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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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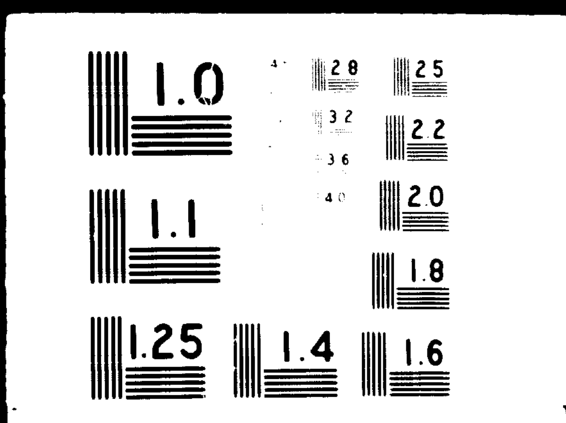

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PRACTICAL EXPERIENCES IN THE USE OF MIXED TROPICAL HARDWOOD FOR THE MANUFACTURE OF PULP AND PAPER 1/

by
B. K. Mayer
Manager, Technical Services
St. Regis Paper Company
West Nyack, New York, U.S.A.

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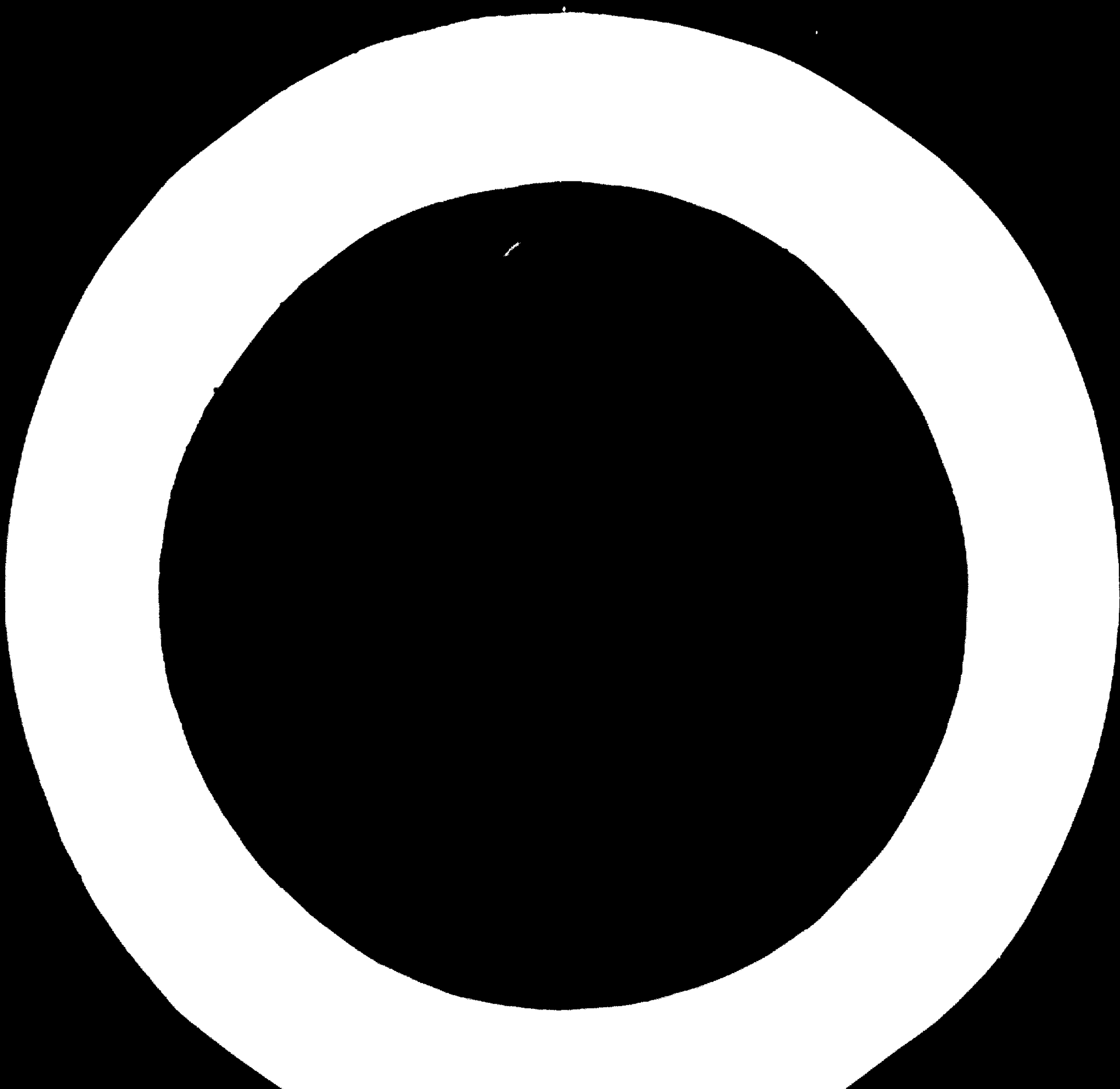

INTRODUCTION

Hundreds of pilot plant and dozens of semi-commercial pulping and papermaking trials have been conducted on random and selected mixtures of tropical hardwoods. The morphological parameters, the pulping response and the handsheet characteristics of literally a thousand species have been reported in the last 25 years (Ref. 1).

These studies consistently reveal that each major tropical forest section in the world has numerous hardwood species satisfactory for papermaking pulp. In general it is found that about half of the species (not the standing volume!) are suitable for kraft, about a third for NSSC or cold soda, a quarter for sulfite and dissolving, and 10-20% for groundwood or modified groundwood.

In view of the huge, existing growing stocks, these proportions ought to have resulted in the establishment of large pulping centers in various parts of the world. That this failed to take place is probably due to the following major factors:

(1) The local markets are small, poorly defined and/or unstable.
(2) The infrastructures required to support a major industrial complex are absent or inadequate (roads, power, ports, transportation, maintenance, technicians, etc.).
(3) The logging conditions are extremely adverse and a wide variety of serious technical obstacles are associated with manufacture of pulp and paper from these hardwoods.

This report concerns itself only with the technology of conversion to pulp and paper. However it is obvious that a thorough analysis of the marketing and civil engineering problems must be conducted before serious consideration is given to the establishment of a mill (Ref. 2).

BACKGROUND

Investigators of tropical hardwoods for the manufacture of pulp and paper have generally been optimistic about large-scale technical feasibility. However, many predictions of processing difficulties can be found in their reports. Isolated attempts to objectively define these problems were made through semi-commercial operations such as the Ivory Coast installation in the early 50's. The results of such trials have rarely been made public. It was not until the mid-sixties that one could assume a successful technology had been established. In that decade five companies built facilities for pulping only mixed tropical hardwoods, and a dozen mills in India and Japan supplemented their more-favored raw materials with substantial proportions of MTHW's (mixed tropical hardwoods).

A few of these mills have reported some of their operating experiences (Ref. 3, 4, 5), but a useful body of evidence was not established. Therefore, when St. Regis was asked if it could make a contribution to this meeting we offered to conduct a letter survey of companies known to be cooking MTHW in order to obtain a spectrum of operating problems specific to this raw material. UNIDO also requested that factors which have hindered the growth of this industry be identified, that suggestions be made for the elimination of manufacturing difficulties, and that long-range programs be formulated which would permit the full-scale continuous use of tropical hardwoods for pulp. These last two requests are particularly challenging to North American pulp producers, who have successfully solved all the minor production problems associated with their hardwoods.

SCOPE OF SURVEY

The survey was to exclude tropical plantation grown species (e.g. eucalypta), and it was originally intended to restrict it to mixtures. However, the experiences of users of single species or genera were drawn upon in order to illustrate possible solutions to general problems (e.g. latex, via heavea sp).

Today only five mills have operating lines processing only MTHW's. Most of these mills are integrated, i.e. use the pulp they manufacture. One outstanding example, Carton de Colombia, is here today disclosing for the first time the factors which assured their successful operation. Two more mills will be going into production shortly. Several mills in India are processing small proportions of MTHW's (10-25%) and bamboo, etc. Six mills in Japan are known to be using selected tropical hardwoods to augment their native supplies (Ref. 6).

Useful replies were not received from all of the mills, and it was necessary to supplement this information by reference to the literature and by communications with the experts of tropical forestry research institutions, consultants, and Paper Industry Associations. The cooperation of these contributors is acknowledged with gratitude. It is our sincere hope that today's disclosures will encourage others to record their experiences for the benefit of those who must some day utilize this vast, troublesome resource.

RESULTS OF SURVEY

A list of the mills contacted in the course of this survey is given in Table I. The tabulation shows who replied to the questionnaire, the mixtures and the pulping processes in use. Carton de Colombia, PICOP and Rustan are shown for the sake of completeness. The latter two indicated a willingness to share their experiences, once they have substantial production experience. Other speakers on today's panel will reveal additional mills and details, especially for India.

Many suggestions for additional information and possible users, or trial users, were followed up. Most of these led to organizations deep in planning studies who understandably could not discuss their technical information. The tabulation therefore represents, to the best of our knowledge, an accurate and up-to-date list of major users of mixed tropical hardwoods.

The responses from the individual mills and abstracts of key literature describing operating experiences have been reduced to 'case histories' and are appended to this report.

TABLE I

MAJOR USERS OF MIXED TROPICAL HARDWOODS

	Country	Reply	Using	Process
Mills using 100% MTHWs				
Bataan Pulp & Paper mills	Philippines	None	lauans	150 T/d Kraft
Carton de Colombia	Colombia	(Not contacted)	100 sp	200 T/d Kraft
Chung Hwa Pulp Corp.	Taiwan	Useful	100 sp	250 T/d Kraft
Industrias Klabin do Parana de Celulose SA	Brasil	Negative	many	40 T/d NSSC, Kraft?
Paper Industries Corp (PICOP)	Philippines	On stream late 71		
Rustan Pulp & Paper Mills	Philippines	On stream late 71		
Formosa Chemicals and Fiber Corp.	Taiwan	Useful	many	120 T/d Dissolving
Japanese Mills using some THWs				
Daishowa Paper Mfg. Co., Ltd.		'Proprietary'	Hevea	NSSC?
Hokuetzu Paper Co., Ltd.		None	Cambodian chips	?
Kauzaki Paper Mfg. Co., Ltd.		None	Mangroves	?
Nagoya Pulp Co., Ltd.**(also Jugo, Ltd.)		Useful	lauans	Kraft
Sanyo Pulp Co., Ltd.		Useful	Hevea, mangrove	Kraft, Dissolving
Oji Paper Co., Ltd.		None	Iauans	?
			Sumatra wood	
Indian Mills using some THWs				
Bengal Paper Mills Co., Ltd.		None	Many + Bamboo	Kraft
Star Paper Mills, Ltd.		Useful	17 sp + Pine	Kraft
Andhra Pradesh Paper Mills, Ltd.		None	?	?
Rohtas Industries, Ltd.		None	?	?
Central Pulp Mills, Ltd.		None	Experimental	

** Associated with Chung-Hwa Pulp Corp.

The practical experiences of these mills have been collated by manufacturing functions and are described below under appropriate headings. Comments and suggestions for improving operations, based on the author's experiences and the suggestions of experts, are given at the end of each section.

PRACTICAL EXPERIENCES

Wood Procurement

Up to one or two hundred species may exist in the procurement area of a mill. Of these only a portion are suitable for any given type of pulp. Very low density woods may be uneconomical with respect to yield, strength or digester capacity, but some low density woods are the only ones suitable for groundwood or refiner mechanical pulp. Light colored woods are preferred for these processes and are also often set aside for bleachable pulp production. Exceptionally heavy species are avoided because of difficulty of splitting, chipping, penetration during cooking and poor papermaking properties. Highly colored species, whose dyes survive pulping and bleaching to an exceptional degree, are avoided. Highly lignified species that result in low yield or high bleach demand are also avoided.

Minor or major problems may also exist with respect to species containing toxic substances, allergens, high mineral content and obnoxious poly-phenols, resins and latex. Where used they require special quality control and/or operating procedures noted below.

The acceptable species must be identified by a knowledgeable individual, and he must train the cutting crews in their selection. Oversize, knotty and heavily fluted specimens are not logged because of equipment limitations. Hollow and decayed trees must be identified and avoided. Substandard wood may be used for road and bridge building, etc.

Woodyard receipts are inspected and substandard wood is diverted to steam boilers.

In addition to the logistical and technical factors, cultural patterns may seriously interfere with the procurement of adequate supplies. In India, for example, the demand for fuel-wood is so great that mills are forced to use virtually unacceptable left-overs, stumps, roots and branches (Ref. 4).

The above factors, when coupled with the highly-publicized difficulties of logging in tropical regions, appear to make a tropical forest more of a liability than an asset (Ref. 2, 7, 9).

Carton de Colombia is planting pines, eucalypts and other fast-growing hardwood species which will completely supply its needs within a few years (Ref. 8). It is believed that Klabin is similarly engaged.

All of the experts contacted were unanimous in their beliefs that the typical tropical forests would be converted to plantations of selected native or exotic hardwood types, specially selected for the products demanded by the market. Indigenous MTHW's would be consumed only until the plantations were on a sustained yield basis.

If their beliefs are correct one of the recommendations coming out of this meeting should be the establishment of accelerated programs for the development of certified seed sources for the plantations. These sources should include low density species (similar to Tilia or Populus), which would be suitable for processing into newsprint and publication grades, and long fibered dense species (similar to Platanus or Betula) which would be suitable for kraft pulp and almost as strong as spruce kraft. Medium density, medium fiber length species (such as the Eucalypts) are highly satisfactory for cultural papers, corrugating medium, and in many cases, for dissolving pulp. The species would be chosen for reliability of reforestation as well as for freedom from conversion problems.

However, it will be many decades before the present stands are consumed and we should address ourselves to improving techniques for logging in existing tropical forests. Studies must be conducted on how best to convert these forest areas to plantations. Problems plaguing pure plantations must be anticipated and solved beforehand.

Wood Yard

Decay during storage is a serious problem in many areas. Excessive decay carries the following penalties:

(1) Serious loss in yield, thereby increasing the load on the liquor preparation system, evaporators and recovery. Chemical costs are greatly increased.
(2) Serious losses in strength.
(3) Increased staining of the wood which often results in increased bleach demand or lower brightness, and in increased costs.

Decay is minimized most economically by keeping inventories at very low levels.

Outside chip storage (OCS) would appear to be unsatisfactory in certain areas, but not all. Concern over the environment, as well as economics, would rule out fungicides based on heavy metals and non-degradable toxins. The need to develop a low-cost degradable fungicide is indicated.

An acceptable method for arresting fungal activity would be to dry chips to 20% moisture. Such a procedure may have desirable side effects (like seasoning). The thermal costs may be reasonable but the equipment costs may be prohibitive. No reports on chemical debarking were received. This procedure, though tedious, may have some merit in reducing moisture as well as facilitating bark removal.

Bark Removal

Because of their high density, tropical hardwoods place serious structural demands on drum barkers. Pre-soaking is used to facilitate bark removal. Hand peeling could be dangerous in the case of species with poisonous sap (e.g. Gewa). Mechanical ressers require excessive maintenance and are unsuited for crooked wood.

Hydraulic barking was not reported but may avoid some of the shortcomings of the other methods. North American experience indicates that the bark of many hardwoods makes acceptable and economical pulp via kraft and NSSC processes. This may be the case for tropicals also.

Chipping

Chipper knife life is very short in some areas because of high wood density and high ash (silica) content. Dry, dense wood may be virtually impossible to chip.

In view of the general concern about and problems connected with penetration problems of tropical hardwoods, it is strange that no reports were received of trials with P-chippers or chip shredding. P-chips might be a little easier to make than standard, and chip shredding is an established method for improving penetration. Chips should be made as thin and short as possible to improve penetration. At the very least chips over 3/4" long should be removed by screening and reprocessed.

Blending

Strong recommendations were made for thorough blending of wood and chips to assure a uniform day-to-day mixture. This is best accomplished by simultaneously logging in different areas and blending in the yard. If this is impossible then the chips should be blended using OCS piles or silos for the various types.

Cooking

The thermal and chemical environment applied to tropical hardwoods is generally 10-30% more severe than for temperate zone hardwoods. Conditions cited for kraft cooks were 16-19% active alkali and maximum temperatures of 168-175°C with about one hour at maximum. Hardwoods and softwoods should not be cooked together (but bamboo is acceptable). Because of the wide range of wood density encountered in a given forest it is very important that the dry weight of the chips to the digester be uniform, or measured, so that the proper amount of chemical may be charged.

Dirty blows are a problem with batch digesters using wood of very high density. This can be minimized by digester design and by using relatively high liquor ratio.

NSSC is made at one mill from MTHW's using conventional chemical and temperatures but very long cooking time (4-3/4 hr.).

Dissolving pulp is successfully made in one mill from mixed mangroves using the sulfite process. Mixed mangroves are also used to manufacture bleached kraft. For these species bleach demand is somewhat higher than normally experienced due to their high lignin content.

Mixed lauans are being converted to bleached kraft using conditions equal to those for temperate hardwoods.

Penetration problems, resulting in high K No's, dirty pulp and excessive knots are mentioned repeatedly. These could be minimized by stringent chip screening, chip shredding, increasing the penetration time, using forced circulation (from the middle to the top and bottom), and/or using more alkali. The dirt in HW Kraft pulps increases exponentially for K No's above 15. Chips should be covered with liquor and the top liquor distributing ring should be designed to provide good basting as the liquor level goes down during the cook. Pre-steaming is not recommended. Ease of penetration is not only a function of wood density but also of wood porosity (inclusions, tyloses, etc.).

The Sloman counter-current process may prove particularly beneficial for high density mixed tropical hardwoods.

Groundwood, Chemigroundwood and Cold Soda Pulps

No operating information was received concerning these processes. However, it is known that selected species are being used to a limited extent. Pilot plant studies have shown that 10-30% of the species in most forests are suitable, especially for the hybrid pulping processes. The preferred species are light colored and of low density.

The flexibility of stone groundwood or refiner mechanical pulping systems might be extended by post-treating pulps with caustic to improve pulp strength. Brightness is thereby decreased but can be restored by bleaching (Ref. 11).

Bleaching

The bleachability of chemical pulps is more or less directly related to their lignin content (Roe No, K No, etc.) except in the case of stains due to minerals, fungi, etc., and refractory organic constituents such as polyphenols. Bleachability is not necessarily related to the color of the wood or the pulp. MTHW's are successfully bleached to 83 GE using CEHEH, and to 86-89 GE using CEDED sequences.

Overbleaching must be avoided or else there will be operating problems on the papermachines (see below).

Some references to cold soda pulp bleaching did not mention a little-known method for improving bleach response - that of pretreating with sulfuric acid, followed by washing.

Problems due to Minor Wood Constituents

Latex: Many tropical species contain latex, although not as much as hevea sp. It can appear in the pulp as balls that will deposit on equipment and interfere with normal operation of washers, screens, refiners, machine wires, etc. Two mills have flotation stages in the brown stock systems where these lighter-than-water contaminants can be skimmed off.

New methods to improve the cleaning of reclaimed fibers are currently being studied in the U.S.A. If successful the technology can be applied to the above problem.

Poly-phenols: A substantial number of tropical hardwoods contain compounds similar to those found in eucalypts. One mill reported that a gelatinous scale develops in black liquor evaporators when using MTHW's in its kraft system. The scaling is minimized when storing the pulpwood for several months. Other scaling problems from this source could be alleviated by methods developed by the Australian pulp industry, e.g. rinsing equipment in a solution of hypochlorite at pH 8 (Ref. 10).

Silica and Ash: The literature repeatedly implies that the high levels of silica and ash found in some species are detrimental. However, no references were made of operating difficulties other than chipping. Should these arise it would seem that the expertise developed by users of bamboo or straw could be applied.

No difficulties were reported by one mill cooking wood with 1% ash when this wood represented 20% of the mixture. Oxalate crystals are removed by one mill using a special acid treatment.

Resin: The extractives in Lauan sp. show up in the pulp as small flecks. These can be minimized but not eliminated by surfactants in the extraction stages and by low consistency centri-cleaning. Cooking additives were found ineffective.

It was claimed at one time in the U.S.A. that pre-bleaching with hypochlorite tends to minimize difficulties from materials of this type.

Stock Preparation

Very high density hardwoods result in (kraft) pulps which are definitely difficult to refine and at best result in pulp with lower bonding strength (tensile, fold, etc.). If refined to conventional levels the pulp is undesirably low in freeness and opacity. Such species are therefore kept to a minimum, or diverted to tolerant paper grades.

Disk refiners (pressurized) should be used because of their higher efficiency. HCR (high consistency refining) as well as very low consistencies (2-3%) should be investigated to determine if unique refining responses exist for these very thick-walled fibers. Other refining variables such as pH and temperature should also be studied for possible benefits.

Papermaking

Once properly prepared, MTHW pulps are no more difficult to run on the papermachine than temperate zone hardwood pulps.

Hardwood pulps in general and the short-fibered hardwoods in particular, have very low wet-web strength. Furnishes high in hardwood are therefore susceptible to

(1) breaks at the open draws of the wet end,
(2) crumbing (picking) at the wet presses,
(3) linting in the dryers, if poorly bonded,
(4) poorer runnability through calenders and supercalenders.

Excessive refining of high density pulpwood fibers or of overbleached fibers will result in poor drainage stock and a low consistency web at the couch. This leads to excessive breaks and crumbing at the presses.

Wet-end breaks are also caused by short-term variations in basis weight and drainage as well as by shives and fiber lumps. Linting in the dryers can be avoided by raising sheet temperature gradually. Vessel segment picking is minimized by refining and by size-pressing.

Bonding aids in the furnish, such as cationic starches, should also help minimize some of the above problems.

In all cases except for the few very long-fibered hardwoods (> 1.5 mm) some long-fibered pulp is required to get the sheet through the machine and to provide adequate end-use strength properties. Vacuum pick-ups would be desirable on high speed machines to compensate for the low wet-web strength and minimize long fiber requirements.

CONCLUSION

The technical problems associated with the use of MTHW's for pulp and paper manufacture have been reduced to a tolerable level by exercising reasonable care in the selection of wood and pulping equipment. Such difficulties that remain will be overcome by the introduction of additional special techniques and more modern process equipment. These improvements will gather momentum as the demand of the local markets increases, or if pulpwood shortages in developed countries become acute.

The economic problems of utilization of this resource reside heavily in the costs of extraction of usable species. The successful mills appear to be avoiding these high costs by concentrating on forests of relatively homogeneous composition or by working the fringes of the true tropical areas. Here they can nibble away at the rain forest and replace it with more amenable species.

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APPENDIX

Case History I

Chung Hwa Pulp Corporation (Taiwan)
Production: 250 T/d Bleached HW Kraft
Wood Selection: 100 species of tropical hardwoods are accepted, consisting of Lauraceae 40%, Fuagaceae 30%; misc. 30%. Cinnamomum camphora is rejected for bleachability and Laportea Paulownia & Albizzia are rejected because of low density.
Wood Yard: No problems experienced with respect to decay, chipping or storage.
Cooking: Must use 18% AA in mill, (vs 16% predicted by lab studies) to reach 15 K No.
Extractives: Have some problems with pitch and use control aids.
Bleaching: Wood color is not a problem. Using CED to 80 GE, and CEDED to 88 GE. Building a new system using D/CEHDED for 150 T/d. Recommend this sequence for tropical hardwoods. Brightness stability is very good.
Brown Stock System: Have no problems washing or screening the pulp.
Pulp Drying: No difficulties.

Case History II

Formosa Chemicals & Fiber Corp. (Taiwan)
Production: 120 T/d Dissolving Pulp
Wood Selection: Use low to medium density mixed species (0.35-0.70 sp gr). Decayed wood is rejected at the stump and represents about 5% of available volume.
Wood Yard: Store 20,000 tons of pulpwood.
Wood Room: Use 2 barking drums, dry, for 20 T/hr (5 m⌀ x 12 m long, 9 rpm). Green wood barks easiest. Use 50" Norman chipper. Oversize rechipped.
Cooking: 180 m^3 stainless lined digesters; 50 BDT chips; 3/1 liquor ratio. Total cooking time 12 hrs. to 10 K No. and DP of 1500.
Screening & Cleaning: Reject fine parenchyma and ray cells using side hill screen. Other equipment conventional.
Bleaching: Use the following sequence - chlorination, extraction - low consistency, extraction - high consistency, soak, hypochlorite, cleaning, sulfur dioxide sour. Interstage vacuum washers throughout.
Product End Use: Viscose rayon staple.

Case History III

Klabin do Parana (Brasil)
A communication from Klabin stated that they are using 'very little hardwood mixed with P. pine and Eucalypts'.
For the record we insert the following translation of G. Petroff's reference to Klabin hardwood pulps as they appeared in Carton et Cellulose, (Nov. 70).
Production: 40 T/d either NSSC or high yield kraft
Wood Selection: Their forest contains about 150 species of hardwoods with densities varying from 0.23 to 1.11, fiber length 0.5 to 2.2 mm, AB extract 0.3 to 16.5%, pentosans 8 to 20%, lignin 17 to 45%. Color and hardness vary considerably. About 50% of species available are field-picked for pulping; these have densities from 0.3 to 0.9! This mixed hardwood is pulped two ways:
I. Neutral sulfite: 180°C, 13% sulfite, 5.1 ratio, 4.8 hrs., spherical digesters 40m^3, 80% yield. Defibrated one pass through Bauer or Sprout-Waldron. Energy 1200 kwh/t. Used for corrugating medium.
II. HiYield Kraft: 175°C, 16% active alkali, 18% sulfidity, 4 hours, same digesters, 70% yield. Energy required is more than above. Used for cylinder carton board.
Wood requirement, either process: 5-7 steres/t pulp.

Case History IV

Sanyo Pulp Co., Ltd. (Japan)
Production: About 80 T/d rubberwood pulp, (20% of total production) from malay chips - part by acid sulfite for dissolving pulp - part by sulfate process for paper pulp.
Wood Selection: Tapped portions of trees must be eliminated to prevent excessive problems with latex in pulp. Experimenting with fungicides on shiploads to reduce formation of blue stain. Odor of fermenting chips can be objectionable, especially when unloading.
Fiber Morphology: Fibers similar to Japanese hardwoods - diameter 22 microns; wall thickness 3 microns; length 1.5 mm; density, 0.54. Rubberwood is relatively high in ash (0.9%) and in hot water solubles (5.9%) but lower in pentosans, (19%) than Japanese hardwoods
Cooking: Chips are mixed with local species and cooked by Ca-base sulfite process for dissolving pulp. Would prefer to cook separately to achieve optimum Kappa number and lower screenings. Chips are mixed with local species and cooked by the kraft process. Yield, screenings and bleach ability are similar to local species.
Screening: Pulp is screened and cleaned intensively to remove latex particles. Equipment includes Cowan screens, Lindblad screens, Bauer cleaners and flat screens. Finally, a special flotation unit is used to remove the remaining, lighter-than-water latex particles. Final latex content is less than 0.02%.
Bleaching: The sulfite pulp from blue-stained chips is higher than normal in bleach demand. Extra chlorine and caustic is used. Care must be taken not to overbleach, so as not to impair washing rates.
End-Use Properties: Both pulp types are fully equivalent to Japanese hardwoods with respect to papermaking and viscose qualities.

Case History V

Sanyo Pulp Co., Ltd. (Japan)
Production: About 70 T/d mangrove pulp (about 20% of production) from Philippine logs - part by acid sulfite process for dissolving pulp - part by kraft process for paper pulp.
Wood Selection: All species were found suitable for kraft and Brugiera, Rhizophora and Ceriops were suitable for dissolving pulp. Bark removal should be thorough to minimize dirt in pulp. No problems with storage or decay.
Morphology: Specific gravity is high at 0.7-0.8 and wall thickness at 9 microns is (much) higher than Japanese average. Fiber length at 1.5 mm is also higher than native species. Lignin and pentosans are at the levels of most Japanese hardwoods, ash content is higher and pitch lower.
Cooking: The high gravity of mangrove wood requires that additional chemical be charged to the digesters by increasing the acid strength. Sulfite pulp yield is higher and Kappa number lower, compared to native species. However, the Kappa number of kraft pulp from this genera is higher.
Washing and Screening: The thick-walled fibers wash more readily than native species. Calcium oxalate inclusions are removed by a special acid extraction step to avoid viscose conversion problems.
Bleaching: Conventional sequences are used. The sulfite pulp bleaches more readily and the kraft pulp less readily than native species.
End-Use Properties: The strength of papers made with mangrove kraft is lower than normal because of the thick cell walls. The proportions used are tailored to the various grades of paper. Conversion to rayon, and rayon filament qualities are equivalent to Japanese hardwoods.

Case History VI

Nagoya Pulp Co. (Japan)
Abstracted from "Bleached Kraft Pulp from Lauan", Toyonoba Oka, IPPTA Souvenir 1969, Vol. VI, No. S, pp 123-133.
Production: Bleached market kraft pulp from 100% lauan waste chips.
Morphology and Extractives: Detailed descriptions are given.
Cooking: Digesters 50 m^3, indirect steaming, forced circulation. 19% AA, 27% sulphidity, 65 minutes to top temperature of 167°C, at maximum temperature for 50 minutes. Yield 46% at Roe #2.7. Problems with feeding chips (bridging) and channeling.
Bleaching: CEHED conventional to 86 GE using 110 lb. chlorine, 32 lb. hypo, 12 lb. chlorine dioxide and 62 lb. NaOH.
Papermaking Properties: Pulp is of good strength but troubled with specks and flecks due to vessel segments and non-saponifiable extractives. Article details mechanical and chemical treatments to minimize the resin content of the pulp.

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