Continuous Cooking of Pulp
Energy-Saving Equipment and Modifications

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It is now 30 years since the first commercial continuous digester for chemical pulp was started. The basic technical and economical incentives behind the development of the first digester are today even more valid and can be put into following keywords:

ENERGY ENVIRONMENT ECONOMICS

It was early recognized that in the developing of a continuous digester for making high quality pulps, unbleached as well as pulps for bleaching, there were certain fundamentals which could not be overlooked - presteaming, good impregenation, and uniform heating. The mentioned fundamentals were also incorporated in the first unit and are still there. One important factor was, however, not recognized and that was the sensitivity of the fibers to mechanical action in presence of alkali at high temperatures, which resulted in an inferior pulp quality, especially in tear strength. This problem was solved by cooling the pulp before the discharge, – the "cold blow" was introduced. Later this was followed by the "Hi-Heat" countercurrent washing in the bottom part of the digester. This further improved the pulp quality and, more important, it simplified the succeeding brown stock washing installation.

The equipment and the various machine elements incorporated in a continuous digester system have of course been steadily improved upon. The digester performance is of great importance for the production efficiency in a pulp and paper mill. Many claims have been made over the years that the continuous digesters endanger the reliability of the production. Such claims were indisputable in the early days, before the machine elements had been sufficiently developed and enough running experience gathered. Likewise, every new mill with a new crew has to learn to run its digester, as well as its paper machines. Systematic preventive maintenance is vital to the success of a continuous digester as well as other machines in a efficient mill of today. 98 - 99% performance is today common for many continuous digesters.

The dominant chemical pulp to be produced for a longtime to come will be by the kraft process or its modifications. I will, therefore, now first present some important points in the continuous cooking systems without going into any details, and then show how these systems can be applied to modifications of the kraft process and other pulping processes.

Figure 1. Shows a flow sheet of a Kamyr standard continuous digester. It is first the controlled chip feed followed by the horizontal presteaming vessel, where the chips are being deaired and preheated under low pressure, normally with steam recovered from the flash tanks.

The feeding into high pressure is one of the most striking features of the Kamyr continuous system. No mechanical action on chips is done, which is an essential condition for producing high quality pulp.

In the top of the digester, ample time is given the chips for good impregnation under hydrostatic pressure, about 1000 KPa, and at a temperature well

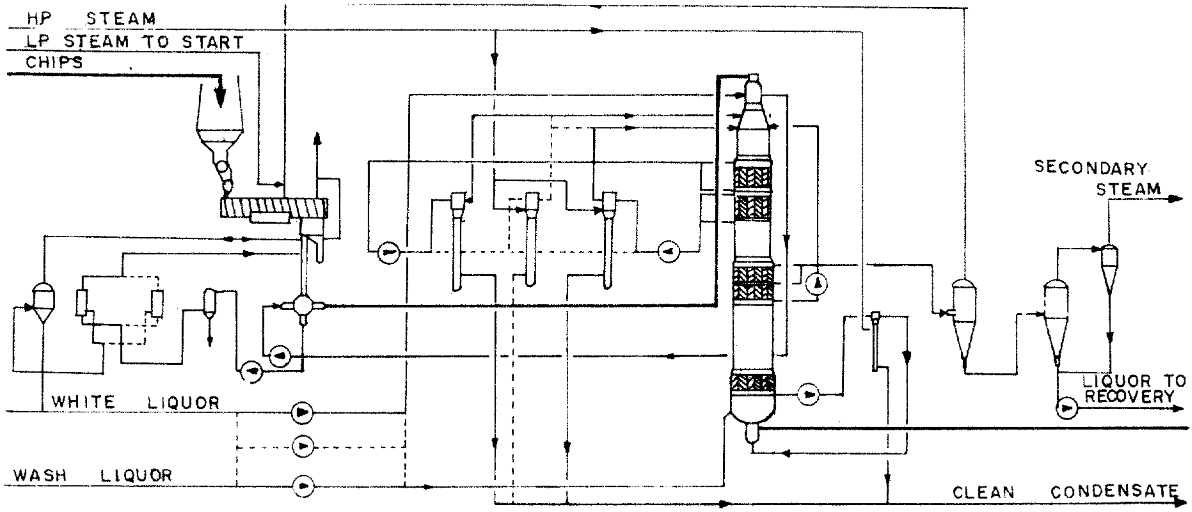

Figure 1.

below the cooking temperature. Impregnation is a very important factor in order to obtain the best possible uniformity of the end product and also in order to reduce wood consumption to a minimum for a given production. What makes the Kamyr impregnation so efficient is that it starts with the pre-steaming, followed by an impregnation under hydrostatic pressure at temperatures around 100°C. The more difficult raw material and the less there is of it, the more important is the impregnation.

Uniform and well controlled heating to cooking temperature is obtained through good liquor circulations.

Another important characteristic is the washing inside in the lower half of the digester. More about this Hi-Heat washing later.

Kamyr has also devleoped other types of digesters, the combined vapour/liquid phase digester is one type as shown in Figure 2. The impregnation in this digester is carried out in the feeding circulation and in the inclined or inverted top separator. Although short, the result from many different pulping processes has shown that the time is quite satisfactory for many processes and also for many types of wood.

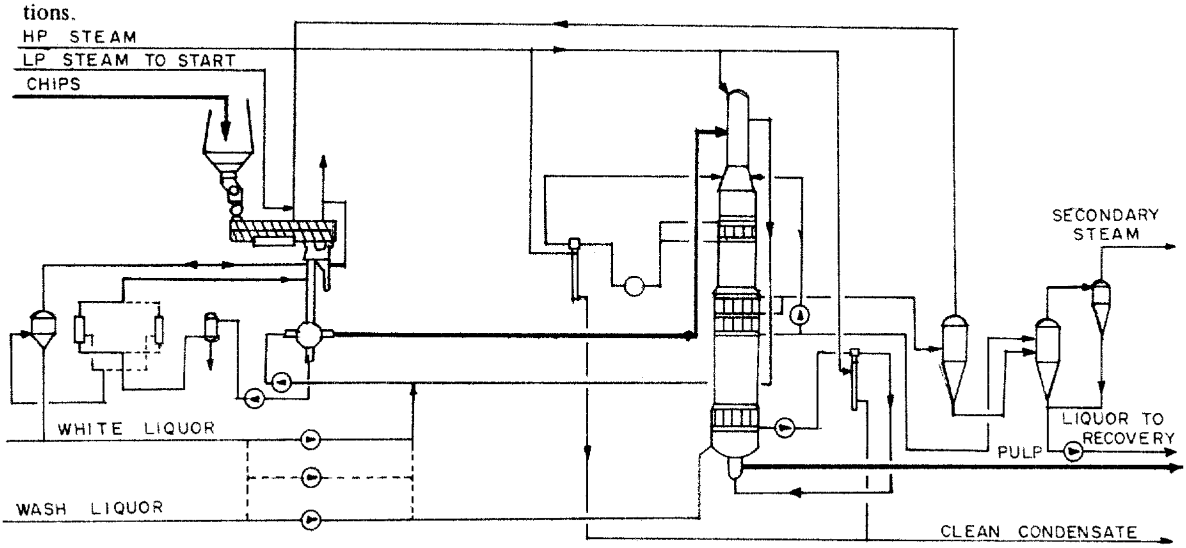

Figure 2.

Several digesters of this type are now in operation and for such different processes as bisulphite, both sodium, magnesium and ammonium, high brightness as well as corrugating grade NSSC pulps, and also used for bleached hardwood kraft pulp, mainly the types of hardwood which are easy to impregnate. Such a hardwood is, for instance, the types of eucalyptus which are nowadays planted in many part of the world.

Another digester type or digester system is the Kamyr two-vessel system, which is a combination of the vapour/liquid phase digester with a high pressure impregnation vessel installed in front as shown in Figure 3. After the standard feeding-in apparatus, the chips and liquor and fed to the top of the vertical down flow impregnation pressure vessel with a retention time of about 30 minutes at approximately 1000 KPa pressure. The purpose of this vessel is to provide adequate impregnation to the various size chip fractions at high pressure and low temperature. These conditions are desirable in order to reach higher yields and lower rejects, particularly with the lower alkali charge and when operating dryer woods. It also reduces refining -equirements. From the bottom of the vessel the chips are transferred to the inverted top separator of the vapour/liquid phase digester. The transport of chips from the impregnator to the digester is carried out by a liquor circulation.

This digester system gives close to ideal impregnation and is, therefore, used when this is of importance, for instance for manufacture of high yield kraft pulp for liner board. This is also a very useful type of digester system because it can very well be used in processes of twostage type.

Any of the two first mentioned digester types can easily be arranged with a high pressure impregnator and this has also been done in some cases. It has also been done with the object to increase the capacity in some cases.

Figure 4 shows a steam feeder digester for wood residuals or annual plants like reed, alphagrass bagasses, etc.

Above described Kamyr digester systems with certain exceptions for the steam feeder digester are all nowadays equipped with "Hi-Heat" washing inside the digester (Figure 5). After a certain retention time, the cooked chips reach the washing zone, where they are subject to a radial displacement wash in order to stop the cooking reaction. The main washing is then carried out counter-currently in the "Hi-Heat" diffusion stage by introducing water or wash liquor from subsequent washing equipment. The washing is performed at an elevated temperature (120 - 130°C). The pulp is blown through a blow unit with a variable blow valve and a flow meter. In the upper part of the washing zone, the counter-

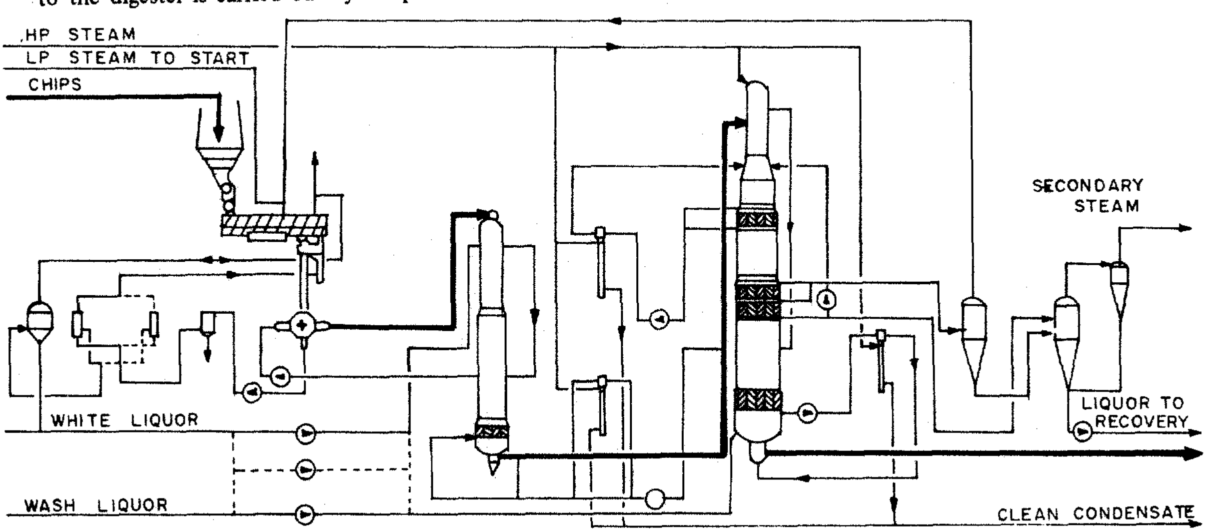

Figure 3.

current liquor is extracted and recycled for the displacement and then flashed for recovery of steam before being sent to the evaporation plant. The water or wash liquor introduced in the bottom has a temperature of 75 - 80°C, ensuring "cold blow" conditions. Th pulp is discharged at 80 - 85°C, and since the chemical content at the same time is very low, the potential fibre strength will be fully conserved.

Good washing results are obtained by only "Hi-Heat" washing in the digester. The effect of this washing has resulted in a considerable reduction in the following washing plant, which does not only mean a great reduction in capital investment but also a very important simplification in operation and reduced maintenance. An economic evaluation, taking the salt cake losses, evaporation cost and the boiler operation into account, will show an economic optimum with washing losses about 15 Kgs of salt

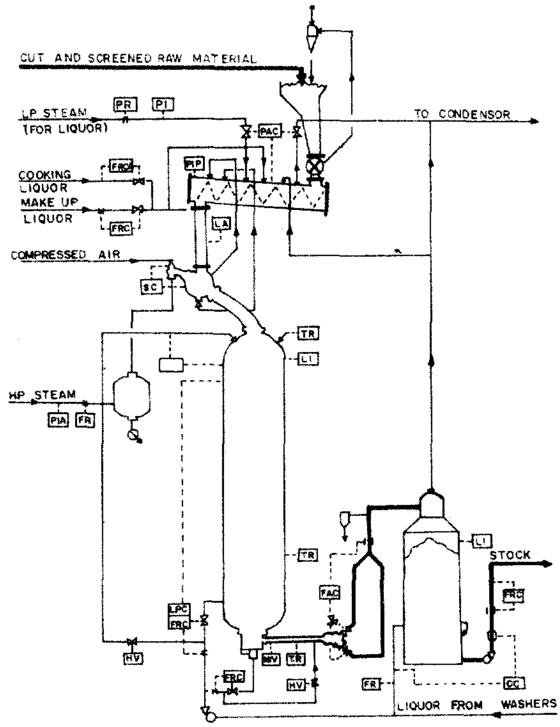

Figure 5.

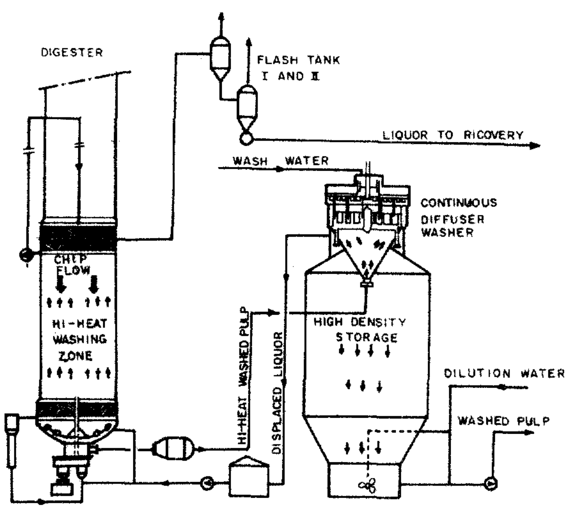

Figure 4.

cake at a dilution factor of 2.5 – 2.8. This is, however, not taking the environmental question in consideration. This means that "Hi-Heat" wash is comparable to 3 wash filters.

If you should, by legislation for instance, be forced to improve on the washing from environmental point of view, this can easily be done in a Kamyr installation by adding a Kamyr continuous diffuser. Such a diffuser replaces the drum washers with all their auxiliaries. Since the diffuser can also be operated by remote control, the digester operator can easily handle both cooking and washing.

The high price level of energy and consideration of .environmental effects are factors of vital importance in the pulp industry today. To adapt the industry to this new situation, a strong emphasis on new developments is required. A problem is that there is a inherent conflict between the environmental goals to reduce pollutions and the economic goal to reduce energy consumption. The methods available to treat mill emissions and effluent generally add to the energy requirements per unit of manufactured product. The continuous pulping systems are in this respect superior to the batch systems.

A problem with the kraft process is the odour from reduced sulphur components. In batch cooking the collection of the blow gases is done in the so called "Vaporspheres", gas buffers. They receive the batch flow of gases and deliver a continuous flow of gases for treatment. Here, the fundamental virtue of continuous cooking is obvious. However, there are also other points in a kraft mill which require collection and treatment of the malodorous gases and one of the main concerns is the recovery boiler. It is to be remembered that it is the community environmental impact which is the problem. There is of little or no consequence to the natural environment in terms of concentration, or toxicity.

One of the original arguments in favour of continuous cooking, the superior heat economy, still holds and has become accentuated through refinements of the system. The continuous system is also superior with regard to electrical energy. But when comparing batch with continuous, it is to be remembered that the continuous digester has a built-in washing with high efficiency and a blow-heat recovery system.

In the above described cooking systems, there is a slight difference in regard to heat economy. The first unit, the standard digester, is indirectly heated and thus the high pressure steam condensate is recovered. In the vapour-liquid phase digester without or with high pressure impregnation, the heating is by direct steam, and thus the condensate dilutes the black liquor. This is, however, to a certain degree compensated by a lower liquor to wood ratio in these digesters.

In order to improve the heat economy, some further improvements have been developed and installed in recent two-vessel digester systems (Figue 6). The main part of the heating is indirect with steam in the transfer circulation between the impregnation vessel and the digester in order to minimize the dilution with condensate. Further, the alkali consumption is controlled and, if necessary, adjusted in this transfer circulation. This is often necessary when

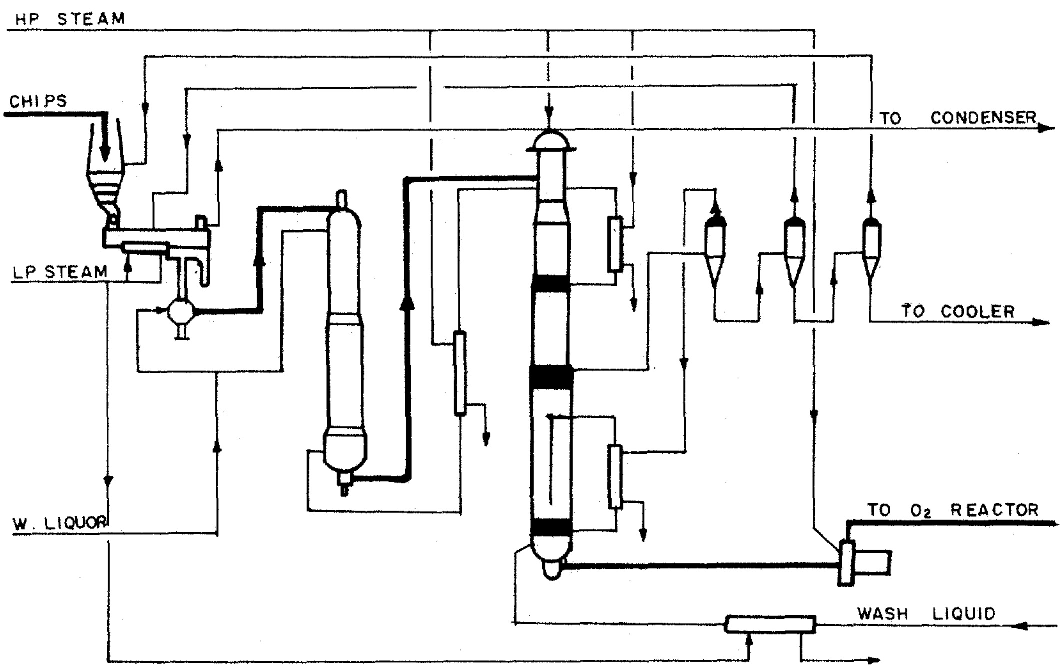

Figure 6.

having a non-uniform chip quality. Further, the heat recovery and odour are controlled by flashing the black liquor in three steps instead of two. The steam from the first step containing the main part of the malodorous gases and turpentine, is used in the "Hi-Heat" exchanger, and the condensate and non-condensables are sent to separate treatment. The second flash is used in the steaming vessel, and the third flash is sent to the chip bin.

Figure 7. shows a pre-evaporation system using flashsteam from the Kamyr digester system and which has advantages with regard to both heat economy as well as environmental control.

The majority of mills for manufacture of unbleached kraft pulp will no doubt be integrated, and the main product liner board, sack (bag) paper and other types of packaging products.

The pulping to higher yields without jeopardizing the runability on the paper machines and the quality of the final product are here of utmost importance for the economy when considering the scarcity and high prices of wood in many areas. The two-vessel digester is, as mentioned, specially suited for high-yield kraft pulp due to the very good impregnation. By integrating a disc refiner in the blow line, the pulp can be finally washed in a continuous diffuser still under closed conditions (Figure 8), which very much simplifies the whole system.

The refiner used for the fiber separation is a single disc refiner, especially designed for this particular application. Power applied varies between 30 - 50 KWh per ton, depending on through-put and pulp yield. The blow line refiner must have the ability to defiberize the chips into a pulp with a minimum

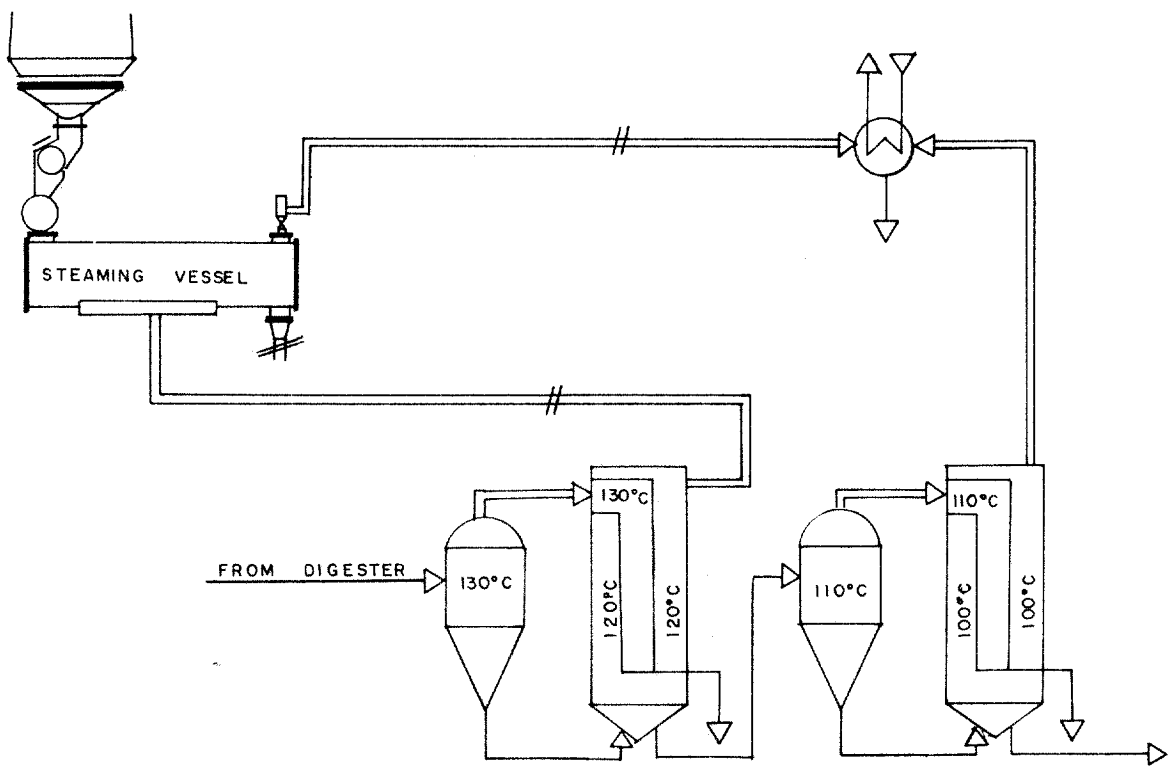

Figure 7

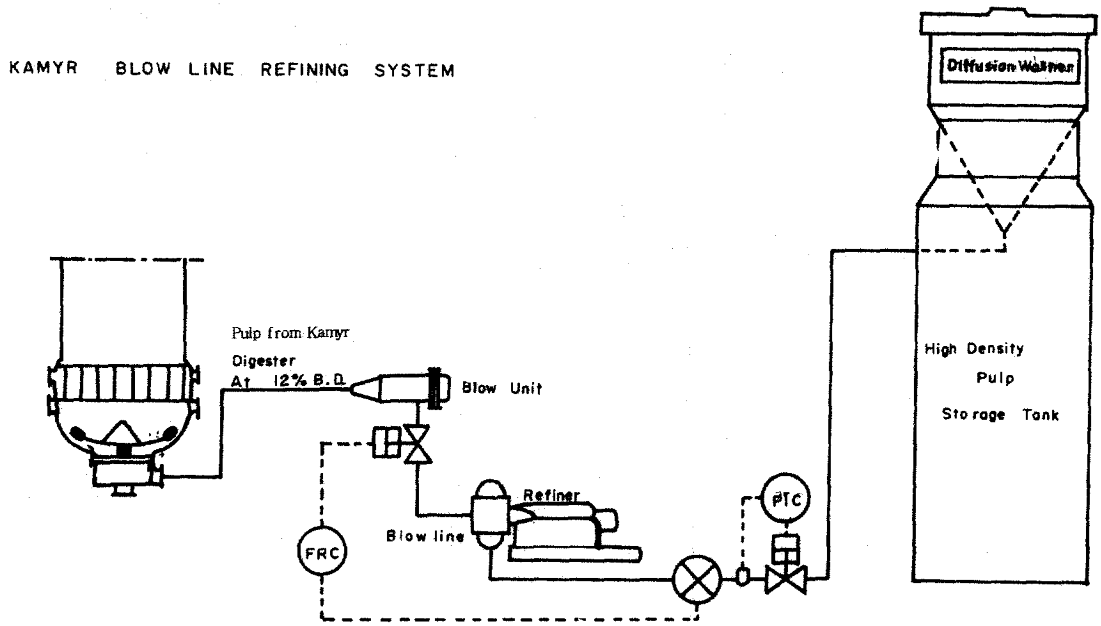

Figure 8.

of fiber bundles and shives. However, too much refining may negatively affect the washing efficiency because of the increased drainage resistance of the pulp. Shive content and drainage must therefore be balanced against each other to optimize the in-line defibering. In order to ensure good washing and at the same time achieve a low shive content, a second refiner stage, preferably at high consistency, is necessary.

In high yield pulps, the yield increase means a higher lignin content and these pulps are, therefore, not suitable for bleaching. However, an increase in yield can be obtained by stabilizing the carbohydrates in wood chips before or in the beginning of a kraft cook against alkaline degradation. There are many such methods developed but not so many are commercially adopted. One of them is the polysulfide pulping. This method can be used in batch digesters as well as in continuous digesters but the latter is to be preferred and especially the two-vessel digester. In the early work, polysulfide was produced by dissolving elementary sulphur in the white liquor. In extended mill operation, this resulted in increased sulfidity through build-up of sulphur containing compounds in the closed cooking liquor regeneration cycle and also in an increased emission of sulphur compounds, mainly sulphur dioxide. This became environmentally prohibitive.

A method has now been developed based on the regeneration of polysulfide from the sulfide present in the green or white liquor. It is used commercially under the trade name "Moxy". In this method the white liquor is catalytically oxidized with air. Several mills have adopted this process, of which the most are operating continuous digesters. One of them is M. Peterson & Søn A/S, moss, Norway. The mill products consist of speciality liner, sack paper and general purpose packaging paper. The digester is of the two-vessel type (Figure 3) and has a capacity of 450 tons per day of softwood kraft pulp. They have chosen this system in order to get maximum impregnation so that they could increase the Kappa number, an for the advantages in polysulfide pulping. The treatment of the chips is done in the impregnation vessel at a temperature of 110 - 125°C to obtain maximum yield increase. At higher temperatures the polysulfide is decomposed. The sulfidity of the white liquor is around 45% before the oxidation. The white liquor contains 7 - 9 g/l of polysulfide after the oxidation and this corresponds to a charge of 1.5% polysulfide calculated on wood. This gives an increase in yield of 2 - 2.5%.

Another method to increase the pulp yield is by adding antraquinone (AQ) or a derivate of AQ. After the first publication of Bach and Fiehn in 1972, the investigations and publications of this additive in various magazines are numerous, and some mills are using this technique. The ordinary process operation is practiced and no changes in other departments have been necessary. The eventual toxicity of DDA has also been thoroughly investigated by various trailas, and the results have confirmed the DDA additives' toxicity as negative.

The quality of pulps obtained in these above described methods is like the normal kraft pulps except for a somewhat lower tear strength, which is explained by the higher content of hemi-cellulose.

Regarding the economical aspects, there are three main factors to be considered, namely lower cost for less specific wood consumption, higher cost for additional fuel to compensate for lower heat value in black liquor, and additional cost for conversion of the white liquor to polysulfide white liquor or cost of additive chemical. The total contribution to production economy from these three factors will of course differ due to the local conditions. In addition, the effect on total costs will depend strongly on assumptions made regarding production strategy. When introducing a yield increasing process, the mill may run with equal input of wood or equal output of pulp or perhaps equal through-put of organic substance through the recovery boiler. The latter alternative results in more favourable outcome in most cases.

In a modern fiber line, the cooking, washing and screening operate as a closed system. This is also valid when an oxygen delifgnification stage is included. That means that the dissolved substances are recovered and burned, which means no water pollution. The bleaching plant is, however, still open and is therefore responsible for the water pollution. A method to reduce this pollution is to decrease the lignin content of the unbleached pulp either by an oxygen stage or by prolonged delignification in the cooking. This must, however, be done without decreasing the viscosity and strength properties. Studies of the sulphate cook with modified alkali profile shows promise in this respect. The two-vessel digester system is very suitable for the modified kraft cooking and there is experience available on process modifications that can be used, e.g. two separate alkali charges, counter-current impregnation and partial counter-current pulping.

From the environmental viewpoint it is obvious that the elimination of sulphur in the alkaline pulping processes would be a step forward. The old soda process has once again come into focus but in a modified version as soda-oxygen pulping or the even newer soda-anthraquinon approach. It is, however, to be noticed that not even a soda pulp mill is odorless. There is enough sulphur coming into the process through the oil used and the water and wood for formation of malodorous gases noticable to the surroundings. This will force the mills to use low-sulphur fuels and take other measures which will add to the costs.

The soda-oxygen pulping process is a natural extension of the principle of oxygen bleaching, now well established in many bleached pulp mills. In order to preserve the strength properties, the oxygen has to be applied to hard, very mildly cooked soda pulps, just above the point of fibre liberation with Kappa number of the order or 50 for hardwoods and 80 - 100 for softwoods. The objective of the subsequent oxygen stage is to reduce the lignin content to the level of normal chemical unbleached pulps. As there is a question of high-yield pulping, the continuous degester systems with blow-line defibration as described earlier are the most suitable. The oxygen delignification technology used today is based

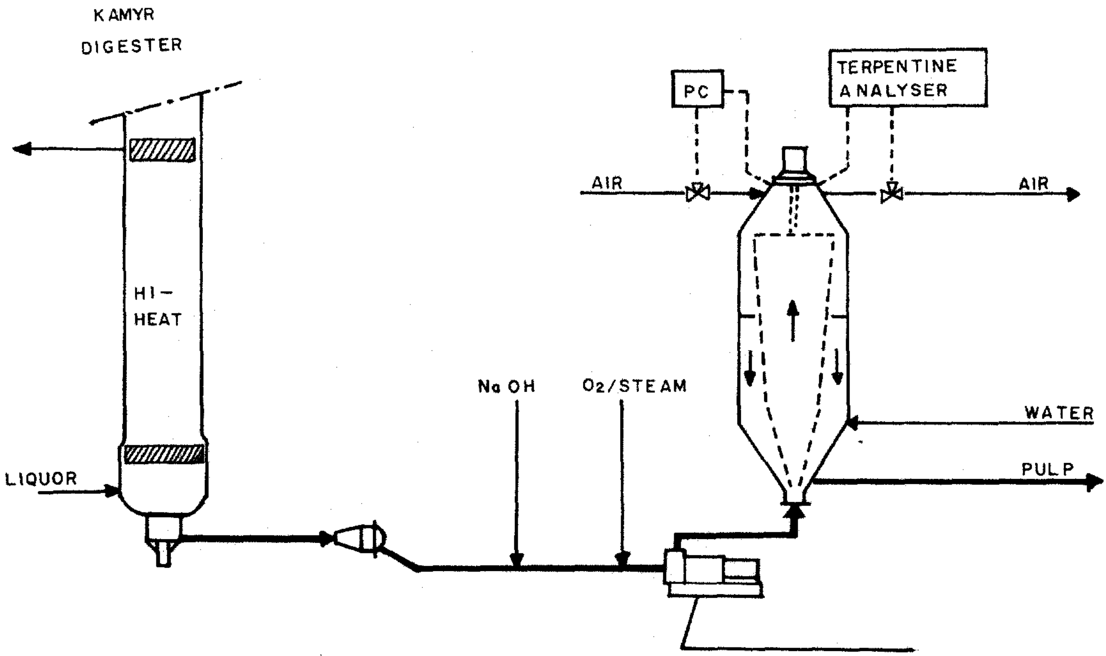

Figure 9.

on high consistency (25 - 30%) and relatively complicated and with high investment cost. Kamyr has developed a simplified technology and based on pilot-plant trials a commercial unit for oxygen delignification with 10% consistency will be started in the middle of this year. In this unit high-yield kraft pulp of Kappa number 60 will be delignified to Kappa number 20 - 25, and the pulp will then be bleached. Figure 9 (pilot plant).

The application of oxygen to a single stage pulping process does in practise pose more difficulty. We are dealing with a gas of quite restricted solubility and this coupled with diffusion rate and the specific oxidation rate determine the overall kinetics.

An alternative is to reduce the chips to fibres by thermomechanical or chemi-thermomechanical means and then subject them to the soda-oxygen treatment. This is still in research scale.

There is a strong case for further development of a single stage process or perhaps more logically the combining of alkali - pre-treatment and oxygen delignification phase sequentially in one continuous process vessel. This concept, patented and under development in Japan, is based on a modified Kamyr digester with three phases, precooking, washing and oxygen treatment.

The netural sulphite pulp (NSSC) is mainly produced from hardwoods and is semichemical. The mild chemical conditions and by limiting the delignification, the hemi-cellulose in hardwoods are preserved, which gives the corrugating medium board the desired stiff structure. For the NSSC-pulping there are many more continuous digester systems on the market than for chemical pulps. I will in this paper not compare the virtues of the various types. In case of Kamyr, there is the vaporliquor phase digester (Figure 2) which is used, and this in combination with blowline defibration and subsequent diffuser washing. This system very much simplifies the washing and refining operation.

The most of the mills today is still controlled by

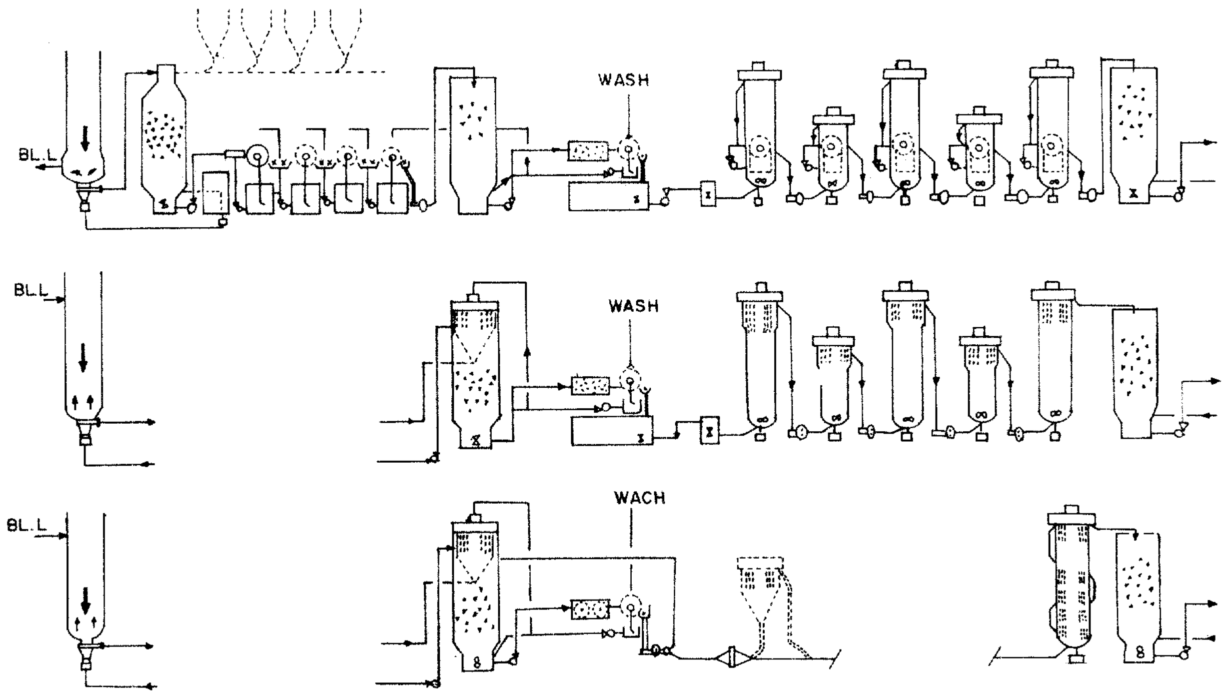

Figure 10.

analog instrumentation. However, often a user is seeking an optimum of control in the aim of higher efficiency, not only for process-control of separate departments, but also for production control of the complete mill. The trend in the recent years has been towards small dedicated computers, which can be integrated in a complete production and process control system. As the continuous equipment is outmost adaptable for these systems, Kamyr has together with the Accuray company developed computer control for their systems.

Table 1. KWH/TON 90% BLEACHED PULP

	Low Energy	Conv.
Cooking & Washing	45	70
O_2-Stage & Wash	45	85
Screening	50	55
Bleaching	45	125
Total	185	335
Difference	–	+150

All the mentioned equipment are important parts of an energy-saving modern pulp line. In Figure 10 one can see the development of pulp equipment, where the latest alternatives are reprensented by a Kamyr digester with "Hi-Heat" wash, a diffuser washer and a displacement bleach plant which means the pollution from the mill is reduced to a minimum and also energy use as shown in Table 1 and 2.

Table 2. PER TON 90% BLEACHED PULP

		Low Energy	Conv.
Steam (Ton)			
	Cooking	0.75	1.7
	O_2-Stage	0.20	0.1
	Bleaching	–	0.4
	Total	0.95	2.2
Water		13.5	35