SPECIAL NUMBER
OF THE
Proceedings of the
SUGAR TECHNOLOGISTS ASSOCIATION OF INDIA
1955

Issued on the occasion of the 9th Congress of the
International Society of Sugarcane Technologists
held in India at Delhi from 25th January to 2nd
February 1956.

BY THE
SUGAR TECHNOLOGISTS' ASSOCIATION OF INDIA
Nawabganj, Kanpur
India
This Special Number of the Proceedings of the Sugar Technologists' Association of India, issued on the occasion of the 9th Congress of the International Society of Sugarcane Technologists held in India from 25th January to 2nd February, 1956, is dedicated to Fellow Technologists in all parts of the world.
This Association was started in 1925. It is an organization of scientific workers and others directly interested in the Technological advancement of the sugar industry. Its affairs are run by a Council elected each year by its own members. The Council is assisted by Standing Committees on Research and Investigations, on Publications, on Off-Season Employment and on Uniform System of Chemical Control.

The office of the Association is situated on premises kindly made available to it by the Indian Institute of Sugar Technology, Kanpur.

The Association endeavours to serve the sugar industry. It solicits your co-operation in this task.
PATRONS.

1. Seth Banarsi Das Ji
2. Seth B. M. Birla.
4. Shri C. P. Sinha.
5. Shri D. D. Puri.
7. Shri G. N. Koula.
8. Dr. Sir Gokul Chand Narang.
10. Seth Kishori Lal Ji.
11. Shri Krishna Chandra.
12. Shri Karam Chand Thapar.
17. Lala Gurusaran Lal.
18. Shri Lakhand Hirachand.
19. Shri Bharat Ram.
23. Sir Sureendra Singh Majithia.
24. Seth Shanti Prasad Jain.
25. Shri A. B. Shakespeare, C.I.E.
26. Dr. A. Jardine.
27. Shri H. H. Dodds.
28. Sir Padampat Singania.
29. Shri S. K. D. Bhargava.
31. Seth Mangtiram Jaipuria.
32. Seth Radhakrishen Ram Narain Ruia.
33. Shri T. G. Armstrong.
34. Shri V. D. Jhunjunwala.
35. Shri Govindji Raoji.
36. Dr. John Van Nostrand Dorr.
37. Shri S. K. Somaiya.
38. Shri S. S. Kanoria.
39. Shri Mohan Lal Bajoria.
40. Shri Charat Ram.

HONORARY FELLOWS.

1. Dr. F. W. Zerban.
2. Shri R. C. Srivastava.
4. Shri R. P. Sanghi.
5. Dr. H. N. Batham.
6. Dr. K. C. Baneiji.
OFFICE-BEARERS

1954-55

President
Desraj Narang.

Vice-President
J. M. Saha.

Vice-President
K. S. G. Doss.

Secretary
N. G. Varma.

Treasure
D. R. Parmar.

Editor
S. G. Sen.

Members of the Council

J. S. Bhal
H. N. S. Awasthy
G. Bakshi

Assistant Secretary
S. C. Sen.
S. C. Gupta.
S. N. Gundu Rao

Staff

Senior Assistant
R. G. Pradhan.

Junior Assistant
J. N. Misra.

Past Presidents

1925-1936 (late) Noel Deer.
1938-1942 Desraj Narang.
1942-1944 Lalchand Hirachand.
1946-1955 Desraj Narang.
CONTENTS

1. Some Experiments on the Velocity of Growth of Sucrose by Andrew Van Hook. 1

2. General Picture of the Sugar Factories in the Indian Union with Special Reference to the varieties crushed and the recovery of Sugar by N. L. Dutt & K. V. Gopala Ayar. ... 5

3. Effect of Ecological Factors and Traumatism on Juice Quality, Part II. Effect of Frost on Sugarcane Crop by S. C. Sen and J. C. Bhargava. ... 21

4. Progress of Mechanical Sugarcane-Cultivation in India by D. H. Dafy. 31

5. Some Aspects of A Mill by E. B. L. Bedell. ... 41

6. The Introduction of The Defecation Method for the Production of Raw Sugar in Natal by K. Douwes Dekker. ... 49

7. Making Big Grain Sugar: (New Vacuum Pan Crystallisers help) by S. N. Gundu Rao. ... 55

8. ION-EXCHANGE in Cane Sugar Industry by K. P. Govindan, N. Krishnaswamy & S. L. Kapur. ... 61

9. A note on the Limitations of Usual Methods of Sugar Analysis by H. C. de Whalley. ... 67

10. Standardisation of the Quality of Indian Sugar and Improvement in quality resulting therefrom by R. C. Srisastava. ... 69

11. Instrumentation of Chemical Industries by K. K. Bhargava. ... 73

12. The Problem of High Purity Final Molasses: A Plea for Setting Down Reliable Standards by K. L. Khanna, A. S. Charanwati & B. D. N. Sinha. ... 83


15. Evaluation of Molasses as a Raw Material for Alcohol Manufacture by B. K. Jha & D. R. Dhiagra. 111
Some Experiments on the Velocity of Growth of Sucrose

by
Andrew Van Hook Ph. D.
Professor (Physical Chemistry)
Chemistry Department
College of the Holy Cross
Worcester, Mass., U.S.A.

The validity of the very fundamental data of Kucharenko, on the rates of growth of sucrose crystals has now been suspect for some time. His values appear to be too high; especially at higher concentrations and elevated temperatures. Many plausible reasons may be suggested to account for these deviations, but only two will be examined in this preliminary report.

Heat of Crystallization.

The crystallization of sucrose from aqueous solution evolves at least several Kilocalories per mol according to the temperature. If this heat were not immediately and completely dissipated from the growing environment, it would cause a temperature disturbance which could lead to fallacious growth rates. To investigate this possibility, one end of a Chromel-Alumel thermocouple was imbedded in a small (0.24 g.) sucrose crystal. The other junction was submerged in pure mother liquor. This syrup was not agitated at all, after temperature equilibration, in one series of experiments; and stirred gently at 15 rpm, in another series. The measuring circuit was sensitive to 0.001 mv., or capable of detecting temperature differences of 0.025°C, 0.50, and 60°C. Thermostats were used, and the highest concentration of appropriate syrups were approximately the same as Kucharenko's extremes.

In no case was any temperature difference detected during normal growth of the single crystal. At the highest temperature, extraneous grain was visible sometime after the growth had commenced, and shortly thereafter an increasing negative temperature gradient was established. Apparently, the total crystallization on this false grain amounted to more than on the parent single crystal; yet the total adjustment was not detected by refractometer until some time later. As long as no additional grain was visible, there was no temperature difference indicated by the thermocouple. The maximum difference observed after detecting grain visibly, but before being disclosed by the refractometer, amounted to — 7 microvolts, or 0.175°C. This occurred in a 76.5% syrup, at 60°C.

It may be concluded from these trials that the heat evolved in the normal growth of single sucrose crystals is dissipated completely under ordinary conditions.

Technique.

A second reason which may account for the presumably high results of Kucharenko may lie in the procedure he employed. Kucharenko removed the growing crystals, periodically, from their mother liquors in order to determine the increment of growth. This, of necessity, involved a certain thermal shock when operating at temperatures different from that of the room in which the crystals were weighed. The hazards of this operation are discussed in Part VI of his series of papers.
Kucharenko also gave elaborate directions for the preparation of his seed crystals but is not clear that his measurements were performed on crystals which had assumed a regular and constant growth rate. Ordinarily this proceeds only after considerable growth in an uninterrupted fashion.

These objections may be eliminated by the simple expedients of making growth measurements without removing the crystal from its nutrient medium, and only after a constant and normal rate is established. To investigate this situation under these conditions, a small (approximately 3 mm. long), well formed, clear, single crystal of sucrose was cemented by its truncated end to a glass supporting rod. This was then submerged in a large excess (300 g., or more) of clear and cured supersaturated syrup. The surface of this solution was covered with a thin layer of mineral oil, and the entire vessel enclosed in order to avoid contamination by extraneous seed. Gentle agitation was provided through a sealed in propeller which turned at approximately 15 rpm. The lineal growth of the crystal was measured, without interrupting its progress, by means of a traveling microscope. Normal growth was assured when the increment of breadth and width assumed constant values in proportion to the demands of the axial dimensions.

The complete log of a single run is given in Fig. I, and the final results of a complete series at 30°C ± 0.05° are presented in Fig II.

The run depicted in Fig. I had been preceded by an identical trial with this same crystal, so that the usual period of fast growth was not accentuated in this particular case. Distances and increments between the ortho-pinacoid faces (100) and the basal pinacoids (001) were used to calculate the a : c axial ratio, which, in this particular case coincided almost identically (1.42-1.43) with that demanded by the fundamental ratio of 1.43. This concurrence was taken as fitting the necessary criterion for normal growth. Other increments, of course, could be used for the same purpose.

The original data of Kucharenko are given for comparison on Fig. II. The two rate constants are connected by a constant factor which has been computed from crystallographic considerations to be: G. V. in mg m²: min. = 94 (G. V. in mm. min⁻¹). However, some variation of this conversion factor is suggested by other computations, so that an exact comparison of these rate figures should be postponed until a more accurate figure is available. (The slope of Kucharenko's curve through the lower points of Fig. II is 1070 mot, while that computed for the other curve is 715, in the same units.)

The important feature which these curves demonstrate is that the deviation from linearity which appears in Kucharenko's values is apparently not a real growth factor. It is more likely the result of the method used. The more linear pattern of the present results not only confirms the suspicion referred to above, but is also in line with some values which have been reported by De Vries, at 60°. It is hoped that these investigations may be continued over the complete temperature and concentration range covered by Kucharenko, and even extended over and beyond the realm of modern sugar boiling conditions.

References.
3. Grut, E.; Compte Rendu C. I. T. S., 90 (1953), Brussels
5. ICUMSA. XI, Subj. 12, Paris (1954); I. S. J. LVII, 273 (1955)
8. Phelps, F. P.; Int. Soc. Cane Sugar Tech., IV (1932)
11. Vavrinecz, G.; Deutsche Zuckerind. 3, 107 (1938)
Fig. 1 Distances between pinacoid faces. Distances and increments between the pinacoids were in accord with the axial demands throughout this run.
General Picture of the Sugar Factories in Indian Union with special reference to varieties crushed and the recovery of sugar.

by

N. L. Dutt, M. Sc., ASSO. I.A.R.I., F.A.Sc., DIRECTOR

&

K. V. Gopala Aiyar, B. A., Dip. T. I CHEMIST

(Sugarcane Breeding Institute, Coimbatore)

en, as everybody knows, a snance of the Indian Sugar : introduction of protection nt of India in 1931. From a g upon imports from foreign ost the entire volume of its white sugar, India has become 's after protection completely the matter of white sugar. Factories in the pre-protection >t and in two years after the on, the number of factories 1941 the number of factories d. The production of white d risen from the preprotec­ kaks tons to over 11 lakhs in hed the figure of 14.83 lakhs he year 1954-55 the produc­ugar went up to the record khs tns. This phenomenal reads like romance and is d in the annals of the growth n the world, is not a little due to the improved sugarcane varieties bred at Coimbatore which have now saturated the whole of India and even spread to foreign countries. During the renaissance there has also been a very significant improvement in the average yield of cane in India as well as in the matter of cane quality enabling higher recovery of sugar in the factories. The average yield of cane rose from about 10 tons to 15.6 tons in 1936-37 and the all-India average recovery of sugar per cent cane rose from 8.69 in 1934-35 to 10.28 in 1942-43, though there has been stagnation and even some deterioration both in yield of cane and recovery of sugar lately. The improvement, creditable as it is, pales into insignificance when we compare the results obtained in the other important sugarcane countries in the world like Java, Hawaii, Cuba, Queensland, Natal, etc. Below are given the average yields of cane per acre and the recovery of sugar per cent cane in different countries:
### Average yield of cane and sugar recovery in different countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Yield per acre</th>
<th>Recovery of sugar per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sugarcane (Tons)</td>
<td>Sugar (Tons)</td>
</tr>
<tr>
<td>Cuba 1950</td>
<td>15.65</td>
<td>2.07</td>
</tr>
<tr>
<td>Louisiana 1950-51</td>
<td>19.60</td>
<td>1.53</td>
</tr>
<tr>
<td>Puerto Rico 1949</td>
<td>27.76</td>
<td>3.32</td>
</tr>
<tr>
<td>Hawaii 1951</td>
<td>77.42</td>
<td>8.63</td>
</tr>
<tr>
<td>Mauritius 1951-52</td>
<td>27.60</td>
<td>3.02</td>
</tr>
<tr>
<td>Natal 1950-51</td>
<td>30.70</td>
<td>3.39</td>
</tr>
<tr>
<td>Taiwan 1949</td>
<td>20.32</td>
<td>2.49</td>
</tr>
<tr>
<td>Australia 1949</td>
<td>24.98</td>
<td>3.23</td>
</tr>
<tr>
<td>Java 1956</td>
<td>56.20</td>
<td>6.46</td>
</tr>
<tr>
<td>India 1951-52</td>
<td>12.47</td>
<td>1.19</td>
</tr>
<tr>
<td>India 1953-54</td>
<td>13.99</td>
<td>1.40</td>
</tr>
</tbody>
</table>

It is seen that India is at the very bottom as regards cane yields and the quality of cane crushed and recovery of sugar per cent is about the lowest. While it cannot be gainsaid that India has to make much leeway both as regards yield of cane and the quality of cane it has to be pointed out that it is not quite fair to compare the average results of a vast country like India which has a tremendous range of climatic and soil variation and where the bulk of the area (nearly 80%) is in the sub-tropical region of extremes of temperature in the summer and winter, with comparatively small concentrated areas like Java, Hawaii, etc. where the climate and other environmental conditions are much more favourable. If the tropical regions of Bombay and certain parts of Madras are taken into consideration the results are not so bad. In selected areas in Bombay the results obtained both in yield of cane and the sugar per cent cane compare favourably with the results obtained in the other important sugarcane countries like Java, Hawaii, etc.

In the following pages are given in very brief outline the varieties in cultivation and their performance both in the field and in the factory as well as other conditions in the factories in the Indian Union.

**United Provinces.**

United Provinces (now Uttar Pradesh) is the most important region in India in the matter of white sugar production. This state contains the largest concentration of sugar factories and produces nearly 55% of the total production in the Indian Union. Uttar Pradesh is usually divided into five ranges based on climatic soil and other conditions for cane development and varietal work. They are (1) Western U. P., (2) Rohilkhand, (3) Central U. P., (4) Mid-Eastern U. P. and (5) Eastern U. P., and it will be convenient and worth while to consider the factories in U. P. range-wise.

**Western U. P.**

There are 16 factories working in this range comprising the districts of Dehra Dun,
The recoveries in this range are generally less than 10% ranging from 9 to 10%. The average recovery (1946-47 to 1950-51) is 9.69% with a Pol. % cane of 11.93. In general, it can be said that the best quality of cane and recoveries above 10% are attained in Lhaksar, Deoband and Mohiuddinpur while at the other end of the table come Doiwala, Modinagar and Daurala. The quality of cane and recovery fluctuates considerably when we go from place to place according to the soil and other conditions. In general, it can be said that in the heavy soils and waterlogged areas as Lhaksar and Mohiuddinpur the quality of cane and recovery are higher while in the sandy and sandy loam areas as in Daurala, Modinagar, etc. the quality of cane is poor. The better quality of cane and recovery at Deoband is more than anything else due to the varietal position. Here the main varieties are Co. 421 & Co. 313 and Co. 312 has been almost completely eliminated. The average yield in the different ranges generally vary from 300 to 450 mds. acre. The lowest yields are obtained in Lhaksar while Daurala, Sakhoti Tanda, Begumabad, Khasaui and Meerut City record more than 400 mds. per acre.

The curve of maturity and recovery during the different periods in a season in all the factories shows the same picture of low recovery in December and steeply rising recoveries towards the end of the season in March and April. More often the crushing season is over before the peak maturity and recoveries are reached. This reveals the urgent need of early varieties which can be crushed in the earlier part of the season and extending the season at least up to the end of April with the present late varieties.

As regards varietal position the main variety in all the zones south of Muzaffarnagar and in Shamli is still Co. 312. The proportion of Co. 312 increases as we go south becoming almost cent per cent. as we come to Begumabad. In Amroha, Lhaksar, Deoband and Rohana Kalan, Co. 421 occupies the major variety. In Amroha Co. 421 occupies the dominant position while in Doiwala Co. 356 is the major variety. Co. 421 is giving good results both as regards yield and quality in most of the zones. Co. 421 and to some extent Co. S. 245 are the two varieties which can replace Co. 312 with advantage as mid-season varieties. Co. 453 is the best yielder in all the zones and is being rapidly taken up by the cultivators. Its greatest disadvantage is that it is very late in ripening and as there is no strict control or schedule of crushing according to varieties and maturity. Co. 453 is being supplied earlier in the season and whenever it is coming in large quantities recoveries have gone down. The only early variety is Co. 313 and where it is grown in large areas as in Deoband the recoveries are higher. Co. S. 321 is the new early variety that is in trials and its progress and achievement are to be watched.

Bhalukband Range, U. P.

This range covers the districts of Bareilly, Bijnor, Etah, Pilibhit, Shahjahanpur, Moradabad, Nainital and Rampur and in this range 13 factories are working. The recoveries in this range are in general a shade lower than those in Western Uttar Pradesh and Central Uttar Pradesh. The average recovery is 9.59 with a Pol. % cane of 12.03. Kashipur, Gokulnagar, Dauspur, Baheri and Barelly factories record very poor recoveries while on the top of the scale are Neoli, Raja-Ka-Shahpur, Bijnor and Pilibhit. As regards varietal position. Co. 421 is the dominant variety (80% of the area) in Bareilly, Pilibhit, Rosa and Raja-Ka-Shahpur.
while this variety shared with Co. 453 the position in Seohara, Rampur (Buland and Rosa), Kasipur and Gokulnagar. In all the areas especially in the Tarai and low lying Khaddar area Co. 453 is the best yielder though it is poor in quality and late in ripening. Co. S. 186 occupied about 20% of the area in Dhanpur. It is performing well and giving good results. In Neoli, Co. 312 is still the dominant variety though there are signs of deteriorations of this variety in this area, and actual mill tests showed that it is poorer than Co. 421 both in quality and yield. It is noteworthy that Neoli records about the best recovery in this range. Co. 527 is grown in about 10% of the area in Seohara and its performance both in yield and quality in places where facility for irrigation are available as in low lying Khaddar areas is very good. Co. 313 and Co. 331 still continue to occupy considerable areas in Baheri.

In the Rohilkhand range because of better growth conditions the varieties ripen very late and are comparatively poor in quality and hence the recoveries obtained are very low. The urgent need of this area is the introduction of the good yielding early canes, and these two varieties CoS. 321 and Co. 622 which gave in mill tests recovery of more than 19% by the end of January as compared to less than 9% with the daily cane and especially Co. 622 which is superior in yield to CoS. 321, may well fill the gap.

Central Range, U. P.

This range comprises the districts of Kheri, Sitapur, Hardoi, Bara Banki, Fyzabad and Jaunpur and there are in all 10 factories working.

As a whole the quality of cane and recovery in this range are better than those in Rohilkhand range. The average Poi. % cane and recovery (1946-47 to 1950-51) are 12.21% and 9.63%. The best recovery for 1951-52 in this range was recorded by Golagokarnnath via. 9.80, Maholi (The Lakshmiji Sugar Mills) coming closely behind with a recovery of 9.74. The lowest quality of cane and recovery obtained was in Khamaria (Alra Sugar Factory) where the recovery was only 9.77. All the other factories showed more than 9.0 p.c. cent recovery. In Khamaria the conditions are more or less similar to those existing in Rohilkhand Terai. Here it is found that in the beginning of the season, the quality of cane is better than in other places and there practically no change in the quality of cane and recovery from December to March. The quality of cane is, if at all, better in December than in February. The varieties in cultivation are Co. 356 and Co. 393 both of which are performing very well in the area, Co. 336 giving the best yield. The higher recovery in Golagokarannath is mainly due to the satisfactory varietal position there. The proportion of varieties are: Co. 453 = 35%, Co. 327 = 10%, Co. 313 = 10%, and the rest miscellaneous. Co. 327 in this factory as also in Hargaoon yields about as much as Co. 453 in irrigated areas and the quality is definitely better. In Maholi and Hardoi, the major variety is Co. 421 though Co. 453 also occupies almost equal position in Maholi. Co. 453 is the dominant variety in Bara Banki and the major variety in Golagokarannath and Hargaoon. In Burhwal and Biswan and to a lesser extent in Shagonj, Co. 313 occupies the dominant position. It is noteworthy that though Co. 313 occupies about 50% of the area in these factories, recoveries are comparatively low. This is to some extent due to the fact that Co. 313 had deteriorated in this area both in yield and quality due to severe red rot attack especially
in the low lying areas of Biswan. In Motinagar Co. 393 is the dominant variety occupying 85% of the area and its performance both in the field and the factory is satisfactory though it is not as early as it is in some other places. Regarding new promising varieties mention must be made of Co. 617 which is performing well in Hargaon and most other places.

**Mid-Eastern U. P.**

In this range which comprises the districts of Gonda, Bahraich and Basti, there are nine factories. The quality of cane and recoveries in this range are in general better than in other ranges in U. P. The average recovery is as much as 9.99% with a Pol. % cane of 12.22. In Basti, Walterganj and Bahbhan, the major variety is CoS. 109 and the performance of this variety both in the field and the factory is good. Co. 453 which was the other leading variety in these factories as usual yielded better than all the others, but was poor in quality. In Basti which recorded the highest recovery viz. 10.31% in this range during 1951-52, Co. 413 occupied considerable areas, as much as 17 percent of the total. Bahbhan which is noted for high recovery in this range was getting even higher recovery in the previous years when crushing was extended up to April and even May and they were crushing Co. 356 and Co. 370 as late varieties. In 1944-45 which Co. 370 and Co. 356 in cultivation the factory recorded a Pol. in cane of 14.56% and record recovery of 12.08% for the month of April. The lowest quality of cane and recovery were recorded in Jarwal Road. In this factory area there is a vast multiplicity of varieties grown, Co. 453 and Co. 356 being the main varieties. Co. 205, is still grown in this region. The main causes of the low quality of cane and recovery are that he canes are very badly affected by diseases and pests like wilt, red-rot and borer. As a matter of fact the quality is not worse than what it is actually because the mofussil cane is healthier than the local or Gate canes. It is remarkable that in this area where almost every other variety is very badly attacked Co. 395 is absolutely free from diseases. The variety is also richer and earlier than the other varieties in cultivation. In Munderwa and to a small extent in Khalilabad, Nawabganj and Bahbhan, CoS. 109 is the main variety while Co. 453 occupies the dominant position in Tulsipur and also to some extent in Nawabganj where CoS. 109 and Co. 453 are grown in more or less equal proportion. Regarding the other varieties under trial or cultivation in this range mention must be made of B. 0.11 is very good in quality also.

**Eastern U. P.**

This range has the greatest concentration of factories in not only in Uttar Pradesh but also in the whole of the Indian Union. The range consists of only two districts viz. Deoria and Gorakhpur and there are 18 factories working.

The average quality of cane and recovery in the factories in this range are a shade better than those obtaining in the other ranges in Uttar Pradesh, the average recoveries obtaining being 9.09% with a Pol. % cane of 12.39. One characteristic feature of the factories in this range is the comparatively shorter crushing season. The season is finished generally by the middle of March itself or at the most by the end of March. The peak period of maturity and recovery is generally reached in this range by the end of February and thereafter there is steady deterioration in quality of cane.
The factories at Gauribazar, Sardarnagar and Purtabpore (Maiwara), are in the forefront in this range as regards quality of cane crushed and recovery. The average sucrose % cane and recovery in Gauribazar (during 1947-48 to 1951-52) are 12.78% and 10.73% respectively. The main varieties crushed in this factory are Co. 453 (25.62%) and Co. 419 (21.93%) and smaller proportions of Co. 395, Co. 513 and CoS. 109. It is interesting to note that in spite of the large proportion of Co. 419 in this area, the final quality of cane and recovery are not affected. Co. 419 gives very poor results in the earliest part of the season, but in the later part of the season after mid-February, it gives far better results than the other varieties. This has been the experience with Co. 419 in the factory at Baitalpore also where this variety occupies even greater proportions, viz. 56%. In Baitalpore recoveries more than 11% are attained during the later part of the season. In the big factory at Sardarnagar, in this area the varietal position is quite different. The major varieties in this area are Co. 419 and Co. 356. In the farm of the factory, the main varieties are PO. 2878, Co. 356 and CoS. 109 and all the three are doing very well both as regards yield and quality. In Purtabpore which is in the border of Uttar Pradesh and Bihar which gets 40% of its supplies from the Bihar side, the main varieties are Co. 453 (60.9%) and Co. 513 (3.8%). In the trials of new varieties in Purtabpore, Co. 622 has given the best results in the mill tests, and it has given very good yield too and is very promising. Another promising variety in the farm is B. O. 21 which combines good growth and quality. It is interesting to note that Co. 453 which is very late in ripening in the Western and other ranges of Uttar Pradesh and which has been the cause of decline in recovery in most of the factories in these ranges, is quite good in quality and not at all late in ripening in Eastern Uttar Pradesh.

At the other end of the table as regards quality of cane and recovery are the factories at Anandnagar, Siwsa Bazar, Ghughli and Lakhniganj with recoveries of just 10% or less. In Anandnagar, Co. 453, is the main variety occupying 64.51% of the total area, the other variety being CoS. 109. In this area which is mostly tarai, Co. 453 which is very good as far as yield is considered, is rather poor in quality of cane. In the trials in this area CoS. 443 and CoS. 416 are very promising. Of these, CoS. 443 is very good in yield, and CoS. 416 is very early and rich, in Ghughli, the main varieties are Co. 453, Co. 331 and Co. 395. The existence of Co. 331 in considerable quantities in this area, is responsible for the low recovery in this factory. Similarly in Kathkuiyan in the low lying areas, Co. 331 is still favoured in spite of its susceptibility to red rot as also in the low lying areas of Khadda and Chhittauni. In the above low lying areas, Co. 331 is fourirling and gives the best results as far as growth is considered but in quality it is very poor. In Siwa Bazar, Co. 356 is the dominant variety occupying 50% of the area. Co. 356 is also the dominant variety in Chhittauni, Khadda, Ramkola, Kathkuiyan and Padrauna and is doing very well as regards the growth and yield though as regards quality Co. 356 is rather poor and late in ripening. In Pipraich, CoS. 109 is the major variety and its performance in the area both as regards growth and quality is quite good. In Captaiinganj also CoS. 109 is the major variety though the proportion is far less than in Pipraich. In Captaiinganj Co. 395, Co. 513 and Co. 419 are the other important varieties.
and Co. 453 has been almost eliminated.

The factory at Tamkahi is on the border of Uttar Pradesh and Bihar and here as in Purtabpore, the main variety is Co. 513 forming 73.4% of the total crush. In Tamkahi previous to 1946-47, the main variety was Co. 313 and the quality of cane and recovery were slightly better being 12.44% (sucrose in cane) and 10.40% recovery as compared to 12.35% and 10.20% in the later period. The difference in quality and recovery during the day of Co. 313 is not as great as obtaining in most of the factories in Bihar where generally the recoveries were higher by 0.5% during the Co. 313 period.

Bihar.

Next to Uttar Pradesh, Bihar is the most important sugar producing state in the Indian Union. This state produces on an average 2,25,000 tons of white sugar which forms 19.21% of the average total production of India. Of the 28 factories in Bihar all but four are situated in the North Bihar comprising the districts of Champaran, Saran, Muzaffarpur and Darbhanga. The four factories in South Bihar are in the districts of Patna, Gaya and Shahabad.

In the Champaran district, there are nine factories working. In Harinar, Narkatiaganj and Bagaha, B. O. 11 has spread the maximum and is now the predominant variety, the proportion being 65%, 47% and 44% respectively in the three factories. In Narkatiaganj, Co. 453 occupies almost the same proportion as B. O. 11 while in the other two factories Co. 513 is the next important variety. The average recovery in this district (1947-48 to 1951-52) is 10.32 with a Pol. % cane of 12.77. The Harinar and Narkatiaganj factories report higher quality of cane and recovery than the rest. The recoveries during the previous period (1942-43 to 1947-48) when Co. 313 occupying a dominant position were far higher. In Bagaha, the quality of cane and recovery have all along been very poor. Even in those days when the area was saturated with Co. 313 the recovery was only 10.34% and during the present period it is only 9.87%.

In Bagaha area, B. O. 11 is doing very well and there is not much sign of disease, though as mentioned earlier, the quality of cane in this area is poor.

In Laturia where at present Co. 513 is the dominant variety the average quality of cane is quite good, about the best in this district, the Pol.% cane being 13. 11%. But because of the greater losses in manufacture the average recovery obtained is comparatively low being only 10.37%. Co. 453 is still the predominant variety in Chanpatia, Sagauli and Barachakia, the proportion varying from 90% in Chanpatia, to 80.68% in Barachakia. In spite of the fact that Co. 453 is occupying the maximum proportion in these areas, the quality of cane as represented by Pol. in cane is not much lower than that in the other factories in this district. The average Pol. in cane in Barachakia, Sagauli and Chanpatia are 12.73%, 12.71% and 12.40% respectively. In Majhaulia and Motihari, Co. 513 is the major variety with Co. 453 occupying almost an equal proportion in Majhaulia, the average Pol. in cane and recovery in these two factories are 12.50% and 10.38% and 10.44%. In Majhaulia, B. O. 11 is doing very well while Co. 453 is badly diseased. In the trials in the farm B. O. 3 and B. O. 21 appear to be good for waterlogged low areas, B. O. 14 and B. O. 28 are the promising new varieties in Majhaulia. In Motihari in the trials B. O. 21 and B. O. 22 have given even better yields than Co. 453, and as B. O. 21 is satisfactory in the quality, this variety is promising.
There are seven factories working in the Saran district. The average quality of cane (sucrose % cane) and recovery in all these factories during 1947-48 to 1951-1952 are 12.77% and 10.62% respectively. Among these factories, the Marhowrah and Sidhwallia factories stand foremost as regards quality of cane and recovery. The average Pol in cane and recovery in these two factories are 12.02% and 10.74% and 13.07% and 10.15% respectively. In Marhowrah the main varieties at present are Co. 453 (46.63%) and Co. 513 (43.8%). B. 0.11 forms only 4.44% of the total crush. In the period before 1947-48 when the predominant variety, the quality of its cane and recovery were even higher. The Pol. % cane and recovery during that period were 13.5% and 11.46%. In this area in the trials the most promising varieties are B. 0.21 and B. 0.17. In Sidhwalia also the main varieties are Co. 513 and Co. 453 but the proportion of Co. 513 is slightly more than that of Co. 453. There is still Co. 213 in this area and it formed as much as 13.23% of the total crush. Among the new varieties B. 0.21 is the most promising here also. The factory at Sasamusa gets the poorest recovery in this district though the low recovery (9.62%) is to some extent due to the greater losses in this factory. In Siwan, Hathua and Harkhua also because of greater losses the recoveries are comparatively lower, being only 10.21%, 10.18% and 10.26% respectively though the quality of cane is not poor the Pol. % cane being 12.84%, and 12.73% and 12.89% respectively. In all these factories the predominant variety is Co. 513, the proportion of which varies from 30.82% in Hathua to 47.52% in Harkhua. Co. 453 is the next major variety in all these factories, the proportion varying from 31.37% in Harkhua to only 6.65% in Hathua, except in Siwan where Co. 313 is the next prominent variety to Co. 513. Co. 513 appears to be the best variety at present for this tract both as regards yield and quality.

The five factories in the Darbhanga district are at Samastipur, Ryam, Hasanpur Road, Lohat and Sakri. Among these, Ryam and Sakri stand foremost in quality of cane and recovery. These two factories are about the best in the whole of Bihar in quality of cane and recovery. The Pol. % cane and recovery in Ryam during 1947-48 to 1951-52 are 13.23% and 11.29% respectively while the corresponding figures for Sakri are 13.39% and 10.89%. Due to greater losses in manufacture in Sakri, the recovery is lower than in Ryam though the quality of cane is even slightly better than in Ryam. The predominant cane variety in Sakri is still Co. 313. The presence of Co. 313 as the predominant variety in this area explains the high quality of cane obtaining in this factory. The varietal position in Ryam is a little different. Here Co. 313 is the major variety forming 56 — 59% of the total crush and Co 513 is also existing in large quantities forming 36.09% of the total cane crushed in this factory. The Ryam area is mainly a flooded and water-logged low lying area. In this area drying up and deterioration of cane do not occur till the end of the season in April. B. 0.11 is disappointing in performance in this area. Among new varieties on trial, B. 0.17 is very promising both in growth and quality. Though Lohat is adjacent to Sakri and the varietal position there is satisfactory, the main varieties being Co. 513 (61.3%) and Co. 313 (26.3%), the quality of cane and recovery are comparatively very poor, the average Pol. % cane and recovery being only 12.54% and 9.91% respectively. In this area, a lot of mofussil cane which are
stale are crushed. Hassanpur Road Samastipur are comparatively low in quality of cane and recovery, Hassanpur Road being even poorer than Samastipur, the recovery being only just 10.00% while it is 10.23% in Samastipur. In Samastipur Co.453 is the dominant variety constituting 59.2% and B. 0.11 is the next best variety forming 22.2%. In Hassanpur Road, Co. 513 and B.0.11 are the major varieties forming 36.03% and 31.06% of the total cane crushed in the factory. Co. 455 forms 30.04% and Co.313, 12.80%. The Hassanpur Road zone which comprising low lying areas where water-logging is frequent, Co. 513 comes up very well.

The Muzaffarpur district, contains only three factories. Of these, in Motipur and to some extent in Righa, the quality of cane crushed and recovery are above average, the average pol. in cane and recovery for these two factories being 13.06% and 11.06% and 12.87% and 10.49%. In the newly erected factory at Garaul, the quality of cane is only just average, the pol. in cane being only 12.52% and the recovery is rather poor being only 9.83%. In Motipur which compares favourably with the best of the factories in Bihar in quality of cane and recovery, Co. 513 still occupies the predominant position, the proportion being 68%. Co. 455 is the next important variety forming 20% of the total crush. In this area Co. 313 is flourishing well, in the farm, Co. 557 which was released by the Bihar Department for its high quality and which however did not establish itself anywhere because of its low yield, is also doing well. Of the new varieties under trial B. O. 21 is the most promising in this area. The varietal position in Righa is quite different. B. O. 10 is the predominant variety forming 41.5% while the other important varieties are Co. 453 (20.72%) and Co. 313 (20.92%). B. O. 11 is not popular in this area as it dries up later in the season. The comparatively lower quality of cane in Garaul is not due to the varietal position as Co. 313 and Co. 513 are the predominant varieties. In this zone in which about 40% of the area are low lands where the soils are medium to heavy and where there is sufficient moisture, ripening is comparatively delayed. B. O. 11 is also coming up well in this area. Among the new varieties under trial, B. O. 26 appears to be the most promising.

South Bihar.

There are four factories in South Bihar in the districts of Shahabad, Gaya and Patna. The average quality of cane and recovery in the factories in South Bihar are poorer than those in North Bihar, the average recovery being only 9.64. In Bihta the dominant variety is Co. 453 which occupies 66.39% of the total area. About 20% of the area in this zone is under a variety which is called Co. 622 but which appears to be not Co. 622. This variety grows very well in this area but is very poor in juice quality and is very late in ripening. Co. K. 32 which occupies 7.09% of this area is doing very well both in growth and quality and is promising. In Dalmianagar also Co. 453 is the predominant variety occupying 67.61% of the area. Co. K. 32 has spread to a greater extent in this area than in Bihta and is giving good yield and good quality. Of the new varieties under trial in Dalmianagar B. O. 14 is the most promising. The cane quality in Gurau is better than that in Dalmianagar and Bihta. The cane ripens very early in this area reaching the peak in the end of January and there is rapid deterioration by the end of February itself. The main varieties in this factory are Co. 453, Co. 313 and Co. K. 28. In the Warsaliganj
area, the main varieties are Co. 385, Co. 419 and Co. 453. Co. 419 is very popular in this area and is the best yielder.

**Bombay State.**

After Uttar Pradesh and Bihar, the next important state as regards the number of cane sugar factories and the quantity of sugar produced is the Bombay State. There are fourteen factories working in Bombay State and these on an average produce 10.83% of the total production of the Indian Union. In acre yields of cane and in recovery of sugar % cane, the Bombay State stands foremost in India. In many of the factories yields of cane obtained almost approach the yields obtained in the best of the sugarcane growing countries like Hawaii, Java, etc. and some of the factories like Kolhapur report recovery of sugar % cane comparable to those obtained in the best of the sugarcane growing countries as regards recovery of sugar viz. Queensland. The average recovery in the factories in the state (1949-50 to 1953-54) is 11.46% and the Pol. % cane is 13.88%.

Kolhapur leads the other factories as regards cane quality and recovery. The average Pol. % cane and recovery during the last five year period are 15.27% and 12.90%. Kolhapur and Ugar which also generally report very good quality of cane and high recovery stand in a separate category from the other factories in the Bombay State. They are not served by the Deccan Canal system. They are irrigated by lift irrigation from the rivers 'Panchganga' and 'Krishna' respectively. The climatic conditions in Kolhapur are such that the cane ripens very early and the peak period of maturity is reached by the end of January itself. Another feature of Kolhapur which probably has some bearing on cane quality is that cane is transplanted from nurseries in what is called the Rajpooj method of planting. Walchandnagar and Maharashtra come next as regards cane quality and recovery with 14.29% and 11.98% and 14.22% and 11.81% respectively. In Phaltan also the Pol. % cane is above 14 %. At the other end of the table as regards cane quality and recovery comes Saswad Mali with 12.92% Pol. % cane and 10.71% recovery.

As regards yield of cane Saswad Mali Sugar Factory stands foremost with an average yield of 66.09 tons during the last five year period. If we take the last 3 years into consideration when POJ. 2878 had been completely replaced by Co. 419, the average yield of all crop works out to 72.38 tons. The average yield of adabli crop alone is 82 tons. The Maharashtra Sugar Mills and Godavari Sugar Mills (in 1954-55) (Sakharwadi and Lakshmiwadi), Belvandi and Belapur come next as regards yields of cane. Changdeo Sugar Mills recorded the lowest yields viz. an average 33.3 tons for all crops.

Co. 419 is the only cane variety grown in all the factories except Irinhas Maharashtra-Shreepur. In Shreepur POJ. 2878 still forms 37.02% of the total. In previous years (1948-49) the POJ. 2878 was the major variety forming 63.04% of the total. In Malinagar also POJ. 2878 continued to occupy major proportion till very recently. POJ. 2878 has now completely been eliminated since 1951-52. It is interesting to note that this change over has resulted in remarkable increase in yield. The yields which were of the order of 56 tons when POJ. 2878 persisted as a major variety jumped upto 72.0 tons with the complete saturation of Co. 419. In Walchandnagar also POJ. 2878 still persists though only to a small extent.

Co. 475 which was introduced for a short
period in most of the factories because of its good performance both in the field and in the factory has been completely given up in all the factories due to its susceptibility to diseases. It is grown to a small extent still in Belanadi where it continues to give good performance.

In the Godavari Sugar Mills Ltd., Sakarwadi and Luxmiwadi for the heavy alkaline patch Co. 605 is found to be suitable and is being grown to some extent. Previously Co. 421 was the variety for these areas and now Co. 605 has taken its place.

As regards new varieties under trial in the various Government farms and in the factory estate Co. 605 has shown better results than Co. 419. This variety gives definitely better yields than Co. 419, and in spite of the slight comparatively lower quality and recovery, it gives more sugar per acre than Co. 419.

The standard manural dose is 450 lb. N. for the annual crop. There has been a tendency to increase the manural dose recently in most of the factories. In Mallikarjuna the usual dose is 600 to 650 lb. N. Recently the Godavari Sugar Mills have increased the manural dose considerably with an attempt to boost up yields. In Kolhapur and Ugu, the manural application is generally much lower, being only 300 to 350 lb. N.

**Madras State (including Andhra)**

In the Madras State (undivided—including Andhra), there are thirteen factories working and these produce on an average 6.6% of the total production of India.

Though the Madras factories are in the tropical region where conditions for cane growth and cultivation are optimum, the average recovery in the factories in Madras are very low. The average Pol. % cane and recovery (1948-49 to 1952-53) are only 11.5% and 9.3% respectively. On the basis of sugar recoveries and potentialities for improvement, the Madras factories could be roughly classified into three groups:

(a) Factories where already the same quality is satisfactory and recoveries of more than 10% are obtained, comprising the factories at Sreeharaswaram and Bobili.

(b) Factories where recoveries are at present low but can be easily improved by the introduction of suitable early varieties and slight changes in the crushing schedule. This group consists of the factories at Anakapalli, Enneliopakilla (now Devapur), Samaikot and Hasper. The new factories at Tanuku and Pohapura should be included in this group.

(c) Factories where the problem of low recoveries is rather serious and to effect improvement in this regard is difficult, and where the climate and soil conditions appear to have set a limit. These are at Vuyyuru, Nelloreppam, Putlug and Pudumudipalayam.

The two factories in the first group especially Sreeharaswaram are in the forefront as regards cane quality and recovery. There is a planned attempt to balance the varietal position with suitable early, mid-season and late varieties and a crushing schedule according to maturity of varieties. Co. 527 is the early variety while Co. 421 and Co. 419 are the mid-season and late varieties respectively. The better quality of cane and recovery at Sreeharaswaram as compared to Bobili is due to better manufacturing efficiency and also to some extent to the fact that the proportion of ear variety Co. 419 is more at Bobili while Sreeharaswaram has more of the early variety Co. 527.
In the factories in the second group, Co. 419 is the main or rather only variety grown and it has not been possible to introduce the early variety Co. 527 because of the striking superiority in yield of Co. 419 and as such, no improvement in recovery could be made. The factory at Hospet however has been able to show considerable improvement in recovery without changing the variety. Hospet is in a separate category as regards soil and climatic conditions and here the ripening conditions are not so unfavourable as in the other regions in Madras State. The low recovery in Hospet previously in spite of favourable soil and climatic conditions, almost approaching those in the Bombay Deccan factory region, was mainly due to the fact that the canes were planted late in April and May and harvested when they were very immature. Now the planting is being done early in January and the factory is now getting very good recoveries almost as much as Seethangaram. The recovery is now 10.22% as compared to 9.55% previously.

The new factory at Tanuku which climatically is in the same category as the factories in the second group, is recording very good recoveries. The quality of cane in this area is about the best in Madras State even better than that at Seethanagaram (the Pol. or sucrose in cane being 13.13%) though the recovery obtained is slightly lower due to comparatively greater loss in manufacture. The strikingly superior quality of cane in Tanuku appears to be mainly due to the peculiar soil conditions. Soils are heavy and clayey and are situated in a low-lying swampy area where waterlogged conditions exist. These conditions though not quite conducive to growth and yield, are very favourable for better ripening and sucrose accumulation in cane.

Coming to the last group of factories where the problem of low recovery is more serious and where the climatic conditions are very unfavourable for ripening viz., comparatively heavy rains during October, November and December, the absence of pronounced dry cold ripening season, we find that there has been a complete revolution in the varietal position in Vuyyuru. Here Co. 419 which was the previous main variety has almost completely been eliminated and Co. 527 the early rich variety is the dominating variety. This has resulted in considerable improvement in cane quality and recovery (from 8.84% to 98.5%) though it is still lower than at Hospet, Seethangaram and Tanuku.

In Nellikuppam also, there has been considerable changes in the varietal position. The varieties Co. 281 and POJ. 2878 have almost been completely eliminated and the area under Co. 349 is dwindling. The variety Co. 527 which was introduced only a few years ago is the dominating variety now. In spite of the preponderance of the early rich variety Co. 527 in this area, the recovery though it has improved a little is still very low being less than 9%. Adsali planting or long duration crop has also been tried in the farm with Co. 527 and still there has not been any striking improvement in quality of cane and recovery. This emphasizes the unfavourable climatic conditions in this area which sets a limit to improvement in this regard. In Nellikuppam area among the new varieties under trial Co. 658 is coming up very well, and is being introduced on large-scale cultivation. Co. 711 and Co. 785, are two other varieties which are very promising and expected to come up.

In Pugalur, Co. 449 is doing very well as a second to Co. 419 and among new varieties under trial Co. 467 is the most promising. It
gives as much yield as Co. 419 and is comparatively free from disease and is nonflowering. It gives very good gur too. In Pandiarapuram the cane quality and recovery are very low. There are two areas in this region supplying cane to this factory viz. the gardenland irrigated from well where the main variety is Co. 421 and the wetlands area irrigated by canal irrigation in the Periyar canal delta area where the main variety cultivated is Co. 419.

**Mysore State.**

There are at present two factories in Mysore viz. Mandya and Hospet. Of these, Hospet was till very recently in the undivided Madras State and has been considered under the Madras State factories. Mandya factory has probably the longest crushing season in India. In normal years the crushing begins in August and continues upto almost May next. There are usually two planting periods in this area—the first season from February to May and the second season from June to November. Due to shortage of water there has not been much of February-May planting and so the factory has to depend for its usually long crushing season mainly on the July-November planting. The average Pol. % cane and recovery during the period (1948-49 to 1952-53) are 12. 89% and 9. 81%. During 1951-52 and 1952-53, however, the recoveries were very good being 11. 61% and 11. 37% respectively. In 1943-44, more than 80% of the area was under H. M. 320 and only 20% under Co. 419. By 1948-49 H. M. 320 has been completely eliminated and Co. 419 has become 100% and since then Co. 419 is the only variety grown.

**Hyderabad State**

There is only one factory now working in the state with two plants functioning side by side viz. The Nizam Sugar Factory Ltd., Shakharnagar. The combined capacity of the two plants is 3,100 tons of cane per day. There has been a significant improvement in the quality of cane and recovery in this factory in recent years. The average value for Pol. in cane and recovery during the period 1948-49 to 1952-53 are 12.81% and 9.88% as compared to only 12.22% and 9.06% during the previous quinquennial period. The recovery could have been more for the quality of cane crushed if the manufacturing losses were not as great as they are now. There has been also a corresponding change in the varietal position. POJ. 2878 which occupied as much as 35. 42% of the total area during the period 1943-44 to 1947-48 has been completely eliminated and the area under Co. 419 has increased from 50.40% to 70.1%. Co. 475 which was introduced only recently has come to occupy 10%.

Among the new varieties under trial Co. 467 is very promising and the area under this variety is being increased rapidly. Co. 605 is coming up very well in bad alkaline lands where Co. 419 and other varieties are failure.

**West Bengal.**

The only factory operating in West Bengal is the Ramnugger Cane and Sugar Co. Ltd. at Plassey. This factory, has been doing very well and has been all along getting very high recoveries, though there has been a decline in the last two years. The average Pol. in cane and recovery during the period 1948-49 to 1952-53 are 13.21% and 10.75%.

The varietal position now is as follows: Co. 453-45%; Co. 313-38%; B. O. 11-5%; Others-15% while a few years previously the main cane was Co. 313 forming 86% of the crush and Co. 453 formed only 9%. This change in the
varietal position has been responsible for the decline in recovery from 11.23% in 1950-51 to 10.23% in 1952-53 but it has resulted in better yield in the factory farm which was previously growing only Co. 413 and is now mainly growing Co. 453. Co. 527 is not popular in this factory area. Though it gives about as good yield as Co. 453 it is not so rich and early as in other places. Mill tests on this variety have shown that it is not as rich as Co. 313 and only a shade better than Co. 453. In other areas of West Bengal Co. 527 is quite popular and it gives very good quality juice. B. 0.29 is a promising variety among the new varieties under trial. It gives as good yield as Co. 453.

**Madhya Bharat.**

There are five factories working in this area and these on an average produce only 13,000 tons of sugar annually. The average recovery in these factories is rather low being 9.26 which is less than that in Uttar Pradesh and Bihar and other places and the same as that in the Madras State. The cane supply position in all the factories except Dabra is unsatisfactory and the factories except in a few years do not have a full season. In recovery, Jaora and Dabra are the best with average recovery of 9.45% and 9.35% respectively while Mehidpur Road gets the poorest recovery — the average being 8.77 though the quality of cane is almost as good as in other factories. The recovery in Dalaula 8.97 with the same quality of cane as in other places. The quality of cane in Sarangpur is better than that in the other factories in Madhya Bharat though the actual recovery obtained is lower due to high manufacturing losses. In 1950-51 however this factory obtained a recovery of 9.5%.

The main varieties in cultivation in Mehidpur Road, Jaora, and Dalaula are the old Co. canes Co. 213 and Co. 210. Co. 419 and Co. 453 have been introduced in the areas and is spreading. In Dabra the main varieties are Co. 312 and Co. 453 while in Sarangpur area the main variety is Co. 419.

**Greater Rajasthan.**

There are two factories working in Rajasthan viz. (1) The Bikaner Industrial Corporation Ltd., Sri Ganganagar and (2) The Mewar Sugar Mills Ltd., Bhopal Sagar. In Ganganagar which is situated in the northern part of Rajasthan and where the climatic and other conditions are akin to those in Punjab, the cane quality and recovery are very poor — the average recovery is only 7.66. The quality of cane in Bhopal Sagar which is in the south Rajasthan are much better the average recovery being 9.46%. Sri Ganganagar is subjected to frost. The main variety in Sri Ganganagar is Co. 312 while in Bhopal Sagar the dominant variety is Co. 419 with the old varieties Co. 290 and Co. 210 and Co. 213 still occupying considerable areas. Co. 421 is coming up very well in the alkaline soils in Bhopal Sagar and Co. 527 is also doing well there as early variety giving good yields.

**Punjab And PEPSU.**

There are three factories in Punjab and PEPSU viz. (1) The Saraswati Sugar Mills Ltd. Abdullapur, (2) The Mahaluxmi Sugar Mills Ltd., Hamira and (3) The Jagatjit Sugar Mills Ltd., Phagwara. The factory at Abdullapur is in Punjab while the other two at Hamira and Phagwara are in PEPSU. Though the two factories at Hamira and Phagwara are in PEPSU the major part of their cane supplies come from Punjab. The quality of cane and recovery in Abdullapur are very good better than most of the factories in Western Uttar Pradesh to which this factory
is contiguous. The recovery obtained is generally above 10%. The other two factories Hamira and Phagwara record almost the lowest quality of cane and recovery. The recoveries in these two factories are on an average only 8 to 8.5%. Hamira and Phagwara are subject to frost while Abdullahpur does not suffer from frost. Hamira and Phagwara get their supplies both from PEPSU where 80% of the area is Co. 285 and the other is Co. 312. In Abdullahpur, Co. 313, Co. 421 and Co. 453 are the main varieties, the proportion of each variety varying from 32% in the case of Co. 313 to 19% in the case of Co. 453.

**Bhopal.**

The Bhopal Sugar Industries Ltd., Sehore is the only factory in the Bhopal State. The soils and climatic conditions in this area are more or less similar to those in the Bombay-Deccan tract. The quality of cane and recovery are rather low as in the other areas in southern Madhya Bharat to which this factory is contiguous. The average Pol % cane and recovery are 11.50% and 9.19% respectively. The main varieties are Co. 421 and POJ. 2967 occupying 55% and 35% respectively. The other varieties are Co. 605, Co. 453 and Co. 617.

**Orissa.**

There is only one factory working in Orissa viz. the Jęypore Sugar Co. at Rayagada. The average quality of cane and recovery in this factory are much lower than those at Seethanagaram and Bobbili to which it is contiguous. The recovery is only 9.32%. The main varieties in this area now are Co. 419, Co. 513 and Co. 527. This is mainly a dry area with little or no facilities for irrigation. The cane crop begins to dry up very early in the season and there is rapid deterioration.

**Travancore & Cochin.**

The Pamba River is the only factory in the State. Due to peculiar conditions existing in this area, the quality of cane and consequently recovery are very low though the canes are healthy and well grown. This area receives heavy rain in both the south west and north east monsoons and cane crops which are generally grown by the side of the rivers are flooded and almost submerged normally twice in the year. During 1951-52 there was a third flooding in October and consequently the quality of cane and recovery touched the lowest level. Even in the peak period during 1951-52 the Pol in cane was only just 10 per cent and purity of primary juice just touching the 80 per cent mark and season’s recovery was only 6.6%. The main cane varieties grown are Co. 349 and POJ. 2725. Co. 419 comes up very well and yields better than others, but it is not encouraged by the factory because of its late ripening character. In spite of the very low purity of the juices, the clarification is very easy and good and with the simple defecation and single sulphite methods adopted very high quality sugar is bagged.
Effect of Ecological Factors and Traumatism on Juice Quality

PART D. EFFECT OF FROST ON SUGARCANE CROP

By

S. C. SEN M. Sc., D. Sc., F.R.I.C., F.I.C.
Asst. Prof. of Sugar Chemistry,

&

J. C. Bhargava, Bsc., Assoc. I.I.S.T.

(INDIAN INSTITUTE OF SUGAR TECHNOLOGY, KANPUR.)

Consequent on a depression in sugar recovery during the optimum production period, January and February, 1955, in sugar factories of Dehradun and Rampur districts, a survey was instituted at the request of the Government of Uttar Pradesh, to enquire into the causes thereof and the work done in this connection strongly suggested an association between the observed fall in the sugar recovery and the depression in juice quality of standing sugarcane crops, affected by FROST. An analytical examination of canes affected by frost against normal canes (unaffected) showed that juices of affected canes suffered a setback in sucrose content accruing up to 3-4 units.

In the light of the above observation detailed investigations in the three factories areas, namely Shree Janki Sugar Mills Limited, Doiwala, Dehradun and Baland Sugar Factory and Raza Sugar Factory, Rampur, were taken up during February and March, 1955, in Dehradun and Rampur districts respectively.


Due to severe cold during end of December, 1954 and early January, 1955 in Dehradun district dew over the plant leaves were frozen in area where the wave of the cold wind passed. Consequently, a large number of plants were affected, particularly, the tender crops like Banana or Papaya. The leaves of these frost affected plants were completely dried up, which was observed during the survey of cane crop. Frosting was noticed between 30th December '54 and 2nd January 1955 in some of the places of the reserved area of this sugar factory.

The reserved area of Shree Janki Sugar Mills Limited, is distributed to three unions, namely, (i) Dehradun (ii) Doiwala and (iii) Lakshar Union. In Dehradun Union, there are four centres (a) Harbatpur (b) Harawala (c) Badripur and (d) Dehradun. In Doiwala union there are only two centres (a) Doiwala and (b) Raiwala and Lakshar Union consists of three centres — (a) Pathri (b) Jawalapur and (c) Begampur. The expected cane supply to this factory was 3.5 lacs maunds from Dehradun, 5.5 lacs maunds from Doiwala and 6.0 lacs maunds cane from Lakshar union.

Canes of Dehradun union were found most affected by frost, the extent of affection on eye estimation was over 60.0 percent and the top leaves of frost affected canes in most fields were found dried up. In some of the fields the entire leaves of the crop were dried up completely and it seemed that the plants were
affected by Red Rot or Wilt. A few suspected cane stalks were brought to Kanpur and examined in consultation with Dr. Mathur, the Mycologist, Uttar Pradesh, but none of the suspected diseases was detected. The canes of Lakshar Union were not at all affected, whereas, canes of Doiwala union were slightly affected by frost.

EK 28 a popular cane variety (not recommended by the Government for the factory) is very soft and thick, very well suited for chewing, occupied about 150 acres in Badripur centre of Dehradun Union. These canes are exported to Delhi and fetch more price than the scheduled cane price. This variety was most affected and we could see no field whose top leaves were not dried up. The intensity of damage near the same place in other varieties was much less and this leads a suspicion that soft canes are perhaps more susceptible to frost. A systematic investigation was taken up with different varieties in different localities where canes were damaged by frost.

Four cane varieties were selected according to the nature of the rind and fibre content and their intensity of damage affected by frost was examined. At least 10 whole clumps of each variety was sampled at random from a field of roughly 1/40 th. acre, brought to Shree Janki Sugar Mills, and analysed for fibre and juice quality. The varietal character has been found very prominent. EK 28, the softest cane has been affected by frost the most, causing depression in sucrose content, while Co. 453 the hardest cane suffered the least. The other varieties, Co. 356 and Co. 421 medium canes indicated a depression in sucrose content between the softest cane EK 28 and the hardest cane Co 453. In general, the rate of deterioration of canes affected by frost has been found to vary inversely with the fibre content of the cane, greater the fibre content, lesser, is the deterioration, contrary to the observation made by Sen in cut canes.

A. Varietal behaviour of canes towards Frost.

<table>
<thead>
<tr>
<th>Date of sampling</th>
<th>Varieties</th>
<th>Brix</th>
<th>Pol</th>
<th>Purity</th>
<th>Invent Sugar</th>
<th>Fibre</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14—2—55</td>
<td>Co 453</td>
<td>17.4</td>
<td>14.76</td>
<td>84.5</td>
<td>0.48</td>
<td>16.4</td>
<td>All leaves dry.</td>
</tr>
<tr>
<td></td>
<td>Co 356</td>
<td>16.3</td>
<td>13.58</td>
<td>82.9</td>
<td>0.62</td>
<td>15.2</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>Co 421</td>
<td>15.8</td>
<td>12.97</td>
<td>81.8</td>
<td>0.77</td>
<td>14.1</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>EK 28</td>
<td>15.0</td>
<td>12.10</td>
<td>80.1</td>
<td>1.00</td>
<td>12.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>15—2—55</td>
<td>Co 453</td>
<td>17.7</td>
<td>15.09</td>
<td>85.0</td>
<td>0.50</td>
<td>16.6</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>Co 356</td>
<td>16.6</td>
<td>13.81</td>
<td>82.9</td>
<td>0.60</td>
<td>15.5</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>Co 421</td>
<td>15.6</td>
<td>12.72</td>
<td>81.3</td>
<td>0.86</td>
<td>13.9</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>EK 28</td>
<td>15.1</td>
<td>12.19</td>
<td>80.3</td>
<td>1.02</td>
<td>12.4</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

TABLE I. Showing the varietal behaviour of canes towards frost.
B. Comparative study of frost affected cases with the normal cases.

Top leaves of a few promising varieties of canes affected by frost were dried up either fully or partially. In order to test efficiently the extent of deterioration in relation to the intensity of affection by frost, seven to ten whole clumps of such fully or partially affected canes of different varieties collected from different localities, were brought to Shri Janki Sugar Mills, crushed and analysed. Since it was difficult to get healthy canes from affected fields, healthy cane samples were brought from Lakshar Union, where canes were not at all affected.

<table>
<thead>
<tr>
<th>Places</th>
<th>All leaves</th>
<th>dry</th>
<th>Leaves</th>
<th>partially dry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brix</td>
<td>Pol</td>
<td>Purity</td>
<td>Invert</td>
</tr>
<tr>
<td>Co. 356</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Dehradun Centre</td>
<td>16.0</td>
<td>13.24</td>
<td>82.3</td>
<td>1.04</td>
</tr>
<tr>
<td>Badripur</td>
<td>15.1</td>
<td>12.19</td>
<td>80.3</td>
<td>1.16</td>
</tr>
<tr>
<td>Harawala</td>
<td>16.3</td>
<td>13.58</td>
<td>82.9</td>
<td>0.96</td>
</tr>
<tr>
<td>Doiwala</td>
<td>15.8</td>
<td>12.97</td>
<td>81.8</td>
<td>1.02</td>
</tr>
<tr>
<td>Raiwala</td>
<td>16.7</td>
<td>12.92</td>
<td>77.4</td>
<td>1.14</td>
</tr>
<tr>
<td>Lakshar Union</td>
<td>All leaves fresh and green</td>
<td>19.3</td>
<td>16.73</td>
<td>86.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Co. 421</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehradun Centre</td>
<td>15.8</td>
<td>12.97</td>
<td>81.8</td>
<td>0.92</td>
<td>17.6</td>
<td>14.96</td>
<td>84.8</td>
<td>0.74</td>
</tr>
<tr>
<td>Badripur</td>
<td>16.2</td>
<td>13.41</td>
<td>82.6</td>
<td>0.89</td>
<td>17.9</td>
<td>15.34</td>
<td>85.3</td>
<td>0.82</td>
</tr>
<tr>
<td>Harawala</td>
<td>16.7</td>
<td>13.99</td>
<td>83.4</td>
<td>0.96</td>
<td>17.7</td>
<td>15.09</td>
<td>85.0</td>
<td>0.67</td>
</tr>
<tr>
<td>Doiwala</td>
<td>16.3</td>
<td>13.50</td>
<td>82.7</td>
<td>1.08</td>
<td>16.4</td>
<td>14.92</td>
<td>85.1</td>
<td>0.52</td>
</tr>
<tr>
<td>Raiwala</td>
<td>15.6</td>
<td>12.72</td>
<td>81.3</td>
<td>1.16</td>
<td>17.6</td>
<td>15.01</td>
<td>84.9</td>
<td>0.52</td>
</tr>
<tr>
<td>Lakshar Union</td>
<td>All leaves fresh and green</td>
<td>18.8</td>
<td>15.99</td>
<td>84.9</td>
<td>0.83</td>
<td>19.4</td>
<td>16.89</td>
<td>86.9</td>
</tr>
</tbody>
</table>
It is clear from the results that a district difference in sucrose content between the healthy or partially or fully affected canes was observed; greater the intensity of affection, greater is the depression in sucrose content. This corroborates the work of Khanna and Sen, wherein they have shown that the defoliated canes suffer a set back in sucrose content compared to normal canes.

On comparing the analytical results of the frost affected canes and healthy canes, a depression of 1 - 3 units in sucrose content is observed, which is likely to cause a great reduction in sugar recovery.

C. MILL TEST.

To get a clear idea to what extent the mill suffers in the production with the frost affected canes, it is but essential to carry out mill tests. Several mill tests were conducted by the factory as well as by us. A strong association between the fall in sugar recovery and depression in sucrose content of canes affected by frost was observed.

(a) MILL TEST WITH EK - 28.

The day to day mill test with the softest variety EK 28 was conducted by the factory (Table III). This shows a very low recovery which may not be profitable at all for milling.

Table III

<p>| Mill test of EK 28 collected from Badripur centre and conducted by Shree Janki Sugar Mills. |
|----------------------------------------------|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Dates</th>
<th>Canes crushed in Mts. Srs. cane</th>
<th>Bagasse in %</th>
<th>Juice in %</th>
<th>Brix %</th>
<th>Pol Pol in Juice %</th>
<th>Pol Pol in Bagasse %</th>
<th>Expected Recovery %</th>
</tr>
</thead>
<tbody>
<tr>
<td>30, 2, 55</td>
<td>993-25</td>
<td>53.4</td>
<td>46.5</td>
<td>14.4</td>
<td>9.65</td>
<td>67.3</td>
<td>5.6</td>
</tr>
<tr>
<td>31, 2, 55</td>
<td>985-05</td>
<td>50.0</td>
<td>50.0</td>
<td>14.6</td>
<td>9.66</td>
<td>68.0</td>
<td>6.0</td>
</tr>
<tr>
<td>1, 2, 55</td>
<td>873.35</td>
<td>50.5</td>
<td>49.4</td>
<td>14.7</td>
<td>9.96</td>
<td>67.4</td>
<td>6.0</td>
</tr>
<tr>
<td>2, 2, 55</td>
<td>1164-10</td>
<td>55.2</td>
<td>44.7</td>
<td>14.3</td>
<td>9.75</td>
<td>67.0</td>
<td>6.0</td>
</tr>
<tr>
<td>3, 2, 55</td>
<td>1360-00</td>
<td>54.4</td>
<td>45.4</td>
<td>15.0</td>
<td>9.95</td>
<td>66.3</td>
<td>6.0</td>
</tr>
<tr>
<td>4, 2, 55</td>
<td>927.25</td>
<td>55.3</td>
<td>44.6</td>
<td>14.0</td>
<td>9.42</td>
<td>67.0</td>
<td>6.0</td>
</tr>
<tr>
<td>5, 2, 55</td>
<td>1241-25</td>
<td>56.5</td>
<td>43.4</td>
<td>14.7</td>
<td>10.02</td>
<td>67.5</td>
<td>6.0</td>
</tr>
<tr>
<td>6, 2, 55</td>
<td>1466-15</td>
<td>50.5</td>
<td>49.4</td>
<td>15.4</td>
<td>10.48</td>
<td>67.5</td>
<td>6.0</td>
</tr>
<tr>
<td>7, 2, 55</td>
<td>1150-30</td>
<td>55.3</td>
<td>44.6</td>
<td>14.3</td>
<td>9.32</td>
<td>66.4</td>
<td>6.0</td>
</tr>
<tr>
<td>8, 2, 55</td>
<td>1317-00</td>
<td>55.4</td>
<td>45.4</td>
<td>14.8</td>
<td>9.99</td>
<td>67.3</td>
<td>6.1</td>
</tr>
<tr>
<td>9, 2, 55</td>
<td>1000-10</td>
<td>56.3</td>
<td>43.6</td>
<td>14.7</td>
<td>10.16</td>
<td>68.7</td>
<td>5.9</td>
</tr>
<tr>
<td>10, 2, 55</td>
<td>977-25</td>
<td>55.3</td>
<td>44.6</td>
<td>16.3</td>
<td>11.16</td>
<td>68.8</td>
<td>6.0</td>
</tr>
</tbody>
</table>
A comparative statement of sugar recovery of different varieties of canes affected or non-affected by frost during February, 1955 (Tables III & IV) clearly indicated that the depression in recovery due to frost in EK 28, the softest cane was about one percent lower than in other varieties, which are comparatively harder than EK 28. The rate of deterioration has been found inversely proportional to the fibre content confirming our previous observation. Besides, a higher fibre-content in the frost affected canes compared to healthy cane of the same variety was also observed.
Table

**Statement showing mill test of healthy normal canes and frosted canes other than EK 28 during Frosted Canes.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Mads. Srs.</th>
<th>Cane Gross wt.</th>
<th>Milled Juice</th>
<th>Primary Juice</th>
<th>Brix</th>
<th>Pol.</th>
<th>Purity</th>
<th>%</th>
<th>%</th>
<th>Mixed Juice</th>
<th>Sugar</th>
<th>Purity</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>Calculated Recovery</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.55</td>
<td>5817-4</td>
<td>5845</td>
<td>0.30</td>
<td>5817</td>
<td>15.8</td>
<td>11.60</td>
<td>73.5</td>
<td>9.74</td>
<td>71.7</td>
<td>9.55</td>
<td>18.1</td>
<td>66.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2.55</td>
<td>8946-17</td>
<td>8933</td>
<td>0.30</td>
<td>8946</td>
<td>15.6</td>
<td>11.76</td>
<td>74.0</td>
<td>9.34</td>
<td>72.2</td>
<td>9.35</td>
<td>17.3</td>
<td>69.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2.55</td>
<td>8046-18</td>
<td>8046</td>
<td>0.30</td>
<td>8046</td>
<td>15.9</td>
<td>11.81</td>
<td>73.3</td>
<td>9.17</td>
<td>73.7</td>
<td>9.30</td>
<td>16.7</td>
<td>67.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2.55</td>
<td>8178-31</td>
<td>8178</td>
<td>0.30</td>
<td>8178</td>
<td>15.7</td>
<td>11.50</td>
<td>72.9</td>
<td>9.60</td>
<td>71.2</td>
<td>9.19</td>
<td>16.5</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.55</td>
<td>7380-3</td>
<td>7380</td>
<td>0.30</td>
<td>7380</td>
<td>15.7</td>
<td>11.50</td>
<td>72.9</td>
<td>9.60</td>
<td>71.2</td>
<td>9.19</td>
<td>16.5</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2.55</td>
<td>6992-7</td>
<td>6992</td>
<td>0.30</td>
<td>6992</td>
<td>15.8</td>
<td>11.63</td>
<td>72.7</td>
<td>10.19</td>
<td>70.4</td>
<td>9.63</td>
<td>16.3</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.2.55</td>
<td>8759-9</td>
<td>8759</td>
<td>0.30</td>
<td>8759</td>
<td>15.9</td>
<td>11.63</td>
<td>72.7</td>
<td>10.19</td>
<td>70.4</td>
<td>9.63</td>
<td>16.3</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.2.55</td>
<td>8144-27</td>
<td>8144</td>
<td>0.30</td>
<td>8144</td>
<td>15.4</td>
<td>11.16</td>
<td>72.1</td>
<td>9.89</td>
<td>70.7</td>
<td>9.76</td>
<td>16.3</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.2.55</td>
<td>4473-0</td>
<td>4473</td>
<td>0.30</td>
<td>4473</td>
<td>15.7</td>
<td>11.61</td>
<td>74.1</td>
<td>10.15</td>
<td>72.4</td>
<td>9.19</td>
<td>16.4</td>
<td>64.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.2.55</td>
<td>3228-31</td>
<td>3228</td>
<td>0.30</td>
<td>3228</td>
<td>15.8</td>
<td>11.20</td>
<td>71.4</td>
<td>9.09</td>
<td>69.7</td>
<td>8.76</td>
<td>17.8</td>
<td>57.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table

**Showing The Mill Test of Frosted Cane of Dehradun Union and Healthy Cane of Lakshar Union**

<table>
<thead>
<tr>
<th>Dates</th>
<th>Mads. Srs.</th>
<th>Cane Gross wt.</th>
<th>Milled. Juice</th>
<th>Net weight</th>
<th>Primary Juice</th>
<th>%</th>
<th>%</th>
<th>Mixed Juice</th>
<th>Brix</th>
<th>Pol.</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2.55</td>
<td>6245-27</td>
<td>4998</td>
<td>0.30</td>
<td>4945</td>
<td>15.8</td>
<td>11.63</td>
<td>73.3</td>
<td>8.89</td>
<td>71.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.2.55</td>
<td>4933-36</td>
<td>3875</td>
<td>0.30</td>
<td>3864</td>
<td>15.3</td>
<td>11.75</td>
<td>76.4</td>
<td>9.69</td>
<td>73.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.2.55</td>
<td>5474-37</td>
<td>4394</td>
<td>0.325</td>
<td>4390</td>
<td>15.6</td>
<td>11.27</td>
<td>71.8</td>
<td>9.59</td>
<td>69.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.2.55</td>
<td>2291-21</td>
<td>1782</td>
<td>0.25</td>
<td>1777</td>
<td>15.7</td>
<td>10.79</td>
<td>68.5</td>
<td>8.83</td>
<td>66.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.2.55</td>
<td>1353-15</td>
<td>1190-25</td>
<td>0.25</td>
<td>1187</td>
<td>18.3</td>
<td>14.94</td>
<td>81.9</td>
<td>10.83</td>
<td>79.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.2.55</td>
<td>1345-0</td>
<td>1157-27</td>
<td>0.25</td>
<td>1154</td>
<td>18.3</td>
<td>14.91</td>
<td>81.3</td>
<td>11.96</td>
<td>80.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IV.

February, 1955.  

**Mixed Varieties of Co. 453 & 421.**

<table>
<thead>
<tr>
<th>Healthy canes brought from unaffected area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantities of canes crushed.</td>
</tr>
<tr>
<td>Mds. Srs.</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>9182-96</td>
</tr>
<tr>
<td>5055-23</td>
</tr>
<tr>
<td>4453-22</td>
</tr>
<tr>
<td>5821-9</td>
</tr>
<tr>
<td>5691-37</td>
</tr>
<tr>
<td>6507-32</td>
</tr>
<tr>
<td>6040-31</td>
</tr>
<tr>
<td>1855-13</td>
</tr>
<tr>
<td>907-0</td>
</tr>
<tr>
<td>10571-0</td>
</tr>
</tbody>
</table>

V.

Conducted At the Janki Sugar Mills Limited, Doiwala.

<table>
<thead>
<tr>
<th>Last Mill Juice</th>
<th>Imbibi-</th>
<th>Imbibi-</th>
<th>Mixed Bagasse</th>
<th>Pol Pol</th>
<th>Recovery very</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Purity</td>
<td>tion Water. %</td>
<td>Juice %</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>4.08</td>
<td>66.5</td>
<td>1207</td>
<td>19.3</td>
<td>79.7</td>
<td>39.5</td>
</tr>
<tr>
<td>3.94</td>
<td>70.6</td>
<td>741</td>
<td>15.0</td>
<td>78.3</td>
<td>36.7</td>
</tr>
<tr>
<td>4.88</td>
<td>67.5</td>
<td>847</td>
<td>15.4</td>
<td>80.0</td>
<td>35.4</td>
</tr>
<tr>
<td>3.97</td>
<td>65.5</td>
<td>466</td>
<td>20.3</td>
<td>77.4</td>
<td>42.7</td>
</tr>
<tr>
<td>3.70</td>
<td>74.5</td>
<td>264</td>
<td>19.4</td>
<td>87.6</td>
<td>31.8</td>
</tr>
<tr>
<td>5.47</td>
<td>79.7</td>
<td>275</td>
<td>20.4</td>
<td>85.8</td>
<td>34. 6</td>
</tr>
</tbody>
</table>
The mill tests conducted by us at Shree Janki Sugar Mills Ltd., Doiwala between 11. 2. 55 and 15. 2. 55 are shown in Table V. In spite of our best attempts healthy canes of any variety could not be found from any field of affected locality, therefore, healthy canes were sampled from the unaffected Lakshar Union for comparison. Here also, a depression to an extent about 3 units in the recovery was found.

C. Effect of irrigation on the frost affected plots.

The general belief in the locality was that if lands were irrigated within, before or immediately after frosting, the canes are not much affected. A few samples collected and analysed on 16. 1. 55 by Shri A. P. Verma, Senior Research Assistant, Plant Physiology Section, Shahjahanpur at Shree Janki Sugar Mills Ltd., was considered by us and the results shown in Table VI.

Table VI.

Showing the effect of irrigation on frost affected canes.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Particulars</th>
<th>PH</th>
<th>Brix.</th>
<th>Pol. %</th>
<th>Purity %</th>
<th>Expected Recovery %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co.453</td>
<td>Irrigated</td>
<td>5.1</td>
<td>15.3</td>
<td>11.21</td>
<td>72.8</td>
<td>5.82</td>
</tr>
<tr>
<td>Co.421</td>
<td>Un-irrigated</td>
<td>5.5</td>
<td>15.5</td>
<td>11.66</td>
<td>74.7</td>
<td>6.11</td>
</tr>
<tr>
<td>Co.356</td>
<td>Half dry</td>
<td>5.0</td>
<td>17.0</td>
<td>12.15</td>
<td>71.0</td>
<td>6.16</td>
</tr>
<tr>
<td>Co.356</td>
<td>Full dry</td>
<td>4.8</td>
<td>18.8</td>
<td>12.78</td>
<td>67.7</td>
<td>6.18</td>
</tr>
<tr>
<td></td>
<td>(unirrigated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co.356</td>
<td>Irrigated</td>
<td>5.3</td>
<td>16.6</td>
<td>11.91</td>
<td>71.5</td>
<td>6.08</td>
</tr>
</tbody>
</table>

The results indicated in Table VI did not confirm the belief. A few more analysis was conducted through Hand Refractometer on fields, but no relation with the irrigation and the damage caused by frost was obtained.

To be more certain and to confirm the views of the belief, a few experiments on the frost affected canes in some Agricultural farm with the help of the District Cane Officer, Saharanpur were arranged. The plots were irrigated weekly. Although no proper record could be maintained, intimation was received from the District Cane Officer Saharanpur that green leaves shot out from the leaf tuft of the frost affected canes after a month or so and the juice quality improved. He further cited specific evidence that the variety EK 28 which suffered most due to frost and indicated poorest recovery, was greatly improved due to continued irrigation and they were transported to Delhi in the latter part of April for chewing purposes. All these confirm that continued irrigation for some time has beneficial effect on juice quality of frost affected canes.
D. Observation in Rampur District.

Similarly, at Rampur district, in the same area of Raza or Buland Sugar factories, the dews were frozen on the 1st and 2nd January, 1955, almost at the same time as at Doiwala. Due to freezing of the dews over the leaves, the aqueous portion inside the leaves cells were solidified and increased in volume, and consequently the cells were ruptured. This stopped the metabolic function and the leaves began to dry. The canes of this district were not only affected by frost but also suffered due to hail storms. The deterioration in sucrose content in the sugarcane crop set in soon after the frost and hail storm. In this district the intensity of affection in cane plants due to frost was much less than what had been observed at Doiwala. Hardly any field with complete dry leaves was observed. As before, a strong association between the drop in sucrose content and the intensity of affection was observed.

Similar experiments with sugarcane crops conducted at Doiwala (Tables II - IV) were also carried out at Rampur District. The results confirmed the observation made at Doiwala. The mill tests conducted at Raza or Buland Sugar factory indicated the same results as was observed at Doiwala. The results are not included in the paper to economise space.

Summary

1. Due to frost, the aqueous portion of the leaves cells solidifies, increases in volume and ruptures the cells. Consequently, the metabolic function of the leaves ceases and the leaves dry up causing a depression in juice quality.
2. The degree of depression in sucrose content in the frost affected crop has been found proportional to the intensity of damage caused by frost.
3. The intensity of affection due to frost has been found inversely proportional to the fibre content. Higher the fibre content lesser is the degree of affection.
4. The frost affected canes at Doiwala district have shown a drop of 1-3 units in sucrose content whereas in Rampur district the drop in sugar content did not exceed 2.0 units.
5. The immediate effect of irrigation over the frost affected canes is negligible but continued irrigation helps in the shooting up of green leaves and formation of cane sugar.

Acknowledgement.

The authors are indebted to Dr. K. S. G. Doss, D. Sc., F. R. I. C., F. Inst. P., F. A. Sc., Director, Indian Institute of Sugar Technology, Kanpur, for his kind encouragement and facilities offered in this investigation.

References.

Progress of Mechanical Sugarcane-Cultivation in India

By

D. H. Duyf,

General Manager, The Gwalior Sugar Co., Ltd., Dabra

(Madhya Bharat).

The sugarcane farmers in India have taken rapidly to mechanised farming. The big sugarcane plantations do all the preparatory tillage of land by fairly heavy tractors and modern implements. Many cultivators with smaller holding have followed this example with lighter types of tractors. The outcome of the work is good. The cost of jungle-clearing and preparing land for sugarcane cultivation is fairly low compared to the cost in other countries.

Since a large scale White Sugar Industry is comparatively new to India good use could be made of the latest technique of mechanical preparation of the seed bed. While adopting new methods the sugarcane farmers have made modifications on tractors and implements to suit local conditions. Side by side the bigger concerns have built up their own, well-equipped repair-and-service workshops, in some of these Diesel-fuel-injection Pumps are being tested and overhauled completely by properly trained mechanics.

Scope of Tractor Work.

Often the question is asked as to what is the minimum holding in India to allow the economic use of a Tractor. The answer is that there are Tractors of different sizes and for different purposes, but it appears that in sugarcane growing areas, a Farmer owning about 60 acres of land of which 25 acres under a cash crop like sugarcane can afford to keep a Tractor of about 30 H.P. He should use such a Tractor for ploughing, interculturing, transport work and other jobs like water pumping, spraying for plant protection etc. Smaller holders could pool their resources in a Cooperative Society and do their heavy ploughing work. In India the economics of Tractors versus bullock or manual-work is often discussed, however, since good bullocks have gone up in price considerably and forward farmers are becoming more tractor-minded, much is to be said in favour of Tractors, provided they are well-maintained.

Still the bullock is used widely also in large mechanical farms specially for interculture of sugarcane. It is my experience that with the comparative cheap labour and good bullocks in India, some of the land operations are done better by the old fashioned methods. However, Tractor work has always the advantage that land operations are done timely and “in season”. Also full advantage of speedy work by Tractors can be had when land operations are to be completed when the land is exactly in proper tilth. This will influence always better yields.

Preparatory Tillage.

There is nothing new to report here. The Conventional Ploughs and Harrows are used. We generally find that a Disc Plough is more useful for work in India than the Mould-Board. In the following pages I will deal with soil conditions as they exist in the Farms of the
Gwalior Agriculture Co. Ltd. in Dabra. The soils here are a heavy type of "mar" soil. To make land ready before sowing of green manuring or before sowing another crop after the ratoon has been harvested, the requirements are normally one ploughing and two harrowings. It is common practice after this work that the land is left fallow. Farmers who have got irrigation-water available will start putting in green manure under irrigation before the outbreak of the monsoon.

As regards the cost of ploughing and harrowing this depends on many factors and depends on the implements and tractors used, conditions for tractor and type of land under cultivation. We have worked wheel tractors on our estate whereby the cost came to Rs. 9/- per acre inclusive of depreciation while tractor-tractors could do the work, though gave a much larger output, at Rs. 16/- per acre to a depth of 11". This is the cost when Tractors and Implements are fairly new. If they are older the per acre cost goes up to Rs.25/- per acre. Harrowing is half the ploughing cost.

My experience is that one has to be very careful about the choice for tractors and once a tractor is in use it should be put to maximum utility. To check up the utility of tractors I have investigated in other parts of the world and in many parts of India the number of hours a tractor is in use and find that in countries with high rainfall the number of hours ploughing can be done in one year is between 900 & 1000 hours while in many parts of India a performance could be made of 2000 to 2500 hours per year. Also it is often found that ploughing is done in the wrong time of the year when the soil is hard, while a tractor could be used with much more efficiency when put in full use when the soil is a little moist and easier to plough.

As regards the number of hours of work per year there is certainly much advantage in using tractors for other purposes, also whereby for instance for a small holding a wheel-tractor can be used besides for ploughing of land also for interculturing of row crops, for driving a pump or another stationary machine, or for transport. In that case, with the same establishment, much more utility is created for the tractor and thus cheaper overall work. With trac-tractors there are also various possibilities specially in large Concerns which own sugar factories and farms. In Dabra a heavy tractor was used successfully for making many miles of drains upto 6 ft. deep with the help of a chain tractor fitted with a dragline. At a cost of Rs. 18/- per 1000 cft. Another tractor of the same type is used with an attachment of a grapple and works for 5 months of the year for unloading of sugarcane at the sugar-cane carrier. In some Farms the attachment of bulldozer is useful. One of our tractors which was going "to be pensioned" is now put to work to drive a baling press for a large harvest of paddy straw. This is light work and the tractor concerned gets another lease of life.
As regards preparatory tillage we have made in Dabra on rather a big scale experiments with a big size Rotavator. This was purchased in 1950 at the cost of Rs. 13,000/- and attached to a 80 H.P. Tractor. The Rotavator was primarily used to plough large areas under green manure and did this work successfully, if there was a sufficient long break in the monsoon. Subsequently it was used for burying sugarcane trash in the fields after the second ratoon was harvested. This burying of trash can only be done successfully if the soil is reasonably soft. In clayey soil which has been exposed to the sun for some time it does not work because the rotating knives cannot penetrate successfully and it takes much too much power of the tractor at high expense to handle such type of soil.

Soil Improvement.

To prove the utility of ploughing back large quantities of trash and crop-residue in the soil will bring us to the subject of soil scientists. I wish to state here only that soils which are subject to hot sun for a long period and which soils are irrigated frequently or receive heavy rainfall, soon will lose its original fertility. The loss of organic matter is rapid under such circumstances. It is therefore most important to build up organic matter again and not let the micro-organism disappear gradually. Ploughing in of organic matter helps but the farmer has to help it to decompose. Green manure which has collected nitrogen in nodules decomposes fast. In India specially in regions with heavy soil and hot winds the farmer has to continue the process of ploughing in organic matter. Also keeping a crop-cover in the hot season will help to maintain fertility by preserving organic matter. Therefore we have experimented here on a large scale to sow green manure two months before the monsoon. Study of the soil and the crop proves that with the maintenance of organic matter, considerable economics can be made on the fertiliser bill and the land keeps its potential value.

Ratooning of Sugarcane.

In this crop 100% mechanisation can be applied.

After the harvest of plant cane the field left behind should receive immediate attention for ratooning. Much scientific and practical study of ratooning has been made in the Dabra sugarcane farms. The aim was to create such conditions for growth of the Ratoon crop which nearly equal tillage and seed cane, and sowing is quite a high expenditure on the plant crop, this heavy expenditure can be divided over plant and Ratoon cane and thus the burden of this heavy initial expenditure on both crops will not be so high. Generally we find that Co. varieties like Co. 453, Co. 312 and Co. 617 are vigorous ratooners.
To begin with, we experimented by cutting down the stubbles by hand with specially sharpened gourahs until 4" below the top of ridge. The tillering and subsequent growth on such cut-off ridges were always more vigorous than on the "untreated" ridges, the deeper eyebuds gave better and easier tillering. Moreover, the earth so cut-off had a chance for aeration again and could be used later for "earthing-up". Another advantage was that weeds developed between the plants on the ridge could be exterminated.

Hand cutting of cane stools normally is very slow, so we use since the last 6 years successfully a stubble-shaver to deal with this important problem. This handy implement consists of a frame on 2 wheels (preferably with pneumatic tyres) to which is attached a fast revolving blade with knife-edge of 30" diameter. Via 2 bevel wheels it is driven by the power-take-off of a Tractor which pulls the implement at a speed of 2½ miles/hour over the ridges. For adjustment while "on the run" and differing while turning in the headland the stubble-shaver operator travels on the machine. Skill and endurance is required of this man, and he gets extra pay, but the job done is most effective for successful ratooning.

The next operation is proper off-barring. We have tried with ordinary disc harrow though there was much danger to the stool and less germination. Then rigid-tines and spring-tines were used. In sandy soil sometimes the plant was dislodged, while in hard clay soil the tines could not penetrate sufficiently - the best we found was the so-called disc-bolider which is a gang of 5 cut-away discs bar controlled by hydraulic lift. We now manufacture these implements locally from worn-out harrow discs, and they are very useful in the hard ratoon field.

After irrigation and growth of the plant the field is treated again by a tractor-equipped with fertiliser-bins and a tool-bar with middle buster for a light-earthing up. The outlets of the bins drop the fertilisers exactly where required and a furrow is made with the middle busters, thereby slightly packing the plants and making the beginning of a ridge like in plantcane. The same Tractor with fertiliser-bins springtines or middle-busters attached to a hydraulic tool-bar is used for Plantcane in the early stages.

We normally plant and ratoon 3' foot apart with varieties like Co. 453 and Co. 717, sometimes we give a second earthing after the cane is 2' high. At the same time the
before putting the land under sugarcane. Those cultivators who wish to do planting in the month of October very often have no spare time to attend to the crop because they are busy with the harvest of the Kharif crop and sowing of the winter crop. Thus in that time of the year there is very little labour available in rural areas. The same is experienced in Dahra where in the past because of shortage of labour in the months of September and October about 300 acres out of 800 acres sugarcane could be planted by hand, and the rest was done from the end of January till the middle of February when more labour was available.

The early crops always give a better yield and at the same time have developed a good root system by the time the hot season sets in and thus can easily survive the hot weather. In order to complete all planting before the end of October we had to make our own Mechanical Sugarcane Planter, which I am describing below:

**Mechanical Planter.**

The small machine as used here, is attached to either a tractor of 24 H.P. or to a tractor of 32 H.P. The first design made locally was based on an existing Potato Planter which was fixed on the hydraulically controlled Tool-bar of the Tractor. Two men drop sugarcane seedlings through chutes which seedlings are laid behind the middlebusters which make the furrows. The seed is covered up again by earth, falling down after the tractor has passed. When these machines were new in our Farms it was interesting to encourage this kind of planting whereby the Farm Overseer tries to make the best possible modifications to increase the output. When a Case Planter is used it is very important that no time is lost by the refilling of the Hopper of the Planter. We find now that best method is to load the seedlings after they have been dipped in an antiseptic solution, packed in bags. This makes handling easier and cheaper at both ends of the field.

If soils are of good tilth and fine structure these Planters with trained operators can work faultlessly and the field can be irrigated immediately after the planter has been over the field. If the land is full of clods then it is necessary to let labour work over the field to cover sets. Actually we conducted this covering operation in clotty soils with the addition of fertiliser, so that this does not become a separate item of expense. It will be possible to construct for soils of good structure a simple planter with fertiliser attachment for two furrows. Such planters will assure a good performance and speed.

**Dyer Carrier Planter.**

We have also given an illustration herewith of a bigger planter, which has been built on a big size Dyer-carrier with three subsoiler standards. The standards have wings to make the furrows (3 at a time) and the chutes are built in such a way that the seedlings just drop on rolled-back earth. The hopper is of big capacity. While turning and travelling
furnows become better channels for irrigation and later in the rainy season useful drains, which is very important for heavy soils like those in Dabra.

I have been dealing at length with the subject "Ratooning" because it is so important to do the land operations in time. In an sugarcane plantation all labour during harvesting are geared on speedy harvesting and often labour is not available to attend to work on the crop for next year and timely ratooning is often neglected. Therefore mechanized ratooning comes to us as a solution of quite a problem and helps for better yields and cheaper cane-production.

Cost of Stubble Shaving.

Because of the rapid wearing out of the revolving disc (cost Rs. 200/-) of this implement, the cost compared to labour cost is rather high. Allowing depreciation on an initial cost of Rs. 300/- of the whole stubble-shaver, the cost per day with an output of 6 acres at a speed of 23 miles per hour is Rs. 76/- or Rs. 12/- per acre. The cost for labour per acre is the same. The main consideration however is that Ratooning (stubble-shaving) is also to be done during the very busy harvesting season, so no labour is available for cutting the Ratoon Stubbles.

Cost of Final Earthing-Up.

Tractor with Middle Buster: Rs. 7/-
Bullock & Ridger: Rs. 12/-
By Hand: Rs. 12/-

Here we see that it is distinctly cheaper to do the work by Tractor, at the same time a Tractor of 36 H. P. can do 18 acres per day, while a pair of bullock does 2½ acres a day. For one acre earthing 10 men are required who earn Rs. 1/4/- per day. So the cost by hand thus comes as high as Rs. 12/6/- which is very high indeed and which the advent of modern Tractors impracticable, even in a country where labour is not expensive.


The cutting of seed-cane and the planting of the sugarcane sets normally with two eyebuds are done by hand. The furrows in which the cane is planted are fairly shallow but many farms plant to a depth of 6" and later on earth-up all the sugarcane growth on built-up ridges. Planting by hand is done with great care with eyebuds placed sideways for better and equally timed germination. While in Southern India and specially in the Deccan area planting is done as early as the month of June, and the crop reaches maturity after 18 months, in most part of U. P. the planting is done in the month of February and the average crop is allowed a total growing time of about 11 months. In Northern India it is now generally agreed that there is a great advantage in early planting say in the month of October, the trouble is that the cultivators cannot get their land ready in time and some cultivators even try to get a small crop during the winter.
the whole hopper can be lifted up with the help of a wheel-clutch. It works very well in heavy soils and specially in plots which are longer than our conventional 10 acre plots of 660 ft. sq. This machine has the great advantage that it can have more output, however, the loading of seedlings needs more labour. Pulled by a tractor of 60 H.P., it can cover 12 acres a day. One has to be careful again in selecting trained men for this work. While we do work at a pitch we have to keep two shifts on this implement.

**Cane Cutter.**

Because of the speed of the planting, and shortage of labour the cutting of seedlings is also done mechanically with the help of a kind of chaff-cutter attached to a stationary small Japanese Tractor.

### Cost of Mechanical Planting

<table>
<thead>
<tr>
<th></th>
<th>Small Tractor 24 H.P.</th>
<th>Hopper &amp; Tractor 36 H.P.</th>
<th>Dyer Carrier Planter</th>
<th>Hand Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output per day of 12 hours</td>
<td>4 acres.</td>
<td>7 acres.</td>
<td>12 acres.</td>
<td></td>
</tr>
<tr>
<td>Labour required on Tractor and Hopper</td>
<td>6.</td>
<td>6.</td>
<td>8.</td>
<td></td>
</tr>
<tr>
<td>Other labour required for cane cutting transport etc.</td>
<td>29</td>
<td>54</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>Total labour.</td>
<td>35</td>
<td>60</td>
<td>96</td>
<td>119</td>
</tr>
<tr>
<td>Cost per acre per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Labour.</td>
<td>10-0</td>
<td>9-0</td>
<td>9-12 Labour</td>
<td>13-8</td>
</tr>
<tr>
<td>(b) Tractor.</td>
<td>7-8</td>
<td>4-9</td>
<td>12-0 Ridging.</td>
<td>5-0</td>
</tr>
<tr>
<td></td>
<td>17-8</td>
<td>14-1</td>
<td>21-12</td>
<td>18-8</td>
</tr>
</tbody>
</table>
From the above it can be seen that there is only a distinct advantage as regards cost when the planter attached to the 36 H. P. Tractor is in operation. In lighter soil than ours the cost of Rs. 16/- can be reduced to below Rs. 10/- per acre, but still the same number of operators and labourers is required.

The main consideration however is the speed of work and to complete this planting, with much less labour, in the shortest possible time. Even the big Dyer Carrier Planter comes in useful with a capacity of 12 acres/day. We have stated earlier that there are many handicaps with the Farmers in Northern India to complete what we call autumn planting, which is planting done later than Adasali planting like in Deccan, but it gives the advantage to get the cane planted and allow it to germinate, say by the 1st week of November, i.e. before the cold winter comes to the plains of Northern India.

If the rains are not too late, preparatory tillage can start by the middle of September and planting by the end of September. After deducting the customary holidays I work out that 36 working days can be had by the 10th of November when we normally stop planting work.

In case 700 acres are to be planted within 1st October to 10th November, 3 Hopper Tractors 37 H. P. will be required for planting 20 acres per day or the whole area within the prescribed time with minimum labour.

For 3 Machines.

For Tractor and Hopper 18 men. 100 men.
For other work total. 162 men. 240 women.

From the above it will be seen that for completing the programme of 700 acres in time with mechanical means, 180 labourers are required per day for planting 20 acres of whom 18 fairly highly skilled, against for hand planting at least 340 labourers per day for planting 20 acres which are difficult to recruit when in rural India every body is busy to reap the Kharif crop and plant the Rabi crop.

October planting though a bit more expensive in labour, seed and irrigation gives a definite increase of yield over February planting, which increase I estimate to be in Northern India well over 25%. It is therefore in the interest of the Planter and the sugar manufacturer to increase the yield by adopting early planting in October and do this successfully with a simple type of mechanical planter which can be manufactured locally.

The initial cost of the planter as used on a 36 H. P. Tractor costs when made locally about Rs. 250/- assuming a Tractor is available with hydraulic-operated tool bar and middle-buster.

Green-Manure.

With the progress in Agriculture in India specially in irrigated areas, the cultivator has become increasingly fertilizer-and manure-minded. Foreign visitors to India will now observe that in better developed areas the cow dung is no more used as fuel, but as a valuable manure! Also the farmers are developing the increase of green-manure. There are many legumes like the famous moong of the U. P. and cowpeas used very successfully. With bigger Farms much use is made as green manure in the rainy (summer) season —

San or Sasai or Sunhemp (Crotalaria Juncea) Dhaincha (Sesbania aculeata)
These popular green manures can be grown at fairly low cost and will give at least 55 lbs. of Nitrogen per acre plus a lot of organic matter. Both grow under irrigated conditions luxuriously and also under well divided rainfall. When plenty of irrigation is available the seed can be put in (broadcasted behind a disc harrow and covered with a plank) attached to the same implement. A set back is that it is difficult to bury the crop timely after say 7 weeks of growth, because the land is wet.

If the crop is grown under irrigation it can be put in early i.e. before the real monsoon has set in and the land is at a later time rather unworkable, specially clay-soil. Early sowing has the advantage that the green manure rots completely before the land is made ready for sugarcane planting.

Normally the Farmer in India waits till the rain come and then tries to plough in the month of August, but then rainfalls abundant. If he is lucky and gets a dry spell, then a plough or harrow may do the trick, however often the tractors get bogged and no progress is made.

In our Farms we have to deal every year with 800 acres of green manure. The Rotavator and Harrows do good work when conditions are favourable, though more often than not the work is held up in late planted sanai because of excessive rain on our sticky soils. The cost per acre of burying green-manure is anything between Rs. 18/- and Rs. 30/- per acre.

Meanwhile we had made locally for all our wheel-tractors so called puddling wheels as shown in the illustration herewith. It is a simple attachment on the rear-shafts of a wheeltractor used here for puddling land for paddy, which paddy is grown primarily to destroy kasgrass which appeared in our fields after sugarcane. The use of these wheels in green manure obviated heavy and expensive ploughing work in such lands after inundation by rain-water or irrigation-water. The thus equipped Tractors took like a duck to water.

The green manure buried in this way with these specially equipped tractors is just buried as we want it without any loss of power and expense. Attached to the hydraulic toolbar a wide plank is attached to smooth down the plants and cover slightly with sludge. Precautions have to be taken to keep the water in the field with the help of bunds, but the work is done as a complete job at very low cost. The water is to be drained immediately after the Tractor leaves the field.

Cost of ploughing under wet condition average. Rs. 24/- per acre.

Cost of trampling with puddling wheels. Rs. 7/- " "

Summary.

We have described in this note various practical methods of modern Indian Sugar-cane Farming. The main object is to give
my fellow Farmers the benefit of our experience in this part of India.

The main points stressed were the good use our Tractors can be put to for achieving timely land-operations. The methods described when followed up will bring better yields to the cultivators and side by side bring down the costprice of sugarcane. In this way the sugar Industry in due course will produce sugar at a lower costprice.
A mill engine does a lot more than squeeze the cane between the ‘feed’ and ‘discharge’ rollers of the three roller mills of the tandem.

The engine has to overcome many different kinds of resistances and by no means does the cane absorb all the power in its passage through the mills.

The total power required is dependent on:

1. Number of mills
2. Speed of mills
3. Hydraulic loads
4. Fibre per unit time
5. Settings
6. Gear efficiency
7. Engine efficiency
8. Gear and scraper friction
9. Trashplate friction
10. Inter carrier friction
11. Nature of fibre

and it would be impossible to concoct a single formula which would show the effect of all these factors.

Fibre per unit time and the number of ‘pressings’ are occasionally linked together in BHP calculations. The Formulæ given below are based on mill details only of a 3-roller mill and these were published many years ago by someone whose name unfortunately is not now known.

### Power to grind cane.

\[
Q = \text{hydraulic load in metric tons} \\
D = \text{Diameter of roller in metres} \\
V = \text{Peripheral speed in metres per min.} \\
L = \text{Length in metres} \\
\]

\[
\text{Power for milling fibre = } \frac{Q \times D \times V}{0.032} \\
\text{Frictional HP of bearings = } \frac{Q \times V}{0.00195} \\
\text{HP absorbed by trashplate = } D \times V \times L \times 1.315 \\
\text{Fricition HP absorbed by gears, scrapers, carriers etc = } \frac{22\% \times \text{total}}{100} \\
\]

If we apply these formulæ to a 30" x 60" mill having a peripheral speed of 30 ft per min then we get the following results:

- HP for milling fibre = 85.45
- HP for bearings = 59.81
- HP for trashplates = 13.94
- HP for gears = 35.02

Total 194.22

of which 44% was required for milling fibre. In the above the hydraulic load was 336 metric tons.

### The Trashplate.

From the following data:

- Trashplate size 15" x 60", crush 1200 tons
- 15% fibre, coefficient of friction over the
trashplate 0.45, 280 lbs. fibre per minute we arrive at the following figures:

Pressure per sq. inch on the plate...... 38.60 lbs.
The fibre at any instant on the trashplate is given by $280 \times \frac{15}{30 \times 19} = 11.70$ lbs which is equivalent to 0.103 lbs. per sq. inch of surface.

During working the amount of fibre which enters the mill must be the same as the amount that passes out. There cannot be any packing or else the discharge roller would be passing more fibre than entered and obviously this is not possible when the plate is properly set. On the other hand when the slope is too great and the heel does not curve into the approach to the discharge opening packing does take place and the hydraulic weights begin to work spasmodically.

If the Trashplate drop is calculated on an allowance of 140 cuins per pound fibre per min: the drop in this case would be 1.95 inches. Treated as a rectangle the volume above the plate would be $60 \times 15 \times 1.95$ or 1755 cuins. Half this space is occupied by 11.7 lbs. fibre which works out to 79.5 cuins per lb.

There is very little that engineers all over the world know about a trashplate. For instance who knows anything about the movement of bagasse over the surface; does it move faster at the roller or has it a uniform motion; does the opening at the feed roller bear any relationship to the feed opening and if it does then where does the 13 degree angle come into the picture. Is the slope really necessary? In theory the surface is part of a rectangular spiral and the slope is 4% of its width but after a heavy crop it is none of these things. After the crop the plates exhibit some weird shapes and settings, perhaps 50% of the teeth have broken, the heel gap is more than an inch and yet there has been no mill trouble. Perhaps the plate has been blamed for a great deal for which the rollers have been responsible.

It appears to be the set practice to reduce the Trashplate drop from mill to mill. This procedure is unwarranted. With compound maceration there is very little change in the composition of the material entering each mill from the point of view of moisture and fibre contents. It should also be borne in mind that the grooving in the later mills is of smaller pitch in which case, logically, the drop should be increased rather than decreased. Another reason for keeping the drop the same is that the fibre absorbs all the added water and in passing through the feed has a great many pockets of juice which need room to sort themselves out before reaching the discharge roller. A reduction in the drop is therefore detrimental to back roller extraction.

The "roaring Mill" is still thought to be the hallmark of good work whereas it is the audible complaint of a mill against a maladjusted trashplate. Friction over the surface is excessive, the top scraper develops a high frequency vibration and sometimes the draw bolt of the trashplate fractures. A mill should hum under the strain but the noise should not fill the whole factory. The roaring mill will make deep grooves in the plate surface but if the plate had been properly set all signs of grooving would disappear midway while at the toe end the grooving would be shallow.

Of far more importance than the exact slope is the curving of the heel into the approach to the discharge opening. The plate tooth ridge should make an angle more than 90 degrees to the line joining the point of
contact to the centre of the roller and the trash bar should be dead under the centre of the top roller.

It is also advisable to give each mill a trash plate with its own particular profile and not to use the same form for all the mills.

**How much slope.**

Noel Deerr gave us the Height-Pressure formula. Within a certain range of pressure the relationship

\[ \text{height} \times \text{pressure}^4 \text{ is Constant.} \]

Let us assume that the average pressure on the trash plate is located where the drop is measured, that is, under the centre of the top roller.

If the average pressure is 40 lbs. per sq. inch then the sum of the extremes at the toe and heel must be 80. In other words the pressure at the toe might be 60 and at the heel 20.

The drop was given earlier as being 1.95

If \( P_a \), \( P_b \) and \( P_c \) be the pressures at the toe, centre and heel and if \( h_a \), \( h_b \) and \( h_c \) be the respective heights then

\[ h_a P_a^4, h_b P_b^4, h_c P_c^4 \text{ must be equal,} \]

where \( h_b P_b = 1.95 \times 40^4 \), where \( P_a = 60 \) and \( P_c = 20 \). This gives a slope of 0.914 inches showing that the toe is too high and the heel too low. Using 56 and 24 instead of 60 and 20 the slope becomes 0.69.

Noel Deerr proved that if bagasse is allowed to expand between successive pressings of the same pressure intensity more and more juice is expressed.

The behaviour of the bagasse between the top roller and trash plate imposes a limit on the extent of the expansion which by practical necessity is satisfied by the 13 degree angle and a 4% width of the plate as the slope. These two conditions shorten the difference between the pressures at the toe and heel.

The writer does not guarantee the figures as set down and whether we accept them or not does not matter but from them it is possible to learn something useful.

**Roller Journals & Bearings.**

The fitting of roller journal is a science and not an art. A little more than red lead and scraper technique is required to stop journals from wearing at the inner fillets. This sort of destruction is to be seen in many factories and some engineers have expressed the view that such wear is inevitable. Heavy wear at the inner fillets clearly shows that high pressures have developed at these places and thence we must conclude that an otherwise well fitted bearing has somehow failed. The deflection formula for a freely supported uniformly loaded beam is

\[ \frac{5 W L^4}{384 E I} \]

and a 30 x 60 roller shaft carrying a uniform load of 55 tons per foot between the outside fillets will deflect about 0.003". To allow for this deflection the insides of the bearings should be free of 'markings' while the outsides should bear a little hard. If this is done, as soon as the rollers take up the hydraulic load the shafts will deflect and distribute the pressure all over the bearing surface. Occasionally one finds a 14" journal measuring 13½ at the inner fillets. This will not happen if the bearings are set up as described.

**Fuel Economy.**

Fuel economy is bound up with heat conservation. To conserve heat the following precautions have to be taken:
1. To prevent the escape of heat from valves, glands, leaking joints, uninsulated pipes, blowing safety valves, engine drain cocks, bypassed steam traps, excessive carryover from boilers, too wide piston ring gaps.

Notes—

At 160 psig a leak area of 0.04 sq.ins will pass 350 lbs steam per hour and this should help to indicate the vast loss of heat in a factory where steam is blowing all over the place.

2. To reduce the amount of work to be done by speeding up the process by operating at a higher load factor and the wetness of steam to the prime movers.

3. Level out as far as possible the peaks and valves.

4. Use the full boiler pressure and reduce the back pressure.

5. Stop loss of condensate and loss of temperature, curtail the size of the collection tank and lag all pipes and the tank.

6. Use the condensates of the 2nd, 3rd and 4th cells where normally cold water is used and for maceration.

7. Reduce blow-down losses by using clean condensate.

8. Seal off the boiler and flue brickwork against air infiltration.

9. Bleed steam for heating but not when there is ample exhaust available.

The fundamentals of Fuel Economy are—

1. To make a pound of bagasse generate more steam.

2. To make a pound of EXHAUST do more heating.

3. To make a pound of boiler steam produce more power.

Bagasse will generate more steam when its moisture content is reduced, when the FEED Water temperature is increased and by pre-heating the air for combustion.

An ECONOMISER will look after the FEED Water temperature and broadly speaking.

(a) Every degree rise in FEED temperature lowers the flue gas temperature by 2 degrees.

(b) Every 10 degrees rise in FEED temperature saves one percent fuel.

If the flue gas temperature is reduced from 600 F to 350 F saving would be 12.5% but in practice actually about 11%. For an AIR PRE-HEATER it is claimed that for every 30 to 35 degrees rise in temperature 1% fuel is saved. If from an initial temperature of 80 F the air is raised to 460 F, that is, a rise of 380 degrees then 11% fuel would be saved.

To this be added the advantages of Balanced Draught which eliminates air infiltration, controlled excess air, reduced fuel entrainment and gives a steady steam pressure, greater flexibility of steam generation and better combustion of bagasse. It should be possible to reduce the consumption of bagasse by 12 to 15% by the installation of both the ECONOMISER & AIR PRE-HEATER so that a factory which operates on 34% bagasse on cane—an all steam driven factory — would then work with 28% bagasse on cane.

The pound of EXHAUST will do more heating when the proportion between the boiler heating surface in use and the CONDENSING SURFACE (manufacturing house Heating Surface) are in proportion. A rough guide is that there should be 1.24 sq. ft. of condensing surface to every sq. ft. of boiler.
heating surface. The condensing surface should be correctly proportioned between Juice Heaters, Evaporators and Pans. Whenever possible "bleed steam" heating should be done.

The pound of steam will produce more power when the thermo-dynamical efficiency of all the prime movers is improved. A 100 to 150 degrees of SUPERHEAT achieves this. Engine types vary in steam consumption per horse power. A piston valve takes 39 to 42 lbs. per HP whereas a Drop Valve engine will require 33 to 35 pounds of steam per HP. With the latter higher steam pressures are an advantage.

100 degrees of Superheat saves 10% fuel and 150 degrees about 14.5%.

A SUPERHEATER does not reduce the temperature of the flue gases so that fuel saving by reducing the flue gas temperatures by means of an ECONOMISER or AIR PRE­HEATER or both is still possible.

Milling Efficiency.

Efficient milling is not possible unless everything in the mill is just right.

The mill engines must have the power in proportion to the fibre rate per hour, the roller journals must be large enough to sustain a hydraulic load of 33 to 60 tons per foot length of roller, the roller bearings must be in good condition. In the boiling house the evaporator must be large enough to handle up to 30% added water. The cane knives must do a good job.

The aim of milling is to produce a low density juice from the last two rollers of the last mill combined with a low moisture content in the final bagasse.

The IDEAL BRIX CURVE tells us the lowest value which can be reached and the actual curves of brixes produced by the mill tells us where the mill is not functioning properly.

The "Fibre in the primary bagasse" indicates the efficiency of the primary mills and the higher it is the better the performance. Hence the first thing to do is to get the crusher and first mill working against the hydraulic loads with the feed roller of the first mill getting rid of a high percentage of juice. At the bagasse from this mill should be tested for sugar and moisture. If these two tests are satisfactory then concentrate on the 2nd mill in an endeavour to get a brix near to the Ideal as possible.

This process is to be repeated for the subsequent mills. It is necessary to make sure that the mill as a whole is working properly, that the feed is reasonably constant and that the compound maceration system is functioning well and that the mill engines are running at their proper speeds, this is, the speeds for which the mills have been set.

The "Fibre in the primary bagasse" is the most important single feature in the whole milling process and determines the final result more than any other secondary mill.

When the Primary Extraction is high the control of other mills is easier. When the milling efficiency is high the difference between the purities of the primary juice and the last mill juice is certain to be anything up to 18 units.

This means that the E. R. Q. V. LMJ/PJ will be low and this low figure is often interpreted as being due to bad sanitation whereas it is nothing of the sort.

Mill Control by Brix Curves is essentially the responsibility of a Chemist with such experience. If such a Chemist is not on the
Laboratory Staff then the factory is losing recovery. Without this kind of information the Engineer cannot be blamed for his bagasse losses. Mill Control is a whole time job and the sooner this is realised the better for all concerned.

Future Trends.

Twentyfive to thirty years ago the boiler steam pressure rarely exceeded 125 psig. It was the universal belief that higher pressures were not suitable for Sugar Factories. Java was using multistublar boilers with large drums at 100 psig and large engine cylinders.

To reduce the size of the boiler drums Steam Reducing Valves were introduced, steam was generated at 160 psig and reduced to 125 psig while the size of engine cylinders remained much the same.

With the growth of electrical power came the semi-electric factory to be followed some years later by complete electrification but the uneconomical aspects of the double conversion of energy, namely, steam to electrical and electrical to mechanical remained. Now we have the Steam Turbine.

The major portion of mechanical power in a factory is absorbed by the mills and the centrifugal machines and with the turbine drive at these two places and electrical power elsewhere, using high pressure steam, bagasse economy is sure to be stepped up.

In an ordinary steam engine driven factory the elevation of steam pressure from the now common 160 to 200 psig would mean a rise in the Adiabatic heat drop from 107.3 to 123.3 with exhaust pressures of 10 and 15 psig respectively.

If sufficient Superheat is added to give a dry exhaust, that is a final temperature of 600 F the adiabatic heat drop would be 146.3 and theoretically the steam consumption for power would be cut by 20% while the loss of exhaust steam due to initial wetness would be eliminated and partly offset the reduction in the available exhaust.

If evaporators and pans could be designed to use steam at 20 psig with boiler pressure at 250 psig we get a two fold advantage namely lower power steam consumption, a ready means of creating a shortage of exhaust steam.

It looks as if in the not too distant future we shall see some remarkable advances in fuel or bagasse economy now that bagasse is not a waste product but a raw material for new industries.

Overhauling Machinery.

For how many seasons should an engine work in a sugar factory before it is stripped for complete overhauling.

Vertical High Speed engines are to be found in a great variety of industries which have no dead season. They work non-stop day in and day out for considerable periods. One advertisement states that an engine worked for 40 years during which only a piston ring was changed.

Let us try to find an answer to the above question because constant overhauling of such engines eventually results in renewals and in sugar factories it has become more or less an annual necessity. It is a pernicious practice and something should be done about it.

How did one engine work for forty years? The reasons probably are as follows —

1. It was installed in a dustless room.
2. It was given clean steam free from suspended solids.
3. It was perfectly lubricated and the oil
in the crank chamber was free from emulsion and at normal temperature, about 136 °F.

4. It was perfectly fitted, that is, bearing tolerances, the oil pump was functioning properly and maintaining 20/25 psig pressure.

5. The gland packings were just tight enough or the metallic glands were a perfect fit.

6. The swab was not used to oil the piston and valve rods.

An engine which is run continuously is better off than an engine which is frequently stopped for the good reason that no rust forms in the cylinders. The oil in the cylinders of a High Speed Engine is being continuously washed off and within an hour of stopping the rust is visible. In the case of an engine lubricated with a compounded oil the surface of the cylinder is always coated with a film of emulsion which protects it for a longer period after it has stopped. The rust causes wear of the rings and valves. The steam from a sugar factory boiler is not clean because during the periodic cleaning raw water is used, the suspended solids are increased and are never got rid of during the whole crop. In some factories this trouble is much more than in others. The atmosphere, especially, towards the end of the crop, is dust laden and the wicked swab adds to the abrasive dust. All other conditions are attainable and it is up to the engineers to attain them.

Nevertheless an engine should work for five seasons without there being any need for scraping bearings changing of rings, skimming of piston rods and valve rods, renewing of metallic glands. Immediately the engine is stopped at the end of the crop the piston and valve should be removed and all parts greased and the covers put back. The swab should be ruthlessly eliminated and the best glands and packings used. The annual cost of repairs can be reduced by careful and intelligent overhauling.
The Introduction of The Defecation Method For The Production Of Raw Sugar In Natal

By

K. Douwes Dekker Ph. D.,
Director, Sugar Milling Research Institute,
University of Natal, Durban (Natal)

N. B. In this paper the main systems of juice clarification are called:
(a) the defecation system, when lime
(b) the sulphitation system, when lime and sulphur dioxide
(c) the carbonatation system, when lime and carbon dioxide are used as main clarifying agents.

Raw Sugar Production

In most raw cane sugar producing factories mixed juice is clarified by the defecation method. The method is cheap, the quantity of lime being roundabout 1.5 lbs. per ton (of 2,000 lbs) of cane. Generally speaking the results of the defecation system are satisfactory, although complaints have been heard when "difficult" cane had to be processed, and also when the refining qualities of some raw sugars were discussed.

In Natal it has been customary to clarify mixed juice by sulphitation process, both for the production of raw and mill white sugar. The necessity of applying the more expensive sulphitation process, using up to 5.7 lbs of lime, 2.0 lbs of sulphur and 0.7 lbs of phosphoric paste per ton of cane, has been queried from time to time, but the general opinion, partly based on trials carried out long ago, and incompletely described, was that the nature of the Natal juices did not allow them to be clarified with lime only.

However, in 1954 season, one of the mills decided to make a serious attempt at introducing the defecation system, and with the cooperation of the Sugar Milling Research Institute, succeeded in making it a complete success. At present (October 1955) altogether five Natal raw sugar mills clarify mixed juice by the defecation process.

A few questions arose however in connection with the change over from sulphitation to defecation. As such should be mentioned:
(a) will recovery be affected by the change over?

Since it is not likely that the Undetermined Loss of sucrose will be influenced significantly, a change in recovery will be due either to more or less sucrose respectively being lost in filter cake, or in final molasses. Java experience indicates that sulphitation factories produce more filter cake and lose more sucrose in this product than defecation factories, as is shown by the following average data for the years 1938 - 1940. Pol. in filter cake % pol in cane in defecation factories 0.57, and in sulphitation factories 0.84 respectively. It is true that the Java factories operated plate and frame presses whilst Natal factories have ins-
talled rotary filters, but since the quantity of bagacillo has to be proportional to solids in mud, it may be expected that in Natal also the weight of filter cake in defecation factories will be somewhat smaller than in sulphitation factories (the more so since Natal sulphitation factories use more lime and sulphur than Java factories) and that defecation factories will lose less sucrose in this product. Reliable actual data are however not yet available.

With respect to the exhaustion of the final molasses it was realised that a change of viscosity might have some effect. If defecation molasses is more viscous than sulphitation molasses, maximum exhaustion might be endangered, particularly if the capacity of the C - centrifugal battery is not generous.

Literature does not provide information on the relative viscosities of defecation and sulphitation molasses produced from the same cane, but the following data were thought to indicate that defecation molasses is slightly more viscous. About 1928 the Java sugar industry operated a great number of defecation mills and it was thought that the average number of forerunners of the two groups could be considered as providing some information on the relative viscosities of the final molasses produced by the two systems of juice clarification, since there were no reasons to assume that on the whole there would be much difference in the quality of the grain of the D - strikes, in the cane varieties crushed by the two groups, or in the climatic or other conditions affecting the growth of the cane. Nor was it reasonable to assume that the owners of one group of mills were prepared to spend more capital on centrifugal capacity than the owners of the other group, in an attempt to achieve a lower purity of final molasses. Since 60 defecation mills had installed a centrifugal capacity, which on the average was equal to 1.37 (40" x 18") pre-cutters per 100 metric tons of cane crushed per 24 hours, and 73 sulphitation mills a capacity equal to 1.21 pre-cutters, the conclusion seemed justified that Java defecation molasses was slightly more viscous than sulphitation molasses.

Attempts were made to confirm this conclusion for Natal conditions by determining the viscosities of the last sulphitation molasses produced before the change-over to defecation, and of the first molasses produced after that moment. Samples were first brought to the same purity. The tests have not yet been completed, but the first impression is that differences are slight. This result agrees with the fact that recovery seems to be, at the utmost, unimportantly affected by the change-over, but some caution is required in connection with this statement since the usual fluctuations in weekly and monthly factory data prevent drawing very strict conclusions.

In this connection one point should not be forgotten. It is well known that the brix of final molasses differs considerably from the dry matter content, but it is not always realised that this difference depends on the method of clarification applied.

To calculate the (approximate) dry matter percentage of final molasses, Sijlmans in Java used the following formula for defecation molasses:

\[
\text{Dry matter percentage} = \text{Brix} - 0.72 \times \text{sulphated ash percentage} \quad (1)
\]

and for sulphitation molasses:

\[
\text{Dry matter percentage} = \text{Brix} - 0.86 \times \text{sulphated ash percentage} \quad (1/)
\]

1/ brix determined in 1:9 in dilution.
Hence for the same dry matter and ash percentage, according to these formulae, the brix of sulphitation molasses is 2 units higher than of defecation molasses if the ash content is 14%, i.e. whilst the true purities of the two types of molasses are the same, the gravity purity of the defecation molasses (at 35% sucrose and 80% dry matter) would be 38.8 and of the sulphitation molasses 38.0. In other words, if after changing over from sulphitation to defecation the gravity purity of the final molasses would appear to have risen by 0.8 unit the true purity would have remained the same.

Similar discrepancies were found for Natal molasses. They had also to be taken into account when the viscosities of the two types of molasses were compared, and more attention had to be paid to the accurate determination of the dry matter content of final molasses. In this respect a study will be made of the dry matter percentage as determined by drying, using the vacuum oven as described by S. D. Gardner (1) and by the Karl Fischer method.

(b) will the quality of the raw sugar be affected?

Unfortunately consensus of opinion does not exist on the relative significance of certain properties of raw sugar in respect of its refining quality, but it is possible to specify some properties which should not be overlooked. As such we mention the colour of the affinated sugar, and its content of certain impurities which either affect the filtrability or in some other way impede refining operations. Size and regularity of grain fall into this category also, but are irrelevant to our present problem since the method of clarification will not be likely to affect grain quality.

In respect of colour the Sugar Milling Research Institute carried out tests on raw sugars which had previously been affinated by a standardised washing process. As criterion for colour the Attenuation Index at 505 mu of a 50° brix solution of the sugar was used, the solution previously having been filtered over HyfloCel.

The following data were found:

<table>
<thead>
<tr>
<th>Affinated</th>
<th>505 mu</th>
<th>Factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natal</td>
<td>0.15</td>
<td>A</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.13</td>
<td>B</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.44</td>
<td>C</td>
</tr>
<tr>
<td>Australia</td>
<td>0.23</td>
<td>D</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.15</td>
<td>E</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.58</td>
<td>F</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.20</td>
<td>G</td>
</tr>
<tr>
<td>&quot;</td>
<td>0.15</td>
<td>H</td>
</tr>
</tbody>
</table>

Two conclusions were drawn from these and similar data, i.e.

(i) the colour content of affinated raw sugar varies considerably from mill to mill, whether produced by sulphitation or by defecation. Evidence was obtained that some operations on the pan stage have considerable effect on the colour of the sugar,

(ii) raw sugar produced by sulphitation generally contains somewhat less colour than raw sugar produced by defecation.

Starch being one of the impurities in raw sugar influencing the filtrability, and Natal raws having a rather high starch content, this impurity was regularly determined by the Sugar Milling Research Institute in production samples of raw sugar from defecation and sulphitation mills. There was little evidence for assuming that sulphitation raw sugar contains less starch than defecation raw sugar.

The following data may illustrate this point:

<table>
<thead>
<tr>
<th>Raw sugar produced by sulphitation, factory</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>p.p.m.</td>
<td>420 - 580</td>
<td>260</td>
<td>590 - 620</td>
<td>420</td>
<td>930</td>
<td>590</td>
</tr>
</tbody>
</table>

In both groups we find high and low starch contents.

Also of importance for the refining quality of the raw sugar is the CaO content of ash of the sugar. The CaO content of the ash of defecation raw sugars appeared to be lower than of practically all sulphitation sugars, t. w. 10-12% and 15-20% respectively.

Comparative filtrability tests have not yet been carried out, but will be done in the near future.

(c) the need of using phosphoric paste.

As has been shown above, Natal sulphitation factories use a considerable quantity of phosphoric paste, and when changing over to defecation were somewhat reluctant to reduce this amount. The result was that mud levels in the clarifier were sometimes inconveniently high. Investigating the P2O5 content of mixed juice of defecation mills showed this to be higher than had been assumed. viz. P2O5 was usually near 300 and sometimes as high as 500 p.p.m. At present the defecation factories use either a very small amount of phosphoric paste or none at all, and abnormally high mud levels are no longer experienced. In a single case it appeared difficult to concentrate the mud, and solids % mud were 3% in comparison with 3.5 - 4.5% before changing over. It was thought however that the introduction of the defecation process was not the only factor responsible for this drop in mud concentration, juice quality having changed simultaneously.

(d) the correct way of liming mixed juice

Various methods of liming were tried out. From experience in other countries it was known that no hard and fast rules about the best method of liming can be given, although general experience — which was confirmed by laboratory tests carried out by the Sugar Milling Research Institute — seems to indicate that it is beneficial to raise the pH of mixed juice gradually. Gradual raising of the pH of mixed juice is at present effected by some of the mills which continuously lime the muds from the subsiders to give a "clear" filtrate of pH 8.0 — 8.5.
clear filtrates are returned to cold mixed juice, which is then heated to 130-160°F, and shows a pH, as determined in the laboratory, of about 6. The juice is next limed batchwise to a pH of about 7.8 (measured at room temperature), heated to 213°F and settled. The pH of clarified juice obtained is between 7.0 and 7.3. The juices are of good appearance, quite brilliant, and not much darker than sulphitation juices. The mud levels in the subsider are normal and the filters operate normally. The danger of this method is that over-liming the hot juice will cause undesirable destruction of reducing sugars.

(c) scaling of heater and evaporator tubes.

Natal sulphitation factories generally experience rather heavy scaling of the tubes of the evaporators which have to be cleaned every week-end. Pre-boiling with alkali or acid is not necessary, but the labour required for mechanical cleaning is an expensive item.

After changing over to defecation the rate of scaling decreased considerably and some of the factories which apply defecation found that a period of three weeks between cleaning operations was a definite possibility. In particular the first vessels remained clean for a much longer period than when the sulphitation method was followed.

The sulphitation method also necessitates the changing over of the first and second set of juice heaters at least every shift. The factories now applying defecation have found that changing over is no longer necessary.

Raw sugar as raw material for the production of mill white sugar.

Following the introduction of the defecation process one of the mills developed a novel method of producing mill white sugar by melting part of their raw sugar and boiling white sugar from the unclarified melt.

It is customary for sulphitation white sugar mills in Natal to turn out about 60% of their sugar as mill white (usually from A massecuite only), the remainder being produced as either so-called Government Grade sugar (an over 98°V polarising sugar sold at reduced price) or as raw sugar for refining purposes.

The mill mentioned above succeeded in producing the usual 60% of their sugar as mill white of a quality ranging amongst the best Natal sulphitation mill whites by washing defecation raw sugar to a polarisation of about 99.2° and melting this excellently afinated sugar to a melt from which three white sugar boilings could be obtained without any filtration or clarification, i.e. the quality of the sugar from the third strike was still good enough to allow this sugar to be mixed and bagged with the sugar from the first and second strikes. The molasses from the third mill white strike was returned to the raw sugar producing part of the factory.

Undoubtedly this mill has added a new facet to the old problem — but still of much present interest — of finding the economical balance between improving the clarification effect and increasing the purity of the sugar by continued remelting.

Corresponding to the fact that the clarification effect of carbonatation is better than that of sulphitation, and sulphitation better than that of defecation, a better mill white is produced by carbonatation than by sulphitation, whilst the sugar directly produced by defecation does not fall into the mill white class. If it is desirable to improve the quality of sulphitation mill white, two methods are generally applicable, t. w. (a) improving the
clarification effect by changing over to a more efficient method of juice clarification (carbonatation) and (b) remelting some of the sugar in order to bag a sugar which has been boiled from a higher purity medium.

Since the carbonatation method of clarification is always expensive, improving the quality of sulphitation mill white by remelting either the C, the B and C, or even the A, B and C sugar is normal. Improving, by remelting, the purity of the sugar produced by defecation up till the point where the sugar would be of mill white quality has been tried in Java, but the result was not satisfactory. As far as is known the method is not applied in any other country on factory scale. But as said above, an excellent mill white is now being manufactured in Natal by this method.

The following data illustrate the quality of the remelted defecation mill white sugar in comparison with normal Natal mill white data:

<table>
<thead>
<tr>
<th></th>
<th>Remelted defecation sugar</th>
<th>Sulphitation mill white</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuation Index at 420 mÅ</td>
<td>0.170</td>
<td>0.200</td>
</tr>
<tr>
<td>&quot; at 720 mÅ</td>
<td>0.035</td>
<td>0.044</td>
</tr>
<tr>
<td>Colour Index</td>
<td>100</td>
<td>112</td>
</tr>
<tr>
<td>Ash (determined conductometrically)</td>
<td>0.010</td>
<td>0.078</td>
</tr>
<tr>
<td>Monochromatic specification of reflection curve of solid sugar:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brightness</td>
<td>74.8%</td>
<td>77.0%</td>
</tr>
<tr>
<td>Colorimetric Purity</td>
<td>7.45%</td>
<td>9.29%</td>
</tr>
<tr>
<td>Dominant Wavelength</td>
<td>575.1 mÅ</td>
<td>575.9 mÅ</td>
</tr>
</tbody>
</table>

Sugar Milling Research Institute, University of Natal, DURBAN.

* Higher than of remelted defecation sugar due to finer grain.
Making Big Grain Sugar
( New Vacuum Pan Crystallisers help)

By
S. N. Gundu Rao, B.Sc., A.H.B.T.I.,
Chief Chemist & Manager,
Ravalgaon Sugar Farm Ltd., Ravalgaon, (Nasik).

Man has several crazes. One such is the love for big grain sugar. Obviously, there is no logic behind such fads. To the discerning housewife, who finds most of the sugar lost dissolved in the Tea-cup it is most annoying. To the producing Technologist, it is a constant source of headache. To the nation it is a source of waste involving more fuel, more loss of sugar in processing and extra expenses due to extra demand on capacity at the Pan and filter Stations. All the same the demand for big grain sugar is ever on the increase. Business is business and you have to produce so as you get your profit and the consumer buys for his fads.

Impurities in Sugar Crystal.

Though crystallisation is itself a purification process, the crystals are not 100 percent pure, but have impurities in them depending on the composition of the solution in which they are born and grown. Experiments on the correlation between composition of sugar solutions and the produced sugar carried out at the Experimental Station of the Java Sugar Industry showed that the correlation between non-sugar concentration and the non-sugar content of the solid sugar is a logarithmic one. Considering the chemical composition of the raw sugar and the colour of the solid sugar made from it, it was found that the brightness is given by the ratio conductivity/gravimetric ash. When this ratio is high, it is possible to obtain a sugar of a high brightness. When the ratio is low, the sugar gets a greyish tint. The studies further indicate that for the most part the precipitable non-sugars SiO₂, Fe₂O₃, Al₂O₃ and CaO influence the greyish shade of the crystallised sugar. When the quality of the sugar to be manufactured was fixed, it was possible to fix the allowable limit of concentration of harmful non-sugars. A. Baudecloque studying the distribution of impurities in the raw sugar crystal found that 40 percent to 50 percent of the total ash of a sugar crystal lies on the surface without forming an integral part of the same and from which it can be mechanically removed by washing with a saturated syrup. From the surface to the centre the ash content of the crystal decreases to about a fifth of what it is on the surface. The increase of ash content from the centre to the surface of the crystal is explained by the fact that the first small grain is formed when the oversaturated syrup is at its highest purity. As the crystal grows, the new layers are deposited from a mother liquor that is continually becoming more impure. In view of the presence of nearly 50% of the impurities on the surface, Baudecloque has stressed on the importance of cleaning the crystal surfaces by better centrifugal...
work and control of pan boiling operation to reduce the formation of twins and agglomerates that impede the washing process.

**Grain size Vs. Colour & Purity of Sugar.**

Making big grain sugar of good colour is a continuous struggle against the entry of coloured and colourless non-sugars into the crystal. As each layer of crystal is formed it adsorbs the impurities from the mother liquor, while the next layer is building up and covering the impurities. There are thus layers of adsorbed impurities between successive layers of sucrose in the crystal, the concentration of impurities in the layer depending on their concentration in the mother liquor at the time. Though the total surface area of crystals per unit cubic content decreases with increase in the size of the crystals, the area of the successive layers of the individual crystal is increasing. Simultaneously, the concentration of impurities and colour in the mother liquor are on the increase. The area of the adsorbent and the concentration of the adsorbate are both in favour of greater adsorption of impurities in the crystal with growing size. Another factor that is likely to influence the impurities in between the crystal layers is the rate of boiling. Considering the necessarily slower rate of boiling with increase in grain size the tendency for an increase in the included colour and impurities is greater. The composition and quality of the solution in which the crystals are grown therefore assume greater importance when producing big grain sugar. It has been observed that big grains during their final stages of development are more sensitive to the presence of impurities and colour in the mother liquor. When the size of the crystal increases in a high purity liquor and the boiling rate has to be reduced to keep step with the crystallisation rate natural circulation is reduced. The tendency for twins, agglomerates and fine grains increases. Some suitable form of mechanical circulation becomes necessary to ensure uniform and positive movement of crystals and to maintain optimum ratio of crystal to mother liquor. The Rotary and Stationary types of Vacuum Pan Crystallisers developed at Ravalgaon and described later provide the best type of mixing and circulation required for making big grain sugar in high purity melts.

**Measure to improve the quality of Crystallising Solution.**

Researches into the clarification of juices, have been with the sole object of making it a suitable medium to produce good quality sugars. Direct consumption white sugar cannot be prepared from defecation syrups, while the same is possible from sulphitation and carbonation syrups. The sugars produced from carbonation syrups are definitely superior to those produced from sulphitation syrups. The best sugars are produced from charcoal or active carbon filtered refinery melts in which colour and impurities are least.

Middle juice carbonation is superior to the normal carbonation process. Several modifications to the normal sulphitation process claim superiority in respect of elimination of colour and impurities and hence suitability for producing big grain sugar. Some of these techniques are beset with difficulties, which when overcome may greatly help improve sugar quality. Continuous sulphitation with automatic proportioning and addition of chemicals, automatic temperature and pH Control together with equipment that enable faster processing will greatly help improve quality.

Other conditions of processing and equipment remaining the same, the size to which the crystal can be developed without getting off
coloured, depends on the clarification process. Thus it is normally difficult to produce a 29 C (I. S. S.) sugar with the usual sulphitation syrup, using C massecuite sugar as seed, while the same is possible with carbonation syrups. It is difficult to prevent off colour beyond C grain size even with carbonation syrups and normal boiling process. With impure syrups it appears that the tendency to absorb colour and impurities from the mother liquor and getting off coloured increases after a certain size limit when it becomes necessary to change to a better medium if the quality of sugar is to be produced with normal sulphitation syrup, the growth from D size to C size should be achieved in melt of high purity, with very little admixture of syrup. Further increase in grain size should be in colour free, clear and pure melt. It is found that even slight colour in pure melt in the final stages of big grain production influences the colour of the sugar.

An interesting observation during practical pan boiling that has been made is that even a slightly off coloured seed when developed in high purity clear and colourless melts results in good sugar without the trace of original off colour. Whether this improvement is due to a masking and dilution by the better and whiter layers of sugar deposited or due to a gradual release of the adsorbed and occluded impurities from the outer layers of the crystal to the comparatively purer mother liquor due to a concentration gradient of impurities, remains to be established. Preliminary experiments conducted by repeatedly growing crystals in coloured and colourless melts have indicated the possibility of such a phenomena. The phenomena should be in operation whenever a seed grown in a lower purity medium is transferred to a higher purity medium. It becomes ineffective only if the boiling in the lower purity medium is continued till the impurities get too deep seated. The most important point that emerges from the foregoing observations is that using bold grain sugar seeds the transfer of growing crystal at different stages of the growth from the comparatively purer mother liquor surrounding it to a purer medium the stage being determined by the available quality of liquor and the ultimate size of grain required. It is significant in this connection that greater improvement in quality of sulphitation sugars was possible only when the double seed low grade massecuite sugar was melted as B seed grain seeded and developed in a higher purity medium was used. This improvement has encouraged many factories to melt the surplus B grains also, thus further adding to the quantity of melt.

The degree to which the remelting can be carried out is determined by the premium on quality as compared to the extra costs involved. Discussing the influence of non-sugar Honig observes: "We have the opportunity to redress the concentration of non-sugars in the juices and liquors to be crystallized by the remelting process. For the economy of the working methods it is recommended that a compromise between the intensive purification of juices and a limited remelting process be worked out." Though some factories are changing over to the carbonation process, to meet the increasing demand for quality sugar, the limitations imposed by the availability of good quality lime stone, transport and extra costs involved, necessitate the majority of factories to continue the sulphitation process with such improvements as are simple and do not add much to the cost. In the present state of technology major improvement in quality in sulphitation factories should, therefore, be expected by
melting the low grade sugars, the extent of such melting being determined by the premium paid for quality sugars. When the melt is made, it can be processed in two ways, viz., i. it can be mixed with the available syrup and the resulting high purity syrup utilised for developing big grains, ii. the crystal can be grown in the syrup to an optimum size, after which it can be grown separately in the pure melt. The latter procedure has been found to be better. This observation in practice is in keeping with the principles discussed before.

Improvement in Technique & Equipment.

Having obtained the best possible medium that economic factors permit, it is imperative that a proper technique and most suitable equipment are used. In any scheme of boiling, it is most essential that non-sugar circulation is reduced to the minimum if not completely avoided. This is the one most important single factor that determines the final shade of sugar. It is impossible to produce a lustrous big grain sugar without any off-colour if at any stage in the process non-sugars are recycled. Non-sugars should always take the shortest route to the final molasses, as the sugars should, to the bags, for best results.

High gravity factor centrifugals particularly at the low-grade station greatly help, reduction, provided the syrup classification devices are very efficient and the mixing of the heavy molasses and washings does not take place. Unfortunately, none of the syrup classification devices is efficient enough to ensure a satisfactory separation with the highly viscous low grade molasses. In such cases double curing becomes absolutely essential even with high gravity factor machines. Improvements in graining techniques which ensure uniform grain size with good purging qualities, improvements in boiling and curing equipment such as Pans with mechanical circulation, centrifuges with high gravity factor and reheating elements in the Pugmills, all help in making bold grain sugar of good quality.

Making big grains at Ravalgaon.

(j) Revolving Vacuum Pan Crystalizer.—A scheme of research on sugar candy manufacture was started at Ravalgaon in 1941. The research was a joint co-ordinated effort between the Indian Institute of Sugar Technology and the Ravalgaon Sugar Farm Ltd. One of the outstanding developments from this work is the revolving Vacuum Pan Crystalizer, which has been developed to obtain independent and perfectly shaped sugar crystals of big size (Sugar Candy), as against the lumps of crystal conglomerates that were being produced in the Tals and other Stationery Crystalising Units.

The revolving vacuum pan Crystalizer is shown in Figure 1. The Unit which has been designed and fabricated at Ravalgaon has been working satisfactorily for the last seven years. Regular independent and bright crystals of Sugar Candy up to 4" size are regularly being produced.

The Crystalizer consists of a Cylindrical Drum $A$, with baffles $B$, fixed lengthwise on the inside surface, and tyres $C$ and gear $D$ on the outside surface. The drum is placed horizontally and revolves round a central tubular shaft $S$ with tyres moving on idler pulleys. One end of the drum $F$ is enlarged to accommodate the vapour draw-off pipe $V$. Sight glasses and man hole doors etc., are fixed at suitable places. Vapour is drawn out through the central hollow shaft, and the steam, water and syrup connections also pass through the hollow shaft. Steam Tubes $T$ are arranged lengthwise inside the drum below the shaft.
with common headers and the condensate is removed by a special device. A condenser and a vacuum pump form part of the complete unit. Boiling is done as usual with 20 vacuum and 10 to 15 lbs. per square inch of steam pressure. While sugar melt clarified and filtered is used as raw material and regular independent candy crystals of various sizes are produced from seed crystals. The seed crystals can be good quality sugar from the factory or graded irregular bits of sugar candy.

Due to the necessarily smaller heating surface that can be accommodated in this design, it is ideally suited for making big size coffee crystals and still bigger crystals. The ideal movement of the crystals obtained in this crystalliser enables most sparkling crystals of big size to be produced.

(b) The Ravalgaon Vacuum Pan Crystalliser:
The revolving type of vacuum pan crystalliser developed at Ravalgaon and described above, has its limitations in respect of capacity, heating surface and complicated construction due to central hollow shaft, gears, tyres etc. The Stationary type of Vacuum Pan Crystalliser, which is much simpler and shown in figure 2 was, therefore, developed for making big grain sugar. (Patent application has been submitted).

The Vacuum Pan Crystalliser consists of a Cylindrical Shell A, with a central stirrer shaft B to which the stirring arms C are fixed to ensure continuous and effective movement of the crystals in the bath of boiling syrup. The specially shaped stirrer arms C are fixed on the shaft B in a staggered manner and have horizontal and wide enough flats fixed at the end. These flat ends move very close to the surface of the shell, which is rendered possible by the design of the heating coil E.

The heating coils E consists of tubes F passing through the shell, the continuity being maintained by external connections G to the tubes. The tubes pass through the shell without being welded to it through specially designed stuffing box and gland H. The boiling is uniform and good without spurring as the area for vapour escape is sufficiently wide and the hydrostatic head responsible for local rises of temperature is less. Positive and efficient circulation and steady boiling ensure uniform conditions throughout the mass resulting in a very uniform and rapid development of the crystals.

The vapours pass through a specially designed centrifugal type separator S to eliminate entrainment losses into the condenser. The other usual fitting, are manhole J, seed inlet K, syrup inlet L, cut over opening M, discharge openings N, Thermometer O, proof stick P, Cuitometer connections Q, Sight Glasses T, and Vacuum Gauge V.

The features of the new design are:
(a) Positive stirring due to the stirrer arms which are sufficient and staggered and which move very close to the cylindrical shell.
(b) A new design of heating elements which consist of coils formed from tubes passing through the shell externally connected to provided continuity. These coils arranged one above the other and independent of each other to enable boiling at different levels.
(c) Specially designed gland and stuffing box, which enable the tubes to pass through the shell without being welded to it and which are leak proof.

The Procedure.
According to the procedure at Ravalgaon, triple cured C sugar is melted in water to get a clear colour free melt. The B masscuite is
grained on syrup and developed with A heavy. The B massecuite is single cured, washed well in the centrifugals, made into a magma with A light and used as seed for A massecuite. Using the B seed the grains in A massecuite are developed to D or C sizes (I.S.S.) with syrup, A light and the mother liquor from the special massecuite. The A massecuite is single cured washed well made into a magma with water or A light. The magma is then taken into the Stationary Vacuum Pan Crystalliser and the Crystals in this special massecuite developed on triple cured C melt plus surplus B sugar melt to B, A or AA sizes (I.S.S.). The mother liquor is reduced till it develops colour, when it is sent to the A massecuite. The special massecuite is single cured in the after workers, steam dried and dropped. In effect the new Vacuum Pan Crystalliser is interposed between A fore-workers and after workers. The results have been remarkable and the best quality of bold grain with sparkle and whiteness have been obtained.

The author’s grateful thanks are due to Seth Govindji Raoji, Director, Ravalgaon Sugar Farm Ltd., for his interest and encouragement.

References.

2. A. Baudelecque—Sugar...May, 1955, Page 52.
Cane-sugar Industry is one of the biggest food industries in India. There are about 162 factories producing about 16 lakh tons of sugar, against an annual consumption of about 18 lakh tons. This shortage could be met by increasing sugar cane crop acreage, cultivation of better variety of cane, restricting the manufacture of gur and improving the existing method of sugar extraction and purification. All factories in India produce white sugar direct from cane, by clarifying the juice either by sulphitation or by carbonation process. In the west, however, due to economic and other reasons, factories located in the cane growing area, produce brown or raw sugar, which is subsequently converted to white sugar at the refineries located elsewhere. The present method for recovering sugar from cane or beet has remained substantially unchanged for over hundred years. In recent years, however, there has been growing interest in the application of deionisation technique for the purification of beet and cane sugar.

Clarified juice from the sulphited or carbonated process contains various inorganic salts which constitute the ash. Besides this, certain organic non-sugar bodies are also present. The presence of these impurities hinders complete crystallisation of all the sugar and also affects the quality. Removal of these interfering substances will lead to recovery of more sugar of a better quality than hitherto possible. Ion-exchange resins have been studied for the removal of these interfering substances.

This review aims at presenting the developments in this field setting forth the advantages and the possible shortcomings of this method for cane sugar juice treatment.

The use of deionisation operation for the treatment of sugar juices and syrups has been tried on both pilot plant and full scale plant units (1) with varying degrees of success and conclusions arrived at are conflicting. The economic of the process of cane and beet juice deionisation has been reviewed (2) and favourable reports have been made. The application of ion-exchange technique to the sugar industries is still open to considerable question, although technically the operation has achieved the goal. Adoption of the ion-exchange process for sugar juice purification has been retarded purely on account of economic reasons, viz. cost of regenerants,
initial cost of resins and necessary equipment etc. The views on the economics of the process are varied. Some have concluded that the process is economically sound \(11,14,14\) and others to the contrary \(9,5,15\). Therefore, it would be worthwhile to re-examine the problem carefully by considering the recent developments in the manufacture of ion-exchange resins, improvements in the regeneration techniques, the nature of the regenerants used and the quality and quantity of the by-products recovered, as all these factors will affect the material balance. The main disadvantages to be considered are the effects due to dilution of the juice, inversion, loss in ion-exchange capacity due to repeated operation and rinse water requirements.

**Ion-Exchange Resins**—Although the chemistry of the synthesis of the various ion-exchange resins is quite simple in principle, certain aspects of their production are exacting. Since the resins represent capital investments for many applications, durability is a factor that is as important or even more so than capacity. For many applications, the resins must exhibit resistance to physical breakdown, chemical degradation and solubility. The resins should be produced within narrow limits of particle size specification.

In the early stages of sugar refining, the resins used were mostly sulphonated coal type cation-exchange resins and weakly basic anion-exchange resins. With the developments in the synthesis of both cation and anion exchange resins of the phenolic and polystyrene based types, the life and efficiency of the resins have been considerably improved.

Payne and co-workers \(10\) have studied the practical life and capacity of a variety of resins in sugar cane processing. According to them the choice of ion-exchange resins for commercial scale purification of solutions depends, not so much upon the initial cost and the capacity, as upon the useful life in the particular application as measured by capacity losses. Unfortunately, the manufacturers’ data on the capacity for inorganic ions and stability in any one application, usually water treatment, is not a dependable guide for the selection of a resin for deionising a solution, such as sugar cane juice, in a sugar factory. They have observed that the cation exchangers are stable without much loss in capacity whereas the anion exchangers appeared to be less stable. The sulphonated carbonaceous cation exchangers have been shown to lose their capacity considerably whereas the sulphonated phenolic and sulphonated polystyrene based resins do not.

**Techniques**

In the ion-exchange process three different techniques can be adopted for treating the cane juice.

1. **Conventional deionisation**—In this, the juice is first percolated through a bed of acid activated strong cation-exchange resin and the resulting acidic effluent is then passed through a bed of alkali activated (weak or strong) anion-exchange resin. The chief disadvantage in this method is that due to the formation of an acidic effluent, there is the danger of inversion of sucrose. This defect can be obviated by conducting the process at a low temperature (below 15°C) or by adopting the reverse deionisation technique at ordinary temperatures.

2. **Reverse Deionisation**—In contrast to the above, the juice is first percolated through a strongly basic anion-exchange resin and the resulting alkaline effluent is passed through
a bed of weakly acidic cation-exchange resin. Since no acidity is encountered in any stage of the operation the danger of inversion is completely removed (6).

(3) Monobed Deionisation:—When equivalent quantities of suitable cation and anion-exchange resins in the regenerated form are intimately mixed and packed in a single column they offer a means to remove both cations and anions simultaneously and most effectively from any solution. This monobed technique can be advantageously employed for the deionisation of sugar cane juice for the acidity produced by cation-exchange will be immediately removed by the anion-exchange process and hence losses due to inversion can be greatly minimised and higher temperatures up to nearly 70°C, can be tolerated in this technique. The capital cost is decreased and there is saving in floor space. Also, rinse water requirement after the regeneration is lower than in the above two techniques.

Laboratory tests under various procedures with different resins and adopting different regeneration techniques have been carried out (12). A purity rise of about 5-10 units has been obtained and the ion-exchange process is considered suitable and economic for juices containing less than a 0.6% ash on weight of cane.

Regenerants

The regenerants commonly used for activating exhausted cation and anion-exchange resins in treatment of sugar cane juice are 2 to 5% solutions of sulphuric acid, hydrochloric acid, sodium hydroxide, sodium carbonate and ammonia. The quantity and the regenerant to be used are governed by the nature of the ion-exchange resin. For the regeneration process it is the usual practice to employ slight excess of regenerants for stripping the beds free of cations and anions. The spent regenerants which thus contain some quantity of unused acid or alkali can be considered for reuse as regenerant. This is the basis for the multiple stage regeneration technique adopted in large scale installations. This involves saving that portion of acid or alkali (which is sufficiently free of mineral contaminants to permit reuse) from any cycle for use as regenerant in a subsequent cycle by supplementing with fresh acid or alkali. It is thus possible to salvage 1/3 to 1/2 the quantity of the excess acid or alkali for reuse.

Ammonia can be used as a regenerant for cation-exchange resins (12). Von Lilienskiold (14) considered the use of base exchangers in the sugar industry and observed that the ion exchangers cannot be operated in an ammonium cycle to avoid a low pH since ammonium salts are most harmful in subsequent sugar boiling, resulting in poor greyish sugar. But it would appear that ammonia holds forth great promise for use as regenerant for anion exchange resins due to the following reasons.

As a result of its low equivalent weight, anhydrous ammonia can be procured at the point of consumption at a lower price than other regenerants. Excess ammonia used in regeneration is much more easily rinsed from an anion bed than is caustic soda. Ammonia has an added advantage as a regenerant in that all the ammonia used ultimately appears in the regenerant waste as an ammonium salt. It should be
noted that ammonia cannot, however, be used for regenerating strongly basic anion exchangers. Cotton et al. (4) have standardised a process for recovering ammonia used for regenerating anion exchanger beds.

**Recovery of By Products.**

In processing any type of sugar solution, there is the possibility of recovering regenerant wastes rich in nitrogen, potash, organic material and sometimes, phosphates for use as fertilizers. On any sizeable installation the recovery of these by-products can be integrated with the ion-exchange process so as to reduce the cost of regenerants by one-half or more. When sulphuric acid and ammonia are used as regenerants for the cation and anion beds respectively, the resulting spent solutions contain sulphates and ammonium salts. A mixture of the two spent effluents can be fed directly to irrigation water for obtaining the beneficial action due to ammonium sulphate. Another recovery of value as fertilizer relates to potassium from the cation regenerant effluent which amounts to about 25 lbs/ton of cane (6).

The ion-exchange treatment helps in solving the problem of molasses by producing instead an edible syrup which can find ready market in our growing confectionery industry.

The recovery of the many amino acids as by-products in sugar manufacture has been considered by Steochi and Gliozzi (13). One of the valuable by products obtained by the ion-exchange process of refining cane sugar is aconitic acid. This may be recovered as the relatively insoluble calcium-magnesium salt. Derivatives of aconitic acid find use as plasticizers, stabilizers, surface active agents and detergents (6).

**Other Advantages.**

The elimination of evaporator scaling by ion-exchange is one practical achievement which will appeal to most producers to whom descaling problems are very well familiar during the crushing season. Standby evaporators are too expensive at present day equipment costs but are often necessary to maintain output in the face of scale formation. The ion-exchange process by removing the scale forming salts from the juice avoids the scaling problem and thus reduces wear and tear on plant generally and ensures continuity of production in the refinery and associated distillary operations (4).

Another important advantage which is yet to be proved may arise from the use of raw juice as such for treatment with the resins. If this is successful the serious shortage of sulphur need not handicap the producers and a preliminary flocculation treatment to remove the suspended and colloidal impurities may be the only treatment necessary before passing through the resins.

In the Ghosh method (7) of electrolytic purification of cane juice a possible source of impurity is the dissolved iron from the electrodes. It is possible to combine a system of ion-exchange resins with the above electrolytic technique to remove the iron.

Among the disadvantages attached to the ion-exchange process of cane sugar deionisation the effect of dilution of the juice and loss in capacity of the resins due to repeated operations have been shown to be negligibly small (1). Regarding inversion it has already been shown that proper techniques will obviate this difficulty. Rinse requirements can be minimised to a large extent by the use of suitable and efficient regenerants and
reuse of part of the rinse water for diluting the regenerants. The progress reported from different full scale plants engaged in the deionisation of cane juice supports the contention that this technique takes less space than bone char or activated carbon operations, is cheaper and prevents scaling in the evaporators (1).

In India which is one of the principal producers of cane sugar in the world, the impact of the development of the ion-exchange process will lead to the economic development of the sugar industry. The National Chemical Laboratory is interested in both the fundamental and applied aspects of the ion-exchange techniques. Studies have been carried out particularly in the preparation of ion exchange resins from indigenous sources and studying their utilisation to treat cane juice (on a laboratory scale) and for brackish water treatment, etc. It is planned to conduct further trials on deionisation of cane juice under the auspices of the National Research Development Corporation at the Indian Institute of Sugar Technology, Kanpur, to further assess the economics of the process.

References.
Note On The Limitations Of Usual Methods Of Sugar Analysis.

By

H. C. S. de Whalley,
Director of Research, Tata & Lyle Ltd., Research Laboratory,
Kent, England.

1. Pol, Brix, Ash, Invert sugar and Water give information insufficient to explain many anomalous results.

2. Presence of oligosaccharides, e.g. Kestose, etc. nullify correct estimation of Sucrose by Clerget methods.

3. Reducing matter commonly but erroneously termed invert sugar, does include some non-sugar and also some anhydrides of hexose sugars. Ash by conductivity gives variable agreement with sulphated ash and in the case of cane molasses is quite useless as inorganic constituents are partly precipitated on dilution with water for testing.

4. Solids or Water content by hydrometer or drying is incorrect for cane molasses. Special drying methods as outlined by Gardiner and Farmiloe enable true solids to be determined. The method is lengthy, requires a very experienced analyst, and is unsuitable for routine work. It has however been utilised to devise a correction (based on sulphate ash content) of Refractive Index Solids which is suitable for routine work.

5. Sugar research workers and refinery chemists should be provided with apparatus for the new techniques. Chromatography, column & paper. Electrophoresis, especially for oligosaccharides, sugar alcohols, amino acids and other organic acids in sugar products. Flame photometers to enable composition of ash to be rapidly determined. A Gardiner oven has already been requested for India. Attention is also directed to error due to use of wet lead defecant in polarisation of raw sugars and the tables published by Eynon and Gaskin for correcting this error.
Standardisation of the Quality of Indian sugar and Improvement in Quality Resulting therefrom

By

R. C. Srivastava, B. Sc., C. I. E., O. B. E.

Voc. Director, Indian Institute of Sugar Technology, Kanpur.

Those of us who have knowledge of the Indian Sugar Industry during 1920's and early 1930's, may recollect that the usual practice in those days was for factories to define the qualities of their sugars as No. I crystal or No. II crystal and corresponding grades of crushed sugar. No. I was obtained from A-masséculite and No. II from B-masséculite. Usually the B-masséculite system of pan boiling was followed, the sugar from C-masséculite being used for preparing Seed-magma. For selling sugar samples were drawn from each lot (that is sugar from each pan of masséculite) and these were sent to the Selling Agents for inviting offers. The sample tins showed the name of factory, the lot number and the number of bags.

This was a simple system and worked satisfactorily with the few factories which were able to produce regularly sugar of a more or less uniform quality but for others it gave rise to many difficulties. Thus the so-called "No. I crystal" sugar of one factory may not be of a quality similar to "No. II crystal" of another factory and in some cases all the bags of sugar produced by some factories in one lot were not of the same quality. Under such chaotic conditions the marketing of sugar was a sort of gamble. At this time large shipments of sugar were imported from Java, and the quality of this sugar was defined in contracts simply in terms of the Dutch Sugar Standards, such as J. S. 25 and over, and not one bag among the thousands that were imported, gave rise to any dispute.

Some time in 1934-35 a meeting of Indian Sugar Factory Owners and sugar merchants was held in Kanpur and they decided that the question of standardisation of the Indian made sugars should be referred to the Government Sugar Technologist as an impartial Official and he may be requested to evolve suitable sugar standards for India. Accordingly research work was undertaken on the subject. For purposes of guidance sugar standards from Java and several other countries were collected and examined.

As a result of these investigations and after collecting information from several important markets regarding the basis on which the quality of sugar was judged by merchants, a set of standards was eventually evolved for trial, and for continuing this work and making further improvements in the light of experience, a Bureau of Sugar Standards was formed under the Imperial (now Indian) Council of Agricultural Research.

The main difficulty which faced the Bureau of Sugar Standards was to cover the very wide range of qualities of Indian sugars which were manufactured then.
Subsequently when the Imperial (now Indian) Institute of Sugar Technology was established the Bureau of Sugar Standards was merged with the Institute.

The Indian Sugar Standards, issued by the Bureau of Sugar Standards, have been in use now for the last two decades. As already explained these standards were so designed as to grade, as far as possible, every quality of crystal or crushed sugar produced in the country. This objective method has not only facilitated trading in sugar but has also helped the manufacturers to improve the quality of their sugars.

In 1941-42 these standards consisted of 70 grades for crystal and 6 grades for crushed sugar as given below:

(a) **Crystal Sugars:**
- 10 colour standards Nos. 19 to 29.
- 7 grain standards Nos. A to G.
- (combinations give $10 \times 7 = 70$ qualities of crystal sugar.)

(b) **Crushed sugar:**
- 6 colour standards Nos. 8 to 13.

These standards underwent certain changes from time to time according to the needs of the industry. In 1950-51 these standards consisted of 48 grades for crystal sugars (6 colours 24 to 29 x 8 grain sizes AA to G) and 3 grades for crushed sugar Nos. 11 to 13.

In 1954-55 the sugar standards underwent a fundamental change. Instead of being two separate series for colour and grain size they were redivided to form one series of combined standards; each standard grade representing both colour and grain size of a particular specification. In all 15 standards grades were retained for crystal sugar and one for crushed sugar as given below:

(a) **For Crystal Sugar:**
- A29, B29, C29, D29, E29
- A28, B28, C28, D28, E28
- A27, B27, C27, D27, E27

(b) **For Crushed Sugar:**
- I. S. S. No. 13.

One of the functions assigned to the Bureau was also to persuade the factories to reduce the number of too many qualities of sugar they were producing. While it has been possible to make a stride in the matter of quality of Indian sugar from the average of D-24 in 1935 to D-28 which is now the most predominant and common quality produced in recent years, the sugar industry continues to suffer from one serious defect, that is, the production of too many grades by several factories inspite of the persistent efforts of the Bureau of Sugar Standards. This is revealed from the study of ten years' data relating to the number of grades produced by factories during the period 1944-45 to 1953-54, as contained in the table given in appendix 'A'. It would be observed from this table that—

1. The number of grades produced in any of these years varied between 15 and 23, for the industry as a whole;

2. (a) only 10.75% of working factories have been able to confine their production to one grade;
   - (b) 12.84% to two grades;
   - (c) 16.64% to three grades;
   - (d) 14.44% to four grades;
   - (e) 13.83% to five grades;
   - (f) 9.80% to six grades, and
   - (g) a large majority of factories viz. 78.34% still produce up to six grades.
From the foregoing, it is clear that the industry has not been able to maintain uniformity in the quality of sugar produced.

This non-uniformity may be with regard to either the grain size and or the colour of the sugar produced. In the case of grain size, the non-uniformity may be due to unsatisfactory pan-boiling technique or lack of equipment.

As regards colour, the non-uniformity may be attributed to the following factors:

(a) Variations in the quality of juice with season and with different qualities of cane crushed.

(b) Changing factory conditions in respect of steam and vacuum conditions, and

(c) insufficient control over manufacturing operations on the part of operatives.

While it is true that a proper attention to these details would result in considerable reduction in the large number of grades that are produced now, a certain amount of variation is inevitable. The time has now come when the range of variation in quality should be narrowed down. One of the methods by which this can be done is by narrowing down the measuring scale itself. From a perusal of graphs at appendix 'B' it will be seen that the bulk of sugars produced are confined more or less to 29 & 28 colour and C, D and E grain size. Let us add one more standard grade for colour viz. ISS No. 30. Sugars are even at present being produced which are definitely whiter in colour than ISS No. 29 and in order to provide an incentive for producing still better sugar grades the price differentials may be as follows:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Price Differential</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISS C</td>
<td>20 annas</td>
</tr>
<tr>
<td>ISS D</td>
<td>14 &quot;</td>
</tr>
<tr>
<td>ISS E</td>
<td>9 &quot;</td>
</tr>
<tr>
<td>ISS 29</td>
<td>6 annas</td>
</tr>
<tr>
<td>ISS 28</td>
<td>1 anna</td>
</tr>
<tr>
<td>ISS 27</td>
<td>5 annas</td>
</tr>
</tbody>
</table>

Sugars which are inferior in quality to ISS C30 would have to be specified as "Below Grade" and those that are superior to ISS C30 should have no preference and would be classed as C30 only.

Advantages of the proposed Scheme:

The merchants and dealers are greatly inconvenienced by the large number of grades and the greater the latitude for manufacturers in the matter of production of different grades the greater will be the variation in quality.

It is believed that if the above suggestions are put into effect we shall be achieving a better measure of uniformity in the quality of sugars produced in our country, ultimately narrowing down the production to only four grades viz. C30, D30, C29 and D29.

Acknowledgement:

The author gratefully acknowledges the help received from the Indian Institute of Sugar Technology, Kanpur for much of the statistical material presented in this paper. He has also to thank Mr. N. C. Verma of the Institute for valuable help in preparing the paper. Mr. Verma has been associated with the Bureau of Sugar Standards from its inception and thus possesses unique experience of the Indian Sugar Standards.

Kanpur:
made by factories during last ten years.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Factories</th>
<th>Percentage of Factories</th>
<th>No. of Workers</th>
<th>Percentage of Workers</th>
<th>No. of Lattices</th>
<th>Percentage of Lattices</th>
<th>No. of Centa</th>
<th>Percentage of Centa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948-49</td>
<td>17</td>
<td>12.50</td>
<td>16</td>
<td>11.85</td>
<td>26</td>
<td>20.97</td>
<td>17</td>
<td>12.60</td>
</tr>
<tr>
<td>1946-47</td>
<td>18</td>
<td>13.28</td>
<td>16</td>
<td>11.85</td>
<td>13</td>
<td>10.48</td>
<td>17</td>
<td>12.60</td>
</tr>
<tr>
<td>1945-46</td>
<td>27</td>
<td>19.85</td>
<td>17</td>
<td>12.39</td>
<td>11</td>
<td>8.87</td>
<td>16</td>
<td>11.85</td>
</tr>
<tr>
<td>1944-45</td>
<td>13</td>
<td>9.56</td>
<td>18</td>
<td>13.34</td>
<td>13</td>
<td>10.48</td>
<td>17</td>
<td>1.60</td>
</tr>
<tr>
<td>7</td>
<td>5.15</td>
<td>9</td>
<td>6.67</td>
<td>5</td>
<td>4.03</td>
<td>3</td>
<td>2.22</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>5.88</td>
<td>5</td>
<td>3.70</td>
<td>5</td>
<td>4.03</td>
<td>7</td>
<td>5.19</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>2.94</td>
<td>4</td>
<td>2.96</td>
<td>3</td>
<td>2.42</td>
<td>1</td>
<td>0.74</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2.21</td>
<td>6</td>
<td>4.45</td>
<td>1</td>
<td>0.81</td>
<td>5</td>
<td>3.70</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2.21</td>
<td>1</td>
<td>0.74</td>
<td>2</td>
<td>1.61</td>
<td>2</td>
<td>1.48</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>.74</td>
<td>2</td>
<td>1.48</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.74</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>.74</td>
<td>2</td>
<td>1.48</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.82</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>.74</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.74</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>.74</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>.82</td>
<td>—</td>
</tr>
<tr>
<td>756</td>
<td>100</td>
<td>135</td>
<td>100</td>
<td>124</td>
<td>100.00</td>
<td>132</td>
<td>97.78</td>
<td>122</td>
</tr>
</tbody>
</table>
### APPENDIX

Statement showing the number of qualities of sugar

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Grades</td>
<td>Percentage of Grades</td>
<td>No. of Grades</td>
<td>Percentage of Grades</td>
</tr>
<tr>
<td>One</td>
<td>10</td>
<td>7.46</td>
<td>15</td>
<td>11.45</td>
</tr>
<tr>
<td>Two</td>
<td>15</td>
<td>9.70</td>
<td>17</td>
<td>12.98</td>
</tr>
<tr>
<td>Three</td>
<td>24</td>
<td>17.91</td>
<td>17</td>
<td>12.98</td>
</tr>
<tr>
<td>Four</td>
<td>18</td>
<td>13.45</td>
<td>25</td>
<td>19.09</td>
</tr>
<tr>
<td>Five</td>
<td>20</td>
<td>14.52</td>
<td>16</td>
<td>12.22</td>
</tr>
<tr>
<td>Six</td>
<td>14</td>
<td>10.45</td>
<td>11</td>
<td>8.40</td>
</tr>
<tr>
<td>Seven</td>
<td>8</td>
<td>5.97</td>
<td>10</td>
<td>9.16</td>
</tr>
<tr>
<td>Eight</td>
<td>7</td>
<td>5.22</td>
<td>7</td>
<td>5.34</td>
</tr>
<tr>
<td>Nine</td>
<td>8</td>
<td>5.97</td>
<td>4</td>
<td>3.05</td>
</tr>
<tr>
<td>Ten</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>0.76</td>
</tr>
<tr>
<td>Eleven</td>
<td>3</td>
<td>2.24</td>
<td>6</td>
<td>0.76</td>
</tr>
<tr>
<td>Twelve</td>
<td>1</td>
<td>0.75</td>
<td>2</td>
<td>1.53</td>
</tr>
<tr>
<td>Thirteen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourteen</td>
<td>1</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifteen</td>
<td>2</td>
<td>1.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sixteen</td>
<td>4</td>
<td>2.99</td>
<td>3</td>
<td>2.28</td>
</tr>
<tr>
<td>Seventeen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eighteen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nineteen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twenty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twentyone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twentytwo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twentythree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** 134 100.00 131 100.00 137 100 137 100
Instrumentation of Chemical Industries

By
K. K. Bhargava M. Sc., Ph. D.
Sugar, Alcohol & Starch Technologist,
5, Royal Exchange Place, Calcutta—1

Instruments are applied to chemical industries to improve yield, increase production, maintain quality, maximise efficiency of the process and to reduce operating costs. Instrumentation has grown to such important proportions in the area of Industrial Chemistry and Chemical Engineering that it will be fair to say that most of our present industrial plants could not operate efficiently without instruments and in many cases automatic instrument control has become indispensable. Atomic energy plants have literally miles of instrument panels. In many chemical plants instrument would and should cost 20% of the total cost of the plant.

Universities and Institutions teaching chemical engineering would do well to follow out-line of the instrumentation Laboratory work given herein:

1. Adjustment, calibration and maintenance of indicating Bourdon gage.
2. The link-type pressure recorder.
3. The industrial fluid flow recorder.
4. The liquid density recorder.
5. The liquid level recorder.
7. Studies, in pyrometry measurements and instruments.
8. Humidity studies — measurement and control.
9. Analysis of moisture in gases by dew point method.
10. Studies in practical automatic control — the proportional pressure controller.
11. Practical and mathematical analysis of process and instrument characteristics.

Automation is not new in the Sugar, Alcohol and Paper Industries of other countries, where measuring instruments and automatic control of temperature, pressure, flow density and other properties are an integral part of the equipment.

In India, however, the chemical tests which determine the quality and essential characteristics of a product and insure safe and economical operation of the plant have been carried out through Laboratory analyses of samples collected by manual sampling. This analysis is of little value in the control of a process since the resultant data may describe the condition which no longer exists and the information obtained is received by the Plant Superintendent too late to correct operational errors at the time they occur.
### Table 1.

**Physical-Chemical Properties Currently being used for control of Industrial Processes.**

<table>
<thead>
<tr>
<th>Fundamental property utilized.</th>
<th>Actual measurement made.</th>
<th>Instrument used.</th>
<th>Limitations on measurement</th>
<th>Used to measure or control.</th>
<th>Typical application.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vapour pressure difference between saturated boiling liquid and same vapour of unknown superheat.</td>
<td>Temperature of equilibrium of deliquescent salt and moisture in gas.</td>
<td>Vapour must be same composition as ref. liquid.</td>
<td>Vapour composition.</td>
<td>Control of interestage refrigeration cooler.</td>
</tr>
<tr>
<td></td>
<td>Temperature of equilibrium of deliquescent salt and moisture in gas.</td>
<td>Temperature of equilibrium of deliquescent salt and moisture in gas.</td>
<td>Vapour must be same composition as ref. liquid.</td>
<td>Vapour composition.</td>
<td>Control of interestage refrigeration cooler.</td>
</tr>
<tr>
<td></td>
<td>Difference in temperature of solution before and after addition.</td>
<td>— do —</td>
<td>Effect of heat of reaction.</td>
<td>— do —</td>
<td>Humidity control of natural gas.</td>
</tr>
</tbody>
</table>
Thus corrective action initiated in good faith may or may not prove effective as it does not take into account changes during the intervening period.

By proper choice of measure variable, however, conventional industrial instruments can often be applied to continuous measurements of composition on concentration, alkalinity or acidity, partial or absolute pressure, heat of reaction or heat of solution, electrical to heat conductivity, specific gravity or viscosity, rise or lowering of boiling points to obtain laboratory accuracy. They offer advantages of lower cost and easier maintenance over specifically analytical instruments such as spectrophotographs. And because of their ability to measure quality in the flow stream without the removal of samples they minimize sampling errors and permit application of the measurement to continuous control.

The application of instruments for such quality measurements can readily be divided by Physical-Chemical properties on which the measurement depends. A list of such Physical-Chemical properties currently being used for control of industrial processes is given herein :-
Position of chain weighted plummet, electrical potential of glass cadmium electrode system.

OR potential Electrical potential of Pt, OR potential of Pt-Au, or similar electrode system.

Solution
Electrical conductivity
Specific electric resistance of solution.

Dielectric constant
Change of capacitance of fixed spacing electrical capacitor.

Viscosity
Motor load on agitator or rotating drum.
Torque on rotating drum.
Loss across orifice plate.

Detected Concentration
Self-balancing potentiometer.

Detection of minute quantities of acid or alkali; obtain optimum reaction conditions for improved yield; control reaction time; determine end point of neutralization in sugar, paper and alcohol industries.

Detection of minute traces of oxidants and reductants (CN, Cl₂, SO₂, H₂S) in solutions or air (by scrubbing) determination of reaction end points (CN, Cl₂) (SO₂, H₂S); obtaining optimum conditions for bacteriological action.

Dilution of concentration to specific concentration of electrolytes; detecting contamination with electrolytes (boiler water); detecting efficiency of wash.

Measurement of shear; thickness of sheet; concentration of certain organics.
SOLVENT EXTRACTION

Diff. Temp.

Alcohol to

Steam

DIFF.

TREATMENT

ACETONE

WATER

SOLVENTS

DIFF.

Pump

Fig. 1. Implementation for control of loss of alcohol in beer column.

Fig. 2. Calibration curve of temperature difference vs. concentration of alcohol appearing on extraction column tray shown in Fig. 1.
If it is known that the vapour mixture contains one component which is in a saturated condition, it is possible by measuring the differential temperature between the boiling liquid of the pure component and the temperature of unknown mixed saturated vapour to determine the purity of the saturated vapour under varying pressure conditions. This measurement has been used successfully to record and control the amount of alcohol reaching the bottom of fractionating column or Beer column of Alcohol distillation train.

In this particular instance indicated in the figure, temperature difference is measured between the temperature of water condensate boiling in the reference chamber and condensing distillate from the 2nd or 3rd plate from the bottom of the Beer column. If any alcohol reaches this tray, it immediately depresses the temperature of the condensing distillate before the referring temperature.

Instruments having a range of $-1^\circ$ to $+1^\circ$ C which permit accurate reading of as little as $0.02\%$ of ethyl Alcohol (Figure 2) can be had in the market.

The device may cause an alarm when alcohol appears on the tray or preferably, pneumatically set the control index on the flow controller to reduce feed to the column or to increase the flow of sparging steam; thus loss of Alcohol in the spent wash is preventive.

In actual practice the temperature difference is measured between two condensing chambers in one of which steam is fed continuously which condenses in the central connecting core and reboils condensing again in the adjoining chamber. If the temperature in these two chambers is equal to non-condensable gases exist in the relief line. As the partial pressure of non-condensable gases would increase the temperature in the chamber after the central core will decrease compared to the temperature of the first condensing chamber. Further, by controlling the temperature difference, it should be possible to vent off non-condensable gases without wasting steam.

A similar measurement, comparing the temperature of a reference chamber with the temperature of steam flowing in a line, is used to measure and control the superheat of steam provided negligible non-condensable gases are present.

Composition control by pressure-temperature relation control.

This has proved to be valuable in the control of composition of material on the trays of fractionating columns either in precision distillation of multiple component mixtures or separation of components having very small differences in boiling point, particularly where composition of feed stocks vary.

By measurement of the composition on a tray a few trays above or below the feed tray, it is possible to prevent major upsets in the column by correcting reflux ratio or heat to the column, before changes in inventory of the entire column have occurred and off-quality over-head produced.

The device for measuring such deviation from pre-determined composition is known as the dVp Cell. It consists of sealed system which is filled with a mixture of exactly the composition desired as liquid of the tray in which the instrument is installed.

Successful installation of instruments as above include columns separating isobutane and n-butane and the rectifying column of an ethyl alcohol distillation train.

The desirable range for such an instrument would depend on both rate of change of
vapour pressure with composition and on existing column pressure and must be computed for each tray composition.

**Heat Reaction.**

Instruments utilising this property would record temperature difference of solution before and after addition by means of resistance bulbs.

**Rise of boiling point of solutions.**

Instruments constructed by utilising this fundamental property would record with resistance bulbs difference in temperature between boiling distilled water and boiling solution at same pressure.

Due to certain limitation imposed by varying pressure conditions, boiling point rise can be applied to evaporators and concentration vessels which be equipped with sensitive and rapid absolute pressure control.

The maintenance of a specified absolute pressure in evaporators and in the vacuum pans specially is extremely important to obtain the best grain quality because the boiling temperature of the massaquete is a function of the temperature of the solution; further an increase in the absolute pressure causes a decrease in the super saturation. Conversely, decreasing absolute pressure increases super saturation. Instrument of precision control is required for determination of absolute pressure should so operate as to correlate and control air-pressure of the condenser water line to values which be functions of the absolute pressure within the vacuum pan.

Instrument of suitable design is described in the October 1953 issue of 'Sugar' by Mr. James D. Price.

Similarly while operating a multiple-effect evaporator it is essential to maintain a critical temperature at the constant value and for this an absolute pressure controller should be utilised in such a way that it may throttle the flow of cooling water to the barometric condenser.

**Specific Gravity**

Specific gravity as a measure of concentration of solution has been accepted in many process industries. A conventional hydrometer, of course, is not suitable nor adoptable for control methods although recently an instrument known as Densitrol has been constructed on the basis of a modification of the hydrometer principle.

A common method of specific gravity measurement with control instruments is by means of the air bubble differential pressure principle. A common application of this method is the control of the concentration of caustic in continuous mercerizing baths. The difference between pressure across fixed bubble tubes and the pressure across known reference chamber is the measure of specific gravity of the unknown solution.

This property can also be utilised in preparing lime slurry on a continuous basis concentration of lime in the milk of lime can be continuously measured by an air bubble system, the level drops due to withdrawal of the milk of lime from the preparation tank, the water flow increases and the speed of the dry feeder feeding lime is also increased proportionally. This operation is automatically varied by the specific gravity controller continuously re-setting the ratio between water in put and feeder speed.

This property can further be utilised to control the working of an evaporator set.

**pH Measurement**

Three electro chemical properties of solution can now be measured with precision by
industrial instruments. These are Hydrogen-ion concentration, Oxidation - Reduction Potential and solution conductivity.

The measurement of pH by determining the voltage of a glass calomel electrode system with an instrument having an impedance in excess of $10^{10}$ ohms is well known. pH is sometimes used as a means detecting or measuring minute concentrations of Acids or Alkalis in solutions.

The pH of solutions is often maintained with a narrow limit in order to force reaction to the end point or to improve yield. For instance in clarification of cane juice control of the pH is necessary to prevent inversion and to improve clarification. Similarly in the treatment of cyanide waste by chlorination, control of the pH of the solution is necessary to prevent the formation of cyanogen chloride.

The measurement of pH is also used to determine the end point of reaction such as sulphonating or carbonating cane juice; chlorination of starch and continuous fermentation in a Distillery.

Oxidation Reduction Potential

Instruments working on this property are being used for the determination and control of minute concentrations of oxidants and reductants solutions. It has been applied for detection of cyanide, chlorine, sulphur dioxide and hydrogen sulphide insolutions.

Another field which is yet to be completely explored is the maintenance of optimum bacteriological growth condition by means of the maintenance of oxidation - reduction potential at proper levels. Some work has been done in this direction to control the conditions of air to a activates sewage treatment plant and to control conditions in a sewage sludge digester.

Solution Conductivity

The most common use of solution conductivity is in detecting contamination in condensate being returned to the boiler as boiler feed water. In application, of course, it cannot be calibrated in terms of a specific salt since the contamination may consist of any one of a number of contaminants plus various mixtures. Fortunately in a Sugar Factory there is only one contaminant a calibration can be manipulated and devised in equivalent concentration of sugar. In other industries calibration used is the equivalent concentration of sodium chloride. Such protection is important in industries such as suad to pick up possible condense leakage and to check condemates from Evaporaters, Crystallizers and similar equipments where the spoil is likely to contaminate condensate and endanger boiler efficiency and safety.

Another application for similar measurement is the control of efficiency of water demineralizers.

In counter-current washers such as Filter Presses where it is desired to use a minimum amount of wash water, the use of conductivity difference provides means of measurement of the efficiency of the washing on a continuous basis.

Dielectric Constant

Dielectric constant is measured in terms of the capacitance effect on an electrical condensor element in or around which the fluid is placed for test. Capacitance element for more precise measurement of dielectric constant may be two or more insulated plates or cylinders in a closed container through which the test fluid flows under pressure. Capacitance changes in the sample cells resulting in dielectric constant changes in the filling fluid are measured by means of high frequency oscillating circuits and frequency meter.
Measurement of this constant can help in determining concentration of constituents in liquid mixture or in maintaining constant weight and quality.

For instance the weight of rubber being passed between capacity plates can be maintained constant by controlling the nip of the calender roll. Similarly the moisture of sheeted material such as paper can be determined by means of the moisture pick up device whose equilibrium moisture is in turn determined by capacity measurement.

Applications in which this dielectric constant phenomena are basis for the measurement include reaction kinetics, chromatography, thickness of plastic plates, solvents in oil, water in alcohols, aromatics in paraffin-naphthene mixtures, level measurement and control in liquids such as cane juices and granular solids.

Viscosity

Viscosity is an important physical property of fluids that may be employed for control of many chemical and petroleum refining processes. It is specially useful for monitoring the distillation of crude oil for control of sugar masscuites in vacuum pans and for evaluation of finished chemicals and high quality lubricants.

One interesting application involves the evaluation of portland cement quality by measurement of the viscosity-time curve for a sample prepared in standard conditions.

Commercially viscosity can be measured by determining motor-load required to rotate revolving drum in a viscous liquor.

Continuous viscosity determination instruments have been built by various firms in America and Europe.

Apart from the above mentioned process control equipment and techniques, numerous other measurements related to specific physical or physical-chemical properties have been used successfully.

Application of radio-activity in measuring thickness of metal pipes and plates or thinness of plastic and movement sheet material, in detecting corrosion or liquid level inside closed vessels, and in following flow of products through pipe lines has been made during the past few years.

The use of thermal conductivity to determine gas concentration and the use of the paramagnetic effect to determine oxygen concentration represent two important measurements which have recently been reduced to commercial practice.

Refractive index is an extensively used physical characteristic by means of which chemical compounds may be identified and measured in simple mixtures.

Application of apparatus for continuous measurement and control of refractive index is very useful in boiling sugar masscuites in vacuum pans.

Other applications include; total aromatics in paraffin-naphthene mixtures, aromatics in paraffins, styrene in C9 aromatic mixtures, butadiene product quality and separation efficiency on chromatographic columns.

Refractometers are of two general types - transmission and reflection. Transmission instruments require transparent samples and depend on refracted ray whereas reflection refractometers operate on clear, semi-transparent or opaque samples and depend only on light intensity measurement.

Recently infrared analysers and spectrometers have come into use as continuous recording analytical instruments. Applications that have been made with non-dispersion analysers include measurement of carbon...
In this article I have dealt with the general industrial instrumentation and given reference to application of basic physical chemical properties on which control instruments should be made or have been made for various chemical industries including paper, alcohol and sugar but if readers be interested in further detailed instrumentation of sugar processing, I would advise them to read the articles published in “Sugar Journal” Magazine issues of February 1953, March 1953 and July 1953 as also to an article published in July 1955 issue of “Sugar” by Peter T. Crosby.

As for those who be interested particularly in the paper industry I would refer them to various articles which have appeared on Industrial Instrumentation with particular reference to Paper Industry in the various issues of the Magazine Tappi during 1952-55.

The field and subject of process instrumentation has become a complex mixture of new scientific applications and well designed instrumental arrangements employing many long established basic principles of instrumentation and process engineering but I have reviewed in this article recent activities in instrumentation laying stress upon new, improved, and expanded analytical applications.

I must, however, once again mention certain specific reasons why the Management of an Industrial Concern, large or small, can easily justify an investment in instrumentation. A few of these most important reasons are (1) better quality and uniformity of product; (2) accident prevention; (3) accelerating the conversion of batch processes to continuous processes; (4) savings of materials, fuel and electric energy; (5) labour saving in the sense of increasing productivity bringing about higher wages and lower prices, (6) prolonging the service life of process equipment and (7) increasing production from process equipment.

A direct relationship has been observed between the degree of control and quality of the product. Since random variations in the process operating affect the composition and purity of the material product, either the specifications for the end product must fit an average production quality or a large percentage rejection must be expected. In general, therefore, product quality standards can be raised by reducing the amplitude of such variations through an adequate control means. This observation would certainly serve as a guidance for the degree of instrumentation that be done economically.

I would, therefore, end this article with a suggestion that the three chemical industries, paper, sugar and alcohol should combine together to establish an active instrument research group for the purpose of developing improved methods of measurement and control for process applications in these industries.
The Problem of High Purity Final Molasses: A Plea for Setting Down Reliable Standards

By
K. L. Khanna, B.Sc., (Agri.) A.I.A.R.I, F.A.Sc.,
Director, Sugarcane & Development,
Bihar.

A. S. Chacravarti, Ph.D., A.R.I.C., D.I.C.,
Central Sugarcane Research Station,
and
B. D. N. Sinha,
Central Sugarcane Research Station,
Pusa, Bihar.

I. Introduction.

The studies reported in this paper had their genesis in the problem of continued high purity final molasses obtained at Majhaulia Sugar Factory over the last decade which was referred to the station for solution. In earlier communications (1, 2), it was shown that the somewhat higher sugar loss at this factory as compared to the neighbouring concerns at Narkatiaganj and Harinagar was primarily due to a higher production of molasses, the contribution of poor exhaustion being insignificant. Further, even the actual higher loss arising out of production of more molasses as judged on sucrose basis was much less than the supposed loss computed on pol basis. The narrower gap between apparent and gravity purities at Majhaulia seemed to be due to a considerably lower reducing sugar content in the material of this factory. In this connection, probable causes for higher molasses production were suggested, measures for agronomical amelioration being also discussed. In the present paper, results of further confirmatory studies undertaken during the 1954-55 season have been reported, a preliminary attempt being also made at setting down more reliable standards for judging the exhaustion of final molasses than those currently in vogue in this country.

II. Experimental.

12 hour composite samples of final molasses were collected from the three factories on the same day and several such sets of samples analysed for apparent, gravity and true purities, the last named criterion being included particularly in view of the higher ash contents observed at Majhaulia which were likely to increase the difference between hydrometer brix and true solids and thus render even the gravity purity inadequate as a true index of exhaustion.

True purity, however, was not based on actual determinations of true solids but the latter was calculated from hydrometer brix
and ash content according to the formula of Fort and McKaig Jr. (3):

\[ \text{True solids} = \text{Hydrometer brix} - 1.08 \times \text{Ash} \% \]

Reducing sugars were also determined in all samples.

III. Discussion.

The results presented in table I would show that, as in the previous years, the mean apparent purities of the samples examined were considerably higher at Majhaulia as compared to Harinagar and Narkatiaganj (particularly the latter with an apparent purity lower by 6.2 units). However, considering the entire seasonal performance, the gap is not so wide, being 3.9 and 2.3 units higher at Majhaulia as compared to Narkatiaganj and Harinagar respectively. As before, reducing sugar contents were considerably lower and ash markedly higher at Majhaulia than in the other two factories.

The mean gravity purity of the samples is 2.1 unit higher at Majhaulia as compared to the two other factories which is only one-third of the 6.2 units difference observed against Narkatiaganj in respect of apparent purity. The seasonal average for gravity purity is assumed to bear the same difference from the mean value of the samples as is observed in case of apparent purity, the values estimated in this manner are practically identical for the three factories. The same holds good with regard to the true purity of molasses at the three factories. It would therefore appear that there is hardly any high purity molasses problem at Majhaulia worth mention, if the neighbouring factories are taken for comparison. This year’s findings thus corroborate the view point advanced in previous years.

A comparison of the pol and sucrose losses in molasses at the three factories has been made in table II, using Narkatiaganj factory as the standard (this factory recorded lowest pol loss in molasses as also lowest production of molasses percent cane). Excess pol and sucrose losses over Narkatiaganj have been split up into two constituents, viz.

(i) excess loss due to higher production of molasses and
(ii) excess loss due to higher purity of molasses.

The following features are clearly brought out:

1. Pol. loss in molasses.
   (a) On the basis of mean apparent purity of samples examined:
   At Majhaulia, excess pol loss over Narkatiaganj is 0.36 of which 0.17 is due to higher production and 0.19 due to higher purity. The corresponding figures in case of Harinagar are 0.21, 0.16 and 0.05.

2. Sucrose loss in molasses:
   (a) Calculated on gravity purity.
   On the basis of mean gravity purity of samples examined:
   At Majhaulia, an excess sucrose loss of 0.24 is recorded, the contribution of higher production and higher purity being 0.18 and 0.06 respectively. Corresponding figures for Harinagar are 0.17 and 0.00.

This year’s findings thus corroborate the view point advanced in previous years.
production and 0.01 due to higher purity; similar figures for Harinagar being 0.16, 0.17 and 0.01. It is thus clear that the contribution of higher purity is practically nil in both cases.

(ii) Calculated on true purity.

(a) On the basis of mean true purity of samples examined:

The total excess sucrose loss at Majhaulia is 0.27 of which 0.20 is due to higher production and 0.07 due to higher purity. The corresponding figures for Harinagar are 0.19, 0.20 and -0.01.

(b) On the basis of season's true purity:

The figure for Majhaulia are 0.18, 0.19 and -0.01, those for Harinagar being identical. It is thus seen that there is no excess sucrose loss at either factory due to higher purity of molasses.

The calculation of excess sucrose loss under 2 (i) (b) and 2 (ii) (b) is based on the assumption that the difference between the mean value of the samples examined and the season's average is identical for the three categories of purity, viz. apparent, gravity and true purities. This is a reasonable proposition but even if it is not allowed and conclusions must be based on the mean values of samples, excess sucrose loss at Majhaulia due to higher purity is merely 0.06/0.07 according as gravity or true purity is used. Even this is insignificant in comparison to the supposed higher loss of sugar due to poorer exhaustion, viz. 0.36 (excess pol loss in molasses percent cane as compared to Narkatiaganj). However, it is evident from the apparent purity figures for the Majhaulia samples that the samples were greatly divergent (on the high purity side) from the season's average value and the above figures of 0.06/0.07 excess sucrose loss are undoubtedly exaggerated in a great measure.

As regards Harinagar, where the samples conformed more closely to the season's average performance, the excess sucrose loss over Narkatiaganj is practically nil from all points of view. Those observations fully bearout the conclusions drawn in the previous year, viz. that (i) the real loss of sugar in molasses at Majhaulia is considerably lower than it appears on pol basis (ii) the somewhat higher loss at this factory is almost entirely due to a higher production of molasses, the contribution of high purity being insignificant and (iii) apparent purity affords a very unreliable picture of exhaustion and the need is to adopt true purity or at least gravity purity as the index of exhaustion.

If true purity or gravity is to be adopted for routine control, the question arises as to what should be the standards in respect of these criteria that could be taken as indicative of a fairly good exhaustion of the final molasses. Under current practice in the Indian Industry, the generally accepted standard appears to be an apparent purity of 32 or thereabouts. No standards with reference to true or gravity purity, however, seem to have been worked out. Considering the data collected in course of this work (vide table 1) and the seasonal averages (computed as explained earlier), it is not improbable that the true and gravity purities representing a fair exhaustion lie between the respective limits of 42-43 and 37-38. All the samples of Harinagar and Narkatiaganj factories show figures within these ranges (the last named factory also satisfying the condition of about 32 apparent purity and being therefore well exhausted under current standards) and the same holds good with regard to the computed seasonal averages at Majhaulia as well. The individual season samples of this factory do not
show gravity and true purities higher than these standards but, as stated already, they represent a somewhat poorer exhaustion compared to the season's average performance, as reflected in the figures for apparent purity itself. The standards proposed above must doubtless be considered as tentative one and there is no gain-saying the fact that much more work is called for with reference to a large number of factories in different regions and exhaustively covering all stages in the crushing season. The need for such work is urgent in order to enable introduction of true or gravity in routine control. Such a measure would place the question of judging molasses exhaustion on a sound basis and not only eliminate unnecessary concern on this score (as happened in the present case), but also focus attention on this aspect where a real problem exists but passes unheeded due to reliance on the deceptive criterion of apparent purity. Whether gravity purity would prove adequate under conditions obtained in the country or in a particular region or if the more exacting test of true purity will have to be applied remains to be determined. If use of the latter criterion proves imperative, whether true solids would need to be actually determined or if the values computed from ash contents by the Fort McKaig formula (loc. cit) would be adequate as also which of these procedures would be more suited for routine control are yet other aspects to be investigated. Similarly, the possibility of using refractive brix as a more easily determined approximate substitute for true solids needs to be examined.

Apart from a comparison of the performance at the three factories, it may not be out of place to view the degree of exhaustion in the light of certain criteria proposed by other workers in this connection which take into account the composition of the material in-a-vis the limits of exhaustion to be reasonably expected. Thus, Baikow (4, 5), taking into consideration the reducing sugar content of the molasses, regards a level of 59.1 percent total sugars (true sucrose reducing sugars) at 100 Brix as indicative of satisfactory exhaustion. This criterion was based on analyses at the New York Sugar Trade Laboratory of several thousand samples from all parts of the world and later corroborated by Masson (6, 7). Similarly Presas (8), taking account of the total non-sugar content, associates satisfactory exhaustion with a total non-sugars/true sucrose ratio laying between 80 and 90 which might sometimes go up to 100 and in very rare cases even above 100. The figures in respect of these criteria for two seasons depicted in table III would show that the levels envisaged by Baikow and Presas are always excelled in a considerable measure at the three factories concerned. In fact, the results at Majhaulia would appear to be systematically better than in case of the others even though the samples of this factory represented a somewhat poorer exhaustion compared to the average seasonal performance (as explained earlier). This obviously leads to the conclusion that in so far as the criteria of Baikow and Presas indicate the position, the three factories were doing very well with regard to exhaustion of molasses and the performance at Majhaulia, far from being unsatisfactory, was excellent with the material being handled.

IV. SUMMARY.

(1) In this paper, results of comparative studies on the problem of final molasses purity carried out with reference to three factories of Champaran district in North Bihar have been reported.

(2) The deceptive nature of apparent
purity is clearly revealed and the need for using a more reliable criterion for judging exhaustion (such as true purity or gravity purity) indicated.

(3) Certain tentative standards are suggested in respect of the true and gravity purities of a fairly well exhausted final molasses and the need for exhaustive work in this direction stressed so as to enable introduction of one or the other of these criteria in routine control.

(4) The importance of the molasses production factor in determining loss of sugar in this product is forcefully brought out, the inadequacy of concentrating attention on purities alone being strongly indicated.

(5) Considered in the light of certain criteria for judging exhaustion which take into account the chemical composition of the material, all three factories were doing very well, the performance at Majhaulia being excellent with the material handled.

V. Acknowledgment.

The work was carried out as part of the Sugarcane Research Scheme in Bihar being financed jointly by the Government of Bihar and the Indian Central Sugarcane Committee to whom grateful thanks are due. The cooperation extended by Messrs M. P. Sugar Mills Ltd., Majhaulia, Mears New Swadeshi Sugar Mills Ltd., Narkataganj and Messrs Harinagar Sugar Mills Ltd., Harinagar is highly appreciated.

VI. References.

4. Balikov (1951)
5. ——— (1953)
6. Masson (1952)
7. ——— (1953)
8. Presas (1953)

Ibid, 23rd Conv., Symposium on Sugar Loss in Molasses.
Sug. Jour., p.15.
Sugar, 48, 62.
Sugar, 48, 62.
Ibid, 48, 71.
Table II.

<table>
<thead>
<tr>
<th></th>
<th>Pol lost in molasses percent cane</th>
<th>Excess pol lost in molasses percent cane due to higher production</th>
<th>Sucrose lost in molasses percent cane. Due to higher purity.</th>
<th>On the basis of gravity purity</th>
<th>On the basis of true purity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pol lost in molasses percent cane on the basis of molasses production percent cane at Narkatiaganj.</td>
<td>Due to higher purity.</td>
<td>Total.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Based on mean figures of samples.</td>
<td>1.36</td>
<td>1.19</td>
<td>0.17</td>
<td>0.19</td>
<td>0.36</td>
</tr>
<tr>
<td>(b) Based on season’s averages.</td>
<td>1.26</td>
<td>1.11</td>
<td>0.15</td>
<td>0.12</td>
<td>0.27</td>
</tr>
<tr>
<td>(a) Based on mean figures of samples.</td>
<td>1.21</td>
<td>1.05</td>
<td>0.16</td>
<td>0.05</td>
<td>0.21</td>
</tr>
<tr>
<td>(b) Based on season’s averages.</td>
<td>1.19</td>
<td>1.04</td>
<td>0.15</td>
<td>0.05</td>
<td>0.20</td>
</tr>
<tr>
<td>(a) Based on mean figures of samples.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(b) Based on season’s averages.</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Sucrose lost in molasses percent cane on the basis of molasses production % cane at Narkatiaganj.</td>
<td>Excess sucrose lost in molasses percent cane over Narkatiaganj.</td>
<td>On the basis of gravity purity.</td>
<td>On the basis of true purity.</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On the basis of gravity purity.</td>
<td>Due to higher production.</td>
<td>Due to higher production.</td>
<td>Total.</td>
<td>Due to higher production.</td>
</tr>
<tr>
<td>(1) Majhaulia</td>
<td>1.22</td>
<td>1.38</td>
<td>0.18</td>
<td>0.06</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>1.14</td>
<td>1.30</td>
<td>0.14</td>
<td>0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>(2) Harinagar</td>
<td>1.16</td>
<td>1.30</td>
<td>0.17</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>1.14</td>
<td>1.29</td>
<td>0.17</td>
<td>-0.01</td>
<td>0.16</td>
</tr>
<tr>
<td>(3) Narkatiaganj</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table III.
Showing exhaustion at the three factories as judged by the criteria of Baikow and Prasra.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Brix.</th>
<th>True sucrose %</th>
<th>Reducing sugars %</th>
<th>Total sugars per 100 Brix.</th>
<th>Total non sugars %</th>
<th>True sucrose.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Majhauia.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>98.60</td>
<td>38.23</td>
<td>15.40</td>
<td>54.4</td>
<td>117.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>96.99</td>
<td>37.45</td>
<td>13.63</td>
<td>52.6</td>
<td>121.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>94.39</td>
<td>39.01</td>
<td>11.82</td>
<td>58.8</td>
<td>117.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>97.24</td>
<td>39.47</td>
<td>12.35</td>
<td>53.5</td>
<td>114.5</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>96.80</td>
<td>38.54</td>
<td>13.35</td>
<td>53.6</td>
<td>116.4</td>
<td></td>
</tr>
</tbody>
</table>

| 2. Harinagar. |       |                |                   |                             |                   |               |
| 1             | 95.56 | 35.40          | 20.00             | 58.0                        | 113.0             |               |
| 2             | 93.86 | 35.27          | 17.20             | 55.9                        | 112.2             |               |
| 3             | 95.04 | 36.09          | 18.10             | 57.9                        | 110.0             |               |
| 4             | 94.13 | 35.53          | 19.20             | 58.1                        | 111.0             |               |
| Mean          | 94.15 | 32.25          | 19.63             | 57.5                        | 111.5             |               |

| 3. Narkatanganj. |       |                |                   |                             |                   |               |
| 1             | 95.56 | 35.31          | 19.37             | 57.5                        | 115.8             |               |
| 2             | 94.38 | 33.87          | 19.23             | 56.4                        | 109.3             |               |
| 3             | 95.29 | 35.42          | 18.30             | 57.8                        | 111.3             |               |
| 4             | 95.56 | 36.20          | 20.74             | 59.6                        | 106.7             |               |
| Mean          | 94.19 | 35.70          | 19.46             | 58.3                        | 110.8             |               |

| (b) Season 1953-54* |       |                |                   |                             |                   |               |
| 1. Majhauia. |       |                |                   |                             |                   |               |
| 1             | 95.94 | 37.60          | 12.34             | 53.2                        | 117.0             |               |
| 2             | 98.67 | 38.36          | 12.99             | 52.0                        | 123.4             |               |
| 3             | 91.96 | 35.19          | 13.78             | 53.6                        | 140.4             |               |
| 4             | 94.38 | 33.60          | 11.25             | 51.2                        | 124.6             |               |
| Mean          | 94.34 | 36.92          | 12.19             | 52.5                        | 128.5             |               |

| 2. Narkatanganj. |       |                |                   |                             |                   |               |
| 1             | 90.86 | 34.20          | 15.24             | 54.6                        | 150.0             |               |
| 2             | 97.54 | 35.96          | 17.22             | 57.4                        | 169.4             |               |
| 3             | 91.70 | 33.85          | 17.23             | 57.9                        | 169.3             |               |
| Mean          | 91.70 | 35.54          | 16.56             | 56.6                        | 122.9             |               |

* In this season, Harinagar samples were not analysed.
Recent Trends in Sugar Factory Practice

By

Dr. K. S. G. Doss D. Sc. F.R.I.C., F.Inst. P.

and

J. K. P. Agrawal B. Sc., A.I.I.S.T.

Indian Institute of Sugar Technology, Kanpur, India.

Improvements in the technology of sugar manufacture are being effected continuously with a view to cutting down the cost of production, minimising losses, improving the quality of sugar and facilitating the operation and control of machinery and processing. Some of the recent trends in this field have been summarised in the present article.

For weighing cane standing in the fields, experiments conducted at Hawaiian Commercial & Sugar Co. with a-ways radioactive Cobalt and a Geiger Counter, show that the weight of cane can be estimated within about 1.5%. It is found that the cane below the furrow tops could not be weighed. The method would be helpful not only for the estimation of yield, but also in systematic harvesting.

Automatic cane carrier speed control has been introduced in many factories in Jamaica. The system eliminates the human element in the control and utilises maximum power of cane preparators (knives or shredders). The varying current load of motor driving the knives or shredders through a current transformer is made to actuate a relay which controls the pressure of air in a box which is transmitted to a standard diaphragm-controlled valve. The latter is used to throttle the cane carrier drive engine. The systenm is so adjusted that the carrier speed is slowed down when the motor current rises just above full load and stops the carrier if the current reaches fifty percent overload. The loss of time in operation of mills due to chokes at the cane knives or shredders is thus avoided.

New types of mills enabling better trash-plate construction and easier setting and replacement of mills are coming more and more into use, the essential feature being the absence of king bolts and side bolts. Turbine drives are being introduced by which it has been possible to have a push-button control of mills from a central panel. Since 1954 at the Kekaha Sugar Company, Ltd. (Hawaii), the crusher and each of the five mills of a 17-roller tandem is driven by individual steam driven turbines, equipped with a complete auxiliary lubrication system which automatically prevents operation in the event of loss of oil pressure in the turbines or gear. One man, standing at the control panel can control the speeds of each of the turbine separately and also can operate a master control, which can raise or lower the speed of the whole tandem in unison. Continuous pressure feeders have effected reduction in moisture content of final bagasse by about 5%. This would also decrease the pol lost in bagasse.

The use of roller bearings is another important development in reducing power consumption. The other advantages are no wear on roll necks and bore of bearings, no water cooling, lowering of lubrication costs, self-alignment, reduced bending stress on roll necks, easy assembly and dismantling, diagonal roll adjustment and no lateral.
clearance in bearings and head stocks. A new design of the 3 roller mill would be helpful in getting optimum working conditions at varying throughput of cane without resorting to any changes in mill settings. This has been achieved by employing two hydraulic rams, one for the top roll and one for the discharge roll. The pressure ratio at feed and discharge is thereby kept at any desired constant value. In Puerto Rico, recent trend is to have a mill of 33.5 x 66" size rolls with a peripheral speed of 57 feet per minute. Rubber intermediate carriers of high level apron type have also been used and given good service with very little wear even after three seasons of service. A simple arrangement involving the passage of blanket of cane over a magnetic pulley has been described for eliminating tramp iron. Accumulators based on pneumatic principles are being increasingly introduced. The advantages are no inertia, no friction, no moving parts to wear out, long life with little maintenance, quick and cheap erection. Even pressure over the whole length of the mills is also assured. Use of chokeless pumps and vibrating screens in maceration has improved the mill sanitation. Satisfactory results regarding rise in juice purity and consequently sugar yield have been obtained at Guanica Central by the application of Chlorine to the mill juices. 7 lbs. per 1000 tons cane are found to be satisfactory. It has however, been observed that the chlorine causes corrosion of mixed juice pump, heater control valves, and perforated pipes for imbibition water.

A condensation product of ethylene oxide on a polyoxypropylene base known as Extrapol® has been put on the market and it is claimed that it increases the extraction of sugar from cane during milling. No published technical data under controlled conditions are however, available as yet on this product.

Special mention may be made of the recent development of a pilot plant for continuous diffusion process as applied to cane. This has been designed by the National Gas Cylinder Co., and worked at the Fellsmere Sugar Producers' Association's factory at Fellsmere, Fla. They have blue prints for large scale plants with a guarantee of extraction of 97%. Purity of juice would be higher by 2-3 units. The diffusion plant is claimed to require half the weight of steel of the same capacity, less than half the power and is stated to cost half as much and to be operable by two men.

Automatic weighing of bagasse has been achieved taking advantage of gamma radiation from radio-isotopes. This has been successfully worked in Hawaii. The isotopes Co and Cs are used. The error is claimed to be less than 2%. This technique has also been used for checking the weight of raw sugar.

In steam generation, the combustion of bagasse has been improved by the introduction of Spreader Stokers reducing the excess air from 50% to 15%. Considerable saving of labour is also effected. It is reported, however, that there is too much formation of fly ash which can be avoided by putting up an efficient type of dust precipitator. Automatic feed control and automatic combustion control together with some form of bagasse storage between conveyor and feeder are essential for efficient working of Spreader stoker unit. The Spreader stoker would also be very useful for burning the pith obtained as a waste product during the conversion of
Bagasse into paper pulp. Higher steam pressures are being employed. If the fibre in cane is low and extra fuel is needed, cane trash can be used as fuel. It is of interest to note that the Ravalgaon Sugar Factory (District Nasik, Bombay State) has been able to use sugarcane trash successfully in the boiler furnace, getting thereby 5 lbs. equivalent evaporation per lb. of trash. Many factories in India have proceeded with semi-electrification thereby effecting considerable fuel economy.

In clarification, one important advance made recently is the Saha-Jain Process, which has been tried in a number of factories in India resulting in the improvement of the quality of sugar obtained. Ghosh has evolved by experiments in his laboratory a new procedure for electrical method of clarification of cane juice. The new procedure is being worked upon at the Indian Institute of Sugar Technology on a pilot plant scale with a view to assessing its potentialities. Mid-juice carbonation has been successful in Formosa and has been found superior to the De Haan Process in that, filtration rate is better, sugar in cake is lower, purity rise is higher and consumption of lime is lower. The calcium content of the clarified juice is also lower in this process. Continuous lifting and sulphitation equipment is becoming popular. This gives better control over the processing, as it can be rendered completely automatic. The radio-isotopes have been used successfully in elucidating the role of added phosphate in clarification.

Some linear polymers such as Lytron x-886 have been employed in order to improve flocculation, settling and filtration. There are, however, no technical data under controlled conditions proving their advantages. Automatic temperature regulation is possible by thermostatic devices and controls in the heating of juices. In place of lime, active magnesia has been found to give better results in clarification although the reports from different sources are not uniformly favourable. At Ravalgaon, di-calcium phosphate stabilised by sulphur dioxide has been shown to be satisfactory for clarification. Bentonite as a clarificant is receiving attention. Used as an auxiliary, it has helped in improving clarity, settling rate and filtering rate, as revealed by the trials at the Indian Institute of Sugar Technology. It had no effect on purity rise or the quality of sugar. The problem of treating Oliver filtrates to avoid re-circulation of non-sugars is continuing to receive attention, but is still a baffling problem. Apart from the use of the continuous centrifuge, the other attempts to solve the problem have been in the direction of using auxiliary filter presses, or a small continuous clarifier for separately treating the cloudy filtrate, employing filtering or settling aids. Continuous settlers, and rotary filters are becoming more and more common advances mainly being saving of labour, reduction of pol losses and improvement of control of processing. Recently, important modifications have been introduced in the design of the continuous clarifier which enhance the throughput for a given volume of the clarifier. The main changes in design are in diminishing the size of the flocculating cell, increasing the depth of the settling compartments, having separate mud extraction for each pair of settling compartments and modifying the mode of feed so as to enhance the efficiency of subsidation. A new type of vertical leaf type pressure filter has given satisfactory results regarding efficiency and maintenance costs.
Sealed down takes in the evaporators are becoming more and more common. A single-shell 4-effect evaporator is being designed (19). Electrical devices for prevention of scale are being tried out, but their mode of action, if any, continues inexplicable. No published data under controlled conditions are available either to prove or disprove the claims. Amongst the new chemicals introduced for descaling is versene (20), which consists mainly of sodium salt of ethylenediamine tetraacetic acid. This substance is known to form a stable complex with calcium and has also been used successfully for estimating calcium. Foam destroyers of high efficiency are available on the market though they are costly (21). Work is on at the Indian Institute of Sugar Technology to prepare similar products from indigenous raw materials (21) (a).

In pan-boiling, the mechanical circulator is becoming popular. This helps in increasing heat transfer and diminishing the time of boiling. Crystals formed are better due to the good movement of the masses. Since the power consumption by the circulators is dependent on viscosity of the masses, it has been possible to have an automatic feeding system based on this principle. Low head pans are also being introduced. Important advances in crystallizer pan design have been effected under the Candy Scheme sponsored by the Indian Institute of Sugar Technology at the Ravalgaon Sugar Factory (23). The use of a fondant of finely powdered sugar in organic solvents such as isopropyl alcohol has been very helpful for settling (22).

Exhaustion has been improved by the use of cooling and reheating elements in the crystallizers or in mixers. A resistance heating technique for reheating masses is being developed at the Indian Institute of Sugar Technology and has given promising results in the laboratory (26).

Continuous centrifugals are being experimented upon, for high grade masses. They have obviously great advantages in that, the power requirement is small and peak loads are absent, and the wear associated with frequent acceleration and braking is eliminated; but it is found that the crystals get damaged and the last in sugar is affected particularly in larger sizes (25). Changes in design appear to have been effected for largely obviating this difficulty. High speed centrifugals with automatic controls are getting popular in Indian Factories the main advantages being better separation and saving of labour. It is found, however, that double curing of masses is necessary to get a uniformly good quality product.

Turbo-dryer (26) has been used for the first time at the American Sugar Factory at Crookston. 1 lb. of saturated solution enters at a temperature of 125-131°F having 1% moisture and it comes out at a temperature of 120-128°F with 0.5% moisture. The heat required to evaporate the moisture and to heat the air to the exhaust temperature is 416,000 B. Tu. (400 lbs. x 1040 B. Tu./lb.) and 620,000 B. Tu. (30,000 lbs. 158-75) x 0.25). The amount of air required is 67,000 cu. ft. per min. Operating conditions (temperature and humidity of the outside air) vary from factory to factory. The product is beautifully white and lustrous; however, the absence of fines and broken crystals results in a lower density.

Processes have been patented for winning sugar from molasses by a preliminary drying and extraction using an organic solvent and 21 to 43% yield of sugar on dry molasses is claimed (27). A sealed-bin system has been developed by the U. S. Rubber Co., for supplying the sugar in bulk, with the advantage to reduce packs.
ging and shipping charges and eliminate godowns. These containers are made of synthetic rubber and fabric, each having a capacity of about 15 tons of sugar. In Puerto Rico, Aluminium boxes of 20 tons capacity are filled with sugar, loaded in trailers and shipped to United States for sale in the market. The boxes are emptied, cleaned and filled up with merchandise and shipped back to Puerto Rico.

On the Determination of "Whiteness Value"
of White Sugar
By Means of the Two-Point-Estimation Method

By
Minoru Kamoda, B.Sc.,
Research Chemist, Research Laboratory
and
Takeo Yamane, B.Sc.,
Director of Technical Department
Japan Sugar Refineries’ Association Tokyo, Japan.

Whiteness is an extremely important factor in the evaluation of the quality of white sugars. It would be very helpful if a simple method for the determination of whiteness of sugar is established. There is, however, scanty practical information available on this subject.

Dekker (1) recommended to express the generally acknowledged whiteness of white sugars by the "remission value" found by subtracting half of the saturation from the brightness, and remission values above 61 were entitled to be classified as white. Because since the dominant wave length of white sugars varies more or less around 570 m/l and the CIE-chromatically-diagram on which the above-mentioned method is based is not the uniform chromaticity-scale diagram, the whiteness perceived by eyes may be unable to be expressed quantitatively by such a method based on the monochromatic system.

According to the Judd's research (2), on the other hand, the whiteness is expressed by the degree of approach of the sample color to the color of the standard white on the alpha-beta chromaticity diagram known as the uniform chromaticity-scale diagram. Here the formula for whiteness is based on the following definition:

$$ W = 1 - \frac{\triangle E_{MgO \text{to Specimen}}}{\triangle E_{MgO \text{to Black}}} $$

where magnesium oxide (MgO) is taken as the whiteness standard and the size of color difference $E$ is given in units known as NBS units (2). This relation gives a scale of whiteness from 1.00 for the whiteness standard to zero for the perfect black (brightness Y = zero) and the values obtained have been found to correlate well with visual estimates of whiteness for white or near white specimens. Since this index of whiteness is applicable only to white or near-white specimens, it can be computed from the following equation:

$$ w = 1 - \frac{\{30(a^2 + \beta^2)^{1.3} + \{1 - Y/100\}\}}{\{30(a^2 + \beta^2)^{1.3} + \{1 - Y/100\}\} + 1.00 - \chi \sqrt{\beta^2)} $$

where Y is the brightness and the value of $a, \beta$ is described in the following section 'Judd's whiteness'.

Judd's whiteness has been proved to be of important value for control in connection...
with the laundering of textiles, use of chemical bleaches and so-called optical bleaches. The present authors estimated Judd's index of whiteness for many samples of white sugars and found it quite satisfactory as well as correlated with visual estimation. But, a drawback of this method is the great amount of time taken for the determination of the reflectance curve and the calculation of the whiteness; the same is for Dekker's remission value.

The object of this paper is to present a simple method "the two-point-estimation method," based on the general rule of color space and to recommend the "whiteness value" obtained by this method since it is well correlated with Judd's whiteness and as well as with the visual estimation; "whiteness value" is calculated simply from two reflectance values at 560 m\( \mu \) and 540 m\( \mu \) using the accompanying table (Table II).

Expression of Colors of White Sugars by the Monochromatic System

Thirty-six samples of refined sugars including fifteen of granulate, fourteen of soft white superior and seven of soft white medium were collected at random. The reflectances of these samples were measured at thirty points between 400 m\( \mu \) and 700 m\( \mu \) with a spectrophotometer. For all the following reflectance measurements, a Beckman-type spectrophotometer made by the Hitachi Machinery Co. (Tokyo) was used. The color for each sample was calculated by determining the trichromatic coefficients according to the selected ordinate method of Hardy for Illuminant C and expressing the results in the monochromatic system. The brightness, excitation purity and dominant wave length thus obtained for each sample are shown in column 1-3 of Table I. Such a method had been used (1,3) so far with success for determining the color of refined sugars in solution and solid, but color differences are not apparent from these values.

Judd's Whiteness

The chromacity coordinates \( a \) and \( b \) of any color in the above said equation are computed from the trichromatic coefficients in the standard CIE coordinate system by the following defining equations:

\[
\begin{align*}
a &= 2.4266x - 1.3631y - 0.3214 / 1.0000x + 2.2633y + 1.1054 \\
B &= 0.5710x + 1.2447y - 0.5708 / 1.0000x + 2.2633y + 1.1054
\end{align*}
\]

\( a \) and \( B \) for each sample were then calculated from the trichromatic coefficients according to the above equations, and the whiteness was calculated from values \( a \), \( B \) and \( Y \), by the equation (1). The whiteness thus obtained is given in column 4 of Table I. The No. of samples is arranged in the table in ascending order of this whiteness. A comparison between columns 1 and 4 shows that Judd's whiteness decreases almost exactly in the same order as the purity increases, while there is no such relationship between the brightness and Judd's whiteness. It is noted, therefore that the purity is the most important factor to express the whiteness and the brightness is secondary.
In Fig. 1 are shown the reflectance curves for the white and black specimens and three white sugars. Considering the relation between such spectral reflectance curves and the three attributes of color, the following general rule may be deduced; the white specimen which has the lightest color, also has the highest reflectance and the black specimen which has the darkest color reflects least. Both the white and black specimens, so-called a chromatic color specimens, are essentially non-selective in their reflectance and they have neutral color as shown in Fig. 1. Granulated sugars, whose color is lighter than either of soft white medium, reflect more at every part of the spectrum than soft white medium do. It is evident that reflectance is related to the lightness of color perceived. Furthermore granulated sugar, soft white superior and soft white medium have progressively more saturated colors, that is, progressively distinct from any achromatic color and their corresponding reflectance curves are progressively steeper. It may be, therefore, noted that the saturation of the perceived color corresponds to the steepness of the reflectance curve. So it seems reasonable to conclude that if the reflectance curves of samples to be tested are the higher and the flatter, i.e., the nearer to the type of the reflectance curve of the white specimen, the whiter are the colors perceived.
with the laundering of textiles, use of chemical bleaches and so-called optical bleaches. The present authors estimated Judd's index of whiteness for many samples of white sugars and found it quite satisfactory as well as correlated with visual estimation. But, a drawback of this method is the great amount of time taken for the determination of the reflectance curve and the calculation of the whiteness; the same is for Dekker's remission value.

The object of this paper is to present a simple method "the two-point-estimation method," based on the general rule of color space and to recommend the "whiteness value" obtained by this method since it is well correlated with Judd's whiteness and as well as with the visual estimation; "whiteness value" is calculated simply from two reflectance values at 560 and 540 m\(\mu\) using the accompanying table (Table II).

**Expression of Colors of White Sugars by the Monochromatic System**

Thirty-six samples of refined sugars including fifteen of granulate, fourteen of soft white superior and seven of soft white medium were collected at random. The reflectances of these samples were measured at thirty points between 400 m\(\mu\) and 700 m\(\mu\) with a spectrophotometer. For all the following reflectance measurements, a Beckman-type spectrophotometer made by the Hitachi Machinery Co. (Tokyo) was used. The color for each sample was calculated by determining the trichromatic coefficients according to the selected ordinate method of Hardy for Illuminant C and expressing the results in the monochromatic system. The brightness, excitation purity and dominant wave length thus obtained for each sample are shown in column 1 - 3 of Table I. Such a method had been used (1,3) so far with success for determining the color of refined sugars in solution and solid, but color differences are not apparent from these values.

**Judd's Whiteness**

The chromacity coordinates \(a\) and \(B\) of any color in the above said equation are computed from the trichromatic coefficients in the standard CIE coordinate system by the following defining equations:

\[
\begin{align*}
a &= 2.4266x - 1.3631y - 0.3216y \\
B &= 0.5710x + 1.2447y - 0.5708y
\end{align*}
\]

\(a\) and \(B\) for each sample were then calculated from the trichromatic coefficients according to the above equations, and the whiteness was calculated from values \(a\), \(B\) and \(Y\), by the equation (1). The whiteness thus obtained is given in column 4 of Table I. The No. of samples is arranged in the table in ascending order of this whiteness. A comparison between columns 1 and 4 shows that Judd's whiteness decreases almost exactly in the same order as the purity increases, while there is no such relationship between the brightness and Judd's whiteness. It is noted, therefore that the purity is the most important factor to express the whiteness and the brightness is secondary.
101

"Whiteness Value" by the Two-Point Estimation Method

Fig. 1

Reflectance Curves of Complete White and Black Specimens and White Sugars

In Fig. 1 are shown the reflectance curves for the white and black specimens and three white sugars. Considering the relation between such spectral reflectance curves and the three attributes of color, the following general rule may be deduced: the white specimen which has the lightest color, also has the highest reflectance and the black specimen which has the darkest color reflects least. Both the white and black specimens, so-called a chromatic color specimens, are essentially non-selective in their reflectance and they have neutral color as shown in Fig. 1. Granulated sugars, whose color is lighter than either of soft white medium, reflect more at every part of the spectrum than soft white medium do. It is evident that reflectance is related to the lightness of color perceived. Furthermore granulated sugar, soft white superior and soft white medium have progressively more saturated colors, that is, progressively distinct from any achromatic color and their corresponding reflectance curves are progressively steeper. It may be, therefore, noted that the saturation of the perceived color corresponds to the steepness of the reflectance curve. So it seems reasonable to conclude that if the reflectance curves of samples to be tested are the higher and the flatter, i.e., the nearer to the type of the reflectance curve of the white specimen, the whiter are the colors perceived.
Assume that two suitable points between 400 and 700 μm are selected as A and B shown in Fig. 2. The reflectance of a sample at wave length A μm may be considered to correspond to the height of its reflectance curve and the difference of two reflectances at A and B μm the steepness of the reflectance curve. As shown in Fig. 1 the reflectance curves of white sugars are smooth and rise toward the red end of the spectrum and descend toward the blue end to the different grade depending on the color of samples.

Attempt was then made to select two suitable points between 400 and 700 μm and to establish a relation between a proper combination of the reflectance values at these two points and Judd's whiteness. For this purpose two points of wave length 450 and 560 μm were selected as cited above. If reflectance at 450 μm is the larger and the difference (Refl. 560−Refl. 450) is the smaller, the sugar tested is the whiter; therefore if the value (Refl. 460/Refl. 560−Refl. 450) is the larger, the sugar is perceived as the whiter. As shown in column 5 of Table 1, the values (Refl. 460/Refl. 560−Refl. 450) agree well in their sequence with Judd's whiteness (column 4). However the graph of the values (Refl. 460/Refl. 560−Refl. 450) against Judd's whiteness was a curve rather than a straight line expected. An equation to correct such a curvature therefore, was derived from the estimation data by calculation with the least square method; it is as follows:

\[
\text{Whiteness} = -2.13066x + 0.38395x^2 - 9.44274x^3 + 5.15424x^4 - 1.35089x^5 + 0.14000x^6
\]

where \(x\) is logarithm of (Refl. 460/Refl. 560−Refl. 450).

The figures calculated in this way are correlated well with Judd's whiteness as illustrated in Fig 3 and the named "whiteness value." Whiteness values of white sugar are shown in column 1 of Table 1. In the ideal case of a complete white sugar, this value is 1. It is seen that whiteness values for granulate sugar vary from 0.966 to 0.766, those for soft
white superior from 0.931 to 0.832 and those for soft white medium from 0.510 to 0.140. The table to calculate "whiteness value" from \((\text{Refl.} 450/\text{Refl.} 560 - \text{Refl.} 450)\) is shown in Table II; this table was made for convenient use directly from the value \((\text{Refl.} 450/\text{Refl.} 560 - \text{Refl.} 450)\), not from its logarithm as used in the above equation.

**Fig. 3**

Graph of "Whiteness Value" Against Judd's Whiteness

The effect grain-size variation on reflectance value is particularly important. Keane and Brice (4) found that the coarse-grained sugars had lower reflectances then the fine-grained sugars. Browne and Zerban (5) commented also on the effect of grain size on reflectance values, referring to the work done by the Java Sugar Experiment Station. By our two-point-estimation method, however, we are able to determine the whiteness of a given sample perceived by the eye just as it is, e.g., coarse or fine, etc. Therefore this method can be used without difficulty for the evaluation of products in practice.

**Example:** Reflectance of the sample No. 14

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>Reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>93.6</td>
</tr>
<tr>
<td>565</td>
<td>96.2</td>
</tr>
</tbody>
</table>

\[ \frac{\text{Refl.} 450}{\text{Refl.} 560 - \text{Refl.} 450} = 36.00 \]

Looking up whiteness value nearest to 36.00 in Table II, we find 0.910.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.990</td>
<td>0.909</td>
<td>35.6</td>
<td>0.869</td>
<td>22.3</td>
<td>0.829</td>
<td>18.8</td>
<td>0.490</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>0.889</td>
<td>397</td>
<td>76.5</td>
<td>34.8</td>
<td>21.9</td>
<td>7</td>
<td>16.5</td>
<td>70</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>393</td>
<td>81.7</td>
<td>34.2</td>
<td>21.7</td>
<td>6</td>
<td>16.4</td>
<td>60</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>382</td>
<td>78.1</td>
<td>33.6</td>
<td>21.5</td>
<td>5</td>
<td>16.3</td>
<td>50</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>381</td>
<td>76.4</td>
<td>90.9</td>
<td>33.0</td>
<td>0.864</td>
<td>21.3</td>
<td>0.824</td>
<td>16.2</td>
<td>0.440</td>
</tr>
<tr>
<td>5</td>
<td>380</td>
<td>74.5</td>
<td>31.7</td>
<td>21.1</td>
<td>5</td>
<td>16.1</td>
<td>30</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>0.884</td>
<td>376</td>
<td>72.7</td>
<td>31.3</td>
<td>20.9</td>
<td>2</td>
<td>16.0</td>
<td>20</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>370</td>
<td>70.9</td>
<td>31.2</td>
<td>20.7</td>
<td>1</td>
<td>15.9</td>
<td>10</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>367</td>
<td>69.2</td>
<td>31.0</td>
<td>20.6</td>
<td>0</td>
<td>15.6</td>
<td>00</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>363</td>
<td>0.939</td>
<td>67.1</td>
<td>0.899</td>
<td>30.7</td>
<td>0.859</td>
<td>20.5</td>
<td>0.810</td>
<td>15.0</td>
</tr>
<tr>
<td>0.879</td>
<td>354</td>
<td>65.3</td>
<td>30.0</td>
<td>20.3</td>
<td>80</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>348</td>
<td>61.6</td>
<td>29.6</td>
<td>19.9</td>
<td>60</td>
<td>4.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>341</td>
<td>60.0</td>
<td>29.3</td>
<td>19.8</td>
<td>0.790</td>
<td>13.6</td>
<td>50</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>333</td>
<td>0.934</td>
<td>58.4</td>
<td>0.894</td>
<td>28.9</td>
<td>0.854</td>
<td>19.5</td>
<td>70</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>328</td>
<td>56.8</td>
<td>28.6</td>
<td>19.4</td>
<td>60</td>
<td>12.0</td>
<td>30</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>0.874</td>
<td>323</td>
<td>53.2</td>
<td>28.0</td>
<td>19.3</td>
<td>50</td>
<td>11.5</td>
<td>20</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>316</td>
<td>54.8</td>
<td>27.6</td>
<td>19.2</td>
<td>10</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>309</td>
<td>53.7</td>
<td>27.4</td>
<td>19.1</td>
<td>0.740</td>
<td>11.1</td>
<td>00</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>300</td>
<td>52.6</td>
<td>27.2</td>
<td>0.849</td>
<td>18.9</td>
<td>20</td>
<td>10.4</td>
<td>0.290</td>
<td>4.1</td>
</tr>
<tr>
<td>0</td>
<td>292</td>
<td>51.5</td>
<td>26.8</td>
<td>18.8</td>
<td>10</td>
<td>10.0</td>
<td>80</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Grade</td>
<td>Brightness</td>
<td>Dominant Wave Length</td>
<td>Purity</td>
<td>Judd's Whiteness</td>
<td>Reflect.</td>
<td>Reflect.</td>
<td>Whitenss Value</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-------</td>
<td>------------</td>
<td>----------------------</td>
<td>--------</td>
<td>------------------</td>
<td>----------</td>
<td>----------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>G</td>
<td>95-20</td>
<td>558-59</td>
<td>0-24</td>
<td>0-967</td>
<td>237-0</td>
<td>0-966</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>G</td>
<td>95-60</td>
<td>568-59</td>
<td>0-32</td>
<td>0-964</td>
<td>186-7</td>
<td>0-963</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>G</td>
<td>96-20</td>
<td>568-56</td>
<td>0-38</td>
<td>0-963</td>
<td>159-3</td>
<td>0-961</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>G</td>
<td>96-24</td>
<td>568-59</td>
<td>0-48</td>
<td>0-959</td>
<td>136-4</td>
<td>0-959</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>G</td>
<td>93-50</td>
<td>569-59</td>
<td>0-51</td>
<td>0-958</td>
<td>125-6</td>
<td>0-958</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>G</td>
<td>95-20</td>
<td>567-88</td>
<td>0-67</td>
<td>0-951</td>
<td>112-6</td>
<td>0-951</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>65-28</td>
<td>568-49</td>
<td>0-81</td>
<td>0-942</td>
<td>07-1</td>
<td>0-939</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>G</td>
<td>95-66</td>
<td>569-06</td>
<td>1-02</td>
<td>0-932</td>
<td>05-2</td>
<td>0-932</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>S</td>
<td>93-60</td>
<td>575-47</td>
<td>1-06</td>
<td>0-930</td>
<td>04-8</td>
<td>0-931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>G</td>
<td>96-44</td>
<td>569-03</td>
<td>1-10</td>
<td>0-928</td>
<td>03-6</td>
<td>0-929</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>G</td>
<td>94-94</td>
<td>569-35</td>
<td>1-24</td>
<td>0-920</td>
<td>02-2</td>
<td>0-920</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>G</td>
<td>93-62</td>
<td>571-05</td>
<td>1-34</td>
<td>0-913</td>
<td>01-3</td>
<td>0-913</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>G</td>
<td>94-12</td>
<td>568-59</td>
<td>1-37</td>
<td>0-912</td>
<td>01-2</td>
<td>0-912</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>S</td>
<td>96-12</td>
<td>569-53</td>
<td>1-42</td>
<td>0-912</td>
<td>01-0</td>
<td>0-910</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>S</td>
<td>92-50</td>
<td>569-23</td>
<td>1-48</td>
<td>0-907</td>
<td>03-8</td>
<td>0-907</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>G</td>
<td>95-21</td>
<td>569-20</td>
<td>1-56</td>
<td>0-905</td>
<td>03-0</td>
<td>0-904</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>S</td>
<td>93-57</td>
<td>571-01</td>
<td>1-77</td>
<td>0-896</td>
<td>02-9</td>
<td>0-894</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>S</td>
<td>92-68</td>
<td>569-35</td>
<td>1-77</td>
<td>0-893</td>
<td>02-8</td>
<td>0-893</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>S</td>
<td>95-71</td>
<td>573-38</td>
<td>2-09</td>
<td>0-881</td>
<td>02-8</td>
<td>0-880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>S</td>
<td>95-60</td>
<td>571-98</td>
<td>2-18</td>
<td>0-873</td>
<td>02-4</td>
<td>0-879</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>S</td>
<td>95-64</td>
<td>572-14</td>
<td>2-28</td>
<td>0-873</td>
<td>02-9</td>
<td>0-877</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>S</td>
<td>92-87</td>
<td>571-90</td>
<td>2-31</td>
<td>0-868</td>
<td>02-8</td>
<td>0-872</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>S</td>
<td>92-50</td>
<td>573-59</td>
<td>2-29</td>
<td>0-867</td>
<td>01-9</td>
<td>0-867</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>S</td>
<td>93-44</td>
<td>573-45</td>
<td>2-66</td>
<td>0-849</td>
<td>02-7</td>
<td>0-861</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>S</td>
<td>90-31</td>
<td>573-09</td>
<td>2-77</td>
<td>0-840</td>
<td>02-5</td>
<td>0-859</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>S</td>
<td>93-12</td>
<td>573-75</td>
<td>3-06</td>
<td>0-829</td>
<td>01-5</td>
<td>0-843</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>S</td>
<td>99-12</td>
<td>575-33</td>
<td>3-27</td>
<td>0-818</td>
<td>01-1</td>
<td>0-832</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>S</td>
<td>86-92</td>
<td>574-42</td>
<td>3-55</td>
<td>0-776</td>
<td>03-3</td>
<td>0-800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>G</td>
<td>84-76</td>
<td>574-12</td>
<td>4-23</td>
<td>0-766</td>
<td>02-0</td>
<td>0-760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>M</td>
<td>83-33</td>
<td>575-06</td>
<td>9-05</td>
<td>0-519</td>
<td>03-1</td>
<td>0-510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>M</td>
<td>85-72</td>
<td>576-92</td>
<td>9-91</td>
<td>0-463</td>
<td>03-1</td>
<td>0-440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>M</td>
<td>71-72</td>
<td>576-40</td>
<td>10-00</td>
<td>0-454</td>
<td>02-2</td>
<td>0-400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>M</td>
<td>72-70</td>
<td>576-39</td>
<td>12-35</td>
<td>0-458</td>
<td>02-9</td>
<td>0-270</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>M</td>
<td>71-69</td>
<td>576-91</td>
<td>12-45</td>
<td>0-439</td>
<td>03-9</td>
<td>0-230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>M</td>
<td>68-01</td>
<td>577-92</td>
<td>13-79</td>
<td>0-447</td>
<td>03-7</td>
<td>0-240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>M</td>
<td>59-97</td>
<td>577-69</td>
<td>13-52</td>
<td>0-465</td>
<td>03-1</td>
<td>0-140</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*G: Granulate  S: Soft White  Superior  M: Soft White  Medium
<table>
<thead>
<tr>
<th>#</th>
<th>0.969</th>
<th>285.8</th>
<th>7</th>
<th>50.3</th>
<th>7</th>
<th>26.6</th>
<th>7</th>
<th>18.7</th>
<th>0</th>
<th>9</th>
<th>7</th>
<th>70</th>
<th>3.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>272.3</td>
<td>6</td>
<td>49.3</td>
<td>6</td>
<td>26.3</td>
<td>6</td>
<td>18.6</td>
<td>0</td>
<td>690</td>
<td>9</td>
<td>40</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>260.0</td>
<td>5</td>
<td>48.2</td>
<td>5</td>
<td>25.0</td>
<td>5</td>
<td>18.5</td>
<td>0</td>
<td>690</td>
<td>9</td>
<td>40</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>237.0</td>
<td>0.924</td>
<td>47.2</td>
<td>80</td>
<td>9.2</td>
<td>20</td>
<td>3.6</td>
<td>0</td>
<td>35</td>
<td>9</td>
<td>60</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>219.9</td>
<td>3</td>
<td>46.2</td>
<td>0.884</td>
<td>25.7</td>
<td>0.844</td>
<td>18.4</td>
<td>70</td>
<td>8.9</td>
<td>00</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>45.1</td>
<td>3</td>
<td>25.5</td>
<td>3</td>
<td>18.3</td>
<td>60</td>
<td>8.8</td>
<td>0</td>
<td>180</td>
<td>5</td>
<td>40</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>188.7</td>
<td>0</td>
<td>43.2</td>
<td>1</td>
<td>24.9</td>
<td>1</td>
<td>18.0</td>
<td>0</td>
<td>640</td>
<td>8</td>
<td>20</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>158.3</td>
<td>0.919</td>
<td>42.2</td>
<td>0</td>
<td>24.6</td>
<td>0</td>
<td>17.9</td>
<td>0</td>
<td>640</td>
<td>8</td>
<td>20</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>147.2</td>
<td>8</td>
<td>41.5</td>
<td>0.879</td>
<td>24.4</td>
<td>0.839</td>
<td>17.8</td>
<td>20</td>
<td>7.8</td>
<td>0</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>132.6</td>
<td>5</td>
<td>39.4</td>
<td>6</td>
<td>23.7</td>
<td>6</td>
<td>17.5</td>
<td>0</td>
<td>500</td>
<td>7</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>120.2</td>
<td>5</td>
<td>23.5</td>
<td>5</td>
<td>17.4</td>
<td>5</td>
<td>0.500</td>
<td>7</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>117.5</td>
<td>0.914</td>
<td>38.7</td>
<td>8</td>
<td>7.2</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>112.8</td>
<td>3</td>
<td>38.1</td>
<td>0.874</td>
<td>23.3</td>
<td>0.834</td>
<td>17.3</td>
<td>70</td>
<td>7.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>38.0</td>
<td>3</td>
<td>23.0</td>
<td>3</td>
<td>17.2</td>
<td>60</td>
<td>6.9</td>
<td>0</td>
<td>50</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>108.5</td>
<td>1</td>
<td>36.9</td>
<td>2</td>
<td>22.8</td>
<td>2</td>
<td>17.6</td>
<td>50</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>104.3</td>
<td>0</td>
<td>36.0</td>
<td>1</td>
<td>22.6</td>
<td>1</td>
<td>17.0</td>
<td>0</td>
<td>540</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100.2</td>
<td>0</td>
<td>22.4</td>
<td>0</td>
<td>16.9</td>
<td>0</td>
<td>6.5</td>
<td>0</td>
<td>65</td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>98.3</td>
<td>20</td>
<td>6.4</td>
<td>19</td>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>92.5</td>
<td>20</td>
<td>6.2</td>
<td>0</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Statistical Analysis of "Whiteness Value"

The object of this section is to ascertain the compatibility between the visual whiteness estimations made by observers and the "whiteness value" obtained by the two-point-estimation method.

1. Accuracy of Whiteness Estimation Test by the Eye.

Six with sugars including three samples each of granulate and soft white superior were compared according to the Scheffes' method for making analysis of variance for paired comparisons. The numerical values of the main effects of such estimation test for each sample, obtained from the judging scores, were $a_1=1.233$, $a_2=0.816$, $a_3=0.650$, $a_4=0.283$, $a_5=0.683$, $a_6=1.000$. It was found from the result of variance analysis of the observation data that the whiteness for each sample was able to be estimated by the main effect only. Therefore, it may be concluded that the whiteness of these samples perceived is in the order of Nos. 1, 2, 4, 3, 5, and 6.

In order to assure the confidence for such an experiment, the "estimation" about the differences was then made. With confidence $1-\alpha$, all statements about the differences of the $\{a_i-a_j\}$ are expressed as follows: $a_i-a_j-Y_\alpha a_i-a_j+Y_\alpha$ where the "yardstick" $Y_\alpha$ is calculated from the mean square for error; $Y_\alpha$ with confidence coefficients of $1-\xi$, i.e., 95 percent and 99 percent were respectively $Y_{0.05}=0.462$, $Y_{0.01}=0.549$. And the differences $(a_i-a_j)$ were as follows: $(a_1-a_2)=0.417$, $(a_2-a_3)=0.533$, $(a_3-a_4)=0.933$, $(a_4-a_5)=0.033$, $(a_5-a_6)=0.317$. The quantitative statements about the possible differences are listed as shown on Table III.

Table III. Quantitative Statements about the Differences.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>3</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_i$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_4$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*There is a significant difference with 95 percent confidence.

**There is a significant difference with 99 percent confidence.

†Grade: — G : Granulate, S : Soft White Superior.
The table shows, for example, that in the case of the difference \((a_1-a_2) = 1.233 - 0.816 = 0.417\), this value is not significant with 95 percent confidence because this value is less than the "yardstick" \(Y_{0.05} = 0.462\), while in the case of \((a_1-a_4) = 1.233 - 0.283 = 0.950\), this value is significant with 99 percent confidence because this value is larger than \(Y_{0.01} = 0.549\).

The differences observed between Nos. 1—2, Nos. 3—5, Nos. 3—6, Nos. 5—6 are not significant with 95 percent confidence.

2. **Accuracy of the Whiteness Value by Means of the Two-Point-Estimation Method**

The whiteness values were determined on the same samples as used in the preceding experiment. The result obtained is shown in table IV.

Table No. IV.

Whiteness Value Obtained by the Two-Point-Estimation Method.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Measuring No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.962</td>
<td>0.960</td>
<td>0.906</td>
<td>0.912</td>
<td>0.891</td>
<td>0.879</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.963</td>
<td>0.956</td>
<td>0.907</td>
<td>0.912</td>
<td>0.898</td>
<td>0.877</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.964</td>
<td>0.951</td>
<td>0.899</td>
<td>0.912</td>
<td>0.893</td>
<td>0.881</td>
<td></td>
</tr>
</tbody>
</table>

Mean value: 0.963, 0.959, 0.904, 0.912, 0.894, 0.879

The whiteness of these samples is in the order of Nos. 1, 2, 3, 4, 5, and 6. From the result of variance analysis of these data, the "estimation" about the differences for each mean value was then made and \(\beta\) estimate value about the difference, was as follows: \(\beta_{0.01} = 0.0049\), \(\beta_{0.05} = 0.0070\). A table of the quantitative statements about the differences was made as shown in Table V.

Table V

Quantitative Statements about the Differences

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Measuring No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.963</td>
<td>0.959</td>
<td>0.913</td>
<td>0.904</td>
<td>0.894</td>
<td>0.876</td>
<td></td>
</tr>
</tbody>
</table>

Sample No. | Order | 1   | 2   | 3   | 4   | 5   | 6   |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.004</td>
<td>0.011*</td>
<td>0.012*</td>
<td>0.013***</td>
<td>0.014***</td>
<td>0.015***</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.003**</td>
<td>0.004**</td>
<td>0.005**</td>
<td>0.006**</td>
<td>0.007**</td>
<td>0.008**</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0.009**</td>
<td>0.010**</td>
<td>0.011**</td>
<td>0.012**</td>
<td>0.013**</td>
<td>0.014**</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0.005**</td>
<td>0.006**</td>
<td>0.007**</td>
<td>0.008**</td>
<td>0.009**</td>
<td>0.010**</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0.007**</td>
<td>0.008**</td>
<td>0.009**</td>
<td>0.010**</td>
<td>0.011**</td>
<td>0.012**</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0.008**</td>
<td>0.009**</td>
<td>0.010**</td>
<td>0.011**</td>
<td>0.012**</td>
<td>0.013**</td>
</tr>
</tbody>
</table>

** The same as in Table III.

The table shows that all differences, except that of (Nos. 1—2) are significant with 99% confidence because those figures in this table are larger than \(\beta_{0.01} = 0.0070\).

It may be concluded from the estimation about the possible differences as shown in Table III and V that the results obtained by our two-point-estimation method correlates well with the preceding visual estimates but the former estimation was carried on with much higher confidence than the latter.
Summary

In order to measure the whiteness of white sugars quite a simple but satisfactory method, was devised and the result obtained is summarized as follows:

1. The reflectances of thirty-six white sugars were measured at thirty points between 400 µm and 700 µm, and the results obtained were expressed in the monochromatic system. However color difference is unable to be expressed numerically by such values in the monochromatic system and naturally whiteness is also unable to be expressed numerically.

2. Judd's whiteness for each sample was then calculated. This index of whiteness was found to correlate well with visual estimations of whiteness for all samples of white and near-white sugars, but a drawback of this method is the great amount of time taken for the termination of the reflectance curve and the calculation of the whiteness.

3. From a consideration of characteristics of reflectance curve, a simple method named "two-point-estimation method," was devised for determination of whiteness of sugar, having a close relation with Judd's whiteness and the value obtained by this method was named "whiteness value." This value can be obtained by measuring the reflectances at two wave lengths, 420 and 560 µm and on the annexed table looking up the whiteness value nearest to the value(Refl.450/Refl.560-Refl.450). In the ideal case of a complete white sugar, this value is 1.

4. To ascertain the compatibility between the visual whiteness estimations made by observers and the whiteness value obtained by the two-point-estimation method, statistical analysis of accuracy of these methods was made. It was found that the results obtained by our two-point-estimation method correlates well with the visual estimates but the former estimation was carried on with much higher confidence than the latter.

Acknowledgment.

The writers wish to express their thanks to Mr. M. Tashiro of Shibaura Seito Co. for his helpful suggestions in the statistical aspect.

References

1. K. Douwes Dekker
2. D. B. Judd
4. J. C. Keane, B. A. Brice
5. G. A. Browne, F. W. Zerban
6. H. Scheffe

Int. Sug. J., 52, 123 (1950)
Anal. Chem., 23, 308 (1951); 24, 168 (1952)
J. Amer. Stat. Assoc., 47, 381 (1952)
Evaluation of Molasses as a Raw Material for Alcohol Manufacture

By

Dr. B. K. Jha, M.Sc., Ph. D., (Birmingham)

and

Dr. D. R. Dhingra, M.Sc., Ph. D., (Liverpool) M.I.M. Chem. E., F. I. C.,
Principal, H. B. Technological Institute, Kanpur.

1. Origin.

The only raw material available in large quantities in India for an economic production of alcohol is molasses which is the waste product of sugar industry. It is the residual syrupy liquid from which recovery of sucrose is no longer economically feasible. This product is commonly known as the inal or blackstrap molasses, from “stroop” meaning syrup in Dutch (1). As it is derived from cane juice, the components of the juice constitute the major part of molasses. In addition, it contains the altered reaction products produced during the processing of cane juice. For clarification, the juice (pH 5-6) is treated with calcium hydroxide to pH 8 and heated over several hours at around 200°F to precipitate the suspended materials—proteins, waxes and fats (2). After filtration, the clarified juice is heated in a bank of vacuum evaporators to concentrate it to a syrup and to effect crystallisation of sucrose. After the separation of sugar crystals the final residual syrup is waste molasses. Its pH is 5.8.

2. Composition.

The composition of molasses is very complex. The principal constituents fall under the group of carbohydrates, vitamins, nitrogen compounds, non-nitrogenous acids, pigments, waxes, sterols and lipids, odorants and inorganic compounds. Thus, apart from its principal constituent sugar, molasses contains the impurities of raw juice which have been left behind after the recovery of sucrose. It also contains certain decomposition or altered products of sugar which are formed during the manufacturing process through the employment of chemicals and heat. The composition of molasses varies with the characteristics of cane and the processing employed. The method of clarification—liming, sulphitation or carbonation, particularly influences the composition of non-sugars.

As an illustration, the composition of blackstrap molasses as presented by Spencer and Meade (3) is given in Table 1.
<table>
<thead>
<tr>
<th></th>
<th>Per cent.</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>25.00</td>
<td>20.00</td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica, SiO₂</td>
<td>2.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Potash, K₂O</td>
<td>2.00</td>
<td>3.50</td>
</tr>
<tr>
<td>Lime, CaO</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Magnesia, MgO</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Phosphoric acid, P₂O₅</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Sulphuric acid, S₈O₅</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>Chlorine, Cl</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Soda, iron, etc., Na₂O, etc.</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td><strong>Sugars</strong></td>
<td>62.00</td>
<td></td>
</tr>
<tr>
<td>Sucrose</td>
<td>32.00</td>
<td></td>
</tr>
<tr>
<td>Dextrose</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>Levulose</td>
<td>16.00</td>
<td></td>
</tr>
<tr>
<td><strong>Nitrogenous bodies</strong> (Total N = 0.5%)</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Albuminoids</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Amides (as asparagin)</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Amido acids (as aspartic)</td>
<td></td>
<td>1.70</td>
</tr>
<tr>
<td>Nitric acid</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Ammonia</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>Xanthin bodies</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Other nitrogenous bodies</td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Soluble gums</strong></td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>(Xylan, araban, pectin, etc.)</td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td><strong>Free acids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Melassinic, glutinic, saccharinic acids, etc.)</td>
<td></td>
<td>5.00</td>
</tr>
<tr>
<td><strong>Combined acids</strong></td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>
3. Sugars in Molasses.

From the distillers' point of view the constituents of molasses are classified as sugars and non-sugars as it is from the sugars that alcohol is produced.

The principal sugar in molasses, as in cane juice, is sucrose. Unlike beet molasses, cane molasses also contains considerable quantities of reducing sugars. The ratio of sucrose to reducing sugars is 1.5 : 2.5: 1 molasses. However, this proportion is very variable depending chiefly on the quantity of invert sugars existing in the cane and on the methods employed in sugar manufacture. In ripe cane the quantity of reducing sugars is low, 10 percent while in unripe cane or in cane which has suffered changes it goes up to 35 percent. The average content is, however 20 - 25%, Sucrose averages 30 - 40 percent.

In an average molasses the apparent purity (Pol x 100 : Brix apparent) is around 30 and the absolute purity (Actual saccharose x 100: Actual Brix) is around 40. Prinsen - Geerling bases the purity of molasses on ratio, Reducing substances: Ash.

The reducing substances in cane molasses are mainly glucose and fructose. They are, however, not in equal proportions as in invert sugar, but unequal and variable depending on the quality of cane and processing. In addition to invert sugars, small quantities of mannose and certain unfermentable reducing material termed, "glucose" are also found in molasses.

4. The Nonsugars.

Davies (4) has described the composition of non-sugars. Their distribution in final molasses is shown (5) in table II and III.

<table>
<thead>
<tr>
<th>Table II. Composition of Molasses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
</tr>
<tr>
<td>Dry Substance</td>
</tr>
<tr>
<td>Saccharose</td>
</tr>
<tr>
<td>Saccharose % dry substance</td>
</tr>
<tr>
<td>Reducing sugars</td>
</tr>
<tr>
<td>Non-fermentable red. sug.</td>
</tr>
<tr>
<td>Non-fermentable red. sug. % reducing sugars</td>
</tr>
<tr>
<td>Colour % nonsugars</td>
</tr>
<tr>
<td>Ash % dry substance</td>
</tr>
<tr>
<td>Ash % nonsugars</td>
</tr>
<tr>
<td>SiO₂ % nonsugars</td>
</tr>
<tr>
<td>CaO % nonsugars</td>
</tr>
<tr>
<td>MgO % nonsugars</td>
</tr>
<tr>
<td>Fe₂O₃ % non sugars</td>
</tr>
<tr>
<td>Al₂O₃ % nonsugars</td>
</tr>
<tr>
<td>P₂O₅ % nonsugars</td>
</tr>
<tr>
<td>S₃O₆ % nonsugars</td>
</tr>
<tr>
<td>Molasses % cane 2.5 - 2.7%</td>
</tr>
<tr>
<td>Average 2.6%</td>
</tr>
<tr>
<td>Clear juice % cane, average 150%</td>
</tr>
<tr>
<td>Brix clear juice 16.5 - 17.0</td>
</tr>
</tbody>
</table>
III. and the monomeric anhydride of fructose. Zerban (7) has reported the presence of allulose (psicose) in the unfermentable portion of molasses as well as in distillery spent wort. The presence of allulose has been demonstrated in the products formed by heating sucrose solutions (10).

It is not only the carbohydrate material which forms unfermentable products but the amino acids and their amides present in molasses react with the sugars. Both glucose and fructose thus react with asparagine (11). The presence of asparagine induces the conversion of glucose into unfermentable material. It has been estimated that an average of 68 percent of the combined nitrogen of molasses is found in the unfermentable products.

Apart from Sucrose and invert sugars, which are convertible into alcohol, cane molasses contains unfermentable carbohydrate material which was formerly referred to as “glucose” (6). Subsequent work has shown that this unfermentable material is a complex mixture and is not a single carbohydrate. These are formed as a result of the action of alkali or acid on invert sugars during the clarification and subsequent treatment. Zerban and Sattler (7) have demonstrated the formation of unfermentable reducing substances by heating invert sugar syrup at pH 4.5. Wolfrom and Blair (8) heated a concentrated aqueous solution of fructose and in the resulting unfermentable products di-D-fructofuranose 1, 2', 2', 3'-dianhydride and a new difructose anhydride were detected. Investigations on products formed by heating sucrose syrups and fructose solutions and subsequent fermentation (9) indicate the presence of the 3 dimers of fructose, the dibheterolevulosans, D-allulose and the monomeric anhydride of fructose.

The evaluation of molasses for distillery use is commonly based on its reducing value after inversion which is taken to indicate total invert sugars. But in practice the alcohol yield from molasses is always lower than that indicated by analysis and the residue after complete fermentation still reduces Fehling solution. This is due to the presence in molasses of unfermentable substances which like invert sugars, also give a reducing value. These substances are collectively known as unfermentable reducing “sugars” although they are not, what we understand to be, sugars. There

### Table III.

<table>
<thead>
<tr>
<th>Nonsugars in Final Molasses</th>
<th>Grams per liter of Glcass Juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing sugars</td>
<td>4.7 - 5.1</td>
</tr>
<tr>
<td>Non-fermentable red sugars</td>
<td>0.9 - 1.0</td>
</tr>
<tr>
<td>Ash</td>
<td>3.5 - 3.5</td>
</tr>
<tr>
<td>Nonsugars (index-poly-sugars)</td>
<td>11.4 - 12.0</td>
</tr>
<tr>
<td>CaO</td>
<td>0.240 - 0.300</td>
</tr>
<tr>
<td>MgO</td>
<td>0.026 - 0.038</td>
</tr>
<tr>
<td>FeO</td>
<td>0.021 - 0.026</td>
</tr>
<tr>
<td>Al₃PO₄</td>
<td>-0.014</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.08 - 1.04</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.021 - 0.035</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.022 - 0.070</td>
</tr>
</tbody>
</table>

5. Unfermentable Products.

Apart from Sucrose and invert sugars, which are convertible into alcohol, cane molasses contains unfermentable carbohydrate material which was formerly referred to as “glucose” (6). Subsequent work has shown that this unfermentable material is a complex mixture and is not a single carbohydrate. These are formed as a result of the action of alkali or acid on invert sugars during the clarification and subsequent treatment. Zerban and Sattler (7) have demonstrated the formation of unfermentable reducing substances by heating invert sugar syrup at pH 4.5. Wolfrom and Blair (8) heated a concentrated aqueous solution of fructose and in the resulting unfermentable products di-D-fructofuranose 1, 2', 2', 3'-dianhydride and a new difructose anhydride were detected. Investigations on products formed by heating sucrose syrups and fructose solutions and subsequent fermentation (9) indicate the presence of the 3 dimers of fructose, the dibheterolevulosans, D-allulose and the monomeric anhydride of fructose.

Zerban (7) has reported the presence of allulose (psicose) in the unfermentable portion of molasses as well as in distillery spent wort. The presence of allulose has been demonstrated in the products formed by heating sucrose solutions (10).

It is not only the carbohydrate material which forms unfermentable products but the amino acids and their amides present in molasses react with the sugars. Both glucose and fructose thus react with asparagine (11). The presence of asparagine induces the conversion of glucose into unfermentable material. It has been estimated that an average of 68 percent of the combined nitrogen of molasses is found in the unfermentable products.

The amino acids undergo with sugars or their dehydration products another type of reaction known as the “Maillard” or “browning” reaction (12), (13), (14) to yield dark coloured polymeric substances which impart the characteristic colour to molasses and separate out as brown to black solids known as “melanoidins”.

6. Fermentability of Molasses.

The evaluation of molasses for distillery use is commonly based on its reducing value after inversion which is taken to indicate total invert sugars. But in practice the alcohol yield from molasses is always lower than that indicated by analysis and the residue after complete fermentation still reduces Fehling solution. This is due to the presence in molasses of unfermentable substances which like invert sugars, also give a reducing value. These substances are collectively known as unfermentable reducing “sugars” although they are not, what we understand to be, sugars. There
are many products of sugar decomposition which are also reducing (15), (16). About 10 percent of the reducing power of the unfermentable substances in cane molasses is attributed to certain volatile constituents such as Hydroxy-methyl-furfural, acetoin, levulinic acid, formic acid, methyl glyoxal and acetol. It would, therefore, be an error to treat the reducing value of molasses as being due solely to glucose and fructose. Their total content has been estimated (17) to be 10.1 and 10.7 percent of the solids in Louisiana and Cuba molasses respectively.

Kervegant (18) has reported (Table IV) the amounts of unfermentable reducing material in cane molasses from different sources.

Table IV

Unfermentable Reducing Matter in Cane Molasses (Calculated as per cent. glucose)

<table>
<thead>
<tr>
<th>Source</th>
<th>Author</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>Pellet &amp; Mennier</td>
<td>2.4</td>
</tr>
<tr>
<td>Queensland</td>
<td>Barker</td>
<td>2.4</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Deer</td>
<td>3.2</td>
</tr>
<tr>
<td>Demerara</td>
<td>Boname</td>
<td>3.0</td>
</tr>
<tr>
<td>Maurice</td>
<td>Fairault</td>
<td>3.0-8</td>
</tr>
<tr>
<td>Martinique</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Java</td>
<td>Waterman, La Bastide</td>
<td>2.2-9</td>
</tr>
<tr>
<td>Cuba</td>
<td>(Inverted Syrup)</td>
<td>2.3</td>
</tr>
</tbody>
</table>

The apparent unfermentable reducing sugar content in cane molasses is around 2.5—5 percent (sometimes exceeding 6 percent) and in high test molasses it is 1.5—3.5 percent but in beet molasses it is as low as 0.1—1.1 percent (6), (19—23).

The presence of invert sugars, whether originating from cane juice or formed during the manufacturing process, plays a decisive role in the formation of reducing substances. A juice which is higher in invert sugar content gives molasses containing proportionately larger quantities of unfermentable reducing substances in molasses. According to Martínez Dalmau (24) the amount of unfermentable reducing material in cane molasses varies directly with the ratio of invert sugar to total sugars in the molasses.

Kilp has indicated a proportionality between the ash content and unfermentable reducing material of molasses (25). A high melanoidin content in molasses also goes with a proportionately high content of unfermentable reducing substances (26). Since the formation of melanoidins is at the expense of amino acids it explains why yeast is unable to utilise the greater part of the nitrogen in molasses (27), (28).

7. Deterioration of Molasses.

A common observation of the distillers is that old stocks of molasses do not give the same fermentation efficiency as the new produce although the apparent sugar content as judged from reducing values has not much changed. This is obviously, due to a slow alteration in the fermentability of sugars contained in it. Browne (29) has studied the changes in two samples of Cuban molasses over 21 years. He found in them a loss of 18.69 and 28.18 percent of sucrose. The corresponding gain in invert sugar amounted to 19.67 and 29.66 percent respectively but the actual increase was found to be 4.47 and 9.04 percent only. This shows that the greater part of invert sugar was destroyed. The results obtained by Browne for one of these samples are given in Table IV, which shows that the deterioration of molasses is very slow. But, nevertheless, molasses which has remained in storage for a long time not only decreases in total sugar values but it becomes increasingly resistant to efficient fermentation.
Table IV.

<table>
<thead>
<tr>
<th>Date of analysis</th>
<th>Saccharose</th>
<th>Reducers</th>
<th>Total Reducers</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1914</td>
<td>31.30</td>
<td>19.10</td>
<td>50.54</td>
</tr>
<tr>
<td>October 1914</td>
<td>30.73</td>
<td>18.74</td>
<td>49.59</td>
</tr>
<tr>
<td>May 1915</td>
<td>30.00</td>
<td>18.19</td>
<td>48.19</td>
</tr>
<tr>
<td>April 1916</td>
<td>29.74</td>
<td>18.84</td>
<td>48.58</td>
</tr>
<tr>
<td>Sept. 1917</td>
<td>28.65</td>
<td>19.93</td>
<td>48.58</td>
</tr>
<tr>
<td>August 1918</td>
<td>25.01</td>
<td>20.56</td>
<td>45.57</td>
</tr>
<tr>
<td>August 1921</td>
<td>24.93</td>
<td>20.93</td>
<td>45.85</td>
</tr>
<tr>
<td>January 1923</td>
<td>23.13</td>
<td>21.07</td>
<td>44.20</td>
</tr>
<tr>
<td>July 1927</td>
<td>20.98</td>
<td>21.00</td>
<td>41.98</td>
</tr>
<tr>
<td>March 1928</td>
<td>18.94</td>
<td>21.50</td>
<td>40.44</td>
</tr>
<tr>
<td>March 1935</td>
<td>12.61</td>
<td>25.57</td>
<td>38.18</td>
</tr>
<tr>
<td>Variations</td>
<td>-18.69</td>
<td>+4.47</td>
<td>-14.22</td>
</tr>
</tbody>
</table>

Even when stored under good conditions, molasses undergoes a progressive inversion of saccharose resulting in the reduction of total sugars. La Bastide (30) examined samples of fresh molasses and then at later periods. He observed a reduction in fermentable sugars of 0.58% after 4 months and of 1.21% after 18 months; and an increase in the unfermentable reducing substances by 3.42 to 3.99 per cent after 4 months and by 4.21 per cent after 10 months. The extent of changes in molasses produced by the different processes viz., defecation, sulphitation or carbonation, are about the same. Koffler (31) has also reported progressive inversion of saccharose during storage, accompanied by reduction in Brix, a decrease in pH and an increase in coloration.

8. Froth Fermentation.

As against the slow deterioration of molasses in the above manner another type of deterioration is frequently observed which is violent and spontaneous. It is accompanied by increase in temperature and evolution of gas. The large quantity of gas formed produces copious foam. Hence, the phenomenon is known as "froth fermentation". The evolved gas is a mixture of carbon dioxide, formic acid, acetic acid and acrid fumes of unknown composition. In extreme cases so much heat is developed in the process that the molasses chars and turns into a solid black mass (29, 32, 33).

Habif (32) has given the analysis of such carbonised molasses:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>6.64</td>
<td>1.00</td>
<td>0.76</td>
</tr>
<tr>
<td>Ash</td>
<td>19.40</td>
<td>72.20</td>
<td>72.20</td>
</tr>
<tr>
<td>Organic matter</td>
<td>0.00</td>
<td>0.76</td>
<td>0.76</td>
</tr>
</tbody>
</table>

This phenomenon has recently been observed in a number of Indian sugar factories. Froth fermentation, first described by Durin in 1883 was for a long time attributed
to the activity of micro-organisms (34-36). Classen (37) opposed the fermentation theory and suggested that froth fermentation was caused by chemical decomposition of the organic non-sugars. This has been confirmed by subsequent workers. Brown stated that the spontaneous deterioration of sugar cane molasses is due mainly to the reactions between unstable organic substances (originally produced by the action of lime upon invert sugar) and the reducing sugars in molasses. Following Maillard's work (42) on melanoidine Lafar (43) and subsequent investigators (44-48) attributed the phenomenon to the reaction of invert sugars at high temperature with the amino acids and amides with evolution of carbon dioxide which produces foam.

The extent of decomposition varies with the composition of the original juice and the nature of processing it undergoes; the chief factors being temperature, pH and time. Overliming and over-heating are highly important contributory causes. It is stated that the greatest predisposing factor in froth fermentation is the temperature at which the molasses is stored. The critical temperature of storage varies with different molasses. According to Hucker and Brooks (48) excessive foaming occurs when the temperature of stored molasses rises to 40°C. However, the critical temperature ranges from 40 to 45°C. According to Honig (49) the reduction in fermentable sugars of molasses is 2-3% per year when stored at 30-35°C; an increase in temperature by 10° quadruples the loss.

The susceptibility of black straps to spontaneous fermentation increases with its density and viscosity. Neuville (50) has shown that a molasses of 93.35 Brix obtained from an Egyptian sugar factory in 1938 suffered a particularly rapid decomposition than the molasses of 90 Brix of the same origin. Molasses susceptible to froth-fermentation contains more non-fermentable sugars than normal molasses. There is a close relationship between the unfermentable reducing sugars content of molasses and its frothing tendency. Slow deterioration is largely a loss of sucrose as such or the decomposition of the invert sugar formed from it, whereas, the rapid deterioration is largely at the expense of the invert sugar already present. It may be mentioned that irrespective of actual losses in sugar values due to spontaneous fermentation, the fermentation efficiency is always adversely affected by it.

9. Microbial Decomposition.

Even though the spontaneous deterioration of molasses is not due to the activity of micro-organisms, they cause other changes in molasses. Thermophilic bacteria were found by Lafar (43) and Gillet (51) in molasses undergoing froth fermentation. Nelson (52) states that lactic acid in molasses arises from bacterial action. The presence of acetic and propionic acids serves as a rough index of the activity of microorganisms in molasses. The microbial count of sugar mill products according to Millstein et al (53) is given in Table V.
Table V. Microbial count of sugar Mill Products. (Number of bacteria per ml.)

<table>
<thead>
<tr>
<th>Product</th>
<th>Mesophilic Bacteria</th>
<th>Thermophilic Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Optimal growth at 15-40°C)</td>
<td>(Optimal growth at 40-60°C)</td>
</tr>
<tr>
<td></td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>Raw Juice</td>
<td>80,00,000</td>
<td>75,00,000</td>
</tr>
<tr>
<td>Clarifier Effluent</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Press Juice</td>
<td>0</td>
<td>51,000</td>
</tr>
<tr>
<td>Evaporator Syrup</td>
<td>200</td>
<td>3,300</td>
</tr>
<tr>
<td>Storage Tank Syrup</td>
<td>1,300</td>
<td>7,100</td>
</tr>
<tr>
<td>Crystalliser contents</td>
<td>2,000</td>
<td>44,000</td>
</tr>
<tr>
<td>Massecuite</td>
<td>1,200</td>
<td>10,600</td>
</tr>
<tr>
<td>Raw Sugar</td>
<td>340</td>
<td>5,100</td>
</tr>
<tr>
<td>Molasses</td>
<td>300</td>
<td>3,10,000</td>
</tr>
</tbody>
</table>

In certain cases a reduction in the sugar content of molasses accompanied by modification of flavour and odour is due to the action of microbial ferments. Ashby found a wild yeast (Torula) in Jamaican molasses capable of fermenting at 90° Brix. Owen, Church, Hucker and Pedersen have reported the presence of numerous yeasts, bacteria and moulds in molasses which attack the sugars in relatively strong concentrations. Certain moulds, particularly Aspergillus repens, can attack sucrose in concentration of 65-70° Brix.

At normal densities, however, blackstrap is practically immune from microbial attack. The maximum density limit for microbial activity is in the range of 75-80° Brix. The density limits for microbial and chemical action in molasses during storage is given in Table VI. The mould fungi are capable of inducing inversion of sucrose at densities of 75° to 80° Brix. These cause slight deterioration on surface films which may become diluted due to absorption of moisture.

Table VI. Density Limits of Microbial and Chemical Activity.

<table>
<thead>
<tr>
<th></th>
<th>% Total solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous Decomposition</td>
<td>75-100</td>
</tr>
<tr>
<td>Autogenous Enzymic Inversion</td>
<td>0-85</td>
</tr>
<tr>
<td>Mould Fungi activity</td>
<td>0-75</td>
</tr>
<tr>
<td>Yeast activity</td>
<td>0-75</td>
</tr>
<tr>
<td>Bacterial activity</td>
<td>0-65</td>
</tr>
</tbody>
</table>

Mould activity in molasses is usually at the expense of sucrose and not of total sugars while yeast activity is largely at the expense of the reducing sugars which results in depreciating the value of molasses. Owen (54) gives an example of the destruction of sugar by Torula yeast in Cuban molasses diluted to 71° Brix (Table VII).
Table VII.

<table>
<thead>
<tr>
<th>Brix</th>
<th>Original molasses</th>
<th>After two months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
<td>71.30</td>
<td>68.39</td>
</tr>
<tr>
<td>Pol direct</td>
<td>49.60</td>
<td>52.00</td>
</tr>
<tr>
<td>Saccharose Clerget</td>
<td>54.65</td>
<td>49.96</td>
</tr>
<tr>
<td>Reducing Sugars</td>
<td>11.49</td>
<td>6.50</td>
</tr>
<tr>
<td>Total sugars</td>
<td>66.14</td>
<td>56.46</td>
</tr>
<tr>
<td>No. of Torula/gm.</td>
<td>—</td>
<td>2,080.00</td>
</tr>
</tbody>
</table>

Browne (55) isolated a species of Monilia (M. nigra) which could invert sucrose solutions up to 64° Brix. Grieg Smith (56), Noel Deen and Norris (57), Browne (55), Owen (58), Kopeloff (59), Church (60), Van der Bijl (61), and Ammons investigating the role of bacteria on sugar decomposition observed that all the species tested were incapable of inducing inversion of sucrose at densities greater than 60° Brix. Thus, at normal densities the deterioration of molasses cannot be attributed to bacterial action.

On account of limited capacity of covered steel or pucka tanks in the sugar factories, a common occurrence in India, a considerable quantity of molasses is stored each season in open dug out pits. Under these conditions, particularly due to dilution during rains, the extent of deterioration through microbial activity becomes very significant. The type and extent of microbial activity in molasses is indicated in Table VIII, after Owen.

Table VIII.

<table>
<thead>
<tr>
<th>Density in Brix.</th>
<th>Type of Microbial Action</th>
<th>Predominant effect upon sugar content</th>
<th>Rate of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>75-80</td>
<td>Biochemical</td>
<td>Sucrose inverted</td>
<td>Very Slow.</td>
</tr>
<tr>
<td>70-75</td>
<td>Mould Fungi</td>
<td>Sucrose inverted</td>
<td>Very slow.</td>
</tr>
<tr>
<td>60-72</td>
<td>Yeast</td>
<td>Invert Sugar fermented</td>
<td>Slow change except at lower levels.</td>
</tr>
<tr>
<td>50-62</td>
<td>Bacteria</td>
<td>Sucrose converted into gum</td>
<td>Slow except at lower levels.</td>
</tr>
</tbody>
</table>
The actual deterioration, due to microbial activity, measured in terms of loss of sugar may appear to be of not much significance. But, frequently the distiller experiences a much greater fall in fermentation efficiency than would correspond to the actual sugar loss. Such sluggish fermentation is attributed to the production of substances inhibitory to yeast growth and fermentation, which are not revealed by the usual chemical analysis of molasses. Of these inhibitory substances oxalic and citric acids are produced by moulds and butyric acid by bacteria. Formic acid may also result from this fermentation. Lebedeff (62) has shown that oxalic acid in a concentration of 0.001 per cent inhibits yeast activity while a concentration of 0.1 to 0.2 per cent completely inactivates the yeast. Neale and Maercker (63) have reported that butyric acid in a concentration of 0.05 per cent completely inactivates the yeast while concentrations as low as 0.015 per cent retard yeast growth (64). Citric acid has been found to be injurious to yeast in concentrations of 0.2-0.4 per cent but the tolerance of yeast for this acid varies greatly (66).

Formic acid inhibits yeast growth in such low concentrations as 0.08 per cent. Zerban found a formic acid content of 0.139 and 0.154 per cent in Cuban molasses.

The production of yeast inhibitory substances by microorganisms in molasses is favoured under bad storage conditions when the surface film becomes dilute. Over long periods these inhibitors may accumulate in sufficient concentration to exercise a detrimental effect on fermentation. When molasses is stored in dug out ditches exposed to air and rain the butyric bacteria find suitable ground for development and give rise to harmful quantities of butyric acid over long storage. Many of the products of microbial activity contain disagreeable aromatic principles which eventually pass into distilled alcohol and produce an inferior product.

It is, therefore, of the utmost importance that molasses should be well conserved in covered tanks and possibly also protected from the direct heat of the Sun.


The value of molasses as a raw material for the production of alcohol alters widely from the time of its production to its ultimate utilization in fermentation. During storage, the sugars suffer a chemical or biochemical transformation and are rendered unfermentable. The production of poisonous substances (formic, butyric, oxalic acids etc.) inhibits yeast activity. In addition, a high ash content makes the yeast function with difficulty (67). The chief mineral constituents are the salts of potassium, calcium, and in some cases sodium chloride. The balance of mineral substances in molasses is also sometimes defective. It is especially the case where the solution of molasses is not physiologically balanced for yeast growth.

The molasses most suitable for fermentation is that which has a high density, high total sugars and high nitrogen and phosphoric acid; but at the same time, has little ash and gums. The aromatic substances in molasses are also important as they may impart a disagreeable odour and flavour to spirit. Fresh molasses always gives a better product than that which has been kept long in storage. Old molasses gives a blackish foam and small yield of alcohol.

Arroyo has given an example (Table IX) of the qualities of molasses from the distillers' point of view (18).
Table IX

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
<td>87.60</td>
<td>85.49</td>
<td>88.20</td>
</tr>
<tr>
<td>Saccharose</td>
<td>36.44</td>
<td>31.30</td>
<td>34.61</td>
</tr>
<tr>
<td>Reducing Sugars</td>
<td>19.61</td>
<td>19.96</td>
<td>13.50</td>
</tr>
<tr>
<td>Total Sugars</td>
<td>57.97</td>
<td>52.91</td>
<td>49.93</td>
</tr>
<tr>
<td>Ash</td>
<td>7.31</td>
<td>9.35</td>
<td>11.57</td>
</tr>
<tr>
<td>N Total</td>
<td>1.10</td>
<td>0.60</td>
<td>0.45</td>
</tr>
<tr>
<td>P2O5 Total</td>
<td>0.19</td>
<td>0.09</td>
<td>0.21</td>
</tr>
<tr>
<td>Gums</td>
<td>2.00</td>
<td>2.55</td>
<td>3.75</td>
</tr>
<tr>
<td>pH</td>
<td>5.50</td>
<td>5.70</td>
<td>6.30</td>
</tr>
</tbody>
</table>

Ratio

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sugars: Ash</td>
<td>7.93</td>
<td>5.65</td>
<td>.31</td>
</tr>
<tr>
<td>P2O5 : N</td>
<td>0.17</td>
<td>0.13</td>
<td>0.47</td>
</tr>
<tr>
<td>Gums : Total Sugars</td>
<td>0.03</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Aroma (Distillation vapours)</td>
<td>Excellent</td>
<td>Good</td>
<td>Indifferent</td>
</tr>
</tbody>
</table>

The above molasses in 3 fermentation experiments gave the following yield of alcohol at different concentrations:

Table X

<table>
<thead>
<tr>
<th>Grade of Molasses</th>
<th>Alcohol % total sugars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Good</td>
<td>46.09</td>
</tr>
<tr>
<td>Fair</td>
<td>43.97</td>
</tr>
<tr>
<td>Poor</td>
<td>40.68</td>
</tr>
</tbody>
</table>
Arroyo has based the quality of molasses on the Total Sugar: Ash ratio. According to him if this ratio equals or is more than 6.5/1 the molasses is excellent; if between 6.1/1 and 4.5/1 it is good; and, if less than 4.5/1 then the molasses is of poor quality. The nitrogenous material in molasses is regarded sufficient if the total Nitrogen reaches 1% by weight. If it is less than 1%, addition of ammonium sulphate is necessary. As for phosphoric acid the optimum content is 0.2-0.25% (as P₂O₅). The P₂O₅ : N ratio should be around 1/5; an excess of phosphoric acid in relation to nitrogen inhibits fermentation.

The microbial flora of molasses is represented by bacteria (principally the subtilis, mesentericus and butyricus groups) moulds and yeasts (generally the Torula type). According to Church, the number of bacteria in molasses leaving the centrifugals varies between 10 to 7,000 per gram., while mold spores are 40,000 and in some cases 200,000. Owen has reported that in the final molasses, the number of microorganisms may reach a maximum of 100,000 per gram. Only certain bacteria are able to withstand the high temperatures of cane juice processing and survive in the molasses. The majority of the microorganisms enter as infection during centrifuging and subsequent handling.

In order to obtain good conditions for alcoholic fermentation the molasses is diluted, acidified and nutritive salts added. It is advantageous to remove a part of the ash and other substances such as organic acids and gums which retard the development of yeast, by suitable processing. Since molasses presents a wide variation in composition, it is necessary to analyse each lot in order to determine precisely the best treatment to adopt.

References.

2. Honig, P. — Sugar, 47, No. 6,31 (1932).
37. Glassen, H. Sent, Zuckerind, 13, 327 (1858).
42. Maillard, L. C., Compt. rend. 154, 66 (1911).
54. O. Wen, W. L., Sugar XXXVIII, No. 9, 22 (1943).
58. O. Wen, W. L., La, Exp. Station Bull, 125 (1911).
59. Kopeloff, La. Exp. Station Bull 175 (1920).
60. Church, Sugar (1921).
63. Neale and Maercker, Spiritus Industries (1881).