Progressive Methods in Kraft Pulping

Gunnar Collin

An increasing shortage of fibre raw materials, a high price level of energy and consideration of environmental effects are some factors of vital importance in today's pulp and paper industry. To adapt the industry to this new situation, a strong emphasis on new developments is required.

A problem is that there is an inherent conflict between the environmental goals to reduce industrial pollution and the economic goal to reduce the energy consumption. The methods available to treat mill emissions and effluent generally add to the energy requirements per unit of manufactured product.

The pulp and paper industry is in most countries the largest energy consumer, and at the same time also the largest polluter. But there are few industries that have made such improvements regarding energy and environment conservation as the pulp and paper industry.

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A modern mill for bleached kraft pulp has a total consumption of primary heat (steam) of 20 GJ per ton of pulp and 780 kWh of electric power. These are good figures, but there are still possibilities for improvements. This presentation will be limited to only a part of the mill and this is in the area of cooking, washing and bleaching. These sections consume approx. 30% of the primary heat and electric power used in the whole mill.

Cooking and Washing

If we now start with the cooking and washing sections for unbleaced pulp, you will find that the Kamyr continuous system incorporates the main washing in the digester, which is of importance when making comparison with other systems available on the market. Both batch and continuous digesters release significant amounts of blow steam, relief steam and/or extracted liquo flash steam. The continuous system has there an advantage.

Figure 1 illustrates a modern fiber line for bleached kraft pulp and the consumption of primary heat and power is shown in table 1.

Table 1

	Steam GJ/ton	El-power kWh/ton
Digester	2.6	50
Diffuser	—	6
Screening and Thickening	—	55
Bleaching	1.8	126
	4.4	236

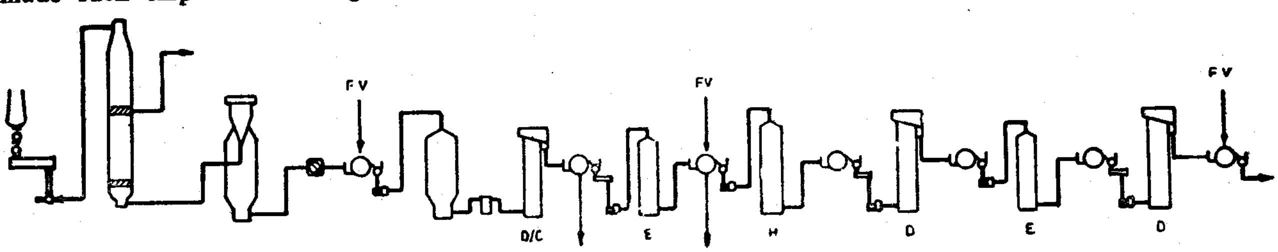

Fig. 1

With a closed screening system and a washing loss of 6 kg Na_2SO_4/ton of pulp, which is carried on to the bleach plant. the discharge of pollutants amounts to 17 kg/t BOD_7 and 160 Pt-units (kg/t). The emission to the air is in this case small. The odorous sulphur compounds formed during the cooking are relieved in flash cyclones and sent to the cond nsate stripping and burning. A small amount is, however, escaping via the chip feeding. In addition come also small amounts of chlorine compounds via the ventilation over the washers in the bleach plant.

What can now be improved ?

In the digester, chips, chip moisture, white liquor and black liquor (if necessary) are all heated to 170°C. The chip moisture does not only consume steam but it also dilutes the black liquor, resulting in extra evaporation. Since some time there are trials going on with counter-current impregnation in a mill in the U.S. The principle is shown in **Figure 2.** Instead of adding the white liquor to the feeding circulation it is added in the upper cooking circulation and goes from there countercurrently to the chips and a portion of the extraction is then taken from the make-up flow in top circulation. The amount taken out corresponds to the chip moisture. This has resulted in a steam-saving of 20 to 30%. An additional energy saving can be realized with counter-current impregnation if the extracted water can be used in the caustic area by-passing the evaporator.

Another way to improve the heat economy and also the odour problem is a better use of the heat content of the extracted black liquor. The Kamyr continuous digester produces an extracted black liquor with a temperature around 160°C. The heat content of this black liquor is normally used for the presteaming of chips and preparation of hot water in a way shown on **Figure 3.** A system of this type, however, has certain drawbacks. The heat contained in the black liquor is used rather ineffectively, odourus compounds in the black liquor are released in the first flash tank and thus they enter the presteaming vessel. Through the low pressure feeder odorous gases pass into the surroundings. Methanol and turpentine recovery is also ineffective due to the condensation of the vapours on the chips in the steaming vessel and thus a high level is built up in the digester, resulting in losses through the washing plant. A flash steam evaporator as shown on **Figure 4** provides a simple solution to the drawbacks mentioned. The flash steam from tank No. 1 is taken into an

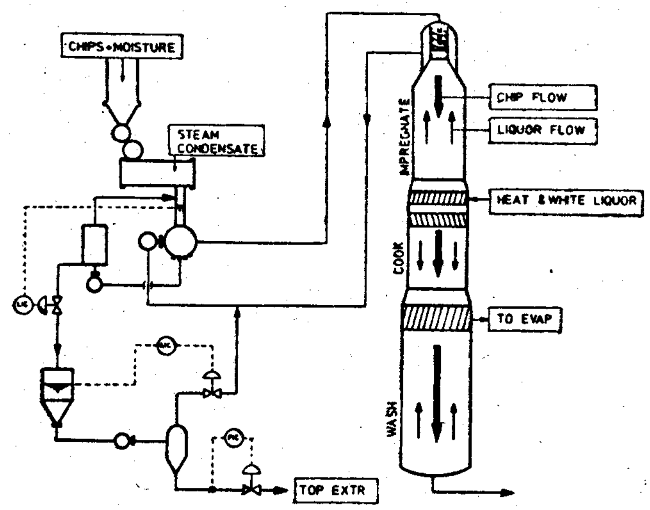

Fig. 2

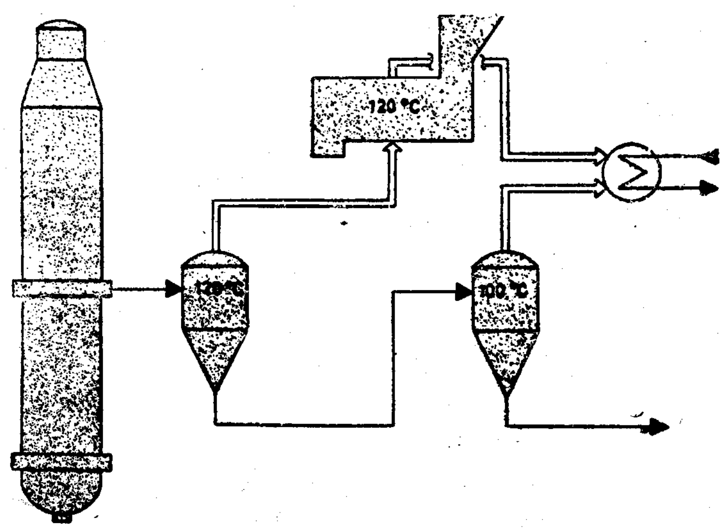

Fig 3

evaporator unit of the free flow type, where also the black liquor is taken. A temperature difference between vapour and liquor is created by allowing the black liquor to expand additionally about 10°C in the evaporating unit. The flash steam from the No. 1 tank condenses on the evaporator heat surface and an equivalent amount of steam is evaporated from the black liquor. Thus the steam going to the presteaming vessel is approximately the same as before. In this way, about 0.5 ton of water per ton of pulp is evaporated. Odorous gases, turpentine, methanol etc. released in the first flash tank do not enter the steaming vessel and digester but can be removed from the system.

Figure 5 shows schematically the flow of volatile sulphur compounds in a conventional flash system. The corresponding flow for the flash evaporation system is shown in Figure 6.

The same kind of circulation is also valid for turpentine and thus an increased yield of turpentine can be expected.

Another possibility to reduce the odor and increase turpentine yield is shown in Figure 7. This is a three flash system where the flash steam with the volatile compounds are used for heating the "Hi-Heat" wash. The second and third flash are as in the conventional system.

The degree of washing has been determined by strictly economic factors, i.e. the recovery of cooking chemicals. The washing

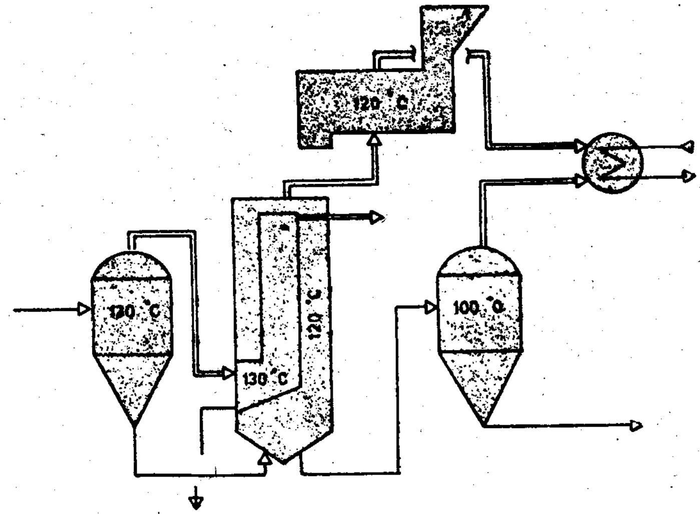

Fig. 4

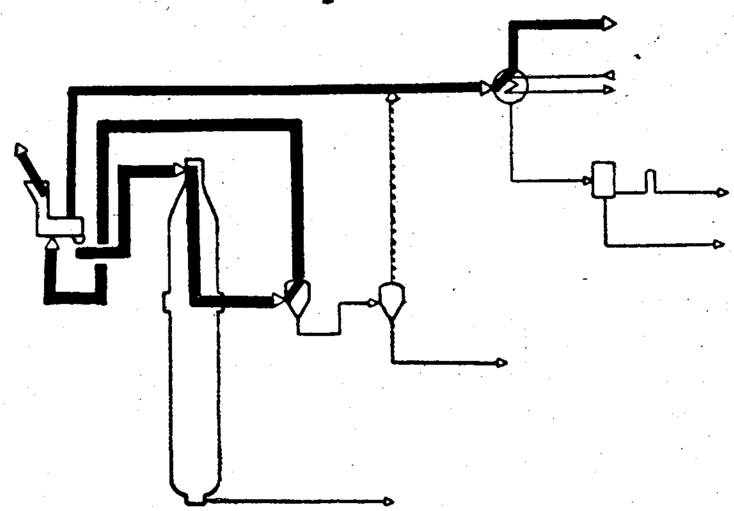

Fig. 5

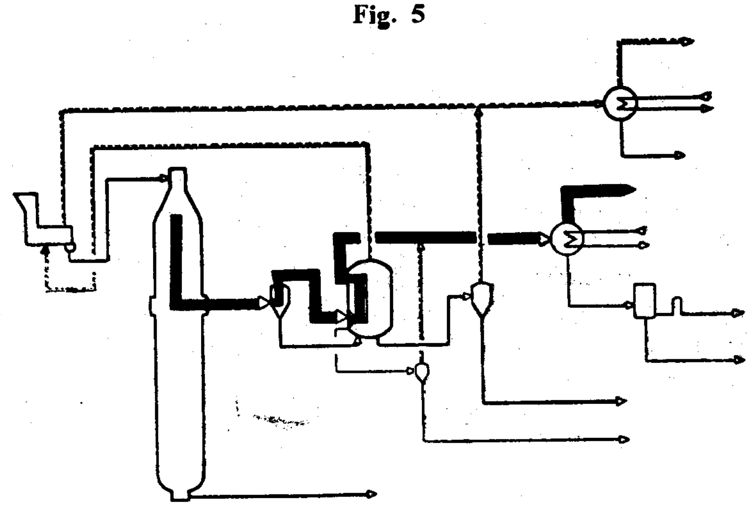

Fig. 6

section has therefore, been one of the biggest polluters. Today the washing is determined by environmental aspects. Where you before had three washers in series, you have now to use four and even use thickener after screening as fifth washer. One of the big features with a continuous digester is the built-in Hi-heat counter-current washing. This is a combined diffusion and displacement washing in the bottom part of the digester. The washing temperature is comparatively high, around 130°C and the time normally three hours, but this can be longer or shorter depending upon the number of washing stages following Normall the requirements are higher than what can be obtained with only washing in the digester. Kamyr has, therefore, developed a continuous diffuser as a complement. This is in order to have a complete, closed washing without air entrainment. This has today been accepted as a standard solution. After the washing you have to screen, and this has to be done in a closed system and thus the thickener after the screening can be used as the final wash stage. By such a system you can allow the remaining chemicals to be carried over into the bleach plant or on to the paper machines.

The scarcity of wood and the increasing wood cost make the yield question of utmost importance. Three examples of ways and means to increase the yield of both unbleached and bleached grades of pulp will be given.

The first is inline defibration (refining). This new technique for the defibration of the cooked and washed chips in the blow line of a continuous digester has been, jointly developed by Defibrator and Kamyr. **Figure 8.** The system has the following advantages : Simplicity, yield increase, elimination of screens, and lends itself for complete closing. Mill results confirm that liner board pulp can be produced at Kappa number levels of 100 and sack paper at 70 from Scandinavian Pine. Inline defibration has also been adopted by mills producing pulp for bleaching.

A **Second** method to increase the yield is to adopt polysulfide pulping. It has been known for many years that the addition of sulphur to white liquor gives an increased pulp yield. The reason for not being more commonly adopted is that the sulphur addition increases the sulphidity and consequently the level of odor. Recently a new technique of preparing the polysulfide liquor

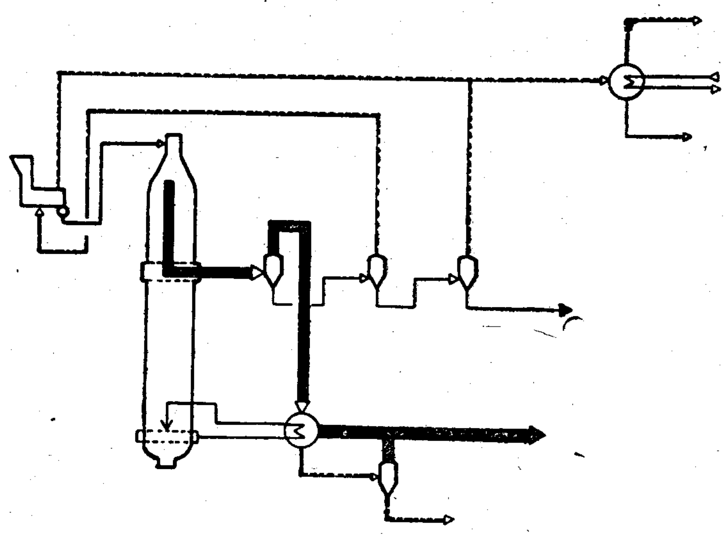

Fig. 7

KAMYR BLOW LINE REFINING SYSTEM

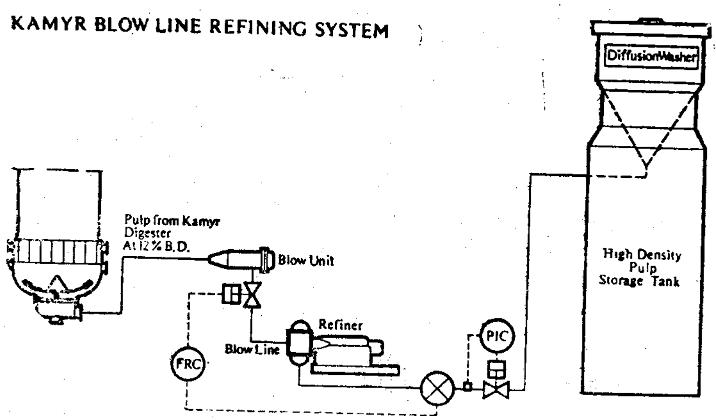

Fig. 8

has been developed, so called Moxy system. The method employs oxidation of kraft white liquor using solid catalysts for the liquid/air reaction. The method has been tested for approximately half a year in a two-vessel Kamyr digester at the Peterson and Søn kraft pulp mill at Moss. Norway. The result is very promising. An increased pulp yield in the range of 2.5–3.0 % has been obtained and there is no increase in smell around the mill. The strength properties of the pulp are quite satisfactory. The Kamyr two-vessel digester system is very well suited for the process. In the impregnation vessel the chips are impregnated at a high pressure and at a temperature of 115°C, which increases to 128°C due to heat of reaction. These conditions are close to ideal to obtain full effect in pulp yield increase of the polysulfide sulphur charged. It is important that the polysulfide sulphur enters into the interior of chips before a too high temperature is reached. Otherwise the polysulfide will decompose. The Kamyr hydraulic standard digester can also be used for polysulfide pulping. The yield increase obtained in the cooking remains throughout the bleaching.

A third method to increase the yield Is to adopt oxygen delignification. Oxygen bleaching is today recognized as an effective method to reduce the water pollution in the bleaching plant. But another big feature with oxygen delignification is an increased yield. Oxygen is a more selective delignification agent than the kraft process. This is not always recognized. By cooking softwood pulp to a kappa number of 70 instead of 30–35 and then proceed with an oxygen stage to around 20 and final bleaching, approx. 1.5 % (abs) higher yield is obtained. This will be further discussed in next section.

Bleaching

When coming to the bleaching, you are then entering a different section both regarding polution and energy consumption. The bleach plants so far consume almost 20–25 % of the electric power used for pulp manufacture and are the most polluting contributor. Oxygen treatment has been introduced and is today one of the most interesting processes to solve part of the pollution problems. A drawback, however, with today's conventional oxygen treatment equipment is the high investment cost which has been one of the reasons for the slow development.

An oxygen delignification stage is shown on Figure 9, and involves the following stages : Thickening to high consistency, 25–30 %, feeding into high pressure, fluffing, controlled retention with good contact gas-fibre, and final washing.

Intensive work is going on in order to simplify the equipment necessary. Kamyr has a new concept which very much will

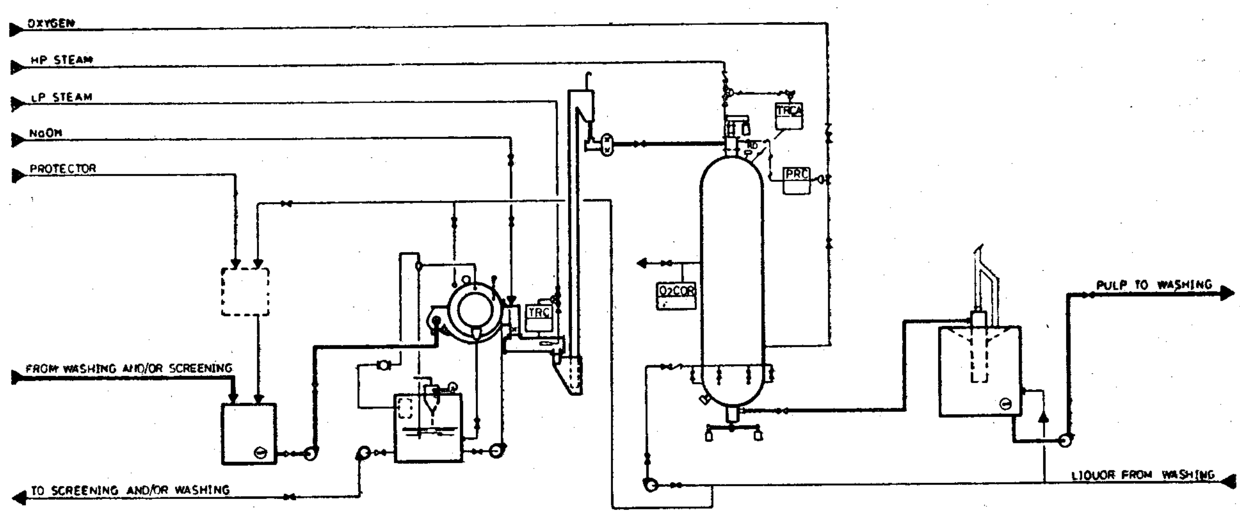

Fig. 9

reduce the investment cost. This has been tested in a pilot plant whith a capacity of up to 120 tons per day. The principle of the system is shown in **Figure 10.** Hi-heat washed pulp from the blow line of the digester is taken after the blow unit and sodium hydroxide or oxidized white liquor is added. Oxygen and steam are added to the pulp at the inlet of an inline defibrator, where the oxygen is intimately mixed and dispersed into the pulp suspension, which has a consistency of about 8 %. The pulp with oxygen flows into a conical type upflow reactor with a retention time of 30 minutes. At the top, the pulp is scraped over into the periphery of the reactor vessel, where the pulp is diluted and blown.

The mill normally cooks unbleached pulp of Kappa number 60. This pulp has been delignified in the oxygen stage to Kappa number 30-20, a considerable step. The results from the trials have so far been very promising, both from an operation point of view and with regard to the quality of the pulp. Further development is planned with the possibility to carry out the oxygen delignification in two stages with a short first stage and splitting the charge of sodium hydroxide as well as oxygen between the two stages. This in order to study the possibility of larger delignification steps and also to lower Kappa numbers.

In the conventional bleach plants today, the pulp is treated in 5 to 6 consecutive stages with washing in between. The operational principle of a drum washer includes internal liquid circulation, which amounts to roughly a hundred times the pulp throughput. When this and the pumping energy needed to transport the pulp from stage to stage is considered, the fairly high electric energy requirements in conventional bleaching are understandable. Because of the long retention times needed (1-4 hours) for each of the treatments, and the current consistency level (10-15 %), the bleaeh plants require large space.

The corrosiveness of the chlorine chemicals used demands that the equipment is built out of expensive acid proof material, such as special quality stainless steel, Hastelloy C or titanium. Both the operating and capital costs are thus high in bleaching.

The present stream pollution regulations call for a considerable reduction, preferably complete elimination of bleach plant effluents. This is basically possible to achieve by closing the liquid circuits and through application of the counter current washing principle. The problem is, however, that corrosive compounds as acid chlorides will accumulate in the circuits to a level higher in order of magnitude than presently which means that the capital expenditures of bleaching will increase considerably since expensive corrosion resistant materials have to be used.

The aforementioned factors plus increasing cost of energy call for a new technique which features reduced use of materials of construction, reduced space requirements as well as reduced effluent volumes and energy demand.

Professor Howard Rapson of Canada proposed in 1965 his dynamic bleaching method. He observed that if bleaching agents are displaced through a pulp bed instead of mixed into the pulp,

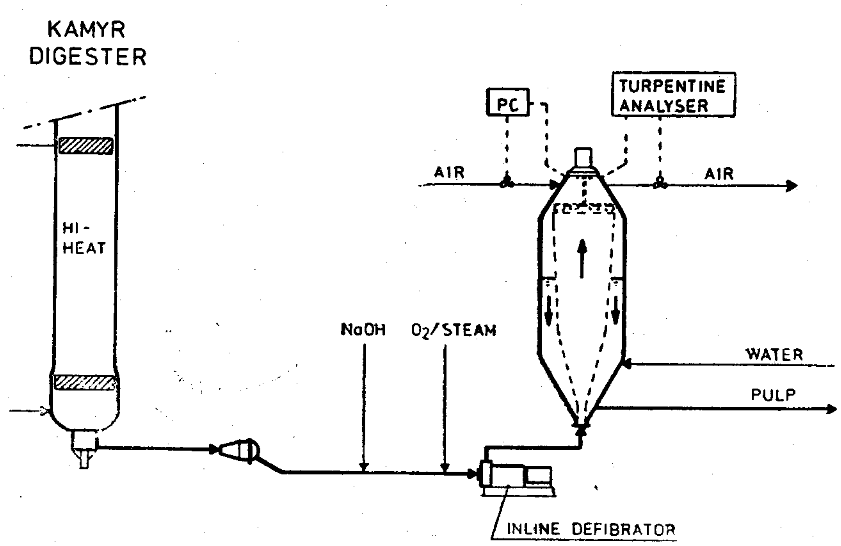

Fig. 10

very rapid bleaching can be performed. This method has been further evaluated by a number of laboratories throughout the world. It was concluded that the high bleaching rates were achieved through continuous displacement of the reaction products by fresh chemicals and that maximum active chemical concentration was maintained at the fiber surface throughout the whole reaction period. Since no equipment to meet the requirement of the new method was available at the time, it was proposed that this new process remained a theoretical curiosity.

The continuous diffuser developed by Kamyr for washing after the continuous digester is a displacement washing device. The diffuser has also been placed in the bleaching tower and operates without the dilution circuit typical for the drum washer. This type of bleach plants can be considered as a step towards the displacement bleach plants.

In the year of 1970 the idea to combine the continuous diffuser with the principles of dynamic bleaching was born. Since it was proved that a bleaching stage could be performed in 5-10 minutes, it was felt that several displcement stages of the diffuser type could be built in the same tower. If the liquid circuits could be completely closed, the demand for active chemical exhaustion in a stage could be eliminated and the chemical concentrations set at their optimal levels. The power consumption would be considerably reduced since pulp transfer from tower to tower would be eliminated. Heat would be saved both through the closed circuits applied, which means less heat losses with effluents, and because intermediary contact with the atmosphere would be reduced.

Preliminary tests in 1970 in a small pilot plant installation were so convincing that it was decided to build a four-sage pilot plant with a capacity of 120 tons per day. This pilot plant started up in early 1972. The assembly drawing in **Figure 11** shows the diffuser arrangement in the four-stage pilot plant.

During three years both the

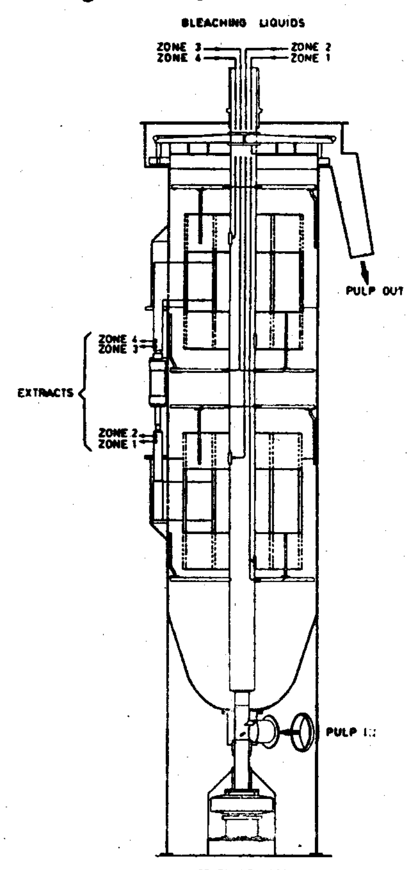

Fig. 11

machine concept as well as various bleach sequences were tested. The results from these trials showed that the displacement bleaching process gives a product with properties that compare favourably with conventionally bleached pulp. Further benefits are a low water consumption, low energy, heat as well as electric consumption, and a small space requirement.

The first commercial installation was started at the end of 1975 and a second unit at end of 1976. Both these units consisted of a conventional chlorination stage followed by a four-stage E-D-E D displacement tower. The capacity of the units is 500 tons per day. A third unit will be started in the middle of 1977.

Until recently the thought had been that the chlorination stage could only with difficulty be incorporated in the displacement system, because of its low consistency. Work was therefore started on the development of a new chlorination mixer that could work at 10% consistency. This mixer is now a reality and the first commercial unit will be started in the middle of 1977. This mixer utilizes the fluidization-dispersion principle and will so far be used in a set of two in series. The pilot plant trials did not only demonstrate the benefit of the principle but also proved that the chlorination equipment becomes much simpler and that good process control is easier to achieve with this principle than in conventional processes.

Figure 12 shows a flow sheet of a future displacement bleach plant including medium density chlorination. In such a unit, further reductions in effluent volumes can be obtained. Such a bleach plant has a consumption of electrical power of 45 kWh per ton, and no fresh steam as the secondary heat from a Kamyr digester can be used. The total effluent volume is 12 m³ per ton of pulp.

As you may have noticed, there are possibilities to improve both the environment and energy situation in the fiberline, and only a few possibilities have been indicated above.

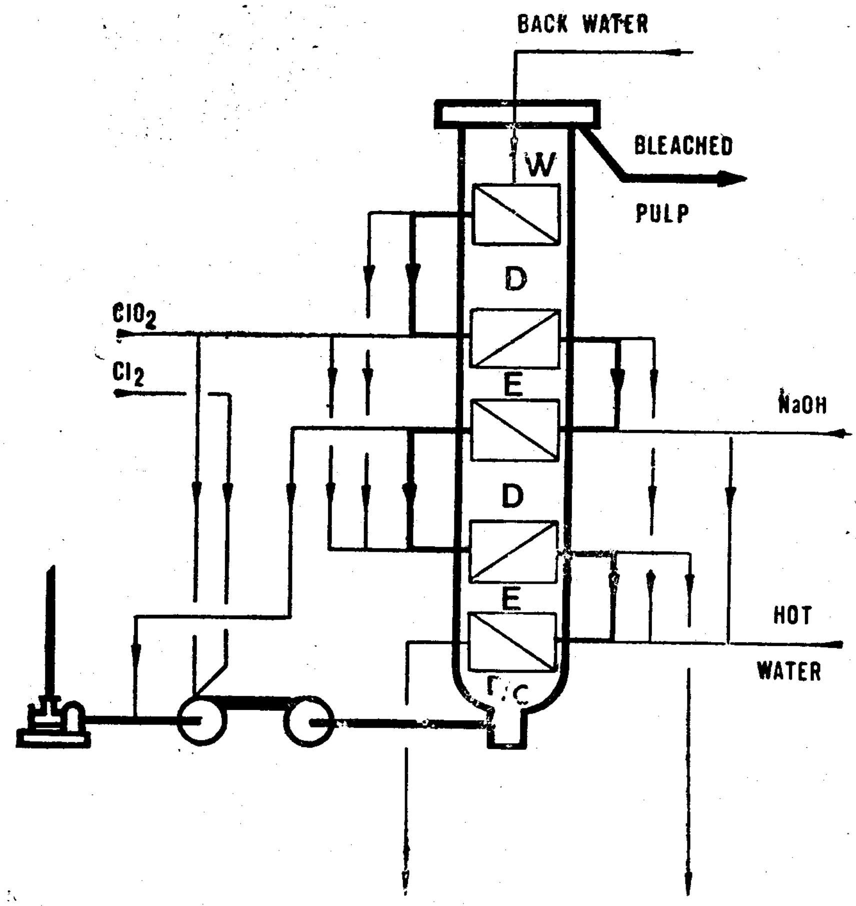

Fig. 12