Newsprint Production from Rice Straw and/or Bagasses Using Nitric Acid Chemimechanical and Semichemical Pulping Processes

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ABSTRACT

Chemimechanical and semichemical pulping of rice straw and bagasse with nitric acid results in high yield pulps of high opacity, with properties close to or superior to softwood groundwood pulps. Full chemical pulps can also be produced. The waste liquor from nitric acid pulping should be a good fertilizer and the value of the nitric acid could be recovered by using the mill effluent as a fertilizer. At the same time this would solve the effluent problems of pulp mills based on rice straw, which cannot have chemical recovery because of the high silica content of rice straw, or small bagasse pulp mills, where chemical recovery cannot be justified for economic reasons.

Experimental optimum conditions were established for the production of high yield nitric acid chemimechanical rice straw pulps and nitric acid chemimechanical and semichemical bagasse pulps suitable for the production of newsprint. Evaluation of optimum furnishes for newsprint from blends of nitric acid chemimechanical and semichemical pulps and long fiber chemical wood pulps were carried out on a small experimental paper machine. Tentative flowsheets have been prepared for the nitric acid chemimechanical and semichemical processes utilizing equipment currently available on the market. Hypothetical capital and manufacturing costs and preliminary economic analysis have been developed for a theoretical 300 ton/day newsprint mill.

Keywords: Nitric acid pulping; bagasse newsprint; straw newsprint

A. INTRODUCTION

The increased demand for paper production has initiated a widespread search for fibrous raw materials other than wood. On a world-scale basis, non-wood fibers now constitute only about 6% of the total raw materials for paper production (1). Among the many non-wood fibers, rice straw and sugar cane bagasse are among the most promising fibrous raw materials for the paper industry. The pulping of rice straw has been carried out mostly by the soda process to make high grade paper (2, 3) and by the lime, lime-soda or soda processes for the production of straw board and corrugating medium. Straw has also been pulped by the neutral sulfite process (4), the sulfate process (2, 4), and to a limited extent by nitric acid pulping (5-7). A considerable amount of work has been done on alkaline pulping of bagasse for producing high quality paper (8), sanitary tissues, corrugating medium, linerboard and wrapping papers. Bagasse has also been cooked with lime (9) and subjected to the sulfite process (10, 11). Again, little work has been done on pulping of bagasse by the nitric acid pulping process (12, 13).

Today, most of the major types of paper are being produced from straw and bagasse in countries where wood resources are inadequate or inaccessible. The only major exception is newsprint.

Newsprint is usually composed of 15-25% long fiber chemical pulp and 75-85% mechanical pulp. The long fiber chemical pulp provides the strength required for the production of newsprint on high speed paper machines and printing on high speed rotary presses. The mechanical pulp provides the opacity and the excellent printing characteristics of newsprint. The mechanical pulp most commonly used in newsprint is softwood groundwood, refiner mechanical or thermomechanical pulp or mixtures thereof. Although hardwood groundwood, chemigroundwood and chemimechanical pulps have been used to substitute for all or part of the softwood mechanical pulp commonly used, the attempts to substitute bagasse mechanical, chemimechanical or semichemical pulp for softwood mechanical pulp have not been very successful. The opacity and printability of bagasse newsprint, of acceptable basis weight, were usually unsatisfactory.

In previous work (7, 13), detailed studies on the rapid nitric acid pulping of rice straw and bagasse were carried out for the production of various types of chemimechanical, semichemical and chemical pulps.

The aim of the present work is to select the most satisfactory pulping and bleaching conditions for the production of nitric acid chemimechanical rice straw pulp and nitric acid chemimechanical and semichemical bagasse pulps, that would be suitable as a substitute for mechanical wood pulp and to carry out different trials on an experimental paper machine with various furnishes of these pulps, along with softwood pulp, for the production of papers that would meet the demands of strength, opacity, brightness and printability required for newsprint.

A secondary objective is to select a tentative processing sequence and equipment configuration (using standard equipment available on the market) for the commercial production of nitric acid chemimechanical and semichemical pulps, so that capital costs as well as tentative manufacturing costs can be developed for comparison with conventional processes and to determine whether or not the production of newsprint using straw or bagasse nitric acid pulps could be profitable.

B. EXPERIMENTAL WORK AND RESULTS

B.1 Pulping, Bleaching and Papermaking Trials

The raw materials used were wet cleaned Egyptian rice straw and wet depithed Egyptian bagasse. Two stage cooks (HNO_3 followed by NaOH) were carried out in an electrically heated rotating digester with washing between the nitric acid and the caustic soda cooks. After the caustic soda cooks, the pulps were washed and the pulps produced were then subjected to single stage disc refining at 3% consistency in the case of chemimechanical rice straw and semichemical bagasse, and two stage disc refining in the case of the chemimechanical bagasse. Pulping was followed by bleaching. Table 1 indicates the optimum pulping conditions and Tables 2 and 3 indicate the optimum bleaching conditions.

The physical properties of the bleached nitric acid straw and bagasse pulps, and the bleached softwood and groundwood pulps used as furnish components in the newsprint papermaking trials are shown in Table 4.

Evaluation of optimum blends for newsprint manufacture from the prepared nitric acid pulps and long fiber wood pulps, in comparison to newsprint from long fiber wood pulp and stone groundwood pulp, was carried out on a small experimental paper machine. The results are presented in Table 5.

B.2 Discussion of Results Obtained

a) General

Chemimechanical and semichemical pulps are produced by first softening the cellulosic material by mild chemical treatment followed by attrition and fiber separation in a refiner. The difference lies in the amount of chemical used and the amount of attrition applied. Chemimechanical pulps have a low chemical charge and use more power for attrition. Semichemical pulps have a higher chemical charge and use less power for attrition.

Semichemical pulps have a higher yield than chemical pulps with strength properties intermediate between mechanical pulps and chemical pulps, moderate brightness and higher opacity than chemical pulps.

Chemimechanical pulps have a lower yield than mechanical pulps but a higher yield than semichemical pulps. The characteristic features of chemimechanical pulps are high yield, moderate strength and brightness and higher opacity than semichemical or chemical pulps. High opacity is one of the primary requirements of newsprint and the requirement that has proven to be the most difficult to meet when attempts are made to use non-wood fibers such as bagasse for the production of newsprint.

Previous attempts to produce newsprint from bagasse used the refiner mechanical process, which gave good opacity but poor strength, and semichemical processes, which gave good strength but poor opacity. Thus the present work concentrated on the chemimechanical process for the production of pulps suitable for newsprint and, to a lesser degree, the semichemical process. Also, most previous work involved the use of the alkaline or alkaline sulphite processes which tended to result in lower opacities even when relatively low quantities of chemicals were used. The opacities obtained by the rapid nitric acid process are considerably higher.

b) Nitric Acid Chemimechanical Rice Straw Pulps

The cooking conditions of the nitric acid chemimechanical rice straw pulp are shown in Table 1. Pulping of rice straw with 5% HNO_3 then 3% NaOH and single stage disk refining were found to be the optimum pulping conditions for production of the nitric acid chemimechanical rice straw pulp for the experimental work carried out. These conditions gave a fairly high yield (78%) and good opacity (94%).

The bleaching of nitric acid chemimechanical rice straw pulp was carried out in a two stage bleaching sequence (H-P), using 5% available chlorine as hypochlorite followed by 1% hydrogen peroxide which gave a satisfactory brightness of 66 GE and an overall yield of 72% for the bleached pulp (Table 3) The bleached pulp has satisfactory strength and good opacity (Table 4). The physical properties of the hand sheets are superior to that of stone groundwood as far as tear, breaking length and brightness are concerned and the printing opacity is only slightly lower.

c) Nitric Acid Chemimechanical Bagasse Pulps

Table 1 shows that satisfactory chemimechanical bagasse pulp was obtained by the rapid nitric acid pulping of depithed bagasse with 4% HNO_3 at 80°C for 30 minutes, followed by 2% NaOH at 95°C for another 30 minutes, and then two stage refining. It should be noted that in the case of chemimechanical bagasse pulp the chemical usage is lower, the yield (91%) is higher and the opacity (98.5%) is higher than for chemimechanical rice straw pulp. However, the chemimechanical bagasse pulp required two stage refining while rice straw pulp required only single stage refining.

Nitric acid chemimechanical bagasse pulp was very difficult to bleach. After bleaching trials, the best bleaching was obtained with a single stage peroxide bleach using 5% peroxide. Even so, the brightness obtained was only 55 GE (Table 3).

The overall yield of the bleached chemimechanical bagasse pulp (87%) was higher in comparison to the chemimechanical rice straw pulp (72%). The opacity of the bleached nitric acid chemimechanical bagasse pulp was exceptionally high (98.2%) and the physical properties were in the same range as those of groundwood pulp, but lower than those of bleached chemimechanical rice straw (Table 4).

d) Nitric Acid Semichemical Bagasse Pulp

Nitric acid semichemical bagasse pulp was obtained by increasing the nitric acid charge from 4% to 7% and sodium hydroxide charge in the second stage cook from 2% to 7% resulting in a decrease in yield from 91% to 65%. As expected, the opacity decreased from 98.5% for the chemimechanical bagasse pulp to 93% for the semichemical bagasse pulp.

In contrast to the chemimechanical bagasse pulp, the nitric acid semichemical bagasse pulp was easily bleached by a C-E-H sequence to give a good brightness of 67 GE. The bleached pulp had superior tear and breaking length in comparison to stone groundwood and chemimechanical bagasse pulp (Table 4). Nitric acid semichemical bagasse pulp has comparable strength but much higher opacity (93%) than that of soda and sulfite bagasse pulps (10, 15).

e) Newsprint from Nitric Acid Rice Straw and Bagasse Pulps

Properties of the individual components used in the newsprint furnish are compiled in Table 4. The bleached nitric acid chemimechanical rice straw pulp used is brighter and has higher strength properties than the groundwood pulp, but a slightly lower opacity. The bleached nitric acid chemimechanical bagasse pulp has comparable properties to groundwood except for lower brightness. In comparison to chemical wood pulp, the nitric acid semichemical bagasse pulp has lower strength (especially tear), as can be expected, but has much higher opacity, which is an advantage in the case of any furnish for newsprint.

The properties of newsprint made on an experimental paper machine using optimum blends of nitric acid rice straw and bagasse pulps are shown in Table 5 as well as the properties of newsprint made on the same machine entirely from wood pulp (Test 5, Table 5) to serve as a reference base for comparisons.

Bleached nitric acid chemimechanical rice straw pulp used as 80% of the furnish together with 20% of bleached softwood kraft pulp produced a newsprint (Test 3, Table 5) that had superior properties in comparison to the reference newsprint from wood, as regards strength and brightness, with only slightly lower opacity.

Bleached nitric acid chemimechanical bagasse pulp when used as the main furnish component (80%) resulted in a newsprint of low brightness but otherwise satisfactory properties, even at a relatively low basis weight (Test 6, Table 5). The low brightness would make it almost impossible to market the newsprint internationally. However, low brightness newsprint is often acceptable in national or regional markets.

A blend of 35% bleached nitric acid chemimechanical bagasse and 45% bleached nitric acid chemimechanical rice straw pulp, together with 20% long fiber pulp gave a satisfactory newsprint (Test 2, Table 5) as regards appearance, strength and printability, also at a low basis weight of 48.3 g/m^2.

A blend of 50% bleached nitric acid semichemical bagasse pulp, 30% bleached nitric acid chemimechanical rice straw and 20% bleached softwood also produced newsprint that had superior properties in comparison to the reference paper with only slightly lower printing opacity (Test 1, Table 5).

When bleached nitric acid semichemical bagasse pulp was used as the main furnish (Test 4, Table 5), the newsprint paper produced fulfilled all the requirements of strength, opacity and brightness.

C. PROPOSED PROJECT MODEL

C.1 General

The tests carried out to date show clearly that newsprint with satisfactory properties can be produced from rice straw and bagasse by the rapid nitric acid process. The question is - could it be done profitably on a commercial scale?

The model selected for analysis is a 300 ton per day (105,000 ton/year) newsprint mill.

The reasons for selecting this capacity are:

- a mill of this capacity should be economically viable if manufacturing costs are reasonable.
- the capacity suits quite a number of national and regional markets in the regions where rice straw and bagasse would be available.
- bearing in mind the lower drainage rates of rice straw and bagasse pulps, 105,000 ton/annum will call for a paper machine about as wide and fast as can be considered feasible for the production of newsprint from an ease of operation point of view.

In the development of manufacturing costs, furnishes consisting of mixtures of rice straw and bagasse pulps were not considered, even though satisfactory newsprint could be produced from these furnishes, as this would require two pulp mills which would increase costs considerably.

In all cases 20% fully bleached softwood kraft pulp, as used in the experimental work, was considered to be the long fiber fraction of the furnish even though it is likely that less costly, semi-bleached softwood kraft would serve in some furnishes and the quantity of long fiber pulp might be decreased by several percentage points.

On the foregoing basis, assuming a newsprint moisture content of 6%, miscellaneous losses of 3% and that, at times, the clay content might be as low as 5% retained clay, a capacity of 220 T/D was selected for the non-wood fiber pulp mill.

Because of the low chemical charge and the high yields of the chemimechanical and semichemical nitric acid pulps, no chemical recovery of caustic soda has been considered for the production of any of the pulps. Nor has any provision been made for effluent treatment. It has been assumed that the effluent, which is an effective fertilizer, would be disposed of in irrigation systems, or otherwise distributed to farmlands in the region.

Although the production of pulp from straw and bagasse differs substantially from the production of pulp from wood, there is little difference in the production of paper. Essentially stock preparation and the paper machine configurations are the same as those used for the production of papers from wood pulps. The only difference in stock preparation is that very little refining is required for bagasse pulps and little or no refining is required for straw pulps. In the case of the paper machine the main difference is that the machine speeds will be slower when straw or bagasse pulps form the main part of the furnish and consequently, for the same production, a paper machine using straw and bagasse pulps will be wider.

C.2 Selection of Equipment

C.2.1 Pulping and Bleaching

The equipment selected to establish capital costs is all standard equipment readily available on the market. No equipment of special design is involved. Consequently the added risk of untried equipment would be avoided.

As regards process, the pulping systems for chemimechanical rice straw pulp and chemimechanical and semichemical bagasse pulp are identical. The equipment would differ only as regards capacity because of the differences in yield.

Because pulping is rapid, the digesters should be continuous. Since a high liquor to straw or bagasse ratio is desired, the horizontal screw and tube digesters usually used for pulping straw or bagasse are not too suitable. Also, as the cooking temperature is below the boiling point, pressure feeders and dischargers are not necessary. Stainless steel M & D digesters in which a liquid level can be maintained were selected as being the most suitable.

Although the liquor to straw or bagasse ratio is less for the first stage nitric acid cook than for the second stage caustic soda cook, the digesters would be the same size, as the volume is dictated by the bulk density of the straw or bagasse and not the liquor.

The material as discharged from the first stage nitric acid cook is like sodden straw or bagasse in appearance and texture and could not be washed well on drum or table washers. Consequently, a screw press was selected for removal of the nitric acid spent liquor. Even after the second stage cook, the straw or bagasse still preserves much of its original form and is not fiberized. Consequently, a disk refiner has been selected to open up the cooked straw or bagasse so that an effective final wash is feasible. A belt washer was selected for washing the crude pulp thoroughly prior to final refining, as there might be problems in attempting to wash such a coarse pulp on drum washers.

High consistency refining was selected for the production of rice straw nitric acid chemimechanical pulp. In the case of bagasse nitric acid chemimechanical pulp, a second stage of low consistency refining follows the high consistency refining. Screening and cleaning is conventional.

The bleaching equipment selected is strictly conventional, differing only in the bleaching sequence used to bleach the type of pulp to be produced. No high density storage towers are proposed as the mill would continuously produce only one type of pulp and one type of paper.

C.2.2 Stock Preparation and Paper Machines

The stock preparation system would be conventional. The paper machine selected would differ slightly from a machine of the same capacity using wood pulp. The differences would be:

- the machine would be slower and wider
- the wire would be longer
- the moisture content of the sheet leaving the press section would be higher and hence the steam consumption would be higher
- the shrinkage would be higher which will call for more indrives in the drier section.

A five roll (1400 mm) machine trimming 7000 mm at 92% efficiency would give the required production at a speed of about 660 m/min.

C.3 Description of Proposed Mill

C.3.1 Raw Material Handling and Storage

a) Rice Straw

For the rice straw pulp mill it was assumed that the rice straw would be delivered by truck in bales and stored in piles using cranes for piling. Straw would be reclaimed by crane and trailers towed by tractors.

The straw would then be cut in star choppers followed by dedusting and dry cleaning. The dry cleaned straw would then be wet cleaned in hydrapulpers and dewatering screens and pressed to 35% dry content before entering a live bottom surge storage bin. From the bin the straw is fed at a controlled rate to the digester feed system.

b) Bagasse

For the bagasse pulp mill alternatives it was assumed that the bagasse would be moist depithed at the sugar mill and supplied to the pulp mill by belt conveyor. The pith would be fed to the sugar mill boilers as fuel. A wet bulk pile storage system was assumed. The moist depithed bagasse as received would go into a slusher where it would be mixed with acidified water and pumped at 2.5-3.5% consistency through pipes (partly permanent, partly movable) to a paved storage area where the water drains away and a pile is built up. The water which flows through the piles goes back to the slusher.

The bagasse would be reclaimed from the piles by a front-end loader and dumped into a slusher from which it would be pumped to wet depithing screens at the pulp mill after which the wet depithed bagasse is pressed to 35% dry content before going to a live bottom surge storage bin ahead of the digester feed system. From the bin, the bagasse would be fed at a controlled rate to the digester feed system.

The system would be the same for chemimechanical and semichemical bagasse pulp. The only difference would be capacity. The system for the semichemical pulp mill would be larger because of the lower yield.

C.3.2 Pulp Mill

The processes for the production of unbleached nitric acid chemimechanical rice straw pulp and unbleached nitric acid chemimechanical and semichemical bagasse pulps are essentially the same, except that two stage refining is required for bagasse chemimechanical pulp instead of single stage (see Fig. 1).

The cleaned straw or bagasse at 35% dry content is discharged from the live bottom bin into a conveyor feeding a mixer ahead of the first digester. The objective of the mixer is to permit the addition of steam and some nitric acid to wilt the straw or bagasse so that it is more easily compacted. From the mixer the straw or bagasse would go to a compaction screw whose sole function is to compress the straw or bagasse to a higher bulk density, so that it is easier to feed into the continuous digester and to permit the use of a smaller digester, because of the higher bulk density due to the compaction screw. Feed into the M & D digester would be simply by gravity. The liquid level in the digester would be maintained at the level required to attain the desired liquor to straw or bagasse ratio.

The digester would discharge by gravity into a mixing conveyor where spent caustic liquor would be added for dilution before the straw or bagasse goes to a screw press for removal of the spent nitric acid cooking liquor. From the screw press, the bagasse or straw goes into a bin and lift system to another mixer and compaction screw ahead of the second stage caustic digester.

Again, this digester would discharge into a mixer for dilution and then a screw press for preliminary removal of spent caustic liquor. The straw or bagasse would then pass through a fiberizing disk refiner to open up the cooked straw or bagasse and reduce it to crude pulp. The crude pulp would then be washed on a belt washer after which the pulp would go to one or two stages of refining, depending on the raw material and the type of pulp being produced. These refiners carry out the final reduction of the crude pulp to unbleached pulp. The pulp is then screened in a pressure screen and cleaned in centrifugal cleaners before being bleached.

In the case of rice straw chemimechanical pulping, a two stage hypochlorite/peroxide bleaching sequence is used and in the case of bagasse, a single peroxide stage is used for chemimechanical pulp and a two stage chlorination/extractive hypochlorite sequence with final acidification by SO_2 would be used for the production of bleached semichemical bagasse pulp (see Figs. 2 and 3).

C.3.3 Stock Preparation, Paper Machine and Finishing

The stock preparation for the proposed mill model is strictly conventional and essentially the same as would be used for a newsprint mill producing newsprint from wood pulp. The stock preparation system would include:

- a pulper for slushing long fiber pulp with dump chest and deflaker
- a wet and dry end broke and white water recovery system with deflakers, broke tower, broke decker, saveall and broke and white water chests
- clay, dye and chemical additive systems
- disk refiners for purchased pulp and nonwood fiber pulp for strength development and freeness control
- stock proportioner, mixing chest and machine chest.

No block diagrams have been prepared as the systems would be quite conventional.

The paper machine would be a more or less conventional newsprint machine with a twin fan pump approach flow system with pressure screens and cleaners, pressure headbox, a somewhat longer wire part, a no-draw press section, drier section with four or five indrives and an enclosed hood, calendar stack, reel, and a machine winder.

The machine would be fitted with dry and wet end pulpers, a crane for dry and wet end maintenance, and a gantry crane for reel handling. A semi-automatic roll wrapping and heading machine would be provided for wrapping the rolls. No block diagram is included as the entire system is conventional.

C.3.4 Other Facilities

It was assumed that power would not be available and consequently the proposed model includes steam power generation using oil as the fuel. The proposed model also includes mill services such as water treatment, extensive mill shops and stores for maintenance and repair, fire protection, internal telephone system and office equipment.

D. PROJECT MODEL CONSUMPTION FIGURES

D.1 Pulp

Based on the yield figures obtained through experimental work, the quantity of rice straw required for the production of one ton of nitric acid chemimechanical pulp is 1400 kg. However, this is the quantity of wet cleaned, rice straw. Taking into account wet cleaning losses of 10%, chopping and dry cleaning losses of 7% and losses in storage and handling of 7%, the quantity of rice straw that would have to be purchased is 1800 kg.

In the case of nitric acid chemimechanical bagasse pulp and semichemical bagasse pulp, the quantities of wet depithed bagasse required per ton of pulp produced are 1150 kg and 1600 kg respectively. If the bagasse is purchased on a moist depithed basis including water solubles, and wet depithing losses of 8% and storage losses of water solubles and fiber of 10% are taken into account, the amount of moist depithed bagasse that has to be purchased for the production of nitric acid chemimechanical pulp becomes 1400 kg and the amount of bagasse that must be purchased for the production of nitric acid semichemical pulp becomes 1950 kg.

Nitric acid and sodium hydroxide consumptions for pulping are in accordance with the experimental work. Bleaching chemical consumptions also follow the experimental work with the exception of the bleaching of bagasse semichemical pulp where a two stage chlorination/extractive hypochlorite sequence with a slightly lower chlorine and caustic consumption (for extraction) is suggested.

In the experimental work calcium hypochlorite was used. As it was felt that the bleaching of bagasse semichemical pulp could be simplified by using an extractive hypochlorite stage, it was necessary to change to sodium hypochlorite in the study model; at least for bagasse semichemical pulp. It was decided to change all to sodium hypochlorite to keep all alternatives on the same basis.

The additional caustic soda required for hypo is included in the chemical consumption figures. Also in the case of peroxide bleaching, it was assumed that sodium peroxide would be used and chemical quantities for sodium peroxide are included.

Refining power consumption was taken at 300 KWH/ton for rice straw chemimechanical pulp, 250 KWH/ton for bagasse semichemical pulp and 500 KWH/ton for bagasse chemimechanical pulp. Steam figures were calculated according to process flows. The consumption figures per BD metric ton pulp used to establish the consumption figures for newsprint are given in Table 6.

Labour figures were calculated from preliminary manning tables based on productivity factors of developing countries.

D.2 Paper

Newsprint is sold on an as is air dry basis. It has been assumed that the moisture content will be 6% (wet basis). Thus, for the production of 1000 kg of newsprint at 6% moisture content the weight of the bone dry furnish is 940 kg and assuming 3% system losses, the amount of furnish required is 970 kg. If 5% of the furnish is clay, the weight of clay required per ton of newsprint is 48 kg and the balance 922 kg is the weight of the fiber fraction of the furnish. Of this, 20% or 184 kg is the BD long fiber fraction. Consequently, the amount of nonwood pulp in the furnish is 738 kg BD. Since pulp is purchased on a defined air dry basis (10% moisture), the amount of air dry long fiber pulp that must be purchased is 204 kg per air dry ton of newsprint.

The power consumption of the paper mill is taken at 650 KWH per ton of newsprint plus refining power for purchased pulp and final refining of non-wood pulp. Steam consumption is taken as 2000 kg per ton of newsprint. The consumption figures for the production of one ton of newsprint thus become as shown in Table 7.

E. Hypothetical Project Model Costs

E.1 Estimated Capital Cost

The capital cost of the paper mill and mill services for the three possible newsprint pulp and paper mills will be virtually identical. The variation in capital cost of the three pulp mills are also not large. The capital costs involved range from U.S. $188,000,000 for a nitric acid chemimechanical rice straw newsprint mill to U.S. $192,200,000 for a nitric acid semichemical bagasse newsprint mill, as tabulated in Table 8.

E.2 Estimated Manufacturing Costs

The costs of the various manufacturing materials and services used to establish manufacturing costs are based on international prices and current prices in the Middle East and are given in Table 9. These figures, together with the consumption figures of Section D were used to calculate the major manufacturing cost components. Repair and consumable material costs, maintenance costs and other miscellaneous direct and indirect manufacturing costs were taken from cost data of newsprint mills. Total variable manufacturing costs per one metric ton of air dry newsprint (6% moisture) are given in Table 10 and range from U.S. $323.50 per ton for newsprint utilizing chemimechanical rice straw pulp to U.S. $387.70 per ton for newsprint utilizing chemimechanical bagasse pulp. Fixed manufacturing costs are given in Table 11.

E.3 Estimated Sales Prices

An estimated sale price of U.S. $715.00 per metric ton was selected for the finacial analysis. Acutual prices will vary.

F. FINANCIAL ANALYSIS

F.1 General

The purpose of the financial analysis is to determine if the proposed newsprint mill project has an acceptable return on the investment. The analysis takes into account the capital requirements, probable operating revenues and costs, depreciation/amortization, interest charges, income taxes and investment incentives, where applicable.

The Financial Planning and Control (FIPAC) computer model has been used to simulate year-to-year production, revenues and expenses, and the financial return on investment for the project has been estimated using the discounted cash flow method.

The time frame for the project has been set at 15 years and the complete analysis has been performed in constant dollars, the assumption being that prices and costs will tend to move upward and downward during the projected life of the project at about the same rate.

In order to estimate the project return, we have assumed a tax rate on earnings of 30% with a grace period of 4 years from start-up of the mill.

There is no provision in the analysis for loss carry forward, and taxes are assumed to be paid in the year that they are incurred.

F.2 Financial Structure

For the analysis, it has been assumed that 35% of the capital required for the project would be equity capital and that 65% of the capital required would be borrowed capital. For a developing country, in most cases, this division also corresponds roughly to the division between local capital requirements and foreign capital requirements for a pulp and paper project.

It was assumed that the equity capital would be provided in local currency and that 80% of the borrowed capital would be in the form of long term export credits provided by the supplier of machinery and equipment and 20% of the foreign capital requirements would be short term credits provided by foreign banks.

The interest rate on the debt has been fixed at 10% with a 4 year grace period from the loan signing date followed by a 8 year re-payment schedule.

F.3 Hypothetical Project Return

Based on the technical and financial assumptions, the following returns on investment (R.O.I.) were obtained for a 300 T/D newsprint mill utilizing nitric acid pulps:

PROJECT	R.O.I.
Chemimechanical Rice Straw Newsprint Mill	11.5%
Chemimechanical Bagasse Newsprint Mill	8.5%
Semichemical Bagasse Newsprint Mill	8.9%

Although the production of newsprint at the rate of 300 T/D is profitable (which is frequently no the case for mills attempting to produce newsprint from non-2ood fibers), the rate of return is not particulary attractive.

As a production rate of 300 T/D is on the small side for newsprint, a sensitivity analysis on the effect of increasing the production was made for the rice straw model with the following results:

PRODUCTION	PRODUCTION INCREASE	R.O.I.
300 T/D	--	11.5%
330 T/D	10%	13.2%
360 T/D	20%	14.8%

Since an increase in production showed a substantial increase in the return on the investment, a further analysis of the rice straw case was made for the very maximum production that could possibly be considered for a single machine operation. A very wide paper machine (9100 mm trimmed) operating at high speed (850/min) could produce 500 T/D, which would certainly represent the very maximum from a technical and operating point of view, as well as from considerations of the economic radius of straw collection.

The capital cost in thousands U.S. dollars used for this case as compared to the 300 T/D base case for rice straw are as follows:

	300 T/D	500 T/D
Direct Plant Cost	162,800	219,800
Interest During Construction	13,200	15,500
Capitalized Start-up Expenses	4,000	6,700
Working Capital	8,000	13,400
Total Capital Requirements:	188,000	255,400

The variable manufacturing costs were held constant at U.S. $323.50 per air dry ton of. newsprint; however, fixed manufacturing costs were increased from U.S. $4,550,000 to U.S. $6,500,000 per annum.

The resulting return on investment for a 500 T/D newsprint mill utilizing chemimechanical rice straw pulp was 15.2% versus the 11.5% R.O.I. for a 300 T/D mill.

As can be seen, the return at a production rate of 500 T/D is attractive, however it is most unlikely that such a production rate can actually be attained. A production of 150,000 tons/year or about 425 tons/day is more reasonable. Even at this level a project based on rice straw should be attractive.

G. CONCLUSIONS

From the foregoing the following conslusions may be drawn:

1) Using the nitric acid chemimechanical or semichemical processes, it is possible to produce pulps from rice straw and bagasse that can be used as the major furnish component of newsprint.

2) Chemimechanical and semichemical pulps produced from rice straw and bagasse by the nitric acid process have a higher opacity than chemimechanical and semichemical pulps produced by other processes using caustic soda and/or sodium sulphite.

3) By using the nitric acid process, the operating and maintenance problems and costs of a chemical recovery system are avoided.

4) Effluent problems are avoided as the effluent is a fertilizer.

5) The possibility of using rice straw for newsprint production should be of special interest as there is no need for fuel substitution as is the case with bagasse.

6) At the chosen production rate of 300 T/D, the production of newsprint is profitable but the return on investments is not particularly attractive. However, there can be other factors such as import substitution, assured source of supply and regional development, that might make a newsprint project attractive to a particular country. The sensitivity analysis shows that at higher production levels, the production of newsprint becomes more attractive.

7) At production levels of 425 to 500 tons/day, the production of newsprint from rice straw becomes attractive.

8) The nitric acid process shows promise and further research work would seem to be justified.

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TABLE 1. COOKING CONDITIONS FOR NITRIC ACID/SODA PULPING OF RICE STRAW AND BAGASSE

	Nitric Acid Stage				Sodium Hydroxide Stage				Unbleached Pulp		
Cook	%[1]	Liquor Ratio	Temp (°C)	Time (min)	%[1]	Liquor Ratio	Temp (°C)	Time (min)	Yield[2] %	Opacity %	Bright. (% GE)
Chemimechanical Rice Straw	5	6:1	95	30	3	10:1	95	30	78	94.0	31
Chemimechanical Bagasse	4	6:1	80	30	2	10:1	95	30	91	98.5	38
Semichemical Bagasse	7	6:1	95	30	7	10:1	95	30	65	93.0	25

1. The % chemicals are based on oven dry weight of raw materials.
2. Yields are based on the weight of material charged into the first stage nitric acid cook.

TABLE 2. BLEACHING CONDITIONS USED IN EXPERIMENTAL WORK

Bleaching Stage	Time (min)	Temperature (°C)	Consistency (%)
Chlorination	30	25	3
Caustic Extraction	120	60	10
Hypochlorite	180	40	8
Peroxide	180	70	12

TABLE 3. BLEACHING OF NITRIC ACID RICE STRAW AND BAGASSE PULPS

	Unbleached Pulp			Chemical Charges per Bleaching Stage[1]				Bleached Pulp			
	Yield (%)	Opacity (%)	Bright. (% GE)	Chlorination (%)	Caustic Extraction (%)	Hypochlorite (%)	Peroxide (%)	Bleaching[2] Yield (%)	Opacity (%)	Bright. (% GE)	Total[3] Yield (%)
Chemimechanical Rice Straw	78	94.0	31	-	-	5	1	92	-	66	72
Chemimechanical Bagasse	91	98.5	38	-	-	-	5	96	-	55	87
Semichemical Bagasse	65	93.0	25	3	2	3	-	95	-	67	62

1. The % chemicals are based on the oven dry weight of the nitric acid pulps.
2. Bleaching yields are based on the weight of unbleached nitric acid pulps.
3. Total yields are based on the weight of material charged into the first stage nitric acid cook.

TABLE 4. PROPERTIES OF FURNISH COMPONENTS

	Bleached Nitric Acid Chemimechanical Rice Straw Pulp	Bleached Nitric Acid Chemimechanical Bagasse Pulp	Bleached Nitric Acid Semichemical Bagasse Pulp	Bleached Softwood Kraft Pulp	Groundwood Pulp
°SR	60.0	60.0	30.0	30.0	68.0
Bulk, cm^3/gm	2.2	2.8	1.7	1.7	2.6
Tear Factor	67.0	29.6	43.3	120.0	31.0
Breaking Length, km	3.5	2.79	5.4	7.5	3.1
Printing Opacity, %	94.0	98.2	93.0	81.0	97.0
Brightness, % GE	67.0	52.2	65.0	84.0	57.0

TABLE 5. COMPARISON BETWEEN NEWSPRINT FURNISHES CONTAINING NITRIC ACID CHEMIMECHANICAL RICE STRAW, CHEMIMECHANICAL BAGASSE AND SEMICHEMICAL BAGASSE PULPS

Test No.	Bleached Chemi-Mechanical Rice Straw (%)	Bleached Chemi-Mechanical Bagasse (%)	Bleached Semi-Chemical Bagasse (%)	Bleached Softwood Kraft (%)	Ground-Wood (%)	Talc (%)	Ash (%)	Basis Weight (g/m²)	Bulk (cm³/g)	Breaking Length (km) MD	Breaking Length (km) CD	Tear Factor (km) MD	Tear Factor (km) CD	Printing Opacity (%)	Bright-Ness (% GE)
1	30	-	50	20	-	10	10.8	59.0	1.7	5.2	2.8	54.3	88.0	93.7	71
2	45	35	-	20	-	10	10.4	48.3	1.7	5.0	2.8	44.0	58.0	91.1	65
3	80	-	-	20	-	10	14.2	53.8	1.9	4.6	2.0	59.5	66.9	94.5	72
4	-	-	80	20	-	10	-	51.0	1.6	5.3	2.5	50.0	62.0	93.0	70
5	-	-	-	20	80	-	-	55.0	1.6	3.9	1.9	40.0	58.0	96.8	61
6	-	80	-	20	-	10	-	50.1	2.0	3.6	1.6	-	56.0	95.0	52

TABLE 6. CONSUMPTION FIGURES FOR NITRIC ACID PULPS (per B.D. metric ton pulp produced)

Chemimechanical Rice Straw Pulp		Chemimechanical Bagasse Pulp		Semichemical Bagasse Pulp	
Rice Straw	1800 kg BD	Bagasse	1400 kg BD	Bagasse	1950 kg BD
Nitric Acid	70 kg	Nitric Acid	46 kg	Nitric Acid	112 kg
Sodium Hydroxide	125 kg*	Sodium Hydroxide	65 kg*	Sodium Hydroxide	165 kg*
Chlorine	55 kg			Chlorine	30 kg
Hydrogen Peroxide	11 kg	Hydrogen Peroxide	52 kg		
Sodium Silicate	33 kg	Sodium Silicate	33 kg		
Epsom Salt	0.5 kg	Epsom Salt	0.5 kg	Sulphur	5 kg
Water	100 m³	Water	100 m³	Water	100 m³
Steam	2300 kg	Steam	2200 kg	Steam	2500 kg
Power	950 KWH	Power	1200 KWH	Power	950 KWH
Labour	8 manhours	Labour	7 manhours	Labour	7 manhours

Note: All chemical quantities are based on 100% BD chemical.
* Includes caustic for cooking, sodium hypo and/or peroxide buffer

TABLE 7. CONSUMPTION FIGURES FOR NEWSPRINT PRODUCED FROM NITRIC ACID PULPS (per air dry ton of newsprint*)

Newsprint Utilizing Chemimechanical Rice Straw Pulp		Newsprint Utilizing Chemimechanical Bagasse Pulp		Newsprint Utilizing Semichemical Bagasse Pulp	
Rice Straw	1330 kg BD	Bagasse	1030 kg BD	Bagasse	1440 kg BD
Nitric Acid	52 kg	Nitric Acid	34 kg	Nitric Acid	83 kg
Sodium Hydroxide	92 kg	Sodium Hydroxide	48 kg	Sodium Hydroxide	122 kg
Chlorine	40 kg			Chlorine	22 kg
Hydrogen Peroxide	8 kg	Hydrogen Peroxide	38 kg	Sulphur	4 kg
Sodium Silicate	24 kg	Sodium Silicate	24 kg		
Epsom Salt	0.4 kg	Epsom Salt	0.4 kg		
Purchase Pulp	204 kg AD	Purchase Pulp	204 kg AD	Purchase Pulp	204 kg
Clay	48 kg	Clay	48 kg	Clay	48 kg
Water	120 m^3	Water	120 m^3	Water	120 m^3
Steam	3700 kg	Steam	3600 kg	Steam	3800 kg
Power	1480 KWH	Power	1710 KWH	Power	1500 KWH
Labour	9 manhours	Labour	8 manhours	Labour	8 manhours

Note: All chemical quantities are based on 100% BD chemical

*Air dry newsprint is assumed to have a 6% moisture content

Air dry pulp by definition has a 10% moisture content regardless of the actual moisture content

TABLE 8. ESTIMATED COSTS IN THOUSANDS U.S. DOLLARS OF ALTERNATIVE HYPOTHETICAL NEWSPRINT MILL MODELS

	Nitric Acid Chemi-mechanical Rice Straw Newsprint Mill	Nitric Acid Chemi-mechanical Bagasse Newsprint Mill	Nitric Acid Semichemical Bagasse Newsprint Mill
Raw Material Transport, Receiving and Preparation Equipment	4,600	5,900	6,200
Pulp Mill and Bleach Plant Equipment	20,200	19,800	20,800
Stock Preparation and Paper Mill Equipment	49,500	49,500	49,500
Steam Power Plant Equipment	10,200	11,500	10,200
Miscellaneous Mill Services Equipment	5,400	5,400	5,400
Structural and Civil Works	32,800	32,800	32,800
Erection	13,200	13,600	13,800
Engineering	16,500	17,000	17,000
Freight	10,400	10,800	11,000
Sub-Total Direct Plant Cost	162,800	166,300	166,700
Interest During Construction	13,200	13,500	13,500
Capitalized Start-Up Expenses	4,000	4,000	4,000
Sub-Total Plant Capital Cost	180,000	183,800	184,200
Working Capital	8,000	8,000	8,000
Total Capital Requirements	188,000	191,800	192,200

* Note a 10% contingency is included in all items of Direct Plant Cost.

TABLE 9. HYPOTHETICAL COST DATA

	Unit	Cost U.S. $
Rice Straw	1000 kg BD	20
Bagasse	1000 kg BD	59**
Nitric Acid	1000 kg	280
Sodium Hydroxide	1000 kg	180*
Chlorine	1000 kg	215*
Hydrogen Peroxide	1000 kg	1600
Sodium Silicate	1000 kg	120
Epsom Salt	1000 kg	120
Sulpher	1000 kg	30*
Fuel Oil	1000 kg	170
Bleached Softwood Kraft	1000 kg AD (900 kg BD)	580
Clay	1000 kg	220
Water	1.0 m^3	0.03

Note: All cost for chemicals are calculated on a 100% BD basis, even though in many cases the chemical is purchased as an aqueous solution.

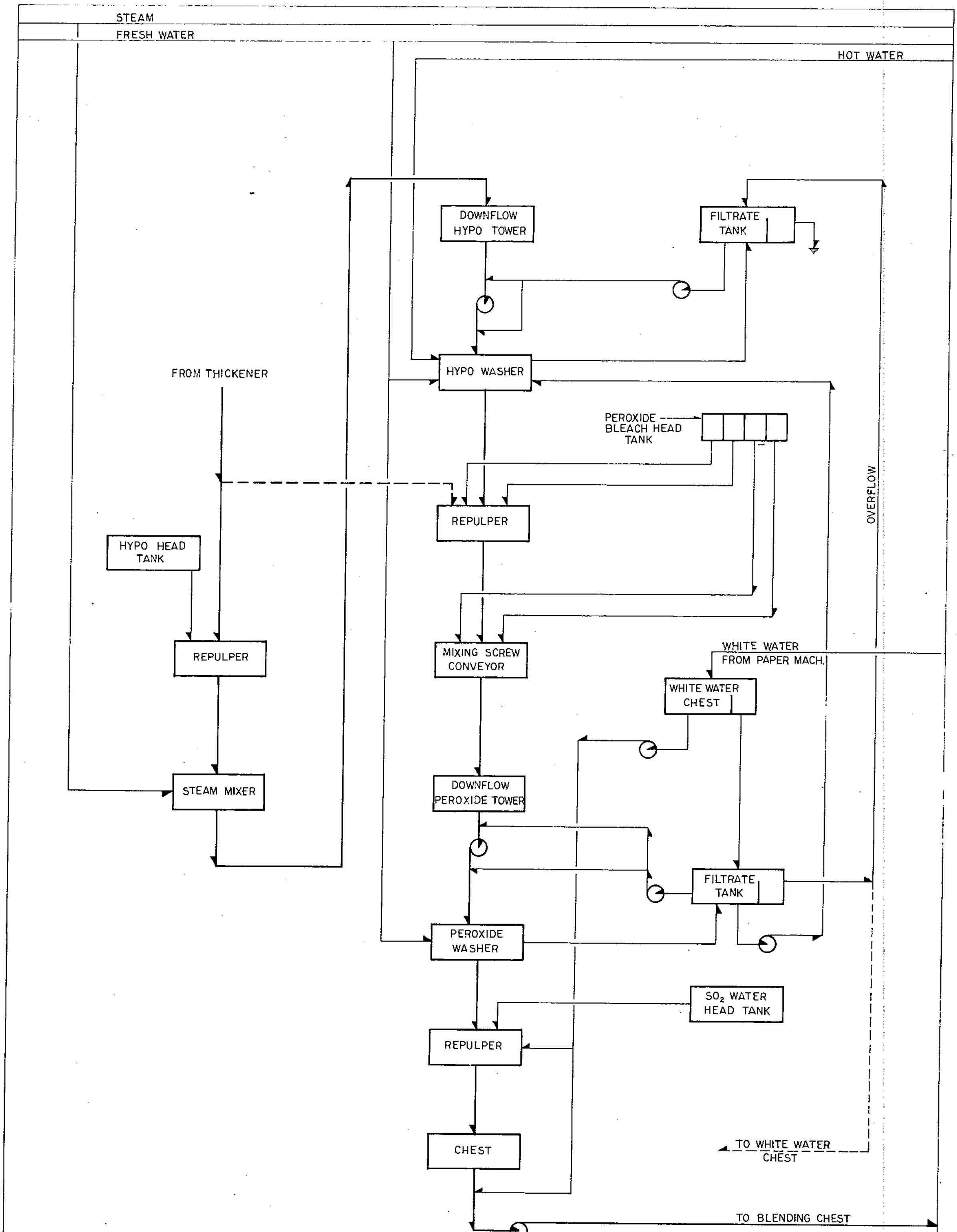
All cost estimates are based on mid-east deliveries.

TABLE 10. HYPOTHETICAL VARIABLE MANUFACTURING COSTS IN U.S. DOLLARS FOR NEWSPRINT PRODUCED FROM NITRIC ACID PULPS PER AID DRY TON OF NEWSPRINT

	Newsprint Utilizing Chemimechanical Rice Straw Pulp	Newsprint Utilizing Chemimechanical Bagasse Pulp	Newsprint Utilizing Semichemical Bagasse Pulp
Fibrous Raw Material	26.60	60.80	85.00
Chemicals	55.50	81.90	50.00
Purchased Pulp	118.30	118.30	118.30
Clay	10.60	10.60	10.60
Miscellaneous Additives	5.20	5.20	5.20
Water	3.60	3.60	3.60
Fuel Oil	80.70	84.30	82.90
Consumable Supplies and Machine Clothing	23.00	23.00	23.00
Total	323.50	387.70	378.60

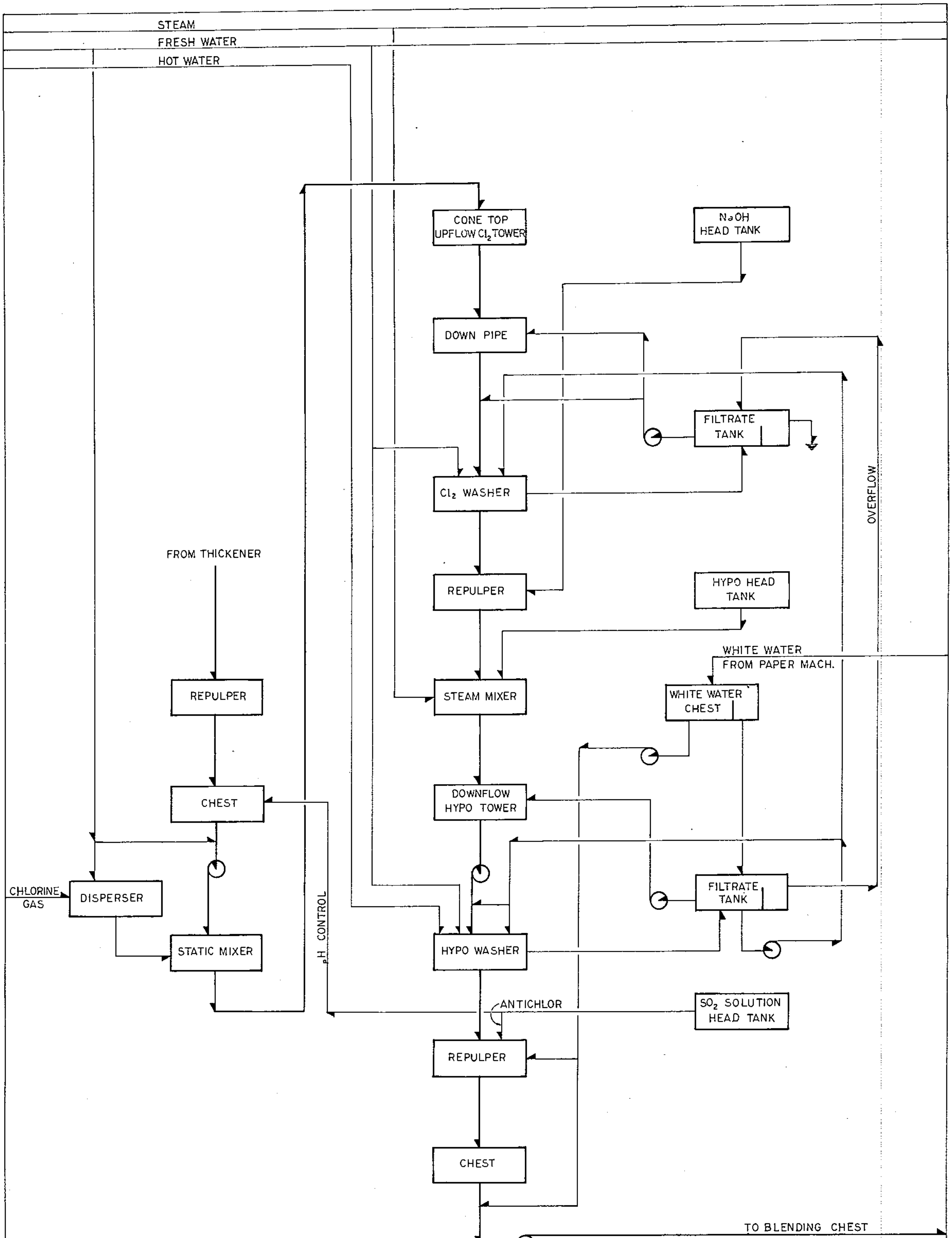
TABLE 11. HYPOTHETICAL FIXED MANUFACTURING COSTS FOR NEWSPRINT PRODUCED FROM NITRIC ACID PULPS (IN THOUSANDS U.S. DOLLARS PER ANNUM)

	Newsprint Utilizing Chemimechanical Rice Straw Pulp	Newsprint Utilizing Chemimechanical Bagasse Pulp	Newsprint Utilizing Semichemical Bagasse Pulp
Salaries and Fringe Benefits	2,000	1,750	1,750
Insurance and Miscellaneous Expenses	750	750	750
Maintenance	1,800	1,850	1,850
Total Fixed Costs	4,550	4,350	4,350

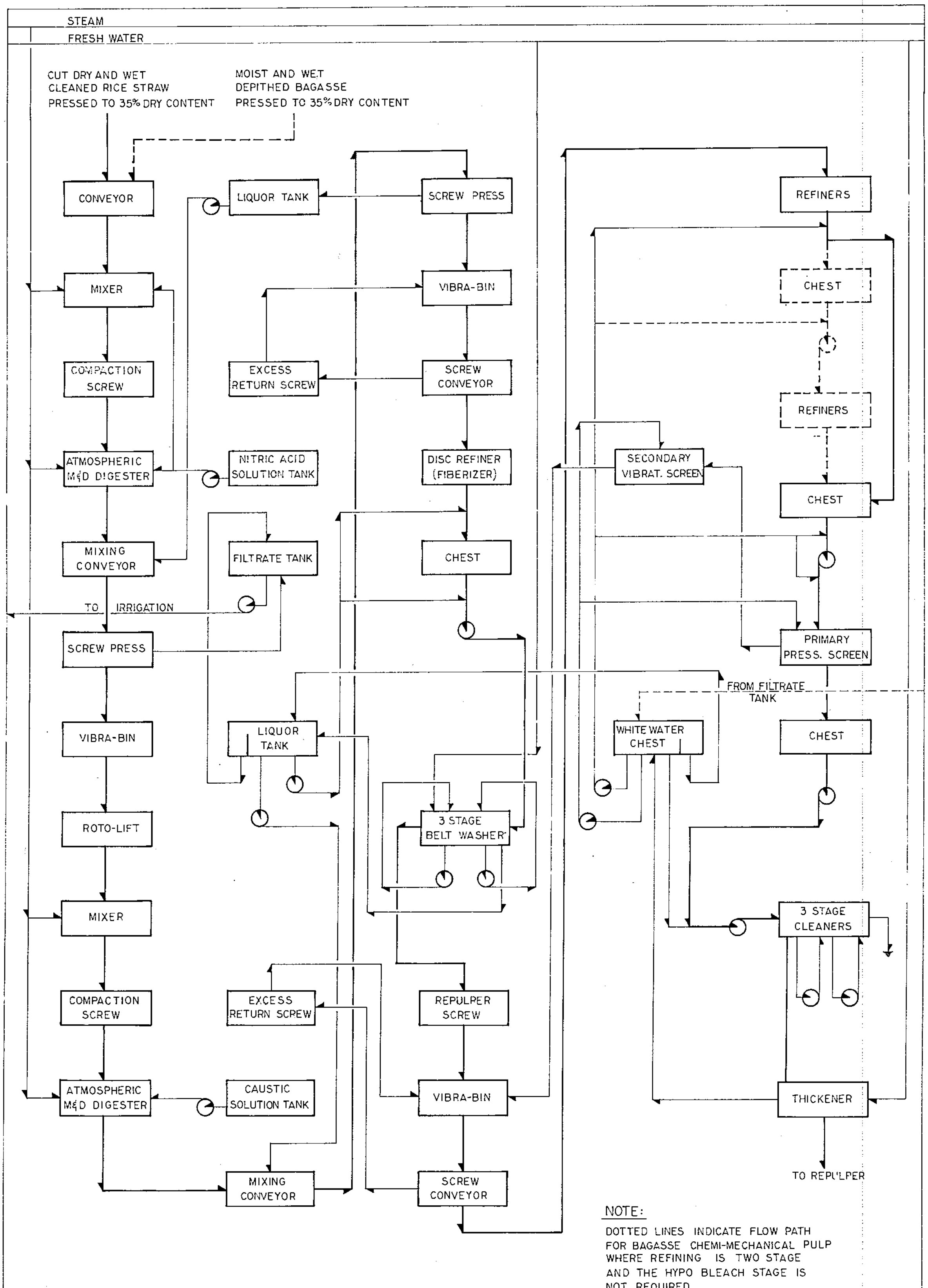


BLOCK DIAGRAM
BLEACHING OF STRAW AND BAGASSE
CHEMI-MECHANICAL PULP

NOTE:
DOTTED LINE INDICATE FLOW PATH FOR BAGASSE CHEMI-MECHANICAL PULP WHERE HYPO BLEACH STAGE IS NOT REQUIRED.



BLOCK DIAGRAM
BLEACHING OF BAGASSE
SEMI-CHEMICAL PULP



BLOCK DIAGRAM
NITRIC ACID CHEMI-MECHANICAL AND SEMI-CHEMICAL
PULPING OF STRAW AND BAGASSE