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APPROPRIATE TECHNOLOGY FOR THE MANUFACTURE OF PULP AND PAPER PRODUCTS

PULPING TECHNOLOGY AND REQUIREMENTS AND POTENTIALITIES OF DEVELOPING COUNTRIES

Background Paper

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PULPING TECHNOLOGY AND REQUIREMENTS AND POTENTIALITIES OF DEVELOPING COUNTRIES

by

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Introduction

1. A given paper product can be manufactured from many different pulp grades, used alone or in blends, with or without addition of fillers and chemicals. In addition, many pulp grades can be made from widely different species of trees or plants. The wide choice of technology thus offered is materially narrowed down by the limitations imposed by local conditions and especially by those prevailing in developing countries. When a choice must be made it helps to know a little about the processes available and be able to assess the applicability of each such process to the end product considered, the raw material available, the size of production desirable and the geographic and economical conditions at the site under consideration. This treatise will endeavour to provide such information.

2. When prices are cited below they refer to the Swedish market in 1978 and are given in US dollars. They are only meant to give approximate cost relations.

Pulping Process

Stone Groundwood (GWP)

3. The process of grinding wood into mechanical pulp was invented in 1840, when the only alternatives were pulps from cotton and straw. Chemical pulps did not arrive until 30 years later. In spite of this early introduction it was only in the 1960-ties that one came to understand the fiber morphological mechanisms and learnt to apply modern technology to the manufacture of this pulp.

4. Shortly afterwards the interest of the scientists and technologists was drawn to the chip refining processes described below. It should be realised that this switch of interest was conditioned more by the offer of new scientific challenges than by an obsolescence of the GWP process. If mechanical pulp is to be produced, the GWP-process is still one of the alternatives that have to be considered.

The process requirements

5. GWP can be produced from poplar, aspen, some species of eucalyptus, gum and most softwoods. Dense hardwoods are not suitable, giving dark and very weak pulps. Pine with a high pitch content may give too much operating trouble with pitch. In both cases some improvement can be achieved by alkaline grinding. Spruce is the best raw material. The wood to be ground must be available as logs, preferably green from the forest, straight and carefully debarked. Saw mill waste and thinnings are not usable.

6. Electric power of 6 000 V and clean water to an amount of 10-15 m^3/t are the other requirements. The process is simple. The only work requiring specialized training is the periodic sharpening of the grinding stone (once a week), a task conveniently entrusted to the plant superintendant.

Production Cost

Quantity related cost items

7. To produce one ton of GWP (900 kg of bone dry fiber) 2,33 solid cubic meters of debarked wood is needed. The wood yield is difficult to determine accurately but will be in the range of 95-97%. Depending on the pulp grade made (from coarse paper board pulp to pulp for addition to fine printing paper) the energy requirement will be 800-1500 kWh/t. These two cost items are the main ones and they are almost independant of plant size.

8. The following data apply to a non-integrated GWP mill producing a newsgrade pulp; Size 100 t/day

	Quantity	Cost $/ton
Wood	2,33 m^3	83
Electricity grinding Electricity screening, drying	1000 kWh/t 500 kWh/t	50
Fuel oil for drying	80 l/t	7
Wrapping material, stones		6
Sum of quantity related items		146 $/t

Labour cost

9. The labour cost is highly dependent on the size of the plant, but also in a small plant the labour cost is comparatively low. A 100 t/day market pulp mill should require no more than 30 operators costing in Sweden 15 $/t. The staff will add perhaps 5 $/t. We have then counted with 2 operators on 2 shifts in the wood yard, 2 operators on 3 shifts in the groundwood mill and 2 operators on 3 shifts for dewatering, drying and baling, 1 superintendent and 3 maintenance men. This crew will not be much smaller, however small the plant, which means that in Sweden a 50 t/d plant would spend 20 $/t more on labour than a 100 t/d plant. For a plant of 900 t/d the labour cost will be about one third of that of a 100 t/d plant. In Sweden the large plant will have 12 $/t lower labour cost than the small one.

10. In practise it may be more important that the large plant can afford to engage competent specialists on process control, quality control, instrumentation, transportation and preventive maintenance. As a matter of fact, the success of small plant operation, where such operation is desirable, depends on how efficiently modern technology can be applied. A permanent staff of highly qualified specialists is an unnecessary luxury even in the largest plant, and it is today usual in large companies to draw the specialists together in development departments which act as consultants and investigators in the company mills. If a similar service can be provided for small mills, these can be operated just as efficiently, provided only that strict adherence to imposed routines can be maintained at a local level.

Capital cost

11. An estimate made in 1977 by the Swedish Forest Research Institute gave an investment cost of 5 million $ for a 100 t/d GWP mill, 9 million $ for a 350 t/d mill and 21 million $ for a 900 t/d mill. These sums do not cover the wood yard or drying and baling activities. Including these departments the figures would be 9, 15 and 59 million $. Such cost figures should be treated with great care, since they are based on data pertinent only to one particular case and time. It is interesting to note, however, that the investment cost drops from 90 000 $ per daily ton at

100 t/d to 65 000 $ at 900 t/d. In 1972, the Jaakko Pöyry company estimated the same costs at 55 000 $ per daily ton at 100 t/d and 30 000 $ per daily ton at 900 t/d. The ratios are about the same in both cases.

12. At an annuity of 17% the 1977 cost estimates give a capital cost of 45 $/t at 100 t/d and 33 $/t at 900 t/d. The small mill is at a 12 $/t disadvantage, which can be serious in a price competition on the pulp market. However, it should be observed that the 1977 mill is at an even greater disadvantage compared to a mill of the same size built in 1972.

13. Clearly, it is desirable to design more economical small mills. The GWP mill is well suited for such efforts by the comparatively small size of the basic production unit, the grinder. One of the major grinder manufacturers, Tampella OY, Finland, offers standard grinders from 2 000 kW to 7 500 kW having production capacities from 50 to 150 t/d. (In practise one cannot hope for more than perhaps 2/3 of these figures as an average output.)

14. For comparison a continuous Kamyr digester may produce 1 000 tons of pulp per day. Consequently, even a 35 t/d GWP mill can be built up around a standard production unit, economically and technically competitive with the largest unit available. The great cost disadvantage of the small mill depends on the proportionally higher cost of transportation, cleaning and storing. It is a stimulating challenge to minimize this disadvantage by new technology, by standardized design and perhaps by factory assembly of whole production packages.

15. As demonstrated by the table presented later (in the chapter on TMP) the capital cost of the machinery for dewatering, drying and baling of the pulp is about as high as the cost of the groundwood plant. The capital cost will, therefore, become only half as high if the pulp can be pumped directly to a paper mill. The cost per daily ton of the drying and baling equipment is almost independent of the production capacity which is one explanation of the rather low scale factor for a GWP (and TMP) mill. On the other hand it is sometimes not possible to find a standard drying and

baling line of exactly the required capacity, and the result may then be a higher capital cost than that of a slightly lower capacity mill.

Restrictions of location

16. One hundred years ago the now developed countries were dotted with small GWP mills placed at water falls and driven by water turbines sometimes connected directly to the grinders but later usually providing the electricity for the grinder motors. Most of these plants have now disappeared, but there are still cases of paper board mills, finding it advantageous to produce their own need of GWP in one of these old plants.

17. Today, a site for a small GWP mill should in the first place be close to the source of wood and should offer cheap transportation of the pulp to the consumer. The cost of dewatering, drying and baling the pulp was in 1977 about 50 $/t including capital cost. If the GWP mill can be placed adjacent to a paper mill these cost items are eliminated as well as the cost of transportation and handling of the bales and of slushing the pulp in the paper mill.

18. The hot white water, which may be a problem in the pulp mill, will generally be an asset in the paper mill making the paper machines run better. Water pollution abatement and fiber recovery will be cheaper in an integrated mill than in separate pulp and paper mills. An integrated mill also eliminates another problem since GWP in bales of 90% dryness cannot be stored for more than 6 months without quality deterioration. A hot climate enhances such deterioration. As a consequence of all these integration gains a paper mill may find it advantageous to use much more GWP if an integrated GWP plant is available than if it has to rely on a supply - often unreliable - of baled GWP of fluctuating quality. An integrated GWP mill may be good business also in cases where a market GWP mill would be highly uneconomical.

Refiner mechanical pulp (RMP)

19. Refiner mechanical pulp is produced by refining of wood chips in disc refiners without use of chemicals or steam. The same raw materials are used as for GWP but the wood can arrive to the mill either as logs, which are then chipped, or as chips, saw dust and other residues from saw mills and

wood processing industries. The chips can easily be wet before refining and one can therefore allow them to dry out on storage. Prolonged storage of the chips will, however, cause a weight loss due to bacteriological activity - sometimes also a serious brightness loss.

Pulp quality

20. RMP is 50-100% stronger than GWP from the same wood at equal drainage characteristics, but this high strength has to be paid for by the use of about 50% more electric energy (1200-2200 kWh/t). One has a choice of methods to draw advantage of the higher strength of RMP compared to GWP:

1. The percentage of mechanical pulp in a paper can be increased with lower furnish cost as a result.
2. The basic weight of tne paper can be reduced without loss of paper machine efficiency.
3. The paper machine speed can be increased at equal machine efficiency.
4. A coarser pulp can be used, which gives faster drainage, higher bulk and higher stiffness where such characteristics are desirable.
5. Wood species can be used for RMP, which would not give an acceptable GWP.
6. Wood residues can be utilized economically.

In developed countries methods 1 and 2 are the important ones. Historically, factor 6 was responsible for the initial interest in RMP on the American West Coast, where saw mill waste was highly abundant.

21. In a modern saw mill wood canters are used, which produce good quality chips and square beams in one operation. An integrated chip refining plant then becomes partioularly attractive.

22. The strength superiority of RMP is most noticeable with respect to tear resistance - the main factor influencing the frequency of web breaks on the paper machine, which breaks also necessitate the mixing of GWP with 15-25% of chemical pulp (CP). (Tear of RMP can be twice that of GWP.) If the manufacturing process is not properly designed and the operation under control the strength advantage of RMP can be lost due to a high content of woody shives, which give rise to web breaks. In modern well managed mills this stage has been passed.

23. When the RMP process was first developed, it was observed that RMP could give a rougher paper surface than GWP. This disadvantage has also been controlled and both pulp grades now give paper with the same smoothness-density relationship. The use of RMP may, however, call for a heavier calender to obtain a given sheet density or bulk than when GWP is used. Dusting of RMP papers in the printing presses was another initial quality defect which has now been overcome. RMP also holds a lower percentage of fines than GWP and will, therefore, give a somewhat more transparent paper. This disadvantage is balanced by use of a lower percentage of chemical pulp in the paper furnish - the latter also being more transparent than GWP.

Production cost

24. It was mainly the prospect of a cheap raw material for newsprint that prompted and justified the expenses of developing the RMP process. Thus, for a long time all efforts were concentrated on making an acceptable pulp from saw mill waste, while little attention was given to the economy of the process. A general feeling developed that the capital cost of the plant was equal for GWP and RMP and that the higher energy cost of RMP was more than compensated for by a lower wood cost. Today the subject is better explored, but since almost all experience concerns thermomechanical pulp (TMP) the discussion will be limited to a comparison of GWP and TMP (see below).

Thermomechanical pulp (TMP)

25. TMP is a further development of RMP characterized by the addition of a steam treatment of the chips prior to refining. This treatment softens the chips and greatly reduces fiber damage in the initial phase of the fiber separation. As a consequence, TMP will normally have a lower shive content and a higher long fiber fraction than RMP. Dusting and linting will be under better control. Both tensile strength and tear resistance will be higher than for RMP of equal drainage characteristics. To quote firm percentages for these differences would, however, invite many protests from manufacturers of both RMP and TMP.

26. There are many varieties of the RMP and TMP processes adapted to different end products and to different refiner designs. It is today difficult to draw a strict line between the two processes. Today in a

typical TMP plant the chips are presteamed in a pressurized vessel at 120-130°C for 2-3 minutes and then immediately refined at the same pressure. They are then refined in a second stage at atmospheric pressure. Alternatives are pressurized single stage refining, pressurized refining in two stages, atmospheric single stage refining and atmospheric steaming followed by pressurized refining.

Production Cost

Quantity related cost items

27. The wood yield in TMP manufacture may be 1-2% lower than for GWP. Most published records indicate a yield in the range 92-94%. Peroxide bleaching will reduce the yield further by 1-2%. The energy requirement is 400-500 kWh/t higher than for GWP: Count with 1400 kWh/t for a board grade pulp and 1900 kWh/t for a newsgrade pulp including screening and cleaning. This difference between the two processes has remained constant for many years in spite of important process developments and seems to be built into the process. It is not significantly affected by the steaming of the chips (7).

28. For a non-integrated newsgrade TMP mill we have to count as follows:

	Quantity	Cost $/t
Wood	2.40 m^3/t	85
Electricity	2 000 kWh/t	67
Fuel oil for drying	80 l/t	7
Wrapping material, refiner plates		7
Sum of quantity related items		166 $/t

29. This is 20 dollars per ton more than for GWP manufacture. At today's prices in Sweden this cost disadvantage of TMP compared to GWP can be exactly balanced if the content of semi-bleached kraft in the newsprint furnish is reduced from 25% to 10%, which is also being done in mills going from GWP to TMP. The cost disadvantage can also be balanced by going to lower basis weight papers, which can usually be sold at a retained price per unit surface of paper. (The higher strength of TMP allows such a grammage reduction.) Still, the cost disadvantage of TMP is directly proportional

to the unit cost of energy, and it is by no means certain that it can in all cases be justified. Where it is technically possible to grind the wood to be used, it is prudent to take a close look at the economy of the two alternative processes before an investment decision is taken.

Labour cost

30. There is no difference in labour demand between a TMP plant using round wood and a GWP plant with modern transport and grinder feeding arrangements. The curve plant output - labour cost - will also be the same in both cases including office staff:

Capacity t/d	Labour cost $/t
50	40
100	20
350	9
900	7

Where labour is cheaper than in the developed countries (the Swedish wages are at the very top at 50 $/day) a small plant will be more competitive.

Capital cost

31. From an internal report from the Swedish Forest Research Institute in 1977 we quote the following estimated investment costs in millions of U.S. $.

Capacity t/d	Wood yard	GWP plant	TMP plant	Drying and baling	GWP Sum	TMP Sum
50	1	3	3	3	7	7
100	1	5	4	3	9	8
150	2	5	5	5	12	12
200	2	7	7	10	19	19
350	5	9	9	15	29	29
700	7	18	18	20	45	45
900	8	21	23	30	59	61

Capacity of plant t/d	Investment cost $/daily ton		Capital cost $/t	
	GWP	TMP	GWP	TMP
50	140 000	140 000	70	70
100	90 000	80 000	45	40
150	80 000	80 000	40	40
200	95 000	95 000	47	47
350	83 000	83 000	42	42
700	64 000	64 000	32	32
900	65 000	68 000	33	34

For comparison one can cite reference 9, where J Pöyry in 1977 gave a capital cost of 35 $/t for GWP as well as for TMP.

32. For small size plants the situation seems to be the same with respect to capital cost and to labour cost: a 100 t/d plant is relatively competitive with a large plant but for even smaller plants it is necessary to develop a different, more economical design. This will not involve any new and untried technology. It is just a matter of ordinary design work. Only the economic incentive to go ahead with it has been lacking in the developed countries.

Chemimechanical pulp (CMP)

33. CMP is a RMP, which has been manufactured from chips treated with chemicals at room temperature. The chemicals mostly used are sodium sulphite, sodium hydroxide, sodium carbonate and sodium peroxide alone or in different mixtures. Only 2-6% chemicals on the weight of wood are used and up to 50% of the chemicals added may leave the process with the pulp having reacted with the wood constituents without dissolving them. The wood yield should not be allowed to go below 90% if the good optical properties of mechanical pulp are to be retained. Many hardwoods, which cannot give good GWP or TMP, are successfully pulped by the CMP process, now that one has learnt to avoid too much loss of opacity - a serious initial problem.

34. The manufacturing cost will mainly differ from that of RMP due to the chemicals. At 3% Na_2SO_3 + 3% NaOH these will cost around 12 $/t. A 1% reduction of the wood yield means 1 $/t. In CMP manufacture both pulp quality

and economy critically depend on a strict control of the rate of dosage of chemicals. It is also very important to ensure that the chemicals have penetrated the chips before refining. Overtreatment of the chip surfaces will reduce the quality. Therefore, although the process is just as simple as the RMP one, more attention should be given to process control (10).

Labour cost

35. The labour cost for a CMP mill will be identical to the one for a TMP mill as itemized on page 9. The number of operators envisaged for the latter mill will have plenty of time for preparation of chemical solutions and supervision of the chemical reactions.

Capital cost

36. Physically the CMP plant will differ from the TMP plant only by the addition of a 10 m^3 tank for the chemical solution, an impregnator and a somewhat larger preheater. For a production of say 150 t/24 h the extra investment should not exceed 300 000 US $. This means about 2 $/t higher capital cost than for TMP.

Yield loss

37. As far as is known today the wood yield is about the same in the TMP and the CMP processes. The chemicals added may dissolve some lignin, but the objective is to control the process so that the lignin is sulphonated without going into solution. The fibres will then actually increase in weight due to sulphur bound in the fiber wall. If, however, there should be a change of yield one way or the other this will mean about 1 $/t on the raw material cost for each per cent of change.

Conclusion

38. It appears that the chemical cost is the only important factor weighing against CMP. The customer must be willing to pay at least 10 $/t more for CMP than for TMP.

Chemithermomechanical pulp (CTMP)

39. CTMP is a TMP made from chemically pretreated chips. Lately, a number of articles have been published, which report remarkable quality superiorities of CTMP compared to TMP. In particular, higher cleanliness and higher strength are claimed. The energy consumption is not significantly affected by the use of chemicals.

40. The CTMP technology is under rapid development and we still do not know which variety of the process will prevail. The disadvantage of this situation must not be exaggerated. Generally, the procedures adopted are so simple that they can easily be adjusted to fit coming process developments. The investment decisions can only be marginally affected by these. What cannot always be forsseen with certainty is how much is to be gained by going from TMP to CTMP and how the CTMP option will affect the usefulness of a certain wood species.

41. If the problem is to improve the quality of a TMP pulp, there are three possibilities:

1. To apply just the required amount of chemicals to the chips before refining.
2. To treat only part of the chips flow with so much chemicals that optimum pulp quality is obtained and to mix this higher pulp grade with the standard TMP.
3. To treat only the screen rejects with chemicals before the reject refiner

If the problem is to pulp a low quality wood, only the first of the three alternatives will be of interest, and more attention may then have to be given to the impregnation process than in pulping of spruce or pine.

Labour cost

42. The CTMP process differs from the CMP process only by the fact that in the former case the preheater is pressurized and in the latter case it is atmospheric. This will have no effect at all on labour cost.

Capital cost

43. The imprenator and preheater will have to be built as pressure vessels while in the CMP process they are atmospheric. The extra cost of pressurization will add 1-2 $/t to the capital cost compared to CMP.

44. Chemical cost will be the same as for CMP.

Comments

45. The choice between CMP and CTMP will depend on pulp quality considerations and on wood species used. There may also be a desire to produce TMP pulp as well as CMP or CTMP in the same plant. On the other hand, it is possible that with some wood species the CMP process will give a better pulp than the CTMP process.

State of the art in 1978 with respect to CTMP-Pulping

46. It is advisable to start by steaming the chips at atmospheric pressure using excess steam from the process. Thereby, air is expelled and the chips obtain uniform temperature and moisture. No chemicals should be added at this stage. The chips should then be washed in 70°C hot process white water for removal of sand and loose bark and for a more uniform chip moisture. After draining off water from the washed chips one can proceed to impregnation with chemicals. A low temperature at this stage is preferable but it is not feasible to go much below the white water temperature of 70°C. The chemicals penetrating into the wood will swell the fiber wall and react with the lignin making the latter softer and more hydrophilic. A later treatment in the standard TMP preheater causes the modified lignir molecules to polymerize so that they are less easily solubilized. Chemicals, which have not reacted with the wood, will be partly recirculated with the white water back to the CTMP mill. No chemical recovery process is needed.

Process Alternatives

Bleaching of mechanical pulps

47. All mechanical pulps can be bleached to 75-80% brightness with sodium peroxide. If a brightness level of 70% is adequate, bleaching can be done

simply by addition of 2% peroxide to the dilution water going to the first stage refiner while controlling the pH at close to 8. If a brightness above 75% is required, it will be necessary to add a peroxide bleach tower for a 2 hour treatment of the prebleached pulp after screening and dewatering to 15% consistency. It is not usual to wash the pulp after bleaching. Excess peroxide will do no harm to the process or the machinery.

48. While peroxide bleaching of mechanical pulp has been practised for a long time, it is only lately that one has learnt to arrange the process in a way also to obtain an appreciable improvement of strength and cleanliness. According to reference 11, refiner bleaching can give 10% energy saving at a given freeness level and at the same time a 10% tensile strength improvement. Peroxide treatment is, therefore, one of the alternatives if the TMP quality is to be improved. At the 2,5% peroxide level, which may give 75% brightness with spruce wood, the cost of all the chemicals needed (peroxide, alkali, sodium silicate, chelating agents) will amount to 29 US $/t. Peroxide is, therefore, only of interest if a high brightness is needed as well as high strength.

Alkaline sulphite treatment

49. If strength and cleanliness are the prime considerations, an alkaline sulphite treatment should be considered. With 3% sulphite + 3% alkali the cost of the chemicals will be around 12 US $/t. A tensile strength improvement of 40% at a given freeness level appears obtainable with 2% sulphite. The same addition can increase the wet strength of the paper by 30% and raise the brightness from 60% to 65%. The cleanliness of the pulp is dramatically improved, presumably because the shives become softer and more easily disintegrate into fibers in the reject refiner (12).

Alkaline-sulphite plus peroxide

50. If one wants to combine maximum strength with high brightness it is technically possible to add a peroxide tower after an alkaline sulphite CTMP plant. Since a reaction between sulphite and peroxide must be avoided, the stock should be pressed to high dryness before the bleach tower. This involves capital expenses which may make the alternative less attractive. Although the technology required is fully developed no such system is in operation.

51. CTMP can be made both from softwood and hardwood but the chemical reactions in the wood are different. Hardwood calls for more alkali and less sulphite than softwood. The optimum mix can be found by pilot plant experiments if one does not choose to go by published accounts (12, 13, 14, 15).

Ozone treatment

52. Although only one installation is as yet in operation the ozonation process has stirred up a lot of interest. To a process engineer ozonation must certainly appear an intrigering possibility to influence the characteristics of the fiber surfaces. The process, however, is not enough advanced for a detailed presentation to be justified, and the comparative complications of the process do not make it very suitable at this stage for developing countries.

Limitations of mechanical pulps

53. By definition a mechanical pulp is produced by (mainly) mechanical treatment of wood. The wood yield should be above 90% and the pulp, at least in the initial stage, should become more opaque on refining, while chemical pulp on refining becomes more transparent. What this means is that the fibres in mechanical pulps are basically wood particles with most of the intrinsic characteristics of wood. The percentage of cellulose, hemi-cellulose and lignin are about the same as in the virgin wood. However advanced the process, all mechanical pulps are subject to three limitations:

1. A stable brightness above 80% is not obtainable, and any brightness improvement achieved is rapidly lost by exposure of the paper to sunlight.
2. A paper strength adequate for packaging paper is not obtainable.
3. Paper containing mechanical pulp will become brittle and yellow after a number of years and is therefore not suitable for books or important documents.

Main uses of mechanical pulps (MP)

54. MP is used in newsprint and also to some extent in most other printing papers. It is found in many tissue products and sometimes in the center ply of paper board. The important market is newsprint. Newspapers are printed with an oil based ink which is "dried" by absorption of the oil into the

paper, and only MP can give the newsprint the rapid oil absorption required. There is no substitute for MP here. Other pulp characteristics explaining the wide use of MP are high opacity, bulk and stiffness. The comparatively low price of MP makes it desirable to use as much as possible of it considering the quality requirements of the paper and the operating requirements of paper machinery and printing presses.

Water pollution in MP manufacture

55. During grinding and refining 3-5% of the wood are transferred into colloidally or chemically dissolved matter, which eventually ends up in the effluent - either in the pulp mill or later during paper manufacture. The ecologist will talk about a biological oxygen demand of the mill effluent of 10-20 kg/t of pulp in MP manufacture as compared to 20-40 kg/t of pulp in MP manufacture as compared to 20-40 kg/t from a conventional mill for bleached kraft pulp (3) (6).

56. The water pollution caused by an MP mill need not be very alarming. If the use of fresh water is restricted to 10 m^3/t which is entirely feasible, the effluent can be aerated in lagoons at reasonable cost. A retention time of 4-5 days and an energy consumption of 10 kWh/t of pulp should provide a BOD reduction of 60-80% (4). The effluent does not hold any poisonous matter except for wood resinous acids, which do have a toxic effect on fish but which are rapidly broken down by aeration. The main problem is to avoid a local deficiency of oxygen in the recipient immediately below the mill. If the rate of flow in the recipient is sufficient to prevent such a deficiency, there may not be much to worry about technically. In principle this goes for all mechanical pulping processes although the conditions will differ somewhat as shown in the table below.

57. In all mechanical pulping it is advantageous from a pulp quality standpoint to control the temperature of the circulating white water at 70°C. This means that the effluent will be close to this temperature and will have to be cooled down to 35°C before biological treatment. In northern countries this is no problem. In a warm climate, however, an MP mill may cause an undesirably high river temperature. In much cases cooling towers can be used. The technology if fully developed: The white water is cooled in a

heat exchanger and the (clean) cooling water is pumped to the cooling tower and from there back to the heat exchanger. Capital and operating cost for such white water cooling is not unreasonable. For a well run 400 t/d plant it may amount to 24 $/day.

Actual operating conditions with respect to water pollution in Sweden in 1974

	Water usage	Effluent load	
	m^3/t	BOD kg/t	Fiber kg/t
Mechanical pulp mill	78	15	4
Newsprint mills with integrated pulp mills	74	17	10
Chemical pulp mills	190	36	9
Separate paper mills	130	4	4

58. These are average figures for the whole industry. By closing down some old mills and modernizing others it has been possible to substantially improve the situation. In particular, it has been possible to dramatically reduce the fresh water consumption. Some modern integrated newsprint mills are down below 10 m^3/t.

Effluents from mechanical pulp mills

(Data derived from recent publications (3) (20) (21)

	BOD_7 kg/t
GWP-mill	10-15
TMP-mill	10-20
Peroxide bleach plant	10-20

59. As indicated by the wide ranges above, one can significantly influence the BOD-generation by process parameters such as pH, temperatures and system closure. The figures quoted refer to Norway spruce (Picea Alba). Pine of high resin content will give higher BOD-values.

Semichemical pulps

60. The two common grades of semichemical pulp are cold soda pulp (CS) and neutral sulphite semichemical pulp (NSSC).

The cold soda process

61. As the name implies, the raw material is treated with alkali at room temperature before refining. Earlier, this refining was done in pump-through refiners at 4-5% consistency giving pulps of poor cleanliness and strength. The process, which is only applicable to hardwood, was first introduced in 1955 and for some years became quite popular in the U.S., but later it had to yield to the NSSC process (1). A modern cold soda plant would use high consistency refining in 1 500 or 1 800 RPM refiners and would in fact be a CMP plant, although at a yield of 75-85% the pulp should be classified as semichemical rather than as mechanical.

62. Compared to other chemical and semichemical pulping processes the cold soda process has a very uncomplicated system for liquor recovery: Exploration and burning of the waste liquor and leaching of the alkali from the smelt. The only difficulty is to obtain economy from this operation and still avoid water pollution.

63. What made the industry lose interest in the cold soda process was that higher quality pulp could be obtained by other processes using sulphur in some form. Present experiementation in the area of sulphur-free pulping may lead to improved varieties of the cold soda process. The modification could be as simple as the addition of a small amount of catalyst to the alkali. Therefore, also in developing countries understandably wary of untried technology it may be wise to follow closely the developments in this field.

Neutral sulphite semichemical pulp (NSSC)

64. NSSC can be produced from most species of hardwood. The chips are steamed at atmospheric pressure and impregnated with a solution of sodium sulphite and sodium carbonate at a pH of 8-9. The wet chips are digested by steaming (vapour phase) in a pressure vessel at 160-180°C for 15-60 minutes. By this process about half the lignin and one third of the hemicellulose are dissolved. The cellulose, however, is not attacked under normal oooking conditions. The middle lamella, which holds the fibers together, has (especially in hardwoods) high contents of lignin and hemi-

cellulose and is therefore primarily attacked by the cooking process. As a result, a later refining of the digested chips will give comparatively undamaged, strong fibers. Softwood is less suitable for this process because of a lower lignin content of the middle lamella.

65. The wood yield is in the range 75–85% which means that some kind of liquor recovery is necessary in order to limit the pollution of the recipient. Below 75% yield the pulp quality will deteriorate and other pulping processes become more attractive. A normal level of consumption of chemicals is 8–10% sodium sulphite and 2–5% sodium carbonate.

Labour cost

66. A cold soda plant or a NSSC plant will always be a department of a paper mill and the labour cost can be seen as a certain part of the total for the mill or it could be referred only to the extra personnel needed for pulping. For a 150 t/d plant this extra personnel will be:

		Employed
Wood room operators (2 shifts)	3	9
Pulping operators	2	10
Extra maintenance (day-shift)	3	3
Process and quality control	2	2
Superintendent	1	1
Total employed		25
Labour cost:	8 $/t	

Capital cost

67. All modern NSSC mills have been built as integrated parts of kraft pulp and paper mill combines and the capital cost of the NSSC-plant is, therefore, practically impossible to extract. To judge from the relative complexity of the process one can perhaps guess at a capital cost which is 70% of the one of a kraft pulp mill (see below).

Production costs

	Quantity	$/t
Wood (hardwood)	2.4 m^3/t	(50)
Energy refining	300 kWh/t	10
Energy screening, pumping	300 kWh/t	10
Chemicals	12 %	30
Steam for digesting	1.0 t/t	7
Total quantity related cost items:		107 $

68. The production cost of NSSC depends mainly on the cost of the wood used. Where there is a local surplus of hardwood, conditions will be far more advantageous than where hardwood can also go to a kraft mill. Under Swedish conditions NSSC will be 5-10% cheaper than CTMP and 25% cheaper than unbleached high yield kraft.

Use of NSSC

69. The important quality characteristic of NSSC is stiffness combined with a certain tensile strength and absorptivity. The pulp is almost exclusively used for fluting although blended with kraft waste fiber for economy and increased wet strength. It is also possible to mix a little NSSC into the kraft furnish for liner to obtain increased stiffness. In both applications NSSC will give superior paper characteristics compared to CTMP or kraft waste paper.

Recovery of chemicals

70. The NSSC process would lend itself ideally to manufacture of pulp from mixed hardwoods in small plants right in the forests. Instead, we find the NSSC plants to be relatively large and generally built adjacent to a kraft mill. The explanation is that the only practical method of recovering the cooking chemicals is to pump them into a kraft mill black liquor recovery system (cross recovery).

71. The waste liquor (red liquor) obtained by washing of NSSC has a consistency of 8-12% and holds 400 kg of organic matter per ton of pulp. It is nowadays seldom permitted to sewer such quantities of oxygen consuming matter. If the red liquor is evaporated to 50% consistency and burnt in an oven the stack gases can be used for the evaporation process. A regular

recovery boiler is generally not economical in this application. The smelt from the oven now contains the chemicals but unfortunately not in a useful form. Several systems have been developed for conversion of the chemicals but none of them is economically very attractive and all are too complicated for a small, isolated NSSC mill even in a fully developed country (18). These circumstances seem to rule out the building of small NSSC mills in rural areas. On the other hand, locally made fluting of high quality would be desirable in many countries, and suitable wood for such a product is quite often available. It is, therefore, in the interest of developing countries that a more suitable semichemical pulping process be developed.

Sulphate pulp

72. Sulphate pulp is produced by digestion of chips in a liquor of mainly alkali and sodium sulphide at 160-170^{o}C for 2-3 hours. By choosing the appropriate operating conditions one can manufacture a wide range of pulp grades from high yield liner pulp to dissolving pulp. In Sweden 60% of all pulp is manufactured by the sulphate process - also referred to as the kraft process.

73. For developing countries the kraft process has the special attraction that almost any wood can be used - hardwood as well as softwood. It is also possible to process a blend of species without great inconvenience. Unbleached softwood kraft pulp is unsurpassed for packaging papers (sack paper, wrapping paper, liner) while bleached hardwood pulp is a soft, opaque, easily refined pulp of high and stable brightness, suitable for printing paper, tissue and paper board.

74. Still, especially in developing countries, there are reasons for avoiding this process where possible:

1. The scale factor: Due to advanced technology used in kraft pulping and applicable only to large plants a small pulp mill is not competitive with a large one. A large Scandinavian plant produced 200 000 - 400 000 tons per year. In 1972 it was computed that a bleached kraft mill for 35 000 tons/year would cost 2.6 times as much per daily ton as one for 350 000 tons/year. Today this ratio is probably higher. For a mechanical pulp mill the capital cost is

only 25% of that of the kraft mill and the specific cost increases more slowly as the plant size is reduced (19).

2. Availability of chemicals: It may sometimes prove difficult to ensure reliable deliveries of the chemicals and raw materials needed in kraft pulping and bleaching.

3. Technology: Kraft pulping involves a number of chemical processes, which all have to be controlled very strictly. In an isolated small mill it may prove difficult to establish the necessary standard of supervision.

4. Ecology: In a developed country and a large kraft mill it is today possible to avoid both air and water pollution. Even in Sweden a small kraft mill poses almost insurmountable ecological difficulties, because of the exorbitant cost of the required anti-pollution measures. The difficulties are caused mainly by the use of sulphur in the process, but sulphur is in fact also the prerequisite for the favourable quality mix exhibited by kraft pulps. In developed countries small kraft mills are closed down or rebuilt into large, modern units, and the development of new anti-pollution technology is geared exclusively to the needs of the latter type of plant. The same goes for the pulping technology.

The future of kraft pulping

75. Since kraft pulping cannot be entirely avoided in developing countries, it should be realized that the potentials of adapting the kraft process to conditions and requirements of such countries have not really been explored. When a new small plant is ordered like for example the 150 t/d plant at Bai Bang in Vietnam, time will not allow anything but standard technology. Conditions should be more favourable for special development when the plant is to be built on a barge like the one recently shipped from Japan to Brazil. (This, however, was a 750 t/d plant.)

76. What is needed is a fresh look at each process step: perhaps in-line mixing instead of blending tanks, perhaps filters instead of settlers, perhaps presses instead of filters, perhaps ejectors instead of vacuum

pumps and so on. In each such analysis the result should be based on the requirements with respect to capital cost, operating cost, maintenance cost, process efficiency and product quality which apply to the project investigated.

77. Even so, it is not likely that a small kraft mill built today in a developing country will ever be able to compete economically with a large kraft mill built in a developed country in the early 70-ties or earlier. Reference 22 cites actual experiences from a large Canadian pulping company, according to which four 650-800 t/d bleached kraft pulp mills started up in the period 1967-1978, carried the following investment costs per daily ton:

Start-up	Investment cost $/daily t
1967	88 000
1972	105 000
1977	229 000
1979	300 000

78. According to this table at 17% annuity a new large mill will have 100 $/t higher capital cost than a slightly older but still modern mill of the same size. If we add a scale factor of 2.0 a small mill started in 1979 would cost 600 000 $/t and be at a disadvantage of 250 $/t compared to a large plant started up in 1967 - and for a long time the output from the latter plants will dominate the export market. Add to this that a 17% annuity may not always correspond to financial realities for new ventures. The conclusion seems to be that when small kraft mills are built in developing countries, one should from the start count with their becoming economically uncompetitive on the world market. The ventures may still be justified because of the effect on the industrial structure of the country, the reforestation, the labour situation or the foreign exchange.

Sulphur-free pulping processes

79. The trade magazines are today full of references to work on new sulphur-free pulping processes. The interest in this subject is explained partly by mounting public complaints about kraft mill odour, partly by the prospects

of sulphur-free pulping becoming less complicated than kraft pulping. For example, caustizising and lime burning would become unnecessary, gas collection and washing could be eliminated. Anthraquinone pulping is the one of these processes that appears to be the farthest ahead. Pulping with alkali and 0.1-1.0% anthraquinone has given pulps with somewhat higher yields but also somewhat lower strength than kraft. The economy of the process, however, is still not very attractive and at this stage of the technological development of it, it would not be a serious alternative for a project in a developing country (23) (24).

Oxygen-alkali pulping

80. For many years now kraft pulp has been bleached with oxygen in a first bleach stage, which removes about 40% of the lignin from the pulp. Bleaching is then continued in a conventional bleach plant. Attempts are being made to extend this process to the initial delignification of wood. The process is, however, at an early stage of development.

81. One example of this trend is a Finnish process for hardwood pulping, which consists of digestion for 3 hours with 15% alkali at 155°C, refining in-line and immediate treatment with oxygen at 10 bar. The pulp can then be bleached with peroxide to 70% brightness. This is a comparatively simple process. The pulp quality is inferior to kraft but may be satisfactory for many purposes. For example, it could be mixed with kraft pulp for use in liner. Enough data is not available to estimate the economy of the process (25) (26).

Labour demand in kraft pulping

82. This is a subject on which it is extremely difficult to be precise since there is little in common between the two extremes: the 50 000 t/y batch digester plant for unbleached kraft and the 400 000 t/y continuous digester plant with oxygen and chlorine dioxide bleaching. The following statistics refer to Swedish conditions in 1967:

Labour demand in unintegrated kraft mills for bleached, dried and baled pulp:

	Manhours per ton of pulp
Wood handling	1.09
Production of unbleached pulp	1.43
Bleaching	0.41
Dewatering, drying and baling	1.16
Total	4.09

83. This table refer to a 125 000 t/y mill. The scale factor is of little importance in the range above 250 t/24 h. A 100 t/24 h plant, however, should count with at least twice the manhours shown in the table above. The change in labour demand since 1967 is not believed to amount to very much in modern mills but some old mills have been closed down which will have lowered the average values for the country somewhat.

Choice of Process for a Given End Product

Technological Considerations

Newsprint

84. The use of oil based printing inks necessitates mechanical pulp in newsprint. Chemical pulps do not give the paper a fast enough oil absorption.

85. The paper web is subject to transient stresses on the paper machine, in the winder and on the printing press, which necessitates a certain combination of tensile strength, tear resistance and stretch of the paper, characteristics which are obtained by mixing of 10-25% chemical pulp with the mechanical pulp. The mix required depends on wood species, production processes and paper quality requirements.

Raw materials

86. Practically all types of softwood can be used although spruce is preferred to pine (except perhaps Pinus Radiata) due to its lower pitch content and lower energy requirement. In a developing country, however, softwood may be in such a scarce supply that it is more advantageously reserved for packaging papers, for which there is no good alternative to softwood.

87. Hardwood is used for newsprint in several countries. Thus, 6-8 years old poplar is ground in Italy together with no more than 30% softwood. Twenty-five per cent CP is added to the newsprint furnish. A newsprint mill recently started up in Greece has a TMP plant planned for use of poplar (27). The higher strength obtainable with the CTMP process may further increase the usefulness of poplar in newsprint.

88. In Australia, Eucalypt is used as the main constituent of newsprint furnishes. The wood is ground under alkaline conditions using a specially developed technique, which gives the pulp an acceptable wet strength in spite of the short average fiber length (0.9 mm) of Eucalypt (28) (29). If a new plant were to be built today, the technique to be applied would definitely be the one of the CTMP process. Reference 30 reports on a CTMP from Eucalypt using 4% chemicals and 1 200 kWh/t and having a strength comparable to softwood GWP. Reference 31 also demonstrates the suitability of Eucalypt CTMP for newsprint. As far as is known, however, there is still no newsprint mill in operation using Eucalypt CTMP.

89. Aspen is used for RMP and TMP in North American magazine paper mills and could certainly be used also for newsprint (32). Gemlina Arborea is an African hardwood recently attracting interest and found to be a possible choice for newsprint (33). Bagasse can be processed into a pulp, which - although not strictly a MP - lends itself to newsprint manufacture. Bagasse newsprint has been made for a long time on a small scale, but recently a 390 t/d newsprint mill has been built in Peru, which uses 75-90% bagasse fiber prepared according to the Cusi method: The bagasse is given a comparatively weak alkaline cook and is then fractionated. The coarse fraction is refined and the two fractions are then blended. One advantage of this process is that the pulp can be refined without loosing too much drainage (34).

90. In general, the development of many new pulping processes has made it much easier to find a suitable raw material for nesprint. If newsprint manufacture is contemplated in a new location it is advisable to make a careful assessment of the suitability of the raw material available considering all the pulping processes applicable. This can usually be done with adequate reliability by pilot plant pulping at a research laboratory or in the laboratory of some machinery supplier.

Optimum furnish mix

91. There are paper mills operating where newsprint is made from imported pulps exclusively. One example is the American-Israeli Paper Mill at Hadera, Israel. On the European continent there are newsprint mills based on imported wood for grinding and imported dried and baled CP. These mills, however, find it quite difficult to compete with imported newsprint. A better approach is an integrated MP-plant and a regular supply of imported kraft pulp.

92. If softwood is available for MP to a contemplated newsprint mill the feasibility of a single furnish plant becomes interesting. Many articles have been published on the characteristics of newsprint made from 100% TMP. A Finnish paper mill (Kaipola) is actually now offering such paper within a wide bases weight range (35).

93. Newsprint manufacture based on 100% local MP has considerable attraction to a developing country. Capital cost, furnish cost and labour cost should all be lower than if a blend of MP and CP are used. A somewhat lower speed on the paper machine and in the printing room will be no great inconvenience. In case of temporary operating troubles the strength can be boosted by addition of starch or other chemicals. Making newsprint from 100% MP calls for some process modifications, which are easily incorporated in a new plant. The technology is well proven.

94. One particular difficulty of newsprint ventures is that newsprint is such a low price product that one wants to make it on the widest and fastest paper machines possible. In developed countries a modern newsprint machine may have a capacity of 500 t/d. In developing countries the answer to this problem can be to use one paper machine for the manufacture of both newsprint and a number of other paper grades. This is certainly possible, but it will not be easy to design a machine, which fits one product without being sub-optimal for another product. The paper mill system should be designed to allow trouble-free switching from one product to another and the white water system should be compatible to all the products. A high level of paper making competence will be called for.

Magazine papers

95. The title covers a wide range of printing papers holding 60-100% MP. The basis weight range is 25-170 g/m^2. The papers can hold up to 25% fillers and can be unsized, surface sized or coated. They can be glazed or unglazed, bleached or unbleached. This diversity makes magazine paper particularly attractive for manufacture in developing countries. Knowing the technical requirements of the printer (which the printer may not always know himself) and the wood species and fillers available one can, as a rule, find many alternative answers to the equation. Procedures in developed countries should not be copied too closely. For example, surface sizing with starch may be more economical compared to the use of high strength CP than it is in developed countries. Lower surface smoothness requirements may allow pulp of higher bulk to be used a.s.o. The printing presses of the country in question may differ from those of developed countries.

96. Magazine papers and other MP printing papers can be printed by offset, letterpress or rotogravur and each process has its own paper quality requirements calling - to some extent - for different raw materials and paper machine specifications. One specific aspect of this problem is now beginning to concern people in the developed countries. For many years, due to hard competition, paper has been relatively inexpensive commodity, and the market has been responding more strongly to paper quality differences than to the corresponding price differences. As a consequence, the market has become adapted in many cases to brighter, stronger and higher basis weight printing papers than are actually needed. The content of MP in the papers has also been kept below the level technically possible. When a new market is to be built up in a developing country there is no need for emulating such wasteful habits. For example, it should be entirely satisfactory to use paper with 40% MP for school books, pamphlets and communications from the administration. There are a great many published articles on this subject, which would be helpful in a market study, reference 36 being just one example. A government body conducting such a study has the possibility to order trial shipments of papers from established manufacturers in order to establish the feasibility of the applications under consideration.

Fine papers

97. Paper for books and documents which are to be kept for a long time should be made from 100% CP. The lignin constituent of the wood ought to be removed by the cooking and bleaching processes, since it is responsible for the aging and yellowing of paper. It is also desirable to remove a substantial proportion of the hemicelluloses, which tend to make the paper transparent on refining of the pulp. Opacity being more important than strength hardwood CP is used to the highest extent possible considering the demand for paper machine efficiency. A mix of 70% hardwood and 30% softwood kraft is usual in fine papers.

98. For many years bleached hardwood kraft pulp has sold at a surprisingly low price, one reason certainly being the availability of Eucalypt pulp from large new production units. Such pulp can be shipped over long distances and can be stored for many years without quality deterioration. The pulp will be used to a large extent in small unintegrated paper mills, to which it does not matter if the pulp is imported or comes in bales from a pulp mill in the neighbourhood.

99. From a quality standpoint fine paper mills prefer dried, baled pulp to pulp pumped directly from a pulp mill - opacity and formation of the paper are more easily controlled. Pulp quality variations are also more easily taken care of if the pulp arrives as bales. A fine paper mill generally makes a number of paper grades and therefore wants access to many pulps, mixed in suitable proportions to meet the requirements of each paper grade. All this means that to a fine paper mill an integrated pulp mill is likely to be a technological embarrassment. Large integrated fine paper mills are being operated in developed countries because of the considerable economic advantage of integration and because in large mills technology can be applied efficiently to the process difficulties of integration. In a developing country an integrated fine paper mill will be more difficult to justify. At any rate a market pulp mill filling the demand of several paper mills should be studied as an alternative.

Tissue

100. The tissue consumption in a developed country is about 30 kg per year and inhabitant. This figure allows us a rough estimate of the latent demand

for tissue in a certain developing country. To any country with efficient tissue mills this commodity does not need to be a luxury since the manufacture of tissue should meet no great difficulties anywhere.

101. Although a modern tissue machine is a product of advanced technology, it is comparatively simple to operate and maintain. Actually, the latest generation of twin wire tissue machines is a less complicated machine than the previous generation of tissue machines featuring suction breast roll and fourdrinier wire table. Tissue can also be produced economically on quite a moderate scale and from cheap raw materials. At a speed of 900 m/min. the output of a tissue machine will be about 20 t/d and meter width. Even in Sweden there are tissue mills with outputs as low as 10 000 t/year, the average for the whole country being 20 000 t/year. Tissue is manufactured by a creping process: the thin paper web is dried on to a steam heated "yankee" cylinder of 4-5.4 m dia and scraped off from this cylinder by the creping doctor, which operation gives tissue its characteristic softness and bulk.

Location

102. A yankee cylinder of 5 m diameter and 4 m width presents a formidable transportation problem and limits the location of a tissue mill to sites, which can be reached by such a transport. Because of the wear of the creping doctor against the cylinder one has to plan for a replacement of the cylinder after 10-20 years and renewed transportation problems.

103. The low output of most tissue mills makes integration impractical - the pulp mill would become too small. Besides, the runnability of the paper machine is advantageously controlled by manipulation of the furnish composition. Thus, the proportion of hardwood and softwood kraft may determine the adhesion of the web to the cylinder (this adhesion determines the creping process and thereby the paper quality) (37).

104. A tissue mill should, therefore, not be placed in the forest but as close to the market as possible, thereby minimising the cost of shipping the bulky products to the consumers. Another reason for such a location is that deinked newspaper is both a cheap and a suitable raw material and is, of course, best collected in a densely populated area.

Raw materials

105. An estimate by the Swedish Forest Research Institute in 1977 gave the following prices for the pulp grades used in tissue.

			$/t
Deinked news from integrated plant			180
Unbleached GWP	dried, baled		260
Unbleached TMP	"	"	270
Bleached sulphite pulp	"	"	410
Bleached sulphate pulp	"	"	410
Bleached GWP	"	"	300
Bleached TMP	"	"	330

This table is presented only as a guide to the price relations. The important fact to emerge is the low price of deinked news compared to all purchased pulps.

106. Tissue of the best quality with respect to softness and absorptivity is obtained by use of bleached chemical pulps. For economy it is possible, however, to use 50-80% mechanical pulp in some grades. TMP should be preferable to GWP because of a lower fines content and a higher strength, but it is not certain that this always justifies the higher cost of TMP. Hardwood CTMP has not been seriously evaluated for this application, but is likely to give dusting problems due to the short fiber length of hardwood. Tissue with a high content of MP can have acceptable absorption but will be somewhat inferior with respect to softness. Much depends on whether with MP in the furnish one can control the web adhesion to the Yankee cylinder and thereby the creping.

107. A tissue mill built adjacent to a kraft pulp mill can become quite competitive, since slushed pulp will be 75-100 $/t cheaper than baled pulp. One such mill is operating in Sweden. Deinked news normally holds 15-25% chemical fibers, which makes the pulp particularly suited for tissue. A tissue mill adjacent to a large mechanical pulp mill and using part of the pulp output is another possibility. TMP slush pulp is not likely to become cheaper than deinked news, but the supply would be more reliable and of more uniform quality.

Fresh water demand

108. Old tissue mills may report fresh water consumption figures of up to 300 m^3/t mainly due to the water consumption of felt and wire showers. Using modern technology one can reduce this figure to 30 m^3/t. There are even tissue mills operating without an effluent, but this should not be tried unless necessary. Total closing of the white water system will result in a very high salt content in the water and serious corrosion of the expensive perforated rolls used in the paper machine. The chemistry of this situation has been extensively studied, and it has been shown that the rate of corrosion is a function of pH and temperature and of the concentration of organic matter, chloride and sulphate ions (38 - 41). Unless competent chemists are available to watch the reactions it is better to stay with a certain fresh water consumption. Thirty m^3/t can be taken as a first guideline until it has been established what is in each case a safe level of system closure.

Energy requirements

109. A modern tissue machine has a very low energy requirement. A 3,5 m wide machine running at 700 m/min. requires only 30 kW for the drive. Refining of the pulp should take no more than 150 kWh/t. The ventilation fans of the high velocity hood requiring 75 -100 kWh/t are the major energy consumers. The total energy requirement will be around 300 kWh/t.

Heat requirement

110. In tissue drying about half the evaporation is due to heat flow from the cylinder, the other half coming from the gas heated ventilation air. The total heat demand corresponds to about 150 liters of fuel oil per ton of paper.

Liner and Fluting

111. Liner and fluting are the two constituents of corrugated fibreboard. The economic losses due to damage of merchandize shipped in corrugated board boxes can often be traced to the inadequate strength of the corrugated board. The latter is, therefore, sugject to a rigorous quality control. The strength tests on the corrugated board have been correlated to the test values for liner and fluting, which makes it possible to trace strength deficiencies of boxes all the way back to the paper mills.

Kraft liner

Raw Materials

112. Kraft liner is made from unbleached kraft pulp of two grades with slightly different properties:

	Base pulp	Top pulp
Wood yield %	54	48
Kappa Number	80 - 90	45 - 55
Freeness SR	18	30

The base pulp should give the liner high strength, high stiffness and high bulk while the top pulp should give it a cleaner and smoother surface with better printability than the base pulp would give alone. 15 - 20% of NSSC can be mixed into the base pulp for economy and increased stiffness. Alternatively one can mix in about 10% corrugated waste, which also holds NSSC in the fluting. A new Swedish liner machine is designed to make a 3-ply liner with 30% waste pulp constituting the middle ply, which is claimed to give quality advantages.

113. To compete with Scandinavian and North American grades kraft liner has to be made from pine. For local markets it may be possible to use Eucalypt and some other hardwoods. A decision on such use, however, should be based on very careful evaluations of the pulp grades considered. Maybe something can be gained by a judicious use of water repellant or strength promoting chemicals (43). It may also be possible to construct corrugated board boxes with increased weight compensating for a low liner strength and stiffness. There are specialized packaging laboratories available for such studies in many countries.

Technology

114. Kraft liner has a basis weight of 125 - 350 g/m^2, of which the top ply is usually 30 g/m^2 independent of liner basis weight. Kraft liner is a well standardized "bulk" product. A converter can easily switch from one supplier to another and will go by both price and strength data. Hard competition on both counts has resulted in a trend towards large, high-speed liner machines in technically advanced mills, always integrated with a

kraft mill, sometimes also an NSSC mill. The capacity of a modern liner machine is 200 000 - 350 000 t/year. Obviously, it will not be easy for a developing country to compete with such a unit on the open market, where the demand has been constant since 1970. All the same, kraft liner mills in the capacity range 20 000 - 30 000 t/year are being built in developing countries. In South America two kraft liner projects in the range 150 000 - 200 000 t are being built. These plants can very well be justified as suppliers to a local market.

Fluting

Quality

115. Fluting is the corrugated paper, which keeps apart and holds together the two liner plies of corrugated board. The standardised basis weights are 112, 127 and 150 g/m^2. The important characteristic of fluting is stiffness, which is required in the machine direction to prevent "flat" crushing of the board and in the cross direction to give the board rigidity. In proportion to its weight the fluting has more influence than the liner plies on the rigidity of the board. It is, therefore, not practical to combine a high quality liner with a low quality fluting. The two should be of matching qualities.

116. Apart from stiffness fluting needs a certain thermoplasticity in order to take on a fluted configuration in the fluting machine. The absorptivity must be just right to allow a strong glue bond between the flutes of the fluting and the contacting liner plies. The wet strength must be adequate for good machine runnability.

Raw material

117. The fluting made in the large (200 - 700 t/d) Scandinavian fluting mills is based on NSSC from birch made in integrated mills. 10 - 25% corrugated waste are mixed with the NSSC in order to increase the burst strength and lower the cost. Waste fiber, however, will reduce the important stiffness of the paper.

118. On the European continent fluting is being made on much smaller machines using waste paper and even straw pulp as raw material. This

fluting used to be greatly inferior to Scandinavian fluting with respect to stiffness until a practise was adopted to treat the paper with starch and chemicals in a size press on the machine. This development has now made the waste paper based fluting highly competitive. In a developing country a reliable supply of corrugated waste may present a problem, but the same technique of size press treatment may enable manufacture of acceptable fluting from locally made cold soda pulps based on straw or hardwood.

119. Improving the wet strength of fluting by chemicals would be no problem if one did not also have to think of the absorptivity needed for the glue to give strong ply adhesion in the corrugator. In looking for new types of raw material one must not forget the runnability of the paper machine. A wet web of mainly hardwood fibers has a rather low wet strength, and a wood shive remaining in it will easily cause a web break and perhaps half an hour of lost production. It is important that the cooking liquor penetrates the wood properly since parts not reached by chemicals tend to become shives. The shive content can be reduced by refining but there is a limit to how far one can refine without endangering the drainage on the paper machine wire, which is slow enough under the best of conditions.

Paper machines for fluting

120. To make fluting is not easy. The furnish drains slowly and tends to give a sheet with poor formation. The strength requirements call for constant compromising between quality parameters and resetting of machine variables. It is, therefore, of interest to know that new technology has been developed, which has made the undertaking easier. Adopting such technology a new mill can gain important advantages in the competition (44, 45, 46).

121. Such new technology is not always synonymous with a high level of automation and instrumentation. On the contrary, there are developments which decrease the need for instrumentation and significantly lower the capital cost. For ventures in developing countries one should, therefore, neither request the most modern technology nor stipulate that every process has to be conventional and well proven. There are cases where an old second-hand machine is the correct choice and there are cases where it is unpardonable to neglect the opportunity to take advantage of new developments.

Fresh water usage

122. In fluting manufacture from NSSC fines and dissolved matter from the pulp give a very "rich" white water to the sewer. A level of 0.4 g/l of fines and 8 g/l of dissolved matter are normal figures and for a machine with a fresh water consumption of 15 m^3/t (after filtering of the excess white water). Biological treatment of the surplus white water is a rather difficult and expensive project when put in relation to the low cost of the product. It is technically possible to close the system so far that the level of dissolved organic matter reaches 30 g/l. It then becomes feasible to evaporate the surplus water and burn the 50% concentrate (as is in fact being done in a Swedish building board mill).

123. The cost of biological treatment varies within very wide limits. Now that operating experience from the first installations is becoming available it is possible to design more economical plants than those of "the first generation". Reference 47 estimates the US cost in 1976 at 3 $/t for treatment in aerated lagoons and 6 $/t for activated sludge treatment (800 t/d bleached kraft pulp mill). In planning a new production facility one should take into consideration the influence of raw material, machine type and process design on the cost of effluent treatment. It is also important that the anti-pollution regulations are technically and economically realistic. The literature in this field is so voluminous that only a specialist can find the time to digest it, but the specialist chosen for this job should have a thorough background of practical pulp and paper making in order to be able to draw relevant conclusions from the facts reported in the literature (47, 48).

Paper board

124. The basis weight at which paper becomes paper board is not strictly defined, but above 225 g/m^2 we are definitely talking about board.

Kraft liner straddles this line with a basis weight range of 125 - 350 g/m^2. It has been discussed separately.

Solid board is made on one layer usually on a conventional fourdrinier paper machine at basis weights of 150 - 300 g/m^2. The products are often custom made to fit the needs of a certain converter and are produced in small quantities. This is an example of paper making, where paper making skill and customer connections are more important than machinery. Baled pulp is used but can be supplemented by fiber from waste paper treatment plants. The activity is well suited to a developing country, the major prerequisite being to bind a skilled and competent plant manager.

Folding boxboard is used, as the name implies, for boxes. The usual basis weight range is 200 - 400 g/m^2 and the board is built up from at least three plies:

Top ply : 50 - 60 g/m^2. A blend of bleached hardwood and softwood kraft pulps

Center : 100 - 300 g/m^2. The center can consist of one or several plies depending on the type of machine used. The raw material is mechanical pulp or waste fiber. Some chemical pulp can be added. All machine broke goes into the center.

Bottom ply : 40 - 50 g/m^2. As a rule unbleached sulphite or magnefite pulp.

The idea of such multiply boxboard is that each constituent should be where it is best needed and that the total furnish cost should be the lowest with which the quality specifications can be met. The economy of a boxboard plant depends to a large degree on the success of the management in pursuing these objectives. The result should be a flat, dimensionally stable board with a top surface of specified smoothness, brightness, printability and surface strength. Stiffness and bulk, which are also important qualities, are obtained by use of comparatively inexpensive, bulky raw materials in the center of the board. Good adhesion between the plies and good creasability are mainly questions of paper making skill. As a matter of fact, making a competitive quality of paper board requires above all expert craftsmen. It is a waste of money to buy modern, efficient machines and neglect the training of management.

Raw material

125. Very few folding boxboard mills are large enough to absorb the whole output from a kraft mill, especially since, for quality reasons, it is desirable to have access to at least three chemical pulp grades. After all,

a 300 t/d board machine will use only 100 - 150 t/d of chemical pulp.

126. The best grades of folding boxboard are made with mechanical pulp in the center. This pulp should be coarser than newsprint pulp in order to give the board a high bulk. On the other hand, the pulp should give the board adequate strength and internal bond. Dirt and shives in the pulp easily affect the appearance of the board surface. These conflicting requirements make the MP quality a constant concern in the board mill. Three of the latest board machines built (one in the US and two in Sweden) have been equipped with TMP plants in the hope that TMP will make the board bulkier and stronger than GWP. To use baled MP is not very economical. Baled MP will be at least 75 $/t more expensive than slush pulp from an integrated mill, and the board mill white water will be colder. The choice between GWP and TMP depends on wood and other local conditions. Technically, both are feasible, although TMP appears better from a quality standpoint. Apart from the MP the center ply furnish will also hold all the broke produced on the machine, which broke consists to 30 - 50% of bleached chemical pulp. Incidentally, this means that a board machine running poorly will downgrade high grade CP into a substitute for MP - a highly uneconomical process.

127. For strength the center ply often holds 10% sulphite pulp refined to maximum strength. This addition is prompted above all by the need for internal bond strength in the center. The quality requirements of the bottom ply are less stringent and partly different from those of the top ply. Where unbleached sulphite or magnefite pulp is available this grade is preferred to bleached kraft, which is, of course, also possible to use. Coating of the board with a layer of principally clay and starch will much improve the appearance and printability of the board without greatly affecting the functional properties. It would seem that in a developing country one should in the first place try to exhaust the full potential of the far simpler surface sizing process.

128. On the European continent many mills are producing paper board with only waste fiber in the center ply. Such board will be cheaper than board with MP in the center, but the quality characteristics are usually lower. Restrictions on the use of such board for packaging food can be feared for bacteriological reasons. This is of particular concern to food exporting countries.

Paper board machines

129. In the late 70's several folding boxboard machines in the capacity range of 100 000 - 150 000 t/year have started up, and the result has become a large overcapacity of coated boxboard and a very keen competition, where board quality is of deciding importance. At the other end of the scale there are small machines running perhaps 50 m/min. and turning out 10 000 t of paper board/year. Both have their justifications. The large machines will control the market for all standard grades while the small machines can offer products tailor-made for small converters or special purposes.

130. Traditionally the small board machine featured 4 - 6 so-called cylinder formers, each forming one ply on a rotating wire-covered cylinder submerged in a dilute fiber suspension in a vat. Such cylinder machines are inexpensive and easy to operate as long as the speed is not pushed above 90 m/min. Today, the machines have been further simplified and improved. The labor cost per ton of board for such low producing machines will be so high as to be a serious draw-back in developed countries, but this fact should be of far less consequence in a developing country. A competent engineer can probably produce a better board on a slow and narrow machine than on an ultra-modern 400 t/d machine. What is needed in both cases is a modern system design and an understanding of the paper making process (49). The choice of machine design for a new board machine is so rich as to be bewildering, and it is not uncommon that in spite of years of investigations and comparisons the choice made becomes a disappointment. Here, a comparatively conservative approach may be more justified than in most other branches of the paper industry (50).

Location of board machines

131. A board machine using baled pulp and waste paper should have low shipping costs for the raw material to the mill and should be as close to the customers as possible. Even more important is that the recipient can accept the effluent after a reasonable purification. Some board machines are equipped with a Yankee cylinder, and it is then a prerequisite that this cylinder can be transported to the mill site. One important argument against a remote location is that a very intimate contact is desired between the

board converters and the board manufacturer so that the latter has a chance to adjust to the wishes and complaints of the converters. To the latter such a contact and service is the best argument for use of locally produced boards instead of imported board of usually higher quality.

Sack paper

132. Sack paper is made in the basis weights 60, 70, 95 and 105 g/m^2 and used for the manufacture of sacks. Sack paper can be impregnated or coated with various chemicals or it can be laminated with a plastic film (polyethylene). The competition between paper and plastic sacks is very keen and in later years the paper sack has lost some markets to plastic sacks especially where wet strength is important. At the same time the paper sack has found new applications, the major one being for garbage. The advantages of paper sacks compared to plastic sacks are a lower price, better stiffness and combustibility (they can be burnt with the garbage in them).

Raw material

133. In developed countries sack paper is made only from unbleached softwood kraft pulp. Since a sack paper machine is usually restricted to one product and the pulp quality is of deciding importance to the sack paper quality integration with a pulp mill is highly desirable both for economy and for paper quality. The pulp should have the highest yield compatible with the required cleanliness. A wood yield of 48% and a Kappa number of 40 are normal data.

134. The pulp is refined in refiners of special types at both high and low consistency in order to ensure the best strength and stretch of the paper. The energy consumption of a sack paper machine can be:

	kWh/t
Refining	400
Pumping	250
Vacuum pumps	150
Paper machine drive	100
Ventilation fans etc.	100
Total	1 000 kWh/t

This comparatively high energy demand partly depends on the very high dilution of the fiber suspension necessary in order to obtain a well formed sack paper. (At 0.18% headbox consistency four times as much water has to be pumped and drained as in newsprint manufacture.)

135. The important characteristic of sack paper is cross machine tensile energy absorption, which one could refer to as toughness and which is a function partly of the softness, length and inherent strength of the softwood fiber, partly of the refining and paper making processes. For some products, for example for certain bag paper applications, it is possible to mix in mechanical pulp. The strength deterioration obtained can be estimated from the respective strengths and percentages of the two pulp constituents. Kraft pulp made from bamboo should be a first class raw material for sack paper, while the fibers of straw and bagasse pulps are not very suitable for sack paper, while the fibers of straw and bagasse pulps are not very suitable for sack paper.

Machinery

136. Because of the slow growth of the sack paper market no large sack paper machine has been built in Scandinavia for many years. As a consequence, several major machinery developments have not yet been applied to sack paper making, and it is difficult to say what a modern sack paper machine would look like. Probably it would be a twin wire former, a closed transfer press section, a single felted dryer section with a micro creping arrangement and an air dryer. Each of these details represents established technology. In a developing country the same paper machine could be used for bag paper, wrapping paper and wall paper. Papers requiring high stiffness like liner and fluting should not be the first choice for a sack paper machine, which is designed to allow as much shrinkage as possible during drying of the paper. (This gives the paper a higher stretch.)

Location

137. Since a sack paper mill should be integrated with a kraft pulp mill, it should be as large as the market will allow. A capacity below 200 t/day is not very attractive economically. One alternative worth studying would

be the combination of integrated sack paper production with production of baled pulp for other paper mills. The paper mill can conveniently be placed in a rural area close to the wood supply and with adequate water supply.

Technical papers

138. In a developing country there will arise from time to time a need for a small quantity of some technical paper: copying paper, bank note paper, abrasive paper, map paper and so on. If one has in all cases to rely on imported paper, the result will be that the industrial growth of the country is impeded. Now, a small quality paper mill can be made to meet a surprising number of these needs for speciality papers. What must be provided for such a paper mill project is:

1. A high quality, versatile fine paper machine
2. A competent management
3. A file of raw material recipies and paper quality specifications for a great number of speciality papers
4. A paper testing laboratory
5. A supply of baled pulp of all principal grades
6. A supply a fillers and chemicals

In the long run, a paper mill of this type will have a greater impact on the economy of a country than a printing and writing paper mill - often now being given the highest priority. A speciality paper mill will also lend itself best to the important function of training future paper makers. As a matter of fact, it could to great mutual advantage be combined with an institution for teaching of paper technology.

How to Establish a Paper Industry

Management training

139. From time to time in this treatise the importance of management competence has been stressed. This is a subject which for various psychological and sociological reasons is not openly discussed in developed countries in spite of the fact that it is just as important there as in a developing country. In a serious approach to the problems of a developing

country the subject ought to be treated objectively and without shyness, not because it is different there but because in a developing country it may still be time to establish a sound approach to it. However developed a country may be one can hardly overestimate the impact of the manager on the success or failure of a paper mill. Although to some extent this goes for all industrial activity there are few industries where such a diversity of technical, operational and psychological problems have to be faced.

140. In a paper mill the important jobs are done by machines and the machines will tolerate no nonsense from the humans serving them. In a paper mill a high standard of discipline and order is imposed by the machines on the operators - as best illustrated by the often literally deadly danger to the operators if an instruction is not followed. The manager alone can establish the working discipline needed for successful operation.

141. While this is mostly a matter of personal qualifications, the necessary technical competence is more difficult to establish. It is not possible for a manager to delegate matters of technology to subordinates. The manager must take the decisions alone and must understand the implications. This is the case also in the largest paper mills of developed countries even if the fact is sometimes disguised by loose references to committee or working group decisions. To understand what he is doing the manager cannot content himself with common sense or practical operating experience. Much that happens in a paper mill is in the form of physical and chemical processes, which cannot be observed directly by the eye. They have to be studied by their various manifestations, and the manager ought to know how. He also has to know how to control these reactions and have an understanding of their importance to the quality of the pulp or paper being made. To ensure constant technological improvements in his mill the manager must follow the trade literature in order to be able to judge when it is time to apply a new development.

142. The conclusion to draw from these facts is that the first act in the establishment of a paper industry is to train competent plant managers. In a pulp and paper mill there are specialized jobs for engineers trained in mechanical engineering, electrical engineering, road construction, architecture, chemistry, hydro dynamics and a number of other professions. It does not

matter which is the original speciality of the manager, but he should be a graduate engineer with top marks and a good command of English, which happens to be the all dominating language of the trade literature and the more advanced text books on paper making. (Even Scandinavian and German investigations of any consequence are published in English.) During his university years he should have worked as an apprentice and bona fide operator in pulp and paper mills for about 12 months altogether. If not, this tedious stint must be phased in before or during the later theoretical training. (The importance of this part is mainly psychological. The manager must know what it is to be an operator.)

143. The young engineer selected as a management prospect should now be given something like two years of specialized theoretical and applied training in pulp and paper making. Since we have assumed that modern paper mills are still missing in his country the training must be arranged abroad. The first year should be devoted to theoretical studies at some university or institute with special courses in pulp and paper making. Adopting an old practise of English universities the student should be provided with a highly competent "tutor", who assumes the responsibility of advising the student from time to time on courses to take, literature to study and reports to write. The second year should be spent in a development department of some large pulp and paper making company. Although very qualified assignments cannot be expected, the work provides a valuable insight into the operation of large forest industries and provides opportunities for further studies of the technology.

144. After this training a capable engineer should be ready to assume full responsibility for a paper mill being allowed a reasonable number of initial mistakes. A senior technical adviser can be provided as a safeguard during the start up of the mill or the "breaking in" of the manager. The alternative of starting a mill with the help of foreign managers and engineers is possible but only means a postponement of the problems, which must be faced when the foreigners leave.

145. The training programme outlined above can appear simple and easy to organize. There are, however, concealed difficulties to overcome. One

should realize that in most developed countries the paper mills belong to private companies or at any rate to companies anxious to maintain their markets and perhaps wary of new competition from developing countries. In the universities the resources naturally have to be reserved in the first place for the students of the own country. Although nothing of this kind will be openly admitted, one should know that the facts are there. On the other hand, it should be recalled that the services desired, - which can prove extremely important in the long run, - can be bought where necessary at comparatively moderate cost - one of the undeniable advantages of free market economies. And for several reasons a service bought will become more valuable to the buyer than a service received as an official gift - not that the latter are to be spurned.

Product development

146. The trade literature is full of offers for all types of machinery, but it should be understood that a machinery manufacturer is not a paper maker. The big machine manufacturing companies may certainly dispose of engineers with impressive paper making experience, but this is not in the first place what they are set up to sell. It is not wise to buy a machine relying on the supplier to show how to make paper on it. Product development should be the first concern after management training.

147. There are many approaches to this problem:

1. A central laboratory can be organized, where paper samples are analyzed for composition and physical properties. This laboratory could conveniently be part of a training center for mill operators.

2. Experienced paper makers - preferably retired - can be employed and will then bring with them recipees from earlier activities.

3. A co-operation can be established with one or several paper mills in developed countries, interested in selling licenses or consulting services.

4. Experiments can be conducted on a collectively or government owned pilot paper machine.

5. A co-operation can be established with one or several potential customers for development of new paper grades by "trial and error".

All these approaches are feasible and several of them are conveniently combined. The most important of the suggestions above is the establishment of a central pulp and paper testing laboratory. (Such a laboratory will also be a valuable support to importers of pulp in case of pulp quality complaints.)

148. In order to better know what paper grades to develop one can conduct periodically a market survey to find what grades are used in the country and in what quantities. These data are then compared with the consumption pattern of some other country with a somewhat further advanced economy. For this a trained market analyst should be employed. Although such services are also available from international consultants, the local market analyst cannot be entirely replaced by services from outside.

149. Product development may not appear to be a very difficult problem - at least not in the eyes of the layman, who does not know that a paper can hold a dozen constituents and be the result of many dozens of individually controlled reactions. In fact, product development is not very difficult if attacked in a rational and logical manner. What is needed is someone to organize and push the work, ensuring that all methods are used and that new approaches are taken when necessary. What comes to mind is a properly trained sales director with co-ordinating responsibility for product development.

Operator training

150. The relations between a paper machine and its operators are truly remarkable to watch. Work around a paper machine appears to belong to the more strenuous and unpleasant one can find in an industrial society, and still it is always possible to fill the paper mills with loyal and untiring operators. Possibly, one of the attractions of the work lies in the extraordinary challenge of having to cope with the occasional vagaries

and misbehaviours of a paper machine. Possibly also, this challenge will attract to the paper mills a special breed of men.

151. If we accept this theory, the conclusion is that men should not be trained to become paper mill operators but paper mill operators should be trained to understand what they are doing and how their machines function. This is what is being done for example at the Forest Industry Training Center at Markaryd in Sweden and probably also in many other countries. In the larger pulp and paper mills the engineers are periodically engaged in training courses for operators, where the process and the plant are described and discussed in detail. Often, a teacher is engaged full time to organize this activity. The benefits of such training are that the work becomes more interesting and therefore less tiresome. Instrumentation and machinery will be made to function better. Productivity costs and product quality will be affected positively.

152. Training in collective centers and in the separate mills both have their merits. In the centers the teachers may have a better theoretical background and may know more about new developments. In the mills the teachers will deal with the subjects of specific interest to the operators. In the centers operators from different mills will meet and exchange experiences, which greatly activates their interest in the work. Mill training will strengthen the contacts between engineers and operators and will bring latent frustrations into the open to be dealt with.

153. In a developing country with just a few pulp and paper mills the first concern should be a central laboratory combined with a training center and placed adjacent to a university or possibly in a speciality paper mill. A remote rural location should be avoided since one of the objectives is to provide contacts and mental stimulation and avoid in-breeding of the paper makers. Training of engineers must be given the highest priority. After all, one important function of a mill engineer today is to train his operators so the engineers must know their business.

154. Operator training, however, should not be allowed to trail far behind. It can be discussed how theoretical operator training should be.

Obviously, one must limit teaching to what is digestable to the audience. The text books of the Markaryd center are trying to keep theory at a suitable level for the operators and could, if translated, become helpful in new training centers.

155. For training programmes in the mills it is necessary to write detailed descriptions of the machinery and the processes It will probably be necessary to engage someone from outside to do this with the help of the machinery suppliers, who have delivered the machinery. Incidentally, one important side effect of mill site training is that one is forced to define exactly how each manipulation in the whole mill should be performed, which will be very beneficial to the overall performance of the mill.

The mill integration problem

156. The cost of estimates of various pulping processes quoted earlier in this report do not make pulping in developing countries appear very promising. If the cost of imported pulp is compared with the cost of pulp pumped from a pulp mill to a paper machine the comparison will look more favourable to the latter due to the following costs incurred in use of baled pulp:

Dewatering and pressing of pulp
Drying of pulp
Baling including wrapping paper and strings
Storing including capital cost of sheds in pulp mill
Shipping and custom duties for pulp to paper mill
Storing and capital cost of sheds for pulp in paper mill
Slushing and pumping of pulp in paper mill

The total sum will be in the range of 50 - 100 $/t and will be independent of pulp quality. The cheaper the pulp the more to be gained proportionally from integration.

157. There are also other integration benefits even more difficult to put a figure on:

a. The white water system will become warmer giving more efficient drainage on the paper machine wire and higher dryness after the presses.

b. The combined losses of fiber, filler and chemicals will be lower thanks to ties between the white water systems of the pulp mill and the paper mill.

c. All service and maintenance departments can be shared.

d. A pulp quality can be developed to meet the exact requirements of a certain important paper grade.

158. Integration, however, also has its drawbacks, some of which have been dealt with in connection with the discussion of fine papers. One of them is that management can become more concerned about using all the pulp that can be produced than with the development of high priced and high quality papers. Another danger is that for economic reasons a lower quality pulp will be made than one would accept from a pulp supplier.

159. To the paper maker it is very much easier to deliver a paper of a specified quality if he can select from a number of grades in his pulp shed those particularly suited to the paper in question. In a developing country the paper maker is faced with the tedious job of developing all the paper grades the local market can absorb and to the specifications actually required by this market. It is a blessing to him at this stage not to be hampered by all the pulp quality upsets unavoidable in a pulp mill starting up. Except for some standardized bulk grades like newsprint, sack paper and liner most paper grades are conveniently made from imported pulp at the introductory stage. Integration can come later.

160. When the paper mill has to be stopped for maintenance or cleaning the integrated pulp mill must be warned well in advance to avoid fiber and white water losses. The same co-ordination problems will arrive with operating troubles in the pulp mill. (Large modern mills use computer technology for this.)

161. Looked at from the pulp mill superintendent's point of view integration in a mill just starting up means trying to meet pulp quality requirements, which are by necessity poorly defined or quite unknown by the paper makers. It also means dealing with pulp quality complaints, which are sometimes the

results of a misinterpretation of paper machine operating troubles. If the paper machines are properly run in and the paper qualities established when the pulp will start up, the situation will be much easier.

The scale factor of paper mills

162. The market will decide the size of any paper mill to be built, but the economy of the new venture can be quite dependent on the size decided. The two major cost items influenced are capital cost and labor cost. The table below refers to Swedish conditions around 1970 (an unintegrated printing machine).

Capacity of paper machine t/d	Man-hours per ton	Capital cost $/t
25	8	105
50	6	95
100	4	80
200	2	65
300	2	55

163. The two columns are not quite comparable since the labor demand only refers to the paper machine itself while the capital cost refers to the whole paper mill. However, the figures are presented only to demonstrate the scale factors. Some interesting conclusions can be drawn. Above an output of 200 t/d the specific labor demand does not drop any further with increasing machine size, and it is so low that one cannot expect it to be reduced much further by increased automation or instrumentation. The wage level will not mean very much to the profitability of those large paper mills. For machines producing 50 t/d or less the labor cost in developed countries becomes quite important while in a developing country such machines will be more competitive to large machines. According to the table there is a difference of 50 $/t between the capital cost of a 25 t/d and a 300 t/d paper mill, to which should be added the cost of 6 man-hours on the machine and at least as much in the rest of the mill.

164. These are the facts behind the rapid disappearance of small paper mills in developed countries. However, these small mills are also the oldest ones and the most obsolete ones technically. If a medium size or large paper mill is to be built in a developing country a similar mill in a developed country can be copied, and it will even be advisable to adopt some simplifications of it. If, on the other hand, a small size mill is to be built, there will probably be nothing appropriate to copy. It will pay to sit down with experts and look for ways to incorporate new machinery and process developments into the small size mill bearing in mind the wage level of the country in question.

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