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ISLAMIC REPUBLIC OF IRAN

Technical report*

Papers prepared and presented by
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TABLE OF CONTENTS

	PAGE
Latest Status of Waste Paper Treatments for Papermaking by Manfred Judt	1 - 24
Bagasse Utilization in Pulping and Papermaking: The Cuban Experience by Oscar L. Garcia Hector	25 - 48
The Chemistry of Papermaking by Leslie Webb	49 - 70
The Outlook for Pulp and Paper on Small Scale Based on Non-wood Fibres by N.S. Sadawarte	71 - 94
The European Furniture Industry: An Overview Planning and Start-up of Furniture Factories by A. Bassili	95 - 113

LATEST STATUS OF WASTE PAPER TREATMENTS FOR PAPERMAKING

by Dr. Manfred Judt

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Since the mid-eighties a new awareness swept round the world that our resources are limited and recycling of waste materials should become a must, and there was a new revival of reconsidering the use of waste paper in papermaking.

Worldwide (1)(2)(3) nearly 75 Mio tons of recycled fibre were used in the paper and board manufacture in 1988, accounting for almost 1/3 of the total papermaking fibre needs of the industry. The demand for recycled fibre has grown fast - twice as fast as the demand for virgin fibre pulps (5,0 %/a vs. 2,5%/a in 1970 - 88). During the 1980's (in 1980 - 1988) the paper and booard industries use of waste paper grew by 50% and its dependence on this recycled raw material source increased steadily.

The use of recycled fibre (1) will continue to grow. By 1996 comsumption of waste paper will have passed the 100 Mio ton mark and reach 130 Mill. tons by the end of the forecast period in 2001. With the assuption of an avarage growth of 2.6 %/a in the global consumption and production of paper and board (from 226 Mio. tons in 1988 to 317 Mill. tons n 2001) the worldwide recycled fibre utilisation rate is expected to rise from 32,8% in 1988 to 41% in 2001. This means an increase of 55 Mio tons in the worldwide recycled fibre consumption to nearly 130 Mill. tons in

2001.

But now new driving forces are entering the market place: Problems associated with the disposal of solid waste and the general environmental pressure to use more recycled materials. Legislation and mandatory messures are expected to quicken dramatically the recovery and utilisation of waste paper especially in North America.

In California e.g. at least 25% of the newsprint now in use must have 40% recycled content. By the year 2000 the state wants half the newsprint used to have 40% recycled content.

1985 there was a UNIDO supported conference in Bangkok with the title
Waste Paper Utilisation in Pulp and Paper making and the proceedings are a background paper for this workshop.

Let us recapture what was discussed 1985.

International Waste Paper grading (4)

1985 there was a resolution to the world community to create an universal waste paper grade system to facilitate the trade of such papers.
Today I can present a first draft for an European waste paper grading system and I am confident that this initiative will lead to a global system, which really should become an ISO-standard.

Figure 1 shows the different waste paper grades which were used in the German paper industry between 1988 - 1990. The ratio for medium, high quality and kraft pulp containing waste papers is unchanged, while the use of lower grade waste papers is on the increase.

This situation should be similar worldwide. But in the design of new waste paper treatment plants this trend has to be remembered, therefore the designs since 1985 have become more and more sophisticated.

The Waste Paper Treatment Systems

Here are two summaries from 1985 and the corresponding data sheets and flow sheets to demonstrate the state of the art of waste paper utilization in the industry then and today.

The first summary was:

A modern stock preparation system for white paper grades requires for contaminant removal next to cleaning and screening equipment:

A combination of flotation and of washing stages to remove specks, ink, ash, stickies and fines sufficiently and to a controlled extent.

It is essential to have good water clarification of circulating flows.

A dispersion system is recommended for the reduction of stickies which are not removable by flotation, washing, screening and cleaning techniques.

The brightness of the waste paper is not only improved by ink and dirt removal but also a better bleaching is achieved by an integrated washing process.

From a technical as well as an economical point of view it is possible to produce tissue from waste paper as well as from other white paper grades.

The second summary was:
the main factors for selection of machines for a waste paper prepapation are:

1. Effective slushing in high or medium consistency leaving the plastic and other impurities in a sreenable size.

2. Discharge of impurities at a very early stage and without manual intervention using specialized machinery.

3. Effective cleaning and sreening at medium concistency:
a. of flat and relativly coarse cubic particles by means of perforated screenplates with specilized machinery in the extended "A-stage" screening.

Let us use Figure 2 to demonstrate the development of such systems in the last twenty years.

Block 1 and 2 were the basic moduls in the fifties and sixties working at low consistencies. Block 1, 2, and 3 were the improved systems in the seventies and wash-deinking in the USA and flotation deinking in Europe were added.
Block 4 - dispersion units for stickies and plastics were added to overcome some of the problems arising in the paper machine from such contaminants. The stock consistencies were increased considerably and today block 5 second stage deinking by flotation with the possibility of fine stock washing and de-ashing of the stock and bleaching - as a block 6 for the future are under discussion and most operations are carried out at medium consistencies.

In Figure 2 the present situation is shown. Under the different block modules the stock density is given.
Why this trend to higher consistencies in the systems?

In Figure 3 the energy used in the different departments of a paper mill are shown for three different paper grades. In general more energy is needed in the stock preparation plants than for the paper machines and we know the higher the stock consistencies the less energy is needed per ton to treat them. Therefore the mayor trend in the last 7 years was to go to higher and higher stock consistencies in the pulpers, the screens, the cleaners. The limitations are in the flotation deinking technologies.
One other trend was to work in closed systems - e.g. the flotation deinking units are closed, the air is returned to avoid odour and foam problems in the mills.
One other trend is to close the waste paper treatment plant water

system more and more and to introduce special water treatment systems to floculate and/or flotate out dissolved organic materials which will later in the paper machine cause runability problems.

One other trend is to collect and ship the waste paper mostly used news and magazines in sheets and no more in bales to the paper mills. The paper is remoistured on the conveyor belts before it goes in the pre-soaking drum.
There are now special machines opening paper bales before adding them into the high density pulper. Up to 20% energy can be saved by this action.

With more and more household waste paper coming to the mills it is general practice to use a dispersion system with temperatures below 90 °C to prevent the discolouring and loosing of strength especially of wood containing fibres, in board making temperatures up to 130 °C in such dispersing machines are necessary when the presence of bitumenized papers can be expected,
to reduce the bad effect of stickies and plastic on the performance of the paper machine.
One new trend is that fibre fractionation lines are a must in brown stock - kraft paper containing - waste paper treatment lines.

One other trend is the use of more and more screens with slots instead of holes to improve the cleanliness of stock at higher consistencies. Usually about 80% of the total screening area is now witn slots.

The introduction of special cleaners (5) to remove light - dirt is necessary but their use is better in the reject lines than in the main stream due to high energy demands of these cleaners.

The de-inking sludge can be used as a soil conditioner.

There is this trend to close the mill water systems more and more, but there are limits 5 l/kg of produced paper - to avoid odour problems. There is this tendency now to subdivide the water system into sepererate systems and introduce specific treatment systems to floculate or flotate out "Störstoffe" - dissolved organics, colloidal materials, which might later give trouble in the paper machines.

<u>More detailed information on some processes (6)</u>

Refining of waste paper stock mainly kraft containing papers

Recycled paper loses strength mainly because of the fiber stiffening and hornification that occur when virgin fibers are dried during their initial papermaking cycle. This phenomena is difficult to reverse. Some of the lost strength can be regained by making the recycled fiber more flexible, thereby increasing the surface area for bonding. Repulping under alkaline conditions and refining are the most commonly used methods to improve the strength of secondary fiber.

Alkali treatment helps to swell the secondary fiber, which increases the surface area available for bonding. A 3% NaOH treatment at 10% pulp consistency for 30 min at 70°C is typical of conditions commonly used. High-shear-field (HSF) treatment in a pulp consistency range of 10 - 20%, can be used to produce an effect similar to refining. It is assumed that the fiber wall structure is modified by the brushing and bending action, which increases the bonding area. The HSF treatment produces less fines than refining, and this results in less freeness loss.

A combination of alkali and HSF treatment may be a better alternative to obtain high product quality from secondary fiber. The strength properties of the recycled paper obtained by the combination alkali/HSF treatment are higher than those obtained by refining and, in some cases, are comparable with the virgin pulp. The combination treatment seems most effective in restoring ring crush and Concora flat crush strength. This treatment offers a potentially valuable, practical method of increasing the use of secondary fiber in boxboard as well as corrugating medium.

Enzymes can be used to increase the freeness of the secondary fiber without affecting the quality of the final product. A preparation of cellulase and hemicellulase at 0,2% enzyme concentration , 30 min, 10% pulp consistency, pH 5, and 45°C was the most economical and practical level examined for the pulps investigated.

Fibre fractionation

In paper production from virgin raw materials, each stock quality is processed seperately. The respective fibre properties can thus be collectivly adjusted to suite production requirements. This is undertaken for example by seperate refining of short and long fibre stocks.
On the other hand, in waste paper recycling, the raw material generally has an extremely wide fibre length spectrum. As with virgin raw materials paper producers wish to selectively process the waste paper stocks, too.
The equipment available for the waste paper processor today includes machinery capable of screening an extremly wide variety of raw materials into long and short fibre fractions. This process is known as fractionation.
Industrial fibre fractionation is an European development first applied at the end of the 1970s. World wide interest in this technology is growing. In central Europe it has become practically indispensable.

De-inking

The printing inks used in offset or gravure printing do not normally enter into a chemical reaction with the fibres, but attach to them physically after drying. When the fibres are caused to swell, preferably in an alkine medium, the ink particles are detached from them. Following this, the particles are dispersed and hydrophobized by means of suitable additives and then discharged from the system.

Standard deinking chemicals fail to remove either the recently developed printing inks for copying machines, computer or laser printers nor the newly introduced flexo inks which are coming into use in the newsprint sector.

For this reason, special deinking additives have been developed for these types of printings. Combining wetting and dissolving properties, these additives reduce the surface tension of the water.

Peroxide use in waste paper treatment

About 75% of the 6 mio. tons of waste paper which were used 1991 in the German paper industry was for board and brown paper production (test liner, corrugating medium)
but 1,5 - 1,6 Mio tons were de-inked and this quantity is increasing each year.
A standart recipe for de-inking is:

0,85% Mg O

1% H_2O_2

3% NaOH

0,2% DTPA (Diethylen - Triaamin - Penta - acetic acid)

0,6% soaps

0,2% dispersing agents

One other recipe is:

0,7% NaOH

1% Peroxide

2% sodium silicate

1% DTPA

1,5% soaps (e.g. Serfax)

This recipe is preferred for de-inking house hold papers. To de-ink white papers mostly wood free the quantities of the chemicals is about half. The percentages given above are on dry waste paper.

It was found that peroxides can often be more effective in increasing the brigthness of waste stock by adding some e.g. in the pulper when slushing at high consistencies only or in the disperger at 30% consistency and temperatures of 90 °C where the mixing of the peroxides into the pulp is best.

One other condition of high brigthness gains is the time for treatment. It should be longer than 15 minutes.
Bleaching of the stock at the end of the treatment line often has only small brigthness increases. Here is an example:
1% H_2O_2 gave an increase from 58 to 65 but an application of 0,5% H_2O_2 in the pulper with 12 - 15% consistency gave a final brigthness of 63 already.

The de-inking units are operated in the first stage at pH values of 8,5 - 9 while in the second stage a neutral to slightly acid condition is preferred.

If there is a final peroxide bleaching stage then an acid wash and addition of DTPA is a must to get good results.

Recent research

The influence of ageing on the deinkability behaviour of offset-printed newspapers.

It is a well known fact that the deinkablity of offset-printed waste papers decreases with the age of the printed product. This effect depends on the content of binder components which dry by oxidation and of alkyde resins in particular. In the course of time these substances cause crosslinking phenomena in the ink film, thus rentering ink removal more difficult.

The ongoing development of flexo-printing (7) in recent years has opened up new avenues: being no longer limited to packaging applications, the flexoprint technology has at least entered the newsprint sector.
Using water as a solvent, flexographic printing processes are highly advantageous under both printing and ecological aspects. Treatment of flexo-printed waste paper is influenced by the hydrophilic nature of flexo inks, which becomes particulary relevant in the case of flotation deinking.
To cope with these new problems, chemical methods have been devised which allow an extensive use of flexoprinted waste papers in deinking plants.
Lab-scale trials have been conducted for various types of flexo-printed material added in different proportions. It has been shown that the effectiveness of some flexo-deinking chemicals is far superior to that of conventional fatty acids. The share of flexo-

printed paper in the trials was between 10 and 70%. The use of such flexo-deinking products in flotation deinking gave brightness levels comparable to those of wash deinking.

Until recently, wash deinking was the only generally accepted method of deinking for flexo-printed waste papers.

If during flotation of flexo-printed material pH values are reduced by excluding sodium hydroxide solution, the brightness gain can be increased to a level identical to that of flexo-free waste paper.

The best results are obtained with a combination of flotation and wash deinking stages.

In the final analysis, deinking problems encountered with flexo-printed waste papers are to be traced to the size distribution of the printing ink.

Two Stage, Alkaline-Acidic Flotation, a process to elimate difficult removable printing inks from waste paper pulp

Water soluble printing inks for flexo printing are not eliminated in a conventional deinking process by froth flotation. The reason is the water solubility of the printing ink under alkaline conditions. Alkaline conditions are essential to remove the printing inks from the fibers, on the other hand their hydrophilic character makes it impossible to collect these soluble inks with fatty acids. Therefore a modification of the deinking process is necessary. With a process sequence using: washing - thickening - alkaline flotation, mixtures of printed material from offset or flexo-printing can be deinked properly.

Another possibility is the modification of the froth flotation process. Because the solubility of the flexo inks based on polyacrylic acid binders decreases significantly under acidic conditions, these inks can undergo froth flotation under slightly acidic conditions in the presence of cationic surfactants. Mixtures of waste paper printed with offset and flexo printing inks can undergo a deinking process starting with an alkaline flotation and subsequently followed by an acidic flotation step. The acidic post flotation in the presence of quarternary ammonium compounds is also improving the brightness of conventionally printed waste paper.

Summary:

A great deal of progress has been made in resent years in the processing of secondary fibre which includes the de-inking. This has lead to a better quality secondary stock with fewer contaminants. As greater attention is given to the proper conditioning and cleanliness of the stock prior to reaching the machine chest, the problems on the paper machine will be reduced (8). Contaminants reduce machine efficiency and paper quality. They increase deposits on clothing and rolls cause abrasion and reduce chemical additive efficiency.

Significant developments in multilayer technology have led to more effective use of recycled fibre, particulary in the production of board and tissue.

During a recent PTS - de-inking seminar (9) it was anounced by Firma Huber, ink manufacture, that there are now flotable flexo-printing inks on the market and it is hoped that world wide the printers will adopt these new ink systems to make the de-inking of flexo-graphic papers easier.

Two major companies Escher Wyss and Voith, Germany will have information meetings for customers and interested parties in September and November 1992 to release new information on how to further improve the existing waste paper treatment systems.

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Wochenblatt für Papierfabrikation, 8, 1992, p. 273 ff.

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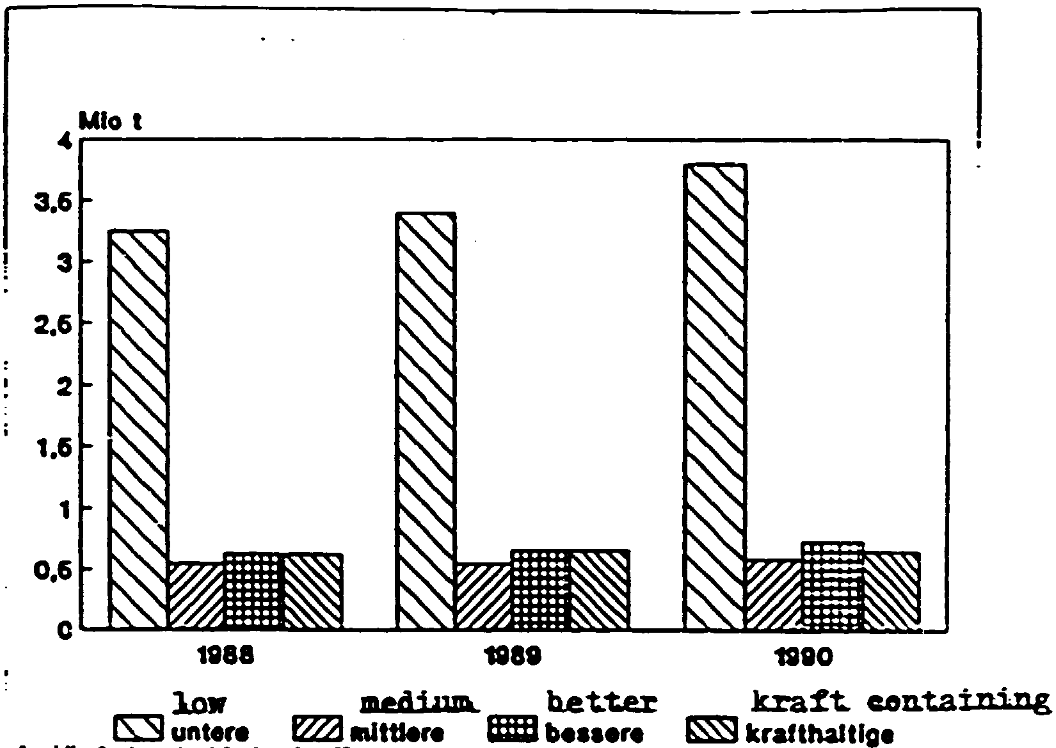
Papiertechnische Stiftung, Heßstraße 130a, D-8000 Munich 40

WASTE PAPER CONSUMPTION IN GERMANY

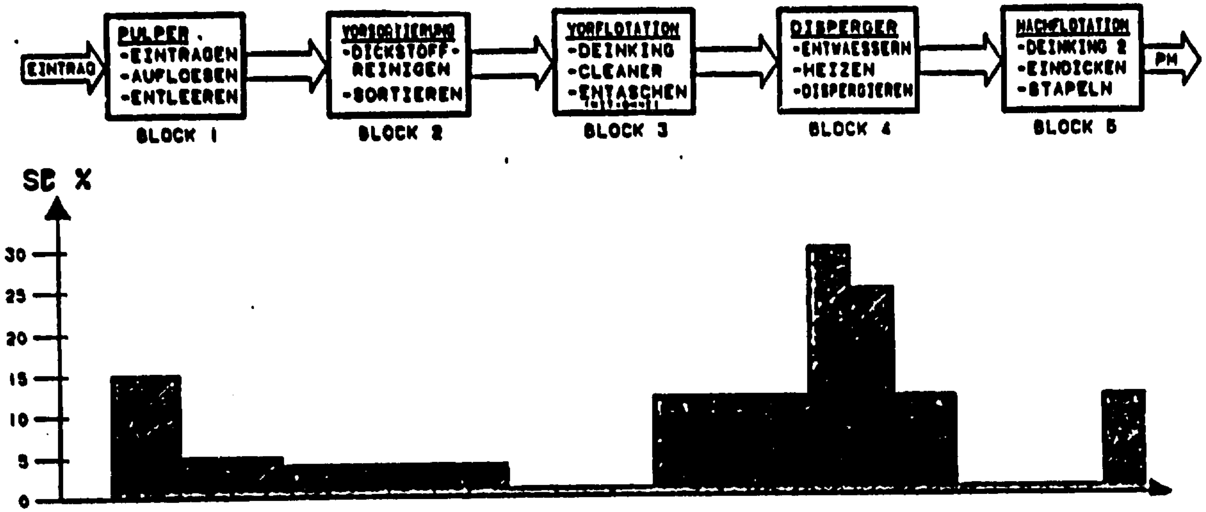


Graphik: Bundesverband Papierrohstoffe

Waste paper

Fig. 1

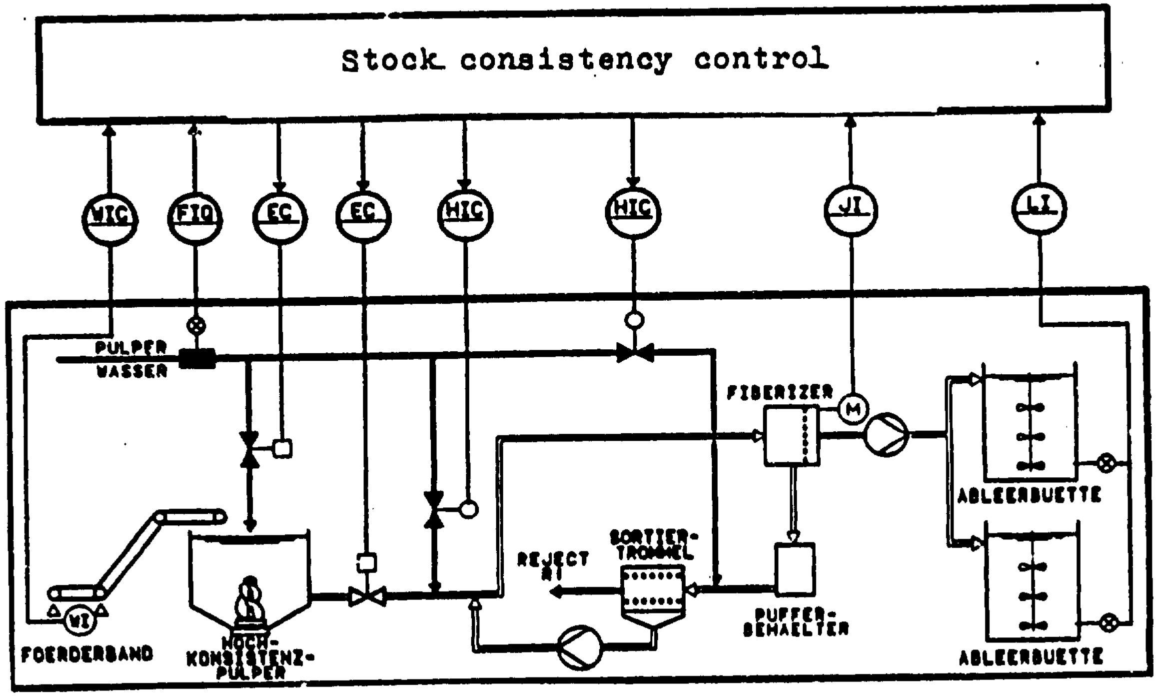
Pulper	sorting	flotation	ser	flotation
charging slushing discharg-ing	high density cleaning screen-ing	de-inking cleaning de-ash-ing	thickening heating disper-sing.	deink-ing thicke-ning storing



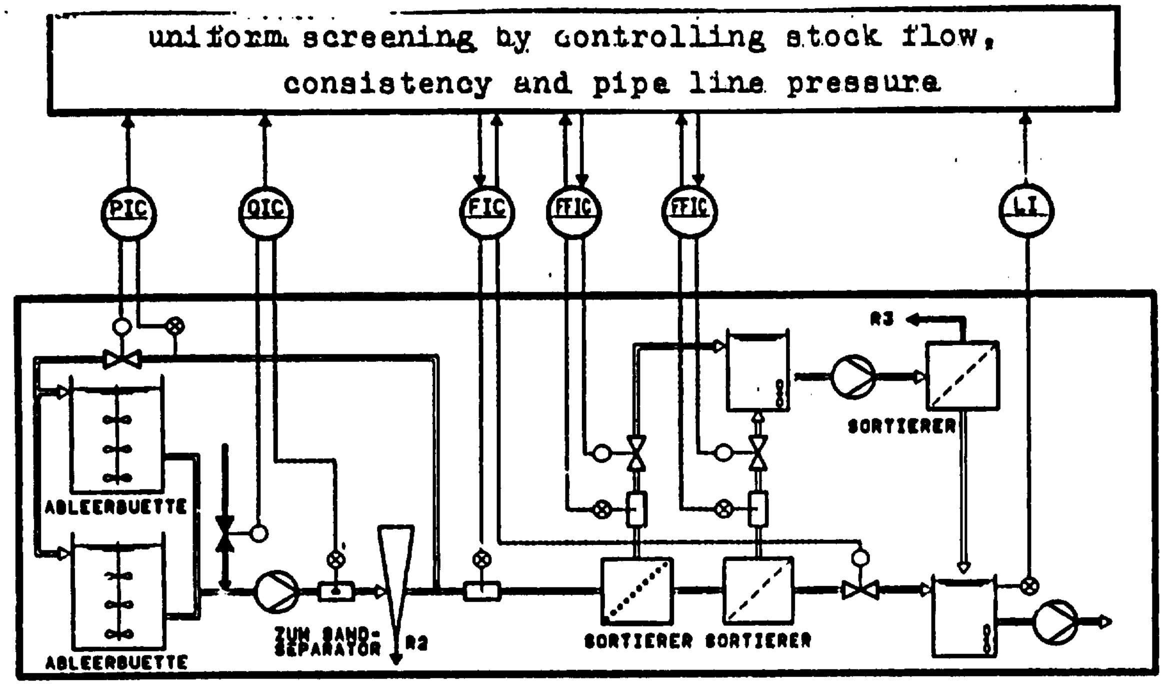
variation of stock consistency
in a waste paper treatment plant.

Fig. 2

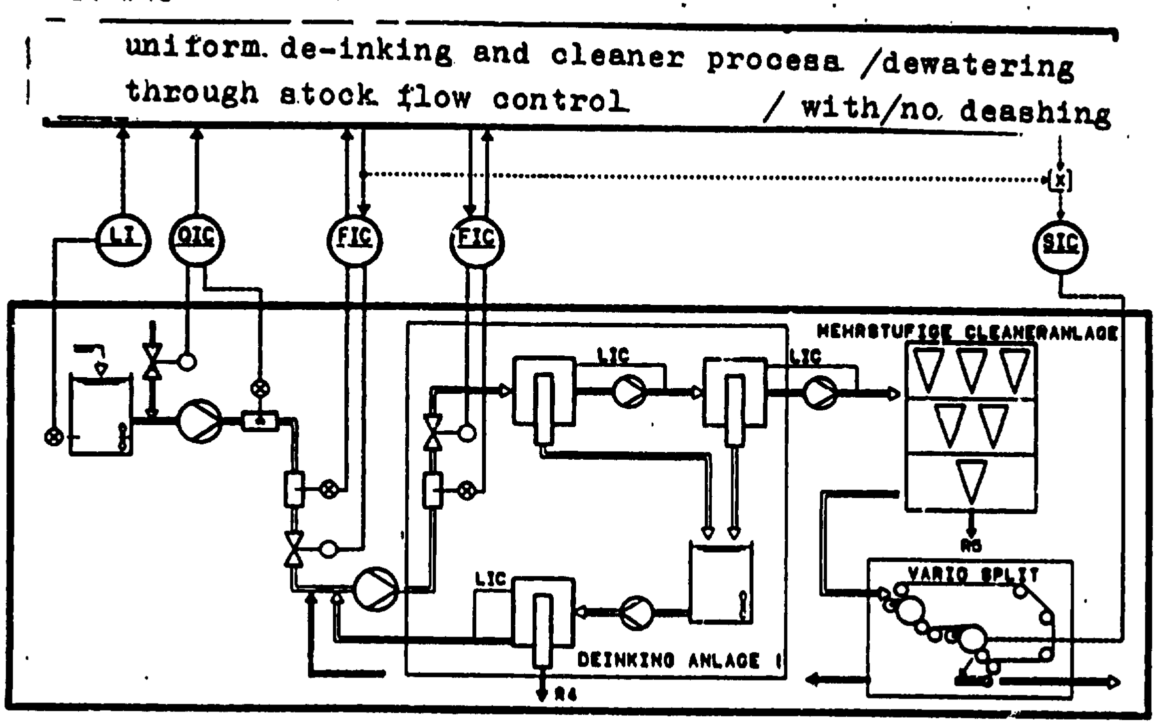
18


Stock consistency control
WIC
FIQ
EC
EC
HIC
HIC
JI
LI
PULPER WASSER
FIBERIZER
M
ABLEERBUETTE
ABLEERBUETTE
REJECT RI
SORTIER-TROMMEL
PUFFER-BEHAELTER
WI
FOERDERBAND
HOCH-KONSISTENZ-PULPER

BLOCK 1

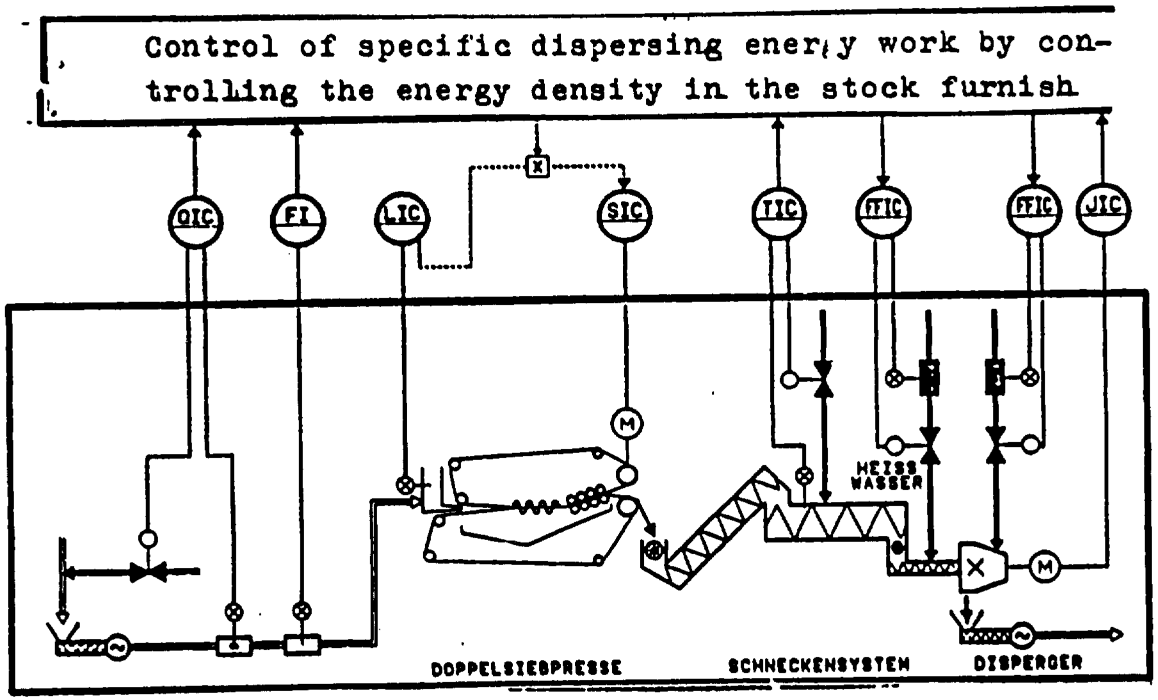

uniform screening by controlling stock flow,
consistency and pipe line pressure
PIC
QIC
FIC
FFIC
FFIC
LI
ABLEERBUETTE
ABLEERBUETTE
ZUM SAND-
SEPARATOR
R2
SORTIERER
SORTIERER
SORTIERER
R3

BLOCK 2



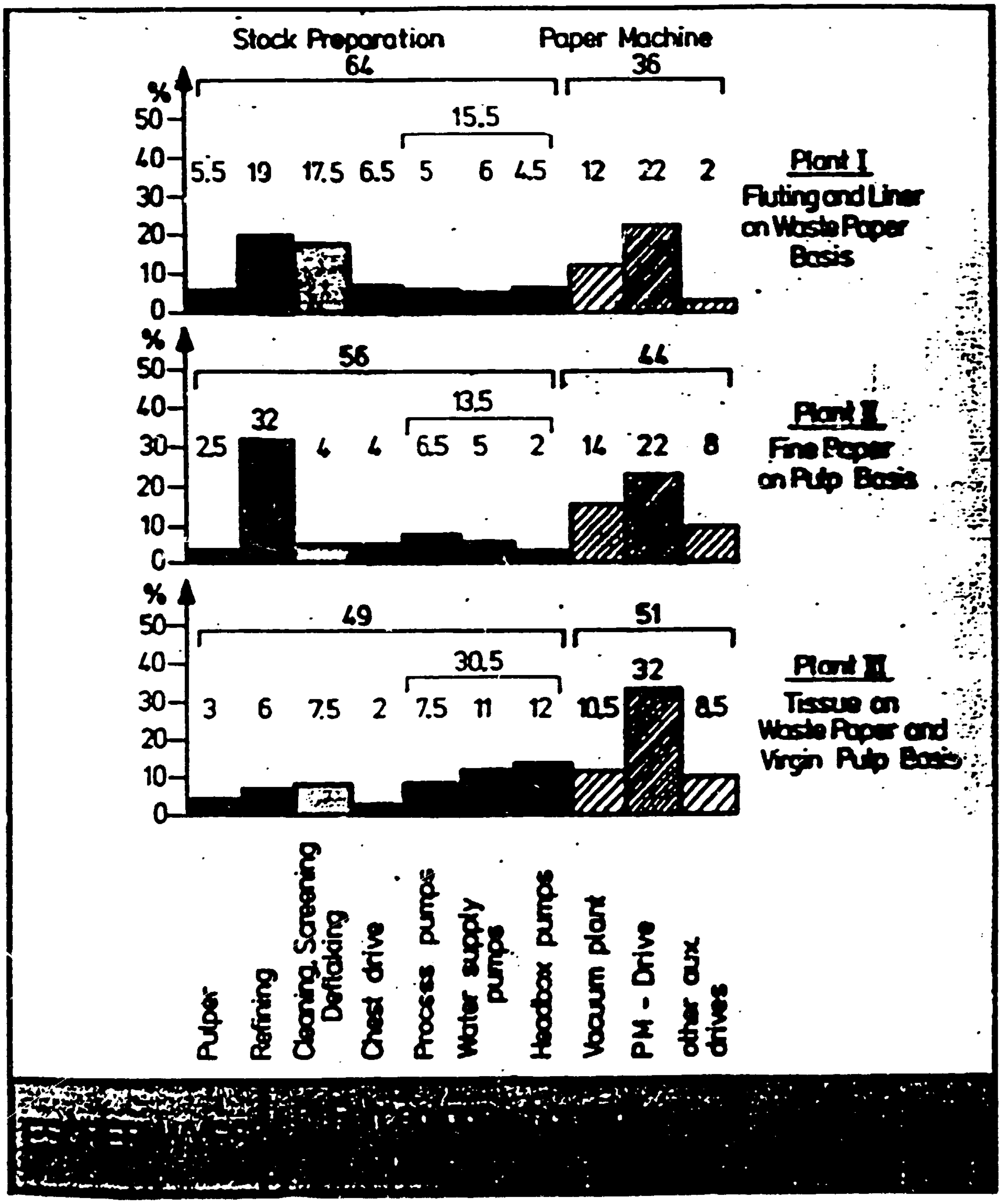
uniform de-inking and cleaner process /dewatering
through stock flow control / with/no deashing
LI
QIC
FIC
FIC
SIC
X
LIC
LIC
LIC
MEHRSTUFIGE CLEANERANLAGE
R5
VARIO SPLIT
DEINKING ANLAGE I
R4

BLOCK 3


Control of specific dispersing energy work by controlling the energy density in the stock furnish
QIC
FI
LIC
SIC
TIC
FFIC
FFIC
JIC
M
HEISS WASSER
M
DOPPELSIEBPRESSE
SCHNECKENSYSTEM
DISPERGER

BLOCK 4

	Regeltechnische Kurzzeichen:	Abbreviations for controls
WIC	= Produktionsmengen –	Waste paper quantitiy calculation
EC	= Ventilsteuerung	valve control
FI	= Stoffmengenmessung	pulp flow measurement
FIQ	= Wassermengen – Zählung	water flow measurement
FIC	= Stoffmengenregelung	pulp flow control
FFIC	= Stoffmengen-Verhältnisregelung	pulp flow ration control
HIC	= Handsteuerung	manual control
JI	= Wirkleistungsmessung	power imput measurement
JIC	= Wirkleistungsregelung	power imput control
LI	= Niveaumessung	level measurement
LIC	= Niveauregelung	level control
PIC	= Druckregelung	pressure control
QIC	= Stoffdichteregelung	consistency control
SIC	= Drehzahlregelung	revolution control
TIC	= Temperaturregelung	temperature control


Stock Preparation
64
Paper Machine
36
%
50
40
30
20
10
0
15.5
5.5
19
17.5
6.5
5
6
4.5
12
22
2
Plant I
Fluting and Liner on Waste Paper Basis
56
44
13.5
2.5
32
4
4
6.5
5
2
14
22
8
Plant II
Fine Paper on Pulp Basis
49
51
30.5
3
6
7.5
2
7.5
11
12
10.5
32
8.5
Plant III
Tissue on Waste Paper and Virgin Pulp Basis
Pulper
Refining
Cleaning, Screening Deflaking
Chest drive
Process pumps
Water supply pumps
Headbox pumps
Vacuum plant
PM - Drive
other aux. drives

UNIDO PROJECT IRA/94/067

BAGASSE UTILIZATION IN PULPING AND PAPERMAKING: THE CUBAN EXPERIENCE

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Keywords: Bagasse, bagasse fiber preparation, high yield pulping, bagasse papermaking, pollution control, bagasse pulp bleaching,bagasse papers.

Teheran, October 1994

1. INTRODUCTION

Bagasse is the residue from the process of manufacturing sugar from cane and the traditional and most widely application of bagasse is the combustion for the steam generation for the sugar factory.

For sugar producing countries the studies of bagasse as raw material for pulp and paper are very important because it is available in large amounts concentrated in the sugar factories every year.

Sugar cane production in 1991 was 68 420 375 MT that yields about 80 000 000 MT/OD bagasse (1). In 1990 the world bagasse pulp production (96 mills) was near 2 500 000 tons. The larger mill based on bagasse have been increasing the capacity up to 250 to 300 tons per day. The bagasse pulp production in 1990 was only 1,4 % of the total world production of pulp (186 million tons). (2)

Bagasse pulps are used in practically all grades of paper, including bag, wrapping, printing, toilet tissue, toweling, glassine, corrugating medium, linerboard, bleached boards and coating base stock.

As an agriculture residue of short length fiber the bagasse must be studied according to its particular morphology, physical and chemical composition. Among the technical requirements these factors and the kinetics of pulping are the most important and valuable data, to optimize the use of bagasse in the pulp and paper industry.

During more than 30 years, first at ICIDCA By-products Research Center and since 1981 in CUBA-9 laboratories and production facilities basic and technological research has been made in Cuba in the field of bagasse pulping and papermaking. Special emphasis has been made in high yield pulping of bagasse.

This paper reflects a general overview of the current design philosophy and developments in this field, not only considering the CUBA-9 Research Center contributions but also our opinions concerning the world-wide "State of the Art", according our experience in Cuba.

2. BAGASSE STORAGE AND PREPARATION

Physically bagasse is constituted by four fractions, whose relative magnitude depends on the sugar agroindustrial process. (3)

	Percent
Fiber or bagasse	45
Non soluble solids	2-3
Soluble solids	2-3
Water	49-51

The component designated as fiber represents the whole organic solids non soluble in water originated from the cane stalk. This fraction will be the element required for pulp production.

The non-soluble solids are constituted mainly by inorganic substances such as rocks, soil and extraneous materials. The composition of this fraction will depend on the agricultural cane harvesting and type of soil.

The soluble solids are composed mainly of residual sucrose not extracted in the sugar mill and a minor content of waxes. This fraction is interesting for the storage of bagasse, because it is a source of fermentation that could degrade the bagasse.

The water present in bagasse is retained within it through absorption and capillarity mechanisms. Capillarity plays an important role in the impregnation and cooking processes in connection with the accessibility of chemicals inside the fibers.

Particle Size Distribution

When bagasse leaves the sugar mill it is very heterogeneous with a particle size distribution ranging from 1,0 to 35,0 mm and average of 20 mm. (3,4,5)

The curve distribution of particle size will depend mainly on the cane preparation equipment and also on the sugar extraction machinery and cane variety.

The curve distribution of particle size is very important for bagasse pulping. If the distribution of particles is out of rule it can happen:

- Low efficiency in depithing of bagasse or very high losses.
- Difficulties on mixing the bagasse with water and pumping for industrial operation in the factory.
- Decrease in the average length fiber average of bagasse fibers.
- Difficulties in bagasse chemical impregnation.

It is very well known that bagasse production can be considered only as a sugar cane residue, because there is a compromise between the cane bagasse preparation in the sugar factory and the quality of bagasse generated. If the bagasse will be used as raw material for pulp production the fiber obtained in the sugar factory must be preserved from equipment with high cutting effect.

A recommended particle size distribution according CUBA-9 experience for good depithed bagasse is:

a. Retained on(%)

mesh 1	1,0-3,0	mesh10	15,0-25,0
mesh 2,5	30,0-40	mesh16	25,0-35,0

b. Through(%)

mesh 16	10-15

MESH: According to American Society of Testing Materials (ASTM) standards.

Density and Humidity

These are very important properties related with the industrial use of bagasse. (3)

Because of bagasse morphology there are a lot of empty areas between particles in addition to the pores and lumen volume. This total empty volume defines the bulk density which depends on different factors mainly the degree of compactness and the humidity.

There is also the basic density which excludes from bagasse the volume between particles and the absolute density of the substrate. The average of absolute density according ICIDCA determination is 1,51 g/cm^3. (5)

The moisture of bagasse is directly related with the hygroscopic level of pith which is highly hygroscopic and with the particle porosity. The bagasse is characterized by a great water absorption capacity, between 80-85 % moisture; normally the equilibrium moisture is between 9-10 %.

Bagasse is a short fiber material comparable with some types of hardwoods but it doesn't mean that bagasse lignin nature, or bagasse cooking kinetics are similar to hardwoods. Nevertheless the final strength properties with strong influence of fiber length will be near those from hardwood species. (5)

Bagasse Depithing and Storage

Bagasse must be depithed for pulp production. The pith is not a fiber element. It comes from the parenchymatous tissue, which contains the sucrose juice in the sugar cane so the pith will be extremely swollen by chemicals. The parenchymatous cells contain big vacuoles and the cell wall is constituted by high quantities of silica, and inorganic materials. For these reasons, the presence of pith will introduce a lot of negative consequences in pulp and paper industry: (6)

- High consumption of chemicals in pulping (20 times its weight).
- High content of inorganics which will interfere in bleaching and pulping.
- Fines generation in the paper machine, with low drainage on fourdrinier, and weak sheets with low strength properties.
- Silica troubles in recovering processes and disk refiners.

The chemicals for pulping and bleaching are in close relation with a good preparation of bagasse. It means that the first important thing to do in the bagasse technology is to decide which type of pulp for paper will be produced and then study the physical, chemical and morphological characteristics of the available bagasse and how to prepare it to be successful. If the bagasse preparation is not efficient, the pulp will not have good quality.

The depithing of bagasse must be performed combining moist and wet methods. The first normally is obtained from the sugar factory (depithing machinery such as Horkell, Kimberly Clark, Pallman, Caribe 1150, and others) and the second stage is part of bagasse preparation in the pulp plant combining good storage with different processes to remove the residual pith before cooking. The process will be used to purify the bagasse increasing the fiber content without cutting or degrading the fiber. After depithing it is necessary to know the fiber and pith content and distribution of fiber length. The content of fiber and no fiber elements and curve distribution of particle size is necessary to know how the material has been homogeneously prepared for cooking.

During the storage bagasse is "digested" by the continuous addition of water and control of pH. After some months of storage the residual pith is easily removed, the cells are more accessible, the air is almost excluded and the chemicals will penetrate very easily, with efficient cooking. Always stored bagasse consumes less chemicals than fresh bagasse.

Sometimes the bagasse storage includes the use of biologic liquors, specially when the bagasse is greatly affected by the presence of microorganisms which originates according to Lacey (7) from the early harvesting of sugar cane. This degradation could affect the brightness of bagasse, and also the destruction and modification of the chemical components with serious losses of yield and quality.

There are different liquors developed in the world to prevent this problem, based on lactic bacteria which consume the residual sugars in the stored bagasse and produce acid pH values (4-4,5) avoiding cellulosic fermentation processes inside the pile. Bambanaste (6) has developed a new Natural Biologic liquor based in the appropriate microflore of bagasse with good economic results.

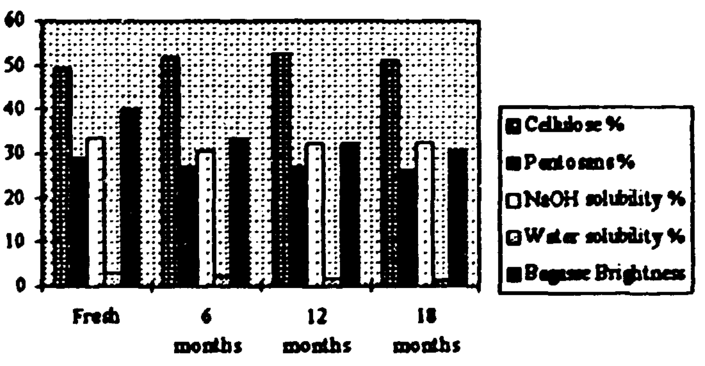
The main factors to be controlled in the storage (Bulk storage) are:

- Temperature inside the pile (water and biological liquor).
- Good compactness of pile to avoid air and fermentation.
- Good anaerobic conditions.
- pH between 4-4,5.

A good biological control of piles is one of the most important factors to be obtained as part of bagasse PULPING in addition to depithing factors. DEPITHING and STORAGE of bagasse will give the quality of material that will influence the final quality of bagasse pulp and paper. The pulping of bagasse begins in the storage. This is a concept.

The Cuban experience in the variation of chemical and physical properties of stored bagasse is shown in Figure 1. (6)

Fig 1. PHYSICAL AND CHEMICAL PROPERTIES OF STORED BAGASSE



Saving in NaOH after 6 months reaches 30 %, and 35 % after 18 months.

Bagasse can also be stored in bales. The bales are pre-dried below 20 % moisture specially when the material will be transported at long distances. In this case the bagasse cost is higher, but it will be preserved without fermentation as fresh bagasse.

Before use in the pulping factory the bales must be broken and the bagasse must be send to a wet system in order to supply the water inside the fibers and vessels, otherwise it will cause many troubles in pumping and cooking of bagasse and in pulp quality.

3. CHEMICAL PULPING OF BAGASSE

Chemical pulping knowledge for wood is a very well established subject since sulfite and sulphate processes were developed. From the end of the XIX century and in spite of the explotion of mechanical processes in the last 20 years, sixty nine percent of the total production of the world is composed of chemical pulps.

Chemical pulp production of bagasse is in the order of 2,17 million tons (89 plants) over the world mainly for the production of different qualities of writing and printing papers and boards.

Chemical pulping of bagasse has been associated from industrial practice with alkaline processes, mainly soda process. There are still a few sulphate bagasse pulp plants depending on local conditions and availability of raw materials.

In the last years CUBA-9 has developed a bisulfite sulfite pulping technology for bagasse for different paper pulp qualities taking into consideration the chemical structure and composition of bagasse lignin. (8)

Alkaline Pulping. Soda and Sulphate Processes

As has been demonstrated, alkaline pulping of bagasse is quite different from the same for woods. This is regarding particle size distribution, high porosity and high chemical reactivity of bagasse lignin. Delignification kinetics of bagasse is characterized by a very high delignification rate and selectivity in the early steps of reaction, and a higher reactivity than woods.

Considering all these bagasse characteristics, it appears that traditional differences between soda and sulphate pulping of woods would be of minor significance when pulping bagasse and it is possible to produce a high quality soda pulp with a simple process and less pollution. (8)

Early works developed in CUBA-9 have demonstrated that when sulfidity of alkaline bagasse pulping increases from zero up to 15 % permanganate number decreases only 1,0-2,0 units with an increase of 10 % in strength properties (mainly tear factor).

Further increase of sulfidity does not have a significant effect on lignin content.

This is the reason why a majority of chemical pulp plants of bagasse are based on the soda process

In Table 1 typical results of alkaline soda and sulfate processes and properties of pulps are presented. (9)

Table 1: COMPARATIVE RESULTS OF BAGASSE SODA AND SULFATE PROCESS AND PROPERTIES OF PULPS

PARAMETER	Unit	TECHNOLOGY	
		Soda	Sulfate
Tota yield	%	61,7	62,1
Classified pulp yield	%	57,1	57,4
Permanganate Number	-	10,6	8,1
Kappa Number	-	21,6	14,6
Canadian Standard	ml	256	256
Burst IndexFreness	Kpam/g	5,0	5,2
Density	g/m	0,69	0,70
Tension Index	N.m/g	61,8	64,6
Final Brightness	%	87-89	87-89
Tear Index	mN.m/g	5,2	5,5

Technology Description of Alkaline Process for Bagasse

Whole bagasse with 55 % fiber content is moist depithed in the sugar mill and then wet bulk stored and wet depithed in the pulp plant to reach 82-84 % fiber. Depithing and storage operations are selected taking into consideration local conditions and technical and economical advantages.

Pulping is carried out generally in tubular continuos digesters with typical screw feeder like Pandia or American Defibrator.

Cooking temperature is between 160-170 xs°C, 12 % of active alkali and 10-20 minutes of retention time.

Three steps countercurrent washing are operated efficiently with a dilution factor between 2-3 and final pulp consistency of 12 %. Filtrate from the first washer is sent to recovery.

Washed pulp is diluted and is sent to screening and cleaning area. First step screening is pressurized and vibratory screens are used in the second step. Accepted fraction from the first screening step is sent to a battery of four centrifuge cleaning steps. Rejects from the vibrating screen can be recirculated to digestion or for disposal. Accepted fraction from first step centrifugal cleaning is normally thickened and sent to the bleaching area. Bleaching is carried out in three or four steps combining Chlorine Alkaline Extraction. Hypoclorite and/chlorine Dioxide. More recently, peroxides, oxygen and ozone have been used with good results in bleaching with less pollution.

4. HIGH YIELD PULPING OF BAGASSE

In the last 25-30 years several high yield processes have been developed for softwoods such as: RMP, TMP, SGWP and CTMP. The main objective of these technologies was to get a mechanical or mechanical type of pulp to substitute the traditional SGW and later partially or totally the chemical pulp in different paper and board furnishes.

This processes were based on the disk refiner development and high flexibility of softwood fibers, that submitted to thermal softening and refining effect, produces a defibration with a good relation of fines fraction with high opacity and bonding power.

As we have seen from early chapters the bagasse fibers will never give similar results because they have very low flexibility and collapsibility and when submitted to thermal softening and refining effect a lot of fibers will break at the middle lamella level producing a very high fine fraction with high opacity but low bonding power. This is the reason why mechanical and thermomechanical processes for bagasse and many hardwoods haven't succeeded by themselves. Other high yield processes have been developed with a good combination of chemical pretreatment and thermal or mechanical processes. (13, 14).

It is important for bagasse and many hardwood varieties to prepare the fibers before refining action by a mild chemical pretreatment followed by a multistep refining at high to medium consistency. This is the key of the high yield pulping of bagasse.

Refining of Pretreated Bagasse

Bagasse fibers have very thick cell walls and poor flexibility breaking very easily at the middle lamella level with formation of short fibers and high proportion of fines and poor bonding power. When well pretreated bagasse is used, the breaking is at the level between the internal layers S1 and S2 with the liberation of fibers and an adequate relation of fines with high opacity and bonding power. The refination effect produces heterogeneous material composed of two main fractions: fiber fraction and fines fraction. Short fragments of fibers are the undesirable fines, while the two last components are the desirable fines with high specific surface and opacificant power. A good proportion of all different fractions will give the paper potential of the pulp.

CUBA-9 Chemimechanical High Yield Pulp (CMP). Comparison with other Available Technologies.

CUBA-9's relies on a single pulp for most of the furnishes, with the chemi-mechanical pulp designed for an adequate balance between strength, optical and printing properties. Other mills have used the concept of mixing several pulps using the blend according to the properties of each one. This gives at the end three or even four different pulping lines with high investment costs and a complicated process associated with the semi-chemical bagasse newsprint plants.

There are several designed technologies to produce mechanical type of bagasse pulps. With differences between them in investment, operation costs, quality and price of final products. The most known developed processes are: Enso-Gutzeit, Giris-HZ-Process, SPB-Beloit, Hawzell process, Peadco-Technip, Sprout-Bauer and CUBA-9.

The main purpose for producing high yield pulps from bagasse is connected with the field of newsprint type quality or with the addition of mechanical grade pulp for cultural papers to decrease the costs of paper and to increase the printing properties.

Many newsprint experts including Atchison (15) have the conviction that a newsprint sheet produced from bagasse must contain a substantial proportion of mechanical type pulp with a minimum of 50 %.

CUBA-9 technology starts from a storage with microbiological control followed by wet bagasse depithing. Further a mild chemical pretreatment to obtain the softening and swelling of fibers for a further two refining step process. The refining generates fibers with high bonding power and adequate fines proportion.

Chemi-Thermomechanical(CTMP) Pulping of Bagasse

Since early April of this year CUBA-9 has been testing a new CTMP process in their facilities. and these are the first results disclosed so far. The reason for testing the new process was the need of the reduction of virgin fiber costs in the production of corrugating medium from bagasse.

CUBA-9 had obtained very good quality corrugating medium with the CMP technology, but growing competition from recycled fiber called for a full scale test of the process, in pilot plant trials since 1992.

Process parameters used were 5,0 % caustic soda on bagasse, 120°C temperature and 2 ATA pressure. Pulp results are shown in Table 2.

Table 2: CTMP PULP EVALUATION

PARAMETER	UNIT	VALUE
Yield (Ref.pulp)	%	82,9
KAPPA Nr.		62
Refining Energy	kWh/Ton	330
COD	Kg/Ton	219
BOD	kg/Ton	153
Density	Kg/m^3	302
Tear Index	$N.m^2/g$	4,18
Burst Index	$Kpa.m^2/g$	1,2
Tensile Index	Nm/g	25,5
CMT	N	355

5. BLEACHING OF CHEMICAL AND HIGH YIELD PULPS

Bleaching of Bagasse Chemical Pulps

Due to its high lignin reactivity bagasse pulps bleaches fast and homogeneously with chemical agents such as hydrogen peroxide, ozone and oxygen, in combination with small doses or even absence of chlorine compounds.

Chlorine free bleaching schemes for bagasse chemical pulps are already available complying with the growing claim for ecological preservation. Oxygen is capable of reducing the original Kappa number by 50 % and after a peroxide stage (O-P sequence) final brightness exceeds 85 ISO. Other combinations using ozone and peroxide (Z-P) are even more attractive due to their excellent preservation of fiber quality and very clean effluents. The bleaching areas of future bagasse pulp plants shows great promise, with lower investment costs, high efficiency and low pollution.

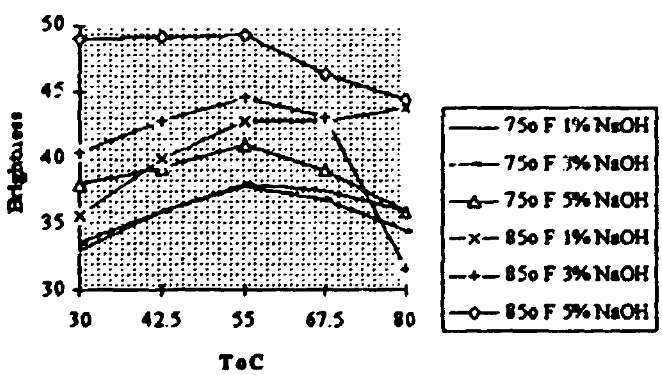
Bleaching of Bagasse High Yield Pulps. Chromophores Generation.

Chromophores formation is a very common fact during pulping and bleaching of pulping raw materials. Especially bagasse is very sensitive to chromophores production mainly related with the bagasse lignin structure that is very reactive and easily hydrolyzed in alkaline solutions and sensitive to oxidant products. The chromophores depend also on the intensity of alkaline treatment, temperature of impregnation and content of inorganic material of bagasse.

In pulping practice it is very convenient to avoid the generation of chromophores using suitable chemicals and studying the effect of temperature and time in impregnation, to produce a pulp easily bleached by chromophores removal agents such as peroxide. Drastic impregnation parameters will give a lignin deeply modified, only extracted by using powerful bleaching agents, decreasing the yield and printing properties of paper.

Some of these impregnation parameters have been studied connected with optical properties of pulp (Brightness and yellowing). The effects on brightness depending on fiber content of bagasse and impregnation parameters (temperature and NaOH) are shown in Figure 2.

Fig. 2 Cooking Parameters vs. Brightness .



6. ENVIROMENTAL PROTECTION AND POLLUTION CONTROL IN BAGASSE PULP AND PAPER MILLS.

The knowledge about bagasse pulping and papermaking in the past 30 years by far exceeds the enviromental management and effluent treatment know-how. We have seen many mills paying the price of a budget shortcut on the effluent treatment installation. And, very often, the final disaster of an enviromental shutdown.

Another deceiving case is that of expensive facilities rended useless by poor operation.

We will briefly discuss the particulars of the effluent discharges of the bagasse pulp and paper industry.

Bagasse Storage Effluents

Bagasse storage is a necessity to the industry due to the cyclic nature of the sugar crop. The predominant storage methods are bulk storage with both microbiological and water preservation, and dryed bagasse in bales. The former method has gained wide acceptance because of the reduction in fire hazard, reduced losses and greater pulp yield. In the the case of bulk storage the main factor is the amount of water recirculation during the formation of the pile.

Table 3 shows the pollution capacity of the storage effluents.

Table 3: POLLUTION POTENTIAL OF STORAGE EFFLUENTS

Properties (Kg/ton bagasse)	Biological liquor w/recycling	Water recirculation
COD	5,4	16,5
BOD	2,8	10,2
Total Solids	3,9	-
Soluble Solids	0,1	0,5
Dissolved Solids	3,8	-

These loads are taken from actual reports, but in our opinion they can be lowered considerably by careful operation.

In Cuba the bulk storage systems use water recirculation. The Jatibonico mill uses pile temperature and pH as guidelines, and have reduced water input to 1 m^3/ton stored bagasse. Data shown in Table 3 is taken from this mill.

Depithing Effluents

This is another must in the bagasse pulping process. Both the moist and wet depithing methods are used. The first choice should be to moist depith (50 % humidity) as much as possible in the sugar mill. The pith can be used as animal feed or as boiler fuel, up to 30-50 % mixture with bagasse.

The wet depithing system can be either an open or closed system. Table 4 shows emissions obtained from data gathered in Cuban mills.

Table 4: EMISSIONS OF WET DEPITHING

		Open System	Closed System
Flow	m^3/ton of depithed bagasse	30-60	10-40
Suspended Solids	Kg/ton of depithed bagasse	60-120	10-40
BOD5	Kg/ton of depithed bagasse	10-30	5-10

To close the system it is necessary to separate the solids by mechanical means, which is not difficult. The dissolved organic matter will be higher coming out of biological liquor stored bagasse, which is less recirculated.

Therefore both depithing and storage effluent treatments should be designed together. In general these effluents are easily biodegradable and can be treated alone or combined with other effluents.

The main problem is the disposal of the wet pith, normally betweeen 80 to 120 Kg per ton of depithed bagasse.

There are several solutions proposed for this problems, but all must be studied for local conditions. Among them are:

- Biogas generation, using mixtures with filtermud from the sugar mill. With a residence time of 15-20 days, 300 m^3/ton of dry material is available.
- Compost, for soil improvement.

Chemical and Semichemical Pulp Mills

The Jatibonico paper mill in Cuba, which can produce 200 tons/day of bleached bagasse pulp sing a C-E-H-CLO_2 sequence and 200 tons/day of writing and printing papers uses a primary clarifier sedimentation system, followed by an intensive treatment by aereated lagoons, with contact stabilization and secondary sedimentation of the mud produced in the biological treatment. Treated wastewater is sent to a river and filter muds are thickened and pressed in a double wire press.

The plant has a recovery boiler and white liquor preparation facilities.

Pulping

As mentioned in preceding chapters, the main bagasse pulping processes are alkaline in nature, mostly kraft and soda. The kraft process has gained ground because of higher yields and easier to bleach pulps, specially in higher capacity plants. Although both processes are quite similar, the malodourous emissions of the kraft sulphur compounds are present. In any case, odor emissions are lower than in kraft woood pulp plants, due to less extractives and sulfurity level.

The main issue in pulping effluents is the presence of an alkali recovery plant. Very high levels are present without recovery, as shown in Table 6.

The relative cost of recovery plants increases as the plant capacity decreases, as shown in Figure 3.

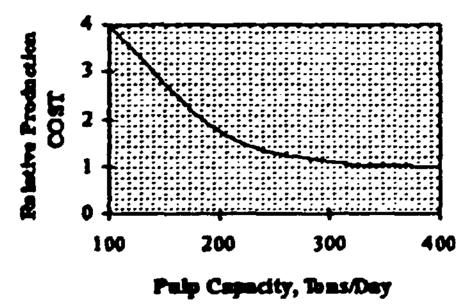


Fig.3 PRODUCTION COSTS IN BLACK LIQUOR RECOVERY

There are many mills operating without recovery plants for this reason. The design used for cost calculations is the classical Tomlinson recovery boiler. To avoid this handicap, new recovery systems have been designed, for use in small size plants, and/or semi-chemical processes. Among them are fluidized bed systems, Chinese small scale black liquor boilers, Ferrite (Direct Alkaly Recovery System)etc, but all of them are not yet proven and reliable.

Washing, Screening and Cleaning

The main solution for this area is the use of internal measures. Among them is important to:

- Increase the washing efficiency, to have as high a number of solids to recovery as possible, with less fiber loss. It is important to point out that bagasse pulps are more difficult to wash, because of lower drainage than comparable wood pulps. Poor depithing also decreases washing efficiency.
- To close the screening system.
- Avoid accidental spills.

These measures should always be the first step to introduce in existing mills. The experience in the rest of the pulping industry is a useful source of information.

Bleaching

Bleaching effluent is very aggresive, not only due to color and organic matter, but also for the presence of toxic waste harmful to animal wildlife. As is the case of pulping, bagasse bleaching effuents are less contaminant than those of wood pulps. Chlorine attack is more selective, allowing less stages and total chlorine. In Jatibonico mill 88°GE is obtained with a CEHD sequence. But still the highly toxic chlorine compounds are present. Therefore, all modern plants ahould be designed with the following criteria:

1. Modifying the conventional bleaching sequences. It is convenient to modify the CEH sequence for C-E/H or C-C-E/H-H in older mills. (22)

2. Introducing the oxygen bleaching sequence, allowing recycling of residual water to the recovery system. Oxygen is added as an extension to delignification first stage, without affecting pulp quality. Oxygen bleaching is applied with success in mills at Colombia (Propal) and Venezuela (Venepal). Fifty percent reduction in chlorine consumption and a simpler effluent treatment are benefits. A problem is to find suitable small capacity oxygen generators.

3. Use of less toxic bleaching agents. An "ecological" paper has been produced at CUBA-9 using a C-P instead of the classical CEH sequence attaining comparable brightness levels with vastly reduced contamination.

In the case of old plants the principles discussed by Perkins (20) could be applied for CEH sequence open plants. Designs are available by CUBA-9 to reduce water consumption to 30 m^3/ton pulp.

High Yield Pulping Effluent Treatment

During the high yield pulping process, there are a number of particular operations which produce different emissions, such as impregnation, washing, screening and bleaching.

Impregnation

The most common process calls for a 4-6 % NaOH treatment on incoming bagasse.

Table 5 shows typical effluent values.

Table 5: BAGASSE HIGH YIELD PULP EFFLUENT CHARACTERISTICS

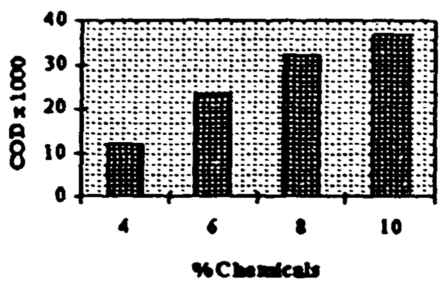
SOURCE	COD Kg/Ton	BOD Kg/Ton	Total Solids Kg/Ton	Soluble Solids Kg/Ton	Dissolved Solids Kg/Ton	Flow m^3/Ton
Impregnation	23	15,3	31,2	2,05	29,1	3
Washing, reening and cleaning.	37	24,2	19,6	15,8	4,1	33
Bleaching and neutralizati on.	10	3	21,4	3,21	17,7	16,0
TOTAL	70	42,5	72,5	21,6	51	52

Eighty percent of the load for high yield pulp comes out of the impregnation, washing and screening processes, and this is the main problem to be solved.

A 200 TPD high yield pulp plant discharges the same amount of solids as a 44 TPD chemical pulp unit, therefore a conventional recovery operation is not viable unless the liquor is sent to a nearby chemical pulp plant.

The total organic load (As COD) is smaller in the case of high yield pulp. (Figure 4) (14)

Fig 4. PULPING COD vs. PERCENT CHEMICALS



Therefore a simple primary sedimentation and biological oxidation treatment is required, using aereated lagoons. This principle can also be applied to semichemical pulping, if the percent chemicals is less than 7 %.

Washing, Screening and Cleaning

Washing is made in one stage at medium dilution factors, taking away the dissolved organic matter. Normally the yield is in the 82-88 % range. During the screening process, rejects in the range of 5-20 % are present, and the best solution is to recirculate them in the proper position. Cleaning is a conventional operation. All these processes can be improved by modern equipment and methods.

Bleaching and Neutralization

In the case of high yield pulps peroxide brightening is used and no delignification or chlorine compounds are present, hence a low emission is obtained.

Table 6: COMPARISON WITH CHEMICAL PULPING EFFLUENTS (AFTER TREATMENT)

	BOD kg/t	**COD kg/t**	**Soluble Solids kg/ton**
UNTREATED			
Semichemical, open washing and screening.	250	350	-
High yield	46	70	21,6
Chemical No. Recovery	235-360	966	5-30
Chemical W/Recovery	38		12
TREATED			
High yield	4,5	-	1,08

Conclusions

Pollution abatement in the bagasse pulp and paper industry is in obvious need of its own further development, not relying only on the achievements of the wood industry.

- There is a need for a technical and economically viable process for small capacity bagasse liquor recovery plants.
- New pulping processes with less contaminations are needed.
- The real toxicity of bagasse pulping and bleaching effluents is yet to be accurately defined.
- The need for a deeper environmental culture in the bagasse pulping industry is spreading, but funds are required to find the solutions.

7. APPLICATION OF BAGASSE PULPS IN VARIOUS GRADES OF PAPER.

So far we have mentioned that intrinsic bagasse properties determine the resulting paper quality and applications.

We must remind that bagasse is:

- A heterogenous material.
- A short fiber material, with rigid fibers coming from the sugar cane bark and thick cellular walls.
- A very reactive lignin located in the cell wall, and a harder to remove lignin in the inter-cellular middle lamella.
- Easily removed hemicelluloses from the secondary wall.

Another important factor is that bagasse should always be depithed and stored according to the final end product.

Now we will describe the current applications of different grades of paper according to various pulp grades.

Writing and Printing Papers

The writing and printing paper market can be divided in 4 segments:

a) High quality, meaning bright and permanent papers, made from chemical pulps.
b) Newspaper

c) Medium quality, meaning less bright, less permanent papers, for use in books, journals, notebooks, pamphlets, catalogs, leaflets, etc.
d) Special papers and boards, for specific uses.

In recent years, the term "wood containing" papers is loosing its significanse after the rapid growth of mechanical pulp technology for certain applications. This means that buyers look for use, applicability and price rather than fibrous composition.

Another important factor is the ecological scenario. The market is looking for "enviromental friendly" products and they have a price advantage.

On the other hand, the use of coated or light coated papers from bagasse has room for improvement.

These are factors that must be considered when deciding a new bagasse paper mill.

The classical bagasse chemical pulp has lower resistance, than its wood coungerpart Brightness is normally 82°GE with 3 bleaching stages and 88°GE with 4 stages, and is marketed in many countries. But to be competitive, the mill should support a recovery unit, have adequate effluent treatment facilities, and should be equipped with O_2 bleaching to cut down chlorine consumption.

This indirectly sets the capacity of the mill in the 150 ton/day range, bringing up the issue of massive bagasse supply problems. For this capacity, a sugar mill of at least 3 500-4 000 MT cane crushing capacity should deliver all its bagasse.

But chemical bagasse pulp is suited for bond papers and can fill a share of the market for quality, permanent papers.

Bagasse Coated Papers

Coating of bagasse based papers opens a wider scope of application, especially for chemical pulp papers. There is ample experience from Stanger, South Africa, Venepal, Venezuela and Propal-2 in Colombia. Also Kimberly-Clark from Mexico has also produced it. A UNDP financed project has installed a pilot plant in Cuba for the study of coated bagasse paper for different applications.

Use of High Yield Pulps

According to CUBA-9's experience, strength has not been a limiting factor for the use in writing and printing. The BCTMP pulp from hardwoods already reaches 80°GE, the best achieved for bagasse high yield is 65°GE. And brightness is the price fixer for mechanical type pulps.

According to several feasibility studies, there are two distinct investment possibilities.

A) An integrated pulp and paper mill, with the advantange of reasonable rates of return at capacities as low as 30 000 tons/year, operating with sugar mills of 1 000 MT/day crushing capacity (all bagasse substituted by an alternate fuel) or 4 000 MT/day (25 % excess bagasse). The mill would produce with a high percent of high yield pulp, at a cost of roughly $1000/Ton. Paper of 58-62 brightness can be used in schoolbooks, notebooks, printed material and catalogs. (24)

B) A small high yield pulp unit, adjacent to a chemical pulp mill, using their recovery and effluent treatment installation, reducing fiber costs in the case of less permanent papers.

A typical furnish, with a balance of bagasse chemical pulp, would be:

Table 7: WRITING AND PRINTING PAPER WITH HIGH YIELD PULP. (23)

Bagasse high yield pulp	%	20
Bleached kraft, coniferous	%	15
Bagasse weight	gm/m²	60
Apparent density	kg/m³	780
Mean Tensile Index	Nm/g	37,4
Brightness	Elrepho	75
Opacity	Elrepho	79
Ash	%	8

Industrial and Packaging Papers

Corrugating Medium

This has been one of the most succesful uses of bagasse worldwide. The process most widely applied is semi-chemical pulping. Later CUBA-9 tested a CMP process which gave increased strength properties, while the power consumption was still considered high compared to the conventional semi-chemical process. Therefore, a new CTMP process was tested early this year. Table 8 shows a comparison of the main consumption figures for the three mentioned technologies.

Table 8: CONSUMPTION FIGURES FOR CORRUGATING MEDIUM

PROCESS	Semi-chemical	CMP	CTMP
Mill	Felixtown, South Africa	CUBA-9	CUBA-9
Bagasse, 50 % Humidity	3,50	2,82	2,70
Pulp yield, %	70	75-78	80,3
HP-days/ton	6,0-8,3	19,2	18,3
Chemicals(pulping), %	7,75-11,3	6,0-6,5	5,0-5,3
Furnish, %	60 Semichemical Bagasse 40 % (OCC) Kraft Waste	60 Chemimecha-nical Bagasse 40 % (OCC) Kraft Waste	60 CTMP Bagasse 40 % (OCC) Kraft Waste

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THE CHEMISTRY OF PAPERMAKING

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1. Introduction

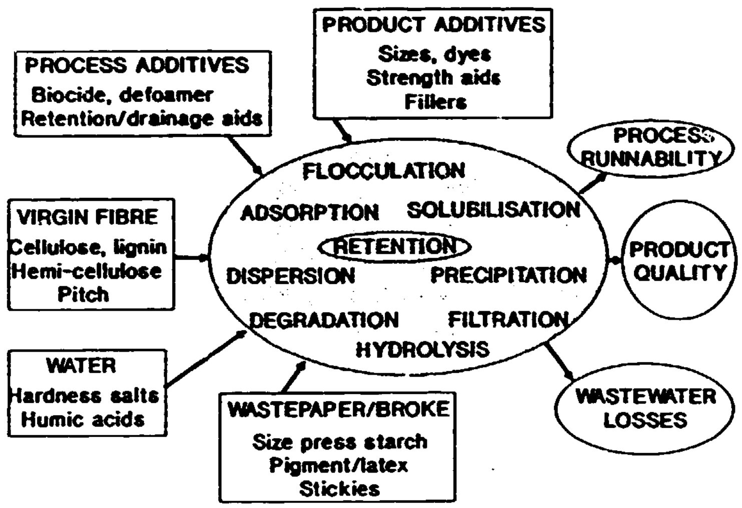
Paper is a complex matrix in which fibres provide the strong backbone and other chemicals contribute specific attributes such as sizing and wet strength. Water is an essential (and the largest tonnage) component in conventional papermaking and other chemicals (eg biocides, defoamers) are therefore needed to ensure that undesirable reactions do not take place within the papermaking system before the paper web is formed and during water recycling. In all papermaking systems, some chemicals that are not purposely added to the wet end enter with broke and/or wastepaper. These materials (eg coating fillers, size press starches, pulp hemi-celluloses) represent a potential disturbing influence on the wet end and are generally less easily retained than chemicals added deliberately to the wet end. This complex matrix of materials is shown schematically in Figure 1.

It is evident from this simple picture that there is enormous scope for interactions (some desirable, others undesirable) to take place between the system components before they are (hopefully) retained in the paper. The study of wet end chemistry is concerned with the interaction between all components of the papermaking furnish from the pulper through to the press section, including any changes occurring during water recycling. The key objective in trying to understand wet end chemistry is optimisation of the retention characteristics of the whole furnish and of the distribution of individual components within the formed sheet. This has to be achieved in a manner consistent with acceptable paper quality (formation, 2-sidedness, etc) and machine performance (drainage, runnability, etc).

Materials entering the papermaking system can be classified in terms of their functionality (as will be described later in this paper), in terms of their size (an important factor determining their ease of retention) and their charge (which determines some of their interactions with one another). As fibres are quite long compared with the openings in the wire fabrics used to form the paper web, they are well-retained in the paper and do not build-up in the papermaking system. By contrast, most other papermaking materials are much smaller in size and are less well retained, unless steps (eg addition of retention aids) are taken to overcome this handicap.

As most papermaking chemicals are purchased in a fully-functional, ready-to-use state, there us little classical reaction chemistry taking place on the paper machine. What chemistry there is tends to be associated with problems such as deposition. The most important aspect of wet end chemistry is that between particles (particularly the high surface area fines fraction) which are mediated by the ever-present water molecules and the dissolved substances. These considerations relating to particle interactions and retention phenomena will be discussed as each type of papermaking chemical is described in this paper. In the final section of the paper, some comments will be made about the selection criteria for papermaking chemicals.

FIGURE 1 WET END CHEMISTRY INTERACTIONS

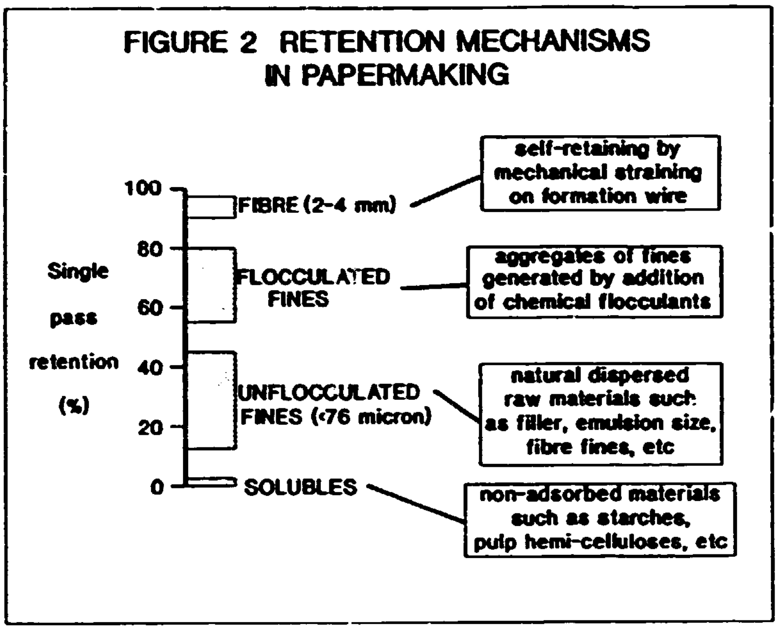


2. Retention/drainage aids

Although the reasons for using retention and drainage aids are quite different, they will be discussed together in view of the similarity and often dual-role of the chemicals used to achieve these effects. Drainage aids are used to increase machine output through facilitating water removal from the fibrous web. Retention aids are added to increase the single pass retention (SPR) of particulate solids (fibre and filler plus adsorbed chemicals) on the papermaking wire and thus maximise efficient use of raw materials. There are other benefits from improved wire retention:

* more stable SPR leading to improved product uniformity and less broke
* a lower flowbox consistency and hence better paper formation/strength
* a cleaner system, as there are lower levels of deposit-forming, recycled solids
* more uniform paper quality (eg less 2-sidedness)
* better efficiency of chemicals that are associated with the particulate fraction
* greater degree of water closure possible before encountering problems
* faster equilibration at grade changes.

The single pass retention of particulate solids is primarily dependent on their state of aggregation at the time that the sheet is formed (ie at the flowbox slice) (Figure 2). The objective behind the addition of retention aids is to promote increased aggregation of the fines <u>without</u> unacceptable aggregation of the fibres and hence poor sheet formation. Conventional retention aids have no effect on the SPR of dissolved solids, unless precipitation or adsorption takes place. The ease of drainage of the papermaking stock is also affected by its particle size distribution and by the surface chemistry of the particles. Drainage is also improved by aggregation of fines that would otherwise fill the gaps between the fibres, but maximum drainage is achieved by the use of chemicals giving small, dense particulate aggregates rather than large., voluminous flocs.



Retention measurements are normally made by taking manual samples of the papermaking suspension at the machine flowbox and of the whitewater draining through the wire. The single pa - wire retention is calculated from the analysed concentrations as follows:

$$SPR (\%) = \frac{100\ (\text{Flowbox concentration - whitewater concentration})}{\text{Flowbox concentration}}$$

The whitewater sample can be taken at several places such as at the first drainage tray or of the combined whitewater from both trays or from both trays plus the vacuum box water. The first tray position gives the most sensitive indication of variations in wire retention. The simplest retention parameter is the total particulate retention which is calculated from total consistencies (measured by sample filtration followed by drying). On fine paper machines, filler retention is a good measure of overall fines retentions and is measured by simply ashing the filtered samples. Fines retention is measured by separating the fines from each sample by washing through a standard 200 mesh (76 micron) screen and measuring the residual fibre concentrations. The wire retention of the fines fraction is calculated by difference. The wire retention of other components (eg starch, size) is more difficult, but can be measured with the appropriate analytical equipment.

Papermaking fines tend to remain dispersed due to the repulsion between the negatively-charged particles. Retention/drainage aids are able to bring the fines together (flocculation) either by neutralising these negative charges or by forming links (chemical bridges) between them. One of the first papermaking retention/drainage aids was alum due to its ability to form, under acid conditions, cationic complexes which could neutralise the negative particle charges. However, these flocs were quite weak and easily broken down by machine turbulence. The most prevalent retention/drainage aids today are organic polymers of many different types, which tend to be used in combination with one another or with inorganic materials such as silica or bentonite.

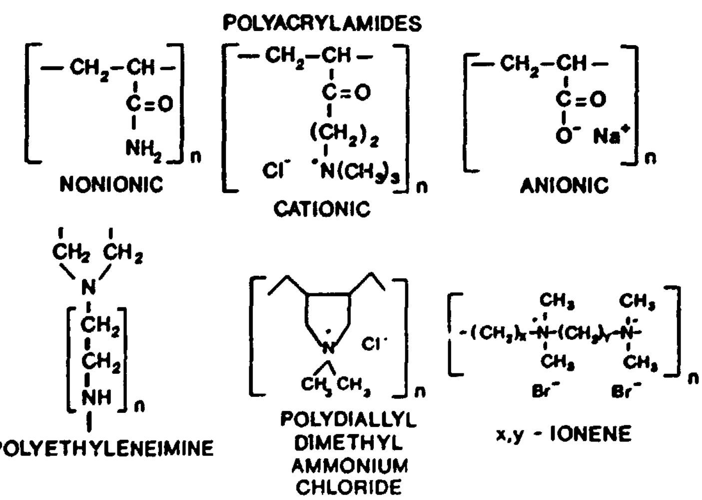
Many of the present-day systems are described as multi-functional in the sense that they are designed to maximise concurrently retention, drainage and paper strength.

Polyacrylamides (PAMs) are the most widely used conventional polymeric retention aids as they can be easily produced with a wide range of chain lengths and charge character (Figure 3). The essentially nonionic polyacrylamide is rarely used in this form as a retention aid, but can be co-polymerised with other chemicals to give anionic polymers or cationic polymers. The types used as retention aids are low-moderate charge polyelectrolytes (either cationic or anionic) of medium-high molecular mass (5-20M Daltons). As fairly long chain polymers, PAMs are able to bridge between particles which produces strong flocs. In most applications today, polyacrylamides are being used as part of multi-component systems, as in Allied Colloids' Hydrocol system with bentonite (a swelling montmorillinite clay).

Polyethyleneimines (PEIs) (Figure 3) are not as widely used as polyacrylamides across different paper grades, but tend to be used in certain sectors such as newsprint and board. The polymer has a lower chain length (up to about 1M Daltons) than polyacrylamides used as retention aids, but a higher cationic charge density. The high charge and relatively low molecular weight mean that PEI functions as a flocculant by a combination of charge neutralisation and "patch" attraction.

Polyamines are a generic group of polymers made by a condensation reaction between alkylamines and epichlorhydrin. Poly-DADMACs are a class of cationic polymers made by polymerising diallyldimethylammonium chloride (Figure 3). Both polymer types have lower molecular weights than PEI with a maximum of about 0.5M Daltons and are fully cationised over the whole pH range. Both polyamines and poly-DADMACs are rarely used alone as retention aids, but increasingly as the charge neutralising chemical in two (or three) component systems.

FIGURE 3 CHEMICAL STRUCTURE OF SELECTED RETENTION AND DRAINAGE AIDS



Polyethyleneoxides (PEOs) are nonionic polymers of high molecular weight (5-7M for the grades used as retention aids). Their use has so far been restricted to newsprint mills which often have difficulty in using more conventional polyelectrolytes economically due to the presence of interfering materials. Although it is effective alone, PEO is generally used with a phenol formaldehyde resin in a two component system due to the strong synergy between the two chemicals.

Cationic starches are widely used as dry strength additives in papermaking, but, being cationic polymers, they are also able to improve retention and drainage. However, since their retention effect is always secondary to their strengthening effect, cationic starches are nearly always used with other specific retention aid chemicals. The best example of a multi-component system harnessing the presence of cationic starch is Eka Nobel's Compozil with colloidal silica (an extremely fine dispersion, average size about 5nm, of negatively-charged silica particles).

Most (although not all) of the commonly-used retention aid polymers are cationic in character. This means that they have a strong electrostatic attraction to negatively-charged material whether this is particulate or dissolved. Most of the particulate solids in papermaking are negatively-charged, but there is increasing quantities of negatively-charged dissolved solids (sometimes called "anionic trash") present. These materials originate from both virgin pulps (eg some hemi-celluloses and lignin derivatives) and wastepaper/broke (some size press starches and dispersants present in coating pigments). Being water soluble and therefore having a very low wire retention, the concentrations of such material build up significantly on machines with closed water systems.

Added cationic additives will interact with both particulate and dissolved anionic materials, the net effect being dependent on their relative concentrations, the chain length of the polymers concerned and the hydrodynamics of the system. Cationic material consumed by dissolved anionic substances may lose its functionality and be poorly-retained. Retention aid systems are being developed to neutralise the effect of such interfering substances and thus allow cationic additives to function effectively and be well-retained. The types of chemical employed are adsorbents such as bentonite and low molar mass, cationic polymers such as PEI and poly-DADMACs and poly-aluminium chloride (PAC).

Retention/drainage aids are usually added to the paper suspension just before the sheet is formed in order to minimise the adverse effects of turbulence on floc formation. The production of strong, shear-resistant flocs is becoming an increasingly-important selection criterion for retention/drainage aids due to the continuing escalation in machine speeds. The doses employed are 0.1-1.5 kg/tonne paper for synthetic polymers, 2-5 kg/tonne for starches and 1-10 kg/tonne for bentonites. In this way, the "natural" fines retention on the forming wire can be increased from, say, 30% to 80% without an unacceptable deterioration in the paper's formation.

3. Deposit control chemicals

The papermaking system represents a near-ideal environment for the proliferation of deposits of all types due to the high concentration of chemicals/nutrients and a moderate temperature. Actual deposits are a complex matrix of accumulated debris, which can have various origins:
* microbiological slimes of bacteria and fungi
* pitch extracted from resinous matter in virgin fibres
* "white pitch" from latices in coated broke
* stickies from adhesive contaminants in wastepaper
* hydrolysis products from synthetic AKD and ASA sizes
* inorganic precipitates such as calcium sulphate.

Uncontrolled deposition can cause a range of problems for the papermaker such as web breaks, pipe blockages, corrosion, degradation of raw materials, product defects/disfiguration, etc. The potential for deposit formation can be minimised by selecting raw materials with good retention characteristics and with a low/zero content of deposit-forming components; by maximising single pass retention on the wire; by "good housekeeping" practises involving regular machine cleaning and by using/maintaining effective showering systems on wires and felts. However, an important aspect of wet end chemistry is the control of deposition by chemical dosing.

Pitch is a generic term for a complex mixture of saturated/unsaturated fatty acids/esters, resin acids and neutral unsaponifiables. Softwoods (particularly pines) have much higher levels of extractives than do hardwoods. The nature and concentration of the residual pitch in the pulp depends on the pulping process, the main pitch problems being on machines using mechanical and sulphite pulps. It is controlled in the paper mill by addition of alum, talc and dispersants at the wet end or by spraying polymers onto the formation wire. Newer methods are upstream control at the pulp mill using fungal pre-treatment of the wood chips and in-mill treatment using enzymes. White pitch from coated broke can be controlled by polymer addition to the broke pulper.

Stickies are now a very well-known class of deposit-forming materials that nearly all wastepaper-based mills have to face. They are present in many types of wastepaper as a result of the incorporation of adhesives during conversion of the paper/board to the finished article, such as magazines and packagings. The adhesives are of two main types - the contact adhesives such as styrene butadiene rubber (SBR), vinyl acrylate, acrylonitrile, etc and the "hot melt" adhesives such as ethyl vinyl acetate (EVA), waxes and tackifying resins (eg phthalates). As well as the normal range of deposit problems, stickies also cause "stick-downs" in the dried sheet leading to runnability problems at the re-winder.

Large primary stickies can be removed by mechanical methods (eg screens, reverse cleaners, flotation deinking), but they are less effective in removing the much smaller secondary stickies generated by mechanical action on the stock. Chemical treatment can be applied to the fibre suspension or to the wire/felts as described above for pitch control. Stock treatment utilises several mechanisms such as macro-coating, charge adjustment, surface stabilisation and encapsulation/detackification.

Slime is an inherent problem in most papermaking systems, although individual mills vary enormously in their tolerance to levels of bacteria and fungi. The only raw material that is treated to minimise intake of micro-organisms is fresh water. In addition to maximising wire retention and good housekeeping, a range of organic chemicals is added to papermaking systems to control slime outbreaks by reducing the number of micro-organisms present to an acceptable level. In many papermaking systems, control of anaerobic bacteria as well as aerobic bacteria is necessary in order to eliminate production of explosive gases such as hydrogen and of odorous sulphides and organic acids. Chemicals used include chlorinated organic compounds, brominated organic compounds, organosulphur compounds, organonitrogen compounds and aldehydes. The biocide formulation may include dispersants and/or surfactants to aid distribution and penetration of the slime masses. The use of enzymes for slime control has been attempted, but is not completely effective without continuing use of biocides.

4. Mineral fillers and loadings

These finely-divided minerals are used in certain paper grades (mainly printing/writing papers) to improve the optical and physical properties of the formed sheet. They increase the sheet opacity and surface smoothness, but reduce its strength and bulk. As the name "filler" suggests, they are also used to cheapen the papermaking furnish as they are considerably cheaper than virgin fibres. In this context, it is important to distinguish between the cheap, general-purpose fillers such as clay, talc and calcium carbonate and the speciality minerals such as titanium dioxide and calcined clays. The latter are used sparingly (eg at low levels in light-weight grades to improve opacity without sacrificing strength) as they are considerably more expensive than virgin fibre. Mineral pigments are also used in the conventional aqueous coating of some papers in order to improve printability.

All mineral loadings are fine particle distributions below about 10 microns maximum particle diameter, but with widely different particle shapes. Calcium carbonates and titanium dioxide are both broadly spherical particles, but the latter are much smaller with nearly all particles below 1 micron diameter. The kaolin clays have a similar particle size distribution to the carbonates, but their flat, platey character retards the rate of water removal during paper drying. On the other hand, this property makes it possible to achieve higher paper gloss after calendering for clay-filled compared to carbonate-filled papers. The surface properties of filler particles are modified in the presence of other papermaking materials such as fibres.

The traditional papermaking filler/pigment has been kaolin clay, which is compatible with the traditional acid papermaking conditions. Calcium carbonates were available in a variety of forms (natural ground limestone, chalk, marble or synthetic precipitated grades), but could not be easily used under acid conditions due to their solubility. However, over the last 20 years or so, there has been a big shift in the balance between these two main types of wet end filler used in papermaking, notably in the wood-free grades where calcium carbonate is now the dominant filler throughout the world.

In addition to the lower cost of calcium carbonates in many regions, they also have superior papermaking characteristics in terms of higher brightness and easier water removal. In the wood-free sector, their use has been made possible by the development of sizing chemicals that work effectively at neutral/alkaline pH. In the last few years, precipitated calcium carbonates (PCCs) have begun to be produced on a .large scale in so-called satellite plants by flue gas-carbonation of lime slurries. They are even brighter and have superior opacifying characteristics compared to natural carbonates, thus enabling them to replace expensive titanium dioxide.

The wood-containing sector has remained more loyal to clay filler, but calcium carbonates are now being used in some grades such as LWC (light-weight coated) papers. Although not sized, wood-containing papers are normally made under acid conditions in order to preclude the loss of brightness that occurs under neutral/alkaline conditions. This loss of brightness can be tolerated more in the coated wood-containing paper such as LWC than the uncoated grades such as SC (super-calendered) papers. The higher brightness of carbonates can off-set to some degree the brightness drop resulting from the higher papermaking pH.

Conventional pigment coating is carried out solely to improve the printability of paper. The main coating pigments are again clay and calcium carbonate, but others (titanium dioxide, satin white, barium sulphate, etc) are also used in smaller quantities in specific grades. Because of their particle shape, clay pigments give better gloss than carbonates, which are thus mainly used for matt-coated papers. The use of carbonates in coating has been another factor in the spread of neutral/alkaline papermaking as the chemistry of the wet end had to be able to contend with the presence of carbonates from the coated broke. On some coated paper grades, the only filler present at the wet end is from the recycling of coated broke.

The amounts of fillers present in papers varies enormously from zero to about 50%. Deliberate addition of filler is absent in the making of tissue, towel and most packaging grades except for the liner ply of some multi-ply boards. Traditional newsprint also contains zero filler, but is added at low levels (up to 5%) on lighter grades in order to maintain opacity and is present incidentally in recycled grades from its presence in the magazine furnish. Uncoated wood-free and wood-containing papers contain up to 30% filler, but this can be raised to about 50% if they are coated. Papers containing up to about 80% filler have been in the laboratory, but this requires either special manufacturing methods or high doses of other chemicals in order to compensate for the impaired strength of the product.

As negatively-charged fine particles, the natural wire retention of fillers is often low (<50%) and retention aids are thus always used to improve fines retention on filler-containing machines. The high fines content at normal filler levels increases the demand for chemicals that function by surface coverage, eg retention aids and sizes. This is greatest for coating-derived fillers, but their wire retention is similar to that of the slightly-larger wet end fillers provided retention aids are used. Perhaps surprisingly, the wire retention of fillers is improved by fibre refining as it increases the likelihood of hetero-flocculation between filler and fibre fines. Filler retained in the paper impairs paper strength through interference with inter-fibre bonding and is compensated for by addition of dry strength additives at the wet end and at the size press.

5. Sizing chemicals

Sizes are added to paper to improve the paper's resistance to penetration of a liquid, normally of water. This usually involves addition of a hydrophobic (water-hating) material to the fibre suspension before the web is formed. The penetration of water into the body of the paper can also be slowed down by closing off the capillaries of the formed sheet by addition of a film-forming chemical such as starch. This is known as surface sizing and is normally carried out at the size press. Resistance to penetration of non-aqueous liquids can be achieved by addition of fluoro-chemicals, usually added to the surface of the paper.

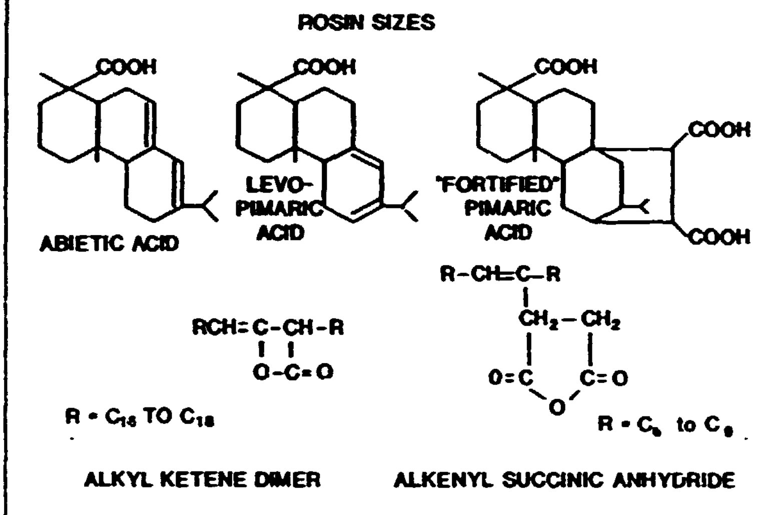
The main technique for assessing sizing efficiency is the Cobb test, which involves contacting a circular area of paper with water for a defined time (most commonly 1 minute) and measuring the water pick-up in g/m^2. Another technique is the Hercules Sizing Test (HST), which involves measuring the time (in seconds) for a water-based dye to become visible on the other side of the paper. Contact angle measurements are not widely used in sizing specifications, except for paper with stringent sizing requirements such as carbonless copy paper. Unsized ("water-leaf") papers have 1 minute Cobb values exceeding 200 g/m^2, which can be reduced to below 20 g/m^2 by the addition of size. For effective sizing, the size chemical must be well retained by the fibre and the molecule oriented in the optimum way with the hydrophobic part of the amphipathic size molecule pointing away from the cellulose. It is also necessary to cover all the exposed fibre surfaces before effective water resistance is achieved, otherwise water is wicked in through the uncovered fibre surfaces.

There are three main sizing chemicals added at the wet end - rosin, alkyl ketene dimer (AKD) and alkenyl succinic anhydride (ASA) (Figure 4). Of these, AKD is sometimes also added at the size press with starch, but as one of the reasons for sizing is to control the pick-up of starch at the size press (and of the coating mix at coaters), wet end addition is the normal technique. There are other sizing agents based on stearates, polyurethanes and polyacrylates, but they tend to be added at the size press rather than at the wet end. Over the last 30 years, there has been a big swing away from traditional rosin size used under acid conditions with alum to the use of AKD/ASA sizes used under neutral/alkaline conditions. This has been driven by a host of factors, but mainly by the desire to replace clay by calcium carbonate filler, the use of which is incompatible with acid conditions.

Rosin size` is obtained from softwood trees, mainly by distillation of tall oil which is separated from Kraft pulping liquors after acidification. Rosin is a complex mixture of predominantly (90%) polycyclic resin acids (abietic and pimaric acids and their derivatives) plus a minor fraction (10%) of neutral compounds (resin/fatty acid esters and alcohols). The efficiency of natural rosin may be improved by carrying out a Diels-Alder reaction with maleic anhydride, which introduces two additional carboxyl groups into levopimaric acid (Figure 4). Their improved efficiency is thought to be due to reduced particle size and improved bonding, as the molecule itself is much less hydrophobic than natural rosin.

For wet end addition, the rosin has to be converted into a water-soluble or water-dispersible form. The most common type used to be rosin soaps, but most rosin sizes

FIGURE 4 MAIN SIZING CHEMICALS



used today are rosin emulsions containing 80-90% free rosin emulsified by the addition of casein. Emulsified rosin sizes have the advantages of being able to function at a higher pH (5-6 cf 4-5 for soaps) and being less affected by hardness salts in the water than soap size. In order to achieve good sizing with rosin, the traditional approach has been to use alum, which can react with the rosin to form the aluminium "dirosinate", but the extent of this reaction at the wet end depends, inter alia, on the form of the rosin added. For rosin emulsions, there is little chemical reaction at the wet end and the emulsified rosin particles are thus retained by a hetero-flocculation mechanism with other particulates and the aluminium species by adsorption of the cationic complexes onto the whole particulate matrix, not just on the rosin. Once retained, the rosin is oriented with the hydrophilic part pointing towards the fibre and the hydrophobic part towards any external liquids.

Polyaluminium chloride has been used in place of alum to size at more neutral pH values as it maintains its cationicity at higher pH levels than does alum. The latest types of rosin size are emulsions containing a cationic polymer as an emulsifier/retention promoter and enough aluminium for reaction with the rosin in the drying section. They are designed to operate as one-pack systems at neutral pH in the presence of calcium carbonate filler. In addition to lowering the amount of alum used, other benefits found include less foam, improved fibre/filler retention and more stable operation. Existing experience is mainly on wood-free machines, but successful results have also been achieved with mechanical pulp and wastepaper furnishes.

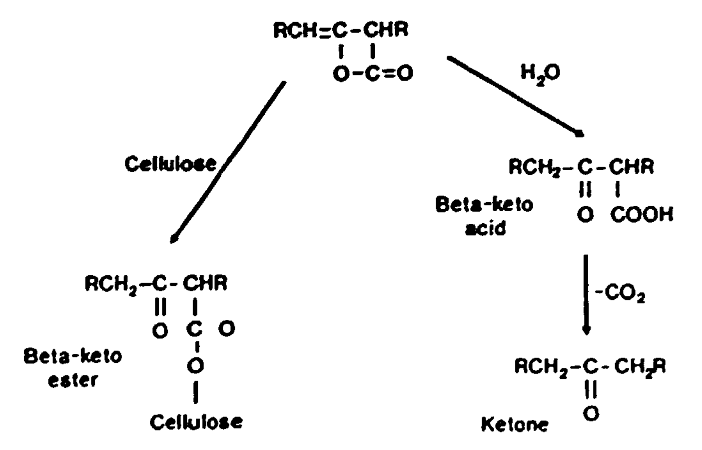
Rosin addition rates vary widely depending on individual circumstances, but are typically 0.3-0.5% on fibre for wood-free papers. Levels well above 1% on fibre may be needed, however, for the more difficult hard-sized grades, eg wastepaper-based "fish boxes". Alum doses (as $Al_2(SO_4)_3.18H_2O$) cover a similar range from 0.5% to 2%, but much higher doses are sometimes used when alum is (incorrectly) added for pH control. This is better done with sulphuric acid.

Alkyl ketene dimer (AKD) size has a lactone ring structure (the hydrophilic part) attached to hydrophobic alkyl groups (Figure 5). It is made from animal or vegetable fatty acids, eg hydrogenated tallow based on palmitic and stearic acids. AKD is a light brown, waxy solid with a melting point of about 50°C and is sold commercially as a liquid emulsion with solids contents from about 6 to 25%. AKD sizes are sometimes called reactive sizes due to their chemical reaction with cellulose (Figure 5), unlike rosin which does not size by chemical reaction, but by forming a physical barrier/film preventing water penetration.

In addition to the active AKD sizing component, the size formulation usually contains a cationic emulsifier/retention promoter and, sometimes, a cure promoter. The exceptions are the newly-developed anionic AKDs. The original AKD formulations launched in the 1950s/60s were emulsified with cationic starch and were often used in combination with separate addition of a polyamidoamine-epichlorhydrin (PAE) resin as a retention/cure promoter. One of the major limitations with AKD as a sizing agent is the rather slow development of sizing during drying, sometimes leading to an unsized sheet before the size press or at the reel. However, the rate of sizing is critically dependent on the temperature achieved in the sheet during drying and this can be expedited by increasing the sheet pH or by the presence of cure promoters such as PAE resins.

Both within the concentrated emulsion and after addition to the paper machine wet end, AKD can hydrolyse by opening of the lactone ring to generate the beta-keto-acid, which then decarboxylates to the dialkyl ketone under alkaline conditions (Figure 5). This is minimised in the emulsion by maintaining the pH at about 3 and by storage at the lowest practical temperature. Hydrolysis of the AKD is undesirable at the wet end as the degradation products contribute to deposition problems and any ketone in the sheet does not contribute to sizing (in fact it may have a desizing effect) and, more importantly, it decreases the friction coefficient of the paper leading to a very slippy surface.

FIGURE 5 REACTIONS OF AKD



As a fine particle emulsion (typically 0.5-1 micron), the AKD size is retained by a hetero-flocculation mechanism with the rest of the particulate matrix. Retention is affected little by pH, but is adversely affected by alum and anionic substances. In the sizing of filled papers, there is likely to be some electrostatic attraction between the cationic AKD and the anionic fillers and it has been shown that there is usually a good correlation between fines retention on the wire and AKD retention. Once retained in the paper, the sizing effect is generated as the paper is heated in the drying section. Although it has now been proven that some of the added AKD does react with cellulose, the major part of the AKD retained in the paper makes no direct contribution towards sizing, although its presence appears to be necessary to the smaller fraction achieving its sizing effect. The amount of AKD needed to achieve a Cobb value of 25 g/m^2 covers the range 100-400 g AKD/tonne fibre, depending on pulp type. This compares with typical addition rates for wood-free fine papers of 500-1500 g AKD/tonne in the presence of fillers. Doses of the liquid emulsion vary widely from about 1% on fibre to above 4% for hard sized, difficult furnishes.

Alkenyl succinic anhydride (ASA) sizes are less widely used in Europe for neutral sizing compared to AKD sizes, but are more prevalent in North America. The size is manufactured by reacting a petroleum fraction containing a mixture of alkenes (usually C_{15} to C_{20}) with maleic anhydride. The resultant succinic anhydride is a brown oil, which is much more reactive than AKD and is not therefore normally sold as a ready-to-use emulsion, but the emulsion is prepared on-site. Exceptions to this are the water-in-oil ASA emulsions, which only need dispersing in water before use and the saponified ASA sizes used mainly in Japan. All the other major suppliers of ASA sizing systems purchase the ASA oil and provide an emulsification system using their own chemical auxiliaries.

The mechanism of ASA sizing is one of direct ester formation with cellulose. The main problem with ASA sizes is hydrolysis at the wet end and in the sheet, but this is more severe than with AKD sizes due to ASA's greater reactivity. Wet end hydrolysis generates the di-acid, which can then react with calcium ions to form the very tacky calcium soap. Deposits can be minimised by the addition of small doses of alum (ca 0.1%) to form the aluminium soap which is less tacky. High temperature and pH accelerate ASA hydrolysis. Retention of the hydrolysate in the paper does not cause a slippy surface (as in the case of AKD), but it can act as a desizing agent. Consequently, high single pass retention of ASA is critical to good runnability and product quality.

The quality of the on-site produced emulsion is one of the important variables determining ASA's overall performance. Commercial systems offered to paper mills vary in terms of the chemical(s) used for emulsification and the level of mechanical agitation during emulsification. The additional chemicals can include stabilisers to inhibit particle coalescence, promoters to induce hetero-flocculation with fibres and activators to facilitate efficient emulsification in low-shear preparation plants. The traditional chemical that acts as a promoter and stabiliser is cationic starch, but emulsification systems based on synthetic polymers are also in use. Cationic starches with quaternary (rather than tertiary) nitrogens are the most effective for consistent ASA retention. The normal ratio of starch:ASA is 2:1, but ASA sizing efficiency continues to increase up to a 5:1 ratio due to the stabilising effect of starch on emulsion particle size (optimum 0.5-3 microns).

Although the emulsion is made cationic to maximise retention, retention aids are essential to achieve reasonable on-machine wire retentions and thus limit the hydrolysis problem. Once retained in the sheet, ASA sizing develops more rapidly than with AKD sizes and there are usually no problems from inadequate cure at the size press or at the final reel. Addition rates are 0.1-0.4 kg ASA/tonne paper covering the applications from wood-free fine papers to wastepaper-based boards.

6. Dry strength additives

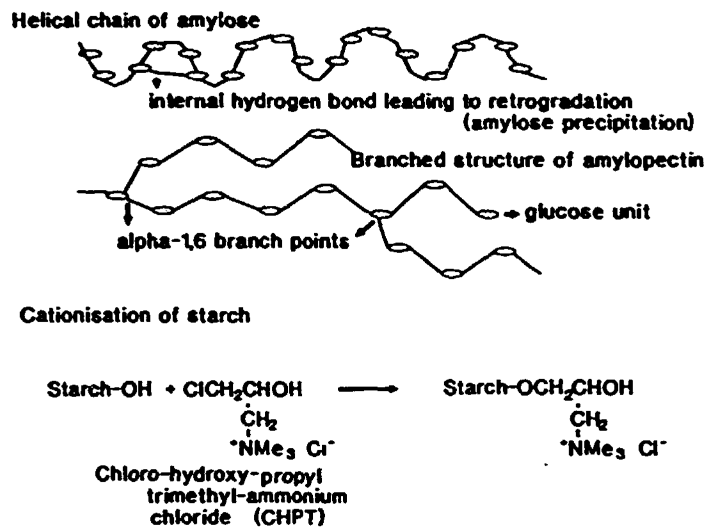
The main objective in refining of fibres is to improve their strength characteristics through changes in fibre length and the extent of fibrillation. This leads to increased fibre flexibility and fibre surface area available for bonding. Whilst the main strength properties such as tensile and burst strength are thereby improved by refining, tear strength generally suffers a drop due to fibre shortening. The closer fibrous structure also leads to better formation and increased sheet density and opacity and therefore to decreased bulk and air permeability. Before the paper is formed, however, refining generates fine particles which impair wire retention, drainage and water removal, but provide an increased surface area for interaction with fillers and chemical additives.

A complimentary way of improving paper strength (with none of the side-effects such as impaired drainage) is through the addition of chemicals. In some grades, chemicals are used instead of refining, but chemicals tend generally to be used with refining to give an overall optimum system in terms of productivity and product performance. Dry strength additives are most widely used in the making of filler-containing papers, where the filler has a negative impact on strength and in wastepaper-based papers, which are inherently weaker than comparable pulp-based alternatives.

Dry strength chemicals can be added at the wet end before the paper is made and/or to the paper surface by spraying or by immersion at the size press. Wet end addition gives a more uniform distribution of the chemical in the paper's z-direction, whereas, in surface addition, the chemical tends to be concentrated at the surface to give a hard film. The main type of chemical used as dry strength additives are starches, but natural gums and synthetic chemicals (eg polyacrylamides) are also used for special applications. Starch is a natural, renewable and biodegradable material obtained from a variety of sources - wheat, maize/corn, potatoes, rice, tapioca, etc, each type having slightly different characteristics in terms of the two constituent polymers (amylose and amylopectin) and their chain length (Figure 6).

The native starches are nonionic or slightly anionic in character and thus have very poor affinity for the negatively-charged particulate solids. Starch retention at the wet end is improved by cationising the starch (Figure 6), which is then attracted to the particulate matrix by electrostatic forces. The cationisation of the starch is normally carried out by the starch supplier, but this can also be done in situ at the mill. In some cases, anionic starches or combinations of anionic and cationic starches may be the most efficient, depending on the charge distribution at the wet end. Cationisation of potato starches produces starches with some amphoteric character. The degree of starch cationicity is an important characteristic and is expressed as either the degree of substitution (DS) or by the measured nitrogen content of the starch. Theoretically, starches could be cationised so that each glucose unit in the starch chain contains 3

FIGURE 6 STARCH FORMULAE



cationic groups (DS = 3), but the maximum practical/economic level is starch with a DS of about 0.05, which corresponds to a nitrogen content of about 0.5%..

The adsorption of cationic starch on fibre depends on many factors related to the water such as pH and the presence of cations such as calcium/aluminium; related to the pulp such as carboxyl content and surface area; and related to the starch itself such as DS and dose. Cationic starch (like most other cationic materials) adsorbs preferentially on the fines fraction, which can then be deposited on the fibre fraction thus raising its retention. However, the distribution of starch between fibre, fines and water depends on the starch cationicity and the dose employed. It is normal to reduce the starch cationicity as the starch dose is increased with typical cationic starch doses at the wet end of 0.2-1%.

After cationic starch, the main wet end dry strength additive is polyacrylamide, but this has a much lower chain length than polyacrylamide used as a retention aid. The molar mass of the dry strength polymers is measured in hundreds of thousands of Daltons with an upper limit of about 1M. At this molar mass, the polymers are not able to bridge effectively between particles and retention is thus dependent on the extent of adsorption on individual particles. The doses of polyacrylamide dry strength agents are much higher than when they are used as retention aids, in the range 0.1-0.5% on fibre. Guar gums are also used as wet end dry strength additives. Guar is a galactomannan polysaccharide with a branched structure somewhat similar to that of the amylopectin fraction of starch. The different position of the hydroxyl groups compared to starch is believed to account for its good adsorption on cellulose. Like starch, guar can be cationised and cationic guar improves particulate retention and sheet drainage due to the small flocs that are formed by virtue of its low charge and low molecular weight.

7. Wet strength additives

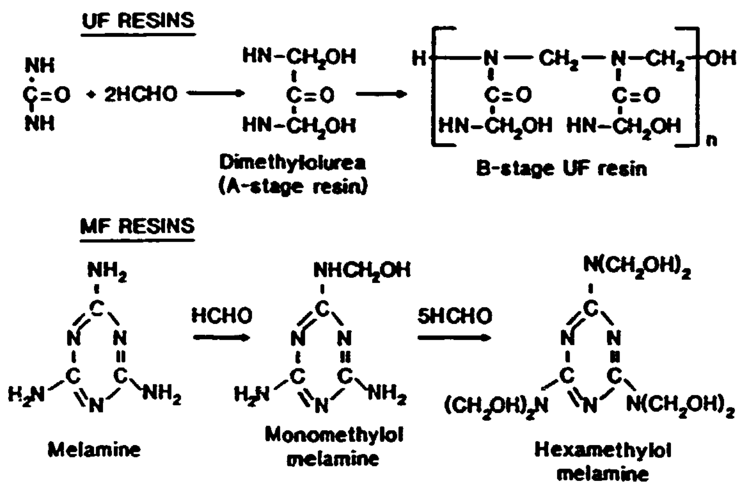
Wet strength is the ability of the paper to resist disintegration when saturated with water. In the absence of specific chemical treatment to enhance wet strength, paper retains less than 10% of its dry strength when wetted. Wet strength should not be confused with sizing, which only slows down the absorption of water and has only a small effect on wet strength. The poor wet strength of cellulose affirms the fact that much of its dry strength is attributable to hydrogen bonding, which would be expected to be easily disrupted by water molecules. The strength of paper can be partially maintained under wet conditions by the addition of chemicals to the paper suspension before the sheet is formed. At best, the paper then retains about 50% of its dry strength. The main grades utilising this treatment are towel products, sack papers, photographic papers and label papers.

There are two broad categories of wet strength chemical - the acid-curing formaldehyde-based resins with urea (UF) or melamine (MF) and the neutral-curing polyamidoamine-epichlorhydrin (PAE) resins. Other chemicals to give either permanent or temporary wet strength include polyethyleneimine, dialdehyde starches and glyoxylated polyacrylamides. Wet strength can also be introduced by the incorporation of latices or by surface treatment of the paper with a cross-linking chemical such as formaldehyde. The chemistry of the UF and MF resins is shown in Figure 7. The normal papermaking resin is the B-stage resin, which then reacts further in the drying section to form the 3-dimensional cross-linked C-stage resin, which physically protects the fibre from water penetration. The soluble UF resins are retained by adsorption on fibre, whereas the colloidal MF resins are retained by a hetero-flocculation mechanism. Once retained, both resins need acid conditions (sheet pH<5) to cure, but the MF resins are less sensitive in this respect and cure more rapidly on-machine. The superior wet strength characteristics of the MF resins are counter-balanced by greater cost and by the deleterious effect of sulphate ions on performance.

The free formaldehyde content of UF/MF resins is important in terms of resin performance and possible release of formaldehyde to atmosphere during use. Traditional levels of free formaldehyde are up to 2% for UFs and up to 5% for MFs. Resins with a low content of free formaldehyde can be produced, but this tends to reduce efficiency. The level of free formaldehyde is an equilibrium concentration, which tends to re-establish itself whatever the free formaldehyde level at the time of packing. The supplied resins contain 25-40% UF solids and 6-12% MF solids and are usually added at the end of the thick stock system for good adsorption. Resin performance depends very much on process conditions, particularly pH and curing time with the formaldehyde-based resins.

The chemistry of the PAE resins is shown in Figure 8. The B-stage resin is water soluble and its natural cationic character ensures good adsorption on fibre. The factors affecting adsorption of the resin are similar to those for any soluble cationic polymer, but, as the PAE resins are much more cationic, they have an even stronger tendency to adsorb on the fines fraction. Prior addition of a low molar mass cationic polymer can saturate the fines and neutralise any anionic interferences present, thus allowing the wet strength resin to be adsorbed on the well-retained fibre fraction. Conversely, the addition of high doses of resin to achieve a high wet:dry strength may exceed the

FIGURE 7 CHEMISTRY OF UF AND MF RESINS



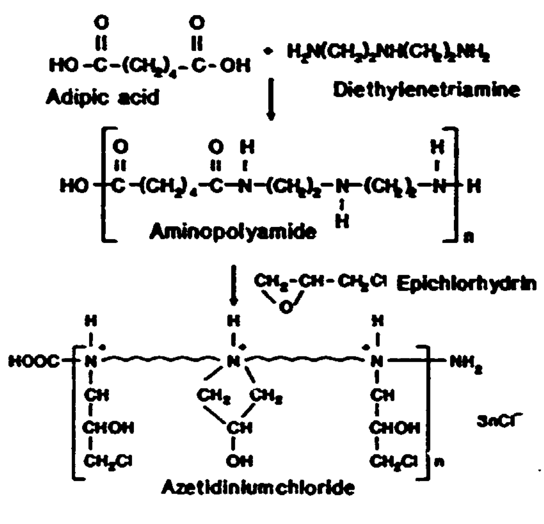
adsorption capacity of the fibres. In these cases, it has been found that the prior addition of anionic polymers such as carboxymethylcellulose (CMC) improves resin retention by providing an increased number of anionic sites on the fibre for resin adsorption. Residual chlorine in the furnish reduces resin efficiency by oxidising and chlorinating the molecule and leads to alkaline hydrolysis.

Once retained, the cure rate of PAE resins is much slower than for UF/MF resins, but is not influenced by pH over the normal range of 4-8. Sheet temperature has a significant influence on the cure of PPE resins, but on-machine cure is at best about 50% of the ultimate cure, which can take up to 2 weeks to achieve depending on storage temperature. In contrast to UF/MF resins, PPE resins do not significantly improve the dry strength of the paper. Once fully cured, wastepaper/broke containing PAE resins are very difficult to repulp due to the permanent nature of the wet strength effect. UF/MF-strengthened papers can be repulped quite easily with simple cold or hot acid treatment, but PAE-strengthened papers require the addition of hypochlorite/alkali at elevated temperature to hydrolyse the cured resin. The PAE resins do not release any volatile components during use, but can contribute to the AOX (adsorbable organohalogen) content of wastewaters when they are not retained in the paper. During synthesis of the PAE resins, epichlorhydrin can also generate dichloropropanol (DCP), a suspected carcinogen. For both these reasons, a new range of PAE resins is now available with reduced AOX and DCP contents.

8. Colorants and brighteners

The ability to produce papers with tints or deep shades is very important in certain sectors such as tissue/towel and printings/writings. Some types of paper such as fluting and liner have a "natural" colour due to the presence of residual lignin from the unbleached pulp. At the other extreme, there are high whiteness papers, which incorporate fluorescent chemicals to overcome any yellowness from low levels of

FIGURE 8 CHEMISTRY OF PAE RESINS



lignin in the bleached pulp. The use of certain minerals such as titanium dioxide could be looked on as form of colouring due to their high natural brightness. There are two classes of colorants: water-soluble dyestuffs and particulate pigments (either inorganics such as iron oxides and carbon black or insoluble organics such as phthalocyanines). Pigments are mainly used where a high degree of light fastness is required, but are used more in surface applications than at the wet end.

Wet end colorants are mainly water-soluble dyes added at either very low doses (0.01% on paper) to give a tinted paper or at high doses (up to 10% on paper) for very deep shades. Water soluble dyes are of two basic types:

* anionic or acid dyes, in which the anion is the chromophor and the cation is either sodium or potassium. These dyes have a relatively poor affinity for cellulose as the chromophor is negatively charged. This led to the development of the so-called "direct" dyes, which are modified anionic dyes with better substantivity to bleached chemical pulps.

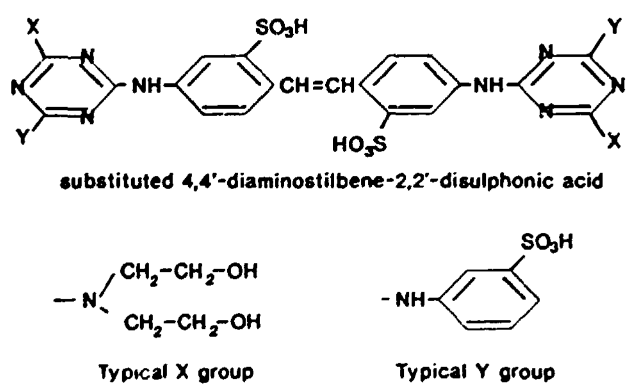
* cationic or basic dyes, in which the cation is the chromophor and the anion is typically a hydrochloride, chloride or sulphate group. These dyes have a good affinity for unbleached chemical/mechanical pulps.

Metal ions are incorporated in some dyes (eg copper in phthalocyanines) in order to improve light fastness. The most widely-used papermaking dyes are the azo-based anionic dyes, but fixing agents such as alum or cationic polymers (eg dicyandiamide) are needed to give good adsorption on fibre. As a large proportion of the dye will be associated with the fines fraction, high fines retention is desirable to achieve consistent coloration and to minimise 2-sidedness. Dye retention is better in hard waters than in soft waters as the calcium/magnesium ions can precipitate the dissolved dyes, which are then more effectively taken up by the fibres. A minimum water hardness of 50 mg $CaCO_3$/l is desirable for efficient dye retention in the absence of alum. Today, most mills are using continuous dosing of liquid dyes, usually at the end of the thick stock system. Because of certain inherent difficulties with wet end dying (long colour changes, contaminated whitewater, colour 2-sidedness), there has long been interest in surface dying. However, the use of this technique is still limited (due to problems of 2-sidedness, mottle and bleed fastness), but development of new surface application techniques could change this.

Most fluorescent brightening agents (FBAs) (also called fluorescent whiteners or optical brighteners) are triazinyl derivatives of 4,4'-diaminostilbene-2,2'-disulphonic acid (Figure 9), which has a similar structure to that of anionic direct dyes. The X group is a dialkylamine and the Y group a substituted benzylamine, which are selected to give the required solubility, substantivity, shade and acid stability. The benzylamines have varying degrees of sulphonation to control the water solubility and hence fibre substantivity. The most common wet end FBA is the tetra-sulphonated type.

FBAs function through their ability to absorb light in the near ultra-violet and re-emit the light (fluoresce) at a higher wavelength in the blue region of the visible spectrum. The ability of the FBA to function in this way is affected by exposure of the dilute FBA solution to light, which converts the substantive FBA with a trans-stilbene link to the non-substantive FBA with a cis-stilbene link. At the machine wet end, the anionic FBA can be "quenched" by cationic materials such as alum and polymers and this changes the fluorescence of the FBA from the blue to the green region. As with anionic dyes, the adsorption of FBAs is enhanced by hardness salts and by increased temperature. It should be added to the thick stock before the addition of any cationic additives. In view of the difficulties with retention and the fact that the FBA is only really needed at the paper surface, FBAs are frequently added at the size press or the coater.

FIGURE 9 CHEMISTRY OF FLUORESCENT BRIGHTENING AGENTS



9. Surface application of chemicals

Chemicals can be added to the surface of the formed paper sheet in three ways:

* by spraying onto the sheet, most commonly to apply slurries of uncooked starches between the plys on multi-ply machines in order to improve ply bonding

* by immersion/impregnation, most commonly to apply solutions of cooked starches at the size press on machines making printing/writing papers and recycled boards

* by metered application in some form of coater, usually to apply a slurry of pigment and binder to make conventional coated papers.

In this paper, only addition at the size press will be discussed. The term "size press" is usually somewhat of a misnomer today as size press chemicals are added mainly to improve the surface strength of the paper. Although the bulk strength of the paper can be improved by reducing the viscosity of the added solution, chemicals such as starches tend to concentrate at the paper surface due to their good film-forming properties. The uptake of water by capillary action is thus reduced as the surface pores are closed off by the set film. Sizing with hydrophobic chemicals such as AKD can be carried out at the size press, but some wet end sizing is still often used in order to control pick-up of the size press solution.

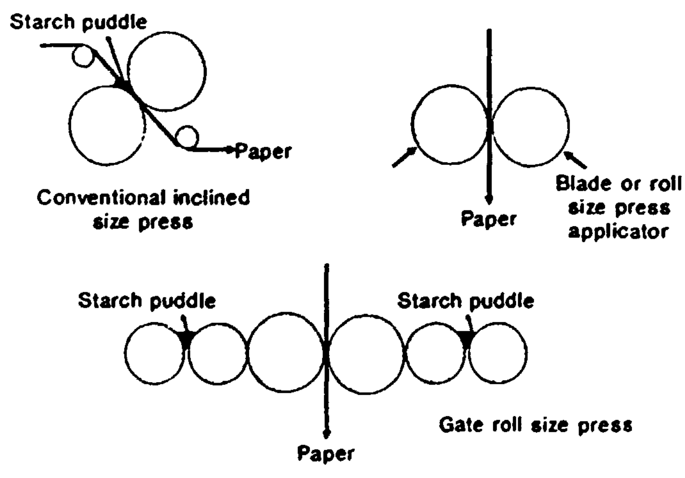
Size press technologies are now moving away from the traditional inclined size press towards technologies to new technologies (Figure 10) which give more control over the pick-up of the added chemicals and which can be operated at higher machine speeds without splashing problems. The gate roll size press applies the solution from an off-set pond formed between two small applicator rolls, but this system is complex and requires solutions of high viscosity thus limiting paper impregnation. Current size press designs are mainly based on applying the size press solution directly to the size press rolls using blades and grooved or smooth rolls. In the fine paper sector, these types of size press are being increasingly used to apply low quantities of starch/pigment mixtures and thus improve the paper's printing quality.

For uncoated papers, starch addition at the size press improves the printing surface in terms of smoothness/ink hold-out and reduces dusting/linting problems. Some impregnation is required to augment fibre/filler bonding. For recycled packaging grades, starch addition at the size press improves all strength properties, particularly stiffness, by concentrating the starch at the paper surface. There are a wide range of starch types available for surface application from the in-mill converted native starches to supplier-modified starches with varying functionalities. All starches are solubilised by maintaining the starch slurry at about 90°C for several minutes, but native starch solutions are usually too viscous for use at normal size press concentrations (5-10% solids content). Such starches are thus usually converted to a usable form by cooking in the presence of chemicals (hydrogen peroxide or ammonium persulphate) or enzymes (amylase), which reduce the starch's chain length and thus its viscosity. As this conversion degrades the starch, it has to be closely controlled in order to minimise the reduction in the starch's strength-giving properties.

The starch manufacturer can chemically modify native starches for a variety of reasons. Oxidised starches are reasonably cheap and produce more stable solutions than converted native starches, but introduce anionic material to the wet end when size press-treated broke is recycled. Starch ethers and esters also produce more stable solutions and produce very strong starch films with enhanced resistance to oil/grease. They are also poorly retained when broke is repulped, but interfere less with wet end chemistry as they are not anionic. Cationic starches like those widely used for wet end addition, but generally of lower cationic character, are being increasingly used at the size press, despite their higher price, as they combine stability, good film-forming and high retention in recycled broke. The most stable starch solutions are produced by starches with low amylose content such as the waxy maize type.

One of the most recently-developed starch types is the hydrophobic cationic starches, which are able to offset the normal small impairment of sizing caused by the addition of the conventional hydrophilic starches at the size press. However as mentioned above, other hydrophobic chemicals can be incorporated in the size press solution in order to achieve this effect. Anionic AKD sizes have been added in this way for some time, particularly on paper machines where wire retention of the fines fraction is poor or where the water system is very closed. Polyurethanes and copolymers of styrene-maleic anhydride (SMA) or styrene-acrylic acid are all compatible with starch solutions and are used in the production of fine papers to improve ink hold-out in printing and to reduce the penetration of coating solids. Enhanced oil/grease resistance can be achieved by the addition of fluorochemicals, some of which also improve water resistance. Other chemicals such as fluorescent brightening agents can also be added with starch solutions at the size press.

FIGURE 10 SIZE PRESS TECHNOLOGIES



10. Selection of chemical additives

The overall use of papermaking chemicals has never been greater and, despite attempts to move chemical addition away from the wet end to the paper surface, this trend looks set to continue. Papermaking chemicals have always evolved to match the changing machine conditions and due to the ingenuity of chemical suppliers in producing new chemical entities in response to the quality requirements of the papermaker. However, the conventional selection criterion of cost-performance for a specific application is gradually being extended to include factors that are less under the papermaker's control. Whilst some of these are legislative requirements (eg product restrictions in terms of user safety), others are reacting to market pressures or customer perceptions (eg chlorine-free pulps). Even within the normal area of cost-performance, however, raw materials have had to contend with considerable changes in the design of papermaking machinery and in product specifications.

The prices of raw materials do not move inexorably in one direction, as exemplified by the recent collapse and the current rapid rise in the world price of virgin pulps. These shifts have some effect on the cost-performance of fibres versus other ways of achieving a particular product effect. Fibrous raw materials are evolving continuously due to changes in pulping/bleaching practices, but most of these have been motivated by environmental and/or energy factors. The increased use of CTMP pulps and non-deinked wastepaper introduces into the papermaking system a greater level of non-cellulosic materials, which could cause more control problems. Use of wastepaper also has implications in terms of strength additives and slime control. The increased use of calcium carbonate is a classical example of better cost-performance against other minerals and, due to the increased strength of neutral papers, against fibre as well. This happens to coincide quite fortuitously with a range of environmental benefits related to waste generation and system efficiency.

The main changes in papermaking machinery are related to increased outputs from faster machine speeds and greater water removal before the drying section. Both these place greater pressure on the state of aggregation of fibre/filler in terms of both retention and drainage characteristics. Operation at higher system consistencies is motivated in part by possible energy savings, but should be accompanied by better chemical efficiencies. Whilst few paper machines are able to operate with no wastewater discharge outside the mill, there is continuing interest in closing up the water system on most types of paper machine for a variety of environmental and cost reasons. The accompanying changes in process chemistry lead to a range of potential problems from the build-up of energy and chemicals. Chemical additives thus need to be more resistant to degradation at the higher temperatures and less affected by the presence of interfering substances such as poorly-retained starches and anionic debris.

There are two continuing trends in product specifications - lowering grammages and rising filler contents for filled papers. Both put pressure on effective retention aid systems. Quality management programmes for products (eg ISO 9000) place emphasis on controlling defects at source, which means more stable wet end operation through better control of wet end chemistry. This interest happens to coincide with the development and successful demonstration of the benefits of monitoring/control sensors for various aspects of wet end chemistry such as wire retention and charge. The resulting more stable retentions have led to dramatic reductions in process variability such as decreased web breaks and to more consistent product grammage and filler content.

All paper products have to be safe to use, but there is little specific legislation in this area. In some countries, there are migration limits on materials such as heavy metals and there are positive listings of acceptable substances for contact with foods. One particular set of substances has pre-occupied the pulp and paper industry over the last few years and this is the chlorinated dioxins formed when chemical pulp is bleached with chlorine under certain conditions. There are no mandatory dioxin standards for paper products, but this concern has now extended to wider issues related to pulp bleaching with chlorine compounds. Both elemental chlorine-free (ECF) and totally chlorine-free (TCF) bleaching generate pulps with non-detectable levels of dioxins in the product. Similar concerns apply to all papermaking raw materials as exemplified by the development of wet strength resins with reduced levels of chlorinated organics.

Criteria to judge the overall environmental-soundness of paper products are now being developed in various eco-labelling schemes and other initiatives. An important element within such systems is the development of criteria for environmentally-sound papermaking raw materials of all types. A profile of an ideal papermaking raw material could be the following:

* primary raw materials should be sustainable and renewable
* supplied material should not contain or generate substances classified as hazardous to human health
* supplied material should not contain or generate substances classified as dangerous to the environment
* functional papermaking materials should be capable of being well-retained in paper
* process chemicals and other non-retained materials should:
  - be capable of being easily removed by conventional wastewater treatment processes
  - not adversely affect the efficiency of such processes and
  - not adversely affect the disposal or re-use of wastewater sludges
* any process chemicals and non-retained materials that are not removable by wastewater treatment should not be persistent in the aquatic environment
* retained materials should:
  - retain their functionality during wastepaper recycling
  - not impair the wastepaper recycling process
  - not impair and be useful during other methods of wastepaper re-use.

Such criteria will become more important in the future, although, realistically, selected raw materials will still have to do well in terms of the normal cost-performance test.

THE OUTLOOK FOR PULP & PAPER ON SMALL SCALE BASED ON NON WOOD FIBRES

C O N T E N T S

1.0 Introduction

2.0 The World Scenario

3.0 Small Scale Pulp & Paper Mills

4.0 Indian Scenario
- 4.1 Raw Material Requirement For Projected Demand, And Options
- 4.2 Non wood Fibre A Logical Choice For Developing World
- 4.3 Various Fibres and Size of Installations
- 4.4 Bagasse - A Forerunner

5.0 Problems Associated With Use of Non Wood Fibre
- 5.1 Collection, Transportation and Storage
- 5.2 Depithing
- 5.3 Pulping
- 5.4 Washing
- 5.5 Bleaching
- 5.6 Fibre Characteristics and Silica Content

6.0 Paper Making

7.0 Speciality Papers From Non Wood Fibrous Raw Materials

8.0 Rebuild & Modernization - A Continuous Need For Survival

9.0 Recovery of Chemicals & Pollution Abatement
- 9.1 Abscence of Chemical Recovery Due to High Silica Content
- 9.2 Magnitude of The Problem in Economic Terms
- 9.3 Varicus Technologies Under Experimentation
- 9.4 Pollution Loads With & Without Recovery
- 9.5 Conventional & New Effluent Treatment Methods

10.0 Outlook After Liberlization and Globalization

11.0 Outlook - Summary

1.0 Introduction

I am indeed grateful to UNIDO and the organizers of Iran for inviting me to this beautiful city of Tehran to share with you some of my experience in the field of pulp & paper making in the small & medium sector.

Having spent over 35 years in the pulp & paper Industry and having had the previlage of looking from the close quarter, both the advances in the developed world and the efforts the developing world is making to improve their operations, I have always found that the success of any small scale operation essentially depends upon the entrepreneural spirit at the back of the operation.

There is a basic difference between the operation of a large unit and a small unit. In case of a large unit the entrepreneur has a team of professionals at his command and also has a necessary financial power to aquire the best available technology & equipment to excel operations of the organization. As against this an entrepreneur who starts his enteprise on a small scale is basically a one-man-show. It is his perception about the technology, it is his skill in trying to adopt it through an equipment manufacturer to get translated for his operations at an affordable price. It is only his deep insight about the business environment such as raw material, market and minimum essential product quality specifications, that he can find ways not only to survive in the industry but to prosper.

During the later part of the paper, I shall take certain illustrations to express these points further. After having said this, let me give you some of my thoughts on the overall pulp & paper Industry's future and the outlook for small mills in the developing world with special reference to utilization of non wood fibre.

Being a member of FAO (Food & Agriculture Organization) Advisory Committee, a United Nations Body, I had attended a conference in Budapest, Hungary,in May 1994. Based on the inputs from the experts comming from various parts of the world, the secreteriate has compiled the information in the form of Executive Summary. It will not be out of place for me to give some excerpts from the document.

As regards to world scenario the document has said as follows.

2.0 The World Scenario

The main points highlighted in this report are,

a. The growth of paper industry has been predominantly a function of economic growth.

b. In the 3 decades since 1961, world consumption has increased more than threefold, from 77 million tons to 243 million tons in 1992.

c. The consumption pattern of 243 million tons is,

		Millon tons
Newsprint		32
Writing-Printing & Communication		70
Other papers		141
paperboards & household	12	
packaging	129	

d. Per capital consumption of paper averages 45 kg. worldwide, developed countries average is 150 kg, developing countries average is 10 kg. The consumption varies widely from 20-300 Kg in the developed world and less than 1 kg to 10 kg for developing world.

e. The projected per annum growth of paper consumption by 2010 is at a rate of just over 3.1% for the world, 2.3% for the developed world, 5.8% for the developing world.

f. The total demand for the world by 2010 is expected to reach 440 million tons.

g. The fibre consumption for developed countries,

	1970 %	1992 %
Wood pulp	76	61
Other fibre	4	6
Recovered paper	20	30

h. The figures for 1992 for the developing countries are,

Wood pulp	30
Other fibre	33
Recovered paper	37

i. Additives of non fibrous material constitutes 6% of the total furnish and share of coated papers is increasing.

j. About 16.5 million tons, 10% of the world production of pulp & paper is pulp of other fibre. China produces 12 million tons, India 1.8 million tons and Latin America 0.7 million tons. The rew materials are wheat & rice straw, bagasse, bamboo and reeds.

k. Recovered wastepaper is an important source for pulp and paper production and accounts for 33% of the input in both the developed and developing countries. Recycling of wastepaper is optimum when collection and transport cost can be kept to minimum.

3.0 Small Scale Pulp & Paper Mills

The concept of small pulp & paper mills is quite old. The size varies with the changing times, circumstances and with location of plant.

At a time, when large scale operators over 500 TPD were considered as economic operators in North America, I had seen in Japan, in late '50s, paper making on small scale of 5 TPD engaged in the manufacture of tissue for local requirements and also there was a corrugated media for conversion in a factory located within distance of 5 Kms. Even in those days, mechanical pulp of 10 TPD capacity was manufactured on small 3 pocket grinders.
During the same time I was pleesently surprised to visit a 10 TPD newsprint mill running on a purchased wet lap ground pulp, in Japan. This product was being exported to Asian countries. It is therefore a skill of the entrepreneur who used available resources in the most optimal manner.

In '50s and '60s, Japan had shown unusual skill in scaling down the bigger piece of equipment to a reduced scale by using appropriate technology and altering the equipment at an affordable price. Later, this lead was taken by South Korea and Taiwan. China had already demonstrated skills in marketing simpler functional equipment on smaller scale. Most of the equipment was using wastepaper. Though reasonable amount of sophistication was available from various sources in terms of paper making, equipment, the pulping of agricultural residues was still premitive.

During 1980s and 1990s India has made big progress in offering machines from 10 TPD to 100 TPD. These smaller machines in these times were not economic to manufacture in Europe, USA & Japan.

A typical small pulp mill of 10 TPD in China, India or Malaysia was composed of,

- Simple straw chopper
- Rotary drum for screening
- Spherical digester, manual loaded
- Washing & bleaching in poacher

this was quite an ineffecient operation.

However, in those days imports were restricted, power & chemical prices were lower and environment legislation was not practised and garment subsidies supported the small scale operations, mills could go by without recovery of chemicals. In 1970s, even 20 TPD bagasse mill was established comprising of,

- Spherical digester
- 3 stage counter current watching
- 3 stage CEH bleaching sequence with washing arrangement

With the passage of time, it has become increasingly important to design a mill which is Economically Viable Environmentally Acceptable (EVEA).
Presence of silica in non wood fibres hindered the progress of

establishing satisfactory recovery process. However, for the sake of catagories, it is desirable to segregate units as :

- Non integrated operations
- Integrated without recovery
- Integrated with recovery of chemicals and heat & cogeneration

The development of this industry can be possible only with the close cooperation of owner, equipment manufacturer and the consultant.

Paper mills on small scale in the developing world will rely mainly on wastepaper and non wood fibres.

When one reviews the capacities under operation in the developing world, it can be seen that

Capacities	**can be termed as**	**with raw material**
Below 50 TPD	Small	Wastepaper or premitive pulping
50 to 100 TPD	Medium	Modified pulping with or without recovery
100 TPD & above	Large	Fully integrated with pulping, recovery and cogeneration

Under the circumstances, small and medium sectors will be discussed and eventually these two groups will form a single group as small scale to focus attention to make it EVEA.

Lot of good equipment for wastepaper treatment such as,

- Hydrapulpers - low & high consistancy
- Rag catcher
- High density cleaners
- Turbo separators
- Low pressure cleaners/ reverse cleaners
- Special screens
- Deinking equipment

are available and the buyer can engineer the system to suit his requirement.

Pulping of non wood fibre on small scale however, posseses number of challanges, some of them have been well accepted while others remain to be solved. Let us know about these complexities.

4.0 Indian Scenario

4.1 Raw Material Requirement For Projected Demand, And Options

Table #7 in the annexure gives quantities of raw material requirement based on projected demand and consumption pattern in India. Bamboo and wood availability is showing a downward trend creating a deficit. There are three options available to augment the deficit,

a. Large scale captive plantations of bamboo and hard wood.
b. Import of logs, chips, pulp and wastepaper.
c. Encourage use of locally available agricultural residues (Non Wood Fibres).

The first option though continuously demanded by the industry and essential for steady growth, is not making a headway because of various regulations of aforestation.

The second option though available to the developing world in large quantities, will require considerable changes to improve transport and handling system for chips and wood. The import of pulp and paper will mean a pressure on foreign exchange resources and will be related to import policies of the respective Governments.

In this context, the third option needs greater attention from the industry and all concerned.

4.2 Nonwood Fibre A Logical Choice For Developing World

Most of the nations in the developing world are thickly populated. Because of the pressure on land, of population, for food and fuel and indiscriminate cutting of green cover, the Governments are discouraging industry to cut forest for industrial use. In many places the industries' plea for granting denuded forest areas for industrial plantation is not acceded to.

The Indian consumption pattern of non wood plant fibre pulp are outlined in Table #5 in the annexure. It will be seen from Table #6 in the annexure that the use of bamboo and hard wood is steadily declining from 85% in 1970 to 47% in 1991 and a further downward trend is expected to 31% by 2000, as against increase in use of bagasse, cereal straws, wastepaper, etc., in last two decades.

4.3 Various fibres and Size of installations

The non wood plant fibres which are currently being used and those which offer potential for future use for paper making pulps include agricultural residues such as Bagasse and Straw, the natural growing plants such as Bamboo and Grasses and the fibres which are grown for their fibre content such as Kenaf, Jute, Hemp, Sisal, Cotton etc.

The availability of straw is related to production of food grains such as rice and wheat. Even though the food production is on the increase, the availability of straw depends on number of factors such as cattle fodder, thatching roofs, fuel, etc. Another impediment in the increase of the use of straw is the lack of chemical recovery system because of higher silica content. Hence bagasse scores over straw in many ways.

The major players in non wood capacities in the Asia Pacific region are China, India, Indonesia and Thailand. Table #3 in the annexure indicates that non wood fibre represents more than 70% in China, India, Thailand, while 45% for Indonesia. The figure shown as 70% in India also includes about 35% as bamboo leaving balance 35% for non wood.

Table #4 in the annexure indicates more than 60% of plants fall in the category of less than 50 TPD.

4.4 Bagasse - A Forerunner

Bagasse had a 2% share in the total raw material composition in 1970 which increased to 18% in 1990 and is estimated to rise to a level of 22% by 2001.

Very large quantities of bagasse is released by sugar mills of which majority of the quantity is consumed by sugar mills for fuel. If the total quantity of bagasse is made for pulp manufacturing it would meet the entire need of developing worlds' cellulosic material. Number of measures can be taken by the sugar industry to make their operations fuel efficient which in turn can release bagasse in excess ranging upto 10%.

Tamilnadu Newsprints & Papers Limited, popularly known as TNPL, a large scale integrated mill in India has successfully implemented a scheme of 300 TPD plant for the production of newsprint and writing & printing paper by introducing chemi-mechanical and chemical pulps from bagasse. It is likely that two or more such units will be set up in the country by end of 1997. TNPL however, has made an attempt of substituting fuel requirements at sugar mills and has released entire bagasse from the cluster of sugar mills in turn.

Introduction of Soda-AQ pulping and oxygen bleaching is desirable.

5.0 Problems Associated With Use of Non wood Fibre

5.1 Collection, Transportation and Storage

Besides the above factors, collection, transportation, storage of agro-residues calls for special attention. The cost of transport is also high due to bulky nature of bagasse, cereal straw, grasses, etc. To solve this problem one may consider setting up a central station for dusting and heavy duty baling press to reduce the costs. Similarly, depithing and baling station for bagasse can be set-up at sugar mills to reduse transportation cost and to supply unwanted seperated pith back to sugar mills for fuel needs. This is mainly applicable to small capacity mills where bagasse is stored in bales. The economic distance is 100 Kms radius for a paper mill to procure this raw material at affordable price. The storage and collection of non wood fibres even at the mills call for series of measures to reduce cost, decay and loss of cellulosic material.

5.2 Depithing

Bagasse has a hard rind of good fibre value and about 30% pith which has no fibre value but has fuel value. Hence, depithing is an essential step towards obtaining better quality pulp. Depithing reduces cooking and bleaching chemicals in pulping, improves dewatering during washing, paper making, improves runability of paper machines due to less press pick-up and improves physical strength properties.

Moist depithing, dry depithing and wet depithing are the three types of depithing being practised. Amongst the 3, wet depithing gives the best results as residual sugars are removed as also reduces foaming in pulping.

Due care is required to dry and wet cleaning of straw to remove fine and grit. This helps in improving further process of cooking, washing and bleaching.

5.3 Pulping

The pulping technologies are well advanced and pulps from mechnical to high brightness chemical could be made depending on the end use requirement. For small scale operations (10 - 30 TPD) rotary digesters are used, whereas for medium scale (40 - 60 TPD) Pandia type continuous digesters and Sunds defilterator digesters are used.

5.4 Washing

Pulp washing is an area where the mills encounter a number of problems due to slow drainage characteristics of bagasse and straw pulp. Hence larger washing area - twice the washing area compared to wood - and counter current multistage washing is employed. The residual sugars in bagasse lead to foaming and foam breaker will help in tackling the problem. Wet depithed bagasse has lesser foam generating tendency. Recently, couple of installations have come where twin belt washers are used for pulp washing. The advantages are :

1. Less space requirement
2. Lower water consumption
3. Black liquor with higher solids content and lower operating costs

The screening and cleaning equipment to remove shives, dirt, black specs are also available for small scale operations.

5.5 Bleaching

Pulps from depithed bagasse could be bleached to 80% brightness by conventional CEH sequence. The bleach chemical consumptions are lowered due to easy bleachability of bagasse pulp. Recent developments on large scale show that by using oxygen, chlorine dioxide and oxygen peroxide pulps with 85%+ brightness could be obtained without strength loss and with lower bleach plant pollution.

5.6 Fibre Characteristics and Silica Content

Table #8 in the annexure outlines fibre dimensions of agro-residues as also those of pulp woods. It is evident from the table that L/d ratio are very high for non wood fibres against those of wood fibres. This adversly affects the physical properties of paper.

Silica content plays very important role in operating recovery process of chemicals as against 1 to 2% silica present in bamboo and bagasse, wheat straw contains 6% silica while rice straw contains more than 11%. Unless suitable chemical recovery system is successsfully designed and operated for a smaller scale of operations, the growth is hindered.

6.0 Paper Making

The high pentosan content of some non wood pulps reduces power consumption in refining due to easier swelling of fibres. Rice Straw pulp, due to its short fibre length and slow drainage, does not need refining at all. In fact, excessive agitation is to be avoided or else the stock gets hydrated.

For agricultural residues pulps 3-8 hpd/T of power is required as against 15-20hpd/T for bamboo. Generally continuous refining is employed for these pulps.

When long fibered pulps are used along with agricultural residue pulps, separate refining of long fibre pulps and short fibre pulps is suggested before final refining to attain homogeneity. However, high consistency mixed refining of hard wood and wheat straw or esparto could be done with suitable plate pattern to ensure minimum damage to fibres. High consistency refining will create rubbing action between fibres without further damage to fibres by way of reduced fibre length. Refiners, with wide bars or disc refiners fitted with specially designed grooves, are suitable to acheive these results.

For separate refining of long fibre/wastepaper pulp, proper controls through instrumentation for maintaining furnish composition are necessary. Any variation in the percentages of short fibres and broke pulp results in hours of production losses due to breakages particularly when bagasse and straws are the major portion in the furnish.

Slow drainage, limitation to acheive high dryness at Press Part, poor wet strength, tendency to blistering and cockling due to rapid drying and high shrinkage are the general problems associated with design of Paper Machines.

Some of the points to be considered while designing a Paper Machine for non wood fibrous raw materials are :

Wire Part

20-30% longer wire for greater drainage area is required to maintain the required stock consistency at Head Box so as to achieve the desired formation. Use of foils, vacuum foils and additional suction boxes with increased opening area on covers, are other features. Mono-filament and multi-filament synthetic fabrics reduced downtime.

Press Part

Even with improved Press Part configuration, Web moisture content will be higher compared to wood pulps. Web dryness comparably improves when non wood fibrous furnish is only 35-50%. In bleached writing and printing papers, moisture content of paper web ranges from 62-65% when non wood fibre constitutes 75-80% of furnish. Presence of water in fibre matrix, which is not freely associated but is imbedded in fibre walls, is typical of these fibres. This physico-chemical phenomenon provides the limitations to achieving high dryness by increased bonding at Press Part. Sheet crushing and felt marking are experienced. These can be overcome to a large extent by improved Press design. A smoothing Press after the Wet Press is an essential requirement to provide compact sheet to Dryers.

Use of open type of felts with high porosity aids in achieving further dryness of the paper web. Fines bound with size and filler particles tend to clog up the felt pores and reduce water absorbency. Periodical chemical cleaning of felts is necessary.

Web should be supported in Press Section to avoid breaks as web is susceptible to break at the slightest draw fluctuations.

Retention aids and functional additives like modified starches would help reduce fines and fluff problem.

Drying

These papers need an extended drying surface area and should be carried out at elevated temperatures. High cross directional shrinkage during web drying is a main phenomenon. Provision of camber rolls on moist sheet at critical points reduces this shrinkage. High shrinkage factor adversely affects the dimensional stability of paper. Provision of dry-fabrics or mesh dryers in Dryer Section following first Dryer Group provides greater permeability; evaporated water can be easily removed. Other features for improved drying are pocket ventilation and provision of high velocity hoods.

7.0 Speciality Papers From Non Wood Fibrous Raw Materials

Non wood fibres produced out of Kenaf bast or stem, sisal, hemp etc. are used for manufacture of speciality papers like tea bags, carbon tissue, bible paper, condenser tissue, cigarette paper, etc. because of their exceptional fibre characteristics.

High quality rags, cotton staple fibre and cotton linters form another group containing high percentage of alpha cellulose. Pulp produced from these is used for superior quality writing and printing grades such a bonds, currency paper, drawing papers and document papers which need permanence. Great care and caution is to be exercised both at the Stock Preparation of Paper Machine with these pulps. The pulps such as rag, hemp, abaca, flax and sisal require extensive refining for longer periods in Beaters in view of their exceptionally longer fibre length and low pentosan contents. They are often refined at high consistency.

8.0 Rebuild and Modernization - A Continuous Ned For Survival

Just as writing papers, variety of kraft papers like corrugating media test liner and duplex are made throughout the developing world on smaller foundrinier or cylinder mould machines by using wastepaper as a major furnish and varying degree of Non wood fibre furnish machines or of straight foundrinier type with standard press and drying sections. The specifications of machines are:

Width	: 1.2m to3.2m
Capacity	: 5 TPD to 100 TPD
Speed	: 100m/min to 300m/min.
Basis weight	: 40gsm to 150gsm

The conscraint for small scale is always the capital. One starts with a simple straight forward machine and there always exists an opportunity of modernization and upgradation of machine by,

- Increasing the speed
- Convert existing drive system by changing from commutator motor to thyristor drive to sectional

electrical drive.

- Make necessary changes in Head box, Wire part, dewatering zone foils, wet section boxes.
- Pick up press and compact press
- Efficient drying system, cascade system, hood and pocket ventilation and efficient condensate removal system.
- Modified calender with swimming rolls.
- Adequate pope reel and rewinding system.

In one of the mills a 2.4 meter wide machine making 15 TPD has been converted to 100 TPD by adopting above steps.

Similarly a multi-cylinder Board machine of 1.5 meter wide originally producing hardly 10 TPD has been converted to 60 TPD by,

- Increase in speed
- Increasing of additional vats
- Improving vat designs
- Incorporating efficient couch and suction system for pick up roll
- Efficient felt washing system
- Mould cleaning system
- Heavy duty presses
- Adding dryer hood and condensate system
- Conversion of calender

Besides, these steps are also needed to reduce overall

- Water consumption
- Steam and Power consumption
- Fibre loss by installation of save all
- Overall waste reduction and to make the operation economical with proper approach and good engineering, todays equipment industry offers an excellent opportunity for rejuvenation and modernizing the mill.

This process continues until the time the unit is still economic. Once the competition makes it difficult for a small unit to continue within a specific country, the machine gets sold to other country where conditions makes this economic. That is why substantial capacity in developing world has increased by importing used machines and modernizing them to a viable level.

9.0 Recovery of Chemicals & Pollution Abatment

9.1 Absence of Chemical Recovery Due to High Silica Content

Conventional combustion routes require that the black liquor be concentrated to at least 45% solids in multiple effect evaporators and to about +60% solids in direct contact evaporators, before firing the furnace oil as supplimentary fuel.

The single biggest technical problem which has so far eluded solution for the small pulp and paper mills in India is the absence of the dependable, EVEA chemical recovery system. Though, on one side, the raw material problem appears to have been taken care of, objectionable effluent streams have nullified the prospects of expansion of these mills. These productions have become serious pollution centres.

The dark brown coloured discharge from the pulping section apart from SS and BOD levels, is the main cause of concern to the industry.

9.2 Magnitude of The Problem in Economic Terms

In addition to draining of pulping chemicals alongwith black liquor is a huge national loss in the form of electrical energy consumed for manufacturing of these chemicals. The stringent pollution control laws being enforced in various countries would in most probabilty force the industry to either stop pulping agro-residues and change over to wastepaper or increase pulping capacity to a viable capacity with recovery unit.

9.3 Various Technologies Under Experimentation

Though few chemical recovery systems are available for 50 to 100 TPD mills, they are ineffecient and solve the pollution problem partially. Some chemical recovery systems are still at the pilot stage of development. The characteristics of black liquor with regards to silica content, viscosity, the amount of fines, etc. render the design of a convetional recovery technically difficult.

A cursory review reveals following systems for chemical recovery,

a. Desilication of black liquor followed by evaporators, smelters, waste heat boilers.
b. DARS process (Direct Alkali Recovery System)
c. Copland fluidized process
d. Wet cracking of black liquor
e. Pulse enhanced indirect gasification of black liquor solids.

<u>Naco Process</u>

The Naco process produces pulps from annual fibres like straws and has been tried at Foggia, Italy in a 100-TPD plant. The process was invented by Mr. Franco Nardi of Italy and the plant was designed by M/s. Sunds Defibrator, Sweden. The heart of the process is a Turbo pulper designed by the inventor. Besides wheat straw, other types of annual raw materials such as bagasse and rice straw have been studied. The main pulping chemical is Sodium Carbonate recovered from previous pulping, with small amounts of Caustic as make up chemical.

In this process, initially, the straw is treated with water and small amounts (1-2%) of Caustic in an open Pulper to remove wax, silica and other impurities. The straw is then separated from

stones and sand by a Cyclone Separator and fed to a Washing and Dewatering Screw with fresh water showers. Then it is dewatered in a special type Press to 25-30% dryness. The silica removal is around 45% depending on efficiency of the process. Then the straw is passed to a Refiner where nodes are partially broken and then pumped to Turbo Pulper.
In Turbo Pulper the cooking chemical is Caustic Soda/ Sodium Carbonate (25% on B.D) is added with oxygen at 6-8 bar and 135-140^{O}C temperature and a reaction time of two hours is maintained. The pulp is then washed with hot water in a Twin Roll Press. The yields are of the order of 50% on straw with an unbleached brightness of 50-52% and Kappa no. 15-16 Single stage bleaching with Hypo or Peroxide results in pulp brightness of 80%.

Bleaching with O zone in Turbo Pulper at high pH and low pulp consistency at temperatures of 20-45^{O}C is reported to give pulps of the order of 75% brigthtness.

Naco process has advantages like simple process techynology, lower pollution load etc.

It is desirable that some more information is available about the operating data, effeciency and economy size.

DARS Recovery Process

The adoption of normal recovery process for the spent liquors of other agricultural residues is difficult due to high capital costs involved and also the size of the mills using them. Use of soda pulping for these fibrous raw materials is growing due to its low cost and adaptability with oxygen delignification, etc. Keeping these in view, a new technology is being advocated for silica-rich, non-sulfur processes. The process is popularly known as Ferrite Recovery Process or DARS (Direct Alkali Recovery System). This was studied by Dr. Geoff Covey and his team at Australian Paper Mills.

In this process, evaporated Spent Liquor is burnt with Ferric Oxide in a suitable furnace to form Sodium Ferrite. The organics in spent liquor are burned off giving Sodium Carbonate which reacts with Ferric Oxide. When treated with warm water, Sodium Ferrite will yield Sodium Hydroxide; the cooking chemical and Ferric Oxide is regenerated and can be reused. A reaction temperature of around 900^{O}C for 15 minutes in a fluid bed furnace is found to be optimum for Sodium Ferrite formation. A slight excess of molar ratio of 1:6 is sufficient for good reaction and will help in providing excess reaction area in fluidised bed furnace. The hydrolysis of Sodioum Ferrite to recover Sodium Hydroxide is carried out at 90-95^{O}C for 15 minutes. Lower concentration of Caustic in reacting liquor will help in better recovery. Generally a 3 to 4 satage counter current washing of Sodium Ferrite to higher Caustic concentration will help in maximising recovery. Impurities like Silica and others entering the system are removed from Ferrite by cold water washing and treating the wash water with Lime to precipitate the impurities so that the purified wash water can be reused in the process.

Some of the advantages of DARS technology are :

- Low capacity investment
- Applicability to a wide range of mill sizes
- No recaustizing and hence reduced costs
- Elimination of lime kilns; hence fuel saving
- Operational safety compared to conventional recovery boilers
- Higher causticity can be obtained, i.e., 92-95% v/s 80-85% for conventional one
- Highest flexibility in terms of black liquor concentrations (as low as 40%)
- Last, but not the least, tolerance of silica which is most predominant with non wood fibrous raw materials

This technology, in combination with soda-AQ pulping, will give the world a similar, cheaper and odour free pulping process compared to kraft process of non wood firbous raw materials.

In India, plant trials of DARS were reported to have been conducted (M/s. Mandhya National Paper Mills) using 100% bagasse in furnish. The baack liquor was fired in roaster after mixing with required haematite ore to 70 Tw. The trial showed that the conditions of roaster required to be modified and better quality ore used. However, the trial was successful in that and it proved the process is suitable.

The Table #9 in the annexure outlines the merits & demerits of various technologies tried for small mills.

9.4 Pollution Loads With & Without Recovery

All the forest based mills having a capacity of 100 - 200 TPD are equipped with conventional chemical recovery systems,. However, mills using agro-residues are smaller in capacity ranging between 15 - 30 TPD do not have any system for recovery of chemicals.

The load of suspended solids, BOD & COD are about 6 times and colour about 10 times darker from agro based mill compared to a forest based mill with chemical recovery. This situation posses a serious problem for designing a suitable and satisfactory effluent treatment system.

9.5. Conventional & New Effluert Treatment Methods

A conventional primary clarification followed by secondary aerobic activated sludge treatment system could bring the parameters within the prescribed standards of less than 30 mg/L BOD and 100 mg/L suspended solids for forest based mills. However, this is not suitable for agro-based mills due to heavy loads.

It is in this connection that a totally new approach is to be taken. In this system, the effluent coming from various sections are being treated according to its characteristics for e.g. in a paper mill maximum recycling of water is being done to reduce the water consumption as well as seperate the fibre recovery units can be installed to reduce suspended solids. The clarified effluent can be sent to pullp mill for dilution in cleaning and screening plant as well as in the third brown stock washer. The problematic portion being the concentrated black liquor coming out is treated anaerobically to generate biogas which in turn partially supplements thermal energy requirements.

The conventional aerobic treatment is very expensive by way of capital and operating costs. A combination of anaerobic-aerobic treatment is a better proposition to minimize pollutant loads from a small scale operations.

10.0 Outlook After Liberlization and Globalization

With the changing world order it appears that boundries of markets are getting opened tarrifs are rationalized and customers will get wider options to meet their requirements. Survival for the fittest will be the name of the game.

Products will get made where they are EVEA. Under the circumstances it is every likely that smaller ineffecient pulp operators will get closed down, large effecient mother pulp mills will emerge and paper makers on small scale shall optimize their operations by selecting economic furnish and choose products and markets which are profitable.

The word small being relative will continuously go on increasing in size.

11.0 Outlook - Summary

Paper industry is a core sector of the industry and is a growth industry.

The production of pulp and paper in the world in 1992 of 243 million tons is likely to go up to 440 million tons.

The future growth rate per annum for

World averages to	3.1%
Developed world to	2.3%
Developing world to	5.8%

Forest resources in the developing countries are depleting and there is a need to use non wood fibre.

More than 35% of raw mateiral requirement will be met by use of non wood fibre in the developing countries.

More than 80% mills are operating in diffused manner near the agro resources having capacities less than 50 TPD.

Pulping operations of non wood fibre on smaller scale has become uneconomic and environmentally hazardous.

Naco process and DARS system appears to be promising and need to be persued and altered to succeed.

A closer cooperation between the developed and developing world will make this possible. UNIDO has a very key role to play.

Lot of fundemantal research and pilot plant operations have been encouraged by UNIDO and other agencies. There is a great need for demonstration plant.

Number of new technologies are promising, but practical operations still to be established.

Out of non wood fibre, bagasse has proved to be easier material. Many countries have established pulping plants of over 300 TPD.

There is also a growing interest globally to establish large scale pulp mills based on bagasse, straw and kenaf.

It looks logical to optimise benefits of pulp making activity centrally by incorporating latest advances and proven technology.

Establishment of mother pulp mills will have less environmental problems. Pulps wil be better in quality and the production costs will be lower.

A place like Iran offers good opportunity for establishing market pulp mills based on

- Bagasse
- Eucalyptus
- Poplar

With global market scenario, used equipment not viable at one location might become viable in other loaction. This route if taken carefully, can offer substantial reduction in investment for small mills.

Paper making on small scale basically in non integrated sector will have wider options to furnish selection and marketing strategy to reduce cost.

Small mills always need to grow in size, modernize for efficiency, product upgradation. This is possible with adaption of latest technology wherever possible

Entrepreneurs role is very important and a team work of consulting engineers and equipment manufacturers is a neccessicity.

TABLE #1 - CURRENT & PROJECTED CONSUMPTION OF PAPER

	1961			1991			2010		
	World	Developed	Developing	World	Developed	Developing	World	Developed	Developing
Paper (million tons)	77	70	7	243	194	49	440	310	130
Growth in %									
1961-1990	3.7	3.5	6.2						
1990-2010	3.1	2.3	5.8						

(Source - FAO Exec. Summary)

TABLE #2 - PULP (TREND IN COMPOSITION OF WORLD CAPACITY)

	Million Tons (%)				
	1980	%	1992	%	1998
Pulp for Paper	151	100	195	100	-
Wood pulp	139	92	174	89	185
Mechanical	28	18	21	11	20
Thermo-mechanical	5	3	23	12	26
Semi-chemical	10	7	9	5	9
Chemical	95	63	120	61	129
Sulpihite unbleached	7	5	3	2	2
Sulphite bleached	5	3	6	3	6
Sulphate unbleached	36	24	39	20	40
Sulphate bleached & soda pulp	45	30	72	36	80
Other fibre pulp	12	8	21	11	23
Species input to wood pulp					
Non coniferous	30*	22	50	29	55
Coniferous	89*	64	112	64	130
Unspecified	20	40	2	1	-

(Source - FAO Exec. Summary)

* Revised data taking account of greater coverage in 1992, mechanical and thermo-mechnical pulp of Canada is assumed to mainly of coniferous species.

TABLE #3 - NON WOOD PULP CAPACITY

(1000 Tons)

Country	All pulp	1990 Non wood	Non wood %	1995 Non woo %
China	11,708	9,718	83	83
India	1,885	1,330	70	74
Indonesia	1,089	477	43.8	44.(
Thiland	153	153	100	72

(Source Dr. J.E.Atchison)

TABLE #4 - SIZE OF OPERATIONS

	China	India	Indonesia	Thilan
	(percent)			
Less than 50 TPD	67	57	60	58
50 to 100 TPD	21	9	--	14
over 100 TPD	12	34	40	28

(Source PPI Directory 1991)

TABLE #5 - LEADING COUNTRIES IN TOTAL NON WOOD PLANT FIBRE PULP PRODUCTION CAPACITY & PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY

Country	1987 Capacity 1000 mt	1987 % of world	1990 Capacity 1000 mt	1990 % of worl
China	8,122	55.2	10,141	59.4
India	2,040	13.9	2,040	12
USSR	625	4.2	625	3.7
Indonesia	327	2.2	477	2.8
USA	310	2.1	321	1.9
Peru	296	2	296	1.7
Mexico	295	2	295	1.7
Italy	185	1.3	185	1.1
Brazil	175	1.2	175	1
Taiwan	150	1	150	0.9
Argentina	140	1	140	0.8
Venezuela	140	1	140	0.8
Spain	130	0.9	130	0.9
Thailand	110	0.8	140	0.8
Cuba	108	0.7	108	0.6
Algeria	105	0.7	105	0.6
Turkey	103	0.7	103	0.6
Romania	102	0.7	102	0.6
Iraq	101	0.7	101	0.6
Pakistan	100	0.7	150	0.9
Colombia	97	0.6	158	0.9
Sub total for 1st 21 countries	13,761	93.6	16,082	94.2
Estimated total of all countries	14,700	100	17,070	100

(Sources - based on FAO capacity survay 1987-92 & Atchison consultants)

TABLE #6 - CONSUMPTION PATTERN OF BASIC RAW MATERIALS, IN INDIA

Raw Material	% of Total Consumption				Estimates*	
	1970	1980	1985	1990	1995	2000
Bamboo	60	45	27	25	20	15
Tropical hard woods	21	24	16	16	14	10
Market pulp	4	4	8	6	6	6
Sub Total	85	73	51	47	40	31
Cereal Straws	4	4	12	10	10	10
Bagasse	2	7	12	18	19	22
Grasses	3	2	5	3	3	3
Sub Total	9	13	29	31	32	35
Waste paper	6	14	20	22	28	34
TOTAL	100	100	100	100	100	100

(Source - Aptech Paper to FAO 1993)

* Share of waste paper and agro residues will depend upon economics . technical feasibility of agro-residue mills. Ervironmental issues w dictate.

TABLE #7 - QUANTITY OF VARIOUS RAW MATERIAL BASED ON PROJECTED DEMAND & CONSUMPTION PATTERN

	1990-91	1995-96	2000- 01 (000 Tonnes)
PRODUCTION MTPY	2,065	2,650	2,770
Requirement of Pulp MYPY	2,295	2,944	3,077
FOREST BASED %	41	34	25
Raw Material (x 3)TPY	2,820	2,820	2,310
AGRO BASED %	31	32	35
TPY	711	912	1,076
Cereal Straw %	13	10	10
and Grass Pulp TPY	298	294	307
Straw (1 x 4) TPY	1,192	1,176	1,228
Bagasse	18	22	25
Bagasse Pulp TPY	413	647	769
Bagasse as such TPY	2,478	3,886	4,615
WASTE PAPER Waste Paper %	24	28	34
Waste Paper Pulp TPY	550	824	1,046
Waste Paper (as such) TPY	688	1,030	1,307
MARKET PULP	4	6	6

(Source Aptech Paper to FAO, 1993)

TABLE #8 - FIBRE DIMENTIONS OF AGRICULTURAL RESIDUES & PULP WOODS

FIBRE	AVERAGE LENGTH (MM)	AVERAGE DIAMETER (U)	RATIO (L/D)
Straws & Esparto	1.1 - 1.5	9-13	110-120:1
Rice Straw	1.45	8.5	170:1
Stalk & Reeds	1.0 - 1.8	8-20	80-120:1
Sugarcane Fibre	1.7	20	85:1
Woody stalks with bast fibre			
Woody stems	0.2 - 0.3	10-11	< 30:1
Bast fibre	20 - 25	16-22	> 500:1
Leaf fibres	6 - 9	16-18	250-300:1
Bamboos	3 - 4	14	200:1
Coniferous woods	2.7 - 4.6	32-43	75-90:1
Deciduous	0.7 - 1.6	20-40	< 50:1

(Source Aptech Paper to FAO, 1993)

TABLE #9 - MERITS & DEMERITS OF THE VARIOUS PROCESSES FOR THE SMALL PAPER MILLS

The Process	Merits	Demerits
DARS process	a) Replace causticizating and thus reduces the fuel consumption b) The fertile produced can be recycled upto six times c) 30% cheaper than other conventional sources	a) The organics to inorganics ratio drops with each cycle b) Influence of silica is yet to be evaluated
Wet Cracking	a) Can function at very low black liquor concentration b) No evaporation or combustion is involved c) No smelt is produced during the process	a) System operates at very high pressure 1400 psi (20 MPa)
Orgonosolv	a) The lignin and the carbohydrates produced during the process can be recovered and marketed b) The lignin recovered has a low molecular weight and hence is easily bio-degraded	
Membrane process	a) Eliminates evaporation and combustion b) Only the RO concentrate requires causticization	a) The concentrate still carries lignin and sodium and thus may possess disposal problem b) The overall chemical recovery is very low c) Fouling of membrane and the consequent reduction in flux is very frequent d) Silica precipitation may occur due to low active alkali concentration
Gasification process	a) Can handle solids as low as 30% b) Yield a residue of Na_2CO_3 (98% pure) in the form of dry powder c) No smelt and no pressure parts are involved d) Evaporation needed to reach only 30% solids e) At 30% black liquor solids no auxillary fuel is required f) Modular design so as to suit the size of the small mill	
Chemrac process	a) Involves pyrolysis rather than conventional simple combustion b) Divides the recovery into 2 stages c) A normal smelt sodium carbonate and sodium sulphate is left	
Biopulping	a) Pre treatment cost are minimal b) Delignification occurs by a natural process and leaves behind no residues c) Cooking chemical charges drop due to earlier partial delignification brought about by the micro-organisms	

THE EUROPEAN FURNITURE INDUSTRY : AN OVERVIEW*

Size of the sub sector

Although its population is only some 50 per cent more than that of the United States, the European Union's (EU) yearly furniture production is just over double: some ECU 60 billion as against the United States' figure of around ECU 28 billion. Japan, whose population is roughly half of that of the United States, produces about two thirds of the latter's quantity (about ECU 20 billion). Eastern European countries also have large furniture industries: Poland produces some ECU 0.7 billion, Romania and Slovenia (whose population is only 2 million) each produce about ECU 0.4 billion per year.

In the European Union, the largest producer is Germany (33 per cent), followed by Italy (22 per cent), France (13 per cent) and the United Kingdom (12 per cent). Spain comes next with some seven per cent, the share of none of its other members exceeds four per cent. Value of production in 1993 for the then 12 European Union member states is given hereunder:

Germany	ECU 19.8 billion
Italy	ECU 13.1 billion
France	ECU 8.1 billion
United Kingdom	ECU 7.5 billion
Spain	ECU 4.4 billion
Belgium	ECU 2.2 billion
Netherlands	ECU 1.9 billion
Denmark	ECU 1.7 billion
Portugal	ECU 0.8 billion
Greece	ECU 0.4 billion
Ireland	ECU 0.3 billion

To these must be added the production of the European Union's three new members:

Austria	ECU 1.8 billion
Finland	ECU 0.6 billion
Sweden	ECU 0.9 billion

The European Union's furniture industry is its ninth largest industrial sub-sector. It represents some 2 per cent of its total production of manufactured goods. There are over 90,000 enterprises (among which there are a very large number of small enterprises), that employ nearly one million persons. Some 60 per cent work in firms with more than 20 employees, while the balance work in the numerous small firms. The furniture industry employs over 3 per cent of total employment in manufacturing, which shows clearly that, even under European conditions, it is still a labour intensive industry. The size of firms varies considerably from country to country: in Italy, employment in firms having less than 20 persons represents 65 per cent of the total employed, they are 30 per cent of Belgium's total, over 40 per cent of France's industry, but only some 15 per cent

* by Antoine Bassili, Furniture production consultant

of Germany's. The size of firm seems to have some correlation with the type of relationship that the firm has with its designers: in Denmark and Italy, where the custom is to use more free-lance designers (rather than employees of the firm), firms tend to be smaller.

Whereas 60 per cent of the total work force in the European Union is employed by firms with more than 20 employees, they produce some 80 per cent of the total value of the production.

Production and raw materials costs

Cost of materials is of the order of 60 per cent of total costs (except in Italy where it is some 10 per cent higher), cost of labour represents some 30 per cent, and the rest of the value added the balance (about 10 per cent). Cost of energy represents a very small share of inputs (less than 3 per cent), the major items in cost of materials are sawnwood and particle board (some 10 per cent each), hardware fittings and plastics (some 9 per cent each), veneers and textiles (some 6 per cent each) while plywood and the group of adhesives and surface coating materials represent 5 per cent each. There is a considerable degree of specialization and collaboration among the European Union's furniture manufacturers. This is apparent from the fact that "parts of furniture" represent some 20 per cent of material costs. The figures for Germany, Italy and Spain are the highest, indicating a high degree of specialization and a high level of inter-firm collaboration in their wooden furniture industry.

The largest input in volume, particle board, is also the item with lowest unit cost: its cost per cubic meter is about one quarter of that of sawnwood, less than half of the cost of Medium Density Fibreboard (MDF), and one fifth of that of plywood. Veneers cost much more, some six to seven times the price of particle board. The furniture industry consumes some 40 per cent of the European Union's production of particle board, some 12 million cubic meters. This is over three times the volume of sawnwood used. Special mention should be made of MDF. Although its consumption is still only about one million cubic meters, and its price is more than double that of particle board, it is the fastest growing input. Its popularity is due to its good machining properties, its smooth surface, its homogeneity and the large size of the panels available.

Although only about 25 per cent of the upholstered furniture produced has leather covers, leather represents half the amount spent on textiles (i.e. its unit cost is at least 50 per cent higher). Like MDF, the tendency is for increased use of leather, in spite of its higher unit cost.

No statistics exist on total investments nor on investment per worker, but new investments per year are of the order of three per cent of turnover.

Technological developments

Recent technological developments in equipment can be classified under: aiming at increasing productivity (i.e. lowering labour costs and minimizing waste), improving quality, increasing safety and reducing pollution. The lowering of cost of electronic components has resulted in a far wider use of Numerically Controlled (NC) machines, which, with the corresponding speedier setting up, has permitted the production of ever smaller series. This has permitted firms to better cater for the specific needs of their clients and to move to a higher range of products than machines also tend to be more precise. Quality has also been improved not only through the use of better materials (e.g. MDF instead of particle board) but also through the use of better tools (e.g. diamond cutterheads). Cost of tooling has increased, not only due to the increased use of there expensive products, but also because many modern NC machines allow for the whole range of tools needed to produce a product to be fitted onto a shaft, thus reducing not only down time when blunt tools have to be replaced, but also permitting a more flexible production since reduced machine setting times justify producing smaller batches. Waste reduction is not only obtained through more precise machining, but also through the use of robots and airless systems in spraying operations as well as computer software in cutting operations of upholstery producers. European legislation on safety in the work place has led to the design of far safer machines. The same applier to legislation on pollution control, be it noise or emissions. High cost of labour has resulted in mechanization being introduced throughout the production process. In this respect the furniture industry is not really innovating; it is often adapting what has been common for quite some time in the metal working (e.g. NC machines) and the garment industry (e.g. cutting and sewing operations).

Software programs have existed for quite some time for all business operations (accounting, costing, inventory control etc.). They are now increasingly being used for inventory control at the shop floor level (through bar coded labels and readers) and in the design of panel furniture, where not only is the client given a computer generated sketch, but the program also prepares cutting lists, cutting patterns for the panels, controls the inventory and orders as well as being integrated into the business operations (costing, production planning and control etc.). The lowering of costs and the greatly increased capacity of both software and hardware have permitted even smaller furniture manufacturers to introduce CAD programs.

The introduction of all these new technologies has been facilitated by the fact that training of the necessary staff, and especially the upgrading of the skills of staff on board, was made possible through the existence and close collaboration of Europe's specialized Research and Development and training institutions.

Range of products

Wooden furniture represents some 75 per cent of the total value of production. Needless to say, the range of products is enormous. However, the percentage of the production of the major categories is:

Upholstered furniture	15 %
Kitchen furniture	13 %
Dining room furniture	12 %
Bedroom furniture	11 %
Office furniture	10 %

Here again, there is a marked "specialization" within the various countries: Italy's forte is upholstered furniture, Germany's is kitchen furniture while in the United Kingdom and Scandinavia "knock down" (or "ready to assemble" - RTE) furniture is relatively more popular than in the other countries.

Environmental awareness

Among the major problems that the European furniture industry has had to face are those that are related to the increased ecological awareness of the general public. This has resulted in legislation (which has already been enacted or is pending) in the fields of emissions by the factories, be it wood dust or particles of volatile organic compounds from the surface finishing operations, as well as emissions from the products themselves: e.g. emissions of formaldehyde from panels and surface coating materials. This has led to the developr nt and regular use by the furniture industry of boards and other inputs provoking a concentrati . of less than 0.1 part per million (ppm) of formaldehyde in a standardized test chamber. The problems caused by the emissions of the volatile organic materials are being addressed through the development of water based surface finishing materials, though these are not yet in common use. Legislation has also been enacted in certain countries concerning the disposal of packaging materials used by the industry. Certain countries (notably the United Kingdom) have enacted legislation affecting the flammability and toxicity of upholstery foams and materials. Stringent legislation has also been enacted to improve the working place climate, be it to assure better ventilation in spraying booths (or the compulsory wearing of masks), noise abatement (either through the use of noise reducing enclosures or through the wearing of ear muffs or plugs) etc.

There is a growing fad, at least in some European countries, for "Eco" or "green" furniture, i.e. products for which the manufacturer guarantees that only natural materials have been used. This same clientele strives to ban the sale of furniture which uses tropical hardwoods that do not come from a forest that has been certified to be managed on a sustained basis, but so far the corresponding legislation has not been enacted.

Distribution channels

Distribution channels vary considerably from country to country within the European Union. In spite of producing some 50 per cent more furniture than Italy, and it being a net importer instead of a net importer, Germany has a considerably smaller number of outlets than Italy, where the small family furniture retail shops are still common. Among the larger EU countries, France, Spain and the United Kingdom fall between these two extremes.

A relatively new trend was the opening of IKEA outlets in numerous European countries in the last twenty years or so. IKEA was originally a Swedish company that sold mainly Knock down furniture through catalogues. It has a few very large outlets in each country (three in Austria, five in Switzerland etc.), and sells the whole range of house furnishings, specializing in catering to the young. Its designs are "Scandinavian", products are often sold in knock down form, and it emphasizes design and quality, as well as value for money. Quality is guaranteed through the testing of its products and the issuance of the MOBELFAKTA quality label. This was originally developed by Denmark, but has become the quality standard for all Scandinavian furniture. Other European countries have their own quality labels. This is a factor which is considered to facilitate sales, since the buyers have become accustomed to be on the lookout for the label and comparing test results before deciding on a purchase.

and Austria. Belgium's foreign trade was more or less balanced. The furniture industry of Poland, Romania and Slovenia, which are highly export oriented will, no doubt, be playing a larger role in the European Union's industry when the current quotas and other barriers will be relaxed.

Institutions catering to the sector

The sector is serviced by leading international furniture fairs held yearly: Cologne in Germany, Milan in Italy, Copenhagen in Denmark and Valencia in Spain. There exist also large international fairs for components, hardware etc. (Interzum in Cologne in the odd years and Sasmil in Milan in the even years), while developments in woodworking machines are exhibited at the Ligna fair in Hannover, Germany, (odd years) and Interbimall in Milan (even years). Smaller international fairs catering for machinery and equipment are Expobois in Paris and Valencia in Spain.

All the European countries have technical schools teaching the industrial production of furniture e.g. Modling in Austria, Lahti in Finland, Rosenheim in Germany, High Wycombe in the United Kingdom etc. There are also internationally known schools such as the London College of Furniture and the Ecole Boulle in Paris whose reputation attracts also students from outside the EU. The industry also benefits from specialized Research and Development Institutes in the major furniture producing countries, such as the Teknologisk Institute in Taastrup (Denmark), the Centre Technique du Bois et de l'Ameublement (CTBA) in Paris, the Mobelinstitutet in Stockholm (Sweden), the Furniture Research and Development Association (FIRA) in Stevenage (United Kingdom). These not only undertake industry-sponsored research programs, but also organizes short specialized training courses to help update the knowledge of the technicians and operators in the industry. They also have excellent libraries and publications to help diffuse information. Because of its size, the industry is also served by numerous specialized freelance consultants and consulting engineering firms.

Although national standards for furniture existed in all European countries, the European Committee on Standardization (CEN) has established seven Technical Committees for products in the woodworking field. Among these CEN/TC/112, dealing with wood based panels, CEN/TC/175, dealing with roundwood and sawnwood, and CEN/TC/207, dealing with furniture should be mentioned. In this respect it is also worth noting that whereas the obtention of quality labels for products is a desiderata of the purchaser and user of the furniture, some of the major retailers or their purchasing consortia are insisting that the manufacturers obtain the ISO 9000 certification.

Finally, mention must be made of the important role that regional, national and EU wide manufacturers' associations play in promoting the sector, assessing its needs and problems and in lobbying the authorities to help provide solutions.

THE POTENTIAL FOR THE DEVELOPMENT OF IRAN'S FURNITURE INDUSTRY*

The Islamic Republic of Iran certainly has most of the prerequisites for producing furniture on an industrial scale, in large volumes, not only for its own population, but also for exports to neighbouring countries. Certain measures would nevertheless have to be taken to make this possible.

Although the country is no longer well endowed with forest resources, and what it still has is being exploited under limited control, it certainly has far more than its neighbours. If the current plans for the management of existing forests and for the creation of new plantations of commercially desired species are implemented and then strictly adhered to, the situation could be reversed in less than a generation, bearing in mind the possibility to plant fast growing species. In the meantime Iran will have to rely on imports of sawnwood, which is what all countries in its latitude and with its climate are doing. Unlike these countries, Iran can become self sufficient in its requirements for wood based panels, since it is currently implementing a very ambitious plan for the development of its sugar industry based on cane plantations. It is probably the only country in the world that could use the lignocellulosic content of all the bagasse produced, since the region allocated for the development of the sugar industry is also one which has vast untapped reserves of natural gas. (Normally the sugar industry can only use part of the bagasse for its lignocellulosic content, since the vast majority has to be allocated to generate the steam and power needed to produce the sugar. The result of theoretic thermal balances carried out for the sugar industry indicate that excess bagasse is only available in the larger mills, i.e. those crushing more than about 4000 tons of cane per day of operation.) In the case of Iran, the lignocellulosic content of all the bagasse obtained could be used. A rough rule of thumb is that the lignocellulosic content in cane is of the same order of magnitude as its sugar content, clearly showing that extremely large volumes will be available as soon as the sugar mills become operational. It must be pointed out, nevertheless, that other industries (namely the pulp and paper industry) will be competing for this raw material. However, economies of scale in the pulp and paper industry are far larger than in the wood based panels industries, hence some of the sugar mills that will be established could be too small to provide bagasse to a pulp mill. Bagasse has been used successfully for many years to produce fibreboard (both hardboard and insulation board) and particle board. In the more recent past it has been used as a raw material for the production of Medium Density Fibreboard (MDF). This latter product is currently the wonder child of the wood processing industry. According to the MDF update published recently in Wood Based Panels International (WBPI), production in Europe exceeded 2.5 million cubic meters (m3) in 1993, installed capacity was some 3.5 million m3, and is growing at a very fast rate: it was around 4 million m3 by the end of 1994, and is expected to grow by an additional 400,000 m3 in 1995. The installed capacity in North America was, end 1994, some 2.5 million m3, with an additional 1.3 million to come into production in 1995. Latin America had some 300,000 m3 of installed capacity, the CIS (former USSR) states some 570,000 m3, South Africa and Tunisia some 160,000 m3, Israel 86,000 m3, while the fastest growth rates are foreseen for Asia/Oceania, where installed capacity was some 2.5 million m3 in 1993, it increased to 3.4 million m3 in 1994, and additional capacities of some 800,000 m3 are foreseen to come on flow in 1995 and 1.3 million in 1996. World capacity has increased from 9.3 million m3 in 1993 to 10.7 million m3 in 1994, and is estimated by WBPI to reach 14.2 million m3 in 1995/1996. It must be pointed out that economies of scale play a big role in this industry, whatever the raw material used.

* by Antoine Bassili, Furniture production consultant

When using bagasse as raw material even larger capacities can be installed than with wood because all the raw material is delivered cost free at the sugar mill's gate. So far Iran has no production of MDF, and the particle board and fibreboard it produces is using old technologies, resulting in products whose qualities cannot compete neither with imported particle board nor with MDF, even if one bears in mind the considerable price differential. Currently some particle board is imported for use in higher quality furniture that has expensive wood veneer overlays because of the poor quality of the surface of the locally produced boards. In fact, because of its homogeneity, stability and its good machining properties, MDF is increasingly being used to replace sawnwood in Europe and North America. Sawn hardwoods will nonetheless still have to be imported, but, if the Green movements in Europe and North America succeed in making the import of tropical hardwoods subject to strict controls as to its origin (to ensure that it comes from forests that are managed on a sustained yield basis), there will be large volumes of sawn tropical hardwood available at competitive prices from those suppliers who, for a reason or another, cannot meet the European and North American requirements. Wood veneers will also have to be imported.

Iran also has the required industrial infrastructure to produce all the other inputs needed by a modern furniture industry, be it plastic or melamine foils to cover the boards, paints, varnishes and adhesives, the metal hardware fittings as well as textile covering materials, the leather and the foams used by the upholstered furniture industry. Its metal working industry is also in a position to produce all the basic woodworking machines and tools needed by the furniture industry, the more so if the Iranian producers enter into joint ventures or purchase licenses from leading European machine manufacturers to ensure that they are introducing a modern technology.

Not only is Iran's population of 60 million large enough to sustain the production of furniture on an industrial scale, but it also has one of the world's highest growth rates (3.7 per cent), and it is relatively urbanized, creating a higher demand for furniture than a rural population with a similar per capita income. This per capita income is sufficiently large to ensure that demand for consumer durables exists. The local market can be complemented by large demand generated by the affluent populations of the Persian Gulf states, which currently import their higher quality furniture from Europe and produce the lower quality products locally at far higher costs than would be the case if it were made in Iran. A modern Iranian furniture industry could compete successfully in both the higher and lower priced products sold on these markets.

Investments should pose no problem, simply because the furniture industry, even when production is on an industrial scale, is labour intensive. The picture is nonetheless not as rosy: there are certain prerequisites that have to be met.

The major problem to be solved is one of human resources. Traditionally the production of furniture is still regarded as a craft operation where the machine serves man and not man the machine. This means that productivity is low. Modern furniture production is nearer to the production of motor cars, where components are standardized, often being produced by sub-contractors, tasks are repetitive, workers are specialized, and quality of products is high. There is no room for hand finishing and/or repairing to ensure a good fit. To achieve this calls for a totally new work attitude of the labour force, not commonly found in woodworking plants of developing countries. Machine and tool maintenance would also have to be upgraded to ensure low down times and few rejects. This has to go hand in hand with industrial management which takes into account more precise costing, better production planning and control, modern inventory control and purchasing procedures etc.

The second problem that must be addressed relates to the services that this industry can expect (and should receive). These are enumerated hereunder:

Designers will have to be trained to design not only for the aesthetic value of the product but also to take into consideration its strength of the product and to design bearing in mind the production methods used by the factory and the machines and tools available, standardizing as far as possible components and dimensioning furniture so as to minimize waste of raw materials. This will probably call for the changing of curriculae and including in the training of industrial designers aspects of wood technology and furniture construction. In this respect, countries that use freelance designers, such as the Scandinavian countries and Italy have a far more successful and dynamic industry, operating on demand orientation, than those that employ full-time designers, where the range of furniture tends to be more production oriented.

Standards for the various inputs will have to be determined to ensure not only a continuity of supply, but more important that this supply has consistently the same quality. Until such time as national standards are published the firms could create their own internal standards based on the most appropriate foreign ones.

The industry will, sooner than later, need an institution to provide Research and Development and testing facilities, as well as to serve as a center for specialized technical and commercial information and to provide *ad hoc* on the job training and technical consultancy services at plant level. Eventually there will exist a category of former production and technical managers who will have decided to become self employed and open their own consulting engineering or management consulting firms. These will provide advice not only in day to day operations, but also be in a position to prepare investment projects, select technologies appropriate to local conditions and advise on plant layout and the specification and selection of equipment. The existence of such local expertise will avoid (or minimize the risk of) wrong investments being made, which are suitable for the conditions with which the expatriate consultant is familiar but that do not apply to Iran.

Managers, familiar with industrial (serial) production problems will have to be employed. This should pose no major problem, bearing in mind Iran's existing industrial base.

Last, but by no means least, the industry will only prosper if it has a strong and active professional association to cater for its needs and to represent it efficiently at all levels. It must realize that collaboration with its competitors will be more beneficial than if each firm going alone because it will allow better utilization of installed capacity, specialization and higher technical levels to be attained.

PLANNING AND START-UP OF FURNITURE FACTORIES*

Introduction

The aim of this document is to open the eyes of Iran's small and medium entrepreneurs in the furniture industry on the various measures that they have to take to upgrade their operations from a craft (or mechanized craft) level to industrial (serial) production that will ensure efficient operation and higher productivity. The basic difference between the two methods of production is one of managment's concept of the respective roles of men and machines: In craft operations the machine serves man, whereas in serial production the respective roles are reversed. This fundamental change can only be successful if management understands it fully and is willing to make both the attitudinal and physical changes.

Unlike craft production,where production programmes and priorities can change at very short notice by merely instructing the craftsman, efficient serial production calls for a full utilization of the relatively expensive investment in machines necessitating some specialization in the range of products manufactured, an appropriate range of machines, more sophisticated product development, production planning and control, but, on the other hand, a less skilled workforce. An attempt is being made in this document to briefly enumerate the steps that will have to be taken to ensure a successful change from one concept of production to the other.

Feasibility Study

Serial production calls for investment in a wider range of machines than is normally available in craft operations. Since industrial production also necessitates that all the required machines be available, a major investment should be made at the time of conversion from craft production, and the policy of purchasing pieces of equipment "as and when they are needed" can no longer be applied. In order to ensure that as sound an investment as possible is made and that an "optimal" choice is made with respect to range of products to be produced and annual production capacity, a full feasibility study is fully justified. (The existence of such an in-depth study would greatly facilitate the obtention of credit from financial institutions - or avoid a costly mistake being made!).

The contents of a feasibility study are well known and are not covered here, but the following topics are emphasized, because they are often overlooked:

The **market study** should be of sufficient depth to enable a decision to be taken on the range of products to be manufactured. In deciding on this aspect, the country's region to be covered and distribution methods should also be investigated. The intended clientele, and its income bracket (affecting the designs as well as the quality of the products) have to be decided. In assessing the various options as to product range, existing production (both quantitative and qualitative) as well as current demand (affecting size of series) and its growth should be investigated.

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* by Antoine Bassili, Furniture production consultant

Limitations that might affect the range of products selected also include availability of capital and manpower having the required skills as well as reliability of supply of all the raw materials needed by the production. In cases where capital limitations may preclude the production of a certain range of products, this problem could be overcome through a subcontracting arrangement. This aspect could also be investigated. Similarly, limitations related to the non-availability of manpower having the necessary skills could be overcome by identifying the training possibilities and determining their cost.

The importance of **selecting the most appropriate technology** in the feasibility study cannot be over-emphasized. The production of furniture can be classified in the following five main groups:

(a) artisanal operations using only hand tools and power ("craft" operations);

(b) artisanal operations using universal woodworking machines and simple, basic single purpose woodworking machines ("mechanized craft" operations);

(c) small scale serial production using single purpose woodworking machines with jigs, feeding devices, etc.;

(d) special purpose woodworking machines double end tenoners, double edge-banding machines, multi-spindle boring machines, etc.);

(e) machining lines, CNC machines etc.

The majority of the furniture producers in the country operate at levels (a) and (b) - and to a lesser extent (c) - the minority are at level (d), and there are probably none operating at level (e). Because of the relatively low wages, operations at level (c) can be competitive. Level (e) is only suited for producing very special products in very large series and have access to technical support.

The implications of the technology selected on the factory's manpower needs and the necessity - and cost - of training the manpower available to operate the new technology must be fully considered in the feasibility study.

The effects of the various characteristics on the available raw material on the technology selected should also be investigated in the feasibility study.

Size of series is another topic that must be given very serious consideration in the feasibility study. It goes hand in hand with aspects of specialization. Upon analyzing the failure of many small furniture plants in developing countries, it has been found that the most common cause for failure is the non-specialization of these plants: They were operating at the "mechanized craft" level, producing in too small series, components that were not interchangeable and still needed hand-finishing. Furthermore, having invested in as wide a range of machinery as their financial resources permitted, they found that, because of their lack of specialization, the majority of this equipment was not being fully utilized leading to increased overhead costs. Because of the above considerations, implications of size of series and range of products should be given full consideration in preparing the feasibility study.

It is beyond the scope of this document to dwell upon the normal pre-requisites of feasibility studies such as financial analysis etc., but this does not mean that they should not be accorded the importance they deserve.

Size and requirements of buildings

Serial production of furniture cannot be undertaken successfully unless minimal requirements for physical facilities are met.

Sufficient space should be available, not only to ensure an unhindered operation of the machines, but there must also be available sufficient space to store work in process at each of the machines as well as intermediate storage of buffer stocks. It must also be realized that the most sophisticated the machine is, the bigger is its hourly production capacity and the more complicated and lengthy are its set up requirements. This results in producing larger series and thus necessitates more overall storage space in the factory than for simpler, traditional machines.

Clearly defined passages should be planned and marked accordingly, permitting - when the layout of machines is rational - an unhindered flow of components, thus reducing the cost of material handling and working capital requirements for work in progress as well as permitting a speedier delivery of the clients' requirements.

Ample space should be foreseen for future expansion. It is therefore common to purchase more land than is currently warranted and to keep it as a reserve for future expansions. A one-floor factory is preferable to one operating on several floors. The most common flow for industrial production is a so-called "U" flow in a square - or nearly square - building. This permits having inputs and outputs on the same side (useful for road transport) and gives the possibility (provided land is available) for future expansion on three sides.

Lighting can easily be obtained through translucent panels in the roof. Basic woodworking machines are light, and, except for presses, need no special foundations. Floor surfaces must be level and smooth to facilitate internal transport.

By and large, internal partitions are unnecessary except to protect storage areas from the risk of pilferage, to protect the surface finishing area from dust - especially sander dust - and to protect the other areas from the higher risk of explosion that exists in the surface finishing area.

Range of products to be manufactured and its effect on equipment selection

Mention was made, earlier in this document, of the market study that has to be carried out as part of the feasibility study. Once an investment decision has been taken, a further study is needed, not only of the type of products to be manufactured (e.g. panel furniture, solid wood furniture, upholstered furniture) but also of their actual range.

Serial production of furniture calls for interchangeable parts (to permit for example knock-down construction and to allow production in batches which permit components from one batch to be assembled with those from another).

Inventory and tooling costs can be reduced if the factory standardizes its designs, using for example a limited range of profiles for mouldings, a limited range of diameters of dowels, etc. Components such as drawer sides and bottoms should be standardized to permit production in large series for use with a large range of drawer fronts. This not only reduces machine set-up times, but also justifies the purchase of higher capacity machines, thus further reducing production costs. On the other hand, inventory costs increase, but a judicious design policy, which allows a large number of different items to be produced from a relatively small range of components not only overcomes this risk but also facilitates marketing.

Specialization also ensures that equipment purchased can be optimal for the uses intended, and can be fully utilized. Specialization allows for example a chair factory to purchase presses with far smaller platens (hence at a far lower cost) than a "general purpose" factory, which would probably purchase a press large enough to produce doors. The same not only applies to the pallets used for internal transport, but also for the distance between machines, thus also reducing the overall surface area needed and resulting in a corresponding reduction in the cost of the building.

Because it has adopted specialization, the furniture industry of developed countries has been able, in spite of far higher labour costs, to compete successfully with product from developing countries, often not only on their own markets, but also on those of the developing countries themselves.

Plant layout considerations

It is relatively easy, in a plant producing a limited range of products, to study the groups of operations needed to be performed and, based on the most common sequence, develop a layout (sequence of machines) which ensures a logical flow of components in production. Based on this the size of the building needed can be determined.

Identification of the individual machines needed

The next stage in the planning of the furniture factory consists of determining the exact specifications of the machines needed.

The first step is to determine the **sequence of groups of operations** to be performed. This implies listing the operations in very broad categories (such as drying the sawnwood, cross cutting, ripping, planing, moulding, shaping, drilling, turning, tenoning, sanding, pre-assembly, assembly, surface finishing, packing, etc.). It is often useful to consider alternative flows (e.g. surface finishing of components such as drawer fronts or surface finishing of finished elements; cross cutting before or after kiln drying; cross cutting before ripping or *vice versa*, etc.). The relative merits of each alternative on the entire operation, with respect to layout and machine utilization, will have to be carefully studied.

The **level of mechanization** for each group of operations must then be carefully studied. Basically, it would fall within one of the five groups referred to earlier, ranging from hand tools to CNC machines. It is very important to ensure that the plant as a whole will fall within one or two adjacent categories and that wide ranges be avoided. Because of the nature of the products to be made, this is sometimes not possible nor desirable. Examples of such cases are hand carving and marquetry work. High quality, hand carved reproductions of period style chairs should be made on high quality shaping, tenoning and mortizing machines whose level of automation will finally depend on the size of series, labour costs, etc., while the carving will be done by hand.

The overall level of sophistication of the equipment installed should correspond to the skills not only of the operators and saw doctors available (or the skills they could attain after some training), but also of those of the maintenance personnel that the factory will employ directly, as well as those of the personnel of the firms it will be dealing with in its sub-contracted work. The maintainability of the equipment (for instance the automatic controls of drying kilns) is an important factor.

The mechanization of **internal transport** in the plant should correspond to the level of automation of the machines and the range of products. It is even more important to ensure that the **auxiliary services** installed (dust and waste extraction, compressed air, steam) meet the required parameters to permit the correct utilization of the machine and that they are at least as reliable as the machines installed. The productivity of certain types of machines (such as drying tunnels for surface finishing) are greatly reduced if the corresponding investment is not made in the conveyors and infeed and outfeed devices that they need. Another example is the need to instal dust extraction to allow the continuous operations of planers, thicknessers and moulders.

Once the above general considerations have been taken into account, the next step is to determine the **type of machine** that will be purchased. It must be realized that any actual operation in the production of furniture (such as sawing, turning, planing, drilling, glueing, etc.) can be carried out by a wide range of equipment, generally having a similar mode of operation but varying greatly in their capacities, sophistication, and precision of outputs obtained. Lists of such groupings of operations, given in an order of increased sophistication, have been compiled by UNIDO some years ago.

The decision on the technology chosen, after taking into account the pros and cons of the various options (with respect to capacity, investment cost, production cost, etc.) is a task that calls for a highly specialized person. Wrong decisions as to the type of machines result in inappropriate quality, inappropriate process, unnecessarily high prices, high wastes, etc. A wrong decision as to the capacity of the machines selected (or a wrong number of machines in case that it appears that more than one is needed) will result in underutilized capacities or in bottlenecks. Both are undesirable and are very often avoidable. It is also most important to ensure that the equipment selected fully meets the **environmental requirements** with respect to emissions in the air and water effluent (for surface coating or glueing operations), noise (for all woodworking machines with machining heads operating at high revolutions), etc.

In order to have a reasonably correct estimate of the installed capacity needed for any operation, it is necessary to have more than just an idea of the type and range of products to be manufactured and the size of series envisaged to be produced. Production flow and machine loading for any operation can be estimated by calculating the machining time for each batch of components that will be using the machine, thus permitting the selection of a machine for that particular operation that has a capacity and a level of sophistication corresponding to the rest of the production equipment needed to manufacture the product. Unless this is done a bottleneck will appear for one operation and unutilized capacities will be created for the other operations.

The actual methodology for the purchase of the machines (drawing up of the technical specifications, identification of potential suppliers, evaluation and comparison of offers) is often not given the importance it deserves, hasty decisions are taken only to be regretted later on.

<u>Human resource requirements</u>

The importance of adequately trained and motivated personnel, at all levels, to run the factory is seldom fully recognized by the entrepreneur, with the consequent difficulties once it starts operations. Unfortunately very few developing countries have realized the difference between craft and industrial production of furniture and still only provide vocational training for carpenters, joiners and cabinet makers. What is needed is the training of "machine woodworkers", a trade that is taught in the vocational schools of all developed countries. It is very difficult to change the attitude of craftsmen, who have spent their entire working life working at a rhythm where the machine was serving them, to change, all of a sudden to a diametrically opposite concept: that of them serving the machine - i.e. working at its pace and doing all that is in their power to minimize downtime through better planning of materials handling, a speedier set-up and more repetitive work - resulting from machining larger batches.

Another major stumbling block in the change from craft to serial (industrial) production, is the difficulty of changing the attitude of craftsmen to precision in setting up the machines. Traditionally, craftsmen use machines to reduce time consuming-manual work. Machined pieces are normally hand finished and hand fitted during assembly by the craftsmen. It is difficult to get them to realize that they can obtain a sufficiently precise component that will need no further fitting (precisions of $\pm$ 0.3 mm are obtainable from well maintained machines), if only they took the trouble to set the machines more precisely. Special emphasis should therefore be placed in educating (and motivating) craftsmen who will be called upon to produce on an industrial scale.

Industrial production also necessitates a more skilled maintenance crew (saw doctors, mechanical fitters and electricians), if only to improve the dimensional precision of the components through better maintained machines, better sharpened and maintained tools, and a reduction of downtime obtained through preventive maintenance.

The skilled operators are not the only category of staff in an industrial plant that have to have a new outlook - when compared to craft production. Serial production of furniture calls for a totally new category of specialists: technicians and middle managers. Foremen in an "industrial" factory have to have better theoretical knowledge. They have to be leaders of the workers placed under them, because serial production calls for more collaboration and motivation of the workforce. Product development, waste minimization, design of jigs and their manufacture, production planning and control, as well as costing of the products are all far more complicated than in craft operations. Because of the far larger series of production, errors, for example in costing, or unnecessary waste generated in cutting patterns, result in serious losses. Similarly estimating machining times, allocating overheads to various processes and departments, modifying the process to change the location of the bottleneck(s) and reducing overtime costs are topics that are normally not considered in craft or mechanized craft production methods. Unfortunately, very few entrepreneurs in developing countries have recognized the importance of these topics and trained their technical middle management staff in these fields. Since governments have not been sensitive to these problems, it is up to manufacturers' associations to organize courses in these fields for the technicians from the factories of their members.

It must be fully realized by management that the successful operation of a factory does not depend solely on the existence of equipment, but that its manpower has an equally important role to play. Consequently, the recruitment and training of the factory's staff, at all levels, should be given priority and started as soon as the orders for the purchase of the equipment have been placed.

Finalization of the factory's layout

At this stage of the factory's planning, the layout of the machines can be finalized. The exact requirements of each, not only with respect to space for the machine itself (fully extended), but also for all the material to be machined and that has already been machined, as well as for the operators must be determined. The maximum size of the inputs - be they planks or sheets of panels should be taken into account at the input side, and of the components at the output side making allowance for extra volumes of finished material which may accumulate due to delays in arranging internal transport.

Once the layout of the machines has been completed, the final layout and calculations for the auxiliary services - power, compressed air, steam and dust and waste extraction systems - should also be finalized.

Auxiliary services

Power lines are sometimes strung from the roof rather than in channels in the floor. This reduces the cost of laying new lines when equipment is moved from one location to another within the factory. If this system is used, great care should be taken to protect the lines where they come down from the roof from being snatched, creating electrocution risks.

Compressed air lines are laid out hanging from the roof. This allows a slope of about one per cent to be built into the circuit, and a vertical line with a tap is included at the lowest point - furthest from the compressor - to permit bleeding any water that may have condensed in the lines. It is also customary to build the system into a loop - as against a set of lines radiating from the compressor - so as to permit the closing of one section, in case of leaks or maintenance, without starving all points further away from the compressor. Over dimensioning the pipes forming the loop reduces the risk of pressure drops since sufficient compressed air is stored in it for it to become an extension of the storage cylinder. The compressor should be located in a relatively cool area, and it is useful to plant grass in front of its air intake so as to reduce the risk of it sucking abrasive dust and introducing it into the system, thus prolonging the life of the equipment. It is also customary to have the vertical lines to the points of consumption of compressed air first rise some 20 cm above the main circuit before coming down, so as to minimize the risk of condensed water entering the devices using the compressed air.

Steam lines should be properly lagged. Steam is normally only needed by presses and drying kilns. In case the drying is done in dehumidifier kilns, it might be justified to envisage purchasing a press heated with thermal oil, thus eliminating the need for a boiler which is costly to operate and maintain.

Dust and waste extraction systems are major consumers of power. Because the entire line has to operate to extract dust and waste from a single machine, it has become customary in big furniture factories to split the system into smaller ones, and either have a silo for each system, or to transport the dust and waste from the individual cyclones to a central silo using a belt conveyor or some other non pneumatic conveyor. In any case, sander dust should always be extracted in a system independent from the one removing sawdust and planer chips because it is much finer and thus far more likely to explode on ignition instead of merely burning.

Safety considerations

Legislation exists in all developed countries protecting workers from moving parts of machines, etc. Because such legislation does not exist in some developing countries, or, if it does, it is less rigidly enforced, some manufacturers tend to sell equipment to these countries that is not fully protected in order either to simplify it or to reduce costs. Needless to say, purchasers of equipment should insist that all the machines they purchase should come fully protected and ensure that all protection devices originally installed are functioning satisfactorily at all times. It is also in their interest to insist on meeting the environmental requirements of the developed countries, because sooner than later the local authorities will introduce them, and retrofitting the machines to meet these requirements is always more costly (and complicated) than having them built in.

Fire risks exist in all furniture factories.The following locations are the biggest risks, and measures to ensure safety should be taken.

Paints and varnishes should be stored as far away from the main factory as practical and only minimal stocks (e.g. one day's requirements) kept in the surface finishing department. This store should have solid wall construction, but a flimsy roof, so that in case of an explosion or fire, the walls would deflect the blast upwards and protect adjoining property. Because the risk of fire in the surface finishing department is higher than in any other part of the factory, a strict non-smoking policy should be enforced there, and all electric installations (lamps, switches, outlets, etc.) should be explosion proof.

Fire risks near woodworking machines can be minimized by fully maintaining electric motors, switches, etc. and insisting on good housekeeping practices such as clean floors, shelves, etc. as well as the immediate removal of sawdust, offcuts etc. A fire wall, with fire doors that close well and normally remain closed, should separate the surface finishing department from the rest of the factory. Fire hydrants - if practical - should be installed together with the corresponding hoses. These should be complemented by an adequate number of fire extinguishers of the appropriate type - including those for dealing with electric fires - located throughout the factory. Several larger units, on wheels, should also be strategically placed. These, together with the hoses, should be inspected regularly. Their location should be clearly marked and easy access to them assured at all times. The factory's staff should be taught how to use them.

Finally, **first aid kits** should be placed in strategic locations, clearly marked, regularly inspected and "topped up" and the factory's staff should be taught the rudiments of first aid, including dealing with electrocution, burns, application of tourniquets to stop bleeding, etc.

Materials handling

It must be realized that no value is added in moving components from one machine to another. Only costs are added, hence the importance to ensure as low a cost of internal transport possible, while at the same time ensuring the protection of the material transported from damage. There is therefore a strong justification in investing in equipment for materials handling and intermediate storage.

The system most commonly used consists of a sufficient number of pallets (of approximately 80 by 120 cm), with a few pallet transporters. Pallets should have metal strips on the edges of their bases to permit the insertion of sides needed to transport and store turned, smooth or small components and/or sub-assemblies. This system has been found to be more versatile and cost less than the fixed roller paths found in some large factories. Pallets with wheels cost more and are less robust than the system proposed above.

Special racks, on wheels, with a central frame and a number of rods on either side of the frame are commonly used to transport, dry and store panels in the surface finishing department. Larger factories sometimes have monorail conveyors to transport components to the spraying booths and from there to the drying tunnels. Large upholstered sofas are usually transported on special wheeled pallets.

Start up

As indicated previously, the new factory's management should have, at the time of the selection of the equipment and the placement of the orders, identified the training needs and the persons on their staff that will be sent to be trained and, where applicable, negotiated this training as part and parcel of the purchase order of the equipment. If this is done some of the high costs of paying for the fees and travel of the supplier's technicians could be averted. (This is not possible in all cases because of warranty considerations).

The vast majority of the woodworking machines in furniture factories would not, under Iranian conditions, call for expatriate technicians to install and start them up. This can either be done by the factory's maintenance personnel, or by recruiting, for a short period, or under a lump sum contract, more skilled local technicians to undertake these tasks.

Once installed, machines should be run idle, and then operated with tools, and alignments and movement of all pieces should be tested by hand before they are called upon to perform. Bearings should be checked that they do not heat up, and the machine should be stopped immediately when something abnormal is found.

Organization of maintenance

Concurrently with the installation of the machines, the operational manuals supplied with it should be studied by the operators (or, in cases where their level of education precludes this, by the foremen directly supervising them) and by the factory's maintenance staff. When applicable, both should train all the operators likely to be called upon to operate the machine on correct setting, tooling requirements, safety considerations, frequency of lubrication of each of the lubrication points and correct grades of oils and greases used in each point, etc.

A separate file for each machine should be opened and kept by the person responsible for all maintenance activities. It should contain the operating manual, the spare parts catalogue (or "exploded" drawings giving assembly instructions and spare part numbers - if such documents are supplied), the invoice(s) relating to the machine (giving an indication of cost, spare parts and tools delivered, etc. as well as the firm's full address and/or that of the local agent). Information on the auxiliary equipment that the machine needs (such as for example the number, location, type, dimensions, etc. of belts, ball and roller bearings, etc.) is also kept together with similar information on tooling requirements, and details on the location, type, characteristics of all its electric motors, switches and other electric controls.

In bigger plants, it is customary for the maintenance department to analyze these and immediately make any minor modifications which would permit a standardization of these auxiliary items of equipment in the factory and thus reduce the cost of carrying the inventory of spares.

A lubrication schedule *cum* preventive maintenance programme is also drawn up at this stage. (Smaller firms that do not have in-house expertise to do this can usually call upon the technical staff of major oil companies to provide the lubrication schedules).

The machine's number in the plant's inventory is painted on it, and it is entered in its file and the plant's preventive maintenance programme. It is also useful to mark, using appropriate colour codes and/or different symbols, the location of all greasing points and the frequency at which they must be serviced (e.g. daily, weekly, monthly). A record of these should also be kept in the machine's file.

Finally, the file should contain information fed by the operators on repair and maintenance requirements, duration of downtime, giving diagnostic data, as well as on the remedial measures taken, by whom, and the costs incurred. An analysis of these, over a period of time, permits modification of the preventive maintenance programmes (by altering the frequency and/or including new points to be checked). An analysis of these sheets permits changes to be made in the stock of spare parts reducing the risk of running out of spare parts or reducing the inventories if it appears that too high a stock is carried.

Any subsequent modification made to the machine should be entered in the file. It is also useful to keep in this file invoices of any work concerning it that has been sub-contracted to outside firms to permit an easier check as to whether any subsequent failure is covered by that company's warranty or whether it should be borne by the factory.

Drawings for serial production

Unlike the practice used in craft operations of using full size drawings and checking the accuracy of the components by placing them on the drawings, plants producing at an industrial level usually use drawings at an appropriate scale to permit it to be included on a single sheet of standard "A 4" size. Dimensions are indicated and vernier gauges and measuring tapes are used to check that the actual dimensions of the component are identical to those indicated on the drawings. In some more advanced firms, it is customary to also indicate tolerances of key dimensions. These firms also use a system showing "primary" and "complementary" measurements. For example, in assembling the side of a chest of drawers, there are slides on which the drawers run. The distance between the bearing edge of one slide and that of the next is a "primary" measurement (since it affects the sliding of the drawers and their fitting one over the other) while the actual width of the slide is a "complementary" measure.

It is also customary to use simplified notations e.g. O10D20 means: drill a hole diameter 10 mm with a depth of 20 mm; Bev. 3X3 means: machine a bevel of 3 mm on each face. Dowels are indicated by the diameter times their length (e.g. O10X40); etc.

The numbering of the drawings is often also simplified: each product is given a two digit (in larger firms a three digit) number for all identification purposes. An isometric drawing of the assembled piece of furniture (or the three projections) is made, numbering each component - be it wood or non wood - with another two digits. Individual drawings of each component, giving all dimensions, information on the raw material, its quality, as well as machining instructions - such as the number of the jig to be used - are made. It is customary that these drawings be photocopied and the respective photocopy is placed on the pallet of the components to serves as reference throughout the machining operations.

Other advantages of a four digit code is that it can be used to indicate components common to more than one product - for example drawer sides. These are machined in larger batches and kept in an intermediate storage to be drawn upon as and when needed to assemble the products in which they are used. This code is also used for inventory control, costing as well as production planning and control. If another digit is added to the four (or, if more than ten possibilities are needed a letter) it could be used to indicate the species of wood, colour or type of surface finish, etc. and be of interest to the accounting and production planning departments.

Machine setting for serial production

The machine is set up to produce the required components, and, after checking that all safety measures are operational, it is started and a component is produced. This component is usually checked by the foreman or a highly skilled operator who has been entrusted this task. All dimensions are checked, using vernier gauges, metal tapes or other appropriate measuring devices (e.g. protractors, squares). The Furniture Industry Research Association (FIRA), in the United Kingdom, has developed a range of special gauges used to check measurements of furniture components such as position of holes (measuring directly from the hole's center to the edge), dimensions of tenons, angles, etc. Many production managers have found these to be a useful acquisition.

Larger plants, producing a more specialized range of products have found it useful to invest in specially manufactured metal gauges of the "go/no-go" type that are capable of measuring all the principal dimensions of a component. Such gauges are made for each component and labelled accordingly (using the code referred to above).

The importance of insisting on precise machine setting cannot be over emphasized. It must be recalled that the basic difference between craft and serial production lies in the fact that in the former it is possible to finish components by hand, while in the latter case this possibility has been eliminated. It is therefore of utmost importance that all components be fully interchangeable. This can only be achieved through (a) good and precise tool maintenance, (b) good preventive maintenance, and, (c) accurate machine setting.