The Challenge of the Growth of Recycled Fiber Addition to TMP and CTMP Mechanical Pulp Furnishes for the Production of Printing Paper Grades.

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ABSTRACT:-- Worldwide in the last twenty years there has been a dramatic increase in the usage of recycled fiber. In the period 1971-1991 the global production of recycled fiber increased almost three fold from 32 million tons per year (Mt/y) in 1971 to 96 Mt/y in 1991. In this period the production of recycled fiber has increased at a rate more than double that of virgin fiber.

In Asia the rate of growth of recycled fiber (RCF) has been significantly higher than the rest of the world. In 1971 Asia utilized 19% of the total global production of RCF and this had increased to 32% by 1991. In this period the production of RCF in Asia has increased at a rate four times greater than virgin pulp.

In 1971 RCF represented 29% of the total pulp furnish in Asia and this had increased to 50% by 1991. It is predicted by the year 2001 recycled fiber will represent 57% of the total furnish used in Asia. This increased utilization of RCF has had and will continue to have major effects on the furnish composition of printing paper grades.

In Asia the addition level of RCF to printing paper grades are about double that of the rest of the world. For newsprint grades in Asia it is predicted that the addition level of RCF will increase from 43% in 1988 to 49% in 2001 and for printing and writing grades it is predicted that the addition of RCF will increase from 14% in 1988 to 23% in 2001.

This Change in furnish composition will create challenges for both the papermaker and the equipment supplier. There will be significant changes in the design of the pulp supply systems and in the properties of the furnish components. In the paper we will review these changes. We will compare the design of DIP, CTMP and TMP systems. We will show that there are strong similarities not only in the philosophy of the system designs but also in the individual component modules. To simplify the system discussion we have introduced a method of classifying of deinking systems.

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The increasing addition levels of recycled fiber to the high quality printing grades will require the production of high-quality recycled fiber. In our discussion we will show that the increasing level of sophistication in recycled fiber system design will enable the papermaker to produce recycled fiber pulps with the highest quality require. Finally we will compare the properties of pulps produced from modern DIP, TMP, CTMP and other virgin pulp systems.

INTRODUCTION

The objective of this paper is to discuss the effect of the increased utilization of recycled fiber in printing paper grades. For our discussion printing paper grades include newsprint, newsprint specialities (SC and LWC) and printing and writing grades. The furnish used in the production of all paper and board grades can be divided into two major classification -- Virgin fiber and Recycled fiber. Virgin fiber can be defined as the pulp that is produced from a system that processes wood chips. Recycled fiber (RCF) can be defined as the pulp that is produced from a recycled fiber system that processes wastepaper.

Since the mid 1970's the family of mechanical pulps (TMP and CTMP) has become one of the major virgin pulp furnish components for printing grades. In addition the utilization of recycled fiber in these grades has also increased. It is predicted that the addition level of recycled fiber to these grades will increase at a higher rate than the mechanical pulps.

The major recycled fiber pulp that is used for newsprint grades is deinked pulp (DIP) produced either from old newspapers (ONP) or more often from a combination of old newspapers (ONP) and old magazines deinked pulp (DIP) produced from either mixed office wastepaper (MOW) or selected office wastepaper (SOW).

This paper can be divided into three parts. First we will discuss in more detail the market changes and discuss the driving forces, which are causing these changes. Second we will compare the design of TMP/CTMP mechanical pulping systems with those of DIP systems. To simplify these discussions we have introduced a method of classifying of deinking systems. Finally we will discuss the properties of these pulps for the production of printing grades.

MARKET REVIEW

Global Market

There has been a number of published market research reports on the recycled fiber market (1-5). One of the most important and most comprehensive are the series of reports produced by Jaakko Poyry (3). Most of the market data quoted here is taken from these reports. All of these studies predict a large growth in the production of recycled fiber. Later data, which is now becoming available indicates that these forcasts have underestimated the growth of RCF.

In the twenty year period from 1971 to 1991 the worldwide production of paper and board as almost doubled from 130 Mt/y (1971) to 245 Mt/y (1991). In this twenty year period (1971-1991) the growth of recycled fiber has been more than twice that of virgin fiber (*Figure 1*). The production of virgin fiber has increased by 60% from 98 Mt/y (1971) to 159 Mt/y (1991), while the production of recycled fiber has increased by 170% from 32 Mt/y (1971) to 86 Mt/y (1991).

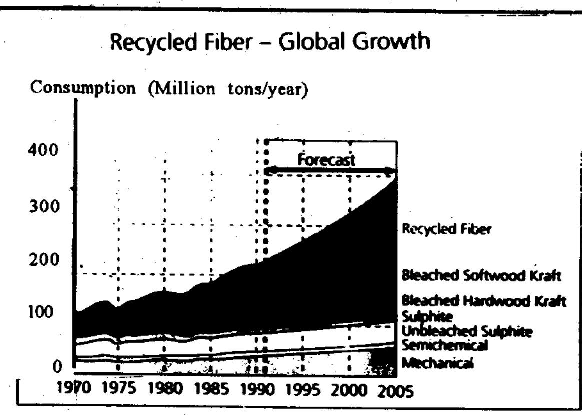


Figure 1. Globally RCF is growing at more than twice the rate of virgin pulp.

It is predicted that this trend will accelerate in the next 10 years. The production of recycled fiber will increase at a rate three times faster than virgin fiber. The production of virgin fiber will increase by 18% from 159 Mt/y (1991) to 187 Mt/y (2001) while the production of recycled fiber will increase by 51% from 86 Mt/y (1991) to 130 Mt/y (2001).

Hence, as is shown in *Table 1*, recycled fiber has increased from 25% of the total worldwide furnish in 1971 to 35% in 1991. It is predicted that recycled fiber will represent 41% of the total worldwide furnish by the year 2001.

Table 1. RCF will represent 41% of total furnish by 2001.

Global Market Growth

Production		1971	1991	2001
Paper and Board	Mt/y	130	245	316
Recycled Fiber	Mt/y	32	86	130
Recycled Fiber	%	25	35	41

There are three major driving forces that are causing this dramatic change in the market. They are economical, technological and environmental forces (*Figure 2*). Traditionally the major driving force has been economics. In most countries, and especially those without significant forest resources, recycled fiber is a lower cost furnish than virgin fiber.

Recycled Fiber Market Growth

Three Major Driving Forces

1 Economical

2 Technological

3 Environmental

Figure 2

The second driving force is technology. The dramatic market growth has over-shadowed to an equally dramatic improvement in the technology of recycling. This is especially true in the technology of deinking. Development in recycled fiber system technology have dramatically improved the quality of the pulp, the papermachine runnability of the pulp and the yield of the system. These latest developments now enable recycling mills to produce a very high-quality recycled fiber with properties similar to virgin pulp. Recycled fiber is now making significant in roads into the higher quality paper grades.

The third factor, environmental legislation, has become more significant in the last five years and will become more important in the next 10 years, For example in the USA, most states have laws or are going to introduce laws to establish minimum addition levels of recycled fiber to various paper grades. Thus in California, recycled fiber must be at least 25% of the newsprint furnish. By the year 2000 this minimum level of recycled fiber addition has to be increased to 50%.

One of the most recent proposed environmental legislation, known as the presidential "Executive Order", is expected to have a very significant impact on the industry. This Executive Order will mandate federal agencies to purchase office stationary with a minimum level of recycled fiber. It is expected that this will become a standard for all states.

Asian market

For the period 1971-1991 the paper and board market in Asia increased at about twice the rate of the rest of the world. The production of all paper and board grades in Asia increased by 170% from 20 Mt/y (1971) to 54 Mt/Y (1991). This rate of growth increased the Asian share of the total paper and board world market from 16% (1971) to 22% (1991).

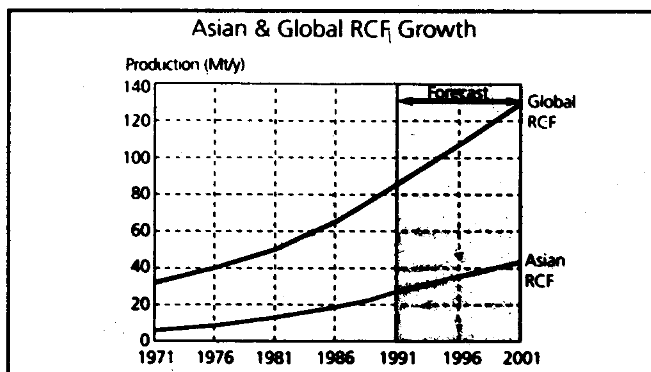


Figure 3. Asian RCF growth highest in the world.

Asia has been at the forefront of the utilization of RCF and the rate of growth of RCF has been significantly higher in Asia than the rest of the world (*figure 3*). In the period, 1971-1991 the production of RCF increased almost five fold from 6 Mt/ y (1971) to 27 Mt/y (1991). The Asian share of the total RCF world market increased from 19% in 1971 to 32% in 1991.

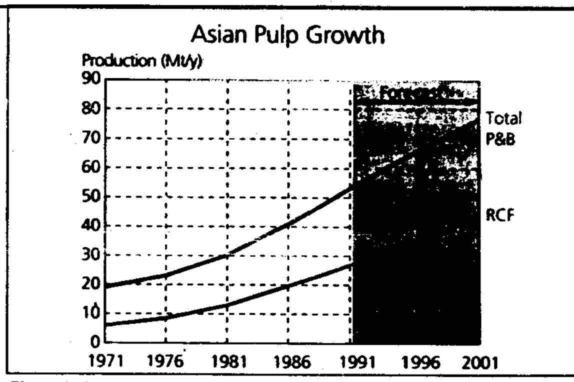


Figure 4. By 2001 RCF will represent 57% of the total furnish in Asia.

Compared to virgin pulp the rate of increased utilization of RCF in Asia has been equally dramatic (*figure 4*). The production of RCF in Asia has increased at a rate of over four times that of virgin fiber. Hence RCF increases its share of the total furnish from 29% in 1971 to 50% in 1991. It is predicted that by the year 2001 RCF will represent 57% of the total furnish used in the Asian market.

This increased utilization of recycled fiber will, on a worldwide basis, increase the addition levels of

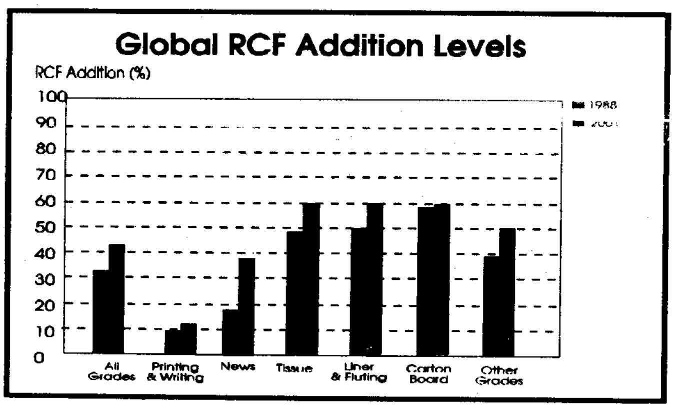


Figure 5. RCF addition increasing fastest in high printing grades.

recycled fiber to every important grade (*Figure 5*). For the lower quality grades, such as cartonboard, liner, fluting and tissue, the recycled fiber content will show some marginally increase so that by the year 2001 recycled fiber will be about 60% of the furnish. For the higher quality grades the increase in level of addition for recycled fiber will be more significant. For newsprint the addition level will increase from 17.5% (1988) to 37.3% (2001), while for printing and writing grades the increase will be from 7.4% (1988) to 12.1% (2001).

In Asia the average addition level for RCF to all the paper and board grades is already high and

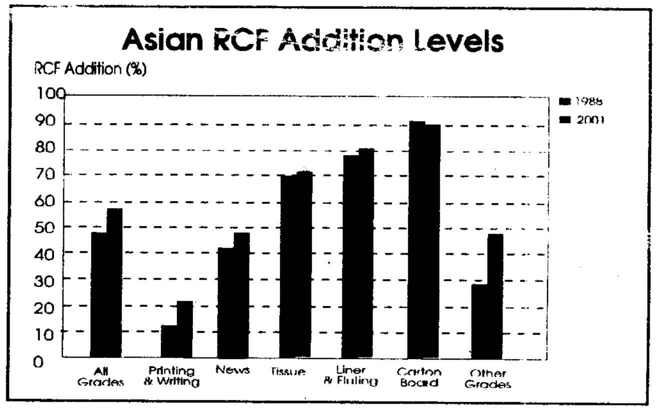


Figure 6. In Asia the RCF addition levels are the highest in the world

will increase from 49% (1988) to 57% (2001). In the lower quality grades the addition level of RCF is very high and these high levels will be maintained or even marginally increased. Thus the RCF addition level to carton board (92%) and tissue (70%) will not significantly change, whilst there will be a marginal increase in the RCF addition level to liner and fluting from 77% (1988) to 81% (2001) (*Figure 6*).

It is in the higher quality printing grades where there will be significant increases in RCF addition levels. For Asian newsprint grades, which already has one of the highest RCF contents in the worlds, the RCF addition level will increase from 49% (1988) to 57% (2001). It is the highest quality grades (printing and writing) where the largest increase in RCF addition levels will occur. The RCF addition level to Asian printing and writing grades will increase from 14% (1988) to 23% (2001).

TMP and CTMP for Printing Paper Grades

Printing paper grades have traditionally been made from a combination of mechanical and chemical pulps. The major driving forces for the utilization of mechanical pulps are economics and quality. Mechanical pulp is a low cost pulp with excellent printing characteristics. It is one of the Major furnish components for both newsprint and printing and writing grades (6).

Mechanical Pulping Systems

Three Major Technological Functions

1 Fiber Separation and Fiber Development

2 Contaminant Removal

3 Bleaching

Figure 7

Mechanical pulping systems are designed to convert wood chips or roundwood into mechanical fiber. A mechanical pulping system has three major technological functions (*Figure 7*):

1) Fiber separation and fiber development

2) Contaminant removal

3) Bleaching

Fiber Separation and Fiber Development

Fiber separation and fiber developments are the most important features of a mechanical pulping system. Usually the fiber separation occurs in a primary preparation stage and fiber developments occurs in the secondary or rejects refining stage.

In some mechanical pulping systems the primary preparation stage can be either grinding or refining. Initially the primary preparation stage was grinding which produced a family of groundwood pulps. Modification of this basic system design can produce pulps such as:

GWD (Stone Ground wood)

PGW (Pressurized Stone Groundwood)

Later the primary preparation process was converted to refining and a family of refiner pulps could be produced. Modification to the basic system design can produce pulps such as:

RMP (Refiner Mechanical Pulp)

TMP (Thermo Mechanical Pulp)

CTMP (Chemical Thermo Mechanical Pulp)

BCTMP (Bleached CTMP)

TMP, introduced in the mid 1960's had significant advantages over RMP TMP is stronger, contained less shives and has a lower bulk. Modifications to the TMP systems, including bleaching and chemical treatment, improved the quality. The TMP process normally consists of a primary pulping stage with pressurized refining at high temperature followed by a second pressurized refining stage. A typical system is shown in *Figure 8.*

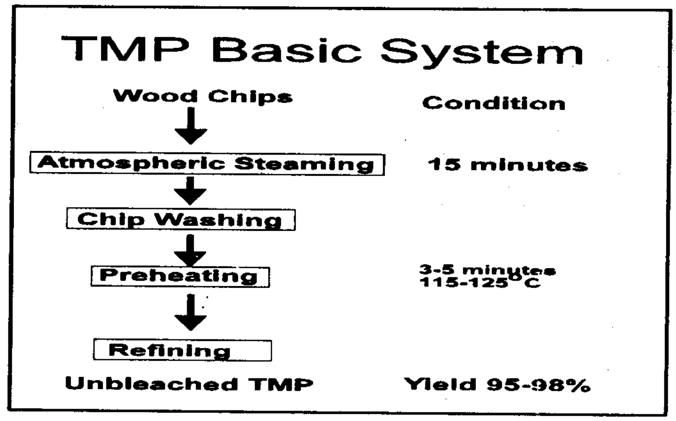


Figure 8

The TMP process is capable of producing pulp from a wide range of softwoods throughout the world and the unbleached pulp is suitable for use as the major furnish component in newsprint and associated grades of paper. Peroxide bleaching is capable of extending the range of application of TMP. In some instances TMP has proven successful as the sole furnish component of newsprint. More usually, however, TMP has been used to decrease substantially the amount of chemical reinforcing pulp required for the production of newsprint.

Contaminant Removal

The contaminant removal modules are screens and cleaners. The design of features of these screens and cleaners are similar to those used in recycled fiber systems. However, because of the higher level of debris and contaminants in wastepaper the screening and cleaning modules in recycled fiber systems are normally more complex.

Bleaching

Although the application of TMP has generally been limited to the lower freeness range, mild chemical modification of TMP in the form of CTMP (*Figure 9*) has extended the useful range of application of high yield pulp to a much broader spectrum of products.

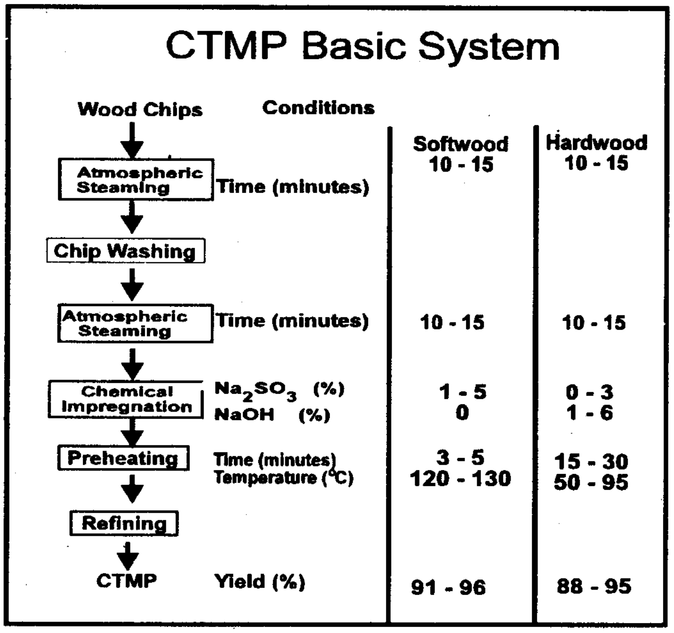


Figure 9

This technology, integrated with peroxide bleaching, is capable of producing pulps suitable for use in printing and writing grades. The chemical treatment not only reduces the shive content and improves the consolidation and bonding properties of the pulp, it also results in a brightness improvement over TMP, thereby provided a more favourable starting point for attaining the high brightness levels necessary for printing and writing grades in conjunction with peroxide bleaching system shown in (*Figure 10*) is a two stage system involving strict counter current bleaching and washing. The first stage medium consistency bleaching is carried out at 15% consistency using residual peroxide and other chemcials remaining in the pulp after the second stage high consistency (30%) bleaching. These residual bleaching chemicals are recovered by adding wash water to the mixing conveyor to dilute the

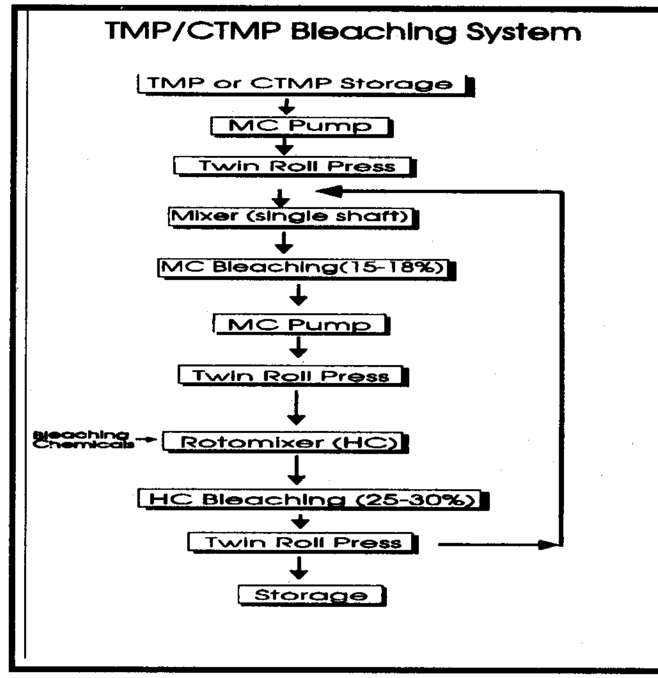


Figure 10

second stage bleached pulp prior to pressing to high solids content for storage. The system water balance demands lower bleaching consistency in the primary bleaching stage as well as in prebleaching during the storage of unbleached pulp if this is practised.

Mechanical Pulping Systems for Printing Grades

The design of TMP/CTMP systems depends primarily on two factors:

1) The fiber morphology of the feed (wood chips)

2) The desired quality of the final pulp

Softwood TMP is very suitable for newsprint while both softwood CTMP and hardwood CTMP can be used in printing and writing grades.

TMP

In Asia a predominant softwood is Chinese red pine (Masson Pine or Pinus Massoniana). A system that would be suitable for processing Masson Pine into TMP for newsprint production is shown in *Figure 11*.

Atmospheric steamed and washed chips are steamed in a small atmospheric bin prior to impreg

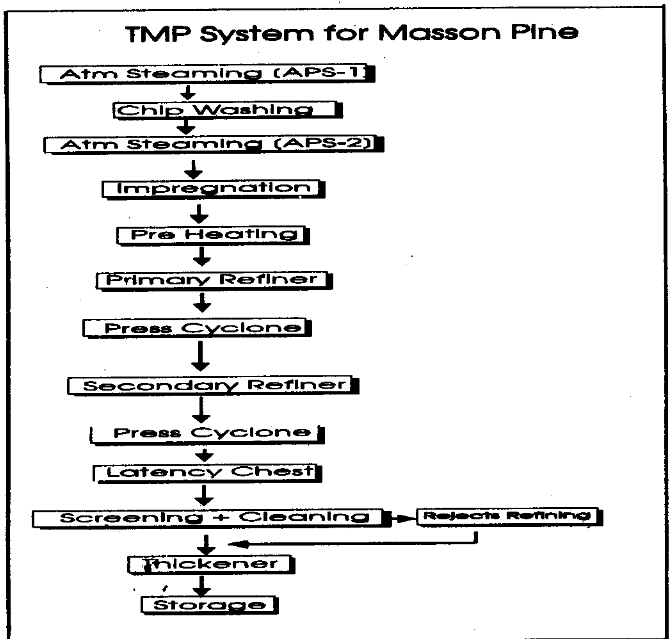


Figure 11

nation with water or sodium sulphite and a chelating agent. The impregnated chips are then preheated for three minutes at 120-125°C prior to two stage pressurized refining. After latency removal, the secondary discharge pulp is screened and cleaned. Combined screen and cleaner rejects are thickened to 35% solids content prior to rejects refining. The refined rejects, after dilution, are screened and four stage cleaned with the primary cleaner accepts joining the main line cleaner accepts prior to the disc filter. Backward flowing steam from the refiners satisfies the steam requirements for atmospheric presteaming and pressurized preheating. The contaminated steam flowing forward with the pulp is recovered at higher pressure from the pressurized cyclones and subsequently converted into clean steam in a reboiler. The normal use for this steam is a papermachine drying, but local conditions will dictate how this excess steam is used.

With minor modifications, and the addition of low consistency post refining, this system would also be suitable for the manufacture of lower freeness pulps suitable for use in SC and LWC grades.

CTMP

The brightness requirements of certain high yield pulps for use in printing papers, as well as in some board and tissue grades, are high. In order to achieve high brightness levels with good economy, an efficient bleach plant is essential. Peroxide bleaching is most effective when carried out at high consistency.

Using a two stage approach to bleaching, the brightness of TMP can be raised to the range 78-80%. Brightness levels in excess of 80% ISO brightness can be achieved on softwood CTMP and even higher brightness levels in the range 83-87% ISO brightness can be achieved on CTMP from certain hardwoods.

A system suitable for the production of bleached hardwood CTMP suitable for printing and

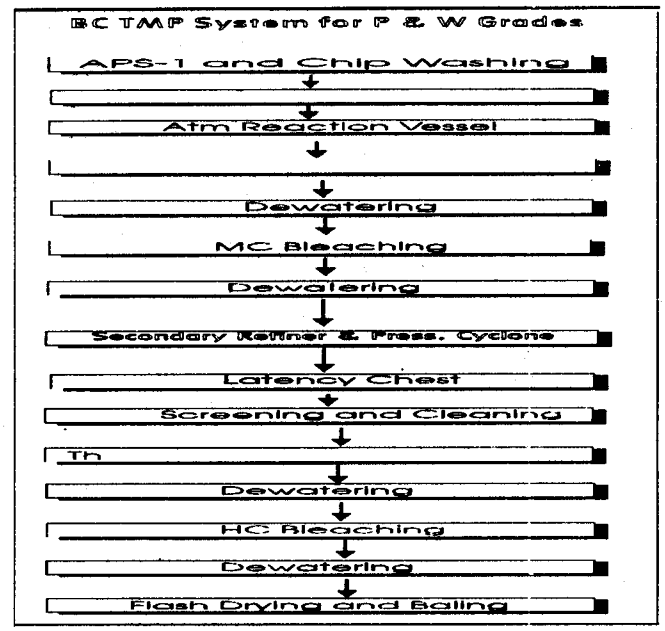


Figure 12

writing grades is shown in *Figure 12*. The preheater used for softwood has been replaced by an atmospheric reaction bin and the system shows a high consistency second stage bleach tower for the production of high brightness pulp. The rejects from a hardwood CTMP screening system are low and can conveniently be returned to the interstage wash chest.

TMP and CTMP in Printing Grades Newsprint and Associated Grades

Traditionally, newsprint has been produced from a 1:3 mixture of chemical pulp and relatively weak stone groundwood pulp. Today, however, the use of refiner based high yield pulps in newsprint and associated grades is well established in those locations where the dominant available wood species is Spruce. TMP has proven itself capable of completely eliminating the requirements for chemical reinforcing pulp in newsprint. For other locations where less preferred species prevail, TMP from available species is normally used in admixture with some chemical reinforcing pulp for newsprint manufacture.

The development of the CTMP process has provided an additional degree of freedom with regard to furnish possibilities for newsprint manufacture. It is thus possible today to utilize pine CTMP in the newsprint furnish in combination with a minimum level of chemical reinforcing pulp.

Wood Containing Printing Papers

These grades are principally represented by the uncoated super calendered (SC) range of papers and by light weight coated (LWC) paper. Both types of paper are used in printed products where high printing quality is required and where key property requirements include good runnability and printability in addition to high surface smoothness, high opacity and high surface strenth. These papers must exhibit excellent surface properties at maintained strength levels. Both SC and LWC furnishes require a high mechanical pulp content and use long-fiber chemical pulp as the reinforcing component.

The SC paper furnish also contains filler and the paper is super calendered to achieve the required level of surface properties. The mechanical pulp component must be used at relatively low freeness level since it is essential to minimize shive content, develop the fines fraction, decrease sheet porosity and develop a pulp which is capable of producing a paper having an extremely smooth surface profile. Thus the replacement of stone groundwood and/or chemical reinforcing pulp by TMP or CTMP must be done at maintained strenth without compromising the surface properties.

Relative to the SC grades, LWC paper grades exert even greater demands on the quality of the base paper and thus on the furnish components since the basis weight levels involved are very low. The coating operation requires a substrate with high strenth, high surface smoothness, extremely low shive content and low porosity. The chemical reinforcing pulp component is generally higher than that of SC papers due to strength considerations.

The low freeness requirements of mechanical pulp for SC and LWC grades translate to high specific energy consumption levels. Recently, low consistency refining trial using the Sunds Defibrator Conflo refiner have indicated that this approach has some significant energy saving benefits as well as some pulp quality advantages over conventional high consistency refining during the latter stages of pulp development during the final 25-30 points of freeness reduction.

Fine Paper Grades

In general, the use of CTMP in fine paper grades has progressed less rapidly than application of this type of pulp in other grades. The potential of bleaching softwood CTMP above 80% ISO brightness and hardwood CTMP to significantly higher brightness levels than this offers new possibilities for the partial replacement of chemical pulp in a number of printing paper applications.

Recycled Fiber for Printing Grades

The design of a recycled fiber system will primarily depend upon the quality of the wastepaper feed material and the desired quality of the final recycled fiber (8). For printing grades the raw material is printed wastepaper such as newspapers, magazines and office waste. The desired quality of the recycled fiber is usually very high and hence recycling systems for print grades are the most sophisticated systems available.

Recycled Fiber Systems

Three Major Technological Functions

1 Contaminant Removal

2 Bleaching

3 Dispersion and Fiber Development

Figure. 13

A recycling system has three major technological functions (figure 13):

1) Contaminant removal

2) Bleaching

3) Dispersion and/ or fiber development.

We can see that a recycled fiber system has the same three technological function as a mechanical pulping system. The major differences between recycled fiber systems and mechanical pulping systems are highlighted as follows:

(1) Contaminant removal

Contaminant removal products for RCF systems are more sophisticated and more complex. There is a wider spectrum of contaminants and a higher concentration of contaminants in wastepaper than in virgin pulps. In fact the most important technological function of a RCF system is the removal of these contaminant.

(2) Bleaching

Bleaching in recycled fiber systems is normally simple compared to mechanical pulping systems. The starting brightness of the wastepaper furnish is higher and the required uplift in brightness is less. However, as lower qualities of wastepaper are used to produce higher quantities of DIP pulps, bleaching modules for RCF systems are becoming more complex to satisfy the requirements for higher brightness and colour removal.

(3) Dispersion and fiber development

The requirements for fiber development for RCF systems are of course a good deal less than mechanical pulping systems. Often the challenge is to minimize any fiber damage. However, as lower-quality wastepaper will be utilized to produce higher-quality RCF the requirement to maximize the strength potential of the RCF pulps will become more and more important.

Contaminant Removal

Contaminant removal is the most important feature of a recycling system. Recycling of wastepaper is essentially a separation process(*Figure 14*). Wastepaper contains two major components- fiber and contaminants. The function of a recycling system is to separate usable fiber from the contaminants.

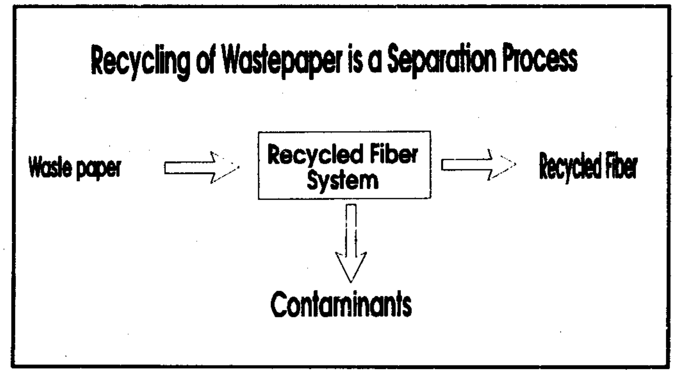


Figure. 14

The contaminants in wastepaper are physically different from the fiber. They are separated in the recycling system by incorporating removal modules which exploit the differences between the properties of the fiber and the contaminants (7).

A list of typical contaminants can include items that vary from large rocks, staples, glass, plastics to waxes, stickies, inks and ash. These contaminants can be removed by exploiting the diffeence in size, shape, density or surface chemistry between the contaminants and the fiber.

Table 2 shows where some typical contaminants are removed in a recycling system. Pulping, detrashing and screening essentially remove the contaminants by size while cleaning removes by density. Flotation and washing exploit the chemical differences between fiber and contaminants, although size is also an important parameter.

Contaminant Removal in RCF Systems

Module	*Major Separation Parameter*	*Typical Contaminants Removed*
Pulping	Size	Plastic bags, Large objects
Cleaning	Density	Staples, Grit, Specks
Screening	Size	Plastics, Stickies
Flotation	Surface Chemistry	Small Ink Particles,
Washing	Surface Chemistry	Very Small Ink Particles

Table 2

A contaminant is easiest to remove when a given property is most differentiated from that of a fiber. As an example, we can correlate the contaminant size with the difficulty of contaminant removal (*Figure 15*). Contaminants can vary in size from sub micron to size approaching a meter. The largest contaminants such as cans, bottles and engine blocks are the easiest to separate. However, as the size of the contaminants approaches that of the fiber, the degree of difficulty of removal increases rapidly. Thus, inks and stickies are the most difficult contaminants to remove.

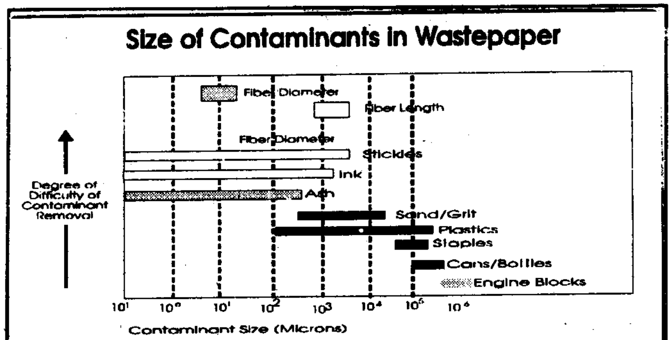


Figure 15. The smaller the contaminant the more difficult to remove.

In *figure 16* we can see some typical contaminants that were removed by the pulping module at Stora Feldmuhle Hylte, a newsprint deinking mill in Sweden.

Fig. 16. A Wide range of interesting contaminants removed in the pulper module.

In the early 1980's a model was developed relating the efficiency of the various removal module to the particle size (8). This is illustrated in *figure 17*, where it can be seen that the smallest particles (up to 20 microns) are removed by washing, the medium-size particles (20-200 microns) are removed by flotation, and the larger-size particles (200 microns +) are removed by cleaning.

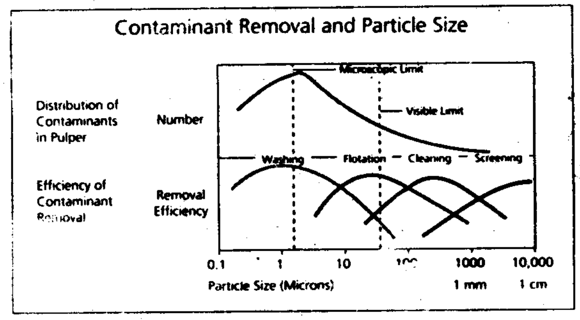


Fig. 17. Particle size is the most important parameter controlling the efficiency of contaminant Removal.

Bleaching

A bleaching system in a recycling system has two major functions:

1) Bleaching of the base fiber

2) Color removal

There has been a number of reviews of bleaching of recycled fiber (9,10). For newsprint systems hydrogen peroxide and sodium hydrosulphite are normally used. For printing grades FAS is also used, mainly of oxygen (11) and ozone (12), although as yet these have not been fully commercialized. A system, which is in the early stage of commercialization is a system for the oxygen delignification of brown OCC for the production of white printing grades (13). Chlorine based bleaching agents are still being used in some countries but it is generally recognized that their usage will be reduced. Hydroxide peroxide is added to the system either in the paper at a high consistency bleaching stage or more recently in the dispersion/refining stage. Sodium hydrosulphite and FAS are normally added at a dedicated bleaching stage although there has been recent reports of addition at the dispersion/refining stage (14).

Dispersion and Refining

Virtually all modern recycling systems for the production of high quality newsprint and printing and writing grades have a dispersion stage (15), Whose primary function is to disperse contaminants such as ink and sticks to a smaller particle size range. Many mills that require an improvement in the strength properties either choose a dispersion module that can also improve the strength properties by refining and/or install a low consistency refining stage (16). This is often referred to as a post refining stage. This choice is, in many cases, the resultant of two contributing forces.

First as the quality of the wastepaper decreases, the strength properties are lowered, and secondly as the recycled fiber is added to higher and higher quality grades the strength properties of the recycled fiber become more and more important.

Recycled Fiber Systems for Printing Grades

Recycled fiber systems for printing grades are by tradition called deinking systems. This is because ink is one of the most difficult contaminants to remove. The flotation ink removal module can be considered to be the technical heart of the deinking system. The final recycled fiber pulp is called deinked pulp or DIP. A review of deinking systems has recently been published (17)

Classification of Deinking Systems

At present (1994) the global production of DIP is approximately 20 Mt/y, which is produced from about 600 major deinking systems. Few, if any, of these systems are identical and they are not relatively easy to categorize. However, we have developed a classification of deinking systems, which we believe is a good aid in the understanding of deinking system technology.

We have classified deinking systems in a matrix manner with the following two important criteria:

(1) Technology of Ink Removal

In a deinking system ink can be removed either by washing technology, flotation technology or a combination of both.

(2) Degree of system complexity

The degree of system complexity or sophistication can be related to the number of major water loops. Traditionally all deinking systems were single loop systems. About 15 years ago two loop systems were introduced which have now become the standard for high-quality deinking systems. Recently three loop systems have been introduced.

Classification of Deinkig Systems

Complexity	Technology		
	Washing *only*	Flotation *only*	Combination
One Loop	W-I	F-I	C-I
Two Loop	W-II	F-II	C-II
Three Loop	W-III	F-III	C-III

Figure 18. Classification based on ink RemovaL Technology and complexity.

In North America deinking systems had been traditionally based on washing only technology whilst in Europe the deinking systems had been traditionally based on flotation only technology. In washing only systems, the only ink removed from the main line is the inky effluent of the washing module. In flotation only systems, the only ink removed from the main line is the inky foam from the flotation module. Most technical advances made during the last ten years have involved combination systems, which utilize both flotation and washing to remove ink from the main line.

The disadvantages of traditional washing technology (e.g., high water consumption, cost of clarification chemicals, low yields, poor speck removal) have provided most of the impetus for the development of the flotation module, while the limitation of flotation (poor ash removal poor removal of very small ink particles) have determined the need for washing.

For classification purposes we have designated the systems either W (washing), F (flotation) or C (Combination).

The degree of complexity of a deinking can be related to the number of loops. A loop can be defined as a section of the mainline which can be considered to have a closed water circuit. A loop would end with a dewatering device with an output consistency of more than 10%. Traditionally all deinking systems were single loop systems. About

15 years ago two loops deinking systems were introduced. In a two-loop system a second loop containing more contaminant removal modules was added to the traditional single loop. The major objectives of this second loop were to:

(1) Improve the quality of the final DIP product

(2) Improve the paper runnability of the final DIP.

(3) Utilize a lower-quality wastepaper

(4) Increase the addition level of DIP to the papermaking furnishes.

The last five years have seen the introduction of the three-loop systems which have further enhanced the performance of deinking systems. For classification purposes we can refer to systems as single loop (I), two loop (II) or three loop (III).

To complete our classification code we can consider for example a single loop flotation system as F-I, a two loop washing system as W-II and a three loop combination system as C-III.

Using this classification we can now discuss mill examples of each of these type of deinking system.

Flotation Only Deinking Systems

Traditionally, flotation only system design was

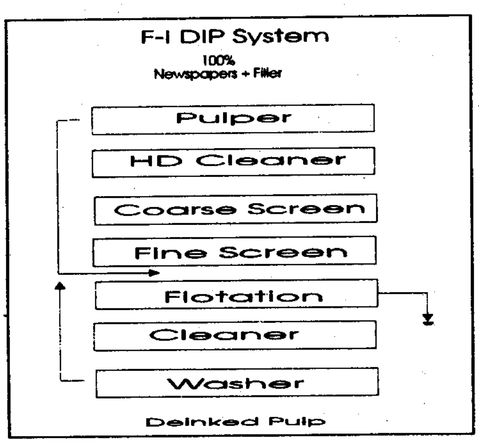


Fig. 19. Flotation Single Loop, Papelera Peninsular,

the standard European deinking system for printing grades. Although the system often incorporates a washing or thickening stage, the inky effluent (grey water) is recirculated within the system. This type of system gives the highest yield and lowest chemical cost for rejects treatment.

A typical example of the flotation only single loop system (F-I) is the news deinking system that was started up in 1984 at Papelera Peninsular in Madrid, Spain (8). The system schematic is shown in *Figure 19*. This is a single loop system with a reported yield of 94%.

This basic system design can be improved by the addition of bleaching and dispersion modules. One of the most sophisticated flotation only systems is the news dekinking two loop system at Haindl (Germany) which started up in 1993 (18). In this system, the first standard loop is followed by a dispersion module and a post-flotation loop. This post-flotation loop improves the quality and runnability of the DIP and will be discussed in detail later.

Washing Only Deinking Systems

Traditionally the washing only system was the standard North American deinking system. This type of system is very suitable for the removal of very fine ink (e.g. flexo) and the removal of ash. A typical example of a washing only single loop system (W-I) is the Garden States DIP system in New Jersey, U.S.A. This system, designed for the production of DIP from 100% newspapers, is shown in Figure 20. The deinked pulp is used as a 100%

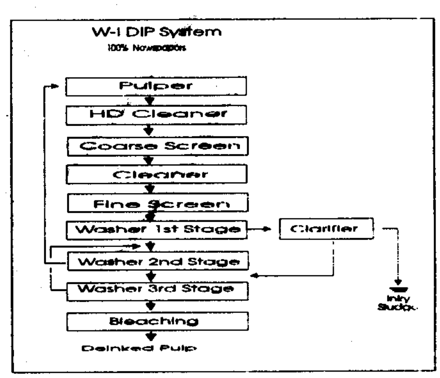


Fig. 20. Washing Single Loop, Garden States, New Jersey, USA.

furnish for the production of newsprint.

Single-Loop Combination Deinking System (C-I DIP Systems)

About 70% of combination systems contain only a single loop. A typical example is Stone Container's Snowflake (19) deinking mill in Arizora, USA, which was modified from a washing system in 1989. The schematic of this system is shown in Figure 21. The raw material is 50% ONP (old newspapers) and 50% OMG (old magazines), and the final deinked pulp constitues 80% of the newsprint furnish.

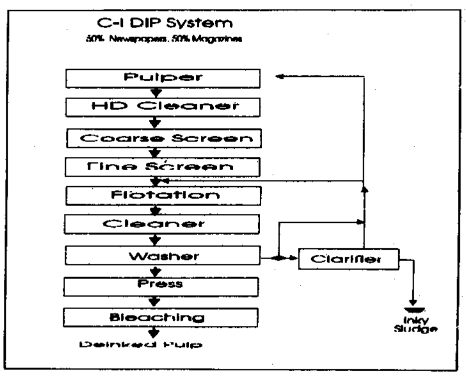


Fig. 21. Combination Single Loop, Stone Container, Arizona, U.S.A.

The quality of the DIP produced from a system such as this can be improved by the addition of more intensive washing, bleaching and dispersion modules.

Two-Loop Combination Deinking System (C-II DIP System)

In the late 1970's and early 1980's combination two-loop systems were introduced. The concept was to add to the single-loop system a second loop which would improve the quality and runnability of the DIP. These two-loop systems have included a hot loop, an acid loop, a post- flotation loop, a washing loop or a soaking loop.

Acid Loop

A major advance in deinking technology occurred in 1983 with the introduction of the acid loop concept by Bridgewater Paper Co, Ellesmere Port, UK., (Consolidated-Bathurst). This concept, shown in *figure 22,* is based on the premise that deinked pulp manufactured under alkaline conditions suffers

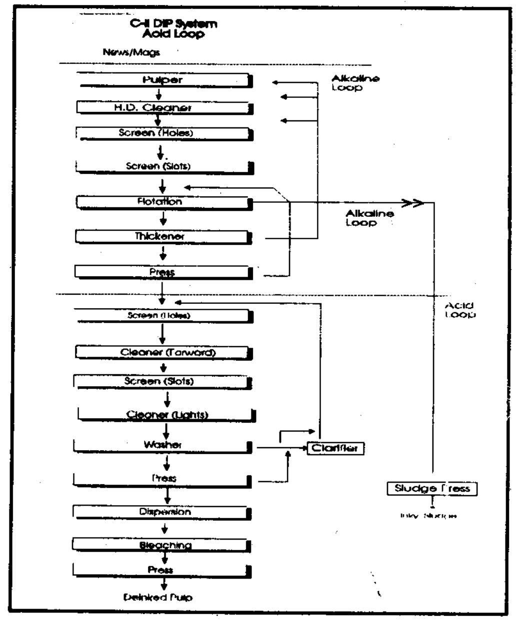


Fig.22 Combination Two Loop, Bridgewater Paper, Ellesmere Port, U.K.

acid shock when it enters an acidic paper machine loop. This shock causes colloidal matter and possibly soluble chemicals to precipitate out as sticky contaminants. The system concept is to condition the deinked pulp by adding a second acid loop to the first alkaline loop. In the acid loop, the colloidal and sticky contaminants are precipitated out and removed by screens, cleaners and washing modules, and any residual chemicals are also washed out. Other improvements include the addition of dispersion and bleaching after the acid loop.

The major benefit of the acid loop is better machine runnability due to the reduction in stickies. As a result, more DIP can be used in higher quality grades. A lower quality waste paper can be utilized. However, the trend to produce newsprint in neutral or mild alkaline conditions has inhibited the growth of the acid loop systems.

Post Flotation Loop

In 1987, the Stora Feldmuhle Hylte newsprint deinking mill in Sweden, built a two-loop system that incorporated a second loop using post-flotation (21). This system is illustrated in Figure 23.

The concept of the post-flotation system is to add to a single loop system, a dispersion stage followed by a second loop that includes a second flotation module. This system design is based on the

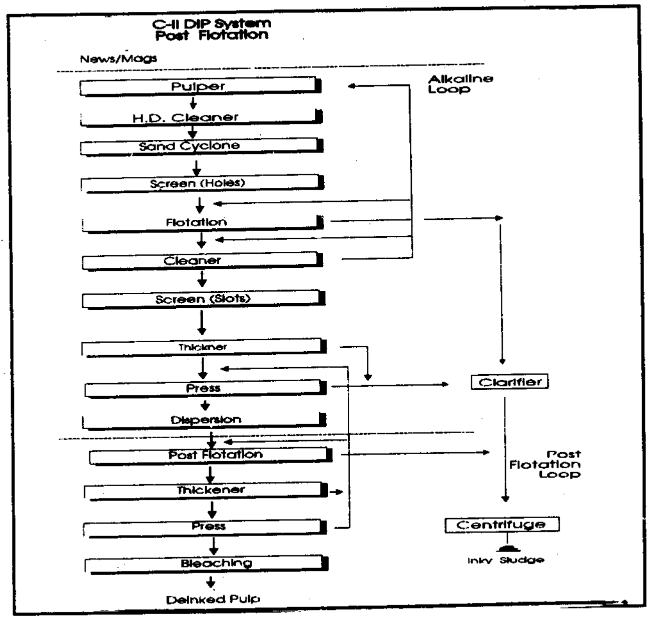


Fig. 23 Combination Two Loop Stora Feldmuhle Hylte, Sweden.

premise that any residual ink that was not removed in the first loop is broken down by the dispersion stage into many small particles and is removed by the post flotation loop. This system design has four major benefits:

1. The loss in brightness that occurs across the dispersion module can be recovered as the ink is removed in the post-flotation loop.

2. The fine ink that would have been carried to the paper machine is removed for better paper machine runnability.

3. Stickies are removed by post-flotation, which also improves the runnability of the paper machine.

4. Residual chemicals are removed in this loop, which also improves runnability. For this reason, the second loop is often run with no flotation chemicals.

Post-Flotation has proven so successful that many mills are now using it, and it is without a doubt the state-of the art technology for the production of high quality deinked pulps.

Soaking Stage

Deinking systems incorporating a soaking or swelling tower have been popular in Japan for many years and are now beginning to appear in some mills in North America. The objective of these systems is to produce a speck-free deinked pulp. It is generally recognized that ink is more difficult to remove from the fiber for Japanese wastepaper than for European or North American. Soaking helps release the ink from the fiber.

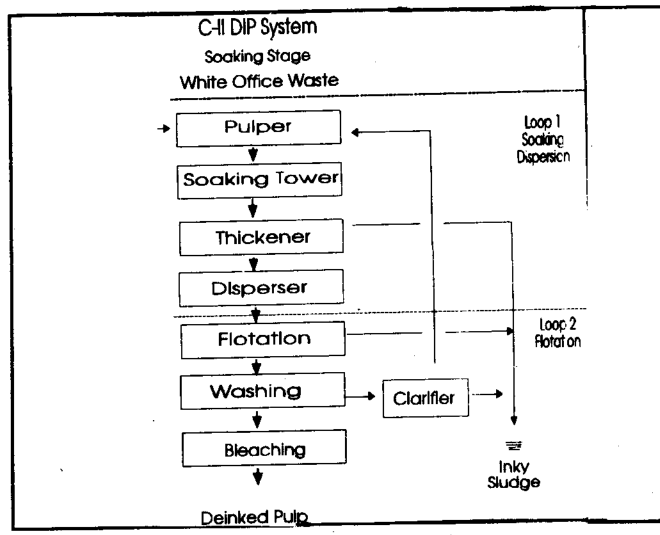


Fig. 24 Combination Two Loop, Medori, Japan.

A typical example, illustrated in *Figure 24*, is the Medori white deinking system (22). After pulping, there is a washing/thickening loop and a soaking tower. The pulp remains in the soaking tower for six or twelve hours to soften the ink binders. After the soaking tower, there is a dispersion module followed by a flotation loop.

More sophisticated soaking systems have two dispersion stages: one before and one, after the soaking tower. Some mills in North America also use dispersion and soaking. After the first washing loop, there is a dispersion module followed by a soaking/bleaching tower and a flotation loop.

Three-Loop Combination Systems (C-III DIP System)

In the last five years there has been a significant research effort focused on the development of three loop combination deinking systems. A third loop has been added to attack the issue of the quality of the wastepaper or the final product. We will review two examples; The first for deinking a news/mag furnish with a high level of flexographic and second for deinking mixed office waste to produce a high quality DIP pulp suitable for printing and writing grades. The novel feature of the mixed office waste system is the utilization of two stage of dispersion. Which we can term a "Double Dispersion System".

Flexo Removal System

The first three loop system to start up in North America was at Newstech, Vancouver, Canada. The mill was started up in 1992 to produce deinked market pulp from ONP and OMG for use in the production of newsprint. The wastepaper used has a very high content of flexographic inks, and the washing modules are designed to remove this flexo ink. The first loop is a conventional alkaline loop with washing and flotation. The second loop is an acid loop with fine screens, cleaning, washing and dispersion and the third loop contains washing and bleaching stages (23) (*Figure 25*).

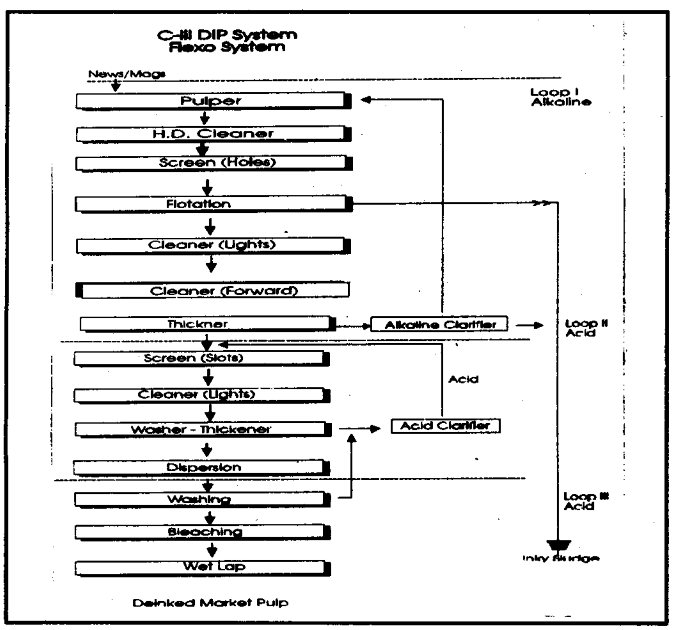
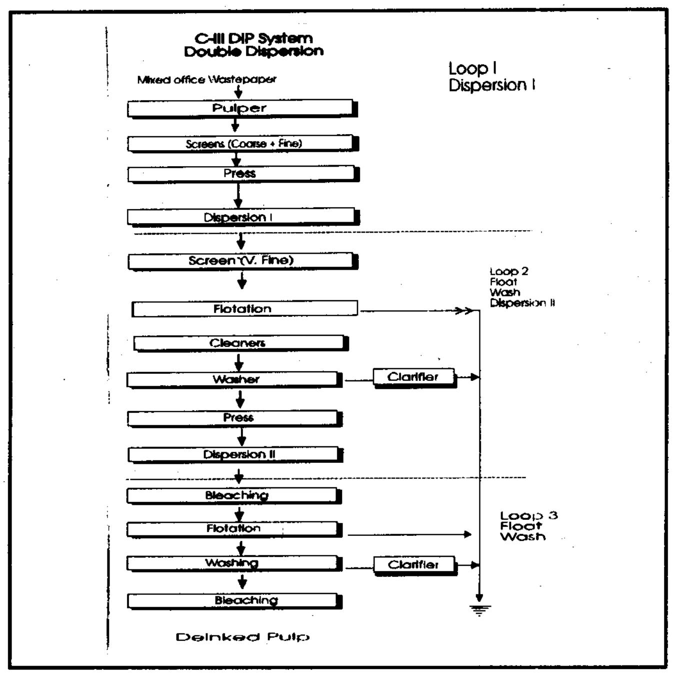


Fig. 25 Combination Three Loop, Newstech, Vancouver, Canada.

Double Dispersion System

This system is designed to deink mixed office waste to produce a very high quality deinked pulp that would be suitable for high addition level to printing and writing grades. The novel feature of this system is the introduction of a second stage of dispersion. This system is shown in *figure 26*. The major modules in the first loop are pulping, screening, pressing and dispersion. In the second loop the major modules are very fine screening, flotation, cleaning, washing, pressing and the second stage dispersion. Bleaching is carried out in the dispersion unit. The third loop contains a second stage of flotation (post-flotation), washing and a second stage of bleaching.

Fig. 26. Three Loop Combination System. Designed to deink mixed office wastepaper for printing and writing grades.



Stora Feldmuhle Hylte, Sweden				
Parameter	Unit	DIP	TMP	GWD
Shive content	STFI	14	67	149
Brightness (ISO)	%	59	57	61
Density	kg/m³	440	320	340
Tensile	KNm/Kg	37	38	30
Tear	Nm²/kg	7.6	8.6	4.5
Addition Level	%	40-55	25-28	15-20

Table 3. Newsprint Pulp Samples

COMPARISON OF THE PROPERTIES OF VIRGIN PULP AND DEINKED PULP

For a comparison of the properties of virgin and deinked pulp the most important issues are the physical properties, the optical properties, paper machine runnability and printability.

A number of laboratory studies including those of Howard and Bichard (23, 24) showed that the greatest change in fiber properties is caused by the first recycle and that, after about four recycles, most of the physical properties have stabilized. In other words, the repeated recycling of fibers does not cause any irreverisible damage. There was no significant loss of fiber strength, no change in fiber length, and no fiber brittleness. The main change in properties is the loss of bonding ability, which can be recovered to an extent by refining, chemical additives, fractionation and blending with virgin pulp.

We will now review mill data from three deinking mills producing DIP pulp for newsprint and three deinking mills producing DIP pulp for printing and writing grades.

DIP for Newsprint Grades

The three mills are Stora-Feldmuhle Hylte (Sweden), Bridgewater Paper Company (England) and Shotton Paper (Wales).

Stora Feldmuhle Hylte Bruk AB, Sweden (C-II DIP System)

Stora Feldmuhle Hylte has a newsprint deinking mill located in southern Sweden. They have published (17) a comparison of their DIP, TMP and groundwood and some of the properties are shown in Table 4. The shive content is much lower for the deinked pulp. Brightness is of the same order. Tensile and tear properties of DIP are better than GWD and similar to TMP. The major difference is that DIP has a higher density than TMP and GWD.

Bridgewater paper, England, UK. (C-II DIP System)

Table 4 gives a comparison of DIP and CTMP from the mill at Ellesmore Port in England (20). It can be seen that DIP has a higher tear and stretch, similar breaking length and lower smoothness and bulk than CTMP. This mill regards the lower bulk as a benefit.

Bridgewater Paper, England			
Parameter	Units	DIP	CTMP
Tear Index	Nm^2/Kg	7.6	6.2
Breaking Length	km	4.5	4.7
Stretch	%	2.41	1.85
Smoothness Bendtsen	ml/min	1.45	1.76
Bulk	Cm^3/gm	2.1	2.4
Addition Level	%	70-80	20-30

Table 4. Newsprint Pulp samples

Shotton Paper, Wales				
Parameter	Units	100% TMP	75% TMP 25% DIP	55% TMP 45% DIP
Bulk	Cm^3/g	1.64	1.57	1.53
Brightness (ISO)	%	58.6	58.6	58.8
Opacity	%	92.4	92.8	93.0
Roughness	ml/min	100.0	81.0	80.0
Porosity	ml/min	328	258	202
Tensile MD	kNm/kg	52.7	52.4	52.5
Tear CD	Nm^2/kg	5.69	6.00	5.96
Stretch CD	%	2.89	2.96	2.93
Burst	$kPam^2/g$	1.69	1.67	1.68
Ash	%	0.5	2.5	2.9

Table 5. Newsprint paper making samples.

(3) Shotton Paper, Wales, U.K. (F-I DIP System)

Shotton Paper located in North Wales, U.K. produces newsprint from TMP and DIP. *Table 5* contains a very interesting comparison of three paper machine samples of newsprint made from 100% TMP, 75% TMP/ 25% DIP and 55% TMP/45% DTP (24).

For these three mixtures there was no significant change in the optical properties (brightness, opacity) or in the strength properties (tensile, tear or stretch and burst). For higher DIP additions there was a significant reduction in bulk, roughness and porosity. However, it should be noted that DIP carries ash and the ash level in the paper increased from less than 0.5% for 100% TMP to nearly 3.0% for 55% TMP/45% DIP.

In general this review shows that there was no significant difference in strength and optical properties. The major differences between DIP and mechanical pulps are residual contaminant levels and density. DIP can contain an unacceptable level of residual contaminants such as ink and stickies. These can cause problems of quality and runnability. Ink specks can detract from the visual appearance of the sheet, while stickies can cause paper machine runnability and printability problems.

The density of DIP is higher than mechanical pulps. Some mills look upon this as a benefit because a reel of DIP newsprint will have more paper by area than a reel of mechanical pulp. A further consequence is that printing runs for DIP newsprint can be longer than mechanical pulp newsprint.

DIP for Printing and Writing Grades

Laboratory studies have shown that deinked pulp can be used for up to 78% of the furnish for bond/offset paper grades with no significant loss of papermaking potential (25).

We will now review detailed data from two printing and writing mills and also comment a recent review of North American mills producing DIP for printing and writing grades.

Desencrage Cascades, Canada (C-II DIP System)

A white deinked market pulp produced by a deinking mill in Quebec, Canada, Desencrage Cascades (26), compares well with a range of mechanical and chemical pulps (*Table 6*).

The brightness of DIP was similar to softwood BCTMP and softwood kraft. BCTMP (25% SWD/ 75% HWD) had the highest brightness (GE 85%). This was six points higher than the DIP. However, if necessary this brightness of the DIP could be improved by incorporating a dedicated bleaching module in the DIP system. For this application it was not necessary. Freeness of the pulps are similar. Physical strength properties are similar with the deinked pulp having a lower tensile and burst but a similar tear. The strength properties of the DIP could have been improved by low consistency post refining.

Crosse Point Miami Mill, Ohio, USA

Parameter	Unit	Recycled Fiber	Mechanical Pulp		Chemical Pulps	
		DIP	BCTMP	SHWK	SSWK	NSWK
Tear	mN	139	155	59	297	362
Brightness	GE%	79.5	79.6	86.5	85.7	86.6
Opacity	%	79.7	80.6	79.8	74.2	79.2
L*		91.5	95.6	96.9	96.0	96.3
a*		-0.9	-0.3	-0.9	-1.0	-0.9
b*		3.6	9.4	4.2	4.4	3.7

Table 7. Pulp samples for Printing and Writing grades.

Crosse Pointe Miami Mill, USa (C-I DIP System)

The Miami Mill of the Crosse Pointe Company in Ohio, USA, produces DIP for use in their printing and writing grades. Rubio recently published (27) a comparison of their DIP with various virgin pulps (*Table 7*) and he comments as follows:

Desencrage Cascades, Quebec, Canada

Parameter	Unit	DIP	Mechanical Pulp		Chemical Pulp	
		White Market Pulp	BCTMP 100% SWD	BCTMP 25% SWD 75% HWD	Kraft 100% HWD	Kraft 100% SWD
Freeness	ml CSF	420	483	360	461	485
Tensile	kNm/kg	42.3	41.3	53.2	49.2	81.5
Tear	Nm²/kg	10.3	9.3	5.0	7.1	11.1
Burst	kPam²/g	2.5	2.9	2.8	3.85	7.6
Brightness	GE%	79.0	78.0	85.0	84.6	76.8

Table 6. Pulp samples for Printing and Writing Grades.

"The strength differences between pulps is not surprising. That deinked pulp is stronger than HWK (hardwood kraft), but weaker than SWK (softwood kraft), is expected since the DIP pulp is derived from a mixture of papers."

The mill has successfully used the rule of the thumb that deinked fiber is equivalent to a 3:1 ratio of HWK to SWK. This belief has been supported by the production of a standard grade with 100% recycled fiber at customer request.

Replacement of HWK with deinked fiber improves the tear of the furnish because deinked contains some softwood. Burst strength is more easily developed because of the presence of long fibers and because deinked fiber requires much less refining.

Review of North American Printing and Writing DIP Mills

A survey of 33 North American printing and writing mills, which utilize DIP was recently published (29). The data is given in Table 8. It can be seen that the average brightness is of the order of 81-82 and the Tappi dirt count is about 13 ppm.

In general the review of laboratory data, and mill data shows that DIP is suitable for use in high quality printing and writing grades. The biggest quality problem is specks. It is this that is driving the technology to produce more efficient dispersion, flotation and cleaning modules and more sophisticated system designs.

Survey of North American Printing and Writing DIP Mills

	Brightness GE%	TAPPI Dirt (ppm)	Freeness (CSF)
Average	81.6	13.0	445
Range	75-85	4-35	300-600
Std. Dev	2.6	7.0	60

Addition Level of DIP: 10-50%

Table 8.

Recycled Newsprint vs Virgin Newsprint Central European Survey of Printers

Parameter	Recycled Newsprint	Virgin Newsprint
Runnability	Equal	Equal
Linting	Poorer	Better
Print through	Better	Poorer
Opacity	Higher	Lower
Ink Absorption	Less	More
Bulk	Lower	Higher

Table 9. 1991 survey by IFRA

Recyled Newsprint vs Virgin Newsprint North American Survey of Printers

Opinion	*Percentage*
No Difference	18%
Recycled Better	49%
Virgin Better	33%

Table 10. 1991 survey by the Journal "Editior and Publishers"

Runnability

The issue of runnability involves both the paper machine and off-machine processes such as printing. The paper machine runnability of deinked pulps is determined mainly by the concentration of any residual contaminants and the nature of the recycled fiber. The worst runnability problems are probably caused by sticky deposits. Several approaches have been taken to solve this problem, including the addition of talc and other chemicals (30), efforts to improve the "electrostatic" climate of the paper machine back-water system (31), and the addition of a profile correction system, the reduction of open draws, and the adjustment of reel and winding operating conditions (32).

Printability

With regard to printability, surveys of newspaper printers (33,34) have shown that there is no significant difference between the physical and optical properties of recycled fiber and virgin fiber newsprint (*Table 9*). In fact, many printers preferred recycled fiber newsprint because of its superior print-through, opacity and ink absorption (*Table 10*).

CONCLUSION

It can be concluded that, with appropriate technology, the properties of recycled fibers can be developed to closely approach those of virgin pulp in both paper properties and runnability. In fact, many producers of virgin pulp are being challenged to tailor their pulps for use with recycled fiber pulps (2).

The major conclusion of this paper is that recycled fiber can be an excellent complement to virgin fiber. Consequently, it should no longer be considered of "secondary" importance, but should be viewed as a papermaking material with distinctive properties that can meet the requirement of papermakers well into the 21st century.

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