Technology and Environmental Issues Face the Pulp and Paper Industry

U.S. pulp manufacturing is dominated by the krafi process, which uses chemicals in production and bleaching. However, chlorine use has come under scrutiny. Improvements in mechanical pulping, increased wastepaper utilization, and alternafive pulping methods are options available to meet changing market and regulatory conditions.

The U.S. pulp and paper industry is a competitive player in world markets and a major contributor to the U.S. economy. However, recent economic and environmental trends have buffeted the industry. The recent recession lowered mill utilization rates. At the same time, mandatory recycling and recycled-content laws and regulations brought additional pulping capacity on the market. Lethargic economic conditions in major overseas markets further depressed prices. The result has been poor profits and even some losses. In addition, concerns about dioxins--a byproduct of chlorine bleaching--has led the Environmental Protection Agency (EPA) to propose new regulations to reduce and eventually eliminate chlorine from pulpmaking.

A wide array of pulping methods exist for producing paper and paperboard products. Major categories are processes that use chemicals to dissolve wood and other fibers and those that use primarily mechanical energy to grind the fibers into pulp. Increasingly, recycled wastepaper is also an important source of pulp.

Chemical pulping is by far the most common processing technology. The sulfate or kraft process, as it is called, is the primary method used in the United States, accounting for over **80** percent of pulping capacity (table **7).** The older sulfite process still has a 2-percent share. In comparison, mechanical pulping methods account for about 10 percent of U.S. capacity and semichemical, 6 percent. Dissolving pulp for making rayon, acetate, cellophane, and cellulose products account for the remaining 2 percent.

In 1992, the United States used about **87** million tons of paper and paperboard. Half of this amount consisted of paper boxes and wrapping papers, another third was printing and writing papers and newsprint, while the remainder was tissue and miscellaneous products.

Table 7--U.S. woodpulp capacity, 1970-92

Year	Bleached softwood sulfate	Bleached hardwood sulfate	Unbleached sulfate	Sulfite	Semi-chemical	Mechanical	Dissolving and special alpha	Total 1/
				--1,000 tons--				
1970	7,798	5,781	16,811	2,490	3,811	4,799	1,736	44,725
1971	8,266	6,008	17,091	2,414	3,814	4,680	1,772	45,731
1972	8,971	6,093	17,702	2,353	3,937	5,812	1,756	46,760
1973	8,842	6,936	18,475	2,378	4,171	5,802	1,754	48,459
1974	8,923	7,138	18,451	2,401	4,233	5,930	1,824	48,995
1975	9,025	7,208	18,758	2,420	4,246	6,090	1,671	49,418
1976	9,355	7,227	19,293	2,417	4,402	6,204	1,571	50,469
1977	10,048	7,322	19,552	2,525	4,514	6,442	1,648	51,849
1978	10,442	7,729	19,732	2,095	4,572	6,507	1,573	52,714
1979	10,897	8,078	19,923	2,004	4,553	6,572	1,551	53,636
1980	11,339	8,356	20,288	1,909	4,601	7,069	1,590	55,214
1981	11,757	8,559	20,972	1,855	4,597	7,434	1,598	56,831
1982	12,052	8,705	21,435	1,780	4,734	5,780	1,606	57,638
1983	12,111	9,179	21,206	1,788	4,490	5,814	1,525	57,590
1984	12,490	9,867	21,372	1,750	4,652	6,122	1,487	59,001
1985	12,874	10,750	21,182	1,738	4,650	5,964	1,454	58,617
1986	13,169	11,402	21,381	1,703	4,631	6,058	1,399	59,743
1987	13,623	11,823	21,733	1,646	4,697	5,942	1,389	61,172
1988	14,056	12,450	22,145	1,627	4,787	6,432	1,450	62,950
1989	14,196	13,125	22,465	1,644	4,753	6,636	1,465	64,289
1990	14,412	13,407	22,742	1,689	4,669	6,957	1,486	65,985
1991	15,023	14,097	22,903	1,697	4,547	7,081	1,493	67,402
1992	15,636	14,919	23,062	1,706	4,473	7,077	1,493	68,977

11 Includes screening and other miscellaneous pulps. Therefore, columns do not add to the total.

Source: Pulp and Paper 1993 North American Factbook. Miller Freeman Publications, San Francisco, CA. 1993.

Chemical Pulping Popular With Industry

Chemical pulps are distinguished by cooking woodchips or other fiber sources in a digester that separates the cellulose fibers from the hemicellulose, lignin, and other components. Lignin--a brown, organic material that accounts for about 20 to 30 percent of wood--tends to discolor and weaken paper products over time. Chemical treatments usually remove most of the lignin, while mechanical processes leave much of it.

Kraft pulping can use many wood species and yield strong, easily bleached fibers. The spent cooking liquor (a residual black liquid) also can be washed from the pulp, concentrated, and used for chemical recovery or burnt for fuel in the pulp mill. Bleached haft pulp possesses strength and whiteness, which are preferred for most grades of paper, particularly printing and writing papers. Because of its strength, unbleached kraft pulp is used for brown paper bags, wrapping paper, and shipping sacks.

One of the chief advantages of the kraft process is its economies of scale. Since it is based upon liquid vessels, enlarging their size increases the volume of production faster than the associated variable costs. Therefore, new kraft pulp mills have grown larger over time. A new mill may require $1 billion or more to build. However, few new kraft mills have been built in recent years. Most capacity expansion has been incremental additions to existing mills.

The disadvantages of haft pulping include:

- Low pulp yields of about 45 to 55 percent of wood input;
- Corrosiveness that requires special metals and equipment;
- Potential safety hazards, such as those associated with sulfur compounds; and
- Adverse environmental impacts, such as bleaching waste water discharged into lakes and rivers, which might contain traces of dioxin and other undesirable chlorinated organics, as well as reduce the amount of dissolved oxygen in the water.

Bleaching Techniques Under Scrutiny

Pulp is often bleached to improve purity and brightness. Pulp brightness is measured by optical test instruments using an index of brightness points. Bleached chemical pulps have brightness indices of 85 to 90, semi-bleached chemical pulps of 70 to 80, and groundwood pulps of 55 to 65.

Various methods and chemicals are used for bleaching. One of the most common methods used with kraft pulps employs pure chlorine to remove the remaining lignin. The use of this process has been called into question because of the possible production of dioxins, which have been associated with some forms of cancer. In response, industry has greatly reduced unwanted dioxin byproducts, and new technology makes it possible to detect even minute amounts. EPA has issued proposed regulations that would virtually eliminate discharges of dioxin into rivers by 1998 through the use of chlorine-free technology and/or reduced chlorine use. The agency estimates these changes would cost at least $4 billion, while industry puts the price tag at up to $10 billion. Industry has proposed chlorine dioxide as an alternative to free chlorine.

Mechanical pulping processes use chemicals such as sodium hypochlorite, hydrogen peroxide, or sodium hydrosulfite that typically are not associated with dioxin problems. Totally chlorine free (TCF) pulps can be made with the sulfite and bleached chemi-thermomechanical methods. However, only a few producers--several companies in Sweden and Finland--are now capable of making TCF kraft pulp that is bleached with chemicals such as peroxide, ozone, and oxygen. USDA's Forest Products Laboratory is seeking to establish a consortium with industry to study the potential of an oxygen-and-metal-catalyst bleaching process it has patented with Clark Atlanta University. Research also has been conducted using enzymes for bleaching.

An alternative to bleaching would be to change the standards and preferences of paper users. High-quality business printing and writing papers typically contain chemical pulps bleached for high brightness. Nearly half of all paper and paperboard products use some bleached pulp. The Environmental Defense Fund has established a taskforce of major business users of high grade paper to study and define environmentally preferable papers and to promote these papers to meet personal and business needs. One problem is the large investment U.S. companies have in existing technology--kraft pulping and chlorine-based bleaching.

Technology Improving Mechanical Pulping and Related Processes

The mechanical energy used to convert pulpwood or woodchips to pulp is the distinguishing feature of the mechanical pulping process. The traditional groundwood (GW) grinding process has been only marginally improved since its invention a century ago. The process, which uses short logs, has been declining in popularity in recent decades, but still has a residual capacity of about 8 million tons per day in North America. Pressurized groundwood (PGW) uses a process developed in Finland that makes pulp by grinding logs in a pressurized atmosphere with a conventional grinder. This process improves the strength of the pulp *(1)*.

Refiner mechanical pulp (RMP) is made by fiberizing wood chips in large non-pressurized disc refiners. RMP typically uses sawmill residues and is especially popular in the Pacific Northwest. Thermomechanical pulping (TMP) improved the RMP process by prestreaming the chips and fiberizing them in a pressurized refiner. This method has been particularly successful in the southern United States. A further modification of the TMP process chemically pretreats chips prior to their exposure to steam heat. This method, called chemi-thennomechanical pulping (CTMP), was developed in Scandinavia in the late 1970's and is particularly popular in Canada.

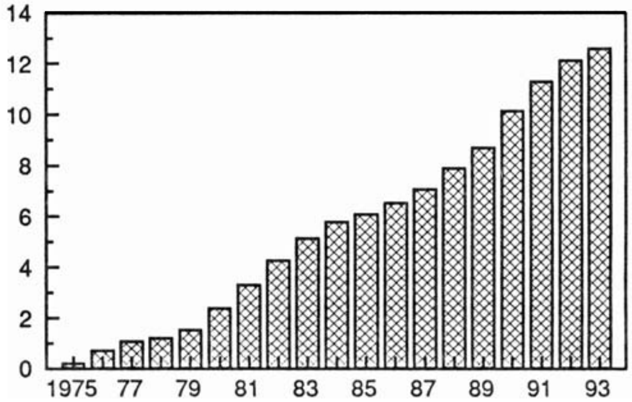
The principal advantage of mechanical pulping methods are higher yields, 90 to 95 percent, compared to chemical yields of 45 to 55 percent (table 8). Mechanical pulping mills are also less expensive to build and can be economical on a smaller scale. However, the pulping requires more energy. The pulps have lower strength and brightness compared to chemical pulps, but higher opacity. Chemical pretreatment of wood chips enhances fiber strength properties and slightly lowers the pulp yield. TMP and CTMP capacity has been growing rapidly in recent years and now exceeds groundwood capacity in North America (figure 7). Major uses for TMP and CTMP pulp include newsprint, uncoated groundwood, and coated publication papers.

A bleached chemi-thermomechanical pulp (BCTMP) mill, on a per ton basis, costs less than one half as much as a new kraft pulpmill and uses about half as much wood as a kraft mill, plus it does not use chlorine compounds for bleaching. Aspen and spruce BCTMP have brightness indexes comparable to chemical pulps. These levels combined with enhancing fillers and coating bring BCTMP close to the brightness of bleached kraft pulps. Switching to neutral alkaline sizing would further improve its smoothness and brightness. Demand for BCTMP is strong in the Far East and growing in Europe. In the United States, it has been restrained by established printing and writing standards that limit mechanical pulp content to 10 percent in free-sheet grades.

Figure 7

Thermomechanical and Chemi-Thermomechanical Pulping Capacity in the United States and Canada

Million metric tons



Source: Pulp and Paper 1993 Factbook, Miller Freeman Publications, San Francisco. CA. 1993.

Deinking and Wastepaper Utilization on the Rise

Wastepaper recycling is a growing part of the paper industry. High-grade papers, newspapers, magazines, and corrugated boxes are recycled in large quantities. Typically, wastepaper goes through a deinking process to remove printing inks, paper coatings, and other contaminates to produce secondary pulp. Washing, screening, and flotation are used alone or in various combinations.

Deinking capacity has grown rapidly in the last 5 years. Overall wastepaper utilization by U.S. mills has increased from 18.7 million tons in 1987 to 26.1 million tons in 1992 (table 9). Further gains are an industry priority. The American Forest and Paper association recently announced a new goal of increasing wastepaper recovery rates by 25 percent by 2000. The principal uses of deinked pulp are newsprint, tissue, and paperboard grades for making boxes, bags, and wrapping paper.

Table 8--Comparison of kraft and mechancial pulp properties 1/

Pulp type	Yield	Burst index 2/	Tear index 2/	Tensile index 2/	Opacity	Density
	Percent				Percent	Kg/m3
Kraft	45-55	7.10	6.40	116	82	773
Groundwood pulp	95	0.91	1.90	28	97	421
Refiner mechanical pulp	95	0.92	2.00	30	92	389
Thermomechanical pulp	95	1.00	3.80	28	92	417
Chemi-thermomechanical pulp	94	2.10	6.70	47	84	499
Biomechanical pulp	84-95	1.3-1.6	2.5-4.0	30-35	95	402

1/All measurements standardized to 100 ml Canadian Standard Freeness. 2/ Measures the strength of paper in international system units.

Source: Mary Beth Wall, Analysis of Biopulping, a preliminary report submitted in partial fulfillment of Ph.D., 1990, on file at USDA Forest Products Laboratory, Madison. WI.

Table 9--Utilization of wastepaper by U.S. paper and paperboard mills, 1970-92

Year	Wastepaper	Paper and paperboard produced	Utilization rate
	--1,000 tons--		Percent
1970	11,803	51,671	22.8
1971	12,106	53,163	22.8
1972	12,925	57,434	22.5
1973	14,094	59,900	23.5
1974	13,982	59,040	23.7
1975	11,748	50,976	23.0
1976	13,622	58,329	23.4
1977	14,058	60,040	23.4
1978	14,760	62,047	23.8
1979	15,361	64,345	23.9
1980	14,922	63,600	23.5
1981	15,037	64,259	23.4
1982	14,433	60,951	23.7
1983	15,638	66,748	23.4
1984	16,724	70,248	23.8
1985	16,371	68,683	23.8
1986	17,935	72,505	24.7
1987	18,694	75,949	24.6
1988	19,684	78,085	25.2
1989	20,219	78,356	25.8
1990	21,791	80,352	27.1
1991	23,808	80,971	29.4
1992	26,109	83,521	31.3

Source: Pulp and Paper 1993 North American Factbook. Miller Freeman.

One important and growing concept in wastepaper utilization is mini-mills, which are smaller mills located near wastepaper sources and end-use markets. They typically use existing technology and discharge little or no effluent into waterways because they use either a closed system or send it directly to a municipal sewer system. At least 35 wastepaper mills are operating or proposed for construction. They most often produce corrugated medium and linerboard for container board and boxes (2). They may also make tissue, newsprint, and fine grade papers.

Mini-mills provide an alternative where raw material availability and cost, environmental constraints, and/or market demand do not justify larger mills. The economic viability of mini-mills depends upon:

- An efficient design that minimizes capital investment and operating costs;
- A location that minimizes freight charges for rawmaterials and products, thus offsetting labor and other operating cost advantages that traditional mills may possess; and
- Dependable, low-cost raw materials, which may be encouraged by tax incentivesand cooperative programs with municipalities.

Various Technologies Offer Alternatives

The concept of organosolv pulping, which uses organic solvents such as ethanol and methanol to remove lignin, was first proposed in the 1930's, but only recently has a serious attempt been made to commercialize it. In 1989, Repap Enterprises, Inc., began operating a 33-ton-per-day demonstration project in Newcastle, New Brunswick, with the assistance of the Canadian government. The company is looking for a site for a 250-ton-per-day commercial-size mill. Another variation has been developed in Germany and is being commercialized by MD Papier Organocell. A third organosolv process has been investigated by researchers at the University of Alabama.

Advantages of organosolv pulping include lower capital costs, diminished environmental impacts (because byproducts are recovered), and no chlorine. The disadvantages are the complex technology required to wash the pulp and recover the volatile chemicals used in the process and a possible fire or explosion. The chemicals are best used on certain types of hardwoods and may not work with mixed wood species.

A number of processes using various chemicals to improve bleaching or pulping have also been developed. Andritz Sprout-Bauer of Germany has introduced an alkaline peroxide mechanical pulping process to improve bleaching and reduce energy use by as much as 35 percent. C-I-L, Inc. (Montreal, Canada) uses anthraquinone to enhance the kraft process by reducing cooking time and alkali consumption while increasing pulp yields. Kraftanlagen Heidelberg and Feldmuhle AG of Germany are developing an alkali-sulfite-anthraquinone-methanol (ASAM) process to produce a chlorine-free, kraft-like pulp with high brightness and improved yields. The ASAM method also does not produce the sulfur compounds responsible for the pungent odors associated with pulp mills.

Biopulping involves modifying the cell wall in wood by highly specialized white-rot fungi leaving the cellulose for pulping. The organisms soften up the chips for easier delignification by either mechanical or chemical methods. Research on biopulping has been conducted by a number of companies and institutions in the United States and Sweden during the last 40 years. In 1987, a biopulping consortium was established involving the USDA Forest Products Laboratory, the University of Wisconsin, and industry participants to study biomechanical pulping.

Biopulping provides an opportunity to reduce the energy required to refine wood chips and increase the refiner throughputfor mechanical pulping. In addition, organisms would replace chemicals used in the CTMPprocess. Biopulping may also be used in conjunction with chemical pulping processes to pretreat wood chips and reduce chemical use.

Two promising fungi have been found for aspen and loblolly pine. In laboratory experiments, using the organisms reduced electricity consumption in subsequent processing, which resulted in energy savings of 25 to 50 percent. The pulp also had better strength properties than GW, RMP, and TMP. [Thomas Marcin (608) 231-9366]

1. Pulp and Paper *1993* Fact Book. San Francisco, CA; Miller Freeman Publications; 1993.

2. "Will Mini-Mills Play a Maxi-Role in the Future of U.S. Papermaking?" Pulp and Paper, 67(1993):39-47.