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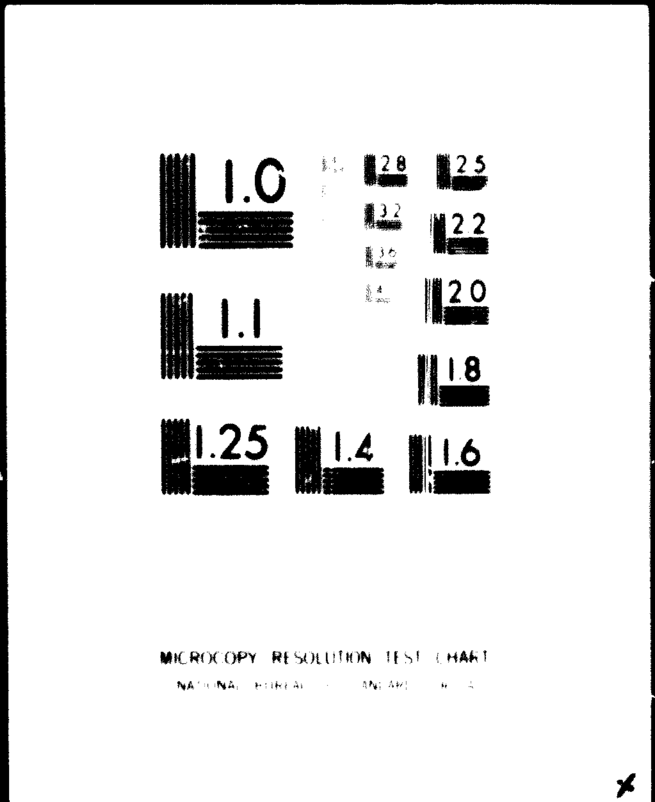
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REPORT P2368/1
5 DECEMBER 1969

UNITED NATIONS

NEW YORK U.S.A.

UTILIZATION OF BAGASSE

REVIEW OF BAGASSE TECHNOLOGY

SANDWELL

SANDWELL

REPORT P2368/1
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SUMMARY

1. This Report presents the results of the first part of a study on the utilization of bagasse and comprises a review of the technology concerning the production of various products from bagasse.

2. Sugar cane is grown in many tropical and semi-tropical countries located within the 30 degree north and south parallels of latitude. Bagasse on a dry fibre basis, constitutes about 13 percent of the weight of the cane and is about 1.17 times the quantity of raw sugar produced. Based on 1967 statistics the total amount of bagasse available in the world is about 44 million metric tons as dry fibre.

3. Total utilization of bagasse as a raw material is only about 5 percent of the quantity available. The major portion is used as a fuel by the sugar factories.

4. Over 40 pulp mills throughout the world, with daily capacities in excess of about 20 ADMTPD* use bagasse. Total output in 1966 was about 500,000 MTPA or 10 percent of the quantity of pulp produced from non-wood fibres and about 0.6 percent of the total world production of pulp.

5. Sixteen plants use bagasse as the raw material for the manufacture of building board and two plants produce furfural from bagasse.

6. Bagasse is comprised of two main components, fibre and pith. These are similar in most respects but fibre dimensions and alpha cellulose content are markedly different. Well depithed bagasse is similar to hardwoods in most fibre characteristics.

7. Depithing bagasse is a major problem and about 35 percent of the weight of bagasse should be removed as pith to prepare a satisfactory raw material for the manufacture of either a paper pulp or building board. The various depithing units available are discussed.

8. Bagasse is produced over a limited period each year, and to supply a user on a year round basis it must be stored. Two systems exist, bale and bulk storage. The merits of these systems are discussed.

*ADMTPD - Air dry metric tons per day. For this and other abbreviations see Appendix 1.

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9. Bagasse is now used primarily as a fuel. If other fuels are used, one ton of fuel oil will replace 6 tons of green bagasse and one ton of coal will replace 4 ton of green bagasse at about 50 percent moisture content. Value of the bagasse would be the cost of the replacement fuel plus transportation charges, allowances to the sugar factory to cover handling and profit, and any expenses that might be incurred in modifying the sugar factory's power boilers to permit the use of the alternative fuel.

10. For a sugar factory producing only raw sugar the total bagasse available is not required as fuel. About 16 percent of this bagasse is surplus and could be used as a raw material. Its value would be the transportation charge and an allowance to the sugar factory.

11. Pulps for the manufacture of fine papers, corrugating medium and wrapping and linerboard are now produced from bagasse. For fine papers and corrugating medium the content of bagasse pulp in the furnish can be up to 90 percent of the total. These products can be of high quality and can compete in many markets with those based on wood pulps. For wrapping paper and linerboard, about half of the furnish should be a long fibre pulp to produce an acceptable product.

12. The various pulping processes in use at the present time have been reviewed. The major ones include the Peadco, Cusi and Celdecor-Pomilio. Of these, the Peadco process is used for the production of about half of all of the pulp now obtained from bagasse.

13. Processes and techniques used for producing the various grades of building board from bagasse have been reviewed. Softboard, particleboard and hardboard similar to those produced from wood, can be made from bagasse.

14. Utilization of bagasse for the manufacture of furfural and briquettes is discussed. Also, several possibilities for utilizing pith are reviewed.

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INTRODUCTION

The United Nations on behalf of the United Nations Industrial Development Organization has authorized Sandwell and Company Limited to undertake a study of the utilization of bagasse, a by-product in the production of cane sugar. This study was initiated by a request from the Government of Mauritius for assistance in developing means of utilizing the bagasse produced by the cane sugar industry of that country. The study has been carried out in two parts. The first part provides a review and evaluation of the technology available and in use at the present time for the utilization of bagasse. The second part of the study provides a description of the cane sugar industry in Mauritius and an assessment of how the various means of utilizing bagasse, as developed in the first part of the study, can be applied to the bagasse available there.

Results are presented in two reports. This Report covers the review of bagasse technology. Required information concerning the use of bagasse as a raw material for the production of pulp has been obtained from mill visits and discussions with operating and research personnel and also from published information in trade journals and from previous studies undertaken by Sandwell. Information concerning the production of board products from bagasse has been provided by Columbia Engineering Company of Vancouver, specialists in the design and construction of board plants from both wood and bagasse.

The assessment of the utilization of bagasse in Mauritius is covered in Report P2368/2.

PRODUCTION OF CANE SUGAR

General

Cane sugar is produced from sugar cane, Saccharum officinarum, which is cultivated in many tropical and semi-tropical countries of the world. Sugar cane is a large plant which grows to 2-4 meters in height and has a stem diameter of 4-6 centimeters.

Based on data available from the sugar industry in Mauritius the green weight of cane contains about 12.5 percent sucrose and 13 percent fibrous material. The remainder is water plus minor amounts of impurities. Composition of the cane will depend on variety, cultivation and other factors but the above data are typical for the cane produced in most areas of the world. The overall recovery of raw sugar from sucrose is about 85 percent so that the yield of commercial sugar is about 11 percent of the weight of cane. The amount of fibrous material (bagasse) from any cane sugar operation is thus about 1.17 times the quantity of raw sugar produced.

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A list of the major sugar producing countries of the world and the production levels for 1967 are provided in Appendix 2. A summary of the production data is shown in Table 1.

Table 1 - Production of Cane Sugar and Sugar Cane(1)

Area	Raw Cane Sugar MT	Estimated Sugar Cane MT
Europe	47,000	400,000
North and Central America	14,249,000	129,000,000
South America	7,878,000	71,600,000
Asia - less China	6,320,000	57,400,000
China Mainland (estimated)	1,850,000	16,800,000
Africa	4,108,000	37,400,000
Oceania	2,688,000	24,400,000
World Totals	37,140,000	337,000,000

According to the estimated production of sugar cane shown in Table 1 the amount of bagasse that would be available as a by-product of the cane sugar industry in 1967 in the various areas of the world is shown in Table 2.

Table 2 - Production of Bagasse

Area	Bagasse BDMT 1967
North and Central America	17,000,000
South America	9,000,000
Asia (includes Mainland China)	10,000,000
Africa (includes small amount in Europe	5,000,000
Oceania	3,000,000
Total	44,000,000

Cultivation and Harvesting of Sugar Cane

The procedures used for growing and harvesting sugar cane have a major influence on the quality of the bagasse and hence on that of any pulp or building board product that might be produced from it.

(1) For Bibliography see Appendix 1.

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Sugar cane is grown, generally, in a zone extending around the world at the equator and limited by approximately the 30 degree north and south parallels of latitude. However, procedures for cultivating and harvesting cane are widely varied and depend on climate, variety of cane and the economy of the country. Depending on local conditions the cane may be grown on one or two year cycles and harvesting can be extended over periods ranging from three months to eleven months each year.

In Louisiana, U.S.A. sugar cane is grown on an annual basis and harvesting is carried out over a 90-day period. In Peru, cane crops are staggered so that harvesting can be extended over essentially the whole year (about eleven months).

In India, South Africa, Australia and the Far East the cane is grown on one or two year cycles and harvesting is carried out over approximately half the year.

Cane is usually grown separately but in certain areas, especially where land may be at a premium, cultivation of cane and other crops can be undertaken concurrently with the other crops being grown between the rows while the cane is still small.

Harvesting techriques are also widely varied and range from completely manual to completely mechanized. In certain areas, when the cane is mature and ready for cutting, the fields are set on fire to burn off the dried tops and leaves. The cane is then harvested either manually or mechanically.

For mechanical harvesting, equipment cuts the cane at ground level and piles it into rows. The cane is loaded onto trucks and transported to the sugar factory. For manual harvesting, the cane is cut by hand with special knives, topped and stripped of leaves, collected into piles and transported to the factory.

Cane regrows from the roots after harvesting and several additional crops (ratoons) can be harvested from each planting. The number of ratoons varies between two and ten and depends on cane variety, type of cultivation and the practice of the planter. Based on data from the industry in Mauritius, the yield of virgin cane averages 85 metric tons per hectare-year but by the sixth ratoon the yield drops to about 68 metric tons.

As noted, the length of the harvesting season varies from about three to eleven months each year. If bagasse is to be used as a raw material it would thus be available over a varying period of time and must be stored in order to support an industry on a full-year basis. This is discussed in a subsequent section. The type of harvesting determines the amount of dirt in the bagasse and whether or not it contains carbon.

Production of Sugar

The extraction of sugar from sugar cane is achieved by crushing the cane to squeeze out the sugar-containing juice. An alternative approach which is now in commercial use in a small number of factories is to use a diffusion extraction technique whereby the sugar is leached from cane which has been coarsely shredded. Although this approach has been known for a number of years its use has not grown rapidly.

Sugar factories vary somewhat throughout the world but the principle of the crushing mills is common to all and is essentially as follows.

The cane after receipt by the sugar factory may be washed to remove soil carried with the cane and also carbon if the cane had been burned. It is then broken up with conventional rotary knives. Cane is crushed in a series of three-roll crushers, the number of which can vary from four to seven. Pressure on the rolls, which are grooved, is increased at each stage to assure maximum extraction of juice. Maceration water is applied to the terminal press roll and used countercurrently at each stage until it is mixed with the virgin juice obtained at the first crusher.

The bagasse is removed at the final stage. Its composition can vary widely depending on the efficiency of the sugar extraction by the crushers. Moisture content is in the range of 46 to 52 percent and fibre content has a similar range. Also contained in the bagasse are soluble sugars ranging from 2 to 6 percent and various other impurities. The average analysis for the bagasse produced in 1967 in Mauritius is:

Moisture	48.5%
Fibre	49%
Solubles and other impurities	2.5%

This bagasse was obtained from manually harvested cane which would be very clean and the extraction efficiency is claimed to be above average.

The mixed raw juice is clarified to separate dirt washed from the cane by the extraction process as well as fibre fines. Clarified juice is then concentrated in multiple effect evaporators which in the final stages are under vacuum, until the concentration of the sugar syrup is sufficiently high that on seeding and cooling raw sugar will crystallize from the solution. The mother liquor is further concentrated under vacuum and a second batch of sugar is crystallized. This batch is less pure than that obtained from the first crystallization and is re-dissolved in the original solution at one of the later stages of evaporation. In this way only one grade of raw sugar is produced for marketing, that which is obtained from the first crystallization. The mother liquor (molasses) from the second crystallization, contains about 33 percent sucrose which is impractical to isolate because of other impurities and is marketed as such for cattle feed.

PROPERTIES OF BAGASSE

Physical Properties

Structurally, the sugar cane stalk consists of various types of fibrous cell tissue as illustrated in Figure 1, Appendix 4. These fibrous constituents comprise the major portion of the solid material in bagasse. The remainder consists of residual sugars and other solubles, dirt and some extraneous materials.

There are four main components in the fibre structure of sugar cane. As shown in Figure 1 these include the rind, fibrovascular bundles, parenchyma cells and vessel segments. The first two comprise the major portion of the true fibre in bagasse and are the most important components in the production of pulp or board products. The rind constitutes the outer shell of the stalk and is composed of long fibres. The fibrovascular bundles, also long fibres, lie parallel to the length of the stalk but are dispersed across it. Parenchyma cells and vessel segments make up the major portion of the volume of the interior of the stalk, the latter being closely associated with the fibre bundles. Both of these components are of irregular shape, are thin walled and soft and are thus easily fractured during the crushing process which releases the sugar juice contained primarily in these cells.

The distribution of these components in the fibre structure of sugar cane can vary widely depending on such factors as cane variety, soil, cultivation and weather. The approximate composition (5) of the dry weight of fibrous material in bagasse is as follows:

Fibre	40%
Parenchyma cells	40%
Vessel segments	20%

For industrial considerations the fibrous material in bagasse is normally classified simply into fibre and pith. The fibre includes the true fibre plus a portion of the other components whereas the pith is comprised of a large portion of the parenchyma cells plus some of the vessel segments. The pith content is usually indicated to be of the order of 35 percent of the total fibrous material although measured analytically it can vary appreciably, not only because of a variable distribution of the different components in the cane but also because of varying crushing techniques which can result in broken fibres being analyzed as pith.

Cell dimensions, on which papermaking characteristics of the material depend, are more difficult to measure, and the results of the measurements are more difficult to interpret than in the case for wood. This difficulty is due largely to the greater variety of cell types and the greater percentage of non-fibrous cells in bagasse than in wood. Softwoods are composed primarily of tracheid cells and measurements are usually limited to that type of cell. Hardwoods contain tracheids, libriform fibres and vessel segments. Bagasse however, is comprised of fibre from two types of tissue, the rind and vascular bundles, and to a lesser extent from the vessel segments and parenchyma cells in addition to the pith. Minor amounts of the other cells are also present.

The analytical techniques used to determine the amount of fibre and pith in bagasse are empirical in nature and no standard procedure exists. Although a common principle has been adopted for this test by essentially all pulp and board mills, minor differences have evolved. Consequently, comparison of results from different sources are not always valid.

Typical measurements for fibre dimensions are listed in Table 3.

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Table 3 - Fibre Dimensions of Bagasse and Other Papermaking Raw Materials (5, 6)

	Fibre Length mm	Fibre Width mm	Length-to-Width Ratio
Bagasse fibre	(1.7	0.020	85
	(1.22	0.018	68
	(1.82	0.023	79
	(1.24	0.021	59
Average	1.40	0.02	70
Bagasse pith	0.4	0.08	5
Cereal straw	1.5	0.013	110
Esparto	1.1	0.009	120
Jack pine	3.0	0.040	75
Red spruce	2.7	0.032	85
Aspen	1.0	0.026	40
Douglas fir	5.0	-	100
White spruce	3.5	-	120
White pine	3.5	-	100
Aspen	1.3	-	56
Red gum	1.6	-	57

The dimensions of the bagasse fibre vary from about 1.2 mm to 1.8 mm in length and average about 0.02 mm in width. The ratio of the two dimensions thus averages about 70,a value just below the range calculated for many softwoods. The length of the bagasse fibre is similar to that of hardwood but being somewhat thinner would have a higher length-to-width ratio and thus should have greater flexibility. The dimensions of pith are very different in that the fibre length and width are about 0.4 mm and 0.08 mm respectively. The ratio is thus only about 5 compared with about 70 for the fibre.

Chemical Composition

The chemical composition of bagasse compared with other annual plants and woods is listed in Table 4. As will be discussed, whole bagasse is not used for pulping and some depithing is always carried out. Consequently, data on bagasse fibre is of greater interest. The ash content of whole bagasse and of pith is several times that of bagasse fibre which in turn is somewhat higher than that of wood. This ash is largely dirt collected with the bagasse during the harvesting operation and is increased through the use of mechanical harvesters and the practice of burning to eliminate leaves and tops.

The content of extractives in bagasse has relatively little significance. All bagasse results from the extraction of sugar juice from the cane, and depending on the efficiency of that operation, there will be a variable amount of water soluble material remaining. The difference in the extractives content of the pith and fibre fractions can be attributed mainly to the large difference in surface areas of the two components.

The pentosan content of bagasse is high being 1 to 1.5 times that of hardwoods and 3 to 5 times that of softwoods. This pentosan is uniformly distributed

Table 4 - Chemical Composition of Bagasse Fibre and Other Papermaking Raw Materials (5,6,7)

	Ash %	Ether Solubility %	Hot Water Solubility %	Pentosan %	Lignin %	Cellulose %	Alpha-Cellulose %
Bagasse							
(whole)	2.3	8.4 [a]	10.0	29.0	18.5		33.6
Bagasse							
(pith)	2.4	0.3	1.9	28.5	20.2	77.7	34.8
(fibre)	0.70	0.1	0.9	27.9	20.8	77.8	42.5
(whole)	1.65	0.3	2.5	26.7	20.2	76.6	38.1
Cereal Straws							
(European)	8.7	1.3	12.6	26.8	16.5	73.2	36.0
(American)	8.1	4.1 [a]	12.3	27.0	16.0		37.4
(Holland)		1.7	12.5	25.1	16.3		36.2
Bamboo	2.3	0.7	7.8	28.5	23.0		34.8
Trembling Aspen Populus tremuloides	0.3	1.0	3	23	17	82	51
White Birch Betula papyrifera		1.5	4	26	25		41
Balsam fir Abies balsamea	0.5	1	4	11	29	70	44
Jack pine Pinus banksiana		2	4	13	27	72	49
White spruce Picea glauca	0.3	1.5	3	11	27	73	49

Notes a) Ethanol-benzene extract

between the pith and fibre fractions. It would be expected to be largely retained in pulps produced from bagasse especially by alkaline processes, the most commonly used commercially for bagasse. The presence of pentosan would account for the easy beating of bagasse pulp and would explain why bagasse pulp tends to form a stiff sheet of paper.

Because of its high pentosan content, bagasse has been used commercially as a raw material for the manufacture of such chemicals as furfural. This outlet for bagasse will be discussed in a subsequent section.

The lignin content of bagasse, either fibre or pith, is about three quarters that of a softwood but equal to or slightly higher than that of a hardwood. This relatively low content combined with the degree of physical breakdown of the starting material would suggest that bagasse can be easily pulped, a feature which is borne out in practice.

As noted in Table 4, the holocellulose content of bagasse is about 77-78 percent, which is 5 percentage points higher than that of the average softwood but is below the value of 82 for aspen. The holocellulose content of other hardwoods varies quite widely with 76 for sugar maple, 78 for beech and 85 for cherry. This component in bagasse is thus about midway between the amounts in the hard and soft woods.

Although the holocellulose content of bagasse is high the alpha cellulose content is low. Also, there is a marked difference between the amounts of alpha cellulose in the pith and in the fibre fractions of bagasse. The fibre fraction contains about 42 percent, which is at the low end of the range for hardwoods. For soft woods the value is in the high forties. Pith contains only about 35 percent. The alpha cellulose content and the fibre dimensions of the two fractions are the major differences between bagasse pith and fibre.

UTILIZATION OF BAGASSE

General

At present, bagasse is used either as a fuel by the sugar factory or as a raw material for the manufacture of pulp and paper products, of various types of building board and of certain chemicals. Dry bagasse is composed of three major components: fibre, pith and residual sugar. The pith and residual sugars are of no value in the manufacture of pulp and board products so must be removed from the bagasse. A chart indicating the breakdown of a given quantity of sugar cane into its major components is shown in Figure 2, Appendix 4. Also shown are the quantities of pulp and building board that could be produced. The preparation of this chart has been based on average data for the sugar industry in Mauritius and on typical depithing and pulping yields. The major relationships which have been used are as follows:

Fibre in cane	14%
Fibre in whole bagasse	49%
Bagasse removed as pith	35%
Average storage loss	6%
Pulping yield	50%
Bleaching yield	92%

As noted in the chart the maximum amount of bleached pulp that could be produced in any cane sugar area is about 4 percent of the total weight of cane or 31 percent of the dry weight of bagasse fibre. Similarly for board products about 66 percent of the dry weight of bagasse fibre would be the maximum potential production level. This assumes that no bagasse is used for fuel.

In Figure 3, Appendix 4 a chart is included whereby the amounts of the various grades of paper that can be produced from bagasse may be estimated from the weight of the cane available. This chart is based on typical data for fibre content, depithing yield, pulping and bleaching yield and bagasse pulp content in the papers.

Historical and Geographical Utilization

As indicated earlier about 44 million metric tons of bagasse, dry weight, are now produced annually throughout the world as a by-product of the cane sugar industry. A recent estimate (2) indicates that in 1965 about 500,000 metric tons of pulp were produced from this material which would require about 1.6 million metric tons of dry bagasse fibre or about 3.5 percent of the total amount of bagasse produced. Even at this level, the use of bagasse as a raw material for the production of paper pulps has increased more than 30 fold during the past 20 years.

The amount of pulp produced from bagasse in 1965 accounted for about 10 percent of the total production of about 5 million metric tons of pulp from non-wood fibres. In turn, this pulp amounted to approximately 6 percent of the total of all new pulp produced, 83 million metric tons.

The first reported attempt to produce a papermaking pulp from bagasse took place in France (3) in 1844. The paper made from it was considered to have some value. Numerous attempts to produce bagasse pulps commercially were made from that time to the 1930's in various parts of the world but none of these lasted more than a few years.

Two mills were started in Taiwan in 1939 but were destroyed during the war. One was rebuilt during the latter part of the war. A mill was also started in Peru in 1939 by W. R. Grace & Company and has been in continual production since that time. About the same time a mill was built in the Philippines and shortly thereafter one in Cuba. These mills, with a combined capacity of about 15,000 metric tons annually, accounted for the total world production of papermaking pulps from bagasse until several years after World War II.

Several plants have used bagasse as the raw material for the production of insulating and building boards. The oldest of these is the Celotex Corporation plant in the United States which commenced operation in 1920.

Information concerning the actual number of mills that now use bagasse is meagre but there are between one and two hundred. However, a large number of these, located in Mainland China and Taiwan, are very small with daily capacities of only a few tons. There are now approximately forty mills, in at least twenty four countries, with daily capacity levels in excess of twenty tons that use bagasse as the raw material for a papermaking pulp.

In India the paper industry was based originally on bamboo with little wood or other plant fibres being used. There are now seven mills in India which were designed to use bagasse but it is understood that two of these have achieved no more than intermittent operation even though construction has been complete for several years. In Mexico there are four mills using bagasse and in each of Brazil, Cuba and Peru three mills. A partial list of the larger bagasse mills is provided in Appendix 3.

As noted earlier most of the bagasse mills are very small when compared with mills based on the use of wood. The mill of Cia Industrial de San Cristobal, in Mexico has a nominal capacity in excess of 200 metric tons per day and is claimed to be the largest mill based exclusively on bagasse. The output of the Propal mill in Colombia has recently been increased to nearly 200 metric ton per day. Two of the Grace mills have nominal capacities of about 150 metric tons daily. Many of the recently installed mills have daily capacities of the order of 100 metric tons.

The history of the manufacture of board products from bagasse has included a number of successes and failures. At present there are reported to be 16 plants in operation although one of these is described as being only a pilot plant and another has been operated only intermittently. Four other plants have been built within the last 10-12 years but have subsequently been closed. A former bagasse plant has been converted to wood as the raw material. Three new plants are under construction and are scheduled to start up during the next two years. Locations of the board plants are widely distributed throughout the world and only four countries, United States, Cuba, Mexico and Taiwan, have two plants each. A list of those mills now in operation or under construction is provided in Appendix 3.

Size of the board plants varies from about 25 metric tons per day to 550 metric tons per day. The largest is the Celotex plant. The most common size appears to be about 50 metric tons per day.

Attempts have been made to use bagasse in the production of briquettes and various chemicals. However, based on information available at the present time no plant is now producing briquettes. Two plants of the Quaker Oats Company, or an affiliate, produce furfural from whole bagasse. One is located in the United States and the other in the West Indies. The output is used primarily in the manufacture of nylon.

<u>Pulp Products</u>

Bagasse pulp has been used for the production of practically all types of paper and paperboard products including printing and writing, tissue, wrapping, linerboard, paperboards and experimentally, newsprint. The Grace operation in Peru provides an illustration of the different grades that can be produced from bagasse. The two Grace mills, located at Paramonga and Cartavio each have a nominal capacity of 150 metric tons per day of pulp. Three grades of pulp are produced: unbleached pulp in about 70 percent yield for corrugating medium, unbleached pulp in 65 percent yield for linerboard, bag and wrapping papers, and a bleachable grade of pulp in about 50 percent yield. This last grade is bleached to a brightness level of 80 or 85 GE depending on the product and is used in writing and printing papers, tissue and certain grades of paperboards. The proportions of bagasse pulp that are incorporated in the various types of paper and board are listed in Table 5.

Table 5 - Utilization of Bagasse Pulp in Paper and Paperboard by Grade (Peru)

Paper and Paperboard	Bagasse Pulp In Furnish %	Other Pulps in Furnish Type	%
Facial Tissue	55	Kraft	45
Toilet Tissue	75	Kraft	25
Various Writing and Printing	70-90	Kraft	10-30
Bag and Wrapping	45-55	Kraft	20-45
		Waste and Broke	15-30
Bristol Board	71	Kraft	23
		Waste and Broke	6
Corrugating Medium	40	Kraft	5
		Waste and Broke	55
Linerboard	30-40	Kraft	0-15
		Waste and Broke	55-60

The operation at San Cristobal provides a further example of the range of products that can be produced from bagasse pulps (4). This mill, operated by Cia Industrial de San Cristobal in Mexico, produces bleached and unbleached pulps. About half of the output is sold competitively to other papermakers and the rest is converted on the company's paper machines into various grades of paper including writing, printing, wrapping and tissue. San Cristobal pulp is used elsewhere in Mexico to produce corrugating medium, ledger, carbonizing, greaseproof and wax-based papers and boxboard. It is used to a lesser extent in the furnish for bag and sack papers and for linerboard. Recently a semi-chemical pulp that can be produced by San Cristobal has been used experimentally in commercial trials for the production of various grades of wrapping paper and newsprint. The newsprint was claimed to have performed satisfactorily on high-speed rotary presses. The various grades of paper produced both commercially and experimentally from bagasse at the San Cristobal mill are listed in Table 6.

Table 6 - Grades of Paper and Paperboard Produced at San Cristobal (4)

Paper and Paperboard	Bagasse Pulp in Furnish Type	%	Other Pulps in Furnish Type	%
Wrapping	Chemical	70	Kraft	30
Wrapping*	Semi-chemical	67	Kraft	33
Sack*	Semi-chemical	40	Kraft	60
Notebook	Chemical	67	Kraft	33
Bleached Board	Chemical	100	-	-
Writing and Printing I*	Semi-chemical	100	-	-
Writing and Printing II	Chemical	100	-	-
Newsprint I*	Semi-chemical	95	Kraft	5
Newsprint II*	Semi-chemical	75	Kraft	10
			Groundwood	15

* Experimental

Many other mills that use bagasse produce a range of pulps and paper products similar to that produced at the above mentioned mills. A partial listing of these mills is given in Appendix 3.

Building Board Products

Bagasse has been used as the raw material in the manufacture of softboard, particleboard and more recently hardboards. The Celotex plant, mentioned earlier, has produced a softboard having a density of about 300 kg/m^3 by a wet process since it commenced operation in 1920. This product has found its best application in acoustic tile.

Hardboard can also be produced effectively by a wet process from bagasse. The density, up to 1,000 kg/m^3, and quality are equivalent to those of comparable products produced from wood pulp. However, the majority of plants, utilizing bagasse as a raw material for the production of board, produce a medium density particleboard (650 kg/m^3) by a dry process involving the mixing of prepared bagasse with a resin, and curing it under pressure.

A recent trend has been to produce boards by the dry process at different densities by varying the pressure on the forming press. The Tablopan plant in Venezuela is designed to produce the full range of boards by the dry process. A listing of the various board plants throughout the world is given in Appendix 3.

DEPITHING BAGASSE

Effect of Pith on Properties of Product

As noted earlier, bagasse contains about 35 percent pith as determined by existing analytical procedures. The pith, having a low alpha cellulose content and being composed of short fibre material is a poor papermaking fibre and should be removed from bagasse as completely as possible. Several advantages accrue from the removal of pith (3, 8).

1. A major reduction in chemical requirements for pulping is achieved as the chemicals act more readily on pith than on the fibre portion of bagasse.

2. Bleaching chemical requirements are decreased as pith has a high chlorine demand.

3. Much of the dirt picked up with the bagasse during harvesting tends to accumulate in the pith fraction and can be removed with the pith.

4. Drainage and drying of the finished sheet is improved.

5. Less cleaning of the paper machine is required as pith has a tendency to adhere to press rolls, wires and felt.

6. Overall strength properties of the paper sheet are improved.

7. The paper sheet is not as brittle and is less "tinny" than one made from bagasse containing pith.

Experimental work carried out some time ago (9) demonstrates the necessity of separating pith from the bagasse fibre. As shown in Table 7, this work indicates that ash content in bagasse, based on the average distribution in three samples of fractionated pith, is concentrated in the finer fractions. The ash is stated to consist largely of soil picked up with the cane during harvesting operations

Table 7 - Ash Content of Fractionated Bagasse Pith

Fraction		Percentage of Pith	Percentage of Total Ash in Bagasse
+14	mesh	none	-
-14+20	mesh	9	8
-20+60	mesh	73	11
-60+80	mesh	7	22
-80	mesh	11	36
			77%

(remaining ash is with fibre)

and consequently contains a high proportion of silica. Knapp, Wethern and coworkers (6) in their extensive investigations of the pulping of bagasse showed that for several varieties of Hawaiian bagasse the ash is distributed as follows:

	Ash Content
Whole Bagasse	1.3-2.0%
Pith	1.8-2.4%
Bagasse Fibre	0.6-0.8%

Ash content of the fibre is thus only about a third of that of pith. The amounts of silica in the ash from both fibre and pith are similar but vary over a wide range for the several samples tested. The amount is approximately half of the total ash content of the sample.

Various wood species used for pulping contain about 0.3 percent ash with silica accounting for only a very small portion of this. Other annual plants contain considerably more ash. Wheat straw and esparto contain 6-8 percent and rice straw contains 14-20 percent of which at least a third is silica. The problems in pulping caused by silica in the bagasse are discussed in another section of this report.

The effect of pith content on the strength, yield and bleach consumption of bagasse pulps is demonstrated by some early experimental work (9) carried out in Taiwan. Yield, tensile, burst, and bleach demand were determined after pulping bagasse that contained decreasing amounts of pith. Results of these tests are shown in Figure 4, Appendix 4. Based on the analytical determinations used for this work the bagasse contained 30 percent pith. As shown in the graph, strength of the pulp continues to increase until the pith is completely removed but the greatest increase occurs by removal of the last 50 percent.

Yield of pulp from depithed bagasse reaches a level of about 50 percent when half of the pith is removed but increases very little with the removal of additional pith. If whole bagasse is pulped the yield of a similar grade of pulp is about 37 percent which would indicate that essentially half of the pith is removed chemically by the pulping chemical.

The bleach consumption shown in Figure 4 is also significant. When whole bagasse is pulped, chlorine demand can reach 30 percent of the weight of pulp. As pith is removed the bleach demand decreases rapidly to a level of about 5 percent chlorine for completely depithed bagasse.

Knapp and Wethern (6) also investigated the effect of pith on the strength of the pulp. Results of their work confirmed and paralleled the above observations.

At a number of the older installations that use bagasse as raw material for the production of paper or board products, either no depithing or only partial depitning is carried out. At the present time many mills remove only about 20 percent of the weight of bagasse, or slightly more than half of the pith. At other mills more extensive depithing is carried out and about 35 percent of the weight of bagasse is removed. It is now generally recognized that high quality pulp and board can be produced only when the bagasse has been effectively depithed.

When bagasse is to be used on a year round basis, storage is required in most areas of the world because of the period of the crushing season. Depithing and storage are interrelated and a recent trend is to depith all the bagasse during the crushing season so that pith can be used as fuel at the sugar mill so as to provide an effective and economically attractive means for its disposal. Depithed bagasse would then be stored, not whole bagasse.

Depithing Methods

Some of the earliest plants using bagasse, employed conventional rotary or vibrating screens at either the sugar mill or the pulp or board plant to remove loose pith and dirt. As the necessity of removing pith became more generally recognized, the bagasse was milled to separate the fibre bundles and to loosen pith after which the material was screened. The operation was usually carried out at the use mill but the disposal of pith became such a problem that the process had to be transferred to the sugar factory. In this way the pith could be readily disposed of as fuel. Establishing the depithing station at the sugar factory requires that the operation be based on the use of bagasse as it is produced, at a moisture content of about 50 percent.

At the present time the depithing process is based on operating with either a moist or a wet system. All depithing involves the same basic approach whereby bagasse is shredded or abraided mechanically to break up the fibre bundles and release the pith from the fibre. The two components are then separated by screening either within the depithing unit or as a separate operation.

For moist depithing the bagasse is shredded without the addition of any amount of water to the system. Depithing is carried out at the moisture content of the bagasse as it is received from the sugar mill or from storage. In the former case the moisture content averages 50 percent, in the latter as low as 20 percent although at some mills water is added to the stored bagasse prior to depithing to adjust the moisture content to about 50 percent. For wet methods the shredding action is carried out in water at consistencies of less than 10 percent.

Depithing systems now in use at major pulp mills are listed in Table 8.

Table 8 - Depithing Systems for Bagasse

System	Type	Stages	Moisture Content %	Pith Removed %	Unit
Peadco Depither	Moist	1	50	35	Vertical, swing hammer (motor overhead)
Peadco Pneumatic Flail	Moist	1	50	35	Vertical, swing hammer (motor at base)
Rietz	Moist Wet	2	50) 90)	up to 50	Vertical, fixed hammer. Units same for both stages
SPM	Moist	2*	50	35*	Horizontal double shaft swing hammer
Horkel (10)	Moist Wet	2	50) 90)	35	Horizontal swing hammer. Units same for both stages
Cusi (11)	Moist Wet	2	20-30) 90)	18	First stage hammer mill. Second stage scraping mill

In addition to those units listed in Table 8, other types of hammer mills have been used in several installations including the Raymond and Ayotla. The Raymond unit is a vertical hammer mill in which loosening of the pith is effected but the pith and fibre are separated in a subsequent operation. Design of the Ayotla unit is based on the Horkel machine but the hammers have been modified to provide better depithing with less fibre damage. Other vertical, swing hammer mills, that incorporate gravity feed and discharge have also been designed specifically for processing bagasse.

Hydropulpers have been used but the amount of pith removed is small. Use of the hydropulper provides a clean product and reduces the solubles content but the action is too gentle to effect a good separation of pith from fibre. In at least

*This unit has been used commercially in a single stage to remove 20 percent and experimentally in two stages to remove 35 percent of the bagasse as pith.

two installations a hydropulper has been installed ahead of a wet depithing stage for re-wetting and slurrying the bagasse.

The Rietz wet system and the SPM system have each been adopted by three particleboard plants to date for depithing bagasse.

Peadco System

In a typical moist system, such as the Peadco Depithing system, the operating principle consists in the use of centrifugal action to separate dirt and the two main fractions of bagasse. The unit is comprised of a vertically mounted rotor with hinged arms housed in a perforated shell through which the pith is discharged. Bagasse received directly from the sugar factory at 50 percent moisture is fed in at the top of the depither. Dirt and sand are expelled first by centrifugal action. The rotor arms revolving through the bagasse provide a rubbing action, largely of fibre against fibre whereby pith is mechanically separated from the fibre bundles. By centrifugal action this pith is forced against and through the perforated housing of the unit to effect removal of the pith. Fibrous material is discharged through the bottom of the unit. The degree of depithing can be controlled so that about 35 percent of the feed can be separated. Only a single stage is required to effect this degree of separation.

Peadco depithing units have been modified considerably during the past 10 years. The original unit was a pneumatic flail which involved mounting the hammer mill above the drive unit. Bagasse was fed into the top of the mill and was carried down and through the unit by an air stream, hence its name. Also, the pith was removed from the external surface of the screen by air. For the gravity machine, the mounting was reversed so that the two fractions of bagasse could be removed from the machine by conveyors rather than by fans. The bagasse is fed to, and is moved through the unit by gravity. Subsequent modifications have involved changes to the design of the rotor. The latest Peadco unit has a capacity of about 4 bone dry metric tons of accepted fibre per hour. The power consumption is about 19 kWh/MT whereas for the pneumatic flail machine it is about double this amount.

SPM System

The SPM system is designed to use moist bagasse. The machine is a double shaft, horizontally mounted hammer mill which permits gravity feed. The lower half of the housing is perforated to permit separation of the pith from the fibre and its removal in a single operation. Fans are used for fibre and pith removal. Throughput is high as each machine can produce over 11 tons per hour of dry accepted fibre at a power consumption of about 22 kWh/MT including that used for the fans.

Horkel System

The Horkel system was developed during the early 1950's. The unit is a horizontally mounted hammer mill which combines milling and screening in a single unit. The fibre is carried through the mill axially by long hammers. Pith and dirt are discharged through the screen. The unit is designed for use under either moist or wet conditions. In several installations moist depithing is carried out at the sugar factory. The partly depithed bagasse is then trucked to the pulp mill where it is stored and prior to use is depithed under wet conditions in a second stage. This approach permits use of a portion of the pith as fuel. However, at one location the second stage of depithing has been eliminated because of corrosion to the depither caused by acidic impurities which developed in the bagasse during storage. The hammers of the Horkel mill have been modified at a number of locations to improve the depithing action.

Rietz System

The Rietz mill was developed in conjunction with an extensive development program carried out by the Hawaiian Sugar Planters Association and the Crown Zellerbach Company (6). The unit can be used for both moist and wet depithing. The machine is a vertically mounted fixed hammer mill which permits gravity feed and discharge. The rotor operates at high speed and the throughput is greater than that of the Horkel. The fibre bundles are separated by high speed hammer impact, intense agitation and interaction of the bagasse particles. Separated pith and dirt are discharted through the screen housing. As originally conceived the Rietz unit was used only in a wet system but subsequently a moist and wet system was developed to permit disposal of at least a portion of the pith as fuel without dewatering.

From pilot plant operation with this unit, the observation has been made that depithing should be carried out as soon as possible after the bagasse is produced at the sugar factory as freshly ground cane fibre is highly resilient. Under these conditions depithing will cause the least amount of damage to the bagasse in the form of broken fibres. Also, the second wet stage of depithing should be carried out immediately after the first stage, not after an intervening storage period. The wet stage permits essentially complete removal of the residual, soluble sugars contained in the bagasse.

In the Rietz system, approximately 50 percent of bagasse is removed as pith. About two thirds of this is separated by moist, and the remainder by wet depithing. By depithing to this extent a certain amount of soft, low strength fibres are rejected in addition to the normal pith. Output of the unit, in two stages, is 6 tons per hour of accepted dry fibre. The total power consumption is about 35 kWh/MT.

Comment

Both the moist and wet systems have certain advantages and disadvantages as do the different types of depithers. The following comments are concerned with features of the various depithing units and systems.

The wet depithing method effectively removes all of the soluble sugars from the bagasse. However, with the moist system most of these impurities are removed if depithing is thorough because the solubles tend to be concentrated in the pith.

Wet depithing provides a cleaner bagasse as much of the dirt is washed out during the depithing operation.

Pith can be utilized more effectively and economically from moist depithing. It is discharged from the depither at essentially the moisture content of the feed bagasse and can be used directly as fuel. Pith from wet depithing requires dewatering which is a difficult and expensive operation with such a highly absorbent material.

Regarding the type of equipment available, depithing units with a vertical mounting would be expected to give a higher throughput than the horizontally mounted machines because the total periphery of the housing can be used as a screen to extract pith. Also, the action of the hammers would be uniform for the full rotation whereas in the horizontal unit this action would tend to vary as the hammer is rotated from its upper position where the bagasse is introduced, to the corresponding lower position where the pith is discharged. However, both of these factors are considered to be of relatively minor importance and a slight increase in the power input would be expected to compensate for them.

A comparison of the quality of the fibre produced by the different systems and units can not be carried out effectively without a controlled test program. As the analytical test for determining pith content is completely empirical, with no standard procedure in use throughout the industry, a direct comparison of results from the various mills would not be meaningful. It may be safely stated that the depithing systems and units in use at most of the major mills, can provide good clean fibre that is a satisfactory raw material for the production of high quality bleached pulp. In many areas of the world this pulp is competing effectively against wood based pulps.

STORAGE OF BAGASSE

General

As discussed in a preceding section sugar cane is harvested for varying periods of time each year in the different growing areas of the world. Thus, to use the by-product bagasse as a raw material on a year round basis storage for a portion of the year's requirement must be provided.

There are at present two main approaches to the storage of bagasse; these are to store in bale or in bulk form. The major problem during storage is to control degradation which appears to be influenced by the amount of air present and also by the amount of moisture and water soluble impurities in the bagasse.

Bale Storage

The first mills obtained whole bagasse from a sugar factory and stored it in bale form. This type of storage was adopted largely for convenience as it facilitated handling. The techniques used have been refined over the years and the present approach to bale storage may be described briefly as follows.

Bagasse is baled at the sugar factory at a moisture content of about 50 percent either before or after depithing depending on the system used by the pulp mill or board plant and on the fuel requirement of the sugar factory. The bales average 45 x 50 x 75 centimeters in size and weigh about 100 kilograms wet or 50 kilograms dry. Bales are stored in carefully constructed piles usually adjacent to the use point. At one mill each pile measure 38 meters in length by 21 meters wide by 9.5 meters high and contains about 600 metric tons of dry bagasse or approximately

12,000 bales. The piles are constructed so that there is free circulation of air around each bale. Each pile is covered with some material which will provide protection from rain. Usually a thatch, prepared from grasses, reeds or dry cane leaves is the most economical source of covering material.

During the initial storage period of about 6 weeks, the internal temperature of each bale increases to about 80°C and then gradually decreases during the remaining storage period. This temperature rise results largely from the fermentation of residual sugars contained in the bagasse. The design of the storage pile is critical in order to permit free air circulation to dissipate this heat otherwise spontaneous combustion can occur. If depithing is carried out before storage, the temperature rise during this initial period is less. It is claimed that some increase in temperature is desirable in order to sterilize the bagasse so as to prevent degradation. Also, the heat generated accelerates drying of the bagasse and the moisture content during storage will normally decrease from 50 percent to about 20 percent. In certain dry areas, a moisture content as low as 12 percent is regularly obtained. This decrease in moisture content is also a factor in curtailing degradation.

After the bagasse has been stored for 6 to 8 weeks and the temperature in the bale has started to decrease, further storage for long periods of time is possible provided the piles are adequately protected from rain. When the piles become wet, serious degradation usually occurs.

Loss of material during storage can vary widely and is a result of both degradation and handling. For a well run operation the total loss will be of the order of 15 percent of the weight of bagasse. Manpower requirements to build and maintain a storage pile and to retrieve the bales for use based on the experience at several mills, is about 20 men per shift for a 100 ton per day mill.

When the bagasse is withdrawn from the pile, it may be depithed or sent directly to process depending on its treatment prior to storage. Depithing may be carried out on the material as it leaves the pile or a water spray may be used in the bale-breaker to increase the moisture content.

Two major problems can arise from depithing dry bagasse. The generation of dust is excessive and this has been responsible at a number of locations for a lung infection among workmen. This is attributed to a fungus growth that develops in the bagasse and is carried with the dust. This infection, bagassosis, is difficult to combat once it has become established. If dry bagasse must be depithed, adequate ventilation is required to control dust. The other problem associated with dry depithing is that the bagasse becomes brittle as it dries out, and is thus easily fractured. A large amount of fibre fines is produced and is separated with the pith.

Bulk Storage

There are several techniques in use or under development for bulk storage. These include the Ritter, Valentine and Rietz processes. A description of each follows.

Ritter

Ritter storage (12) involves the use of a biological culture containing lactic acid bacteria as a preservative. Installations at Ngoye Paper Mills in South

Africa and at Ledesma in Argentina are examples of this system. The installation at Ngoye is described briefly. Sufficient whole bagasse is stored to supply a 50 ton per day mill producing corrugating medium. At present no depithing is carried out on the bagasse and a cold soda process is used to produce the pulp in a yield of about 55 percent. This mill is installing depithing equipment which will be located at the sugar factory to process green bagasse and about 20 percent of which will be separated as pith. In future only the depithed bagasse will be stored.

At present, whole bagasse is obtained from the sugar factory by conveyor belt. From this belt the bagasse is carried in a dilute aqueous slurry, less than 5 percent, in overhead channels to the storage area. The culture, prepared in separate tanks, is mixed with the bagasse slurry as it is allowed to flow onto the storage pad. The liquor drains from the bagasse via transverse channels in the pad, is collected in canals running along the sides of the storage pad and is recycled for reuse.

A minimum storage period of about three months is required due to the length of the cutting season and it is standard practice at this mill to store all bagasse for this period. It is considered that this storage period is necessary

a. to assure that properties of the bagasse are uniform for pulping and

b. to effect some separation of the pith from the fibre.

The storage pile is built to a height of about 10 meters and no additional water is added during the storage period but the surface of the pile is left unprotected. Rain in any amount is not considered to cause damage. Some initial heating in the pile occurs and the average temperature during storage is about 40°C. Profiles of the density on a moist basis, and of the moisture content of the pile are shown in Table 9.

Table 9 - Density and Moisture Content of Bulk Stored Bagasse

Depth in Pile	Density of Pile kg/m^3	Moisture Content %
0.6 - 1.5m (top)	560	76.1
1.5 - 4.5m	720	75.1
4.5 - 7.5m	850	76.3
7.5 - 10.0m (bottom)	925	73.9

It is expected that these values will change when depithed bagasse is stored.

When bagasse is withdrawn from the pile, waste liquor from the pulping operation is pumped to the pile to slurry the bagasse. This slurry is carried by the transverse channels in the storage pads to a canal running along the side of the pad and on to the pulp mill.

SANDOWELL

The bagasse on the surface of the pile during storage appears to be severely degraded but freshly exposed material at a depth of about a meter has the colour of fresh bagasse and shows no visible signs of deterioration. The principle of this storage process is that the biological liquor maintains the bagasse in an acidic condition at a pH of 4 - 4.5 throughout the storage period in order to curtail bacterial degradation. Residual sugars in the bagasse are broken down and used by the biological culture as nutritive material.

The installation at Ledesma is similar in principle to the one at Ngoye except that it is larger and has incorporated certain modifications to permit more effective handling of the bagasse. The height of the pile is about 17 meters compared to 10 meters at Ngoye.

Valentine

The Valentine technique (13) simply involves the storage of bagasse in bulk with no additives. Green, whole bagasse, is piled in a horseshoe shaped pile to facilitate use of a single belt unloader at a fixed position. The pile is built up to its maximum height - about 18 meters - and then extended lengthwise. Earlier, piles were built to height gradually but this approach tended to permit the entrapment of more air-pockets in the pile. Although a profile has not been developed the average density on a moist basis for the whole pile is about 255 kg/m^3. Attempts have been made to increase the degree of compaction by running a bulldozer over the pile and by use of a water spray. Both approaches are effective but are not considered to be warranted.

During storage the temperature rises slightly but the moisture content remains essentially constant. The out 40 cm of the pile suffers the most deterioration but is considered to have only slightly lower quality than baled bagasse of the same age; the next 60 cm is similar to baled material. The remainder of the pile stays essentially equivalent to fresh bagasse. Covering the pile will improve the quality of the outer layers but these represent only a few percent of the total weight of the pile and in effect provide a cheap covering which is usable.

Depithed and washed bagasse was stored in one experimental pile. Quality of this material after storage was considered to be very good and was not distinguishable from freshly depithed bagasse.

Losses during storage are about 6 percent compared with about 15 percent for bale storage. Manpower requirements are less in that only two men per shift are required to build and draw from a bulk storage pile. The storage area is reduced appreciably in that about 1 m^2/BDMT of bagasse is required for bulk storage compared with about 5 m^2/BDMT for bale storage.

The important factor in the Valentine bulk storage technique is considered to be the elimination of air from the pile. Residual sugar will ferment during the early stage of the storage period but this requires oxygen from air to be sustained. The fermentation can thus be used to scavenge oxygen entrapped in the pile while it is being built. Some heat is generated by this fermentation. If bagasse is depithed prior to storage, the residual sugar content, normally 2-3 percent, is reduced to about one percent of the weight of bagasse. Fermentation of this amount of sugar is considered to be sufficient to use up the oxygen entrapped in a well-built pile and heat generation is expected to be only minor.

SANDOWELL

During the fermentation, acids are produced, primarily acetic, which will decrease the pH and the use of some alkali may be advisable to neutralize these acids.

From the foregoing comment, it may be noted that the principle of this storage technique is essentially opposite to that of bale storage. Sufficient density in a bale can not be developed by the normal baling equipment to reduce the entrapped air to a level low enough to be eliminated by the fermentation process. Consequently, oxidation of the bagasse can occur and the temperature in the bale will rise to 80°C as mentioned earlier or even high if the pile of bales is not carefully constructed and the heat cannot be dissipated effectively.

Rietz

The Rietz technique for bulk storage of bagasse involves the use of a preservative. This technique has been developed for integration with the Rietz depithing system. However, as the wet depithing stage, the second stage, removes essentially all of the residual sugars from the bagasse there will be no fermentation during storage to use up entrained oxygen and oxidation of bagasse can result. Other than that a preservative is required, the technique is similar to that of the Valentine process.

Other

Other approaches to bulk storage have been investigated. Several mills have found that the use of alkali to neutralize the acids developed during storage is effective in controlling degradation.

Tests have been carried out by one mill to compare the effects of bale and bulk storage on the quality of the pulp produced. Both the burst and tear strengths were found to be higher for pulps produced from bagasse that had been stored in bulk.

VALUE OF BAGASSE

Fuel Value

The major use for bagasse at the present time is as fuel for the sugar factories. As noted earlier only about 3.5 percent of the total bagasse produced in the world it utilized as a raw material for the production of paper pulps. A smaller quantity is used for the production of building board products and other materials, such as furfural. Consequently, well over 90 percent of the bagasse is burned. Most of this is used as fuel for the power boilers, but a portion is burned simply for disposal.

The moisture content of bagasse varies widely and can range from as low as 20 percent after storage to about 55 percent from the cane crushers in certain sugar factories. The composition (14) of a typical bagasse is:

Dry fibrous material	52%	(carbon	45%
		(hydrogen	6%
		(oxygen	46%
		(ash	3%
Soluble material	3%	sucrose, and other sugars	
Water	45%		
	100%		

The gross or higher calorific value of bone dry bagasse including the solubles is generally considered to be approximately 4,600 kcal/kg. With 45 percent moisture the gross calorific value is 2,530 kcal/kg or with 50 percent moisture the value is 2,300 kcal/kg.

Bagasse fired boilers have low efficiency because of the large amount of heat required to vaporize the moisture present in the bagasse. Efficiency levels of 55 to 60 percent for various types of furnaces with bagasse containing 45 percent moisture are normal. At these levels the available heat in steam is 1,400 to 1,500 kcal/kg of green bagasse fired.

As other fuels can be used effectively by the sugar factories, equivalent amounts of bagasse could be released for other purposes. In Table 10 the gross calorific value and the available heats in steam for a number of common fuels are shown compared with bagasse.

Table 10 - Comparison of Bagasse and Various Fuels

Fuel	Gross Calorific Value kcal/kg	Typical Boiler Efficiency %	Available Heat in Steam kcal/kg of fuel
Bone dry bagasse	4,600	80	3,700
Moist bagasse			
- 50% water	2,300	53 - 58	1,200 - 1,300
- 48% water	2,400	54 - 59	1,300 - 1,400
- 45% water	2,530	55 - 60	1,400 - 1,500
South African Coal	6,700	76	5,100
Fuel Oil (Bunker C)	10,000	80 - 85	8,200

By comparing the values shown in Table 10 it may be seen that one ton of fuel oil will replace approximately 6 tons of green bagasse. Also, one ton of coal will replace about 4 tons of green bagasse. These ratios are dependent on the gross calorific value of the fuels employed, the moisture content of the bagasse, and on the boiler efficiency. A chart has been included, Figure 5, Appendix 4, which permits an estimate of the quantity of various alternative fuels that would be required based on the moisture content of the bagasse and the operating conditions of the power boilers.

SANDOWELL

If the delivered price of fuel oil is about US $25 per metric ton, the value of the bagasse that it could replace would be about US $4.15 per metric ton of green bagasse or US $8.45 per metric ton of dry fibrous material. If coal is the alternative fuel at a delivered price of US $27 per metric ton the replacement value of the bagasse would be about US $6.75 per ton of green bagasse. Fuel oil would be the cheaper of these two alternative fuels. If bagasse is to be used as a raw material its value would be the cost per ton of green bagasse to provide the required amount of the alternative fuel.

In addition to the direct fuel replacement value as calculated above, the expense of modifying the power boilers at the sugar factories to permit the firing of fuel oil would have to be covered. The bagasse user could undertake to make the required modifications with the expense becoming a part of the total capital investment required. Alternatively, the price paid for the bagasse could be adjusted to comprise the fuel replacement value and the cost of modifying the power boilers including an allowance for a reasonable rate of return on the required capital amortized over a number of years.

The extent of the modifications to the power boilers would vary over a wide range depending on their type and condition. Many types of power boilers could not be effectively modified and full replacement would have to be made. Others would require only the installation of the oil burning unit. This situation would have to be assessed separately for each installation.

In most areas where bagasse is used as a raw material it is purchased at the fuel replacement value as calculated above plus an allowance to the sugar factory to cover handling charges and a small profit. Information from several mills indicates that this allowance averages about US $2.00 per ton of green bagasse but it can vary widely.

Based on the data used to prepare the chart in Figure 2, Appendix 4, the quantity of bagasse required to produce bleached pulp may be estimated to be as follows:

Item	Units	Amount
Green whole bagasse	MT/BDMt (bleached pulp)	7.24
	MT/ADMT (bleached pulp)	6.52

If the sugar factory is paid an allowance of US $2.00 plus the fuel replacement value of US $4.15 per metric ton of green bagasse, the cost of the whole bagasse required per air dry ton of bleached pulp would be about US $40. By comparison, the cost of hardwood per air dry metric ton of an equivalent bleached pulp can range from about US $35 to US $52 based on information from Canadian and European mills. Thus bagasse is not a cheap source of fibre relative to wood especially if an outlet for the pith in bagasse can not be developed.

As pith has the same chemical composition as whole bagasse it would have the same gross calorific value and could be used as a fuel. Using a mixture of whole bagasse and pith to fire the sugar factory's power boilers would present no

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operating problems provided the pith does not constitute more than about two thirds of the total quantity of fuel. If more pith must be burned some modification to the power boilers would be required. By returning pith to the sugar factory for credit at its fuel value, the user would purchase only depithed bagasse. From the data given above, the quantity of depithed bagasse required may be calculated to be 4.25 metric tons (moist weight) per air dry metric ton of bleached pulp and would have a total value of US $26.

The foregoing estimates of the cost of bagasse have been based on the use of only that material which would be available from a local sugar factory whereby no transportation costs would be incurred. This is the situation at many existing mills. For other mills, bagasse is collected from a number of factories as far distant as 50 kilometers from the use point. If it is assumed that average transportation charges are of the order of US $2.00 per ton of green bagasse, the cost of bagasse per air dry ton of bleached pulp may be calculated to be US $53 if the pith can not be used. At this level, the cost of bagasse would be higher than that of a hardwood.

Surplus Bagasse

Sugar factories producing only raw sugar normally do not require the total quantity of bagasse that would be available. The surplus portion is dependent on a number of factors including the thermal requirements of the factory, the type and condition of the power boilers and the moisture content of the bagasse. In Report P2368/2 it is shown that in Mauritius about 16 percent of the bagasse is surplus. This bagasse would have either no, or nominal value to cover handling and to provide a small profit to the sugar factory. For those mills that use surplus bagasse the cost averages US $2.00 per metric ton of green bagasse plus transportation charges. By assuming, as in the previous case, that transportation charges average about US $2.00 per ton, the cost of bagasse to a pulp mill would be about US $26 per air dry metric ton of bleached pulp if the pith can not be used. If it can be used, and this would be probable because the sugar factories would be burning bagasse, the cost of bagasse would be reduced to about US $17 per air dry metric ton of bleached pulp.

Contracts

As discussed, the cost of bagasse to the user can be highly variable depending primarily on the price of alternative fuels and the fuel requirements of the sugar factory. Also, it is important that the user purchase only the material that is required. The type of contract that is prepared to cover the supply of bagasse can have a major influence on the potential profitability of the mill.

Depithed fibre is the raw material required for the production of pulp and building board while the material available is whole green bagasse. This contains about 46 to 52 percent fibrous material of which 35 percent is removed as pith. Unless the user can find an effective means of pith disposal, the contract for the supply of bagasse should be based on the depithed fibre content even though the pith may be non-returnable as fuel. As the calorific heat value of pith is similar to that of whole bagasse or depithed fibre it is reasonable to consider its return to the sugar factory for credit.

PULP AND PAPER PRODUCTS

General

Bagasse pulps are used in the manufacture of essentially all grades of paper including bag, wrapping, printing and writing, toilet and facial tissue, towelling, corrugating medium, linerboard, bleached boards and to a limited extent newsprint. The extent to which bagasse pulp is used in the furnish of the various grades of paper can be varied over a wide range and typical values have already been listed in Tables 3 and 4 based on information from Grace in Peru and San Cristobal in Mexico.

In many grades of paper and paperboard products, the bagasse pulp can be the major portion of the furnish. For others, when more strength (particularly tear) is required, the content of bagasse pulp may be only 30 percent. To achieve optimum properties in the finished sheet it has been found that the two pulps should be refined separately and then blended. In this way the short fibre pulps are refined to develop maximum tensile and burst and the long fibre pulps are refined just enough to develop maximum tear.

Bleached Pulps

Bagasse pulps are sold in relatively large quantities in the domestic markets of Mexico and Taiwan and to a lesser extent in several other countries. Fully bleached pulp is the principal grade marketed. Taiwan Pulp and Paper in Taiwan also sells bleached pulp to several neighboring countries, primarily Japan, India and Hong Kong, and at the present time is the only company exporting a bagasse pulp.

With increasing use of bagasse in the manufacture of pulps, trading should increase proportionately with bleached pulps continuing to be the principal type handled. As discussed in an earlier section, the physical properties of bagasse fibre are similar in many aspects to those of hardwood fibre and a comparable pulp should be obtained. Although a direct comparison of these pulps would not be valid unless their testing could be carried out in the same laboratory, an indication of the relationship may be obtained by considering a number of results from several sources. Comparative data for various bleached bagasse and hardwood pulps are shown in Table 11.

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Table 11 - Strength Properties of Bleached Bagasse and Hardwood Pulps

Item	Unit	Amount							
		Soda Pulps		Sulphate Pulps					
		Bagasse	Bagasse	Eucalyptus		Birch	Beech	Mixed	
		1	2	3	4	5	6	7a	8b
Freeness	ml	415	400	500	500	500	500	500	480
Breaking Length	km	4.2	-	5.2	5.8	7.0	5.8	3.6	6.9
Burst Factor		22	35	33	43	60	33	-	38
Tear Factor		53	60	99	92	88	98	98	87
Brightness	GE	83	80	88	84	88	88	88	82

a) United States species
b) Venezuelan species

The data shown in Table 11 indicate that the tear strength of commercial samples of bagasse soda pulp is lower than that of hardwood sulphate pulps. Other properties are slightly lower but tne ranges overlap. Based on experimental results (6) the sulphate process with bagasse yields only a slightly stronger pulp than the soda process. The differences are not as great as those observed when wood is pulped and are considered to be less than those observed between two soda pulps from bagasse, from cane of different varieties or grown under different conditions.

The bagasse pulps considered in Table 11 are from operating mills that use all the pulp produced internally for the manufacture of paper. On the other hand the hardwood pulps are primarily market pulps. Under these circumstances, the hardwood pulps would be expected to be produced with maximum strength properties to enhance their marketability whereas this would not necessarily be the case with the bagasse pulps.

Bleached Paper and Paperboards

Many grades of bleached paper and paperboard can be produced effectively from bagasse pulps. These include printing and writing papers, tissue and various bleached paperboard products. Although some bagasse mills are completely integrated with a multi-product paper mill a large number produce bleached pulps exclusively and manufacture only the related paper products.

Valentine Pulp and Paper in the United States, Propal in Colombia, Kimberley Clark in Mexico, and Ledesma in Argentina produce only bleached pulps by the soda process. Rafinodora Paulista in Brazil and Taiwan Pulp and Paper use respectively the Celdecor-Pomilio and sulphate processes to produce a similar product.

These mills produce pulps at a brightness level of 80-85 GE. The pulps are blended with various long or short fibre pulps obtained usually from wood. If a long fibre pulp from North American softwoods is used the amount of bagasse pulp in the paper furnish can vary from about 70 percent for an airmail bond to 90 percent for book papers and 92 percent for lightweight paperboards for mailing

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cards. If a short fibre pulp is used, for example from eucalyptus, the amount of bagasse pulp has to be decreased to between 35 and 50 percent of the furnish for comparable grades of paper.

Representative strength data for fine papers prepared from bagasse pulps and from hardwood pulps are shown in Table 12.

Table 12 - Strength Properties of Various Fine Papers

Item	Units	Amount 1	Amount 2	Amount 3
Pulp Furnish				
- Bagasse	%	90	-	-
- Long Fibre	%	10	-	-
- Hardwood				
- Type			Eucalyptus	Birch
- Amount	%		100	100
Properties of Paper				
- Basis Weight	g/m²	90	74	75
- Breaking Length MD	km	5.5	5.4	5.0
CD	km	2.2	4.2	3.9
- Burst Factor		22	43	60
- Tear Factor MD		62	90	82
CD		77	92	81
- Brightness	GE	83	89	88

As with the comparison of pulps, discussed in the preceding section, the data in Table 12 are only indicative of the relative quality of the various types of paper. The papers produced from bagasse pulps have lower burst and tear than those from hardwood pulps.

Wrapping and Linerboard

Several pulp mills produce a grade of pulp that is used in the manufacture of wrapping papers and linerboard. The soda process is usually employed and the yield of pulp is about 65 percent based on depithed bagasse. The Grace mill in Peru and the San Cristobal mill in Mexico produce pulps of this type.

Strength of the bagasse pulp is not comparable to that of a long fibre unbleached sulphate pulp as is normally used for the manufacture of wrapping papers and linerboard. To produce a satisfactory sheet therefore, a large proportion of the furnish must consist of these long fibre pulps. The normal proportion of bagasse pulp that may be employed, as shown in Table 3 in an earlier section of this report, is 30-40 percent for linerboard and 45-55 percent for wrapping papers. Some experimental furnishes have been produced as shown in Table 4 that can contain up to 70 percent bagasse pulp.

Wrapping papers and linerboard containing bagasse pulps are usually used domestically and would not compete effectively in foreign markets against products normally produced from long fibre sulphate pulps. However, for countries having a limited supply of pulpwood, the use of bagasse pulp does permit the replacement of material that would otherwise have to be imported.

Corrugating Medium

A number of mills produce a pulp from bagasse for use in the manufacture of corrugating medium. Rigesa in Brazil, Ngoye Pulp and Paper in South Africa, W. R. Grace & Company in Peru are several examples. This pulp is usually produced by the soda process but the cold soda process is used by Ngoye. Yield from the soda process is about 70 percent on the weight of feed to the digester.

The quality of this pulp for corrugating medium is considered to be very good. At most mills the pulp is mixed with repulped waste paper to provide the furnish for the sheet. The proportion of bagasse pulp in the furnish is 40 to 50 percent and the remainder can be waste paper only or waste paper plus a small amount of sulphate pulp.

The properties of a representative corrugating medium containing a bagasse soda pulp in the furnish are compared with those of a corrugating medium prepared from a hardwood neutral sulphite semi-chemical pulp in Table 13.

Table 13 - Properties of Various Corrugating Mediums

Item	Units	Amount	
		1	2
Pulp in Furnish			
- Bagasse	%	50	-
- Waste Paper	%	50	-
- Hardwood	%	-	100
Properties of Sheet			
- Thickness	mills	8	8.2
- Burst		40 - 48	42
- Tear MD		94 - 100	48
CD		105 - 109	62
- Concora		70 - 80	90

Newsprint

Bagasse pulps can be used in a furnish for newsprint. As noted earlier the San Cristobal Company in Mexico has experimented with the use of a semi-chemical pulp from bagasse for this purpose. This pulp is obtained by subjecting partially depithed bagasse to a mild soda cook. Screening removes a portion of the treated pulp. The remaining material can be pulped by a regular digestion to produce a bleachable grade of pulp or it can be refined for use as a semi-chemical pulp. This semi-chemical pulp has been used experimentally for 75 to 95 percent of the newsprint furnish; the remainder was sulphate pulp or sulphate pulp plus groundwood.

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Taiwan Pulp and Paper sells a small portion of its bleached bagasse pulp to a paper mill in Taiwan for use in the manufacture of newsprint. The furnish is made up of:

45-50% bleached bagasse pulp,
40% pine groundwood, and
10-15% long fibre bleached sulphate pulp.

In this application, bagasse pulp is used to replace a portion of the groundwood; this newsprint is used exclusively for color work.

As a part of their program on the experimental pulping of bagasse, which was undertaken in the 1950's, the Hawaiian Sugar Planters Association and the Crown Zellerbach Corporation investigated (6) the preparation of pulps from bagasse that could be used for newsprint grades of paper. Two approaches (15) were considered. A mechanical pulp was prepared directly from depithed bagasse by refining and, alternatively a pulp was prepared by treating the depithed bagasse with alkali for one hour at 70-100°C and atmospheric pressure, followed by refining. The chemical usage in this alkaline treatment was about 5 percent caustic soda on the weight of feed, so the treatment was essentially a cold soda cook.

The mechanical bagasse pulp was used experimentally in mixtures with chemical pulps produced from either wood or bagasse. The properties of an all bagasse newsprint containing 40 percent soda and 60 percent mechanical pulps compared favourably with a conventional United States newsprint produced from 22 percent softwood sulphite and 78 percent softwood groundwood pulps.

The cold soda bagasse pulp was also used experimentally with both bagasse sulphate and hemlock sulphite pulps in furnishes for newsprint. A comparison of the properties of the papers produced is shown in Table 14.

Table 14 - Newsprint Produced from Bagasse Pulps

Item	Units	Typical U.S. Newsprint	Newsprint from Bagasse Pulps 1	2	3
Pulp in Furnish					
- Cold Soda Bagasse	%	-	90	75	90
- Bagasse Sulphate	%	-	10	25	-
- Hemlock Sulphite	%	-	-	-	10
Properties of Sheet					
- Burst	%	22 - 26	26	29	32
- Tear	g/sheet	15 - 17	17	22	20
- Opacity	%	86 - 91	89	89	86

Although the possibility of using bagasse pulps in the manufacture of newsprint has been demonstrated experimentally the only pulp used commercially for this purpose is the small amount sold by Taiwan Pulp and Paper as mentioned above. Economic justification for extensive use of bagasse pulps in this field has yet to be established.

Dissolving Pulp

Bagasse pulps have not been used commercially as dissolving pulps for the manufacture of rayon or other cellulose derivatives. However, a number of studies have been carried out and the technical feasibility of producing this type of pulp has been established even though production is unlikely to be justified economically.

Experimental work carried out in Taiwan (16) is representative of these studies. This work showed that the depithed bagasse would require a pre-hydrolysis with steam prior to pulping, which for this work was based on the sulphate process. The pulp produced was then subjected to an acid treatment claimed to be required to remove ash. A conventional three stage bleach was used, but to produce a high alpha cellulose pulp a chlorine dioxide stage was also necessary. By using this sequence, a pulp having an alpha cellulose content of about 94 percent with 4-6 percent pentosan could be produced. Spinning trials indicated that a satisfactory viscose could be prepared.

PULPING AND RECOVERY PROCESSES

General

As discussed earlier, bagasse has been used as the raw material in the manufacture of essentially all types of paper and paperboard products. The principal pulping methods developed and used for wood have also been used for bagasse. At the present time the soda, sulphate and cold soda pulping processes are in commercial use. Monosulphite and neutral sulphite processes have also been used.

Bagasse has been found to be an easy pulping raw material as would be expected from its physical properties and chemical composition. Soda pulping is the most common approach in use today. This results from two main factors, namely:

a. Pulp produced by the soda process is essentially equivalent in strength properties to that produced by sulphate pulping and,

b. Most countries that utilize bagasse do not have saltcake, required for the sulphate process, available domestically. Imported material would be high priced compared to caustic soda which is usually produced locally.

The soda pulping process has been integrated with bagasse handling techniques and a number of processes have been developed that cover the overall approach of producing pulp from bagasse. They include bagasse preparation and storage, pulping and bleaching. The pulping stage of each of these processes is based on the use of caustic soda although saltcake could be used alternatively in most circumstances. These processes include the Peadco, Cusi and Celdecor-Pomilio and will be described later.

Three mills pulping bagasse are reported to be using the sulphate process. The mill of Taiwan Pulp and Paper Corporation (17) adopted this process about 12 years ago after having used the soda, monosulphite and neutral sulphite processes in succession. Since that time the sulphate process has been adapted to bagasse pulping and at the present time this mill produces only one grade of bleached pulp which is sold as a market pulp or is converted directly to paper products.

Taiwan Pulp and Paper uses vertical, stationary digesters. The depithed bagasse is impregnated with cooking liquor prior to being charged to the digester which, not being equipped with circulation, is used essentially as a retention tower. The chemical charge is 12 percent total alkali on the feed to the digester and the sulphidity is about 22 percent. After the pulp is blown, it is washed, screened and bleached.

The cold soda process is employed by at least one mill, to produce a grade of pulp for corrugating medium. At this mill the bagasse is treated with about 10 percent of its weight of caustic soda at a consistency of about 10 percent. Cooking is at 90°C and atmospheric pressure for a period of about 3.5 hours. The digested bagasse is refined in a double disc refiner and is then blended with repulped waste paper to provide the furnish for corrugating medium. The yield of pulp is only 55 percent due to the use of undepithed bagasse from which some pith is removed by the pulping process.

As mentioned above, several other processes, including monosulphite and neutral sulphite had been evaluated by Taiwan Pulp and Paper Corporation. These processes have been investigated at other locations but are not at the present time in use. The lime process is still used by a number of very small plants. By this technique the bagasse is mixed with lime and held for about a week. After this period it is washed and defiberized mechanically to produce a pulp.

The digesters that are now in use for pulping bagasse include rotary, stationary and continuous types. The same considerations apply to selecting a digester for bagasse pulping as for wood pulping. For all recent installations, continuous digesters have been installed.

In general, bagasse pulp is easy to bleach and most mills use a three or four stage bleaching sequence consisting of chlorination, alkaline extraction and one or two hypochlorite stages. Final brightness levels of 80-85 GE are usually obtained and total bleach consumption is 6-7 percent as available chlorine. About 4 percent chlorine is used in the first stage with the remainder being used as calcium or sodium hypochlorite in the final stages. The use of chlorine dioxide, as with wood pulps, would undoubtedly permit higher brightness levels, with minimal strength loss, to be achieved.

Peadco

The Peadco process (24), as developed by the Process Evaluation and Development Corporation, a subsidiary of W. R. Grace & Company is used by eight mills, located in Central and South America, having a combined nominal capacity of the order of 800 metric tons of pulp per day. These mills thus account for essentially as much pulp production from bagasse as the total of all other bagasse mills combined.

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The process is based on soda pulping and incorporates the following stages: depithing, pulping, refining and bleaching. Peadco depithing has been discussed in an earlier section of this report.

Pulping is carried out in a continuous digester and conditions are varied to provide pulps with the properties required for the paper products produced. The pulps are graded according to fibre classification for unbleached pulps and to fibre classification and chlorine demand for bleached pulps.

The first stage of the Peadco pulping process incorporates the impregnation of the depithed bagasse, either green or from storage, with hot black liquor for a short period at atmosphere pressure. This liquor is expelled in the screw feeder to the digester and with it about 12 percent of the weight of the depithed bagasse. Caustic soda, the cooking liquor, plus steam are added to the fibre as it enters the digester. Pulping is carried out as a vapor phase cook at a retention time of about 20 minutes. For the various grades of pulp, the digester conditions are as shown in Table 15; the only variable being the chemical charge.

Table 15 - Digester Conditions for Peadco Pulping Process

Pulp Grade		Bleachable Pulp	Linerboard Wrapping	Corrugating Medium
Permanganate Number		23	28	34
Yield	%	50	65	70
Caustic Soda Charge (on depithed bagasse)	%	11	7	5
Digester Conditions				
- Temperature	°F	347	347	347
- Pressure	psi	125	125	125
- Retention Time	min	20	20	20

Pulp as discharged from the digester can be fed directly to a refiner at the pressure and temperature of the digester. This step in the Peadco system has been evaluated experimentally with favourable results but has not yet been incorporated in a commercial operation. By use of the refining step screen rejects would be essentially eliminated and somewhat higher pulp yields could be achieved. At existing locations which use the Peadco system, the pulp is discharged directly from the digester to a blow tank.

Bleaching is carried out in a three-stage sequence incorporating chlorination, alkaline extraction and hypochlorite oxidation. The total chlorine demand to achieve a brightness level of 85 GE is 6-7 percent available chlorine on the weight of bleached pulp.

Cusi

The Cusi process (4, 11) is based on an approach to handling bagasse for the production of various grades of pulp that was developed by Dr. D. S. Cusi. This process is used by Cia Industrial de San Cristobal in Mexico to produce in excess of 200 metric tons per day of pulp; the largest output of bagasse pulp at a single location.

The process includes depithing as well as pulping as was mentioned earlier. About 20 percent of the bagasse is removed as pith. The pulping phase of the process involves the fractionation of the depithed bagasse into two fibre fractions; designated Fibres A and B. This fractionation is achieved by means of a mild soda cook (20-25 minutes at 80°C, atmospheric pressure and a chemical charge, caustic soda, of 6-8 percent on the weight of feed). The two fractions are separated by screening. The A Fibre amounting to 15-18 percent of the weight of depithed bagasse passes the screen and the retained material is B Fibre. The A Fibre is mixed with kraft waste and is used in the manufacture of corrugating medium. The B Fibre is pulped or refined to provide the desired product.

For pulping the B Fibre, it is impregnated with an excess of dilute caustic soda. This liquor is expressed in rotary presses to provide a fibre consistency of about 35 percent so that the net chemical pick-up by the B Fibre is about 10 percent of its weight of caustic soda.

The cook is carried out in the vapour phase at 155-160°C for 10-12 minutes in a continuous digester. The pulp after being washed may be used for such paper products as wrapping and linerboard in the unbleached state. Alternatively, the pulp may be bleached in a normal three-stage plant to a level of about 83 GE with a bleach consumption of about 6 percent as available chlorine. The yield of unbleached pulp from the B Fibre is about 55 percent based on the weight of feed to the digester. The overall utilization of the bagasse, as expressed by the yield of A Fibre and of unbleached pulp from the B Fibre, amounts to about 50-52 percent of the bagasse fed to the depithers.

If a semi-chemical pulp is desired, the B Fibre is refined. Such a pulp has been used experimentally, as discussed earlier, in the furnish for newsprint and several other types of paper products. This pulp is not at present being produced commercially.

Celdecor-Pomilio

The Celdecor-Pomilio process (18) was developed by Professor Umberto Pomilio of Italy originally for the pulping of straw but has been applied to various other fibrous plants including bagasse. It is used at the present time by six mills producing pulp from bagasse. Each of these mills has an average capacity of about 30 tons per day. They are widely dispersed geographically with mills in Mexico, Brazil, Philippines, India, China and Spain.

This process involves a preliminary treatment of the depithed bagasse with caustic soda, in a 2-3 percent solution, at 110-130°C for a period of about 3 hours. Alkali consumption in this stage is 6-9 percent of the weight of material fed to the digester. After washing, pressing to a consistency of 30 percent and fluffing, the pulp is chlorinated with 12-18 percent chlorine on the weight of pulp for a period of about 30 minutes. High consistency operation in this chlorination stage has been found to provide advantages over that at low consistency for incompletely fiberized materials such as those obtained from the alkali cook. After washing, the chlorinated pulp is treated with caustic soda, and is then bleached in one or two stages of hypochlorite bleaching. The overall yield of bleached pulp is 40-45 percent and the total chemical consumption is about 220 kg of caustic soda and 190 kg of chlorine per ton of pulp produced. The chemical requirements are thus reasonably well in balance for the operation of a chloralkali plant which is usually included as an integral part of the mill installation.

Pulp from the first stage caustic soda treatment can be used directly for the production of corrugating medium or for other grades requiring an unbleached pulp. The fully bleached pulp having a brightness of 80-85 GE is used in the furnish for a variety of grades of writing and printing papers.

Recovery of Pulping Chemicals

Several bagasse pulp mills have installed recovery units to process black liquor from the pulping operation. These mills include Kimberley Clark in Mexico, Ledesma in Argentina and Taiwan Pulp and Paper. The unit in Taiwan has been in operation for about twelve years in conjunction with a sulphate pulping process. The one in Argentina has been in operation for five years and the Mexican mill was started up early this year. Both of the latter units are used with soda pulping processes.

The installation in Taiwan is based on a recovery furnace supplied by Combustion Engineering. As this was the first recovery system to handle black liquor from the pulping of bagasse many problems were encountered but the process has now been developed successfully. The black liquor is evaporated to a concentration of about 60 percent solids. The chemical makeup is saltcake or anhydrous sodium sulphate obtained locally in Taiwan as by-products of the viscose spinning industry. The smelt produced by the furnace is dissolved to give green liquor which is then causticized. The lime mud is sewered as this provides a means of disposing of the silica contained in the black liquor which would otherwise build up in the system. The saltcake required for make up is about 45 kilograms per ton of pulp produced.

At the Ledesma and Kimberley Clark mills the furnaces have been supplied by Babcock and Wilcox. At the former location the black liquor is recovered at a concentration of about 8.5 percent solids and is evaporated in quintuple effect and flue gas evaporators to 65 percent solids. The carbonate smelt is used to form green liquor which is causticized with lime. The lime mud is calcined at this mill and no problems have been encountered that can be attributed to the silica content of the black liquor. This situation is considered to result from the fact that all the cane used is hand cut and is thus clean and low in silica. Overall efficiency of the recovery operation is estimated to be about 88 percent. No operating information is available as yet for the Kimberley Clark mill.

Silica content of the black liquor from pulping bagasse would appear to be the major problem in operating a recovery process. The concentration of silica can vary widely depending on the area in which the cane is grown, growing conditions, type of cane, harvesting methods and other factors. Silica causes fouling of the evaporator tubes, slag formation in the furnace and smelt buildup on the walls of the furnace. It hinders settling of the mud in the recausticizing plant, fuses lime particles into lumps in the lime kiln and generally increases the soda and lime losses throughout the recovery system. If allowed to buildup in the system it would also affect strength and sheet forming properties of the pulp.

Silica can be removed from the black liquor or from the overall system by a number of processes. The simplest approach is to sewer the lime muds from the causticizing stage as is carried out by Taiwan Pulp and Paper. This technique has the disadvantage of creating a disposal problem for the large quantity of lime mud that would be formed. Also because the lime would not be recovered, operating costs would be increased.

An alternative approach to removing silica is the Kokusaka process. In this process black liquor is taken from the evaporators when the concentration is between 20 and 30 percent solids and is treated with lime to precipitate calcium silicate which is separated by centrifuging. The clarified black liquor is then returned to the evaporators for further concentration prior to being fed to the recovery furnace. This process would be expensive to operate and also the capital investment would be high.

Bagasse black liquor has a slightly higher viscosity than that from the pulping of wood. The viscosity tends to increase sharply with solids content and this can create problems in evaporating and burning the liquor. This effect can be reduced and the combustion characteristics of the liquor improved by increasing the residual free alkali content of the liquor.

Composite Pulp Mill

Based on the foregoing consideration of the various processes used for the preparation, storage and pulping of bagasse, a pulp mill may be designed which incorporates optimum features in each stage. The installation of a pulp mill in Mauritius is described in Report P2368/2. This mill incorporates many of the process and design features discussed above. The mill is designed to provide an output of 100 ADMTPD of a bleached bagasse pulp which could be utilized in the production of printing and writing papers. Other grades of pulp could be produced simply by altering the pulping conditions. The main features of the mill are as follows.

The mill would be located adjacent to a large sugar factory which could supply all or at least a major portion of the bagasse requirements. The remainder would be trucked to the pulp mill in bulk. All bagasse would be depithed during the crushing season so that the pith could be utilized as fuel by the local sugar factory. The mill would thus purchase only that quantity of depithed bagasse that it would either use directly in process or place in storage for use during the non-crushing season.

Depithing would be carried out in a single stage, at the moisture content of the bagasse as received from the sugar factory, to remove 35 percent of the weight of bagasse as pith. Storage of depithed bagasse would be based on the bulk system as developed by Valentine Pulp and Paper.

For use, the depithed bagasse from storage or directly from the depithing operation would be washed and then impregnated with cooking liquor and fed to the digester.

The digester would be a standard, horizontal continuous digester with screw feeder and pulping would be carried out by the soda process. Chemical charge would be 12 percent caustic soda on the weight of feed to the digester. The yield of unbleached pulp from the digester would be about 50 percent based on the weight of feed.

Bleaching would be carried out in a standard three or four stage sequence consisting of chlorination, alkaline extraction and one or two hypochlorite stages to give a final brightness of about 85 GE.

The black liquor from the pulping process would be evaporated and treated in a recovery boiler. The carbonate smelt would be converted to green liquor and causticized but the lime mud would be sewered to prevent build-up of silica, originally present in the bagasse, in the cooking liquor.

The pulp after washing and cleaning would be fluff dried in an oil fired dryer and baled for shipment. Alternatively, the pulp might be used on site for the production of various grades of finished papers.

For the pulp mill described above the approximate direct manufacturing costs are estimated to be as shown in Table 16.

Table 16 - Unit Manufacturing Costs
100 ADMTPD Bleached Pulp Mill

Item	Unit Cost /ADMT of Bleached Pulp
Bagasse	US $ 27.10
Chemicals	7.10
Fuel Oil	
- Power Generation	9.30
- Process	10.50
Other Materials	8.50
Labour, Administration and Overhead	13.20
Total	US $ 75.70

These estimates have been developed on the basis that the mill would be located adjacent to a sugar factory which could supply whole bagasse and could use the pith as fuel. Costs are those developed for Report P2368/2 except that the quantity of depithed bagasse used would be charged to the process at a price of US $6.15 per green metric ton which comprises the fuel replacement value plus any allowance to the sugar factory. The assumption has been made that neither electric power nor chemicals (chlorine and caustic soda) are available in sufficient quantity to supply the mill and provision must be included for on-site production of the requirements.

In addition to the costs shown in Table 16 there would be charges for depreciation, interest and taxes plus an allowance for head office expenses each of which could vary widely.

Direct capital required for the pulp mill would be about US $12,300,000 plus an additional US $1,600,000 to cover working capital and start-up expenses. The direct capital would thus be about US $123,000 per daily metric ton of installed capacity and the total investment approximately US $139,000 per daily metric ton.

BUILDING BOARD PRODUCTS AND PROCESSES

Products

The same range of building board products can be produced from either bagasse or wood, and the common types include softboard, particleboard and hardboard. Each of these may be classified by its end use and formerly, also by mode of production. However, because of rapidly changing technology, boards for different end uses can be made in several ways. A description of these different types follows.

Softboard is used as interior panelling, acoustic tile and insulation board while a higher-density, treated softboard is used as sheathing for frame construction. The major portion is produced in 13 mm thickness at a specific gravity of 0.25. Because of the low specific gravity, it has very low strength properties. This board has normally been produced by a wet process but with recent developments a good quality product can also be produced by a dry process.

Particleboard is the term normally used to describe the medium density product that has found widespread use in the furniture core and cabinet fields. It is also used in many construction applications such as wall panelling , partitions, form work for concrete structures, and floor underlay. The material most frequently produced has a specific gravity of 0.65 and is from 19 mm to 30 mm in thickness. At this specific gravity, particleboard has a strength and stiffness of 25 to 60 percent that of plywood of the same thickness. Because of this relatively low strength and the fact that it is produced with interior-type resins, particleboard has not been used in exterior applications especially if plywood is available at reasonable cost. Particleboard is manufactured by a dry process. Normally, a smooth surface board can be produced at a lower cost than the lumber used for core material for plywoods or veneered panels, and thus can frequently be used to economic advantage in painted or laminated applications.

Hardboard is usually a thin high density product referred to freely as "Masonite" from the process, product and the company that first introduced it to the market. Hardboards are usually dark in color and much of the output is produced by a screen-back wet process, that produces a characteristic rough face on one side. It has high strength and stiffness, and is widely used in furniture manufacture, wall panelling and for concrete forms. As a medium density material, it has found a major outlet as exterior sheathing. The specific gravity range is from 0.75 to 1.00.

Hardboard is characterized by the property that on exposure to moisture it has low linear expansion which has significance in applications requiring large panels. This board can be "tempered", a process whereby oil is cured in the board. This stiffens and strengthens the board and also improves its moisture resistance. Hardboards with both sides smooth can be produced by making a special softboard which is then repressed into a hardboard. A similar material can also be produced by the dry process. A smooth, hard, relatively non-absorbent surface is a prime requisite for a hardboard as it is often painted or printed and thus should have no fibre pattern that might show through these coatings.

Production Methods

Generally, the softboards and hardboards are characterized by a fine fibrous structure that is felted in a wet-mat-forming process by which they are normally produced. Little or no resin is required as a binder. On the other hand, particleboards are usually produced by a dry process from a thin flake, sliver or chip (from wood) mixed with a relatively large amount of resin as the binder. There is essentially no felting of the individual fibres into a mat. Hardboards can also be produced by a compromise of the two processes. By a semi-dry process, a board can be produced in which the fibre structure is finely divided but some resin is required to provide the primary bond.

As bagasse is a fibrous material that can be finely divided with ease the dry process would appear to have the greatest potential with the density being varied to provide the type of board required. However both wet and dry processes are in use and will be described briefly.

Because the pith in bagasse has a very large surface area and is a highly absorbent material, the final properties of the board are strongly influenced by the amount of pith that is retained in the bagasse. Pith does provide the advantage that, being of small particle size, it will fill in around larger particles to produce a dense structure. This feature is largely offset by the fact that pith has a greater water absorption and that larger amounts of resin must be used to provide the required moisture resistance. It is generally recognized that the removal of pith is desirable. Depithing requirements are similar whether bagasse is to be used in the manufacture of paper or board products.

Wet Process

In the wet process, bagasse fibre after depithing is screened and washed to remove dirt and is then subjected to a mild digestion followed by mechanical refining. Either rotary batch digesters or continuous units are used. The large plant of Celotex Corporation incorporates a continuous digester plus pressurized refining. The digestion involves a steam cook without chemicals under high pressure to soften the material and so permit effective refining at reasonable power consumption. At other installations, following digestion the fibre is washed and is then refined and screened with oversize material being recirculated back to the refiner.

Early board plants used only a hydro-pulper for bagasse cooking, but this did not provide the required softening of the fibre for an efficient refining operation.

Dry Process

For certain dry processes, the bagasse may have been milled sufficiently in the depithing operation to serve as raw material for the production of particleboard. Normally, depithed bagasse is processed further and is milled or refined in a disc refiner fitted with plates to produce a cutting or abraiding action. The additional pith isolated can be screened out, particularly if the original depithing was incomplete.

These milling operations are affected by the moisture content of the bagasse. The higher the content the better the quality of the building board that can be produced but the power requirements will be increased. The milling of the bagasse fibre provides the advantage of breaking up the fibre bundles in the bagasse which could act as capillaries to transmit moisture into the finished board. This problem has been observed in many boards produced from bagasse that has been completely depithed. The tendency of a board to absorb moisture restricts its effective utilization in many applications for which dimensional stability is of importance.

After milling or refining the fibre is dried to the moisture content required for the mat forming and pressing operations. If phenolic resin is used it may be blended with the fibre before drying. With urea resins which are more sensitive to heat, the fibre is usually dried to 2-4 percent moisture before applying the resin so that after blending the moisture content of the mat going to the forming and pressing operation will be 8 to 12 percent. The phenolic resin can be blended with the fibre at a lower resin solids content and the blended material can then be dried to the desired moisture content, 4 to 10 percent, for forming and pressing. In the semi-dry process the fibre is dried after blending with resin to approximately 30 percent moisture content. The balance of the moisture is removed in the hot press by use of a screen on one side of the mat to allow the escape of the water as steam.

Resins are blended with bagasse fibre in an attrition mill or high speed blender. With the attrition mill a substantial amount of milling of the fibre can be achieved. The blender incorporates nozzles to spray the resin onto the fibre as it is mixed. Waxes or other additives can be added at this stage. If it is necessary to spray the wax, an emulsion containing 30 to 50 percent water is preferred otherwise molten wax can be used.

In nearly all cases the fibre is dried in a flash dryer. The input moisture content should not vary too widely as this will result in variable drying which can affect resin efficiency. Also the material should not be over dried or its temperature can increase to cause deterioration of pre-applied resins and case hardening of the material or can result in fires and explosions.

If bagasse is prepared for the production of building board to have optimum properties it must be in a fine fibrous form and must be effectively blended with the resins, waxes or other additives.

Mat Forming

Most wet process systems for hardboard or softboard utilize a fourdrinier screen or a rotary cylinder machine similar to those used in the paper industry. Some small operations use batch type wet-mat forming stations (Chapman process). The water which drains from the screens is normally returned to the stock chests and is recirculated.

In some operations the mat is passed through a set of rolls to dewater and consolidate it. Following this, the mat for softboard is trimmed to length and width and is then dried in a tunnel type dryer. For hardboard, the wet trimmed mat is placed on a wire screen mesh on a caul and then loaded into the hot press. As the press is closed, pressure forces out a large amount of the remaining water but the balance must be removed by drying. The screen mesh allows this water to escape from the board in the form of steam. This method produces a smooth one side, screenback board.

A combination of the softboard process followed by hot pressing to produce hardboard is known as the repressed softboard method. This system resembles a softboard line to the point of final trimming. The dried board is then loaded into a hot press and is repressed to a hardboard. A board with two good surfaces can be produced by this method. However, the plant investment is greater than for a standard wet or a dry process plant.

Another technique that has been used is radio frequency heating to complete the softboard mat drying process and to preheat the mat just prior to pressing. In several instances the radio frequency unit has been troublesome and has been removed from the system.

In the semi-dry process, the fibre is delivered to the forming machine at about 30 percent moisture. The machine is normally a vacuum unit with several heads. The fibre is fed to the various heads in such a manner that fine face fibres are formed on the top and the bottom of the mat with coarse fibres in the center. The vacuum felter forms the mat on a fourdrinier screen, but the medium is air rather than water. As in the wet system, the high moisture content requires the use of a screen to permit moisture to escape in the hot pressing operation.

There are several types of dry process hardboard formers. However, vacuum felters with multiple heads or with a special single head by which fine fibres can be concentrated in the top and bottom layers seem to predominate, especially in recent plant installations. The dry process vacuum felter operates in a similar way to the semi-dry process vacuum felter. The mat may be consolidated by a pre-press which reduces the height of the mat and may in some cases compress the edges. The mat is then trimmed to width and length and may be placed on a caul for pressing or may be inserted into the hot press in a caulless system that places the mat directly on the hot plates of the press.

In order to achieve hard smooth board surfaces as well as other necessary mechanical properties, the moisture content in the various layers of a dry process mat going into the press must be carefully controlled. Because of the increased explosion hazard in dry process hardboard plants, there has been a trend toward leaving a higher moisture content in the mat. This excess moisture can be subsequently removed from the board by lowering the hot press pressure at some point in the pressing cycle to permit steam to escape. The pressure is then increased to reset the face of the board.

Presses used in the manufacture of board products can be of the single opening or multi-opening types. The former type is considered to provide maximum flexibility as required in the manufacture of a wide variety of board types and sizes in one plant. The single opening presses can vary in size from about 1m x 2m to 2.5m x 7.5m and practically any size required can be fabricated. For the multi-opening presses, the sizes are normally smaller than for the single opening presses but the number of openings can be as high as 10. Pressures can also be varied over a wide range to produce the full range of board densities, from about 300 kg/m^3 to 1,000 kg/m^3.

Finishing Techniques

Almost all hardboards, whether made from wood or bagasse in a dry or a wet process, require humidification after pressing to establish equilibrium moisture conditions.

The high temperature hot pressing will have lowered the moisture content to such an extent that the board will warp rapidly from moisture pick-up in a non-uniform pattern.

The humidifying step consists in exposing the boards to several hours of relatively high temperature, high humidity conditions. The moisture can be restored by actually dipping the board in a water tank or by running it through a roll applicator fed with water. The latest, large capacity hardboard plants utilize a wicket type of continuous humidifier. In this unit, the boards are held in a vertical position at a spacing of about one inch as they are passed through the humidity chamber. In smaller plants and also in many of the older plants, a batch type system is used whereby the boards are stacked either vertically or horizontally on racks which are then rolled into a chamber resembling a lumber dry kiln. This batch process is simpler to operate and has certain advantages in a plant producing a large variety of products in relatively short runs, a situation which complicates the operation of a continuous humidifier.

In some hardboard plants and also in some other types of specialty board plants the board may be heat treated to improve its properties. This involves baking the board to extend the natural or synthetic resin bonding of the fibres further than can be accomplished in the hot press. Heat treating may also be used to relieve stresses generated during the pressing operation and also to facilitate the application of various moisture resistant compounds such as tempering oils. Heat decreases the viscosity of the material to assist penetration of the board, and assists the removal of any solvents. "Tempering" hardboard, which consists of applying a drying oil followed by baking, will result in better moisture resistance and in higher breaking strength and stiffness. However, the board becomes more brittle. Any heat treatment must be followed by humidification so that the board will have the correct moisture content when shipped.

Alternatively, in order to obtain moisture resistance, medium density hardboard or particleboard for siding may be subjected to a post treatment of hot stacking. If the board is produced with a phenolic resin binder, it will normally be placed immediately in a hot stack for a period of up to three days to allow the slower reacting phenolic resin to complete its polymerization and also to allow a better distribution of sizing agents. If the board is heat treated, this process will usually replace hot stacking.

For urea-bonded boards a limited hot stacking procedure is advantageous because it allows polymerization of the resin to continue, and also permits the sizing agents such as wax to become more effectively distributed. Depending on the production system, the hot press cycle time, and other factors, hot stacking of urea resin boards can last from one to three days. Care must be taken to assure that the moisture content in the urea-bonded building board is not too high, as this will result in a steaming action in the hot stack which can deteriorate the board properties. A high moisture condition usually occurs in boards that are produced with high density faces. To overcome this problem the urea-bonded boards are usually cooled as they emerge from the hot press. This allows moisture to flash off and some of the free formaldehyde to escape. The cooling process should not be carried too far as hot stacking may be affected.

The panel trimming and finishing of a bagasse board will be similar to that of a wood-based board. It should be noted that some phenolic-bonded bagasse boards will be more brittle than urea-bonded boards from wood. Also, if the proper depithing and fibre preparation steps have not been followed, there would be a substantial amount of abrasion due to included dirt and silica. For this reason, tooling for the finishing operation should be carefully selected. Carbide tipped saws will be a necessity.

The remanufacture of board may also be carried out and this can consist of cutting the board to size, edge and face milling, film laminating, painting, graining, plus the fabrication of various items from board products. These items include cabinets, doors, structural components for housing and many others.

Composite Building Board Plant

Based on the foregoing considerations of the various phases of the manufacture of building board, a plant may be designed which incorporates the optimum features of each phase. The installation of a plant in Mauritius is described in Report P2368/2. This plant incorporates many of the features described above to provide an output of 45 BDMTPD of a wide variety of board products. The main features are as follows:

The plant would be located adjacent to a major sugar factory which could supply the bagasse requirements and could also use the pith produced. The plant would thus purchase only depithed bagasse.

Depithing would be carried out during the crushing season in a single stage to remove 35 percent of the weight of bagasse as pith. Bagasse would be depithed as received from the sugar factory at 50 percent moisture content, and the pith returned to the factory for use as fuel.

Depithed bagasse would be stored in a bulk pile. Material for process could be used either directly from the depithing operation or from storage.

For use, the depithed bagasse would be washed and refined and would then be dried in a flash dryer to a moisture content of about 4 percent, bone dry basis.

The dry fibre would be blended with resin, principally of the urea-formaldehyde type, and formed into a mat and pressed. The mat former would be the multiple head type to provide good surface properties to the board.

The press could be either a single opening type of large platen size or a multi-opening unit. The type of press would be selected to have the desired flexibility to provide the variety of board products dictated by markets requirements. The type of finishing, and re-manufacture of the board would also depend on markets.

For such a board plant as described above the approximate unit manufacturing costs are estimated to be as shown in Table 17. Bagasse has been charged to the operation at a cost comprising the fuel replacement value and an allowance to the sugar factory, as for the composite pulp mill discussed earlier.

Table 17 - Unit Manufacturing Costs for 45 BDMTPD Building Board Plant

Item	Unit Cost /BDMT Building Board
Bagasse	US $ 13.40
Resin	23.30
Fuel Oil	4.50
Electric Power	5.20
Other Materials	2.90
Labour, Administration and Overhead	23.40
Total	US $ 72.70

In addition to the costs shown in Table 17 there would be charges for depreciation, interest and taxes and an allowance for head office expenses, each of which can vary widely.

The direct capital required for the board plant is about US $3,100,000 with an additional US $625,000 to cover working capital and start-up expense. The direct capital cost is thus US $69,000 per daily metric ton of installed capacity and the total investment is approximately US $83,000 per daily ton.

CHEMICALS AND OTHER PRODUCTS FROM BAGASSE

Furfural

Furfural is used primarily as a raw material in the manufacture of nylon but also to a lesser extent in the manufacture of thermo-setting plastics and adhesives, as a solvent in the synthetic rubber and petroleum industries, and for several other uses. It can be produced from any product having a high pentosan content. Commercially it is produced from corn cobs, oat hulls, cotton seed and rice hulls and also from whole bagasse. Experimentally it has been produced from many other raw materials.

Quaker Oats of the United States controls the world's production of furfural, and produces essentially the total output either directly or by license of its process. This company operates a plant in the United States and in a joint venture operates a plant at Central Romana in the Dominican Republic that use bagasse as the raw material. The capacity of each of these plants is estimated to be of the order of 15,000 tons a year.

The process used involves the digestion of whole bagasse, pith can be used equally well, with dilute sulphuric acid for a period of 6-8 hours at 153°C and a pressure of about five atmospheres. The digester is heated by steam which is also used to remove the furfural as it is formed, in the form of a steam distillate.

The digesters are operated on a batch basis and for each 200 kilograms of dry bagasse, 2 kilograms of sulphuric acid and 160-260 kilograms of steam are required to yield about 10 kilograms of furfural. The residue is used as fuel for generating the steam requirements. The overall yield of furfural from the dry weight of bagasse is about 5 percent although a number of experimental investigations have indicated that the recovery should be of the order of 9 percent. A plant having a capacity of the order of 5,000 tons per year is considered to be the minimum size that can be justified. Such a plant would require about 100,000 tons of dry bagasse as raw material.

The major market areas for furfural are the United States, Europe and Japan.

Briquettes

Production of charcoal briquettes from bagasse has been investigated experimentally. The process involves in sequence

a. carbonization of the bagasse, in bale form,

b. mixing the charcoal with molasses and extruding the mixture and,

c. carbonization of the briquettes.

By this operation about 270 kilograms of dry bagasse and 100 kilograms of molasses will produce 100 kilograms of charcoal briquettes.

The charcoal obtained has a very high surface area and thus can be used as an absorbent in various applications.

Although several small scale commercial operations have been established they did not prove to be economically viable and have since been closed.

Pith Disposal

The pith removed from bagasse used as the raw material for the production of paper pulp or building board presents many problems in its disposal. The most effective means of getting rid of this material has been to burn it in power boilers for the generation of steam, however a large number of existing pulp mills are not equipped to dispose of pith efficiently. Alternatively, a portion of the pith produced may be used as an ingredient of a cattle food supplement.

The heat content and fuel value of pith are the same as those of whole bagasse. Consequently, the burning of pith in a power boiler is simply a handling problem. Fly ash is excessive and addition of the required amount of air is difficult. From experience with operating power boilers, it is considered that pith can constitute up to about two-thirds of the feed for a bagasse fed power boiler without creating handling problems. Amounts in excess of this require the installation of special grates in the furnace to support the pith. Furnaces have also been altered or designed to use only pith as the fuel.

Pith has been used in certain areas as a mulch for cropland. Dyeing the pith to be similar to a peat moss in color has also been considered as a means of improving the marketability of the material.

Pith is being used effectively at a number of locations as an ingredient of cattle food supplement. The pith is used in a mixture with molasses and protein. Based on animal nutrition studies this food supplement should consist of one half cereal, a quarter roughage and a quarter protein. Crude molasses from the production of raw sugar is an excellent source of the cereal. Pith can be used as the roughage as it provides two features. It can be effectively assimilated by cattle and hence provide some food value. Also, because of its high surface area it can absorb a large quantity of a liquid such as molasses. The protein is usually added as a solid and can be of such material as fish meal. Whole bagasse in this outlet is not a satisfactory ingredient as too high a proportion of the material can not be assimilated by cattle.

Dosage for either dairy or beef cattle is considered to be about 5 kilograms per head per day but a somewhat lower dosage can be used with beef cattle if other foods have a satisfactory nutritional level.

Production of this food supplement involves drying the pith to a low moisture content, mixing it with the molasses and protein. The mixture may be pelleted or left as a loose powdery mixture. Additional drying is then carried out to remove tackiness associated with the molasses.

The use of pith as a filter aid or absorbent has also been investigated. Because of its large surface area, this outlet is considered to have good potential and experimental tests have provided promising results. No commercial operation has as yet been established.

CONCLUSIONS

This report has presented a review of the technology concerning the utilization of bagasse as a raw material for the production of pulp, building board and various other products. From this review the following conclusions have been drawn.

1. Bagasse is now used primarily as a fuel by the sugar factories and only about 5 percent of the total quantity available is used as a raw material. The quantity of pulp produced from bagasse is about 0.6 percent of the total world production of pulp from all fibre sources.

2. Dry bagasse is comprised of fibre and pith and these components are similar in most respects. However, because of the short fibre length of pith and its low alpha cellulose content compared with those of the fibre it has no value in the production of either a paper pulp or a building board and should be removed. Well depithed bagasse is similar to hardwood in most fibre characteristics.

3. Depithing can be carried out in one or two stages, either moist or wet, but about 35 percent of the total weight of the bagasse should be removed as pith to obtain a satisfactory raw material.

4. Storage of bagasse is essential in most areas as cane crushing is carried out for only a portion of each year. Bagasse may be stored in bale or bulk form, either before or after depithing. The recent trend has been to store fully depithed bagasse in a bulk pile.

5. Bagasse is now used primarily as a fuel and to use it as a raw material would require the purchase of a replacement fuel. The value of the bagasse used would comprise the cost of this other fuel, transportation charges, allowances to the sugar factory to cover handling and profit, and those charges incurred in modifying the power boilers to permit use of the alternative fuel.

6. A sugar factory producing only raw sugar does not normally require as fuel all of the bagasse available. This surplus could be used as a raw material and its value would be the transportation costs and an allowance to the sugar factory.

7. Bagasse pulps can be used in amounts of up to 90 percent of the furnish for many grades of fine papers and paperboard. These products are marketed in various circumstances in competition with products based on only wood pulps.

   The furnish for corrugating medium can be based exclusively on bagasse pulp but normally waste paper is used as well. Strength properties are in general comparable to those of a wood based sheet. For wrapping papers and linerboard the quantity of long fibre pulp in the furnish must be increased to about half of the total to obtain an acceptable product.

8. Essentially all pulping techniques used for wood have been used for bagasse. The soda process is the most common. Of the various techniques for using caustic soda, the Peadco process is considered to be the most important and it is used for the production of as much bagasse pulp as all other processes and techniques combined.

9. All types and grades of building board products can be produced effectively from bagasse. Equipment and techniques now available permit the full range of grades to be produced in one installation. The products are of comparable quality to those produced from wood.

10. Whole bagasse is used as a raw material in the manufacture of furfural. Pith may be used in a mixture with protein and molasses as a food supplement for dairy and beef cattle. It may also be used as a filter medium or as a mulch.

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APPENDIX 1

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APPENDIX 1

GLOSSARY OF TERMS AND BIBLIOGRAPHY

(F2368/1)

APPENDIX 1 - GLOSSARY OF TERMS AND BIBLIOGRAPHY

GLOSSARY OF TERMS

A	-	Annum
ADMT	-	Air dry metric ton (10% moisture, 90% bone dry fibre)
ADMTPA	-	Air dry metric tons per annum
ADMTPD	-	Air dry metric tons per day
BDMT	-	Bone dry metric ton
BDMTPA	-	Bone dry metric tons per annum
BDMTPD	-	Bone dry metric tons per day
Bl	-	Bleached
cal	-	Calorie
^oC	-	Temperature, degrees centrigrade
CD	-	Cross machine direction
D	-	Days
GE	-	Brightness, GE scale
kg	-	Kilogram
kg/m^3	-	Kilogram per cubic meter
kcal	-	Kilocalorie
kcal/kg	-	Kilocalorie per kilogram
kWh	-	Kilowatt hour
kWh/MT	-	Kilowatt hour per metric ton
MD	-	Machine direction
m^2	-	Square meters
m^3	-	Cubic meters
mm	-	Millimeter
MT	-	Metric ton

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APPENDIX 2

CANE SUGAR PRODUCING COUNTRIES

(P2368/1)

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REPORT P2368/1
UTILIZATION OF BAGASSE

UNITED NATIONS
NEW YORK U.S.A.

REVIEW OF BAGASSE TECHNOLOGY

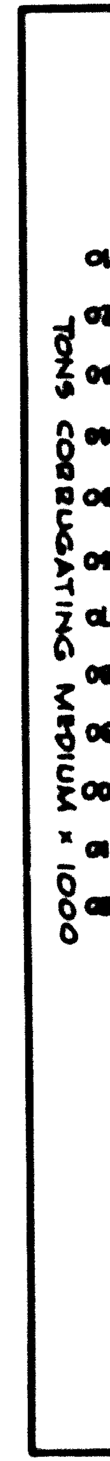
DATE 5 DECEMBER 1969

APPENDIX 2 - CANE SUGAR PRODUCING COUNTRIES 1966 - 1967 CROP YEAR (1)

Country	Raw Cane Sugar Production Metric Tons
Europe	
Madeira	3,000
Spain	44,000
Total	47,000
North and Central America	
Antigua	5,000
Barbadoes	204,000
British Honduras	59,000
Costa Rica	116,000
Cuba	6,128,000
Dominican Republic	760,000
El Salvidor	130,000
Grenada	1.000
Guadeloupe	137,000
Guatemala	181,000
Haiti	52,000
Honduras	49,000
Jamaica	464,000
Martinique	55,000
Mexico	2,538,000
Nicaragua	102,000
Panama	64,000
Puerto Rico	742,000
St. Kits	39,000
Trinidad	203,000
United States (Continental)	1,101,000
Hawaii	1,119,000
Total	14,249,000
South America	
Argentina	1,040,000
Bolivia	88,000
Brazil	4,390,000
Colombia	587,000
Ecuador	193,000
Guyana	347,000
Paraguay	36,000
Peru	775,000
Surinam	18,000
Uruguay	10,000
Venezuela	394,000
Total	7,878,000

Country	Raw Cane Sugar Production Metric Tons
Asia	
Burma	71,000
Ceylon	10,000
Taiwan (China)	780,000
India	2,309,000
Indonesia	605,000
Iran	38,000
Japan	89,000
Nepal	9,000
Pakistan	431,000
Philippines	1,549,000
Ryukyun Islands	199,000
Thailand	230,000
Total	6,320,000
Mainland China	1,850,000
Africa	
Angola	71,000
Congo	67,000
Ethiopia	84,000
Kenya	76,000
Madagascar	111,000
Mauritius	562,000
Mozambique	179,000
Reunion	224,000
Somalia	36,000
South Africa	1,628,000
South Rhodesia	260,000
Sudan	76,000
Swaziland	151,000
Tanzania	83,000
Uganda	149,000
United Arab Republic	351,000
Total	4,108,000
Oceania	
Australia	2,380,000
Fiji	308,000
Total	2,688,000
World Totals	37,140,000

APPENDIX 3



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APPENDIX 3

BAGASSE PULP MILLS

AND

BUILDING BOARD PLANTS

(P2368/1)

REVIEW OF BAGASSE TECHNOLOGY

APPENDIX 3 - BAGASSE PULP MILLS AND BUILDING BOARD PLANTS

BAGASSE PULP MILLS

Mill and Location	Capacity ADMTPD	Digester	Process	Product
North and Central America and West Indies				
1. Valentine Pulp and Paper, Lockport La. U.S.A.	90	Rotary	Soda	Bleached pulp for writing printing and tissue papers
2. Fabrica de Celulosa El Pilar, Mexico City, Mexico	55	Stationary	Soda-Chlorine	Bleached pulp for fine paper
3. Cia Industrial de San Cristobal, S.A., Mexico City, Mexico	230	Defibrator Continuous	Soda	Bleached and unbleached pulp for fine papers, tissues wrapping
4. Kimberley Clark de Mexico, Orizaba, Mexico	75	Defibrator Continuous	Soda	Bleached pulp for printing and tissue
5. Celulosa Orizabena, Orizaba, Mexico	10			Bleached pulp
6. Productora de Papel S.A., Monterrey, Mexico	60		Soda	Corrugating medium linerboard

BAGASSE PULP MILLS (Cont'd)

Mill and Location	Capacity ADMTPD	Digester	Process	Product
North and Central America and West Indies				
7. Puerto Rica International Paper, Arecibo, Puerto Rico	120	Defibrator Continuous	Soda	Corrugating medium
8. Papelera Pulpa (19), Ignaza, Cuba	60	Black Clawson Pandia Continuous	Soda	Bleached and unbleached pulp for fine papers, linerboard and corrugating medium
South America				
1. Ledesma S.A., Argentina	110	Black Clawson Pandia Continuous	Soda	Bleached pulp for writing and printing
2. Celulosa Argentina, Tacuman, Argentina	2		Soda	Unbleached pulp for wrapping
3. Rigesa, Sao Paulo, Brazil	60	Spherical	Soda	Unbleached pulp for corrugating medium
4. Rafinadora Paulista S.A., Sao Paula, Brazil	30	Pomilio Continuous	Soda-Chlorine	Bleached pulp for printing, writing
5. Fabrica Nacional de Carton, Cali, Colombia	60	Defibrator Continuous	Soda	Unbleached pulp for linerboard
6. Propal (International Paper & W. R. Grace) (20), Cali, Colombia	165	Defibrator Continuous	Soda	Bleached and Unbleached pulp for tissue, printing

(P2368/1, App. 3)

BAGASSE PULP MILLS (Cont'd)

Mills and Location	Capacity ADMTPD	Digester	Process	Product
South America				
7. Cia Papelera Trujillo Trujillo, Peru	150	Defibrator Continuous	Soda	Unbleached pulp for sacks wrapping, and corrugated medium
8. Celulosica Y Papelera Del Norte Lima, Peru	15	Rotary	Soda	Unbleached pulp for sacks wrapping
9. Sociadad Paramonga (21) Paramonga, Peru	150	Defibrator Continuous	Soda	Bleached and unbleached pulp for corrugated medium, liner, printing, wrapping, tissues
10. Venezolana de Pulpa Y Papel Caracas, Venezuela	100	Defibrator Continuous	Soda	Corrugating medium, bleached pulp
Asia				
1. Arco Pulp and Paper Rizal, Philippine Islands	20	Rotary	Soda	Bleached pulp
2. Central Azucarera de Baies Baies, Negros, Philippine Island	30	Pomilio Continuous	Soda-Chlorine	Bleached pulp
3. Rohtas Industries Limited Dalmianagar, India	18	Pomilio Continuous	Soda-Chlorine	Bleached pulp
4. Mandya National Paper Mills (22) Belagula Mysore, India	35	B. C. Pandia Continuous	Soda	Bleached pulp for printing, writing

BAGASSE PULP MILLS (Cont'd)

Mills and Location	Capacity ADMTPD	Digester	Process	Product
Asia				
5. Seshasayee Paper & Boards (23) Erode, Madras, India	70	B.C. Pandia Continuous	Soda	Bleached pulp for printing, writing
6. Shri Gopal Paper Mills Jagadhan, India	30		Soda	Bleached pulp for printing, writing
7. Bengal Paper Mills Raniganj, India	7		Sulphate	Bleached pulp for printing, writing
8. Strawboard Manufacturing Saharanpur, India	16		Lime	Strawboard
9. Jaswent Sugar Mills Meerut, India	20		Lime	Strawboard
10. Pearl River Paper Mill Canton, China			Soda-Chlorine	
11. Pao Lung, Taiwan	40	B.C. Pandia Continuous	Soda	
12. Taiwan Pulp and Paper Hsunying & Tatu, Taiwan	150	Stationary	Sulphate	Bleached pulp for printing, writing and market pulp
13. North Bengal Paper North Bengal, East Pakistan	60	Defibrator Continuous	Soda	Bleached pulp
14. Pakistan Paper Charsadda, West Pakistan	60	Defibrator Continuous	Soda	Bleached pulp

(P2368/1, App. 3)

BAGASSE PULP MILLS (Cont'd)

Mills and Locations	Capacity ADMTPD	Digester	Process	Product
Europe and Africa				
1. Empresa Nacional de Celulosa Motril Motril, Andalucia, Spain	36	Pomilio Continuous	Soda Chlorine	Bleached and unbleached pulp for range of papers.
2. Edfu, Egypt	60	B.C.Pandia Continuous	Kraft	
3. Ngoye Paper Mills	50	Atmospheric Steep	Cold Soda	Corrugating medium

BAGASSE BUILDING BOARD PLANTS

Mills and Locations	Capacity	Digester	Process	Product
North and Central America and West Indies				
1. Grefco Vacherie La. U.S.A.	80-90	Dry		Particleboard
2. Celotex Corporation Marrero La. U.S.A.	550	Wet		Softboard, accoustic tile
3. Panag Port Louis, Gualeloupe		Dry		Particleboard
4. Standard Building Products Kingston, Jamaica	50-100	Dry		Particleboard
5. Cuban Bagasse Products Los Cruces, Cuba	40	Dry		Particleboard
6. Compania Cubana Primadera Cuba	50	Wet		Hardboard
7. Imusa Mexico City, Mexico		Wet		Hardboard

(P2368/1, App. 3)

BAGASSE BUILDING BOARD PLANTS (Cont'd)

Mills and Location	Capacity ADMTPD	Digester	Process	Product
North and Central America and West Indies				
8. Fibro Aglutiandos Naucalpan, Mexico	5		Dry	Particleboard
South America				
1. Tablopan de Venezuela San Matio, Venezuela	45-70		Dry	Softboard, particleboard, hardboard
2. Venezuela			Wet (from pith)	Softboard
3. Peru	30 (Under Construction)	Dry		Particleboard
Asia				
1. Taiwan Sugar Corporation Taiwan	50	Dry		Particleboard
2. Taiwan Sugar Corporation Chi-Chow, Taiwan	60	Wet		Softboard, hardboard
3. Crescent Sugar Mills Lyallpur, Pakistan	30 (Under Construction)	Dry		Particleboard
4. Crescent Sugar Mills Lyallpur, Pakistan	60 (Under Construction)	Wet		Hardboard
5. Okinawa, Japan	50	Dry		Particleboard

BAGASSE BUILDING BOARD PLANTS (Cont'd)

Mills and Locations	Capacity ADMTPD	Digester	Process	Product
Asia				
6. Anil Hardboards Bombay, India			Wet	Softboard, hardboard
Africa				
1. Komombo, Egypt	30		Dry	Particleboard
2. Bagapan Reunion	42		Dry	Particleboard

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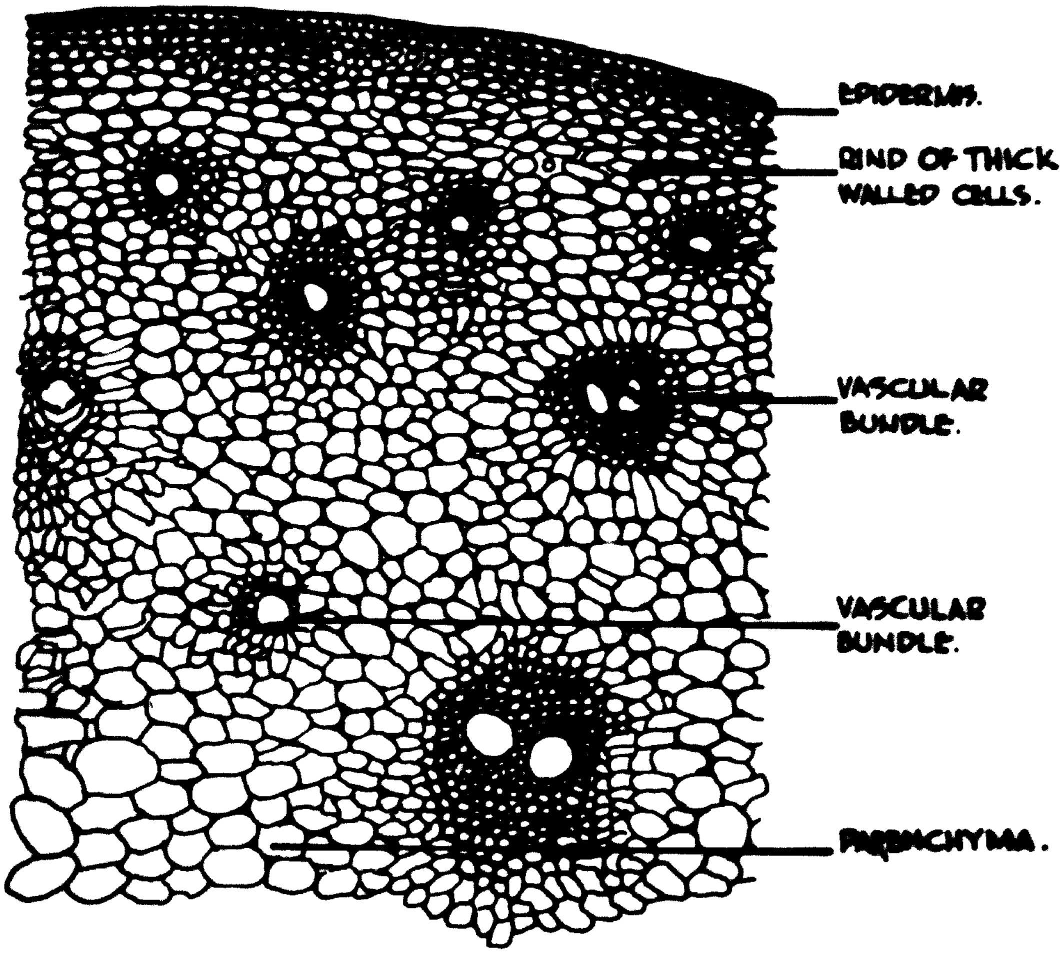
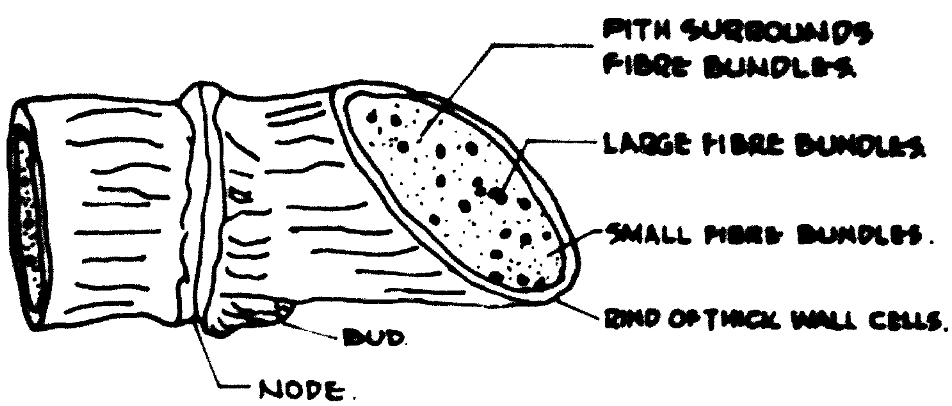
APPENDIX 4

ILLUSTRATIONS

(P2368/1)



CROSS SECTION.



TYPICAL CANE STALK.

DWG. No.	REFERENCE	REF. No.	REV	BY	DATE	REVISION	APP'D.

			DAY	MO	YR
APPROVED	SCALE	——			
DATE	DR'N	G.W.	29	9	69
	CH'K'D				
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	APP'D				

UTILIZATION OF BAGASSE
CROSS SECTION OF SUGAR CANE

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DWG. A. 2368 - 1 REV

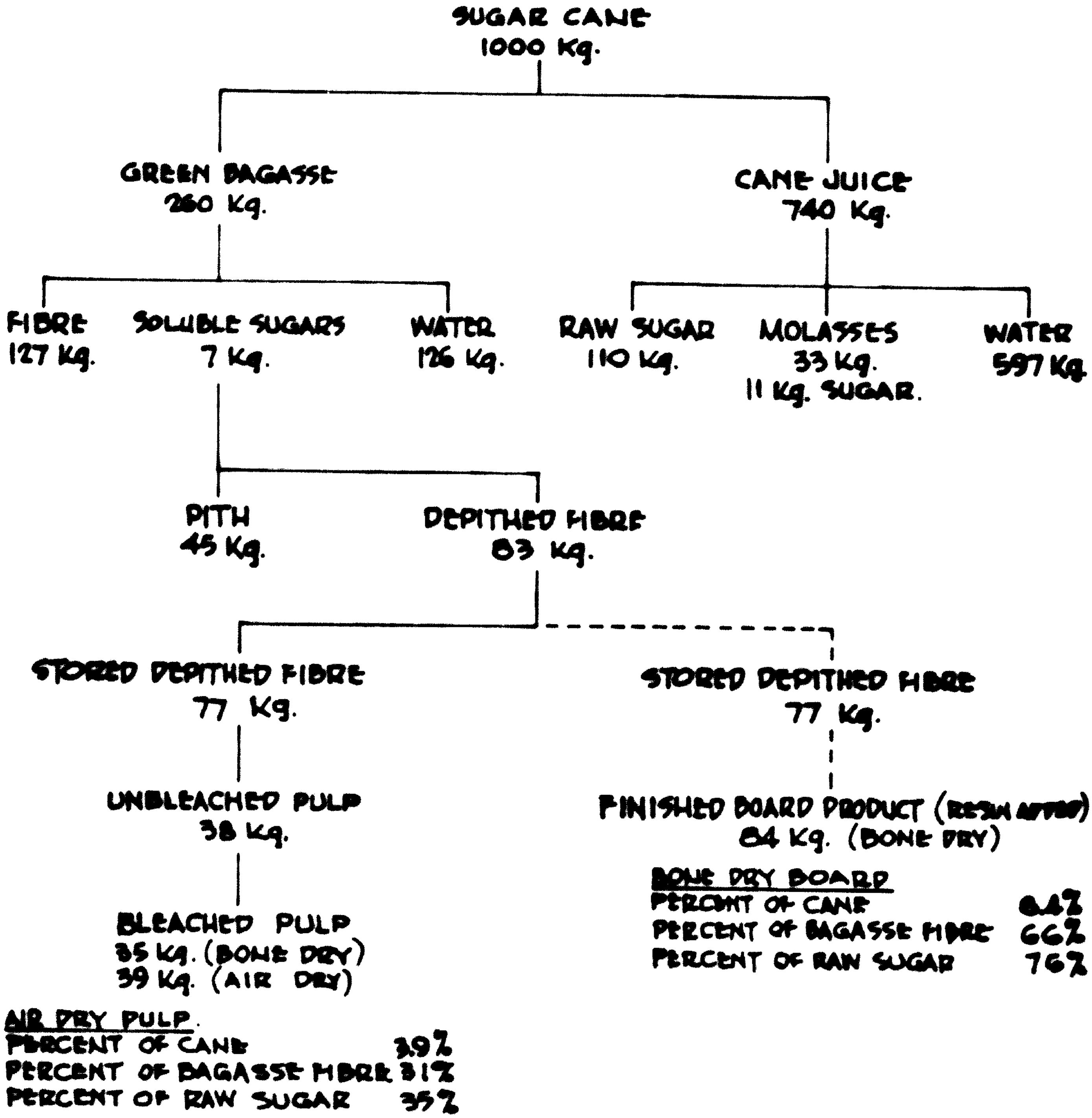

FIGURE 2. – P.2368/1

DWG. No. | REFERENCE | REF. No. | REV. | BY | DATE | REVISION | APP'D.

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SCALE –

DR'N G.W. 19 9 69

CH'K'D

APP'D

APP'D

UTILIZATION OF BAGASSE.

DISTRIBUTION OF COMPONENTS OF SUGAR CANE AND PULP AND BOARD PRODUCTION.

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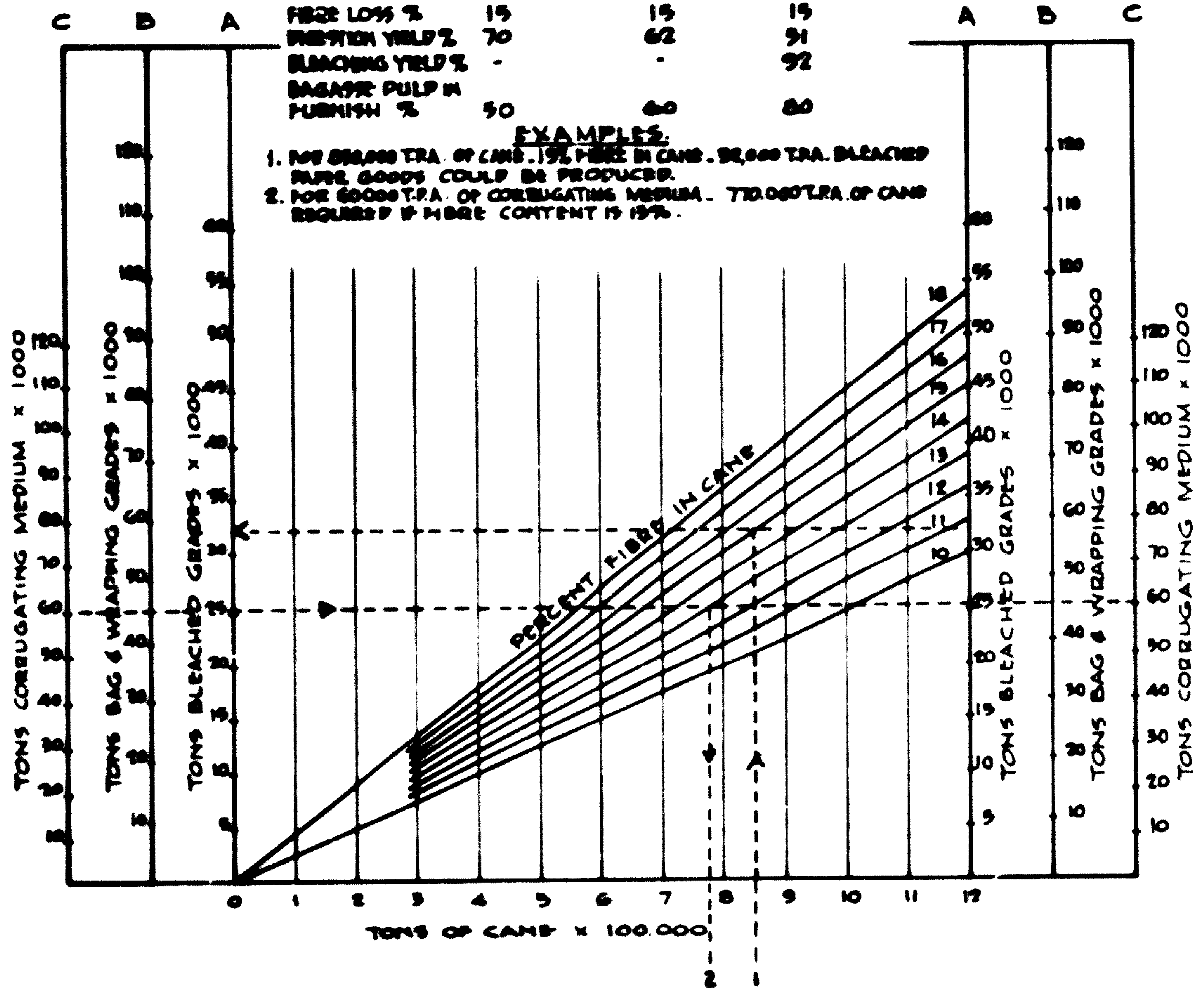
BASIS.	CORRUGATING MEDIUM.	BAG & WRAPPING.	BLEACHED PULP.
DEPITHING YIELD %	90	90	90
FIBRE LOSS %	15	15	15
DIGESTION YIELD %	70	62	51
BLEACHING YIELD %	-	-	92
BAGASSE PULP IN FURNISH %	50	60	80

EXAMPLES.

1. FOR 850,000 T.P.A. OF CANE, 15% FIBRE IN CANE - 32,000 T.P.A. BLEACHED PAPER GOODS COULD BE PRODUCED.
2. FOR 60000 T.P.A. OF CORRUGATING MEDIUM - 770.000 T.P.A. OF CANE REQUIRED IF FIBRE CONTENT IS 15%.



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APP'D

APP'D

UTILIZATION OF BAGASSE

PAPER PRODUCTION FROM SUGAR CANE

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DWG. A.2368 - 3 REV

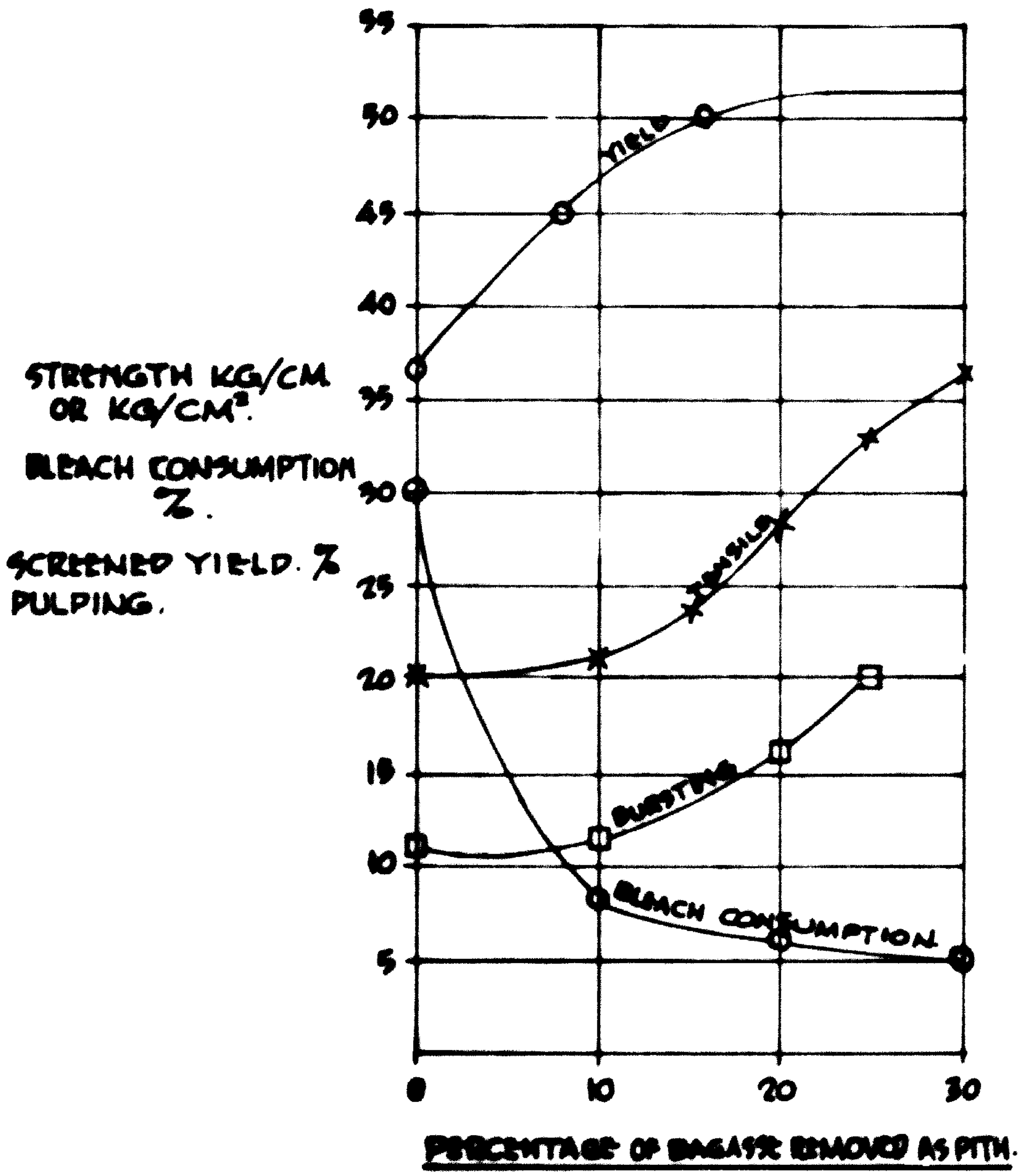

FIGURE 4 - P. 2368/1

DWG. No.	REFERENCE	REF. No.	REV	BY	DATE	REVISION	APP'D

			DAY	MO	YR
APPROVED	SCALE	—			
DATE	DR'N	G.W.	19	9	69
	CH'K'D				
A	APP'D				
	APP'D				

UTILIZATION OF BAGASSE.

EFFECT OF PITH ON PULP PROPERTIES.

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DWG. A.2368-4 REV

EXAMPLE: [illegible] EFFICIENCY FOR SUBSTITUTE FUEL (OIL)
[illegible] MOISTURE IN BAGASSE
12.5% CO_2 IN FLUE GAS. 512°F STACK TEMPERATURE
1. FROM CHART I, READ EXCESS AIR AT 60%.
2. ENTER CHART II AT 512°F TO 60% EXCESS AIR, THEN HORIZONTAL TO CHART III
3. FROM INTERSECTION WITH [illegible] MOISTURE PROCEED PARALLEL TO AVAILABLE HEAT LINES TO REFERENCE LINE
4. PROCEED HORIZONTALLY TO CHART IV TO INTERSECTION WITH FUEL AND EFFICIENCY LINE THEN VERTICALLY DOWN, READING [illegible] LBS BAGASSE, EQUIVALENT TO 1 LB. OIL.

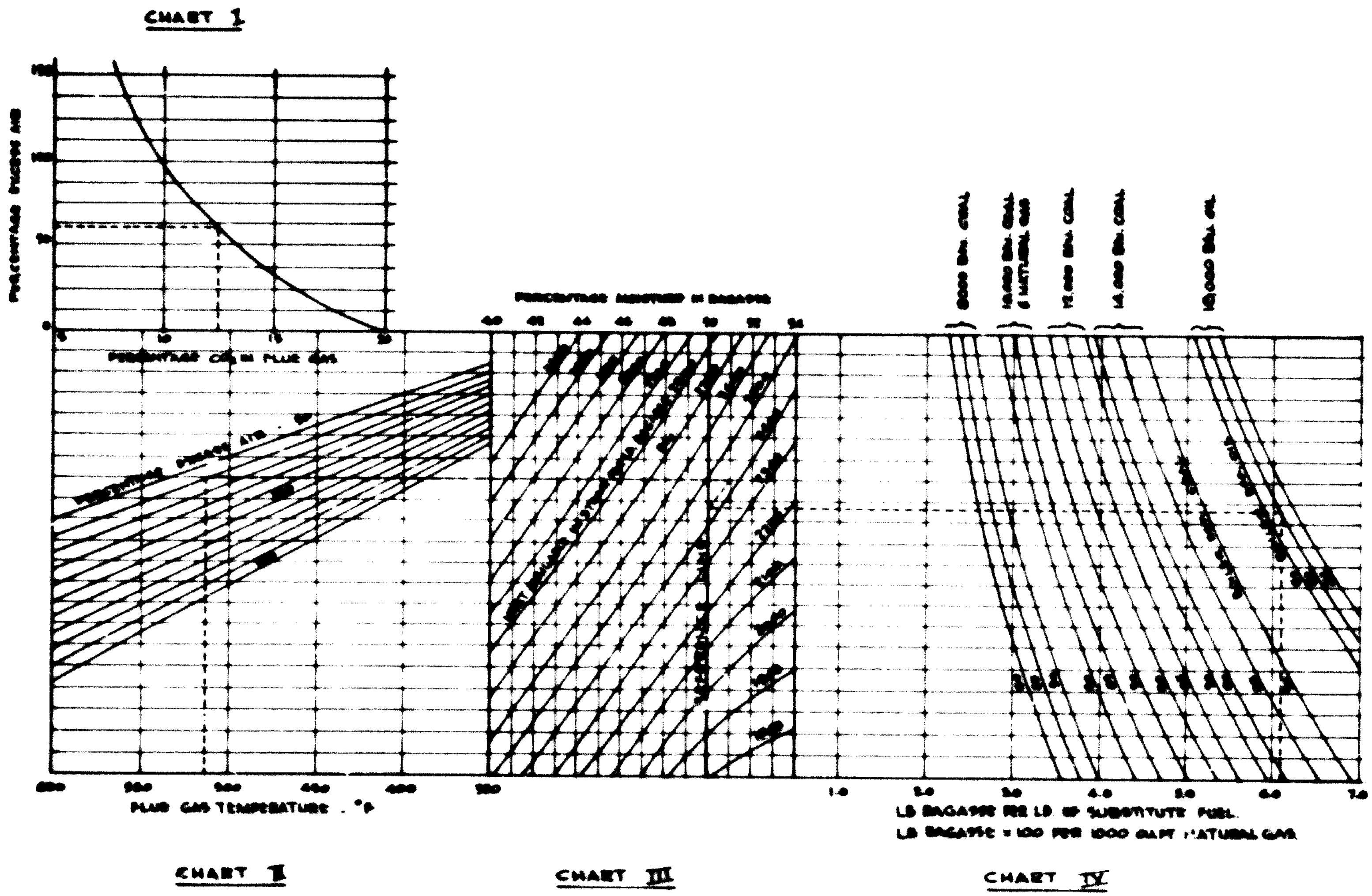

FIGURE 9. P. 2368/1

UTILIZATION OF BAGASSE

FUEL REPLACEMENT OF BAGASSE

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