SOME ASPECTS OF BULK STORAGE OF VHP SUGAR IN DURBAN

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Abstract

Much information is available on bulk storage of refined and raw sugars but some comments on storage of VHP (Very High Pol) sugar under the local climatic conditions may be of interest. The climatic conditions inside and outside storage silos were measured and compared. The readings have been graphically plotted, and comments thereon are listed.

Introduction

Sugar is known to have hygroscopic properties and its behaviour on bulk storage in Durban is of interest. Additionally, the main product bulk-stored at S.A. Sugar Terminals is VHP sugar, the properties of which differ somewhat from both refined and raw sugars.

A fairly lengthy storage experience at the Terminals indicates that very little, if any, deterioration occurs during bulk storage of VHP sugar in the silos, but it was felt that an examination of changes in silo temperature and humidity over a period of some months would indicate how the stored sugar affects the atmosphere of the silos, when these are not air-conditioned in any way but merely kept closed to the outside environment.

A recording thermohygrograph was placed in silo II on 27th August 1974 and a humidity and air temperature were recorded until 30th January 1975. This information was graphically compared with the ambient conditions observed outside the silo. During the period of observation silo II (maximum capacity 218 000 tons) remained about half-loaded with VHP sugar.

Some comments on the information obtained are listed below:

Humidity measurements

A scrutiny of the relative humidity recorded outside and inside the silo over a period of some four months, reveals a number of interesting points.

(A) A general average of outside relative humidity appeared to be about 80%, whereas inside the silo this value dropped to about 60%. The difference of some 20% may be due to the dehydrating effect of sugar stored in the silo, with the exclusion of the outside atmosphere. An average equilibrium relative humidity of 60%, as observed in the silo, is very near that found by Douwes Dekker[1] and somewhat below that of 70-75% given by Tubb,[2] but this is probably due to the fact that VHP sugar differs in this aspect from refined sugar. (Lyle,[3] Bagster,[4] and Meade[5]).

(B) The relative humidity curves of the outside and inside of the silo show similar profiles, with rapid inside adjustment where the humidity differential is small, and somewhat delayed changes with greater outside humidity fluctuations. The above effect is to be expected in an enclosed, non-ventilated silo where there is no free atmospheric access.

A further general observation is that, whereas the outside R H (Relative Humidity) variation appeared to be ± 15%, the silo R H varied by ± 10%. A general smoothing out of humidity cycling was probably caused by the stored sugar.

In assessing this information it must be remembered that the measurements were carried out at a single point in the silo and it has not been possible to establish the R H gradient within the silo. Such gradient probably exists and varies with the height, proximity to the sugar surface, etc.

(C) The stored sugar in the silo is found to form a superficial crust within 5-10 days and this surface coating appears to protect the pile from further humidification and deterioration. Whereas the normal moisture content of V H P sugar is of the order of 0,10%, it has been found (Table 1) that the crust moisture content averages 0,20% and occasionally rises above 0,50%.

TABLE 1

Crust formed on VHP sugar stored in Silo 2 was sampled daily from 2nd December 1974 until 3rd January, 1975 and the summary of % moisture results is given below

	Top of Pile	Halfway down Pile	Bottom of Pile
Maximum	0,457	0,234	0,534
Minimum	0,089	0,089	0,069
Average	0,209	0,118	0,160

A calculation based on the silo being half-full (as at the time of this test) gives the following:

Silo volume 290 000 m^3
Sugar volume 80 000 m^3
Air volume 210 000 m^3

Assuming average temperature of 25°C at 80% R H, the weight of water vapour in the available air space should be 3,8 t but it actually (at 60% R H) was 2,9 t. (Weast[5]).

Thus the difference of 3,8 — 2,9 t = 0,9 say 1 t, had to be accounted for and it seems very likely that it was absorbed by the stored sugar.

The shape of the sugar pile was roughly that of a regular cone with a surface of 9 100 m^2 and total volume, of 25 mm thick crust, of 230 m^3. If 1 t of moisture was absorbed by the above volume of sugar, the latter's moisture content was increased $1/230 \times 100 = 0{,}42\,\%$ and this is well within the range found.

It thus appears that the sugar pile superficially absorbs moisture, forming a crust which is richer in moisture nearer the surface. The crust appears to build up to a thickness of 25 — 36 mm and forms a protective cover. The difference between the average silo R H and ambient R H is probably due to absorption of air moisture by the sugar. It has not been established whether the crust builds up to a maximum thickness nor whether there is a corresponding loss of moisture from the skin when the external R H drops significantly.

It was decided to assess quantitatively the moisture change which takes place in the crust. To this purpose sugar crust (selected for uniformity) was sampled to a depth of 40 mm and samples at 10 mm intervals were analysed (Table 2). The moisture gain of the outermost layer is perceptible, and there is a progressive decrease towards normal moisture content at depth.

TABLE 2

Samples of crust taken in Silo 2 at progressive depths of 1 cm to a total depth of 4 cm

Depth	% Moisture content		
	January 1975	February 1975	March 1975
1 cm	0,12	0,17	0,11
2 cm	0,11	0,16	0,09
3 cm	0,10	0,13	0,08
4 cm	0,10	0,11	0,08

Tests were also carried out to determine whether the moisture content of the crust varies with the height of the sugar on the pile. Ten samples of the crust at 3 m intervals were taken from top to bottom (approximately 30 m) of the pile. The moisture determinations indicate that the lower areas of crust are more moist. Additionally the uppermost sample taken near the silo roof showed a higher moisture content, but this was probably caused by moisture absorption by accumulated dust which settled near the top. (Table 3).

TABLE 3

Silo 2 sugar — Moisture determination in crust formed on pile 30 m high, samples taken at 3 m intervals

Height	% Moisture content		
	9/2/75	9/3/75	11/3/75
3 metres	0,487	0,289*	0,179
6 metres	0,170	0,199	0,155
9 metres	0,243	0,115	0,129
12 metres	0,165	0,144	0,129
15 metres	0,145	0,200	0,129
18 metres	0,129	0,189	0,139
21 metres	0,234	0,144	0,104
24 metres	0,435	0,189	0,184
27 metres	0,342	0,179	0,394*
30 metres (Top) . .	0,503	0,189	0,349*

*Indicates that a fair amount of sugar dust was found on the sampling site.

Temperature measurements

Temperatures inside and outside the silo were recorded over the same calendar period. Inspection of the graphical plot reveals a rather similar picture to that of R H, with the external temperatures being generally higher (average ± 26°C) than those recorded in the silo (average ± 24°C).

It is apparent that the daily temperature fluctuation of the order of ± 4°C externally, was usually followed by ± 1½°C temperature variation in the silo. The high daily temperatures in the silo were recorded at about 16h00-18h00 and the lowest at about 04h00-06h00. Since the highest external temperatures are recorded at about 12h00-14h00, some 4 hours delay occurs in transmission of heat through the structure of the silo. This insulating effect of the structure of the silo is probably shown by the ± 2°C lower average silo temperature.

Examination of a typical thermohygrograph weekly record chart (Fig. 1) shows that the daily relative humidity usually varied inversely with the air temperature in the silo and this effect has been noted elsewhere (Bagster[6]).

As in the case of R H measurements, the air temperatures in the silo were recorded in one location only and no account is taken here of temperature gradient in the silo, e.g. perceptibly higher temperatures were noted near the silo roof on hot sunny days (Table 4).

TABLE 4

Temperature gradient in Silo 2

Date	Site	Temp.°C
7/3/75	West Ground	24,8
	West ⅓ up	25,5
	West ½ up	26,8
	West ¾ up	28,9
	West Top	29,1
	East Ground	27,4
	East ⅓ up	27,8
	East ½ up	27,9
	East ¾ up	28,1
	East Top	28,3
10/3/75	West Ground	28,2
	West ⅓ up	29,0
	West ½ up	29,2
	West ¾ up	29,2
	West Top	29,3
	East Ground	27,7
	East ⅓ up	28,8
	East ½ up	29,0
	East ¾ up	29,0
	East Top	29,1

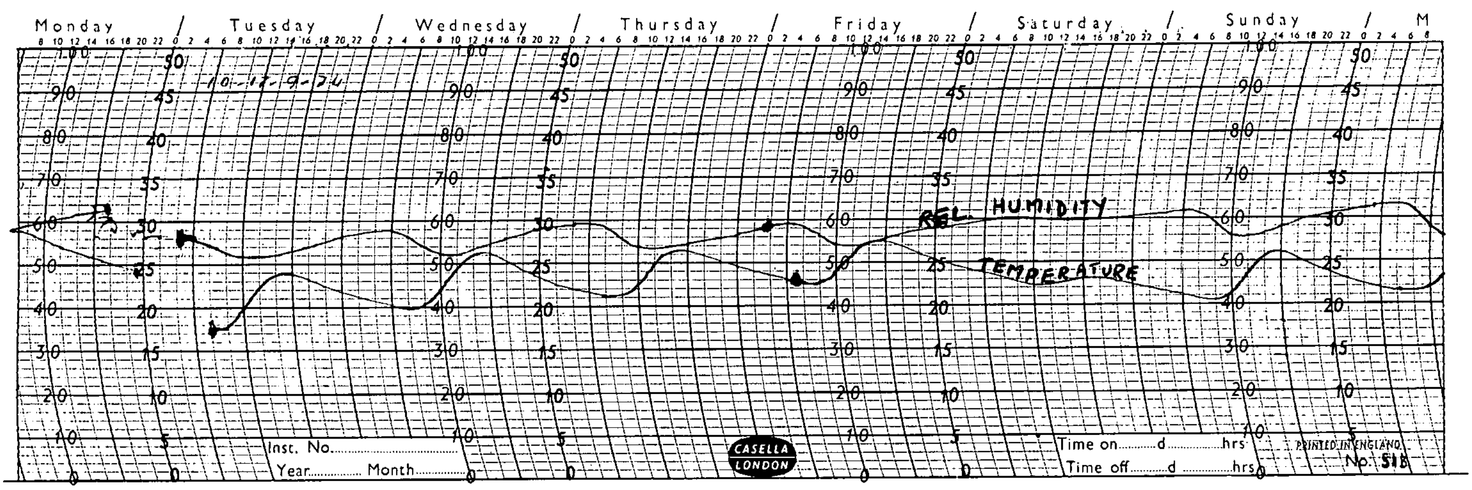

FIGURE 1

It is considered that with the smoothing out of temperature fluctuations and a slightly lower average of 1½°C internal temperature of the silo, favourable sugar storage conditions are maintained. This agrees with observations made by Meade[7].

With the exception of moisture pick-up in the crust and a very slight colour deterioration therein, no other deleterious effects were observed on V H P sugar stored in the silo for more than six months. There was no evidence of lumping in the inner sugar due to moisture migration mentioned by Tubb[2] and the outside thin crust exerted a beneficial protective action. This behaviour of raw sugar stored in a semi-tropical climate is noted by Baikov.[8]

Dew point measurements

The silo and ambient dew-point temperature records were plotted on the same time scale as the relative humidities and air temperatures. It was desired to check at times when condensation occurred in the silo. On these occasions beads of moisture were visible on the metal work and those structures, which had been previously coated with a layer of dust, were coated with a layer of thick sugar syrup.

Normally, the outside dew-point averaged about 16-17°C with that of the silo being about 18-19°C. On the occasions when there was a significant rise in the outside relative humidity (this usually occurred after a rainfall) a lesser change followed in the silo and a reversal of the outside and inside dew-points resulted where the former became higher than the latter. The condensation in the silo (which is thought to be connected with the above phenomenon) did not last for more than 12-18 hours and very speedy "drying-up" took place when the weather conditions returned to normal.

Three such incidents of recorded silo condensation took place on 2nd and 20th December 1974 and on 17th January 1975.

Problems caused by dusty sugar

Although V H P sugar carries a coating of molasses around its crystals and should thus be less prone to generation of dust, it is found that dusty V H P sugar is received at S.A. Sugar Terminals mainly during the winter season.

The reasons for the occurrence of this phenomenon are not clear, but may be related to the quality of winter-harvested cane and/or generally lower humidity prevalent during this time. Under the latter circumstances, there appears to be a decrease in moisture content of V H P sugar railed to the Terminal, and often the magnitude of the moisture drop is proportional to the distance of travel and the time taken to reach the Terminal. This phenomenon could perhaps be accounted for by the reduction of the "bound" moisture during the period between the despatch of the sugar and its delivery to the Terminal (Powers[9]).

As yet, the dusty sugar cannot be identified prior to tipping and handling, but manifests itself immediately on removal from the truck. From this time onward it affects plant machinery, necessitates extra cleaning, and presents a possible explosion hazard. On entry into the silo the dust is again prominent in the silo atmosphere but, with cessation of sugar movement, it gradually settles out, forming a top of the crust on the sugar pile referred to earlier on, and a fairly compact white layer on other surfaces. Once settled, the dust appears to consolidate (possibly by absorption of atmospheric moisture) and causes no further problems.

Analytical examination of sugar dust reveals that it is of lower purity than V H P sugar and contains considerably higher moisture (Table 5).

TABLE 5
Sugar dust analyses

Sample from	Pol	Moisture
Molasses mixing plant .	97,0	0,91
Silo 1	94,0	1,41
Silo 2	89,8	2,05

During the coating of V H P sugar with High Test Molasses for export purposes, dusty sugar batches again generate large quantities of dust, transferring the explosion hazard to the Molasses Coating Plant.

Literature dealing with the risk of sugar dust explosion (Tubb,[1] Lyle,[3] Hulett's I B 270,[10] Rotgers *et al*,[11] De Whalley,[12] Kuhnen[13]) describes conditions likely to promote the risk, namely:

(*a*) Handling of dry and usually purified sugar.
(*b*) Low humidity (50% R H).
(*c*) Concentration and particle size of dust (17,5 — 32,5 gm/m³).
(*d*) Ignition promoters such as sparks, flames, electrostatic discharges etc.

The Terminal conditions generally are unfavourable for this type of explosion risk and Fig. 1 records only a single instance of silo humidity below 50% R H. Although the dust concentrations have not been determined quantitatively, the observations appear to fall short of 2½ - 3½ metre visibility mentioned in the literature. Nevertheless, the danger of primary initiator explosion is fully appreciated and strict precautions as recommended by Allen,[13] against accidental ignition are being observed by the operating staff.

An 'anti dusty sugar campaign' was commenced at the beginning of the 1974/75 season and the producing mills were immediately contacted on receipt of dusty sugar at the Terminal and were requested to take corrective action, which usually consisted of either taking steps to maintain maximum permissible moisture (0,12 - 0,18% depending on pol) or reducing the pol of V H P sugar to the minimum limit of 99,30°. This campaign was also supported by a monthly "merit list" compiled on visual records of various mill receipts.

Surprisingly good results were obtained by these relatively simple means and towards the end of 1974 the dust investigation work had to be abandoned for want of dust.

Conclusion

It appears that the storage of V H P sugar at S.A. Sugar Terminals in Durban is influenced by several factors such as:

(1) Fairly even and slightly lower than ambient storage temperature.
(2) Equilibrium relative humidity of stored V H P sugar appears to be in the neighbourhood of 60% and this is above the level considered critical from the viewpoint of explosion hazard.
(3) A crust of 25-36 mm thick, forms on the stored sugar and protects it from deterioration, consequently no moisture migration problems have arisen in the stored sugar.
(4) Very little deterioration of silo-stored sugar has been noticed and the changes that occur, probably do so in the crust layer.
(5) Sugar dust, caused by movement of sugar in the silo, settles on the stored sugar and superficially alters the colour and moisture content of the upper portion of the protective crust.

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