energy utilization, or in other words more efficient power generation, is founded on the rising cost of energy and the use of bagasse for other purposes. According to the geographical location and depending on the crop season and the energy situation, bagasse may be used, in part, for the manufacture of paper, pressed board or cellulose. This has led to the significant evolution of bagasse-fired medium pressure boilers working with better efficiencies than the old low-pressure boilers, as well as to the development of improved fuel utilization by "biomass" firing, i.e. the combustion of dried pelletized bagasse. This combustion moreover offers the advantage of not contaminating the air, since bagasse contains practically no sulphur which, as we know, coming from fossil fuels has most detrimental effects on the environment.

Application of the steam turbine

Meeting the latest requirements of engineering technology, modern cane sugar factories nowadays are not only independent of the public electricity supply but may even be in a position to export electric current. They thus ease the load on the public grid and increase the profitability of their own plant. The prerequisite to this independence is the use of steam turbines.

The sugar industry requires:

- reliable and trouble-free operating prime movers,
- economical operation,
- easy maintenance,

and, in the case of the mechanical drives,

- high starting torques,
- flexibility, i.e. wide speed adjustment range,
- rugged construction, and
- low investment cost.

Modern steam turbines meet all these requirements. Moreover, they offer advantages such as low space requirements, simple foundation design, easy operation and maintenance and provide the great advantage of oil-free exhaust steam which is highly desirable for proper operation of the preheaters, evaporators and vacuum pans downstream, and even the boiler itself.

For many years steam turbines such as those offered by KKK have been employed in the sugar industry to drive alternators, cane knives, shredders, cane mills, pumps, fans and compressors. The heart of the sugar factory power station is the turbo-alternator. Whether steam turbines of single-stage or multi-stage design are selected to drive the alternator depends on the general conception of the plant, i.e. its size, the number of electrical drives and steam turbines installed, the geographical location and the campaign or operation period per year. The steam turbine gains particular importance as a topping turbine for generation of electricity in the extension and modernization of cane sugar factories when a new medium-pressure boiler is installed and the existing steam turbines are retained unchanged.

Because of its simple design, the single-stage turbine has a lower investment cost; however, its efficiency is lower than that of a multi-stage turbine. In the case of small turbines, of single stage design and with outputs up to 3000 kW for mechanical drive duties, the demand for energy saving and highest possible economy of operation is met by achieving an optimum combination of rotational speed and turbine wheel diameter. Machines can be directly coupled but, in the case of the most important mechanical drives in the sugar industry, gear drives are employed. Economies can be made where the manufacturer offers a modular system with assembly from standardized components which include a range of turbine wheels of different diameters and corresponding integral gearing of various ratios.

With increasing drive ratings, the turbine control system has had to meet more and more stringent requirements for control response speed, accuracy and range. Modern hydraulic speed governors have to meet NEMA specifications with class B, C or D parameters. Those provided by KKK operate at a control oil pressure of 10 bar and, in accordance with the requirements of the driven machine, may be incorporated into plant control systems of various kinds by fitting electrically, pneumatically or hydraulically actuated adjusting devices or may be adjusted simply from a remote control panel.

If the turbines are operated primarily at constant speed with relatively constant load – for example, when they drive cane knives, shredders or pumps – simple throttle control is sufficient. In the case of frequently changing loads, especially when the turbines drive alternators or mills, control by several hydraulically actuated nozzle group control valves is more economical. The higher capital cost required is paid off within a short time by the steam saved and/or by the higher output gained.

The steam turbine in cane preparation

The greatest amount of mechanical energy required and thus the main field of application for mechanical turbine drives can be found in cane preparation. Cane knives, shredders, unigrators and mills are equipped with individual drives. These machines without exception run at low speeds. However, turbines are characteristically high-speed machines. In order to match the speed of the driven machine and at the same time ensure internal optimization with steam conditions, these turbines may be fitted with integral gears. Especially with the extremely slow-running cane mills, use of a generally expensive "turbo gear stage" in the intermediate gearing is thereby eliminated.

The standard series of KKK geared steam turbines covers a speed range between 900 and 4000 rpm. With such units, turbine and single-stage gear form one unit; the Curtis–type turbine wheel with two rows of blades is fitted to the pinion shaft outside the bearings – the so-called "overhung design". The turbine casing is flange-fitted to the bearing housing and the gear housing itself, and also the forced lubricated multiface sleeve bearings, are horizontally split. The steam-end bearing of the turbine shaft, i.e. the pinion shaft, is designed as a journal bearing and the non steam-end bearing as a combined journal and thrust bearing.

Only one shaft seal – either labyrinth or carbon ring, depending on the frame size – is required to seal off the turbine exhaust steam space. By comparison with direct drive turbines of between-bearings design having a separate gearbox, the thermal load on the steam-conducting parts have no influence on bearings, gear or alignment with the driven machine, allowing a fast start-up from cold. With 2 instead of 4 shaft bearings on the high-speed side, bearing losses are lower, while the number of wearing parts is smaller and construction is more compact.

Bearings and gear may be inspected by opening the horizontally-split gear casing without disconnecting the steam piping. To inspect the turbine wheel, reversing blades and nozzles only the exhaust steam cover has to be removed. This is fitted to the turbine casing and to the exhaust steam pipework by simple ring flanges which can easily be kept pressure tight.

Safety and control devices

Small steam turbines used to drive cane knives, etc., are provided with a range of safety devices and control instruments required for trouble-free operation. An over-speed trip device shuts off the turbine by means of an emergency valve, while an electric oil pump is governed by a pressure switch to ensure that the continuous oil pressure remains within the set range (8 - 9.5 bar). An alarm at the control panel is activated if a pressure switch detects a rise in lubricating oil pressure above 1.0 bar, while if it falls below 0.5 bar, the turbine is automatically shut off by the lubricating oil trip switch. Any signal from the plant requiring the turbine to be shut down does so by means of a solenoid valve.

Cane mill drives

Apart from the roller length and diameter, the throughput of a cane mill depends on roller speed and on the bagasse blanket. To achieve a satisfactory relationship between investment cost and throughput, it might be thought best to increase speed and blanket thickness. These reduce extraction, however, as the length of time for squeezing out the juice is diminished in the one case and in the other the length of the path for the juice inside the bagasse layer is increased.

To attempt to compensate for this by increasing the number of mills in the tandem is only appropriate to a limited extent, and it is therefore important to operate with a bagasse blanket thickness and a mill speed optimized for the chosen throughput and extraction. In general higher speeds are combined with lower blanket thicknesses and *vice-versa*. The optimum relationship between the two depends, among other things, on the origin and type of cane, weather conditions, etc., and while it may be a management objective to maintain even feeding, this cannot be achieved in practice.

As a consequence, it is desirable to have the flexibility to control the speeds of the individual mills in order to maintain uniform milling, and to be able to adjust these as the top roller loads and/or gap widths vary. This requirement cannot be met by a group drive for the mill tandem but only by individual drive. The steam turbine perfectly meets this requirement since it provides a wide speed range, offering at the same time great reliability and simple operation. Moreover, it can be designed so compact as to be easily accommodated alongside the mill, together with the respective gearbox.

Mill drives operate at varying loads usually in a range of 60 - 120% of the nominal speed. The total power consumption of the milling plant is so considerable that the higher capital cost of automatic nozzle group control is fully justified by the steam quantity saved. A common form of mill drive speed control is the proportional speed governor. This is driven from the turbine shaft by a lay gear. The flying weights make the leaf spring bend, pulling the control piston upwards. Oil flows off the control edge and the impulse pressure falls. The nozzle group control valves are moved via hydraulic servomotors. Impulse pressure and the preset spring forces determine the opening range of the individual control valves.

Remote control and supervision

To ensure that operation is as trouble-free as possible, the drives for cane preparation and milling may be remote controlled and monitored from a central control panel, with control effected electrically. The panel should be mounted on the mill platform where there is good all-round visibility. The panel should contain, for each turbine, signal lamps indicating:

the operating condition of the auxiliary oil pump,
low lubricating oil pressure, high oil temperature,
the position of the solenoid valve, and the remote mill drive speedindicator.

Control facilities should also be provided for:

remote shut-down,
starting the auxiliary oil pump, and speed adjustment of the mill drives, both jointly and individually.

In modern plants additional remote indicating instruments may be fitted to monitor live steam pressure and temperature, exhaust steam pressure and the thickness of the bagasse layer. Clearly, a master trip switch for emergency shut down of the entire plant should also be installed.

Design criteria

One of the unquestioned advantages of the steam turbine is its high starting torque; however, this may be something of a liability if its starting characteristics are not properly considered. Well-known engineering companies specializing in the planning of sugar factories specify that the mill drive turbine should develop a starting torque of 200% of the nominal torque, i.e. the torque at nominal speed and design output. This requirement may be based on experience and can without a doubt be justified. When starting the mill, a high breakaway torque may be required, and in all cases the mill gears are dimensioned for this shock loading.

This requirement may, however, become critical when, after shut down, the mill, loaded with cane, is restarted and accelerated to operating speed. The diagram (Figure 2) shows the (transient) variation of turbine torque available, plotted against the operating speed. The turbine has to be rated for the most difficult operating condition and it must be expected that in the starting phase of the milling plant, the turbines are not under manual control. Under these circumstances the maximum possible steam flow, corresponding to the entire nozzle cross-sectional area, will flow through the turbine unthrottled as is the case with the automatic rapid start-up of a stand-by turbine.

The speed governor takes effect only at the preset minimum operating speed, thereby controlling the valves to a position corresponding to the load. Curve "N" shows the variation of the torque available without "overload nozzles". Depending on the steam conditions, a single-stage steam turbine has a starting torque of 130 - 150% of the nominal torque. On run up, the drive torque first increases to 160 – 170% and then decreases to the nominal torque as the speed rises.

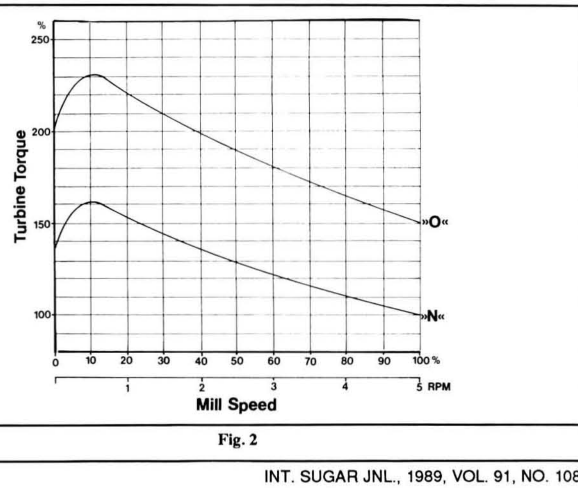


Fig. 2

In order to meet the requirement of 200% of starting torque, more drive output is necessary and this can only be achieved by a higher steam flow. The turbines must therefore be equipped with "overload nozzles". Variation in the "overload" torque available is shown by curve "O". From this it will be seen that drive torque can increase to approximately 230% of nominal torque, which is not a transient shock load but could conceivably be an operating condition for a longer period. Consequently, if the overload nozzles are not closed right away at very low speed, the mill gearing could be overloaded and damaged. This danger can be avoided by overdimensioning the mill gears but the technically best and most reliable solution is to the installation of a coupling with torque limitation. The higher capital cost compared with a normal flexible coupling should be offset against the increased operating safety of the plant.

Steam turbine drive of pumps and compressors

In the sugar industry, steam turbine drives are not only of advantage for specific cane milling machinery but also generally for pumps, including product pumps, boiler feed pumps and circulating pumps, as well as for the boiler fan and air compressor.

The boiler feed pump drive turbine may be fitted with a pressure or differential pressure governor while the boiler fan drive may be controlled by a speed governor with electric adjustment interfaced with the boiler control system. In this way, advantage is taken of the variable speed of the turbine, with resulting energy saving.

The advantages of the steam turbine, the possibility of matching its control with the general governing, control and supervisory system, and its adaptation to the loads concerned, ensure economical operation and add to the profitability of the sugar factory.

A practical approach to energy management in a sugar factory

continued from page 15

deux aspects de base: l'installation dans l'usine d'un équipement approprié quant à son efficience sur le plan d'énergie, et une conduite de l'usine par des gens sensibilisés à cet égard. L'article traite essentiellement du second aspect, c.à.d. des problèmes se rapportant à l'opération. On y propose une stratégie faisant appel à une approche "Gestion par Objectifs" afin d'optimiser l'efficience sur le plan énergétique en réduisant au minimum toute consommation inutile d'énergie. Partout où c'est possible on a, lors de l'établissement du programme, utilisé pour le contrôle des paramètres standards. On évite ainsi le besoin d'un grand nombre de débitmètres et on simplifie la rédaction du rapport.

Ein praktisches Herangehen an die Frage der Energieverwaltung in einer Zuckerfabrik

Jeder Versuch, Energie in einer Zuckerfabrik zu verwalten, besteht aus zwei Grundaspekten: dem Installieren von energetisch leistungsfähigen Vorrichtungen und dem energetisch günstigen Betrieb der Zuckerfabrik. In diesem Aufsatz handelt es sich um den zweiten Gesichtspunkt, d.h. die Betriebsaspekte. Dem Verfasser wird ein Weg zur Optimisierung des energetischen Wirkungsgrads mittels Verringerung des unnötigen Energieverbrauchs unter Verwendung der "Verwaltung durch Ziele" vorgeschlagen. Für die Überwachung des Programms verwendet man womöglich Standard-Betriebsregelungsparameter; dadurch ist eine grosse Anzahl von Durchflussmessern nicht nötig und dass Verfassen von Berichten ist einfach.

APPENDIX I

Energy management control

Boiler station	Target O_2	Actual O_2	Target C % ash	Actual C % ash
Boiler No. 1	5 - 7	6	1 - 2	2
Boiler No. 2	5 - 7	5	10 - 15	11
Boiler No. 3	5 - 7	7	10 - 15	14
Boiler No. 4	5 - 7	3	10 - 15	16

	Units	Target	Actual	To-date
Extraction				
Imbibition on fibre	%	420	412	422
Raw house				
Evaporator make-up	tonnes/week	0	65	36
Syrup Brix		65	68	64
Filtrate Brix		8	8	7
Movement Water A	kg/m³ mct	75	72	78
Movement water B	kg/m³ mct	25	23	25
Movement water C	kg/m³ mct	25	21	24
Blow-up Brix A		70	72	71
Blow-up Brix B		70	69	70
Remelt Brix		70	67	69
Sweet water Brix		15	15	16
Refinery				
Raw melt		65	66	65
Decolorized liquor ΔBx		3	4	3
Fine liquor Brix		65	63	64
Evaporator make-up	tonnes/week	0	12	14
Sweet water Brix		5	6	5
Coal burnt	tonnes/week	100	128	106

World sugar production estimate, 1988/89[1]

	1988/89	1987/88
	tonnes, raw value	
BEET SUGAR		
Belgium	1,011,000	874,000
Denmark	570,000	422,000
France	4,350,000	3,973,000
Germany, West	3,160,000	2,963,000
Greece	272,000	197,000
Holland	1,065,000	1,064,000
Ireland	217,000	242,000
Italy	1,706,000	1,867,000
Portugal	5,000	5,000
Spain	1,250,000	1,072,000
UK	1,465,000	1,335,000
Total EEC	*15,071,000*	*14,014,000*
Austria	380,000	390,000
Finland	133,000	64,000
Sweden	427,000	275,000
Switzerland	123,000	123,000
Turkey	1,595,000	1,784,000
Yugoslavia	707,000	913,000
Total West Europe	*18,436,000*	*17,563,000*
Albania	45,000	40,000
Bulgaria	105,000	110,000
Czechoslovakia	720,000	770,000
Germany, East	715,000	760,000
Hungary	532,000	533,000
Poland	1,750,000	1,823,000
Rumania	430,000	450,000
USSR	9,900,000	9,800,000
Total East Europe	*14,197,000*	*14,286,000*
Afghanistan	2,000	6,000
China	980,000	725,000
Iran	470,000	577,000
Iraq	20,000	20,000
Japan	685,000	680,000
Pakistan	38,000	41,000
Syria	40,000	40,000
Total Asia	*2,235,000*	*2,089,000*
Canada	120,000	147,000
USA	3,084,,000	3,586,000
Total N & C America	*3,204,000*	*3,733,000*
Chile	455,000	441,000
Uruguay	18,000	25,000
Total S. America	*473,000*	*466,000*
Algeria	11,000	11,000
Egypt	99,000	96,000
Morocco	400,000	365,000
Tunisia	27,000	27,000
Total Africa	*537,000*	*499,000*
Total Beet Sugar	39,082,000	38,636,000

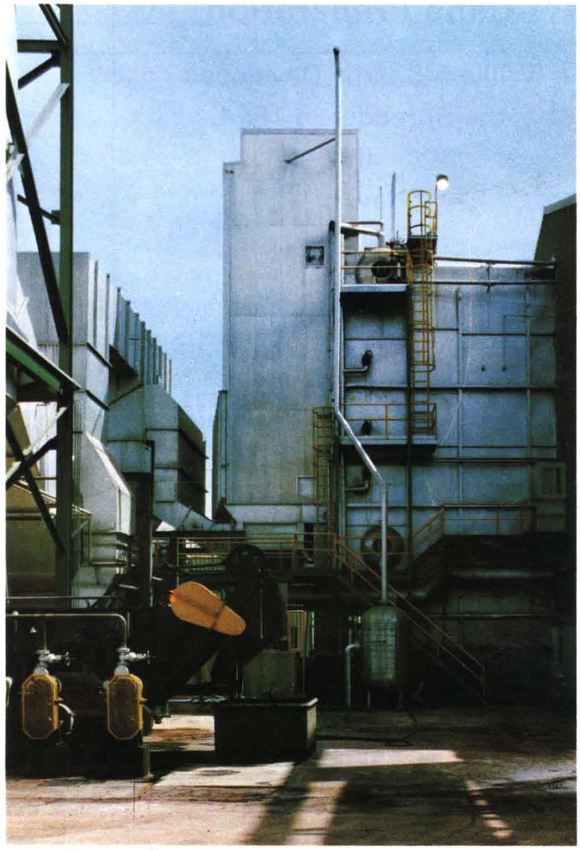
	1988/89	1987/88
	tonnes, raw value	
CANE SUGAR		
Spain	16,000	16,000
Total EEC	*16,000*	*16,000*
Bangladesh	199,000	194,000
Burma	68,000	41,000
China	5,545,000	4,816,000
India	11,050,000	9,900,000
Indonesia	2,070,000	2,317,000
Iran	640,000	713,000
Iraq	27,000	26,000
Japan	940,000	939,000
Malaysia	95,000	84,000
Nepal	30,000	30,000
Pakistan	1,988,000	1,936,000
Philippines	1,546,000	1,369,000
Sri Lanka	38,000	29,000
Syria	40,000	40,000
Taiwan	590,000	645,000
Thailand	3,100,000	2,705,000
Vietnam	470,000	460,000
Total Asia	*28,438,000*	*26,250,000*
Barbados	85,000	83,000
Belize	90,000	87,000
Costa Rica	232,000	219,000
Cuba	7,900,000	7,300,000
Dominican Republic	920,000	790,000
Guadeloupe	65,000	676,000
Guatemala	685,000	668,000
Haiti	40,000	35,000
Honduras	177,000	173,000
Jamaica	160,000	221,000
Martinique	7,000	9,000
Mexico	3,800,000	3,822,000
Nicaragua	235,000	225,000
Panama	110,000	107,000
Puerto Rico	95,000	93,000
St. Kitts	31,000	25,000
El Salvador	189,000	200,000
Trinidad	90,000	94,000
USA - Hawaii	890,000	904,0-00
- Mainland	2,150,000	2,132,000
Total N & C. America	*17,951,000*	*17,254,000*
Argentina	1,150,000	1,063,000
Bolivia	140,000	167,000
Brazil	8,850,000	8,458,000
Colombia	1,400,000	1,391,000
Ecuador	280,000	341,000
Guyana	255,000	225,000
Paraguay	90,000	112,000
Peru	600,000	565,000
Surinam	3,000	1,000
Uruguay	51,000	68,000

	1988/89	1987/88
	tonnes, raw value	
Venezuela	606,000	608,000
Total South America	*13,425,000*	*12,999,000*
Angola	12,000	13,000
Burkina Faso	27,000	27,000
Cameroun	80,000	81,000
Chad	27,000	26,000
Congo	35,000	38,000
Egypt	929,000	895,000
Ethiopia	210,000	205,000
Gabon	15,000	15,000
Guinea	15,000	15,000
Ivory Coast	167,000	152,000
Kenya	435,000	420,000
Madagascar	119,000	107,000
Malawi	184,000	175,000
Mali	20,000	20,000
Mauritius	652,000	733,000
Morocco	87,000	78,000
Mozambique	50,000	55,000
Nigeria	71,000	63,000
Réunion	240,000	225,000
Rwanda	4,000	4,000
Senegal	79,000	78,000
Sierra Leone	6,000	6,000
Somalia	45,000	35,000
South Africa	2,100,000	2,235,000
Sudan	530,000	443,000
Swaziland	445,000	461,000
Tanzania	107,000	110,000
Uganda	49,000	40,000
Zambia	155,000	145,000
Zaire	75,000	76,000
Zimbabwe	410,000	430,000
Total Africa	*7,380,000*	*7,406,000*
Australia	3,750,000	3,510,000
Fiji	384,000	416,000
Papua-New Guinea	43,000	24,000
Total Oceania	*4,177,000*	*3,950,000*
Total Cane Sugar	69,152,000	65,786,000
World Total	108,234,000	104,422,000

Finland sugar forecast[2]

Suomen Sokeri Oy. expect the domestic beet crop to yield 123,500 tonnes of white sugar in 1988, compared with 65,000 tonnes in 1987. The balance of the expected consumption of 200,000 tonnes will be made up by refining imported raw sugar.

1 F. O. Licht, *Int. Sugar Rpt.*, 1988, **120**, 514 - 518.
2 *Reuter Sugar Newsletter*, October 4, 1988.



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