

SOME NOTES ON THE PROPERTIES OF RAW SUGAR IN CONNECTION WITH DETERIORATION DURING STORAGE

By Dr. K. DOUWES DEKKER and Miss M. J. DOUWES DEKKER.

Introduction.

At the beginning of 1951 it became apparent that the 1950 season's raw sugar stored in the warehouses of Hulett's S.A. Refineries was gradually deteriorating. The storing and melting system applied at the refinery does not allow direct comparison between the composition of individual parcels at the beginning and the end of the storing period. However, a glance at the average analytical data of the sugar as supplied by the individual mills and the sugar melted in March and April, 1951, discloses conclusively that deterioration occurred (Table 1).

TABLE 1.

Name of mill.	Polarization, degrees.	Reducing sugars, per cent.	Ash, per cent.	Moisture, per cent.	Safety factor.
UF ...	98.18	0.21	0.45	0.67	0.37
ZM ...	98.21	0.23	0.45	0.63	0.35
FX ...	98.49	0.18	0.32	0.61	0.40
AK ...	98.27	0.17	0.30	0.68	0.39
DL ...	98.57	0.19	0.29	0.54	0.38
MV ...	98.42	0.21	0.39	0.53	0.34
TS ...	98.51	0.16	0.33	0.57	0.38
Average season					
1950 ...	98.45	0.18	0.33	0.59	0.38
Melt Mar./April					
1951 ...	97.25	1.27	0.34	0.60	—

The S.M.R.I. was asked to study the causes of the deterioration, the aim being to formulate measures which might prevent similar losses in future years. The deterioration of raw sugar under various conditions has frequently been studied as a general problem in many countries, and as a result of these studies it is usually agreed—

- (a) that the deterioration reactions are mainly of a microbiological nature, and
- (b) that the velocity of deterioration can be reduced efficiently by keeping the moisture content of the sugar at a low value.

Our knowledge of the occurrence and activity of micro-organisms which may stimulate deterioration during storage is at present insufficient to warrant practical recommendations. We therefore have to concentrate on the moisture content side of the problem in fighting deterioration. This means that the sugar has to be manufactured with a low moisture percentage, and that no moisture shall be absorbed afterwards.

Both requirements, the production of sugar of low moisture content and the prevention of absorption of moisture during transport and storage, present a number of interesting problems—some of a more academic, and some of a more practical nature, which were fully discussed with the representatives of the factories. A repetition of these discussions would be trying to the patience of the audience. Therefore only two subjects were selected for this paper. The first deals with a point which, although important, is sometimes neglected when sugar of low moisture content has to be produced, i.e. the quality of the grain; the second is related to the problem of transport and storage, i.e. the absorption of moisture from the air by sugars of differing hygroscopicity.

Size and regularity of sugar crystals.

It is a well recognised fact that the centrifuging qualities of a massecuite, other conditions being the same, are proportionately better the larger and the more regular the size of the crystals. This argument is mainly used when the washing (affination) of raw sugar in the refinery is discussed, but should also be remembered when the measures required to produce a sugar of a low moisture content have to be studied. The aim of the centrifuging process is to separate as completely as possible crystals and molasses, and the amount of molasses adhering to the centrifuged crystals should therefore be as small as possible. This aim is better achieved when the sugar consists of relatively large, uniform, single crystals than when the crystals are of differing size, and especially when conglomerates occur to a large extent. Therefore, full attention should be given to the quality of the crystals of the sugar, and it is known that some boiling schemes are more appropriate in this respect than other ones. The selected scheme should aim at the formation of single crystals in particular, since conglomerates, consisting of two or more crystals which have grown together and which often differ in size, hold small amounts of molasses in the niches, and these particles of molasses are very difficult to remove by washing or steaming. This paper, however, was not written to discuss the merits of the various boiling schemes, since the subject has been covered in another publication of the S.M.R.I.,¹ nor shall we enlarge upon the construction of vacuum pans, which also has a bearing on the formation of conglomerates; but in what follows the results of an investigation into the grain quality of the raw sugars as supplied to the refinery are reported, since this gives us insight into the present situation.

To study the grain characteristics of a sugar, it is customary to conduct a sieving test. The results of such a test depend on the details of the method employed; in the first place on the size of the openings of the screens used, and to a lesser degree on the weight of the sample, the period of shaking the sieves, etc. It is therefore necessary to standardise the test. If the number of screens used in a test is n , the sugar sample is divided into $n+1$ fractions. The weight of these fractions expressed as percentages of the total weight of the sample constitutes the results of the test. For example, if five screens are used the grain quality of the sugar is characterised by six percentage figures. To simplify the procedure this number has to be reduced; our chief aim is to judge the grain quality of a sugar on the smallest possible number of criteria.

A sieving test enables us to classify a sugar as to grain quality. If the specifications for the various types of grain in which sugar can be produced are drawn up in terms of the simplified results of a sieving test, classification of a sugar is simply a matter of comparing the results of the sieving test of this sugar with the standardised specifications for the various classes.

The methods to be used for reducing the number of the figures expressing the result of the test and the specifications for various classes of grain are matters of mutual agreement. Since no advantage can be seen at present in devising a new scheme for Natal, we have followed in this investigation the method developed about twenty years ago by the Java Experiment Station, and since then employed with satisfactory results.

- (a) The test is carried out as described in Appendix I. Five Tyler Standard Screen-scale sieves (10, 14, 20, 28 and 48 mesh; openings in mm. 1.651, 1.168, 0.833, 0.859 and 0.295) divide the sugar

into six fractions, of which No. 1 fraction is the coarse, and No. 6 fraction the fine one.

- (b) The ultimate characteristics are—
- (i) the specific grain size of the sugar (s.g.s.), which is calculated from the weights of the fractions by a method described in Appendix II;
 - (ii) the weight of the main fraction;
 - (iii) the weight of the finest fraction(s).
- (c) The specification of grain classes is in this way reduced to agreement upon—
- (i) the upper and lower limits for the grain size;
 - (ii) the fraction which will be called the main fraction, and upon the minimum weight of this fraction;
 - (iii) the fractions which will be called the finest fraction(s) and upon the maximum weight of this (these) fraction(s).
 - (iv) The following classes of grain have been specified in Java for various destinations: coarse, normal, fine, very fine. In consultation with a number of refineries all over the world, "normal" grain was selected as most suitable for refinery sugar.
 - (v) The specifications for "normal" grain are: The specific grain size has to be more than 0.9, and less than 1.05 mm.; the third fraction is the main fraction. The third fraction should constitute more than 45 per cent. of the weight of the sugar; the finest fractions are the fifth plus the sixth. The added weights of these fractions should be less than 10 per cent. of the weight of the sugar.

In Table 2 the results are given of sieving tests carried out on samples of 1951 raw sugar kindly pro-

TABLE 2.

	Standardised requirements for normal grain.	UF.	ZM.	FX.	DL.	TS.	HR.
Specific grain size (mm.)	0.9—1.05	0.53	0.61	0.64	0.81	0.81	0.58
Main (3rd fraction) (per cent.)	≥ 45%	8.1	21.5	32.9	48.8	47.4	22.1
Finest (5th and 6 fraction) (per cent.)...	≤ 10%	47.9	27.8	15.9	12.2	9.7	33.5
First fraction (per cent.)	—	0	0.3	0	0.1	0.5	0.1
Second fraction (per cent.)	—	1.8	3.9	1.3	15.8	13.1	2.7
Fourth fraction (per cent.)	—	43.9	45.9	49.8	21.9	29.2	42.8

vided by five mills and the refinery. In the top part of the table the ultimate criteria are given; in the lower part the weights of the fractions which are not strictly necessary for the judgment of the quality of the grain. Before discussing these results we have

to draw attention to two complications. In the first place, it is not possible to sieve raw sugar as such, because the crystals stick together and are not separated in the sieving test. The sugar has to be washed with a saturated alcoholic solution of sucrose

to loosen the crystals. The details of this procedure are described in Appendix I. The samples used in this investigation were washed before being sieved. Further, it should be realised that the results of a sieving test are enhanced by the presence of rolled grain (conglomerates) which directs the crystal units to a coarser fraction than agrees with the size of the single crystals. If rolled grain is present the results of the sieving test should therefore be supplemented by a

for the probability of deterioration of raw sugar. The safety factor indicates what part of the total non-sugar content of the sugar is water, and is found by dividing the moisture percentage by 100—the polarization of the sugar. Originally it was thought that a safety factor of 0.33 indicated satisfactory keeping qualities, but later on it was realised that this value was high, especially when the sugar had to be stored in tropical countries. The maximum safety factor

TABLE 3.—OCCURRENCE OF CONGLOMERATES.

Factory.	Weight of sample (gr.)	Percentage by weight.		Number of		Factory.	Weight of sample (gr.)	Percentage by weight.		Number of	
		Conglomerates.	Single crystals.	Conglomerates.	Single crystals.			Conglomerates.	Single crystals.		
Third fraction.						Fourth fraction.					
UF	0.1221	89.9	10.2	200	19	UF	0.1613	81.7	18.3	454	109
ZM	0.1865	91.5	8.5	255	41	ZM	0.1798	77.5	22.5	425	156
FX	0.2083	75.6	24.4	200	79	FX	0.1039	46.3	53.7	129	159
DL	0.2593	58.9	41.1	146	121	DL	0.1483	48.5	51.5	195	193
TS	0.2087	64.2	35.8	134	80	TS	0.1793	43.6	56.4	175	215
HR	0.2202	81.6	18.4	218	60	HR	0.1041	65.2	34.8	93	100

photo-micrograph of the grain, or by the results of the determination of the percentage of conglomerates in each fraction.

The results of such determination for each of the sugars examined are given in Table 3. It was not deemed necessary to examine either the first and second fractions, because of the small percentage of crystals in these fractions, nor the fifth and sixth fractions, because since the formation of conglomerates tends to increase the size of the particles, conglomerates are not likely to be present to a large extent in these fine fractions. Table 3 therefore contains only the result of the tests carried out on the third and fourth fractions.

Conclusions. Table 2 shows that the examined samples were finer and less regular than required by the standards for refinery sugar. Moreover, the sugar of the third sieved fraction consisted of 60 to 90 per cent. of conglomerates, and the sugar of the fourth fraction of 45 to 80 per cent. of conglomerates. The curing of such sugars requires more energy and considerably more water than a sugar consisting of single crystals complying with the requirements specified above.

The interaction between raw sugar and the humidity of the atmosphere.

In the introduction to this paper we have seen that by aiming at a low moisture percentage of stored sugar the probability of the sugar deteriorating can be reduced considerably. Control of the moisture percentage is therefore essential, but it is obvious that the moisture percentage as such is not the correct criterion. The so-called Safety Factor, introduced by the Colonial Sugar Refining Company of Australia, is now generally used as a useful criterion

allowed in Java raw sugars which have to be stored is 0.23. In the years 1931-1935, when enormous quantities of sugar had to be stored in that country, this maximum value proved to be a reliable safeguard.

Table 1 shows clearly that the 1950 sugars received by the refinery contained too much moisture for safe storing and the subsequent deterioration had therefore to be ascribed to this cause. Some doubt arose about eventual absorption of moisture during transport from mill to refinery and during storage, but the analysis of the sugars as given by the mills and other evidence also, showed that the primary cause of the deterioration was the production of sugar of too high a moisture content. Notwithstanding this fact, it was thought advisable to study more closely the interaction between Natal raw sugar and the humidity of the air. The following investigation has to be considered in this light, but before discussing the results we should say a few words about the physico-chemical aspects of this interaction. From the very outset it is necessary to keep in mind the following points:—

1. Every raw sugar crystal is coated with a thin film of molasses, which is saturated with sucrose and further contains all the moisture and practically all the nonsucrose.
2. It is the properties of this film which determine the behaviour of the sugar in relation to the surrounding air.
3. The deterioration reactions occur in this film.

Further, we have to remember that every aqueous solution exercises a vapour pressure the value of which depends on the composition of the solution and the temperature. If the air above such a solution

contains water vapour the partial pressure of which is lower than the vapour pressure exercised by the solution, water will evaporate from the solution, and if the vapour pressure of the air is higher water will condense on to the solution. If both pressures are equal, solution and air are in equilibrium. The vapour pressure of the solution depends on its composition. Dissolved matter reduces the pressure, and the pressure of concentrated solutions is usually less than the pressure of diluted solutions. If so, the concentrated solution is called more hygroscopic. The vapour pressure of air is usually expressed as the relative humidity (R.H.), air in equilibrium with pure water having a R.H. of 100 per cent. Since the vapour pressure of an aqueous solution is less than the vapour pressure of pure water of the same temperature, aqueous solutions are in equilibrium with air of a R.H. of less than 100 per cent. A pure saturated sucrose solution, for example, is in equilibrium with air (of the same temperature) of 84.5 per cent. R.H. Since the concentration of a saturated sucrose solution increases when the purity decreases, the R.H. of air in equilibrium with sucrose solutions of lower purity is always less than 84.5 per cent. Impure saturated sucrose solutions are therefore more hygroscopic than chemically pure saturated sucrose solutions. The film coating refined sugar crystals is an almost pure sucrose solution; and the film coating raw sugar crystals has a much lower purity. The R.H. of air in equilibrium with raw sugar is therefore usually lower than the R.H. of air in equilibrium with refined sugar. Raw sugar more readily attracts moisture from the air than refined sugar. However, the following has to be considered. If a raw sugar which is in equilibrium with air of 73 per cent. R.H. is exposed to air of 65 per cent. R.H. the sugar will dry out. This means that the film surrounding the crystals becomes more concentrated and more hygroscopic, and when the right amount of water has evaporated the sugar will be in equilibrium, at a lower moisture percentage, with air of 65 per cent. R.H. On the other hand, the sugar, if exposed to air of 77 per cent. R.H. will absorb moisture from the air, and the concentration of the film will be reduced until a point is reached at which the sugar is in equilibrium with air of 77 per cent. R.H.

We see that there is a tendency for the sugar to adjust its moisture content until the vapour pressure of the sugar is equal to the vapour pressure of the air. Of course the same applies to refined sugar, and therefore it is not quite correct to say that raw sugar is more hygroscopic than refined sugar. It is more correct to say that raw sugar of the usual composition is more hygroscopic than refined sugar of, for example, a moisture content of 0.04 per cent. The film on refined sugar crystals containing 0.04 per cent. moisture has such a high purity that the vapour

pressure approximates the vapour pressure of a pure, saturated sucrose solution, while the vapour pressure of raw sugar of the usual composition (i.e. of a limited moisture percentage) corresponds to air of 70 to 75 per cent. R.H.

The object of our investigation was to determine the equilibrium relative humidity* of the raw sugars as supplied to the refinery by the various mills.

Six samples† of the 1951 season sugar were obtained from Umfolozi, Zululand, Felixton, Darnall, Tongaat and the refinery. The analysis of these sugars gave the following results:—

	UF.	ZM.	FX.	DL.	TS.	HR.
Polarization, per cent.	98.50	98.55	99.35	99.10	98.75	99.00
Moisture, per cent.	0.43	0.52	0.086	0.28	0.50	0.37
Reducing sugars, cent.	0.22	0.16	0.05	0.12	0.17	0.14
Sulphated ash, cent.	0.16	0.43	0.19	0.38	0.32	0.35
Safety factor ...	0.29	0.36	0.13	0.31	0.40	0.35

A set of six desiccators was provided with a fair portion of sulphuric acid of the following concentrations (percentage by weight): 43.0, 38.2, 35.5, 33.0, 30.0 and 27.0 respectively. The vapour pressures of these solutions correspond with 50, 60, 65, 70 and 75 per cent. R.H. An accurately weighed 15 gram sample of each of the six sugars was placed in each desiccator in a flat type weighing bottle. After 8, 18 and 36 days the weights of the samples were again ascertained and the alterations of the moisture percentage of the sugars were computed from the alterations in weight. The alterations in moisture content are recorded in Table 4. For example, the top line of the first column states that in 8 days the moisture percentage of UF sugar in an atmosphere of 50 per cent. R.H. was reduced by 0.21 per cent., i.e. from the original 0.43 per cent. to 0.22 per cent.

At the end of the experiment the percentages of reducing sugar were again determined. The results are given in Table 5.

The conclusions to be drawn from this simple experiment are:—

1. Whereas all samples dried out in air of 50, 60 and 65 per cent. R.H., and all sugars absorbed moisture at 80 per cent. R.H., only two sugars (UF and FX) could absorb moisture from air of 70 per

* Miss Bienenstock and Powers (Int. Sugar Journal 53 (1951), 254) introduced this term in a recently published article. It is perhaps interesting to know that the Dutch translation of this term has been in use in Java for at least 15 years. It was about the year 1934 that the Java Sugar Experiment Station determined the E.R.H. of many sugars, both raws, plantation whites and refined, by a method similar to that used by these British authors. The Java method, however, involved the use of sulphuric acid of various concentrations; disturbing effects due to inversion by acid fumes were never observed.

† These samples were also used for the determination of the grain characteristics as discussed in the first part of this paper.

TABLE 4.—ALTERATIONS IN THE MOISTURE PERCENTAGE OF RAW SUGARS EXPOSED TO AIR OF DIFFERENT RELATIVE HUMIDITIES.

		Relative humidity of air in desiccator.						
		After	50%	60%	65%	70%	75%	80%
UF	8 days	—	—	—	—	—	—	—
	Original moisture 0.43 per cent.	8 days	-0.21	-0.09	-0.01	+0.11	+0.33	+0.50
	18 days	-0.01	-0.03	-0.01	+0.01	+0.05	+0.52	
	36 days	-0.02	-0.00	-0.00	+0.00	+0.00	+0.34	
ZM	8 days	-0.37	-0.27	-0.23	+0.18	+0.04	+0.51	
	Original moisture 0.52 per cent.	18 days	-0.02	-0.06	-0.00	-0.00	+0.03	+0.37
	36 days	-0.01	—	-0.00	-0.00	+0.04	+0.59	
FX	8 days	-0.02	—	-0.00	+0.02	+0.04	+0.12	
	Original moisture 0.086 per cent.	18 days	-0.01	—	-0.00	+0.00	+0.01	+0.03
	36 days	-0.01	—	-0.00	+0.00	+0.01	+0.00	
DL	8 days	-0.20	-0.15	-0.11	-0.07	+0.06	+0.25	
	Original moisture 0.28 per cent.	18 days	-0.02	-0.00	-0.00	+0.02	+0.02	+0.03
	36 days	-0.04	+0.01	-0.00	-0.01	+0.01	+0.30	
TS	8 days	-0.39	-0.35	-0.18	-0.10	-0.06	+0.16	
	Original moisture 0.50 per cent.	18 days	-0.02	-0.01	-0.02	-0.00	+0.01	+0.03
	36 days	-0.02	—	-0.00	-0.00	-0.01	+0.03	
HR	8 days	-0.25	-0.20	-0.17	-0.13	-0.03	+0.29	
	Original moisture 0.37 per cent.	18 days	-0.01	-0.03	-0.01	-0.00	+0.01	+0.10
	36 days	-0.02	-0.00	-0.00	-0.00	+0.04	+0.10	

TABLE 5.

REDUCING SUGAR PERCENTAGES AT END OF THE TEST.

	Original per-centage.	Relative humidity of air in desiccator.				
		60%	65%	70%	75%	80%
UF ...	0.22	0.22	0.21	0.20	0.20	3.01
ZM ...	0.12	0.12	0.12	0.12	0.26	15.73
FX ...	0.05	0.04	0.05	0.05	0.05	0.22
DL ...	0.12	0.12	0.11	0.12	0.13	6.90
TS ...	0.15	0.15	0.15	0.15	0.19	14.60
HR ...	0.14	0.14	0.13	0.14	0.87	4.38

cent. R.H., while two other sugars (TS and HR) lost weight in air of even 75 per cent. R.H. It appears that (as was to be expected!) the sugars with the highest S.F. (TS, ZM and HR) are the least hygroscopic, while the sugars with the low S.F. (UF and FX) are most hygroscopic.

2. The sugars which dried out reached equilibrium within eight days, for in the second period of the experiment the alterations in weight were already negligible, while at 80 per cent. R.H. equilibrium was not reached at all. Two sugars (ZM and DL) absorbed more moisture in the third than in the first period. Deterioration reactions apparently make sugar more and more hygroscopic.

3. The sugars exposed to air of 70 per cent. R.H. and less did not show an increased reducing sugar percentage in the 36 days of the experiment. In air

of 75 per cent. R.H. the ZM and HR sugars deteriorated perceptibly, and at 80 per cent. deterioration was considerable in all cases with the exception of FX sugar, which showed only a slight increase in the reducing sugar percentage. ZM, DL and TS sugars deteriorated very fast. We tried to correlate the velocity of the deterioration of the samples with the results of the bacteriological analysis carried out throughout the season on various samples of sugar of the mills involved, because we thought that the sugar of the mills which had regularly produced sugar fairly free of harmful organisms might deteriorate more slowly than the sugar of mills producing badly contaminated sugar, but such correlation could not be traced. In this respect a tentative conclusion on work on deterioration carried out by the Queensland Bureau of Experiment Stations is worth repetition here²: "The incidence of deterioration under commercial conditions cannot be correlated with any known single factor, and in most cases reported of in recent years there is abundant conflicting evidence." One of the factors studied was the contamination with harmful micro-organisms. This statement is brought to the fore here because it is sometimes alleged that the deterioration problem can be solved simply by producing sugar free of micro-organisms. In our opinion, although we applaud every attempt to reduce the contamination of sugar, the solution of the deterioration problem has to be found in a different way.

A few weeks later the test was repeated with fresh portions of the same sugars. The relative humidities of the air in the desiccators were now 65, 67, 69, 71 and 73 per cent. In satisfactory agreement with the results of the first experiment, it was now found that the equilibrium relative humidities for the sugars examined were: UF 67 per cent., ZM 73 per cent., FX 67 per cent., DL 71 per cent. and HR 73 per cent. The TS sugar, however, the E.R.H. of which had in the first test been found to be a little over 75 per cent., appeared now to be able to absorb moisture from air of 73 and even 71 per cent. R.H. The sugar, which in the period of five weeks between the two tests had been kept in a tightly closed bottle, had apparently become more hygroscopic. In this short period the sugar had already deteriorated noticeably, as was apparent from a particular odour and the increase of the reducing sugar content from 0.17 to 0.81 per cent.

It is possible to calculate approximately, from the data in Table 4, the E.R.H. which the sugars would have shown if the moisture content had been reduced to a corresponding S.F. of 0.23. The calculated E.R.H. values are:—

UF ...	61 per cent.	DL ...	66 per cent.
ZM ...	64 per cent.	TS ...	63 per cent.
FX ...	66 per cent.	HR ...	65 per cent.

Raw sugar of 0.23 safety factor is therefore very likely to have a E.R.H. value of about 65 per cent., and is able to absorb moisture from air of the same temperature and 65 per cent. and higher relative humidity. The average, maximum and minimum daily relative humidity values for Durban for the weeks of the crushing season 1951 are given in Table 6 for the purpose of judging the probability of absorption of moisture by the sugar during transport from mill to refinery. These data were kindly provided by the Meteorological Office at Stamford Hill Aerodrome.

TABLE 6.

RELATIVE HUMIDITIES IN DURBAN, 1951.

	Per cent.				Per cent.		
	Av.	Max.	Min.		Av.	Max.	Min.
May 7-13 ...	69	82	59	Sept. 3-9 ...	75	82	65
" 14-20 ...	71	82	63	" 10-16 ...	82	94	73
" 21-27 ...	75	79	71	" 17-23 ...	77	88	73
" 28-3 ...	69	78	67	" 24-30 ...	85	88	81
June 4-10 ...	63	71	54	Oct. 1-7 ...	85	92	78
" 11-17 ...	64	67	61	" 8-14 ...	82	88	72
" 18-24 ...	73	79	68	" 15-21 ...	82	85	74
" 25-1 ...	66	74	50	" 22-28 ...	85	94	74
July 2-8 ...	72	79	66	" 29-4 ...	77	85	69
" 9-15 ...	68	75	59	Nov. 5-11 ...	78	85	75
" 16-22 ...	64	69	58	" 12-18 ...	77	82	65
" 23-29 ...	59	77	32	" 19-25 ...	82	91	76
" 30-5 ...	64	76	51	" 26-2 ...	80	87	77
Aug. 6-12 ...	75	79	64	Dec. 3-9 ...	85	88	81
" 13-19 ...	83	88	79	" 10-16 ...	86	92	74
" 20-26 ...	83	94	75	" 17-23 ...	81	85	77
" 27-2 ...	84	90	77	" 24-30 ...	82	85	77

Table 6 shows that sugar of 0.23 safety factor is usually not stable in the Durban climate. If this type of sugar had been produced in 1951, absorption of moisture during transport from factory to refinery would have been a possibility, especially in August and later.

We do not think, however, that much moisture could have been absorbed during the few days of transport. The period of transport is short and the temperature of the sugar in the trucks is very likely to be higher than the temperature of the surrounding atmosphere. In the first place, the temperature of freshly produced sugar as loaded on the truck is likely to be somewhat higher than room temperature, and, secondly, we have to consider the heating of the trucks in the day time by the sun. The vapour pressure of the sugar is increased in proportion to the rise in temperature, and for this reason serious absorption of moisture seems unlikely. Drying-out of the sugar is, in our opinion, more likely, and loss of weight has in fact, been observed. It is true that the S.F. of the sugar involved was higher than 0.23, but altogether there does not seem to be much reason to fear serious moisture absorption during transport when 0.23 safety factor sugar is produced. However, when such sugar has to be stored in Durban, more difficulties can be anticipated.

The critical months for storage are apparently January, February, March and April. As an example of the weather conditions in Durban during these months, Table 7 gives the relative humidities for 1951.

TABLE 7.

RELATIVE HUMIDITIES IN DURBAN, 1951.

	Per cent.				Per cent.		
	Av.	Max.	Min.		Av.	Max.	Min.
Jan. 1-7 ...	76	88	66	Mar. 5-11 ...	84	94	77
" 8-14 ...	84	90	78	" 12-18 ...	84	90	70
" 15-21 ...	81	90	75	" 19-25 ...	78	87	70
" 22-28 ...	83	88	63	" 26-1 ...	85	88	77
" 29-4 ...	74	82	66	Apr. 2-8 ...	85	96	78
Feb. 5-11 ...	87	90	84	" 9-15 ...	84	88	78
" 12-18 ...	86	90	82	" 16-22 ...	78	92	60
" 19-25 ...	82	87	69	" 23-29 ...	78	87	74
" 26-4 ...	69	80	50				

It is obvious from the data in Table 7 that 0.23 S.F. sugar will absorb moisture during storage in these months unless special precautions are taken. Without a further study, it is difficult to say what precautions are required. Heating of the storerooms with steam pipes will probably be most effective, but other remedies capable of retarding the absorption sufficiently to prevent the sugar from deteriorating in the relative short period of storage are also known.

Before concluding this paper, we should like to give warning against a false conclusion which might be drawn from our data. It would be wrong to conclude that the production of 0.23 S.F. sugar would be a

waste of energy and costs because of its not being stable in the Durban climate. The first step in curbing deterioration during storage is to produce a sufficiently dry sugar. When a higher S.F. sugar has to

be stored no practical measure can stop deterioration; only when a "safe" sugar is produced, are we able to store this sugar, even under rather adverse weather conditions, so that deterioration is negligible.

Appendix I.

SIEVING TEST FOR RAW SUGAR.

1. Washing of the sugar. To loosen the crystals by removing the film of molasses coating, the individual crystals of 70 grams of raw sugar are vigorously shaken for about half an hour with a sufficient quantity of an alcoholic saturated sucrose solution. This solution is prepared by dissolving refined sugar in 92 per cent. alcohol. It is advisable to place some sugar on the bottom of the bottle in which the solution is kept.

The wet sugar is then transferred into a small linen or twill bag (to prevent the loss of fine crystals) and the excess of liquor is spun off in a laboratory centrifuge.

Finally, the sugar is dried in a hot place (in the

sun, for example) in an open dish on a suitable shaking apparatus, which prevents the subsequent caking together of the sugar crystals.

The total quantity of dried sugar has to be used for the sieving test in order to avoid losing fine crystals.

2. Sieving test. Five Tyler standard screen-scale sieves (10, 14, 20, 28 and 48 mesh) are used. The weight of the sugar to be sifted is determined, the sugar is placed on the top sieve and sifting is carried out for 10 minutes,* after which the weight of the six fractions is ascertained.† The weights of the fractions are expressed as percentages of the total weight of the sugar sifted.

Appendix II.

CALCULATION OF SPECIFIC GRAIN SIZE.

The method followed is also used for the classification of some types of soil (sand). The main criterion calculated from the results of the sieving test is the "specific surface" (U) of the material tested. U is the ratio between the total surface of all particles and the total surface of the same weight of particles the diameter of which is 1 cm. The particles are supposed to be spheres.³ U is calculated from Zunker's formula,

$$U = \frac{4.343}{\log d_2 - \log d_1} \left(\frac{1}{d_1} - \frac{1}{d_2} \right)$$

in which d_1 = the diameter of the smallest particle,
 d_2 = the diameter of the largest particle.

The specific grain size (S.g.s.) is calculated from U by the simple formula: $\text{S.g.s.} = \frac{10}{U}$ mm.

In the following table the values for U and S.g.s., as computed from the openings of the Tyler sieves, are given for the six fractions of a sugar sieving test. d_1 of the sixth fraction is assumed to be 0.15 mm. Since the use of three decimals is not necessary and suggests a false degree of accuracy the values of U and S.g.s., which are actually used in the computation of a sugar sieving test, are also given.

	U .	S.g.s. mm.	U . For practical use in sugar analysis.	S.g.s.
First fraction...	4.712	2.122	4.8	2.1
Second ,, ...	7.235	1.382	7.2	1.4
Third ,, ...	10.17	0.983	10.0	1.0
Fourth ,, ...	14.37	0.695	14.3	0.7
Fifth ,, ...	24.47	0.409	25.0	0.4
Sixth ,, ...	48.49	0.206	50.0	0.2

To calculate the specific grain size of a sugar from the sieve test results, the weight of each fraction (expressed as a percentage of the total weight) is multiplied by the corresponding value of U . The products are added and the sum divided by 100. The quotient is the specific surface of the sugar tested, which divided into 10 gives the specific grain size in mm.

* To obtain correct results it is advisable to use a shaking apparatus, for example, the Ro-Tap hand or motor-operated machine.

† For white sugar, sieving tests take 50 grams of sugar.

Example—

	Sieve test result, Per cent.	U.	Product.
First fraction	1	4.8	4.8
Second ,,	15	7.2	108.0
Third ,,	55	10.0	550.0
Fourth ,,	26	14.3	371.8
Fifth ,,	2	25.0	50.0
Sixth ,,	1	50.0	50.0

$$\frac{\text{Sum of products}}{100} = 11.346.$$

$$\text{S.g.s.} = \frac{10}{11.346} = 0.88 \text{ mm.}$$

REFERENCES.

¹ Chs. G. M. Perk : The Use of Molasses instead of Syrup for the Graining of Low Grade Masecutes. Communication from the S.M.R.I. 1951, No. 9.

² Australian Sugar Journal 43 (1951), 135.

³ K. Douwes Dekker : Verhandelingen Proefstation voor de Java Suikerindustrie (1936), No. 19.

Mr. Dymond remarked that this subject had been discussed off and on for a number of years, but that, thanks to Dr. Douwes Dekker's excellent paper, we now had some conclusions on which to base our future work. The Chairman enquired whether Mr. Tonner would care to say a few words regarding the paper.

Mr. Tonner said that two points in particular had struck him most forcibly. Firstly, was the fact that the sample of Refinery sugar which had been kept in a closed bottle at the S.M.R.I. laboratories had deteriorated in five weeks from 0.17 to 0.81 per cent.

reducing sugars. This fact caused him to wonder whether deterioration could be checked even under the most satisfactory storage conditions. The second point was that even sugar of 0.23 safety factor tended to deteriorate owing to our unstable weather conditions. Despite this fact, Mr. Tonner was of the opinion that 0.23 safety factor is the target at which we should aim. He concluded by congratulating Dr. Douwes Dekker on his paper.

Mr. Henry enquired whether Dr. Douwes Dekker had any information on deterioration in export sugars of other countries.

Dr. Douwes Dekker replied that such deterioration had taken place in Australia, and emphasised that exporting of sugars in bulk complicated the problem of transporting and storing.

Mr. Dymond enquired whether Dr. Douwes Dekker had any information on the consignment of bulk sugar exported to England last year, and Dr. Douwes Dekker replied that perhaps Mr. Tonner had some information.

Mr. Tonner said that no information was available and that the importers were interested mainly in the weight of the sugar rather than in deterioration. He indicated that in his own opinion deterioration in bulk would be less than with bagged sugar, since it is conceivable that only the surface of the bulk would be affected by being in contact with atmospheric conditions.

Mr. Dymond observed that this view was substantiated by the sugar stored at Reunion during the first war. This sugar too deteriorated only on the exposed surfaces.

Mr. Lewis concluded the discussion by proposing a vote of thanks to Miss Douwes Dekker for her part in the paper.