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SEMINAR ON COMPARATIVE PULPING PROCESSES
INCLUDING THE MONOPULP PROCESS *

Alexandria, 26-30 April 1986

US/RAF/84/239

Prepared by

The Chemical Industries Branch
Industrial Operations Technology Division
Department of Industrial Operations

456

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SUMMARY

The discussions revealed that there is a need for such conferences where new ideas are presented and where under a neutral chairmanship, an objective discussion takes place on the pros and cons of such new technologies and their benefits for developing countries. UNIDO can play a vital role here in disseminating up-to-date information from engineering companies and research organizations.

It was realized that very often new processes are tested or are developed only for one or two raw-materials exclusively wood-based, and that such new processes, in order to be accepted by developing countries, do need to be further developed incorporating the raw materials mostly available in developing countries, i.e. non-woody fibres.

For the low-cost integrated paper mill process, there was only theoretical interest, because the work was based on eucalyptus plantation wood only, and in many African countries, such wood is not available or not favoured. The proposal to make an energy-autark mill was supported by the participants but the idea to use wood/wood-waste as fuel to produce steam and generate back-pressure power in countries where deforestation is already a major problem, did not find any sympathy. The high electrical power consumption per ton and the peroxide bleaching recommended were criticized. There is an urgent need to have non-woody materials tested and the peroxide bleaching should be replaced by the orthodox bleaching methods like two-stage sodium hypo-chlorit in order to really evaluate the possibility of these high-yield pulping processes for starting small pulp/paper mills in developing countries.

The participants, very much impressed by the Government of Sweden's willingness of financing such studies, asked whether such non-woody studies could again be financed by donors, e.g. Sweden.

There was also great interest to avoid the classical pulping chemicals sodium or sulphur-based and to learn whether oxygen, if possible, produced indigenously in a pulp mill, could do an excellent pulping/bleaching job in small pulp mills using non-woody materials.

More research should be done in this field.

The recovery of chemicals, often not done in small mills, is of greatest importance to reduce production costs and to avoid pollution of rivers.

There is an urgent need for a low-cost, easy-to-operate process. The discussions showed that the DARS process has some potential but it was also called a knife-edge process which means that the process is very difficult to control under practical conditions. First experiences of a full-scale production unit in Australia have to be and evaluated.

The wet-cleaning of fibrous non-woody materials before pulping, although high in energy-consumption, brings many advantages, like

- removal of sand, of salts (from salty soils or plant intake of fertilizers) silica;
- more uniform and faster penetration of cooking liquors, thereby equalizing the moisture variations in the raw-materials, thereby guaranteeing more uniform pulp.

More appropriate pulping machinery for cooking and washing are recommended for future mills.

The use of non-sulphur pulping chemicals should be favoured.

The principle of selective pulping for non-woody materials, as now been described and practically carried out in the NACO process for straws, needs more research comprising other non-woody fibres like bamboo, cotton stalks, etc..

UNIDO is very thankful for the foresight of SIDA to allow UNIDO to organize such specialized small technical seminars with experienced mill personnel in Africa, thereby bringing forward the consolidated know-how and the science of pulping and paper-making of non-woody materials.

Many questions have been raised which demand further research and developing work of the international community.

The special conditions existing in Africa must be remembered and considered in future research & development programmes.

There is a great future in pulp/paper making in developing countries in Africa, because, as the latest FAO statistics show, the expansion of the pulp/paper industry in many of these developing countries will be double to triple the expansion rate, now existing in many developed countries.

In general, it was felt that good new ideas have come to the attention of the participants from developing countries but the basis for the research work was always very small and only of interest to developed countries, (e.g.: eucalyptus plantations which often do not exist or are not favoured in developing countries).

Therefore, a plea goes again to researchers and developers in developed countries, whenever they bring out new processes or new machinery, they should also incorporate in their testing non-woody materials (e.g. straws, reeds, bagasse, bamboo, kenaf, jute, cotton-stalks...) which still, in most developing countries, are the fibre basis for the pulp mills.

OBJECTIVES

The objectives of this Technical Seminar were:

- 1) To come to a better understanding of the various pulping processes suitable for small-scale pulp/paper mills in developing countries;
- 2) To have a better guidance for future technical research & development work appropriate for developing countries;
- 3) To establish a closer link and co-operation between developers and researchers and users of such new pulping processes, e.g. the NACO process in pulp/paper making.

The participants were very thankful for this Technical Seminar and the speakers also were very pleased to have much time for discussing their work with the participants, who often, very critically, demanded more information or further research work.

UNIDO benefitted greatly during this Seminar by obtaining a lot of first-hand information from the mills in Africa. A number of new project proposals for further down-to-earth research & development work for the mills or in the countries were the result of the Technical Seminar.

RECOMMENDATIONS

1. High yield pulping is for many developing countries a good method for starting their local pulp/paper industry. One such process is the low-cost integrated pulp/paper mill approach (Monopulping). It was realized that the research work done so far has been limited to eucalyptus only.

More development work is needed for African countries including the local fibrous materials available like straw, bagasse, tropical hardwoods and pinus (in Tanzania).

As the monopulping concept research work was financed by SIDA (Swedish International Development Authority), further development work characteristics for African developing countries might be again financed by SIDA.

Special efforts should be made to reduce the power consumption of the process. Also to find low-cost bleaching methods suitable for developing countries.

2. To become independent of classical pulping chemicals, further research in oxygen pulping of non-woody fibre materials, like sisal, cotton stalk, banana stems and sugar cane tops is necessary, e.g.: using wafer chips from eucalyptus in the Sudan.
3. It was observed that the wet cleaning system has the advantage of saving chemicals, reduction of silica and quality improved. However, there are problems related to high energy consumption and non-uniformity in pulp cooking due to problems on the screw press prior to the cooking stage. Screw conveyors should never be longer than 2.5 m - otherwise roping. It is therefore recommended that further work is conducted to improve the system.
4. The foaming tendency of green bamboo and green straw and reeds can be greatly reduced after their storage of 4 - 6 weeks before pulping.

5. There is now a first continuous digester (Kamyr) for rice-straw pulping in Letges, Indonesia. Continuous feeding is ever so important and special designs are necessary for feeding either bagasse or wheat straw or reeds.
6. Disc presses for dewatering non-woody pulps are highly recommended.
7. It was noted that the first commercial application of the DARS (Direct Alkali Recovery System) has just gone into operation at APPM Barnie Tasmania. It is recommended that the results of this operation are carefully monitored. Depending on the commercial success of this process it is recommended to study the extension of this system to small scale non-wood based pulp mill.
8. There is a non-effluent unbleached soft-wood pulp plant (135.000 t.p.a.) in Swaziland which is the biggest kraft pulp mill in the developing countries. Exchange of know-how is recommended.
9. Lagooning of pulp and paper wastes and its problems have been solved in the Hunyani pulp/paper mill in Zimbabwe. Exchange of know-how is recommended.
10. Some companies lagoon their black liquor and by government law are not allowed to send effluents into rivers. This is done in Zimbabwe for many years. Examinations should be carried out to determine the mineral resources potential of such dumps.
11. Application of Reverse Osmosis (RO) and Ultra Filtration (UF) Method of chemical recovery system was considered as a possibility for small scale non-wood fibre pulp mills. RO technology is very good in discolouring bleach plant effluents. It is recommended that further intensified mill scale studies be initiated soon.
12. Work of bio-treatment of bagasse and its advantages should be made known more efficiently in developing countries.

13. Three research groups have worked on desilication in the last 10 years and presented their results. There are now laboratory and semi-production plant and desilication experiences available. A first production unit (180 tpa bagasse pulp) has started up in Indonesia. All parties should support each other and exchange information to make other future production plants successful in their desilication efforts.

14. There are training centres for operators, technicians and engineers in the RAKTA rice straw/pulp/paper mill in Egypt and in the EDFU bagasse pulp mill (Egypt). Foreign personnel are also trained in such centres. Interested parties should approach the Egyptian Government, through their Governments for acceptance, by also indicating the specific training programmes required.

15. Concern was expressed that often the private industry in African countries is not informed through Government channels on UN activities. More information and better channels of communication in future is requested.

PREPARATION OF THE CONFERENCE

1) PROJECT HISTORY

The project idea was discussed by SIDA and UNIDO in Vienna in October 1982. The project proposal was submitted in November 1984 and was cleared for financing on 10 January 1985. The PAD was issued on 18 March 1985.

2) UNIDO'S ACTIVITIES

January 1986: First informative telex Misc 05630 was sent out to UNDP Offices in the 9 countries, as specified below, inviting them to nominate candidates:

- Mozambique
- Iraq
- Zimbabwe
- Tanzania
- Swaziland
- Sudan
- Kenya
- Ethiopia
- Egypt

20 February 86: Letters of invitation were sent out to the following companies:

- CELPAP, Sweden
- HURTER, Canada
- KRAFT/NLAGEN HEIDELBERG, F.R.G.
- FLEDIC, Canada
- BABCOCK AND WILCOX, U.S.A.
- SUNDS, Sweden

An informative telex was sent to FAO and Agenda was pouched.

- 7 March 1986 - The recruitment of the following speakers/consultants was initiated:
- Mr. Basu
 - Mr. Bleier
 - Mr. Jeyasingam
- 28 February 86 - The Aide-memoire was sent to all UNDP Offices mentioned above.
- 9 April 1986 - An additional consultant, Mr. M. Narby, was recruited.
- by 14 April 1986 - Nominations for 14 countries from 8 countries were received, namely:
- Ethiopia (2 participants)
 - Iraq (2 participants)*
 - Kenya (2 participants)*
 - - Sudan (3 participants)
 - Swaziland(1 participant)
 - Zimbabwe (1 participant)
 - Tanzania (3 participants)
 - Egypt (**)
- * These participants did not arrive due to difficulties in timely arrangement of their visas.
- ** Egypt, as the host-country, was very strongly represented and participated actively in the lectures/discussions.

All nominated candidates were accepted by UNIDO.

3) CONFERENCE

The following background papers were supplied by UNIDO to the participants and were used during the technical seminar:

- Alternative Pulping Processes - by M. Judt
- Research Problems in Developing Countries using non-woody fibres as seen by UNIDO - by M. Judt
- Appropriate Industrial Technology for Paper Products and Small Paper Mills (ID/232/3)
- Small Scale Paper Making - ILO

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* = UNIDO nominated participants

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TECHNICAL AGENDA

Saturday, 26 April 1986

Inauguration:

08.30 - 09.30 Registration
09.30 - 10.15 Opening Ceremony
 Introduction by:
 - Mr. Taber Bishr, RAKTA
 - Mr. B. Kyrklund, FAO
 - Mr. M. Judt, UNIDO
 - Speech given by Mr. A. Saleh, Vice Minister
 and First Secretary of Ministry of Industry

10.15 - 11.15 Coffee Break

Chairmanship: UNIDO

11.15 - 12.15 Alternative Pulping Processes by
 Messrs. Bleier/Judt, UNIDO and
 Discussion
12.15 - 14.00 Lunch Break
14.00 - 17.00 Survey of Straw Pulping Methods
 by Mr. T. Jeyasingam, UNIDO
 Soda-Nitric Acid Pulping of Rice
 Straw by Mr. Hassan Ibrahim, RAKTA
 Mill, Egypt

Sunday, 27 April 1986

Chairmanship: FAO

- 09.15 - 19.45 **Small Scale Pulping
FAO's Activities in Small Scale
Pulping, by Mr. B. Kyrklund, FAO**
- 09.45 - 10.30 **Monopulping and its future for
developing countries, by Mr. Narby,
CELPAP, Sweden**
- 10.30 - 11.00 **Coffee-Break**
- 11.00 - 12.30 **Different Application of OPCO Process
NSCMP - High Yield Pulping Process for
Small Pulp Mill
summarized by Mr. B. Kyrklund, FAO**
- 12.30 - 14.00 **Lunch Break**

Chairmanship: UNIDO

- 14.00 - 15.30 **Country Paper EGYPT
Country Paper SUDAN
Discussion**
- 15.30 - 16.00 **Coffee-Break**
- 16.00 - 17.00 **The NACO Process - A selective Pulping
Process for Annual Fibre Raw Material -
by Mr. T. Franzen, SUNDS Defibrator
Discussion**

Monday, 28 April 1986

Chairmanship: UNIDO

09.15 ~ 10.30	Mechano-Chemical Depithing of Bagasse, by Mr. El-Rehim, RAKTA Mills, Egypt DARS Process, presented by Mr. B. Kyrklund, FAO Discussion
10.30 ~ 11.00	Coffee Break
11.00 ~ 12.30	Country Paper ZIMBABWE Soda Recovery based on Ultra Filtration by Mr. S. Basu, UNIDO Discussions
12.30 ~ 14.00	Lunch Break
14.00 ~ 15.30	Country Paper ETHIOPIA Desilication of Rice Straw Black Liquor by Mr. Hassan Ibrahim, RAKTA Mill, Egypt Discussion
15.30 ~ 16.00	Coffee Break
16.00 ~ 17.00	Country Paper TANZANIA Desilication of Bagasse Black Liquor by Mr. Kopfmann, Heidelberger Kraftanlagen Discussion

Tuesday, 29 April, 1986

Visit to the RAKTA Mill in Alexandria

Wednesday, 30 April 1986

Chairmanship: UNIDO

09.15 - 10.30	Country Paper SWAZILAND Desilication of Bamboo Black Liquor by Mr. Bleier, UNIDO
10.30 - 11.00	Coffee Break
11.00 - 12.30	Final Discussions Recommendations by Participants Summary of Discussions

OPENING ADDRESS
to
THE SEMINAR ON COMPARATIVE PULPING PROCESSES
INCLUDING THE MONOPULP PROCESS
by
MR. A. SALEH, VICE MINISTER AND FIRST SECRETARY
MINISTRY OF INDUSTRY
on
SATURDAY, 26 APRIL, 1986

Ladies and Gentlemen, Distinguished Guests,

I have all the pleasure to welcome you on behalf of the Egyptian Government in Alexandria, one of the oldest historical cities in the world, civilization, history - as well as the oldest library worldwide.

Welcome to this meeting, leaders of new technology in the pulp and paper industry and manufacture from agricultural residues and non-wood fibres.

Dear guests, our conference consists of a wide number of specialized personnel, scientists and experts in the pulp and paper technology, we welcome you all to Alexandria and hope to achieve all the targets that we have planned to improve the future of the under-developed countries despite of all the economical problems and constraints.

We all know that Egypt has been a pioneer in the field of paper, long ago the pharaoes have produced paper from "papyrus" cellulosic material.

Paper, same like food and energy, is one of man's life necessities and any reduction in the consumption per capita will directly affect the life standard specially in the under-developed countries. Therefore, the evidence of this conference goes without saying for the progress of the third-world.

However, most of the third-world nations do not possess forests due to nature distribution. Therefore, under the heavy demand and strong needs the only alternative seems to be the agricultural residues such as rice straw, bagasse, reeds, etc..

The conference has as a principle aim the future of the agricultural residues pulping methods, as main raw material in the under-developed countries.

I do believe that this international meeting will describe a general survey of several trials, efforts & hard work which have been accomplished by each country member of this conference, all having the same target to find alternatives to wood pulp with all the related procedures.

I would also like to mention the importance of paper and board production in the field of wrapping and packaging where the technical and scientific research serve the user for the best. The main points which will be discussed are:

- 1) New technical methods selection for agricultural residues pulping.
- 2) Beneficial use of sugar-cane bagasse for the production of magazines and newsprint papers.
- 3) Production of high yield pulp from rice straw.
- 4) New techniques for the silicates separation from the black liquor.
- 5) Chemical recovery of black liquor resulting from cooking.
- 6) Treatment of industrial wastes for pollution control and abatement.

As a whole the aims are:

- 1) Alternative sources other than wood trees from forests. Beneficial use of agricultural residues sufficiently present in the developing countries such as rice straw bagasse, reeds, cotton stalks and wheat straw.

- 2) Advanced methods and techniques for the chemical recovery of cellulosic materials in order to:
 - a) Increase the national return for the under-developed countries;
 - b) Lower the energy consumption;
 - c) Reduce the chemicals consumption used for pulping;
 - d) Chemical recovery to cut the cost and control the environmental pollution;
 - e) Upgrade the fibre properties, treatment and preparation methods for writing, printing and wrapping production

- 3) Advanced technology transfer and initiation of the specific technical frames for the under-developed countries.

We are expecting that this conference will deal with some economical points of the pulp & paper production concerning various aspects influencing the progress and evolution such as:

- 1) Definition of the plant species giving adequate pulp yields.
- 2) Selection of the agricultural areas and the collection methods.
- 3) Economical collection of agricultural residues and transportation to production sites.
- 4) Storage techniques and treatment of such agricultural residues.

Egypt has been the first country to use its agricultural residues such as rice straw, reed and bagasse. Egypt has used more than four million tons during the past 25 years since the beginning of paper production.

However, today we are here in this conference, with all the scientists experts those who have done a lot of work successfully in the pulping technology field.

We all have to take into consideration our General Company for Paper Industry - RAKTA, which has been established 25 years ago and has used more than two million tons of rice straw to produce writing and printing papers.

Finally, I would like to thank:

- United Nations Industrial Development Organization (UNIDO);
- Food and Agricultural Organization (FAO);
- Representatives of the associated countries in the conference;
- Administrative and Managing Director from Vienna and Alexandria.

Wishing everybody an agreeable stay in Alexandria.

WELCOMING ADDRESS

to

THE SEMINAR ON COMPARATIVE PULPING PROCESSES
INCLUDING THE MONOPULP PROCESS

by

MR. MANFRED JUDT

SENIOR INDUSTRIAL DEVELOPMENT OFFICER, UNIDO

at

THE MONTAZAH SHERATON HOTEL, ALEXANDRIA

26 April, 1986

Your Excellency, Mr. Chairman, Ladies and Gentlemen,

It is a great privilege for me to welcome you on behalf of UNIDO to this international seminar on comparative pulping processes including the Monopulp Process, here in Alexandria.

UNIDO is especially grateful to your country because in the last 15 years you supported our work in developing countries in many ways with good experts, like e.g. Mr. Ibrahim, who worked several times in Turkey and Sudan; you gave excellent training for UNIDO to many fellows, e.g. in the RAKTA Mill, and now you are hosting this seminar for Africa here in Alexandria, in the town which was the data centre or information bank of the civilized world about 2000 years ago. On 800.000 papyrus rolls the history, the know-how of mankind deeds and achievements were written. And then a fire destroyed the past! But Alexandria is still a Mekka for pulp/paper-makers.

Your country's know-how in non-woody fibre pulping and paper-making like straw, reeds, bagasse, is demonstrated e.g. in the RAKTA Mill - the biggest rice straw soda pulp mill in the world, in Efdu in the bagasse kraft pulp mill and in your country's capability to mix such furnishes, also with waste paper to make many good papers and boards.

Dedicated research work was and is done in Alexandria and Cairo for non-woody fibrous materials which is of universal interest, like e.g. for

- soda and nitric acid pulping
- desilication of rice straw black liquors
- chemi-mechanical pulping processes and bagasse depithing processes
- not to forget the papyrus research by Prof. Ragab.

You may know that my organization, the United Nations Industrial Development Organization, is expected to play a principle role in, and be responsible for reviewing and promoting the co-ordination of all activities of the United Nations system in the field of industrial development. In fulfilling this task UNIDO activities are of two fundamental types - operational and supporting. Whereas the operational activities normally are carried out in the field by experts engaged in the industry, the supporting activities are also in organizing technical meetings with the purpose of examining the present state of knowledge in pulp and paper technologies and then promoting and transferring technical know-how in and among developing countries. This pulp and paper meeting is therefore part of UNIDO's supporting activities in this field.

Reviewing the development - on an international scale - of pulping/papermaking over, say, the last decade, one finds that the industry has continued on its path of "economy of scale" i.e. towards an ever-increasing size of single industrial units. Without radically departing from established technology, the successful search for more efficient and more reliable processes and installations, has brought forth advances towards higher specialization and sophistication.

But also world-wide there is a trend to make pulping processes simpler, lower in energy-consumption, to make pulps with higher yields and use more and more low-cost wood waste materials and in developing countries, specially here in Africa, agricultural waste materials in pulp and paper making. Of course, the recycling of waste-paper furnishes

is also increasing and has become for many countries of utmost importance.

The Swedish Government and UNIDO/FAO agreed and SIDA was kind to finance this Technical Workshop that a critical review of the present status of pulping, especially of high yield pulping methods and chemical recovery systems used would be worthwhile to be discussed together with pulp makers of African countries.

It is hoped that during this conference the developing countries may benefit after adaption from a quicker transfer of some of the existing pulping and chemical recovery know-how and thereby be supported in their endeavours to increase and strengthen their pulp and paper making facilities at, if possible, lower production costs.

It is hoped that during this conference a number of recommendations will be made on how by joint efforts also with the help of the UN-organizations new initiatives in pulping research, in raw material development, in desilicization, in small-scale pulping and chemical recovery, to name a few possibilities, might be started.

UNIDO is very grateful to the Government of Egypt who volunteered to host this conference here in Alexandria, and I am very thankful for the excellent work done by the Mill Management of the RAKTA Mill here in Alexandria, in preparing and organizing this workshop.

14 participants from 7 countries in Africa are here to share their experiences with us. Your participation in the discussions, your resolutions at the end of the conference will be highly appreciated and will determine the success of this conference.

I am sure that this meeting will reach satisfactory conclusions regarding the best ways and means of promoting industrial development in the pulp and paper sector in developing countries especially here in Africa.

I trust you will give us your opinion as to the most effective way in which UNIDO could implement these conclusions. We value your advice and we shall do our best to carry out your suggestions and thereby benefit the developing countries.

Again, I would like to thank the Mill Management of the RAKTA Mill for hosting this meeting in this country. Without your organization, this meeting would not have been possible. A special thank you goes to all the speakers who will present papers which will guide us during this meeting.

In conclusion, I would like to thank you all for accepting our invitation to this meeting. I wish you every success in your deliberations.

ALTERNATIVE PULPING PROCESSES

by

P. Bleier and M. Judt

Reviewing the development - on an international scale - of pulping over, say, the last decade, one finds that the pulp industry has continued on its path of "economy of scale", i.e. towards an ever increasing size of single industrial units.

Without radically departing from established technology, the successful search for more efficient and more reliable processes and installations has brought forth advances towards higher specialization and sophistication.

The second industrial revolution of computer control and regulation of all industrial activities has completely reshaped paper-making and somewhat slower also pulping; new methods to measure process parameter permit electronic engineers to design systems for controlling the complex chemical events in fibre production and in chemical recovery.

Today's giant pulping units require enormous financial efforts and a highly developed infrastructure of material resources, of transportation, of labour qualification and of marketing. Such demands, however, cannot be met by non-industrialized countries, eager to develop their resources to cater for the need of their growing population. They require adequate, but certainly smaller and simpler pulp and paper-making units, in accordance with modest infra-structure and markets and with the completely different local material and labour resources.

Experience has shown that western R&D concentrating on optimization or large scale pulping is only of limited help for problem solving for developing countries' pulping.

Here approaches are demanded that may appear to the western eye to be "unconventional", more likely to be attended to by "outsiders", either by qualified but unbiased academics or by people from the mill floor, conversant with everyday pulp and papermaking reality.

Unfortunately, little assistance to developing countries is forthcoming from the highly competent teams of cellulose chemistry, electronic engineers, chemists, biologists and others assembled by the potent suppliers to the western pulping industry.

All the same, it is important to carefully scrutinize all pulping development becoming public for their possible significance and application in developing countries.

With this perspective in view the pulp and papermaking unit in UNIDO, Vienna, has attempted to collect relevant publications over a period of years. A list of pertinent literature is available to participants of this Seminar.

Allow us now to make a few remarks of a more general nature on some of the points under discussion in this seminar:

FIBRE SOURCES

About 95 % of the world pulp production still is wood-based. The largest portion of fibres still is derived from conifers with their comparatively long fibres, ease of penetration and ease of defibration. The utilization of deciduous wood has made great strides, particularly from plantations of non-indigenous eucalypts, gmelina etc. in tropical rainbelt locations. Indigenous hardwoods are mostly harder and harder to pulp, also because of being mixtures of species with variable properties.

With available forest area diminishing due to population pressure in developing countries (the bulk of wood still serves as firewood, mainly for cooking), future fibres supply will increasingly have to rely on annually renewable non-woody sources,

i.e. on agricultural residues. Fertile soils are increasingly in demand for food production, leaving little room for industrial crops. Instead of taking up the challenges posed in pulping this special type of material, to them of "insignificant importance" at present, the industrial world has chosen to discontinue its utilization. Non-wood pulping has become almost exclusively a concern of the developing world. This seminar should supply evidence of much of the work done so far in this field in non-industrial tropical countries.

The open structure of straws and other annuals is advantageous for speedy penetration by cooking chemicals, but - unless vapour phase pulping can be practiced - it requires large amounts of liquor, rendering recovery uneconomic due to high dilution. Other troublesome features needing special attention are low paper strength, problems of storage, of handling and of grit and of chemical recovery because of difficult brown stock washing, of silica and of low black liquor heat content.

ENERGY

The defibering of plant tissue is energy consuming. In mechanical pulping most energy required is converted into heat, with only a minor fraction utilized for fibre separation; the industrial high temperature chemical pulping processes are crude and heavy fisted in comparison to the soft paths taken by nature. However, biotechnological pulping is still far from practical applicability because of the slow action of natural fungal enzymes. By applying the powerful tool of genetic engineering for enzyme production, advances in bio-technical defibration are likely.

Small pulping units should not try to generate their own electricity inspite of the advantages of heat/energy coupling or utilization of excess heat in black liquor combustion or in thermo-mechanical pulping. In a world of diminishing or costlier fossil fuels, the use of spent liquor organics and of other renewable agricultural or forestry resources becomes increasingly important.

Direct use of solar energy for evaporation in dry countries is under consideration although solar ponds can hardly be economic wherever space is not cheaply available.

For most industrial processes higher temperatures are required than can be directly supplied by the sun.

CMP AND CTMP (CHEMO-MECHANICAL PULP AND CHEMO-THERMO-MECHANICAL PULP)

Mechanical pulping is attractive from the point of view of maximal yield and of reduced effluent load. The price to be paid for this is the high energy demand mentioned earlier and also breakage of fibres with loss of strength and increased fines. The advancing CMP and CTMP processes attempt to find an optimal compromise between purely mechanical and purely chemical pulping. Treatment before refining generally is alkalisation and sulfonation for swelling and for partial solution to weaken the interfibre material of plant tissue.

Up to now the main application of chemo-mechanical pulping is with softwoods that lend themselves for this technology but unfortunately are often not available in tropical countries. Some species of eucalyptus and poplar are equally candidates for CMP/CTMP and some units have started operating.

In hardwood the penetration of chips with pre-treatment chemicals is critical, but seems to come under control with pre-steaming and treatment in helical presses.

Very little information is available on the theoretically attractive application of chemo-mechanical pulping on agricultural residues; no industrial operation is known. Possibly, it is the grit contaminating all material harvested in the fields that prevents easy adoption; without grit removal the working-life of refiner disks is uneconomically short. Because of the eminent importance of opacity for newsprint and for other light weight printing stock CMP (e.g. Enzo Gutzeit) has advantages over pressurized pulping.

The traditional image of mechanical and high yield pulps being inferior - "only good enough for packaging" - is no more justified. Modern technology of bleaching and of fibre cleaning permits production of high yield pulps for printing; reduction in paper brightness should be acceptable for all printing base except for four-colour work.

The use of some mechanical pulp in coating base has become accepted practice.

The economic and ecologic advantages of high yield pulping are obvious.

NO SULFUR PULPING AND NO CLORINE BLEACHING

The accepted practice in chemical pulping is the sulfur aided kraft process and bleaching with varying oxidized chlorine-compounds. Both classes of materials are highly corrosive for chemical plant and without the use of expensive and complex equipment, pollute the atmosphere and effluents.

These drawbacks of conventional pulping can easier be avoided when agricultural crops are used as fibre source. In alkaline oxygen pulping of wood a major hinderance is the difficult penetration of the active chemical into the wood chip; this is much less problematical with the open textured agricultural stalk material.

Therefore oxygen pulping of non-woody fibre sources will be an interesting alternative technology, whenever small and reliable oxygen generators become available to the industry.

On the debit side of oxygen pulping - up to the present - is decreased mechanical strength. This problem might be solved by better control of chemical oxygen transfer as evidenced by the good results of soda/hydrogenperoxide pulping. The proposed application of dry strength resins with better effects on soda/oxygen pulps than on conventional material because of increased carbonyl and carboxyl groups also should be followed up.

Medium consistency oxygen bleaching applied in primary bleaching stages has made great strides recently.

The announced Italian Naco process, utilizing ozone and oxygen in series for pulping and bleaching also may turn out to be a valuable contribution to oxygen delignification.

It is obvious, that spent liquors from oxygen delignification in pulping and bleaching permit simplified and less corrosive chemical recovery.

UTILIZATION Na_2CO_3 (NOT CAUSTICIZED SODA) IN PULPING

The use of sodium carbonate i.e. of so called "Non Active Alkali" mixed to caustic soda in a proportion of 60 : 40 has proven beneficial also for improved opacity of the pulp obtained. ^{*/} The patent situation, being somewhat restrictive in this field, should not be permitted to hold back advances easing simplified chemical recovery. Caustification of green liquor is a heavy burden on investment and on operational costs. Lime sludge separation and lime burning stands in the way of most attempts to simplify chemical recovery operations.

ORGANOSOLVPULPING

New recent efforts, partly on pilot plant scale, document renewed interest and shed new light on alcohol pulping. Whilst alkaline pulping causes condensation and polymerisation reactions of lignin increasing its insolubility, it is stated, that the treatment of lignocellulose material with slightly alkaline aqueous alcohol mixtures at elevated temperature depolymerize native lignin and render it soluble. The solid ligninous residue

^{*/} A number of authors have found the admixture of some sodium carbonate useful in soda pulping. It also can be assumed that the non-caustic portion of white liquor has some positive function. It has to be seen whether pulping can be conducted with only the make up part being in the form of caustic soda.

after distillation of alcohol for reclaiming should find interesting applications. Organosol pulp has been proven to have acceptable papermaking properties. From the point of view of chemical recycling the non-corrosive alcohol process appears to be most attractive.

MEMBRANE SEPARATION, UTILIZATION OF PULPING BY-PRODUCTS

The last few years have witnessed the entry of membrane separation, i.e. reverse osmosis and ultrafiltration into many different fields of chemical technology.

In theory, membrane filtration should be economic compared to separation by evaporation, because it does not require elevated temperatures and avoids the loss of latent heat of evaporation. In practice, technical advances in selectivity and in stability of the ultrafiltering membranes have made this technology a promising contributor to chemical recycling in pulping. It is feasible to separate high molecular organics - mainly alkali lignins - from inorganic salts and organic monomers and oligomers; the latter can also be concentrated, separated from pure water available for re-use.

The problem of eventual disposal of the lignin fraction is still open. To start with, it will probably have to be dried and burned. Similarly to organosolve lignin, it is a potentially valuable material - and one of the most abundant in nature. Becoming available separated from pulping chemicals, new efforts for its intelligent utilization are called for.

BROWN STOCK WASHING

The first step in the recovery of pulping chemicals is the separation of fibres from spent pulping liquor. For this, adequate technology is available in conventional wood pulping. This is not the case for straw pulping; the higher proportion of fines, i.e. parenchyma cells, in combination with silica clog the screens and

slow down drainage so much, that conventional equipment only can be used with greatly reduced efficiency. Still, one must assume, that the vast experience in filtration, dealing at times with much more refractory materials, once applied to the problem of fibre separation in straw pulping, should provide adequate solutions. The aim must be displacement of the spent liquor contained in the fibre mat with the least dilution in order to reduce the load on chemical recovery.

DESILICATION

Grasses and straws take up from the soil 10 to 100 times more silica than does pulp wood. Such silica dissolves more or less completely in alkaline pulping and its presence in spent liquor interferes by complications in all stages of conventional chemical recovery. Without removal it accumulates in closed systems so that even wood pulpers need to "bleed out" i.e. reject siliceous material. In non-wood pulping the graver situation - at present - is met by complete rejection and deposition of siliceous lime mud. This, of course, is unsatisfactory, also because it does not help with difficulties in earlier recovery stages.

Earlier unsuccessful attempts at desilication and the low priority of non-wood pulping have resulted in acceptance of the silica problems. In recent years some hopeful work has commenced to tackle this key problem of non-wood pulping chemical recovery. A report on the UNIDO project of desilication is included in the programme of this seminar.

COMBUSTION; CAUSTIFICATION

The relieving feature in burning valuable organic substances is that next to the disposal of material that cannot be applied usefully, it saves fuel by providing a major part of the process energy. Superior materials used in recovery boiler design, permitting higher steam pressures will permit higher energy yields in black liquor combustion. Investigations to gain insight in the highly

complex course of chemical events in the different zones of recovery boilers of conventional installation units could also help to assist in the construction of simplified combustion units as required by pulpers in developing countries.

The present day recovery boiler is the costliest and the most complicated unit in chemical pulping and requires qualified labour not always available. Therefore, simplification, for instance by separating the burning and the steam raising units has high priority also if some efficiency has to be sacrificed.

Fluidized bed combustion is well accepted in the paper and pulp industry mainly for burning forest residues like bark. Although fluid bed combustion can be conducted at lower temperature and is easier to control, initial optimism as to its application in soda spent liquor incineration has been dampened; potassium salts, chlorides and other impurities lower the melting temperature; with over agglomeration of molten slag a fluid bed cannot be maintained. Separation at low temperature prevents rapid and complete combustion.

Fluid bed incineration in the ferrite process nicely avoids the problem of adhesion by the speedy reaction of molten sodium carbonate with iron oxide under formation of sodium ferrite. Development work in a number of countries seems to have succeeded to bring this process to the stage of technical applicability.

A major advantage of the ferrite process is, that it makes a special caustification step superfluous. In contact with hot water, sodium ferrite hydrolyses under formation of caustic soda of higher causticity than obtained in conventional lime caustification. It is hoped that the ferrite or DARS process (DARS standing for direct alkali recovery system) will become a true and practicable alternative in chemical recovery also under the special conditions prevailing in developing countries; it is hoped that the licensing conditions will not seriously impair its wide-spread application.

EFFLUENT TREATMENT

Legal enforcement of effluent treatment standards is expected to become reality in most developing countries. In the past a certain negligence has acted as restraint for research and development work in this field. Applying present-day biotechnological methods, should make it possible to find practicable systems of aerobic and anaerobic BOD reduction under tropical conditions.

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CRITICAL ANALYSIS OF STRAW PULPING METHODS -
WORLD - WIDE

by
Thampoe Jeyasingam

Once upon a time straw was an important material for the paper industry in the developed countries of the world such as USA, West Germany, Holland, France, Italy, etc. What is now known as Corrugating Medium and is now largely produced from the semi-chemical pulp of hardwoods was then produced as straw paper from straw in USA and West Europe. The grey rigid board of today produced from recycled paper was then produced from straw as yellow straw board. Mills in Holland used to specialize in this particular type of yellow straw board and this was exported to several countries of the world to produce rigid book covers and rigid boxes. Will straw then eventually phase out due to the encroachment of woody materials and secondary fibre? The indications are that straw will continue to be an important raw material for a number of countries world-wide. This, in particular, is true in many countries in Asia, Africa, East Europe and Latin America.

The main reason that supports the use of straw as a raw material is its ready availability as a residue of food crops, namely wheat, rice, barley, oats etc. Besides its ready availability, the other factors that will continue to make straw an important raw material for developing countries are as follows:

- The world is heading towards a shortage of woody material for the paper industry.
- Strict environmental laws and protective measures are being adopted to prevent the indiscriminate cutting of wood.
- The so-called green revolution has given emphasis to agricultural production in most developing countries.
- The incentives being offered for the promotion of agricultural based industries such as paper in developing countries.
- An increased demand for cultural grades of paper in developing countries because of emphasis given to eliminate illiteracy.

- An increase in demand for industrial grades of paper in developing countries due to the switch over from traditional packaging materials made out of wood and leafy materials to paper packaging materials.
- Hard currency is becoming more and more scarce for developing countries and there is a need to produce paper using indigenous materials, particularly straw.

On account of the above reasons, the developing countries of the world will continue to depend on agricultural residues and the most popular choice appears to be straw. Progress in the application of straw is being hindered because of the shortcomings related to this raw material and the inadequacy of today's pulping technology to combat these problems. The emphasis in today's pulp and paper technology is for the promotion and development of wood based raw materials. It is important to realize the pulping technology and equipment needed for straw pulp mills cannot simply be a copy of wood pulping technology. The chemical composition and the morphological structure of straw require equipment and technology that are best suited to this type of material.

This paper will therefore analyze the problem areas of today's pulping technology related to straw pulping. Steps taken to remedy these problems would no doubt enhance the greater use of straw for the paper industry.

STORAGE OF STRAW

Generally speaking what happens inside the pulp mill has a direct relationship to the condition of the raw material and this in particular has to be greatly emphasized for straw and its storage prior to processing.

The moisture content of the straw should be generally kept under 15 % and the optimum range is somewhere between 10 to 12 %. With higher moisture content straw is subject to microbiological degradation and decay. Straw thus affected has the following disadvantages:

- Consumes more chemicals;
- Poor yield;
- Poor physical strength properties;
- Poor brightness.

Besides the above problems there is a great danger of slow combustion developing in the stack creating a potential fire hazard.

One of the problems in straw pulp mill management is obtaining good quality straw with an optimum range of moisture for the processing of paper pulp. This problem is now more severe than a decade ago because farmers are gradually giving up bale production in preference for cylindrical rolls which are difficult to store unlike the convenient rectangular bales that could be built up into stacks and protected with a layer of loose straw to prevent moisture penetrating into the stack. Although some efforts have been made to cover stacks made up of rolls with polyethylene sheets, this idea has not been well accepted. The mills continue to clamour for a supply of straw in bales and the farmers prefer to get away from bales to rolls. The most economical way of handling storage and supply of straw from the fields to the mill is therefore still open for further improvements.

STRAW PREPARATION

1) Dry Preparation Method

This is the most common method adopted for the preparation of straw prior to digestion. Disc or rotary drum type of cutters are used to reduce the length of the straw. The cut straw is then conveyed pneumatically to screens and cyclones to separate grain, sand and dust present along with the straw.

Advantages of the System

It is a simple system that requires less energy to operate and requires relatively low capital cost.

Disadvantages of the System

It could only work satisfactorily if the moisture content of the straw is less than 15 %. The pneumatic conveying system gets choked up with straw and the dust screens get plugged up when operating with moist straw. In consequence the dry preparation systems do not work satisfactorily in areas where there is much rainfall or snow unless the straw is stored under cover and transported into the mill in dry conditions. Mills do not like the idea of providing storage sheds to overcome these difficulties on account of the high cost of providing buildings. Here is an area open for further development as to how straw could be efficiently collected, handled and stored up prior to processing. Some newsprint mills in USA that are working on deinked waste paper have developed simple, low cost storage sheds that cost about 50 % of the cost of conventional buildings. These buildings are dome shaped and are constructed out of light steel and covered with vinyl. This could be a possibility for straw pulp mills. Another alternative that could be applied is to use the hot flue gases of boilers to dry the straw to suitable moisture content prior to processing. The techno economics of applying these possibilities have to be worked out.

2) Wet Preparation Method

The wet preparation system essentially is based on the use of a hydra pulper. The hydro pulper that is used for this purpose is fitted with an extraction plate and a rotor that are specially designed. On account of the mechanical forces created inside the pulper the sand, grit and leafy materials are separated and eventually escape out of the pulper through a valve. The straw thus cleaned contains much lower percentage of leafy material which does not contribute much anyway to the fibre content of the straw pulp. About 25 % of the total weight of rice straw and about 10 % of the weight of wheat straw is lost through this method.

Advantages of this System

This system is suitable for the processing of straw with moisture content higher than 15 % which cannot be satisfactorily handled by the Dry Process. It is more suitable for rice straw which has a high amount of loose sand, grit and leafy materials. The rubbing action provided in the pulper helps to remove a fair amount of silica prior to further processing. It is estimated that about 20 to 25 % of the silica is removed by this cleaning method.

Disadvantages of this System

It requires a relatively higher capital investment and requires more energy for processing compared with the dry system.

3) Caustic Pre-treatment Preparation Method

This is a new system being developed as part of the NACO Process. Here again the essential part of this pre-treatment is a specially designed hydra pulper with junk trap. Bales of straw are delivered into the pulper where it undergoes cutting and slicing in the pulper. Following the hydra pulper is a DKP disc press for dewatering the straw and a system for cleaning the waste water to be recycled back to the pulper. This pre-treatment is conducted in the pulper and about 1½ to 2 % caustic soda is used. A substantial portion of unwanted materials is removed and the silica content of straw gets reduced by about 40 %.

Advantages of the System

It is possible to feed straw to the system with high moisture content. There is a reduction in the silica content of the straw prior to the processing into pulp on account of caustic treatment. It is reported that the silica content of wheat straw is reduced from 7.5% to 3 %.

Disadvantages of the System

Compared to the Dry System of cleaning there is additional capital cost for the pre-treatment equipment. A higher energy cost is also involved because of the electric energy needed for the pulper drive and heat energy needed for the cooking of straw with higher moisture content.

CONVEYING OF STRAW

Most pulp mill designers provide mechanical screw conveyors for the straw after it has been reduced in length by the straw cutter. Several mechanical problems are experienced in the straw pulp mill on account of mechanical screws being applied for such a task. Straw, unlike wood chips has a tendency to rope. This results in frequent mechanical breakdowns and interruptions to production.

Experience indicates mechanical screws if applied for such a purpose could be used only for short distances of 2 to 2½ metres without intermediate supports. When the distances to be conveyed are higher, the preferred choice would be the use of rubber conveyor belts in place of screw conveyers.

WEIGHING OF STRAW

Several mills have adopted the system of weighing straw using the principle normally employed for wood chips by using a belt weightometer. Experience in working with this measuring instrument indicates inaccuracies in relation to the input of straw to the digester. Due to these inaccuracies the measurement of straw using such type of weightometers is ignored and the digester feeding is then controlled mostly by relying on operator judgement or on an approximation of weight by counting the bales fed into the digester.

New ideas and new development using more accurate type of weightometers are needed for straw pulping.

MOISTURE OF STRAW

In most mills, the measurement of the moisture content of straw is based on random sampling by the oven drying method which is slow, laborious and not quite representative.

New accurate and fast on line measuring devices are needed for a better control on the pulping of straw. Very few mills have adopted such a new system to control pulping conditions.

PULPING SYSTEM: (Batch and Continuous.)

Batch System of Pulping

The high bulk of straw accounts for a special design for the cooking vessel. To obtain uniformity of cooking, spherical digesters or tumbling digesters are used. The solid: liquid ratio for cooking has to be maintained high in order to obtain uniformity in cooking. Normally cooking is done by direct steam. Pressure is built in these digesters generally around 5 - 7 kg/cm². On account of the bulky nature of the material the digesters take considerable time for packing. To improve packing as well as to help uniform cooking some form of pre-impregnation is done prior to the raw material being admitted into the digester. Packing densities of 150 - 190 kg/m³ OD straw are obtained, compared with 180-270 kg/m³ for wood chips. The total cooking cycle in batch digesters could vary between 6 - 8 hours.

Some of the well-known pulping systems that apply to the batch process are: The Lime process, Soda process, Neutral Sulphite process and Kraft process.

1) The Lime Process (By Batch System)

This process is one of the oldest processes for the production of corrugating medium, and yellow straw board from straw. Cooking with lime is still practiced by some mills as this has no adverse effects to the environment as in the case of caustic soda cooking. The effluent in some mills is used for irrigation of food crops.

Cooking is done using either spherical rotary digesters or tumbling digester.

Typical Cooking Conditions:

Chemical	-	lime 7 to 10 % as CaO
Temperature	-	130° to 140°C
Time	-	3 to 5 Hours
Solid to Liquid		
Ratio	-	1:2

Advantages

- Simple process to produce corrugating medium;
- Cooking with lime has no adverse effects to the environment as in the case of caustic soda and neutral sulphite cooking.

Disadvantages

- In some mills the pulp due to improper washing causes problems on wires and wet felts. The felts and wires get easily blinded unless proper showers are used on both wires and felts.

2) Soda Cooking (By Batch System)

Soda cooking for straw by batch process is widely applied all over the world. Both spherical rotary digesters as well as tumbling digesters are used. The amount of caustic soda needed for producing bleachable grade of paper ranges from 10 to 25 % on the dry weight of straw. The temperature of cooking could be varied depending on the time allowed for cooking, as for example a low temperature of 140°C will require a longer time and a high temperature of 170°C will require a shorter time for cooking.

Typical Cooking Conditions:

Chemical	-	NaOH 10 to 12% on OD Wt
Temperature	-	150° to 170°C
Solid to Liquid		
Ratio	-	1:2 to 3
Time	-	2½ to 4 Hours
Yield (Bleached		
Grades)	-	35 to 40 % on OD Straw

Advantages

- Chemical recovery and heat recovery is possible with certain limitations due to silica.
- A well established process for producing bleached grades of pulp using batch digesters.

Disadvantages

A good effluent disposal system is needed if chemical recovery is not practiced.

3) Kraft Process (By Batch System)

For the cooking of straw, Kraft process or Sulphate process is not so popular as in the case of Soda. This is because the increase of strength properties obtained by Sulphate process is marginal compared with the Soda process. In most parts of the world Salt Cake is an expensive chemical compared to Caustic Soda and it also adds to the air pollution due to sulphur compound emissions. However, there is a mill in Calarasi (Romania) producing about 50 000 TPY of bleached straw pulp by the Kraft process.

Typical Cooking Conditions:

Chemical	-	NaOH - 10 to 12% } Na ₂ S - 2 to 2 % } on OD straw
Temperature	-	150 to 170°C
Solid to Liquid Ratio	-	1:2 to 3
Time	-	2½ to 4 Hours
Yield	-	35 to 40 % on OD Straw

Advantages

- Chemical recovery and heat recovery is possible with certain limitations due to silica.

Disadvantages

- A good efficient disposal system is needed if chemical recovery is not practiced.
- Additional capital investment is needed on account of the use of Sodium Sulphide and the problems related to air emissions containing sulphur compounds.

4) Neutral or Mono-Sulphite Process (By Batch System)

The acid sulphite process is not suitable for cooking straw. There is loss of strength as well as yield when the acid sulphite process is used as compared with the soda, kraft or neutral sulphite processes.

The sodium sulphite used for cooking straw is normally buffered using either caustic soda or sodium carbonate to obtain a neutral pH. However, some of the mills prefer a slightly alkaline pH of 8 to 9. This process of cooking gives a milder reaction to the straw compared with the soda process and the resulting pulp therefore contains more ash than in the soda process.

Typical Cooking Conditions:

Chemical	- Na_2SO_3	- 8-12 % on OD straw
	- NaOH or Na_2CO_3	- 2-4 % on OD straw
Temperature		- 160 - 170°C
Solid: liquid Ratio		- 1:3 to 4
Yield (For Bleached Grade)		- 35 - 40 % on OD straw

CONTINUOUS SYSTEM OF PULPING

Some of the continuous type of systems applied for straw pulping are as follows:

- Pandia
- Kamyr
- Celdecor-Pomilio
- Mechano-Chemical Process
- Escher-Wyss MCP Digester
- HF
- SAICA Digester
- NALCO

1) **Pandia Digestion System**

The Pandia type of continuous digester basically consists of the following:

- A screw feeder which also functions as an impregnation unit.
- A pair of horizontal cooking tubes fitted with screw conveyors and joined together by inter-connecting tubes.
- A rotary discharger for pulp.

System of Operation

The raw material is conveyed to a pre-impregnator when a digester is installed with one, otherwise it goes directly to the screw feeder. The feeding to the digester is regulated by a metering device. A certain percentage of the cooking liquor is added to the fibrous material in the pre-impregnator to soften the raw material. The raw material is then compressed through the screw feeder. The principle of the screw feeder is to densify the material by compression so that a plug could be formed. This plug is expected to form a seal and prevent the escape of steam as well as blow backs. The compressed material gets decompressed when it leaves the screw feeder and enters the vertical chamber (or reaction tube) that connects the screw feeder to the first digester tube. The decompression of this material is made easier when it gets in contact with the steam and cooking liquor in the reaction chamber. The continued cooking of the material in the digester tubes is facilitated by the intimate mixing of the chemicals and the heat produced by the steam. For a satisfactory operation a solid to liquid ratio of 1:3 is generally maintained. The cooking time in the digester could be regulated by changing the speed of the conveyor screws that carry the material through the digester tubes.

Design Variables

The digester could be designed for an output as low as 15 TPD to a maximum output of 200 TPD. This would depend on the following:

- Diameter of the tubes
- Number of tubes
- Speed of conveyor drives

Typical Cooking Conditions for Straw

	<u>Wheat Straw</u>	<u>Rice Straw</u>
Pulping Process	- Soda	Soda
Chemical as Na ₂ O %	- 10	10
Dwell time (minutes)	- 8	5.5
Pressure (PSI)	- 80	100
Yield %	- 50	39

Advantages

- Economy in steam usage.

Disadvantages

- Problem of blow back.
- Heavy maintenance on screw feeder due to the abrasive nature of straw due to silica.
- Uniform feeding is critical to the digester.

2) Kamyr Digestion System

This is a well-known and well-applied system for wood but is not so well applied for non-woody materials. For wood pulping the cooking liquor is pre-heated using pre-heaters and is pumped into the digester by a forced circulation system. In the case of non-woody materials direct steam is used. The writer is aware and familiar with one single application of the Kamyr system for straw and this is in the AFYON Mills in Turkey.

The straw is introduced through a rotary valve to the pre-impregnator where it is thoroughly mixed with hot cooking liquor and with the flash steam from the blow tank. From the pre-impregnator the material is then discharged through a low pressure (LP) rotary feeder to a low pressure inter-connecting tube prior to admission to the high pressure (HP) rotary valve. The pressure inside this connecting tube is generally around 15 - 35 psi. The material then passes through the HP rotary feeder which has three openings. The feeding of the material, the discharge of the material and the steam admission takes place through these 3 openings depending on the position of the openings based on the rotary movement of the valve. When the valve is aligned in the vertical position the pocket of the valve gets positioned with the other two openings, namely the openings to the asthma valve and to the digester. When this happens, steam gets released from the asthma valve and forces the straw from the pocket of the rotor valve into the digester. It is estimated that 80 % of the steam required is admitted to the digester by the asthma valve. The pulp gets discharged from the digester through an adjustable orifice to the blow receiver.

Advantages

- Efficient utilization of flash steam.
- Effective control on cooking time that could be varied from a few minutes to up to 3 or more hours.
- Two stage arrangement with low pressure cooking and high pressure cooking which is helpful to delignify with minimum damage to fibre.
- The design arrangement of LP and HP feed valves that prevent blow back problems.

Disadvantages

- Heavy maintenance problems on the LP and HP feeder valves due to the abrasive nature of the straw.

3) CELDECOR - Pomilio Process

The chief chemicals used in this pulping process are Caustic Soda and Chlorine. This process is advantageous to countries that do not have a well established chemical industry.

The Caustic Soda and Chlorine required for pulping are produced and consumed in proportions to the output of the electrolytic cell. What the mill requires therefore is common salt (NaCl) as the starting chemical.

The pulping is conducted in three operations, namely:

- Mild digestion with Caustic Soda up to 115 to 130°C in an open digestion tower.
- Chlorination in the gas phase. This is conducted in a down flow chlorination tower. Chlorine is admitted as gas through orifices in the tower walls and through a central pipe so that the penetration is uniform
- Alkalization is conducted at room temperature.

Typical Chemical Consumption for Producing
Bleached Wheat Straw Pulp

Yield	..	48 %
Consumption to produce 1 ton AD pulp		
NaOH for digestion	-	17.4 %
NaOH for Alkaline Wash	-	<u>3.1 %</u>
Total NaOH	-	20.5 %
Chlorine as gas for direct use	-	14.5 %
Chlorine for Hypo	-	<u>0.7 %</u>
Total Cl ₂	-	15.2 %
Power Requirement Pulp Mill	-	425 KWH
(Straw Preparation and Pulping)		
Steam for cooking and bleaching	-	2.2 Tons

Advantages

- Useful for some developing countries where transport of Caustic Soda and Chlorine is difficult and expensive.

Disadvantages

- It is an obsolete system with problems related to corrosion, but there are some mills in Vietnam and Italy still operating with this system. However, no new mills have been built within the last two decades applying this process.

4) Mechano-Chemical Process

This process is based on the development at the Northern Regional Research Laboratory, Peoria, Illinois, as a result of work done by LATHROP and ARONOVSKY. The process is not widely in use and as far as the writer is aware there were a few mills employing this process in Holland to produce corrugating medium from straw but these mills are not functioning at present.

The essential equipment for this process is a hydropulper. The pulping of straw is conducted at atmospheric pressure and at a temperature of 95 - 100°C. The chemicals used for cooking are either caustic soda or a mixture of caustic soda and sodium sulphite. Straw from the cutter is fed to the pulper by means of a conveyor belt. Fresh cooking liquor is mixed with the spent liquor and then added to the pulper to obtain a solid : liquid ratio of 1:15 - 1:12 range. The required temperature of 95 - 100°C is obtained by using direct steam to the pulper. The mechanical action provided by the pulper helps delignification by opening up the straw and exposing an increased surface area for reaction with the chemicals.

The degree of pulping depends on the following:

- Percentage of chemicals used
- Consistency
- Temperature
- Amount of mechanical action inside the pulper

Typical Cooking Conditions

Chemical	-	NaOH 5-6 % on OD. Wt
Temperature	-	95 - 98 %
Consistency	-	10 %
Time	-	45 - 60 Minutes
Yield	-	70 to 78 %

Advantages

- Simplicity of operation;
- Low capital investment.

Disadvantages

- High chemical consumption;
- High power consumption;
- High steam requirement.

According to the writer the pulp produced is only suitable for unbleached grades such as corrugating medium (It is claimed bleached grades could be produced.)

5) Escher-Wyss (France) and MCP Process

This is a continuous type of cooking process applied to straw. There are only three mills using this process, one in each of these countries - France, Spain and Yugoslavia. The cooking system produces an unbleached grade of pulp mainly for the manufacture of unbleached grades such as corrugating medium. The chemicals used for cooking could be either caustic soda alone or a combination of caustic soda and lime or lime alone.

The digester used for cooking is designed to work at atmospheric pressure and is essentially made up of four tubes and an extractor as outlined below:

- An impregnator tube
- A pre-cooking tube
- A cooking tube
- A disintegrator tube
- An extractor

Cut straw entering the impregnator tube is sprayed at the mouth of the tube with both white liquor and spent liquor. In the impregnator tube the straw is mixed with the chemicals by the movement of the screw. The temperature in this tube is generally in the range of 80 - 85°C and the consistency is between 20 - 25 %. From the impregnator tube the straw is discharged into the pre-cooking tube where the temperature is raised to 100 °C. From here the straw is discharged into the cooking tube where the temperature is still maintained at 100°C but there is more intense mechanical action provided by using two screws rotating in opposite directions. (All the other three tubes have only a single screw used principally for conveying. The final phase of the mechanical and chemical action is completed in the fourth tube - the disintegrator tube. The temperature in the disintegrator tube is in the range of 90 - 95°C. From this tube the straw is discharged into the extractor which extracts the spent liquor thereby increasing the consistency from about 25 to 35 %.

Typical Cooking Conditions

Chemicals	-	NaOH or lime or combination of NaOH and lime NaOH alone 6 - 7 % on OD straw as claimed by supplier but mills experience 8 % NaOH
Consistency	-	20 - 25 %
Temperature	-	95 - 98°C
Pressure	-	Atmospheric
Cooking Time	-	2 to 2½ hours
Yield (for unbleached grades)	-	70 % (designed value claimed by supplier) - 55 % (mills actual performance)

Advantages

This process is claimed to use less chemicals and less steam as compared to pressure cooking.

Disadvantages

- Frequent mechanical problems related to the conveyor screws of the digester tubes.
- To prevent plugging inside the digester tubes more chemicals have to be used compared to pressure cooking.
- On account of increased chemical usage the yield drops from 70 % (which is common to semi-chemical pulping) to about 53 %.
- Due to the low temperature of 95 - 98°C the chemical penetration is poor and this results in heavy screen rejects.

6) H.F. Process (Højbygaard Fabrik)

This process was developed in Denmark for the production of semi-chemical pulp from straw to produce corrugating medium. This method essentially uses a DIFFUSER where the pulping takes place. The diffuser works on the counter current principle so that the residual chemicals and heat could be efficiently utilized. The diffuser is made up of 3 zones. The first pass is the impregnation zone where the straw is admitted and residual chemical and heat is used up. Then the straw ascends up by the screw conveyor to the second zone for digestion at a temperature of 95 to 98°C. The final zone is the washing zone where the lignin and pentosans are washed away and the heat is transferred to the washing water. The digestion time is 4 hours.

Typical Cooking Conditions

Chemical	- NaOH 6 to 7 %
Temperature	- 95 to 98°C
Time	- 4 hours
Yield	- 75 to 78 %
Stock Consistency at Discharge end	- 12 to 18 %

Advantages

- A simple type of operation working on atmospheric pressure.
- Steam requirement is estimated to be low.
- Water requirement is estimated to be low.

Disadvantages

- The process is suitable only to produce corrugating medium.
- Requires relatively high defibering energy since the cooked straw fibres are still joined together to form the straw stem. This would mean high input of energy is needed in the pulper and refiners for defibration.
- Requires waste paper usage as an essential integral part for operation on the paper machine.

7) The SAICA Process

(Sociedad Anonima De Industrias Celulosicas Aragonesas)

The processing of straw by this system is nearly similar to HF process. The SAICA Mill is located in Zaragoza in Spain and is using this process to produce semi-chemical pulp that is blended with corrugated container waste to produce corrugating medium.

The cooking of straw takes place in a continuous digester of special design developed by SAICA. The digester is of cylindrical shape and is inclined at an angle of 5° to the horizontal. Straw is conveyed through the digester at a constant rate by means of two parallel screws rotating at low speed in opposite directions. The digester, as in the case of the HF process, performs three basic functions:

- Pre-impregnation
- Cooking
- Counter current washing

Pre-impregnation is done at the digester entry and at the lowest position of the digester. The straw that is hammer milled is fed to the impregnation zone where it is mixed with a regulated quantity of spent cooking liquor.

In the cooking zone the straw gets cooked at atmospheric pressure and the heating is indirect through a steam jacket. Cooking is done with caustic soda admitted at mid point to the digester and mixed with a controlled amount of black liquor.

In the washing zone the pulp washing is done using white water from the paper machine consuming about 8 m³ of water per ton of pulp. The spent liquor is collected from the digester and is pumped back to the feed chute for pre-impregnation. The excess spent liquor is pumped out for disposal. The pulp discharged from the digester is fed into a screw press and raised to a consistency of 37.5 %. The extracted liquor is then returned to the digester.

Typical Cooking Conditions

Chemicals	- NaOH - 5 % on OD straw
Consistency	- 20 - 25 %
Temperature	- 98°C
Pressure	- Atmospheric
Yield	- 71%

Advantages

It is a simple processing system to produce semi-chemical pulp.

Disadvantages

Due to the low temperature in the digester the penetration of the chemical used is poor. Therefore more mechanical action is needed to defiber the pulp. This increased mechanical action decreases the strength properties and makes it necessary to use more waste paper to produce corrugating medium. The paper machines' runnability as well as the desired physical properties of the corrugating medium are well developed using only a maximum of 25 to 30 % semi-chemical pulp for this

process. The mill uses about 70 to 75 % of corrugated container waste with the straw pulp.

8) NACO Process

This is a new process for the continuous pulping of straw. The pulping system is based on an Italian patent using caustic soda and oxygen for delignification followed by ozone bleaching.

A 100 TPD plant for chemical pulp production is now under construction for commercial production in Foggia, Italy, complete with a chemical recovery system. This mill is expected to be in full operation by about the end of 1985.

The NACO process is considered to be the technological solution to some of the major problems caused by cooking and bleaching chemicals. This is because the NACO process does not use chemicals such as sulphur and chlorine in the process.

The NACO process as applied to the first commercial plant is essentially made up of the following sections:

- Pre-treatment Section
- Delignification Section
- Bleaching Section

Pre-treatment for straw is conducted in a pulper where it is treated with 1½ to 2% NaOH. After treatment in the pulper the straw gets dewatered in a SUNDS DKP press prior to delignification.

Delignification

The delignification section is made up of a pressurized single disc refiner, a turbo pulper, an oxygen mixer and a combined up flow-down flow oxygen reactor.

The turbo-pulper performs an important function in the process.

Due to the spherical shape of the pulper, a very intensive mechanical action takes place in the pulper. The mechanical action provided inside the pulper results in fibre separation and increases the surface of the raw material. At the same time the oxygen that is admitted into the turbo-pulper gets well mixed with the alkali-fibre suspension. The turbo-pulper is operated at a pressure of 6 to 8 kg/cm³.

The pulp is continuously pumped out from the turbo-pulper to the oxygen reactor. The oxygen reactor that follows the turbo pulper is provided with an up-flow - down-flow arrangement. Excess of oxygen is brought from the top of the reactor to the turbo pulper. After the pulp passes through the oxygen reactor it is washed on a displacement wash press.

Bleaching

At the time of the writer's visit to this plant a possible bleaching process to be integrated to the delignification section was under consideration. Trials with a two stage system using 2 % hydrogen peroxide (100 % H₂O₂ basis) and 3 % hypochlorite (Active Cl₂ basis) resulted in a brightness of higher than 80. The possibility of bleaching with ozone as an alternative was also under consideration.

Chemical Recovery System

The chemical and heat recovery system for the NACO process was being supplied by Lurgi. The spent liquor after evaporation on multiple effect evaporators will be subjected to combustion in a Lurgi designed recovery boiler. The smelt is then dissolved to produce a sodium carbonate solution which is directly used in the turbo pulper without causticizing.

Typical Processing Conditions

Chemicals	- NaOH 1½ % OD straw for pre-treatment NaOH 6 % OD straw for delignification
Temperature	- 130°C in Turbo Pulper - 75°C temperature of pulp discharged from oxygen reactor

Consistency	- Turbo pulper 10 %
	- Oxygen reactor, 7 %
Yield	- 60 % on pre-treated straw (i.e. 20 % loss during pre-treatment.)

Advantages

- There is reduced pollution because chlorine and sulphur are not used in the pulping and bleaching processes.
- Less capital investment is required for the chemical recovery system.
- It is economically feasible to operate small sized plants using this process. (Mills that require a conventional recovery system have to operate their pulp mills at a minimum capacity of 200 TPD to be economically feasible).
- Sodium carbonate is directly used for processing thus avoiding the use of a recausticizing plant.

Disadvantages

- The heat recovery from the black liquor is poor.
- In the case of countries where oxygen cannot be obtained, additional capital is required to produce oxygen for pulping at the mill site.

BATCH VERSUS CONTINUOUS PULPING METHODS

In the preceding pages the various well-known and commercially applied cooking process systems have been discussed. At this point it may be worthwhile to examine the advantages and disadvantages of both the batch and continuous cooking systems.

Batch Systems: Advantages

- They are simple and easy to operate and maintain;
- High flexibility to all cooking conditions based on raw material conditions;
- Flexibility to operate mill at reduced capacity without shutting down the entire mill due to maintenance problems;
- Uniformity of feeding not critical.

Batch Systems: Disadvantages

- Require more operating personnel;
- Require relatively more steam and electric energy.

Continuous Systems: Advantages

- Require relatively less steam and energy;
- Require fewer operating personnel;
- Claimed to produce more uniform pulp.

Continuous Systems: Disadvantages

- Less flexible to operate and maintain;
- The whole pulp mill is likely to be shut down for maintenance problems and breakdowns;
- Uniform feeding is critical;
- High maintenance upkeep standards are required;
- The availability of spare parts is crucial.

OTHER MINOR PROCESS SYSTEMS

There are various pulping process systems which are patented and are either in the process of development or ready for commercial application but not yet well applied commercially.

1) Nitrocell Process

This process depends on the use of Nitric Acid as the cooking chemical.

Advantages

- Claimed to have low effluent discharge with useful by-products.

Disadvantages

- Special engineering required to work with nitric acid.

2) Ammonia Process (Thillaimuttu Patent)

This process depends on the use of Ammonium Hydroxide as the cooking chemical.

Advantages

- Ammonia has the advantage of simple recovery by steam stripping.
- This process is also environmentally accepted.

Disadvantages

- Requires further study to determine its commercial viability;
- The ammonia process could have problems due to poor bleaching and poor strength properties.

Comments

- Besides the Thillaimuttu process, there are other ammonia process systems being claimed on the basis of lab work and pilot scale trials which are not yet commercially applied.

3) Hopes Process

This process for cooking straw is based on the use of sodium hydroxide plus oxygen delignification applied in two stages.

Advantages

The use of oxygen has advantages as it is not polluting to the environment.

Disadvantages

Requires further study for making the process commercially viable. Oxygen in combination with other alkalies has been investigated and the first commercially designed plant is the NACO process described earlier.

4) Soda-Chlorite Process

This process depends on the use of sodium hydroxide plus sodium chlorite in separate stages.

Disadvantages

The use of chlorine compounds could make chemical recovery difficult.

5) Soda-AQ Pulping

The cooking of straw using caustic soda and AQ is not yet well established. However, there is one positive report from a mill in the People's Republic of China. According to this report the use of AQ has the following advantage:

- Faster delignification accompanied by lower alkali consumption and higher pulp yields.

SODA/NITRIC ACID PULPING OF RICE STRAW

by

M. A. El-Taraboulsi

and

H. Ibrahim

Abstract

A reversed and rapid Soda/Nitric Acid pulping of rice straw was carried out for the first time with the purpose of cutting down the consumption of nitric acid while maintaining the attractive productive and non-polluting aspects of conventional Nitric acid/Soda pulping. Experimental optimum conditions were established for the production of satisfactory Soda/Nitric acid chemical pulp with saving of approximately 33 % of nitric acid and 11.2 % of overall cost of added pulping chemicals in comparison with conventional Nitric acid/Soda pulping. The obtained pulp had superior strength and was bleached to 75 % Photovolt brightness by a simplified EH sequence with omission of the chlorination stage. Successful preliminary evaluation of the neutralized mixed acid and alkaline spent pulping liquors as a fertilizer was also carried out.

A. Introduction

Nitric acid/soda pulping has been developed recently (1,2,3) as a productive (short cooking cycle) non-polluting (effluent problems are avoided as effluent is a fertilizer) process for the production of chemimechanical, semichemical and chemical rice straw and bagasse pulps. Preliminary economic analysis have also been developed for a theoretical 300 tpd newsprint mill utilizing chemimechanical nitric straw and bagasse pulp (3). The nitric acid process thus shows promise and further research work would seem to be justified. The aim of the present investigation is an attempt to further develop the process by carrying out - for the first time - a reversed soda/nitric acid pulping of rice straw with the purpose of cutting down the consumption of nitric acid while maintaining the attractive, productive and non-polluting aspects of the process. Also, a preliminary evaluation of the waste liquor as a fertilizer is carried out.

B. Experimental Work and Results

B.1 Pulping and Bleaching

The raw material used was wet-cleaned Egyptian rice straw. A conventional two-stage cook No. 3, Table I (Nitric acid followed by sodium hydroxide) was carried out in an electrically heated rotary digester with washing between the nitric acid and caustic soda stages. After the soda stage, the pulp was washed and fiberized in a hollander beater without load at the indicated fiberizing time in Table I.

The reversed two-stage cooks No. 4, Table I (soda followed by nitric acid) were carried out similarly with the exception of reversing the order of added chemicals.

For comparative evaluation, both single-stage pressure and mild soda pulping of rice straw (cooks No. 1 and 2, Table I) were also carried out. Chemical analysis of the obtained pulp is shown in Table I, while the physical properties of unbleached pulp at the indicated beating time are shown in Table II.

Pulping was followed by bleaching by CEH (Chlorination-caustic Extraction - Hypochlorite) sequence and a simplified EH sequence in case of the developed soda/nitric pulping as shown in Table III.

B.2 Effect of Neutralized Nitric/Soda Waste Liquors on Plants

The acid and alkaline waste pulping liquors were mixed in proportion to their titratable acidity and alkalinity to give a pH of about 6.5 of the mixed solution. This solution was used for plant tests. Germination tests were carried out with seeds of garden peas (var. Kelvedon Wonder). Four tests were set up in glass dishes. Each dish contained cotton wool covered with a filter paper. Fifty seeds were placed in each dish and the following liquid added:

- (a) 100 ml distilled water
- (b) 100 ml mixed waste liquor diluted 1 : 20 with distilled water
- (c) 100 ml mixed waste liquor diluted 1 : 10 with distilled water
- (d) 100 ml mixed waste liquor undiluted

The dishes were covered and placed in an incubator at 20°C.

After 10 days the number of germinated seeds were counted.

The germination rates were as follows:

- (a) 48 (96 %)
- (b) 50 (100 %)
- (c) 49 (98 %)
- (d) 39 (78 %)

Thus, the diluted (1 : 20) mixed waste liquor shows the best (100 %) germination.

C. Discussion of Results

C.1 Soda/Nitric vs. Nitric/Soda Pulping of Rice Straw

Table 1 shows that satisfactory chemical rice straw pulp was obtained by either rapid nitric acid pulping with 6 % HNO₃ at 95°C for 30 min., followed by 7 % NaOH (based on O.D. nitric pulp or 5.56 % with respect to O.D. straw) at 95°C for another 30 min., or by reversed 7 % NaOH at 95°C for 60 min. followed by 6 % HNO₃ (based on O.D. soda pulp or 4 % based on O.D. straw at 95°C for another 30 min. to give a 47.8 % overall yield pulp.

It should be noted however, that in the case of the developed soda/nitric process (cook No. 4.b, Table 1), the chemical usage is lower with saving of about 33 % of nitric acid and about 11.2 % overall saving of the cost of added chemicals in comparison with conventional nitric/soda process (cook No. 3, Table 1). The soda/nitric pulp has also the added advantages of lower ash, Permanganate No., Cl₂ No. and improved breaking length and tear factor.

In an attempt to lower the chemical use and increase the yield, a satisfactory high yield unbleached pulp of 60 % was obtained by soda/nitric pulping (Cook No. 4-C, Table I) using 6 % NaOH and only 2.8 % HNO_3 with respect to O.D. straw. The high yield soda/nitric pulp has surprisingly superior physical properties (Table III) compared to all nitric acid pulping which may be attributed to less chemical degradation of the holocellulose content and the more effective fiberization of the disc refiner.

After bleaching trials, the best bleaching was obtained by CEH sequence in case of nitric/soda pulp to an 80% Photovolt brightness with rather a high 13.7 % available chlorine consumption. However, the developed soda/nitric pulp (Cook No. 4-b, Table I) was best bleached with a simplified EH sequence to 75 % Photovolt brightness with 4 % NaOH in the extraction (E) stage and a lower 11.9 % Cl_2 consumption in the hypo (H) stage (Cook No. 4-b, Table III). The soda/nitric pulp although of slightly lower brightness, yet it was distinctly cleaner and almost free of speaks compared to both soda and nitric/soda pulps.

C.2 Comparative Evaluation of Soda Vs. Nitric Pulping of Rice Straw

Tables I to III indicate that mild soda pulping (4) is superior to pressure soda pulping as far as the yield of bleached pulp (41 % vs 38 % for pressure soda) lower ash (3.2 % vs 13.8 %), higher alpha - cellulose and strength. On the other hand, the pressure soda pulping has the advantage of being more productive (90 min. cooking time vs 300 min. for mild soda process) and hence more pulp per digester is produced. The pressure soda process is more economic on account of using much less cooking and bleaching chemicals (10 % NaOH on O.D. straw and 4.7 % total Cl_2 demand on O.D. pulp vs. 13 % NaOH and 6.0 % total Cl_2 for mild soda process). Furthermore, the pressure soda pulp has better opacity, brightness stability and higher bulk which make it more suitable for writing and printing papers. This is most probably due to its relatively higher silica content which simultaneously make it possible to cut down the addition of fillers in papermaking (5,6,7,8).

However, both soda processes are polluting unless the spent pulping liquor is treated for recovery of chemicals to give a clean process.

On the other hand the nitric process is a non-polluting process as the spent pulping liquor can be used as a fertilizer. The soda/nitric pulping, besides being non-polluting is a faster continuous process with less capital cost due to omission of chlorination-stage in bleaching.

C.3 Selection of Equipment for Soda/Nitric Pulping and Bleaching

Because pulping is rapid, the digesters should be continuous. Since a high liquor to straw ratio is desired, the horizontal screw and tube digesters are not too suitable. Also, as the cooking temperature is below the boiling point, pressure feeders and dischargers are not necessary. Stainless steel digesters in which a liquid level can be maintained is selected as being the most suitable (3). The material as discharged from the first stage soda pulping cannot be well washed on drum or table washers. Consequently, a screw press is selected for separation of soda spent liquor. After the second nitric acid stage pulping in a similar continuous digester, the pulp can be disc-refined at low amp. load to open up the cooked straw so that an effective final wash is feasible. The bleaching equipment is strictly conventional with omission of the chlorination tower.

D. Conclusions

From the foregoing, the following conclusions may be drawn:

1. The reversed and developed soda/nitric acid pulping of rice straw is superior to conventional nitric acid/soda pulping since it results in appreciable saving of nitric acid and in the overall cost of added chemicals while maintaining the attractive productive and non-polluting aspects of nitric acid pulping.
2. By using the nitric acid process, no chemical recovery plant is needed as the spent liquor is used as fertilizer.
3. Comparative evaluation of all soda and nitric acid pulping processes indicates that while the mild soda process gives pulp of higher yield and strength, the pressure soda process is more productive and more economic. On the other hand, the soda/nitric acid process is more attractive than the soda process with regard to its productivity and non-polluting aspects.

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Table 1. COOKING CONDITIONS FOR SCDA, NITRIC ACID / SODA AND SODA/NITRIC ACID PULPING OF RICE STRAW

Cook No.	Sodium Hydroxide Stage				Nitric Acid Stage				Fiberizing Time	Total Yield	Chemical Analyze							
	Liquor ratio	Temp. °C	Time. min.	Yield, %	Liquor ratio	Temp. °C	Time, min.	Yield, %			Ash %	Lignin %	Insol. (cellul) %	-Col. %	K No.	Clg No.		
1- Pressure	10	170	90	48.4	-	-	-	-	10	48.4	13.8	5.92	82.35	60.0	10.1	3.4		
Solid Scd.	13	90	100	50.0	-	-	-	-	30	50.0	3.21	6.37	90.53	63.37	12.9	3.9		
NaOH	7.0 ^a	95	30	47.7	6:1	95	30	79.5	30	47.7	14.3	9.1	87.8	67.8	21.9	8.7		
NaOH / HNO ₃	8.0 ^b	95	60	65.0	6:1	95	30	45.8	15	45.8	6.9	4.4	91.6	66.9	18.7	6.8		
	7.0	95	60	67.0	6:1	95	30	47.8	20	47.8	7.9	9.4	88.1	64.3	19.1	7.0		
	6.0	95	60	70.0	6:1	95	30	60.0	20	60.0	8.1	10.4	85.9	57.4	19.8	7.8		

^a based on o.d. nitric pulp
^b based on o.d. straw
^c based on o.d. NaOH pulp.

Table II. Physical - Strength Properties of Unbleached Rice Straw Pulp

Cook No.	Brightn- ess Ph. V. %	Initial Freeness °SR	Beating Time min.	Physical Properties at 50 °SR				
				Density g/cm ³	Burst Factor	Breaking length, m.	Tear factor	Double Fold, No.
1. Pressure Soda	38.5	25	22.0	0.562	29.5	4600	31.0	28
2. Mild Soda	33.5	45	3.5	0.667	44.0	5950	45.5	112
3. KNO ₃ / NaOH	35.5	42	10.0	0.550	29.0	4350	44.5	22
4. NaOH/HNO ₃ -	(a)	33	20.0	0.637	27.4	4780	29.4	4
	(b)	33.0	38	15.0	0.610	4750	46.0	15
	(c)	29.5	55	-	0.548	34.0	5429	47.1

Table III. Bleaching Of Rice Straw Pulp

Bleaching Conditions:

	Consistency, %	Temp., °C	Time, min.	pH
I- Chlorination	3.0	20	60	1-2
II- Caustic-Extraction	10.0	65	60	10-11
III- Hypochlorite	6.0	40	120	9-9.5

Type of pulp	Pressure Soda	Mild Soda	HNO ₃ /NaOH	NaOH / HNO ₃					
				(4-a)		(4-b)		(4-c)	
I. Chlorination									
Added Cl ₂ /o.d. pulp, %	3.5	4.0	9.0	7.0	-	7.1	-	8.0	-
Consumed Cl ₂ /o.d. pulp, %	3.4	3.9	8.7	6.8	-	7.0	-	7.8	-
II. Caustic - Extraction									
Added NaOH/o.d. pulp, %	2.0	2.0	2.0	2.0	4.0	2.0	4.0	2.0	4.0
III. Hypo									
Added Cl ₂ /o.d; pulp, %	1.5	2.5	6.0	7.5	12.0	7.5	12.0	7.5	12.0
Consumed Cl ₂ /o.d. pulp, %	1.3	2.1	5.0	7.3	11.9	7.3	11.9	7.4	11.9
Total Cl ₂ consumption, %	4.7	6.0	13.7	14.1		14.3	11.9	15.2	11.9
Brightness (Ph.V.), %	80.0	80.0	80.0	78.5	76.5	75.5	75.5	65.5	58.0
Bl. pulp yield/unbl.pulp,%	78.4	81.9	83.3	85.0	85.1	81.4	82.2	78.9	81.3
" " " /o.d.straw,%	38.0	41.0	39.7	38.1	40.7	38.9	39.3	47.3	48.8

PRINTING AND WRITING PAPERS BASED ON CHEMI-MECHANICAL
PULPING - AN ECONOMICALLY VIABLE PROPOSITION

by
B. Kyrklund ^{1/}

INTRODUCTION

One of the major constraints for establishment of pulp and paper mills in developing countries is the small size of the potential market in most of these countries. An economically viable integrated pulp and paper mill in an industrialized country needs to have a production of 100 - 150,000 tons per year, but production from such a mill would be at least ten times too large for most developing countries.

Efforts have been made on several occasions to scale down the minimum viable size of a pulp and paper mill to be more in balance with domestic market demand. As a general rule, it can be said that chemical pulp production from wood integrated with papermaking can, under certain conditions, be viable at a capacity of about 35,000 tons per year. Efforts to further reduce the minimum capacity of this type of mill have not in general been successful, except where very special conditions exist combined with incentives. The reason for this has usually been the marked economies of scale of chemical pulp production. A great part of the investment in such a mill also refers to investments in a recovery boiler plant, a steam plant, power supply, effluent treatment, etc.

A chemi-mechanical pulp mill has the advantage over a chemical pulp mill inasmuch as the economies of scale are not quite as marked. In addition, the investment in the actual fibre line a chemi-mechanical pulp mill is about 50 percent of the total investment requirement, compared to about 25 percent in a chemical pulp mill. The reduction of investment requirement and, accordingly, in the minimum viable size of a mill would, therefore, seem more easily achieved with that type of process than when chemical pulping is employed, concentrating on efforts to simplify the design of the fibre line.

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A study was, therefore, undertaken by FAC in 1982 into the possibilities of establishment of viable small pulp and paper mills based on chemi-mechanical pulping. In the following, a review will be presented of a mill producing 15,000 tons ^{2/} per year of wood-containing printing and writing paper.

The Pulp and Paper Mill Studied

Figure 1 presents a block flow-sheet of the integrated pulp and paper mill which was taken to be studied. Following chipping, screening and chip washing, the chips would be impregnated with caustic and peroxide solutions which form the pulping agents. After the pre-treatment with chemicals, the chips would be refined in two stages with peroxide bleaching employed in the second-stage refiner. The resulting pulp would be agitated in a chest for latency removal and, thereafter, thickened for high-density storage. No screening or cleaning would be employed in the pulp mill. These operations would be carried out in conjunction with the stock preparation for the paper machine which would be of simple, slow-speed design. The mill would include a finishing department with facilities for cutting all of the production into sheets. As regards the ancillary departments, the steam supply would be based on wood-fired low-pressure boiler and the power would be supplied from the national grid.

In the design of the mill for costing purposes, it was assumed that the wood raw material - hardwood- would be delivered debarked to the mill. The layout of the pulp mill is such that gravity flow is used to the extent possible in order to benefit from the considerable cost reduction from elimination of high-density stock transport systems. This was done to the extent that gravity flow was used from the impregnation stage in the pulp plant to the latency chest. Further details of the mill design are provided in the original report on the study.

Capital cost estimates for the mill were prepared on the basis of information obtained from equipment suppliers on major items of equipment and from cost data available in FAO files. All costs reflect the level of mid 82.

^{2/} Metric tons are used throughout this paper.

Capital Cost Estimates

For the economic evaluation of the mill the estimates were prepared to reflect two cases:

- 1) A pulp mill producing 13,000 tons per year of chemi-mechanical pulp established in conjunction with an already existing paper mill producing 15,000 tons per year of printing and writing paper. In this case, cost estimates both as regards capital costs and manufacturing costs reflect the additional cost over and above those of an already existing mill with its service departments;
- 2) A greenfield, fully integrated printing and writing paper mill producing 15,000 tons per year of paper from 100 percent chemi-mechanical pulp from hardwoods.

A summary of the plant capital estimates for the two cases is shown in Table 1. Thus the total plant capital for the pulp mill alone would be US\$ 8.3 million whereas a new, integrated pulp and paper mill would require a plant capital of US\$ 32.3 million. The total investment, as shown in Table 2, would then amount to US\$ 9.0 million for the pulp mill and US\$ 38.0 million for the integrated mill.

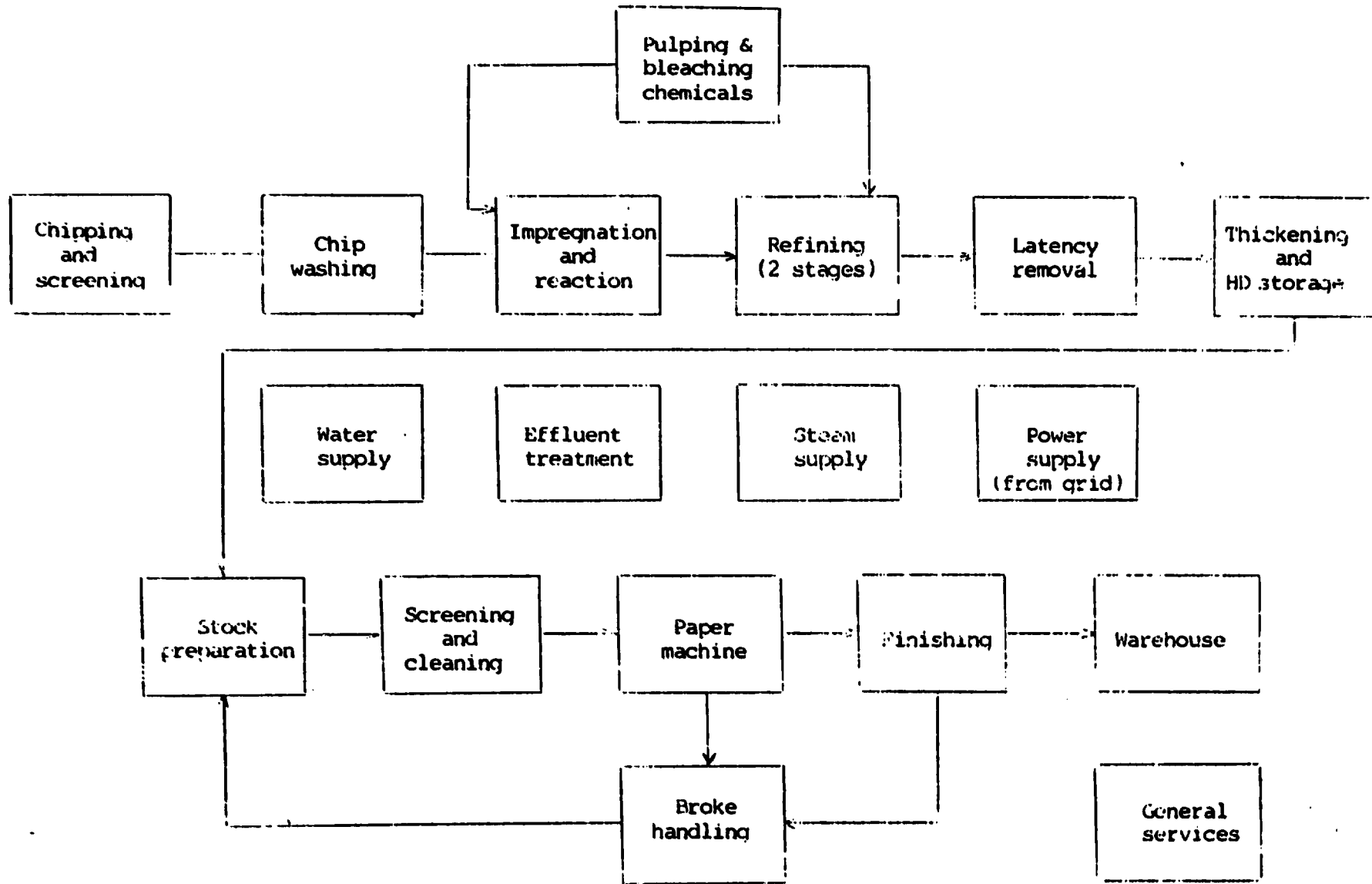


Fig. 1 - Block flow sheet of mill

Table 1
Plant Capital Estimate

<u>Item</u>	US\$ Million	
	<u>Pulp Mill</u>	<u>Integrated Mill</u>
Structures	1.4	4.4
Equipment		
- material	4.0	17.4
- installation	<u>1.2</u>	<u>4.0</u>
Total direct cost	6.6	25.0
Engineering	0.6	2.2
Construction overhead	0.3	1.3
Contingencies	<u>0.8</u>	<u>3.0</u>
Total Plant Capital	8.3	32.3

Table 2
Total Investment Estimate

<u>Item</u>	US \$ Million	
	<u>Pulp Mill</u>	<u>Integrated Mill</u>
Plant capital	8.3	32.3
Working capital	0.6	1.4
Pre-operational and start-up expenses	0.2	0.5
Interest during construction	<u>1.1</u>	<u>3.8</u>
Total investment	9.0	38.0

Manufacturing Cost Estimate

The manufacturing cost estimates and the mill design concept were based on alkali-peroxide pulping of hardwoods. Thus the yield of pulp on pulping would be 85 percent with a specific refining power consumption of 900 kWh per bone-dry ton. The target brightness of the pulp after bleaching in the second-stage refiner would be 70. The most important unit costs for inputs are given in Table 3.

Table 3
Most Important Unit Costs Used

<u>Item</u>	<u>Unit</u>	<u>Price</u>
Pulpwood	US\$/m ³ s ^{1/}	25
Hydrogen peroxide	US\$/MT ^{2/}	860
Fuelwood chips	US\$/m ³ s	22
Electric power	US\$/MWh	30

In general, these unit costs reflect the prices which are charged in a number of developing countries. However, great variations may be found in the costs of hydrogen peroxide and electric power.

A summary of the manufacturing costs for the two cases is shown in Table 4. The cost of chemicals is the major component both in the pulp mill as such and in the integrated mill. The cost of pulpwood is also a major component in the manufacturing cost of the pulp mill but it is of relatively little importance in the costs of the integrated mill. The total annual manufacturing cost estimates are, accordingly, US\$ 3.5 million for the pulp mill and US\$ 7.8 million for the integrated mill. It could be mentioned

1/ m³s = cubic metres solid

2/ MT = metric ton

that the relatively high labour cost of the integrated mill reflects the high degree of employment provided in the finishing department.

Table 4
Manufacturing Cost Estimates

Item	Pulp Mill		Integrated Mill	
	<u>US\$ million/A</u>	<u>%</u>	<u>US\$ million/A</u>	<u>%</u>
Pulpwood	0.7	20	0.7	8
Chemicals	1.1	31	2.1	27
Fuelwood	-	-	0.6	8
Electric Power	0.5	14	0.9	12
Other Materials	0.2	6	0.6	8
Labour	0.4	11	1.3	17
Administration and Overheads	0.3	9	0.9	12
Contingencies	<u>0.3</u>	<u>9</u>	<u>0.7</u>	<u>8</u>
	3.5	100	7.8	100

Sales Price Requirements

When a study of this kind is prepared for a specific location, it is customary to evaluate the return on investment starting from a sales price which is fixed by the local conditions. In this case, however, such an approach cannot be used since the estimates do not refer to any specific location, not even a specific country. For this reason, the evaluation of the viability of the mills is based on the price required for the product to obtain 12 percent compounded interest on the investment over a period of twenty years. The results arrived at in this way are US\$ 362 per air-dry ton of pulp (in slush form for pumping to the paper mill from high-density storage) and US\$ 860 per finished ton of paper in sheet form.

As regards the price requirement for the paper, US\$ 860 is frequently paid in many developing countries and even considerably higher prices are charged in some countries. As regards the pulp price, the acceptability of US\$ 362 per air-dry ton in a specific mill depends entirely on what alternatives raw materials are available and at what cost.

Nevertheless, the price seems to be within or below the price range of high-grade waste paper for printing and writing paper production, although its relative competitiveness would have to be established in each case specifically. It may, nevertheless, be concluded that both cases seem to have prospects for viable production of pulp and paper on a comparatively small scale in many developing countries.

Sensitivity Analysis

Figure 2 illustrates the sensitivity of the pulp price at a constant capital recovery rate or internal rate of return of 12 percent to changes in manufacturing cost or total investment. Thus an increase of investment from US\$ 9 to 11 million would increase the price requirement from about US \$ 360 per air-dry ton to about US\$ 385 at constant manufacturing cost. It can, therefore, be concluded that the viability of the pulp mill would not be seriously sensitive to increases in the total investment, since an increase of over 20 percent in the investment requirement would only require a price increase of slightly over US\$ 20 per ton at constant rate of capital recovery.

The sensitivity to changes of manufacturing cost, on the other hand, is far more marked since an increase of 20 percent in manufacturing cost calls for the price to increase up to about US\$ 410 per air-dry ton.

The same kind of diagram is shown in Figure 3 for the sensitivity of the integrated paper mill. It can be concluded also in this case that the paper price required for a capital recovery rate of 12 percent on the investment is more sensitive to changes in manufacturing costs than to changes in investment cost.

Table 5 presents the sensitivity of the two cases with regard to variation in the most important cost and price parameters. From the data shown, it can be concluded that the viability of neither the pulp mill nor the integrated mill is significantly sensitive to variation in the cost of pulpwood.

As mentioned in the beginning of this paper, there are great variations in developing countries in the cost of peroxide and electric power. Increasing the cost of peroxide from US\$ 860 per ton in the base case to a price as high as US\$ 2,000 per ton would increase the cost of pulping chemicals by 60 percent. This would reduce the rate of capital recovery from 12 percent of 1.8 percent for the pulp mill or the pulp price at capital recovery rate retained at 12 percent would have to be increased to US\$ 414 per air-dry ton. However, such an increase in pulping chemical cost would not by any means affect the viability of the integrated paper mill to the same extent.

Similarly, if the power consumption in the pulp mill was increased by 100 percent at a constant price of US\$ per MWh, the rate of capital recovery would reduce to 4.7 percent or the pulp price would have to be increased to US\$ 400 per air-dry ton to maintain a rate of 12 percent. Again, the effect on the integrated mill would be less serious. Assuming, on the other hand, that the increase in overall power cost, rather than being caused by increased consumption, were due to a 100 percent price increase to US\$ 60 per MWh, the rate of capital recovery of the integrated mill would fall below 10 percent to 9.1 percent and the price of paper required for 12 percent rate of recovery would be US\$ 921 per finished ton.

Finally, it can be noted that a reduction in sales price by 10 percent from the base price arrived at in this study would have serious consequences on the viability of both the pulp mill and the integrated paper mill.

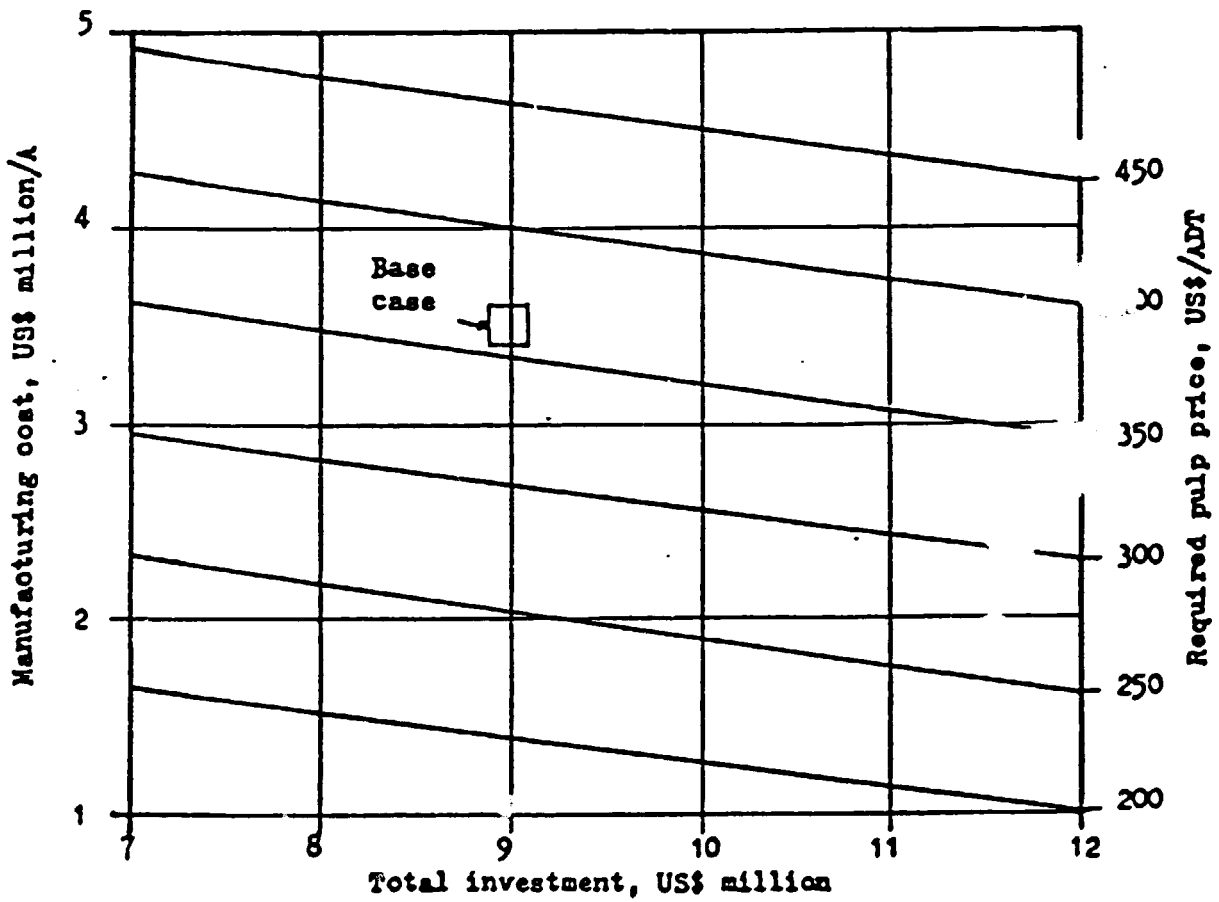


Fig. 2 - Pulp price at constant capital recovery rate (12%)

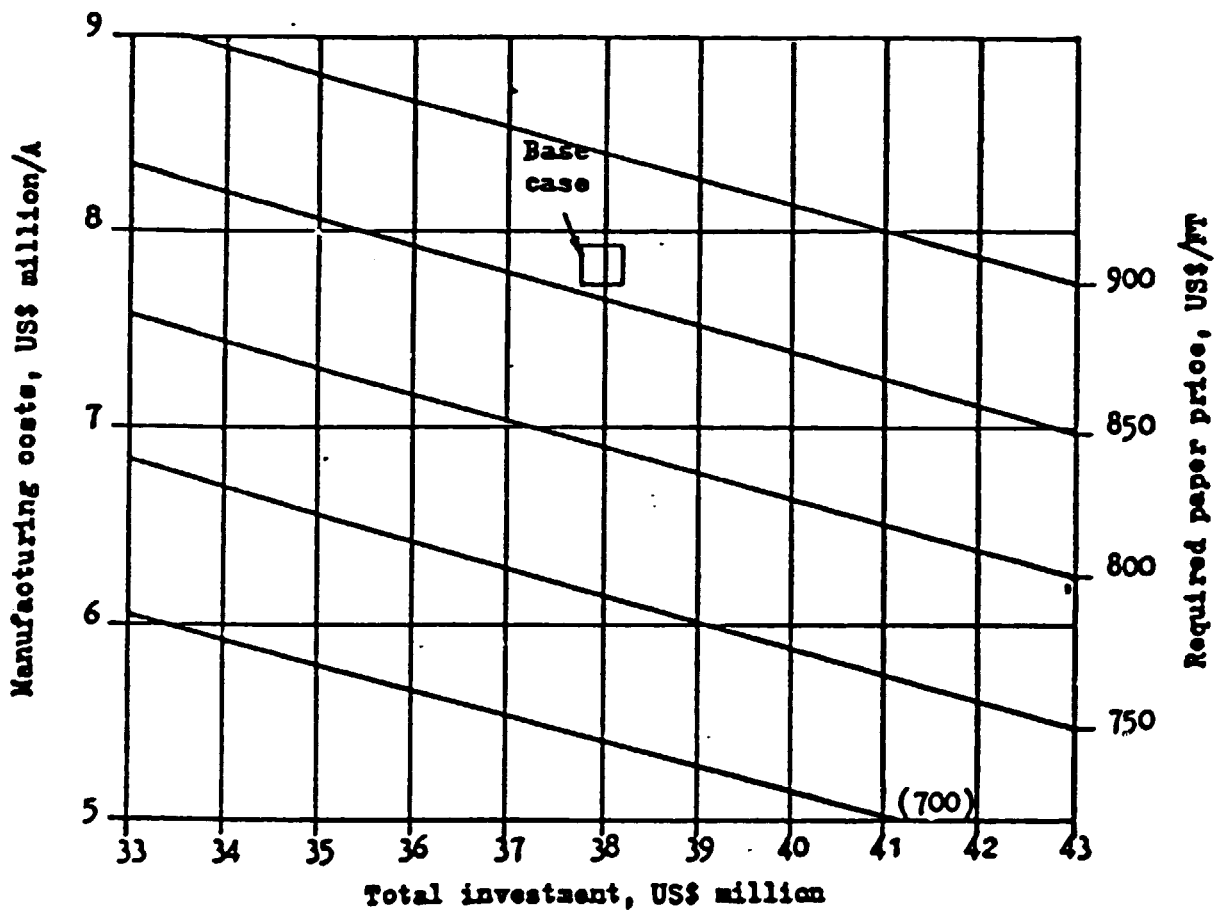


Fig. 3 - Paper price at constant capital recovery rate (12%)

Table 5

Sensitivity of Cases to Variations in Most Important Price Parameters

Item	Pulp mill			Integrated mill	
	Change, %	Rate of capital recovery, %	Pulp price at 12% US\$/ADP	Rate of capital recovery, %	Paper price at 12% US\$/PI
Pulpwood	+ 20	10.1	373	11.6	869
Pulping chemicals	+ 60	1.8	416	10.0	904
Power					
- in pulping only	+ 100	4.7	400	10.5	893
- in all departments	+ 100	4.7	400	9.1	921
Sales price	- 10	5.2	362	7.7	860

Concluding Remarks

Although the present study has used certain assumptions regarding the process of pulping, it should be mentioned that there are a number of various options which are more or less covered by the same cost estimates insofar as total manufacturing cost and investment are concerned. In order to establish the most appropriate process to be used, due consideration has to be given to the raw material, availability of certain chemicals and at what cost, as well as the cost of wood and electric power under specific conditions. Only then can the final answer be given as to whether or not a project of this kind is viable under the actual prevailing conditions in a country. Nevertheless, it can be concluded from the data presented here that production of printing and writing paper based on chemi-mechanical pulping of hardwoods can be a viable proposition in many developing countries at a production rate as low as 15 000 tons per year.

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MONOPULPING - A NEW CONCEPT FOR DEVELOPING COUNTRIES

by

Mr. M. Narby

INTRODUCTION

Ladies and Gentlemen, I will now present a paper with the title "Monopulping - A New Concept for Developing Countries". In this paper I will try to answer the two questions:

- Why a Monopulp Concept?
- What is a Monopulp Concept?

In 1982, a Swedish consortium consisting of Celpap International AB, SMW AB and Sunds Defibrator AB presented a new concept for an integrated pulp and paper mill, especially designed for the developing countries. The study was sponsored by the Swedish International Development Authority (SIDA), the Swedish Trade Council and the National Swedish Board for Technical Development.

The study was based on a high yield pulping process suitable for production of both, newsprint as well as writing and printing grades. Laboratory trials on pulping and paper production were part of this study and the test results will be presented later.

BACKGROUND

Developing countries attach great importance to the pulp and paper industry due to its close link with communications and the dissemination of knowledge. During the past two or three decades, a number of developing countries have made substantial investments in pulp and paper ventures. The results vary between the extremes of financial failure and highly successful enterprises. The general pattern, however, has been somewhat disheartening.

Many industrial activities in the developing countries experience the same fate and the paper industry is no exception. On average the capacity utilization for the pulp and paper industry in the developing countries in Africa in 1984 (information for 1985 not yet available) was close to 75 % with variations from 20 % to 100 %, not utilized mills excluded.

A large number of countries import paper, whilst their paper capacity is still underutilized. The reason may be the inability to produce the quality of paper required by the market (newsprint is in demand but the capacity is for printing and writing) or operating problems with the individual mills.

A modern integrated pulp and paper mill is dependent on a number of external physical inputs, such as: fibrous raw materials, chemicals, power, fuel and spares etc. It is essential that all these inputs are available simultaneously, since a failure of one input hampers the entire operation. The total availability of the mill decreases with the number of inputs, the multiplicative effect. Therefore, a small number of inputs from outside the mill is a good means of securing production. The mill should be as self-sufficient as possible.

The size of the mill is often decided on the basis of the minimum economic unit of the major equipment, paper machine and/or pulping line, without reference to other factors. Economy of scale has been used as an argument in favour of a large mill without considering the problems of transport, input availability or even market constraints.

It has been standard practice to install kraft pulp mills in developing countries without evaluating alternative processes. The main advantage of a kraft pulp mill is its universality making it possible to pulp most fibre raw materials to high strength characteristics. However, the kraft process requires large quantities of expensive pulping chemicals. Therefore, the recovery of pulping chemicals is a prerequisite for process economy, apart from the environmental problem if no recovery were adopted. The recovery system also adds on the already high investment cost of a kraft pulp mill.

If we study the consumption pattern of paper in many developing countries, we find that a great proportion of the demand is for newsprint and printing and writing papers. The functional properties for these paper grades are basically: stiffness, dimensional stability, opacity, printability and brightness. When we compare these required properties with those of kraft pulp we will observe that the high strength of kraft pulp is not a major criterion while opacity, stiffness, etc. is known to be better achieved by high yield pulps. Usage of high yield pulp is traditionally limited because its lower brightness compared with highly bleached kraft pulp.

The unrealistically high quality and brightness requirements in industrially advanced countries bear very little functional significance. This is a result of a competitive market, a low price of paper and a high disposable income.

The situation is radically different in most developing countries.

Efforts should therefore be made to investigate whether the major functional properties of paper can be achieved by other pulping processes. The aim should be to develop a process with few inputs and a low capital cost. Or if I may quote UNIDO's invitation to this conference, quote: "Special infrastructural conditions in developing countries often call for new approaches in industrial ventures, avoiding the unmodified adoption of sophisticated technologies as used in the industrialized world", unquote.

THE PRINCIPLES OF THE MONOPULP CONCEPT

What is the Monopulp Concept?

The main objectives of the Monopulp concept study can be summarized as follows:

- to establish appropriate size of and integrated pulp and paper mill.
- to use appropriate technology to reduce operational difficulties.
- to utilize domestic raw materials.
- to obtain independence of outside electrical power systems.
- to minimize costs.
- to manufacture paper from one single pulp, MONOPULP.
- to produce cultural papers, i.e. newsprint and printing & writing papers.

FRAME OF THE STUDY

The Monopulp Concept covers a 100 tpd mill for integrated production of printing paper grades and is based on high yield pulping of hardwood. The concept starts with the woodyard and ends with wrapping and storing the paper before shipment. A power station, waste water treatment plant and all the service and maintenance facilities have been included, but the infrastructure outside the mill has not been dealt with.

This Chemi-Mechanical Pulp (CMP) process, developed by Sunds Defibrator, is a modified high yield process which makes it possible to produce high quality high yield pulp from hardwoods. Eucalyptus, or similar tropical hardwoods, have been assumed to be the fibrous raw material in this study.

In high yield pulping processes lignin dissolutions must be avoided during bleaching. Therefore, the peroxide bleaching process has been chosen. The discharge of pollutants from such bleaching is small and relatively simple to handle.

For the Monopulp Mill it was decided not to rely on any external power system but to calculate with entirely internal power generation based on solid fuels. For the investment cost analysis a combined coal and wood residue fired boiler was decided for generating steam and electric power. The turbine used is a condensing turbine, yielding 22.5 MW. The steam extracted is used in the dryer section of the paper machine.

PROCESS DESCRIPTION

Manual barking directly after felling in the forests is recommended, but if mill barking is preferred, a barking drum and a conveying system has to be installed. The logs are washed before being fed to a horizontal feed chipper followed by a chip screen. Chips are stored in a chip pile corresponding to one week's consumption.

Chips are fed from the chip pile to a live bottom bin prior to chip washing and presteaming. Atmospheric steam generated in the primary stage refiner is used for chip heating before the impregnation. The hot chips are compressed in a plug feeder, which feeds them into the bottom of the up-flow atmospheric impregnation vessel. The retention time is 10 to 15 minutes.

A mixture of caustic soda and sodium liquor is preferable when using eucalyptus, and the charge will be in the order of 30 to 50 kg per tonne of pulp. After excess liquor has drained from the chips at the top section of the vessel, the chips are fed to a surge bin where they undergo alkaline swelling during 10 to 15 minutes.

Primary stage refining incorporates a second plug feeder, a pressurized feed chute and a refiner. The refiner is pressurized and powered by a 7.5 MW, 1,500 rpm, synchronous 10 kV motor. The refiner operates at a steam pressure of 0.25 bar corresponding to a temperature of 138°C.

Prior to the secondary refining stage, the pulp is dewatered in a screw press to approximately 30 percent consistency together with screen and centricleaner rejects. Refining power consumption is estimated at 1,900 kWh/BDT, including rejects. After single stage pressurized screening, the accepted pulp is centricleaned in three stages and predewatered in a disc filter before washing in a twin roll press.

The press operates according to the counter current principle, washing out dissolves organic substances, thus avoiding excessive consumption of bleaching chemicals. Very little liquid is carried forward to the bleaching system as the pulp is discharged at a consistency of 45 %.

Hydrogen-peroxide bleaching is carried out according to the following principle:

- Prewash of the pulp in order to remove dissolved organic matter.
- High chemical concentration in the bleaching tower.
- "Closed" bleaching chemical loop with recirculation of residual chemicals.

For newsprint, a final brightness of 50 to 55 percent ISO is anticipated, while the pulp for printing and writing will be bleached to a brightness of 70 to 75 percent ISO.

A post refiner following the bleaching tower will reduce the freeness level further to 100 ml CSF, adding some 500 kWh per tonne to refining power consumption.

The paper machine is of common fourdrinier type with an inclined size press for surfacing sizing with starch. The production speed will be 290 m/min and 385 m/min for printing and writing papers and newsprint respectively and the basis weight range is between 45 and 100 gsm.

Behind the paper machine there is a rewinder, which produces the different roll sizes wanted by the customers or for the sheet cutters in the converting plant. The rolls (mostly newsprint) are wrapped and placed in the storage room pending shipment to customers.

PAPER QUALITY

The chemi-mechanical hardwood pulp produced by the Monopulp Mill permits manufacture of many grades of uncoated cultural paper, eliminating the need to import softwood pulps. Pulp grades can be varied by using different amounts of bleaching agents, by adding china clay or by varying power input to the refiners.

Within the scope of this project eucalyptus CMP has been produced and different paper grades have been manufactured on a pilot paper machine. The paper was made with different basis weights with and without surface sizing and was machine calendered.

The properties of the paper produced compare favourably with paper produced by conventional methods in industrialized countries.

Newsprint produced exclusively from chemi-mechanical pulp derived from eucalyptus has a tensile index well above that of Scandinavian newsprint furnish (85 % SGW and 15 % BSK), given the same density for the both papers. The tear was only marginally lower than the reference sample.

The brightness of newsprint produced is comparable to that of conventional newsprint. Although the light scattering coefficient and the opacity of the paper produced from eucalyptus pulp were below levels given for the reference samples, the levels were still quite satisfactory.

The characteristics of eucalyptus CMP enable production of many fine paper grades from only CMP with the addition of suitable fillers and with surface sizing. Surface smoothness and ink holdout can be controlled as well as porosity and strength with additives and different degree of refining. The user will observe no other difference than a somewhat lower brightness. For some applications it is possible to make a superior paper by taking advantage of the high stiffness and superior formation of the eucalyptus CMP paper (for example in book paper).

INVESTMENT COSTS

A major problem with new large pulp and paper mills - in industrialized as well as in developing countries - is the heavy investment cost. Today the cost for a new greenfield kraft pulp plant is so high that a pulp price of US\$ 650 per tonne is needed to break even. The current market price is around US\$ 425 per tonne CIF European port.

This is one of the key strengths of the Monopulp Concept.

Investment cost is approximately 70 % of a similar sized integrated kraft pulp mill.

The total fixed investment cost for the monopulp mill is US\$ 82 million at 1986 cost levels and includes machinery, equipment, electrical and instrument installations, buildings, roads and railroad at site, spare parts, engineering and project management, recruitment and start-up expenses.

COST/BENEFIT ANALYSIS

An analysis of the economic cost/benefits per tonne of printing and writing paper, calculated for the first year of full production has been made. This histogram shows the cost of domestic paper and the savings to be made, all calculated as foreign exchange component. Most of the chemicals, the fuel for power generation and loans are in foreign exchange. However, wood and personnel costs are entirely domestic. If the country imports paper, it may have to pay US\$ 700 per tonne on average in foreign currency. Domestic production reduces this figure to approximately US\$ 500 per tonne, capital charges included. It is evident that paper produced with the monopulp concept would have a positive effect on the balance of trade.

CONCLUDING REMARKS

To conclude my paper I would like to present a list of CMP/CTMP installations utilizing hardwoods which I think could be of special interest here.

Celpap is presently commissioned for a feasibility study on a market CTMP mill to be located in the People's Republic of the Congo and based on existing eucalyptus plantations close to Pointe Noir. The preliminary results are very encouraging and full scale pulp and paper mill trials will be performed later this year.

Thank you very much for your attention.

DIFFERENT APPLICATION OF OPCO PULPING PROCESS

by

P. Vinmari

THE OPCO PROCESS

The OPCO process is a patented process for the manufacture of chemi-mechanical pulps and is the property of the Ontario Paper Company. The process is available for license.

WHO MIGHT BE INTERESTED?

The advantages of the OPCO process should be evaluated within the context of the particular mill. Some examples follow.

- 1) A mill with a pollution problem could replace a chemical pulping operation with OPCO to bring its effluent within regulations.
- 2) A mill purchasing SBK could switch to OPCO to reduce furnish costs.
- 3) A TMP operation forced to excessive power consumption to combat a bulk or linting problem could reduce power costs and improve drainage with the OPCO process.
- 4) In a case of a constrained woody supply, OPCO could be used to extend wood resources.
- 5) A machine with drainage or runnability problems could be improved by replacing a part of the TMP with OPCO pulp.
- 6) The OPCO processes should be of interest to anyone running a high speed newsprint machine on a groundwood or groundwood-TMP based furnish, and who wishes to reduce wood or energy costs or to ameliorate an effluent disposal problem.

WHAT DOES IT DO?

The OPCO process produces a new kind of paper making fibre, characterized by the following:

- Environmental acceptability
- High wet web stretch
- High freeness and rapid drainage

- High pulp yields
- Increased brightness
- Increased burst and breaking length
- Reduced refining power
- Reduced bulk and linting

WHAT IS IT?

The OPCO process is a thermo-chemical treatment applied to mechanical pulps, particularly TMP, either after refining or between stages.

It may also be incorporated as an add-on process in existing mechanical pulp lines.

UNDER WHAT CONDITIONS IS THE PROCESS CARRIED OUT?

The process has the flexibility to tailor pulp properties to a wide range of needs. The best configuration involves a number of trade-offs and should be established separately for each application. Some of the factors involved are considered below.

1) Paper Machine Demands

A machine which imposes low stress on the unsupported webs will be satisfied with a less developed pulp.

2) Pulp Development Requirements

Pulp development increases with refining power and with cooking severity. Generally a cook of 160°C for one hour will reduce yield to about 90 % and produce an effluent BOD of around 130 lb/ODT. In most applications milder conditions would be preferred. Maximum refining power is set by the drainage requirements of the furnish.

3) Interstage vs. Post Treatment

Post treatment can yield a pulp with a higher and more permanent wet stretch, for a paper machine which requires this additional stretch for stable operation.

WHAT ARE THE CRITICAL PROCESS REQUIREMENTS?

1) Starting Material

The required starting material is a mechanical pulp consisting mostly of single fibres in a well fibrillated state. RMP can be used but TMP is preferred.

The process is not applicable to:

- TMP produced well above the glass transition temperature of the lignin.
- Pulps produced by refining cooked and chemically softened chips.
- Products derived from species unsuited for mechanical pulp production, such as high density hardwoods.

2) Chemical Requirements

Enough sodium sulphite must be used to leave some residual at the end of the reaction, and to prevent the pH from dropping below about three. Normally between 5 % and 10 % on wood will be used.

Uniformity of mixing is critical; each fibre must be protected by its share of chemical before reaching reaction temperature. This requires particular attention to higher reaction consistencies.

HOW IS THE PROCESS CARRIED OUT?

1) First Stage Refining

Any refiner suitable for mechanical pulp production can be used. Pressurized refiners yield a better product. For interstage treatment, only enough power to separate the fibres need be applied in the first stage - normally under 40 HPD/T. There are some advantages to refining systems which discharge pulp at higher temperatures.

2) Chemical Addition

Two modes of addition are recommended as capable of giving the required uniformity of mixing:

- Addition in the dilution water in the eye of the refiner.
- Addition of excess chemical prior to a screw plug feeder ahead of the reactor.

3) Heating to Reaction Temperature

The insulating properties of a fluff TMP are phenomenal. The modes of conduction and diffusion are normally not adequate to transfer heat to the pulp mass and must be augmented mechanically. There are a number of alternate ways of achieving this.

4) Reactor Configuration

Essential requirements are a pressure vessel equipped with some means of moving pulp in and out, and of such size as to provide a retention time of 30 - 60 minutes, for a bulk density of about 4 lb./cu. ft. Perfect plug flow is not a requirement; unlike lower yield processes, fairly wide variations in time of reaction can be tolerated. Once the pulp is brought to temperature, no heat need be added in the reactor. In a gravity flow system, it must be recognized that this pulp is very prone to bridging.

Although a variety of reactor designs might meet these requirements, we are in the process of designing a system specifically for OPCO application.

5) Second Stage Refining

Second stage refining may be either pressurized or atmospheric. To maximize wet stretch in the product, refining consistency should be high. Energy savings in inter-stage treatment are somewhat greater when most of the refining power is applied in the second stage.

Alternatively, the process may be applied to a single stage TMP as a post-treatment.

EXAMPLES

Thorold spruce chips were refined in a commercial pressurized refiner at a specific energy of 38 HPD/T. A portion of this pulp was reacted at 150°C for 60 minutes with Na_2SO_3 at pH 9 in a commercial continuous digester, and then refined further in a commercial open discharge refiner.

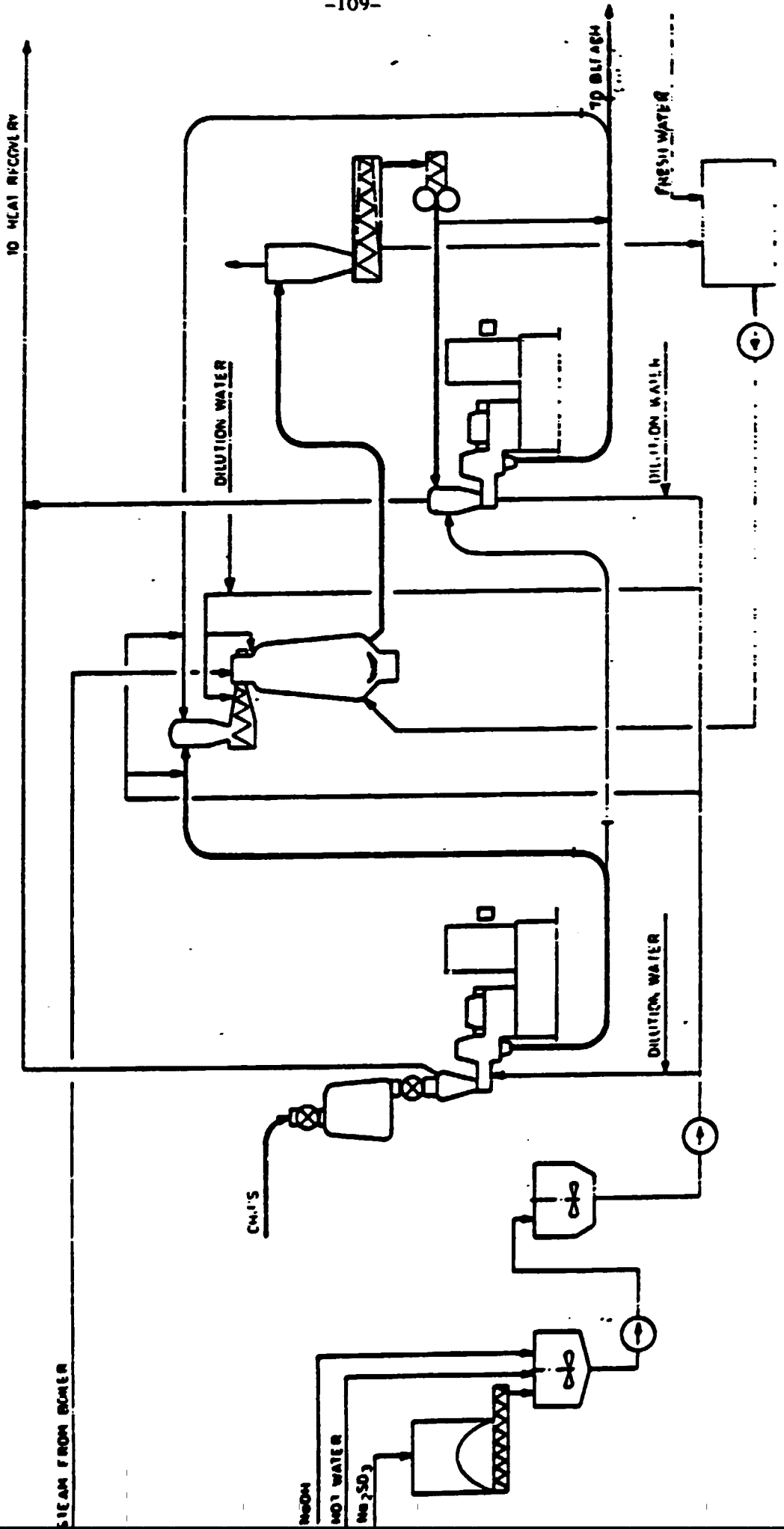
Another portion of the untreated first stage pulp was further refined in the open discharge refiner and a portion of the product reacted at 160°C for 60 minutes in the continuous reactor. The resulting pulps had the following properties, after standard delatency treatment.

<u>Treatment</u>	<u>Untreated TMP</u>	<u>Interstage Treated</u>		<u>Post Treated</u>
Refining Power Total HPD/T	88.1	76.0	88.8	88.1
CSF	136	133	79	161
Drainage Time, Sec.	1.45	2.42	5.16	1.47
Wet Stretch, %	4.8	5.8	6.2	10.6
Wet Tensile, N/m	83	112	126	75
Wet Caliper, mm.	.351	.282	.273	.323
Bulk	2.78	1.89	1.70	2.03
Burst Factor	23	38	42	30
Breaking Length	3900	6200	6900	5200
Tear Factor	85	68	60	64
Dry Stretch	1.9	2.3	2.2	2.2

These data illustrate the salient points of the process.

- Compared to TMP, all OPCO pulps show a markedly reduced bulk and wet caliper.
- Interstage treated pulps refine with less energy to yield pulps with greatly improved wet and dry strength properties.
- Post treated pulps are characterized by exceptional wet stretch which is retained through normal delatency treatments.

OPCO REACTOR TRIAL PLANT
50 BDMTPD



THE OPCO PROCESS - CHEMI-MECHANICAL PULPS WITH UNIQUE PROPERTIES

PART I

The OPCO process was developed to provide a reinforcing fibre at yields in the 90% range, which could be used, in mixture with stone ground-wood, as a furnish for newsprint machines running at high speeds. Some of the requirements of such a pulp are listed in Figure 1. In this list, as in the real world, the bottom line is paper machine runnability - the most important single factor affecting profitability, and the one most often ignored, possibly because it is the least understood.

To understand the relationship of stock properties to machine runnability, look at the web as the paper machine sees it. The pull required to carry the web across an open draw is proportional to mv^2 (1). The higher the speed, and the heavier (wetter) the web, the greater the stress. Why then do breaks not occur exclusively in the first draw where the stress is highest and the sheet is wettest and weakest? In reality, breaks are more frequent in later draws.

Figure 2 shows the stress-strain curves at first press moisture content, of two furnishes actually run on Q.N.S. #3 machine, with an SBK curve included for comparison. In normal operation with HYS furnish, Q.N.S. #3 stretches the web 1.67 % in the first draw. From the graph, the tension required to carry the web across this draw must be about 70 N/m. This same tension, applied to the UHY furnish would stretch the web to its breaking point. On this basis, the UHY furnish should be impossible to run on Q.N.S. # 3. In an actual mill trial, this pulp made paper for only 10 minutes out of 7 hours. SBK, noted for its excellent runnability is distinguished by its high extensibility, not its high wet web strength.

This dependence of runnability on wet stretch, proposed originally for HYS (2,3) has been supported by a survey of 14 mills which showed a striking correlation of machine speed with wet stretch and drainage rate (4), and has been further confirmed and elaborated by studies with a variety of furnishes on an experimental paper machine (5).

The essence of runnability is simply this: as the web is carried through the machine, stretch is traded off to supply the required tension at each point. Traded stretch is not regained when tension is relaxed. When the web runs out of stretch, it breaks. Unused stretch provides the safety margin to absorb perturbations, and to carry and equalize strains around defects. How then to create a pulp with high stretch?

The OPCO process is a thermo-chemical treatment with sodium sulphite, applied to mechanical pulps, which maximizes wet stretch by stabilizing and permanently setting the curl in the pulp fibre. This is illustrated in the microphotographs of Figure 3. Pulp A is a lightly refined TMP with the high stretch and low strength typical of latent pulps. Pulp B is the same pulp with latency removed. Stretch has been traded for improved strength. Pulp C is derived from Pulp A by OPCO treatment, retaining both stretch and strength. Delatency treatment of Pulp C yields Pulp D in which a small increment of stretch is traded for further increases in strength.

The OPCO reaction is normally carried out at a temperature between 130° and 180°C at pulp consistencies over 10 %, using 7 - 10 % sodium sulphite based on wood. Duration of reaction is usually between 15 minutes and 2 hours. Longer reaction times result in lower yield, drainage rate and scattering coefficient. However, product quality is not highly sensitive to reaction time. This has important implications in the design of the reactor; design is greatly simplified when perfect plug flow is not essential, and variations of \pm 50 % in retention time can be tolerated.

The process may be applied between refining stages or as a post-treatment; each mode has advantages and disadvantages.

In attempting to compare the basic properties of pulps produced under various conditions, a serious difficulty arises; the properties of the pulp are highly dependent on the amount of curl in the fibre, i.e. latency. As the fibre is straightened out, the amount the web can

be stretched before it breaks decreases, while the force required to break it increases. Simply straightening the fibres can reduce the freeness of the same pulp by over 100 CSF, half the wet stretch and double the tensile and dry strength. Clearly comparisons made on the basis of such measurements are meaningless unless the pulps are first brought to a common standard state of latency - an impossible task. However, we can measure the properties of a pulp in two different states of latency, and use the line connecting these two points to characterize the pulp. This is illustrated in Figure 4, in which wet tensile vs. wet stretch at rupture are so plotted for a variety of pulps. Quality improves as the line is displaced upward and to the right.

By progressively straightening the fibre we can move upwards along the line defining a particular pulp, but we cannot move off the line. To a first approximation all the lines have the same slope. Pulps can therefore be ranked according to the intercepts of their line at some arbitrary value of stretch to rupture, say 5 %. The resulting value corresponds to the wet tensile strength at rupture which would be measured, if the pulp latency were first so adjusted that the web breaks at 5 % elongation. Note that the 5 % stretch at rupture defines a standard latency condition solely for purposes of comparison; the stretch of the actual furnish may be varied anywhere along the line, depending on the demands of the paper machine.

Benefits of OPCO processing are apparent from Figure 5; under some conditions, equal levels of wet tensile and stretch can be reached at 100 points higher freeness and 40 % less power compared to TMP. Alternatively at equal freeness, or equal power, higher levels of stretch and tensile can be obtained. The process has the flexibility to tailor pulp properties to a particular application.

Improved stress-strain properties are accompanied by, and probably partly a consequence of increased fibre flexibility, which in turn manifests itself in improved consolidation of the web. Better consolidation results in lower caliper in the wet web, and lower bulk in the dry sheet.

Better bonding as well as better consolidation results in lower linting tendencies and probably contributes to the improvements in dry strength obtained by OPCO processing. Thus at equal wet stress-strain properties, OPCO pulps average about $1 \text{ cm}^3/\text{g}$ lower bulk and over 1000 m higher breaking length, and these benefits are obtained at higher freeness and with less power. Figures 6 and 7 illustrate these effects.

OPCO processing increases the brightness of TMP by about 4 points, with a brightness loss of less than 1 point after three months' aging. Scattering coefficient is decreased about 15 %. The process is without a consistent effect on tear.

The special properties of OPCO pulps are the result of optimizing fibre morphology, as well as fibre chemistry - both are necessary. For example, if wood chips are heated with sulphite under OPCO conditions and then refined, the chemistry of the OPCO fibre is duplicated, but not the morphology. This chemically softened chip separates in the refiner to yield a stiff smooth-walled fibre showing little fibrillation. The resulting pulp is characterized by poor consolidation of the web, as revealed by high wet caliper, bulk and air permeability, by picking on the paper machine rolls, and by low wet stretch and runnability. Improvements possible through further refining are limited by the pulp's low capacity to absorb refining power; at normal plate separation, specific energy is low, and attempts to increase it by increasing plate pressure result in pad collapse and plate clashing, or in unacceptably low plate clearances, fibre cutting and loss of tear. The morphology of this pulp is contrasted with that of a typical OPCO pulp in Figure 8. Note that the fibres of the latter are highly kinked, curled, flexible, and well fibrillated. This morphology is established at the moment of fibre separation and is quite unrelated to the effects of subsequent chemical processing. Optimum morphology can be obtained under conditions of thermomechanical refining.

The role of subsequent chemical treatment is to maintain wet stretch by stabilizing curl in the fibre, and to increase fibre flexibility and bonding resulting in lower bulk and higher wet and dry tensile strength.

The salient features of the OPCO process are:

- 1) Yields over 90 % with BOD loadings of the order of 100 lbs/ADT.
- 2) Energy requirements comparable to groundwood.
- 3) Chemical requirements of around 200 lb. of sodium sulphite/CDT.
- 4) A continuous process suitable for automatic control with minimum labour.
- 5) Pulp properties optimized for newsprint manufacture, particularly in the areas of linting, opacity, brightness, reversion, and paper machine and pressroom runnability.

The process economics are probably more dependent on paper machine runnability than on all other factors combined! Good runnability is indicated but not proven by these laboratory investigations. In the final analysis, the only fully reliable instrument for measuring runnability is a commercial high speed machine, and the final test of quality is still the pressroom and ultimately the marketplace. The performance of OPCO pulp in these most demanding of tests is the subject of the following paper.

THE OPCO PROCESS - CHEMI-MECHANICAL PULPS WITH UNIQUE PROPERTIES

PART II

To prove conclusively that a groundwood based furnish could be run efficiently on a commercial high speed paper machine using OPCO pulp as the sole reinforcing fibre was our next task. The inexpensive, low risk route of trials on experimental paper machines was explored, and yielded valuable information (5), but not the conclusive proof sought. A pilot plant to manufacture OPCO pulp for trials on our own machines was unattractive because of both the expense and the time delay. The remaining alternative was a trial in borrowed or rented commercial equipment adapted for our purposes. To make the jump from laboratory to full scale operation in commercial equipment, much of it designed for different purposes, was a high-cost - high-risk decision; it offered no opportunity to learn from experience, and all key parameters had to be guessed right the first time. However, no other option was available.

The requirements for a commercial trial with borrowed or rented equipment were a high-speed paper machine, preferably a fourdrinier with open draws, in proximity to a TMP plant; a groundwood plant; a continuous reactor capable of processing the required 50 - 100 tons of pulp in a reasonable time, and lastly, a willingness on the part of the owners of this equipment to participate in this venture.

Facilities throughout North America and Europe were surveyed and only one really satisfactory combination was located. We were fortunate indeed to secure the cooperation of the United Paper Mills in Finland. Their assistance was vital to the success of the enterprise.

Using our best guesstimate of the degree of refining needed to produce the required stress-strain properties in the OPCO product, TMP was produced in the Kaipola tandem system at a target freeness of 250 CSF, blown to trucks and shipped to the Tampella mill at Heinola for reaction. The reactor was designed to make fluting stock from a chip feed. Only through the heroic efforts of the Tampella crew was it possible to adapt it to our purpose in the available time.

The treated pulp, trucked back to Kaipola, was not screened because the freeness was already a little below target, and a short trial indicated that a freeness drop of another 30 points could be anticipated after screening. The pulp appeared clean, with a low shive content. It was centri-cleaned in a regular 3-stage system at a reject rate of 1.5 %.

The resulting product was a typical OPCO pulp. Figure 9 compares latent and delatent stress-strain properties of this pulp with some OPCO pulps produced in other equipment and regarded as typical, and with the TMP starting material. Other points in the figure indicate the inferior properties of an UHY pulp, and the superb properties of the Kaipola chemical pulp furnish which the OPCO pulp was intended to replace. It concluded that the OPCO pulp prepared in Finland was representative of the process, and in no way exceptional. Table I shows the latent and delatent properties of the pulp and compares them with the properties obtained on the untreated pulp.

Our original intention was to use a mechanical pulp furnish of 100 % groundwood in the trial but this was not possible because of the mill set-up; the highest percentage which could be supplied was 70 % groundwood with 30 % TMP. However, Table II shows that the properties of Kaipola groundwood produced on Roberts grinders, in mixture with 30 % TMP, are comparable to 100 % groundwood, produced on Waterous magazine grinders at Q.N.S.

The final test of all our theories came at 1400 hours, September 5, 1979 at Kaipola, Finland, when chemical pulp consisting of 9 % LYS and 9 % SBK was replaced in a single step with 33 % OPCO pulp on # 5 fourdrinier machine running 30 lb. B.W. at 2400 ft./min. This moment went completely un-noticed by the paper machine, which continued to run as though nothing had happened. OPCO content was reduced to 28 %. There was no change in dry line, in vacuums or in steam consumption. Draws were reduced slightly - a sign of a strong well drained sheet. After about 3 hours, a single break occurred. The tail rethreaded on the first try and the machine was reeling paper again in 6 minutes. Duration of the trial was about 7 hours. More important than the test data, recorded in Table III, was the reaction of highly qualified observers from both companies. There was unanimous and unqualified agreement that our goal of replacing low yield chemical pulp in a newsprint furnish had been achieved.

Most companies feel that being able to sell paper is at least as important as being able to make it. Pressroom acceptability was assessed on both continents.

Offset printing was assessed in a small run at Koillis-Hame, and in a 20,000 copy run at 26,000 i/hr run at Aamulahte in Finland, followed by 218,000 copies at 45,000 i/hr at Ft. Lauderdale. There were no breaks due to paper in any run. Linting was not a problem; at Ft. Lauderdale the lint was considered about equal to that of an ordinary twin wire sheet. Print quality was at least equal to normal production.

At the Washington Star, 131,000 copies were printed by Letterflex, without breaks, wash-ups, or problems. Print quality was marginally better than normal Q.N.S. production. Showthrough was normal and set-off was not a problem. The OPCO sheet meets the demands of the modern press-room in the critical areas of strength, linting, opacity and print quality.

A solution is now at hand to one of the major problems facing the North-American industry - what to do with the groundwood mill. This capacity is installed, paid for, and proven. Groundwood is the major component, and the cheapest component of our newsprint, but traditionally it has required reinforcement with chemical pulp. If chemical pulp is retained, we are faced with huge expenditures for recovery and pollution abatement processes. Often we cannot even be sure in advance that these processes will work. The past decade's record of mill closures in the East is testimony to the gravity of this problem.

If the chemical pulp is abandoned, and the switch made to TMP, the groundwood capacity is rendered obsolete and a host of new problems appear centered on bulk, opacity, linting, and energy. It is worth repeating that the OPCO process, in a mill trial, yielded a low linting sheet from an unscreened pulp prepared from a 250 CSF TMP, at a specific refining energy of only 75 HPD/T. The Finnish trial showed that by substituting OPCO pulp for chemical pulp, we can retain our groundwood mills, reduce pollution to manageable proportions, and reduce our wood requirements without penalty in energy costs or in paper machine or pressroom runnability.

The OPCO process offers an economically attractive way of satisfying the various demands of the paper makers and printers, as well as the conservationists and environmentalists.

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ENVIRONMENTAL ACCEPTABILITY

QUALITY

Brightness & Reversion

Opacity

Linting

Printability

ECONOMY

Wood

Labour

Energy

Chemical

Capital

RUNNABILITY

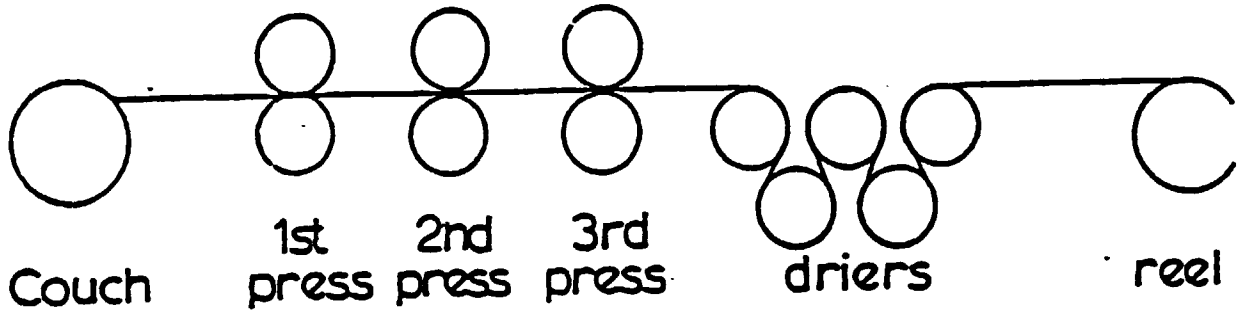
Pressroom

Papermachines

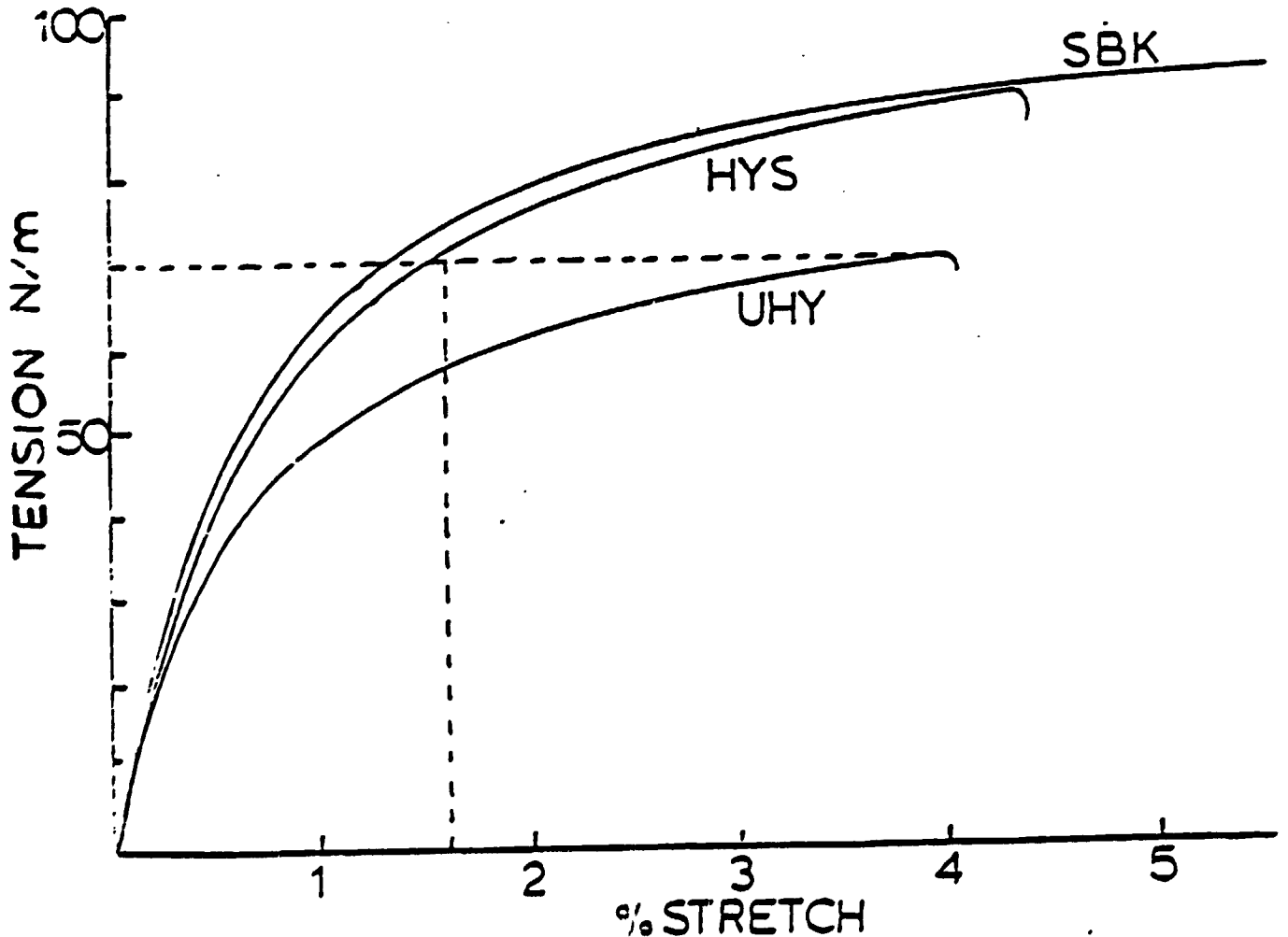
FIGURE 2

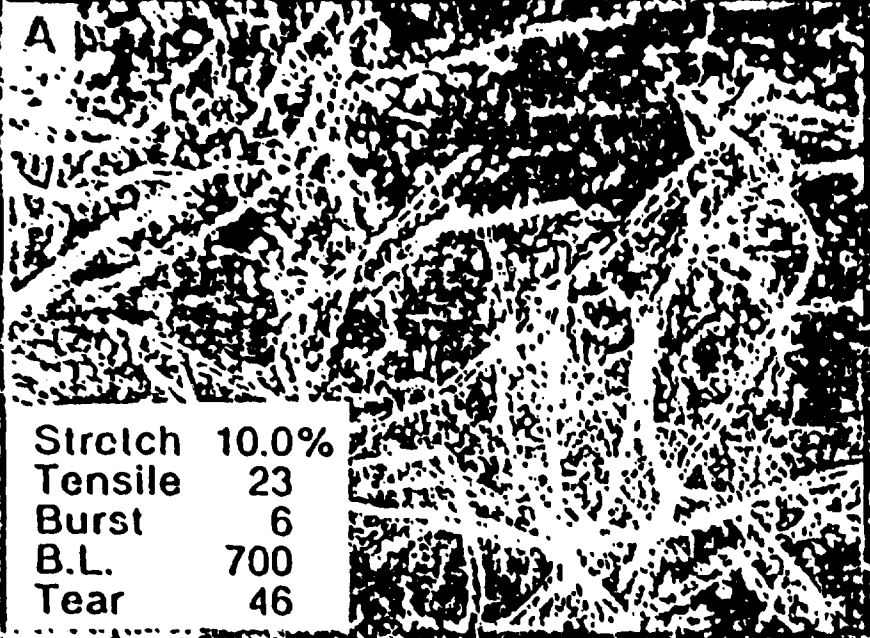
QNS no 3

Solids	15%	30.2%	34.3%	36.5%	93.1%
Draws	0.4%	1.6%	0.7%	0.3%	



Mixed Stock Wet Web Properties

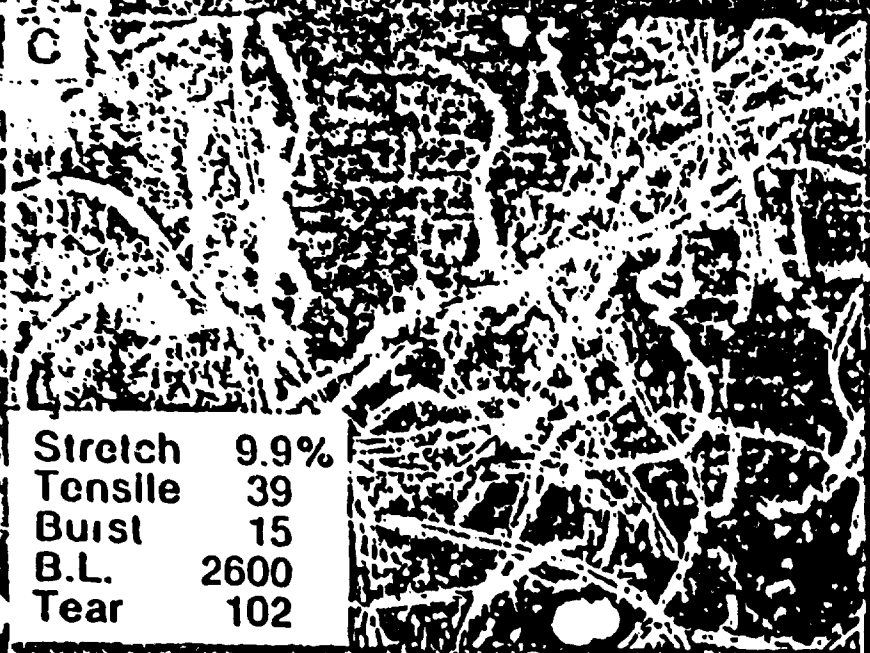




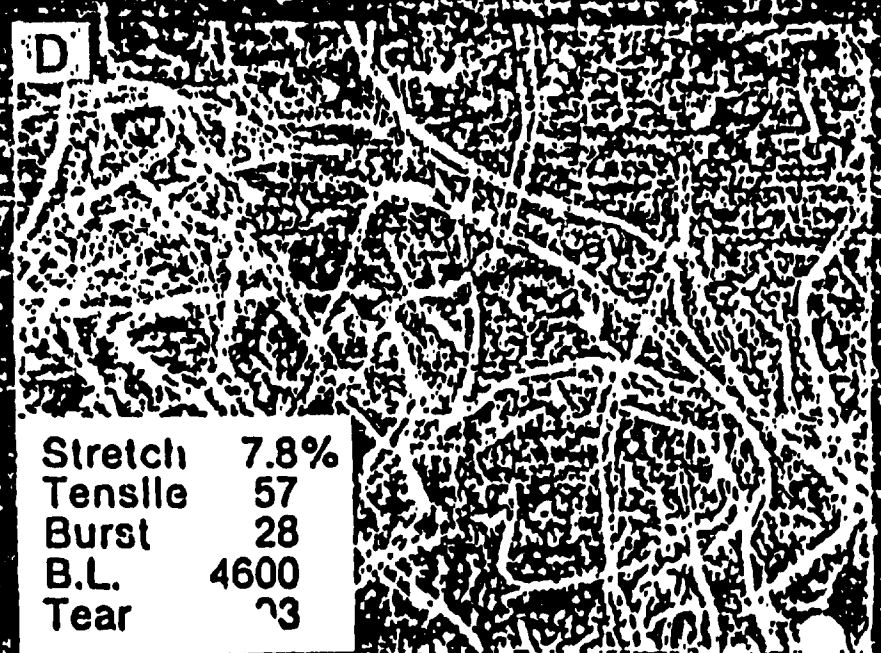
Stretch	10.0%
Tensile	23
Burst	6
B.L.	700
Tear	46



Stretch	4.5%
Tensile	57
Burst	14
B.L.	2500
Tear	98



Stretch	9.9%
Tensile	39
Burst	15
B.L.	2600
Tear	102



Stretch	7.8%
Tensile	57
Burst	28
B.L.	4600
Tear	73

FIGURE 4

COMPARISON of WET WEB
PROPERTIES

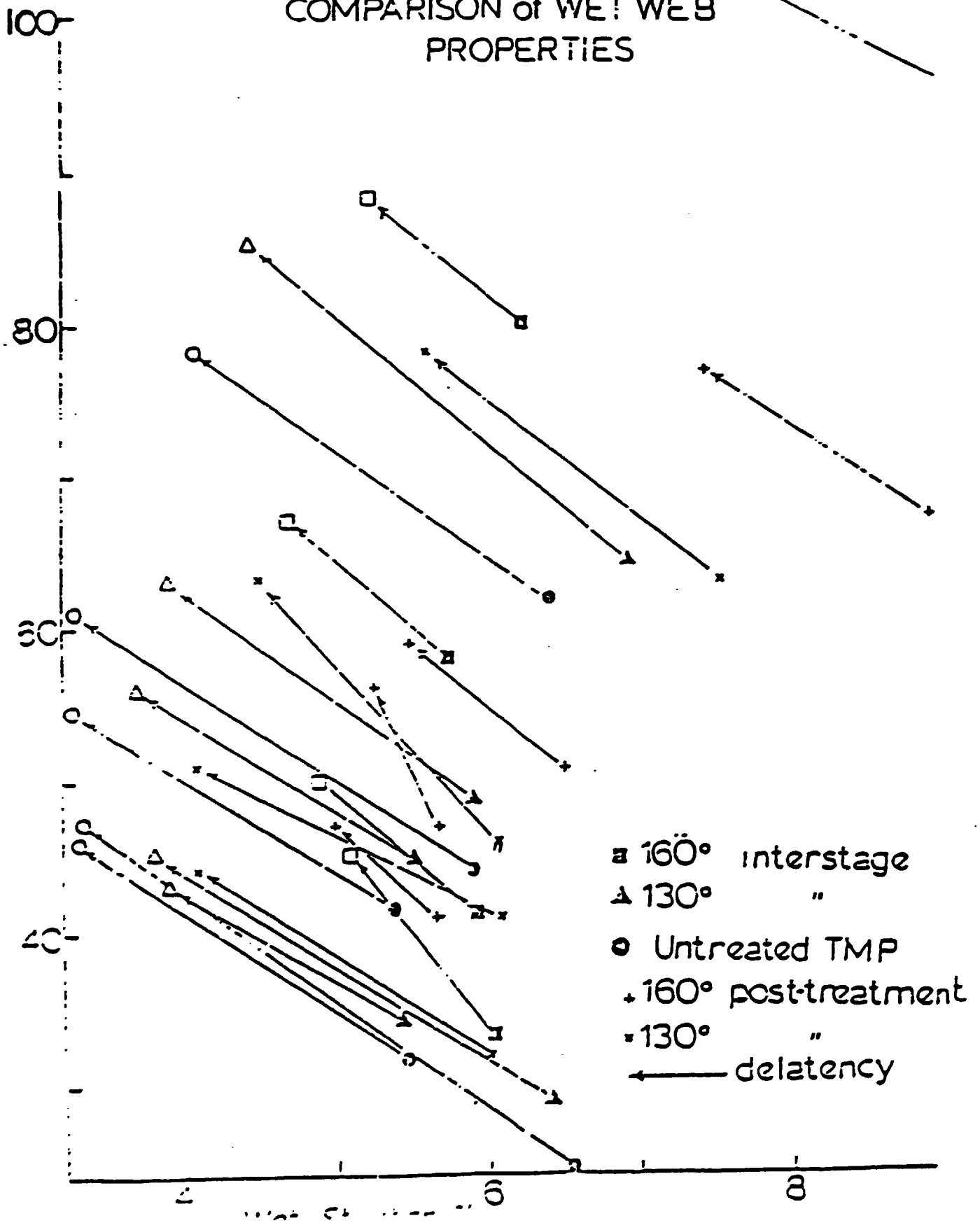


FIGURE 5

REFINING of Opco PULP

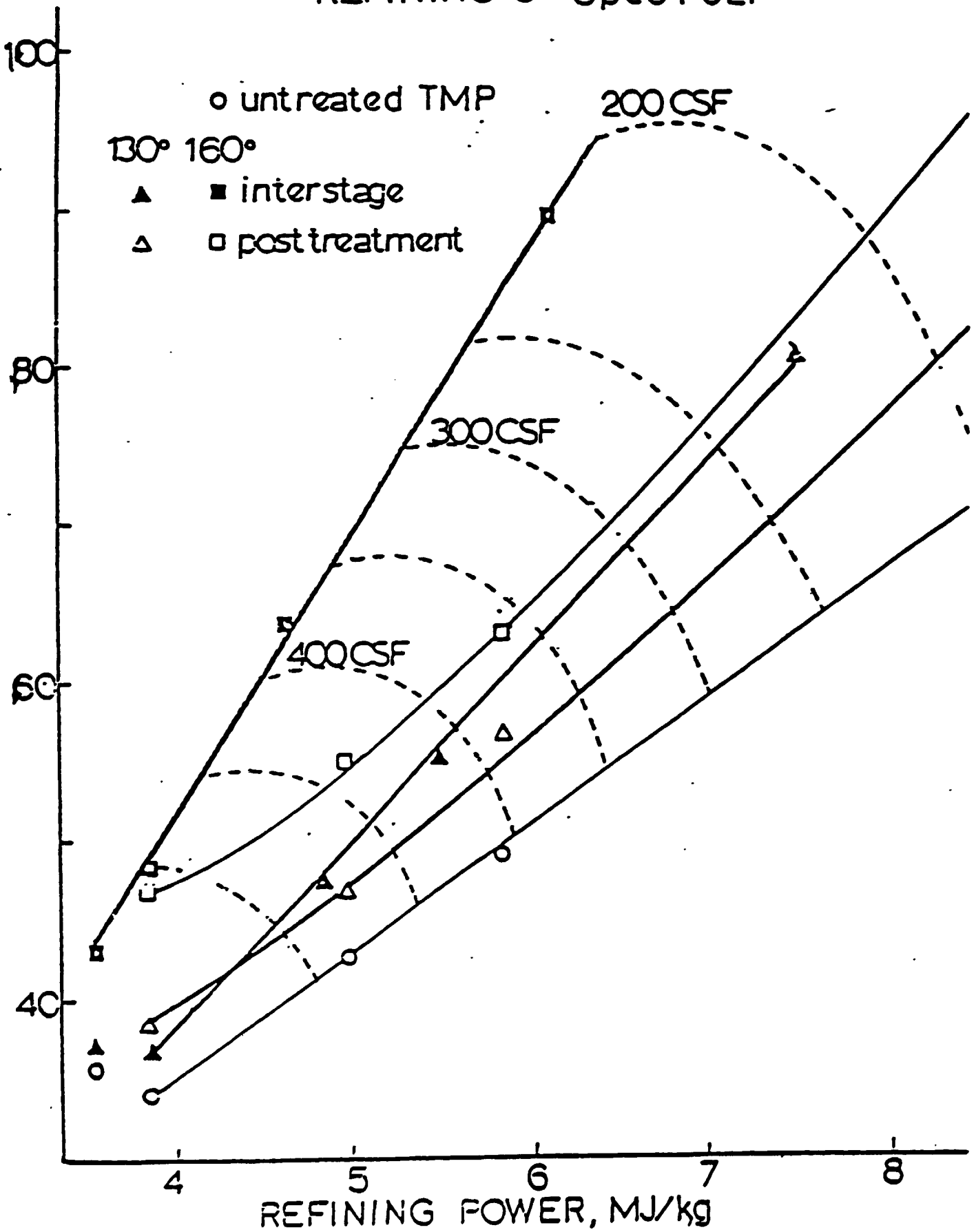


FIGURE 6

REFINING of Opco PULP

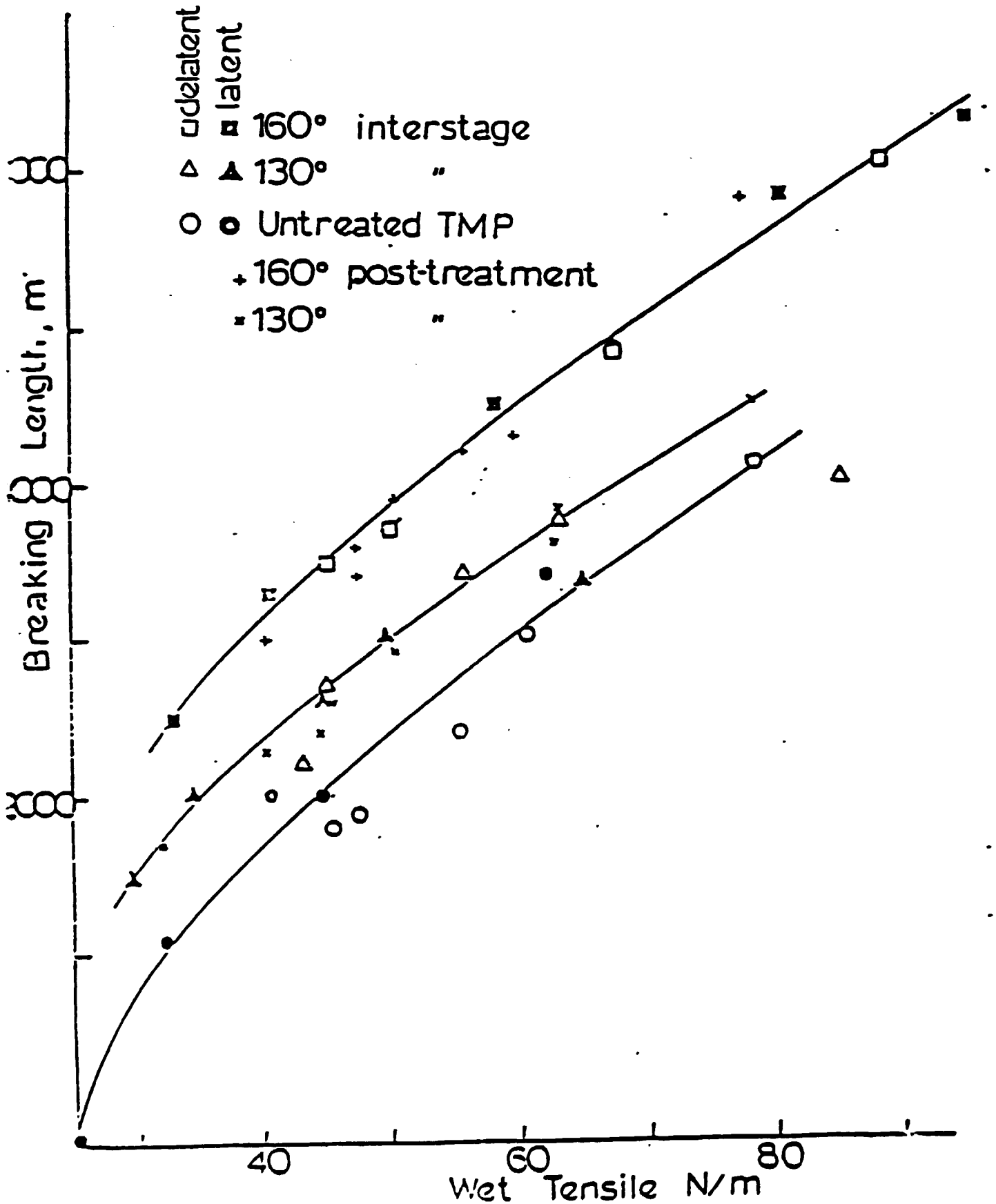
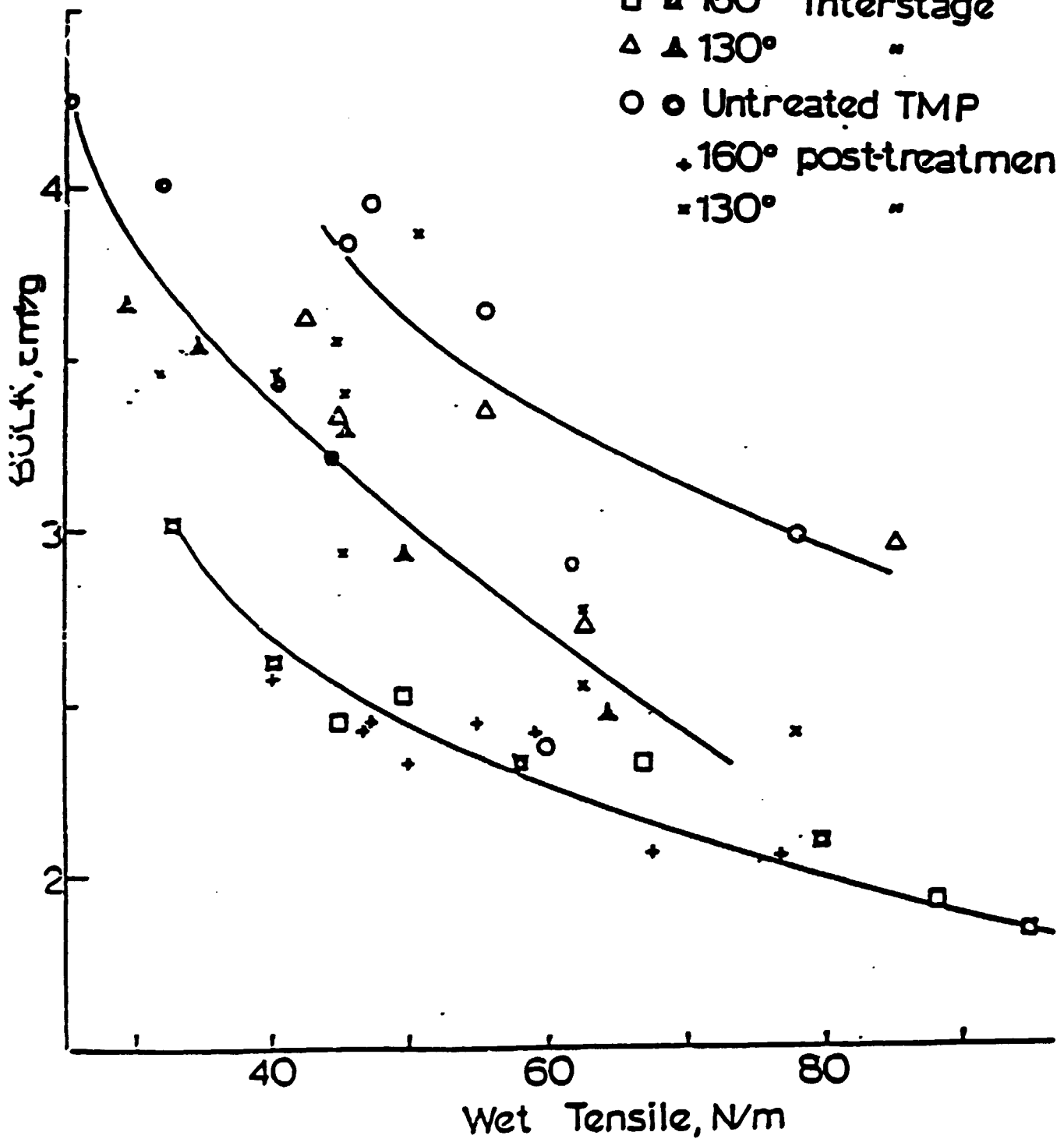


FIGURE 7

REFINING of Opco PULP

- delatent
- latent
- △ 160° interstage
- ▲ 130° " "
- Untreated TMP
- + 160° post-treatment
- × 130° " "



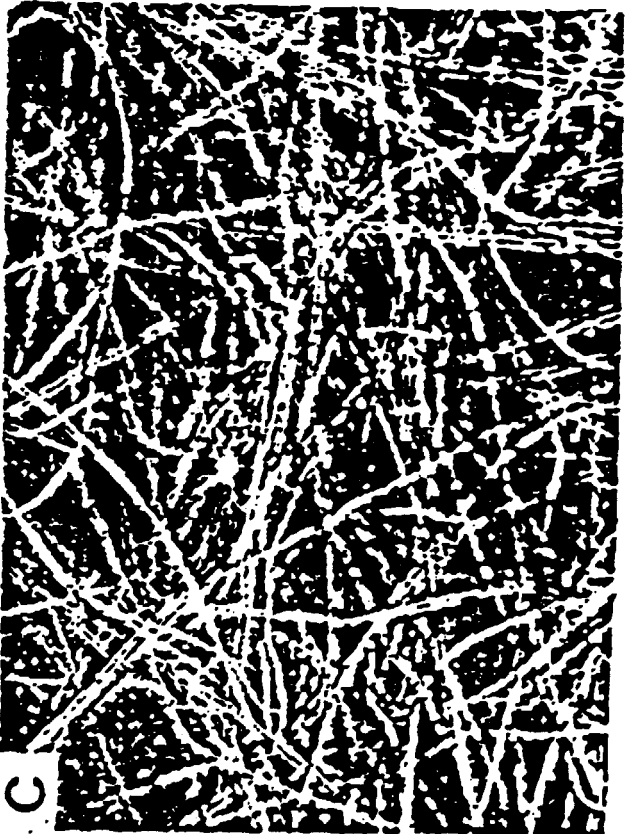
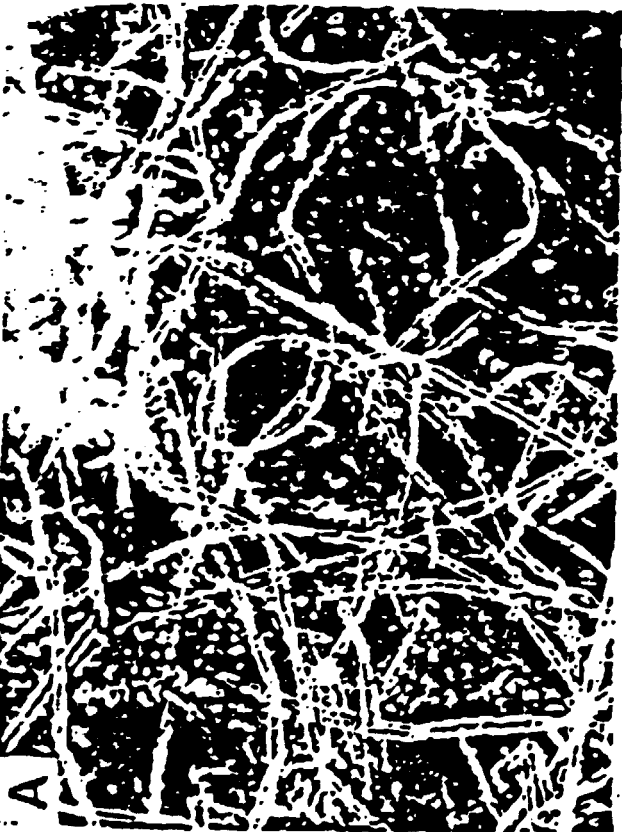
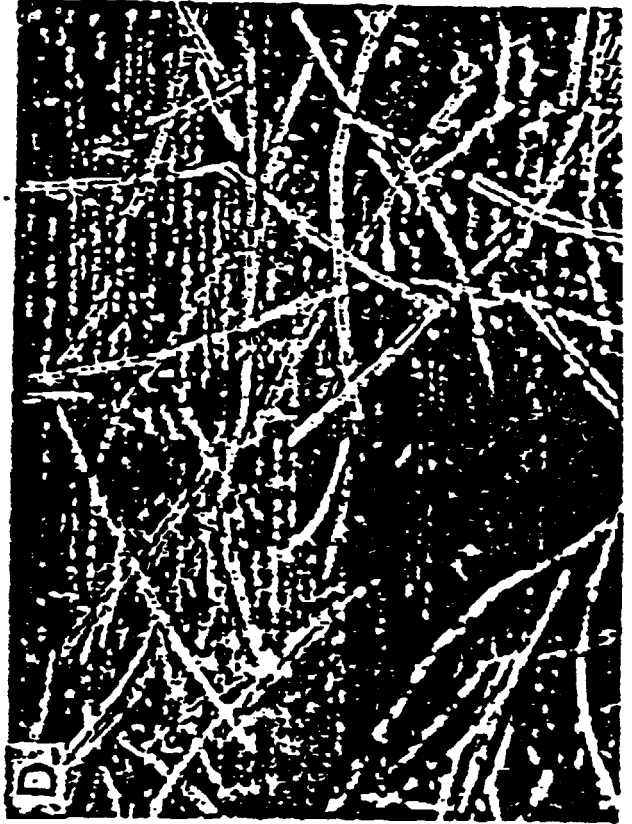
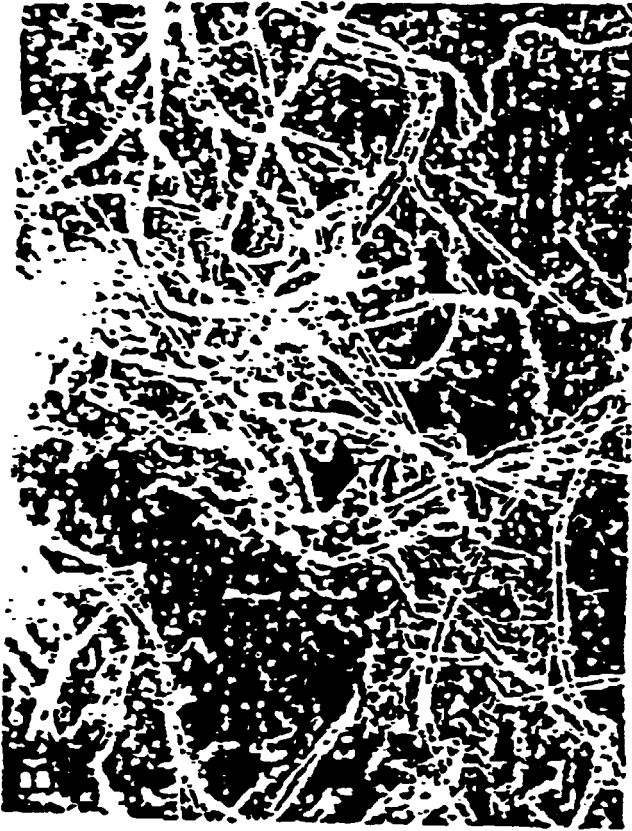


FIGURE 9 · COMPARISON of PULPS

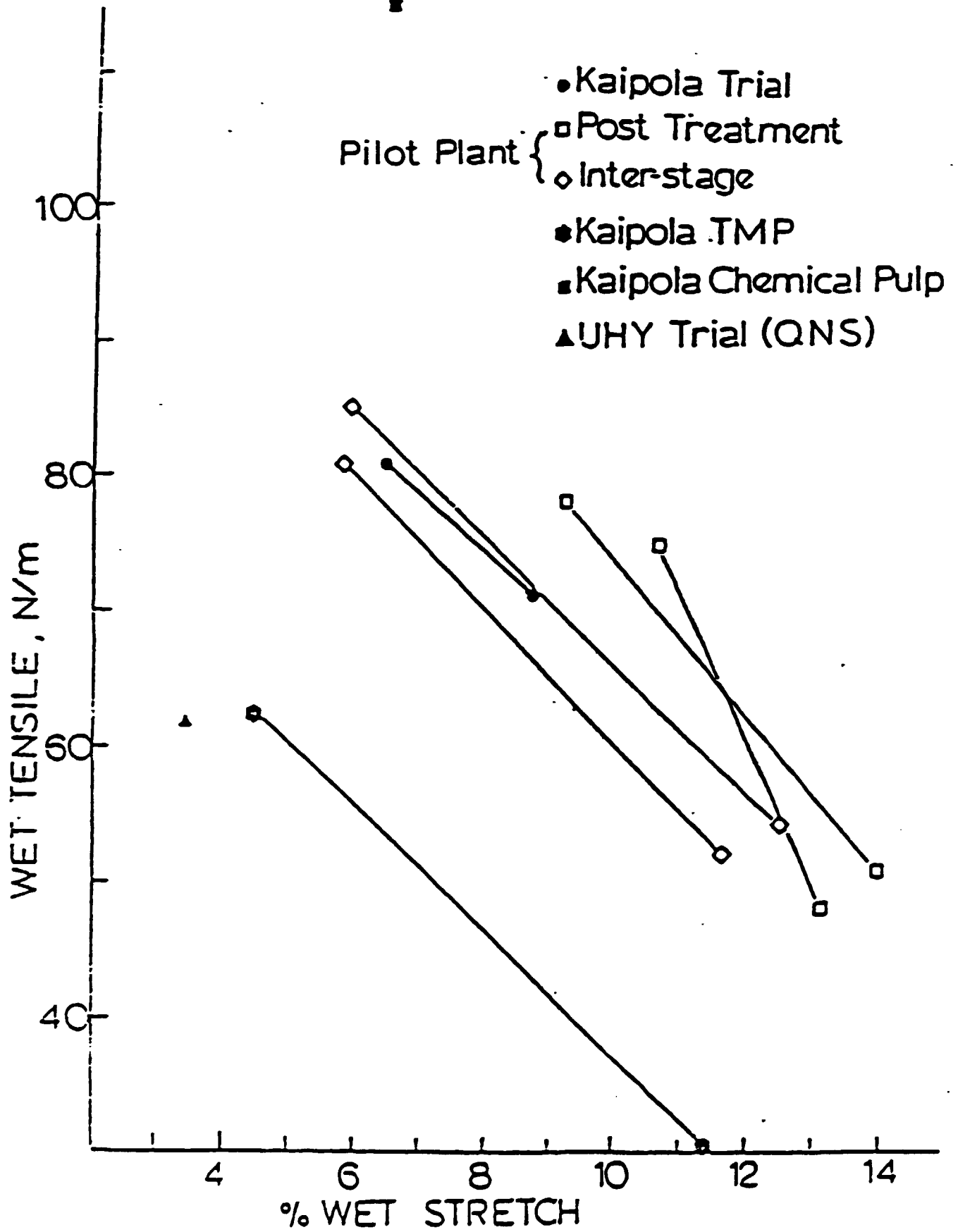


TABLE I

OpcO Pulp

	<u>Untreated</u>		<u>Treated</u>	
	<u>Latent</u>	<u>Delatent</u>	<u>Latent</u>	<u>Delatent</u>
Freezess, CSF	493	265	186	178
Drainage, secs.	0.59	0.74	1.19	1.31
<u>Wet Web Properties</u>				
Tensile (N/m)	30	62	71	81
Stretch (%)	11.3	4.4	8.7	6.5
Caliper (mm)	0.450	0.387	0.335	0.318
<u>Dry Properties</u>				
Bulk	3.55	3.20	2.17	2.02
Burst Index	0.8	1.7	2.9	3.3
Breaking Length	1300	3000	4600	5300
Stretch (%)	1.7	1.6	2.2	2.4
Tear Index	8.3	11.5	9.0	8.0

TABLE II

Mechanical Pulp

	<u>Kaipola</u>	<u>Q.N.S.</u>
Freeness (CSF)	100	78
Drainage (secs.)	2.30	2.56
Wet Tensile (N/m)	67	67
Wet Stretch (%)	5.6	5.0
Burst Index (kPa m ² /g)	1.7	1.6
Tear Index (mN m ² /g)	5.8	4.9

TABLE III

Paper Machine Trial

		<u>Before</u>	<u>During</u>	<u>After</u>
Furnish				
Groundwood	(%)	57	50	58
Trp	(%)	25	22	26
Semibleached kraft	(%)	9	0	8
Unbleached sulphite	(%)	9	0	8
Opco pulp	(%)	0	28	0
P.M. Conditions				
Wire speed	(m/min)	693	694	695
Reel speed	(m/min)	724	724	724
Headbox pressure	(kPa)	63.2	63.8	63.3
Slice opening	(mm)	10	10	10
Supercalender speed	(m/min)	700	700	700
Linear pressure	(K N/m)	190	190	190
Paper Characteristics				
Basis weight	(g/m ²)	48.1	49.8	48.7
Bulk	(cc/g)	1.56	1.57	1.56
Tensile Index M.D.	(Nw/g)	44.5	41.9	41.2
Stretch M.D.	(%)	1.05	1.13	1.11
Tear C.D.	(mN m ² /g)	222	196	203
Burst Index	(kPa m ² /g)	1.43	1.31	1.32
Roughness 1 kg T.S.	(m/min)	86	101	87
W.S.		97	104	92
Brightness I.S.O.	(%)	60.9	59.2	61.2
Opacity I.S.O.	(%)	93.9	93.6	93.6
Porosity	(m/min)	224	213	216
Caliper uncalendered	mm	120	127	123
calendered	mm	75	78	76

NSCMP^R - HIGH YIELD PULPING PROCESS
FOR SMALL PULP MILLS

by

P.K. Kauppi

INTRODUCTION

Of all the process variables present in pulping of woody materials, chemicals have perhaps the most significant impact to the capital and operating costs of a pulp mill. The chemicals influence selection of construction material for the equipment, need for environmental pollution control, and design of the chemical recovery system. The type and rate of chemicals used in pulping determine the energy requirements for the mechanical fibre separation following the chemical treatment stage.

The most dominating force in the development of the Non-Sulphur Chemimechanical Pulping (NSCMP) process has been the commitment to develop a high-yield process which is environmentally sound and simple enough for implementation in small pulp mills. In order to achieve this objective, it was believed that sulphur free pulping chemicals would be most desirable. Sufficient weakening of fibre bonding with sulphur free chemicals was sought to minimize the energy requirements for mechanical fibre separation, as well as to reduce, or completely eliminate, the requirements of chemical recovery.

PULPING

The NSCMP process (6) is covered by a U.S. patent (5) and other patent applications (Assignee: New Fibres International Inc.). The process description together with results of the pulping and paper-making trials have been presented in several publications.

The NSCMP, a high-yield (80 - 90 %) process, is suitable for small and medium-size pulp mills pulping hardwoods, mixtures of woods, and non-wood fibres. This straight-forward and environmentally promising process demonstrates good fibre separation and low refining energy consumption. These highlights of the process are created due

to the affinity of the NSCMP chemicals towards the fibre structures of wood. Impregnation of chemicals into fibre structures followed by vapour-phase cooking appears to be ideal for the NSCMP. The impregnation liquor is a mixture of monoethanolamine and ammonium hydroxide in dilute water solution.

The initial pH, at the start of the cook, is normally below 12.0 and the actual pH depends on the chemical charge and ratio of the chemicals. The latest work has revealed that the pH at the end of the cook is not as critical to the pulp properties as first believed. With a low pH at the end of the cook, only a trace of residual (active) chemicals remain in the digester. This way the pulping chemical consumption can be kept very low and the need for the chemical recovery is practically eliminated.

Over 90 % yield aspen NSCMP pulp was produced (1,2,3,4) with good pulp properties at 350 - 500 ml, CSF and the total refining energy consumption of only 250 kWh/t. A high freeness aspen NSCMP paper was produced on a pilot paper machine with excellent sheet formation and good runnability characteristics. Table 1 compares the pulp properties and Table 2 the refining energy consumptions respectively, of various high-yield hardwood pulps, including NSCMP. Figure 1 illustrates a schematic diagram for aspen NSCMP pilot plant pulp and papermaking trials. The test results clearly confirm that the high-yield NSCMP has excellent fibre separation, extremely low refining energy consumption without heat recovery and good properties at high freeness levels. None of the aspen NSCMP pulp samples were screened.

Table 1 Typical Properties of Various Hardwood Pulps

	NSCMP	NSCMP	NSSC	CMP	SCMP	CTMP	TMP
Wood Species	Aspen	Aspen	Aspen	Aspen	Poplar	Aspen	Aspen
Treatment Time, min.	15	15	21	15	30	60	15
Pulping Yield, %	88.8	91.7	82.9	84.6	90	89.3	90.5
CSF, mL	420	405	400	393	350	80	80
Density, g/cm ³	0.60	0.58	0.46	0.34	0.49	0.62	0.52
Breaking Length, km	5.10	4.85	3.97	2.26	4.8	5.23	3.
Tear Index, mN.m ² /g	6.15	6.63	8.08	3.89	7.1	3.18	2.18
Burst Index, MN/kg	2.79	2.49	2.15	1.10	1.5	2.23	1.16
Ring Crush, kN/m	1.68	1.34	1.06	0.96	-	-	-

Table 2. Typical Refining Energy Consumptions of Various Hardwood and Softwood Pulps.

	NSCMP	SCMP	CTMP	TMP	PGW	GLSC	
Wood Species	Aspen	Spruce-Balsam	Black Spruce	Black Spruce	Soft-Wood	Hard-Wood	**
Pulping Yield, %	91.6	89-92*	94	96	95-97*	74-76	
CSF, mL	365	300-400	100	125	100	342	
Total Refining, Energy MWh/t	0.25	1.4-1.5	2.2	2.7	1.4	0.33	

* Approximate yield

** Predominately oak and gum

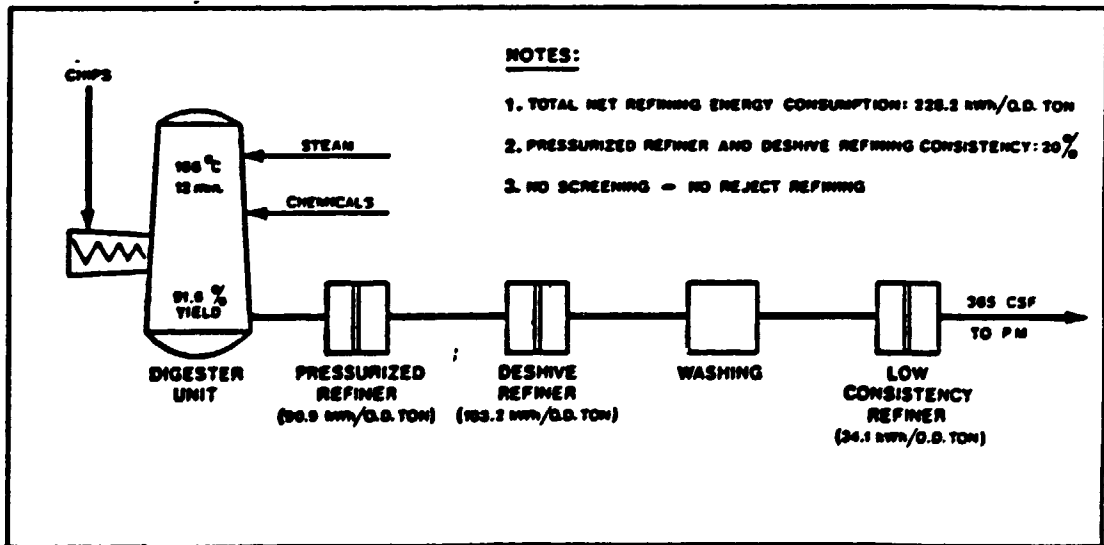


Figure 1. Simplified Pilot Plant Pulping Flow Diagram.

Mixed Southern U.S. hardwoods have been successfully pulped by the NSCMP process. Table 3 shows the results on handsheet testing of three unscreened NSCMP pulp samples of which one sample was mixed with 25 % waste clippings, and a commercial NSSC pulp sample mixed with 30 % clippings. The chips for the NSCMP cooks were atmospherically presteamed for 10 minutes, impregnated with chemicals and vapour phase cooked for 15 - 25 minutes at 170°C. Liquor to wood ratio of 3:1 was maintained in the impregnation stage, and the impregnation liquor was prepared by mixing fresh chemicals and water. The cooked NSCMP chips were defiberized in the Sprout-Waldron Model 105 refiner and beaten to the final freeness in a Valley beater. TAPPI handsheets were made and the physical properties of handsheets were determined in accordance with TAPPI Standard Methods.

Table 3. Typical Handsheet Properties of Mixed Southern Hardwood * NSCMP and NSSC Pulp Samples

	NSCMP 1	NSCMP 2	NSCMP 3	NSSC
Pulping Yield, %	83.7	83.4	86.0	72-78
Amount of Pulp, %	100	100	75	70
Amount of Clippings, %	-	-	25	30
CSF, mL	300	320	403	222
Density, g/cm ³	0.49	0.4	0.49	0.46
Stretch, %	2.63	1.70	2.39	2.10
Tensile Index, kN.m/kg	36.6	30.0	33.5	33.14
Tear Index, mN.m ² /g	5.85	4.40	8.83	6.61
Burst Index, kPa.m ² /g	1.74	1.48	1.69	1.69
Concora, N	273	235.7	237.5	217
Ring Crush, kN/m	1.35	1.42	1.33	1.59

* Predominately Oak

The impregnation liquor of the NSCMP contains only a small amount of chemicals on O.D. fibre basis. The impregnation and cooking conditions can be varied considerably, as was the case between the NSCMP 1 and the NSCMP 2 samples shown in Table 3. The pulping tests confirm good

flexibility of the process with these two chemicals. The optimum pulping conditions, including the ratio of the impregnation chemicals, can be determined on the basis of wood species, desired pulp properties and other conditions.

The preliminary laboratory work on the production of 82-88 % yield kenaf and wheat straw NSCMP pulp has revealed encouraging results. The bleaching work on various wood and non-wood NSCMP pulps indicate that the pulp is bleachable and that pulp properties are considerably improved by bleaching.

RECOVERY

When, for one reason or another, pulping is carried out under conditions where recoverable residual cooking chemicals remain in the digester at the end of the cook, chemicals may be recovered from the process relief vapours. A small amount of residual chemicals could remain in the waste pulping liquor discharged from the pulp washing. A portion of the weak waste liquor may be reused in the pulping. The balance could be evaporated to produce strong waste liquor and burned in a boiler as a high-heat-value (10,000 BTU/lb) liquid fuel, or used as a base (sulphur and sodium free) for the production of lignin by-products. If the NSCMP mill is located on the same mill site of an existing Kraft or Soda mill, it would be possible to dispose of the NSCMP waste pulping liquor in the existing recovery boiler without upsetting the chemical balance of the existing mill.

ENVIRONMENTAL

The gaseous emission from the NSCMP pulping process, including evaporation and liquor burning, are sulphur and sodium free.

Disposal of the NSCMP waste pulping liquor through the existing mill effluent treatment system is possible, but will depend on the current mill operating conditions, and the existing regulations governing the characteristics of the treated effluent discharges entering into receiving waters. Since the NSCMP is a high-yield process, the BOD₅ generated in an NSCMP mill may be reduced to an acceptable level with modern effluent treatment techniques.

CONCLUSIONS

After completion of several years' extensive laboratory and pilot plant work, the development of the NSCMP process is sufficiently advanced for full-scale mill use on the production of high-yield (80 - 90 %) pulps from hardwoods, mixtures of woods and non-wood fibres. The process can use conventional alkali-resistant pulping equipment and, therefore, is suitable for not only new pulp mills, but also for existing mills requiring modifications and/or expansions.

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THE NACO PROCESS
- A SELECTIVE PULPING PROCESS FOR ANNUAL FIBRE RAW MATERIAL

by
T. Franzén

THE NACO PROCESS FOR ANNUAL FIBRE RAW MATERIAL

Summary

This report shall be seen as an intermediate report for a project in Foggia, Italy, where the first Naco process is involved. Today the new digesting plant based on the Naco concept has been in operation for some eight months. The new digesting plant is designed for a production capacity of 100 ADMT/24 h. The production capacity of today is by means of a too small paper mill limited to around 80 ADMT/24 h. The pulp properties from the chemical pulping of wheat straw are well comparable with the corresponding pulp properties from sulphate digesting of Birch or Eucalyptus, why we today dare to say that there are new possibilities to produce excellent pulp from annual fibres raw material.

Later the new recovery system will be started and the total Naco process will be tested. The recovery system is delivered from Lurgi, West Germany. The recovery system consists of an evaporation plant and a recovery boiler, where the liquor from the new Naco pulp washing plant will be first evaporated and then burnt in the recovery boiler and Na_2CO_3 will be recirculated to the digesting plant.

Later a new bleach plant will be built based on the Ozone bleaching technique. In Foggia a new concept for Ozone bleaching has been tested in a pilot plant, which now is ready to be evaluated in a new production plant in Foggia. The new Naco pulping technique means a process almost completely free from pollution problems. The environmental regulations in Italy have forced the new technique and it has for Sunds Defibrator been a big challenge to participate.

GOAL AND SCOPE - FOR THE DEVELOPMENT OF A NEW DIGESTING PROCESS

For many years Sunds Defibrator had been looking for a new process for chemical pulping of annual fibre raw material. In the beginning of the 1980's a co-operation agreement was signed to try to develop a new idea emanating from Mr. Franco Nardi and his technical group in Italy.

The following scope was formed to be the goal for the new chemical pulping process of different annual fibre raw materials:

- Produce a good chemical pulp from annual raw material
- Best chemical pulp and paper properties
- Small pollution load (no sulphur and chlorine involved)
- Simple process technology
- Usable for different types of raw material
- Low in investment costs
- Low operational costs

The new pulping technique was meant to be based on using of the new turbo-pulper designed by Mr. Franco Nardi.

Only a small amount of NaOH should be added to the turbo pulper together with the straw, while Na_2CO_3 should be recovered and reused as alkali together with oxygen (O_2). The need of NaOH should only replace the actual loss of digesting chemicals (from digesting, washing, evaporation and recovery boiler), while Na_2CO_3 should be recycled from the recovery system separated from SiO_2 and organic material.

The first step was to build a "Laboratory Turbo pulper" in order to measure all basic parameters needed for future calculations of the new pulping process. The first "Laboratory Turbo pulper" (see fig. 2) was built and placed at the IPZS pulp and paper mill in Foggia, Italy. The IPZS in Italy were also willing to finance some part of the project in order to define a new process, which later could replace the existing old system.

TEST AND TRIALS

The first thing to study was the correlation between pressure and temperature by operation with NaOH and O₂ in combination, when the first trials had to be made batchwise. Fig 3 shows how the pressure develops as a function of temperature and time.

After that a number of tests with wheat straw was done in order to optimize the pulp properties against the need of digesting chemicals (from the beginning NaOH and oxygen) and digesting temperature.

Fig. 4 shows how the relation between Kappa number and charge of NaOH, when 23 - 25 % Na₂CO₃ was mixed into the pulping solution. At a Kappa number of 15 - 18, the charge of caustic soda was found to be in the region of 6 - 8 %. This chemical balance point has later been found to be very sufficient.

In fig. 5 the relation between lignin content expressed as Kappa number and pulp brightness is shown. From the figure can be seen that straw pulp of a Kappa number of 16 - 18 gives a brightness of 40 - 50 % ISO. It is also noticeable that the Kappa number below 20 gives a high increase in brightness. As can be seen from the diagram in fig. 6, the pulp strength as tensile index and tear index, is not tremendously sensitive to the delignification degree (X- No). The level is acceptable also at Kappa numbers as low as 10.

PILOT PLANT

Based on what was found in the Laboratory unit, a new continuously working pilot plant was built. The turbo pulper was given a diameter of 1.5 m and designed for the same temperature and pressure as the earlier one. The system (see fig. 7) was designed for a pulping production of around 5 ton/24 h and equipped with a small disk refiner of straw and a monopump as feeder of the straw, chemicals and dilution water to the turbo pulper. Chemicals were also foreseen to be charged directly to the turbo pulper. For rotation of the solution, the turbo pulper was equipped with a mixer in the bottom, forcing the pulp to circulate. The idea was to force the oxygen to

react very fast with the pulp in the turbo pulper in order to speed up the delignification work and oxidation of the liquor.

After the pulper the pulp is pumped over to a reactor, where a small final delignification will take place with O_2 during slow rotation via a mixer in the bottom of the reactor. The Kappa will only be some 2 units lower than in the reactor. From the reactor the pulp will be blown over to a blow tank of standard type.

In fig. 8 is shown that the results from continuous operation are better than the corresponding ones from batch digesting. The only way to explain the higher total yield at the same X - No, better pulp properties, lower reject flow etc, is that something very special was developed.

The explanation was later expressed as "a new selective digester".

This selectivity means that all particles (see fig. 9) independent of size will be in the mixture of digesting chemicals and oxygen at a certain pressure and temperature, the necessary time, in order to be almost finally digested. As the time in the turbo pulper will not be 100 % right for every single fibre, the whole fibre flow will be pumped over to the static O_2 -reactor, where the final delignification will take place in order to get an almost constant X - No. in the final pulp production.

This selectivity can be compared with the non-selective digesters, where all chips must have a uniform size to get good pulp properties at a certain time in the digester. This uniform particle size can never be reached with straw, and therefore the digester has to be selective.

Even other types of annual raw material have been tested in the turbo pulper as bagasse rice straw, saw dust and waste from Kraft and corrugated medium. In fig. 10 the results of a test with bagasse are listed. As should be noticed the bagasse raw material was unbeaten and even undepithed, which is the explanation for low drainage resistance ($^{\circ}SR$ 22).

Based on the received results from the trials with the Pilot Plant, it was decided to build a full scale production line for straw pulping at IPZS in Foggia, Italy.

RESULTS FROM OPERATION OF THE NEW PRODUCTION LINE IN FOGGIA

Since the beginning of 1985 the new Naco pulping line has been in operation on wheat straw in Foggia, Italy. From the very beginning the production capacity was 40 - 50 tBDP/24h and has since September been over 75 tBDP/24h. For the moment it is impossible to increase the production more, as the paper machines cannot take more. For the moment the only digesting chemicals used are NaOH and O₂. After new year 85/86 the recovery system will be started and put into operation and the tests with Na₂CO₃ will be started.

Produced pulp is today bleached in a 2-step NaOCl bleach plant before entering the paper machine system.

In fig. 11 the flow sheet of the new Naco digesting system in Foggia is shown. The pretreatment or depithing system is built as a wet system, where straw is mixed with water and some soda in an ordinary open pulper in order to remove wax etc. The straw is then separated from stones and sand in a cyclone separator. The straw is then fed to a washing and dewatering screw, where fresh water is showered over the straw. Finally, the straw is dewatered over a DKP-press. Washing efficiency is calculated to be around 50%, measured on the silica content.

Before entering the Naco pulping system the straw is passing a Sunds Defibrator Refiner machine, where knots are destroyed to a certain level. (Disc clearance 2 mm).

The straw will then be pumped into the pressurized turbo pulper and reactor system as the earlier described. The pressure in the system: 6 bar, and the temperature: 135°C.

In fig. 12 is shown the actual conditions measured from the Naco digesting plant in Foggia per September 30, 1985. The figures still correspond very well to the first tests, made in the laboratory test unit.

In fig. 13 the pulp properties of unbleached Naco digested pulp are shown, which correspond very well to what was received from the test runs in the Pilot plant.

The production system is today equipped with a heat recovery system installed for the blow steam, where all needed fresh water is heated to around 90°C. The pulp is then finally washed over a twin roll press, where the washing efficiency is above 90 % and hot water is used as washing water.

Some troubles with incrustations in the washing press have caused operational problems. The press has to be stopped and washed with acid and high pressure cleaning water. Today some small amounts of soda are added, which have decreased the problems.

Since the start-up of the pulping process in the beginning of the year, the stated pulp production has been kept within stated guarantee limits from the contract. Only small failures in the machinery have stopped the production at a few occasions, and therefore we have to say that the start-up of the new system has been very successful.

OZONE-BLEACHING

During the last three years, tests have even been made with different conditions of ozone-bleaching. From the literature could be found that ozone-bleaching should take place at low pH and high pulp consistency. These conditions are bad for the Naco system and annual fibre material, so other conditions had to be found.

The first test was done at high pulp consistency and at a pH of 3.5. Later some comparable test were made at a pH of 8.4. The straw was circulated in an atmosphere of ozone and oxygen in a circulating pipe system.

Bleaching results are shown in fig. 14 and tell us that low pH is not necessary to use. Other problems were the high dryness of the pulp which was setting the pulp on fire rather frequently. So another pilot for low consistency and high pH was put in operation (see fig. 15). The tests were done in the first turbo pulper built for laboratory trials which now was rebuilt and completed with a small ozonizer, for a production of O_3 gas from O_2 .

The ozone consistency in oxygen could be produced up to 6-7 % while max ozone consistency made from air could be up to 4 %. Electrical consumption when producing O_3 from O_2 was measured to 11 kWh/kg O_3 .

In the new ozone bleaching turbo pulper tests have been carried out with high pH and low pulp consistency and at a pulp temperature of 20 - 45°C. The bleaching conditions and received pulp properties are shown in fig. 16.

NEW O_3 -BLEACH PLANT

Based on carried out trials, Sunds Defibrator will very soon be prepared to offer complete O_3 -bleach plants. The design will be as shown in figure 17. First the pulp has to be cooled down from 95°C after the washing press to 30-40°C. In our described solution this is thought to be done by adding fresh water into the pulp after the dewatering press. As the dilution will go down to approx. 3.5 % the pulp is suggested to be further diluted to 1 - 1.5 % with circulating water. At these conditions the pulp will be screened over pressurized centrifugal screens. After screening the pulp will be dewatered to around 5-6 % pulp consistency. Dewatered pulp at 5-6 % pulp

consistency will then be fed by an ordinary centrifugal pump to the bleaching turbo pulpers. The pressure in the reactors will only be the static pressure of the pulp column. And therefore the pressure of the oxygen to the ozonizers only have to be some 1 bar over pressure.

The total retention time over the reactors will be some 25-30 minutes and the volume will be divided in two units in series and the pulp and ozone in counter-current.

Residual oxygen will be relieved from the turbo pulpers and then dewatered and compressed to 6-7 bar before being reused in the digesting turbo pulper and reactor as earlier described.

The bleached pulp will finally be dewatered over a washing filter before leaving for the paper mill or drying machine.

The final brightness after the O_3 bleaching will not be higher than 75 % ISO, and therefore, if desired, the pulp has to be further bleached with H_2O_2 or NaOC . .

RECOVERY SYSTEM

The total Naco-system even involves a total chemical recovery system, where spent liquor from the pulp washing plant first will be separated from solid silicates and other solid chemicals. After the solids separation of the material, the liquor will be evaporated to around 48 % and then finally burned in new way in a recovery boiler without reaction bed.

From the recovery boiler green liquor will be recovered as Na_2CO_3 , which will be reused in the digesting plant. Remaining silicates will be separated by mixing the black liquor with $Ca(OH)_2$ which in the drainage tank after the boiler will be separated as sludge.

The total system is shown in enclosed block diagram. The system shows the entire system in balance. There will also be some flow of sludge from the recovery boiler, some effluent flow from evaporation plant and some flow of washing water from the pre-treatment and bleaching plant.

There will only be a limited pollution load compared with other straw pulping processes.

CONCLUSIONS

In the field where Sunds Defibrator AB is involved in the fibre line, results obtained up till today, confirm that the pulping process meets the demands of the pulp industry. Plants based on the presented pulping process can be built:

- with relatively small capacity and are not creating logistic problems in supplying non-wood fibre raw materials;
- with an acceptable capital investment level, including a full chemical recovery system;
- with a minimum of impact on the environment.

The Naco process can be used for treating a wide range of raw materials. It is obvious that we have now shown that the process will contribute to the economical production of pulp and paper from raw materials maintained in this report.

Fig.2. Laboratory Turbopulper:

Spherical recipient, ϕ 500 mm.
Design data, 15 bar, 175 C.
Effective volume, 65 litres.

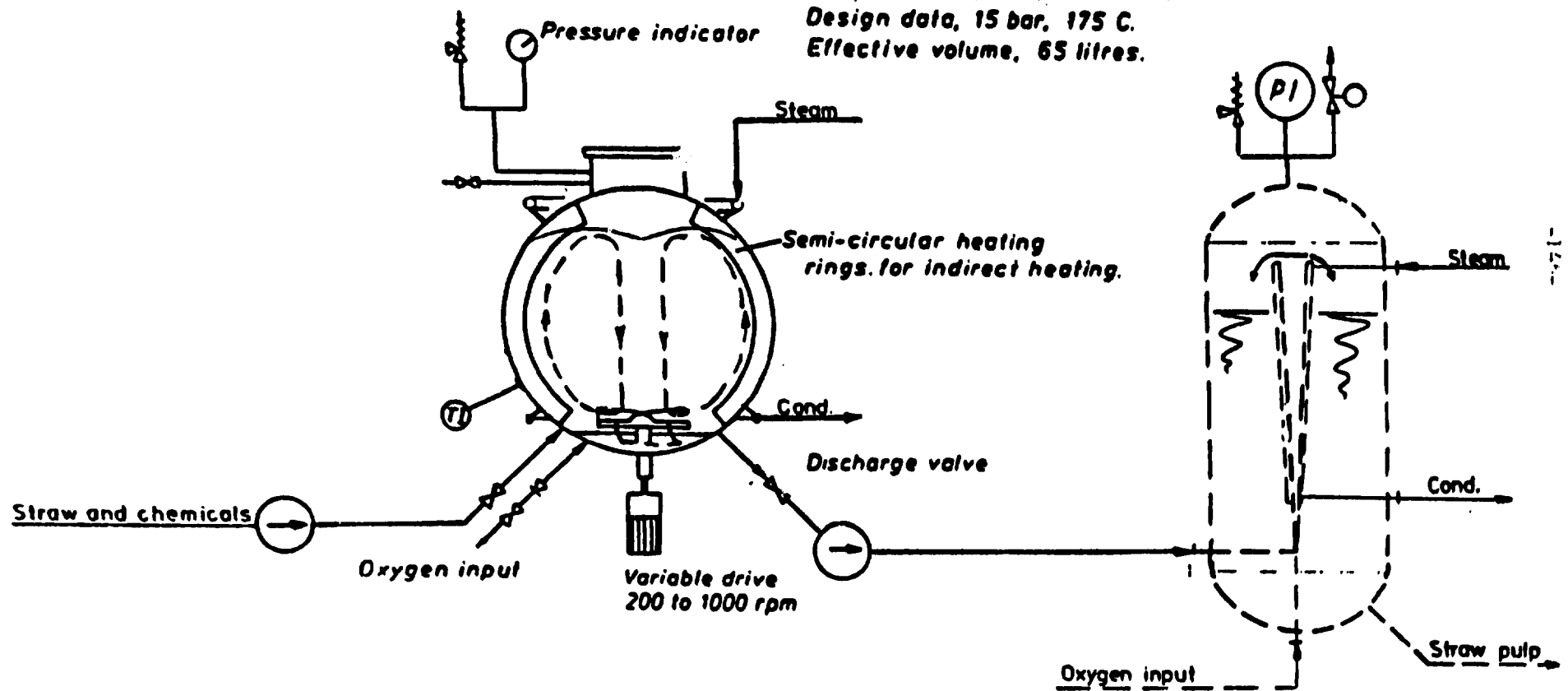


Figure 3. Straw digestion by batch operation using NaOH/O₂ in the laboratory Turbo Pulper. Pressure development as a function of temperature and time.

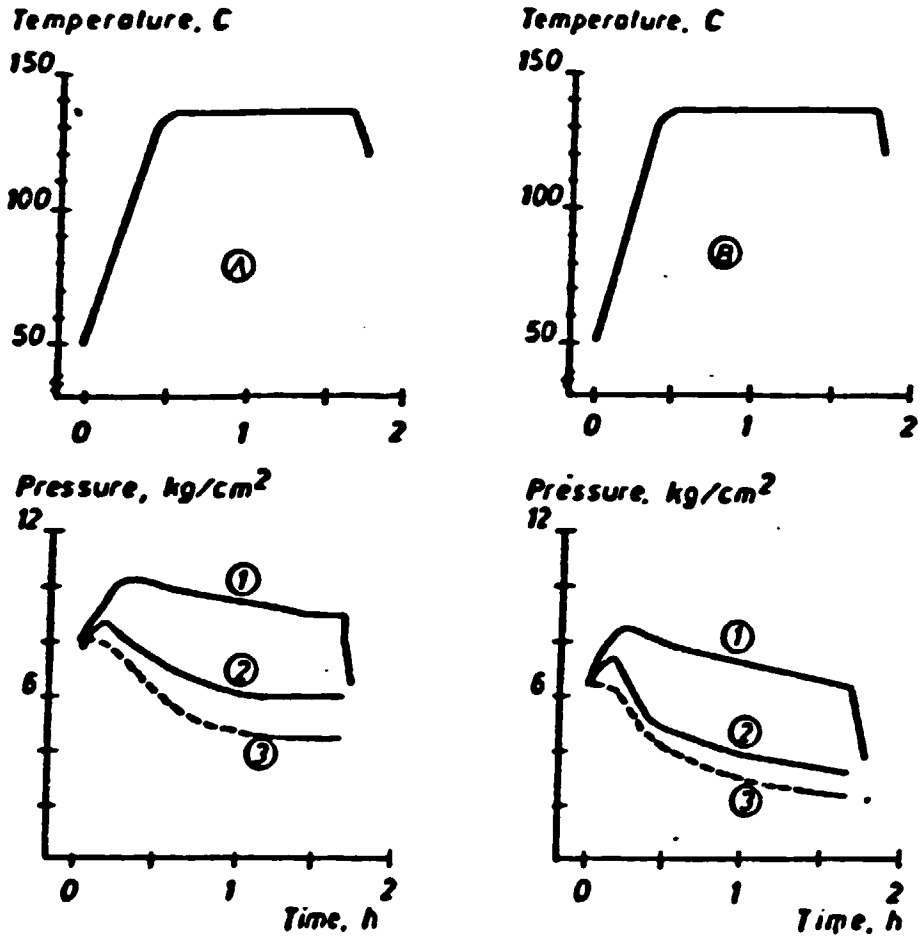


Figure (A) Initial pressure of O₂; bar at 50°C

Figure (B) Initial pressure of O₂; bar at 50°C

(1) Total pressure

(2) Partial pressure of O₂ and CO₂

(3) Ditto corrected to 50°C

Figure 4.
Wheat straw.
Relationship
between
caustic charge
and Kappa number

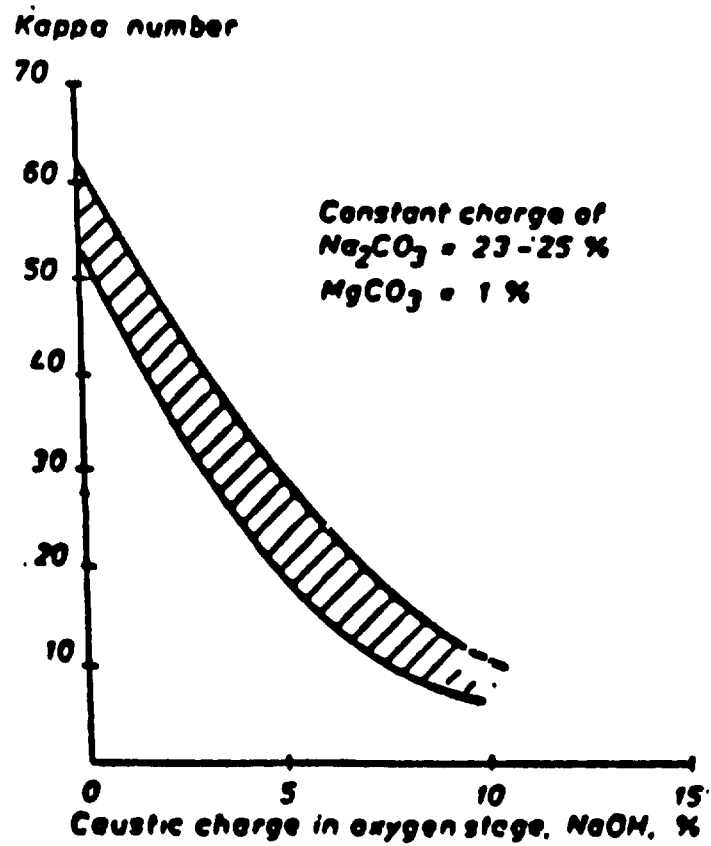


Figure 5.
Wheat straw.
Relationship between
Kappa number and
brightness, ISO.

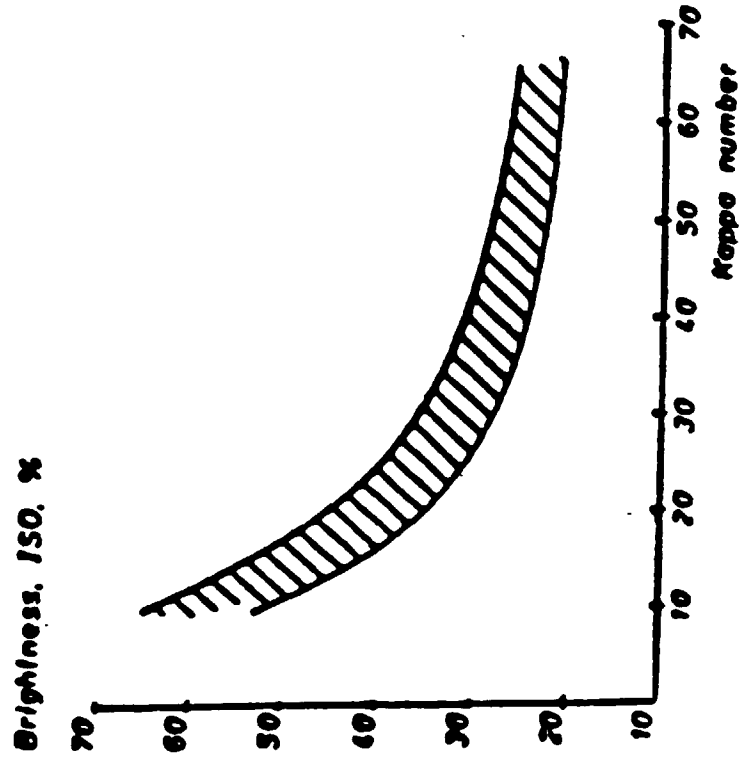


Figure 6. Wheat straw. Tensile and Tear Index vs Kappa number

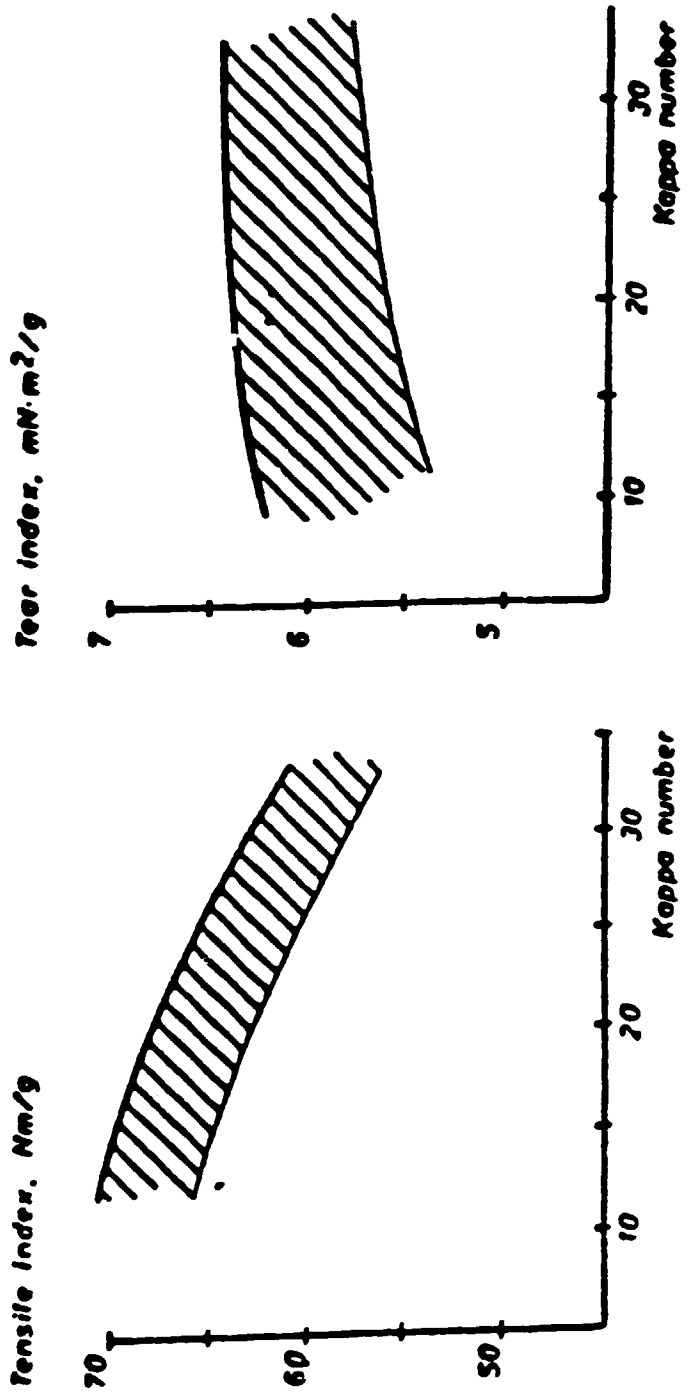


Figure 7. Flow diagram of the NACO pilot plant.

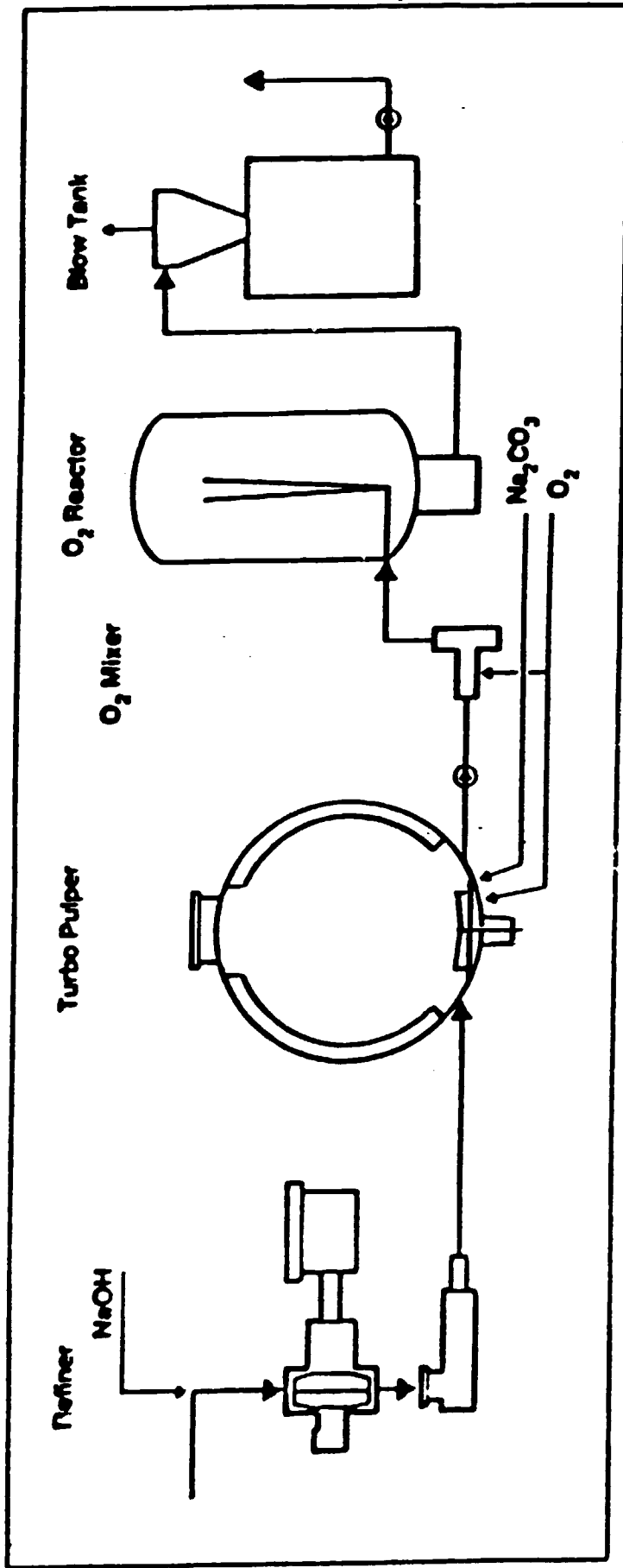


Table 1.

Continuous wheat straw pulping in the NACO pilot plant

Reaction temperature	°C :	135	
Oxygen pressure	bar :	8	
Na ₂ CO ₃ (on b.d. straw)	% :	23.3	
NaOH (on b.d. straw)	% :	5	7
MgCO ₃ (on b.d. straw)	% :	1	
Kappa number	No.:	22	11.5
Brightness (unbleached), ISO	% :	46	59
Drainage resistance	°SR :	27	26
Tensile index	Nm/g :	53	66
Tear index	mN·m ² /g :	4.6	6.1
Burst index	kPa·m ² /g :	2.9	3.5

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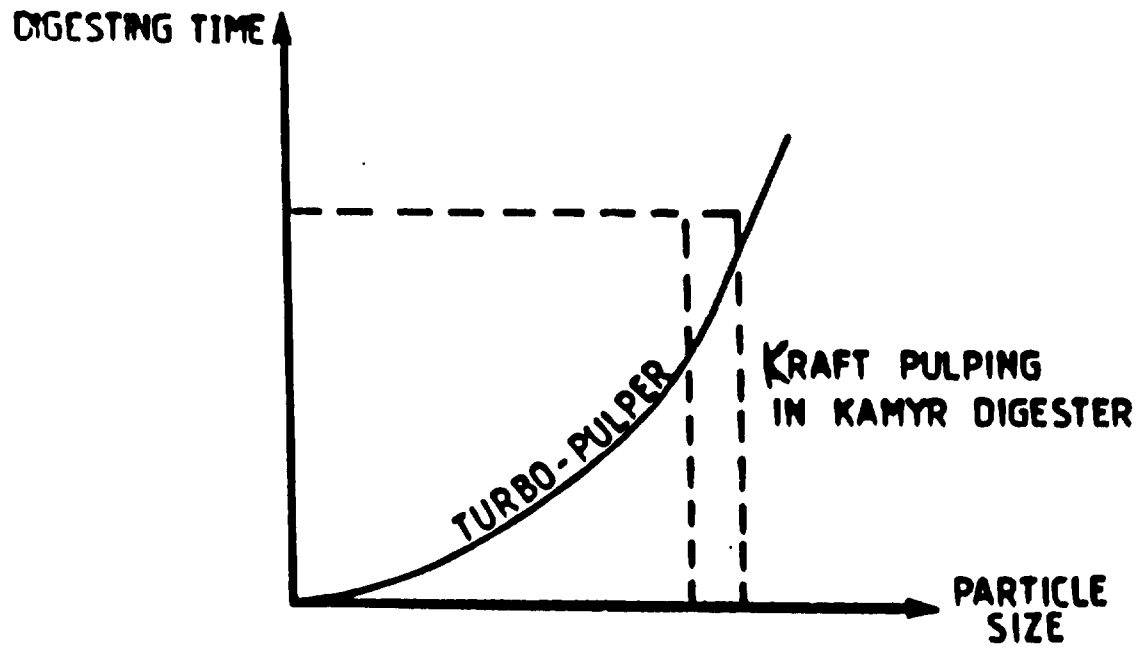


Fig. 9
 SELECTIVE GRADIENT OF TIME IN THE TURBO PULPER
 DEPENDING OF PARTICLE SIZE OF THE FEEDED STRAW
 COMPARED WITH A NORMAL CONTINUOUS DIGESTER

Table 10
Batch bagasse pulping in the NACO pilot plant

Reaction temperature	°C :	130
Oxygen pressure	bar :	7
NaOH (on b.d. bagasse)	% :	15
MgCO ₃ (on b.d. bagasse)	% :	1
Kappa number	:	16
Brightness (unbleached), ISO	% :	49
Drainage resistance	°SR :	22
Tensile index	Nm/g :	47
Tear index	mN·m ² /g :	4.2
Burst index	kPa·m ² /g :	2.0

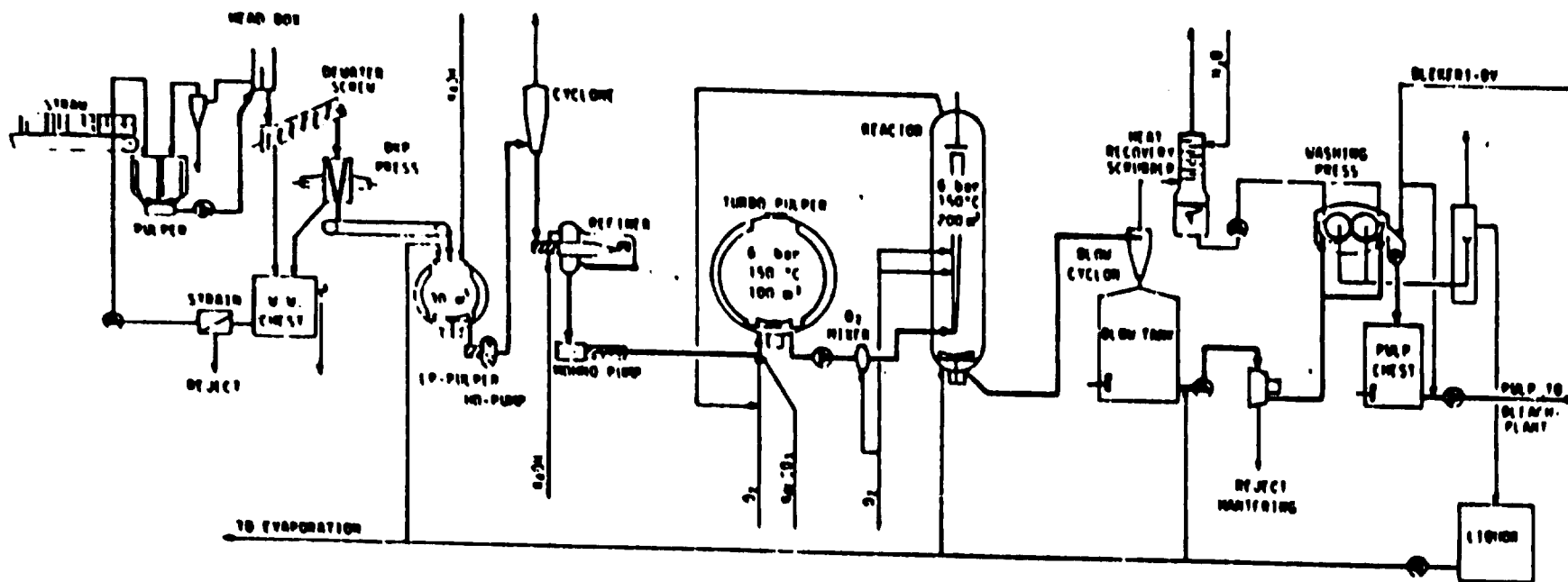


FIG. 11 FLOW SHEET THE NACO PULPING SYSTEM
AT JPZS IN FOGGIA ITALY

Fig. 12

Results from practical operation of the Naco Straw Digesting Plant at Polygrafico, Foggia, per September 30, 1985

	Range	Average	
Pulp production	50-85	75	ton BDP/d
Straw consumption		145	ton BDP/d
Yield		52	%
K-No	15-24	18±2	
Brightness	38-54	40-47	%ISO
NaOH-charge	220-290	265	kg (100% NaOH)/ton BDP
O₂-charge	140-200	160	kg O ₂ /ton BDP
Na₂CO₃-charge	not yet started		
Steam consumption	1.0-1.6	1.4	ton/ton BDP*
Water consumption	8-20	11	m ³ /ton BDP

FIG 13

**PULPING WHEAT STRAW
NACO PROCESS
POLYGRAFICO FOGGIA ITALY**

OPERATION CONDITIONS:	NAOH CHARGE KG/BD TON PULP	270
	O₂ "	165
	TEMPERATURE °C	132
	PRESSURE BAR	6
PULP PROPERTIES:	*SR UNSCREENED	42
	*SR SCREENED	32
	KAPPA NO	13.5
	INTRINSIC VISCOSITY CC/G	728
	BRIGHTNESS % ISO	55
	DENSITY G/CC	0.6
	BREAKING LENGTH KM	7.2
	DOUBLE FOLDING NO	110

Fig 14

OZONE - BLEACHING TESTS

DIFFERENT PH - HIGH CONSISTENCY

OPERATION COND:	O ₃ CHARGE ON BDP	%	1	1
	TEMPERATURE	°C	30	30
	PH		8.4	3.2
	PULP CONSISTENCY	%	45	45
PULP PROPERTIES	°SR UNSCREENED		37	35
	°SR SCREENED		30	29
	KAPPA NO		4.5	4.0
	INTRINSIC VISC.	CC/G	500	550
	BRIGHTNESS	%	74	76
	YELLOWNESS	%	11.4	11.0
	DENSITY	G/CC	0.56	0.57
	BREAKING LENGTH	KM	5.4	5.2
	DOUBLE FOLDING	NO	27	26

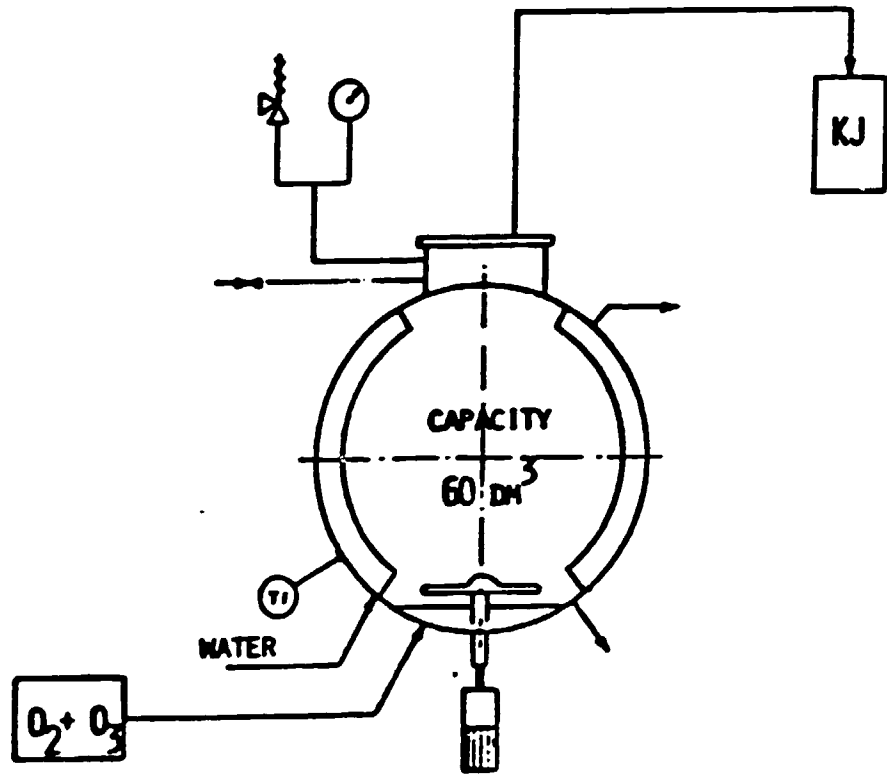


Fig 15 LAB TURBOPULPER

FIG 16

OZONE - BLEACHING TESTS
HIGH PH - LOW PULP CONSISTENCY

OPERATION COND:	O ₃ CHARGE ON BD PULP	%	2	2
	TEMPERATURE	°C	40	40
	PH		7	7
	PULP CONSISTENCY	%	6	2
PULP PROPERTIES:	*SR UNSCREENED		64	60
	*SR SCREENED		50	45
	KAPPA NO		6.1	4
	INTRINSIC VISCOSITY	CC/G	700	650
	BRIGHTNESS	%	74	75
	YELLOWNESS	%	10	9
	DENSITY	G/CC	0.57	0.62
	BREAKING LENGTH	KM	6.2	6.2
	DOUBLE FOLDING	NO	150	200

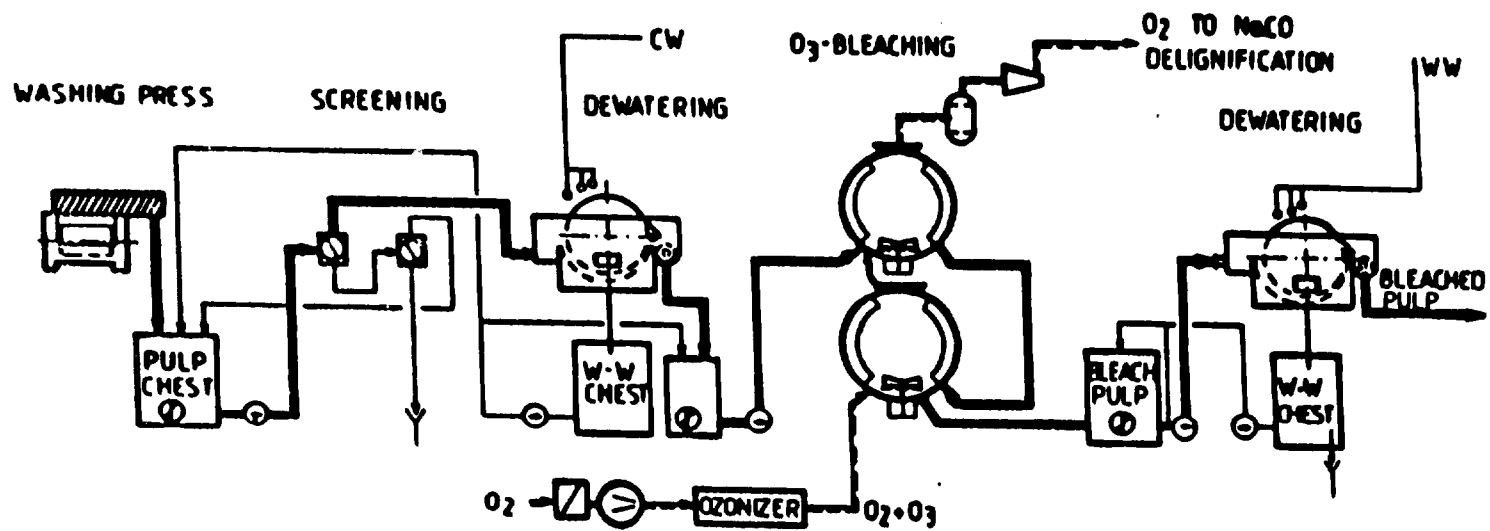


Fig.17 NaClO SYSTEM FOR OZONE BLEACHING

MECHANO CHEMICAL DEPITHING OF BAGASSE

by

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A new and efficient mechano-chemical depithing process is investigated by carrying hydropulper depithing in presence of lime with the aim of increasing the efficiency of depithing and improving cooking results. The presence of lime is effective in breaking the hydrogen bonds between pith and fibre, thus facilitating and increasing the efficiency of depithing. Thus, lime depithing in a hydropulper in presence of 8.8 % lime, 5 % consistency at 55°C for 50 minutes yielded 63.3% useful bagasse fibres which is close to the true fibre content of whole bagasse (60 - 65 %), while water depithing at the same conditions yielded 77.9 % "fibre" in which considerable pith remained clinged to the fibres. At the same time lime depithing removed appreciable amounts of "soluble matters" (17.7 % VS 5.9 % in case of water depithed bagasse) with consumed alkali (lime) in deacetylation and neutralization of end wise degradation products (saccharinic acids) of hemicelluloses. This resulted in a decrease of alkali consumption during NaOH digestion of lime depithed bagasse, thus directing digestion more towards effective delignification with appreciable decrease of chlorine consumption during bleaching, an increase of over - all bleached yield (61 % VS. 50 % for water depithed bagasse), and improved physical characteristics of lime depithed in comparison to water depithed bagasse pulps.

1. Introduction

During recent years, as a result of the tremendous increase in the world consumption of pulp and paper, there has been a great amount of effort expanded towards the development of new sources of fibrous raw materials. The comparatively untapped reservoirs of agricultural residues, as bagasse, straw, etc..., are being extensively studied for the manufacture of pulp and paper of high quality. There are a number

qualifications which a cellulosic raw material must possess in order to be considered suitable for such a purpose. There must be an ample supply of the raw material the year around, it must not deteriorate rapidly in storage and it must be converted economically to a high yield of high quality pulp. Sugar cane bagasse, when properly depithed, is a material which satisfies the above conditions more readily than any other crop fibre.

Bagasse is composed mainly of about 60 - 65 % fibrous material (fibroviscous bundles, and rind fibres), and about 20 - 25 % non-fibrous pith (paranchymatus tissue) as illustrated in one variety of Indian bagasse /1/ : fibre 60.5 %, pith 30.0 %, sugar 7.6 %, and leaf and earth impurities 1.9 %. The bagasse fibre average about 1.4 mm /2/ in length, while the pith cells average only about 0.25 mm in length. Pith cells are undesirable from the pulping point of view due to their shorter length, their greater surface and void volume that pick up dirt and absorb pulping chemicals that react with residual absorbed sugars and hence increase consumption of chemicals /3/.

Also, during strong alkali digestion, the pith tends to swell and become gelatinous thus causing difficulties by closing up the wires of paper machines, decreasing rate, sticking to the press machine with frequent paper breaks, and giving rise to shiny paper spots. Pith therefore must be removed as much as possible before any pulping operation. Removal of pith, by depithing, is not only to improve the quality of paper produced but also for economical reasons since the pith can be used as fuel in the sugar mill.

Intensified efforts on development of depithing of bagasse was started in the early 1950s. It began at that time by dry depithing followed by development of moist and wet depithing. Dry depithing is carried out by screening dry bagasse (75 - 90 % dry content) after subjecting the material to impact forces by hammer mills /4,5/. This process is an inefficient depithing method /6,7/ that yields about 85 % "fibre" and 15 % "pith", i.e.: considerable pith remains clinging to the fibre bundles, and at the same time, there are true fibres in the "pith" portion. The severity of the mechanical treatment during hammer-milling also causes a great deal of damage to the fibres and as a result the screen rejects contain appreciable amounts of broken fibres.

In moist depithing, the bagasse is depithed as it comes from the sugar-mill in the moist condition, normally about 50 % moisture content. The moist bagasse is subjected to impact by a hammer mill surrounded by a specially perforated screen, through which the pith cells pass /6-11/.

Moist depithing is more efficient than dry depithing. However, only partial separation of pith ($\sim 80\%$) occurs and this leaves sufficient amount of sugars in the retained pith to cause fermentation problems of depithed bagasse during storage. Wet depithing is the most widely used process, and it is usually performed as a second stage depithing after moist depithing /12,13/. The most widely used processes are those of Horkel and Rietz /14-23/. In this process the bagasse is first slushed at 10 % consistency in a hydropulper at 70 - 90°C, the material is then diluted to 1-2 % to permit a uniform flow into the top of the Rietz mill /6/. As the stream of bagasse and water falls in the screen chamber, the impact of the hammer arms liberates the pith. The depithed fibres are then discharged from the open bottom of the mill by gravity.

This paper describes, a new mechano-chemical depithing of bagasse in the presence of lime, to increase the efficiency of wet depithing and hence improve the cooking results. The presence of lime is effective in breaking the hydrogen bonds between pith and fibre, thus facilitating and increasing of efficiency of depithing. At the same time lime depithing can be considered as a first stage of a two stage alkali digestion. This would result in a decrease of alkali consumption during NaOH digestion of lime depithed bagasse, thus directing digestion more towards effective delignification with appreciable decrease of chlorine consumption during bleaching in comparison to simple water depithing of bagasse. The depithed bagasse was converted to bleached glassine paper.

2. Experimental

The raw material used was an Egyptian bagasse. Water depithing of bagasse was carried out in a hydropulper at 5 % consistency, for 50 min. at 55°C (by direct steaming), followed by screening at 1 % consistency over 25 mesh screen.

Lime depithing was carried out at the same conditions with addition of 8.8 % lime based on the weight of oven dry bagasse. The results obtained are shown in Table 1. The chemical analysis of the water depithed bagasse is presented in Table 2.

The soda pulping of water depithed and lime depithed bagasse were performed in a 2-dm³ electrically heated, horizontal rotating (at r.p.m.) digester at conditions given in Table 3. Following digestion, the partially disintegrated pulps were washed free of chemicals, disintegrated at 2 % consistency in a laboratory valley beater for 10 minutes without load, and then fiberized under a load of 4.5 kg. for the indicated times given in Table 3. Cook No. 6 was performed in a rotating, indirectly steam heated digester of 300 liter capacity. The pulps thus obtained were analyzed for α-cellulose, β-cellulose, ash, lignin, pentosans, and permanganate number as shown in Table 3.

The different pulps obtained (Table 3) were beaten in a UKro mill (except cook no 6 which was beaten in PFI beater) to about 80° SR freeness and the physical properties evaluated as shown in Table 4.

The unbeaten lime and water depithed bagasse pulps (Table 3) were bleached by CEH sequence as shown in Table 5. Table 6 gives the bleaching conditions. The bleached lime depithed bagasse pulp (cook No 6), was refined in a 12 Sprout Waldron laboratory refiner equipped with C-2976 followed by beating in a PFI beater, while the rest of pulps were beaten in a Valley beater. Standard sheets of unbleached and bleached pulps were made and conditioned for 24 hrs at 53 % relative humidity and 23°C. The physical properties of the bleached pulps are shown in Table 7.

3. Results and Discussion

3.1. Comparison of Hydrapulper Lime Depithing vs. Hydrapulper Water Depithing of Egyptian Bagasse

Hydrapulper water depithing of Egyptian bagasse yielded 77.9 % "fibre", 16.2 % "pith", and 5.9 % "solubles" as shown in Table 1.

The high "fibre" figure means that considerable pith remains clinged to the fibre bundles since the true fibre content ranges only between 60 - 65 %. In other words, the hydropulper water depithing, at the given conditions, is an inefficient depithing procedure. Hydrapulper lime depithing carried out at the same conditions with addition of 8.8 % lime (based on the weight of oven-dry bagasse), yielded 63.3 % "fibre", 19.0 "pith", and 17.7 % "solubles" (Table 1). It is thus clear that lime hydrapulper depithing is much superior to water depithing since the yield of the obtained fibre (63.3 %) is very close to the true fibre content of the whole bagasse (60 - 65 %). This means that the presence of lime is effective in breaking the hydrogen bonds between pith and fibre, thus facilitating and increasing the efficiency of depithing. At the same time lime depithing removed appreciable amounts of "soluble matters" (17.7 % VS. 5.9 % in case of water depithed bagasse) with expected consumed alkali (lime) in deacetylation and neutralization of end wise degradation products (saccharinic acids) of hemicelluloses. The removal of soluble matters at this early stage will lower the consumption of chemicals during the following alkali digestion since the soluble matters are known to react chemically with added chemicals /3/. A proper comparison between the efficiency of water VS. lime depithing will be more apparent by discussing the cooking results in the following sections.

Table 1. Lime and Water Depithed of Egyptian Bagass in Pilot Plant Hydrapulper.

Hydrapulper depithing conditions					Yield %		
Expt. No.	Lime %	Consistency %	Temp. °C	Time min.	Fibre %	Pith %	Soluble matter %
1	-	5	55	50	77.9	16.2	5.9
2	8.8	5	55	50	63.3	19.0	17.7
3	5.0	7	55	20	70.0	25.0	5.0

- a
v Water depithing of bagasse
- b
v on O.D. bagasse
- c
v steam was introduced during the running of the hydrapulper
- d
v Fraction retained on 25 mesh screen.
- e
v Fraction retained on cloth sac
- f
v Soluble obtained by difference
- g
v Lime depithing of bagasse.

Table 2. Chemical Analysis of Water Depithed Bagasse

Determination ^a v	%
Ash	1.6
Lignin (corrected for ash)	20.8
Alcohol-benzene (1:2) extractive	2.3
Cold water extractives	1.2
Hot water extractives	12.8
Holocellulose	81.7
ℓ - cellulose	55.8
Pentosans	31.7

Chemical Analysis were carried out according to TAPPI standard methods (T.15,13,6,1,1,17 and 19 resp.).

Hexano-Chemical Depithing of Bagasse

- 31 -

Table 3. Pulping of Lignin and Water Depithed Bagasse

Cook No.	Type of Depithing	Cooking conditions				Consumed NaOH %	Fiberizing time min.	Pulp yield (after fiberization) %	Chemical analysis						
		Temp. °C	Time hr	NaOH %	Liquor ratio				Ash %	Lignin %	K ₂ SO ₄ %	α-cellulose %		β-cellulose %	
												no.	no.	no.	no.
1	None depithing	50	5	35	1:6	2.9	5	32	69.3	11.7	20.3	81.2	15.2	65.8	0.327
2	"	95	3	35	1:6	4.7	5	32	67.2	7.8	17.5	81.1	18.4	22.2	0.392
3	"	95	3	33	2:6	4.4	5	32	71.8	7.0	16.4	76.3	22.8	25.9	0.373
4	"	95	3	20	1:6	3.7	6	11	74.5	7.5	16.6	78.8	18.3	25.3	0.324
5	"	130	3	10	1:6	4.9	3	12	65.3	4.9	10.1	76.0	20.3	25.3	0.185
6	"	130	3	10	1:6	4.6	5	15	61.4	4.0	10.0	76.2	20.8	25.6	0.160
7	Water depithing	95	3	10	1:6	7.7	12	14	72.1	16.4	22.0	76.4	19.7	26.5	0.574
8	"	130	3	10	1:6	9.9	5	13	64.9	10.9	13.9	75.8	24.9	31.7	0.443

a Carried at 2 % consistency in a laboratory Vally beater under a load of 4.5 Kg.

b The cook was carried in a 300 liter capacity rotating digester

c Fiberization was carried out at 3 % consistency in a clo/lin beater.

3.2. Comparison of Cooking Results of Mild and Pressure Water and Lime Depithed Bagasse

A. The effect of chemical usage.

The range of NaOH used (Table 3) varied from 10 - 15 % (based on the weight of dry depithed bagasse) at 3 temperature levels (mild pulping at 50°C, 95°C, and pressure pulping at 130°C). Pulping of lime depithed at 50°C (exp. No.1, Table 3) needed too much chemicals (15 % NaOH), required prolonged digestion (5 hrs) and yielded unsatisfactory pulp having high lignin content (11.7 % lignin). Mild pulping of lime depithed bagasse for 3 hrs. at 95°C using 10 - 15 % NaOH (exp. no. 2,3 and 4 Table 3) were satisfactory pulps. As expected, as the chemical usage increased from 10 to 15 %, the crude yield gradually decreased from 74.5 to 67.2 %. In general, the range around 10 % chemical usage was considered both economical and satisfactory (exp. 5 and 6, Table 3). For proper comparison between mild pulping (at 95°C), and pressure pulping (at 130°C) of water depithed and lime depithed bagasse, the chemical usage was fixed at 10 % NaOH (experiments nos. 4 to 8, Table 3), and the results obtained are discussed in the following sections.

B. Consumed alkali during alkali digestion as affected by lime, and water depithing methods.

Comparison between mild pulping of lime and water depithing (experiments nos. 4, and 7, Table 3) shows clearly that lime depithed bagasse is superior to water - depithed bagasse since the former consumes less chemicals (3.7 %) as compared to (7.7 %) consumed for exp. no. 7, Table 3. Similarly, pressure pulping of lime and water depithed bagasse (exp. nos. 5 and 8, Table 3) shows that the lime depithed bagasse consumed less alkali (4.9 %) as compared to (8.9 %) consumed for exp. no. 7, Table 3. The increased chemical consumption of the water depithed bagasse is due to the presence of appreciable amounts of soluble matters and retained pith in the water depithed bagasse is due to the presence of appreciable amounts of soluble matters and retained pith in the water depithed bagasse which are known to react chemically with NaOH /3/ and thus increase the consumption of chemicals during digestion.

C. Pulp yield as affected by lime and water depithing methods. The pulp yield of the mild cooks (cooks no. 4 and 7, Table 3) are 74.5 and 72.1 % respectively, and these yields are higher, as expected, than the pressure cooks 65.3 and 64.9 % respectively for cooks no. 5 and 8, Table 3.

D. Lignin and permanganate number as affected by lime and water depithing methods.

Comparison between mild pulping of lime and water-depithed bagasse (exp. nos 4 and 7, Table 3) shows that the lime depithed bagasse yielded pulp containing less lignin (7.5 % lignin and 16.6 permanganate no.) in comparison with 16.4 % lignin and 22 permanganate no. for the water depithed bagasse. Similarly, pressure pulping of lime-depithed bagasse (exp. no. 5, Table 3) yielded pulp containing less lignin (4.8 % lignin, and 10.1 % permanganate no.) in comparison with 10.9 % lignin and 19.9 % permanganate no. for water depithed bagasse. As expected, better delignification, resulted in a lower fiberizing time following digestion of the lime depithed bagasse pulps (a fiberizing time of 4 min for exp. 4, as compared with 12 min. for exp. 7, and a fiberizing time of 2 min. for exp. 5 as compared with 5 min. for exp. 8, Table 3). Also, better delignification of the lime depithed bagasse resulted in a much lower consumption of chemicals during bleaching (Table 5). The lower lignin/pentosan ratio of lime depithed pulps (0.297 and 0.188 for experiments no. 4 and 5, as compared to 0.574 and 0.343 for experiments no. 7 and 8, Table 3) is a further indication of the superiority of pulps obtained from lime depithed bagasse in comparison with pulps obtained from water depithed bagasse.

E. Unbleached pulp strengths as affected by lime and water Depithing methods.

The physical characteristics of the unbleached bagasse pulps are shown in Table 4. As would be expected, satisfactory unbleached glassine papers with good blister tests were obtained only after extensive beating times. In general, the strength developed (particularly tear and fold) from the lime depithed bagasse was much superior to that obtained from the water depithed bagasse pulps.

3.3 Comparison of Bleaching Results of Water and Lime Depithed Bagasse Pulps

Lime depithed bagasse and water depithed bagasse pulps were bleached by CEH sequences, and the results are shown in Table 5. The lime depithed bagasse pulps (in particular exp. nos. 4 and 5, Table 3) were superior to water depithed bagasse pulps (exp. nos 7 and 8, Table 3), since the former pulps consumed less available chlorine during bleaching and gave higher yields of bleached pulps of satisfactory G.E. brightness. The increased total chlorine consumption of the water depithed bagasse pulps is due to the presence of appreciable amounts of lignin and pith in the water depithed bagasse which are known to react chemically with chlorine and thus increase the consumption of chemicals during bleaching. It is of interest that the consumption of chlorine during the chlorination stage is roughly proportional to the percent lignin in the unbleached pulps.

Table 4. Physical Characteristics of Lime and Water Depithed Unbleached Bagasse Pulps.

Cook No.	Initial ^a free-ness	Beat- ing time min.	Free- ness °SR	Basis wt. g/m ²	Burst factor	Tensile kg	Tear factor (double)	Fold	Blister Test	Terpentine test sec.
1	12	60	84	60.1	41.6	5.3	42.6	1804	V.good	1800 ⁺
2	12	70	85	62.2	41.2	5.2	41.2	2130	V.good	1800 ⁺
3	12	70	88	62.6	42.4	5.7	40.9	1877	V.good	1800 ⁺
4	11	70	86	63.6	51.6	6.3	50.3	1634	V.good	1800 ⁺
5	12	70	87	61.9	48.8	6.0	51.7	3315	V.good	1800 ⁺
6 ^b	15	-	88	60.0	53.3	8.2	53.3	3300	V.good	1800 ⁺
7	14	70	87	62.0	41.4	5.7	56.1	976	V.good	1800 ⁺
8	13	60	89	62.6	43.2	5.6	35.8	1334	V.good	1800 ⁺

^a Refer to table 3

^b The pulp was beaten at 6000 revolution in PF1 beater.

Table 5. Bleaching of Lime and Water Depiched Bagasse

Cook No. ^a	Type of depitching	Unbleached pulp yield %	CEP Sequence							
			Avail. Cl ₂ % ^b	Consumed Cl ₂ %	NaOH %	Bl. avail. % Cl ₂	Total Cl ₂ consu- %	Shrink. during bl. %	Over- all yield %	Bright (% G.)
1	Lime depitching	69.3	11.5	11.3	2	3	14.3	17.7	57.0	84
2	" "	67.2	8.7	8.5	2	3	11.5	12.8	58.8	82
3	" "	71.2	8.4	8.2	2	1	9.5	12.7	61.8	81
4	" "	74.5	8.2	8.0	2	2	10.0	14.6	62.5	82
5	" "	65.3	4.0	3.8	2	1	4.8	5.9	61.4	83
6	" "	61.4	4.0	3.8	2	2	5.8	9.8	58.2	83
7	Water depitching	72.1	12.8	12.6	2	2	14.6	25.2	57.3	61
8	" "	64.9	11.5	11.3	2	2	13.3	22.1	50.5	80

^a Refer to Table 3.

^b Optimum dose requirements, based on oven-dry weight of pulp.

Table 6. Bleaching Conditions

Conditions	Value
Chlorination stage (C)	
Time - (min).	30
Temp. 5 (°C)	30
Consistency (%)	3
pH during chlorination	1-3
Caustic extraction (E)	
Time (min.)	60
Temp. (°C)	65
Consistency (%)	10
Hypochlorite stage (H)	
Time (min.)	120
Temp (°C)	45
Consistency (%)	10
pH	8.5

The shrinkage of yield during bleaching is proportional to the original amount of lignin in the unbleached pulps, and the amount of pith remaining in the unbleached pulps. The lignin is dissolved and removed during the bleaching stages, while the pith is gradually removed during washing of the pulp after chlorination, alkali extraction and hypochlorite bleaching. The shrinkage of yield during bleaching of the lime depithed bagasse pulps (exp. no. 5 containing 4.8 % lignin) was only 5.9 %, while the shrinkage of yield of the water depithed bagasse pulps (exp. nos. 7 and 8, containing 16.4 and 10.9 % lignin respectively) was 25.3 and 22.1 % respectively. It is of interest that the lime depithed bagasse pulps (exp. no.5, Table 5) gave a high overall bleached yield (61.4 %), while the yield of the water depithed bagasse pulps (exp. no. 7, Table 5) was only 50.6 %.

3.4 Bleached pulp strengths as affected by lime and water depithing methods.

The physical characteristics of bleached bagasse pulps are shown in Table 7. Satisfactory bleached glassine papers were obtained from the different bagasse pulps. In general, the strength developed (particularly tear and fold) from the lime depithed bagasse pulp bleached by CEH sequence are greater than those developed from the water depithed bagasse pulp bleached by the same CEH sequence. The lower strength properties of the water depithed bleached bagasse pulps is due mostly to their higher pith content in comparison with the lime depithed bleached pulps. In this respect, pith, being short in length, greatly decreases the strength properties (especially tear and fold) of papers.

3.5 Glassine paper from lime depithed bagasse pulps.

Properties of glassine papers from bleached lime depithed bagasse and bleached sulfite wood pulps are shown in Table 8. The lime depithed bagasse pulp has about the same strength, terpentine test and blister test in comparison to the bleached chemical wood sulphite pulps. Properties of glassine paper made on an experimental paper machine are shown in Table 9. The glassine paper produced from lime depithed bagasse fulfils all the requirements of strength, terpentine test and blister test of glassine paper.

Table 7. Physical Characteristics of Lime and Water Depithed Bleached Bagasse Pulp

Cook No.	Initial freeness °SR	Beating time min.	Freeness °SR	Basis wt. g/m ²	Burst factor	Tensile Kg.	Tear factor	Fold (double)	Brightness (% G.E.)	Blister test	Terpen- tine test sec.
1	13	60	87	60.0	42.6	5.2	37	1224	84	V. good	1800 ⁺
2	15	60	84	60.7	39.8	5.3	36.9	1275	82	V. good	1800 ⁺
3	14	60	73	62.6	41.2	4.7	41.1	714	81	negative	-
4	14	60	84	63.3	44.6	5.1	42.3	2227	82	V. good	1800 ⁺
5	15	60	83	60.8	44.8	5.8	46.1	2275	83	V. good	1800 ⁺
6 ^b	16	-	90	60.0	54.8	8.3	53.3	2717	83	V. good	1800 ⁺
7	14	60	89	61.2	48.6	5.0	33.0	1262	80	V. good	1800 ⁺
8	14	60	89	60.1	40.6	5.5	26.6	1335	80	V. good	1800 ⁺

^a Refer to tables 3 and 5.

^b The pulp was refined in Sprout Waldron refiner followed by beating at 6000 revolutions in a PFI beater.

Table 8. Properties of Furnish Components of Bleached Lime Depithed Bagasse Glassine Paper

	Bl. Lime depithed ^a Bagasse Pulp	Bl. Sulphite Wood Pulp
°SR	90	84
Tear Factor	53.3	71.9
Breaking Length (Km)	9.2	9.7
Burst Factor	54.8	69.8
Fold (double)	2717	1855
Terpentine Test (sec.)	1800 ⁺	1800 ⁺
Blisser Test	V.Good	V.Good
Brightness (% G.E.)	83	84

^a Cook No.6, Table 3 (bleached 4 % Cl₂, 2 % NaOH, and 2 % hypochlorite).

Table 9. Comparison Between Glassine Paper from Bleached Lime Depithed Bagasse Pulps and Reference Papers

Test No.	Basis wt. g/m ²	Bleaching length (Km)		Tear factor		Fold (double)		Burnt factor	Bright-ness (% G.E.)	Terpent-ine test sec.	Blister test
		MD	CD	MD	CD	MD	CD				
1	29.5	8.6	4.6	54.2	67.8	1600	1200	43.4	84	1800 ^a	V. good
2	30.0	8.6	4.4	56.4	60.0	1700	1452	44.4	84	1800 ^a	V. good
3	40	8.4	4.6	54.2	67.8	1750	1750	44.3	84	1800 ^a	V. good
4	45	8.8	4.6	54.1	67.8	1881	1551	44.8	84	1800 ^a	V. good
5	50	9.0	5.0	42.0	60	1800	1522	45.1	84	1800 ^a	V. good
6	55	8.8	4.7	50.9	69.1	1922	1499	44.2	84	1800 ^a	V. good
7 ^b	59	8.6	4.6	63.3	66.6	1925	1430	43.1	84	1800 ^a	V. good
Reference paper	40	8.3	4.3	50	55	-	-	42.2	84	1800 ^a	V. good

^a V Furnish composed of 90 % bleached lime depithed bagasse pulp (exp. no. 6 Table 7), 10 % bleached wood sulphite pulp and 1 % TiO₂.

^b V Furnish composed of 100 % bleached wood sulphite pulp.

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DIRECT ALKALI RECOVERY SYSTEM (DARS)

by

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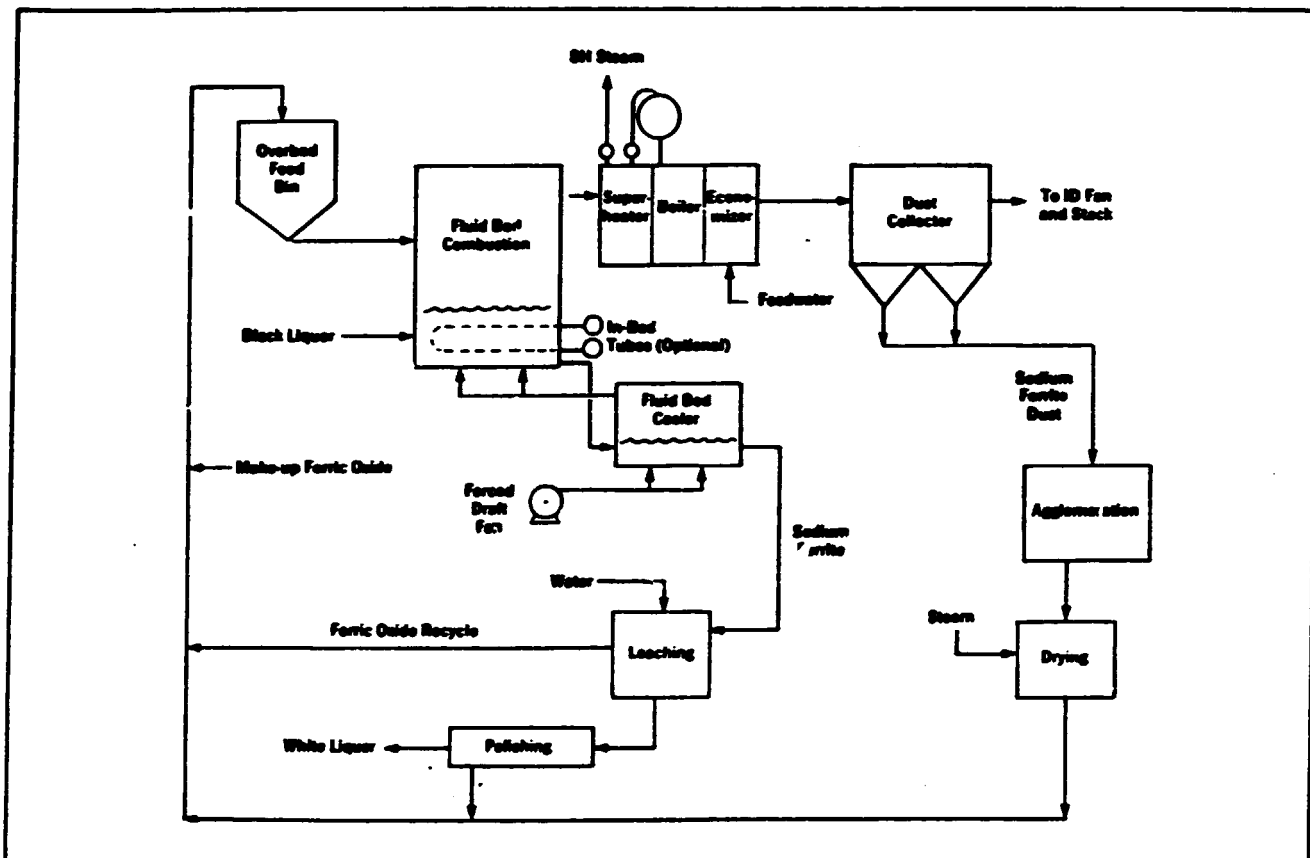
DIRECT ALKALI RECOVERY SYSTEM

The Direct Alkali Recovery System (DARS) is a new method of chemical and energy recovery for soda or soda-anthraquinone black liquor. Invented in 1976 by Toyo Pulp Company of Japan and tested in pilot operations for two years by Australian Paper Manufacturers, the process has now been licensed to Babcock & Wilcox (USA) for sale of commercial units. B&W has an agreement with the Sprout-Waldron Division of Koppers Company, Inc., for the supply of process equipment systems for DARS units.

The process, shown below, burns black liquor in a fluidized bed of ferric oxide (Fe_2O_3) to combust the liquor organics and causticize the sodium directly by forming sodium ferrite ($\text{Na}_2\text{Fe}_2\text{O}_4$), a high melting point solid. No molten smelt is formed. The solid bed product is cooled by contact with incoming combustion air and then leached with water to form high quality white liquor and to regenerate ferric oxide for recycle to the furnace. Dust collected from the boiler flue gas is almost entirely sodium ferrite fines, which are agglomerated and returned to the fluid bed to maximize sodium recovery.

Features

- Up to 99 % soda recovery
- White liquor causticities up to 94 %
- NaOH concentrations up to 300 grams/liter
- Low emissions
- Low corrosion
- No supplemental fuel except for start-ups
- No smelt for explosion hazard.



Closed Systems

There are essentially no uncontrollable losses from the system, except for a small stack loss, which can be minimized by proper selection of dust collection equipment. This results in a closed system with its benefits of low makeup chemical requirements, low process water usage, and low effluent treatment costs. However, non-process elements (NPEs) entering with the wood and make-up chemicals will have a tendency to build up, as would be the case in any closed system. Soluble impurities may be removed by a cold water leach (below the hydrolysis temperature) of the sodium ferrite bed product. Non-soluble impurities may be controlled by batch disposal of a small percentage of the recycled material.

Energy Efficiency

Because the sodium ferrite formation reaction is endothermic (energy-absorbing), the net thermal efficiency of DARS combustion is one or two points lower than conventional recovery. However, this energy deficit is more than made up for elsewhere in the mill. First, there is no lime kiln auxiliary fuel consumption. Second, with continuous digestors, heating steam consumption is lower due to the higher white liquor concentrations. Third, evaporation steam is lower due to less water in the weak black liquor. Finally, no green liquor heating steam is required. These savings add up to an overall energy efficiency in favor of DARS recovery.

Safety and Flexibility

The DARS combustor makes no smelt, so there is no risk of smelt water reaction with its often disastrous consequences. Also, the fluidized bed operates under completely oxidizing conditions, which, coupled with the absence of sulfur from the system, minimizes corrosion problems. The absence of appreciable levels of sulfur also results in the ability to cool flue gases more than would be the case if acid dew point concerns existed. This means more high pressure steam energy from the flue gas is possible.

The fluid bed can burn black liquor from concentrations as low as 35 % solids. Higher calorific heating value and percent solids liquors are combusted by deployment of boiler or superheater tubes in the bed for excess heat removal. This method of heat absorption results in lower total boiler surface requirements due to the high heat transfer coefficients typical of in-bed tubes. And tube erosion can be controlled by application of pin studs, thus prolonging in-bed tube life.

DARS - FLUIDIZED BED RECOVERY AND CAUSTICIZING FOR SODA LIQUOR

Abstract

The Direct Alkali Recovery System (DARS) offers the user the benefits of simplicity, economy, and minimal environmental impact in recovery of energy and cooking chemicals from soda black liquor. White liquor of up to 94 % causticity and 300 grams per liter NaOH can be generated. The first step in the process is fluidized bed combustion of the liquor organics in the presence of ferric oxide, forming sodium ferrite. Soda recovery is completed by a leaching stage to generate white liquor from hydrolysis of the sodium ferrite. Capital and operating costs are lower than conventional soda recovery.

The Industry Dilemma

Since the early 1930's, when the advent of the modern water wall Kraft recovery boiler enabled efficient recovery of heat and chemicals from black liquor, Kraft pulping has rocketed to a position of overwhelming dominance among wood pulping processes in current use (Fig. 1). But today's economic, social, and political environments are causing the pulp and paper industry to look long and hard before committing valuable capital to new and replacement pulp production capacity. Matics (1) and Hatton (2) report that softwood reserves are declining, and hardwoods, while plentiful, remain a relatively untouched resource. World-wide, non-wood raw materials such as bagasse, straw, bamboo, rice hulls and kenaf are in abundant supply. The pulp and paper industry of the 80's and beyond will continue to use processes that produce high yield pulps without sacrificing quality, but the successful realization of this objective will be hampered by concern over the high cost of pollution control, auxiliary fuels, labor and capital. Incremental additions to capacity, as well as replacements of relatively small production lines, will be the rule, and therefore a more economical process in these small sizes (50-600 TPD) will be required.

Kraft pulping, in the long term, will not provide an acceptable response to the problems facing the pulp and paper industry. Kraft mills are expensive, and must be built in very large capacities to be economic. Lime kiln auxiliary fuel consumption adds significantly to the overall production cost. Sulfur in the cooking liquor results in high costs for emission control and maintenance due to corrosion. High operating and maintenance costs are the direct result of a complex and relatively inflexible chemical recovery system. A recovery furnace explosion from water entering the smelt bed can put a boiler out of production for weeks. Finally, keeping the recovery boiler on line at rated capacity requires high sootblowing steam consumption and periodic outages for water washing, both of which add significantly to the cost of producing pulp.

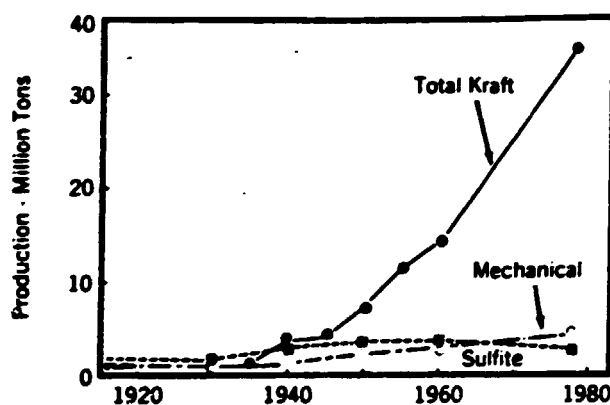


Fig. 1 US Pulp Production

Why Soda/Anthraquinone with DARS?

Soda/AQ pulping with Direct Alkali Recovery System (DARS) heat and chemical recovery is the first technically feasible, economic process to come along which overcomes most, if not all, of Kraft's problems (3,4,5). Compared to Kraft and soda with conventional recovery, soda/AQ with DARS offers the potential not only for smaller minimum economic size, but also for lower initial capital cost in most size ranges. Lack of significant levels of sulfur in the liquor results in lower emissions and negligible corrosion damage to recovery and causticizing equipment. Operating and maintenance costs are lower due to the inherent simplicity of the system and the fact that on-line operation requires no auxiliary fuel consumption. Higher white liquor causticities (94 % for DARS vs. 85 % for conventional recovery) and

higher active alkali concentrations (300 grams per liter as NaOH for DARS vs. 150 grams per liter for conventional recovery) results in lower inorganic dead load and lower evaporator steam consumption. The DARS also permits greater turndown ratios, greater stability and tolerance of upsets, and, best of all, no risk of smelt-water explosions in the black liquor combustor. Finally, soda/AQ with DARS recovery is well-suited for utilization of hardwoods and some non-wood species, as the pulp properties are very close to those achievable with Kraft.

What is Soda/AQ?

Anthraquinone (AQ) was first proposed as an additive for alkaline pulping in 1977 by Holton (6). While applicable to both sulfate and soda pulping, the greatest relative benefits are for the latter, as shown in Fig. 2 and Tables 1 and 2. These results are based on unpublished tests by Mead Corporation, which began using AQ in its Kingsport, Tennessee bleached printing paper mill in 1977 (7,8). Associated Pulp and Paper Mills, Ltd., Burnie, Tasmania, Australia, is also using AQ to improve rate and yield on eucalyptus pulping (9). Virkola (10) reports that AQ is attractive as an additive to circumvent some production bottlenecks situations, but that the current cost of AQ precludes its widespread use in alkaline pulping operations with conventional (high cost) recovery systems.

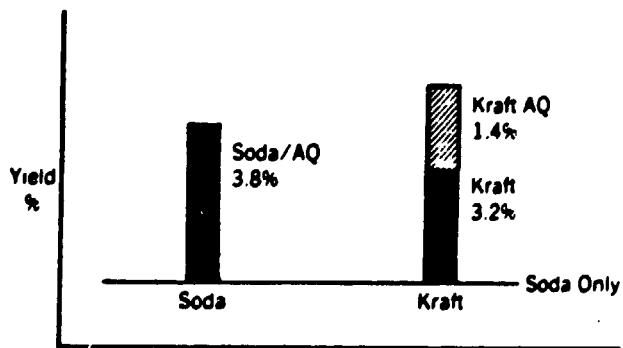


Fig. 2 Yield increase by AQ addition

The DARS Process

The DARS was invented and patented in 1976 by Toyo Pulp of Japan (11). Subsequent improvements to the process involving use of a fluidized bed for black liquor combustion and cold leaching for impurity removal were developed by Australian Paper Manufacturers (APM) of Melbourne, Victoria, and patented in 1980 (12). APM and Toyo have since licensed manufacturing rights for equipment utilized in the DARS process to Babcock & Wilcox.

Table 1
Comparison of Typical Pulping Conditions

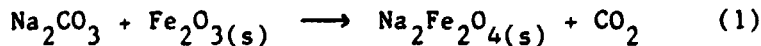
	Soda	Soda/AQ	Kraft
% Active Alkali (as Na ₂ O)	20	17	17
% AQ (dry wood basis)	-	0.1	-
% Sulfidity (AA basis)	-	-	30
Top temperature (°C)	167	167	167
H factor	2400	1500	1100
Yield (%)	43.0	46.6	46.4
Permanganate No.	12.0	12.0	12.4

Table 2
Comparison of Typical Pulp Properties

	Soda	Soda/AQ	Kraft
Tensile (m)	5750	6200	6150
Burst Factor	38	46	42
MIT Fold	110	170	180

*300 CSF, Mixed Hardwood

In the process shown in Fig. 3, black liquor from soda pulp is burned with coarse (1-3mm) particles of hematite (Fe₂O₃) in a fluidized bed combustor. Acceptable liquor firing concentrations can be as low as 40 % solids, with higher levels requiring deployment of boiler or superheater tubes in the bed for excess heat removal. The organics combust, and the residual sodium carbonate reacts with ferric oxide to form sodium ferrite, thus:

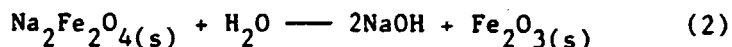


Flue gases pass through a waste heat boiler and gas clean up device (usually a baghouse or multi-clones and a wet scrubber), where entrained dust (predominantly Na₂Fe₂O₄) is removed and agglomerated prior to reinjection into the fluid bed. With extremely low sulfur levels in the flue gas, cold end corrosion is not a problem even at very low exit gas temperatures. Consequently, more sensible heat can be extracted from the gases and higher efficiencies can be achieved.

The solid bed product, consisting mainly of sodium ferrite and excess (unreacted) ferric oxide, passes through a second fluidized bed which acts as a solids cooler/combustion air pre-heater.

In most cases the entire bed product passes to the leaching system, but occasionally there may be a need to remove non-process elements (NPE's) that have entered via the wood or make-up chemicals (note that sulfur buildup from burning fuel oil should not be a problem as the only oil used would be for startups). This is accomplished by further cooling a side stream of the bed product and washing same with relatively cold (approx. 30°C) water in order to dissolve soluble NPE's without causing hydrolysis of the sodium ferrite.

All the sodium ferrite is then hydrolyzed at 90°C - 100°C in a counter-current fashion to recover the sodium hydroxide for white liquor and to regenerate ferric oxide for recycle to the fluid bed:



Reaction (2) is exothermic, and therefore it is not usually necessary to provide additional heat to maintain the reaction at the desired temperature. Leaching at a lower temperature has no deleterious effect beyond reducing the leaching efficiency. The system is capable of producing white liquor of up to 94 % causticity and 300 grams per liter NaOH, which means low inorganic dead load and less water to heat in the digester and evaporate from the black liquor. However, the system is flexible enough to produce higher or lower concentrations if preferred.

Most of the ferric oxide is recovered and recycled with essentially no change of particle size, but a small proportion forms fines which must be removed from the sodium hydroxide by centrifuging. Flocculation and sedimentation (or filtering) can be used if the NaOH concentration is kept below ca. 150 grams per liter.

APM conducted 2½ years of pilot scale tests starting in 1980. During this period the process was thoroughly examined and several variations of both central and auxiliary systems tested. Details of the pilot plant are reported by Covey (13).

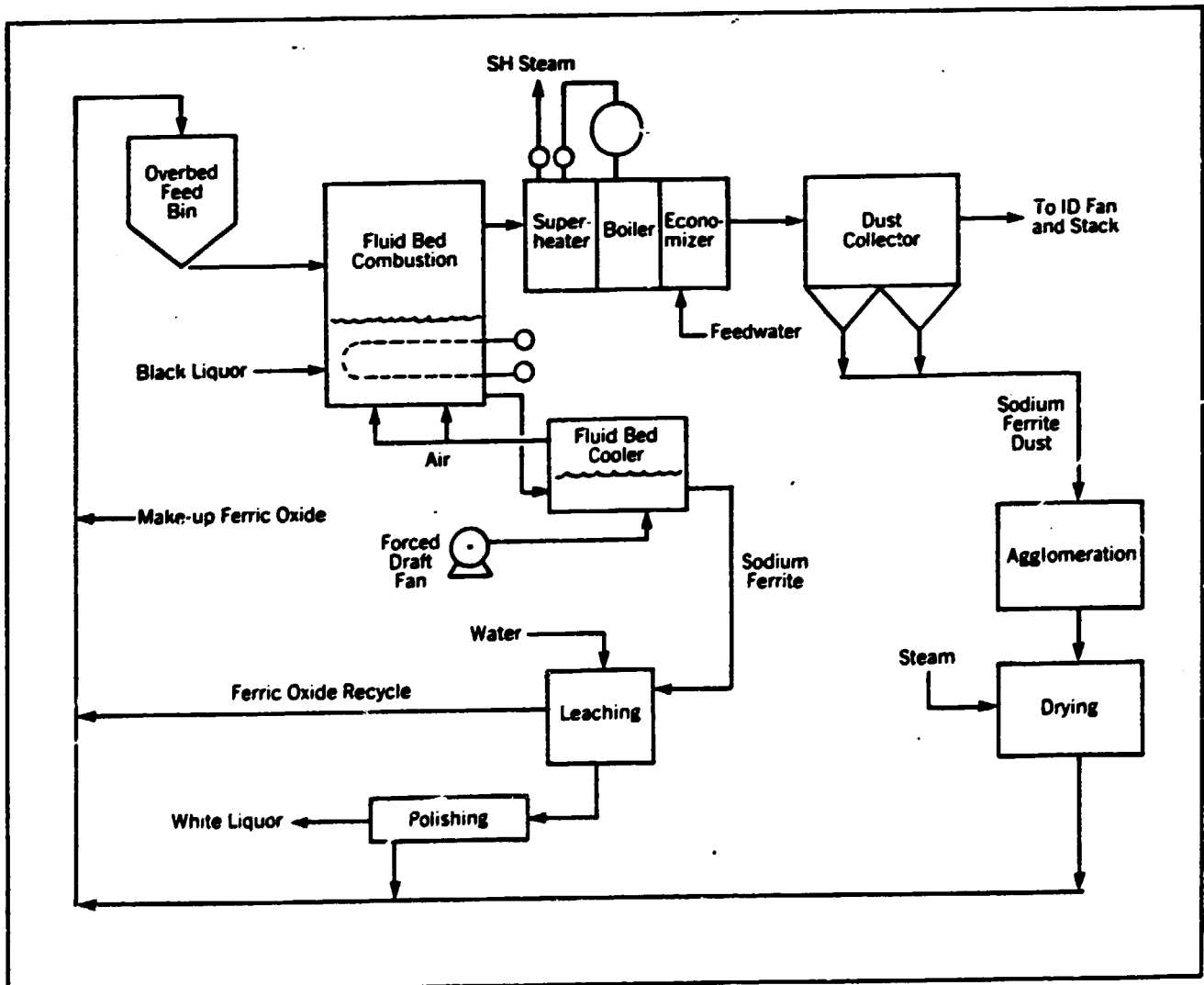


Fig. 3 Direct Alkali System Process Schematic

What about Cost?

In order to demonstrate the cost savings achievable with the DARS over conventional recovery, a comparison was made based on a 200 ODT/day (unbleached) pulp mill. Process schematics for the two systems are shown in Figs. 4 and 5. Table 3 gives an analysis of the steam and power balance which results from consideration of two alternatives for resolving the differences in steam and power production and consumption. Table 4 lists significant operating conditions and assumptions made for the conventional recovery and two DARS options. Data from Tables 3 and 4 are combined to yield the operating cost estimates given in Table 5. Note that savings in purchased items (auxiliary fuel and make-up chemicals) constitute about 80% of the aggregate cost savings of roughly \$ 38.00/ODT estimated for each case relative to conventional recovery.

Available costing data for DAR Systems indicates capital cost for a 200 TPD system to be in the range of \$ 10 - \$ 15 million, subject to site variables and scope of supply. Capital cost estimates obtained on conventional soda recovery systems were widely divergent, owing primarily to the lack of recent data for soda mills of this size range. However, the \$ 10 - \$ 15 million estimate for the DARS is in the lower range of conventional system estimates, and is roughly 20% below the average of the estimates for the conventional systems. Westling and McKean (14) found that DARS capital costs would be roughly 30% lower than a comparable Kraft pulp mill, based on estimates for a 1000 TPD installation, a conclusion that corroborates at least the direction and order of magnitude for expected capital cost savings of the DARS over conventional soda recovery.

Table 3.
Steam and Power Balance (Basis: 1 ODT* Brown Stock)

	Conventional Recovery	DARS			
		Case 1*	Δ	Case 2*	Δ
Steam Generation (kg/ODT) (6030 kPa, 454C)					
Recovery Boiler	4567	4422	145	4422	145
Power Boiler(s)	Base	Base	-0-	-687	-687
Steam Consumption (6030 kPa, 454C)					
Rec. Blr. Sootblowers	454	-0-	-454	-0-	-454
Net H.P. Steam to Turbine	4113	4422	+309	3735	-378
Extraction Steam (1035kPa)					
B.L. Heaters	76	-0-	-76	-0-	-76
Steam Coil Air Heater	429	-0-	-129	-0-	-429
Digester	1711	1740	+29	1740	+29
Smelt shatter Jets	125	-0-	-125	-0-	-125
Process	Base	Base	-0-	Base	-0-
Total	2341	1740	-601	1740	-601
Extraction Steam (275 kPa)					
Evaporators	1662	1380	-282	1380	-282
Deaerator	320	309	-11	309	-11
G.L. Heaters	136	-0-	-136	-0-	-136
Ferric Oxide Dryer	-0-	204	+204	204	+204
Process	Base	Base	-0-	Base	-0-
Total	2118	1893	-225	1893	-225
Steam to Condenser	-345	789	+1134	102	+447
Electricity Generation (kwh/ODT)					
1035 kPa Extraction	Base	-	-56	-	-56
275 kPa Extraction	Base	-	-31	-	-31
Condensing	Base	-	+272	-	+107
Total	Base	-	+185	-	+20

*Case 1: Constant power boiler steam generation

Case 2: Constant net electricity generation

*Oven-dry ton (2000 lb) = .907 metric ton

What Does the Future Promise?

In a 1981 Tappi editorial, J.D. Kramer of St. Regis concluded, "Clearly the leaders of our industry are committed to extend the dominance of Kraft pulping, at least through 1985". (15). Industry planners in 1985 have indicated little propensity to deviate from this strategy.

However, the economic, social and political realities facing the industry in 1985 cannot be ignored. Increased pressure to reduce capital and operating costs, adopt environmentally acceptable processes, and assure long-term resource and energy availability, is forcing a re-evaluation in the pulp and paper industry. Increased usage of the various mechanical pulps (CMP,CTMP,TMP) is an indication of the industry's

effort to squeeze more paper out of a ton of wood without sacrificing quality. Soda/AQ and DARS recovery, with its advantages of reduced costs, reduced emissions, and increased operating flexibility, will take its place among the various solutions to Kraft's problems selected by the pulp and paper industry over the next decade.

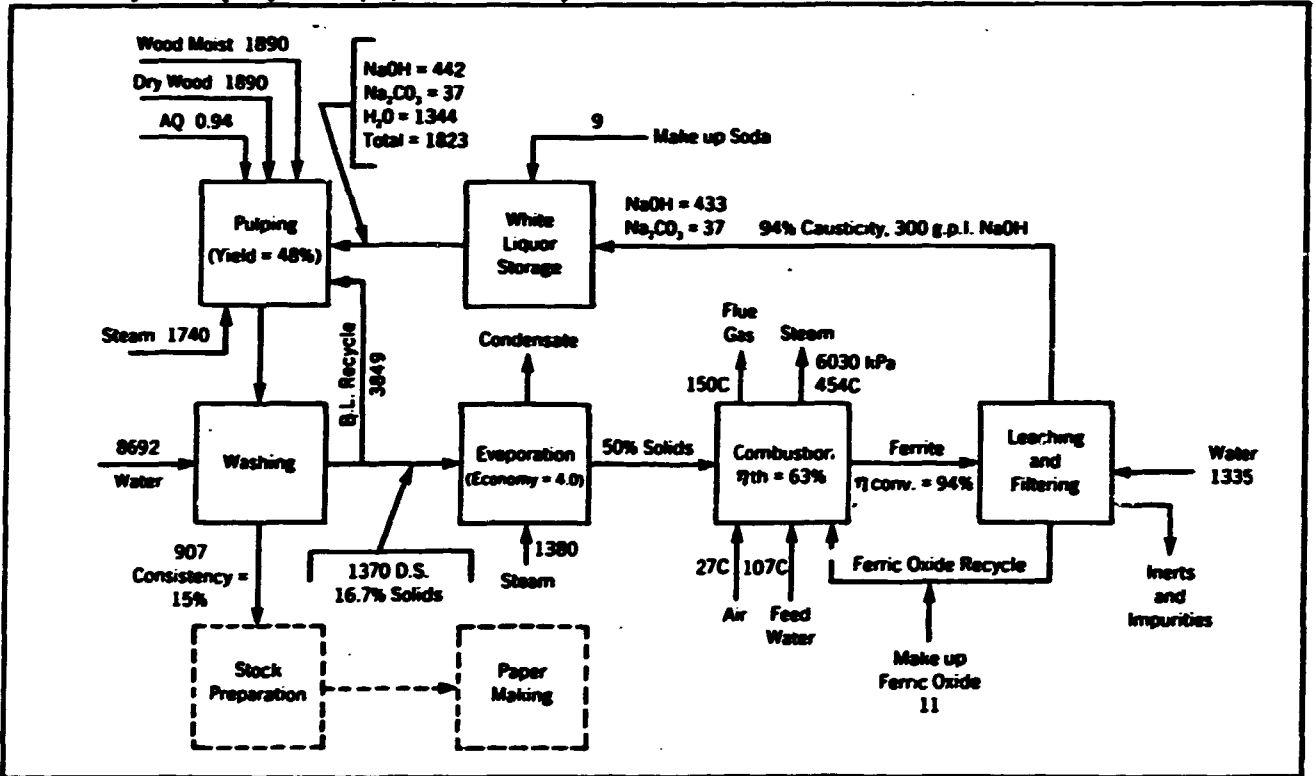


Fig. 4 Soda/AQ with DARS Recovery (Basis 1 ODT^o Brown Stock) All values in kg/ODT^o unless stated otherwise.

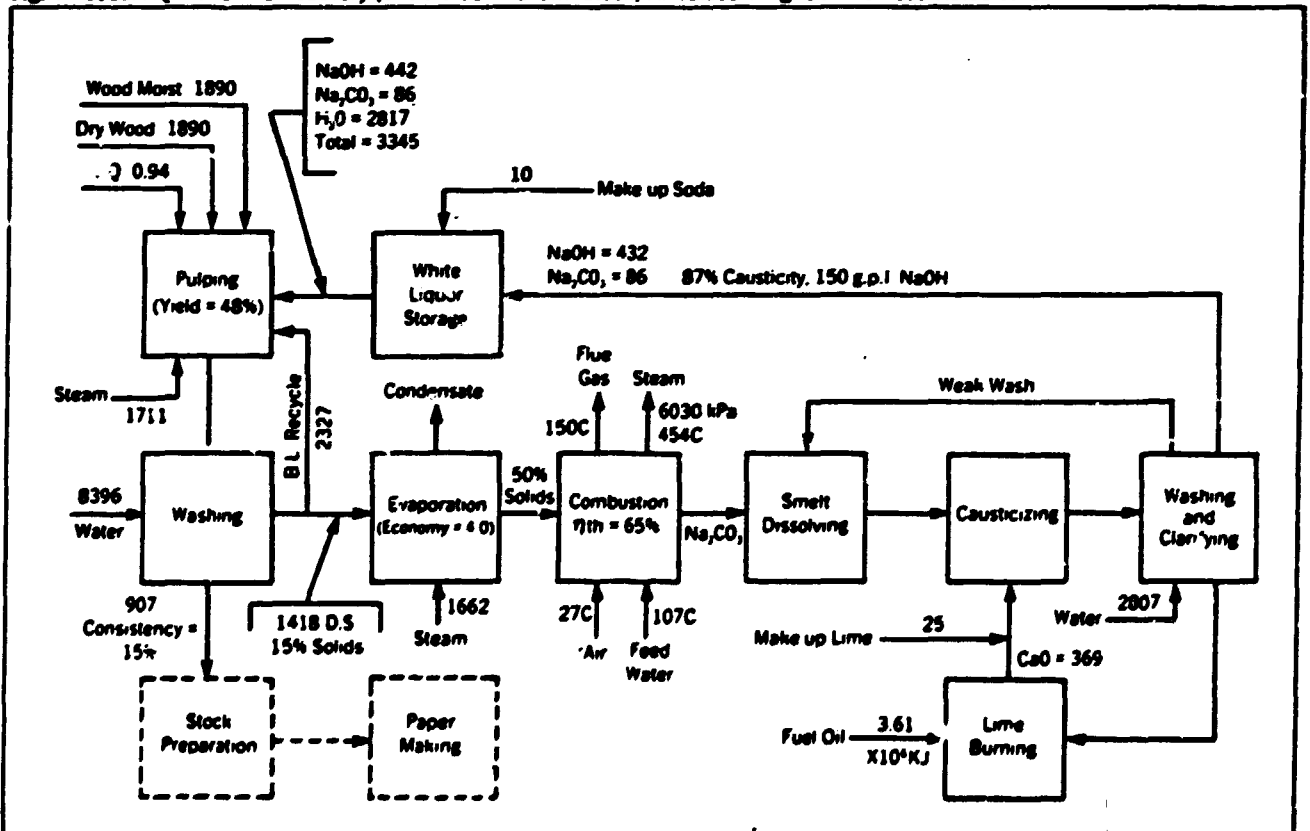


Fig. 5 Soda/AQ with Conventional Recovery (Basis 1 ODT^o Brown Stock) All values in kg/ODT^o unless stated otherwise.

Table 4.
Operating Conditions

Item	Units	Conventional Recovery	DARS	
			Case 1	Case 2
Pulp Output	ODT ^a /day	200	200	200
	AD ^b /year	69,800	69,800	69,800
Wood Species		Mixed HW	Mixed HW	Mixed HW
Yield	%	48	48	48
W.L. Causticity	%	97	94	94
W.L. Concentration	gpl NaOH	150	300	300
Aux Steam (1035kPa)	kg/ODT	2341	1740	1740
Aux Steam (275kPa)	kg/ODT	2118	1893	1893
Condenser Steam	kg/ODT	-345	789	102
Steam To Turbine	kg/ODT	Base	+309	-378
Power Generated	kwh/ODT	Base	+185	+20
Power Consumed	kwh/ODT	Base	+20	+20
Net Export Power	kwh/ODT	Base	+165	-0-
Aux Fuel (Lime Kiln)	kJ/ODT	3.61x10 ⁵	-0-	-0-
Process Water	L/ODT	13,500	12,000	12,000
Make-up Caustic	kg/ODT	10	9	9
Make-up Ferric Oxide	kg/ODT	-0-	11	11
Make-up Lime	kg/ODT	25	-0-	-0-
O&M Labor	mh/ODT	.72	.48	.48

^aOven-dry tons (2000 lb) @ 0% moisture

^bAir-dry metric tons (1000 kg) kg @ 10% moisture

Table 5.
DARS Cost Summary (\$/ODT^a)

Item	Cost Base	Case 1	Case 2
Auxiliary Fuel	\$7.60/10 ³ J	-29.27	-29.27
Generated Power	\$.024/kwh	-3.95	-0-
Generated Steam	\$4.41/1000kg	-0-	-3.03
O&M Manpower	\$15/mh	-3.60	-3.60
Make-up Chemicals			
Caustic	\$154/1000kg	-.13	-.13
Lime	\$83/1000kg	-2.10	-2.10
Fe ₂ O ₃	\$83/1000kg	+.94	+.94
Process Water	\$40/10 ³ L	-.06	-.06
Total Savings		\$38.17	\$37.25

^aOven dry ton (2000 lb) = .907 metric ton

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STUDIES ON THE DEVELOPMENT OF SODA RECOVERY PROCESS
BY ULTRA-FILTRATION

by

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INTRODUCTION

Economical operation of alkaline pulping process (soda or sulfate), the most common and widely used method for the manufacture of pulp and paper, demands that 80 - 90 % of the active alkali must be recovered for re-use, from the spent liquor, called black liquor (B.L.) in industry. Although soda recovery process from B.L. is well established and standardized during the last one hundred years, conventional soda recovery process, based on B.L. evaporation-incineration-lixiviation-causticization operations, is not applicable to smaller capacity pulp and paper units (5 to 30 TPD capacity), due to prohibitive capital investment requirement, and uneconomical operation at lower capacity plant. The complete drainage of valuable soda chemicals in the form of B.L. from small scale paper mills, makes an adverse effect on the cost of pulp production, and creates acute effluent disposal problems.

Apart from its inapplicability in mini pulp and paper mills, the conventional soda recovery process which forms an integral part of the larger capacity pulp and paper mills, cannot be termed as an efficient chemical recovery method inasmuch as the organic matter destroyed by combustion during soda regeneration cycle, represents over 50 % of the weight of the original cellulosic raw material, much of it in the form of valuable by-products. Therefore, conventional soda recovery process has been criticized, and consistent attempts have been made to simplify the process for the recovery of active pulping chemicals along with organic by-products from B.L. (1-5). A critical assessment of the black liquor regeneration process, made in an earlier communication (6), indicated the feasibility of developing a simplified soda recovery process on the basis of lignin precipitation by pressure carbonation, followed by causticization, after lignin separation by coacervation technique (7-8).

However, in B.L. carbonation process, lignin separation remains a serious problem, and the recovered active alkali is always contaminated with coloured constituents of lignin complex. Moreover, soda recovery per cent is considerably reduced due to loss of soda during lignin separation operations.

With the introduction and development of membrane based processes - reverse osmosis (RO), ultrafiltration (UF), and electro dialysis (ED) - during the last two decades, extensive exploratory research and engineering studies have been carried out on the applications of RO/UF/ED techniques in pulp and paper industry for B.L. regeneration with by-product recovery (9 - 12).

CONCEPTUAL FEATURE OF SPIRAL WOUND RO/UF MODULE

The membrane with the supporting woven polyester sailcloth on both sides, along with feed channeling arrangement (with the help of poly-propylene netting for turbulence promotion), and product channel material is wound into a spiral coil around the permeate central tube (Fig.1) whereby a large active membrane surface area is packed in a relatively small tubular housing.

When solute to be concentrated, and recovered in concentrate stream, is in the form of macromolecules (having mol. weight more than 1000), a more porous and open structured membrane (as compared to highly tight RO membrane) is used, and the membrane technique is called ultra-filtration device.

In spisal wound RO/UF module, feed is pumped into the module through an inlet fitting, and distributed across the membrane over an open-grid turbulence promoting layer. Depending on conditions of operation, solute concentration, water temperature, and pressure, 25 - 29 % of the water in the feed is forced through the membranes in stages to appear as solute free (solute rejection level is normally 90 - 95 %) reusable water, while the balance amount of water (10-60% of feed volume) goes out of the RO/UF/module as concentrate stream.

In RO/UF system for ultrafiltration in paper mills for soda recovery, permeate stream contains the free active alkali (mostly in the form of Na_2CO_3), for utilization as pulping chemicals inside the digester, while the concentrate at about 15 - 22 % TDS concentration (containing high mol. wt. lignin complex with associated soda and colouring materials) of about 10 % of the original feed, may be taken out and lagooned for solar evaporation into dried black liquor solids (with more than 80 % organic matter, and containing around 50 % of the total soda charged to the digester).

The concentration of solute in the feed can be increased to high level, by passing the first concentrate stream to the next UF module as the feed, and the second concentrate can be further concentrated in the next stages. Both physico-chemical characteristics of the feed composition, and the membrane surface, together with the molecular sizes of the solutes, are important considerations for the prediction of membrane performance during UF operation.

FEED PRE-TREATMENT SYSTEM BEFORE UF TREATMENT OF BLACK LIQUOR

Since B.L. and Decker effluent (after pulping, washing and screening operation) from pulp mill, contains significant quantity of settleable, as well as non-settleable suspended matters, it is essential to give elaborate feed treatment, before it is taken inside the UF module, for the prevention of membrane fouling, and consequently for improved membrane performance, in terms of steady permeate flux, solute and colour rejection.

Based on extensive B.L. feed pretreatment studies, optimal feed pre-treatment system has been evaluated, which consists of pH adjustment, clari-flocculation, sedimentation, screening of clarified liquor in vibro-screen, and multi-media sand filtration, and finally two stage cartridge filtration. B.L. feed pre-treatment, along with pulp washing and decking flow-sheet, ultrafiltration arrangement is presented in Fig. 2 and 3.

THEORETICAL BACKGROUND AND EXPERIMENTAL WORK

Analysis of B.L. indicates that distribution of soda compounds (expressed as Na₂O content) in soda black liquor could be represented as follows:

<u>Soda Component</u>	<u>% as Na₂O (w/w)</u>
Free NaOH	8 - 10
Free Na ₂ CO ₃	30 - 35
Organo-Soda (with low MW lignin fraction)	15 - 20
Organo-Soda (with high MW lignin fraction)	20 - 30
Na ₂ SiO ₃	5 - 10
Others (soda in extractives and organic acid salts)	10 - 20

Therefore, around 55 - 60 % of the total soda in B.L. is present in low mol. wt. soda fraction (mostly as Na₂CO₃), and therefore could be removed as permeate flux in UF system. High mol. wt. lignin fraction (containing colour bearing constituents) is expected to be rejected at the membrane surface, and could be removed as concentrate stream.

To evaluate the performance of UF system, during treatment of B.L. feed, experiments were carried out in test-cells, which indicated colour rejection of above 90 %, soda recovery at about 50 % (as active soda chemicals mostly as Na₂CO₃) when the feed pressure was maintained at about 15 kg/cm² with feed flow rate 12 - 14 lpm.

Further experiments were carried out in spiral wound UF module (active membrane surface area of 2.80 m²), as per the experimental set-up depicted in Fig. 4.

Long-range evaluation of membrane performance studies, during UF treatment of B.L. feed (concentration range 0.25 % to 10 % TDS), under optimal conditions of feed pressure and flow rate, indicated pronounced membrane fouling, whereby permeate flux was reduced to the level of 50 % of the initial permeate flux, within an operation of four hours.

Therefore, further experiments were carried out after feed pretreatment (as per the arrangement presented in Fig. 2), and permeate flux declining characteristics were reduced considerably, and stabilized flux could be achieved within the range of 15 - 35 lit/m²/hr, depending upon feed concentrations of 2 % to 10 % TDS.

Spiral wound UF experiments were carried out with Cellulose Di-Acetate (DS = 2.55) membrane made indigenously, having pH tolerance 4 - 8, and thermal stability of 40°C. Significantly improved membrane performance could be achieved with non-cellulosic TFC membranes, obtained from the DDS Corporation, Denmark, having pH tolerance of 2 - 11, and thermal stability to above 60°C, in a plate and frame DDS module.

ECONOMIC ATTRACTIVENESS OF THE PROPOSED SODA RECOVERY PROCESS (BASED ON ULTRAFILTRATION) DEVELOPED AT THE IIT - BOMBAY, FOR MINI PULP AND PAPER INDUSTRY

In conventional Mini Pulp & Paper Industry, agricultural residues (straws/bagasse), along with waste-paper/cotton linters/rags, hosiery cuttings etc. are used as the cellulosic raw materials, and pulping is carried out either in spherical pressure digesters or in hydra-pulper (mechano-chemical - MC Pulping process) by soda process, with 8 - 10 % Alkali (based on OD raw material) as Na₂O.

Since there is no soda recovery process in mini paper plants (unlike in bigger capacity pulp and paper plants, where soda recovery process from spent pulping liquor, (called black liquor - BL) is an integral part of the paper manufacturing process, mini paper industry (capacity around 5 to 30 TPD) is passing through acute crisis due to high cost of pulp production, and big pollution problem since the whole amount of BL is discharged to the drains (which goes to the river ultimately).

Approximately 30 % of the paper production in India is manufactured in mini pulp and paper units, which plays an important role not only in India, but also in all the developing countries in Asia-Africa and Latin American countries. Mini pulp and paper units could be scattered throughout the country (including backward districts in States), and all the plants and equipments may be manufactured indigenously in a much shorter period (1-2 years for mini paper units,

compared to 5 - 6 years for the large paper units, having capacity of 100 TPD and above). Moreover, unit capital investment is much smaller in case of mini units, as compared to the larger units (Rs 6500 - Rs 7500 in case of mini units, compared to Rs 17,000 - Rs 18,000 per ton of paper production/year, in larger capacity units).

Under the present socio-economic conditions in a developing country like India, more emphasis should be given to the development of mini pulp and paper units (for meeting the gap between the production and consumption for decentralization of the industries, and for the regional industrial development (with much higher employment opportunities to the backward regions of the country)).

Therefore, for the survival of the mini pulp and paper industry, it is essential to develop a simplified and low-cost soda recovery process from B.L., which could give good amount of economical benefit in ameliorating the present crisis in mini pulp and paper industry.

Against this background of critical situation in mini paper industry, ultra-filtration based soda recovery process, developed at the IIT Bombay, after extensive R&D work during the last 6 - 7 years, may be considered as an appropriate technology for the pulp and paper industry in India, and in developing countries. Soda recovery process based on UF appears to be the best practicable technology for mini pulp and paper industry, which is economically attractive, and environmentally very sound.

PROFITABILITY OF THE PROPOSED UF BASED SODA RECOVERY PROCESS, IF IMPLEMENTED IN MINI PULP AND PAPER INDUSTRY (CAPACITY 5 TO 30 TPD)

On the basis of 45 % unbleached pulp yield (based on agri-residues), and 10 % alkali charge, NaOH charge, NaOH requirement as Na₂O/Ton of pulp production

$$= 1/0.45 \times 0.10 = 0.220 \text{ T} = 220.0 \text{ Kg (conventional Pulping Process)}$$

It has been found that, if agri-residue is given washing with dilute alkali, before actual pulping in hydrapulper (according to MC pulping process), or in spherical pressure digester, alkali consumption could be reduced to at least 20 % of the conventional pulping process, with equivalent or better quality pulp at the same yield.

Therefore, alkali requirement in the proposed pulping process (after giving wet washing, as per details in Ref. 18) is reduced to 176 Kg compared to 220 Kg/Ton of pulp production, a saving of 44 Kg Alkali as $\text{Na}_2\text{O}/\text{T}$ pulp.

Flow sheet of the UF based soda recovery process from B.L. is depicted in Fig. 2 and 3.

As shown in Fig. 1, per ton of pulp production, 15 m^3 of B.L. (Dil) at 2:00/TDS concentration is generated, which after pH adjustment and clari-flocculation, is reduced to 15 m^3 , (stream-2) going to the UF modular system with 50 Nos Pressure Tubes. Similarly, 1800 - 2000 gallons ($7 - 8 \text{ m}^3/\text{T}$) of concentrated B.L. stream from the digester at about 10 - 12 % TDS, is sent to the UF system (after pre-treatment) consisting of 40 Nos Pressure tubes (Stream - 1).

As per the flow diagram of the proposed UF based soda recovery process (Fig. 3), on the basis of 50 % permeation of soda as Na_2O , loss of 5 % soda during pulping and washing, and further 5 % loss of soda during pH adjustment of B.L., followed by clarification, 150 Kg of soda as Na_2O is passed to the UF module as feed, and 80 Kg of Soda is permeated as Na_2O in the permeate of 13.50 m^3 .

In pulping spent liquor (B.L.), 55 - 60 % of the total amount of soda compounds are present in the form of free soda compounds, mostly as Na_2CO_3 . During UF operation, most of the free soda passes to the permeate, thereby recovering around 72 kg of total soda ($80 \text{ kg Na}_2\text{CO}_3$ Na_2O assuming 90 % soda in permeate as Na_2CO_3). Taking 13.50 m^3 permeate (containing soda equivalent to 72 kg of Na_2CO_3 as Na_2O) as recovered soda, 104 kg of Na_2O as NaOH is added to the permeate as solid caustic soda, giving 176 kg of Na_2O to the digester for pulping of straws, after wetwashing with 15 m^3 of decker effluent. For most of the trades of paper, further causticization of 'modified white liquor'

(UF permeated flux) is not necessary, since causticity of the pulping liquor is sufficiently high (after addition of 104 kg of solid caustic soda as Na_2O).

CAPITAL INVESTMENT REQUIREMENT, AND OPERATIONAL COST FOR UF BASED SODA RECOVERY PROCESS IN MINI PULP AND PAPER MILL (CAPACITY - 20 TPD):

Amount of B.L. (from the digester) / of pulp production at 8 - 10 % TDS concentration = 7 m^3 .

On the basis of 10 - 15 % B.L. loss during feed pre-treatment, amount of pre-treated feed to the UF module = 6.30 m^3 .

Permeate flux rate = 3500 lit/D per UF module of 10 m^2 membrane area.
Therefore, No. of membrane modules required/D = $6.30/3.50 \times 20 \times 0.90$
(90 % feed recovery) = 34 = 40 (with 15 % extra)

Amount of diluted B.L. feed to the UF module = $(6.30 \times 0.90 + 9) \text{ M}^3/\text{T}$
(before treatment) = $5.67 + 9 = 14.67 \text{ M}^3$

Amount of treated feed (diluted) to UF module at 2 % TDS
= $12.13 \text{ M}^3/\text{T}$ (assuming 10 % B.L. loss during feed pretreatment)

Permeate flux rate = 5000 lig/D per UF module of 10 m^2 membrane area.
Therefore, No. of UF modules for diluted B.L. feed = $12.13/5 \times 20 \times 0.90$
= 43.60 = 50 (with 15 % more UF modules as spares) (90 % feed recovery)

Permeate flux for diluted B.L. at 2 % TDS, is based on indigenously developed CDA based UF modules, and permeate flux data for concentrated B.L. feed at 8 - 10 % TDS concentration, is based on imported DDS UF modules, which is resistant to higher pH, and higher temperature.

For operational cost estimation, membrane service life is taken as one year for both the CDA, and non-cellulosic membranes.

Permeate flux data used in membrane area estimation is based on average value, when the feed is treated in stages, in parallel - series modular configuration.

Fixed capital investment for membrane modules (50 + 40 = 90 Nos), based on latest quotations received from the RO/UF module manufacturing

$$\begin{aligned}\text{Industry} &= (50 \times 5000 + 50 \times 6000) = 40 \times 8000 + 40 \times 12000 \\ &= \text{Rs } 13.50 \text{ lakhs}\end{aligned}$$

Investment cost is based on standardized pressure tube (10 cm ϕ x 1.80m) cost of Rs 5000 and Rs 8000 respectively for indigenous and imported pressure tubes respectively, and membrane costs of Rs 6000 and Rs 12000 per 10 m^2 spiral membrane pack respectively for indigenous, and imported ones.

Capital investment for other equipments (high pressure pumps, instrumentation, and accessories) = 80 - 100 % of membrane module cost with membranes
= Rs 13.50 lakhs (taking 100 %)

Capital investment for feed pre-treatment facilities (including pH adjustment, clari-flocculation-sedimentation unit, vibro-screen, sand-filters, and cartridge filters of 25 μ and 5 μ) = 70 % of capital cost.

Normally, feed pre-treatment cost varies from 20 - 50 % of capital cost, and 70 % is taken for B.L. feed pre-treatment, since B.L. from pulp mills contain higher loads of suspended materials (both settleable and non-settleable) and therefore, more elaborate feed pre-treatment is recommended for B.L. treatment by ultra-filtration.

Therefore, capital investment requirement = Rs (13.50 + 13.50 + 18.90) lakhs
= Rs 45.90 lakhs - Rs 46 lakhs.

OPERATIONAL COST AND PROFITABILITY

Total operational Cost (C_T) = Membrane replacement cost + Power cost + Chemicals & cartridge filter replacement + Labour & Maintenance (3 % of I_f) + Depreciation (10 of I_f , other than membranes).

- (1) Membrane replacement cost = Rs (50 x 6000 + 40 x 12,000) Lakhs
= Rs 7.80 lakhs
- (2) Power Cost = 7 x 20 x 24 x 320 x 0.50 = Rs 5.38 Lakhs
(On the basis of 7 KW/T power requirement, and power cost of Rs 0.50 per KWH)
- (3) Chemicals & Cartridge filters replacement = Rs 2.00 lakhs (on the basis of calculated requirement).

(4) Labour and Maintenance = $0.03 \times I_f = \text{Rs } (0.03 \times 46) \text{ lakhs} = \text{Rs } 1.38 \text{ lakhs}$

(5) Depreciation = 10 % of I_f (other than membrane)
= $0.10 (46 - 7.80) = \text{Rs } 3.76 \text{ lakhs.}$

Therefore, total operating cost (C_T) = $1 + 2 + 3 + 4 + 5$
= Rs 20.32 lakhs

Total amount of tangible benefits = Recovered Soda for recycling + Water
Recycling and Pollution abatement.

Savings through Soda recycling = $0.072 \times 106/63 \times 20 \times 320 \times 2000$
= Rs 18.02 lakhs. (Na_2CO_3 Cost - Rs 2300/T)

Savings through pollution abatement = Rs (75 x 20 x 320) lakhs
(on the basis of pollution control) = Rs 4.88 lakhs.
cost of Rs 150/T, 50 % pollution
abatement by the proposed UF based soda recovery process).

Therefore, without water recycling benefit into consideration,
expected savings (after meeting operational costs) = Rs (22.90 - 20.32) lakhs
= Rs 2.58 lakhs

Economics of the proposed UF based soda recovery process could be improved considerably, if the lagooned concentrate, after solar evaporation (containing 50 - 55 % of the total soda charged to the pulping digester), is used as fuel for steam generation at the mini pulp and paper mills. Dried black liquor solids, containing over 85 % organic matter, may be used as a high grade fuel, whereby steam generation, and soda recovery could be coupled, in a specially designed fluidized bed boiler. However, further work is necessary on drying and burning characteristics of black liquor solids (from the UF concentrate), which could be utilized in the design of the steam generation boiler with black liquor solids as the main fuel.

Recently, two more alternatives (a) wet-combustion (Zimpro Inc.) of B.L. and (b) Ferrite process, have been suggested as an appropriate soda recovery process, for utilization in mini pulp and paper mills. While techno-economically both the alternatives appear to be sound, for the Mini Pulp and Paper Mills, both the alternatives suffer from the following defects:

- (1) High capital investment, and hazardous evaporation-incineration steps/ with agri-residue based cellulosic raw materials render it unsuitable for mini units,
- (2) High skilled man power requirement, and sophisticated equipments,
- (3) High operating costs due to proprietary nature of the technology.

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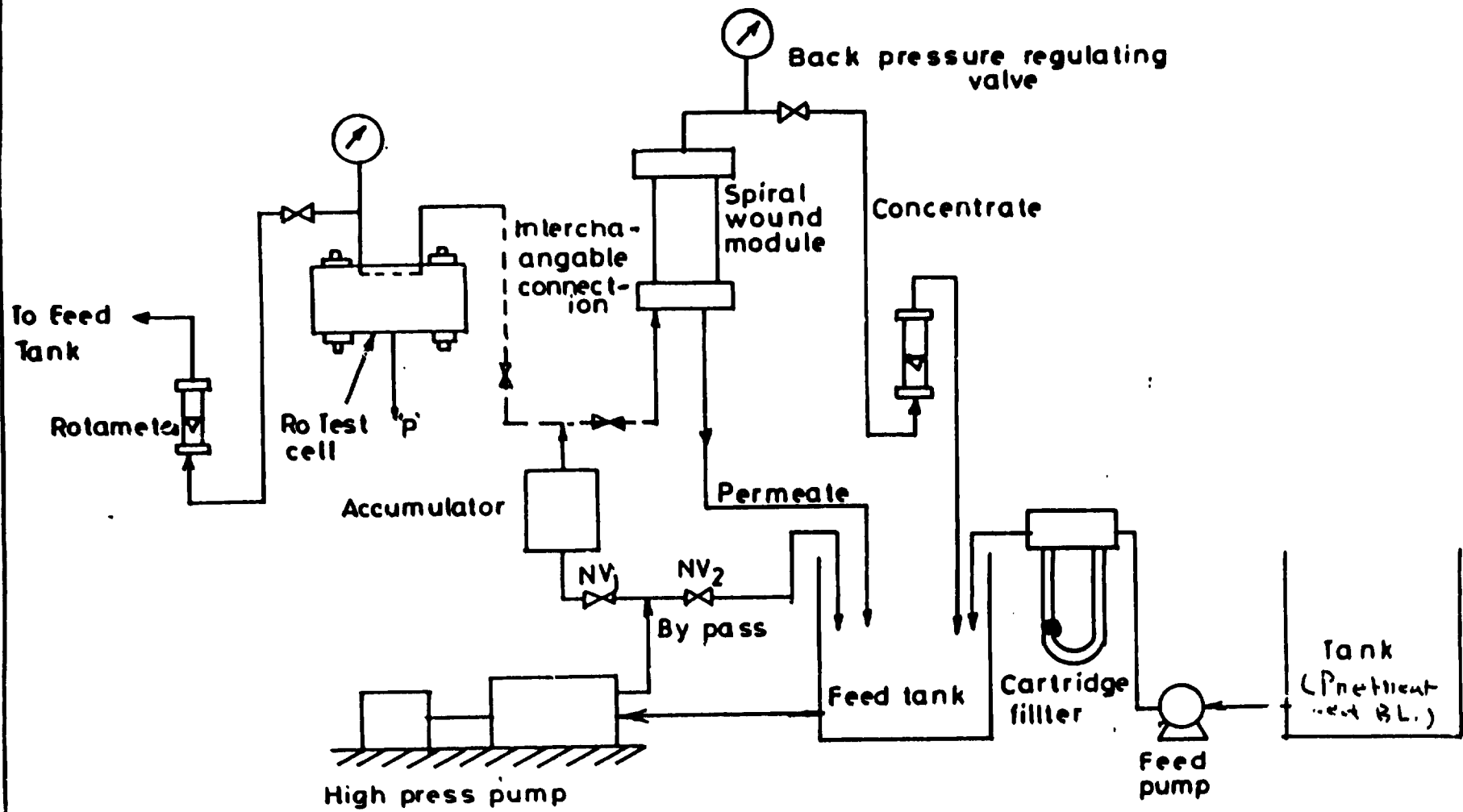


FIG 4. TESTING LOOP FLOW SHEET

RECENT DEVELOPMENTS IN DESILICATION
OF RICE STRAW BLACK LIQUOR

by

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Abstract

Because of the inherent high silica content (8 - 14 g/l) in rice straw black liquor, the recovery of pulping chemicals and heat energy by conventional recovery system was not possible. This is because silica causes serious problems at the various recovery stages (evaporation, combustion, caustification and lime sludge incineration). To solve the problem of silica, RAKTA Paper Company, Egypt and LURGI Co., West Germany have conducted a joint R&D programme. As a result, a new technology for desilication of rice straw black has been developed. Long continuous test runs on a semi-industrial scale under varying mill operating conditions have proved the high efficiency, simplicity and reliability of RAKTA - LURGI desilication system. A desilication degree exceeding 95 % could easily be achieved. The successful desilication of black liquor would enable RAKTA to install a chemical recovery plant to improve the economy of pulp production and to alleviate the problem of environmental pollution. The desilication system could also benefit the existing recovery plants of non-woody pulp mills in overcoming the silica problem and improving the recovery efficiency and economy. It will also promote the establishment of more new pulp mills based on nonwood plant fibre since silica would be no longer a problem in the recovery of heat and chemicals.

Introduction

The economics of chemical pulp production are largely dependent on the recovery of cooking chemicals and heat energy from the spent pulping liquor (black liquor). Pulp mills based on wood have their own chemical recovery plants which could recover over 95 % of the chemicals used in pulping in addition to the heat energy. Pulp mills based on non-wood plant fibres such as bamboo, reed, sugarcane bagasse and wheat straw could also have chemical recovery plants but working at lower efficiency and suffering from troubles mainly due to the presence of high silica content in the black liquor. Of all plant fibres presently used in pulp production, rice straw has the highest silica content which may reach up to 13 % of the straw weight. Chemical recovery from rice straw black liquor containing such a high silica content of 8 - 14 g/l or more would be quite impossible by conventional recovery plants.

On the other hand, recovery is usually necessary to reduce the large quantities of pollutants present in the black liquor that would otherwise be released to the environment causing pollution.

Therefore, to improve the economics of its pulp production and to alleviate the existing problem of environmental pollution, RAKTA had to seek ways and means to solve the silica problem that has long impeded the recovery of heat and chemicals from its rice straw black liquor.

Silica Problem in Chemical Recovery

The presence of high silica content in black liquor would create operating problems at various stages of conventional recovery system (evaporation, combustion, caustification and lime recovery). For instance, silica reduces the evaporating capacity by forming scales and deposits on the evaporator tubes during combustion of the thickened silicious black liquor. Hence, operation has to be frequently stopped to remove the scales and deposits by mechanical and/or chemical means.

In the causticizer, the presence of silica in the green liquor reduces the causticizing efficiency and retards the sedimentation of lime sludge. Furthermore, silica is transferred to the lime sludge as calcium silicate during the causticizing operation. Recovery of lime from a high silicious lime sludge would not be feasible.

Past Studies on Desilication of Nonwood Black Liquor

In view of the silica problems encountered in the recovery of heat and chemicals from nonwood black liquors, attempts have been made to remove the silica from the black liquor before it enters the recovery plant. Most of the investigations conducted on desilication were based on the following methods:

- Lime Method:

Silica could be precipitated as calcium silicate by the addition of quicklime (calcium oxide). The temperature, the quantity of lime and precipitation conditions as well as the concentration of black liquor were found to be very important factors in determining the degree of desilication and the filtration behaviour of the precipitate.

- Carbon Dioxide Method:

Silica could also be precipitated by reducing the pH of the black liquor by introducing carbon dioxide gas or carbon dioxide - containing gas mixture e.g. flue gas. The application of CO₂ - containing gas mixture is preferred to pure CO₂ to prevent local acidification and increased precipitation of lignin.

Precipitation of silica takes place within a pH range of 10.2 - 9.1. Coprecipitation of lignin occurs within tolerable limits in this pH range. Coprecipitation of lignin increases linearly with decreasing pH value and at a pH lower than 9, lignin precipitation intensifies. On the other hand, the silica content in the treated black liquor would depend on the pH value and the temperature.

- Other Methods:

Some other desilication methods using aluminium sulphate, magnesium sulphate, sodium bicarbonate, sulphuric acid were also investigated with varying degree of success.

RAKTA - LURGI Desilication Project

Being aware of the problems encountered in the chemical recovery from high silicious black liquors, particularly from rice straw, the General Co. for Paper Industry "RAKTA" has decided to undertake an extensive Research and Development Programme aiming at developing an efficient and reliable desilication system to render the recovery of heat and chemicals from rice straw black liquor feasible and trouble-free. A work programme was formulated and implemented in two phases.

Phase I

The purpose of this phase was to carry out desilication tests on a laboratory - scale to determine the best method for removing silica from rice straw black liquor before entering the evaporation plant. Two promising methods, namely the lime and the CO_2 (flue gas) for precipitating the silica were selected for investigation. Separation of precipitated silica or calcium silicate was also studied using sedimentation, filtration and centrifugation techniques.

Test results showed that:

- No complete silica precipitation was obtained with any of the precipitating agents (CaO or CO_2) when the black liquor contained low dry solids of approximately 4 % as it came directly from the mill brown stock washing plant.
- Nearly complete silica precipitation was reached when the black liquor was preconcentrated to a dry solids content of about 8 % or higher.
- A desilication degree exceeding 95 % could be achieved by either of the two methods under proper precipitation conditions.

- The sedimentation rate of precipitated silica or calcium silicate was slow. Hence, a relatively long retention time (over 6 hours) of the liquor in the settling tank is required to separate the precipitate. Apart from large settlers needed, long retention time may cause additional precipitation of lignin due to drop of pH on aging.
- Separation of silica precipitate by pressure filter was met with difficulties due to the clogging of filter within a short period of time and a clear filtrate could not be obtained.
- Centrifugal separation of silica precipitate has proved to be the most efficient technique under all precipitation conditions. Centrifugal separation gave the lowest residual silica content in the clarified liquor.
- The separated silica sludge contained useful organic and sodium salts which required further sludge treatment to recover such valuable chemicals.

Phase II

The promising results obtained from the laboratory-scale tests (Phase I) had encouraged "RAKTA" to conclude an agreement with LURGI Co. of West Germany to design and set-up a pilot plant on the premises of RAKTA Mills, Alexandria, Egypt to perform further tests on a semi-industrial scale and to elaborate the desilication method and silica sludge treatment. With financial support granted by the Federal Ministry of Research and Technology of the F.R.G., a pilot plant was installed in 1980 and black liquor desilication tests were conducted jointly with LURGI.

Although a high desilication degree could be achieved by the lime method, this process was excluded from further investigation on the pilot plant-scale. This process is expensive because much lime is consumed and the losses of organic and alkaline substances are relatively high. Besides, some of the polyphenols in black liquor form soluble calcium compounds which would lead to additional calcium scaling of the evaporator. Furthermore, the voluminous calcium silicate sludge may pose a disposal problem.

Therefore, the pilot plant was designed for continuous treatment of black liquor with CO_2 - containing gas i.e. flue gas as the precipitating agent. The pilot plant has a throughput of $2 \text{ m}^3/\text{h}$ which represents 1/50 of the large-scale plant for RAKTA Pulp Mill at a production rate 160 tpd bleached rice straw pulp and black liquor of 2400 m^3 pd or $100 \text{ m}^3/\text{h}$. The equipment selected for the pilot plant is all standard equipment readily available on the market. No equipment of special design was involved to avoid the risk of untried equipment especially when scaled - up to the large size.

RAKTA - LURGI Desilication System

Fig. 1 shows a flow diagram of the desilication and chemical recovery system used in our tests. Weak black of 3 - 5 % dry solids is continuously pumped from the mill brown stock washing plant to a liquor filter for separation of suspended fibres and fines. The removal of these suspended solids is essential to avoid scaling and other troubles in the evaporation plant. All recovered fibre is returned to the pulping line for additional gain. The filter had a throughput of $20 - 40 \text{ m}^3/\text{h}$ to supply not only the required amount of filtered liquor for the desilication tests but also to perform tests on washing the wire of the first brown stock washer with filtered liquor instead of fresh water to increase the initial black liquor concentration. The filtered liquor flows to a dump chest of 12 m^3 capacity, from where it is pumped to an industrial-scale evaporation plant for concentration to approximately 8 % dry solids or higher. The evaporation plant is a 4-effect evaporator (3 falling film effects and 1 forced circulation effect) with a nominal water evaporation rate of 18.5 ton/h. This evaporator was also used for concentrating the desilicated black liquor to the dry solids content required for combustion in a recovery furnace. The behaviour of the liquor during concentration was studied with regard to viscosity to get the necessary data for the design of an industrial-scale evaporation plant.

The preconcentrated black liquor is continuously fed to a precipitator reactor. Flue gas from an oil-fired boiler is simultaneously fed to the reactor by means of a blower. Intensive mixing of the black liquor with flue gas takes place for about one hour retention time where the pH of the liquor is reduced to a predetermined value required for precipitating the silica. The treated black liquor is continuously discharged from the reactor to an intermediate tank. From this tank, the liquor is pumped to a continuously operating centrifugal separator with a design capacity of 2 m³/h to separate the silica sludge from the liquor. The desilicated liquor flows to a storage tank from where it is pumped to the evaporation plant for further concentration to be combusted in a vertical incinerator. The smelt is dissolved in water to produce green liquor.

Silica sludge is separately treated and incinerated at 900 to 1000 °C to a white powder.

Test Results

The results obtained from the semi-industrial scale tests have confirmed the previous laboratory findings. Precipitation of silica by flue gas under proper conditions of liquor solids content, pH, reaction time and temperature and the separation of precipitated silica by centrifugation have resulted in a desilication degree exceeding 95 %.

Long continuous test runs under varying mill operating conditions have proved the high efficiency and reliability of the desilication system developed by RAKTA - LURGI.

The separated silica sludge amounts to about 3 % by weight of the treated black liquor and has approximately 40 % dry solids. The losses in alkali and organic matter are very low amounting to 4.5 % and 3.0 % respectively. However, with the special technique - being developed by RAKTA - LURGI - for the treatment of silica sludge, most of the

residual alkali and organic matter will be recovered and returned to the recovery plant while the silica will be transformed to a snow-white powder suitable for use as a filler in papermaking and/or in plastic and glass industries. In this way, disposal problem of silica sludge will be eliminated and a clean technology will be realized.

Prospects of Black Liquor Desilication

1. Successful desilication of black liquor using RAKTA - LURGI Technology will enable RAKTA Co. to set-up a commercial plant for recovery of heat and chemicals from its spent pulping liquor. Besides the abatement of environmental pollution caused by discharging the mill effluents without treatment, the economy of the company will be significantly improved by the recovery of cooking chemicals (sodium hydroxide) worth of about LE 6 million per year.
2. For the existing recovery plants of non-wood pulp mills which are working at lower efficiency and suffering from silica problems, desilication of black liquor would much improve their efficiency and economy and make the recovery less troublesome. In addition, they would be able to recover lime from the lime sludge.
3. Desilication of black liquor would promote the establishment of more pulp mills based on nonwood fibrous raw materials particularly agricultural residues rich in silica.

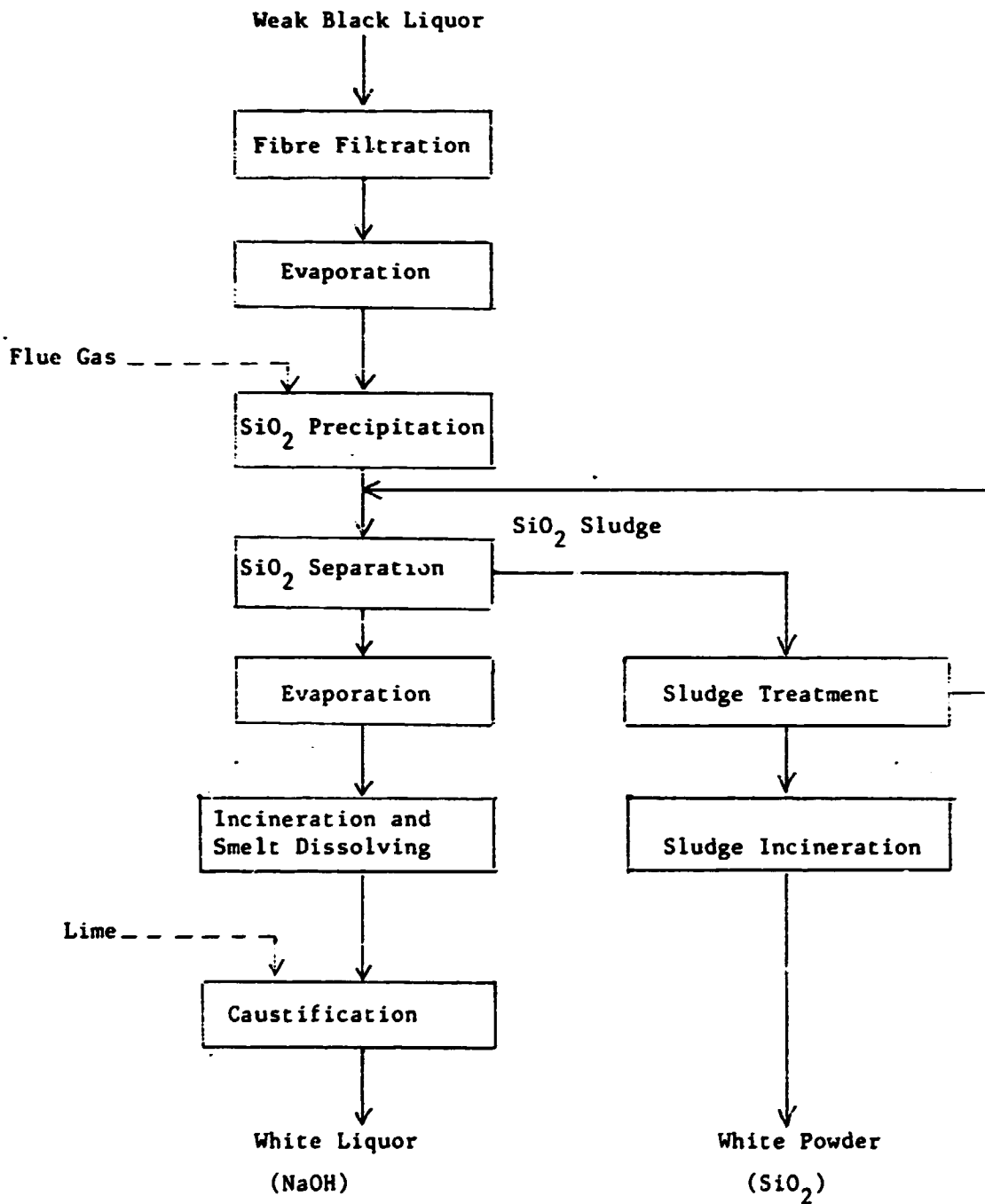


Fig. 1 RAKTA - LURGI Pilot Plant
For Desilication of Rice Straw
Black Liquor and Chemical Recovery

THE DESILICATION OF BLACK LIQUORS

by

K. Kopfmann
Senior Executive
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ABSTRACT

RAKTA - General Company for Paper Industry, El Tabia, Rashid Lane, Alexandria, Egypt and the Pulp Division of Kraftanlagen Heidelberg, Munich, a former division of BKMI Industrieanlagen GmbH, have successfully finalized a joint R+D programme concerning the desilication of black liquor from non-woody fibre pulp mills.

A pilot plant has been installed at the RAKTA mill in 1979 with a capacity of 4 m³/h of black liquor. After almost three years of very extended research work with numerous trial runs the partners succeeded in the development of an efficient and economical process to the extent that it became possible to design the first large scale desilication plant. This desilication plant was supplied to Kertas Letjes, Leces, Indonesia and was started up in 1985.

Besides the aspects and the criteria connected to the subject of black liquor desilication this paper describes the basic features of the pilot plant, the design data for the Letjes mill as well as the results obtained up to now.

1. DESILICATION AND PROBLEM DETERMINATION

Due to the limited availability of wood fibres as raw material in the subtropics and tropics, the pulp industry in these countries is forced to accept agricultural residues as alternative raw material sources in increasing quantities. Additionally, reed and bamboo are utilized to fill the demand of the paper industry. All these annually harvested fibre plants have in common that due to their morphological structure they contain more or less organically combined silica, i.e. "organic silica".

The harvesting methods and the handling of the raw material prior to its final utilization in the pulping industry can increase or reduce the total silica content of the fibrous material which, entering the pulp mill, consists of the "organic silica" and of silica components sticking to the outer surface of the plants originating from the soil. (See Table 1 "Silica Content of Various Raw Materials").

Table 1 - Silica Content of Various Raw Materials

Wood	Traces
Bagasse	1.3 - 1.8 %
Reed	2.5 %
Bamboo	1.0 - 2.0 %
Wheatstraw	3.5 %
Ricestraw	8.0 - 12 %
- maximum	up to 20 %

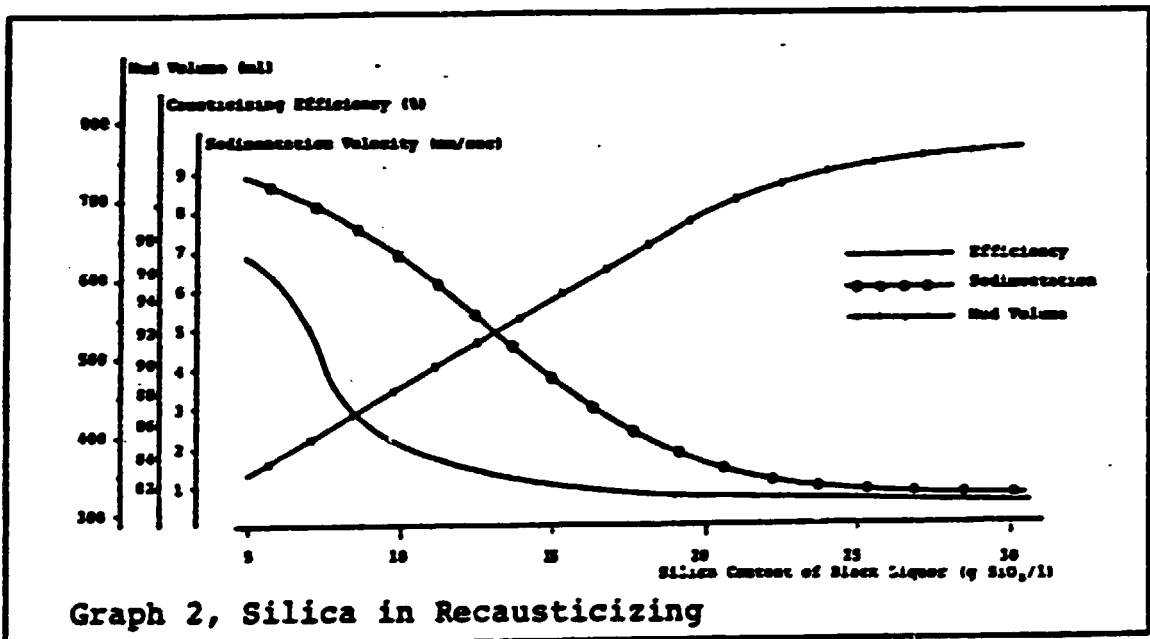
During the cooking process which uses strong alkaline cooking agents, the silica is partly converted to soluble components. The amount of soluble silica compounds in the black liquor is depending on the alkali ratio in the digester, i.e. more alkali dissolves more silica.

In all process stages an elevated silica content is detrimental to the efficiency in many aspects.

In the evaporation system, the silica may precipitate at higher concentration and scale formation will be observed which reduces heat transfer. During incineration of the organic matter the SiO_2 content in the black liquor (7 to 10 % based on TS) is raised to 12 % to 15 % in the smelt resp. green liquor. Therefore the silica influences the melting behaviour and can cause incrustations especially in the economizer and flue duct system, which is also a consequence of the modified melting behaviour.

In the recausticizing system the separation of the lime mud is disturbed by silica and in the lime kiln, if present, additional scaling problems and chemical losses will be observed. (See Graph 2 "Silica in Recausticizing"). Furthermore, it is assumed that unrecoverable sodium-calcium-silica compounds are formed which increase chemical losses.

Graph 2 - Silica in Recausticizing



Graph 2, Silica in Recausticizing

For a pulp mill with its raw material supply depending on non-woody fibres it becomes more and more essential to remove the silica from the process in order to operate the plant with protection of environment in mind and to produce with high efficiency on an economical base. This is especially true and unavoidable in the case of rice straw and can be considered for other non-woody fibres in case bleeding has to be minimized in the lime recycling. On the following pages a silica removal system is presented which, after extensive research, has been realized at an industrial scale for the first time. It is designed to process black liquors from bagasse and rice straw pulping.

2. THE PRINCIPLE

The principle of silica removal is well known since long and is dealt with in various technical papers. During the cooking process, silica is dissolved in a strong alkaline medium e.g. NaOH and water. The pH value of this solution is well above 11. By lowering the pH value with a suitable acid like carbonic acid, the solubility limit is reached for SiO_2 compounds at slightly above pH 9 (in presence of other chemicals). The lignin compounds in the black liquor also reach their solubility limit at around pH 9. Precipitation of SiO_2 out of black liquor further depends on the time gradient at which the pH value drops which also influences the removability and final sludge consistency. Since the chemo-physical process of precipitation is dependent on several side reactions, sufficient capacity for CO_2 injection, maturing of sediments and separation have to be provided the more so since the composition of black liquor as a complex chemical solution is not stable.

The control equipment for pH value, throughput, temperature, etc. has to be carefully designed, especially due to varying black liquor compositions, in order to prevent the precipitation of lignins or other organic compounds.

3. THE DEVELOPMENT

The development of the black liquor desilication system was based on the following considerations:

- a) Removal of unwanted silica and silica compounds ahead of the recovery process so that the entire recovery section can operate without handicaps due to the presence of silica;
- b) No use of additional chemicals which are not already available at low or no cost in the mill;
- c) No restrictions to the cooking process, i.e. all soda and sulphate liquors containing silica to an extent detrimental to chemical recovery can be processed;

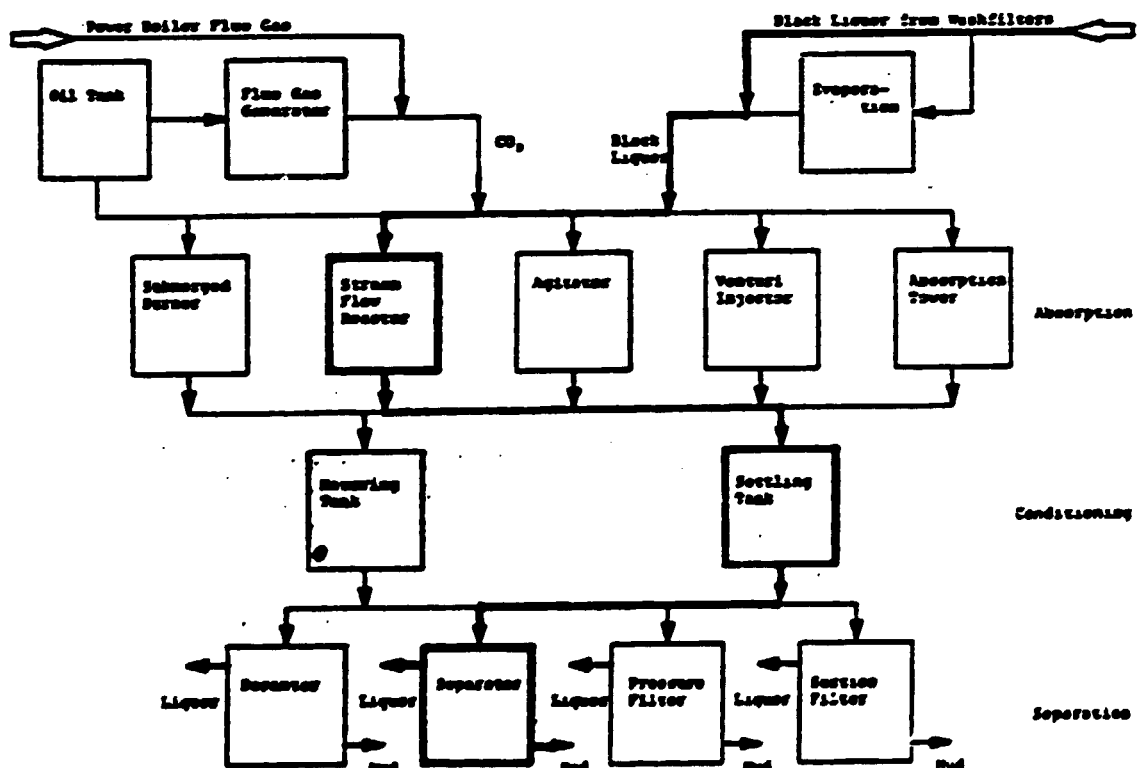
- d) Minimized losses of cooking chemicals, i.e. not affecting the overall recovery efficiency;
- e) Minimized losses of organic matter in order to protect environment;
- f) Separation of silica in a form allowing a safe disposal or further use for other purposes, i.e. low water content of silica sludge and high SiO₂ content of the sludge.

To observe considerations under a) above, the silica has to be removed from the thin black liquor as supplied from the wash filter plant. The only preparatory measure is to filter the black liquor to remove suspended matter like fibrous material.

Considerations under b) above led to the use of CO₂ for SiO₂ precipitation, being available in the flue gas of the steam and/or the recovery boiler or even from the lime kiln.

Taking these considerations as prerequisites, a pilot plant with a capacity of 4 m³/h black liquor was installed at the RAKIA mill in 1979. It was equipped to an extent that allowed a great number of different process conditions to be tested (viz. Block Diagram 3 - Pilot Plant Set Up). Finally, the stream flow reactor to initiate the precipitation and a centrifuge were selected which in combination yielded optimum results.

Block Diagram 3 - Pilot Plant Set-Up



4. MAIN CRITERIA

During a period of almost three years numerous test runs were carried out whereby the following main criteria emerged.

Absorption

The first step of the process involves the contact of CO_2 with the black liquor. After testing of five different pieces of equipment, the highest efficiency was found with a so-called "stream flow reactor". Black liquor and flue gas are mixed with each other under pressurized conditions and pumped into the stream flow reactor. Passing through the reactor, gas and liquor are remixed repeatedly by means of special inserts. Simultaneously, the mixture is subjected to a continuous pressure drop.

The aim of this step is a pH drop in the black liquor obtaining a pH value which achieves a maximum in terms of SiO_2 precipitation and a minimum in terms of lignin precipitation. The required pH value has to be maintained within a rather narrow range.

Special care has to be taken in

- designing the reactor in compliance with the exact operating conditions such as throughput of black liquor and required rate of flow for CO_2 . Also of great importance are, of course, ratio of gas : black liquor, retention time and gradient of pressure decrease.
- monitoring of pH value of black liquor after reaction. pH control should not affect the constant volume of flue gas but should control amount of CO_2 by infiltration of air.
- origin and composition of black liquor. Raw material of pulp, content of active and inactive alkali as well as silica content finally govern individual process conditions. This is also true for other parameters such as temperature and concentration of untreated black liquor as well as "maturation" of black liquor treated with CO_2 .

Separation

As mentioned previously, SiO_2 sludge is separated from the black liquor by means of centrifuges. Selecting the proper type and size of centrifuge has to aim at a high degree of classification as well as at a low moisture content of the separated sludge. While the degree of classification determines the residual SiO_2 content of the black liquor in front of the evaporation system, the dry content of the sludge will not only define the volume of sludge to be handled and disposed of but also the chemical losses depending on the black liquor remaining in the sludge.

Separators with self-discharging bowls have turned out to be of a very suitable type, since their control system allows an easy adjustment to the varying feeding conditions in terms of throughput and amount of sludge.

Nozzle type separators have proved to be unsuitable since they are very sensitive to even slightly varying feeding conditions. Sludge concentration is rather poor, since higher concentrations are bound to plug the nozzles.

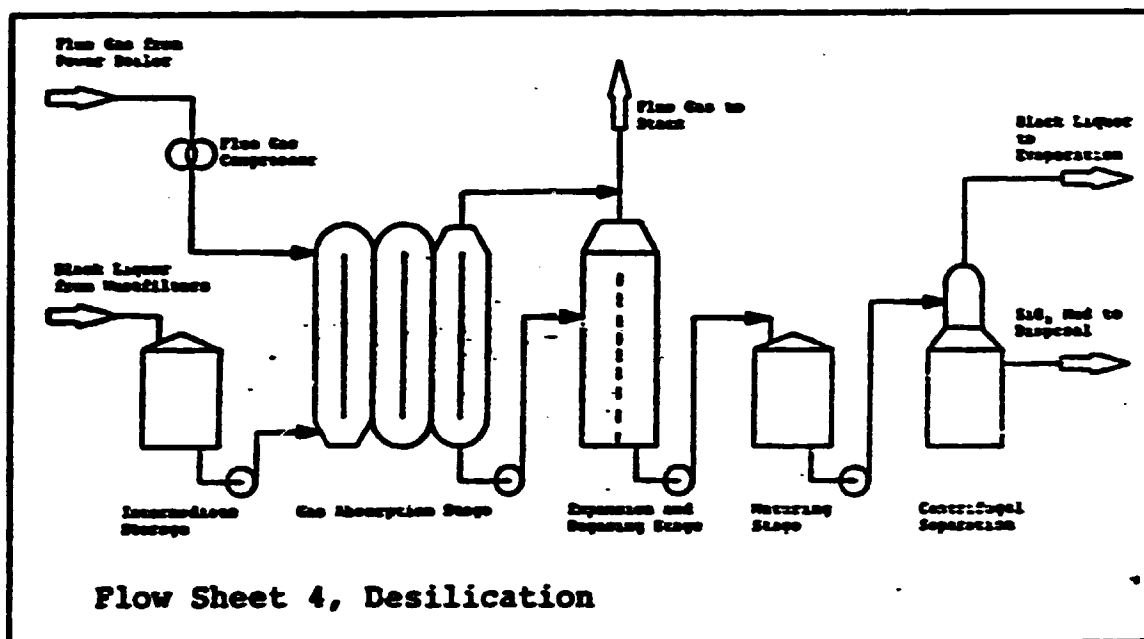
A two-stage separation to reduce sodium losses in sludge is possible but requires a reconditioning of the sludge in front of the second stage, since the silica formation which has been altered during the first step separation has to be rebuilt by a further CO_2 treatment.

5. THE SOLUTION

The final scope of the industrial system for silica elimination consists of

- Flue gas compressors with integrated flue gas cooling
- Flue gas injection and stream flow reactor
- Gas - black liquor separation
- Sludge maturing and storage facilities
- Centrifuge with integrated cleaning system
- Sludge handling facilities

Flow Sheet 4 - Desilication



Consequently, the design of a large scale desilication plant for Letjes IV, Indonesia, with a capacity of $160 \text{ m}^3/\text{h}$ follows these process steps. There mixed black liquor produced from bagasse and rice straw is passed through a black liquor filter and collected in a large storage tank. From there it is pumped to two reactors arranged in parallel. If required, a heat exchanger can be used to adjust the proper temperature of the black liquor. Flue gas of the recovery boiler is cooled by means of water injection; two water ring compressors provide the required pressure to mix the flue gas with the black liquor within the multi-stage reactors.

After the absorption period flue gas and black liquor are separated from each other prior to their discharge from the reactor. A pH control located at the liquor discharge is responsible to maintain a constant pH value by controlling flue gas composition. Passing through a degassing tank equipped with a foam destroyer, the black liquor is pumped into a maturation tank.

In order to prevent the pH value of the treated black liquor to increase again, the black liquor matures under a cover of flue gas. Having observed the proper retention time for the silica sludge to precipitate in the maturation tank, both liquor and sludge are conveyed by means of positive replacement pumps to four centrifugal separators, which are protected from foreign matters by strainers.

The clarified liquor is flowing straight from the separators to the storage tank in front of the evaporation station, while the sludge periodically discharged from the separation is dumped into containers and disposed of.

Centrifugal separators and piping system have to be cleaned periodically using hot water or hot weak caustic soda solution.

6. THE PERFORMANCE

Design data for this first installation were the following:

Capacity (black liquor)	160 m ³ /h D.S.
SiO ₂ content of ingoing black liquor	= 10 % based on TS in black liquor = abt. 7 gr SiO ₂ /l
Reduction of SiO ₂ in black liquor solids	90 %
depending on original SiO ₂ content	.
Ingoing black liquor concentration	8 % T.S.
CO ₂ content of ingoing flue gas	min. 16 % (weight)
SiO ₂ sludge dry content	20 %
Organic matter in discharged sludge	max. 5 % based on sludge
Chemical losses (sodium salts)	3 - 3.5 % based on T.A. in black liquor

The actual performance of the plant has suffered by the fact the the French Company who contractually supplied the hardware for the desilication plant found itself not in a position to supply the type of equipment extensively tested and specified by us. Due to financial reasons, equipment types were altered without our consent and could no longer perform as required. Though the desilication plant at Letjes IV fell short of the design throughput and was faced with mechanical problems, it nevertheless has produced a desilicated liquor according to specification and has proved the suitability of the process.

DESILICATION

by

Mr. P.F. Bleier

SILICA IN PLANTS

Most types of wood - all species useful for fibre-making - contain only very small amounts of silica - less than 0.1 %. Grasses, however, even those with a high degree of lignification like all types of bamboo, take considerable quantities of silica from the soil, - usually a few percent of their dry weight with a maximum in rice straw that can contain over 11 % depending somewhat on variety and on soil.

Very primitive plants like lichen are known to be able to attack rocks by dissolving silica - possibly to obtain dissolved minerals for their nutrition and for improving their foot-hold. To the knowledge of the author no physiological function of silica in higher plants has been described. Improved physical strength of stalks and leaves might possibly have played a role in selection resulting in high silica content.

Different plant organs contain varying amounts of silica. Straw leaves contain more silica than stalks and should be removed before pulping. Rice straw husks are very rich in silica. Bamboo nodes are richer in silica than internodal material; the internodal cavity may contain excreted pure silica.

No biochemistry of silica is available. Some silico-organic compounds have been isolated in plant tissue, particularly of the group of poly-hydroxy aromats, i.e. of tannic compounds. The inorganic silica cannot travel through the plant cell membranes not being soluble, as ion, at ordinary acidity of the plant juices. Deposits in plant tissue of the opal type of hydrated silica, i.e. material of rather low degree of order (crystallinity) has been described.

Extraneous silica from the soil, particularly in agricultural crops may further aggravate silica problems and can be removed by washing. Beyond separation of adventitious soil washing is reported to remove some annual plant silica - possibly by dissolving some low crystalline order material - as evidenced by increased desilication in case of alkaline washing.

SILICA IN PULPING

Acid sulfite pulping which could leave the bulk of silica undissolved in the fibre has not been of interest for many years, also because with straw, yellowish unbleachable aggregates remain that are difficult to remove.

In alkaline pulping processes plant silica dissolves more or less completely depending on the excess of active alkali used. Increased temperature enhances silica solubility. It has been proved that, in highly alkaline spent liquor, all silica is present as monomeric silicate. When most of the pulping alkali is used up during pulping i.e. is neutralized by the organic acids resulting mainly from carbohydrate decomposition, some of the dissolved silica redeposits on the fibre which has been reported in turn to weaken the fibre/fibre bond in papermaking. In this case the silica fraction remaining with the spent liquor is likely to contain polymeric silica and silica aggregates (i.e. "colloidal silica"). The silica dissolved in neutral semichemical processes should be of a similar nature.

SILICA IN CHEMICAL RECOVERY

Silica in spent pulping liquors - in whatever form it may be present - interferes at all stages with the established course of recovery of chemicals, a technology that has been developed to deal only with silica free wood black liquors.

1) Brown Stock Washing

Colloidal silica may partly be responsible for the brown stock washing difficulties because of plugging of the screens of washing cylinders by "suspended solids".

2) Evaporation

On evaporation and concentration the unstable solution of silica in alkali decomposes under scaling at the hot evaporator surfaces. Siliceous scales (the bulk of the scales might consist of lignins and of Calcium Carbonate) do not respond to "boil out" or to chemical treatment and must be removed mechanically causing stand-still and shortened evaporator tube working life.

3) Combustion

In the recovery boiler high viscosity silicate glass is formed that causes "honeycombs" sticking to the boiler walls, plugging of tubes and difficulties in combustion, leading to increased frequency of boiler shutdown for overhaul.

4) Caustification

The silicates dissolved in green liquor are precipitated by lime as calcium silicate; this material interferes with the settling of lime mud so that less white liquor can be decanted; with filtration and washing becoming more difficult, soda losses are increased.

5) Lime Burning

When reburning of lime is attempted in presence of silica, glassy silicates are formed that form sticky rings in the rotary kiln and reduce the efficiency in lime decarbonization. In fact, difficulties and low yield result in omission of lime recycling by most pulpers of siliceous fiber sources. In case lime is expensive, due to long distance haulage, partial lime recycling is practiced.

Not recycled lime needs to be deposited as wet lime mud; rest alkali seems to prevent its utilization for soil improvement - even in lime deficient tropical countries.

DESILICATION

Unless silica is removed in the recovery cycle, it will accumulate in all closed cycle operations. This is even true for low silica kraft wood pulping, where some material is continuously "bled out" to prevent silica accumulation and interference with efficient white liquor preparation. The optimal point for silica removal obviously is at the begin of chemical recovery which is immediately after fibre separation from black liquor. In order to prevent scaling of evaporators weak liquor should be treated. However, in order to reduce the volumes to be treated and possibly also to improve the degree of desilication, treatment could also be postponed after the first stage of evaporation. The large amount of organic material, with complex and pretty unknown chemical properties, present in black liquor complicates desilication. Therefore desilication during combustion or at the green liquor stage also is under consideration - with the disadvantage mentioned.

1) Desilication by burned lime

This probably is the most extensively investigated method of silica removal for chemical recovery. Lime being a cheap chemical and the known low solubility of calcium silicate render this approach most tempting. However, so far, not industrially useful process has emerged.

Lime desilication of black liquor suffers by the fact that about 6 times of the stoichiometrically necessary quantity of lime are necessary in practice to completely precipitate insoluble calcium silicate. Instead of about 1 kg of burnt lime required in theory to remove 1 kg of silica, actually about 6 kg are needed! In the case of rice straw, 1 ton of pulp would require more than 1 ton of burnt lime changing into at least 3 times the amount of wet lime mud to be filtered and to be deposited. Filtration properties of lime mud are difficult and washing to prevent large losses of black liquor chemicals, causes considerable dilution, requiring additional energy for reconcentration.

Some of the polyphenols in black liquor also form soluble calcium compounds, which again leads to additional calcium scaling of evaporator tubes.

Even careful countercurrent multistage calcium treatment of black liquor cannot overcome the handicaps mentioned.

Many of the above complications can be avoided by green liquor treatment with lime, i.e. by fractional caustification. There is however no indication that green liquor desilication has become industrially viable, also because it would leave the silica problems of evaporators and of the recovery boiler untouched.

2) Desilication by Alumina (and by Ferric Oxid)

Alumina has not proved really useful for precipitation of silica dissolved in black liquor. However, when added to the smelt in the recovery furnace, the aluminium silicate formed remains insoluble with the grit, to be removed from green liquor.

One South African pulp mill claims to industrially desilicate in the manner described.

The reports of the fate of silica in the ferrite (DARS) process are somewhat confusing.

Temperatures in DARS Fluid bed combustion are lower and dwell time is shorter than in the standard recovery boiler; also ferric oxide is less basic than aluminium oxide. If - under DARS combustion conditions - silica is insolubilized, desilication would actually take place. Silica or iron silicate would accumulate in the ferric oxide so that one of the advantages of the DARS process, i.e. the recycling of the causticizing agent ferric oxide would become incomplete. Technical and economic aspects of this version should be studied because DARS desilication could be an attractive proposition. The conditions under which DARS desilication does take place are to be defined at the first instance.

Desilication before DARS combustion is required in case silica remains soluble during combustion (as claimed in an early DARS patent) to prevent accumulation in the system.

3) Desilication by Carbonation

For silica precipitation in black liquor by partial acidification, Carbon Dioxide is the only justifiable reagent, because after silica removal and before concentration, black liquor has to be realkalized to regain lignin solution stability. With Carbon Dioxide this can be effected, at least partially, by hot vacuum decarbonation of carbonated black liquor. Using sulfuric acid or acetic acid, two reagents that were regarded worth of consideration, re-alkalisation has to be effected by either lime which complicates matters as partly discussed under 1) or by caustic soda which, unfortunately, is not realistic because more soda is required than the amount needed to compensate soda losses of the pulping process.

Silica precipitation from black liquor by acidification is a useful procedure because it is possible to unsolubilize silica without precipitating alkali lignins whose solubility in water also depends on pH. It is obvious, that acidification must be carried out carefully, avoiding local overacidification at the point of acid addition and establishing for each individual black liquor to be treated the critical lower pH limit to which alkalinity can be reduced for silica precipitation without lignin coprecipitation. Experiments have shown, that - independently of the acid used - the initial point of silica precipitation and the initial point of lignin coprecipitation are reproducible and characteristic for a black liquor.

Utilizing CO₂ gas as an acidifying reagent it is of course important to control concentration, partial pressure, size of gas bubble and velocity of flow, for control of material transfer across the gas/liquid interface which is the determining step for the reaction velocity. Neutralization of alkali and of sodium silicate with the formation of sodium bicarbonate and of silica are likely to be fast reactions.

Black liquor is a complicated buffered system in which pH changes with temperature (measured with temperature compensated glass electrodes) and with concentration. In fact pH drops with temperature increase. Therefore all silica precipitation pH data published in literature without temperature indication are meaningless.

This carbonation unit can be dismantled for easy transport and for re-erection at varying pulp mills.

The new bubble-reactor permitted good control. It was operated in lengthy runs over many months with fresh mill weak black liquor to prove that the process developed to be tolerant to the variations of normal industrial operation.

Hot pilot plant operation permits careful carbonation avoiding irreversible lignin coprecipitation. The voluminous but granular precipitate sediments quickly and can be filtered in a filter press. On exhaustive washing a greyish filtercake is obtained that contains in an air dry condition over 70 % silica. Starting with weak black liquor containing 6 gpl silica a 90 % desilication can be reached.

The repeated and reproducible pilot plant trials have established a level of confidence in bubble reactor carbonation for desilication of weak black liquor to justify the decision of scaling up the operation and ordering a fully industrial sized demonstration unit for carbonation and filtration. This equipment has been manufactured and is at present about to be delivered. It is planned to start large scale carbonation utilizing recovery boiler flue gas containing about 12 % CO_2 ; after recommissioning the lime kiln that has not been in use for many years because of silica problems, lime kiln flue gas with about 30 % Carbon Dioxide will be passed through the reactor.

The team of technologists connected with the desilication project feels that they have good reasons to hope, that after sufficient data will be collected operating the full size demonstration unit, an industrially viable desilication method will have been established.

NOTES ON THE VISIT TO RAKTA MILLS
EL TABIA, EGYPT

by

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The visit to the RAKTA Mills made on April 29th was part of the pulp seminar that was conducted by the joint efforts of UNIDO, FAO, SIDA and the Egyptian Government. The seminar was held from 24th to 30th of April in Alexandria.

The RAKTA mills are operated as a state enterprise under the Ministry of Industry and are located in El Tabia, 30 Km east of Alexandria. This integrated pulp, paper and paperboard mill has the reputation of being one of the largest producers of rice straw pulp. The pulp mill is made up of two lines, one commissioned in 1961 and the second in 1980. The total pulping capacity is 145 TPD (Tons per Day) and the bleaching capacity is 120 TPD. The paper and paperboard production facilities at the mills consist of 4 machines with a total rated production of 310 TPD.

RAW MATERIALS

The principal raw material for the Rakta mills is rice straw. The mill was originally planned on the basis of reed and straw as raw materials, but due to the decline in supply of reed the Rakta pulp mills now works only with rice straw. Rakta found, as was experienced by mills elsewhere, that repeated harvesting of reed brings about a shrinkage in the supply to the mills.

Besides the rice straw pulp produced right at the mill premises, Rakta uses bagasse pulp produced by another state enterprise known as SUGAR AND DISTILLERY CO. This bagasse mill is located at EDFU in the sugar growing areas close to the ASWAN DAM. Secondary fibre processed from locally collected waste paper is largely used in the manufacture of paperboard. The long fibre content for both paper and paperboard manufacture is imported wood pulp.

The average yearly consumption of the above fibrous materials to produce about 90 000 TPY of paper and paper-board is as follows:

- Rice Straw - 120 000 TPY (Tons per Year)
(equal to approximately 23 000 TPY
of Bl. Pulp - 17 000 TPY of Unbl. Pulp)
- Bagasse Pulp
Supplied from EDFU) - 15 000 TPY
- Imported Wood Pulp - 20 000 TPY
- Waste Paper - 15 000 TPY

RAW MATERIAL PREPARATION

Chopping and Drycleaning

The chopping of straw is done at Rakta using NYBLAD cutters. The chopped straw is then pneumatically conveyed to the dust separator which is also of Nyblad design. The exhaust air from the separator which is mainly loaded with dust is handled using cyclone type of wet scrubbers. The sludge from the wet scrubbers is then discharged to the sewer. It is estimated about 10 % of the total weight of straw is lost in the form of dust and foreign matter.

Wet Cleaning

Following the dry cleaning process is the wet cleaning of straw. This is considered an effective step in the pre-treatment of straw, prior to cooking to produce a high quality bleached pulp. The wet cleaning system used at Rakta consists of:

- Two hydra pulpers arranged in series
- Dewatering drums
- Screw presses

The dry cleaned chopped straw undergoes a wet scrubbing action in the hydra pulpers. The consistency maintained in the pulpers is about 3 %. The mechanical action provided in the pulper loosens the sand and grit present in the straw and removes a substantial portion of the leafy material. It is estimated that the silica

content gets reduced from 14 % to 11 % during the wet cleaning process.

Following the scrubbing action in the pulper the straw gets discharged into the dewatering drum designed by KRAUSS MUFFEI where the consistency of the straw gets raised to about 9 % in the first step. Following the dewatering drum, the consistency of the straw is further increased to 27 % in the second step using the screw presses of Krauss Muffei design.

The effluent from the wet cleaning plant is treated on BAUER ARC SCREENS. This results in recovering the useful fibrous materials and helps in recycling 50 % of the water needed in the hydra pulpers of the wet cleaning plant. During the wet cleaning process about 5 % of the total weight of dry cleaned straw gets lost as rejects and this makes a total of 15 % loss both for dry and wet cleaning of straw.

The cleaned straw is provided buffer storage in a silo prior to cooking. It is also possible to by-pass the silo and go for direct feeding to the digester. For a rapid charging of the digester a dual feeding both from the buffer storage (i.e. from silo) as well as direct feeding is possible and this reduces the charging of the digester of 43 m³ capacity to 20 minutes.

Cooking

Rakta employs the Soda Process for cooking straw. Tumbling type digesters (SCHOLZ) are used where cooking is conducted using direct steam. On account of the high silica content of rice straw (i.e. ash content of 16 to 17 %) chemical recovery is not practiced by Rakta.

The cooking conditions adopted by Rakta are as follows:

- | | |
|-----------------------------|-----------------------------|
| - Temperature | - 165 to 170°C |
| - Pressure | - 7 to 8 Bars |
| - Time | - Time to pressure 1.25 hrs |
| Time at pressure | - 2 hours |
| Full cycle (cover to cover) | - 4.5 hours |
| - Caustic Soda | - 10 to 11 % (B.D. Straw) |

Rakta experiences difficulties in maintaining a uniform solid/liquid ratio in the digesters. Fluctuations in solid/liquid ratio vary from 1:3.5 to 1:6. This wide range in solid/liquid ratio occurs due to problems related to the screw presses used for raising the consistency of straw prior to cooking. Another problem experienced by Rakta as a result of wet cleaning is the low density of digester charging. The digester charge obtained at Rakta averages 75 % compared with batch digesters that use the dry cleaning process.

Brown Stock Washing

The brown stock washing is conducted on 3 single stage washers on the new pulping line started in 1980. The old line started in 1961 employs 2 stage washers. The washers are operated without counter current washing, since chemical recovery is not practiced.

Some of the problems experienced by Rakta in this area are common in straw pulp mills elsewhere and are as follows:

- The slow drainage of the straw pulp requires relatively larger capacity washers. This is on account of the high SR of the straw pulp in the range of 45 to 50, thus requiring a specific load of 1.5 to 1.8 TPD/Sq meter of filtering area.
- The high content of silica and 'fines' contained in the pulp causes the gradual blinding of the filter mesh.
- Sudden changes in pH levels during brown stock washing cause problems of hard deposits mainly containing silica on the facing wire and backing wire of washer drums.

Cleaning and Screening

The cleaning and screening takes place in 3 steps. This is made up of the following:

- Vibration Screens
- Centrifugal Screens
- 4 Stage Centri Cleaner System

The screening losses on the Johnsson Vibration Screens average approximately 3 %; the losses on the centrifugal screens and centrifugal cleaners are about 1 and 0.8 % respectively.

BLEACHING

The bleaching on the No. 1 pulp line is designed for a 3 stage C E H System and the new 2nd line has a 4 stage C E H H System. The brightness obtained is between 75 to 78 % GE. It is found that obtaining a brightness higher than 80 GE causes severe degradation to the pulp. The No. 1 bleached line operates with a down flow chlorine tower, but in the more new No. 2 line, the down flow system is not used and an up-flow chlorination system is applied.

Rakta uses a total of 60 to 70 kg chlorine and about 20 kg of NaOH per ton of bleached pulp.

Some of the difficulties experienced by Rakta in this area are as follows:

- Slowness of the rice straw pulp and difficulties of washing the pulp on inter-stage washers as was described earlier under Brown Stock Washers.
- High residueal pH levels of 9 to 10 of unbleached straw pulp.

To overcome the difficulties in the chlorination stage on account of the high pH levels, Rakta now uses HCl to lower the pH prior to the chlorination stage.

STOCK PREPARATION

The stock preparation at Rakta is designed for the use of pulp from straw, bagasse, wood and secondary fibre.

Straw pulp requires very little or no refining on account of the high initial SR in the range of 45 to 48. It is found that any further refining does not contribute to the improvement in the physical strength characteristics of the paper. In the manufacture of writing and printings Rakta claims that it is possible to reach up to 85 % of rice straw pulp blended with 15 % long fibre wood pulp. Currently, however, the machines work with a straw pulp furnish ranging at the most between 45 % to 60 % with the balance made up of bagasse pulp and imported long fibre wood pulp. The addition of long fibre in the fibre furnish is varied to provide better runnability conditions on the machine.

The secondary fibre from the waste paper is mostly used in the manufacture of paperboard. Rakta has done some development work with the assistance provided by UNIDO in the application of a "Fibre Fractionator". This study was conducted to facilitate the use of poor quality of waste paper which is a common problem to developing countries.

Conical refiners are used for the refining of stock needed for the No.1 and 2 paper machines and disc refiners are used for the refining of stock needed for the No. 3 paper machine.

Excessive use of Alum going up to 6 % was one of the problems for Rakta. A heavy dosage of Alum was originally needed to obtain the optimum pH levels for sizing. This was due to the high residual alkali following the bleaching of straw pulp. Rakta has now made improvements to the process by using sulphurous acid at the end of bleaching to lower the high pH at the end of bleaching to a neutral level.

PAPER AND PAPERBOARD MAKING

The manufacture of fine paper (i.e. writings and printings) is done on 3 fourdrier machines known as PM 1,2 and 3. The machines PM 1 and PM 2 went into production in 1961 and are of wire width 3700 mm. These two machines were originally designed for 40 TPD per each machine but were rebuilt in 1977 to produce 60 TPD to make up a total of 120 TPD for both the machines. The No. 3 machine is of wire width 5050 mm and went into production in 1968. This machine was rebuilt in 1984 to increase the production from 60 TPD to 120 TPD.

The board machine which went into operation in 1967 is of capacity 50 TPD. This was also rebuilt in 1985 to produce 70 TPD. The basis weight range for the paper machines is between 50 to 120 g/m² and the paperboard machine 250 to 500 g/m².

Rakta, like other mills, shares the following common problems in using a high percentage of straw pulp in the fibre furnish.

Poor Drainage on the Wire

Rakta uses a wire length of 33 metres for No. 1 and 2 machines and 38 metres for the No. 3 machine. This is equivalent to 15.3 metres for No. 1 and 2 machines and 16.2 metres for the No. 3 machine from breast roll to couch. In spite of the relatively higher length used for drainage it is found that the usage of a high percentage of straw pulp reaching up to 80 % results in lowering the machine speed. For this reason adequate long fibre pulp is blended to counteract the drainage problem.

Runnability and Sticking on the Press

Press sticking and web breaks are other common problems experienced with straw pulp. Rakta, like mills elsewhere, has adopted the following strategies to overcome these problems:

- Use of pick up roll for web transfer from the wire to the press section;
- Bleeding the white water to reduce the "fines" content in circulation;
- Compensating with long fibre in the fibre furnish to obtain runnability on the paper machine.

EFFLUENT HANDLING

There is no simple answer to the handling of the mill effluent for straw based pulp mills. This is on account of the high silica content of straw going up to 20 % in some cases and the difficulty of handling the black liquor using the conventional recovery systems applied for

woody materials. Development work in the desilication of non-wood pulp black liquor has been intensified during the last 5 to 10 years. Rakta with the assistance provided by the West German Government is now working with reputed West German equipment manufacturers to develop a desilicator unit that could be applied to straw pulp mills. This development work at Rakta, as well as the work elsewhere in countries such as Indonesia, India, Italy, etc., is being awaited with great interest to solve the problems of chemical recovery for non-wood fibre pulp mills having a high content of silica in the black liquor.

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COUNTRY PAPER

E G Y P T

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RAKTA

PRODUCTION AND CONSUMPTION OF PAPER AND BOARD IN EGYPT

1. The present Situation for Production & Consumption of Paper and Board

In Egypt the local consumption requirements of paper and board are covered by local production along with the imports. There is no direct exportation of any type of papers or boards.

The local consumption of different types of paper and board actually (83/84) is 492.000 tons, and the imports are 331.000 tons, while the local production is only 161.000 tons (33 % of consumption).

Production of paper and board in Egypt depends on the public sector companies (RAKTA, NAPA, SIMO). These companies produce about 71 % of the local production.

The annual consumption rate per capita of paper is considered to be one of the relative civilization measures among the countries. The comparison proved that in Egypt, the consumption rate per capita is a modest rate compared to developed countries, even when compared to some under-developed countries.

For the near future local production of paper and board, it was concluded that the percentage of consumption (33 %) will increase in 1985 to 38 % and in 1990 to 44 % because of the production start-up of the approved projects. This gap cannot be overcome in the near future, because the paper, board and pulp projects require long periods of study and execution sometimes 5 years.

2. Future Estimates for Production and Consumption of Paper and Board

The actual consumption (1983/84) of paper and board is 492.000 tons, estimated to increase to 805.000 tons in 1990, 1.185.000 in 1995, and 1.746.000 tons in 2000.

This paper has made an assumption for some projects to produce paper, board and pulp. It has also, concluded that the execution of the proposed projects with the actual projects (Present, approved and under execution) will increase the local production to consumption rates of different papers and boards.

The following table indicates the increase of the local production to consumption rates:

	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
	%	%	%	%
Writing and printing papers	51	73	89	63
Newsprint and magazine papers	-	56	35	22
Wrapping and packing papers	29	94	70	53
Multi-layer Board	63	47	75	51
Varieties of Board	70	85	83	81
Tissue Papers	-	80	100	96
Cigarette and fine papers	-	64	93	78
Total	38	74	70	53

In conclusion, the consumption of various types of paper and board is estimated to be 1.746.000 tons by the year 2000. These figures will be covered by 354.000 tons by the year 2000. These figures will be covered by 354.000 tons from the actual projects (present) approved and under execution and by 571.000 tons from the proposed projects.

A gap will still remain between the consumption and the production about 821.000 tons, which will be covered by imports.

3. Proposed Projects for Production of Paper and Board

The actual projects (Present, approved and under execution) of 354.000 tons full capacity: RAKTA/NAPA/SIMO/Modernization of RAKTA/ Modernization of NAPA/KOUS writing and printing projects—line one/ Rebuild and expansion project of EDFU mill/Thick Board project of SIMO/wrapping, board variety cigarette and fine papers projects (private sector), registered and under execution.

For the proposed projects, more should be proposed, studied and executed in order to cope with the developed local consumption and to fill or minimize the gap between the local production and consumption of such vital products, which has a direct effect on the production and service sectors. Table (IV 1) shows the proposed projects in Egypt.

The total production capacity of these projects is 571.000 tons (as final paper and board products). Those operative in 1990 will have a capacity of 243.000 tons, 473.000 tons in 1995, and 571.000 tons in 2000. The full production capacity of these projects will be triple that of the present production. The local production will cover about 38 % of 1985 consumption, 74 % in 1990, 70 % in 1990 and 53 % in 2000.

4. Future Availability of local cellulose raw Materials for Projects (present, approved and proposed) Requirements

This paper (according to previous studies) has calculated and determined the present and future requirements of local raw material amounts for the production of pulp for the different projects (present, approved and proposed).

This was achieved by calculating the required quantities of pulp, from each type and for each project, reaching a full integration between the projects and the pulp manufacturing units, either related to the paper and board production, or project producing pulp for the local market.

The following table summarizes all the requirements:

	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
	(Thousand Tons)			
Rice Straw	140	310	470	470
Bagasse	120	740	980	1070
Waste Papers	170	290	420	520
Linen and its residues		-	11	11

The possible availability of the different raw materials required for the present and the future was also studied. The results are indicated in the Tables IV2 - 4 (in thousand tons).

Table IV:1 Proposed Projects in Egypt

	Quantity in Thousand tons	Year
1. Newsprint and magazine paper/ from bagasse pulp	100	1990
2. Kraft and cement kraft sack project/from bagasse pulp	60	1990
3. Corrugated medium project/ from rice straw pulp	45	1990
4. Manilla and board variety projects/	180	1990/2000
5. Tissue paper project/ from bagasse pulp	24	1990/2000
6. Bagasse pulp projects /	120	1990/2000
7. Cigarette papers and fine Papers /from linen pulp	7	1995
8. Writing and printing papers / Kous/line 2 /from bagasse pulp	60	1995
9. Writing and printing papers Northern Delta/from rice straw pulp	50	1995
10. Multi - layer board project	45	1995

Table IV:2. Rice Straw

	1985		1990		1995		2000	
	Quantity		Quantity		Quantity		Quantity	
	Tons	%	Tons	%	Tons	%	Tons	%
Available	2400	100	2400	100	2400	100	2400	100
Used:								
Animal production	870	36	910	38	960	40	1020	42
Paper & board prod	140	6	310	13	470	20	470	20
Balance	1390	58	1180	49	970	40	910	38

Table IV:3 Bagasse

	1985		1990		1985		2000	
	Quantity		Quantity		Quantity		Quantity	
	Tons	%	Tons	%	Tons	%	Tons	%
Available	1200	100	1600	100	1800	100	2000	100
Used :								
Fuel	980	82	300	19	-	-	-	-
Litter & bedding	100	8	210	13	250	14	300	15
Paper & board prod	120	10	740	46	980	54	1070	53
Balance	-	-	350	22	570	32	630	32

Table IV : 4 Waste Papers

	1985		1990		1995		2000	
	Quantity		Quantity		Quantity		Quantity	
	Tons	%	Tons	%	Tons	%	Tons	%
Available	165	100	240	83	355	85	525	100
Used :								
Paper & Board	170	100	290	100	420	100	520	100
Balance	-	-	-	-	-	-	5	-
Shortage	5	-	50	17	65	15	-	-

Table IV: 5 Different types of paper & board
Consumed during periods 1975-1984
 (in thousand tons)

Types / Years	1975	1979	1980/ 1981	1981/ 1982	1982/ 1983	1983/ 1984
Writing & Printing papers	76	114	116	118	134	128
Newsprint & Magazine papers	41	57	84	107	76	96
Wrapping & Packing papers			137	122	97	132
Tissue papers	94	125	2	2	3	5
Cigarette / Fine papers			3	3	7	7
Multi - layer board			42	39	39	44
varieties of Board	51	69	64	66	76	80
Total	262	365	448	457	432	492

**Table IV:6 Local production of different types
of paper and board during period
(1981 - 1984)**

Types & Companies / year	1981/ 1982	1982/ 1983	1983/ 1984
- <u>Writing & Printing Paper</u>			
RAKTA	39	43	44
NAPA	3	5	8
Total	42	48	52
- <u>Wrapping & Packing Paper</u>			
NAPA	25	24	26
SIMO	9	7	-
Total	34	31	26
- <u>Multi - Layer board</u>			
RAKTA	13	14	13
NAPA	11	12	12
Total	24	26	25
- <u>Variety of board</u>			
NAPA	6	7	6
SIMO	6	9	6
Total	12	12	12
Total of Public Sector Production (3 Co.)	112	117	115
Private companies production (15 Co.)	42	44	46
Total Local Production	154	161	161

Table IV: 7 Imported varieties of paper & board
during periods (1981 - 1984)
(in thousand tons)

Types / years	1981/ 1982	1982/ 1983	1983/ 1984
Writing & Printing papers	76	86	73
Newsprint & Magazine papers	107	77	96
Wrapping & Packing papers	83	61	101
Multi - Layer board	15	13	19
Board varieties	17	24	27
Tissue papers	2	3	5
Cigarette / Fine papers	3	7	7
Total Imported	303	271	331

**Table IV:8 Estimated consumption of different types
of paper & board from 1985 - 2000
(In thousand tons)**

Types /Years	1983/ 84	1985	1990	1995	2000
Writing & Printing papers	128	142	203	290	412
Newsprint & Magazine papers	96	110	177	285	459
Wrapping & Packing papers	132	143	192	257	344
Multi - Layer board	44	49	72	106	156
Varieties of board	80	91	140	216	332
Tissue papers	5	6	10	16	25
Cigarette/Fine papers	7	9	11	15	18
Total	492	550	805	1185	1746

COUNTRY PAPER

S U D A N

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SODA OXYGEN PULPING
A NEW MANUFACTURING TECHNIQUE

INTRODUCTION

The idea of creating a pulp and paper industry in Sudan dates back to the early fifties when the first converting plant, the Blue Nile Co., was established by the private sector to produce solid board and wrapping paper, using the waste paper as raw material.

Few other packing plants were on stream some years later. In the early sixties a paper board mill (Aroma Factory) was installed but for certain reasons was shut down even before coming into full operation.

A paper mill (APEX) based on waste paper, mostly converting waste from packing plants was commissioned in 1983 with a capacity of about 24 T/day, the main product is fluting board (no drainage, no water treatment system).

The demand for paper products has grown rapidly since 1960, the average growth rate for paper and paper board consumption is closed to 6.6 % and is expected to increase at an annual rate of about 7 % in the next five years.

During this period a relatively considerable number of feasibility studies for pulp and paper manufacture in the Sudan has been conducted, but none of them has been implemented as yet.

Due to the shortage in domestic paper-board production and non-existence of local pulp production, Sudan is heavily dependent on imports of paper products, mainly from Sweden, USA, FRG, Kenya etc..

The principal raw material for pulp and paper manufacture is vegetative fibre. In our country the cellulosic raw materials can be divided into two major classes:

1. Wood Fibrous Raw Materials

Naturally growing mixed hardwood species available in Savanna regions and tropical forest located mainly in the South of the Sudan.

Some trials have been made to grow eucalyptus along the Blue Nile and soft wood (pine) in highlands of Gebel Marra in the West and Imatong in the South.

2. Non-Wood Fibrous Raw Materials

(a) Agricultural Residues

Sudan being agriculturally oriented produces annually substantial amounts of agricultural residues such as sorghum and millet straw, cotton stalks, wheat straw, sugar-cane bagasse, kenaf, cotton linters etc..

(b) Non-Wood Plants

These include (1) bamboo which is available at Upper Nile and Blue Nile regions in natural stand and plantations and (2) papyrus in Lake No in the South.

NON-WOOD FIBRES FOR PULP AND PAPER

The world's paper production derives from wood pulp which itself comprises nearly one third of all industrial wood consumption, on a volume basis.

Moreover demand for paper products is increasing very rapidly every year. Thus making up ever-increasing production of industrial uses of wood is putting pressure on forest and it is clearly in the interest of the pulp and paper industry.

This pressure on forest makes it necessary to explore on a large-scale countries raw material.

Certainly a portion of demand can be met through the recycling of the fibre-based products, particularly waste paper.

Although wood no doubt, remains the most important raw material, an addition to the production of pulp and paper will come from the use of non-wood fibre sources such as bagasse, straw, tropical grasses, kenaf and bamboo.

A number of problems have arisen with the use of non-wood fibres for paper manufacture, not least those of pollution. The mills have traditionally been small and not concentrated in one location, but on the other hand, many of them have had no chemical recovery system and thus effluent load has been comparable to a much larger, modern mill. On the other hand, the benefits from paper supply have mostly by offset the environmental problems, and ways have to be found of reducing the pollution load and at the same time of reducing the costs of paper production by achieving a more efficient recycling of the chemicals and raw materials use.

PROBLEMS IN USE OF NON-WOODY FIBRES

From the environmental point of view a major problem in the use of non-woody fibres and in particular of rice straw, is the high silica component.

The silica reduces the efficiency of the recycling and waste water treatment system, it also forms deposits in the evaporators and on boiler tubes.

Since the efficient recovery of cooking chemicals is an important requisite for pollution control as well as for economic running of a pulp mill, this silica problem has to be overcome.

The use of non-wood fibres requires sufficient supplies reasonably at hand to provide a pulp mill with a constant quantity of raw material. In that regard, complicated flowering behaviour of bamboo makes it impractical to rely on the same source all time. Most of non-wood fibres are seasonal in that they can be collected only after the plant has flowered and gone to seed.

The supply to the mill from any one source is therefore not constant and there must be provisions for storage for most of the year. This material must be properly stored so that it does not change its composition and as a consequence produce a pulp of inferior or changing quality. In many instances the pulp from non-woody fibres have less fibre strength and a greater proportion of parenchymatious tissue than pulp from wood. One way round such problems is to mix the fibre plant material with small quantities of rags if available at suitable cost. Even so, the resulting paper quality will depend on many other factors for instance the equipment used and skill of paper-maker. The mills using non-woody fibre sources are generally small, many of less than 50 tonnes/d capacity and therefore because of the economy, gains with size, don't lend themselves to chemical recovery system and other pollution control techniques.

DISADVANTAGES ARISING FROM USE OF NON-WOODY FIBRES

In essence these are:

- The bulkiness of material
- Difficulties in collection and transportation
- The limited size of existing mills
- Labour productivity and economic gains
- Poor pulp stock drainage
- Poor sheet formation
- Poor washing efficiency
- Poor quality of product
- High silica content both in pulp and in black liquor and difficulties in chemical recovery resulting in low efficiency.

The greatest disadvantage stems from environmental impact owing to difficulties in chemical recovery, thus the viscosity and silica content of black liquor and high, both of which influence the normal evaporation operation and lime-mud recovery.

HOW TO OVERCOME THE PROBLEMS AND ELIMINATE THE POLLUTION OF BLACK LIQUOR FROM NON-WOODY FIBRE PULP

First step:

1. Desilication of black liquor before the evaporation process to prevent the formation of scale throughout the whole recovery plant.
2. Removal of silica also avoids sedimentation troubles in costicizing stage owing to the presence of silicon compounds.

Another approach is to remove silica after the recovery boiler and before costicizing, but in this case, sealing on the walls of the equipment will not be avoided.

Well-Known Procedures for Desilication of Alkaline spent Liquors are:

1. Controlled pH reducing, so as to eliminate Silica acid.
2. Addition of continuous such as Calcium, Magnesiums or Aluminium, to form insoluble silicate and precipitate the silica out of the liquor.
3. Combination of both the above mentioned methods.

OXYGEN-SODIUM BICARBONATE PROCESS

The world-wide shortage and increasing environmental pollution have become important problems.

Therefore, in order to develop a pulping method leading to high yield and less environmental pollution, some studies on the preparation of oxygen alkali pulping of various kinds of wood have been conducted and it was found that pulps can be prepared in high yield and brightness.

Based on the experience gained in oxygen bleaching of wood pulp, experiments were started in 1968 to study the preparation of wood pulp by oxygen pulping.

Information available in patent literature indicated that pulps could be prepared by oxygen alkali pulping that shavings gave better results than chips and that a high oxygen pressure would be desirable. It was soon found on incremental addition effective alkali gave better results than addition of the whole amount before the start of the cook.

In agreement with Grangaard and Saunders patent, it was observed that for most types of pulps a fairly low pH level was preferable and that cooking solution containing sodium bicarbonate gave pulps of high total yield.

Reproducible results were achieved by keeping close control over the carbon dioxide concentration in gas phase.

A more recent advancement is the application of pre-cooking of the chips in alkaline medium before the oxygen cook, with no defibrizing treatment between the two stages. A two-stage process has been developed for oxygen pulping of chips (white birch) with sodium bicarbonate as active alkali. The chips are pre-cooked in bicarbonate sodium at 120 - 180°C and then subjected to oxygen, bicarbonate pulping without defibrizing treatment between stages.

Bright pulp at high yield and low Kappa number can be obtained after two hours in oxygen stage without severe depolymerization of the cellulose papers produced from the pulp compare fairly well with those from Kraft hardwood pulps, the process seems to be economically feasible.

IMPLEMENTATION ON A LARGE SCALE

Oxygen pulping by this two-stage process would seem to be practical on a large scale. Special attention was taken during the laboratory research programme to use conditions that could be considered commercially feasible.

A low liquor wood ratio was used in order that existing evaporator capacity in a mill would be sufficient.

Experiments showed that the spent liquor from oxygen stage can advantageously be used in the pre-cooking since the solids content of the spent liquor from the pre-cooking then reaches a reasonable level for feed to evaporators.

Total "cover to cover" cooking times were kept short in order to maximise the pulp, production from a given number of pressure digestion vessels.

This attention to factors of commercial interest was carried through despite the knowledge that the resulting process would not be optimum when viewed from a laboratory point of view.

The factors which need to be considered in comparing oxygen pulping and kraft pulping processes are shown in Table 1.

The evaluation given each factor is based on the present state of two stage process. An attempt to quantify these various factors in terms of application of the new process for a mill in Sweden gave as result a lower capital cost (approximately US\$ 1 million) and a lower operating cost (US\$ 4/ton pulp) for the oxygen process. The mill size was 500 T/day.

Birch oxygen pulps prepared under that today is considered far from optimal conditions were bleached a DPD sequence to a brightness 88 % CE. The pulps were easy to bleach and 89 % brightness could also easily be obtained other three stages bleaching sequence such as CEH and CED. The bleached pulp (total yield 54 %) compared to a bleached kraft pulp (yield 50 %).

SODA-OXYGEN PULPING OF SUDANESE EUCALYPTUS WOOD

The optimum schedules of cooks in laboratory for four species of eucalyptus wood and their mixture was worked out. The nature of cellulose specimens is characterized and the high strength properties were achieved (table II). The results of this work may be useful for organizing the national pulp industry in the Sudan and in some other countries of Africa. The results of this work were discussed at a conference in Leningrad Technological Institute of Pulp and Paper Industry (1980) and were approved.

Earlier was shown that after boiling of eucalyptus in hot alkali solution (0.5 % NaOH), the volume of submicro-capillars increased and the cell walls swelled considerably.

On the basis of this observation we proposed to use soda-oxygen delignification (instead of thin shave which usually employed) industrial chips with the thickness 2 - 3 mm.

An advantage of Soda-Oxygen not only in obtaining high yield or improving mechanical properties but also the cellulose consist in a high value of brightness (up to 60 % and more) table II.

This makes it possible to use the oxygen pulp for paper-making without bleaching process.

It is important to mention that in Soda-Oxygen cooking the residue of under-cook (Brown Shieves) does not exceed 0.6 %.

RESULTS

1. The result clearly shows that it is possible to produce pulp at high yield, low percentage of screenings, with low Kappa number, and high brightness cellulose.
2. These experiments were made a liquor wood ratio of 5:1 to obtain a spent liquor which can be recovered economically.

3. Cooking times were kept short in order to maximize the pulp production from a given number pressure digestion vessels.
4. The pre-cook was carried out with 9.5 % active alkali added as NaHCO_3 in those experiments in which NaHCO_3 was used in oxygen stage and as $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ in the other runs.
5. No equipment was available for the determination of pH in digester but the alkalinity was controlled by concentration of carbon dioxide and determination of active alkali.

Determination of pH in samples was drawn through a cooler under standardized conditions were made at interval (10 min) and used to estimate the amount of active alkali required to maintain pH level.

6. The chips were placed in baskets inserted in the digester. The cooking liquor which was circulated through a heat exchanger, was sprayed over the chips, oxygen was introduced at the bottom of the digester and the gas was released at the top.

Inferior results were obtained when the chips were submerged in the liquor, and all reported experiments were made with the chips above the liquor level.

7. The results indicate that the pre-cook affects the rate of the chemical reaction in the oxygen stage but that it also improves the penetration of dissolved oxygen into the core of the chips.
8. Experiments showed that the spent liquor from the oxygen stage can advantageously be used in the pre-cooking since the solid content of spent liquor from the pre-cooking then reaches a reasonable level for feed to evaporators.
9. Sudanese eucalyptus species can successfully be cooked by one-stage soda-oxygen process because the effect of hot alkali (Na_2CO_3) which increase the volume of submicro-capillars and cell wall smalled considerably, that makes the penetration of dissolved oxygen into the core of the chips easier.

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Table 1.

Comparison of Oxygen and Kraft Pulping Processes

Factor	Oxygen Pulping as compared to Kraft
Chips	Thin (Screened or Sliced)
"Cover to Cover" time	longer (about 50 %)
Pressure	Roughly equal
Causticizing	Not needed
Air pollution equipment	Not needed
Pulps chemical Supply	On-site Oxygen Plant
Furnace oil consumption	Higher
Bleaching Sequence	Shorter/2.3 stages
Bleaching Chemicals	Cheaper
Pulp Yield	Higher.

Properties of soda-oxygen cellulose obtained by alkali dose

18 % Na₂O on wood

Table 11.

Genus	Yield of Cellulose, %	Kappa No.	Break length km	Resistance			Brightness %
				Folding endurance	Burst factor kPa	Tear factor cN	
E. camaldulensis	49.6	24.2	8.0	850	304	56	64
E. hybrid	46.3	26.8	5.7	150	274	51	58
E. microtheca	46.8	19.7	7.0	180	284	58	60
E. tereticornis	48.7	20.0	8.1	550	314	58	61
<u>Mixture of</u>							
E. camaldulensis	48.3	22.5	7.3	190	333	54	60
E. tereticornis							
<u>Mixture of</u>							
E. camaldulensis	47.1	11.6	5.6	110	284	53	75
E. tereticornis							
after removal of "kinos"							

COUNTRY PAPER

Z I M B A B W E

prepared by

Jose de sa Fragona

Hunyani Paper and Packaging Limited

N.S.S.C. PLANT

Meaning of N.S.S.C. - Neutral Sulphite Semi Chemio

The function of this system is to separate the cellulose from the wood by means of chemical pulping to attain a constant standard pulp.

Method

Firstly debarked logs are conveyed to a chipping plant, where they are chipped to $\pm 5/8" \times \frac{1}{2}"$ chips. They are then taken by conveyor to a tower called a silo (capacity ± 100 tonnes). From the bottom of the silo they are taken by conveyor to a Bezner Screen, where they are sorted. The chips which are unable to pass through the screen (over size) are shaken into a chute which goes into a hammer mill. The chips are then broken up into a suitable size to pass through the screen. From the mill they go through the screen. From the screen the chips are conveyed to the chip hopper. The hopper has a level control which can stop/start the conveyor according to hopper level. From the hopper the chips fall into the Screw Feeder. Inside the Feeder a plug is formed. From here they go through the digester. Steam and liquor enter the digester. (Steam pressure 1000 kpa). Inside the digester the steam pressure and the screw action push the contents through to the discharger. The amount of pulp discharged is determined by the valve position on the discharger. From the discharger it passes to the blow tank, where the consistency is reduced to approx. 10 %. From there it passes through a pulp conveyor to the single flow refiner (this is No. 1 Refiner). From the refiner it can either be pumped to No. 1 Washer or No. 2 Chest. (The process at this time) it is being pumped to No. 2 Chest, the stock is now approx. 4 % cons. (diluted in the Chest). From the Chest it is pumped to No. 2 Refiner (this is a twin flow refiner). From the Refiner it is taken to No. 2 Washer. The cons. after the washer is approx. 8 %. From the washer it falls down into the Rhune Press and with the press action the cons. is brought back to 40 - 50 %. From the press it is conveyed to outside storage or diverted to the North Shed Pulper for use on PM 3.

PROBLEMS WHICH COULD OCCUR IN THE PLANT

Steam

Normal running pressure in the digester is 10,5 bars. Low steam pressure will result in the Shaking of the digester (boilers).

Action

If the steam pressure drops the Screw Feeder speed has to be reduced. This will control the shaking of the digester and will enable Boiler-house to bring up their steam-pressure - Again low steam pressure you can easily choke the discharger.

Screw Feeder Control

The amps of the Screw Feeder should be between 60 - 120 amps. If the amps go below 60 amps then you close the blow back valve to prevent it from blowing. By closing the valve you build-up a plug and the plug should be around 90 - 120 amps, then you open the blow back valve - great care has to be taken when forming a plug. If plug is formed too hard you could jam the Screw Feeder.

Discharger Amps

Discharger amps should be 3.5 - 4 amps. If the amps go to 5 amps it means the discharger is not discharging or the discharger is closed, then you try to open it more. If it fails to open, try opening it by hand manually. If there is an obstruction it will shoot out. Proof of it being open (clear) will be the increase of steam being discharged. If no result a Fitter must be called to inspect.

Chemical Addition

You are required to put proper amount of chemicals and see that pumps are working efficiently. The amount of chemical used is determined by the strength of the chemical. (Sulphites) from storage. This is worked by the Lab. result and by looking at the chart provided you are able to add the correct amount.

Start-up Procedure

Inform Boilerhouse.

Check all valves - Start fresh water pump for refiners and screw feeder coupling etc. - start top conveyor - start bucket elevator - hammer mill - Bezner Screen - short conveyor - link belt.

When Chips are coming to Chip Hopper

Start Screw Feeder - when plug has been obtained stop Screw Feeder - open Steam Valve to Screw Feeder (10 bars) - start washer/s (for cycle of water) - start No. 1 chest pump - start No. 1 Refiner. Start Agitator No. 1 chest - start refiner feeder. Start uniflow feeder - start pulp conveyor.

When ready

Start digester - start cooking liquor pump - start sulphite pump No. 1 - start screw feeder - open blow back valve - check No. 1 Refiner - start No. 2 Refiner.

N.S.S.C. CHEMICAL PLANT

FUNCTION

To produce a standard solution of white liquor for process of chemical pulping.

There are two (2) systems in this Plant:

- (1) Sodium Carbonate
- (2) Sodium Sulphite

1. Sodium Carbonate

Firstly carbonate is mixed in water in a mixing tank (26 bags @ 50 kg per bag). From the mixing tank it is pumped to storage tanks. From No. 1 storage tank it is pumped to No. 2 tank. No. 2 tank must be kept at a constant level. This is achieved by means of an overflow pipe fitted to No.2 tank going into No. 1 tank. From No. 2 tank it is pumped to absorption tower to mix with SO_2 .

2. Sodium Sulphite

Firstly sulphur powder is melted in a melting tank (60 kg per hour). The temperature of the sulphur is 120°C . From there it is pumped to a sulphur burner. It is passed to the burner through a sulphur gun. In the burner steam heated air is passed through. With the help of the air the sulphur is sprayed and with an oxy-acet burner the sulphur is ignited. When burning a gas is formed. This is now SO_2 . The temperature in the burner is $\pm 1000^\circ\text{C}$. From the burner the gas passes to a cooling tower. In the cooling tower, with the aid of water sprays, the temperature falls to 60°C .

This water then falls to the bottom of the tower. This now becomes a solution of sulphurous acid. This is extracted from the bottom of the tower by means of a pipeline to a storage tank where it is pumped to PM 3 (paper machine) to help control the pH or is pumped to the lagoons. The SO_2 is now pumped to the absorption tower where it passes through porcelain filters. It is now that the carbonate is pumped from the storage tank where the SO_2 and carb. come into contact and now form sodium sulphite. This is now extracted from the tower at the bottom by pipeline to a collecting tank where it is pumped to storage tanks. From there it is pumped to a mixing tank for use in the NSSC Plant.

LABORATORY TEST ON SULPHITES

Sampling

Samples are taken from 2 areas.

1. From collecting tank after absorption tower. Tested every hour.
2. From storage tank every 3 hours.

Test

Solution is cooled to 25°C 10 mls extracted and diluted to 100 mls with distilled water.

Add 25 mls Iodine and 2 mls Sulphuric Acid and titrate against N10 Sodium Thiosulphate.

White Liquor Reacts with Iodine e.g.

If you react 25 mls of Iodine with a known volume of white liquor, some of the Iodine is eaten up, and the remainder can be found by back titrating with Sodium Thiosulphate. Because Iodine also reacts with it. By subtracting the volume the volume of Sodium Thiosulphate from the original 25 mls Iodine, one can get the actual volume of Iodine used up by the white liquor. In all these reactions solutions of the same strength are used (N10 solutions).

Suppose 6,0 mls is the volume of Sodium Thiosulphate used, it means therefore that 25-6 mls of the Iodine were used up by the white liquor.

N10 Sodium Sulphate = 6,3 g/l, therefore, the strength of the liquor in this case is $(25-6) \times 6,3 \text{ g/l} = 19 \times 6,3 \text{ g/l} = 119,7 \text{ g/l}$.

Properties to Achieve: -

Sulphites - 125 g/l

Carbonates - 145 g/l

pH - 8,5 - 8,9

What to look for in Plant Running

Make sure temp. in burner is correct $\pm 1000^{\circ}\text{C}$.

If temperature is slightly low you can increase sulphur if properties will allow this. It will bring the temperature up. This also applies to the cooling tower temperature.

If burner temperature drops rapidly or if burner goes out check air supply - check sulphur pump - check sulphur gun.

If cooling tower temperature goes high, check cooling water and sprays.

If sulphites are low increase sulphur slightly, if carbonate results will allow and vice-versa.

pH is determined by the concentration of carbonates and or sulphites.

Storage tank level must be kept at a constant level to keep constant amount of carbonate being pumped to absorbtion tower.

COUNTRY PAPER
E T H I O P I A

INTRODUCTION

Ethiopian pulp and paper s.c. which is located at Wonji, about 120 km south of Addis Ababa, started its production of paper and corrugated boxes in February 1970. Since its inception it has been producing printing, writing, wrapping papers and boards with basis weight ranging from 30 g/m² to 350 g/m².

The paper machine was initially designed to produce 25 metric tons per 24 hours of the above grades of paper, employing imported fibre stock as the principle raw material. With 300 working days per year, its capacity was estimated at 7500 tons/annum.

However, by making changes in the production mix, it has been possible to attain a gross yearly production of 8700 tons. It is even possible to surpass this, if production is concentrated on heavier grades of paper with basis weight above 70 g/m².

PAPER AND PAPER BOARD DEMAND IN ETHIOPIA

The consumption of paper and paper board in Ethiopia has remained at an alarmingly low rate over two years, not exceeding 0.8 kg per caput per annum. This is mainly due to the high percentage of illiteracy that had prevailed in the country. It is now more than 7 years, since the National Literacy Campaign has been launched and the achievement scored in eradicating illiteracy is so impressive that the current plan is to totally wipe it out.

In the second place the National Economic Development Campaign has been embarked upon to accelerate the growth in agriculture and industry in the country and to improve the living standards of the masses in general. Along with these plans greater attention is being given to mass education programmes.

The above are the main factors that are strongly influencing the increase in the consumption of paper and paper board from the current figure of about 26000 tons per annum.

Taking into account the project growth rates of 7 % per annum for printing and paper board and 10 % per annum for stationary/exercise books and industrial paper, it is estimated that by 1990/91 the current consumption of 26000 tons could more than double, with the fine grades of paper making up more than 70 % of the total consumption. When the industrialization of the country is intensified, the picture could even change by showing greater consumption of the industrial papers like kraftliner, fluting medium, sack kraft paper and grey board. Ethiopian Pulp and Paper S.C. current share of the market is about 36 %.

To meet the above consumption demand the E.P.P.S.C. is currently handling the expansion of the existing paper machine and pulp mill project based on bagasse.

EXPANSION OF PAPER MILL

This will take place in two phases i.e. phase one, with minor equipment change and heavy maintenance, which will take place in mid December 1986.

Phase 2 Rebuild of PM 1 will take place after PM 2 prefeasibility and feasibility study has been carried out by M/S Arrow Project and will be materialized in 1987-1990.

PULP MILL PROJECT

The prefeasibility study of this project was carried out in 1980 mainly based on bagasse. However, feasibility study was delayed till 1984 after which a contract for a consultancy for feasibility study of the bagasse mill with the other alternative raw materials, such as wheat straw and kenaf were covered and it is found that the bagasse is the most viable compared to the others.

The final draft report is submitted by the consultancy group and as a result the project is found to be viable for local market only.

The bagasse requirement of the proposed pulp mill would amount to 64000 BDTPA of whole green bagasse, which is equivalent to approximately 45000 BDTPA of moist depithed from the sugar mill.

The proposed pulp mill will have a design capacity of 30000 A.D.T.P.A to produce 1200 tons of unbleached pulp and 21000 tons of bleached pulp.

This pulp mill will be in line in 1990. The investment on this project is estimated to be 20 million of dollars. For this a financial and technical preparation is being carried out both by the Government and Ethiopian Pulp and Paper S.C.

COUNTRY PAPER
T A N Z A N I A

prepared by

A. Lipumba
B. Kilembe
A. Shedehwa

CONTENTS

The pulp and paper industry is new in Tanzania. However, feasibility studies to establish a pulp mill based on tropical pine as the raw material was done soon after independence in 1962.

The suggested mill was to have had a capacity of 500 t/d of pulp for export market.

It was not until 1976 that it was decided to go ahead for an integrated pulp and paper mill of a capacity of 250 t/d of finished paper instead of a pulp mill based on an export market.

At the same time (soon after independence) studies were being carried out to establish small paper mills based on recycling waste paper. Actually the study for these small paper industries came into effect in 1974.

KIBO paper industries Ltd. which, up to today, is the biggest paper converter into paper packaging products in the country, came into operation in 1971. Along this paper conversion factory a recycling paper mill of 10 t/d capacity was established in 1978.

This paper recycling plant produced and still produces

1. Corrugating Media and
2. Liner Board

using 75 % waste paper and 25 % imported kraft pulp. This mill was expanded to a capacity of 30 t/d in 1982, to produce corrugating media, liner board and duplex board.

In the same year (1982) another board producing mill (KIBO Match Pulp and Paper Board) came into operation producing Cuplex board utilizing stone ground wood; waste paper and imported kraft pulp.

The integrated pulp and paper mill was constructed between 1979 and 1984 and came into operation in May 1985.

This mill utilizes planted tropical pine (pinus patula, pinus eliote and pinus radiata) as softwoods and eucalyptus and black wattle as hardwoods.

The mill produces - newsprint, kraftliner, sack kraft, testliner and all writing and printing paper.

The mill depends mainly on coal, furnace oil and bark as furnace fuel for its power boiler.

The major target of establishing the mill was import substitution, as we were importing all types of paper grades.

DOMESTIC PAPER CONSUMPTION

The local paper consumption was statistically fixed at 35,000 t of paper per year by 1981 and this figure was to rise to 40,000 t by the year 1986.

However, due to economic constraints pertaining in the country, paper consumption has gone down instead of going up as was previously projected, creating a larger paper surplus, previously unforeseen.

PROBLEMS FACING PAPER INDUSTRY IN TANZANIA

The Southern Paper Mill

This mill which has a big capacity is operating below design capacity due to lack of local market as the user industries have been highly hit by lack of spare parts or imported raw materials due to lack of foreign exchange at the Central Bank in which they depend on.

As a result of these problems, the mill is forced to look for external markets in order to utilize its design capacity. The mill has no fibre raw materials problems.

Another problem which is expected to face this mill is power generated from coal. At present, the mill utilizes imported coal from Zimbabwe and also imported furnace oil which are very expensive and require foreign exchange which the country lacks.

It was previously expected that the mill would use coal produced in Tanzania by 1987, however, construction of the coal mine has not been completed yet and is not expected to be in operation in 1987 as foreseen.

The future plan to overcome the mill power problem is to have an electric power boiler by 1988 if we can get external financing to replace the imported coal and furnace oil which are very expensive as we have surplus electric power supply.

THE RECYCLING PAPER MILLS

These mills also are not operating at their full capacities due to the lack of waste paper, spare parts which depend on foreign exchange and for those based in Dar-es-Salaam face continuous water supply problems as the mill was built to depend on the public water supply system. To solve this problem they need financing to have their own water supply (bore holes etc).

FIBROUS RAW MATERIALS INCLUDING AGRICULTURAL RESIDUES

As previously stated, the country has ample supply of tropical pine and hardwoods to cater for more than one pulp and paper mill of the same capacity as the Southern Paper Mills, hence has no fibrous material problems. At the same time, the country has a good supply of other alternative agricultural residues such as bagasse, rice straw, reeds etc. which at present are just a waste and another alternative being sisal which is in abundance.

As to wood, at least 10,000 ha per year of pine and eucalyptus which matures between 8 - 12 years are being planted. Other future plans are to establish tissue and speciality paper.

COUNTRY PAPER
S W A Z I L A N D

prepared by
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USUTU Pulp Company Limited

USUTU PULP is a conventional unbleached kraft mill with a production rate of 175,000 tonnes per annum.

The mill is situated in an almost central position relative to its suffounding forest area which a mean radial distance of 25 km. Alongside the mill runs the Great Usutu River. USUTU PULP does not and is not permitted to let any of its waste waters into the river, not only because of the two export-oriented industries (a fruit canning factory and two sugar mills) downstream but because there are Government regulations which are to be followed to ensure the absence of river pollution.

Because all the wash liquors have to be received, USUTU although a conventional kraft mill, has had to make an extra investment in the evaporation plant to ensure excess capacity.

Our completely unbleached softwood kraft pulp finds many uses, some traditional such as liner, sack and wrappings and others more unusual - these taking advantage of our pulp properties imparted by the flash drying system used. The flash drying technique was developed by COURTAULDS and it results in a pulp with improved bulk, stretch and tear strength. Because of its abosrbency and bulk, it excels in speciality applications such as saturating base and soft crepe papers. Its high bulk and permeability is used to advantage in filtration products.

Our principal market areas include South Korea, Japan, the Pacific-rim countries, South America, Central and Southern Africa.

THE FOREST

In 1949, the Commonwealth Development Corporation started planting pine trees. The mill was commissioned in 1961 with a production rate of 60,000 tonnes per year while today production has increased to 175,000 air dry tonnes (ADT) per year.

The available forest area is 65,000 ha while the afforested area is 57,000 ha. Today, the sustainable yield of the forest is 840,000 tonnes of wood per annum with bark at 59 % moisture content.

In this area, the climate is temperate and makes for a rapid growth of the trees reach maturity between 15 and 20 years. The average rainfall is 1200 mm with a majority in December to February. The forest elevation varies from 900 to 1850 m.

The three species grown are 1) pinus patula 67 %; 2) pinus elliottii 26 % and increasing 3) balance taeda, kesiya and houndurescence. The average growth rate is 18 m³/ha/year with a range of 12 on poorest sites to more than 25 on the best sites.

Wood is brought in as 5 to 7 m long lengths. The mean radial transport distance from the forest is 25 km.

In 1985 the cost of pine wood delivered at the mill gate was US\$ 10.00/tonne wood.

THE MILL

USUTU has anew woodyard to be commissioned in June this year.

There are four Chipping Lines

- a) Soderhamn line with its own sorting log deck and three Cambio knife debarker. Chipping capacity 1000 tonnes/day;
- b) Two Nicholson lines each with its own sorting log deck and single knife debarker ahead of the chipper. Capacity at 700 tonnes/day each;
- c) Morbark chipping line with its own log deck and knife debarker. Capacity 350 tonnes/day.

The average woodyard throughput today is 2400 tonnes/day wood. The chipping capacities shown are not being realized due to the overall deficient mechanical condition of this woodyard - mainly due to age of the equipment.

Rauma-Repola Woodyard

The new RR is for a capacity of 210,000 ADMT per annum. Logs will be fed into a single drum debarker followed by a RR chipper. While capacity of the new wood is 1000 ADT per day, it is intended that operation time will be 14.5 hours over 351 days per year with the remaining time for maintenance.

The average chipping capacity	230 solid m ³ /hr
Peak capacity	260 solid m ³ /hr
Wood specific volume	1.07s m ³ /tonne

Screening

Chip are screened on a Winbergs thickness screening unit with an average capacity of 375 m³ chips per hour and a peak of 410 m³ chips/hour.

The chip size distribution obtained with the current Soderhamn and Nicholson chippers after the Winbergs Thickness screen is:

Over 8 mm	1.0 %
Prime 2 - 8 mm	95.4 %
Prins 5 mm ϕ and 2 mm	2.6 %
Sawdust	1.0 %

PULP LINE

Digestion

Chips are conveyed to a KAMYK CONTINUOUS VAPOR PHASE DIGESTER with pre-impregnator. The digester with a yield of 47.7, is able to produce 500 and 600 tonnes of pulp per day. Our kappa lam is 35. White liquor sulphidities are 28 - 30 % based on AA. With the Winbergs screen knots rejection rate has been from 4.5 % to 2.2 % on pulp production. Maximum weekly sustained production is 590 ADMT/day final pulp.

Washing and Screening

Washing begins in a KAMYR PRESSURE DIFFUSER. This is followed by a KAMYR ATMOSPHERIC DIFFUSER. The washed pulp is then screened in three SUNDS IMPCO de-knotters. Shives are diverted from the main pulp stream by five MIAMI selectifiers for deshiving in an ASPLUND RGP 600 HP raffinator before being directed back to the main pulp stream. The final washing stage is achieved on two parallel lines of two drum DORR OLIVER WASHERS with barometric legs. Hot condensate wash from the evaporation plant on the last drum washer is 4 to 4.5 m³ ADMT pulp.

FINISHING

Drying and Baling

After the final deshiving of the pulp in two additional parallel ASPLUND raffinators, the washed pulp is dewatered on five parallel SUNDS slurry presses from a consistency of 5 % to 45 %. The liquor from the dewatering is used for dilution (10 - 15 %) after the Brown stock washer and on the last stage washing with hot condensate from the evaporation plant.

No liquor is bled out of the washing plant to the sewer. Final pulp drying is done in six similar flash drying lines with a capacity of 110 ADMTPD each. The pulp is flash dried with hot air at 500°C to a final moisture of 14 %.

Dried pulp is fed to two SUNDS slab presses - producing bales of 240 kg by weight.

The drying and baling plants are the two biggest energy consumers - with drying at 115 kWh/ADMT and baling 60 kWh/ADT.

The bale wrapping, tying and 6 bale unit unitizing is all SUNDS equipment.

Pulp Quality

The pH of pulp before flash drying is 10, while after SO₂ addition, the

pH of final floc pulp is 7.8 Tappi. SO_2 is added in the hot air before flash drying to control fish eye formation, nodules and it also improves the pulp brightness. The shive content averages $150 \text{ mm}^2/\text{m}^2$ while there is an appreciable variation here too depending on process conditions.

Pulp brightness	23 ISO
% washable solids	1.6
Ash	1.2
Easily washable saltcake	5.5 kg Na_2SO_4 /ADMT

Pulp Viscosity

There is a $50 \text{ dm}^3/\text{kg}$ drop in viscosity during the flash drying process.

At a production level of 300 ADMPD Pulp
viscosity before flash drying $1080 \text{ dm}^3/\text{kg}$
viscosity after flash drying $1030 \text{ dm}^3/\text{kg}$

At a production level of 590 ADMTPD pulp
viscosity before flash drying $1010 \text{ dm}^3/\text{kg}$
viscosity after flash drying $960 \text{ dm}^3/\text{kg}$

It should be pointed out, however, that variations in kappa numbers lead to rather unstable variations in the pulp viscosity and pulp strength qualities.

CHEMICAL RECOVERY AND LIQUOR MAKE-UP

Evaporation

Spent liquor from the washing operation is concentrated from 12 % solids (using steam at 270 kPa) in two sets of five-body, five-effects SWNSON vertical long tube evaporators with a capacity of 250 tonnes/hour of condensate. Usutu has had to allow for an excess evaporation capacity of up to 20 % being a closed mill—because under no circumstances is river pollution permitted.

Usucu skims off soap skimmings for crude tall oil recovery at black liquor solids of 30 %. Optimum soap separation is around 28 %. Tall oil recovery is presently 30 kg/ADT. Black liquor solids generation is 1.56 BLS/ADT.

Chemical Recovery Units

The concentrated liquor first passes via direct contact evaporators before being fired in two parallel combustion engineering recovery boiler units. Each boiler is designed for 340 tonnes per day black liquor solids.

The average steaming rate of each boiler is 48 tonnes/hr with an operating pressure of 615 psig and temperature of 410°C.

Boiler feedwater temperature is 140°C.

As usual, sulphur is lost in the form of H₂S following the Cascade evaporator. Typical levels of H₂S are in the range of 200 to 400 ppm. Make-up chemicals are added as 5 kg/ADT of sulphur and 30 kg/ADT of sodium sulphate. Boiler reductions are 90 to 93 %.

Causticising

Two ALLIS CHALMERS kilns each with a capacity of 120 tonnes reburned lime per day are fired with producer gas and coal tar fuel, a by-product from the producer gas plant.

Lime requirements for preparation of digester cooking liquor is 260kg/ADMT pulp. Make-up lime is 15 to 20kg/ADT.

The energy requirements of the kilns is 12 GJ/tonne reburnt lime.

Green liquor consumption at 500 ADMTPD pulp is 3.93 m³/ADMT pulp at 125 gm/L Na₂O T.A.

Power

Total mill's power consumption is 600 kWh/ADT. The average steaming rate of each of the chemical recovery boilers is 48 tonnes/hour at 625 psig and 410°C at rated capacity. The maximum sustainable steaming rate of the woodyard waste fired boiler is 25 tonnes/hour at 625 psig and 410°C. These three steam generators are fed to a single steam receiver which distributes to three turbines, 200 psig and 45 psig reducing stations and a boiler water feed pump.

The woodyard waste fired boiler generates 4.1 tonnes steam/tonne fired material. The two back pressure SIEMENS TURBINES generate 4.2 MW electricity at a steam feed rate of 48 tonnes/hour. Maximum generation on each is 6 MW.

The condensing turbine at a fed rate of 6 tonnes/hour generate 1.2 MW (maximum is 1.3 MW).

85 % of the mill's power consumption is internally generated.

Producer Gas Plant

Producer gas is cleaned and cooled before use by consumers. There are three two-stage DAVY MCKEE units 10ft generator diameter. The thermal rating of each is 56 GJ/hr on bituminous coal at a consumption of 2.86 tonnes/hour each.

MILL WATER REQUIREMENTS AND EFFLUENT

Mill water demand in winter	0.6 m ³ /s
Mill water demand in summer	0.7 m ³ /s

Capacity of water treatment accelerator is around 3,500 m³/day, sand filters at 7,500 m³/day. The Usutu river is generally clean, low turbidity water. In winter turbidity is 10 mg/l while in summer it is up to 100 mg/l with variation of up to 2,000 mg/l due to rainstorms.

Water to the evaporation plant condensers does not go through the water treatment plant. This demand varies from $0.14 \text{ m}^3/\text{s}$ in winter to $0.22 \text{ m}^3/\text{s}$ in summer. The mill has a two-cell cooling tower able to cool $2000 \text{ m}^3/\text{hr}$ water from 46°C to 23°C . When this unit is in operation, the mill can be run with $0.28 \text{ m}^3/\text{s}$ water at full production.

Any water 'effluent' from the mill is permitted only to go through two Cascades by Government regulation. There are stipulated effluent qualities for both streams drawn up by the government to be met by the mill. Six monthly summaries of daily qualities of these two Cascade streams are submitted to the Government who can also conduct a survey of the river quality.

Current Government Permit

Discharge from the Cascades should comply with the following specifications:

- i) ph 5.5 - 10.0
- ii) Suspended solids intake 25 mg/l
- iii) Total dissolved solids not exceed 1.2 kg/ADT.
- iv) COD not to exceed 13 kg/ADT
- v) Temperature not to exceed 50°C .

USUTU pulp has an irrigation scheme, fruit canning factory and sugar factory downstream. The river water is also used for domestic needs immediately downstream of the mill.

The Usutu River reaches its lowest flow in the winter normally in July/August with a total flow of $2.8 \text{ m}^3/\text{s}$.

DEVELOPMENT

USUTU pulp is continually investing in areas that will improve product quality while reducing cost.

A Kamyr Pressure Diffuser washer with a capacity of 850 ADT was commissioned in November 1984. While mill production is 500 to 600 ADT, this unit was aimed at being used as a two-stage washer to improve our figure of 5.5 kg/ADT of easily washable solids in final pulp.

Also in 1984, the Winbergs Thickness Screen with a capacity of up to 675 ADT was installed. It has shown to not only have reduced the liquor charge to the digester but also the rejection of knots. Both these aspects have had positive influences - the former in the liquor recovery cycle while the latter has resulted in improved pulp strength and reduced shive content.

This year, the RAUMA-REPOLA drum debarker is being installed.