THE LABORATORY DETERMINATION OF MOISTURE PER CENT BAGASSE USING THE DIETERT MOISTURE TELLER

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Introduction.

The mechanism of the drying of solids can be divided into two main stages:

(1) The Constant Rate Period, during which stage water is evaporated from completely wet surfaces. The drying process here is similar to the evaporation of water from a free liquid surface, and the rate is constant for constant drying conditions.

(2) The Falling Rate Period, during which stage the rate of drying decreases. The water content of the solid at the beginning of this period is known as the "Critical Water Content". When dried for an extended period, the water content of the solid approaches an ultimate value which depends primarily on the relative humidity of the air, and is termed the "Equilibrium Water Content".

The Constant Rate Period.

Since evaporation during this stage takes place at the surface of the solid, the rate of drying is limited by the rate of diffusion of water vapour through the surface air film out into the main body of air. The rate of evaporation is increased when heat necessary for vaporization is added by conduction from adjacent dry surfaces and by radiation. For the most part, however, the heat is supplied by conduction through the surface film of air. The velocity of the surrounding air affects the thickness of the surface air film, and hence the rate of evaporation. The higher the air velocity, the thinner the surface film and the greater the rate of evaporation. In effect, the rate of drying is also proportional to the difference between the humidity of the air fed into the dryer and the saturated humidity at the temperature of the surface of the solid. Hence, the higher the humidity of the feed air, the slower the rate of evaporation, and, of course, the higher the equilibrium water content.

The Falling Rate Period.

This stage is generally divisible into two secondary zones:

(1) Zone of Unsaturated Surface drying, which follows immediately after the critical water content. The proportion of wetted surface area progressively decreases, but the mechanism of drying is essentially the same as that for the Constant Rate Period, and the same factors influence the rate of evaporation.

(2) Zone where Internal Liquid Diffusion controls, which prevails when the resistance to internal liquid diffusion is greater than the surface resistance to vapour removal. It should be noted that, when internal liquid diffusion controls, air velocity has no influence on the rate of drying, and air humidity is of importance only in its effects on the equilibrium water content. Radiation and conduction of heat from the surroundings are of little effect except in raising the temperature of the solid and hence improving the diffusion constant of the liquid through the material. Internal evaporation may take place in pulpy solids, but the rate of diffusion of vapour through the solid and surface air film is the same as the rate of internal liquid diffusion.

Apparatus.

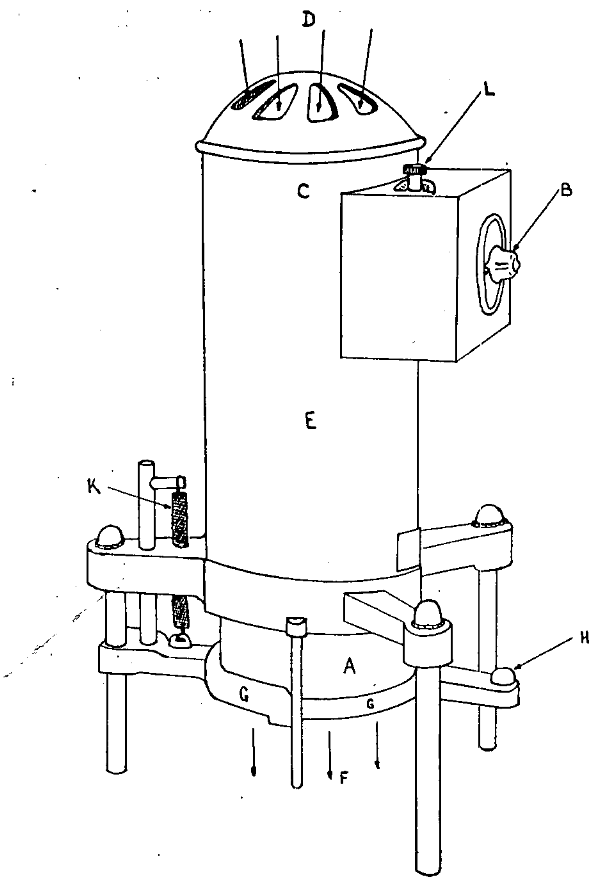
The Dietert Moisture Teller is a dryer of the hot-air type, a fan forcing a flow of air over electrically heated coils and thence onto the material to be dried.

Referring to the diagram, weighed bagasse is contained in the removable tray (A). The apparatus is operated by an automatic timing device (B). As soon as the timer is turned past the three minute mark, a motor, located within the body of the apparatus at (C), is automatically started. The motor drives a fan below it, which draws in air through the vents in the top cover (D). Electric heating coils, within the apparatus at (E) heat the air as it flows down over the bagasse in the removable tray. This tray has a fine sieve, 500 mesh, bottom, through which the moisture-laden air escapes at (F).

To insert the tray into its operating position, the frame (G) is pressed down at the point (H), a rubber tip. The tray is then placed centrally on the frame, and the frame allowed to return to the horizontal position under the tension of the spring (K).

Control of the hot air temperature is effected by means of the temperature controller at (L).

When the period of time selected on the automatic timer has elapsed, the motor cuts out and the heating coils are switched off automatically. The tray containing the now dry bagasse is removed and weighed.



Automatic timers are supplied for either 15, 30 or 60 minutes. A 30 minute timer would probably be best suited to a Sugar Factory Laboratory.

The fine mesh screen forming the bottom of the bagasse tray eventually tends to foul with fine particles of bagasse. This can easily be remedied by cleaning regularly (two or three times a week) with high pressure steam from a hose. The screen can be examined by holding it close to a source of strong light.

Experimental.

Routine laboratory bagasse samples were used for all determinations. These samples were composited over periods lasting one hour according to S.A.S.T.A. Recommended Methods of Control.

Effect of Temperature.

In an attempt to determine the effect of temperature on the rate of drying, samples were dried for successive three-and-a-half minute periods, until constant weight was obtained, at the following temperatures: 212°F., 221°F., 230°F., 248°F., 257°F. and 266°F. (In practice the hot air temperatures varied in cycles over a range of 12°F., increasing and decreasing as the heating elements alternately heated and cooled. Recorded temperatures represent the means of the extremes of variation.) After constant weight was obtained, samples were dried for a further 8 minutes at 266°F., this being considered sufficient to effect complete drying.

TABLE I.

Moisture % Bagasse (Wet Basis) at Different Temps.

Drying Time in Minutes.	212°F.	221°F.	230°F.	248°F.	257°F.	266°F.
0	49.2	49.4	48.8	51.1	52.2	50.7
3½	16.9	16.6	17.1	15.8	16.7	11.0
7	4.6	3.9	5.1	3.3	3.3	1.3
10½	1.5	1.2	1.4	0.6	0.6	0.4
14	0.5	0.7	0.6	0.1	0.3	0.3
17½	0.2	0.6	0.4	0.1	0.2	0.0
21	0.1	0.5	0.2	0.1	0.2	0.0
24½	0.1	0.5	0.2	—	0.2	0.0
28	0.1	0.5	0.2	—	—	—

TABLE II.

Drying Rates (Grams moisture per minute) at Different Temps.

Drying Time (3½ min. Periods)	212°F.	221°F.	230°F.	248°F.	257°F.	266°F.
1	9.23	9.37	9.06	10.09	10.14	11.34
2	3.51	3.63	3.43	3.57	3.83	2.77
3	0.89	0.77	1.06	0.77	0.77	0.26
4	0.29	0.14	0.23	0.14	0.09	0.03
5	0.09	0.03	0.06	—	0.03	0.09
6	0.03	0.03	0.06	—	—	—

As will be observed from these results, at no stage of the drying operation was a constant rate period apparent. This is not altogether surprising since the very heterogeneity of a bagasse sample would result in both constant and falling rate phenomena occurring within the first period of drying. Furthermore, the progressive increase of humidity of the hot air as it passed through the bagasse layer, and the cyclic variation of the hot air temperature over the range of approximately 12°F., would preclude the required constant drying conditions.

The high drying rate in the initial stages at all temperatures may be interpreted as evidence of evaporation from totally and partially wetted surfaces, the rapid fall in drying rate being due to the progressive elimination of totally wetted surfaces. The effect of variation of hot air temperatures during this period appears to have been comparatively small.

During the later stages of drying, however, there was a definite tendency towards complete drying in shorter time at higher temperatures. This may have been the result of higher temperatures causing an improved diffusion constant for the liquid through the solid material, and also simply a higher surface drying-rate on areas not directly exposed to the main air flow.

The practical implications are that drying a sample for 20 minutes without interruption at 266°F. should more than suffice to dry any normal bagasse sample completely. Decomposition at such a temperature is not significant since this is actually the temperature recommended by the Committee on Uniformity of the International Society of Sugar Cane Technologists[1].

Effect of Particle Size.

The fact that drying rates, as shown in Table II, were not a function of temperature alone, promoted the idea that different fractions of the bagasse might have different drying characteristics. A sample was sieved through a coarse wire sieve with $\frac{1}{4}$ inch square holes, and the two fractions obtained were then dried as above at 252°F. for successive drying periods until constant weight was obtained.

TABLE III.

Moisture % Bagasse (Wet Basis) at 252°F. for Different Fractions.

Drying Time in Minutes.	Fine Fraction.	Coarse Fraction.
0	50.0	49.1
$3\frac{1}{2}$	15.1	15.9
7	1.8	3.4
$10\frac{1}{2}$	0.0	1.0
14	0.0	0.3
$17\frac{1}{2}$	0.0	0.2
21	—	0.2
$24\frac{1}{2}$	—	0.1

TABLE IV.

Drying Rate (Grams Moisture per Minute) at 252°F. for Different Fractions.

Drying Time ($3\frac{1}{2}$ min. Periods)	Fine Fraction.	Coarse Fraction.
1	9.97	9.49
2	3.80	3.57
3	0.51	0.69
4	—	0.20
5	—	0.03
6	—	0.00
7	—	0.03

These results illustrate quite clearly the faster drying of fine particles compared with coarse particles. The fact that the initial drying rates were very similar lends credence to the theory that the prolonged falling rate period for the coarse particles was due to internal liquid diffusion controlling, for were it only a matter of there being areas of the coarse particles not directly exposed to the main air flow, the initial drying rate for coarse particles would also have been considerably reduced.

In any event, it becomes apparent that the nature of the bagasse sample, i.e. the relative proportions of fine and coarse particles, will materially affect the length of time required for drying. In practice, then, the more thoroughly the structure of the sugar cane is broken down in the milling process, the greater will be the surface area freely exposed to the surrounding air, and hence the greater will be the rate of drying from the surface, and the shorter will be the distances through which internal liquid diffusion will have to operate.

Accuracy.

As a means of investigating both the accuracy of the apparatus and the reproducibility of results, one large sample of bagasse was thoroughly mixed. Six one-hundred-gram samples were then dried for 20 minutes each at 266°F. in the Dietert Moisture Teller. A further six one-hundred-gram samples were dried at about 225°F. in a laboratory oven. This procedure was carried out three times.

TABLE V.

Comparative Results, Moisture Teller (266°F. 20 Mins.) vs. Laboratory Oven (225°F. 20 hours).

Test No.	1		2		3	
Sample No.	Moisture Teller.	Lab. Oven.	Moisture Teller.	Lab. Oven.	Moisture Teller.	Lab. Oven.
1	51.6	51.0	50.1	49.1	55.7	55.4
2	51.1	51.1	49.7	49.8	55.2	55.2
3	51.1	51.0	49.5	49.7	55.0	55.4
4	51.1	51.7	49.8	49.5	54.9	54.9
5	51.2	51.3	50.0	49.5	55.2	55.5
6	50.9	51.2	50.3	49.7	55.3	54.4
Average	51.2	51.2	49.9	49.6	55.2	55.1

Although a greater number of determinations would have been preferred, the above results are sufficient to corroborate results from overseas where this type of dryer has been used for some years with confidence and success.

The variation of moisture within a sample, despite thorough mixing, may appear significant at first sight. However, a considerably greater number of determinations can be carried out with the Moisture Teller than with the ordinary oven under normal conditions, the effect of which is to give greater significance to the average value for moisture per cent bagasse over any period, and consequently to the calculated value for fibre per cent cane.

Summary.

To ascertain the operating conditions of the Dietert Moisture Teller which would permit accurate moisture determinations on bagasse under any circumstances likely to obtain, preliminary experiments were carried out to study the mechanism of drying. The results are recorded in full, and indicate that the length of time required to dry a sample is not only dependent upon temperature, but also upon the relative proportions of fine and coarse particles in the sample.

The operating conditions decided upon following these investigations were to dry 100 grams of bagasse for 20 minutes at 266°F.

The accuracy of the results obtained by using the Moisture Teller was endorsed by results obtained by drying comparable samples in the Laboratory Oven for 20 hours at 225°F. A difference of 0.1 per cent. moisture between the averages for eighteen samples by the two methods satisfies the requirements of the Laboratory.

The conclusions reached were that this apparatus forms an invaluable adjunct to laboratory equipment, and should improve the accuracy of published figures for moisture per cent. bagasse and fibre per cent. cane.

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[1]Spencer, G. L. and Meade G. P. Cane Sugar Handbook, p. 564. John Wiley & Son Inc., New York, 1945.

Mr. Dymond congratulated Mr. Thompson on his paper and said he was particularly happy that he had been able to present it at this Congress. For many years past they had tried to get the younger men in the Industry to present papers at Congress and Mr. Thompson's paper was particularly valuable. He welcomed it too because of the method by which the determinations and figures had been concisely set out.

Mr. Bentley described the paper as most interesting but he could not reconcile the opinions given by Mr. Thompson that the moisture teller could give a greater number of determinations than obtained through the ordinary oven. The moisture teller could apparently do two samples an hour, while the oven operated at his factory gave five results in two hours. The other point he wished to make was that the line on which they should proceed was in the determination of moisture within two or three minutes rather than half-an-hour. His company was proceeding with the electronic determination of moisture in bagasse. When results were available he would let members know.

Mr. Thompson, in reply to Mr. Bentley, said that the time taken was 20 minutes and not half-an-hour. For most samples 15 minutes was sufficient, but he gave 20 minutes to be on the safe side. The results were actually available within a shorter time than by conventional methods. If this time could be further reduced by other means, so much the better.

Mr. Barnes suggested that the method of electronic determination was worth pursuing. He referred to tests carried out in New Jersey where it was astonishing to see the material drying as it were from the inside outward. A further point was that Dr. Wiggins in the West Indies had been studying moisture determination of bagasse and had used a liquid such as benzine with which the water could be distilled out. This method had been used for many years to test the water in grain. He suggested that more investigation should be conducted.

Mr. Rault said that the vacuum oven in Mr. Bentley's laboratory, although of the same design as the one operating at Mount Edgecombe, appeared to be more efficiently operated. For over 20 years in his laboratory the moisture content of the bagasse from individual mill units had been carried out as a daily routine control and this control was limited by the time taken for a moisture determination. He had found that two hours in the Spencer type oven did not always complete the dessication. There was a risk of showing a moisture content half to one per cent lower than the truth if the time was limited to two hours. In sampling a substance such as bagasse, made up of particles of various sizes, he thought that the average of ten determinations on 100 grams would give a more representative picture of mill conditions than the testing of only one sample of one kilo, however carefully mixed and averaged this sample could be prepared. He thought that the tests carried out by Mr. Thompson proved the Dietert Teller to be a welcome acquisition, increasing the sharpness of control for special investigations, as it could give a moisture test within half an hour, but he would continue with the Spencer oven for the usual routine of hourly moisture determinations.

Mr. Dymond asked how many of these tellers were in use in the Sugar Industry.

He was informed that three were in use in Natal, two in Sugar factories and one at the Masonite factory at Estcourt.

Mr. Galbraith asked Mr. Bentley how long it took to get a result from the oven from the time the sample was placed in the oven, and pointed out that the great advantage of the drier under discussion was the fact that the chemist was able to give the engineer moisture contents within 20 minutes.

Mr. Bentley admitted that the moisture teller did appear to give results sooner when calculated from the time the sample was put into the oven. His factory operated two Spencer ovens and by this means they did minimise the time taken in the tests. He also referred to the cheaper cost of the Spencer ovens as compared with the higher speed machines.

Mr. Dymond said that the results obtained at Darnall with the moisture teller were spectacular when compared with their somewhat antiquated type of oven. With the introduction of a new mill, where moisture information was required in a short time, he felt that the machine teller would be of advantage. Mr. Dymond asked the meeting to accord a vote of thanks to Mr. Thompson. He hoped that in the future more of the younger men would come forward with the presentation of papers to Congress.