REFINED SUGAR CONDITIONING AND STORAGE

By A. M. HOWES

Summary

In view of the wide variation in South African atmospheric conditions and, in particular, its humidity, refined sugar when transported from the humid climate of Durban to the dry climate of Bloemfontein and the Reef, is exposed to conditions which invite "caking". This is the co-cementation of crystals at their various points of contact due to the loss of moisture or the migration of moisture between crystals.[1]

The term "conditioning" is now used to describe the treatment applied in its various forms to refined sugar in order to reduce handling, packing and storage problems.

In recent years there has been a change in the recognised practice of cooling sugar after drying. This change follows the work of Powers[2] which clearly shows that there exists an excess of "bound" moisture within the crystal. This moisture migrates to the surface over a period of several days and its migration rate is dependant upon temperature. A satisfactory condition of Refined Sugar in storage is dependant upon three requirements:

1. The exhaustion of this "bound" moisture.
2. The stability of the surrounding atmosphere, and
3. A necessary ventilation in times of excessive ambient temperatures.

Factors Known to Affect the Condition of Sugar

1. Conglomerates.
2. Grain Size and Distribution.
3. Compression.
4. Moisture Content.
5. Temperature.

1. *Conglomerates* are caused by the adhesion of two or more crystals normally created during one or more of the boiling, curing, and drying processes.

The higher proportion of syrup film held around the crystal interface requires additional washing, drying and more attention in conditioning. Conglomerated crystals not only impede the flow of sugar in high speed packing equipment, but also affect the bulk density of the sugar

Mechanical circulation is considered necessary to reduce the formation of conglomerates. In conjunction with automatic control, circulators are claimed[3] to reduce steam consumption by 33 per cent and increase pan boiling capacity by the same proportion.

2. *Grain Size* is normally controlled in pan boiling to certain limits of "Mean Aperture". If the sugar is completely screened into different fractions as is the practice in some Canadian and American Refineries, there would be little tendency for crystal separation in silos or bins. However, it is necessary to prevent separation if the sugar is not screened. There exists a greater tendency for small grain to consolidate due to an increase in both the surface area and the number of points of contact between crystals; for example, the tendency of icing sugar to cake is significant.

3. *Compression* of sugar occurs in silos or bins where the bulk density might increase between 5 and 6 pér cent above the standard laboratory test figures.[4] Pressure not only in bulk sugar vessels, but also in bagged sugar stacked to appreciable heights will tend to fuse together the fine crystals in particular; more so in the presence of migrating moisture vapour.

4. *Moisture Content* of refined sugar is normally 0.04 per cent, while sucrose purity exceeds 99.93 per cent. A moisture content of 0.08 per cent, that is, double the normal figure would provide a sugar with a definite dampness. This minute quantity of moisture signifies the susceptibility of refined sugar to changes in humidity.

From the time wet sugar enters the granulators for drying there exist three stages of moisture removal. The first is the free moisture around the crystal surface which is removed by evaporation in the granulators. The second stage is the moisture remaining on the crystal in the form of a saturated film of syrup. The latter moisture may be removed either by vaporisation through elevated temperatures or, if by cooling, a state of supersaturation is reached where further crystallisation occurs with the release of more moisture. Now the slow release of this additional moisture at the lower temperature of sugar and surrounding air will surely create a problem where "cooling before packing" is advocated.

The third stage of moisture removal is that moisture described by Powers as "bound" moisture and by others as "inherent" moisture. It is located within the sugar crystal and cannot be removed in the granulators but migrates to the crystal surface during a period of 7 to 10 days. It has been shown that more than 50 per cent of "bound" moisture is liberated within 48 hours.[5] Graph I.

The removal of this moisture is now normally achieved by aeration at the base of the silo or bin with warm dry air at a pressure of approximately 5 lb. per square inch.

5. *Temperature* must be regarded as an essential controlling factor in the removal of all stages of moisture. Furthermore, a constant sugar-bin temperature would assist in maintaining a steady discharge rate and a steady bulk density, both necessary factors for a high speed packing unit.

Storage

In February 1965 a considerable quantity of refined sugar suffered damage from dampness while in storage, possibly as a result of extreme weather conditions.

It is an accepted procedure to seal stores containing packed refined sugar without conditioning the air. If we examine the reasons for sealing the store we must conclude that the intention is to prevent changes in temperature and humidity prevailing within the store.

Some observations made at the time in the Refinery stores were:

1. The dampness was observed on February 17th 1965. (Graphs II and III).
2. The block stack affected was on the west side of the store which is exposed to the afternoon sun.
3. The block stack was built to the maximum height of the roof trusses.
4. The roof and walls are constructed of asbestos on steel frames and the roof has a shallow pitch with very little ventilation.

According to information received from the Louis Botha Meteorological office the ambient temperature at 2 p.m. on 17th February rose to 32.4° C, with a relative humidity of 65 per cent. This would provide an atmosphere with a dewpoint temperature of 27° C. and a humidity of over 0.020 lb. of water per lb. of dry air. Here we have exceeded a condition of equilibrium between saturation temperature and the hygroscopic property of sugar above which moisture is absorbed by the sugar from the atmosphere. This condition has been described as the Equilibrium Relative Humidity of Sugar.

There is little doubt that the temperature of the air above the sugar in the Refinery store exceeded that recorded by Louis Botha on 17th February, due to the absorption of heat and the insulation provided by the asbestos roof.

Conclusion

In the knowledge of the many observations made previously and with our observations over the past year, the following conclusions are drawn:

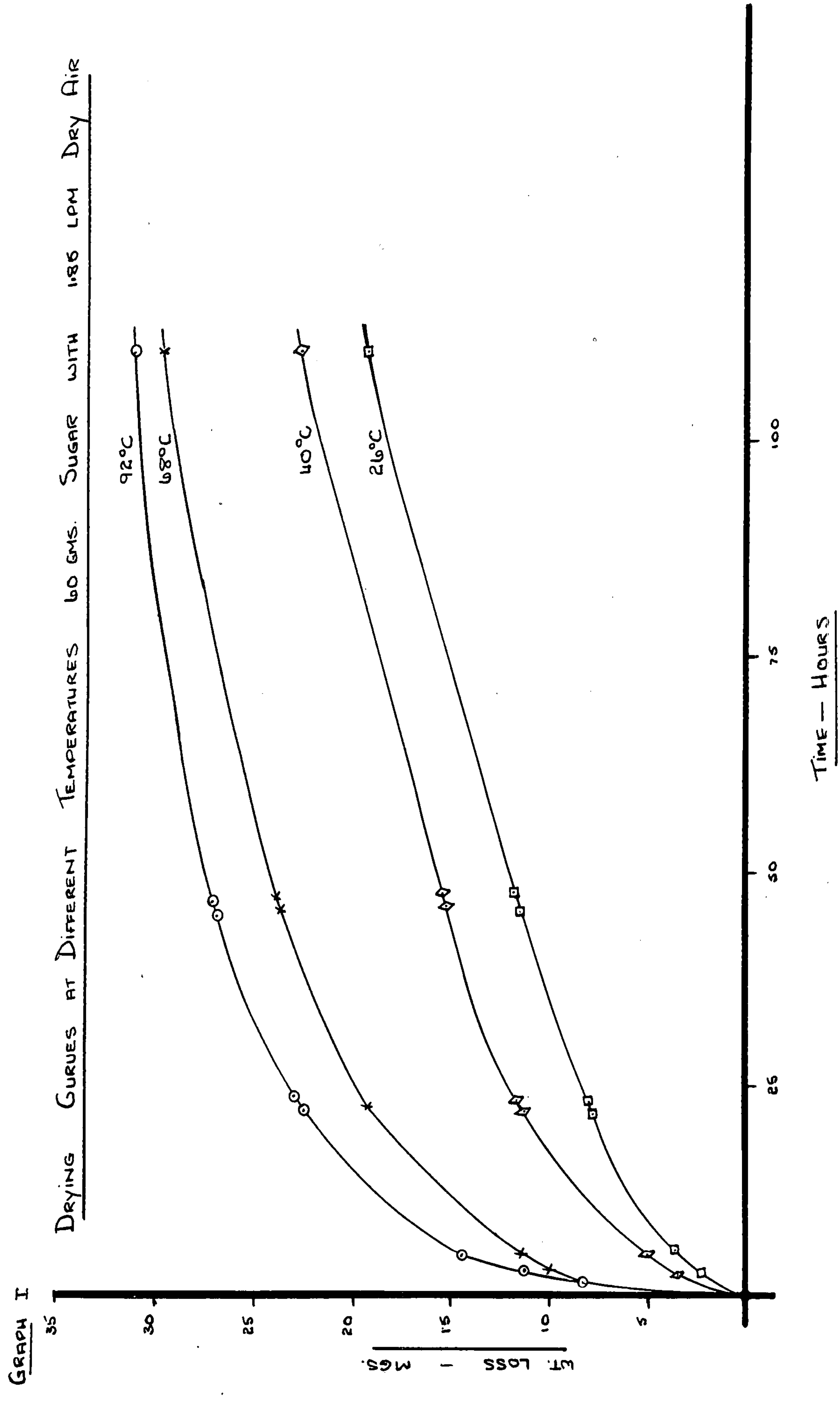
1. Elevated temperatures with a minimum of warm dry aeration are both necessary for optimum conditioning of refined sugar after discharge from the granulators.
2. Sealed storage is to be commended but with provision for forced exhaust ventilation when temperatures reach the critical stage where the hygroscopic property of sugar comes into play.
3. The choice of construction material for the storage roof is significant when considering heat deflection. Aluminium is recommended with either timber or precast concrete framework. Asbestos absorbs and retains a considerable amount of heat while steel framework is a focal point for moisture condensation.
4. Good housekeeping is necessary to keep pockets free of spilled sugar. Exposed sugar will be the first to absorb moisture which in turn will be transmitted through the paper pocket.

Acknowledgments

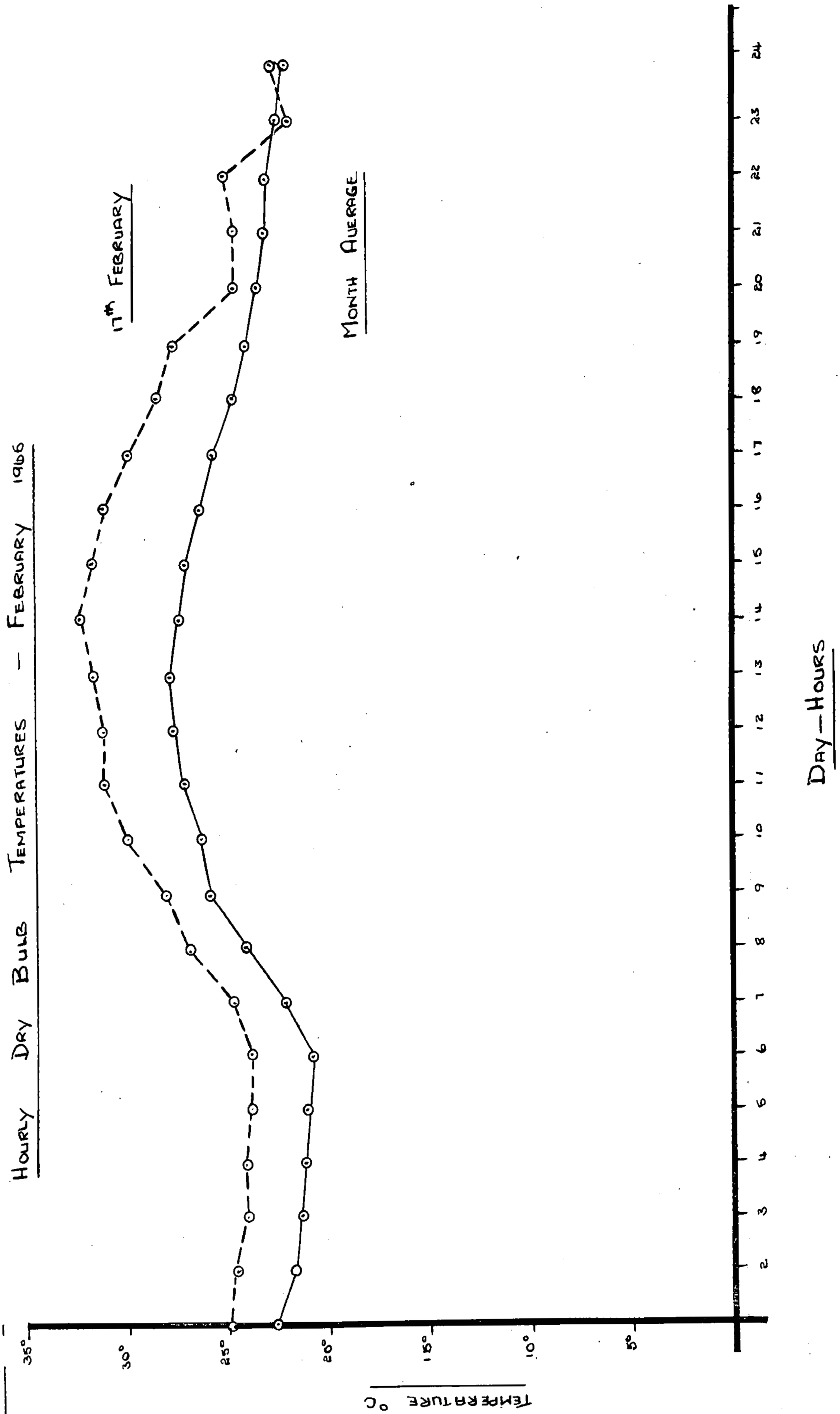
The author wishes to acknowledge the contributions made to this paper by members of the Laboratory and Refinery Staff. Also to record our appreciation to Messrs. J. Lorden and E. Ducel of C. G. Smith & Company Limited, and Mr. A. J. J. Smith of the Louis Botha Meteorological Office for their discussions and information supplied.

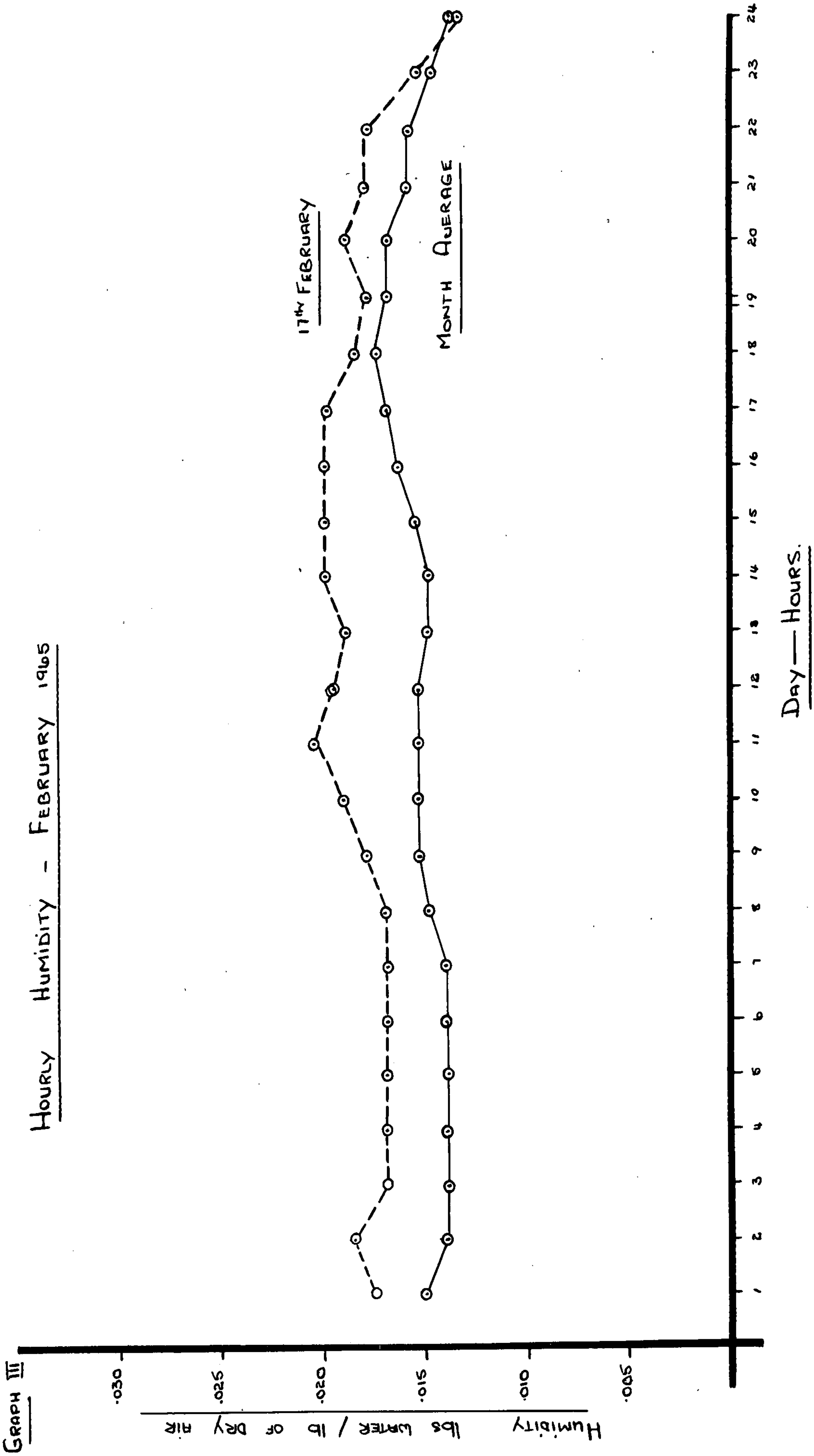
References

1. Alexander, J.B. (1965) Unpublished Reports.
2. Powers, H. E. C. "Sucrose Crystal Studies" I.S.J. Vol. 58, September 1956.
3. Neilson, A. P. and Blankenbach "Investigations into Sugar Boiling". S.I.T. Proceedings, 1964.
4. Baldt, G. H. and Compton, E. F. "Density of Refined Sugar in Bins and Silos." S.I.T. Proceedings, 1960.
5. Schwer, F. W. "Some Fundamentals in Drying Granulated Sugar". S.I.T. Proceedings, 1964.


Graph I
Drying Curves at Different Temperatures 60 gms. Sugar with 1.86 LPM Dry Air
Wt. Loss — Mgs.
Time — Hours
92°C
68°C
40°C
26°C
35
30
25
20
15
10
5
25
50
75
100

GRAPH II


HOURLY DRY BULB TEMPERATURES — FEBRUARY 1966
17th FEBRUARY
MONTH AVERAGE
DAY—HOURS
TEMPERATURE °C
35°
30°
25°
20°
15°
10°
5°
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24


Hourly Humidity - February 1965
17th February
Month Average
Day — Hours.
Humidity lbs water / lb of dry air
·030
·025
·020
·015
·010
·005
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Graph III

Mr. Buchanan: Bearing in mind the general drying rate curve which shows a constant drying rate period followed by two distinct falling rate periods, as would correspond to control by moisture diffussion rates successively from syrup film to air through the syrup layer and through the crystal lattice, it would appear to me that temperature is not necessarily the essential controlling factor in all stages of drying. If the outer syrup layer exists then air velocity and humidity should also be an essential controlling factor in the mosture migration in sucrose.

Mr. Alexander: Mr. Buchanan's reasoning is quite correct but in the case of refined sugar storage the syrup layer is thin compared with crystal size and therefore most of the migrating moisture is in the crystal lattice. For this reason the effect of temperature in controlling moisture migration is much larger than the other effects.