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D02945

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.102/16
30 June 1971

ORIGINAL: ENGLISH

Expert Group Meeting
on Pulp and Paper

Vienna, 13 - 17 September 1971

HOW TO BUILD A LOW COST PULP AND PAPER MILL IN DEVELOPING COUNTRIES

by

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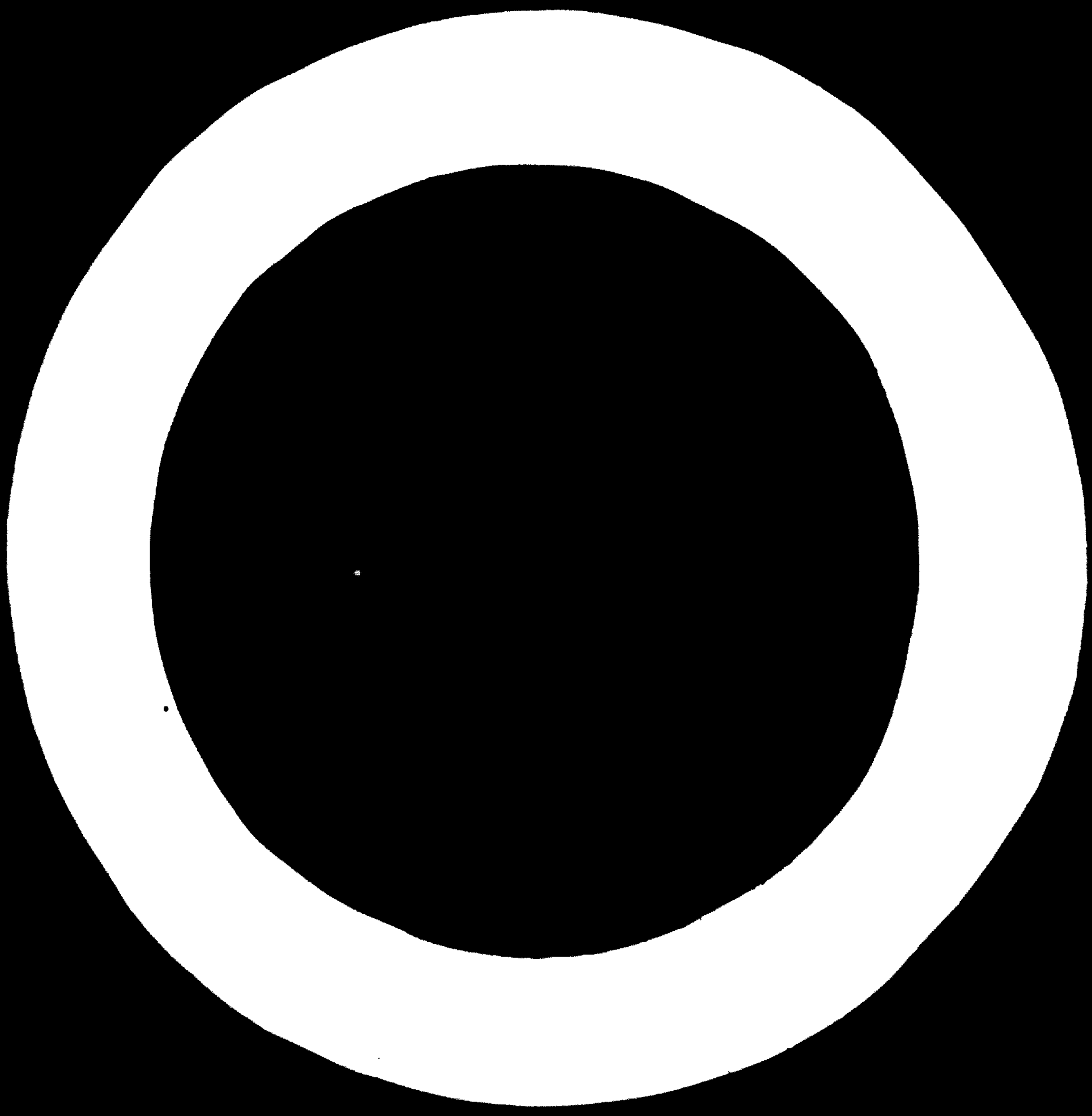


Introduction

The title of the paper poses a very difficult question and no clear-cut recipe can be given, which is applicable generally. Attempt is, therefore, made to analyse and isolate the factors which contribute to the high cost of building pulp and paper mills with special reference to the developing countries. Once, these factors are known and their singular and cummulative effects are assessed, it is possible to formulate a general guide line for building a low cost mill.

The outlines of the general objective of the topics were specified separately for low cost pulp and low cost paper mill. I have, however, taken the liberty of combining both topics in the same report as I believe that most of the mills in the developing countries will be integrated units. Non-integrated paper mills could be an alternative on certain special conditions, which will use waste paper or imported pulp for making paper. These special cases will require additional slushing equipment and/or de-inking system and conventional paper making equipment. Non-integrated pulp mills are seldom considered in the developing countries, unless some special conditions exist like availability of large quantities of fibrous raw material in a concentrated spot, which can support a big size pulp mill. Integration has strong economic motive - specially for small scale mills. Therefore, it is assumed that very few non-integrated mills will be established in these regions.

It has been pointed out by Atchison (1) that the cost of building a pulp and paper mill in a developing country is sometimes 50% above the cost of the same type of mill in the U.S. or in Western Europe. The basic reasons are non-availability of facilities like cheap electricity, bleaching chemicals, mechanical workshop service, etc, which compel a new venture to install its own power house, own chlorine caustic plant and elaborate workshop, etc. As the rule of economy of size is applicable to power plant and caustic plant, their investment is out of all proportion to their contribution.

The effect of mill size on investments is reported in various papers and is summed up in the FAO report (2), which shows clearly the economy of size. Consequently, a developing country is faced with two negative factors.

1/ The economic size of the mill tends to be rather on the big side from the viewpoint of machinery cost.

2/ The total investment would be higher compared to the same mill situated in a developed country.

These two negative factors discourage efforts for investment in pulp and paper industry. There are, however, some positive factors, which outweigh these negative factors, viz.:

1/ Cost of fibrous raw material is the single major item of cost of paper and can, if low, compensate higher capital cost.

2/ Most of the developing countries are situated in the tropical and sub-tropical regions where growth rates are high. Scientific forest management and plantation of new high yield species can give extremely good harvest.

3/ There are a number of agricultural residues like straw, bagasse, etc, which can be processed to produce paper. As utilization of agricultural residues will boost agricultural economy and at the same time provide employment to surplus labour in rural districts, the Governments often support such projects.

4/ Cost of building is low due to climatic condition. Most of the developing countries are favoured with warm climate requiring less protection for equipment and workers.

5/ The market is generally well protected by tariff duty to foster infant industry from outside competition.

6/ Market is not sophisticated and therefore, simpler qualities can be sold without considerable market development activities.

It is, therefore, a challenge to the machine manufacturers and pulp and paper mill designers to find out a way in which the developing countries can begin industrializing in this sector.

The developing countries must face the problems realistically and the following conditions are assumed to be valid for these countries in general:

1/ Raw material situation as regards species and type is varied. Therefore, the quantity of raw material of one or a few selected species available within an economic proximity can only support a small size mill. - This is mainly due to the absence of roads and other transport facilities from forest.

2/ Demand for paper of one or few related varieties is not very big. Consequently, the mill must be geared to produce a number of varieties of paper as demanded by the market.

<u>What does cost</u>

In order to understand the factors which contribute to the cost, I have made a breakdown of the equipment cost under six basic heads:

1. <u>Raw material preparation</u>
   comprising wood receiving terminal, debarking, chipping and chip storage.

2. <u>Pulping</u>
   comprising cooking, washing, screening and storage.

3. <u>Bleaching</u>
   comprising 4-stage bleach plant and bleach liquor preparation.

4. Paper making
   comprising stock preparation, paper machine and finishing.

5. Recovery
   comprising evaporation, recovery boiler and cooking liquor preparation.

6. Utility
   comprising water treatment, power generation and distribution, auxiliary steam boiler, workshop, laboratories and stores, etc.

Figure 1 shows these breakdowns represented in percentage of total machinery cost for mill sizes from 100 to 800 t/24h. The figures refer to conventional sulphate pulping of wood in an integrated paper mill producing writing and printing paper of 40-60 g/sq.m. · It is noteworthy that the percentage of machinery cost for each of the basic heads, i.e. operations, is more or less independent of mill size.

A general conclusion for this is drawn and shown in table I.

Table I

Operation	Percent investment
Debarking and chipping	8
Pulping	11
Bleaching	13
Paper making	29
Recovery of heat and chemicals	20
Utilities	19

It appears from the above that major efforts should be made to reduce machinery cost of bleaching, paper making, recovery of chemicals and utilities, which represent 80% of the machinery cost for sulphate pulp and paper mill.

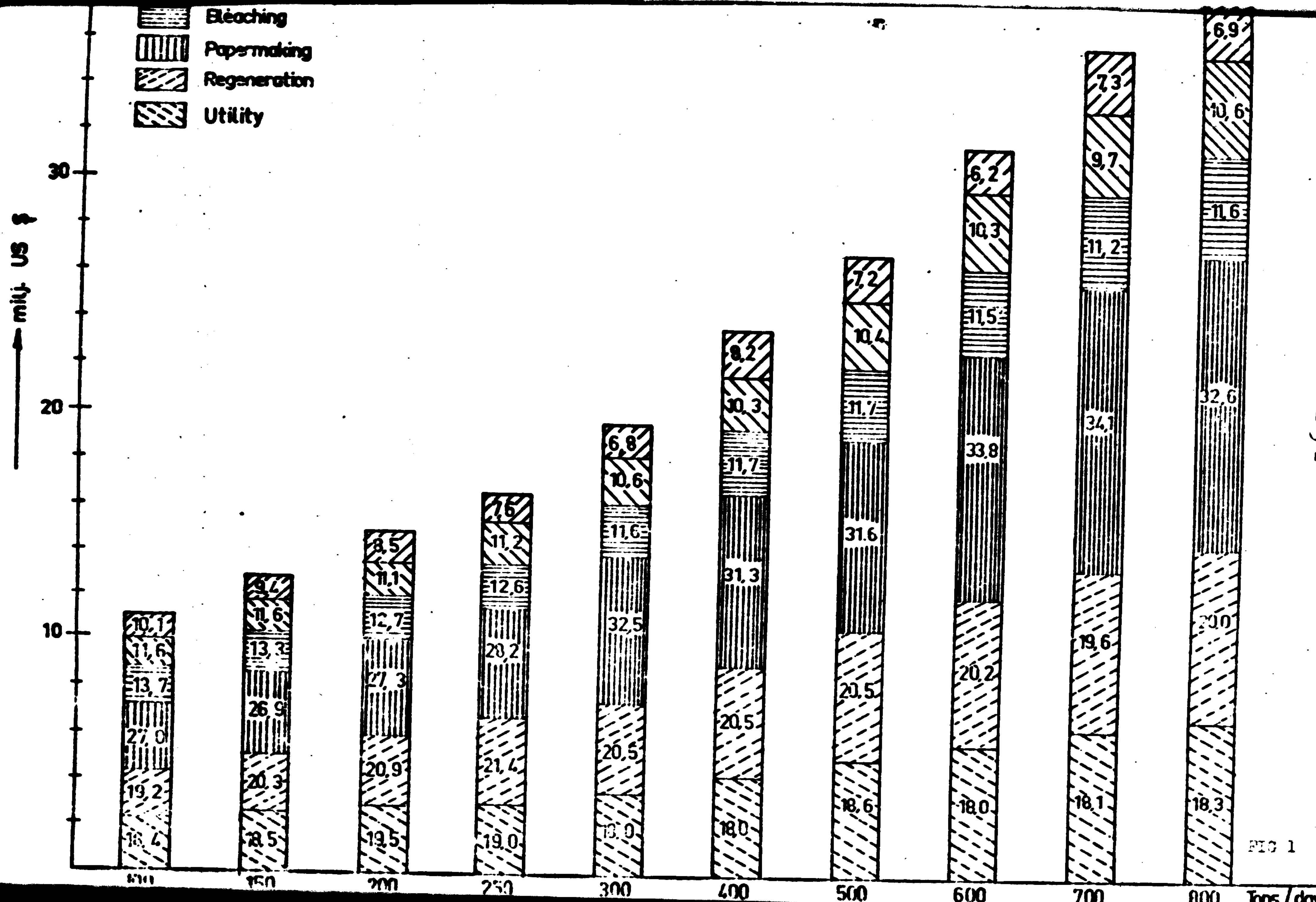

Bleaching
Papermaking
Regeneration
Utility
miIj. US $
10
20
30
10,1
11,6
13,7
27,0
19,2
11,6
13,3
26,9
20,3
8,5
11,1
12,7
27,3
20,9
19,5
11,2
12,6
20,2
21,4
19,0
6,8
10,6
11,6
32,5
20,5
8,2
10,3
11,7
31,3
20,5
18,0
7,2
10,4
11,7
31,6
20,5
18,6
6,2
10,3
11,5
33,8
20,2
18,0
7,3
9,7
11,2
34,1
19,6
18,1
6,9
10,6
11,6
32,6
18,3
150
200
300
400
500
600
700
800
Tons/day

FIG 1

It is interesting in this connection to compare the effects of bleaching and paper making on the increased value of the product. The current international price of unbleached and bleached pulp and unbleached and bleached paper is, therefore, compared in relation to the prevailing price of wood (in Sweden) - all reported as index and shown in tabel II.

Table II

Product	Value index
Fibrous raw material	100
Unbleached kraft pulp	175
Bleached kraft pulp	220
Unbleached kraft paper	270
Bleached kraft paper	290

The above figures are to be compared against the relative cost of establishing integration facilities as shown in table I.

Chemical consumption of alkaline pulping processes is of the order of 35-40% in terms of caustic soda. Consequently chemical and heat recovery has become an integral section of an alkaline pulp mill. Due to high capital cost for this section some of the new installations are trying to avoid chemical recovery by disposing the waste liquor. Adamson (3) reports of a 100 t/24h mill, which plans to dump all waste liquor from soda pulping into the sea as recovery of heat and chemicals does not pay. Contrary result is reported in the secretariate paper (4), which is shown in table III, concluding that under the present price level of chemicals in India, it pays for a 50 t/24h mill to establish both recovery plant and electrolysis plant. Apart from the economical aspect of chemical recovery other factors like pollution, non-availability of cheap pulping chemicals, non-availability of fuel, etc will decide, whether a chemical and heat recovery section will be installed or not.

However, it should be noted that saving of water and avoiding of pollution are of paramount importance not least from economical and ecological standpoint. Modern technique, as developed recently, indicates that for unbleached kraft mill fully closed system can be adopted. Bleached integrated kraft mill can have considerably reduced effluent volume. Choice of alternative pulping process, which does not consume much chemical, may be a way-out.

<u>Table III</u>

Estimated effect of chemical recovery and electrolytic plant on production costs in a 50 t/24h mill producing bleached sulphate pulp (average present conditions in India)

x = manhours

	Description	Unit cost US$	Without recovery & electrolytic plant Consumption /t	Without recovery & electrolytic plant Cost US$/t	With recovery & electrolytic plant Consumption /t	With recovery & electrolytic plant Cost US$/t	Cost differential US$/t
1/	CHEMICALS						
	Saltcake	50 /t	255 kg	12.75	20 kg	0.70	
	Caustic soda	125 /t	75 kg	9.40	-	-	
	Limestone	6 /t	390 kg	2.35	390 kg	2.35	
	Salt	10 /t	-	-	125 kg	1.25	
	Sulphur	70 /t	20 kg	1.40	25 kg	1.75	
	Chlorine	140 /t	70 kg	9.80	-	-	
	S u b t o t a l			35.70		6.05	29.65
2/	FUEL (coal)	8.60/t	800 kg	6.90	500 kg	4.30	2.60
3/	POWER	1.20/kWh	185 kWh	2.20	-		2.20
4/	LABOUR (incl. social charges and supervision)	$0.17/h^x$	$5\ h^x$	0.85	$7\ h^x$	1.20	-0.35
5/	MILL SUPPLIES			0.25	—	1.20	-0.95
1-5/	O p e r a t i n g c o s t			45.90		12.75	33.15
	OVERHEADS						
6/	Depreciation, insurance, property tax and interest on working capital; 14% on fixed investment			9.85		31.65	-21.80
7/	MAINTENANCE, 3% on fixed investment			1.95		6.10	-4.15
1-7/	T o t a l			57.70		50.50	7.20

The utility requirements of a pulp and paper mill varies with the pulping process, degree of secondary heat recovery, degree of closed backwater system, environment pollution laws in force, availability and price of fuel, water, electricity, etc.

By proper choice of a mill site, the utility section can be reduced considerably. It is, therefore, important to make detailed evaluation of the various alternative sites objectively so that the cost reduction does not become a fictive one.

Equipment cost is the major component of the total investment cost of a pulp and paper mill project. A general breakdown of capital estimate for a pulp and paper mill in the industrially developed country compared to a developing country is illustrated in table IV.

Table IV

Item of cost	Industrially developed, %	Developing %
Civil and building	25	17
Process and service equipment	50	65
Equipment installation	5	6
Construction overhead	15	9
Engineering	5	3

It should be noted that the equipment cost of 65% for the developing country includes a good portion of design engineering cost as complete plants are normally purchased by these countries due to financial and other factors, therefore not quite alike. Examination of the above estimate shows that 10% saving in equipment cost will realise a saving of 5% in overall cost in case of a developed country. The same 10% saving in equipment cost for a developing country will achieve 6.5% in overall cost, i e approximately 20% more effective.

It is therefore all the more important to carefully evaluate each processing step in detail before selecting the equipment.

All operations of the pulp and paper mill are today more complicated requiring elaborate instrumentation. This is the result of general industrial development, high labour cost and high raw material cost. Moreover, when the plant sizes are big any interruptions in the process mean considerable loss of production and is therefore avoided. Similarly, material repair and maintenance is minimum. This has led to increased use of sophisticated material like stainless steel and titanium in increasing proportions making the equipment cost very high. All these factors have a cumulative effect on pushing the plant cost higher and higher. In order to build a low cost mill the developing countries must start at a lower gear by judicious selection.

Choice of process

All the foregoing discussions are based on sulphate process as this has been the dominant process because of its versatility and possibility of recovery. It is, however, not out of place here to discuss in general terms the available commercial processes with respect to product quality and requirement of capital investment.

Sulphate process

This is the most favoured process to produce pulp, having the highest strength properties. The yield, however, is somewhat lower compared to bi-sulphite and neutral sulphite due to dissolution of hemicellulose during the progress of the cook. Hardwoods and agricultural residues respond very well to this process and it is possible to delignify to a lower lignin content without severely degrading the pulp. However, as the content of hemicellulose is comparatively high in hardwoods and agricultural residues their retention in the final pulp will increase the yield without negatively affecting paper making properties.

There is some conflicting opinion in this respect with regard to high Kappa number contra low Kappa number. Increase in yield (high Kappa number) must be seen in the light of cost of increased chlorine consumption in order to find out the optimum production cost. For agricultural residues like bagasse it has been pointed out by Villavicencio (5) that prehydrolysis kraft pulp will give possibility to refine more obtaining fibrilation which will give stronger paper.

The economy of the sulphate process lies in its possibility of recovery of chemicals. There are secondary disadvantages of the kraft process which are of some importance. These are.

a/ Odour emission from the kraft mill

The emission of odour can be minimized but complete removal is very difficult. There is little economic gain in odour abatement and it is seldom justifiable unless the demand from the community is overriding.

b/ The effluent from the kraft mill in certain cases is somewhat toxic. Methods have been devised to deal with the effluent but it is expensive. Unless there are severe restrictions imposed by authorities, mills are reluctant to adopt pollution abatement, as stated above.

Soda process

This process is similar to sulphate in most respects, except that the pulp is somewhat poorer in strength than sulphate. The recovery of chemicals is also an economic necessity for this process to be competitive. However, the recovery system is somewhat simpler in absence of sulphur. For hardwoods and agricultural residues the difference in strength properties between sulphate pulp and soda pulp is not so wide and, therefore, a considerable number of soda mills are operating throughout the world. It is theoretically possible and laboratory scale experiments have verified that it would be economically justified to pulp by soda process to a higher Kappa number and proceed with further delignification in bleaching by oxygen (6). This approach seems to be very attractive from the point of view of economy and pollution control. The system will allow recovery of alkali used in oxygen bleaching stage by using the bleach stage surplus filtrate in the counter-current washing of the pulp after digestion. In future it may be possible that pulp bleached only with oxygen will have acceptable brightness for direct conversion to paper where demand of brightness is not very high. The O_2 semibleached pulp has a brightness, which by its lack of yellowness appears brighter.

Bisulphite

This process is quite versatile and has gained popularity mainly due to higher yield and lower chemical consumption.

Magnesium base bisulphite process has been practised without being termed magnifite by one mill in Taiwan and one mill in India for pulping of bamboo. Laboratory experiments have been made successfully on agricultural residues like bagasse. The strength properties of the magnifite pulp are somewhat lower compared to kraft pulp. The unbleached yield is between 5 and 7% higher than kraft and the unbleached brightness is much higher. Bleaching is less expensive than kraft or soda. Bleached yield is of the same order as for bleached kraft.

The main disadvantage of magnifite seems to be the material of construction for pulping equipment which must be acidproof. The advantage of simpler and cheaper recovery system is thereby offset to some extent.

NSSC

The NSSC process is suitable for making coarse pulp for fluting and also for bleached pulp for fine paper. The yield in cooking is of the order of 75% as only partial delignification takes place. The bleached NSSC process gives higher yield than sulphate or soda process due to very selective delignification. High consumption of chlorine and absence of recovery system for chlorine makes the system uneconomic, where price of chlorine is high. Although chlorine has been exclusively used for further delignification of pulp in the prebleaching stage, it is possible to use oxygen to achieve the same delignification and have the possibility to recover the sodium. Such a system (NSSC with O_2 bleaching) will produce bleached chemical pulp of good paper making properties in the yield region of 50-55%. Research in this field is now being carried on.

Considerable efforts are now being directed to find methods to brighten pulp without lignin removal and it is hoped that results will be forthcoming which will make production of high bright high yield pulp possible.

Recently a number of Ammonium base neutral sulphite pulp mills have been installed for production of fluting. This is due to simplified system for pollution control by burning the waste liquor and also low price of ammonia as a base. Ammonium base waste liquor can also be evaporated and dried to produce valuable byproducts which can be used as fertilizer/soil conditioner. Waste liquor from Ammonium base neutral sulphite pulp mills is now exclusively used by a chemical company to produce a soil conditioner/fertilizer after fortification with potassium. This product (Bycobact) (7) is known to give good results in the agriculture. It is therefore hoped that use of ammonium base NSSC process will gain popularity particularly in countries which are largely agricultured as the pulp and paper mill will only borrow the ammonia and will give to the agriculture a humus enriched nitrogenous fertilizer. The economic aspects of ammonium base process is discussed more in detail in a paper by the author (8). Figure 2 shows the flow sheet of an ammonium base neutral sulphite pulp and fertilizer plant.

A comparison of investment costs for the various types of processes is shown in table V.

Table V

Process	Index
Bleached sulphate	275
Unbleached	235
Bleached magnifite	255
Unbleached "	210
NSSC-bleached with recovery	215
NSSC-unbleached "	155
NSSC-ammonium base with byproducts	125
NSSC-unbleached without recovery	100

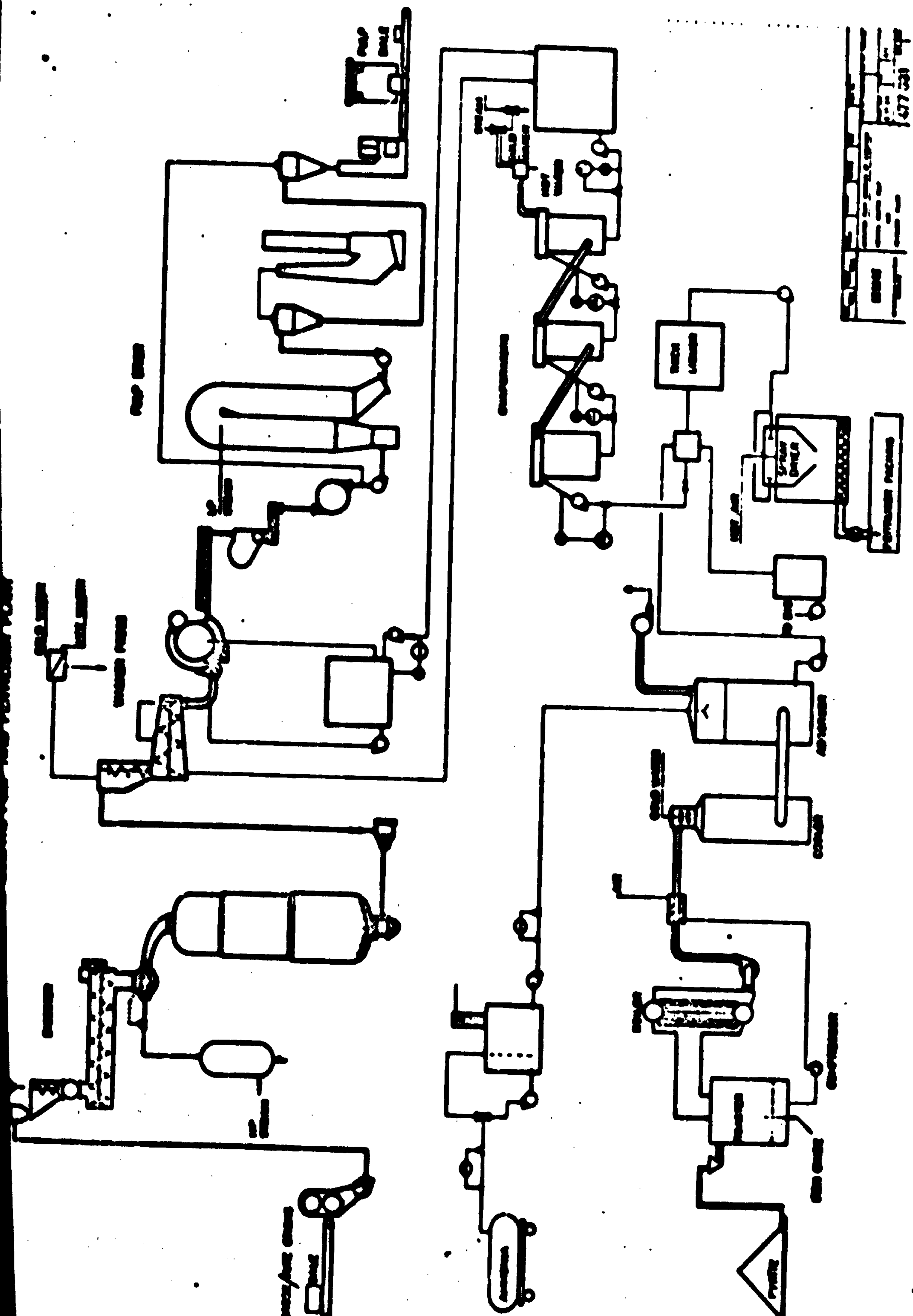


Fig 2

From the foregoing it is apparent that the emphasis usually placed on sulphate process should be somewhat questioned and more attention should be paid to evaluate alternative processes in order to find out the most suitable system.

How to reduce equipment cost

Three major ways to reduce the equipment cost are:

1/ simplified systems
2/ use of cheap material of construction
3/ use of second hand machinery

In the following sections the pulp and paper making process will be discussed in the light of the above three points in the order of their processing steps. The processing steps are dealt under six groups as previously.

1/ Raw material preparation

This section will be entirely dependent upon type of raw material. Main occurring raw materials of importance are:

- wood
- bamboo
- bagasse
- straw

Most of the natural stands of wood occurring in the developing countries are of broad leaf variety and of natural growth. The trees are generally crooked with lots of branches. Plantation of hybrid eucalyptus and pine is now gaining popularity and the impact of plantation on physical character of wood is yet to be felt. It is recommendable that delimbing of the wood is done immediately after felling and only reasonably straight logs are diverted to pulp mill. The natural forest often contains trunks of large diameter - too big to be handled manually. It is felt that debarking and chipping should be done in the forest with maximum use of manual labour. Hand tools for debarking should be devised for this purpose and the logs should be chipped immediately after debarking. This would reduce all following handling cost as the chips can be easily handled by means of pneumatic or simple mechanical conveyors in bulk form.

In case of annual plants like straw, bagasse, etc the preparation section will depend upon the form in which the raw material is available. For bagasse primary depithing is essential immediately after sugar mill crushers to be followed by further rigorous depithing at the pulp mill. The depithing should be preferably done in the dry or moist state in order to simplify disposal of the separated pith. For straw, cutting is necessary followed by dusting for removal of sand and other mechanical impurities. Pneumatic conveying coupled with special type of cyclones can do the dusting and conveying operation simultaneously. Storage of the raw material ahead of pulping is commonly used in case of wood while it is not very common for bulky material like straw, bagasse, etc.

Moreover straw, bagasse, etc are not free flowing materials which give rise to bridging in the silos. Common practice is, however, to have all storage ahead of the preparation section. This procedure, however, requires that the preparation section is working 24 hours a day and is able to supply the needs of the pulping section as and when they arise.

2/ Pulping

The type of pulping system chosen and the raw material to be pulped will decide the type of equipment. It is, however, felt that for the developing countries simpler and very conventional equipment like batch digesters with direct heating would be more convenient due to lower investment cost and operational simplicity. Depending upon the type of process · soda or sulphate, magnifite NSSC and NSSC ammonium base - the material of construction of the equipment will vary. For soda and sulphate conventional boiler plate with low silicon is the most common material. Adequate corrosion allowance should be of the order of 5 - 8 mm. For magnifite process conventional boiler plate with acidproof brick lining can be used instead of stainless steel clad digesters. For NSSC, stainless steel clad digesters would be more suitable than carbon steel although carbon steel digesters can be used when the pH of the liquor at the start is above 10.5. As corrosion is often a local factor and cannot be predicted in advance, it may be possible to use carbon steel digesters in the initial stage and if severe corrosion is noticed, stainless steel overlay can be done. There are installations where carbon steel digesters have been used for NSSC over a period of 15 years without any marked corrosion. This procedure of overlaying with stainless steel is expensive compared to clad steel, as it is very labour intensive. Therefore, it can be conveniently used, where labour cost is low.

Batch digesters with direct heating against continuous digesters in this particular case are compared below:

a/ A continuous digester being a single unit is dependent upon efficient maintenance for ensuring availability. In a batch system there are a number of digesters, and availability of one of them is more secured. The number of rotating machinery requiring constant attention is less for batch system which makes simpler maintenance.

b/ Continuous digesters require elaborate instrumentation for control and operation which also provides better product control and more uniform product. Batch digesters on the other hand can be operated with simpler instrumentation and the control is more difficult although not impossible. Systematized charging of digesters and accurate control of temperature can provide means to produce a uniform quality of pulp. As the raw material fed to the digesters is often varying with regard to moisture and other parameters, control facilities must be very flexible to produce a uniform product out of a non-uniform raw material.

c/ Steam demand for continuous digesters is uniform and low whereas for batch digesters it is fluctuating and high. More efficient use of relief gases for preheating the cooking liquor can reduce steam demand for batch digesters. The steam peaks can be evened out by judiciously spacing digester charging and heating cycles.

d/ Continuous digesters require less floor space and less building volume. This advantage of the continuous digester - although quite considerable - is largely offset by higher machinery cost. As machinery is to be imported it represents foreign exchange requirement which is scarcer than local currency.

e/ Continuous digesters are more competitive from installation cost point of view for larger units. At low capacities continuous digesters are more expensive than conventional batch digesters. Other factors, however, play a major roll in the decision like requirement of very efficient washing which is nowadays demanded by environmental pollution laws.

Batch digesters should be provided with forced circulation system in order to achieve uniform temperature throughout the digester. Normally a force circulation digester is also equipped with heat exchangers for indirect heating of the cooking liquor by steam. This is advantageous from the point of view of overall steam economy but the capital cost is higher. Moreover, scaling of the heat exchanging surface often gives rise to operational problems particularly when the raw material to be pulped is not very clean. Deposits of silica and other material accompanying the chips give hard scale requiring constant and frequent cleaning of the heat exchanging surface, which means a shut-down.

The disadvantages of having direct heating, i e injection of steam in the circulating liquor is the dilution of the liquor. The equivalent amount of water will have to be evaporated in the evaporation plant at a later stage requiring extra steam.

The above arguments are valid for material, which has high bulk density such as wood, bamboo, etc, where the density is of the order of 150 to 200 kg BD/m3.

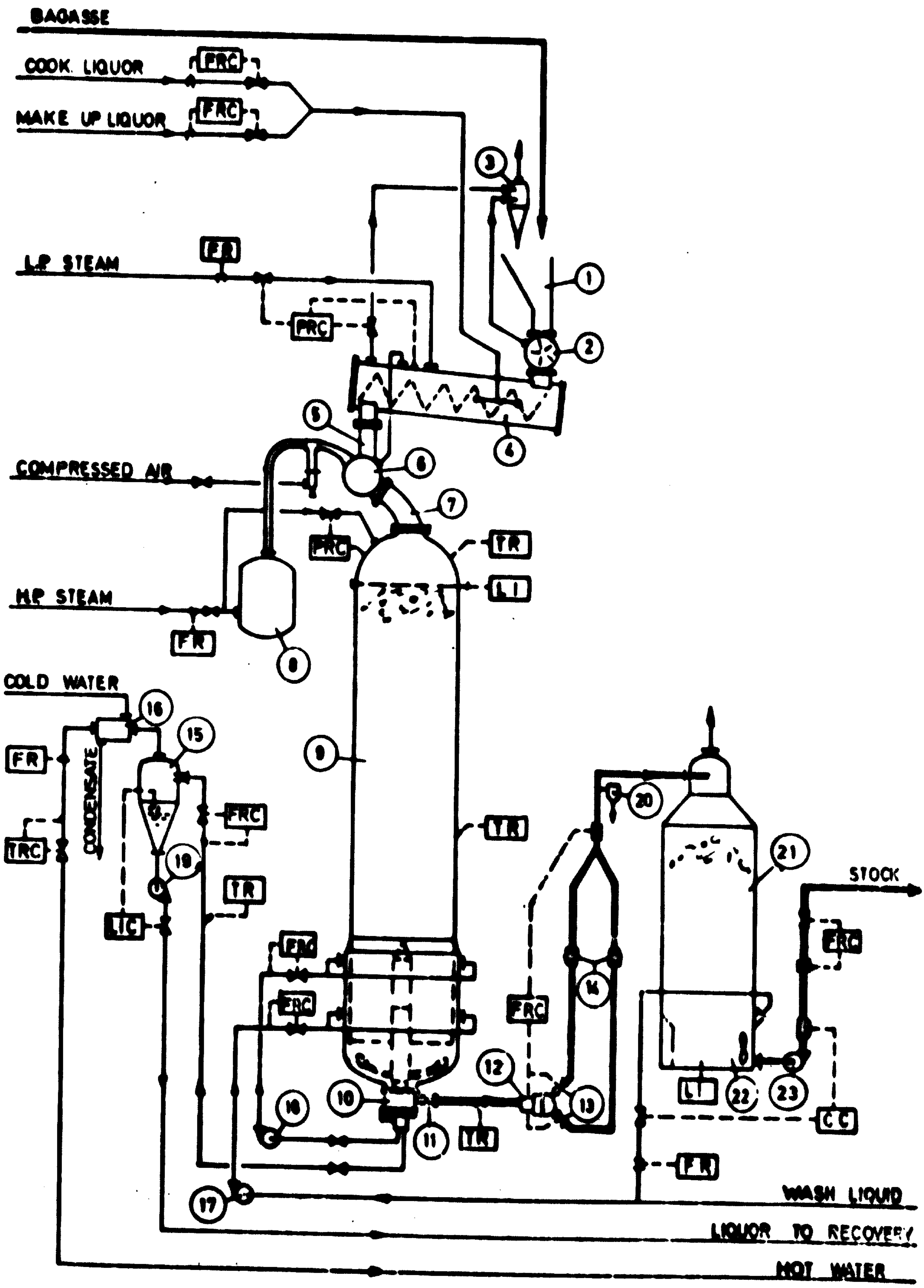
Agricultural residues like straw, bagasse, jute sticks, etc have a low bulk density of the order of 100 to 120 kg BD/m3. This means high digester volume in relation to the capacity. It is for this reason that continuous digesters are more favourable for this type of raw material even for low capacities of the order of 25 t/24h and above.

Persson (9) in his paper gives very clearly the background for utilization of straw as a raw material and also illustrates the new continuous process HF-method (Højbygaard Fabrik), where the diffuser developed for sugar extraction from beet by the Dannish Sugar Co Ltd is used. The process yields semi-chemical pulp at atmosphere pressure. It may be possible that by addition of feeders at the inlet and outlet of the diffuser pressure digestion and washing can be conveniently achieved. Figure 3 illustrates the system proposed.

The other available systems like Celdecor-Pomilio process, Pandia digester, Defibrator digester, Kamyr Digester, etc are all considered to be more capital intensive than the HF-method. One of the major advantage of this HF-method is that washing is also performed immediately after digestion similar to Kamyr unit. For high tonnage the Kamyr system, as illustrated in figure 4, is more suitable than the HF-method or any other available method.

Modified HF digester for agricultural [illegible]

Fig. 3



Kamyr continuous digester for bagasse
Flow sheet
Fig. 4.

Washing and Screening

Normally the pulp after digester is to be blown to a blow tank. In order to recover steam the digester should be set at relief and the pressure brought down before blowing is commenced. The large amount of steam released during the blow should be recovered by a blow heat recovery system. The major quantity of blow condensate can be directly used as hot water for washing the pulp, while only a small quantity need be heat exchanged indirectly to give clean hot water for bleach plant requirement. Final washing of the pulp should be done preferably on screened pulp. This would reduce requirement of an extra washer or decker after screening. Figure 3Ashows a simplified flow sheet of the system proposed, where the pulp is first washed on two washers in series followed by pressure screening and a third washer. All washers should be placed at a high floor level, which would enable pulp to proceed direct to high density storage without any high density pump.

It is recommendable to have large storages as buffer between departments and particularly so when batch system is adopted. Storage volumes are reasonably cheap which contributes to better operation and wider operational flexibility in a system. The material of construction for the blow tank, screen and washers can preferably be carbon steel for sulphate and soda process. For NSSC the blow tank can be of carbon steel but the washers should be preferably of stainless steel. All filtrate tanks can be of carbon steel and inside painted with epoxy to reduce corrosion.

3/ Bleaching

The requirement of final brightness in paper seldom exceeds 80 to 85^{o} GE. In case of an integrated mill where the bleached pulp is directly processed to paper the brightness drop is less compared to when pulp is dried and then processed in a separate paper mill.

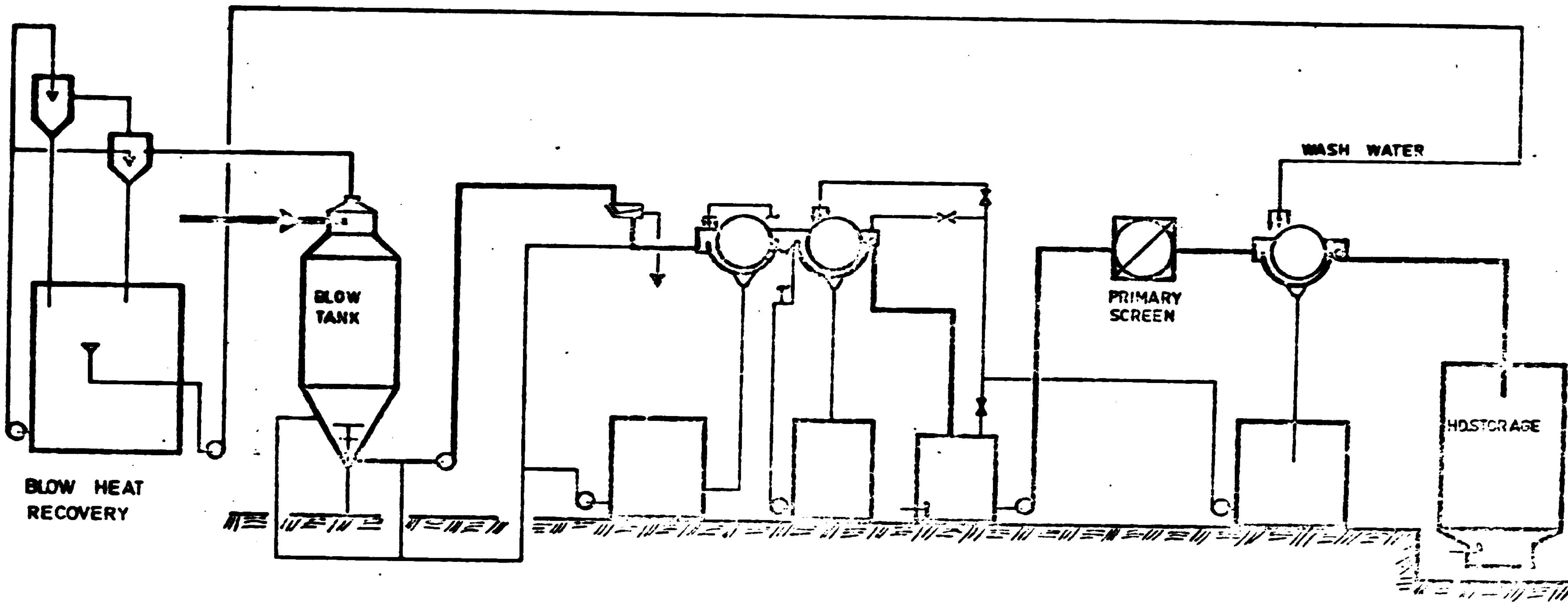
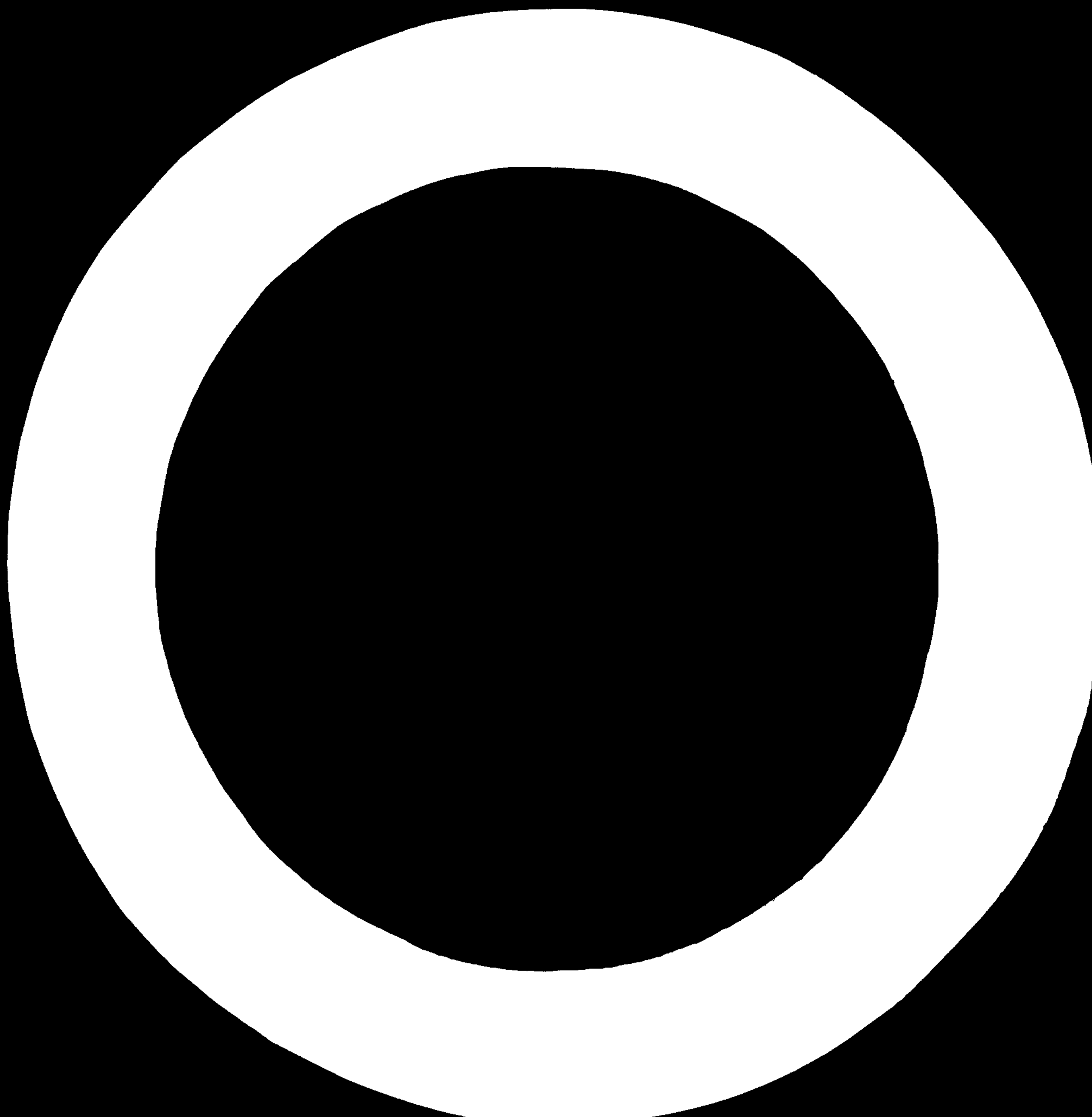


Fig. 3a
Washing & Screening



Bleaching should be done in three or four stages in the following sequence:

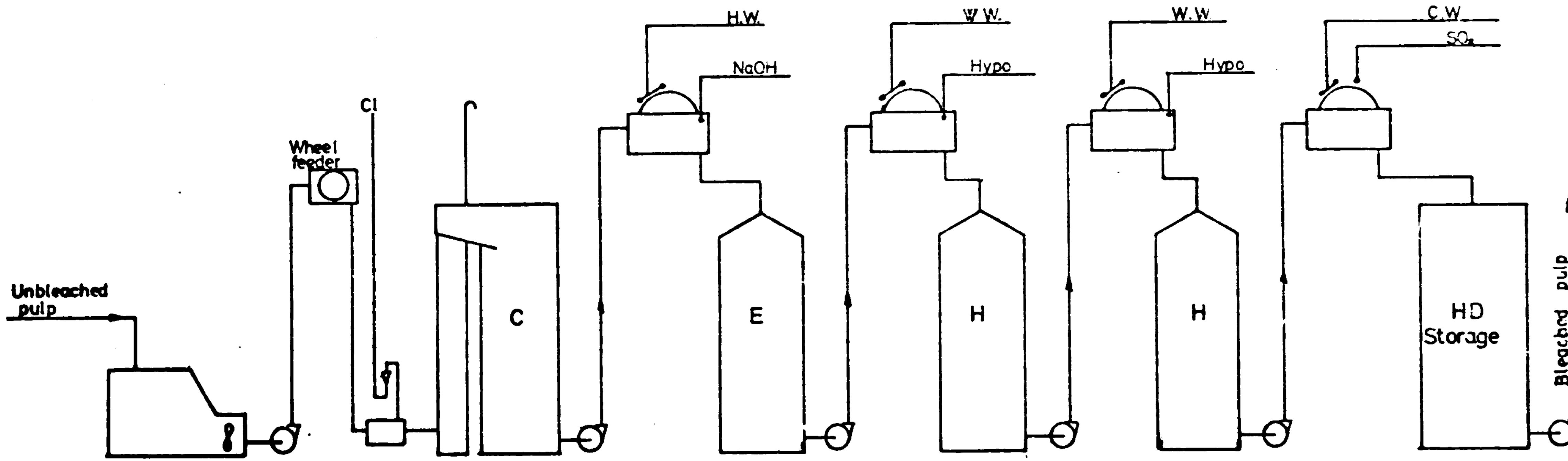
Chlorination - Alkali Extraction - Hypochlorite

Recently considerable work is being carried out for the bleaching of pulp by oxygen, which - it is hoped - in the long run will gain ground. The equipment cost, however, for such an installation is rather high and the development is still considered to be in the experimental stage. Therefore no consideration is made here for oxygen bleaching. Chlorination of pulp is quite problematic in the warm climates, where normal water temperature is above 30°C. Maximum degradation also takes place in this stage mainly due to the large variation in temperature from the winter to the summer months. Efforts are now being made to find a system of gas phase chlorination, which would reduce the reaction time and will also consume less water. In order to overcome the problem of chlorination it is proposed that the chlorination should be done in a short retention upflow tower followed by downflow tower. This will provide means to control the reaction time by varying the level. All the following bleaching stages should be in downflow towers and this will avoid the use of high density pumps. All filters will be placed at a high level for achieving gravity flow to the towers. Simple volumetric measurement of inflow pulp to the chlorination stage followed by level control in the intermediate towers will ensure constant condition. Figure 5 shows the flow sheet of a 3-stage bleaching plant.

Considerable saving in equipment cost can be made by adopting a batch system of bleaching as shown in figure 6 by one upflow tower, one downflow tower and one washer. Bleaching sequence and condition as per table VI.

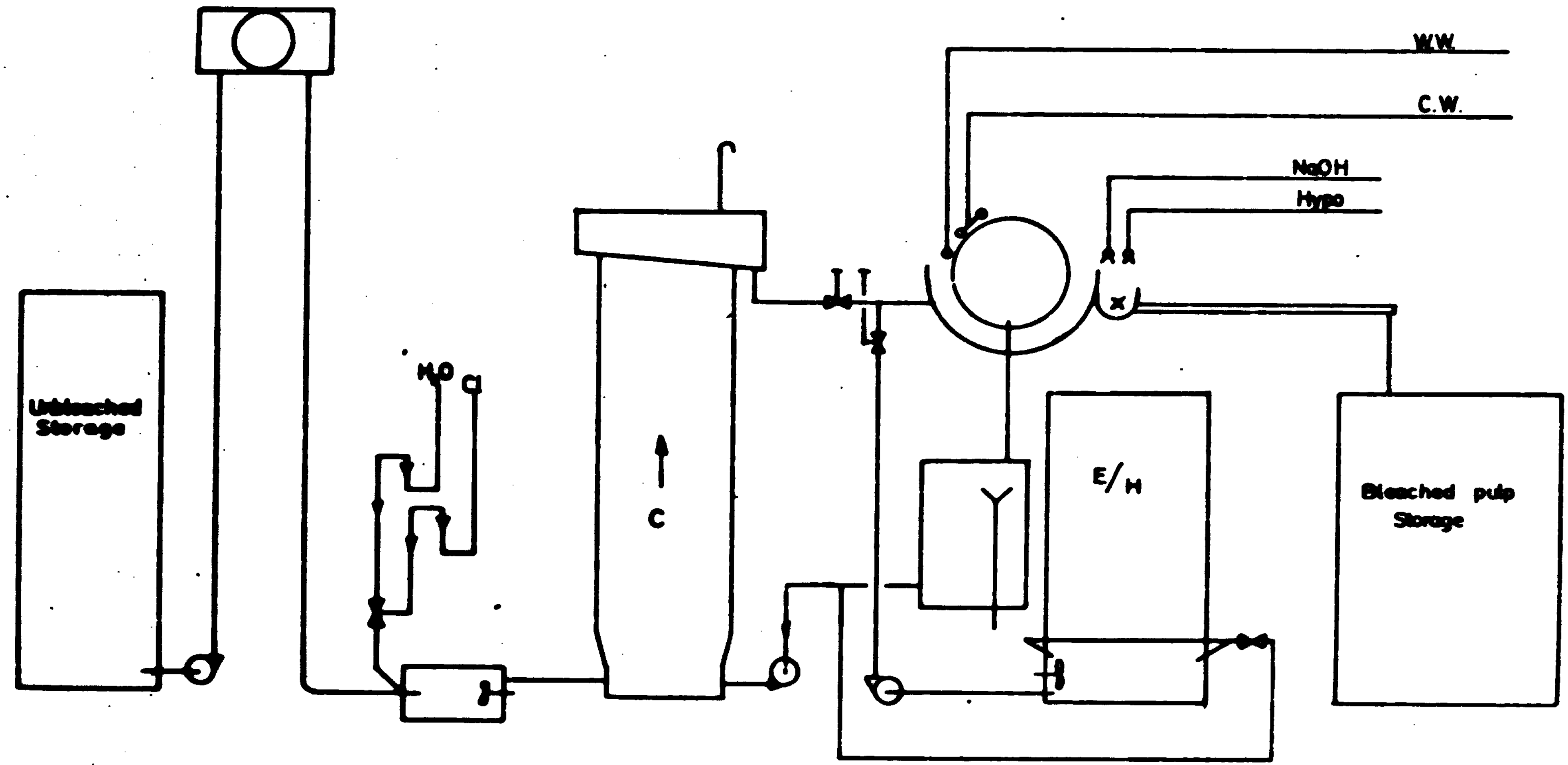
Table VI

Stage	Concentration %	Time minutes	Temperature °C
Chlorination	3.5	60	20
Extraction	10	120	60
Hypochlorite	10	120	35
Hypochlorite	10	120	35



CONTINUOUS BLEACHING SYSTEM (C-E-H-H)

Fig. 5



BATCH BLEACHING SYSTEM C-E-H(-H) USING 1-WASHER

Fig. 6

The unscreened pulp is metered and chlorinated, which rises through the upflow tower. When chlorinated stock starts overflowing into the launder it is piped to the washer and the stock feeding is discontinued. Chlorine stage filtrate or fresh water is then injected at the tower bottom, until all the pulp is displaced. The rate of discharge is controlled to avoid too long or too short chlorination. The stock is to be washed with hot water 70°C and caustic soda is to be added. The alkali extraction stage is carried out in the downflow tower at high consistency. Pulp is diluted at the tower bottom and washed on the washer. The hypochlorite stage follows similarly but the temperature of wash water is adjusted to 30°C for attaining 35°C in the hypo stage.

The transition from the chlorine to alkali and from alkali to hypo stage is easy to recognize for changing operating condition of the washer.

The washer is to be placed at high floor level for allowing gravity flow through the tower without use of additional pump and also for direct conveying to high density storage.

The material of construction for the bleaching towers should be rubber lined carbon steel or tile lined concrete, whichever is found to be cheager. All major piping should be made of PVC and fibreglass reinforced polyester. Agitators and pumps should be lined with rubber and/or plastic to maximum extent. Minimum use of stainless steel will reduce investment cost considerably. Moreover repair of plastic equipment would be simple as they require less elaborate working tools.

Paper Making

The economic condition of the developing countries mainly supports the consumption of the cultural papers, i e newsprint, writing and printing. Table VII illustrates the forecast of consumption (1975) of different grades of paper in S.E. Asia (10) based on an income growth of 2.5% per capita and year.

Table VII

Grade of paper	Percentage
- Newsprint	21
- Printing & Writing	37
- Other paper	17
- Paperboard	25
	100

The furnish for newsprint is normally 80% groundwood and 20% unbleached sulphite or semibleached kraft. The furnish for writing and printing varies widely, but is exclusively from bright pulp. The non-integrated paper mill has wide flexibility in chosing pulp for making paper, while an integrated unit is bound to the quality of pulp produced in the pulp plant. Admixture of small quantities of pulp or deinked waste paper from outside source, however, gives required flexibility in an integrated paper mill.

Paper making operation can be divided into three distinct sections, viz. stock preparation, paper machine and finishing.

The distribution of machinery cost within these three sections is, roughly, as shown in table VIII. This distribution is based on fine paper mill.

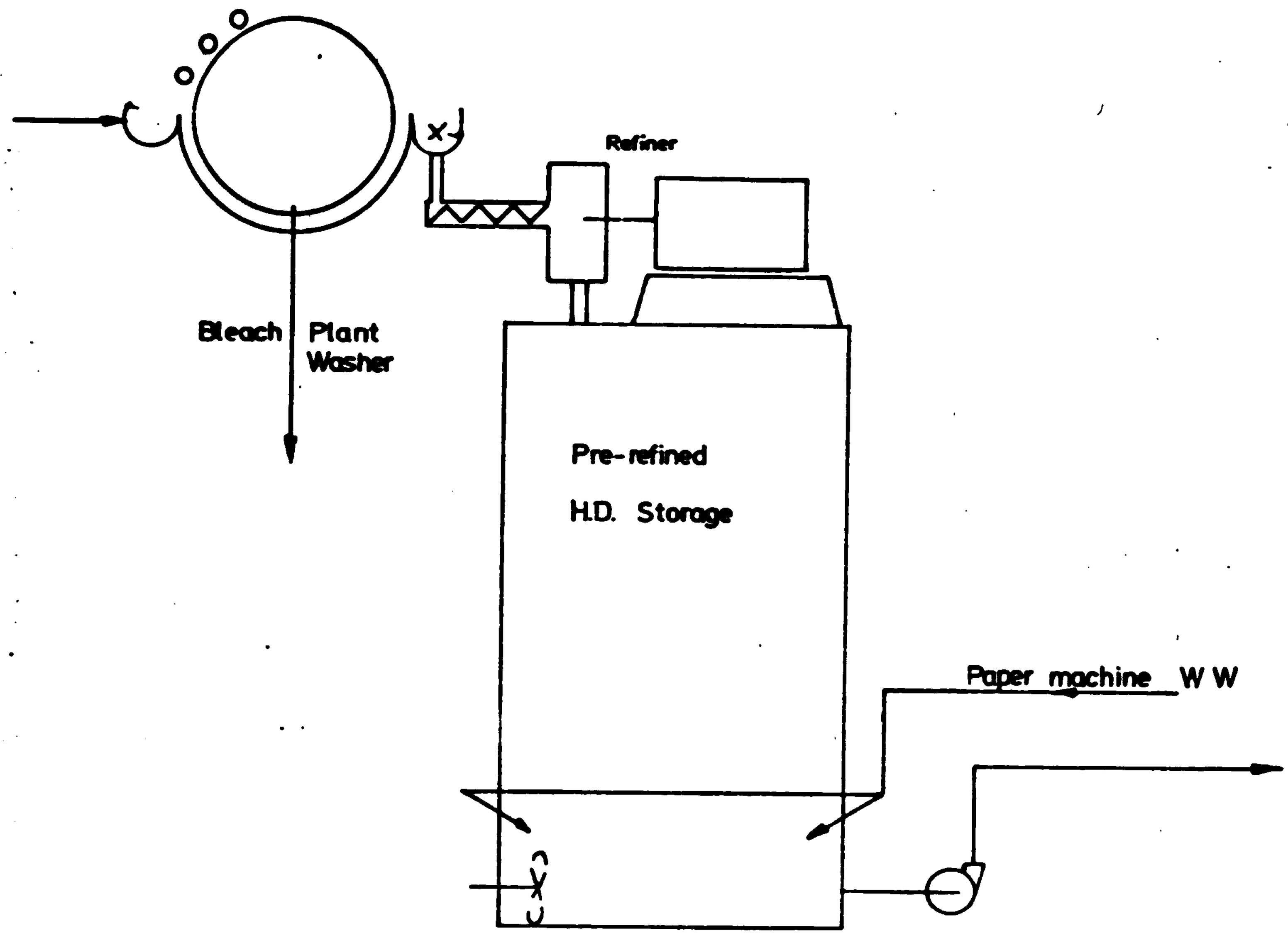
Table VIII

	Cost, %
a/ Stock preparation	20
b/ Paper machine	65
c/ Finishing	15

The stock preparation section comprises refining of virgin fibr proportioning of broke, size, loading, chemicals, stock cleanin and screening. The type of equipment to be chosen for refining is dependent upon quality of pulp and final quality of paper to be produced. Pulp from hardwood and agricultural residues require special treatment in order to utilize the specific inherent properties of these types of fibre. Algar (11) points out that strength development characteristics of eucalyptus kr pulp and probably of short-fibred pulp in general are dependen upon type of beating action employed. Normally higher speed, narrow close spaced tackle, multiple bed plate and higher concentration provide increased opportunity of strength development of short-fibred pulp.

Disc refining of pulp at medium concentration (10-12%) immediately after the bleach plant washer provides a simple arrangement for prerefining of stock. Prerefined stock can thereafter be stored at (10-12%) consistency in the normal way and withdrawn from the tower bottom at suitable consistency for final beating. The arrangement is shown in figure 7.

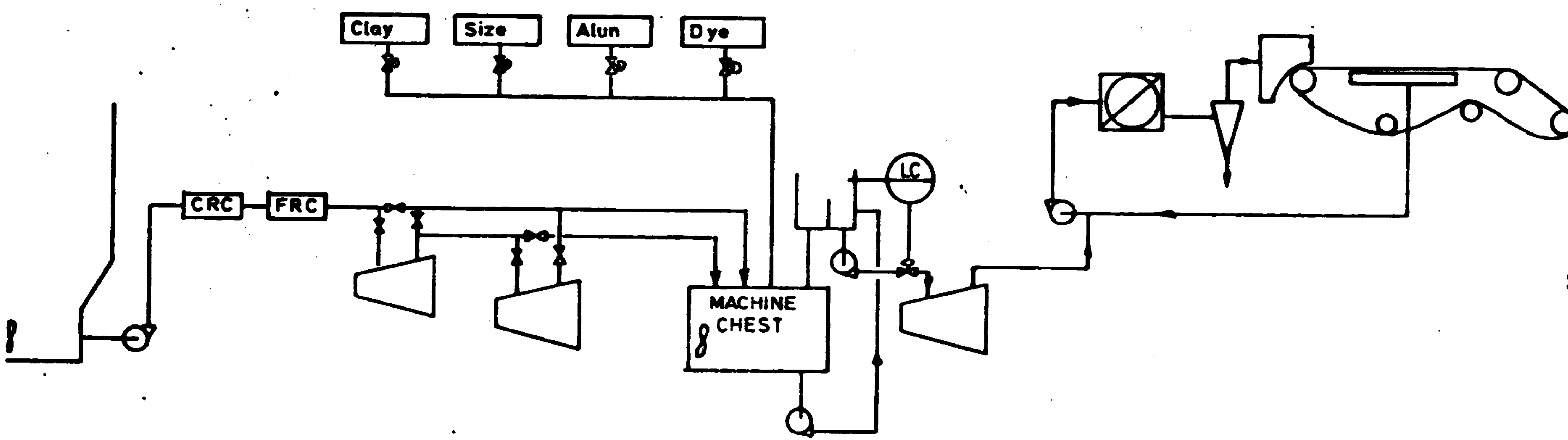
Power consumption in the prerefining stage should be of the order of 50% of the total refining energy. Normal design data for this stage should be 125 kWh per ton. Further refining of the pulp should be done in the consistency range of 5-3% in conical refiners. This arrangement will enable the paper maker to vary the refining within wide limits and at the same time utilize simpler installation.



Disk refining ahead of HD storage tower

Fig. 7

Simple overflow systems should be used for controlling pulp flow. A simplified arrangement is shown in figure (8). Simple control system for proportioning broke, size, stock and consistency control gives ease of maintenance and low cost of instrumentation.



STOCK PREPARATION SYSTEM

Fig 8

The paper machine is the most capital insensitive single machine in a pulp and paper mill. The machine alone represents [illegible] 20 [illegible] of the total machinery cost of a pulp and paper mill. The distribution of capital and operating [illegible] the three sections of a paper machine, wire section, press section and dryer section, is shown in table IX.

Table [illegible]

Section	% of machine cost	% of operating cost	% of water removed
Wire	26	30	97
Press	22	20	2
Dryer	52	50	1

Due to low cost water removal in the wire section and increased stress on sheet uniformity new headbox design has been evolved, which operates at lower consistency for achieving improved formation. This has triggered development in the wire section for increased drainage and has resulted in new high capacity drainage systems. High cost of water removal in the dryer section has brought forward new design of press, which gives higher dryness. Big machines cannot afford down time. Therefore suction transfer has become a standard unit. Machine down-time exceeding 5-6% for breaks etc is today considered uneconomical. Special designs have been evolved to reduce wire and felt change in the machine.

The paper machine is not a single machine but a number of machines put together to work in exact pace with the preceding and following unit. During the last 30 years enormous development has taken place in paper machine, although the basic design remains the same. Despite all this development the paper machine is perhaps the only major machine in a pulp and paper mill, which has departed from the rule of economy of size. The price of the paper machine of various types varies within narrow limits. A standard fourdrinier machine with UNI press and conventional dryer section with calender and reel is priced for different width and shown in figure (90). The effect of wire width on price is so pronounced in the width region of 7 m that from the standpoint of machine cost it would be cheaper to buy two machines of half the width rather than one single machine. However two paper machines would require 50-60% more operating labour and more floor space. Preference for one unit is more dictated by labour cost than any other factor.

These arguments are mainly valid where labour cost is high and building cost is 50% of the machine cost, i e industrially developed contries. For the developing countries the problem is different. It is more important to buy cheaper equipment at the cost of increased labour and higher building cost. Moreover, as maintenance is more time-consuming due to lack of tools, gadgets, spares and skill, one-machine mill often suffers more loss of production than a multipaper machine mill.

Industrially developed countries are today faced with problem of labour shortage and high wage rate. Mills are therefore anxious to replace number of small machines by one large unit. This has resulted in early replacement of paper machines, which are far from obsolete. Number of paper machines below a trim of 80-100' are now operating under great economic strain in all the industrially developed countries. The used equipment market is soaring with old paper making machines and other ancillary equipment. The price of old machines are difficult to judge and they vary depending upon their condition and age.

Price of a fourdrinier paper machine.

Fig 9

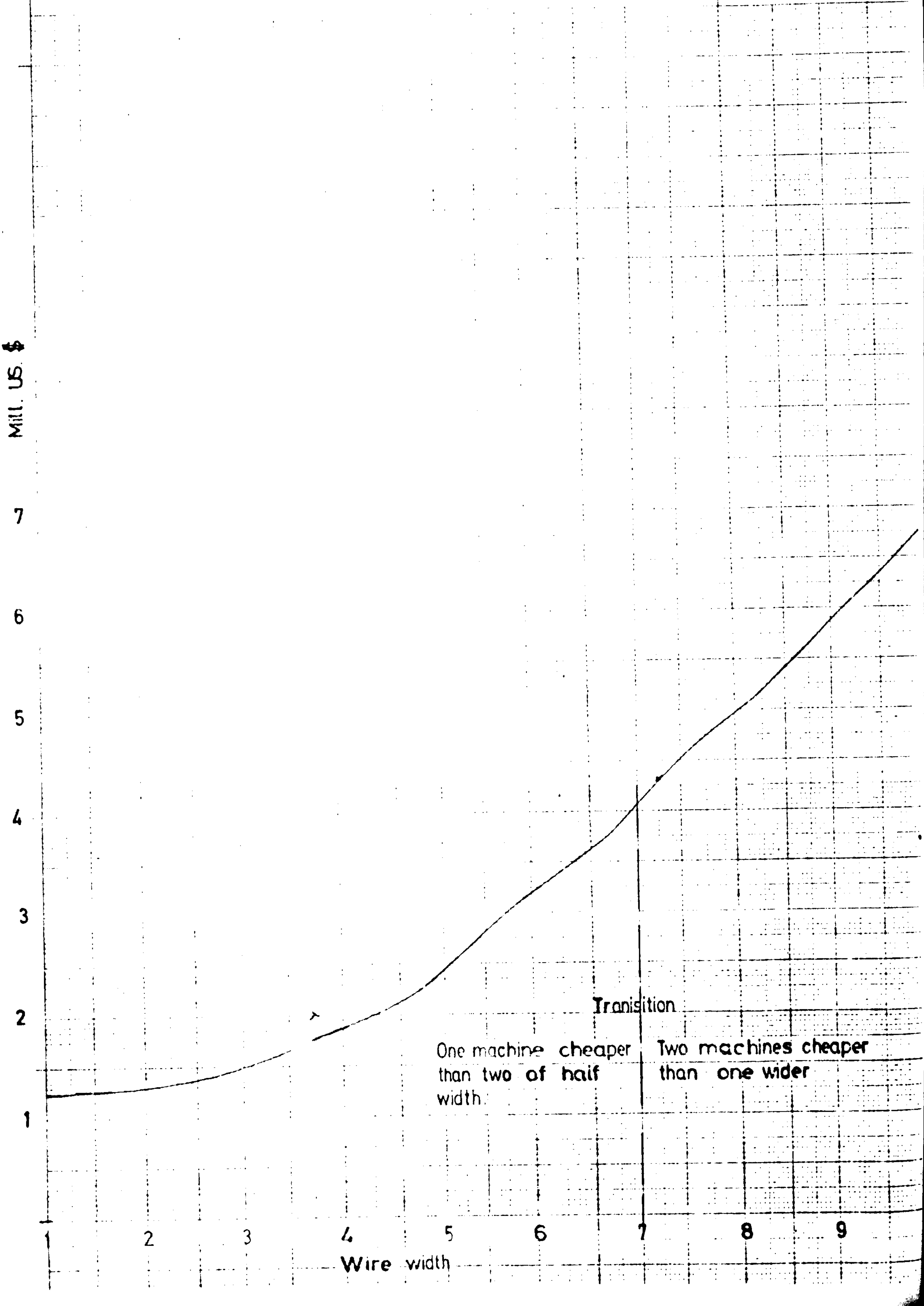


Figure 10 shows two curves used by valuers and insurance company for assessing present worth of machine depending upon age of the machine and original price.

Stenberg (12) pointed out that there is little risk of revolutionary change in a paper machine design and that the effective life span of a machine can be increased by rebuilding sections of paper machine. Life span of paper machines is of the order of 50 years. Many of the old machines are today running at double the original speed after major rebuilding.

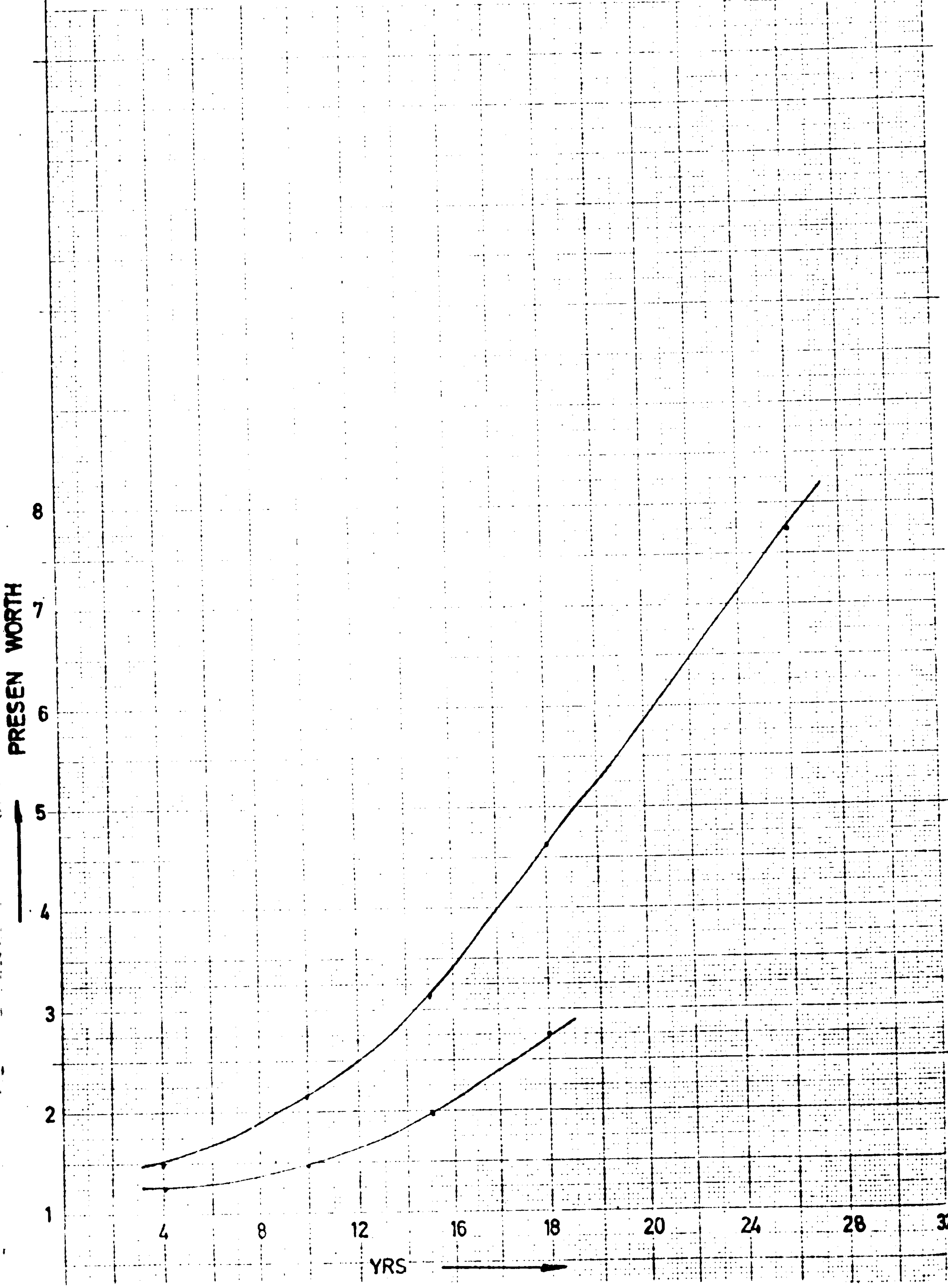
Substantial saving in capital investment and on stream line can be accomplished by 'composite concept . AMF mill reports (13) $ 300,000 to 400,000 saving in capital investment on a 75 t/24h corrugating machine by using this concept which means that the machine incorporates new, used and remanufactured components in a unit specifically designed to fit the mill.

Small scale paper mill can be built exclusively by using second hand machinery at a considerably reduced capital cost. Revamping of a paper machine wet end by installing a new headbox and a new dewatering element will greatly improve quality and production capacity

The press section can be modified to improve dewatering capacity. By installing an enclosed hood over the paper machine and blowing hot air, the capacity of the dryer section can be increased considerably. New drive for the paper machine may be necessary to boost the production. All these steps can result in a low cost paper mill unit, which will process either purchased pulp or deinked waste paper.

PRESENT WORTH FACTOR VS
MACHINE AGE

FIG. 10



Newsprint

Newsprint is a trade name of a paper, which has the following inherent properties:

a/ It is cheap - therefore after use it can be discarded
b/ It withstands rotary press tension
c/ It receives and absorbs printing ink
d/ It is opaque so that both sides can be printed without show through.

Normally newsprint is made from ground spruce 80% and unbleached spruce sulphite 20%.

For the developing countries spruce is a scarce raw material. Therefore newsprint is normally not made except under special conditions like Pakistan using 'Sundari' & Gewa, India using "Salai", Brazil & Australia using eucalyptus. Considerable attempt has been made to produce newsprint-like paper from bagasse by various organisations, but no commercial venture has yet been launched.

The following processes are available.

a/ Simon Cusi
b/ Crown Zellerbach
c/ Aschaffenburger
d/ KMW/Defibrator

Capital as well as operating cost for all these processes was rather high, which is one of the main reasons hindering commercial enterprise.

Bagasse as coming out from crushers in a sugar mill is reasonably white. The colour deteriorates during storage in the outer layer of a bale and also sometimes inside the bale. Biological activity due to presence of sugar is the main reason of colour detoriation.

One of the possible methods which KMW did suggest for Kous newsprint project was drying ahead of baling. This is a costly operation and is effective only in a dry climate like Egypt.

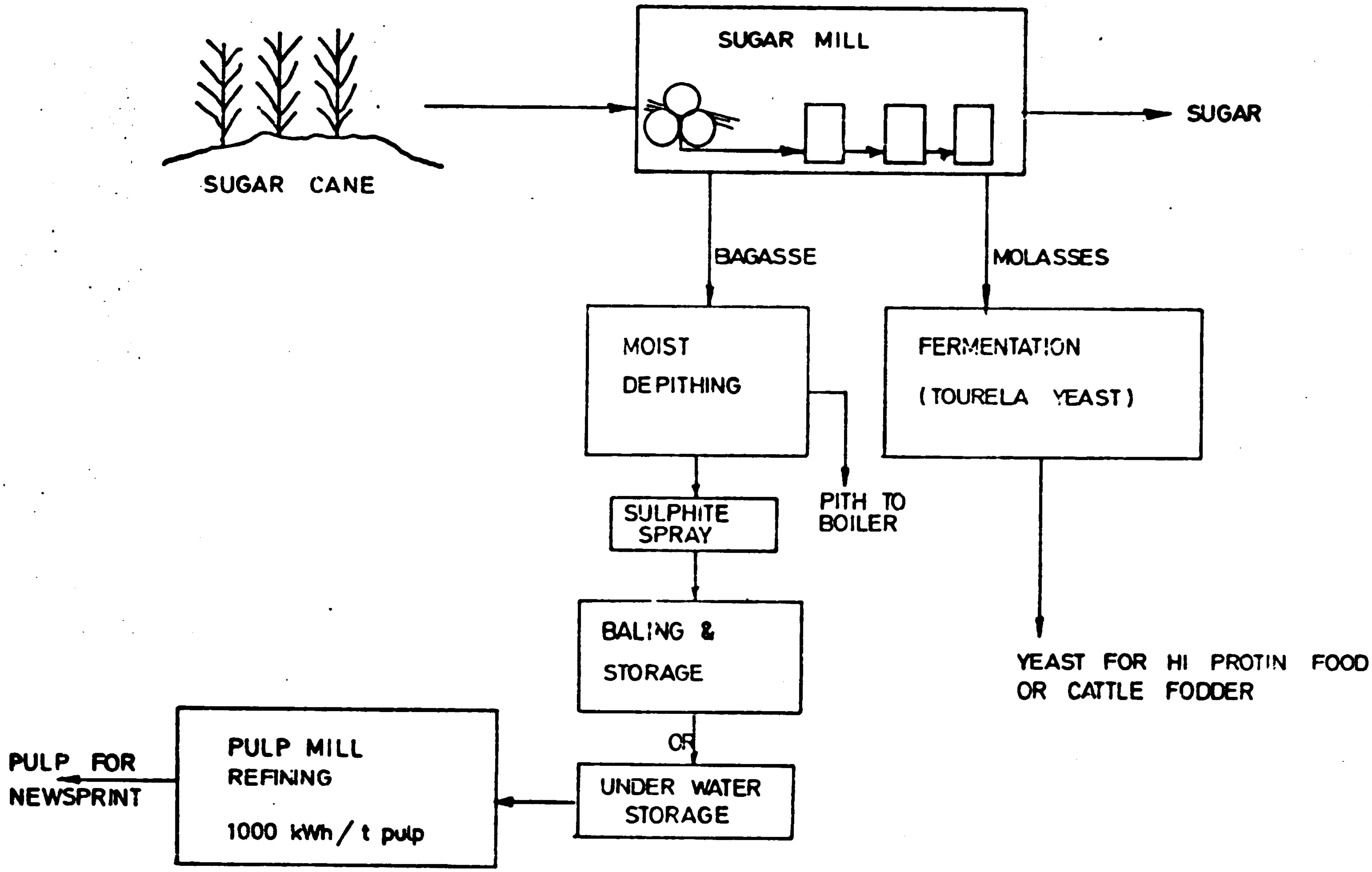
A possible variation suggested is wet bulk storage with chemicals so that the pH is brought down under 4 to avert growth of microorganism.

Mg-sulphite liquor can be used as shown in figure (11).

A possible variation is to store pretreated bagasse in loose form inside an enclosure of the type of a tent with dark colour to absorb heat. Prolonged storage will result in a slow delignification at low temperature.

The treated bagasse can then be quickly heated and refined under pressure to yield a pulp suitable for making newsprint-like paper as regards the premises set forth excepting opacity.

Paper machine design should take care of low retention, low wet strength, high press sticking tendency and high fluff production.



A CANE SUGAR MILL INTEGRATED
TO PRODUCE NEWSPRINT AND PROTIN

Fig. 11.

5/ Recovery section

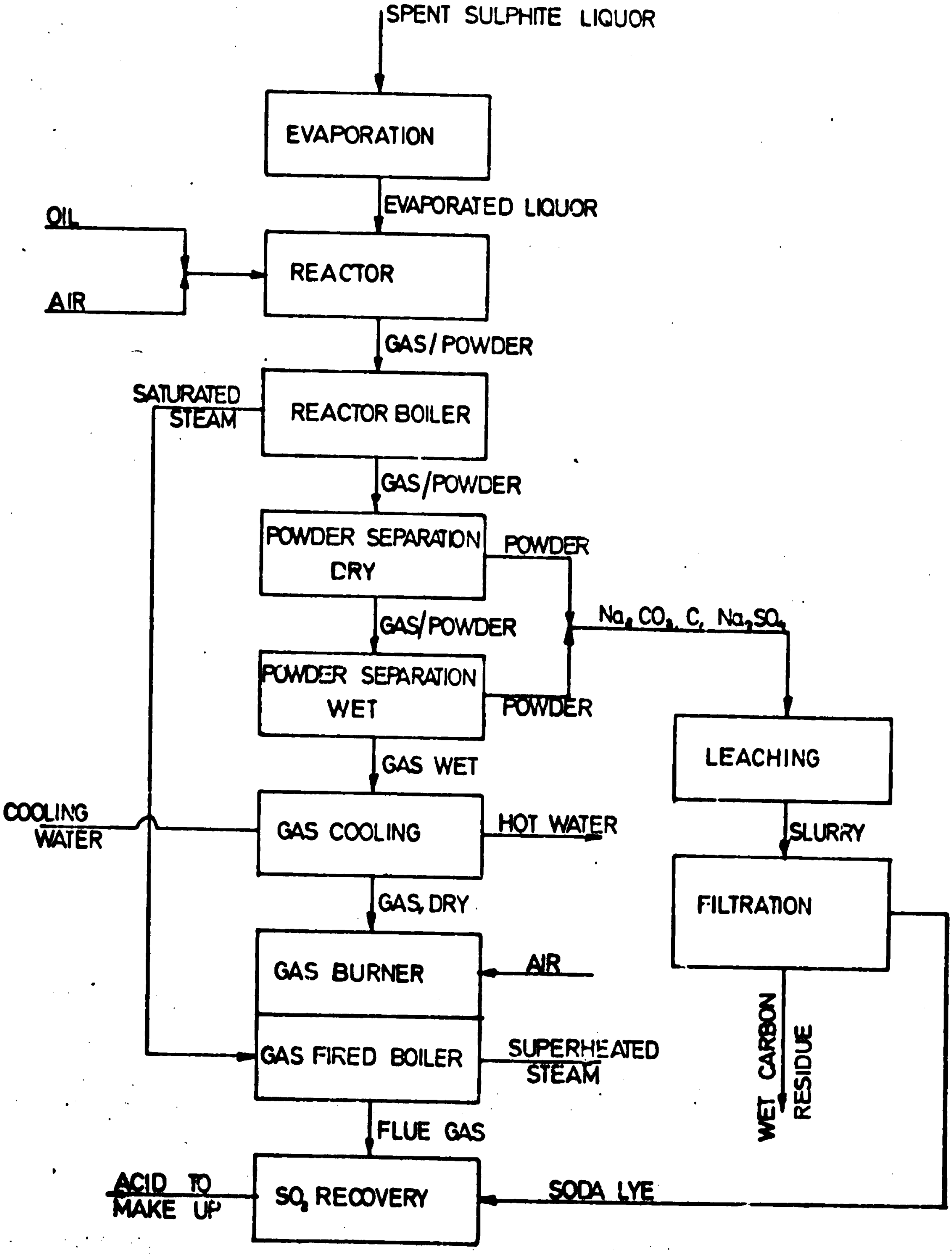
This section will be identical for soda and sulphate. Normal multistage evaporation should be adopted for evaporating liquor to 55-50% solids. It is assumed that the type of raw material used does not give any soap and therefore no skimming is required. The liquor at 55-50% solids is to be fired in a stationary reactor for pyrolysis under reduction atmosphere. The pyrolysis reactor designed by SCA/Billerud (14) converts all sodium salt to Na_2CO_3 and C. The main advantage of this system is that no smelt is formed and the heat recovery is by use of a waste heat boiler and a conventional gas-fired boiler. Figure 12 shows the simplified flow sheet for NSSC recovery and figure 13 for sulphate recovery.

The economy of a sulphate mill lies in the efficiency of the recovery section. This factor is all the more important for mills in the developing countries where the chemical costs are high. For ammonium base neutral sulphite process this problem is solved by converting the waste to a salable product and thereby recover a good portion of the cost. However, the main pulping chemical in such a case is sulphur, which is lost in the system.

Recovery of magnesium base liquor has been much more simplified by fluidised bed reactor (15) and is shown in figure 14.

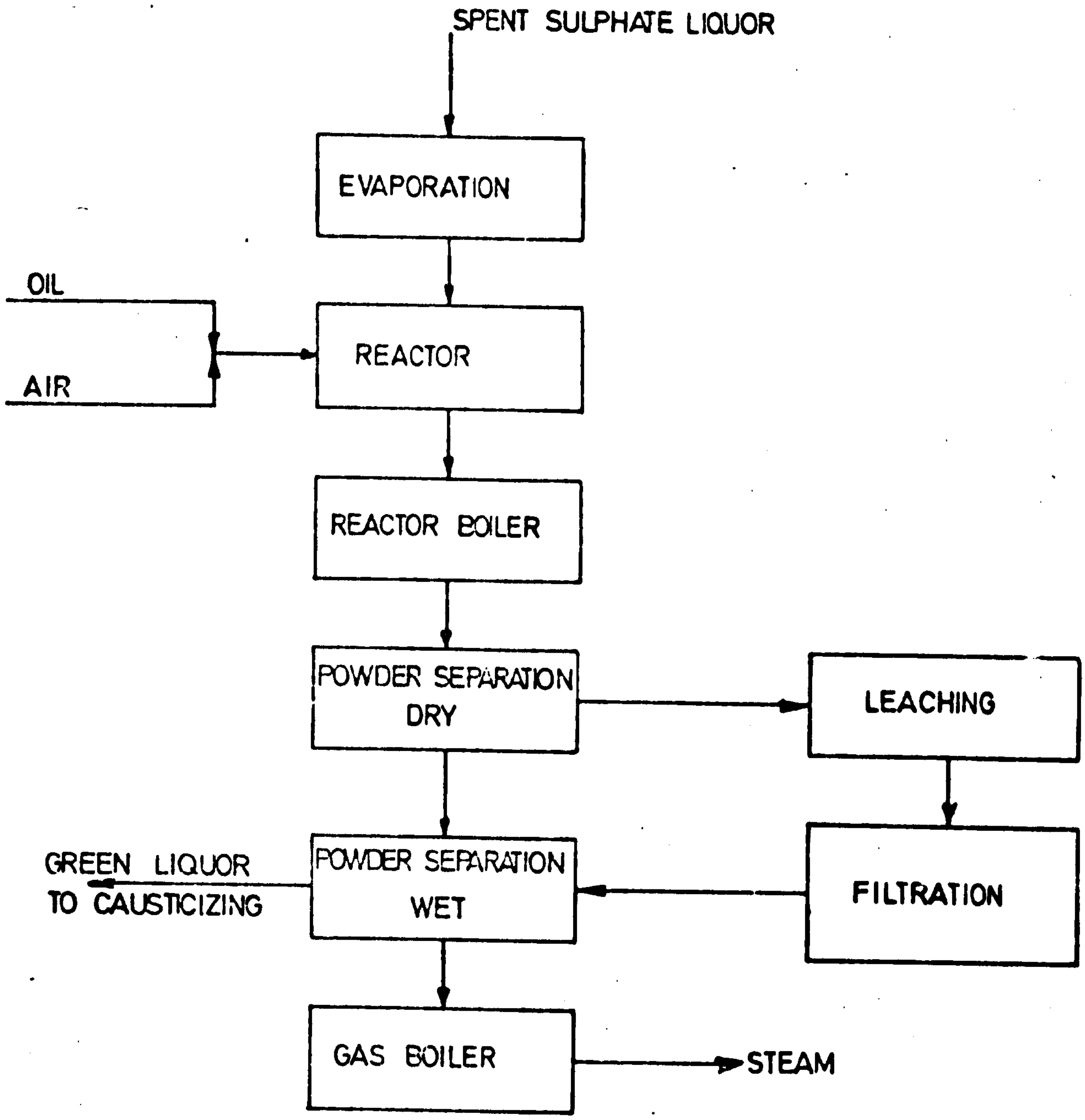
Utility

The utility section differs according to the pulping processes used. Table X shows the comparative figures of the different processes. These figures are very average and cannot be considered as binding, but they are quite realistic figures. Figure 15 shows power & heat balance of the integrated mill, based on sulphate process and figure 16 based on ammonium bisulphite process.

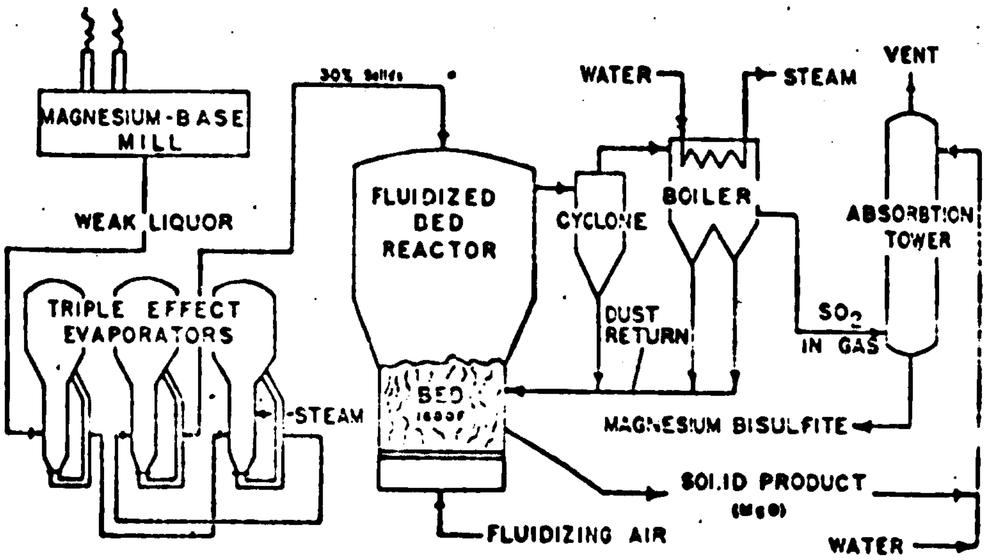


SCA NSSC PROCESS

FIG. 12

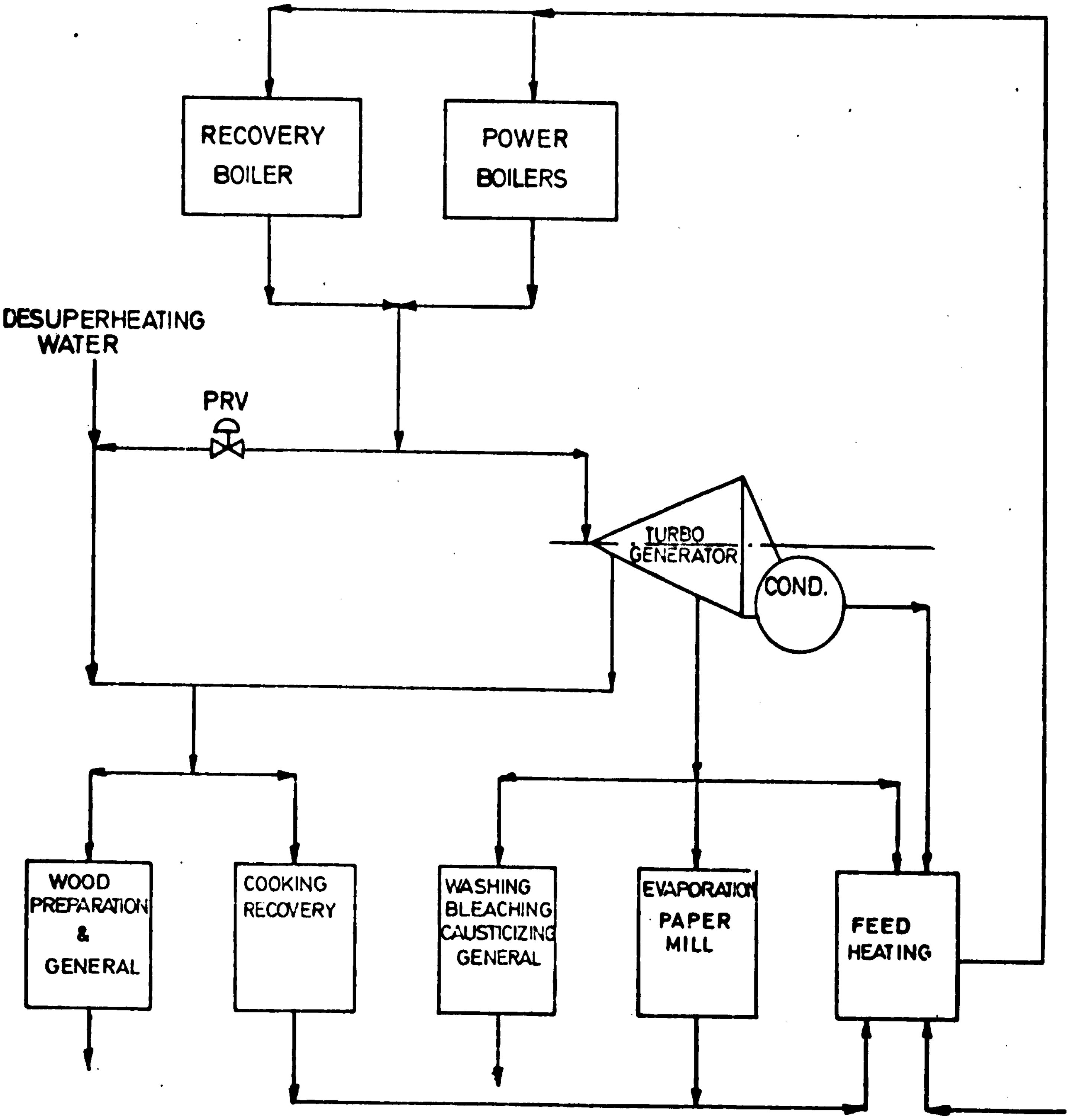


SCA SULPHATE PROCESS
FIG. 13



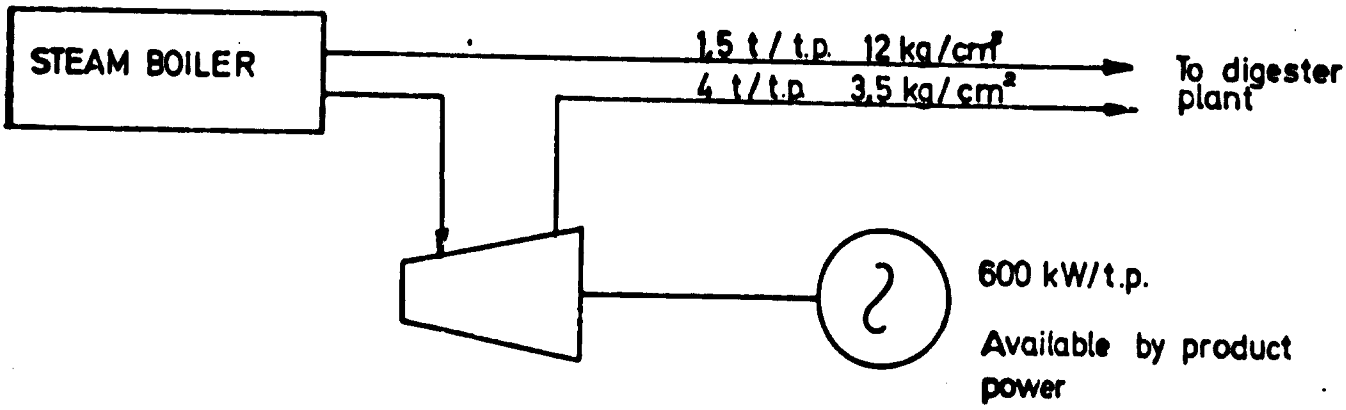
Treatment of magnesium-base waste effluent

Fig. 14



BLEACHED KRAFT PAPERBOARD MILL
POWER GENERATED

FIG. 15



POWER REQUIREMENT 450 kWh / t.p.
STEAM REQUIREMENT 5,5 ton / tp.

ANS PROCESS PULP - FLASH DRIED
POWER & HEAT BALANCE

FIG. 16

Table X

Utility:

		Bl.kraft pulp	Paper mill with int. bl.kraft	Newsprint	Unbl.sulphite pulp
Steam	t/t.p.	5 1/	8 2/	4	4
Power	kWh/t.p.	500 3/	1500 3/	1600	300
Water	m3/t.p.	100 4/	150 4/	150	200

1/ Net requirement 1 t/t.p. as recovery gives 4 t/t.p.

2/ Net requirement 4 t/t paper.

3/ By-product power not accounted.

4/ Very closed system for reduced pollution

Concluding remark

It is found that the investments made and the type of equipment chosen for many of the new installations of pulp and paper mills in the developing countries are not economically justified. This is due to the intricacy of financing these projects. Normally a lump sum contract is placed with one supplier who can offer deferred payment conditions. Equipment manufacturers are seldom interested in dealing with the second hand machines and machines outside their own scope of manufacture. It appears that credit conditions are often the determining factor and all technical considerations are of secondary importance. For the low cost pulp and paper mills to be a reality the technical aspects must lie in the foreground. Judicious thought should be given to secure second hand machinery for the major item like paper machines, turbines, etc which can be easily dismantled and conveniently reerected. Modifications and integration of modern improvement of the second hand machines can also be done before shipment so as to fit in the total picture. Use of second hand machinery requires elaborate design of the total system, which requires thorough knowledge of machinery and process.

Management of such a project should be in the hands of competent people and as long as there is dearth consulting firms should engaged. It is hoped that special cadre of consultants are coming forward for this type of work where system solution as well as adapting old machines to a new system are the main duty.

The opinions expressed in this paper are the author's and do not necessarily mean that it is shared by KMW, although KMW has largely accepted these reasonings. I thank the management of KMW for entrusting me with this duty, which has been more a pleasure than anything else.

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