Bagasse—The promising raw material for the paper industry

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SUMMARY

In the present context of fast depletion of traditional fibrous raw materials for the paper industry, such as soft woods, hard woods, bamboo, which are all forest based, and the need to stop deforestation for ecological reasons, the paper factories all over the world are looking to agricultural residues as raw materials for making different kinds of paper. Of all the agricultural residues, bagasse holds a big promise due to various advantages enumerated in this article.

The sugar factories which had been using bagasse as a captive fuel all these days, have also realised the value of bagasse for other industries, particularly for the paper industry and started economising the use of bagasse as fuel and saving as much bagasse as possible for diversion to the paper industry. The energy conservation measures to be adopted in the sugar factories to achieve the objective of saving bagasse, are indicated in this article.

Handling, storage, depithing, pulping, bleaching of bagasse pulp and the production of newsprint and other kinds of paper are briefly touched in this article. The working of some of the important bagasse based paper plants in the world, is also indicated in this article. Bagasse based paper plants would improve the economics of both the sugar as well as paper industry, particularly in the developing countries of the world.

INTRODUCTION

The developing countries in the world usually import pulp and different kinds of paper from countries like Canada, USA, Sweden, Finland, Norway, etc. which normally produce large quantities of pulp, newsprint and kraft liners, making use of their abundant forest resources, particularly coniferous woods. Thus, the developing countries spend considerable amount of foreign exchange for import of pulp and paper. But due to increasing cost for raw materials, labour, fuel, as well as restrictions on the use of forest resources due to ecological reasons, shortage of traditional fibrous raw materials for the pulp and paper industry is being experienced in different countries and in this context there is a need for every country to become self sufficient so far as their requirements of pulp and paper are concerned. Fortunately, most of the developing countries in the world are agriculture oriented and by a proper planning it should be possible for them to establish pulp and paper factories based on indigenous agricultural residues like straw and bagasse. By this, the developing countries should be able to step up their production of pulp and paper and reach a per capita consumption of at least 40 Kgs for meeting the minimum requirement of literacy, technical education, packing of industrial products etc. Table No. 1 shows the production, consumption and per capita consumption of paper and board and pulp in the world's 20 top countries.

Historically, paper was made from non-wood fibrous raw materials like the jungle grass, straw, wild canes, reeds, cotton rags, etc. Later on, due to the development of efficient chemical pulping methods, these were replaced gradually by woody materials like soft woods to start with, and later on the hard woods. Now-a-days, wood has become the important source of fibrous raw material in the paper industry throughout the world. Soft woods

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*Any views expressed in this article are the personal views of the author.

TABLE—1

	Paper and Board production (1000 tonnes)			Pulp production '000 tonnes			Per capita coneumption (Kgs.)		
	Country	1979	1980	Country	1979	1980	Country	1979	1980
	1	2	3	4	5	6	7	8	9
1.	U.S.A.	57,498	56,764	1. U.S.A.	44,787	45,868	1. U.S.A.	285	272
2.	Japan	17,861	18,088	2. Canada	19,767	19,944	2. Sweden	213	205
3.	Canada	13,531	13,471	3. Japan	9,993	9,788	3. Canada	215	192
4.	U.S.S R.	8,700	8,900	4. U.S.S.R.	8,700	9,000	4. Switzerland	161	168
5.	Fed. Rep. Germany	7.444	7,498	5. Sweden	9,083	8,699	5. Denmark	174	163
6.	Sweden	6,281	6,182	6. Finland	7,037	7.234	6. Finland	165	162
7.	Finland	5,738	5,919	7. China	3,600	3,800	7. Fed. Rep Germany	155	155
8.	France	5,262	5,152	8. Brazil	2,443	3,507	8. Netherlands	148	155
9.	Peoples Rep. China.	4,900	5,100	9. Fep. Rep.	1,966	1,996	9. Japan	151	153
10.	Italy	5,101	4,935	10. France	1,913	1,829	10. Australia	133	145
11.	U.K.	4,198	3,793	11. Norway	1,529	1,494	11. Norway	136	140
12.	Brazil	3,002	3,468	12. Spain	1,225	1,328	12. Belgium	145	138
13.	Spain	2 534	2,565	13. Austria	1,223	1,229	13. Newzeland	147	128
14.	Mexico	2,245	2,462	14. Newzeland	1,101	1,147	14. U.K.	134	122
15.	Netherlands	1,705	1,714	15. Italy	1,188	1,075	15. France	117	116
16.	Rep. Korea	1,630	1,693	16. India	971	1,088	16. Austria	103	107
17.	Austria	1,565	1,616	17. S. Africa	988	1,012	17. Ireland	96	93
18.	Taiwan	1,336	1,479	18. Portugal	728	865	18. Italy	93	87
19.	Australia	1,310	1,491	19. Czechosla	858	853	19. Iceland	83	83
20.	Norway	1.400	1,373	20. Poland	774	821	20. German D.R.	81	82

(Source : Pulp & Paper International—July 1981)

are preferred to hard woods due to their lengthy fibre, being of the order of 3 to 5 mm, leading to the production of better quality of paper. Soft woods and hard woods are the main fibrous raw materials for paper making in countries like Canada and Scandanavian Countries which have abundant forest resources. But all countries in the world do not have the forests and even if they have, the recent thinking of maintaining the ecological balance has made them not to adopt deforestation by indiscriminate felling of trees for fuel wood or for timber or for paper or any other purpose as it leads to erosion of deforested hill sides silting of dams and rivers and flooding of river plains etc. On the other hand, every country is thinking of introducing a massive programme of social forestry to develop fast growing energy plantations, as normal development of forests takes at least 10 years. Deforestation for the sake of pulping woods would require regeneration of the woods after a minimum period of at least 10 years. With these limitations for using the traditional forest resources for pulp and paper making, particularly soft woods, hard woods, eucalyptus, pine, spruce etc., more and more countries are thinking of switching over to non-wood fibres. These are ofthree types :—

i) Natural growing forest plants like bamboo, esparto, sabai grass, reeds, etc.

ii) Fibrous crops like jute, hemp, kenaf, abaca, etc.

iii) Agricultural residues like rice straw, wheat straw, barley straw, sugarcane bagasse, etc.

i) Bamboo is generally grown in Asian countries like India, Burma, China, Thailand, Japan, Philippines, African and South American countries, where it is used in large quantities for the manufacture of paper. It is grown in a regulated way by the Forest Departments and it takes at least 10 years to grow a bamboo crop. Esparto is a grass and is generally grown in southern Europe like France and Spain and northern Africa like Morocco, Algeria, Tunisia etc. Sabai grass is also a variety of grass available in India and Pakistan forests. Different kinds of reeds are available in different countries like China, Korea, USSR, Egypt, Iraq, Rumania, etc.

ii) Jute and Hemp are grown in countries like India, Burma, Thailand, Philippines, whereas Abaca is peculiar to Philippines alone. Kenaf is an annual herbaceous plant grown in semitropical countries and is finding increasing use in the manufacture of paper. It is grown in South Africa, India, Sri Lanka, Morocco, Egypt, Mexico, Cuba, Argentina, etc.

iii) Cereal straws like rice straw, wheat straw and barley straw are generally available in almost all countries, but mainly used as cattle feed, fuel and for other purposes depending on the conditions prevailing in different countries. But, their use as raw material for paper manufacture is gradually increasing. Due to fast depletion of forest resources and the increasing need to arrest indiscriminate felling of wood and deforestation to maintain the ecological balance, more and more countries are looking to agricultural residues for the manufacture of paper. Of all the agricultural residues, bagasse holds a big promise because of many advantages enumerated in the following paragraphs. The main advantage of bagasse is that it is a renewable source of raw material for the paper industry and that sugarcane can be grown in large quantities in all the tropical countries and thus bagasse can be generated in large quantities. In countries like India, new short-duration varieties of sugarcane, which can mature in a period of only 8 months are being developed, which means a much fast growing fibrous raw material will be available to the paper industry by the new cane varieties. Many paper experts and paper machinery manufactures in the world are, therefore, concentrating on the development of new methods of bagasse storage, depithing, pulping, bleaching and paper making, and manufacture of machinery suitable for these operations, as they have all realised that in the future years bagasse would be the only promising raw material for the manufacture of different kinds of paper Similarly, in recent years, the sugar technologists all over the world have a'so become conscious of the value of bagasse as a fibrous raw material for the paper industry.

COMPOSITION AND PRODUCTION OF BAGASSE

The term 'Bagasse' was originally used for the Olive waste. Subsequently, this term was used for anything worthless. After the development of world cane sugar industry, the term 'Bagasse' is used for the fibrous residue left after the sugarcane is crushed in the sugar factories for extraction of cane juice. Bagasse, as it comes out of the milling plant, has about 46 to 52% moisture and is generally known as 'Mill Wet Bagasse'. It also contains small quantities of sugar, which cannot be economically extracted on a commercial scale. and hence sugar is lost in bagasse which is ultimately burnt as fuel in the sugar factory boilers. The composition of bagasse depends on many factors, but on the average the composition of Mill Wet Bagasse is as follows :—

a) Fibre	48.5%
b) Water	48.0%
c) Sugar	3%
d) Minor constituents	0.5%

The averge composition of bone dry bagasse is as follows :—

a) Cellulose	45.0%
b) Pentosans	28.0%
c) Lignin	20.0%
d) Ash	2.0%
e) Sugar	5.0%

The rind portion of sugarcane consits of high quality cellulose and is important for the manufacture of paper. The internal portion of sugarcane is known as pith or parenchyma, which is not fibrous and contains all the cane juice and is not desirable in the manufacture of paper.

The production of mill wet bagasse in any sugar factory depends on the fibre % cane, moisture % bagasse and is approximately about one-third of the total sugarcane crushed, though some countries have reported figures as low as 26% and as high as 38%.

TRADITIONAL USE OF BAGASSE AS CAPTIVE FUEL

Traditionally, from the very inception of the cane sugar industry all over the world, mill wet bagasse is used as captive fuel in the sugar factory boilers for raising steam required for driving the prime movers and for generation of electric power, and use of exhaust steam for concentration of sugarcane juice. Bagasse is the main fuel, and furnace oil, firewood coal are auxiliary fuels used at times when there is no bagasse production due to any breakdown in the plant or at the beginning of the season. Thus, bagasse is the main source of energy input into the sugar factory. It is for this reason that the boilers in the sugar factories are provided with special types of furnaces to simultaneously dry the wet bagasse and burn it. Almost all the constituents of bagasse except water contained in it, are combustible. In fact, it is on account of its water content alone that the calorific value of mill wet bagasse is considerably reduced and hence in the recent years efforts are being made in many sugar factories of different countries for drying bagasse and thereby increase its calorific value for saving bagasse.

Though many critics, other than those intimately connected with the sugar industry, feel that bagasse is wasted in the sugar factories as fuel, the author hopes that the following reasons will convince them of the necessity to use bagasse as a captive fuel in the sugar factories all over the world :—

1) Sugar industry is a seasonal industry dealing with highly perishable raw materials like sugarcane and intermediate products like cane juice, syrup, massecuites, molasses, etc. It cannot therefore afford to part with its ready fuel and depend on extraneous fuels like furnace oil, natural gas, coal, fuel woods, etc. whose supply position in many countries is not certain and in some countries they are not simply available or even if they are available, they are very expensive. This has been proved by facts after the global crisis of petroleum products from 1973 onwards, in the beet sugar factories, which use furnace oil as main fuel and the cane sugar factories, which switched over to p troleum fuels, leading to increased cost of production of sugar.

2) Any dislocation in the supply of extraneous fuels is likely to result in the stoppage of the sugar factory, leading to innumerable difficulties to the sugarcane growers, loss of sugar production, loss of revenue to the government, loss of employment and many other complications.

3) By using bagasse as captive fuel, sugar factories do not require funds for the purchase of extraneous fuels, storage space, transport arrangements, procurement arrangements, staff, etc.

It is a fact that in the past in many countries, the sugar factories had been lavishly using bagasse as fuel. The reason is quite natural that normally, in an abundant supply position of any material, nobody realises its value, as in the times of scarcity In addition to this, before the year 1950 or so, the alternative use of bagasse, particularly as fibrous raw material in the paper industry, was not well developed and saving of bagasse was of no use and on the other hand, it was leading to fire hazard, pollution, etc. In fact, the published literature shows that in some countries even if small quantities of bagasse were saved, to get over the fire hazard the sugar factories had to spend considerable amount of funds to transport it and dump it into the sea. In some other countries, as a means of disposing of surplus bagasse, the sugar factories had to burn the surplus bagasse to raise steam and simply condense the steam in air-cooled condensers to obtain pure boiler feed water.

In the recent years, due to technological developments, bagasse is considered to be a valuable raw material for the manufacture of pulp, paper particle board, furfurol, plastics and for generation of steam to produce surplus electric power. The

cellulose content of bagasse is responsible for its use as fuel and as fibrous raw material, In the paper industry. The pentosan content of bagasse is responsible for its use in the manufacture of furfurol, whereas the lignin content of bagasse is responsible for its use in the manufacture of plastics etc. Though many other products can be theoretically manufactured from bagasse, in actual practice, paper and paper products and furfurol are the main products be.ng produced in many countries on commercial scale. In view of the alternative uses of bagasse, it is high time that the experts in the sugar industry all over the world should also make all possible efforts to use bagasse efficiently as fuel wherever it is available and save as much bagasse as possible for diversion to other needy industries. Wherever alternative fuels like coal or briquetted lignite, peat, etc. are easily available in an uninterrupted way, efforts should be made to instal coal fired boilers in the sugar factories and the extra bagasse should be diverted to the paper industry. After an in depth study of the alternative fuels, the author is not in favour of using petroleum product like the natural gas, furnace oil in the sugar factories, due to the global petroleum crisis that developed from 1973 onwards creating scarcity of the fuels and increasing the cost of production of any commodity based on petroleum fuels. At the present time, when the world sugar prices are very low, increasing the cost of sugar production on this count is disastrous to any country. Coal reserves in many countries are more promising than petroleum fuels.

WAYS AND MEANS OF SAVING BAGASSE

By adopting even commonly known methods of energy conservation in the sugar industry, such as installation of waste heat recovery units like economizers, air preheaters, use of hot condensate as boiler feed water, it is possible for many sugar factories to improve the efficiency of steam generation. Similarly, by proper lagging of all the heating vessels, steam pipe lines. adoption of vapour bleeding from the evaporator to the juice heaters and vacuum pans, installation of vapour line juice heater in the path of vapours from the last body of the evaporator to the condensers and various other measures, the sugar factories can reduce the steam consumption to a considerable extent and thereby reduce the consumption of bagasse as fuel and save bagasse. In addition to these known methods, some of the latest techniques of energy conservation, being adopted in some sugar factories, are as follows :

The calorific value of mill wet bagasse is low, as considerable amount of heat is lost in drying bagasse in the first instance before it can catch fire in the furnace. The gross calorific value of mill wet bagasse with about 50% moisture is 9541 KJ/Kg (4102 BTU/Lb). If this bagasse is partially dried to reduce its moisture content to even about 45%, the gross calorific value increases to 10, 509 KJ/Kg (45.8 BTU/Lb), i.e. an increase of about 10%. By this, the steam raising capacity of bagasse is raised and thus a portion of bagasse produced in a sugar factory can be saved.

Reduction in the moisture content of bagasse has been achieved by many sugar factories in different countries by adopting— 1) improved milling practices, and 2) partial drying of bagasse. Improved milling practices include various milling techniques. For instance, though many sugar factories in different countries reported in the past, low moisture content of bagasse, perhaps the Mourliyan sugar company in Australia is the only factory in the world that has been constantly reporting as low as 41% moisture in bagasse. This is attributed to low mill roller speeds, good cane preparation, etc. The use of 'Lotus' rolls in Cajun sugar factory in Lovisiana, Don Pedro sugar factory in Philippines and elsewhere has been reported to have reduced the moisture in bagasse. Partial drying of bagasse has been effected in many factories in different countries by exposing the mill wet bagasse to the ambient air, making use of improved long bagasse return carrier and other measures In the recent years, 3 sugar factories in Philippines, 2 factories in Hawaii, 2 factories in Florida and 1 in Lousiana have installed large scale bagasse dryers like 'Stern-Rogers', 'Radar-Thompson' and 'Fred-Hausmann', which use the stack gases for drying bagasse from about 50% to 35% moisture and are thereby able to save bagasse. Since 1973, many beet sugar factories in France, Denmark and other continental countries had been using Thermo-Compressors and Mechanical Vapour Recompressors MVR) on the evaporators in order to reduce the consumption of steam and thereby reduce the consumption of furnace oil as fuel, to the extent of about 50% as compared to earlier requirement. A few cane sugar factories, particularly in Florida and India are tryirg to use similar equipment to reduce the consumption of steam and consequently the fuel in the shape of bagasse.

Adoption of all these energy conservation measures in the sugar factories will lead to reduction in steam consumption and fuel requirement, resulting in saving of bagasse for diversion to the paper industry, as is done in India.

BAGASSE AS A RAW MATERIAL IN THE MANUFACTURE OF PAPER

The importance of bagasse as a promising raw material in the manufacture of paper has been realised by almost all the paper technologists in the world towards the middle of the current century. Table No. 2 shows the comparison of bagasse with other fibrous raw materials like straw, soft wood, hard wood, ete.

6. Bagasse has good pulpability, bleaching and brightnesss etc.

7. Paper produced from bagasse has very good bursting strength, opacity and printing characteristics.

However, bagasse has a few disadvantages as compared to the traditional fibrous raw materials, some of which are as follows:—

TABLE—2

Sl. No.	Fiber source	Cellulose (Cross & Bevan)	Alpha Cellulose	Lignin	Pentosans	Ash	Silica	Fiber length	Fiber diameter
a)	Bagasse	54	38	19	30	4	1	800-2800	10-34
b)	Kenaf	52	35	17	22	3	—	730-1600	20.5 (Average)
c)	Cereal, Rice	46	32	14	25	17	10	650-3500	5-24
d)	Straw, others	50	33	17	25	5	5	—	—
e)	Soft wood	58	43	30	11	1	—	2700-3600	32-43
f)	Hard wood	58	44	27	27	1	—	1000-1600	38-50

Source : Pulp & Paper International- March 1982- Page 63.

The advantages of using bagasse as raw material in the manufacture of paper, as compared to the other traditional raw materials like soft woods. hard woods, straw, kenaf, etc. are as follows:—

1. 81 countries in the world at present are growing sugarcane and producing sugar and bagasse, and many more tropical countries are likely to grow sugarcane in the future years. Hence 81 countries at present can use bagasse as a raw material in the paper industry, though it is not realistic to expect that the entire bagasse would be available for the manufacture of paper.

2. Bagasse is of fast renewable nature fibre resources and can be easily collected in large quantities from a few spots like the sugar factories without spending considerable amount on its procurement, transport, etc.

3. Bagasse does not require cutting into pieces, as is necessary in case of wood, bamboo, etc., before pulping and thereby results in saving of equipment, energy, labour etc.

4. Pulp produced from bagasse requires less refining power.

5. Bagasse has less lignin as compared to woods and hence it requres less chemicals for cooking.

1. The cellulose content of mill wet bagasse is only 20% as compared to 90 to 95% in soft woods and 60 to 70% in hard woods and as such, transport of bagasse from the sugar factories to distant paper factories would mean transport of large quantities of pith and associated moisture.

2. Bagasse pulp is short fibred as compared to soft woods and hard woods, as can be seen from the table No. 2. Hence, good quality of paper would need admixture of at least 5% of long fibred pulp like pulp obtained from bamboo, soft wood, cotton rags, cotton linters etc.

3. Bagasse being short Fbred, it is more hydrated and hence it requires larger quantity of steam for drying paper. Hence, the paper making machine has to run slow to allow more time for the drying of paper and this results in reduction in the capacity of the paper machine.

4. The pith is the wall of the cell in which the sugarcane juice is stored. Pith is made up of paranchyma cells. It does not contain any fiber and is therefore not of any use in the manufacture of paper, and on the other hand it is responsible for many disadvantages in the process of manufacture of paper. Some of these are as follows: —

i) Pith is highly absorbent and therefore impurities are deeply absorbed and cannot be easily removed or completely bleached with the moderate chemical treatment adopted in the manufacture of paper. Therefore improper removal of pith would lead to adoption of drastic cooking and bleaching process requiring large quantities of chemicals. Paper made out of bagasse containing more pith has, therefore, more dark shining specks.

ii) Pith has a tendency to swell and turn gelatenous with caustic cooking whereby the wire and felt in the paper machine get clogged, reducing the drainage of water. This also reduces the drying rate of paper, all of which contribute to the reduction in the overall capacity of the paper machine.

iii) Pith has very little strength and hence the paper containing more pith has low strength.

With all these disadvantages of bagasse, particularly on account of its pith content, which is as much as 30% on the weight of dry bagasse, paper technologists all over the world have come to the conclusion by experience that in order to make good quality paper from bagasse, it is very essential to remove as much pith as possible from the bagasse. After realising this, the paper technologists and the manufacturers of paper machinery focussed their attention to develop suitable depithing equipment. In fact, it is only after introducing successful depithing techniques in the bagasse based paper plants that high quality writing and printing papers could be manufactured from bagasse all over the world.

BAGASSE HANDLING AND STORAGE

In the sugar factories, the bagasse produced is continuously fed to the boilers as fuel. The excess bagasse is either heaped or baled and stored and sold to the paper factories. Wherever the bagasse based paper plants are attached to a single sugar factory or cluster of sugar factories, the handling and storage of bagasse is very simple. In fact, the depithing of bagasse can advantageously be done in the sugar factory premises and the pith can be used as fuel in the sugar factory boilers. In some places the pith can be made into briquettes using some kind of low cost binding material and used as fuel, as this method improved the burning characteristics of pith, which is fluffy and has a tendency to get blown out of the furnace, as fly ash. The depithed bagasse can be simply blown into the adjoining paper factory premises by either making use of high capacity centrifugal blowers or by using belt conveyers. This reduces all the expenditure required for baling of bagasse, and transport of bagasse and even storage of bagasse as it can be made use of in the paper factory as soon as it is produced in the sugar factory during the season. It is only for the off season of the sugar factories that the adjoining paper factory has to store the bagasse. In addition, the paper factories attached to sugar factories, can obtain the utilities like steam, power, water, etc. from the sugar factory. and the management and technical personnel may be common to look after the interests of both sugar, as well as paper factories.

In the case of paper factories that are located far away from the sugar factories, the bagasse has to be depithed in the first instance, preferably at the sugar factory, and baled and transported in trucks or railway wagons depending on the circumstances prevailing in different countries. The bulk density of whole bagasse being of the order of only about 100 kg per cubic meter, it is very essential to remove as much pith as possible at the sugar factory itself and bale the depithed bagasse tightly to reduce the cost of transport. Experience has shown that partially depithed bagasse forms much better bales with proper strength for safe handling in transport and storage than full bagasse. Loose bagasse transport should not be attempted, as it increases the transport and handling cost and also results in lot of wastage.

Storage of bagasse is necessary at the paper factory site to meet the demand during the off season of the sugar factories. Normally all these days the practice adopted in many countries is to store bagasse bales procured during the crushing season in sufficient quantity to last till the beginning of the next crushing season. Thus, the paper factories require adequate space for storing the bagasse bales in the open area.

In 1920s and 1930s. the Celotex Corporation in Lousiana (USA) developed a classical method of bagasse bale storage, which is widely followed in many bagasse based paper plants all over the world. This method mainly consists in stacking the bagasse bales of 125 Kg. each with about 50% moisture in pyramid shaped piles with space in between each pile of about 1000 tonnes. The outside of each stack is treated with a preservative like boric acid and the stack is covered on the top with asphalt coated sheet metal. This allows the bagasse in the stack to dry at a controlled rate to prevent overheating & excessive buildup of Aceticacid generated by fermentation of residual sugar in bagasse. In countries like India, Philippines, Taiwan, etc. where there is manual handling of bales, the weight of each bale may be from 25 Kg. to 50 Kg. But, in countries like Mexico, Peru, Argentina, where there is mechanical handling of the bales, the weight of each bale may be of the order of 400 Kg Though the cost of storage of bagasse is less by large sized bales, the heat of fermentation of the residual sugar in bagasse

cannot escape sufficiently fast in large bales, resulting in the rise of temperature to about 70°C in the middle of the bale. Similarly, the Acetic Acid formed during the storage by the fermentation of the residual sugar cannot escape in large bales, resulting in lowering the pH to 2.0 and at high temperature, hydrolysis of cellulose takes place with consequent loss of weight of fibre, as well as deterioration of the fibre. Experience has shown that fresh bagasse consumes more chemicals for pulping and creates foaming problems. Bagasse stored for at least 10 weeks behaves better in pulping. Blackening of the surface of the bagasse bales as a result of fungus growth during storage does not interfere in pulping or reduce the quality of the pulp.

In the recent years, many bagasse based paper plants are adopting "Ritter Biological Pre-Treatment Process" for storage of bagasse. This method developed in South Africa, consists in suspending the partially depithed bagasse in a biological fluid (anticeptic agent) and transporting it to the special storage slab The biological fluid consists lactic acid bacteria cultured in a 2.5% concentrated molasses sollution. It is claimed that by adopting this process, in the secondary depithing the pith is easily removed, as it is softened by the biological fluid and this method is free from all the troubles faced in handling bales of dry bagasse. It is also claimed that in a given space, by adopting this process, more bagasse can be stored than by storing bales of bagasse.

DEPITHING OF BAGASSE

Mainly 3 methods of depithing of bagasse are followed in the bagasse based paper plants working in different countries – 1) Dry depithing, 2) Moist depithing, and 3) Wet depithing. The dry depithing of bagasse was adopted till 1950 when the other methods had not been well developed. In this method, the dry bagasse is beaten in hammer mills and the pith so separated from the fibre is screened and removed. As one would expect, the disadvantages of this process are heavy wear and tear of the equipment, loss of valuable fibre also along with pith production of lot of dust, etc.

In the second method of moist depithing, which is generally done at the sugar factory itself when the mill wet bagasse has about 50% moisture, an equipment known as 'Horkel" depither is used. This was developed at the Lousiana State University in 1950 by Dr. P.H. Horton and Dr. A.G. Keller and hence it is known as Horkel, combining the names of both the inventors. The equipment consists of a split casing in which a rotor with swing hammers work at 800 to 1000 RPM. In the top half, there is the inlet for moist bagasse and in the lower half, there are 2 outlets, one for the discharge of the pith separated and the other for the fibre required in the subsequent process of paper manufacture. The hammers are designed in different shapes, some for lifting the bagasse, some for loosening the pith from the fibre and some for moving the bagasse through the machine and keeping the screen plates clean for quick outlet of the pith. This equipment was subsequently developed by Parson and whittmore Inc., which had put this into commercial operation in Cuba in 1958. Simultaneously, the Hawaiian Sugar Planters Association in Hawaii also developed an equipment known as "Rietz" vertical axis hammer mill.

The third method of wet depithing is generally followed in the paper factories for secondary depithing of bagasse. As its name indicates. this method required large quantities of water to soak the bagasse in a hydrapulper, which is later fed to the depithers like the Horkel or Reitz. Wet depithing has many advantages over dry depithing like the effective removal of pith, leaving a uniform wetting of depithed bagasse, which is responsible for obtaining a uniform cooked pulp quality. Two stage depithing method is normally adopted in many bagasse based paper plants.

The different types of depithers now used in the bagasse based paper plants are—

1. Horkel Depither
2. Rietz Depither
3. Peadco Depither
4. SPM Depither
5. Gunkel Depither

PULPING OF BAGASSE

Having removed the pith from the fibre as far as possible, the next step is to cook the fibre for producing the pulp. Cooking process is mainly meant for loosening the fibre bundles from the adhering lignin by digestion with caustic liquors at high temperture and psessures. As can be seen from table No. 2, the lignin content of bagasse is lower than soft woods and hard woods. Similarly, ihe fibre or alpha cellulose content of bagasse is equal to that of soft wood and lower to that of hard wood. These two factors are responsible for easy pulpability and high yield of pulp from bagasse. as compared to soft and hard woods, which are the conventional fibrous raw materials of the paper industry, throughout the world.

There are different processes of pulping and some of these are as follows:—

Soda Process (NaOH)

2. Soda-Sulphate process (NaOH, Na_2S) Kraft Process
3. Neutral Sulphite and Bisulphite Process (Na_2SO_3, Na_2CO_3)
4. Thermo-Mechanical Process
5. Simon-Cusi Process
6. Dela Roza Proces
7. Peadco Process
8. Ayotla Process

Alkaline pulping. both kraft and soda processe are commonly used in all the countries for pulping of bagasse. Kraft process gives better results, as the bagasse can be digested in a period of just 2 minutes at 340°F (170°C) to give 56 to 60% yield of pulp. The experts in the paper industry are of the opinion that in case of large sized paper plants with chemical recovery system and where odour is not a problem, kraft pulping process is the best for bagasse pulping.

BLEACHING OF BAGASSE PULP

The main objective of bleaching is to obtain a bright pulp by removing lignin, resins, fatty acids, fatty acid esters, etc. Various bleaching chemicals used in the paper industry are Sodium Sulphite, Sodium Peroxide, Hydrogen Peroxide, Sodium Hypochlorite, Chlorine Dioxide, etc. Bagasse pulp obtained by relatively short cooks can be bleached with less chemical consumption, without losing the strength. Three stage bleaching using chlorine dioxide stages, with 2% total chlorine dioxide gave a brightness to the pulp to the extent of over 90% without loss of strength. However, it was found by the experts that removal of soil type of dirt in the bagasse by a thorough cleaning, washing and depithing of bagasse is essential to attain bagasse pulp of high brightness.

The bleached bagasse pulp is then gassed through to paper machine to produce different kinds of paper.

MANUFACTURE OF NEWSPRINT FROM BAGASSE

Newsprint is more or less a low grade paper and it is also a low priced sheet. However, newsprint sheets also have certain characteristics, which are as follows :—

a) Newsprint must have good opacity, which means the matter printed on one side of the paper should not be seen from the other side of the paper.

b) Newsprint must have high ink absorption property. This is due to the reason that printing ink consists of carbon black and mineral oils and in the present day high speed printing machines which take about 30,000 copies per hour, the newsprint should be able to absorb the mineral oil immediately leaving the carbon black so that the letters are not blurred in the high speed printing.

c) The newsprint must have a smooth printing surface, so that the print may appear clean and clear.

d) The newsprint should be soft, flexible and resistant to deformation.

According ro Dr. Joseph E. Atchison[1], who is associated with the manufacture of different kinds of papers including newsprint from bagassse since 1940, a good newsprint could be produced by making use of mechanical pulp, which alone can impart all the desirable characteristics of a good newsprint as indicated above. Mechanical pulp from bagasse can be produced by using Disc Refiners alone, by heating the bagasse followed by Disc Refiners or by using chemi-mechanical process, which involves a very light chemical treatment, followed by the use of Disc Refiners and subsequent bleaching with Hydrosulphite or Peroxide or both. According to him, none of the experiments conducted in the early years for the manufacture of newsprint making use of 100 per cent bagasse chemical pulp resulted in successful commercial production of newsprint. Test runs were carried out at the U. S. Bureau of Standards in 1952, using four processes which were known by their properietors. These were

a) de la Koza Corporation, New York.
b) Valite Corporation New Orleans, Louisiana.
c) H.L. Horn, New York.
d) Kinsley Chemical Co. (Chemical Process) Cleveland, Ohio.

Of the above four processes, the de la Roza process was found to have given some successful results for the production of newsprint. Based on this process, one newsprint plant was installed in Cuba and one was installed in Lousiana based on Valite process. The cost of production of newsprint in the first plant was found to be excessive and it never achieved its installed capacity. The second plant could successfully produce writing and printing papers but it could not produce good quality newsprint. The failure of these two plants in producing good quality newsprint was stated to be on account of using 100 per cent chemical pulp.

In the early 1950s, the W.R. Grace Co. operated

bagasse based newsprint plant in Peru, but the newsprint lacked opacity. Similarly, during the 1950s, one of the large German companies, Aschaffenburger carried out extensive studies on the production of bagasse newsprint based on semi-chemical pulp. In almost all these cases, in order to get even fair opacity, it was necessary to use a heavier weight sheet than the standard newsprint sheet.

For the past 25 years, the Simon Cusi Group had been offering process for the manufacture of newsprint from bagasse based on semi-bleached, semi-chemical bagasse pulp. Two full scale 300 tonne bagasse mills were instal ed by this Group in Peru and Mexico and are stated to be using a portion of mechanical pulp also in producing newsprint.

In the early 1970s, PEADCO (W.R. Grace) was actively working in the bagasse newsprint field. They established a plant in collaboration with the Hawaiian Sugar Planters Association producing mechanical type of pulp from bagasse In may 1982, a similar plant was installed in Paramonga in Peru.

BRIEF WORKING OF BAGASSE BASED PAPER PLANTS IN DIFFERENT COUNTRIES

The working of some of the leading bagasse based paper plants in the world is explained briefly in the following paragraphs.—

COLUMBIA

Productora de Papeles, S.S. (Propab), Cali Columbia:

This plant started its business in 1961 as a joint venture between International Paper Co. and W. R. Grace & Co. This is located in the Valle del Cauca. A major portion of the bagasse required by this plant is obtained on a contract basis from two nearby sugar factories in exchange for coal. The balance bagasse is purchased on a cash basis from other small sugar factories, all of which are located within 30 miles from this paper factory. The 2 sugur factories which supply major portion of bagasse, screen the bagasse and use the pith as fuel in the boilers, while the small suppliers do not adopt this practice. The bagasse is screened in Primary and Secondary screens at the paper factory and screened bagasse is baled and stored outside under metal roofs whereas the separated pith is burnt in the boilers.

The screened bagasse is cooked is 3 "Defibrator" Type of 2 tube horizontal Continuous Digesters having a capacity of 60 tonnes per day. By using 12 to 15% Caustic Soda on the weight of dry bagasse at a pressure of 120 p.s.i.g., the digestion is completed in 18 minutes. The pulp is washed twice on drum washers, bleached with chlorine, caustic extract and sodium hypochlorite in 3 stages. After the usual operations of centri-cleaning and admixing with imported long-fibered wood pulp, 30 to 80 grams per sq. meter (g.s.m.) manifold paper, bond paper, offset paper, wrapping paper (bleached and unbleached), bag paper (bleached and unbleached), Mimeograph papers and match stock papers are made at speeds upto 2250 feet per minute. All these papers are exported to Central American countries also.

PERU

Paramonga Paper Division, Peru

Paramonga Industrial Complex has 10,379 hectares under sugarcane cultivation yielding about 400, 000 tonnes of sugarcane. In addition to this, 190,000 tonnes of sugarcane of private growers is also crushed by the sugar factory. Bagasse does not require much storage at this sugar factory as it works almost round the year.

The bagasse pulp is produced in the paper division of paramonga by making use of three horizontal single tube continuous digesters with three stage washing and bleaching. This pulp is converted into folding boxes, corrugating boards, sanitary tissues, multiwall sacks etc., in the different plants located in the nearby areas having a total capacity of 300 tonnes per day.

Another big bagasse based paper plant with 300 tonnes production per day. known as the Papelera Trujillo, S A (Trupal) has been established by W.R. Grace & Co. at Cartavio. The bagasse is depithed at the sugar factory site adopting Peadco process and the depithed bagasse is delivered to the paper plant. Similar to the Paramonga Paper Division, large storage of bagasse is not necessary, as the sugar factory runs almost throughout the year and supplies bagasse continuously. At this factory, 2 American Defibrator Single Tube Continuous Digestors are used. In this mill, kraft paper and corrugated medium are produced.

MEXICO

The Kimberly Clark de-Mexico, Orizaba mill is the most diversified single mill anywhere in the world in terms of products produced from bagasse. It obtains bagasse supplies from the sugar mills at San Miguelito which is 13 miles away and La Margatia which is 50 miles away. Primary depithing of bagasse is done at the sugar factory and the pith is used as fuel in the factory boilers. At La Margatia sugar Mill, depithed bagasse is hydraulically compressed into Gondola cars, which carry 35 tonnes of bagasse bales per car. At San Miguelito Sugar Mill, the depithed bagasse falls into one of the 5 Pak-Mor Trailors (40 feet long), where it is

compacted by a hydraulic ram to multiply the pay load. At the paper factory site, the bagasse is dumped on a slab and pushed by a tractor into the slat conveyors and moved to two receiving water slurry tanks, which are mechanically agitated. Biological liquor is pumped into these tanks providing a preserving effect along with enzyme action, which starts to free the fibre from gums, waxes, pectins and sugar. The fibre does not deteriorate very much in storage. Consistency is controlled as the slurry is pumped to outside storage piles by open impeller pumps. The piles are built up on sloped and paved storage yard. The excess liquor drains off the piles into a canal returning it to a large plastic coated brick lined storage pit, ready for reuse.

Bagasse is pushed by the Bull dozers into a mixing tank from where it is carried to the outside cleaning and preparation area by a pipeline containing caustic extraction water from the bleachery to counteract corrosion. Water, along with the pith is strained in a stainless steel drainer-conveyor leaving clean bagasse fiber at 12% consistency. This is further de-watered by passing through a screw press and carried by a set of conveyors to the digester, which is American Defibrator type consisting of two horizontal 60" diameter cooking tubes. Cooking time is 20 minutes and the digested pulp is blown into the blow tank from where the pu p is sent to three stage pulp washers of $8' \times 16'$. Bleaching in three stages is also subsequently conducted. Different types of paper are made on five machines, including 2 ply facial tissues, 1 and 2 ply napkins, 1 and 2 ply towels, 1 and 2 ply toilet tissues, etc.

CUBA

Cuba, being a large producer of sugarcane, sugar, bagasse, etc,. the Cuban Sugar Cane Byproducts Institute (ICIDCA) conducted considerable R & D work on the use of bagasse for the manufacture of pulp, paper and other products. As a result of these efforts, with the assistance of UNDP, Cuba could establish in 1981, a pilot plant known as "CUBA-8" at Quivican (35 Kms. south of Havana). This plant is capable of producing 35 tonnes per day of bagasse newsprint, 35 tons/day of mechanical pulp and 5 tons/day dissolving pulp from bagasse. At this experimental plant, "Ritter-type" bulk storage system is employed. Depithed bagasse to the extent of 15,000 tons/year can be stored at this plant. Secondary depithing is done by using Horkel depither. The digester is a 2 tube Pandia unit. The cooked pulp is passed through 2 refiners and washed in a Cowen Screen and then in a 3 stage centrifugal system. Mechanical pulp goes to a peroxide mixer and then to a bleach tower followed by wasing and high density storage. For making dissolving pulp, there is a Scholz tumbling type digester after which the hydrolysis fluid is removed and the bagasse is then cooked by the Soda or Kraft process A full washing, cleaning and screening plant including 3 stage bleaching (CEH) can be used for both the dissolving as well as chemical paper pulps.

This experimental plant is capable of producing different kinds of pulp from bagasse like 1) mechanical pulp 2) thermo mechanical pulp 3) chemimechanical pulp which can be peroxide bleached and 4) Semi chemical pulp 5) Full chemical pulp which can be bleached in 3 stages and dissolving pulp. Training facilities are also available in this experimental plant.

Another commercial scale plant of 250 ton/day bleached bagasse pulp and paper mill is now under construction near Jatibonico, close to the Uruguay Sugar Mill.

INDIA

India is the country, where more and more bagasse is being used for the manufacture of different kinds of paper. In the context of fast depletion of traditional fiberous raw materials, which are mostly forest based and in view of the abundant availability of bagasse, the Government of India have introduced various kinds of incentives for the establishment of a bagasse based paper plants.

Of all the bagasse based paper plants working in India, a special mention has to be made about the Mandya National Paper Mills Ltd., in the State of Karnataka. This is the first successful bagasse based paper plant established in India in 1961 and today, its production capacity is around 60 tonnes of different kinds of paper per day. This unit is based on the surplus bagasse of the neighbouring sugar factories, which sell bagasse to this paper factory. Thus, the method of procurement of bagasse by this paper factory is quite different from most of the bagasse based paper plants in the other countries, as it is dependent on the saved or surplus bagasse of the sugar factories rather than the method adopted in other countries to obtain bagasse by substitution with other fuels like natural gas, furnace oil, coal, etc. This paper factory had been producing excellent quality writing, printing, manifold, duplicating and other kinds of paper, using as much as 86% bagasse fiber in the furnish and making paper ranging from 30 to 200 grams per square meter (Gsm).

In addition to this unit, five more paper factories in India have been making use of small quantities of bagasse saved by the sugar factories and sold to the paper factories. A novel idea conceived in India is

the establishment of small scale paper plants based on surplus bagasse by the sugar factories themselves. Realising the advantages of such small scale paper plants attached to the sugar factories, five sugar factories in india have already established paper plants having a daily production capacity of 25 tonnes of paper. 10 more sugar factories are likely to establish such units. 15 entrepreneurs, who are not having sugar factories are also likely to establish such small scale paper plants making use of surplus bagasse procured from the neighbouring sugar factories.

A large scale paper plant with an annual production capacity of 50,000 tonnes of newsprint and 40,000 tonnes of writing and printing papers is being established in the State of Tamil Nadu with the assistance of the World Bank. This is known as the Tamil Nadu Newsprint and Papers Ltd. This plant propose to procure the entire bagasse produced in the 6 neighbouring Sugar factories by installing coal fired boilers and supplying coal in place of bagasse and this expenditure would be completely borne by the paper factory. This plant is expected to go into production by the end of 1984. Similarly, the State Governments of Maharashtra, Uttar Prad sh, Bihar are also proposising to establish similar units by obtaining the entire bagasse supplies from the neighbouring sugar factories by substituting bagasse with coal.

2 or 3 owners of the paper factories in India are also establishing sugar factories for the sake of obtaining the entire bagasse for the manufacture of paper. With all these developments, India may perhaps be the leading country in the world to make use of bagasse for the manufacture of paper.

In Taiwan, 24 sugar factories managed by the Taiwan Sugar Corporation Ltd., are saving considerable quantities of bagasse. They are supplying bagasse to a paper factory working at Pingtungr which is producing 100,000 tonnes of paper pe, annum.

In Egypt, the EDFU Sugar Mill is also depithing its bagasse and supplying the depithed bagasse to the paper factory having a daily production capacity of 40 tonnes. This plant is producing tissues in combination with imported bleached pulp.

In Philippines, the United Pulp and Paper Co. at Calumpit, Luzon, is making multi ply extensible kraft paper by adopting "Clupak Process". This paper is used for making multi ply sacks for packing cement.

Thus, more and more countries are exploring the possibilites of establishing bagasse based paper plants in the future years.

CONCLUSION

Bagasse is a suitable raw material for the paper industry to replace the traditional raw materials like soft wood, hard wood, bamboo, etc. Bagasse has many advantages, when used as raw material in the paper industry, and thus will improve the economics of the sugar industry, as well as the paper industry and boost up the production of paper in every country.

REFERENCES

1. Atchison, J. E. (1979) Historical development of bagasse newsprint processes proposed and mills built.