

MOISTURE PROBLEMS IN THE SHIPMENT OF REFINED SUGAR IN CONTAINERS

By T. L. EXCELL and V. C. STONE

Sugar Milling Research Institute

Abstract

Containers of refined sugar despatched from Durban by sea to Cape Town have frequently been found to contain varying numbers of wet bags of sugar on arrival. Experiments were set up to establish whether the moisture entered the container from outside, i.e. rain or sea water, or occurred as a consequence of the sugar "sweating". Also examined were the influences of the temperature of the sugar at the time of packing the container and the type of container used. Valuable information was obtained by siting transmitters at various positions within the container and recording the relative humidity and temperature changes inside the container throughout the voyage. It was found that the packing temperature of the sugar was the single most significant factor in influencing the occurrence of wet sugar and that there was no ingress of external moisture.

Introduction

For many years 21-ton containers of refined sugar, despatched from Hulett Refineries (HULREF) by sea to Cape Town, have been found to contain varying numbers of wet bags of sugar on arrival. Although Umfolozi and C.G. Smith sugar is transported in the same way, the incidence of wet sugar was less than with HULREF sugar. Because of the increasing cost of claims paid out for wet sugar, the SMRI was asked to undertake a full investigation into the problem. A study of records of wet sugar occurrence in Cape Town revealed that there was a tendency for the wet sugar to be found on the floor of the container near the doors. The investigation attempted to establish whether moisture was leaking into the containers from outside, due to exposure to rain or sea water, or whether the moisture originated from the sugar itself.

Instrumentation

The temperature and humidity inside the containers were measured by combined temperature and humidity transmitters with 4-20 mA outputs for each parameter. These were placed in protective housings which allowed free air circulation but prevented the transmitters being damaged if the sugar bags shifted. Connection was made to the transmitters by screened cable which passed through the door seal and terminated in a weather proof plug. When the containers were in place, a further cable was connected and run to a portable computer which was housed in a building on the dockside or in suitable accommodation on the ship. The computer was equipped with a 16 channel analogue to digital converter card which read the 4-20 mA outputs of the transmitters. Power for the instruments was provided by a small 24 V laboratory power supply situated at the computer. The data received from the instruments were logged with a data logging programme written by SMRI. Before use the temperature and humidity sensors were calibrated at two points and the readings obtained were entered into the data logging programme so that subsequent readings were all corrected with the calibration constant of that particular transmitter.

Experimental

A series of trials was conducted, one during a period of high humidity in Durban and the remainder when the humidity was low.

Packing temperature of the sugar

All the sugar used for the trials was packed into containers at HULREF under the supervision of SMRI, HULREF and Unicorn staff. Whenever possible the pack size used in the tests was restricted to balers of 2,5 kg units. At HULREF the sugar is normally packed at a temperature exceeding 40°C and since sugar is a poor conductor of heat, this heat is lost slowly. In fact the centre of a pallet of sugar can take up to 7 days to reach ambient temperature. Because of this the temperature of the sugar loaded into containers at HULREF can vary according to the age of the sugar. For this reason both hot and cool sugars were used in the trials. The hot sugar came directly from the packing station at the refinery whereas the cool sugar was older sugar which had to be brought from the Maydon Wharf store. The temperature of the sugar on each pallet was checked prior to packing into the container and the variation between pallets of any one container was seldom greater than 5°C.

Types of containers used

Two types of containers are in use for sugar transportation, i.e. General Purpose containers (GP's) and Reefer boxes (Reefers). A GP is a single metal-walled container with a wooden floor. The side walls of the container have ventilation holes at the front and rear near the ceiling. The contents of the GP are thus exposed via the ventilation holes to environmental conditions outside the container. A Reefer is an insulated, double walled container with no ventilation. The floor consists of metal T-bars on which the cargo rests. The reefer boxes have a port at the back which can be opened to allow a refrigeration unit to be installed. For sugar transport, however, this port is closed and sealed on the outside using a plastic decal.

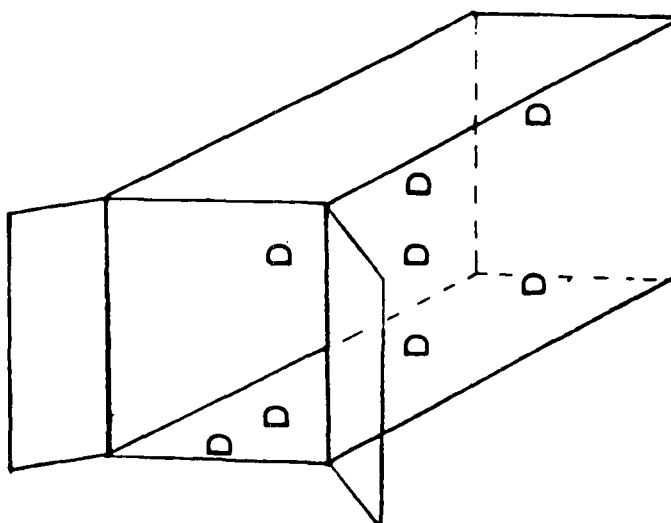


FIGURE 1 Sensor positioning in the containers.

Container floor lining

At HULREF plastic sheets are placed on the floor of both types of containers prior to packing the sugar. This was introduced in an attempt to decrease the incidence of wet sugar. The SMRI trials compared this floor covering to paper and included some containers with no lining at all. In some of the containers fluting paper was laid down over the plastic to act as an indicator and show up damp patches which were not easily visible on the black plastic.

Sensors

Figure 1 shows the positioning of the sensors when all eight were used in one container.

In other trials various combinations of these positions were used in more than one container. The sensors were placed in the container as it was loaded and the cables from the sensors were linked to a computer, initially at the container terminal in Durban and subsequently on board the vessel. In this way temperature and relative humidity inside the container were monitored virtually from the time of packing to the time of unloading at the Cape Town C.G. Smith depot.

Moisture content of the sugar

Although HULREF has sugar conditioning capability, this is reserved for bulk sugar, leaving all the sugar packed into containers unconditioned. This implies that this sugar will undergo a natural conditioning process after packing and in doing so will release moisture which will become available for migration. Since the sugar is packed into paper bags this migratable moisture will be free to move throughout the 20 tons of sugar in the container should a temperature or humidity gradient occur. In order to gain insight into the pattern of this moisture migration through the container, samples were taken at various positions throughout selected containers. The balers, which were sampled on loading, were marked and resampled on discharge at Cape Town. The moisture content was determined by the Karl Fischer method, where the sugar is dissolved in formamide, thereby determining the total moisture content of sugar.

Types of vessels

Two types of vessels are involved in shipping sugar to Cape Town. The Ro-Ro type of vessel, i.e. 'Border' and 'Barrier', is a large drive-on, ferry type ship which carries only a few sugar containers, usually on deck, exposed to weather conditions at sea. The cellular type container vessels, i.e. 'Berg' and 'Breede', carry the large portion of sugar containers and these are stowed in the hold of the ship. For various experimental reasons the Ro-Ro type vessel, the 'Barrier', was used for all but one of the trials.

Rail containers

In order to establish whether HULREF sugar railed to Cape Town would get wet during transport a Reefer box, a GP and a Sartainer were filled with hot sugar and dispatched by rail to Cape Town. The Sartainer was very similar in construction to the GP container i.e. fluted metal walls and a wooden floor, but did not have any ventilation holes. The rail containers were packed on the day after the sea containers during a period of low relative humidity. Due to restrictions, these containers carried only 17,5 tons of sugar compared with 21 tons in sea containers.

Results and Discussion

Sugar condition on opening the containers

Table 1 is a summary of seven sets of results.

Table 1
Average data from seven sets of trials

Container Type	Mean Sugar Temp. °C		Mean Moisture %		No. of wet Bags
	Packing	Opening	Packing	Opening	
GP	25	22	—	—	0
GP	44	26	0,052	0,039	5
Reefer	24	22	0,056	0,036	2
Reefer	45	35	—	—	8

No wet balers were found in any of the GP containers that were packed at a low temperature, average 25°C. Only one out of seven Reefers packed with cool sugar contained wet balers and this was one that was packed in the humid trial. Most of the trial containers packed with hot sugar, both Reefers and GP's, contained wet sugar on unpacking. In most cases in these trials, as well as in historical data, when wet sugar occurred, it was found on the floor of the container near the doors in both Reefers and GP's. Balers which had damp patches on the outside were found generally, on opening, to be wetter on the inside of the baler. This indicates that the moisture which wets the balers probably emerges from the sugar itself.

On opening the hot Reefer that was packed during the high humidity trial, some water flowed out at the doors of the container. This water was found to be free of any salt and it was concluded that the moisture had emerged from the sugar and had not entered the container from an external source, i.e. sea water.

Wet balers were often found against the side walls of GP containers and metal parts of Reefers indicating that temperature gradients had been set up within the container during cooling of the sides and floor of the container.

Moisture profiles

Table 1 gives the average moistures at loading and discharging of the containers. The sugar lost moisture which is to be expected because of natural conditioning of freshly manufactured sugar over the first 72 hours after drying. As all the initial moistures were not the same, the moisture

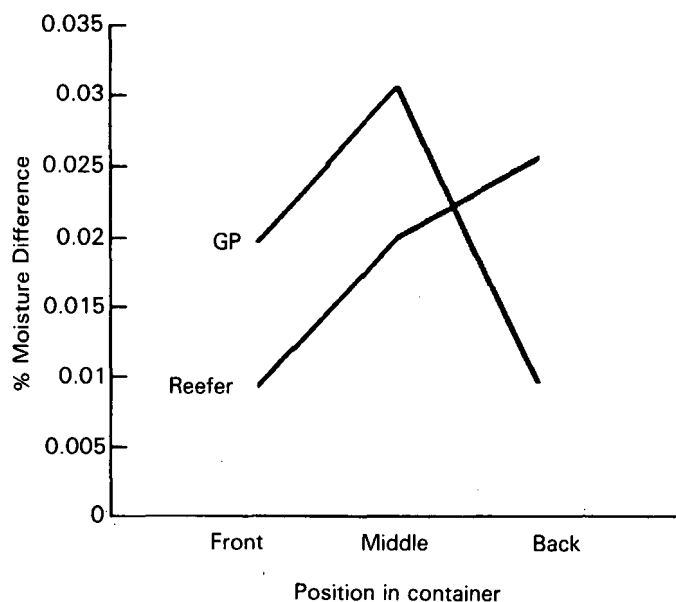


FIGURE 2 Container moisture gradients showing moisture differences (loading minus discharge) throughout the containers.

difference was used to determine where moisture had migrated. Thus if the moisture difference in a particular area is high, it means that moisture has moved away from that area whereas if the difference is low, then moisture has moved to that area.

Figure 2 shows the moisture gradients from the front to the back of two containers – a Reefer and a GP both packed with hot sugar. In the GP container the moisture difference is high in the middle and low at the front and back indicating that moisture has moved away from the middle of the container. In the Reefer the general direction of moisture movement is towards the front of the container.

This ties in with the observations that the wet sugar is often found on the floor at the front of the container. However, since no wet sugar was found in these particular containers, it seems that the migration was not sufficient to cause this. It should be noted that these graphs show only the difference between the sugar moistures on loading and unloading and not what happened to the sugar between these two points in time.

Sensors

Figures 3 to 10 show the temperature and humidity changes within certain containers. These graphs should be read from right to left.

Hot Reefer. Figures 3, 4 and 5 show traces obtained at the front and back at floor level and in the centre of the container. In the centre of the sugar, Figure 4, the temperature remained constant at 50°C but there was a steady drop in RH to a final figure of 31%, indicating that moisture has moved away from this warm area. The front and back, Figures 3 and 5 respectively, show a drop of 7°C. The RH at the

front of the container is more variable and higher than at the back, and this ties in with Figure 4 which indicates that more moisture accumulated by the doors of the container. Although no wet sugar was found in this container the humidities by the door were dangerously high.

Cold Reefer. Only one sensor was fitted in this container and was positioned by the doors on the floor. Figure 6 indicates a temperature drop of 2°C and a slight increase in RH from 55% to 62%. These humidities are below that where sugar absorbs moisture and therefore the sugar in this area was quite safe.

Hot GP. Positioning of the sensors was the same as for the hot Reefer. This container, unlike the Reefer, had no insulation so that the front and back were very susceptible to temperature and humidity changes. Because of these temperature drops at the front and back, moisture migrated to these areas leaving a very low humidity of 25% to 28% in the centre of the container (Figure 8). At the doors (Figure 7) the RH range was 55% to 92% whereas at the back of the container the RH range was 63% to 76% (Figure 9). This ties in with Figure 2 which also shows moisture moving away from the centre of the container but Figure 2 indicates that, at the time of sampling, the moisture content at the back of the container was higher than at the front.

Cold GP. The container had one sensor on the floor by the door. Figure 10 shows that the variations in temperature and humidity were small and the RH was well below a level where moisture would be absorbed by the sugar.

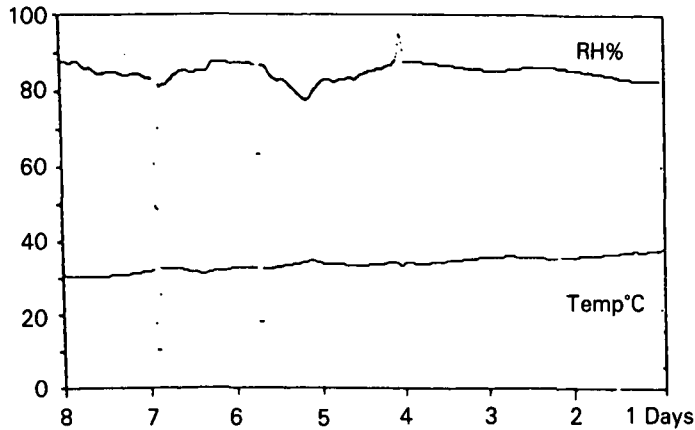


FIGURE 3 Hot Reefer – sensor positioned on the floor near the door

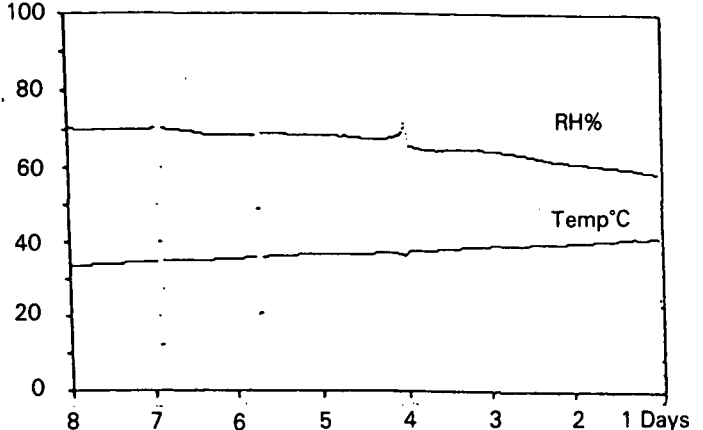


FIGURE 5 Hot Reefer – sensor positioned at the back on the floor.

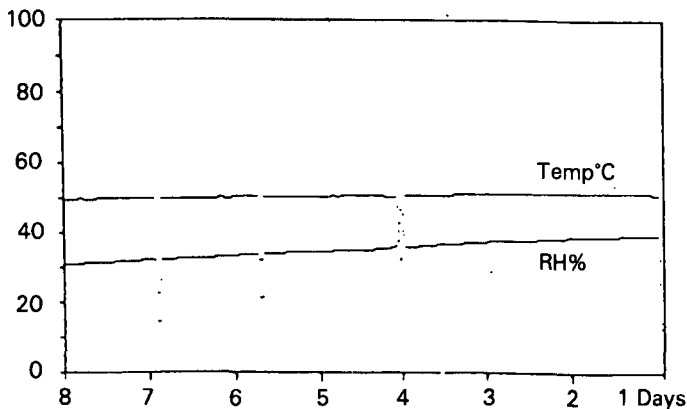


FIGURE 4 Hot Reefer – sensor positioned in the centre of the sugar stack.

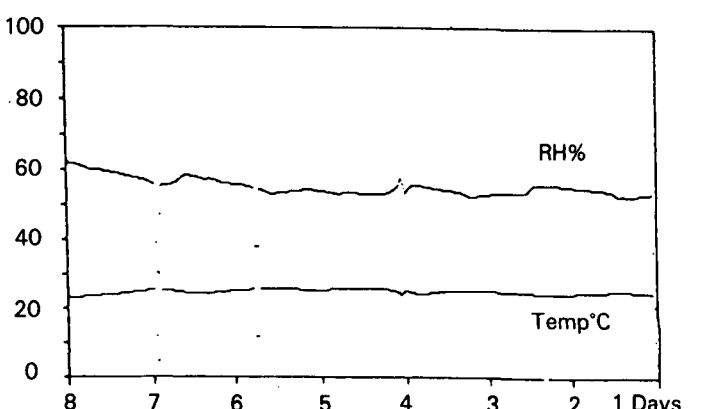


FIGURE 6 Cold Reefer – sensor positioned on the floor by the doors.

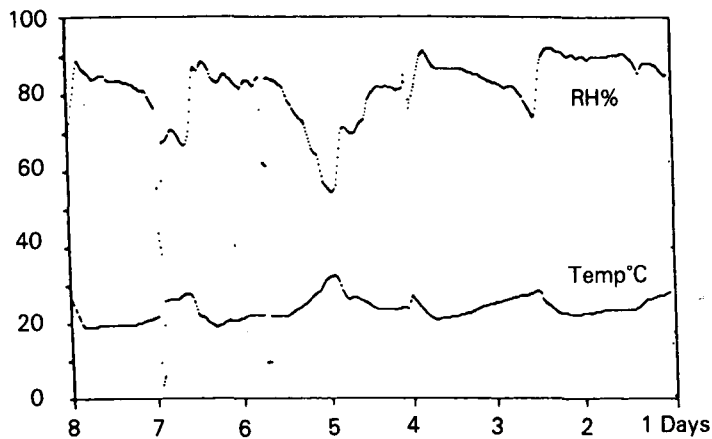


FIGURE 7 Hot GP – sensor positioned on the floor by the doors.

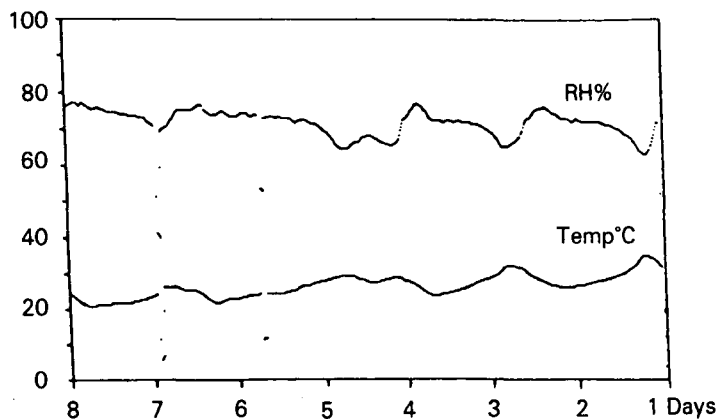


FIGURE 9 Hot GP – sensor positioned on the floor at the back.

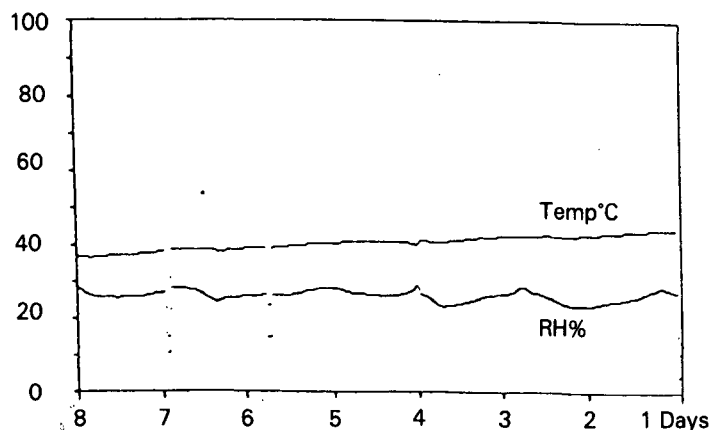


FIGURE 8 Hot GP – sensor positioned in the centre of the sugar stack.

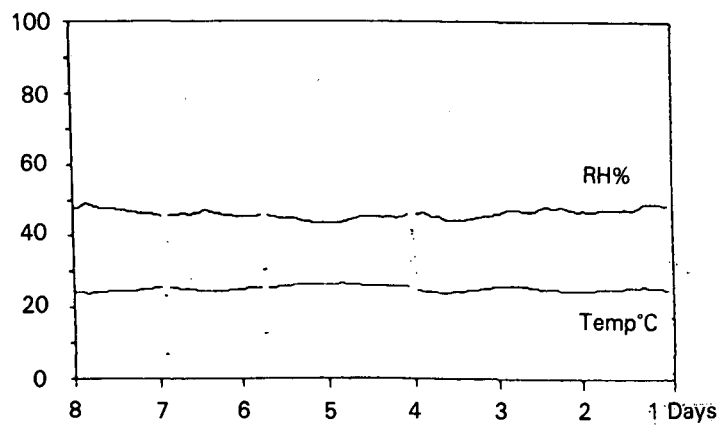


FIGURE 10 Cold GP – sensor positioned on the floor by the doors.

Significance of temperature and type of container

A summary of the number of wet balers in the containers is given in Table 2.

Table 2
Average number of wet balers in seven sets of data

Type of Container	Number of wet balers	
	Packed Cold	Packed Hot
GP	0	5
Reefer	2	8

The variance and estimated effects were calculated using the Yates algorithm. These effects were tested at the 95% level of significance and it was found that only the effect of temperature was significant whereas the type of container was not. From Table 2 it is clear that when sugar is packed cold, very little wet sugar occurs. For hot sugar the picture is very different and the worst case is found to be in the Reefer type container.

Floor lining

In the Reefer containers the plastic sheeting trapped moisture in grooves which were formed as it rested on the T-bar flooring. It was thought that if paper or no floor covering were used the moisture would not be trapped and would migrate to the floor below the bars. This, however, proved not to be the case and the balers became damp in strips corresponding to where the sugar had rested on the T-bar

flooring. The use of paper instead of plastic proved to be disadvantageous in the GP containers as well, where more wet balers were found in containers where no plastic was used on the floor. In some containers, both Reefer and GP's, where the plastic did not fully cover the floor, due to incorrect fitting, the sugar became wet in these exposed areas where the balers made contact with the bare floor.

Rail Containers

The containers which were railed to Cape Town were found to have more wet and caked sugar than those sent by sea at the same time. Table 3 shows the number of damaged balers in the rail containers.

Table 3
Wet or caked balers in railed containers

Container Type	Packing Temperature °C	Discharge Temperature °C	No. of wet Balers
GP	47	30	35+
Reefer	47	40	20
Sartainer	46	33	24

In the ventilated GP container most of the sugar in the first two rows was rock hard. The Reefer and the Sartainer were not ventilated and wet balers were found on the floor as well as in contact with the sides and other metal areas. The Sartainer also contained some hard sugar. The damage to the sugar was probably more extensive in these containers than in the sea containers because of the more severe temperature and humidity changes experienced during transit.

Conclusions

Packing temperature of the sugar

This has been shown to be the only statistically significant factor causing wet sugar. Hot sugar can take several days to reach ambient temperature and these trials show that after 7 days the sugar temperature in the centre of the container can still be above 30°C. Therefore when hot sugar is packed into containers, temperature gradients are set up as the sides of the container begin to cool slowly. This effect causes moisture emerging from the unconditioned sugar to migrate to the cooler parts of the body of the sugar. Since the total quantity of moisture available for migration in a 20 ton container can be from 4 to 10 litres it is obvious that, should a large portion of this water collect in any given area of container, wet sugar will be the result. It is very important therefore that unconditioned sugar be packed at as cool a temperature as possible.

Type of container

It has not been proved beyond reasonable doubt that wet sugar occurs more in either type of container. Certainly in the statistical evaluation the type of container was not a significant factor. From the figures, however, it does appear that when the sugar is hot there is more chance of sugar becoming wet in the Reefers than in GP's. In the GP container larger temperature gradients can be set up because the sides are not insulated and cool more quickly. However, moisture emerging from the sugar can escape through the ventilation holes and therefore there will eventually be less moisture available to cause problems. In the Reefers, however, the cooling of sides is slower but does occur and since the moisture cannot escape, it moves to the cooler areas causing wet sugar. The hotter the sugar, the larger the temperature gradient will be and the greater the probability of wet sugar occurring.

Type of floor covering

These trials showed that for various reasons the floor of the container attracts moisture more than other surfaces. In the case of the GP it could be because it is the surface that is never exposed to warming by the sun and thus remains coolest. Another possible reason is that the wood on the floor of the container is hygroscopic and also plays a part in attracting moisture from the sugar. A third factor is the metal plate on the floor at the front of the container, which is cooler than the wood and will thus draw more moisture towards it. In these trials several wet balers were found in contact with this metal plate and this could explain why wet sugar is always found on the floor by the doors. It has been shown conclusively that when the plastic floor lining was properly fitted, covering the wood, there was less incidence of wet sugar at the sides and back of the container. In the Reefer container the entire floor consists of metal bars and is also the coolest part of the container. The front and back of the floor would cool more quickly than the middle, hence the incidence of wet sugar in these areas. The plastic lining

appeared to have a beneficial effect and in one container wet sugar occurred where a section of flooring had not been covered properly by the plastic.

Rail containers

More wet balers were found in the rail containers than in those sent by sea, probably due to more rapid cooling and larger temperature gradients being formed. The rail containers passed through a very low humidity area and this could account for the drying and subsequent caking of sugar in the GP container.

Recommendations

Conditioning

Ideally the sugar should be conditioned and packed into a package which would prevent reabsorption of moisture from the atmosphere, eg. polylined bags. This option is, however, not possible with the present conditioning capacity at HULREF.

Sugar packing temperature

For unconditioned sugar this should be kept below 30°C whenever possible.

Type of container

If hot sugar is packed the GP containers would be preferable.

Container floor lining

Care should be taken that the plastic covers the entire container floor.

Packaging

Should the packing of cool sugar not be possible, a polylined bag (12,5 and 25 kg) or shrink wrap (balers) could be considered. This would restrain any migratable moisture within the sugar to the 25 kg package, thus preventing the problem of large quantities of moisture moving throughout the container.

Containers

Should neither the packing of cool sugar nor a change in packaging be possible, then containers with more ventilation holes could be considered to allow the moisture emerging from the sugar to escape more freely from the container.

Acknowledgements

The authors would like to thank A. Wienese who provided the data acquisition programme, T. Potter for his assistance and advice on containers and shipping and the staff of SASD, HULREF, Unicorn Lines, Guardian Insurance, C.G. Smith Warehousing (Cape Town) and the Analytical and Engineering Divisions of the SMRI, without whose cooperation this work would not have been possible.