WET BULK STORAGE OF BAGASSE

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ABSTRACT

The findings of a test programme, set up to study wet bulk storage methods for bagasse under South African conditions, are presented in this paper. A feature of the programme is the use of 3 different storage media in the laying down of test piles of between 1 000 and 1 500 bone dry tons each. Performance evaluations could subsequently be made on the basis of (i) commercial scale testwork: yielding storage losses and factory processing data (ii) laboratory testwork: yielding data on the physical and chemical properties of the stored material and also on pulp and paper samples produced under standard conditions, and (iii) microbiological testwork: due account being taken of the fact that the storage of bagasse in the wet state is associated with a considerable bacterial activity and hence results that could not be explained by normal test procedures could possibly be accounted for in biological terms. Other features of the programme are evaluations of (i) time as a variable in wet bulk storage and (ii) the influence of pile dimensions on results. Included in the exercise are the development of a correlation between pile height and bulk density of the stored material; a technique for the measurement of storage losses under wet bulk conditions; and refinements to a number of laboratory procedures.

INTRODUCTION

The sugar milling industry in South Africa has an annual offcrop season of 3 to 5 months. In order to sustain year round pulp production from bagasse, sufficient fibre must be stored during the crushing season. Bagasse storage periods can be minimised by adoption of a first-in first-out method but even under conditions of close supervision, storage times of up to 8 months must be anticipated.

In the wider context of international commodities too, sugarcane bagasse has gained acceptance as an important raw material in the manufacture of pulp and paper. This view is amply borne out by the fact that installed capacity for bagasse pulping attained a level of a million tons per annum in 1973 and that the present growth rate is more than double that applicable to the pulping of wood. This increased utilisation of bagasse is caused by the escalating costs of timber and transport and the desire everywhere to promote the greatest possible use of locally available raw materials. Bagasse is therefore showing advantages over timber in specific circumstances and localities.

The broad picture in regard to the technology of bagasse pulping is also reasonably favourable, with the major problems already overcome. Grey areas do exist, however, and 2 which must be singled out as still demanding attention are (i) fibre preparation aspects and (ii) fibre storage techniques. An improved technology within these two areas would greatly facilitate the establishment of appropriate conditions.
of optimum operating conditions and, in turn, contribute to improved factory performances and results.

Within the pulp and paper industry the majority opinion is that the best method of preparing bagasse for pulping involves the dual operating procedures of depithing followed by storage under wet bulk conditions. However, while there is agreement on the main issues, such unanimity does not extend to the equally important matters of selection of the right equipment for the job and the methods to actually apply in achieving set goals. Nor is this altogether surprising since the circumstances that will influence the final choice of equipment and method will vary from place to place and, furthermore, the test procedures that are so vital in making a fair comparison are frequently absent or at best inadequate.

The foregoing implies 2 things; firstly, that there is a "local" aspect to all technology as applied to an agricultural product such as bagasse and a part of that technology must be generated in each individual operating region and, secondly, that there is still scope for significant improvements in respect of some areas of technology: the need for an accurate method of categorising bagasse being but one notable example.

Against the background of these comments a research programme was initiated in 1972 which had as its main aims (i) gaining meaningful information in specified areas of deficient technology and (ii) turning this knowledge to practical account. Organisations that participated in this programme were Ngoye Paper Mills Ltd, manufacturer of corrugating medium from bagasse at a factory in Natal; the Timber Research Unit of the CSIR, which was responsible for physical and chemical testing of pulp/paper products and raw materials; and the Sugar Milling Research Institute, which was responsible for microbiological and organic chemical testing of bagasse.

Only that part of the work relating to fibre storage is discussed in this report.

GENERAL COMMENTS ON BAGASSE STORAGE

The storage of bagasse in a wet bulk condition is not a new concept. The potential advantages that would flow from the successful application of this type of process were appreciated nearly a half century ago and in this context Dr E. A. Ritter is well known for having devoted considerable time to investigating the problem. However, new processes often suffer long delays before implementation and it was not until 1956 that wet bulk storage was first practised on a commercial scale, the scene of this important event being the Ngoye Paper Mills Factory at Felixton in Natal.

In the wet bulk storage process, bagasse is preferably depithed at the end of the sugar milling tandem and is then hydraulically transported to the storage area in the form of a slurry with a preservative liquid. Excess liquid drains off into channels and is recirculated in a closed system.

This so-called "Ritter Process" is still used in South Africa and is also applied at pulp mills in Argentina, Brazil and Iran, either in its original or modified form.

The principal component of the "Ritter biological liquor" may be likened to a lactic acid producing bacteria. In the presence of a suitable nutrient
(such as molasses or any sucrose containing substrate) the bacteria will multiply at a desirable rate and at negligible cost, yielding a liquor with a pH of approximately 3.8. This liquor is added as a slipstream to the medium being circulated for purposes of transporting and conditioning the entering bagasse and a system pH of slightly below 5 is thereby maintained. At this level of acidity the development of undesirable micro-organisms is prevented and bagasse degradation is contained.

A number of claims regarding the efficiency and beneficial effects of the “Ritter biological liquor” appear in the literature but very few of these have been substantiated. For the record the more important claims are listed below:

- In consequence of the low pH of the storage medium, a part of the pentosan fraction is removed by acid hydrolysis during storage.
- Residual pith adhering to the fibre bundles is loosened during storage.
- Crustations between fibre bundles are opened, thereby facilitating a more uniform penetration of cooking liquor.
- Ritter-stored bagasse results in a bright, high freeness pulp with improved bursting, folding and tensile strengths, irrespective of the age of the pile.
- After 2 years of storage the bagasse is as fresh as the day it was put into storage.
- Losses in storage amount to approximately 5% compared with in excess of 20% in the case of bale stored bagasse.
- A whiter pulp is produced from Ritter stored bagasse compared with bagasse stored by other means.
- A 10-20% saving in digesting/bleaching chemicals is possible by application of the Ritter process.
- When taking health and fire hazard factors into consideration, the safest way to store bagasse is in a wet bulk condition.

Some of these claims are in line with reasonable expectation, i.e. the acidic nature of the storage medium should result in lower pentosan values and accordingly higher cellulose contents. The higher cellulose contents should, in turn, give rise to higher pulping yields and lower chemical consumptions. Again, if the residual pith is selectively loosened and removed before the bagasse reaches the digester, the better physical properties of the raw material should result in an improvement in the quality of the product; always provided that deterioration of the bagasse during storage did not outweigh the other benefits.

One objective of the work programme has been to test the validity of the above listed claims. However, to put this statement in the right perspective it should be noted that the scope of the reported investigation covers wet bulk storage of bagasse in the widest possible context. Three storage media were chosen on basis of either their applicability (Ritter process and Backwater treatment) or their ability to make a significant contribution to the technology of this type of technique (organic acid treatment). The thinking behind this latter treatment was that the creation of a very low pH environment would favour the development of a desirable microflora in a more efficient manner than that normally encountered.

Work along similar lines has been undertaken by other investigators, but on a significantly smaller scale.
PROGRAMME DETAILS

The field work-programme involved the laying down of 3 test piles of approximately 1 200 to 1 500 bone dry metric tons each. As storage media, Ritter Solution, Backwater and an Organic Acid Solution were used. In each instance the piles were subsequently squared off to a measurable shape and finally processed in 3 parts making up a total of 9 factory runs in all.

The above programme was drawn up in such a manner as to take due cognisance of the main practical considerations namely (i) the best utilisation of available segregated storage, viz. 6 000 m²; (ii) an acceptable frequency for factory test runs and (iii) an acceptable loading of laboratory equipment and personnel.

In order to measure the changes that actually occurred between the times that the piles were laid down and ultimately processed, it was considered necessary to collect at least one and preferably 2 sets of intermediate samples and data. This condition was achieved by regarding fresh (green) bagasse as the "reference point" in any particular test series and thereafter adding 3 more "data points" when the storage pile was subsequently processed after 3 distinct time intervals. By this means 4, nominally consistent, sets of data were obtained for each storage medium tested. Details of the programme are as follows:

"reference point": depithed fibre samples were drawn throughout the period of pile laydown (1 week);
2 week storage run: when the first third of the pile was processed through the factory; samples and data being simultaneously collected (48 h);
8 weeks storage run: when the middle third of the pile was processed (48 h);
20 weeks storage run: when the final third of the pile was processed (48 h);

Preparatory work for the laying down of the various piles required considerable organisation in some cases, as evidenced by the following:

a) Ritter Treatment. The standard process\textsuperscript{1}\textsuperscript{*} was applied without modification but was complicated by the inclusion of the storage loss tests described in a later section.
b) Backwater Treatment. This liquid stream is generated downstream of the factory digester and is a composite of flows that are surplus to internal factory requirements. In this regard it is noteworthy that brownstock washing was not practised at the time of the tests and hence a strongly alkaline effluent stream was produced, lying in the pH range 9,5 to 10. Prior to the pile being laid down all drainings from the existing bagasse pile were re-routed to the bagasse reclamation system and the system normally used for circulating biological liquor was then pumped out and replaced with backwater. This liquid was circulated, pumped out to effluent and again replaced with backwater. Thereafter the fluming of fresh bagasse to the storage area was commenced and a rapid drop in pH ensued. As a precaution against re-innocation of the backwater by residual Ritter bacteria, the pH of the circulating liquid was twice raised to a high level by the addition of slug doses of concentrated caustic soda solution.

As seen in Fig. 1 this shock treatment had no lasting effect and for
FIGURE 1. pH profile of circulating liquor during period of backwater pile laydown.
the balance of the laydown period (100 hours) the pH held very steadily in the range 5.1-5.4; this notwithstanding the fact that the backwater make-up rate was also high, viz. of the order 1.5 tons/ton entering bagasse.

c) Organic Acid Treatment. Preparations for this pile were essentially similar to those followed in the case of the Backwater run described above. The main differences were (i) the replacement of backwater by filtered river water and (ii) the adjustment of the pH of the circulating system to the range 4.3-4.5 by the addition of acid. During the full laydown period a total of 3.3 tons of formic acid were added in the form of regular slug doses of 0.2% on circulating system inventory. 1.35 tons of concentrated sulphuric acid were also used to assist in lowering the pH to the desired level.

EXPERIMENTAL WORK ON SITE

Factory tests

Approximately one third of each pile (300-400 bone dry tons) was pulped in the factory after periods of 2, 8 and 20 weeks storage. Stable factory conditions were requested for the duration of the 2-day test runs and all relevant operational data were collected.

Measurement of factory yields

During the past 3 years numerous factory trials have been held with a view to determining the yield of bagasse between storage yard and product paper. As is apparent from Table 1 the results applicable to depithed fibre stored per Ritter process have been very consistent at the 63% level and hence there is no reason to doubt the accuracy of the estimating technique used in these determinations.

<table>
<thead>
<tr>
<th>Date</th>
<th>Yield (%) wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 1969</td>
<td>63</td>
</tr>
<tr>
<td>Feb 1970</td>
<td>63</td>
</tr>
<tr>
<td>Nov 1971</td>
<td>63.1</td>
</tr>
<tr>
<td>Mar 1972</td>
<td>64.3</td>
</tr>
</tbody>
</table>

The technique itself involves the squaring off of the storage pile, or a section of the pile, such that its volume can be accurately measured. Thereafter a number of sample cubes (one meter square and the full height of the pile) are cut from the pile at time of processing and the density of the sample calculated from the sample tare and the dimensions of the 3 sided "hole" created by the removal of the sample for taring. On making adjustment for the moisture contents of the samples, bone dry densities are obtained and these are subsequently averaged for use in calculating the weight of the storage pile.

In the course of various test programmes, a considerable number of test cubes were cut and one product of this work has been the development of a correlation between dry bulk density of stored bagasse and pile height. This appears below as Figure 2.
A further item of interest in regard to the bulk density tests has been the measurement of point densities. Values as high as 210-220 kg/m\(^3\) (dry basis) have been measured near the base of the storage piles at depths of 14 to 15 meters and this would appear to represent a condition of maximum compaction on assuming a fibre density of 1,54 g/cm.\(^3\).

Returning to the matter of the factory yield determination: data obtained at the pulp proportionators, viz. equipment settings and measured consistencies, gives a figure for the quantity of bagasse in the furnish. This figure is then superimposed on the weight of the product paper to give an equivalent weight of bagasse in the product paper. Finally the quantity of bagasse in product paper is related to the bagasse delivered from storage to give the factory yield.

**Measurement of storage losses**

Bagasse losses that occur during storage are not precisely known though it is variously reported that a figure of the order 10\% on dry basis can be expected.\(^8,9\)

The evaluation of storage losses was made a feature of the test programme and 2 separate estimating methods were tried. The procedures adopted are detailed below:

a) *Whole pile method*. This method involved the following steps:

- bagasse supplied to a specific pile was measured by means of two nuclear weigh devices operating in series.
the resultant pile was squared off to a measurable shape and the volume calculated.
the trimmings from the preceding exercise were backloaded into a tip trailer and tared.
density measurements were made during factory processing of the pile and the weight of the pile calculated.
the storage loss was calculated as the difference between the incoming bagasse, net of trimmings, and the weight of the pile at time of processing.
b) Small sample method. This procedure involved the introduction of bagasse test specimens of known weight into the test piles at time of laydown and their subsequent recovery from the piles at time of processing. The weight difference recorded for each test specimen over the storage period was then a measure of the material loss. In this regard each sample was labelled with a numbered plastic disc to facilitate identification on recovery.

The test specimens themselves consisted of open weave plastic bags having dimensions 2 × 1 m and with plastic stitching and zips. Long red-coloured tassels were also stitched around the periphery of the bags to give adequate notice to operatives engaged in cutting of the pile into the factory that a sample was to hand. This latter feature proved highly successful and very few test specimens were damaged.

There are a number of pros and cons to this method. On the positive side it is a method that (i) is easily applied and (ii) can be repeated any number of times at minimal cost; in turn permitting the experimenter to test its reproducibility and also gain information on loss levels at specific localities in the pile, i.e. surface versus centre. On the negative side there are the uncertainties introduced by the use of a sample container per se, notwithstanding its chemical inertness. In this context it is noteworthy that every effort was made to keep the sample in intimate contact with the bulk of the pile by specifying 20 mesh material with approximately 0.5 mm threads.

The extent to which this grade of material contributed to the establishment of a barrier to the free passage through the sample of fine particles, micro-organisms, liquids, gases etc. is not known.

Sampling for physical and chemical testing programme

Approximately one third of each pile was pulped in the factory after 2 weeks, 8 weeks and 20 weeks storage. During the mill runs a number of representative samples of the stored bagasse were taken at minimum 1.5 m below the upper surface of the pile. This was done to ensure that only bagasse stored under anaerobic conditions was included in the sample. Drying was effected in batch equipment consisting of a fixed bed sample container through which hot air was blown. The air flow derived from a 50 kW mobile air heater (Hamworthy “Indirect Heta”) and was supplied at a temperature of between 40 and 45 C. The equipment could handle individual samples of up to 150 kg on an “as received” basis. The samples were dried to approximately 10% moisture content before being shipped by passenger train to Pretoria. For each test run a dried sample of the order 150 to 200 kg was prepared.

Sampling for microbiological testing programme

As in the case of sampling for the physical and chemical testing programme,
samples for the SMRI were drawn in a manner calculated to avoid the known aerobic areas, for example the top meter of the stored piles. Accordingly, each sampling was made up of $3 \times 1$ kg samples drawn from the pile during cutting operations at predetermined levels, viz. one meter from the top, one meter from the bottom and at an intermediate level. Samples were taken in plastic jars for immediate shipment to Durban.

**EXPERIMENTAL WORK ON THE PHYSICAL AND CHEMICAL PROPERTIES OF BAGASSE, BAGASSE PULP AND HANDSHEETS**

**General**

During transport of the samples from the factory, a large proportion of the loose residual pith separated out and accumulated in the bottom of the plastic bags. This pith, together with a certain percentage of fines, was removed in a dry screening operation before the bagasse was laboratory pulped. An average of 10% substance was removed by this means. It is felt that this procedure is equitable in that bagasse is normally transported as a slurry to the factory digester and in so doing passes over equipment that effects a partial removal of free pith and fines.

**Chemical analysis**

The various bagasse samples were analysed for:

- Cellulose content: Seifert method
d- Cross and Bevan-TAPPI standard T 17 m-55
- Lignin content: TAPPI standard T 13 m-54
- Pentosan content: TAPPI standard T 19 m-50
- 1% Caustic Solubility: TAPPI standard T 4 m-51.

The cellulose, lignin and pentosan determinations were performed on extractive free bagasse, prepared according to the TAPPI standards T 6 m-59 and T 1 m-59.

These data are reported in Table 4.

**Pulping**

Soda pulping was done in an electrically heated batch-type, rotary digester. Pulping conditions were as follows:

- Quantity of OD bagasse: 600 or 700 g
- Active alkali charge (as Na₂O): 15 percent
- Liquor: bagasse ratio: 7 : 1 ml/g
- Temperature cycle:
  - i) time to 170°C: 50 min.
  - ii) time at 170°C: varied between 0 and 30 min.
  - iii) Degassing was done at 95, 115 and 135°C until gases non-condensible in water were removed and at such rate that no liquor was lost from the digester.
- Blow down to atmospheric pressure at end of cook: 25 min.

Immediately after removal from the digester, the pulp samples were screened through a 10 mesh screen into a 60 mesh receiving screen by means of a water jet.

**Sheetmaking and testing**

30 g pulp samples were beaten in a PFI beater for 125, 500 and 1 000 counter revolutions according to the Scandinavian Standard Method Scan.
C24:67. Test sheets (60 g/m²) from the 3 beaten samples as well as from an unbeaten sample were prepared on a Rapid Köthen sheet machine. Conditioning and testing of the sheets proceeded according to the relevant Tappi, Scan or Appita Standard Methods, as follows:

- Conditioning before testing: Tappi Standard T402 m-49
- Tearing strength: Appita Standard P400 m-62
- Bursting strength: Appita Standard P403 m-61
- Tensile strength: Appita Standard P404 m-50
- Rupture energy absorbed: These parameters were obtained for stress-strain curves determined with a rheometer
- Modulus of electricity: Appita Standard P403 m-61
- Wetness: Scan Standard M3 :65
- Concora flat crush resistance: Tappi Standard T809os-71

The strength and optical properties are given in Table 5.

**Measurement of the fibre dimensions**

a) **Fibre length.** The graduated bull’s eye technique described by Wilson¹ⁱ was used on macerated material¹² using the selection technique described by Hart and Swindel.¹³ The values reported are the numerical average length of 300 whole fibres.

b) **Fibre diameter and wall thickness.** Fibre diameter and lumen diameter of 150 fibres selected according to Hart and Swindel¹³ were measured with an eyepiece micrometer using a light microscope and objectives and a polariser necessary for Nomarski interference contrast microscopy. Measurements were made at a randomly selected point avoiding a section at both ends of a quarter of the total length of the fibre.

Measurements were made at a magnification of 800 x.

**EXPERIMENTAL WORK ON THE MICROBIOLOGICAL ASPECTS (INCLUDING ORGANIC ACIDS) OF STORED BAGASSE**

**Cultivation of “Ritter type” bacteria**

a) **The cultivation of Streptococcus lactis.** Bacteria present in milk were developed in a dilute molasses solution in accordance with laid down procedures and the pH thereby dropped to 3.6-3.7. This starter culture was used to inoculate tanks filled with 0.2% molasses solution. Conventional identification tests¹⁴,¹⁵,¹⁶ showed that the desired bacterium, viz. *S. lactis*, had been obtained.

b) **The cultivation of Lactobacillus delbrueckii.** The lactic-acid producer *L. delbrueckii* was prepared from fresh bagasse that had been fermented to the point where an active microbial population was present, and thereafter the bacteria were developed in a dilute molasses solution. Subsequent growth of the culture was carried out as described for *S. lactis*. The pH of the *L. delbrueckii* culture was one unit higher than the *S. lactis* culture.

These 2 bacterial species described in the preceding sections, and which ferment carbohydrates to produce lactic acid, are the main constituents of the low pH Ritter biological liquor required in bagasse storage.

The 2 cultures are finally combined into a single storage system and the resultant liquor added as a slipsteam to the solution being used to transport and condition the bagasse. This briefly describes the microbiology of the Ritter process: a process in which an acid medium and anaerobic conditions combine to provide an environment which it is alleged will prevent the development...
of undesirable micro-organisms (cellulose-decomposing bacteria) and thereby facilitating the storage of bagasse over long periods with a minimum of fibre loss.

Anaerobic bacterial counts and organic acid analysis

Samples of bagasse were taken at various depths from the piles in the manner already described. These samples were subsequently analysed for anaerobe population and organic acid content; the latter being the direct result of the carbohydrate fermentation in the piles.

a) Bacterial Counts. Enumeration of anaerobic bacteria present on the fibre was done by a plate count as follows: 1 g of moist bagasse was weighed into 100 ml of sterile water and thoroughly mixed. 1 ml of this suspension was pipetted into 40 ml of sterile molten tomato juice agar, mixed and dispensed into petri-dishes. After solidification of the contents the plates were incubated anaerobically in Jena anaerobic glass jars at the required temperature, which was selected to approximately simulate conditions existing in the storage piles, either 37, 45, 55 or 60 C, depending on the depth of the sample. Plates were incubated for 3 days, the number of viable cells present in the innoculum being ascertained by counting the microscopically visible colonies and multiplying this figure by the dilution factor. Colonies were picked out of the agar and after 4/5 passages, axenic cultures of the bacteria were obtained. These were then identified using recommended procedures.

b) Organic acid contents. The quantities of organic acid present were calculated by means of paper chromatography. The methods used were modifications of those introduced by Kennedy and Barker for volatile organic acids and Olsen for lactic acid. Procedure was as follows: 100 g bagasse was weighed into a conical flask and 500 ml water added. The mixture was shaken for 10 min and the liquid filtered overnight through filter paper containing 4 g Kieselguhr. The filtrate was run through an Amberlite IRA 400 anion exchange column in the carbonate form. The resin was eluted with 200 ml 2N ammonium carbonate, thereby yielding the desired acids as ammonium salts. The eluate was concentrated to 20 ml in a rotary evaporator and 10 ml of the acidified concentrate were spotted onto Whatman no. 1 paper and eluted for 5 hours in the following eluents:

<table>
<thead>
<tr>
<th>Eluent</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isopropanol</td>
<td>350 ml</td>
</tr>
<tr>
<td>Benzene</td>
<td>125 ml</td>
</tr>
<tr>
<td>Indicator solution</td>
<td>164 ml</td>
</tr>
</tbody>
</table>

Lactic acid cannot be analysed using the above chromatographic technique as ammonium lactate is not sufficiently soluble in alcohol. Therefore the concentrate obtained after evaporation of the eluate was acidified to a pH of 4.0 with concentrated hydrochloric acid to obtain the acid in free form. 10 ml of the acidified concentrate were spotted onto Whatman no. 1 paper and eluted for 5 hours in the following eluents:

<table>
<thead>
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</tr>
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<tbody>
<tr>
<td>Isopropanol</td>
<td>350 ml</td>
</tr>
<tr>
<td>Benzene</td>
<td>125 ml</td>
</tr>
</tbody>
</table>
The composition of the indicator solution was as below:

Glacial acetic acid: 50 ml
Bromo cresol green: 350 mg
Bromo phenol blue: 100 mg
Water: 200 ml

After elution, the paper was steamed to remove the acetic acid from the solvent and the acids appeared as yellow spots on a blue background. Quantities were again estimated by comparing the size and intensity of sample spots with those obtained by using a standard of known concentration.

RESULTS AND DISCUSSION

Measurement of storage losses

Of the 2 methods employed to measure storage losses, only the "small sample method" yielded results that could be reasonably regarded as useful, and even then the method as applied suffered from certain defects. These are discussed later.

At the time of laydown of the Ritter pile, a total of eighteen test specimens were strategically located throughout its volume such that six samples would be reclaimed from each section of pile processed. The measured loss figures were then averaged for each run. The results of these experiments are given below:

<table>
<thead>
<tr>
<th>Storage period</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks</td>
<td>1.7</td>
</tr>
<tr>
<td>8 weeks</td>
<td>4.3</td>
</tr>
<tr>
<td>20 weeks</td>
<td>5.3</td>
</tr>
</tbody>
</table>

The test specimens involved in this work were fairly bulky, each weighing approximately 60 kg when introduced to the pile and approximately double that weight when removed. The consequence of this situation was that handling was far from easy and difficulties were experienced in obtaining representative subsamples for moisture determinations. This situation applied both at time of sample introduction and recovery. One of the remedial actions taken was to reduce the number of test specimens used from 18 to 9. As it turned out this was an unfortunate change to have made since halving the number of test specimens lowered the accuracy of the final result to a level that was no longer acceptable: there being some scatter about the mean and 1 doubtful result out of 3 then had the effect of overshadowing any meaningful trend. For this reason, storage loss figures relating to the Backwater and Organic acid treatments are not presented.

In future work the policy will be to introduce more test specimens but of a much smaller size, say one quarter that used in the reported study.

On the score of the results obtained from the Ritter runs: not too much significance should be placed on the loss figure measured after two weeks storage. Nor is it really important to do so as short storage times are almost never applied; but the trend is certainly in the right direction. The results of the 8 and 20 week runs are more interesting, firstly in regard to their uniformity
and secondly in that they would appear to confirm the disappearance of fermentables (approximately 4% on dry basis) but little else.

Preliminary investigations carried out on the reclamation system used for transporting bagasse between the storage area and the digester indicate that further losses of the order 5% occurred (soluble inorganic salts, sand, etc.), in turn implying a total less upstream of the factory processing area of slightly above 10%.

In reference to the “whole pile method” for estimating storage losses, it is recorded that calibration drift evidenced by the nuclear weighers was a serious problem. In consequence considerable doubt must be cast on the worth of the readings, notwithstanding the fact that “acceptable” results could be obtained by adjustment of the measured quantities by the average calibration error in each case.

Condition of the storage piles

At times of factory processing of the piles various data were collected on the physical condition of the contents. This work covered:

a) Moisture profiles. In Table 3 results applicable to the early part of the programme are listed.

<table>
<thead>
<tr>
<th>Storage media</th>
<th>Ritter Liquor</th>
<th>Backwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>2 weeks</td>
<td>8 weeks</td>
</tr>
<tr>
<td>Positions in pile</td>
<td>top 0.5 m</td>
<td>74.3</td>
</tr>
<tr>
<td></td>
<td>at 1 m</td>
<td>77.0</td>
</tr>
<tr>
<td></td>
<td>1.5 m</td>
<td>78.1</td>
</tr>
<tr>
<td></td>
<td>2.5 m</td>
<td>79.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>77.3</td>
</tr>
<tr>
<td></td>
<td>bottom 0.5 m</td>
<td>76.1</td>
</tr>
<tr>
<td>Average</td>
<td>77.3</td>
<td>77.1</td>
</tr>
<tr>
<td>Av excl top</td>
<td>77.9</td>
<td>76.0</td>
</tr>
</tbody>
</table>

Notes: a) figures are volatiles % wet bagasse or “% moisture”.

b) figures are averages of 3 readings.

From this table it is apparent that a fairly uniform moisture level was established: the pile tending to dry-off slowly with time. As would be expected, the top layer of bagasse was the most variable with moisture contents either higher or lower than the mean for the pile in direct relationship to the prevailing weather conditions. Since the moisture levels appeared to lie consistently within the range 75-79%, irrespective of storage medium, this part of the work was discontinued on a formal basis midway through the programme.

b) pH profiles. In Figure 3 a graphical presentation is given of pH measurements made during the time that the storage piles were cut into the factory. Trends are in line with expectation: high pH levels being recorded in the top layers, due principally to leaching out of organic acids by rainfall, and a fairly uniform level existing within the mass of the pile. The pH trend with time or age in storage is also much as expected, reducing as more acids were formed.
FIGURE 3. pH profiles of stored bagasse piles.
FIGURE 4. Temperature profiles of stored bagasse piles.
In this context it is noteworthy that the downward trend in pH was most marked in the early part of the storage period when bacterial activity was at its highest. As available nutrients diminished a more stable system pH developed in the anaerobic part of the pile.

In particular reference to the Backwater treatment, it should be noted that the pH rise at the lowest level (depth of approximately 4 m) is due to the 1,3 tons caustic soda that was applied at time of pile laydown in a crude attempt at sterilising the system.

c) Temperature profiles. In Fig. 4, select data on temperature readings taken in the storage piles at time of processing are presented. In the case of the Ritter and Backwater piles the temperature profiles are much as expected; with fermentation and correspondingly high temperatures occurring in the surface zone, reducing to under 45 C in the centre mass of the pile. With the passage of time a cooling off of the surface zone was apparent as fermentable material became exhausted and the effects of external weather conditions started to exert a greater influence. The centre of the stored mass remained remarkably stable throughout.

The Organic acid pile on the other hand exhibited a number of differences. Due doubtless to the presence of the added acids and accordant low pH, the bacterial activity in the pile was severely inhibited and temperatures were lower throughout. This is particularly noticeable in the two week analysis. After a total storage period of 8 weeks, temperatures in the centre of the pile had risen to the 40 C level, showing that normal activity was returning. After 20 weeks the situation was completely restored. The reasons for the lower temperatures in the surface zone of the Organic acid piles is not fully understood.

d) General comments. In the course of a long test programme, particularly one in which a sizeable interface exists between research and production activities, some mishaps are to be expected. One such event that must be recorded for technical reasons occurred when the circulating liquid used to flume bagasse to the storage area was permitted to overflow a part of the test area. Involved in this accident were the 20 weeks Backwater pile and the 20 weeks Organic acid pile.

By this time the former pile was about 10 weeks old and probably in a fairly stable condition. Furthermore, since the pile was in a settled state, it is doubtful whether the liquid would have penetrated to any extent and, even if it had, whether the penetration would have been general. Accordingly, it is thought that the adverse effects would have been minimal with regard to the physical and chemical properties of the bagasse when it was processed after 20 weeks in storage. On the other hand a change could have taken place in the acids content of the samples even if this was only on a highly localised basis due to channelling. This may explain the one high acid result reported in the 20 weeks Backwater run in Table 7.

The effects of the liquid overflow on the 20 weeks Organic acid pile are more difficult to assess since the accident occurred only shortly after laydown of the pile. However, in so far as the circulating liquid in use at that time was the original organic acid medium, partly contaminated with normal Ritter solution, it is speculated that the change could have been marginal only.
Comparison of pulp properties

The pulp strength values of the various bagasse samples may be compared in different ways:

a) Comparison at constant wetness levels. The wetness of a pulp is indicative of its degree of beating. For a given pulp the development of strength with beating in the same machine correlates well with the wetness of the pulp. However, changes in the kappa number, i.e. changes in the degree of delignification of the pulp, obscures this relationship. Because wetness is included as one of the primary pulp variables in this study, it was felt that comparison of pulp quality of the various bagasse samples at common wetness levels should be avoided.

b) Development of strength during beating. In the case of long-fibred softwood pulps it is known that the bonding strength develops during beating at the expense of tearing strength. However, in the case of short-fibred pulps, such as eucalypt or bagasse pulps, it is not uncommon to find that both the tearing and the bonding strengths increase with beating. This phenomenon was found in this study.

It is known that at common basis weight levels, the bulk specific of a pulp decreases with beating, irrespective of whether it is a long-fibred softwood or a short-fibred hardwood or bagasse pulp. The strength values of different pulps at common bulk specific levels are also known to vary with kappa number.

Therefore a valid way of comparing the pulp strength properties of the different bagasse samples would be to examine the variation of strength values with reference to bulk specific and kappa number.

In the present study an additional variable must be taken into account. Three different storage treatments are compared covering storage periods of 2, 8 and 20 weeks. For each test series an untreated sample was drawn as reference. It is known that the quality of sugarcane is affected by the time of harvesting, i.e. the sugar content of cane reaches a peak during September/October after which it decreases steadily through to the peak growing season in late summer. Since the storage piles were not laid down simultaneously, it is only to be expected that the quality of the bagasse will also vary. The strength of each reference sample was therefore put to unity and the strengths at all other storage periods expressed as a percentage of this figure.

The first step in the analysis was to plot the physical properties against the bulk specific of each individual pulp sample at the different beating points. Figure 5 is an example. From these graphs the physical properties at a common bulk specific level of 1,60 cm³/g was read off.

To eliminate the influence of the degree of delignification, the properties at a bulk specific of 1,60 cm³/g were plotted against the kappa numbers for each bagasse sample. Figure 6 is an example of this type of plot. From these graphs the necessary values for the various physical properties were obtained for a kappa number of 15,0 at a common bulk specific level of 1,60 cm³/g. These values are reported in Table 5.

The effect of storage on the physical and chemical properties of bagasse

General practice in wood anatomical studies is to measure only unbroken
fibres. However, bagasse is a by-product of the sugar industry and the principal objective of the miller is to extract as much of the juice as possible, irrespective of the damage done to the bagasse fibre. It was therefore considered necessary to include all fibres, unbroken and broken, in the fibre length determination.

From the results in Table 4 it appears that even though a wide range of fibre lengths were covered, no definite trend exists between fibre length and storage age. The same applies to the fibre diameter and cell wall thickness. This is to be expected since if measurable dimensional changes were obtained during storage it would be indicative of very severe degradation of the fibre. In the case of fungal attack on wood, the quality of the resultant pulp is adversely affected to a significant extent before any measurable physical changes in wood properties are detectable. In comparison with pulpwood fibres, bagasse fibre is of a similar length to hardwood fibres (0.75-1.5 mm) but considerably shorter than softwood fibres (2.5-4.0 mm). In cross-sectional dimensions the bagasse is narrower than softwood fibre and has comparable cell wall thicknesses.

Both the Cross and Bevan cellulose and Seifert cellulose values were determined. The second method of determination is favoured above the empirical Cross and Bevan standard method because it is more reproducible and gives an estimate of the actual cellulose present after the lignin, hemicelluloses and pentosans have been removed.
An increase in the cellulose and lignin content can be expected if the pentosans are removed in the acid medium during storage. In the case of the Ritter samples the scatter of values obscures any meaningful trend. In the case of the Backwater and Organic acid treated samples an increase in the Seifert cellulose and lignin contents with storage is apparent. However, the twenty week stored Organic acid sample is suspect for reasons discussed elsewhere. In general pentosan analysis on the respective samples reveals no clear trend with age in storage.

Solubility in hot 1% caustic solution is normally a measure of the degree of deterioration resulting from fungal attack. As wood decays, the percentage of alkali-soluble material increases and the pulp yield decreases. Applying this test method to bagasse it was observed that in the case of the Organic acid and Ritter samples a definite decrease in the solubility occurred with age in storage.

It is postulated that in the storage of bagasse, pentosans are hydrolysed in the acid medium causing a decrease in solubility of the bagasse in dilute alkali solution. This postulation is not, however, in line with the results of the pentosan analyses. In this context it is of note that acid storage will not affect the hexosans, but that the hexosans will dissolve in weak alkaline solution.
<table>
<thead>
<tr>
<th></th>
<th>Fibre length (mm)</th>
<th>Fibre diameter (μm)</th>
<th>Cell wall thickness (μm)</th>
<th>Cross &amp; Bevan cellulose (%)</th>
<th>Seifert cellulose (%)</th>
<th>Lignin content (%)</th>
<th>Pentosan content (%)</th>
<th>1% caustic solubility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ritter reference</td>
<td>0.91</td>
<td>20.6</td>
<td>4.7</td>
<td>61.4</td>
<td>42.1</td>
<td>19.5</td>
<td>—</td>
<td>34.9</td>
</tr>
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<td>1.04</td>
<td>20.2</td>
<td>4.9</td>
<td>58.3</td>
<td>43.1</td>
<td>19.8</td>
<td>30.6</td>
<td>32.0</td>
</tr>
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<td>1.08</td>
<td>19.1</td>
<td>5.3</td>
<td>61.2</td>
<td>43.0</td>
<td>19.3</td>
<td>31.5</td>
<td>32.9</td>
</tr>
<tr>
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<td>1.27</td>
<td>19.8</td>
<td>4.6</td>
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<td>42.2</td>
<td>19.0</td>
<td>30.7</td>
<td>29.4</td>
</tr>
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<td>1.20</td>
<td>20.9</td>
<td>5.2</td>
<td>58.3</td>
<td>39.5</td>
<td>18.6</td>
<td>31.5</td>
<td>34.8</td>
</tr>
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<td>18.7</td>
<td>4.2</td>
<td>59.4</td>
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<td>19.3</td>
<td>—</td>
<td>31.8</td>
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<td>18.7</td>
<td>4.2</td>
<td>57.5</td>
<td>41.1</td>
<td>19.1</td>
<td>29.6</td>
<td>32.5</td>
</tr>
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<td>20.6</td>
<td>4.6</td>
<td>—</td>
<td>43.6</td>
<td>20.7</td>
<td>31.2</td>
<td>33.0</td>
</tr>
<tr>
<td>Organic acid reference</td>
<td>1.13</td>
<td>19.8</td>
<td>4.4</td>
<td>60.4</td>
<td>40.8</td>
<td>17.9</td>
<td>30.5</td>
<td>32.9</td>
</tr>
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<td>5.0</td>
<td>60.9</td>
<td>42.3</td>
<td>18.8</td>
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<td>32.4</td>
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<td>22.1</td>
<td>4.7</td>
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<td>41.5</td>
<td>19.2</td>
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<td>31.9</td>
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<td>20.3</td>
<td>4.7</td>
<td>—</td>
<td>44.3</td>
<td>20.4</td>
<td>31.9</td>
<td>31.6</td>
</tr>
</tbody>
</table>
The effect of storage on pulp quality

In the following discussion the results of the 20 week stored Organic acid treatment are ignored for reasons discussed earlier.

From the results in Table 5, it is clear that a significant difference exists between the 3 reference samples. For this reason, all individual test values were expressed as a percentage of the reference value for each treatment.

An increase in tearing strength with period of storage was observed in every case. Based on the magnitude of the increases, the Ritter treatment appears to have the most beneficial effect. Following a rapid initial increase a maximum was reached after about eight weeks in storage whereafter it remained more or less constant. Backwater treatment resulted in a gradual improvement in strength up to 8 weeks, whereafter the rate of improvement increased. The Organic acid treated samples showed a high initial improvement (up to 2 weeks) whereafter the rate of improvement decreased.

Bursting strength, tensile strength and rupture energy absorbed (REA) generally followed similar patterns with increased storage period, irrespective of the treatment received. With increased storage period, improved strength properties were obtained and in a number of cases an optimum strength was obtained, after which small decreases were seen. An exception was found in the case of Backwater storage: a very significant decrease in REA being observed when the storage period was increased from 8 to 20 weeks.

No clear tendency between storage time and modulus of elasticity (MoE) was obtained. In Ritter storage a very significant drop in MoE was observed after 2 weeks of storage but after longer storage periods the original loss was regained and strengths better than the reference value were obtained. During Backwater and Organic acid storage a general decrease in MoE was obtained.

Wetness is an inverse measure of the drainage rate of a pulp. Bagasse pulp is known to be slow draining in comparison with wood pulp. It was found that at a bulk specific of 1.60 cm³/g and a kappa number of 15 the wetness of pulps produced from Ritter stored bagasse was very little affected during storage, irrespective of the age in storage. Under comparable conditions, pulps produced from Backwater or Organic acid stored bagasse showed a significant decrease in drainage rate with increased storage time.

Flat crush resistance tests did not show any trends and values were measured at the 4 kg/10A flute level with the exception of the 20 weeks Backwater stored sample, where a value of 2 was measured.

Several claims concerning the chemical consumption of Ritter stored bagasse are made in the literature. In this study it was found that up to 8 weeks storage, irrespective of the storage medium, a decrease in the consumption of the active alkali occurred with increased storage time. However, after 8 weeks of storage an increase in the consumption was found. It appears that Ritter treated bagasse consumed less chemicals during pulping than bagasse treated by the other methods. In general, excluding MoE, the Ritter treatment resulted in the best quality pulp at the lowest wetness. There is little to choose between the other 2 treatments.

Microbiological evaluation

A summary of the microbiological test results appears in Table 6. Bacterial counts made on the piles revealed that they were highly contaminated,
TABLE 5. Pulp quality of stored bagasse at a bulk specific of 1.60 cm³/g and kappa number of 15.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Tear Factor</th>
<th>Burst Factor</th>
<th>Breaking length (km)</th>
<th>Rupture energy absorbed (J/m²)</th>
<th>Modulus of elasticity (kPa)</th>
<th>Wetness (%)</th>
<th>Concorna flat crush (kg/10 A flutes)</th>
<th>Active alkali consumption at 15 kappa no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ritter reference</td>
<td>50 (100)</td>
<td>35 (100)</td>
<td>5.9 (100)</td>
<td>47 (100)</td>
<td>30 (100)</td>
<td>15 (100)</td>
<td>4.4 (100)</td>
<td>76.4</td>
</tr>
<tr>
<td>Ritter 2 weeks</td>
<td>51 (102)</td>
<td>30 (86)</td>
<td>5.5 (93)</td>
<td>63 (194)</td>
<td>19 (63)</td>
<td>13 (87)</td>
<td>3.8 (86)</td>
<td>70.0</td>
</tr>
<tr>
<td>Ritter 8 weeks</td>
<td>59 (110)</td>
<td>42 (120)</td>
<td>6.9 (117)</td>
<td>72 (153)</td>
<td>33 (119)</td>
<td>14 (93)</td>
<td>4.3 (98)</td>
<td>64.4</td>
</tr>
<tr>
<td>Ritter 20 weeks</td>
<td>69 (120)</td>
<td>39 (111)</td>
<td>6.8 (115)</td>
<td>81 (172)</td>
<td>32 (107)</td>
<td>16 (107)</td>
<td>4.5 (102)</td>
<td>69.2</td>
</tr>
<tr>
<td>Backwater reference</td>
<td>57 (100)</td>
<td>40 (100)</td>
<td>6.7 (100)</td>
<td>60 (100)</td>
<td>32 (100)</td>
<td>13 (100)</td>
<td>4.5 (100)</td>
<td>71.0</td>
</tr>
<tr>
<td>Backwater 2 weeks</td>
<td>56 (98)</td>
<td>41 (102)</td>
<td>6.9 (103)</td>
<td>82 (136)</td>
<td>32 (100)</td>
<td>19 (146)</td>
<td>4.2 (94)</td>
<td>69.6</td>
</tr>
<tr>
<td>Backwater 8 weeks</td>
<td>58 (101)</td>
<td>42 (105)</td>
<td>7.1 (106)</td>
<td>84 (140)</td>
<td>26 (81)</td>
<td>28 (216)</td>
<td>4.4 (98)</td>
<td>69.1</td>
</tr>
<tr>
<td>Backwater 20 weeks</td>
<td>63 (110)</td>
<td>45 (112)</td>
<td>7.2 (108)</td>
<td>61 (102)</td>
<td>27 (84)</td>
<td>37 (284)</td>
<td>2.0 (45)</td>
<td>74.4</td>
</tr>
<tr>
<td>Organic acid reference</td>
<td>50 (100)</td>
<td>34 (100)</td>
<td>6.8 (100)</td>
<td>60 (100)</td>
<td>30 (100)</td>
<td>14 (100)</td>
<td>4.1 (100)</td>
<td>84.6</td>
</tr>
<tr>
<td>Organic acid 2 weeks</td>
<td>53 (106)</td>
<td>42 (124)</td>
<td>7.6 (112)</td>
<td>67 (111)</td>
<td>26 (87)</td>
<td>27 (193)</td>
<td>4.0 (98)</td>
<td>83.7</td>
</tr>
<tr>
<td>Organic acid 8 weeks</td>
<td>54 (108)</td>
<td>40 (118)</td>
<td>7.4 (109)</td>
<td>81 (135)</td>
<td>28 (95)</td>
<td>36 (256)</td>
<td>4.1 (100)</td>
<td>69.6</td>
</tr>
<tr>
<td>Organic acid 20 weeks</td>
<td>57 (114)</td>
<td>30 (88)</td>
<td>5.7 (84)</td>
<td>49 (82)</td>
<td>32 (107)</td>
<td>11 (78)</td>
<td>2.8 (68)</td>
<td>73.4</td>
</tr>
</tbody>
</table>

Note: Figures in brackets give values expressed as a percentage of the reference value for each treatment.
**TABLE 6.** Anaerobic bacteria counts* of stored bagasse.

<table>
<thead>
<tr>
<th>Pile type Code No.</th>
<th>Ritter stored bagasse</th>
<th>Backwater stored bagasse</th>
<th>Organic acid stored bagasse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 weeks</td>
<td>8 weeks</td>
<td>20 weeks</td>
</tr>
<tr>
<td>I - T</td>
<td>not</td>
<td>0</td>
<td>samples</td>
</tr>
<tr>
<td>I - M</td>
<td>4400</td>
<td>800</td>
<td>4400</td>
</tr>
<tr>
<td>I - B</td>
<td>36000</td>
<td>tntc</td>
<td>138600</td>
</tr>
<tr>
<td>II - T</td>
<td>0</td>
<td>3000</td>
<td>0</td>
</tr>
<tr>
<td>II - M</td>
<td>4000</td>
<td>3200</td>
<td>200</td>
</tr>
<tr>
<td>II - B</td>
<td>16000</td>
<td>tntc</td>
<td>134400</td>
</tr>
<tr>
<td>III - T</td>
<td>300</td>
<td>1200</td>
<td>0</td>
</tr>
<tr>
<td>III - M</td>
<td>1000</td>
<td>2000</td>
<td>400</td>
</tr>
<tr>
<td>III - B</td>
<td>40000</td>
<td>tntc</td>
<td>138800</td>
</tr>
</tbody>
</table>

*Notes:* 
- Counts per gram bagasse as received (ca 77% moisture).
- Three sets of 3 samples were drawn from each storage pile: Samples were coded according to the set (Roman numerals) and vertical position in the pile (T, M, B).
- i.e. B — 1 m from the bottom of the heap
- M — from the centre of the heap
- T — 1 m from the top of the heap.
- tntc is an abbreviation for "too numerous to count".
supported active anaerobic fermentation and the bacterial population fluctuated considerably depending on factors existing within the piles. Bearing in mind the size and volume of the piles it was not expected that standard conditions would prevail throughout a given pile. The most stable environment is considered to lie within the centre portion of the pile, with environmental variation increasing towards the top of the piles. Factors influencing the anaerobe spectrum of the pile may be listed as follows:

- **oxygen content** — gradually decreasing with time
- **available carbohydrates** — decreasing with time
- **weather conditions**, i.e., rain, radiation, air movement etc. — affecting the upper layers to the greatest extent.
- **pH** — possibly the most important factor; a low pH *vide* the Organic acid pile at 2 weeks resulting in low anaerobic activity.

From the 20 week runs it is evident that the bagasse piles possessed a unique heterogeneous bacterial population, and that it was a complex ecosystem, maintaining a delicate and variable balance. Distribution of bacteria was dependent on the above listed factors changing and interacting at different points within the pile.

Species identified within the piles included: *Clostridium botulinum*, *C. fallax*, *Bacillus subtilis*, *B. stereothermophilus*, *B.licheniformis* and *B. coagulans*. Plates 1 and 2 give examples of *C. botulinum* and *B. stereothermophilus*.

Lactic acid bacteria were not found in any of 3 piles throughout the storage period, nor was lactic acid detected as being one of the constitutive organic acids. The latter, where figures are available, revealed the expected fluctuating tendencies with contents commonly at their highest when there was a corresponding high viable bacterial count.

In Table 7 the organic acid contents of the various test piles are listed.

---

**PLATE 1.** Example of *C. botulinum*. 
SUMMARY AND CONCLUSIONS

As often happens with technical investigations in which a problem is approached from more than one angle, the findings of the various parts do not point in exactly the same direction.

Unquestionably the most important findings of the microbiological investigation are that within the anaerobic section of the storage pile (i) no cellulose digesting bacteria were identified and (ii) no lactic acid producing bacteria were present. Hence at the end of this first phase of the bagasse storage programme it must be concluded that lactic acid does not control the storage process and that the addition of a “biological liquor” is to this extent of unknown value. It is, however, of note in this regard that lactic acid was present in the initial “Ritter biological liquor” but thereafter was undetected in the Ritter pile as well as the other test piles.

In general, result tend to confirm the view that a highly contaminated material cannot be forced into a certain type of fermentation by the addition of a pure or impure culture of micro-organisms. Ultimately, the type of micro-organism for which conditions are optimal will develop and predominate.

The wet bulk storage process is apparently controlled by a reduction in pH, caused by the presence of volatile organic acids of which acetic and butyric acids are the most important. These acids are produced by Clostridium species; Bacillus fermentation yielding acetic acid only. From the experiments it is evident that organic acid contents are remarkably similar, and the nature of the liquid used in conditioning the stored bagasse does not appear to be a material consideration. Of greater import is the fact that the pile should be of a sufficient size to minimize undesirable surface effects and maintain the highest possible percentage of stored material in an anaerobic state.

On basis of the laboratory work on the fibre raw material and on pulp and paper produced under standard conditions, it is concluded that during
<table>
<thead>
<tr>
<th>Storage type</th>
<th>Age</th>
<th>Code</th>
<th>Acetic (c)</th>
<th>Propionic</th>
<th>Butyric</th>
<th>Valeric</th>
<th>Total acids (c)</th>
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<tr>
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<td>I-M</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>—</td>
</tr>
<tr>
<td></td>
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<td>nd</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>2 weeks</td>
<td>III-M</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>—</td>
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<tr>
<td></td>
<td>8 weeks</td>
<td>I-M</td>
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<td>nd</td>
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<td>nd</td>
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<td>8 weeks</td>
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<td>nd</td>
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<td>nd</td>
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<td>nd</td>
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<td>I-M</td>
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<td>0,03</td>
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<td>0,4</td>
<td>0,30</td>
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<td>II-M</td>
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<td>III-M</td>
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<tr>
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<td>III-M</td>
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<tr>
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<td>0,05</td>
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Note:  

a) Figures refer to acid percentages on bagasse as received (ca 77% moisture).  

b) Acetic acid was not tested for in the organic acid pile, as the 2 acids have practically identical rf values and it was therefore impossible to distinguish between the 2 using the methods described for paper chromatographic separation.  

c) Lactic acid was not detected in any of the samples.  

d) nd is an abbreviation for "not determined".
storage, especially in the case of Backwater and Organic acid treatments, the cellulose and lignin contents of the bagasse increase and that the alkaline solubility decreases with time. It is postulated that material, other than the residual sugars, is lost during storage through acid hydrolysis of the pentosan fraction. This would result in an increase in cellulose and lignin content and a decrease in the alkaline solubility. A possible explanation for the fact that no decrease in the pentosan content was actually observed is that the method used in the laboratory determination is not sufficiently sensitive.

While the results of the physical and chemical investigation do not conflict in any way with the conclusion that anaerobic storage is the essential factor, they do show a preference for one type of storage medium above the others: which represents a point of difference. The Ritter treatment was found to be superior to the Backwater and Organic acid treatments regarding the physical strength, wetness and the chemical consumption of the resultant pulp.

REFERENCES

ALMACENAJE A GRANEL DEL BAGAZO HUMEDO

J. Bruijn, C. Gonin, Lynn McMaster y R. Morgan.

RESUMEN

La industria azucarera en África del Sur tiene una zafra anual de tres a cinco meses. Con el objeto de sostener todo el año la producción de la pulpa del bagazo, suficiente fibra debe ser almacenada durante el ciclo de molienda. Los períodos de almacenaje de bagazo pueden ser reducidos adoptando una filosofía de operación primero en llegar — primero en salir, pero aún bajo condiciones de estricta supervisión se anticipan períodos de almacenaje de hasta 8 meses. Presentados en este artículo están los resultados de una prueba programada y establecida para estudiar los métodos del almacenaje a granel del bagazo húmedo bajo condiciones locales. Una de las características del programa fue el uso de tres diferentes clases de almacenaje amontonando entre 1 000 a 1 500 toneladas diarias en cada una. Realizaciones de evaluaciones podrían consecuentemente ser hechas en base a: (i) Pruebas a escala comercial: restituyendo las pérdidas en el almacenaje y en el proceso de factoría (ii) Pruebas de laboratorios: Restituyendo también la pulpa y papel producidos bajo condiciones standards, y (iii) Pruebas microbiológicas: Tomando en cuenta el hecho de que el almacenaje del bagazo en forma húmeda está asociado con una gran actividad bacterial y de ahí resultados que no pueden ser explicados mediante pruebas normales, sino que podrían ser explicados en términos biológicos. Otras de las características del programa son las evaluaciones de (i) tiempo como una variante significativa y (ii) la influencia de las dimensiones de las pilas en los resultados. Variantes del ejercicio incluyeron el desarrollo de una correlación entre la altura de las pilas y la densidad bruta del material almacenado, una técnica para la medida de las pérdidas en el almacenaje bajo condiciones del bagazo a granel húmedo y refinamientos de un número de procedimientos de laboratorio.