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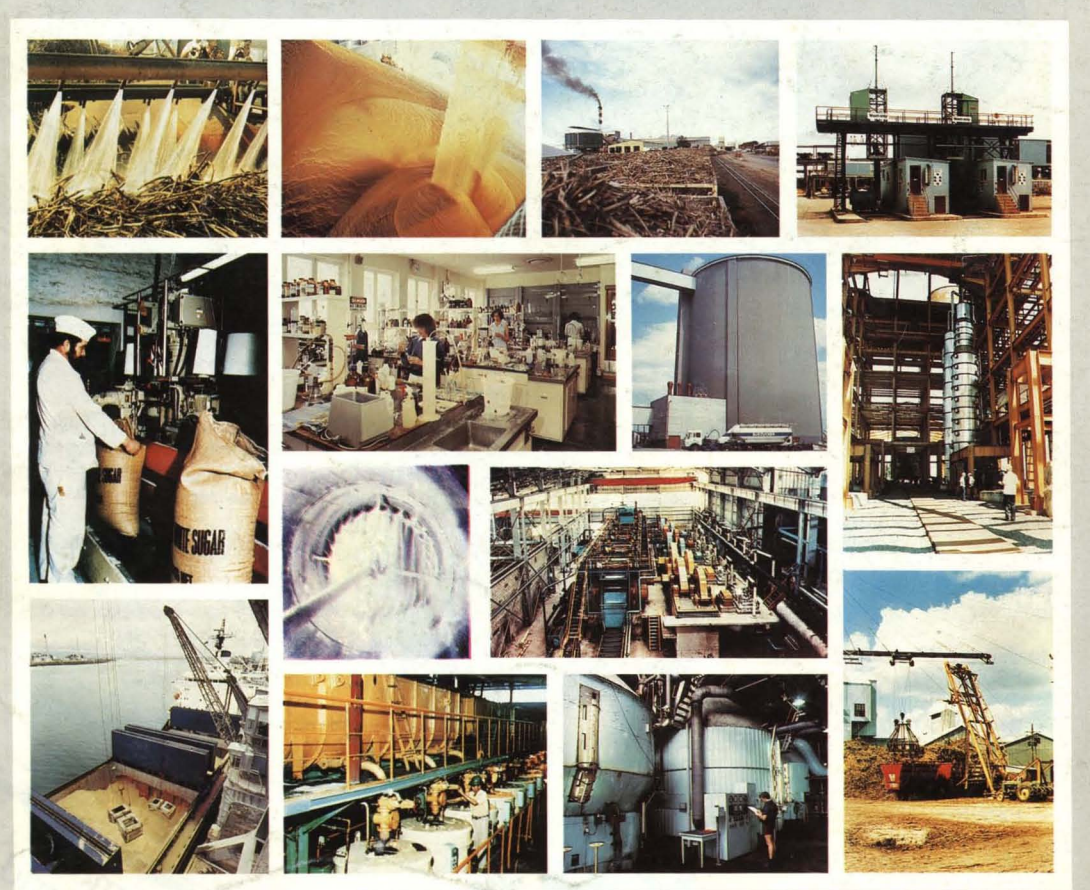

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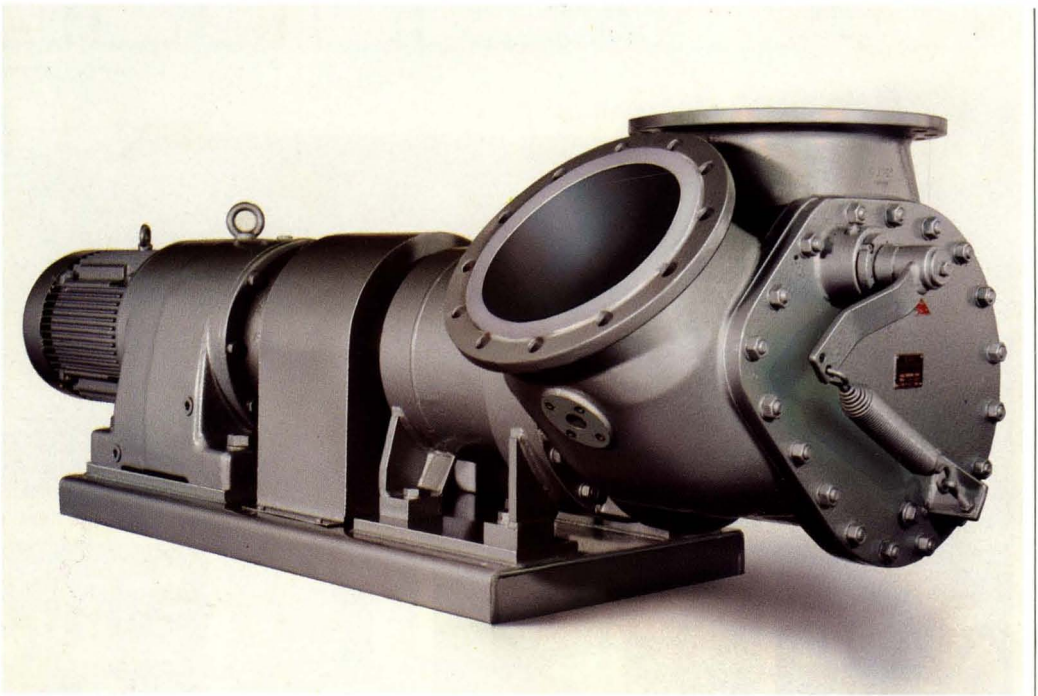

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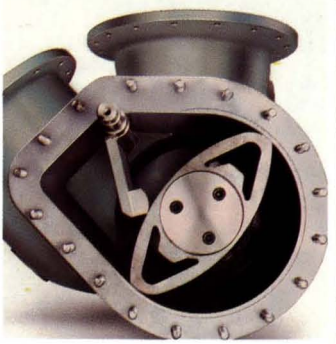

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News and views

World sugar prices

The London Daily Price for raw sugar started the month of September at $122 per tonne and ended it at $121, while that for white sugar fell from $178 to $173 per tonne between September 1 and September 30. A gloomy assessment of market prospects by E. D. & F. Man, coupled with reports of a likely further 400,000-tonnes sale by Brazil in the autumn, resulted in a declining market at the start of the month and the LDP reached $115 on September 8; prospects of a large Indian buying tender improved matters and the price rose to $127.50 a week later, to fall again when the tender did not materialise and sales of Mexican and Colombian sugar sales at lower prices were reported. The LDP fell to $116 on September 23 but then benefited from the news that all sugar under loan to the CCC had been redeemed by producers in California and Florida; earlier it had been feared that this sugar – 265,500 short tons – might be dumped on the world market after the producers had served notice of intention to forfeit on the CCC. The raw sugar price rose to $125 but then declined during the rest of the month.

White sugar prices had tended to follow those for raw sugar fairly closely, with a differential of around $56 per tonne but in the middle of the month this was narrowed to around $52 as the EEC increased the quantities of exports at maximum rebate. Indications that more sugar would be required by India restored the premium to its former level, but a FIRS assessment of a larger European sugar crop at the end of the month reduced it again to $52 on September 30.

Sugar export prospects[1]

In spite of a steady rise in consumption, world gross imports fell from a peak of 32.1 million tonnes in 1981/82 to an estimated 28.4 million tonnes in 1985/86. This is ascribed to four main factors: continued consumption decline in developed countries while domestic production levels are maintained; growth of domestic production in developing importing countries; growth of consumption in exporting countries; and economic problems which affect demand in developing countries. The fall in demand has mainly hit the raw sugar market but the period of growth of the white sugar market now seems to be over.

Loss of market opportunity in the US and Japan is the major factor which has affected raw sugar; production has not yet been trimmed to match the shrinkage and a huge overhang of raw sugar has been the consequence. It is clear that it will not be possible to maintain the current export structure, and raw sugar production for export will have to be curtailed drastically. Some countries may be forced to go out of export production altogether and we may well see a concentration on the supply side during the next few years.

Although white sugar imports are now nearly 40% of the total, against 26% in 1978/79, the absolute volume has stagnated over the past four years in spite of falling prices from 1981. This results from limited cash availability owing to recession in developing countries where demand/income elasticity is high, and the increased degree of self-sufficiency in former importing countries, particularly Indonesia and Mexico. The malaise in the white sugar market has been masked by the rise in Indian import demand which reached an estimated 1.9 million tonnes in 1985/86. Steps have been taken in India to increase production and offtake cannot be expected to continue, rather it will decline.

Efforts by the EEC to restrict subsidies have forced up the premium over raw sugar to the point where tolling becomes remunerative, and Brazilian white sugar is also offering increasing competition. In the background also looms the US re-export program which could lead to significantly higher availabilities; under the Tariff Act of 1930 refiners have access to refunds of tariffs and fees paid during the three years preceding an export. A bill currently before Congress would give those refiners still in business access to all drawback produced since October 1, 1977 and would allow that money to be used until the current Farm Bill's sugar provision expire on October 1, 1991. The refiners estimate that passage of the bill would add about 500,000 short tons annually to sugar supplies until then. Thus competition will become more intense, although, in the long term, the white sugar market can be expected to expand as population growth in developing countries raises import requirements.

World sugar production, 1986/87

The first estimate by the *Czarnikow Sugar Review* of sugar production in the 1986/87 crop year was published recently[2] and is reproduced elsewhere in this issue, together with the latest estimates for 1985/86. The latter season has been characterized by continued improvement over initial expectations, and Czarnikow acknowledges that it is clearly unrealistic at this stage to pretend to be able to forecast production in 1986/87 with close degree of accuracy because, in some cases, production will still be in progress in twelve months time and weather conditions play an important part in the production of all agricultural crops, including sugar.

Nevertheless, on a basis of published beet tests, production targets and reported areas, etc., Czarnikow has produced an assessment of indicated sugar production levels. In Europe, beet sugar output is expected to fall by about 1.2 million tonnes from 1985/86 but the massive protection for the domestic industry built into the US Farm Bill is expected to raise beet sugar output there by 231,000 tonnes. Brazil's planned increase is likely to be affected by the drought in São Paulo state so that the increase is set at only 600,000 tonnes, while the drought in Cuba is also likely to limit recovery from the weather-reduced output of 1985/86. A fall of around 200,000 tonnes in South African

1 F. O. Licht, *Int. Sugar Rpt.*, 1986, **118**, 485 - 489.
2 1986, (1752), 114 - 119.

production is expected to be balanced by increases in several other African countries.

No increase is expected in China but India is expected to produce nearly a million tonnes more. The increase in Pakistan's production is expected to be limited by diversion to gur and khandsari, while a further small drop in production is expected in the Philippines. Czarnikow's projected total is marginally under 100 million tonnes; however, the proportion of cane sugar has been increasing and the indication of cane sugar output, if achieved, would constitute a record.

New Indian sugar policy urged[3]

The Indian Sugar Mills Association has urged the government to come up with a long-term policy on sugar aimed ultimately at achieving self-sufficiency. The Association feels its suggestion at least deserves consideration by the government, given the steady increase in domestic consumption and sustained imbalance between the country's requirements and domestic supplies. The Central government released 8.8 million tonnes of sugar for domestic consumption in 1985/86 against 8.5 million tonnes in 1984/85. In 1980/81, government releases were only just under 6 million tonnes and, thanks to liberal supplies, consumption has increased substantially. Production is expected to rise to 8 million tonnes in 1986/87 but at the same time consumption may be 9 million tonnes.

US price support rates

On September 26 the US Secretary of Agriculture announced that the national (weighted average) price support loan rate for the 1986 crop of domestic cane raw sugar would be 18 cents/lb and that for refined beet sugar would be 21.09 cents/lb. The Market Stabilization Price (MSP) for 1987 was set at 21.78 cents/lb, raw value, up from 21.50 cents/lb for 1986. The MSP is the sum of the loan rate for 1987 (18 cents) plus the adjusted average transportation costs for shipping raw cane sugar (2.93 cents), interest costs of repaying a price support loan (0.65 cents) plus an incentive of 0.2 cents/lb.

This provides good news for the US growers and their 1986 beet crop estimate has been raised by the USDA from 25,032,000 short tons to 25,438,000 tons (against 22,636,000 tons in 1985), while the 1986 cane crop is set at 30,255,000 tons against 29,850,000 tons earlier and 28,213,000 tons in 1985. Should excess supplies force the market below the MSP the USDA might be faced with difficulties through the cost of loan defaults and the need to dispose of forfeited sugar. This occurred earlier this year and the USDA sold some 145,000 tons of sugar to China at below the world price at an estimated $45 million loss. (It will be remembered that the sugar program is supposed to be administered "at no cost to the Federal Government").

US sugar import quotas, 1987

As a result of the extension of the 1985/86 quota, the import quota for 1987 does not have to be announced until December 15; in previous years the USDA was required to announce it by September 15. With increased domestic production expected and a need to maintain market level near to or above the MSP, the only way of limiting supplies has been to cut imports. Market opinion is that the 1987 quota is likely to be reduced to between 800,000 and 1,000,000 short tons for the period to September 30, 1987.

The breakdown of the total, however, is likely to be a matter of political judgements and influence. The Congress has passed legislation excluding South Africa while the CBI countries are lobbying for a freeze on their 1985/86 quota levels, reductions to be at the expense of the more developed countries. Sugar provisions have been attached to anti-drug abuse legislation where it is proposed that sugar import quotas be used as part of reward/penalty system for exporting countries deemed to be supporters or not of US anti-drug legislation. Possible examples quoted by B. W. Dyer & Co.[4] include Bolivia, Colombia and Mexico, which stand to lose quotas of 14,000, 40,000 and 12,500 tons, respectively. In addition it has been proposed that Ecuador's quota be frozen as a reward for promoting free enterprise. Canada could lose its quota because it imports sugar from Cuba, while it is proposed to grant the Philippines "most favoured nation" status which would enable her sugar to enter the US duty free and also entail an increase of quota to the same level as that of the Dominican Republic, ie. from 13.5 to 17% of imports.

It is proposed that the Australian quota be cut from 142,000 tons to below 10,000 tons, while virtual elimination of the quotas for Brazil, Thailand and smaller African suppliers would be required. The Australian government has protested at the proposed cut and has said it would launch an action under the General Agreement on Tariffs and Trade (GATT) against the US if the legislation were enacted, demanding compensation for damages to its sugar industry.

Sugar Industry Technologists Inc.

The Award Committee, under the Chairmanship of Leon A. Anhaiser, has selected the paper "Sure: a new sugar decolorization process" as the winner of the George & Eleanore Meade Award for the best paper presented at the 1986 meeting of S.I.T., held in Baltimore in May last. The paper was presented by Dieter Frank, Lincoln D. Metcalfe and John Park, of Akzo Chemie America. Meade Award plaques will be presented to the authors at the next meeting of Sugar Industry Technologists Inc., to be held in Sydney, Australia, during May 11 - 14, 1987.

Engineering and Architecture conference

The 5th Scientific Conference on Engineering and Architecture is to be held during January 20 - 23, 1987 in the International Conference Centre, Havana, Cuba. Organized by the José Antonio Echeverría Higher Polytechnic Institute, its main topic will be the use of computers and microprocessors in Engineering and Architecture, one of the principal fields (organized by working commissions) being sugar and its by-products. Information may be obtained from Eng. Marcel Andino Zayas, ISPJAE, Marianao, Ciudad de La Habana, Cuba (Telephone 20-7242/20-8454; Telex 512217 bdict cu).

3 *Public Ledger's Commodity Week*, September 13, 1986.
4 *Dyergram*, 1986, (23-86), 2.

Product news

Elliott and energy management

Elliott Company has long been associated with the sugar industry and makes its contribution to energy efficiency and economy by the provision of a range of equipment, developed over more than 50 years of field experience, which includes the YR line of standardized, general purpose steam turbines which have established a reputation for unusually high quality and dependability. Available in ratings up to 3500 h.p. (2600 kW), speeds to 7000 rpm, for input steam pressures up to 900 psi (62 bar) and up to 900°F (482°C), the single-stage YR turbines have babbitted liner-type sealed bearings, casing sealing glands with segmental carbon rings, a dynamically-balanced self-locating rotor and an overspeed trip system.

Elliott also offer several types of single-valve multistage YR series turbines featuring high efficiency, standardized parts, space saving design and high-strength casings, a separate trip system, thin-walled bearings, separate gland covers and traditional running speeds up to 5700 rpm. The approximate range of capacities is up to 4000 h.p. (2980 kW).

A range of turbo-generators from about 5 MW to over 50 MW is supplied by Elliott, who have delivered hundreds of sets throughout the world. The packages include carefully matched components to minimize problems during installation, start-up and operation. They provide complete lubrication systems suited to the individual installation, high quality gears and single baseplate mounting, while Elliott can also provide switchgear, condensers and instrumentation.

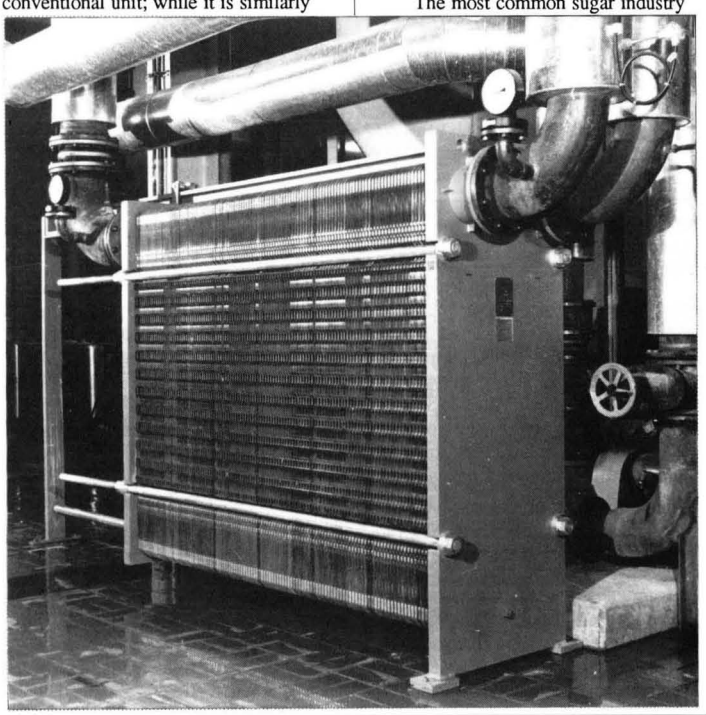
The PAP Plus compressors for oil-free compressed air are often appropriate for only the larger sugar factories and refineries because the smallest capacity is 700 cfm (1200 m³/hr); these energy-efficient machines not only save power – they save manpower. They feature simple, low-cost installation, high base-load and part-load efficiency, high reliability, easy operation, little maintenance, quiet operation, low vibration and small size and weight. Like the turbines, the compressors are backed by complete service, including operation and maintenance training, and expertise provided anywhere in the world.

Further details and descriptive brochures:
Elliott Company,
Jeannette, PA 15644-0800,
U.S.A.

Free-flow plate heat exchangers

For more than 50 years, plate heat exchangers have been in operation for heat transfer duties. The first "free-flow" plate heat exchangers were introduced at the end of the 1950's and there are nowadays sizes ranging from 0.09 to 0.84 m² heat exchange surface per plate. The free-flow plate heat exchanger eliminates the disadvantages of the conventional unit; while it is similarly constructed from corrugated plates, their assembly in the plate pack is different. In the conventional heat exchanger the alternate plates, all having a herringbone configuration, are turned through 180°, which results in many metallic plate-to-plate contact points. The gap between plates thus varies from zero to 8 mm. In a "free-flow" plate heat exchanger there is no metallic contact between plates; they are separated by rubber gaskets which seal the channels from each other and from the outside. The resultant plate-to-plate gap is up to 13 mm on the product side and up to 6 mm on the service side. With the biggest plate, flow capacities up to 700 m³/hour can be achieved in a single unit. Owing to the bigger gap between plates and the thicker plate material required, the heat transfer coefficient in the free-flow plate heat exchanger is smaller than the conventional plate heat exchanger; however, it is some ten times greater than that of the traditional shell-and-tube heat exchanger.

The most common sugar industry



applications up to now have been the heating of raw juice and carbonatation juice, for both of which the so-called multiple-pass free-flow plate heat exchangers are used. These have the disadvantage that the connecting pipework is attached on both sides of the unit, but the relative high juice velocity in the gaps between the plates has a self-cleaning effect which eliminates the need for cleaning during the campaign. Hot water and/or vapour can be used for heating of the juice; in the latter case two inlet vapour connexions are often required to reduce vapour velocity in the connecting pipework. Because of the high heat transfer coefficient, aided by the small gap on the heating side, even very low-grade vapours can be used.

Other interesting applications of the free-flow plate heat exchanger are in the heating of magma and of unfiltered press water (applicable only in the beet sugar industry). This latter application has an especially very short pay-back time, as the need for a rotary filter, with consequent heat loss, is eliminated.

Further details:

GEA Ahlborn GmbH & Co.,
Dept. NAIV,
Voss-Strasse 11/13,
D-3203 Sarstedt,
Germany.

The Bestobell steam trap monitor system

The cost of loss through leaking steam traps is high; unfortunately, most steam traps are installed in closed systems and their loss is difficult to pinpoint. From many energy surveys carried out by Bestobell Valve & Steam products, an average of 15 - 20% of all installed system traps have been found to be in a failed condition. In a typical steam system operating at 100 psi the loss amounts to approximately £500 per week for every 100 steam traps installed. Many methods have been used by industry to identify faulty steam traps. These range from looking at vent pipes from local collection points, breaking of joints on the discharge side of traps, sensing of upstream and downstream temperatures and use of ultrasonic probe instruments to measure noise emitted by traps. All of these methods have drawbacks; they are either costly or require a level of interpretation of the test results.

With these factors in mind, Bestobell has developed their steam trap monitor system. This intrusive device is installed imediately upstream of a steam trap as illustrated. Being the size of a barrel nipple it can be simply fitted either during the initial installation or later. The forged carbon steel body houses a ceramic insulated conductivity probe, the tip of which extends down into a small condensate reservoir formed in the body. The Pen Test Unit is a maintenance-free instrument which is self contained in its design. It consists of a 3 volt lithium battery power source supplying power to the internal circuitry and the probe tip. Indication of test result is by either a red or green L.E.D.

When a steam trap monitor is introduced into a steam trap working correctly the condensate reservoir will be full of liquid. Pressing the check button supplies a voltage across the tip of the probe and the body of the S.T.M. The resistance of the contents of the condensate reservoir is measured by the circuity. When full of condensate this is relatively low and a green pass light results, indicating that the trap is working correctly. If inserted into a steam trap which has failed, the condensate in the condensate reservoir is depleted, owing to the high velocity of the condensate/steam mixture and the deflective action of the probe itself. The space is filled by steam of relatively high resistance which the Pen Test Unit measures. A resultant red light indicates a failed steam trap which is losing live steam.

Where the Pen Test Unit cannot physically be inserted into the monitor owing to space limitations, a 500 mm fly lead is available. The system can be easily extended to provide remote monitoring, while the RS16 remote scanning unit accomodates hard-wired inputs from up to 16 monitors. At one press of a button all 16 are scanned and

results displayed on rows of red or green L.E.D.s. Space is provided on the front of the panel to write the steam trap location details of each input.

The RS16A is an automatic version of RS16; it requires a 240 volt mains supply but continuously monitors the steam traps at a central display point. This unit also has an additional alarm feature allowing it to be cascaded into another RS16A. In this way, zones, each monitored by an RS16A, can further be monitored by another RS16A unit. Identification of the actual failed steam trap(s) merely requires interrogation of the RS16A in the particular zone(s).

Where diplay is required over a long distance, up to 64 steam trap monitors can be linked via four RS16A units to a data highway system. The resultant signal can be transmitted over several kilometres to a receiver via a simple twin cable for subsequent display or input into a computerized energy management system.

Further details:

Bestobell Valve & Steam Products,
Rotherham,
South Yorkshire, UK.

ENERGY MANAGEMENT

Multiple-effect evaporation with vapour bleeding in the cane sugar industry

By Diego Leal, Paul Friedman and Antonio Valdés
(Instituto Cubano de Investigaciones Azucareras, Güiro Marrero, Quivicán, Habana, Cuba)

Introduction

More than 100 years ago, Rillieux enunciated three principles showing the significant benefits that could be achieved by the use of multiple-effect evaporation with vapour bleeding. Although these principles have been widely applied in the beet sugar industry to lower fuel consumption, in the case of the cane sugar industry, with its own fuel, bagasse, the afore-mentioned principles have not been utilized to the same extent.

Owing to the substantial rise in the price of oil and the increase in the use of bagasse as a raw material for paper, particle board, furfural, etc., many cane sugar producers have become aware of the need to increase the energy efficiency of their factories and are now re-examining old concepts which are appropriate for today's situation.

This study describes the experience gained in this regard during the 1981-84 harvest seasons at the Pablo Noriega Experimental Sugar Factory, Quivicán, Cuba, which is part of the Instituto Cubano de Investigaciones Azucareras.

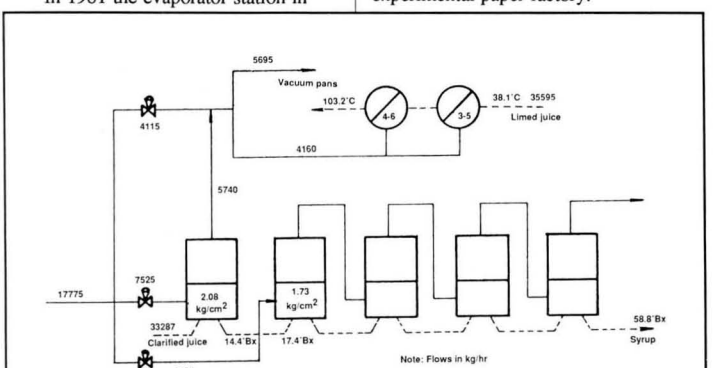
Materials and methods

In 1981 the evaporator station in the Pablo Noriega sugar factory consisted of a pre-evaporator and a quadruple-effect of 1023 m² total heat transfer area as shown in Figure 1. After the 1981 cane harvest it was decided to modernize the evaporator station in order to: (1) increase the capacity of the mill from 863 to 1000 tonnes of cane per day, and (2) decrease the total process steam consumption and obtain surplus bagasse for use in the adjacent CUBA-9 experimental paper factory.

D. Leal

P. Friedman

A. Valdés



Evaporators				Heaters			
Effect No.	H.S., m²	Tube length, m	Tube dia., m	Heater No.	H.S., m²	No. of passes	Tubes/pass
PRE	270	1.50	0.05	3	43.7	4	6
1	236	1.52	0.05	4	43.7	4	6
2	190	1.47	0.05	5	43.7	4	6
3	170	1.20	0.05	6	43.7	4	6
4	186	1.27	0.05				

Fig. 1. Evaporator station at Pablo Noriega sugar factory, 1981 harvest

The SIMEVA computer program was used to design a new evaporator station consisting of a quintuple-effect of 1321 m² total heat transfer area, with vapour bleeding from the first three effects. The new station operated adequately during the 1982 harvest[1,2].

The number of effects with vapour bleeding was increased to four after the 1982 harvest and the process steam requirements were decreased once more[3]. However, some supplementary fuel was used in both the 1982 and 1983 harvests because of problems in the condensate systems of the juice heaters, evaporator effects and vacuum pans; as well as a very low efficiency in the area of steam generation.

These problems were corrected for the 1984 harvest and, in addition, the heating surface areas of several effects were increased and a redundant fifth effect was added as a sixth effect. This resulted[4] in a sextuple-effect with vapour bleeding from the first four effects and with a total heat transfer area of 1690 m², as shown in Figure 2.

Discussion and results

The most important results obtained during the 1981-84 harvest seasons are shown in Table I.

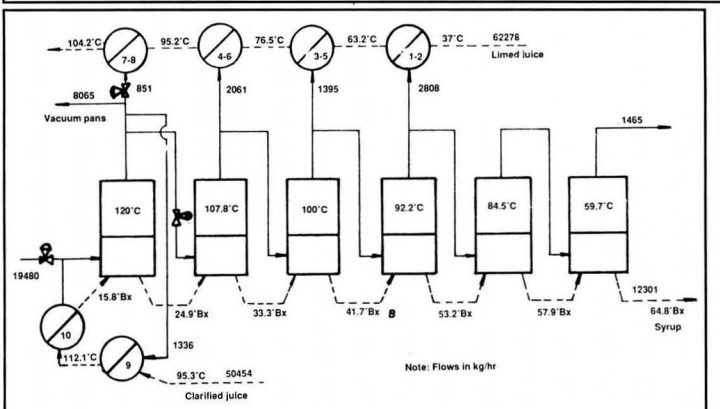
It will be seen that the greatest reduction in process steam consumption occurs when vapour bleeding is first used and smaller reductions are achieved by further vapour bleeding. Since there is only a small decrease in steam consumption by adding a sixth effect it appears that the arrangement of quintuple-effect with vapour bleeding from the first four effects is the most suitable. In Cuba, the new sugar factories now being designed will use this arrangement and modifications are also being carried out in some existing factories[5].

When steam of 240 - 310 kPa (20 - 30 psig) is not available it is not often

1 Friedman *et al.: Paper presented to the 43rd Congress, Asoc. Técn. Azuc. Cuba*, 1981.
2 Idem: *Proc. 18th Congr. ISSCT*, 1983, 1518 - 1531.
3 González & Vázquez: *CubaAzúcar*, 1982, (Oct./Dec.), 3 - 10.
4 Leal *et al.: Paper presented to the 44th Congress, Asoc. Técn. Azuc. Cuba*, 1984.
5 Idem: *Paper presented to the 1st National Energy Forum* (Havana, Cuba), 1984.

Table I. Total process steam consumption at Pablo Noriega sugar factory

Harvest	Evaporator station Arrangement	Area,m²	Clarified juice flow, kg/hr	Total steam % clarified juice	Steam to condenser % process steam
1981	Pre- plus quadruple-effect	1023	32,287	53.4	91.6 (quad)
1982	Quintuple-effect, vapour bleeding from:	1321			
	2 effects		36,850	42.2	22.6
	3 effects		38,690	41.0	20.6
1983	Quintuple-effect, vapour bleeding from 4 effects	1321	43,390	39.7	10.8
1984	Sextuple-effect, vapour bleeding from 4 effects	1690	50,455	39.0	7.5



Evaporators				Heaters			
Effect No.	H.S., m²	Tube length, m	Tube dia., m	Heater No.	H.S., m²	No. of passes	Tubes/pass
1	558	2.38	0.04	1-2	54.6	2	15
2	270	1.50	0.05	3-5	47.4	2	12
3	270	1.83	0.05	4-6	47.4	2	12
4	236	1.47	0.05	7-8	25.5	"Spiral"	
5	170	1.20	0.05	9	39.4	4	36
6	186	1.27	0.05	10	15.48	"Plate"	

Fig. 2. Evaporator station at Pablo Noriega sugar factory, 1984 harvest

possible to use vapour bleeding for the vacuum pans which may require steam of 120 kPa (10 psig). However, Valdes *et al.*[6] demonstrated that the maximum use of vapour bleeding for the stage-wise heating of limed juice is always economically advantageous, as shown in Table II.

The total cost includes depreciation, maintenance and electricity (increased pressure drop for pump) for the additional juice heaters required when using lower pressure steam for heating. The costs used are: \$200/m² heat transfer area, 5% of investment cost for maintenance, depreciation 6.6% per year, \$0.045/kWh and \$15.50/tonne of steam based on \$150/tonne of fuel oil.

On comparing the first alternative, with vapour bleeding from four effects, with the fourth alternative with vapour bleeding from only one effect, the increased profit in a sugar factory of 7000 t.c.d. capacity would be about \$700,000 per harvest and about \$10,000,000 over the 15 years depreciation period.

As was pointed out by Friedman[2], the estimated values for the overall heat transfer coefficients (OHTC) in multiple-effect evaporators used in the cane sugar industry cover a wide range, with a 20 - 40% spread about average values. The experimental results for the case of a quintuple-effect evaporator station with vapour bleeding from 2, 3, and 4 effects were reported by Leal *et al.*[7] and are shown in Table III. U_a and U_r are the OHTC values calculated using the apparent and real temperature differences, respectively.

When one examines the cases of effects without and with vapour bleeding, it can be seen that the OHTC increases owing to increased pressure drop and temperature difference. In the case of effect No. 3, the OHTC rose from 1975 to 2469 W/m²/°C; an increase of more than 25%. In the case of effect No. 4, the increase is from 773 to 817 W/m²/°C, equivalent to more than 10%. In general, when steam is bled from an effect where bleeding was not previously used, an increase in the OHTC of that effect is observed and a decrease in the OHTC of the following effect. However, the overall balance is favourable for an increase in total evaporation.

6 *Paper presented to the 44th Congress, Asoc. Técn. Azuc. Cuba*, 1984.
7 *CubaAzúcar*, 1984, (Jan./March), 3 - 10.

Table II. Economic analysis of stage-wise limed juice heating by vapour bleeding as compared with wxhaust steam for 1000 tonnes of cane per day

Alternative No.	Effects used for heating	Steam saving kg/hr	Steam saving \$/year	Total cost \$/year	Profit, \$/year
1	4-3-2-1	2637	147,000	8401	138,599
2	3-2-1	2269	126,000	6378	119,622
3	2-1	1635	91,000	4939	86,061
4	1-Exhaust	780	43,000	4939	38,061

Table III. Overall heat transfer coefficients measured at Pablo Noriega sugar factory

Effect No.	1	2	3	4	5
Tube length, m	2.12	1.52	1.52	1.24	1.24
Tube diameter, mm	38	38	38	38	38
Quintuple-effect with vapour bleeding from first 2 effects					
Ave. Brix	18.79	27.42	32.95	41.35	52.80
Boiling temp., °C	121.54	110.93	104.90	92.19	64.90
U_a, W/m²/°C	2004	1401	1234	553	402
Real temp. diff., °C	10.12	5.68	4.16	8.30	23.38
U_r, W/m²/°C	2424	1918	1975	773	573
Quintuple-effect with vapour bleeding from first 3 effects					
Ave. Brix	19.99	28.48	35.42	42.58	51.87
Boiling temp., °C	121.54	111.04	102.97	92.19	65.10
U_a, W/m²/°C	2564	1362	1646	543	436
Real temp. diff., °C	10.12	5.19	4.81	8.48	23.79
U_r, W/m²/°C	3102	1948	2469	773	528
Quintuple-effect with vapour bleeding from first 4 effects					
Ave. Brix	19.43	28.45	36.64	44.45	54.08
Boiling temp., °C	121.34	111.84	104.10	87.19	61.21
U_a, W/m²/°C	2617	1781	1654	654	378
Real temp. diff., °C	8.50	4.26	4.16	13.36	22.68
U_r, W/m²/°C	2844	2777	2645	817	460

Conclusions

Increases in vapour bleeding cause significant reductions in total process steam consumption as was shown in the Pablo Noriega sugar factory where a reduction from 53.4% to 39.0% steam on clarified juice was obtained by modifying the pre-evaporator plus quadruple-effect evaporator station to a sextuple-effect with vapour bleeding from the first four effects.

When steam of 240 - 310 kPa (20 - 30 psig) is not available, important reductions in process steam consumption can be achieved by stage-wise heating of limed juice.

When steam is bled from an effect where bleeding was not previously used, the OHTC for that effect is increased while that of the following effect is decreased. However, the overall balance results in an increase in total evaporation for the station.

Summary

The results of different arrangements in the evaporator station of a cane sugar factory are reported. These are: (a) a pre-evaporator plus quadruple-effect; (b) a quintuple-effect with vapour bleeding from 2 effects; (c) the same but with bleeding from 3 effects; (d) the same but with bleeding from 4 effects; and (e) a sextuple-effect with vapour bleeding from 4 effects. It is shown that increased vapour bleeding always reduces steam consumption and that the additional costs for stage-wise heating of limed juice are much less than the savings obtained. The overall heat transfer coefficients for a quintuple-effect with vapour bleeding from 2, 3, and 4 effects are reported.

FACTORY ENGINEERING

Crystal sizing

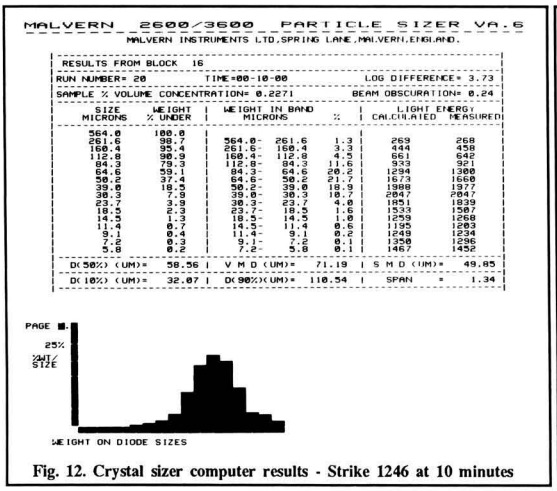
By J S. Hogg, S. C. H. McCarey, J. D. F. Wilkie, D. Brown and E. J. Weatherby

(Continued from page 197)

Factory results

Tests were carried out at Newark in the 1984/85 campaign and in the 1985 thick juice operation.

Because the Malvern equipment is based on a micro-processor, the results can be displayed in a number of ways. The different output formats can be set up by the equipment user depending on the results required for a particular series of tests. For these factory series of tests


MALVERN 2600/3600 PARTICLE SIZER VA.6

MALVERN INSTRUMENTS LTD,SPRING LANE,MALVERN,ENGLAND.

RESULTS FROM BLOCK 16

RUN NUMBER= 20 TIME=00-10-00 LOG DIFFERENCE= 3.73

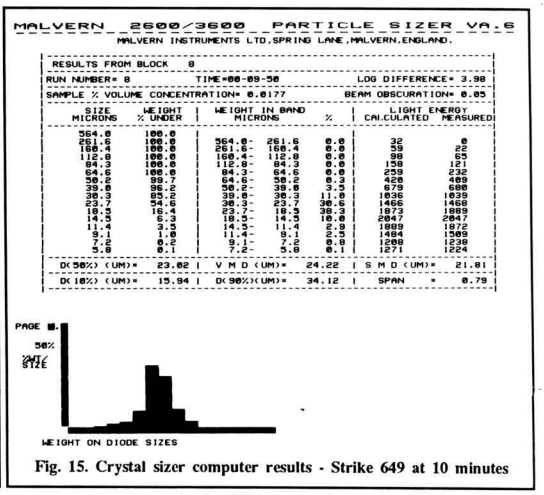
SAMPLE % VOLUME CONCENTRATION= 0.2271 BEAM OBSCURATION= 0.24

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS	%	LIGHT ENERGY CALCULATED	MEASURED
564.0	100.0				
261.6	98.7	564.0- 261.6	1.3	269	268
168.4	95.4	261.6- 168.4	3.3	444	458
112.8	90.9	168.4- 112.8	4.5	661	642
84.3	79.3	112.8- 84.3	11.6	933	921
64.6	59.1	84.3- 64.6	20.2	1294	1300
50.2	37.4	64.6- 50.2	21.7	1673	1660
39.0	18.5	50.2- 39.0	18.9	1988	1977
30.3	7.9	39.0- 30.3	10.7	2047	2047
23.7	3.9	30.3- 23.7	4.0	1851	1839
18.5	2.3	23.7- 18.5	1.6	1533	1507
14.5	1.3	18.5- 14.5	1.0	1259	1268
11.4	0.7	14.5- 11.4	0.6	1195	1203
9.1	0.4	11.4- 9.1	0.2	1249	1234
7.2	0.3	9.1- 7.2	0.1	1350	1296
5.8	0.2	7.2- 5.8	0.1	1467	1452

D(50%) (UM)= 58.56 | V M D (UM)= 71.19 | S M D (UM)= 49.85

D(10%) (UM)= 32.07 | D(90%)(UM)= 110.54 | SPAN = 1.34

Fig. 12. Crystal sizer computer results - Strike 1246 at 10 minutes


MALVERN 2600/3600 PARTICLE SIZER VA.6

MALVERN INSTRUMENTS LTD,SPRING LANE,MALVERN,ENGLAND.

RESULTS FROM BLOCK 8

RUN NUMBER= 8 TIME=00-09-50 LOG DIFFERENCE= 3.98

SAMPLE % VOLUME CONCENTRATION= 0.0177 BEAM OBSCURATION= 0.05

SIZE MICRONS	WEIGHT % UNDER	WEIGHT IN BAND MICRONS	%	LIGHT ENERGY CALCULATED	MEASURED
564.0	100.0				
261.6	100.0	564.0- 261.6	0.0	32	0
168.4	100.0	261.6- 168.4	0.0	59	22
112.8	100.0	168.4- 112.8	0.0	98	65
84.3	100.0	112.8- 84.3	0.0	158	121
64.6	100.0	84.3- 64.6	0.0	259	232
50.2	99.7	64.6- 50.2	0.3	420	409
39.0	96.2	50.2- 39.0	3.5	679	688
30.3	85.2	39.0- 30.3	11.0	1036	1039
23.7	54.6	30.3- 23.7	30.6	1466	1468
18.5	16.4	23.7- 18.5	38.3	1873	1889
14.5	6.3	18.5- 14.5	10.0	2047	2047
11.4	3.5	14.5- 11.4	2.9	1889	1872
9.1	1.0	11.4- 9.1	2.5	1484	1509
7.2	0.2	9.1- 7.2	0.8	1260	1238
5.8	0.1	7.2- 5.8	0.1	1271	1224

D(50%) (UM)= 23.02 | V M D (UM)= 24.22 | S M D (UM)= 21.81

D(10%) (UM)= 15.94 | D(90%)(UM)= 34.12 | SPAN = 0.79

Fig. 15. Crystal sizer computer results - Strike 649 at 10 minutes

a different set of data were chosen to be printed and instead of the cumulative weight above and below band a figure for particle surface area in cm^2 per cm^3 of suspension was given.

A number of tests were carried out of which the following are typical:–

Strike 1246: The results from this white pan strike during the 1984/85 campaign are shown in Figures 12, 13 and 14. The vacuum pan was being operated on fully automatic control generally as described by McCarey & Fearnside[3]. The seed point temperature setting was slightly lower than normal and at the lower supersaturation this gave crystal growth which was slower so that measurements could be made for 20 minutes from seeding.

Figure 12 shows the output from the Malvern computer. Comparison with Figure 7 shows the difference in the displayed results.

Figure 13 is a plot against time of the crystal effective diameter corresponding to 50% of the total crystal weight. This gives an overall picture of the crystal growth during the test period.

The laser particle sizer measures the surface area of the particles and not the volume. However, for plant analysis it would be more useful to have the weight in each size band rather than the area. In order to calculate the weight from the area it is necessary to make assumptions about the particle shape. In the Malvern software it is assumed that all particles are spherical. If it is assumed that all sugar crystals are the same crystalline shape, a mathematical relationship between spheres and crystals can be derived and the weight calculated from the area.

Figure 14 shows weight distribution curves for times from 2 minutes 50 seconds to 18 minutes 20 seconds after seeding. This type of presentation makes it very easy to determine the change in crystal size and distribution throughout the pan boiling cycle.

Strike 649: The results from this white pan strike during the 1985 juice refining operation are shown in Figures

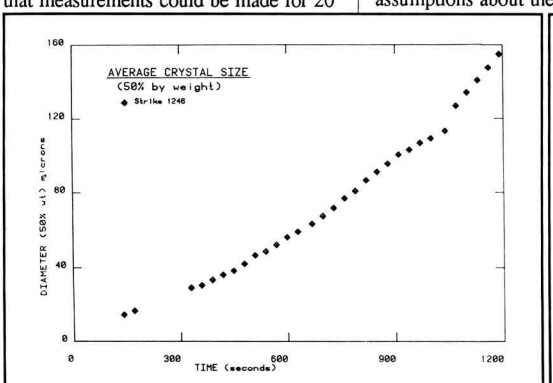


Fig. 13. Average crystal size (1984/85 campaign)

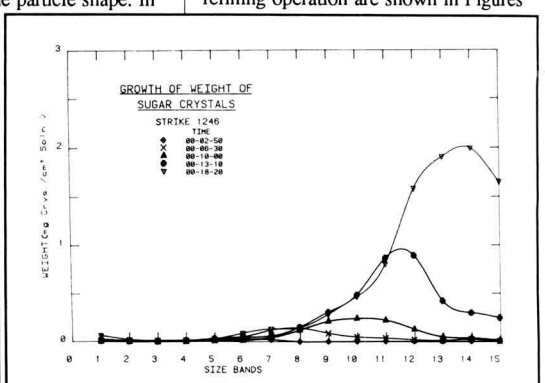
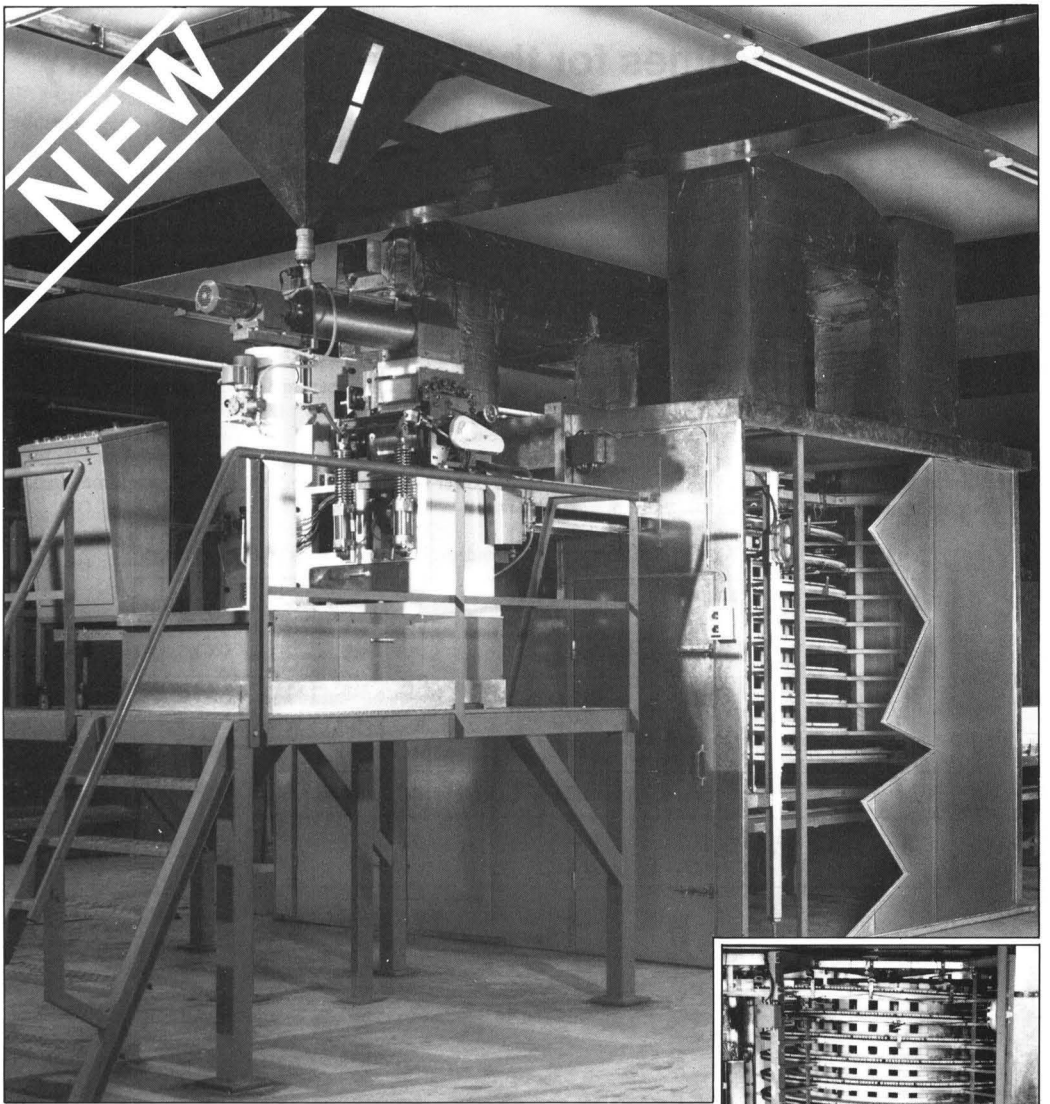


Fig. 14. Growth of weight of sugar crystals (1984/85 campaign)



Today there are more than 300 Elba cube sugar machines and installations with outputs ranging from 80 kgs/hour up to 50 tons/day in operation all over the world.
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As the pressures and temperatures of the steam which can be economically generated in the boiler are considerably higher than required for the process, the steam is first of all expanded in the turbines to the required back pressure. The energy released by the steam expansion is converted into mechanical power to drive machines and electric alternators.

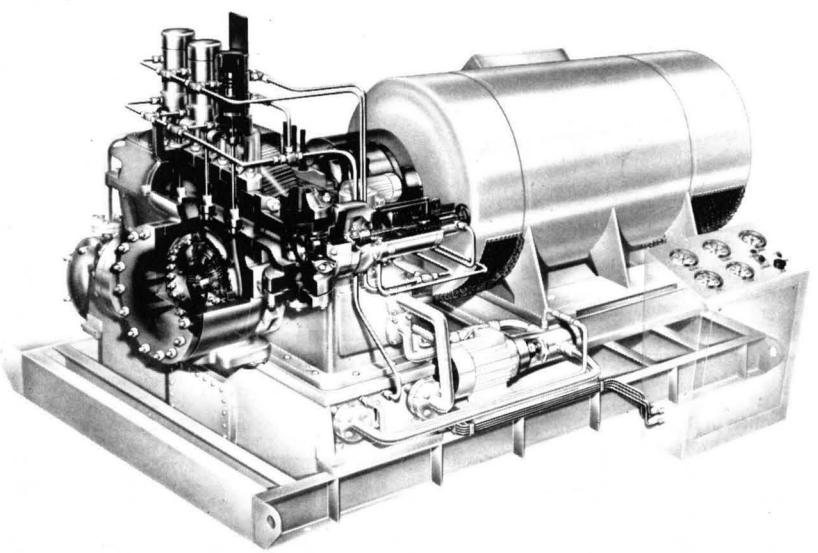
With its compact geared steam turbines and turbo-alternator sets, KKK has been an important supplier to the cane sugar industry all over the world for more than 20 years. We set a high value on RESEARCH and DEVELOPMENT, and this is why the construction of our custom-engineered turbine units is focused on the following:

* Operating safety and reliability
* Economy
* Rapid starting without preheating
* Adaptability to changed steam and power conditions
* Ease of maintenance
* Oil-free exhaust steam

The standardised series of single-stage KKK steam turbines cover a power range from 10 to 5000 kW and, apart from driving alternators, are mainly used to drive the following units:

• Cane knives • Shredders/Unigrators • Milling tandems • Pumps • Fans and Compressors

Turbine series	Power range (kW)	Maximum speed (rpm)	Maximum steam inlet/outlet pressure (bar abs.)	Maximum steam temperature (°C)
BF	10 - 225	4500	126/11	525
AF	100 - 2800	18500	100/26	530
CF	250 - 5000	16000	126/26	530
The new generation of "super-efficient" turbines:				
CFA	150 - 4000	15000	126/26	530
CFR	250 - 4000	22000	65/17	450

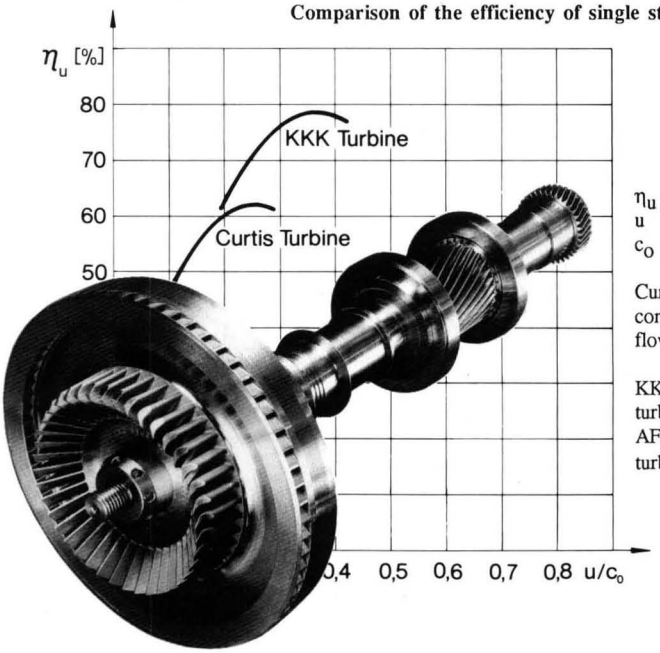


Sectional drawing of a single-stage integrally geared steam turbine with radial steam flow of the new CFR series, equipped with three automatic nozzle-group control valves for a three-phase alternator drive

KKK steam turbines are available either for direct-drive over the whole power range or, for outputs exceeding 200 kW, as compact geared turbines. When they are equipped with automatic nozzle group control valves, they ensure economical operation at partial load, and the steam throughput is considerably lower than that of turbines with simple throttle control.

Are your steam turbines still working profitably? Our single-stage steam turbines of the new CFA and CFR generation, with efficiencies approaching that of multi-stage steam turbines, represent an investment for the future. As a result of this increased efficiency, which exceeds that of conventional single-stage turbines by up to 20%, you can, for example, generate more of your own electricity, which can be fed back into the public system when your internal requirements have been covered, without changing the power of the steam-raising plant. Alternatively, fuel can be saved with a constant power requirement and the boiler power output is reduced. In the case of cane sugar extraction this permits a saving in bagasse, which has become a feedstock of interest for the paper and board manufacturing industries.

Comparison of the efficiency of single stage steam turbines



η_u : Peripheral wheel efficiency
u : Mean blade velocity
c_0 : Steam velocity at nozzle exit

Curtis Turbine: Conventional velocity-compounded Curtis stage with axial steam flow

KKK Turbine: The new generation of KKK turbines AFA/CFA (axial steam flow) and AFR/CFR (radial steam flow) with overhung turbine wheel and optimized rotor dynamics

When systematically replacing your old turbines by turbines from the new KKK turbine generation with simple payback periods slightly longer than one year, an enormous amount of energy can be saved and the overall efficiency of your factory can thus be considerably improved for a process, such as the cane sugar extraction, which depends to a high degree on steam.

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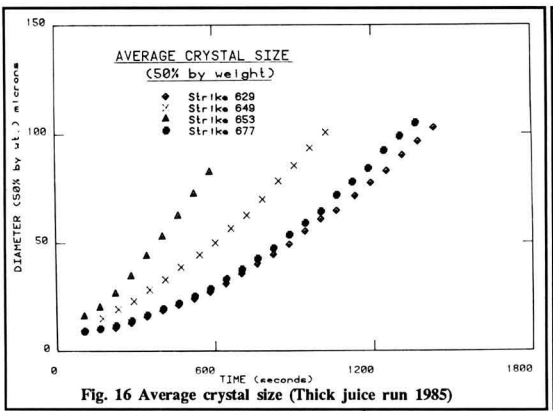


Fig. 16 Average crystal size (Thick juice run 1985)

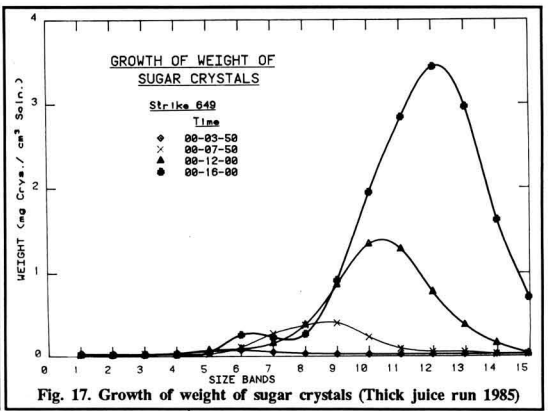


Fig. 17. Growth of weight of sugar crystals (Thick juice run 1985)

15, 16 and 17.

Figure 15 shows the printed output from the later model of Malvern equipment used in this series of tests.

Figure 16 shows the effective crystal diameter for 50% by weight plotted against time for a number of strikes. The supersaturation in the vacuum pan was not measured and indeed probably cannot be measured because of the variation in conditions that inevitably occurs throughput the total pan volume. However, by using the results from the large number of laboratory tests carried out at different supersaturation, it has been possible to estimate the degree of supersaturation corresponding to the curves in Figure 16 (Table II). Figure 17 shows the weight distribution curves for selected times as indicated on the strike 649 curve, Figure 16.

Table II

Strike	Relative supersaturation
653	Just above 1.3
649	1.3
677	1.25
629	1.2

Discussion of results

Sets of data from both the laboratory and plant experiments are shown in the figures. Data showing the increase in the mean crystal diameter corresponding to 50% of the total crystal weight with respect to time indicate that the crystals have grown by an order of magnitude in approximately 15 - 20 minutes, from 7 μm (seed) to 70 μm.

The results show that the laser technique can be used successfully to monitor the growth of sugar crystals in a vacuum crystallizer. Furthermore, the method allows instantaneous analysis of the crystal size to be achieved and inspected with minimum effort from the operator, which is in contrast to the sieve and most other analysis techniques.

The complexity of the crystal growth process is such that even though the conditions are similar for the sets of experiments, the growth rates are quite different. However, small fluctuations in, for example, supersaturation level, pressure, temperature and the number of seed crystals added will cause significant differences in the growth rate of the crystals.

Figure 17 is taken from the data obtained for run 649 and demonstrates the growth of the weight of sugar crystals in each size band as a function of time. It shows a smooth increase in the crystal size distribution through the size bands. The broadening of the distribution is further evidence of the complex nature of the growth of the crystals.

It has been shown that this new technique may be used to follow the early stages of growth of sugar (sucrose) crystals. The experiments have been successful both in the laboratory and in the plant. At present, data are collected up to particle concentration of 1% by volume which may correspond to an obscuration of the light beams of 50%, depending on the size of the crystals. It would be desirable, obviously, to follow the reaction much further towards completion (50% by volume particle concentration).

Future work

The problem of multiple scattering in suspensions of high concentration (greater than 1%) has been mentioned already. However, a mathematical model has been developed, in the Department of Chemical Engineering and Fuel Technology at Sheffield University, to predict the effect of multiple forward scattering in a dense particle field[8]. The model allows the applicability of the sizing method to be extended twenty-five fold, from a light beam obscuration of 50% to that of 98%. Although the model has not yet been tested rigorously against experimental results, early comparisons show good agreement between theory and experiment with only a slight loss of accuracy[8].

Work has also begun on extending measurements in the crystal growth process by the use of a sampling, dilution and analysis technique. This involves removing a concentrated sample of the sugar suspension from the crystallizer, diluting it with a saturated sugar solution and then measuring

8 Felton *et al.*: "Measurement of drop size distribution in dense sprays by laser diffraction" (3rd International Conference on Liquid Atomisation and Spray Systems, Imperial College, London), 1985.

the crystal size distribution as described previously. The experiments performed using this technique will complement those using the model for multiple scattering and comparison of the data from the two approaches will act as cross-check for each technique.

The development of the technique of particle sizing by laser diffraction to obtain a measurement of the growth of the crystal product could lead to change in emphasis in process control. Crystal size may be measured directly and the measurements used to monitor and control the process.

Summary

This paper describes work carried out by Sheffield University staff in co-operation with British Sugar over a three-year period from September 1982. The use of laser light diffraction to measure particle size is well established with commercial equipment available. The project involved the development of a suitable flow cell for sample presentation with extensive testing of the system on a laboratory scale. Following successful completion of this work, two series of tests at a sugar factory have proved the technique for full-scale plant use. The technique of laser diffraction has a concentration limitation set by light obscuration. Further work in two parallel directions is under way to remove this limitation.

Appendix 1

Spherical particle diameter ranges (μm) resolved by lenses of different focal lengths (f)

f = 63 mm μm	f = 100 mm μm	f = 300 mm μm	f = 600 mm μm	f = 800 mm μm	f = 1000 mm μm
118.4 - 54.9	188.0 - 87.2	564.0 - 261.6	1128.0 - 523.2	1503.9 - 697.6	1879.9 - 872.0
54.9 - 33.7	87.2 - 53.5	261.6 - 160.4	523.2 - 320.7	697.6 - 427.6	872.0 - 534.5
33.7 - 23.7	53.5 - 37.6	160.4 - 112.8	320.7 - 225.6	427.6 - 300.8	534.5 - 376.0
23.7 - 17.7	37.6 - 28.1	112.8 - 84.3	225.6 - 168.6	300.8 - 224.8	376.0 - 281.0
17.7 - 13.6	28.1 - 21.5	84.3 - 64.6	168.6 - 129.3	224.8 - 172.4	281.0 - 215.5
13.6 - 10.5	21.5 - 16.7	64.6 - 50.2	129.3 - 100.3	172.4 - 133.8	215.5 - 167.2
10.5 - 8.2	16.7 - 13.0	50.2 - 39.0	100.3 - 78.0	133.8 - 104.0	167.2 - 130.0
8.2 - 6.4	13.0 - 10.1	39.0 - 30.3	78.0 - 60.7	104.0 - 80.9	130.0 - 101.1
6.4 - 5.0	10.1 - 7.9	30.3 - 23.7	60.7 - 47.3	80.9 - 63.1	101.1 - 78.8
5.0 - 3.9	7.9 - 6.2	23.7 - 18.5	47.3 - 36.9	63.1 - 49.2	78.8 - 61.5
3.9 - 3.0	6.2 - 4.8	18.5 - 14.5	36.9 - 29.0	49.2 - 38.6	61.5 - 48.3
3.0 - 2.4	4.8 - 3.8	14.5 - 11.4	29.0 - 22.8	38.6 - 30.4	48.3 - 38.0
2.4 - 1.9	3.8 - 3.0	11.4 - 9.1	22.8 - 18.1	30.4 - 24.1	38.0 - 30.2
1.9 - 1.5	3.0 - 2.4	9.1 - 7.2	18.1 - 14.5	24.1 - 19.3	30.2 - 24.1
1.5 - 1.2	2.4 - 1.9	7.2 - 5.8	14.5 - 11.6	19.3 - 15.5	24.1 - 19.4

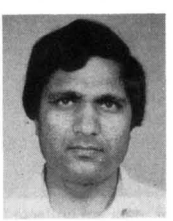
ENERGY MANAGEMENT

Economics of electricity production from sugar cane tops and leaves — a preliminary study

By Kassiap Deepchand*
(Energy Research Group, Cavendish Laboratory, University of Cambridge)

Introduction

Interest in renewable energy sources grew mainly as a result of escalating oil prices in the 1970's and also with the fear that the world's non-renewable energy resources were decreasing and may be depleted within the foreseeable future. Since then significant progress has been made in the field of renewable energy such as solar water heating and cooling, photovoltaics, wind power, ocean wave energy, geothermal energy and biomass. However, increasing importance is being given to biomass, as a renewable resource, in oil-importing



K. Deepchand

* Current address: School of Industrial Technology, University of Mauritius, Réduit, Mauritius

ISJ Abstracts

Cane sugar manufacture

Modification of the double sulphitation process of white sugar manufacture

K. N. Agarwal and G. Singh. *Indian Sugar*, 1985, **35**, 387 - 392.

Trials on the Fabcon juice/syrup purification system as a complement to sulphitation are reported. The juice treatment followed sulphitation, while the syrup process preceded it; polymer was added at 3 - 4 ppm. Tabulated data are presented for the syrup purification and show a fall in viscosity, colour, turbidity and CaO content and a rise in purity as a result of the clarification.

Automation in the sugar factory boiling house

C. D. Rahatekar and R. K. Unde. *Maharashtra Sugar*, 1985, **10**, (9), 47 - 50, 53, 55 - 56.

Descriptions are given of an automatic system for mixed juice liming and pH control in sulphitation and of a DDS pan automation system. The juice system involves continuous monitoring of sulphitation juice pH, which is displayed digitally as well as recorded, and electronic comparison of the value against a pre-set target value; deviation of the measured from the target value causes adjustment to be made automatically in the lime flow to the sulphitation vessel – if the pH is too low more lime is fed to the tank, and if it is too high the flow is diverted back to the lime tank. Results have shown maintenance of pH between 6.7 and 7.2 as against between 6 and 8 with manual operation, while the clear juice lime content has been reduced from 1300 mg CaO per litre to 1150 - 1200 mg/litre. The DDS automatic boiling system has cut the boiling time, increased crystal uniformity, reduced steam and power consumption and improved molasses exhaustion. Mention is also made of new timers installed on the *A*-massecuite centrifugals which have permitted a reduction in: massecuite quantity, low-grade massecuite purity, sugar colour, bagging temperature and steam usage (as a consequence of the lower massecuite volume).

Process control through instrumentation. A study on the performance of a pH control system

R. Chandramouli. *Maharashtra Sugar*, 1985, **10**, (9), 57 - 59, 61 - 62.

Results are discussed of automatic juice liming and pH control using a system identical to that described in the previous abstract. Tabulated data show a reduction in juice CaO content and in pH fluctuation, and an increase in transmission by comparison with manual control.

Automation of the boiling house process

D. S. Lande. *Maharashtra Sugar*, 1985, **10**, (9), 63 - 65, 67 - 68, 77 - 79, 81, 83 - 86.

A survey is presented of automation as used for cane milling (including cane feed to the first mill, imbibition rate, temperature of imbibition water and juice flow), bagasse weighing, clarification, evaporation (including level, Brix and steam temperature or pressure), boiling, molasses conditioning and centrifugalling. Mention is also made of the importance of efficient massecuite reheating, of *C*-sugar purity control and of the need for rapid, automatic recording of bagasse moisture content so as to allow prompt adjustment.

Development of clarification of filtrate by flotation

J. F. Tong, Y. C. Hsiao, C. H. Chen and C. S. Ting. *Rpt. Taiwan Sugar Research Inst.*, 1985, (109), 19 - 28 (*Chinese*).

The recirculation of filtrate from rotary vacuum filters is detrimental to cane juice clarification in the defecation or sulphitation processes. Addition of phosphoric acid and milk of lime brings about coagulation and adsorption of insoluble solids; under the effect of a high M.W. polyacrylamide flocculant, the primary flocs form large flocs that may be removed by flotation. The effects of phosphate dosage, liming pH and flotation time on clear filtrate turbidity and mud volume were determined using an experimental flotation tank 60 cm high and 35 cc in diameter. Optimum conditions were: pH 8.3 - 8.9, 40 - 50 ppm phosphate addition, 5 - 6 ppm flocculant, 10 - 20% air (on volume of filtrate), $1^1/_2$ - 2 minutes flotation and 3 - 4 minutes total retention. Under these circumstances, 68% clear filtrate could be recovered equal in quality to clear juice from a Dorr clarifier with which it could be mixed and sent directly to evaporation. The elimination of recirculation increased clarifier capacity by 25%, and the mud (of 10.5% insoluble solids content) could be mixed with clarifier mud and easily filtered.

Mathematical models of the stages of the raw sugar production process

N. V. Avila S., D. Valdés V., F. Piñon Y. and V. González R. *Centro Azúcar*, 1983, **10**, (3), 3 - 10 (*Spanish*).

A mathematical model of the process of raw sugar production is studied by simulating its different stages: extraction, purification, evaporation, crystallization and centrifugation by multiple regression models. The independent and dependent variables necessary for each stage of the process are determined according to the information obtained. A method is planned to permit reduction of the effects of experimental errors on the model.

Application of an integral thermoenergetic balance of a sugar factory

S. Machado B., R. Espinosa P. and R. G. Carpi. *Centro Azúcar*, 1983, **10**, (3), 11 - 16 (*Spanish*).

Application of a thermal energy balance permits analysis of the consumption of heat and steam in a sugar factory and thus of means of making savings in both.

Influence of microbial contamination of juices on the crystallization stage

M. T. Hernández, H. Cuellar and A. Peña. *Centro Azúcar*, 1983, **10,** (3), 21 - 28 (*Spanish*).

Sugar produced from juices containing dextrans and other metabolic products from microbial infection was found to contain large numbers of small grain and elongated crystals.

Ambiental microflora in the raw cane sugar factory

T. Sais H., L. J. Hernández and M. M. Hernández S. *Centro Azúcar*, 1983, **10,** (3), 29 - 42 (*Spanish*).

The micro-organizms in the air at 17 different locations in a sugar factory in Cienfugeos, Cuba, were identified and counts established per m^3. They proved to be higher than the standards set for food processing plants, and *Staphylococcus* micro-organisms were detected all over the factory. The results of the survey demonstrate the need to establish and observe adequate sanitary measures in raw sugar factories.

Description and simulation of the process of boiling first commercial strikes

U. Korn, M. Rodríguez B. and F. Herrera F. *Centro Azúcar*, 1983, **10,** (3), 43 - 51 (*Spanish*).

An analysis is made of the state variables and a dynamic mathematical model describing the process of boiling high-grade massecuites in batch vacuum pans. The mathematical model was simulated on a digital computer and results are presented. The model is a basis for furthering the synthesis and design of an optimal control system for the process.

Economic analysis of the principal factors which influence the cost of sugar production

C. P. B. Nazco F., M. Molina V. and E. Rodríguez P. *Centro Azúcar*, 1983, **10,** (3), 53 - 66 (*Spanish*).

An analysis shows that the main factors affecting the cost of raw sugar production are: exploitation of the installed capacity, the quality of the sugar cane and efficiency of the factory work.

System approach and formation of the management organization structure in agro-industrial sugar complexes

C. C. Martínez, F. Fernández V. and A. Mena C. *Centro Azúcar*, 1983, **10,** (3), 67 - 73 (*Spanish*).

In this work an analysis is made of the importance of the use of a systematic approach in the work of forming a management structure organization for an agro-industrial complex. The fundamental principles and the phases in which the work is to be carried out are also stated. A number of ways of arranging the work in the creation of the management apparatus are explained.

Influence of the addition of dextran in the clarification of cane juice

E. Bello A. and O. Travieso C. *Centro Azúcar*, 1983, **10,** (3), 75 - 88 (*Spanish*).

Laboratory and factory tests showed that addition of dextran to cane juice was of no advantage since it did not serve as coagulant for suspended particles but rendered the juice more turbid.

Application to industrial cane juices of the balanced clarification process

J. Guerra D. and R. Santana M. *Centro Azúcar*, 1983, **10,** (3), 95 - 106 (*Spanish*).

Factory trials have been made comparing conventional clarification with the authors' "balanced" clarification process in which just sufficient $CaCl_2$ or NaH_2PO_4 is added to provide a stoichiometric molar proportion between the Ca and PO_4 present. The pH is adjusted to the desired level with NaOH. The resulting Ca content in the clear juice is much lower with the "balanced" process while the physical properties of the precipitate are not adversely affected and neither are any other important parameters.

Methods for designing hot liming systems

T. Prieto F., I. Wong P. and N. Mospán. *Centro Azúcar*, 1983, **10,** (3), 107 - 116 (*Spanish*).

A methodology that permits determination of the optimal trajectory for mixing of a liming agent with cane juice during hot liming is presented. Various equations have been developed which can be applied in practice to the evaluation and calculation of some hot liming installations.

Analysis of the incidence on costs of variation in pol and recovery

C. Freixas C. and C. Rivero C. *Centro Azúcar*, 1983, **10,** (3), 117 - 126 (*Spanish*).

An analysis is given of the effects of variations in pol in cane and sugar recovery on the costs in sugar enterprises. Application of the analysis to two enterprises in Camagüey showed that rise in costs due to variation in sugar content in cane amounted to more than 200,000 pesos.

Development of a new automatic control system for optimizing final massecuites

R. Consuegra and P. Friedman. *Control Cibernetica y Automatización*, 1981, **15,** (4), 3 - 8; through *S.I.A.*, 1986, **48,** Abs. 86-169.

Existing methods of controlling supersaturation (via BPE, conductivity or rheometry) are all indirect and their suitabilities vary with massecuite properties, pan conditions and possibly pan design. A new automatic control system is proposed, particularly suitable for final boilings; these have been 30% shorter than with manual control. For producing crystals of specified size in the least possble time (the optimization criterion), supersaturation should be kept

as close as possible to its critical value while ensuring that viscosity remains below a preset limit. Simultaneous measurement of massecuite viscosity by rotary viscometer and mother liquor viscosity by ultrasonic sensor permits direct calculation of both crystal content and supersaturation (given liquor Brix, purity, total inflow and current pan operating parameters). It is recommended to use on-line identification and adaptive control by a circuit comprising only sensors, computer and regulating valves.

Viscosity behaviour of products in several steps in sugar cane mills in Okinawa

Y. Kohda and S. Kawasaki. *Sci. Bull. College Agr.*, (Univ. Ryukyus), 1983, **30,** 489 - 497; through *S.I.A.*, 1986, **48,** Abs. 86-193.

The viscosities of cane molasses from five Japanese factories, and of clarified juice, syrup and 1st and 3rd massecuites from one factory, were measured by means of a rotating-cylinder viscometer. Graphs of viscosity *vs.* shear rate at various temperatures show that at viscosities above about 20 poise, molasses exhibits non-Newtonian behaviour. The temperature dependance of viscosity differed for molasses from different factories; logarithimic grraphs of viscosity *vs.* temperature were approximately straight lines, indicating that the relationship could be expressed by an Arrhenius-type equation. In general, the slope of the graph was greater for molasses from diffusion factories than from milling factories; thus, processing variables such as the method of juice extraction influenced the flow properties of molasses. The viscosity of clarified juice (about 0.01 poise at 50°C) was almost independent of shear rate. Syrup also showed Newtonian behaviour, its viscosity being about 0.1 poise at 50°C. The viscosity of 3rd massecuite was about 10 times that of 1st massecuite, and became more non-Newtonian with increasing crystallization time. The data agreed reasonably well with those previously reported for Hawaiian molasses.

Automation in curing of *C*-massecuites

N. A. Ramaiah. *Maharashtra Sugar*, 1985, **10,** (10), 23 - 24.

Fore-and after-curing of low-grade massecuite is of great importance for controlling sugar losses and maintaining sugar quality, but losses occur because of lack of suitable control for such parameters as wash water addition. Experiments showed good correlation between photoelectric reflectance of *C*-sugar and *C*-massecuite and their purities. Based on this finding, sensors were developed for automatic control of wash water addition; a fall in reflectance indicates a drop in purity, whereupon water flow is increased or massecuite feed decreased.

Automation in process operation

D.P. Kulkarni. *Maharashtra Sugar*, 1985, **10,** (10), 25 - 26, 29.

A general survey is presented of the process stations in a sugar factory that benefit or could benefit from automation; they include weighing of juice, sugar, molasses and filter cake, clarification, evaporation, syrup sulphitation, boiling, crystallization and centrifugalling.

Automation in the sugar factory boiling house

B. L. Mittal. *Maharashtra Sugar*, 1985, **10,** (10), 31 - 33.

Individual process units and processes that could be automated or their automatic operation improved are surveyed, including juice weighing, liming and sulphitation, juice heating, clarification, sulphur burning, vacuum filtration, evaporation, boiling, crystallization, sugar melting and the interlinkage between processes.

Some current and future trends in pan boiling automation in the sugar industry

G. N. Acharya. *Maharashtra Sugar*, 1985, **10,** (10), 35 - 36, 39 - 40.

Automatic boiling control and continuous boiling are discussed, with particular reference to the work done by the Central Electronics Engineering Research Institute (of which the author is director) in this field, including development of the Panometer supersaturation controller based on resistivity, and mathematical modelling and computer simulation of the boiling process.

Pan automation systems - current and future trends with special reference to continuous pan boiling

P. Kapur, V. L. Patil and G. N. Acharya. *Maharashtra Sugar*, 1985, **10,** (10), 55 - 56.

Automation of pan boiling and the advantages of continuous over batch pans are briefly discussed.

Process variables and their inter-relationships for control action in the sugar crystallization process

P. Kapur, V. L. Patil and G. N. Acharya. *Maharashtra Sugar*, 1985, **10,** (10), 59 (*Abstract only*).

The importance of supersaturation as boiling parameter and the variables on which it depends are discussed.

Some design aspects of a microprocessor-based pan controller for the sugar crystallization process

P. Kapur, V. L. Patil, G. K. Gautam and G. N. Acharya. *Maharashtra Sugar*, 1985, **10,** (10), 60 (*Abstract only*).

Variables governing the boiling process are noted and factors influencing selection of a given parameter or parameters discussed. The advantage of a mathematical model of the process for purposes of establishing an automatic control scheme is mentioned, and some of the design aspects of a microprocessor-based pan controller are presented.

Beet sugar manufacture

Chemical aspects of mechanical pulp dewatering

K. Buchholz, R. Tarrach and K. M. Bliesener. *Zuckerind.*, 1986, **111**, 23 - 27 (*German*).

The literature on chemical aspects of beet pulp pressing is reviewed (with 62 references) with particular emphasis on the effects of pressing aids and the ion exchange processes that take place. The chemical composition of beet marc and functions of the cell wall components (cellulose and pectin) are described, as well as the mechanism of dewatering by pressing, with particular reference to the work of Arvidsson *et al.*[1]. Chemical conversions that can affect pressing are discussed (including the effects of freezing, scalding, acids, enzymes and microbial infection) and laboratory experiments mentioned that have shown the extent to which various pulp pre-treatments can improve pressing, including cross-linking of the pectin with polyvalent cations (as already used in practice), more extensive pectin de-esterification so as to increase the cross-linkage effect (not yet technically perfected) and a greater degree of use of biological means such as bacterial infection (the mechanism of which is still unknown). The practical aspects of using aids such as polyvalent cationic salts, e.g. calcium choride, aluminium sulphate and ferric chloride, are examined, including the question of maximum amount to use (as determined by the ion exchange capacity of the pectin). The Al^{+++} and Fe^{+++} cations proved even better than Ca^{++} in raising the pulp solids content; trials on the use of Al salts have continued, but Fe^{+++} ions give a smooth soapy surface to the pulp which is undesirable. The effect of pH on the ion exchange capacity is discussed; temperature and time of contact were found to have no effect on the load capacity within the range of conditions encountered in practice. The proton and ammonium salts concentrations (associated with acidification of diffusion water and the use of condensate) should not be too high. Optimum conditions for the use of aids included a maximum addition of 2.1 meq per 100 g beet (4.1 ppm in the case of Ca^{++}), corresponding to an ion exchange capacity of 4.5 meq/100 g, a minimum concentration of 0.01N, pH > 4 for Ca salts, a contact time of approx. 30 minutes, and a normal diffusion temperature.

Waste water treatment at Plattling sugar factory

Anon. *Zuckerind.*, 1986, **111**, 44 - 45 (*German*).

Previously, waste water treatment at Plattling involved use of an oxidation pond system as 1st stage, followed by double oxidation ditches and post-clarification tanks with activated sludge recycle. However, at times during the beet campaign considerable odour emission occurred in the 1st stage. Under a new arrangement, all the high-load effluent formerly treated in Stage 1 is pre-treated anaerobically with activated sludge at 35 - 36°C, yielding a biogas of 70 - 80% methane content; the degradation rate is 90 - 95% on organic load. By comparison with other activated sludge processes, the anaerobic process (which in future will be used as Stage 1 in place of the oxidation pond system which will act merely as a standby) uses much less energy (because of the absence of need for oxygen supply to the microbes), there is little residual sludge, the biogas is of use as primary energy for pulp drying, and there is no risk of odour emission since the anaerobic process takes place in a sealed tank.

Calculation of the kilowatt-hour costs in generation of its own electricity by a sugar factory, allowing for the exergy efficiency

P. Christodoulou. *Zuckerind*, 1986, **111**, 45 - 49 (*German*).

After failing to sign an agreement with the Greek electricity utility for supply and extraction of power by the five sugar factories, the Greek sugar industry examined the question of electricity costs per kWh. Calculation of the costs by a simple method based on an enthalpy balance, whereby the electrical work is divided by the efficiency of the turboset and boiler, gives values of 4444 - 4705 kJ/kWh for the fuel charge; these are considered very low and about half of those obtainable in a conventional power plant with a condensing turbine. An exergy balance for a boiler provides more accurate information than an enthalpy balance, and a comparison is made between the two approaches for calculation of electricity costs using back-pressure turbines and allowing for fuel exergy. It is shown how the costs fall with increase in pressure and temperature of superheated steam. Results of the calculations provide cost figures similar to those of a power station. It was decided to install thermo-compressors at two factories (the other three already had them), since vapour compression provided a greater fuel economy than utilization of steam exergy by throttling in a reducing valve.

Sucrose crystal growth after the vacuum pans

V. Maurandi, B. Paganelli and A. Rossi. *Zuckerind.*, 1986, **111**, 55 - 58.

A continuous vertical crystallizer is described which contains a number (usually three) compartments, one above the other, provided with a stirrer rotating at 30 - 35 rpm. Massecuite enters the top compartment and is discharged from the bottom one. The pressure is different in each compartment (so that the massecuite temperature also differs), falling towards the bottom of the vessel. Saturated syrup is added between compartments. Massecuite residence time is approx. 30 minutes. The crystallizer is suitable for massecuites of very high purity (nearly 100) and of intermediate purity (90). Three of the crystallizers have been installed in Italian sugar factories. For VHP massecuites, up to 35% increase in crystal yield has been reported, while for intermediate massecuites the residence time has been reduced from 3 - 6 hours to 30 minutes with improved exhaustion.

1 *I.S.J.*, 1957, **59**, 222.

Sugar storage in silos

O. Mikus and L. Budicek. *Sugar Tech. Rev.*, 1986, **13**, 53 - 129.

This review of the literature (156 references) on bulk sugar storage includes data on sugar drying, basic requirements of sugar intended for storage, descriptions of four basic storage methods (unventilated sugar in an unheated silo, unventilated sugar in a silo provided with a heated jacket, ventilated sugar in an unheated silo, and ventilated sugar in a silo with a heated jacket), silo equipment and storage conditions, and sugar dust explosions.

Modernization of the heat economy at Klecina sugar factory

L. Szydlo, W. Lekawski and K. Urbaniec. *Gaz. Cukr.*, 1985, **93**, 134 (*Polish*).

Investigation of causes of abnormally high fuel consumption and of excessive steam consumption in the evaporator despite good beet quality and smooth operation of the factory attributed the problems to operation of two old Babcock & Wilcox boilers of low efficiency, inadequate size of the juice tank before the evaporator (causing shortfalls in evaporator feed and the need to make up with ammoniacal condenser water), steam losses from the steam traps of the evaporator and juice heater, and excessive ammonia gas presence in the evaporator. Remedial measures and their positive effects are described.

Investigation and evaluation of the suitability of a Japanese massecuite viscosity-reducing agent

H. Gruszecka. *Gaz. Cukr.*, 1985, **93**, 147 - 148 (*Polish*).

In laboratory and factory tests, POEM Z-200 at an optimum dosage of 100 - 125 ppm reduced massecuite viscosity, extinguished foaming, significantly reduced the boiling time for all three massecuites in a 3-boiling scheme, increased crystal formation and resulted in improved low-grade massecuite crystallization.

Behaviour of non-sugars during raw juice purification. III. Colloidal compounds

J. Copikova, A. Stechova, P. Kadlec and D. Matejova. *Listy Cukr.*, 1986, **102**, 6 - 10 (*Czech*).

The behaviour of colloidal compounds, particularly polysaccharides, during preliming was investigated; pectin and dextran were acid hydrolysed and determined in the form of (i) monogalacturonic acid, xylose and arabinose, and (ii) glucose, respectively (fructose and galactose not being found in the hydrolysate). The effects of CaO and $CaCO_3$ on the colloid content in each of nine compartments of a Brieghel-Müller prelimer were established and the results expressed by graphs and equations which demonstrated a progressive fall throughout the vessel. Virtually all of the polysaccharide component was removed, and the total colloidal content in thin juice was about 10% of that in raw juice.

A low-grade massecuite stirrer

V. Bulena. *Listy Cukr.*, 1986, **102**, 10 - 13 (*Czech*).

An account is given of trials with an impeller mounted in a modified low-grade pan which reduced the boiling time by an average of 27% and increased the heat transfer coefficient by an average of 179% (allowing the temperature of the heating steam to be reduced from 116° to 103°C). Rated input of the stirrer was 4 - 10 kW.

Information from a visit to Italian sugar factories

R. Stengl and M. Svejka. *Listy Cukr.*, 1986, **102**, 14 - 21 (*Czech*).

An illustrated account is given of equipment and processes at Jesi, Foggia, Ostellato and Ponte Longo factories in Italy which were visited by a delegation from Czechoslovakia at the invitation of Ferriani S.p.A., manufacturers of sugar equipment, samples of which were shown at the various factories.

Sugar recovery from run-offs and molasses by chromatographic separation

M. Mattila. *Ind. Sacc. Ital.*, 1985, **78**, 183 - 188 (*Italian*).

A description is given of the Finnsugar liquid chromatographic process for sugar recovery from beet or cane molasses, for liquid sugar production (if desired) from the sugar-rich fraction using ion-exchange resin and active carbon, and for treatment of the non-sugar fraction to yield animal fodder. Flow diagrams are given for *B*-molasses treatment.

Studies on scale formation using laboratory evaporators

G. Rösner and G. Pollach. *Zuckerind.*, 1986, **111**, 125 - 128 (*German*).

Details are given of two laboratory-scale evaporators that were used in studies on scale formation during concentration of beet and sorghum raw juices. During beet juice evaporation in a unit consisting primarily of a U-shaped tube, inhibitors such as polyacrylates, methacrylates and organophosphates on their own (even at six times the manufacturers' recommended quantities) caused only limited reduction in the formation of a crystalline incrustration, mainly consisting of magnesium oxalate, whereas addition of Ca^{++} ions insolubilized the oxalic acid in the juice and reduced scale formation by 85%; a combination of Ca^{++} and recovered Ca oxalate crystals gave 90% reduction, but Ca^{++} plus organophosphate was not as effective as Ca^{++} alone. Reduction of pH from 5.4 to 4.0 by adding HCl increased the solubility of phosphate, oxalate and aconitate during sorghum juice evaporation and gave a scale-free surface in a plate evaporator, as against a heavily scaled surface in the control; a clear correlation was found between Brix, pH and the amount of dissolved aconitic acid; pH reduction to 4.0 decreased the aconitic acid scale by approx. 60%. However, HCl is not practical because of increased sugar losses and corrosion.

Sugar refining

Recycling of bone char wash waste water using the RO system

K. Shiraishi, K. Hara, H. Uasufuku and H. Hashimoto. *Proc. Research Soc. Japan Sugar Refineries' Tech.*, 1985, **34**, 91 - 100 (*Japanese*).

Waste water from bone char washing was treated by reverse osmosis (RO), which raised its quality sufficiently to allow it to be used again for char washing, in which its efficiency was better (as was its quality) than that of normal industrial town water. A mixture of RO permeate and RO feed water could be used to obtain the usual washing efficiency. Occasional washing of the membranes allowed them to be used for about 2600 hours. The costs of the system are calculated.

Raising the efficiency of powdered active carbons by using powdered filter-aids in sugar refining

V. A. Loseva, I. S. Naumchenko, L. V. Belova and O. V. Shiyanova. *Rpt. Voronezh Technol. Inst.*, 1985, 10 pp; through *Ref. Zhurn. AN SSSR* (*Khim.*), 1985, (18), Abs. 18 R454.

The rate of syrup filtration at Ol'khovatka refinery was studied using different brands of powdered active carbons to which were added kieselguhr and perlite, respectively. Experimental determination of the rate was carried out at a gauge pressure of 0.1 MPa. Use of the carbon/filter-aid mixtures (in which the filter-aid constituted 0.5 - 0.8% of the carbon weight) increased the filtration rate by 70% (with kieselguhr) and by 120% (with perlite). Application of mixtures of Norit Supra Standart carbon, Soviet YAF carbon and kieselguhr increased the filtration rate of 1st refined syrup by 150% and of 2nd refined syrup by 90%.

Effect of certain factors on the filtration rate of refinery syrups using powdered active carbons

V. A. Loseva. *Rpt. Voronezh Technol. Inst.*, 1985, 7 pp; through *Ref. Zhurn. AN SSSR* (*Khim.*), 1985, (18), Abs. 18 R455.

In tests on determination of the filtration rate of refinery syrups (see preceding abstract), a study was made of the effects of temperature and ageing time in the mixer on preparation of a carbon suspension and of syrup Brix on its filtration rate; choice of the type of filter cloth was also investigated. Carbons used in the tests were YAF, Supra Standart, Darco and BL. Optimum for preparation of a carbon suspension were an ageing time of 1 hr and a temperature of 20°C. Use of a suitable filter cloth and control of syrup Brix coupled with use of carbon increases the filtration rate.

Application of surfactants for the refining of raw sugar

V. V. Chopik, R. Cedeño, U. Rosabal, E. González, R. Verdecia and A. Fariñas. *CubaAzúcar*, 1984, (Jan./March), 53 - 59 (*Spanish*).

Full-scale trials were made in the refinery section of a sugar factory in Cuba of a process developed by ICINAZ for colour removal from a raw sugar melt using a quaternary ammonium salt and polyacrylamide flocculant, in a similar manner to the Talofloc-Taloflote system. Colour removal was improved substantially and carbon consumption reduced by 60%. The high liquor filtrability eliminated the need for its dilution and this, combined with economies in steam and filtration materials, aided the technological process and reduced sugar losses.

Jamaican raw sugar quality and the new Amstar and Savannah quality criteria

J. C. P. Chen. *Zuckerind.*, 1985, **110**, 902 - 908.

While considerable improvements have been made in the refining quality of Jamaican raw sugar since 1982, new contracts drawn up by Amstar Corporation and Savannah Foods in place of the old No. 10 Contract insist on a much higher quality. Comparison is made between the old and new contracts, including the methods used for dextran and colour measurement, for which the wavelength and pH are now 420 nm and 8.5, respectively, instead of 560 nm and 7.0. Raw sugar must be of at least 98°S as against 96 - 97°S previously. Reference is made to the results achieved in Australia in reducing both dextran and colour; the contributions made by reductions in burn-to-harvest and processing delays are mentioned.

Optimization of refined sugar massecuite centrifugalling

M. Kaderavek, V. Kavan and O. Mikus. *Listy Cukr.*, 1986, **102**, 31 - 35 *(Czech).*

In view of the considerable quantity of steam required for washing of refined sugar massecuite at a rate of 0.7% on massecuite for about 1 minute, studies were made (using automatic centrifugals) of the effect of washing with steam at 0.5 - 4.4% w/w, 0.54 - 0.90 MPa pressure and 210 - 250°C for 10 - 82 seconds plus water at 0.1 - 4.0% w/w and 44 - 47°C for 19 - 75 sec on the moisture, ash and colour contents of the resultant sugar; the massecuite and run-off parameters were also analysed. Data are tabulated for 19 samples representing highly varying conditions of treatment. Statistical analysis showed that sugar quality was unaffected by steam washing, which could therefore be eliminated. Affination experiments conducted by Friml *et al.*[1] showed that splitting the period of water washing into two of e.g 10 seconds each (before and after complete filling of the basket without any change in the total quantity of water applied) gave a lower colour and ash content than with normal single washing without affecting the sugar moisture content. Six methods used to determine the sugar moisture yielded different results, the Karl Fischer method using formamide giving the highest value, while drying for 90 minutes at 105°C and then cooling in a desiccator on silica gel (which measures the surface moisture) gave the lowest value.

1 "Tech. a technol. reseni novych cukrovaru" (Praha), 1985.

Starch based sweeteners

Studies on the application of pullulanase in the starch saccharification process

L. Slominska and M. Maczynski. *Starch/Stärke*, 1985, **37**, 386 - 390.

Saccharification of starch hydrolysate using glucoamylase to produce D-glucose has a number of disadvantages, including inadequate yield. A higher degree of conversion is possible when debranching enzymes are used; indirect debranching enzymes will act only once the substrate has been modified by other enzymes, whereas direct debranching enzymes such as pullulanase and isoamylase hydrolyse α-1, 6-linkages directly by splitting off the side chains of varying length. Investigations in which starch hydrolysate was saccharified with a combination of commercial glucoamylase and pullulanase showed that, by comparison with glucoamylase used alone, the saccharification time was cut from 72 to 48 hours, the glucose yield rose from 95.8% to 97.6% and the substrate dry solids content at which saccharification was possible increased from 30% to 40%.

An update on high-fructose corn syrup in the United States

S. Vuilleumier. *Sugar y Azúcar*, 1985, **80**, (10), 13, 16 - 17, 20.

An account is given of: estimated HFS and sugar sales in 1978/86, the major markets for HFS, corn costs and HFS prices, estimated manufacturing capacities of HFS producers, the ethanol factor (whereby growth in the alcohol industry has induced the corn wet milling industry to install plant for both HFS and alcohol manufacture), and the production costs of 42% and 55% HFS.

The effect of temperature on the efficiency of chromatographic separation of glucose and fructose on sulphonic cation exchangers

Yu. E. Kuptsevich, I. D. Stal'naya, L. A. Nakhapetyan, A. Ya. Pronin and O. G. Larionov. *Sakhar. Prom.*, 1985, (12), 47 - 50 (*Russian*).

In an investigation of the effect of temperature on separation using KU-2-8 and Dowex 50X4 cation exchange resins, both in Ca^{++} form, it was found that the amount of pure fructose obtained with the former exchanger fell with rise in temperature, while that from the latter resin remained unchanged with temperature variation. For the Soviet resin, 17 - 30°C was the optimum range. Much better results were also achieved with finer resin particles.

Investigation of the process of purifying fructose solutions in fructose and glucose production from sucrose

L. I. Tanashchuk *et al. Rpt. Kiev. Tekh. Inst. Pishch. Prom.*, 1985, 6 pp; through *Ref. Zhurn. AN SSSR* (*Khim.*), 1986, (3), Abs. 3 R441.

Purification of fructose solutions by treatment with cation - anion - cation exchange resin was studied; the process removed Ca^{++}, K^{+}, Na^{+} cations and SO_4^{--} anions as well as a considerable portion of the products of fructose degradation in alkaline and acid medium. The possibility of using granular and powdered active carbon for purification was investigated. Optimum conditions were established for the ion-exchange treatment.

Separation of glucose and fructose by simulated counter-current adsorption

C. B. Ching and D. M. Ruthven. *AIChE Symp. Ser.*, 1985, **81**, (242), 1 - 8; through *Ref. Zhurn. AN SSSR* (*Khim.*), 1986, (3), Abs. 3 R442.

Tests on simulated counter-current separation of the monosaccharides in a mixture of 5 g/100 ml concentration at 29 - 30°C were conducted in an experimental unit consisting of 12 identical columns 5.1 cm in diameter and 100 cm long filled with a Duolite cation exchange resin in Ca^{++} form and provided with automatically controlled valves. The results obtained were used to develop a mathematical model of the process. Fructose separation in the experiments was >94% and purity 85.

Glucose degradation during evaporation

N. A. Arkhipovich *et al. Rpt. Kiev. Tekh. Inst. Pishch. Prom.*, 1985, 10 pp; through *Ref. Zhurn. AN SSSR* (*Khim.*), 1986, (3), Abs. 3 R443.

Glucose degradation during evaporation of its solutions was investigated and the effect established of temperature and duration of the process on the amount of glucose decomposed. The concentration of acids in the solution rose with increase in evaporation time, with consequent considerable fall in pH. This permitted increase in the rate of the degradation reaction and led to formation of dehydration products and their further polymerization. The level of losses resulting from the formation of colouring matter in the form of hydroxymethyl furfural and its polymers was determined as well as the accumulation of organic acids. Glucose degradation rose at a greater rate with formation of organic acids than with formation of colouring matter.

Separation of fructose and glucose by reverse osmosis

S. K. Sung, N. C. Ho and S. G. Young. *Ind. Eng. Chem. Fundamentals*, 1985, **24**, (4), 409 - 412; through *S.I.A.*, 1986, **48**, Abs. 86-425.

The aim was to separate fructose from a glucose-fructose mixture by reverse osmosis at 100 atm and room temperature, using cellulose acetate (CA) and polyvinyl acetate (PVA) membranes. With CA membranes, the fructose concentration in the product was only slightly greater than that in the feed solution. Addition of 20g NaCl, Na_2CO_3 or $NaHSO_3$/litre of feed resulted in better separation of fructose, since these compounds form complexes with glucose. Best results (a separation factor of 1.50) were obtained with the $NaHSO_3$. The PVA membrane gave poor retention of both sugars and salts.

Laboratory studies

Revision of the two-stage floc evaluation method for raw sugar in Taiwan

H. C. Tseng and Y. C. Hsiao. *Rpt. Taiwan Sugar Research Inst.*, 1985, (109), 29 - 35 (*Chinese*).

Although a newly developed two-stage floc evaluation method can quickly indicate a flocculating sugar, 20 - 50% of the sugar samples still remain that need to be measured by a complicated acid-carbonated water method. However, by taking the ratio of the FTU (formazin turbidity unit) of the Hiram Walker test to that of the two-stage method as a floc index, the residual samples can be re-divided. An index greater than 1 indicates a probable flocculating sugar, and about 50% of the samples can be re-separated as non-flocculating sugars.

Calculation of the composition of sugar solutions

J. Dobrzycki and A. Dobrzycki. *Gaz. Cukr.*, 1985, **93**, 153 - 156 (*Polish*).

To facilitate evaluation of the results given by the Polish test for sucrose solubility in molasses, i.e. for determination of molasses exhaustion, formulae have been derived for calculation of the various parameters involved and of constants m and b in the equation of Wagnerowski *et al.* The formulae can be easily calculated using a pocket calculator or personal computer. Raffinose must be allowed for where it is present at more than 0.5%. The technique is demonstrated by worked examples.

The thermodynamic activity of components of the water-sucrose-ammonium chloride system

V. M. Perelygin and V. G. Borisko. *Izv. Vuzov, Pishch. Tekh.*, 1985, (4), 38 - 41 (*Russian*).

Measurements of the saturated vapour pressure of the title system in the temperature range 60 - 90°C showed that it fell with increase in sucrose and ammonium chloride concentration; the increase in chloride concentration caused considerable rise in the activity coefficient of sucrose at a constant coefficient for water, the effect being greater with increase in sucrose concentration. Hence, sucrose solubility will be lower in ammonium chloride solution than in water, so that addition of the chloride will increase the crystallization driving force and so raise the sugar yield from low-grade massecuite. Although increase in sucrose concentration was accomplished by a certain rise in the activity coefficient of the chloride, increase in temperature in the range studied caused it to fall.

Investigation of the thermodielectric effect in sucrose crystallization

L. F. Stepanets, V. O. Shtangeev, I. S. Gulyi and S. A. Arsen'ev. *Izv. Vuzov, Pishch. Tekh.*, 1985, (4), 69 - 71 (*Russian*).

The thermodielectric effect is the redistribution of an electric charge between two phases that accompanies phase transformation in a dielectric. Since sucrose is a ferroelectric with a molecule forming a dipole 1.10×10^{-10} m long and having a polarity of 0.64×10^{-1} ohm, the thermodielectric effect is observed during crystallization. Studies were conducted with a thermodielectric cell consisting of a coaxially arranged heater, a vessel filled with sugar solution (acting as an earthed electrode) and a measuring electrode in a fixed position relative to the body of an analytical balance and connected to a voltmeter. The sugar solution, of 1.05 supersaturation at 70°C and of 99.7, 98.3 or 96.8 purity, was poured into the preheated cell and the measuring electrode immersed in it. During natural cooling to 30°C, the weight of the contents rose as a result of crystallization on the primed measuring electrode; this increase was accompanied by occurrence on the electrode of a positive charge, the level of which rose with fall in purity. The findings may be used to develop means of preventing sugar incrustation on the surfaces of continuous vacuum pans.

Sequential determination of glucose and sucrose with a single detector using flow injection analysis

M. G. Gardell. *Abs. Pap. Pittsburgh Conf. & Expos. Anal. Chem. Appl. Spectrosc.*, (New Orleans), 1985, (1046); through *Ref. Zhurn. AN SSSR (Khim.)*, 1986, (2), Abs. 2 R68.

A method for separate determination of glucose and sucrose has been studied; it uses a detector based on the application of immobilized enzymes with a commercial Flow Injection Analyser. Glucose is measured first, followed by passage of the sample (after automatic invertase treatment) through the detector a second time for measurement of the inverted sucrose as glucose. The measuring range is 0.05 - 5.00% for glucose and 0.01 - 1.00% for sucrose. In the case of high sugar concentrations, the samples are automatically diluted to a required level. Determination of the two sugars takes 90 sec, as against 30 min using HPLC.

Determination of the glucidic fraction in agro-food substrates by HPLC/RI detection

G. Cirilli, C. S. A. Cirilli, C. Pulga and L. Zaghini. *Ind. Alimentari*, 1986, **25**, (234), 35 - 37 (*Italian*).

Details are given of HPLC determination of sugars in e.g. beet and cane molasses using a refractive index indicator and a Hypersil 5 Amino column measuring 250 × 4.6 mm; isocratic elution with 80:20 acetonitrile:distilled water is conducted at a flow rate of 1 - 1.2 ml/min and a temperature of 35°C. The sample is diluted to 2 g/100 ml, extracted with 60:40 acetonitrile:water in a 150 ml flask, filtered and 20 µlitre of the filtrate injected using a Rheodyne 7125 loop injector. Sensitivity of the detector is 0.25×10^{-5} refractive index units. Optimum extraction time is 45 min, while analysis takes 15 - 20 min, including washing. Chromatograms are reproduced, including one showing separation of fructose, glucose and sucrose in beet molasses.

Partially acetylated sucrose. Preparation of 3-O-acetyl sucrose and 3,6'-di-O-acetyl sucrose and the analysis of mixtures of O-acetyl derivatives of sucrose of various degrees of acetylation by thin-layer chromatography with flame ionization detection

K. Capek, T. Vydra, J. Capkova, M. Ranny, M. Blahova and P. Sedmera. *Collect. Czech. Chem. Commun.*, 1985, **50,** (5), 1039 - 1047; through *Anal. Abs.*, 1986, **48,** Abs. 2C13.

Sucrose and O-acetylated derivatives with 1 - 8 acetyl substituents were separated by TLC on layers of Silica gel G (Merck) and the spots detected by spraying with a 1% solution of cerium sulphate in 10% H_2SO_4. Chromarods of type SII (15 cm × 0.9 mm diameter) were also used for TLC, with 62:19:19: benzene:hexane:methanol as the mobile phase and with flame ionization detection. The compounds were separated according to the number of acetyl substituents.

Isolation and identification of humic acid: a prominent colorant present in clarified cane juice

V. Dubey and M. Prasad. *Maharashtra Sugar*, 1985, **10,** (11), 33 - 36, 39 - 40.

See *I.S.J.*, 1986, **88,** 113 - 118.

Simultaneous determination of sucrose and glucose in mixtures by flow-injection analysis with immobilized enzymes

M. Masoom and A. Townshend. *Anal. Chim. Acta*, 1985, **171,** 185 - 194; through *Anal. Abs.*, 1986, **48,** Abs. 3C17.

Sucrose was determined in a flow-injection system by using a manifold comprising columns of β -D-fructofuranosidase/aldose 1-epimerase and glucose oxidase (each immobilized on controlled-pore glass) in sequence, followed by amperometric detection of the hydrogen peroxide produced. At pH 6.8, maximum sensitivity was achieved, the enzymes maintained activity for approx. 12 weeks, and the detection limit was 10 μM sucrose. Incorporation of a controlled bypass around the first column allowed one sample to traverse both columns, thereby permitting the sequential determination of sucrose and glucose (0.1 - 10mM), while the next sample passed through only the glucose oxidase column; accurate determinations were possible within 25 sec. The simultaneous determination of sucrose and glucose was also possible (in 2 min) by means of a single injection, which was split in the apparatus, thus allowing a sucrose-glucose and a glucose peak to be obtained in sequence. For five samples, the coefficient of variation was 1.8% for the combined peak and 2.9% for the glucose peak.

Detection of chlorogenic acid in sugar cane by thin layer chromatography

D. Piñón and R. Gómez. *Cienc. Agric.*, 1984, (21), 122 - 125 (*Spanish*).

A technique is described in which phenolic compounds are extracted from cane leaf tissue with aqueous methanol and subjected to thin layer chromatography on silica gel G using acetic acid:butanol:water (1:4:5 v/v/v) and butanol:ethanol:water (4:1:2.2 v/v/v) as solvents. Spots from the phenols were developed using 1% sodium nitrite in 10% acetic acid solution and the chromatograms examined under ultraviolet light; the R_f values for both solvent mixtures of chlorogenic acid and three standard acids are tabulated. If the chromato-grams are treated with 1N NaOH the spots which develop allow the presence of chlorogenic acid to be demonstrated, and are more intense with varieties which are resistant to red rot than those which are susceptible.

Two methods for determining colloids and their effectiveness

R. Fajardo G., J. Castellanos E., H. Estacio C. and A. Corral A. *Centro Azúcar*, 1983, **10,** (3), 17 - 20 (*Spanish*).

Two methods for colloids determination were compared; one uses coagulation with alcohol and ether while the other is gel filtration or the molecular sieve method using Sephadex G-50. Other components of refinery liquors are precipitated in the first and so the second method is considered more suitable.

Determination of calcium and magnesium in colloidal and microdisperse state in products from the cane sugar manufacturing process

G. Fernández M., M. Darias P. and D. Moreira. *CubaAzúcar*, 1984, (Jan./March), 24 - 27 (*Spanish*).

A number of methods for determination of Ca + Mg in samples of juice, sugar and molasses have been examined and it was concluded that a complexonometric method with a solution of di-sodium EDTA dihydrate using Eriochrome Black T as indicator was accurate. For separate determination of the Ca and Mg an atomic absorption method was suitable.

Evaluation of raw material for the sugar industry

G. Pollach. *Listy Cukr.*, 1986, **102,** 91 - 96 (*Czech*).

The methods used for beet evaluation in Austria, particularly for determination of the alkalinity coefficient and for assessment of the effect of rhizomania on quality, are described.

The beet quality analysis line

Anon. *Sucr. Franç.*, 1986, **103,** 101 (*French*).

A short account is given of the IRIS beet analysis system and of the sequence of operations for polarimetry, measurement of K and Na by flame spectrophotometry, sucrose and glucose determination by an enzymatic/colorimetric method and alpha-amino N by the ninhydrin technique. The date are processed by a micro-computer.

By-products

Some thoughts on by-product utilization in sugar manufacture

D. P. Kulkarni. *Maharashtra Sugar*, 1985, **10,** (8), 11, 13, 15 - 16; (9), 15 - 18.

A survey is presented of bagasse and cane molasses by-products manufacture.

Studies on the fermentative production of L-lysine. II. Identification of L-lysine accumulating bacteria

Y. T. Liu and S. L.Sang. *Rpt. Taiwan Sugar Research Inst.*, 1985, (109), 37 - 45.

Details are given of lysine-producing mutants used at a plant set up by the Taiwan Sugar Corporation and isolated from a newly-obtained strain of glutamic acid bacterium of the *Brevibacterium* genus. The lysine-producing properties of the strains on various sugars, including sucrose, glucose and fructose, are indicated.

Millaquin trial will test new process

Anon. *Australian Canegrower*, 1985, **7,** (11), 41.

Mention is made of a plant for potassium removal from cane molasses by a membrane separation process which was to be tested over a 3-month period at Millaquin; a multiple-effect evaporator is also involved. The desalting process, developed by Syrinx Research Pty. Ltd., has been found to enhance the properties of molasses as animal fodder and pet food additive.

Osmotic dewatering of beet pulp

J. Dobrzycki and S. Wawro. *Tagungsber. Akad. Landwirtschaftswiss. DDR*, 1985, **229,** (2), 405 - 407; through *Ref. Zhurn. AN. SSSR (Khim.)*, 1986, (2), Abs. 2 R468.

Results are reported of investigations in which pulp was brought into contact with heated molasses. It was found that, by this means, the molasses penetrated the pulp tissue and drove out the water.

Acidification of molasses solutions using electrolytic treatment

V. A. Marinchenko, L. V. Kislaya, V. L. Pribyl'skii, V. M. Rogov and O. A. Buts'ko. *Rpt. Kiev. Tech. Inst. Pishch. Prom.*, 1985, 9 pp; through *Ref. Zhurn. AN SSSR (Khim.)*, 1986, (3), Abs. R361.

An electrolytic method is proposed for molasses solution in which the electrodialyser consists of an anode and a cathode zone separated by a membrane. With application of a constant voltage to the electrodes, the pH in the anode zone falls as a result of electrolysis and ion diffusion across the membrane, while it rises in the cathode zone, which should therefore be filled with water. It was found that the specific electricity consumption fell by 76% with fall in molasses concentration from 40 to 10%, while a temperature rise from 20 to 40°C caused a 20% fall in consumption. The possibility is shown of acidifying concentrated molasses (of 45% dry solids) with subsequent dilution with tap water. Five-fold dilution altered the pH of the molasses wort by 0.1 unit. The expected economic effect of electrolytic acidification is 30 roubles per 1000 dl.

Single-cell protein (SCP) production from sugar beet fragments and tails by *Candida utilis* and *Chaetomium cellulolyticum*

S. Popov, S. Gacesa and D. Pejin. *Hemijska Ind.*, 1984, **38,** (10), 307 - 313; through *S.I.A.*, 1986, **48,** Abs. 86 - 214.

Beet tails and fragments constitute 3 - 5% of the root weight and contain about 8 - 10% sugars. Juice extracted from tails and fragments by a laboratory press, and the pulp which remained, were tested as possible substrates for the production of SCP. Tests were carried out in a 14-litre stirred-tank fermenter in batch, fed-batch and continuous modes. In batch fermentations of juice by *C. utilis*, a satisfactory yield of fodder yeast was obtained in 18 - 20 hr; the yield was slightly greater on juice from fragments than on juice from tails. Fed-batch operation for up to 45 hr also gave satisfactory yields, and the reducing sugars content in the fermented broth was practically zero. In continuous operation, yeast yield decreased and nucleic acid content increased with increasing dilution rate in the range 0.1 - 0.33/hr. With yield and protein content as criteria, the optimum dilution rate was 0.12 - 0.13/hr. The pulp was shown to be a suitable substrate for culture of the fungus *C. cellulolyticum;* the product contained 35 - 40% protein on dry solids. On the basis of these results, a process is suggested by which 100 kg fragments + tails could be used to produce 4 kg (dry solids) fodder yeast containing about 50% protein on dry solids and 2.5 kg (dry solids) fungal biomass containing about 35% protein on dry solids.

Study on pick-ups with a view to process automation. Application to a distillery

J. Guerain *et al. Ind. Alim. Agric.*, 1986, **103,** 5 - 12 (*French*).

Automatic measurement, either in the laboratory or on-line, of parameters involved in ethanol fermentation of beet molasses and of beet diffusion variables with the aim of process automation is discussed. The survey includes, for the distillery, automatic sampling, dry solids measurement (based on refractive index, density, conductivity, infra-red and near-infra-red spectrophotometry), sugars determination by HPLC and near-infra-red spectrophometry, and ethanol determination by enzyme, near-infra-red spectrophotometry and densimetry. Diffusion parameters mentioned include the diffusion coefficient, cossettes residence time, sugar content in cossettes and pulp, quantities of cossettes, water, water and juice, and diffusion temperature. A micro-computer program with these and beet slicer rate as input has been introduced at a distillery.

Patents

UNITED KINGDOM

Reaction vessel for enzymatic determination of sucrose

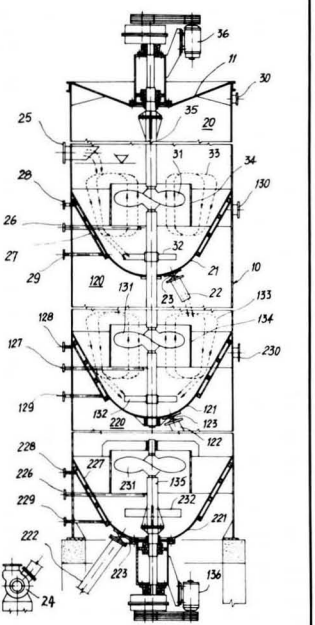
Vysoka Skola Chemicko-Technologicka, of Praha, Czechoslovakia. **2,145,815.** July 27, 1984; April 3, 1985.

Enzymatic reactions such as those involved in the determination of sucrose using invertase and glucose oxidase can be carried out in a special vessel provided with a (magnetic) stirrer, the surface of which carries a layer of the enzyme. Alternatively, the vessel may contain removable stationary parts which carry the enzyme layer. A pH electrode may also be incorporated for quantitative determination of unoxidizable substrates.

Continuous vacuum crystallizer

Eridania Zuccherifici Nazionali SpA, of Genoa, Italy, and Terom SpA, of Bologna, Italy. **2,147,217.** April 30, 1984; May 9, 1985.

A vertical cylindrical vessel is subdivided into three compartments 20, 120, 220, by concave hoppers 21, 121, 221, each of which is provided with a jacket 27, 127, 227 supplied with conditioning water from ducts 28, 121, 228, the water being discharged via ducts 29, 129, 229. Most of the water in the massecuite is evaporated under vacuum, while circulation is provided by two stirrers in each compartment, the upper ones (propellers 31, 131, 231) having a greater pitch than the lower ones 32, 132, 232 which may be horizontal rods designed to provide only horizontal circulation of the massecuite rather than the three-dimensional movement generated by the upper propellers. The high position of the upper stirrers in each compartment ensures that they do



not disturb the lower portion of massecuite containing the larger crystals. Thus, while the concave shape of the bottom of each compartment prevents stagnation, the type and position of the stirrers favour the separation of the larger crystals and their transfer to the next stage. This separation is further promoted by the presence of a cylindrical nozzle 34, 134, 234 surrounding each of the upper stirrers. Compartment 20 receives massecuite from one or more vacuum pans via duct 25, syrup being added via duct 26 to maintain a required consistency. The degree of opening of control valve 23 may be regulated as a function of the massecuite level in compartment 20. The extent of crystal growth is 20% of the initial massecuite in compartment 20, 36% in compartment 120, and 50% in compartment 220.

Glucose isomerization

Nabisco Brands Inc., of Parsippany, NJ, USA. **2,148,298.** October 24, 1984; May 30, 1985.

Glucose in a feed liquor of approx. 30 - 50% carbohydrate by weight (20 - 85%) is isomerized with glucose isomerase obtained from a *Streptomyces* sp., e.g. ATCC 21175, or from *Bacillus stearothermophilus*, at 90 - 140°C (100 - 110°C), pH 3 - 8 (4 - 7), (5 - 6.5) for 2 - 30 minutes to yield 53 - 60% (52%) fructose by weight.

Continuous single-cell protein manufacture

Imperial Chemical Industries PLC, of London, England. **2,151,635.** November 19, 1984; July 24, 1985.

After addition of suitable nutrients (e.g. phosphoric acid, K and Mg sources and trace elements) to clarified beet or (preferably) cane juice, mixing at pH 2 - 4 and 60 - 95°C for 30 min - 3 hours, followed by cooling to 20 - 40°C, fermentation is carried out with a yeast such as *Saccharomyces cerevisiae* at 30 - 40°C; this is preferably done in a "pressure-cycle" vessel in which the culture is continuously circulated around a system comprising a riser and downcomer (connected at the upper and lower ends) by compressed air blown into the culture in the lower part of the riser; N in the form of ammonia is added in the compressed air stream. The SCP obtained is suitable as a component of human or animal feed.

countries having a favourable agroclimatic environment for its production.

Biomass, i.e. all organic matter, is composed mainly of carbohydrate compounds ultimately derived from the process of photosynthesis, but may be in vegetable or animal form. These materials either harvested as grown crops or as wastes from crops grown primarily for food and manufacturing raw materials, are being seriously considered for energy purposes.

One biomass resource of particular significance to Mauritius is sugar cane, the crop occupying 90% of the island's cultivable land area. Sugar cane is known to have a bioconversion efficiency of capture of sunlight of around 4% and this efficiency is much higher than the 1 - 2% achieved on average by most other crops. Under Mauritian conditions around 45 tonnes of dry matter are normally fixed in the sugar cane plant per hectare of land under cane annually. Table I shows a breakdown of this dry matter content of the sugar cane biomass per hectare.

Table I. Sugar cane biomass per hectare[a] (Mauritius, 1982)

		Dry matter, tonnes
Cane stalk		
Fibre	11.35[b]	
Absolute Juice	11.49[c]	22.84
CTL	6.29[d]	
Trash	9.66[e]	
Roots	5.30[e]	21.88
		44.72

a Based on yield of 82.4 tonnes of sugar cane obtained in 1982
b Based on a fibre % cane of 13.77
c Based on a Brix % absolute juice of 16.18
d Assuming a dry matter content of 28% and CTL% harvested cane (fresh weight basis) of 30%
e Based on records from Mauritius Sugar Industry Research Institute

Under current cultural practices, only the millable cane, which constitutes 50% of this dry matter, is harvested and sent to the factory for extraction of sucrose as a major food product; the fibre in the form of bagasse is burnt and supplies all the fuel needs of the factory. An excess of bagasse may be realised in a modern, well-designed factory and possibly used for export electricity or particle board production.

The other 50% consists of the cane tops and leaves (CTL), trash and underground rhizome with the roots. These are agricultural by-products which have been in little demand for food or energy. The rhizome with roots serves as the basis for the establishment of a ratoon cane crop; except for a minor amount collected as fodder for ruminants, the CTL, together with the trash, are generally left in the field. There is therefore a significant quantity of these materials that may be diverted to other uses.

Use of these agricultural by-products for food or energy should thus be a priority especially in the Mauritian context where 70 and 90% respectively of these items are imported. The energy-related products that may potentially be produced from CTL through physical and/or chemical processes are shown in Figure 1. These include electricity, fuel gases with different heating values, and various liquids and solid fuels[1]. These products are strong alternative candidates to replace imported petroleum, domestic natural gas, ammonia and methanol.

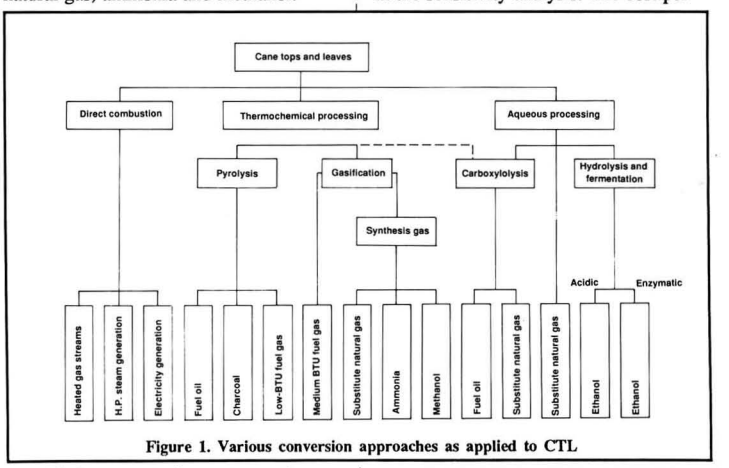


Figure 1. Various conversion approaches as applied to CTL

Under current circumstances in Mauritius, however, electrical power is the most favoured of the energy related products. Tremendous investments have been made, gradually over many years, in the power transmission lines to almost every part of the country. Electricity is a clean source of light, heat and power, and is more conveniently transported to the end user; however its production is largely met by use of imported fuel with its variable international prices, unreliability of supply and significant effect on balance of payments.

This study, therefore, focuses attention on the economics of large scale conversion of CTL to electricity with reference to Mauritius. A review is first presented of the characteristics of CTL and the fibrous residue therefrom. Based on these characteristics, a system is proposed and briefly described; its material and energy balances are examined and subsequently an economic analysis is carried out. In this analysis, a set of parameters is identified and realistic values assigned to these parameters with reference to Mauritius. These values are used for a baseline calculation and subsequently a few parameters are chosen which would have the most significant effect on the overall economic feasibility. A range of values is given to these parameters and are used in the sensitivity analysis. The cost per kWh unit of electricity produced was determined for each set of values or combination thereof and was compared

1 Deepchand: *Proc. Int. Conf. on State of the Art on Biogas Technology, Transfer and Diffusion*, Nov. 17 - 24, 1984.

with those obtained using existing methods of power generation in Mauritius, notably fuel oil, coal and bagasse. Some consideration is also given to by-products from the system.

Characteristics of CTL and fibrous residue therefrom

For every 100 tonnes of cane harvested for sugar manufacture, around 30 tonnes of CTL are available. The annual production of CTL from the 6.5 million tonnes of cane harvested in Mauritius is thus around 2 million tonnes. The average approximate composition, calorific value and bulk density of CTL[2] are given in Table II.

Table II. Approximate composition, calorific value and bulk density of CTL

Dry matter (DM), %	28.0
Protein (N × 6.25) % DM	7.6
Crude fibre % DM	27.0
Crude fat % DM	3.1
Ash % DM	5.4
Nitrogen free extract % DM	56.9
Fibre % fresh material	22.3
Gross calorific value (DM)	16,000 kJ/kg
Net calorific value*	14,740 kJ/kg
Bulk density	240 kg/m^3

* Based on GCV and relationship given by Hugot[3]

From these characteristics, it is observed that fresh CTL have an inappropriate physical size and a high moisture content, low bulk density and a calorific value comparable to other biomass resources. It is known that during combustion, reactions take place at the surface of, or with gases driven off from, the material. For a given weight, therefore, large chunks have little surface area, whilst heat penetration and ease of escape of gases suffer from longer paths. Also a moisture content in excess of 60% (as is the case with fresh CTL) is undesirable in that, under such conditions, problems can occur in furnaces[4]. Most properly designed furnaces can handle residues with moisture content as high as 50 - 55%. Such furnaces are in fact encountered in cane sugar factories and burn bagasse at 50% moisture. Low bulk density is another drawback of such biomass resources and affects transportation cost from the field to, and within, a centralized processing unit.

Size and moisture reductions have been carried out using laboratory-scale equipment (shredder and 3-roller mill) and a fibrous residue having the yield and characteristics shown in Table III was obtained. These characteristics are comparable to those of sugar cane bagasse and therefore such a residue may conveniently be burnt in furnaces designed for bagasse without major modification[5].

Table III. Yield and characteristics of fibrous residues from CTL

Yield/tonne CTL	440 kg
Gross calorific value (0% moisture)	16,000 kJ/kg
Gross calorific value (25% moisture)	11,200 kJ/kg
Net calorific value (0% moisture)	14,740 kJ/kg
Net caloric value (25% moisture)	10,330 kJ/kg
Net caloric value (50% moisture)	6,210 kJ/kg
Particle size	
<1mm	40%
>1mm	60%
Bulk density	110 kg/m^3

System for electricity production

A system for electricity from CTL is schematically presented in Figure 2. The facility handles 90 tonnes of fresh CTL per hour from an area with a cane sugar factory crushing 300 t.c.h. The fresh CTL are unloaded on a lateral feed table and fed to a main carrier. The CTL are prepared in a shredder and the shredded material is conveyed to a dewatering device. This device consists of a tandem of two 3-roller mill units set with the openings between rollers decreasing along the length of the tandem; it dewaters the CTL to yield a fibrous residue of 50% moisture.

60% of the fibrous residue is sent to the top of a boiler furnace in which it is incinerated in a fludized bed mode of combustion. The basic end-product here is thermal energy in the form of steam generated at high pressure (40 bar) and temperature (450°C) from the heat of combustion of the fibrous residue. This steam is then used in condensing turbo-alternators for the production of electricity.

The other 40% of the fibrous residue is pressed in a baling plant similar to one used for bagasse and stored in the form of bales for intercrop electricity generation. Large tight bales are preferred as opposed to other smaller densified materials like pellets because the interior of the bales is very well protected from rain, so that no silo or covering is needed. The energy

2 Idem: *Agric. Wastes*, 1986, **15**, 139 - 148.
3 "Handbook of cane sugar engineering" 3rd Edn. (Elsevier, Amsterdam), 1986, 920.
4 Cheremisinoff *et al.*: "Biomass applications, technology and production". (Marcel Dekker Inc., New York), 1980.
5 Deepchand: *Solar Energy*, 1985, **35**, 477 - 482.

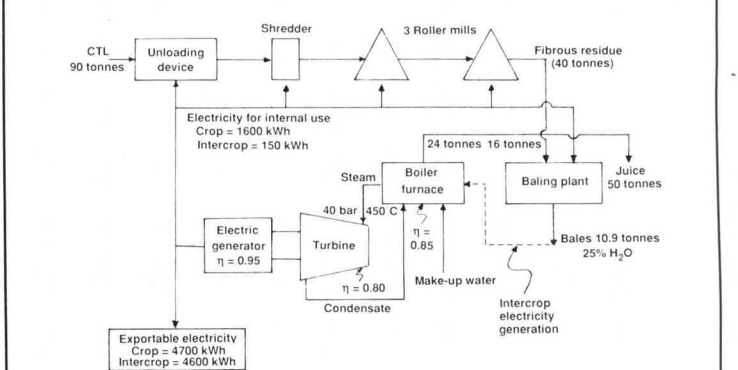
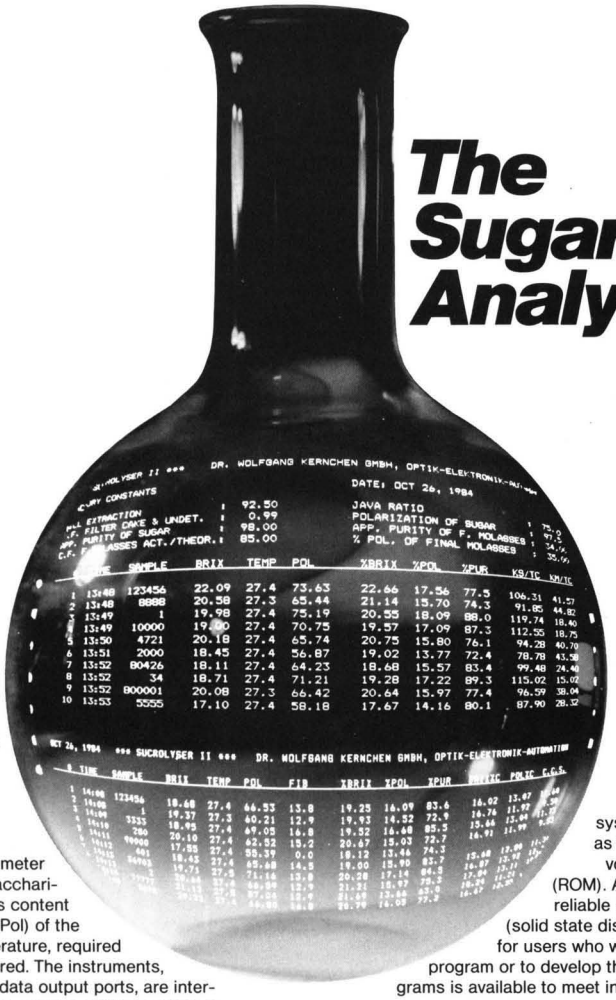


Figure 2. Electricity production from CTL

SUCROLYSER II

The Sugarcane Analyser



SUCROLYSER II is an automatic analyser for sugarcane juice purity determination and for computing quality data such as kg sugar/ton cane or C.C.S.

High precision instruments, BRIXOMAT automatic refractometer and SUCROMAT automatic saccharimeter measure the total solids content (Brix) and the sugar content (Pol) of the cane juice. The sample temperature, required for corrections, is also measured. The instruments, featuring digital displays and data output ports, are interfaced to an APPLE IIe personal computer which evaluates measured and manually entered data. At the end of each analysis, original and computed data appear in a list printout together with date, time and sample number.

SUCROLYSER II is easy to operate. Clear messages on a video display screen safely guide the user. Instruments and data processing equipment are designed for reliable performance under adverse conditions typical for a cane laboratory environment. The computer program for operating the SUCROLYSER II system is normally supplied as "firmware" stored in non-volatile solid state memory (ROM). A diskette drive or a more reliable magnetic bubble memory (solid state disk) are offered as options for users who want to modify an existing program or to develop their own. A choice of programs is available to meet international requirements.

SUCROLYSER II is a powerful tool for improving sugarcane quality and for enhancing relations between planter and sugar factory. If you want more information please ask for our detailed brochure.

We hope you saw a demonstration of the Sucrolyser II system during the XIX Congress of the International Society of Sugar Cane Technologists in Jakarta, Indonesia, August 21 - 23, 1986; if not we invite you to write to us now.

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Western States at Thames Refinery

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Each of the 14 Western States centrifugals at Thames Refinery is d.c. driven and includes programmable control and diagnostics.

consumption in baling and subsequent shredding of the bales is less than that in the pelletization process. The interior of the bales are also stable for prolonged times unless the bales are submerged in water. Stacks of such bales would provide a compact and inexpensive method of storage.

During the crop period, which usually lasts for 140 days per year, both the front end (which includes the weighing, unloading, conveying, shredding, dewatering and baling units), and the back end (that is, the steam and electricity generating plants) are in operation. During the intercrop period (140 days in length), only the back end is in operation. The electrical power requirement for internal use is met from within the system.

Materials and energy balances

The material and energy balances were worked out based on values given in Tables II and III and are presented in Figure 2. The hourly outputs of electrical power, excluding that required for internal use, are 4.7 and 4.6 MWh for the crop and intercrop period, respectively. The facility is assumed to work for 21 hours daily, based on experience with similar facilities operating on bagasse. This corresponds to an annual electrical output of 27.2 GWh from 264,600 tonnes of CTL processed.

Economic analysis

Costing procedure: The cost elements considered in this analysis are the capital cost of the system together with associated operation and maintenance, the raw material (CTL) cost, interest rate and inflation, and the cost of fuel. Based on realistic figures for each of these elements in the Mauritian context, a baseline case was first established and the revenue derived from electrical power generated by this system was calculated. The cost per kWh unit of electrical power was then determined.

For each of the cost elements, a plausible range of figures with proper justification was then determined and sensitivity analysis was performed with the object of estimating the probable impact of these variations on the viability of the system. Selected combinations were also tested. Net present value (NPV) calculations were performed using the different cost estimates. A system is economically viable at NPV equal to or greater than zero. The cost per kWh unit of electrical power from the system was then compared with those of power derived from conventional sources in Mauritius. These sources include fuel oil, coal, hydro-electricity and bagasse. A list of the major cost elements is given in Table IV. This table also shows the values selected for the baseline calculations as well as the range of values used in the sensitivity analysis. Details of the NPV calculations are also given as a footnote to the table. A detailed discussion of the major assumptions and the reasons for choosing them are given below.

Capital cost of equipment and associated operation and maintenance cost: Three values for the capital cost of the facility were used for the baseline and were based on whether the equipment was new, second-hand or a combination of both. Second-hand equipment would be readily available in the immediate future upon the proposed plan for centralization of cane sugar factories in Mauritius[6]. Use in the system under study of second-hand equipment after proper overhaul would reduce foreign exchange requirement significantly compared with what would otherwise be required in a completely new facility or a combination. However, the older the facility the higher would be the operation and maintenance costs. This factor is considered in establishing the baseline figure for this cost element.

The three separate assumptions used for these two parameters are shown in Table V. Case A includes the cost of equipment to weigh, unload, convey, prepare and dewater 90 tonnes of CTL per hour, to bale 40% of the fibrous residue, and to burn 60% (24 tonnes) of this residue in a boiler rated at 40 tonnes per hour steam capacity and a 6.5 MW

6 "Action plan for the Mauritian sugar industry" (Mauritius Sugar Authority, Port Louis), 1985.

Table IV. Assumptions used in economic analysis of electricity production from CTL

Variable	Values used in baseline case	Range of values used in sensitivity analysis
CTL input	264,600 tonnes/year	-
Electricity output	27.2 GWh	-
Capital investment (CI) $\times 10^6$ US $	5.0	3.0 - 7.0
Operation and maintenance % CI	5.0	8.0 - 3.0
CTL cost ($/tonne fr	5.0	3.5 - 7.5
Interest rate, R %	8	8 - 12%
Average inflation S (of $)	5%	5%
System life time (years), N,	20	-

Notes

(1) $NPV = (A-Q-T-M)/(1.0+Z)^N$

where A = Revenue from sale of electricity
Q = the present value of an annual payment of P taking into account inflation rate of 5% of the US dollar
P = the annualized capital charges, given by $CI \times [R/1-(1-R)^{-N}]$
T = total cost of CTL
M = operation and maintenance cost
and Z = R - S

(2) All the financing of the capital is by debt, i.e. by borrowing from banks and none is equity.

(3) Amortization is on a straight line basis using the levelized payment formula with zero residual value assumed.

Table V. Assumptions for capital investment and operation and maintenance cost

Description of facility		Capital Investment (CI)	Operation and maintenance
Front End	Back End	$\times 10^6$ US (1985) dollars	cost (% of CI)
Case A Old	Old	3.0	8.0
Case B Old	New	5.0	5.0
Case C New	new	7.0	3.0

turbo alternator. Such a proposal is implementable in Mauritius, since an indigenous manufacturing sector and skilled labour exist, which have considerable experience over many decades now with the cane sugar factories and can carry out the minor overhaul and modifications required.

Case B refers to a more realistic set-up in which the front end is obtained from a factory which would cease cane sugar manufacturing activity as a result of centralization and the back end is new. It is a fact that there has not been major technological development in the front end pieces of equipment over the past 2 or 3 decades, and the old ones can conveniently be used without much problem. On the other hand, condensing turbo-alternators and automatic boiler furnaces have fairly recently been introduced in Mauritius, and may not be available as second-hand equipment. This back end for Case B has therefore to be acquired as new.

Case C refers to a completely new facility.

Cost of CTL: The cost of collection and transportation of the CTL to a central processing unit would provide a good index to the cost of such biomass. Based on experience in the cost of handling sugar cane stalks in Mauritius, a realistic cost would be $3.50 per tonne, which includes transport cost at $0.2/tonne/km. The distance from field to central processing unit would be 5 to 8 km.

However, such residues have some value to the farmer and a figure of $5.5 dry tonne has been quoted[7] for similar crop residues as a reasonable estimate of their worth for erosion control and supply of nutrient. Some authors, on the other hand, believe that this notion seems to be based on the idea that residues are not good for much else. In some cases, experiments with different straw management procedures in the UK have shown that straw incorporation can actually lead to a reduction in crop yield[8]. Nevertheless the above figures has been assumed for CTL as well, and a price for CTL of $5.00 per tonne is used for the baseline calculation.

However, it is felt that, with such a price, the cane grower has no incentive to send the CTL for conversion to energy unless the benefit of leaving these in the field is proved to be negative.

For example a large-scale removal of these residues implies that more cane inter-rows remain bare, with more incidence of weed growth and hence increased costs for manual or chemical weed control. On the other hand, such a practice would facilitate crop mechanization and stalks with less leafy extraneous matter (meaning better sucrose recovery) would go to the sugar factory; this would limit environmental pollution, the degree and intensity of the crop damage in the event of a fire outbreak; lead to an increased number of inter-rows for intensive food crop production before the field closes in[9]; and lessen the incidence of pests and diseases usually harboured in such plant debris and transmitted to the ratoon crop.

In the sensitivity analysis, therefore, values up to $10 per tonne of CTL are tested, the values higher than the base line price providing an indication of the price which can be tolerated by the system while remaining economically attractive.

It is also recognised that the prices quoted here are on the very low side compared with those quoted in the literature, for example, $20 - 40 per tonne for crop residues such as corn stover, wheat straw or forest residues. Such a discrepancy may be due to the fact that, in Mauritius, CTL are found relatively more concentrated in the sugar cane areas compared with the other crop residues which are scattered so that the cost of collection (depending on whether it is done manually or mechanically) and transportation (being a function of the distance) would be more expensive in these countries.

Interest rate and inflation: An annual rate of interest of 8% is taken for the baseline calculation. Such an interest rate is not uncommon in less developed countries where important projects involving food or energy production are concerned. In the sensitivity analysis, however, the effect of a range of interest rates of 10, 12 and 14% are used to reflect cases where the rates may be higher depending on whether the project is undertaken by the government or a private company.

With the prices of goods taken in terms of US currency (that is, taking into account the devaluation of the Mauritian rupee), inflation is estimated at 5%. This is an overestimate because prices in terms of US dollar have been stable. Prices in this study are in terms of US currency since most imports (90% of the energy and 70% of food) must be paid for in US dollars.

System lifetime: A period of 20 years has been chosen because, from experience with the Mauritian sugar industry, similar equipment as proposed to be used in this system have been maintained under reasonably good working conditions for several decades; the indigenous manufacturing and servicing capacity is of reasonably good standard.

Cost per kWh unit of electrical power: This parameter was used to compare the effect of the values given for the baseline case and the ranges for the sensitivity analysis on the viability of the system. The cost obtained from any given set of values was compared with the actual cost per kWh unit of power obtained from conventional sources in Mauritius.

7 Bungay: "Energy, the biomass options." (Wiley, New York), 1981.
8 Ellis & Lynch: *Agric Research Council Research Review*, 1978, **3**, (2), 29.
9 Deepchand: *Tech. Pub. 2nd World Congr. Engineering and Environment*, 1985, **2**, 3.1 - 01.

Cost of current fuels: Typical costs per kWh unit from fuels currently used in Mauritius are shown in Table VI. Prices, especially for fuel of fossil origin, for example coal and oil, may become substantially lower in the immediate future with oil prices going down. The sensitivity analysis therefore examines a range of prices of 3 to 10 cents per kWh of power from both coal and fuel oil.

Table VI. Comparative cost of electricity, Mauritius, 1985, (cents/kWh)

Source	Cost of fuel	Cost of production	Total cost[a]
Old hydro -electricity[b]	0	1.0	1.0
Fuel oil[c]	8.8[d]	3.1	11.9
Fuel oil[c]	6.9[e]	3.1	10.0
Coal[f]	4.6[d]	6.4	11.0
Coal[f]	3.6[e]	6.4	10.0
Bagasse	3.9	2.0[g]	5.9
CTL[h]	5.0	2.2	7.2

a Ex power station excluding distribution
b Cost is low mainly because all equipment has already been depreciated.
c Based on production efficiency of 40%
d Includes government tax of 22% on imported fuel
e Excluding the government tax of 22%
f Based on a power plant installed capacity of 25 MW, a heat content of 23,000 kJ/kg (10,000 B/lb) and thermal efficiency of 25%
g Actual revenue from sale of electricity by the cane sugar industry before 1985 when bagasse had a zero value. As from 1985, the cost of bagasse is fixed at 3.9 cents per kWh ($13.3/tonne at 50% moisture)
h Baseline values have been used at NPV of investment = 0

Results and discussion

(i) Baseline case

Table VII summarizes the cost per kWh unit of power at NPV = 0 from the various values chosen for the baseline calculations. These are minimum prices required for the project to be economically feasible. It is observed that the power cost from CTL-to-electricity system using baseline values is significantly cheaper than the fuel-oil or coal-to-electricity system at any of the three levels of capital investment with its associated operation and maintenance cost under study. The unit power cost was 6.2, 7.0 and 7.9 US cents per kWh for cases A, B and C, respectively. These cost figures thus represent savings of the order of the 47, 41 and 37% over the fuel oil system and 44, 37 and 29% over the coal-fired system.

Table VII. Results of baseline cases and sensitivity analysis

Cost components		US cents/kWh Case A	Case B	Case C
Baseline values		6.2	7.1	7.9
CTL cost	3.5	5.0	5.6	6.0
($/tonne)	5.0	6.5	7.1	7.4
	6.5	8.0	8.5	8.8
	7.5	9.0	9.5	9.9
	10.0	11.5	12.0	12.4
Interest rate (%)	8	6.5	7.1	7.4
	10	6.6	7.3	7.8
	12	6.8	7.6	8.1
	14	6.9	7.8	8.4

However, when compared with the sugar cane bagasse system (both with bagasse at zero value and $13.3 per tonne), all three cases compare unfavourably. It is to be pointed out that the amount of excess bagasse available would be limited and electricity from the total amount of such bagasse will contribute to a maximum of 100 GWh annually. This represents only 25% of the actual power generated and the strategy CTL-to-electricity is the next alternative based on a locally available and renewable resource which can contribute in reducing our dependence on imported fuels.

The initial conclusion, therefore, is that an economic case exists for large scale conversion of CTL to electricity in the Mauritian context and that, the less the capital investment, the cheaper the electrical power.

(ii) Sensitivity analysis

Results of sensitivity analysis presented in Table VII reveals that, of the various parameters used, CTL cost has the most significant effect on the power cost per unit. A general increase of 1 cent per kWh of power is observed with every dollar increase per tonne of CTL for either case A, B or C.

The price of the alternative fuels also has a considerable bearing on the economics of the system as illustrated graphically in Figure 3. At current prices

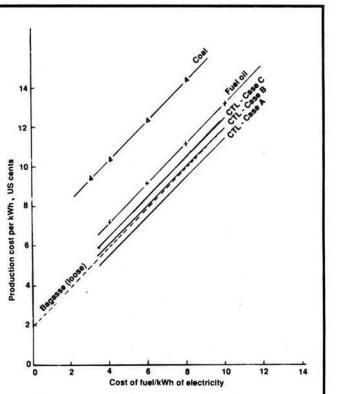


Figure 3. Effect of fuel prices on production cost of electric power

the system of CTL to electricity (baseline case B) would be competitive with fuel oil and coal systems up to prices of CTL of $9.90 and $9.0 per tonne, respectively, while the bagasse system would follow almost the same trends as CTL. Such a proposal would imply that, if the price of power is maintained at its current level, the difference between the above prices of CTL and the one used in the baseline case B could be distributed to the partners (planters and facility owner) in the production system and to the government in the form of the 22% tax being levied on imported fuel (to maintain government revenue).

Alternatively, it is also observed that the system will be attractive as long as the price of fuel oil and coal per kWh of power is above 4 and 0.8 cents, respectively, at CTL price maintained at $5.00 per tonne.

The cost of power is relatively unaffected by interest rates, the rate of increase in price of unit power compared with baseline case B being around 0.1 cent for every 1% increase in interest rate in the range of 8 - 14%. A similar trend was observed for case C but for case A the rate of increase was only 0.05 cents. A low interest rate would therefore be more favourable to the economics of CTL to electricity system.

By-product credit

In this system only the fibrous

fraction has been considered and the juice fraction ignored. However, the juice contains around 4.5% of fermentable sugars and 0.4% nitrogenous matter[2]. The juice has been shown[10] to sustain yeast activity to the same extent as cane molasses (a substrate used for commercial yeast production) on a similar concentration basis and around 10.8 kg of SCP was recovered per tonne of CTL. The juice may also be anaerobically fermented to ethanol and around 8.3 litres of ethanol at 96.5% GL were produced per tonne of CTL in laboratory scale experiments. The nitrogenous matter was also precipitated by heating the juice at 80°C prior to the above fermentation and separated as a protein coagulate. This coagulate was dried and air equilibrated to yield leaf protein in a yield of 3.0 kg per tonne of CTL. Therefore, with a minimal investment to integrate the protein or liquid fuel recovery from the juice fraction in the electricity system, combined with the relevant fermentation process using molasses as the major raw material, more energy and food may be produced from CTL. Such a proposal would thus enhance the credibility of the economics of power production from CTL.

Conclusion and recommendation

In this study a number of major cost components has been identified and their effects on the viability of the CTL conversion to electricity has been investigated. Based on these, it may be concluded that there is a clear-cut cost advantage for large scale utilization of CTL for electricity generation in the Mauritian context. Whereas a market does exist for the product (400 GWh being generated annually), there is a degree of uncertainty as to the technology although a process similar to that used for bagasse has been proposed and analysed. A trial run is therefore justified at this stage to verify laboratory results on a pilot/industrial scale.

However, such a process, if successfully implemented on a large scale, is associated with a number of economic benefits. If the two million tonnes of CTL available annually in Mauritius were to be processed in this manner, around 50% of the total electrical power could be generated from this resource. If a proper sharing ratio of the profits is adopted between the various parties involved in this energy production program, the net revenue of the parties from sugar cane production will rise significantly. Furthermore, the national dependence on imported energy will decrease with the associated beneficial effects on our balance of payments problems. More money could be diverted to the import of newer technology. Concurrently, since collection and loading is meant to be done manually, this strategy will be socially attractive as well in that more jobs will be created.

Acknowledgement

The author is extremely grateful to Sir Michael Stoker, President, and the Governing Body of Clare Hall for election to a Visiting Fellowship; to Professor Richard J. Eden for the opportunity to work within the Cambridge Energy Research Group; and to Mr. Richard Bending, Senior Research Associate at C.E.R.G. for his help in organizing and discussing this program of work and reviewing this paper.

Summary

In this paper a system for the large-scale conversion of sugar cane tops and leaves (CTL) to electricity is proposed and its economics discussed. In the economic analysis, a baseline case is first established based on realistic figures with reference to Mauritius for an identified set of parameters, namely capital cost, cost of CTL, interest rate and inflation, system lifetime, cost of power and cost of current fuels. A range of values is assigned to the parameters which have the most significant effect on the overall economic feasibility and these used in a sensitivity analysis. It is observed that the system is most sensitive to cost of CTL; and that the cost of electrical power from CTL is competitive with that from fossil fuel like oil and coal currently used in Mauritius.

10 Idem: (Ph.D. Thesis, University of Mauritius), 1984.

Facts and figures

Animal fodder from bagasse[1]

The French engineering firm Technip has won a contract from Alimento Vacuno del Occidente (Alivaca) of Venezuela to build a plant for the production of animal feed from bagasse by the Stake II process of steam cracking[2] for which Technip has exclusive rights. The project will cost around $5-6 million and the plant will be sited near Barquisimeto in north-west Venezuela. Production is due to start in early 1988.

Sudan sugar factories rehabilitation[3]

Russel Wilson International, a UK-based consultant, has signed two separate contracts to supervise rehabilitation of the Sennar and Assalaya sugar fctories in central Sudan. The contracts include planning, management and supervision of civil works to repair the factory foundations which have cracked because of severe ground heave problems. As a consequence the processing machinery has been damaged, while minor mechanical and electrical components are also involved.

Brazil-Urugay economic bond[4]

The Presidents of Uruguay and Brazil have signed six accords to integrate their countries' economics, covering science, technology and agriculture. The agreements are the product of a renewed effort to form a common market in South America. Brazil and Argentina discussed such a project when President Sarney visited Argentina in July. Past efforts to integrate the region have largely failed because of political instability and military conflict; however, all three countries have thrown out military rule and elected civilian governments in recent years.

New HFS plant for China[5]

China's output of high fructose syrup will rise substantially when a new plant comes into operation in 1989. The Changsha High Fructose Plant, a joint venture between the China National Technical Import and Export Corporation and Abay S. A. of Belgium, will produce 6000 tonnes of dry starch, 20,000 tonnes of 42% HFS and 18,500 tonnes of 55% HFS per year. China produced about 5000 tonnes of HFS in 1985. The Belgian government has provided 30% of the investiment capital in the form of soft loans.

1 *Public Ledger*, August 23, 1986.
2 See *I.S.J.*, 1980, **82**, 194.
3 F. O. Licht, *Int. Sugar Rpt.*, 1986, **118**, 449.
4 *The Times*, August 15, 1986.
5 F. O. Licht, *Int. Sugar Rpt.*, 1986, **118**, 484.

ENERGY MANAGEMENT

Energy reduction and process integration*

By N. R. Twaite†, H. J. Davenport† and E. K. Macdonald‡

Introduction

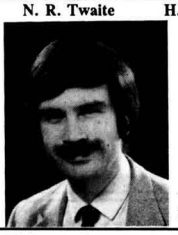
In the late 1960's to late 1970's, British Sugar embarked on a major program of enlarging factory capacities, converting from raw to white sugar manufacturing and closing the smaller, uneconomical plants. The net result was a reduction from eighteen factories operating to the present thirteen, while an increase in daily slice from 64,000 tonnes to 82,000 tonnes of beet has been achieved.

Bury factory was chosen as one of those to be uprated and converted to white sugar production[1]. The factory was designed to slice 7000 tonnes/day of beet with white sugar production equivalent to 5000 tonnes/day and the remainder of the thick juice going to storage. Much of the beet end plant was installed during the1972 off-season with the white sugar conversion plant following during the 1973 off-season. The report[1] gives details of some of the difficulties experienced owing to the commissioning of the new plant and changes required for white sugar production. A quintuple-effect evaporator station, with a total heating surface area of 15,000 m² was installed, with pan floor heating by a mixture of first and second vapour, variable proportions of each being taken to achieve the required thick juice Brix. Figures quoted in the report indicate that a steam consumption of around 41.0% on beet was achieved during the first campaign.

Some four years later, plans to increase sugar production and at the same time rationalize production facilities at fewer factories included the uprating of Bury factory to a design throughput of 11,000 tonnes/day of beet with an increased amount of thick juice, equivalent to 4000 tonnes/day of beet sliced, going to storage. Included in this reconstruction were two 6.0 m dia. BMA tower diffusers with countercurrent cossette minglers and a raw juice heating system based on shell and tube pan vapour heaters and Alfa Laval spiral heat exchangers using process condensate. The evaporator station was extended to a total area of 20,000 m² by installing an additional first effect of two vessels supplied from a vapour thermocompressor which was used to compress from first effect pressure to around exhaust steam pressure. The use of the thermocompressor was necessitated by the large amount of juice going to store, resulting in a much reduced demand at the sugar end. Figure 1 gives the main details of the design heat usage.

N. R. Twaite

H. J. Davenport



E. K. Macdonald

Process energy reduction

The considerable increases from the mid-1970's in prices of oil, followed by gas and, to a lesser extent, coal, resulted in a renewed effort to reduce process energy usage and to consider a policy of using alternative cheaper fuels.

In late 1979, a process engineering section was created within the Engineering Division of British Sugar's Central Offices, one of its main objectives being to reduce the process energy requirement of existing factories' plant and processes, including the study of new plant and process methods with a lower energy requirement. The existing plant studies were carried out jointly between a factory "energy manager" and a central process engineer. The factory energy manager formed a small team to help with the task of identifying and quantifying heat usage and wastage.

The main steps taken were to: (a) install and check the necessary measuring instruments – mainly thermometers and water flow meters, (b) prepare a heat balance for steady running process conditions, (c) compare results with the design heat balance and other factories with similar plant, (d) establish with factory/central process engineers heat saving methods and prepare design heat balances to check the feasibility of proposals, (e) prepare a project, obtain capital money and install/alter plant, and (f) prepare a heat balance to determine how actual figures compare with design; if there was good agreement the balance could be used as a design for the next step of heat economy.

In this way it was possible to get the active involvement of the factory

* *Paper presented to the 28th Tech. Conf., British Sugar plc*, 1986, here slightly condensed

† British Sugar plc.
‡ Energy and Process integration Service, Harwell.

1 Pepper & Higgins: *Paper presented to the 22nd Tech. Conf., British Sugar Corp.*, 1974.

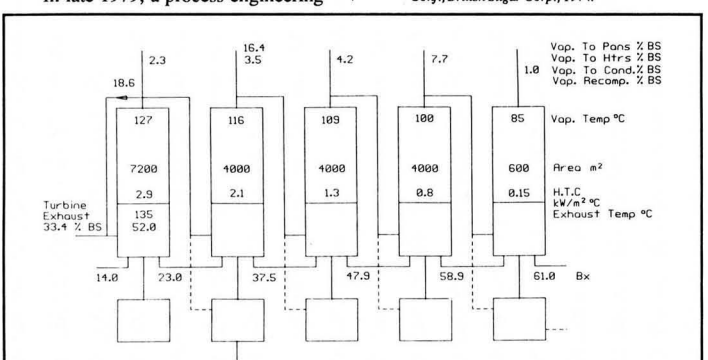


Fig. 1. Design heat balance for Bury St. Edmunds uprated to 11,000 tonnes/day

Table I. Heat balance results compared with design for Bury St. Edmunds

	Design 1977	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	Design 1986
Steam % beet								
Pans	16.4	13.6	15.0	9.3	7.8	8.6	9.0	8.4
Heaters	17.7	19.0	20.0	16.2	17.5	18.0	18.6	16.2
Condenser	1.0	1.89	0.6	0.5	1.1	1.8	2.7	1.0
Total	35.1	34.4	35.6	26.0	26.4	28.4	30.3	25.6
Exhaust	33.4	33.6	36.5	24.4	24.6	23.5	24.0	20.1
Evaporation % beet								
Pans	32.8	27.2	30.0	27.9	24.8	27.5	28.8	35.5
Heaters	52.7	62.1	61.0	50.7	54.3	54.6	56.8	62.3
Condenser	5.0	9.0	3.0	3.0	5.4	9.0	13.6	5.5
Vapour compressor	18.6	18.0	16.4	18.6	16.3	10.9	9.4	0.0
Total	109.1	116.3	110.4	100.2	100.8	102.0	108.6	103.3
From heat balance	96.3	101.4	99.0	86.5	86.1	83.6	89.2	84.1

Table II. Bury St. Edmunds process heat usage, 1980/81 to 1985/86 campaigns

Campaign	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	Design 1986
GJ/100 tonnes white equiv.	999	1005	743	728	616	604	540
Thin juice Brix	13.6	14.1	14.7	15.0	15.4	15.9	15.4
Thin juice draft	129	128	111	113	110	113	110
Brix of juice to pans	64.6	66.3	69.6	70.2	67.9	72.0	72.0
Boiling house efficiency	83.1	83.9	84.1	84.1	87.2	84.4	-
Sugar extraction	82.2	84.1	80.9	82.1	84.7	85.5	-
Sugar end throughput	9.5	9.6	9.5	9.1	10.1	10.6	
Sugar end non-sugars recirculation	36.0	(18)	34.0	33.0	31.0	31.0	

staffs who run the plant and who were able to see the various stages in the reduction of energy use and the consequent changes in operational methods. Table I gives the results of this exercise at Bury over the past six years compared with the design. This shows that exhaust steam demand has been reduced from around 33% to 24% on beet sliced.

Instead of referring to beet sliced as a basis of process energy, it is more useful to base the energy on sugar produced. British Sugar use the units of Gigajoules per 100 tonnes of sugar produced. Table II gives the results on this basis together with some of the other factors that influence the energy usage. Notable changes are:

(i) a steady increase in thin juice Brix and reduction in draft, resulting from decreased water additions to the beet end,

(ii) an increase in Brix of standard liquor to the white pans, requiring less water evaporation,

(iii) a slight increase in boiler house efficiency,

(iv) an increase in sugar extraction,

(v) an increase in sugar end throughput as a percentage of total thick juice produced, and

(vi) a reduced recirculation of syrups and less water additions around the sugar end.

The energy figure includes an allowance for the amount of fuel which will be used to process the stored thick juice from that campaign. This allowance is based on the amount of fuel used to produce white sugar in the previous juice refining run. Hence, any savings in the 1984/85 run reflects a further reduction in the 1985/86 campaign figure.

The majority of the reductions were made by good management control of the processes, together with changes in fundamental operating principles. Minor alterations were made to the plant, mainly fitting of measurement devices and pipework alterations. Many small projects were carried out, such as modifications to heat exchanger systems. The reduction in steam demand at the evaporators resulted in a shortage of the factory's own generated electrical power, such that the difference had to be purchased from the state system. At the same time, use of steam at the thermo-compressor reduced the generating capability by around 1.2 MW. The savings also considerably reduced the thick juice Brix from the evaporators. To keep up the Brix it was necessary to put up to 2% on beet of steam to the evaporator condenser, and to reduce condensate heating on the raw juice spirals so that additional fourth vapour would be drawn from the evaporators.

In 1981, a symposium was held by the Institution of Chemical Engineers entitled "Total Energy Design in Process Plants". One of the papers[2] gave details of a method of analysis of combined heat

2 Townsend & Linnhoff: "Designing total energy systems by systematic methods" (Design Systems Group, ICI Ltd. Corporate Laboratory, Runcorn, Cheshire).

and power systems by an energy bottleneck or "pinch" technique. This method is discussed in more detail below. At that time the concepts supported our increasing view that the thermocompressor was operating in the wrong range to allow for minimum energy usage.

The reduction in steam demand at Bury, from Table I, was almost 30% between the 1977 design and the 1984/85 campaign and represented a practical minimum for the present configuration of plant and process. The factory management, together with central process engineering, carried out a design exercise to find what further reduction could be obtained by removing the vapour compressor and converting the evaporators to a full sextuple-effect station. This was achieved by turning the two compressor bodies into second effects and replacing the small Roberts fifth body with a 2800 m² falling film body as a sixth effect. A further 10% reduction was found to be possible by these proposed changes. The main requirement was to use about 5% on beet of sixth vapour for raw juice heating.

Heating of raw juice

With the installation of countercurrent cossette minglers on the three BMA towers at Bury, cold raw juice was available to the process. The 1977 design allowed for pan vapour heaters, followed by Alfa Laval spiral heaters and finally conventional shell and tube heaters before 1st carbonatation.

The operation of the spiral units was checked at two factories in Holland prior to the Bury installation. The study revealed that, whilst the pressure drop gradually increased through the campaign, chemical cleaning was only necessary at the end of each campaign.

Three 6-pass shell and tube heaters with an area of 470 m² each were used for primary heating of raw juice with vacuum pan vapours at Bury. This was followed by three SHE type I Alfa Laval spiral heaters with process condensate as the heating medium, with both streams piped up in parallel.

Each spiral unit was designed to handle 200 tonnes/hr of raw juice with a pressure drop of 2.06 bar. A juice velocity of 1.9 m/sec was chosen in order to keep the heating surface as clean as possible in service. The units operated at a much higher pressure drop than design, which persisted in spite of a change in heater orientation. As factory capacity increased to over 12,000 tonnes/day, part of the raw juice had to be by-passed to keep the pressure drop to a workable level. This was not detrimental to heat economy as it was not possible to use all the heat in the condensate without too much loss in evaporator Brix compared with the 1977 design.

However, for the 1986 design, it is necessary to make full use of the condensate without exceeding the design pressure drop of 2.05 bar. Tests were carried out in the 1984/85 campaign which gave a pressure drop of 5.2 bar at design flowrate. No explanation was forthcoming so a series of tests with water as the medium was arranged during the 1985 off-season. The results of these trials are shown in Figure 2. They indicate that, on the two units tested, pressure drops were close to the design value. However, the later tests back on raw juice (Figure 2) give a much steeper rate of rise and final value, far more than would be explained by the differences in density and viscosity.

Tests, by three different methods, were then carried out on the raw juice viscosity. Results obtained were:

Design:	0.924 cp at 43°C
	0.634 cp at 65°C
Warren Springs:	1.90 cp at 50°C
	1.70 cp at 60°C
Factory:	1.21 cp at 50°C
	1.16 cp at 60°C
BS Research Laboratories:	0.97 cp at 50°C

None of the above figures explains the high pressure drops so the existing units will be down-rated and a further one is scheduled to be added for the 1986/87 campaign.

The spiral heaters will be followed by conventional shell and tube heaters with sixth and fifth vapour as heating medium. As the critical temperature range of protein deposits is at the spiral state, it is expected that there will be fewer problems with fouling, particularly as design velocities have been kept fairly high.

However, where shell and tube units have been used at other sites in the critical temperature range, they have required cleaning every 1 - 2 days to keep up a reasonable performance. Figure 3 gives results of two tests carried out at King's Lynn factory which shows a 20% to 30% drop in the heat transfer coefficient per day.

(To be continued)

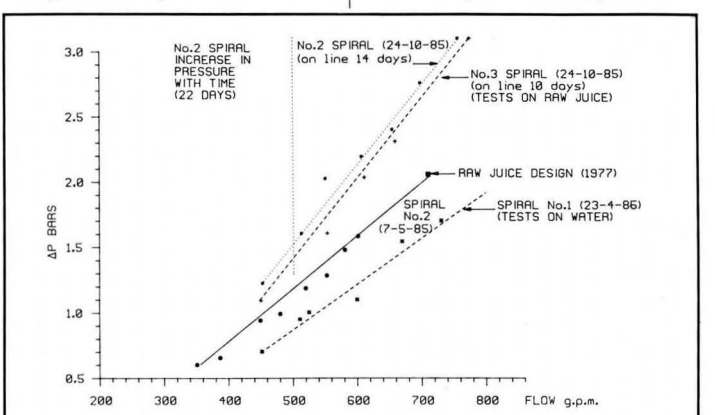


Fig. 2. Pressure tests on Alfa-Laval spiral heat exchangers

Facts and figures

World sugar production estimates, 1986/87[1]

	1986/87	1985/86
	tonnes, raw value	
BEET SUGAR		
Belgium	975,000	1,025,000
Denmark	550,000	576,000
France	3,550,000	4,323,000
Germany, West	3,175,000	3,432,000
Greece	350,000	345,000
Holland	1,150,000	975,000
Ireland	205,000	189,000
Italy	1,675,000	1,352,000
Portugal	5,000	9,000
Spain	950,000	965,000
UK	1,250,000	1,316,000
Total EEC	13,835,000	14,507,000
Albania	30,000	30,000
Austria	275,000	468,000
Bulgaria	150,000	125,000
Czechoslovakia	825,000	935,000
Finland	115,000	103,000
Germany, East	625,000	775,000
Hungary	455,000	575,000
Poland	1,700,000	1,809,000
Rumania	770,000	633,000
Sweden	365,000	345,000
Switzerland	125,000	139,000
Turkey	1,770,000	1,398,000
USSR	7,750,000	8,000,000
Yugoslavia	900,000	1,010,000
Total Europe	*29,690,000*	*30,852,000*
Canada	115,000	55,000
Chile	440,000	420,000
China	1,000,000	983,000
Iran	600,000	545,000
Japan	615,000	624,000
Morocco	250,000	310,000
US	2,950,000	2,719,000
Uruguay	30,000	35,000
Others	199,000	194,000
TOTAL BEET	35,889,000	36,737,000

	1986/87	1985/86
	tonnes, raw value	
CANE SUGAR		
Spain	15,000	16,000
Argentina	1,135,000	1,188,000
Barbados	90,000	110,000
Belize	85,000	95,000
Bolivia	200,000	175,000
Brazil	8,900,000	8,268,000
Colombia	1,300,000	1,200,000
Costa Rica	210,000	221,000
Cuba	7,750,000	7,000,000
Dominican Republic	800,000	765,000
Ecuador	300,000	273,000
French West Indies	55,000	78,000
Gutemala	600,000	575,000
Guyana	260,000	260,000
Haiti	30,000	45,000
Honduras	200,000	170,000
Jamaica	190,000	192,000
Mexico	3,700,000	3,696,000
Nicaragua	250,000	265,000
Panama	150,000	117,000
Paraguay	95,000	92,000
Peru	650,000	625,000
Puerto Rico	90,000	90,000
St. Kitts	25,000	25,000
El Salvador	275,000	275,000
Trinidad	100,000	92,000
USA – Hawaii	915,000	935,000
– Mainland	1,915,000	1,833,000
Uruguay	65,000	65,000
Venezuela	600,000	590,000
Others	6,000	9,000
Total Americas	*30,941,000*	*29,324,000*
Angola	35,000	35,000
Egypt	820,000	800,000
Ethiopia	200,000	200,000
Ivory Coast	155,000	145,000
Kenya	360,000	366,000
Madagascar	110,000	99,000

	1986/87	1985/86
	tonnes, raw value	
Malawi	175,000	154,000
Mauritius	720,000	684,000
Morocco	75,000	75,000
Mozambique	35,000	30,000
Nigeria	90,000	75,000
Réunion	250,000	242,000
South Africa	2,050,000	2,280,000
Sudan	550,000	500,000
Swaziland	460,000	396,000
Tanzania	120,000	105,000
Zaire	50,000	50,000
Zambia	150,000	150,000
Zimbabwe	480,000	456,000
Others	306,000	307,000
Total Africa	*7,191,000*	*7,149,000*
Bangladesh	120,000	80,000
China	4,500,000	4,634,000
India	8,500,000	7,600,000
Indonesia	1,900,000	1,800,000
Iran	250,000	240,000
Japan	290,000	298,000
Malaysia	87,000	85,000
Pakistan	1,350,000	1,195,000
Philippines	1,400,000	1,480,000
Taiwan	600,000	625,000
Thailand	2,500,000	2,595,000
Vietnam	250,000	225,000
Others	121,000	119,000
Total Asia	*21,868,000*	*20,976,000*
Australia	3,300,000	3,439,000
Fiji	462,000	354,000
Others	35,000	35,000
Total Oceania	*3,797,000*	*3,828,000*
TOTAL CANE	63,812,000	61,293,000
TOTAL BEET AND CANE	99,701,000	98,030,000

New Pakistan sugar factory

Karachi Shipyard & Engineering Works Ltd. has signed an agreement for construction of a cane sugar factory for Sanghar Sugar Mills Ltd. It will be located on Sidhri Road, Sanghar, in Sind Province and is to be completed on a turn-key basis, to go into trial and production operation by the end of October 1987. Installed capacity will be 2000 tcd, with provision for expansion to 3000 tcd. The total cost of the project is 367.2 million rupees (£14,670,000) including a foreign exchange component of 117.2 million rupees (£4,680,000). The unit is expected to be producing 38,000 tonnes of white sugar per season within three years. It will be the 30th factory in the private sector in Pakistan, bringing capacity to 70,500 tcd; the public sector includes 12 units with a total capacity of 28,200 tcd.

PERSONAL NOTES

Dr. John Allen, Director of the Sugar Research Institute in Queensland, is to retire from that post at the end of 1986 after 25 years during which, under his control, the Institute has gained an enviable reputation as one of the most advanced centres for technological research in the sugar industry. Dr. Allen has been a prolific contributor to both the Australian (formerly Queensland) and International Societies of Sugar Cane Technologists and is the ISSCT Council member for Australia. He has travelled widely and has many friends who will wish him a long and happy retirement. His replacement as Director will be **Dr. Warren Gellie,** Senior Principal Research Scientist in the Division of Manufacturing Technology of the Commonwealth Scientific & Research Organization.

The Institute is also to lose its Deputy Director, **Mr. Rod Cullen,** who, after 23 years with the SRI, has resigned to become Manager of Engineering Services with the Bundaberg Sugar Co. Ltd.

1 *Czarnikow Sugar Review*, 1986, (1752), 115 - 117.

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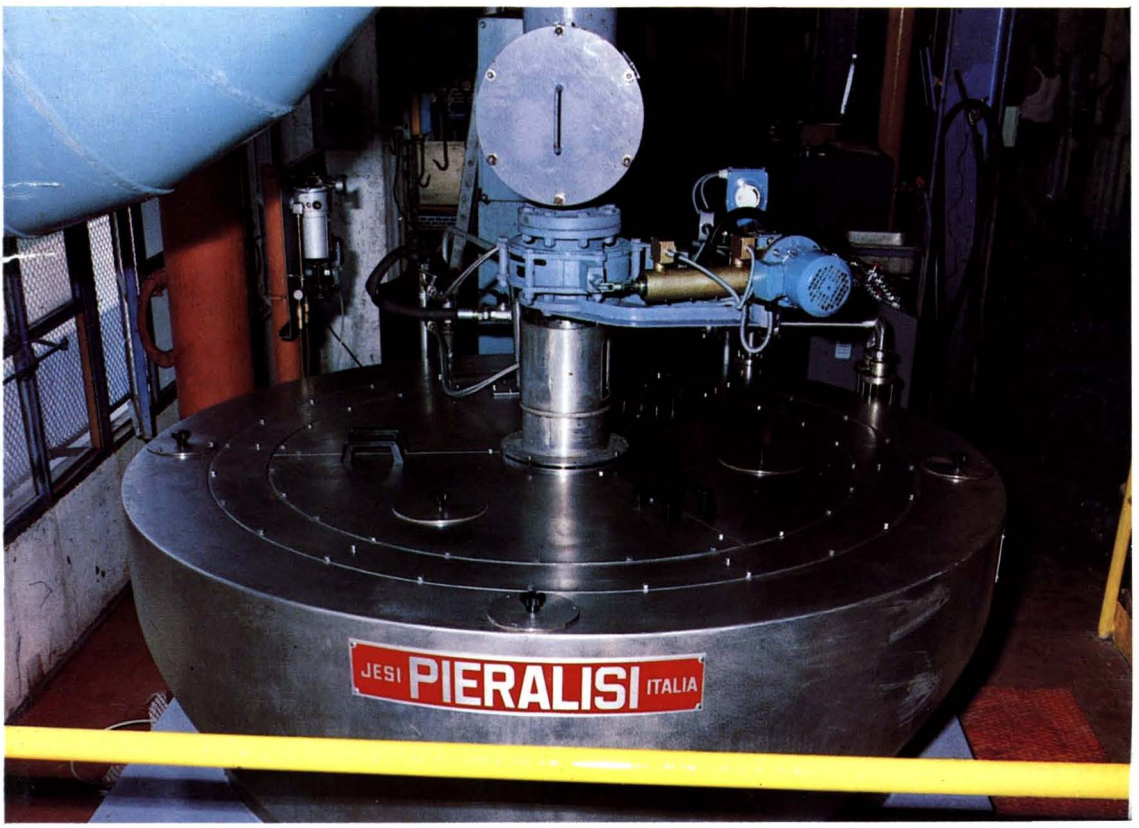

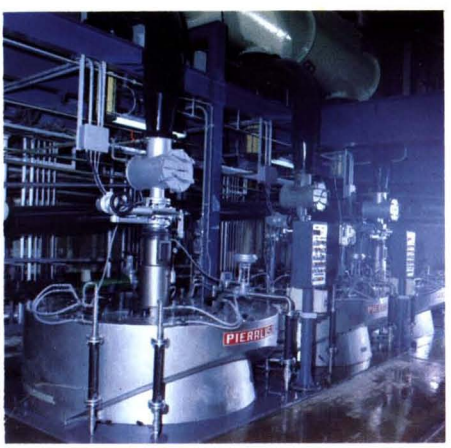

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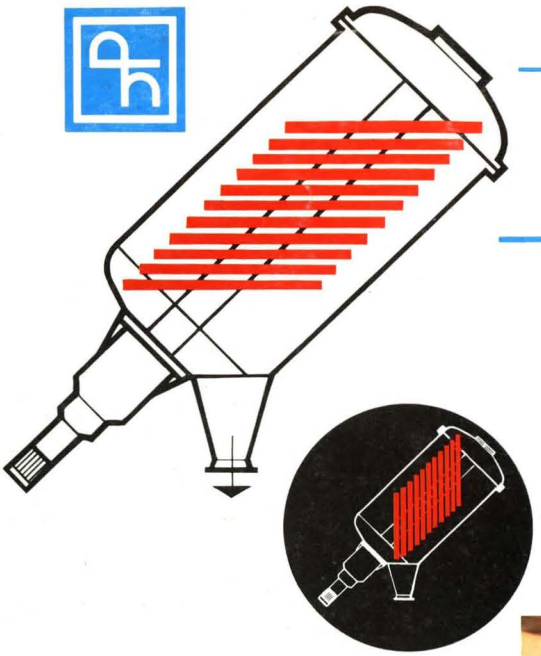
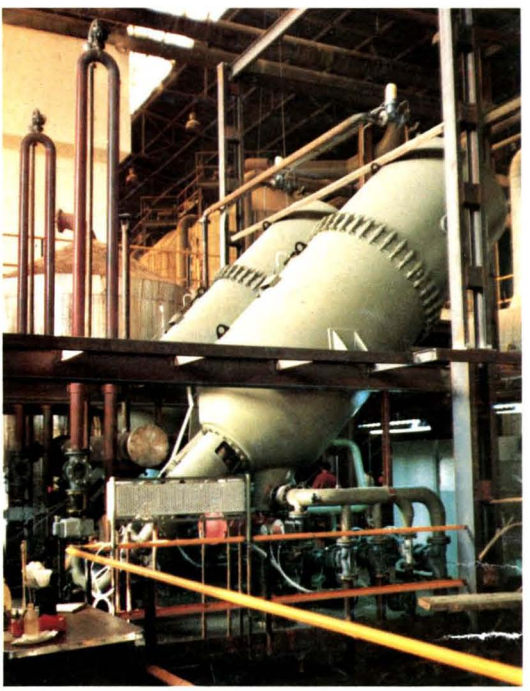


Putsch
Plate Filter

The Darlings of the plant

Schematic drawings show filter in operation with plates in horizontal position and during cake removal in vertical position.



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