

Impact of recycled fiber on sheet forming

Spiro S. Grivas

As greater attention is given to the proper conditioning and cleanliness of the stock prior to reaching the machine chest, problems on the paper machine will be reduced.

Secondary fiber constitutes about 33% of the total furnish worldwide in the production of paper and board. This is projected to increase to 41% in the year 2001 (1).

Machines that produce board and corrugating medium are the largest users of secondary fiber. Producers of newsprint are second, followed by tissue and toweling. The producers of printing and writing grades are also placing increased emphasis on greater use of wastepaper.

Figure 1 illustrates the relatively high cost of fiber for deinked fine paper. Improved recycling methods should reduce costs. However, many fine papers are coated, printed in color, and protected by varnish; others are printed with ultraviolet (UV) inks. This makes contaminant removal and deinking more difficult.

As a result, stock preparation, forming, pressing, and drying on the machine are areas of concern. Certain modifications to paper machine design must be considered when secondary fiber is used in the furnish.

With the increased use of secondary fibers, significant developments have been made in recent years in stock preparation, including deinking. Also, improvements in multilayer technology have brought with them an improved finished product.

In general, the following subjects require attention:

1. **Strength development.** Refining will vary, depending on the type of secondary furnish used for improvement of fiber bond, while keeping fines to a minimum. Lower headbox consistencies, longer forming tables, or multilayer forming are used to get the most out of fiber properties. When necessary, fiber-bonding additives or size presses may be required to obtain the desired results.
2. **Contaminant removal.** State-of-the-art stock processing occurs through better cleaning—forward and reverse—as well as coarse and fine screening. Dispersion is used, if required, in the final stage.
3. **Ink removal.** Improved appearance and higher brightness can be obtained using two flotation deinking stages with intermediate washing.

Dispersion and bleaching are usually added to the final stages of the process.

Stock preparation

OCC system

A modern old corrugated containers (OCC) system will include many, if not all, of the following stages (Fig. 2):

Pulping. Clamp trucks deliver bales to a conveyor where they are discharged into the pulper. Extraction plate hole sizes range from 1/2 in. to 3/4 in.; however, some may have 3/8-in. holes to retain contaminants which are continuously removed by the detrashing unit. Pulper consistency is 4%.

High-density (HD) cleaners. These cleaners remove smaller, heavier contaminants such as sand, grit, and small metal particles.

Coarse screening. This procedure removes larger plastic materials and other impurities. Holes are 0.050-in.-diameter and larger. Basket is contoured.

Forward cleaning. Further removal of heavier contaminants protects fine-slotted screen basket from wear and plugging.

Slotted screens. These screens remove smaller plastic material. Slots range from 0.008 in. to 0.016 in.

Reverse cleaning. This process removes waxes, styrofoam particles, stickies, and hot melts.

Thickening and high-density storage follow reverse cleaning. White water recycling and reject handling systems complete the system. Fractionation and dispersing are optional additions to the system.

Deinking system

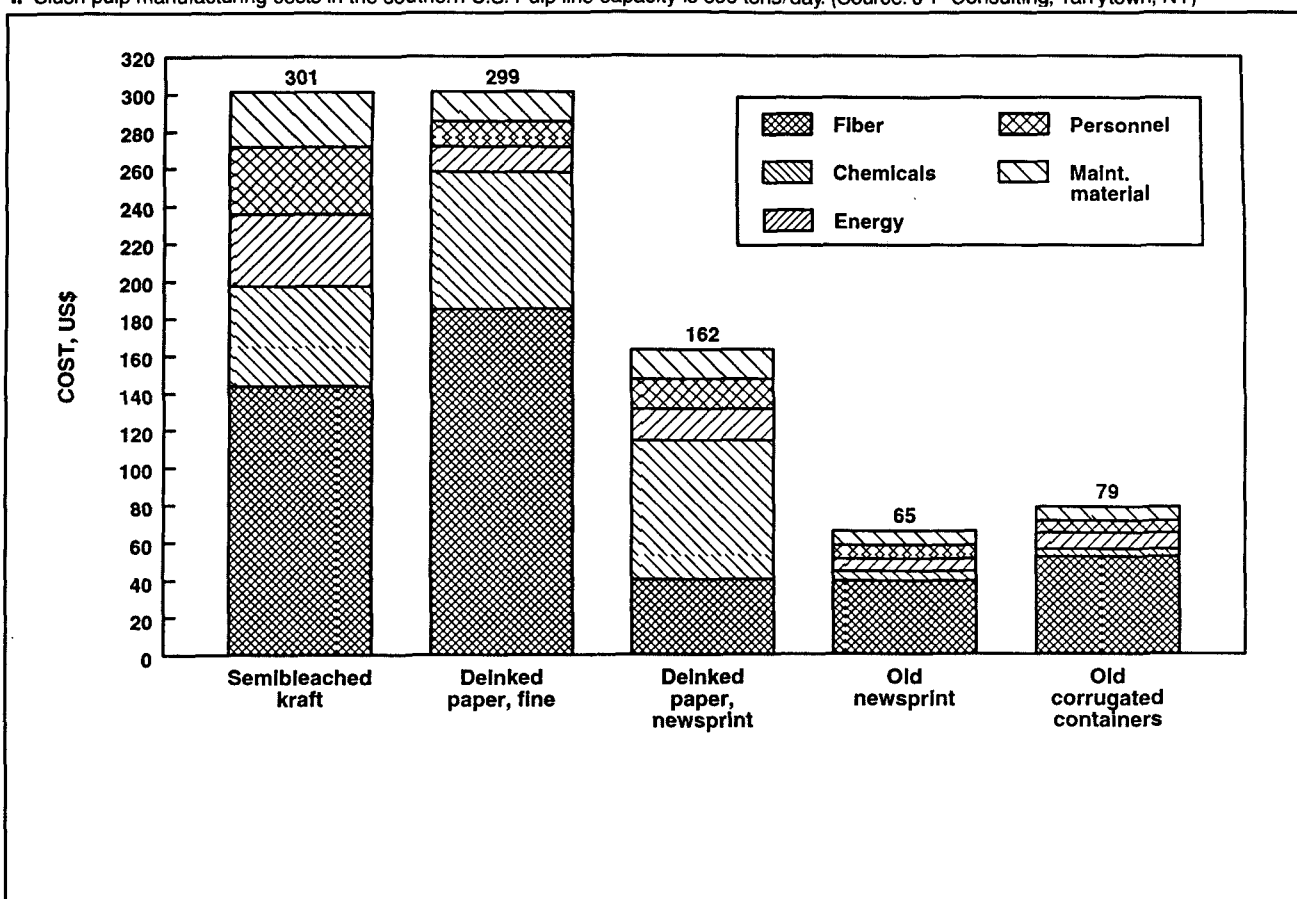
Whereas conventional pulpers are common in an OCC system, a modern deinking system is now equipped with either a high-consistency batch pulper or a high-consistency drum pulper. As shown in Fig. 3, the first flotation step follows prescreening, and post-flotation follows the dispersion stage. Bleaching of stock completes the process.

The most difficult inks to be removed today are:

- **Flexographic inks.** These inks are difficult to remove by flotation; washing must be used.
- **Laser tone inks.** These are hard inks driven into the web. They cannot be chemically dispersed and must be broken up mechanically.
- **UV-cured inks.** These inks are very difficult to remove because of their bond to paper. The inks polymerize on exposure to radiation.

Grivas is a process and technical consultant at Jaakko Pöyry, Inc., 5510 Six Forks Rd., Raleigh, NC 27609.

1. Slush pulp manufacturing costs in the southern U.S. Pulp line capacity is 300 tons/day. (Source: J-P Consulting, Tarrytown, NY)



Multi-ply forming

Structured webs can and are being produced commercially by the following methods:

1. Forming separate plies and combining them into a single web (top-wire formers, cylinder machines, or multifourdriniers).
2. Successive forming of separate plies on preformed web (cylinders or top-wire formers).
3. Multilayered webs from a stratified headbox (with or without top-wire formers).

In most cases, the center plies are made from inexpensive furnishes for economic reasons as well as improved bulk. The outer layers, of course, are of higher grade fiber for enhanced sheet properties and improved appearance.

Regardless of the forming method, when recycled fiber is applied we must bear in mind that:

1. Repeatedly recycled fibers gradually lose strength and papermaking properties.
2. In the case of multi-ply board in the drying process, stickies will tend to migrate from the center to the top and bottom layers. This situation may be caused by insufficient liner coverage or residual contaminants in the center ply.

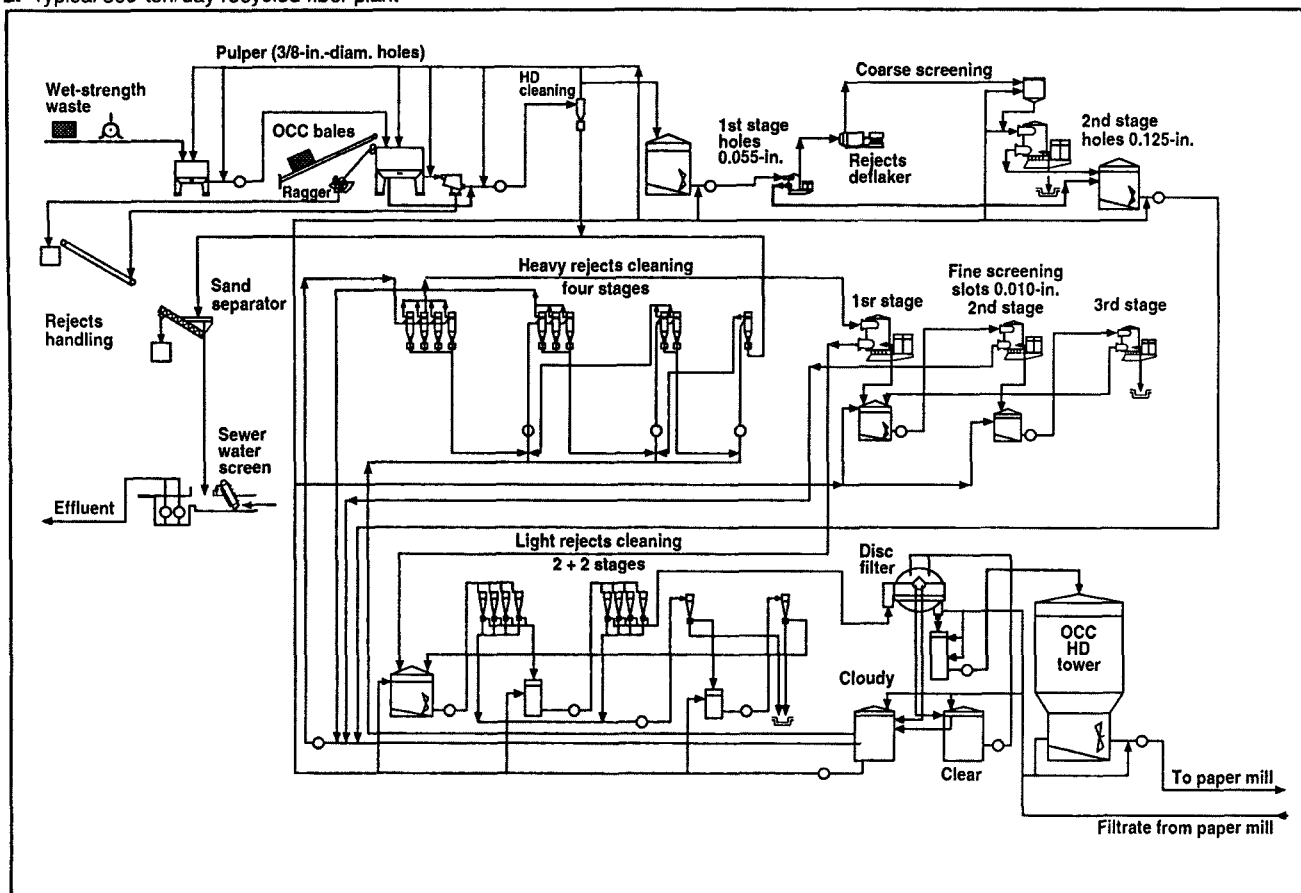
Cylinder formers

Vat machines still are the most commonly used method of forming certain multi-ply boards. The number of cylinders ranges between five and 10 units. Their diameters range from 36 in. to 60 in. (Fig. 4). They produce multi-ply board by forming separate plies on wire-covered cylinders submerged in vats, which are combined to form a single web. Most common grades produced on these machines are folding boxboard, chipboard, gypsum board, and test liner. The basis weight ranges from 150 g/m² to 800 g/m² (30.8–164 lb/1000 ft²). The most commonly used types are illustrated in Fig. 5.

Counter-flow vat. The cylinder mold rotates in a vat. Its rotation is counter to the flow of the stock. The mold is partially submerged in white water, which is extracted at the ends of the mold. Thus, the liquid level in the mold is higher in the center. As a result, the forming pressure differs, which leads to subsequent variation in profile, generally heavier at the ends than in the center. Their main advantage is high pickup. The weight applied per unit is dependent upon cylinder diameter, machine speed, furnish, and freeness. Because of uncontrollable turbulence, formation is generally poor, so the counter-flow vat is used primarily for filler plies.

Uniflow vat. This vat is similar in construction to the counter flow. The difference is the stock flow follows the rotation of the cylinder mold. Consistencies are usually lower, allowing for better formation and lower forming capacity. The uniflow vats are therefore usually located

2. Typical 300-ton/day recycled fiber plant



in the back liner, under liner, and top liner positions. Their pickup is about half that of the counter flow.

The main drawbacks with both of these formers are low machine speed and high MD/CD ratios. Care must be taken as well to maintain good ply bond. For example, top and bottom liner freeness must be higher than middle-ply freeness.

Dry vat. The mold's operation is improved by the addition of an inflatable seal to a counter-flow vat to confine the forming zone into a sector of the cylinder. Additionally, the white water falls unimpeded, creating no back pressure. The result is a more uniform profile.

Half vat. Half of the vat is omitted in the original design to adopt the principle of the dry vat. Additionally, greater access is provided for washup and maintenance. The inlet header could be supplied with multi tubes, with or without recirculation, as with a conventional headbox, to further improve profile.

Stevens former. I mention this former although it is no longer offered. It was perhaps the first to use a headbox to form the web on a cylinder mold. This former was first installed in 1958. A board mill in Michigan had a full complement of these formers producing multi-ply board, while another mill on the West Coast used the Stevens formers as an inexpensive method of producing tissue grades under 610 m/min (2000 ft/min).

Many of the drawbacks of the other formers, such as washing and flocculation, were corrected by the Stevens former. Better formation and profile were achieved by the

adjustable curved roof of the inlet, which controlled the formation and contained the drainage. The inlet had rectifier rolls for stock dispersion and a vacuum exhaust system applied to the mold, which assisted drainage. The drawbacks were problems with roof adjustability, capital cost, and speed limitations in multi-ply applications.

Bristol former. St. Annes board mills in the United Kingdom developed the Inverform process. They sought to provide a better headbox for the Inverform unit. As an outgrowth, it was then applied to under-the-felt cylinder formers. The first former was installed on a cylinder machine at St. Annes in 1976 as a back ply. Today there are over 200 installations. It is now being manufactured by a machinery supplier under the name Bristol Former MKII.

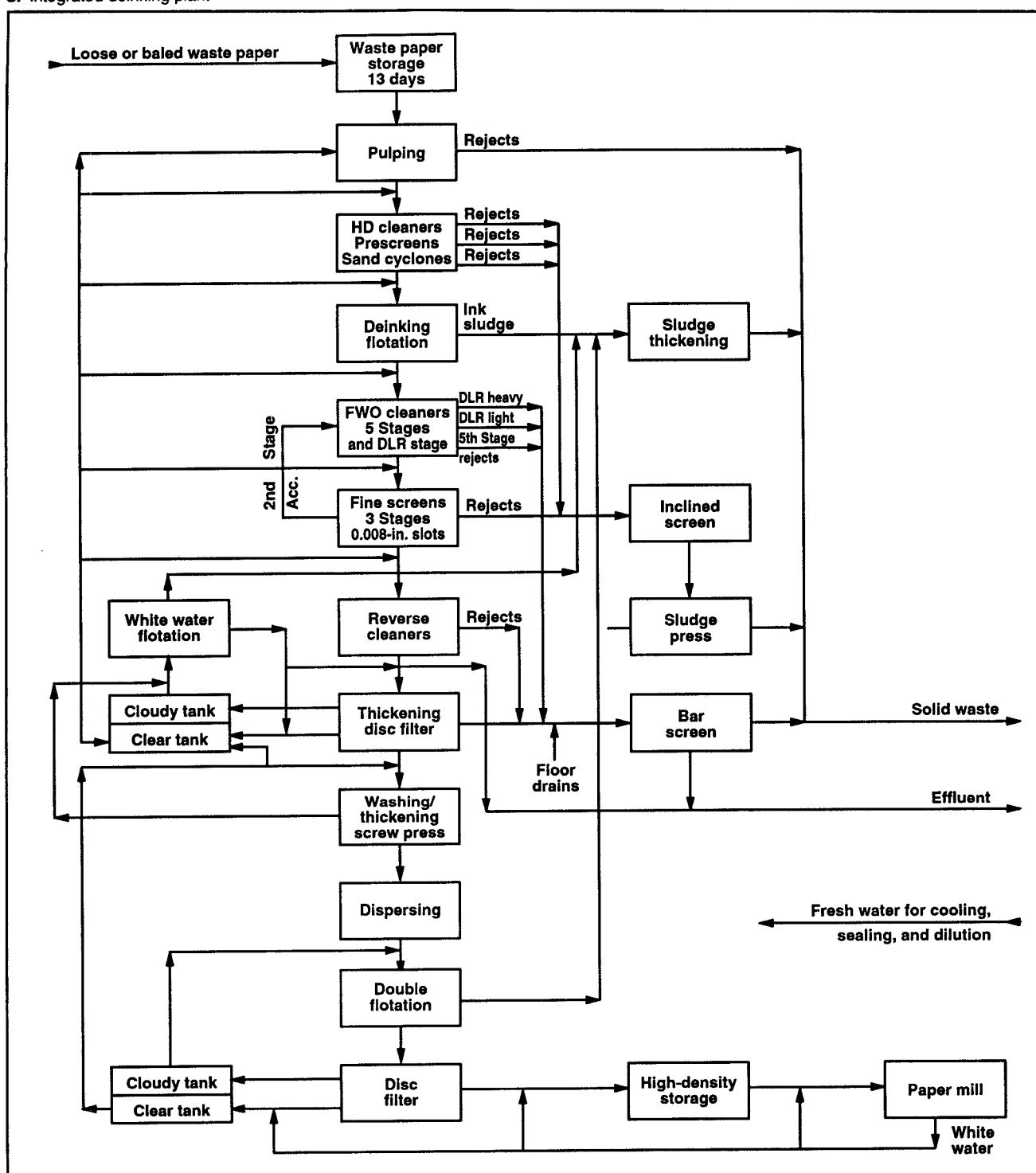
The unit is essentially either a hydraulic headbox or a pressure former with a curved roof, which can operate in the medium to high consistency range. It has approached operating speeds of 250 m/min (820 ft/min).

Suction formers. These formers were developed to produce high-quality board at much higher speeds than the conventional multi-ply formers. These include units manufactured by Tampella, Voith, Manchester (SEW), and Beloit.

These formers usually have a hydraulic headbox with a curved roof (pressure former) to form a web over a suction roll that has up to four suction boxes.

The suction formers can be located under a felt or over a fourdrinier wire. Several board mills have configured

3. Integrated deinking plant



their wet end with this arrangement. These units have succeeded in forming a more uniform sheet at higher speeds. There is more control of MD/CD ratio; however, these formers require close attention in the control of ply bond. One mill in Canada has seven multiformers and is operating up to 229 m/min (750 ft/min) on multi-ply board.

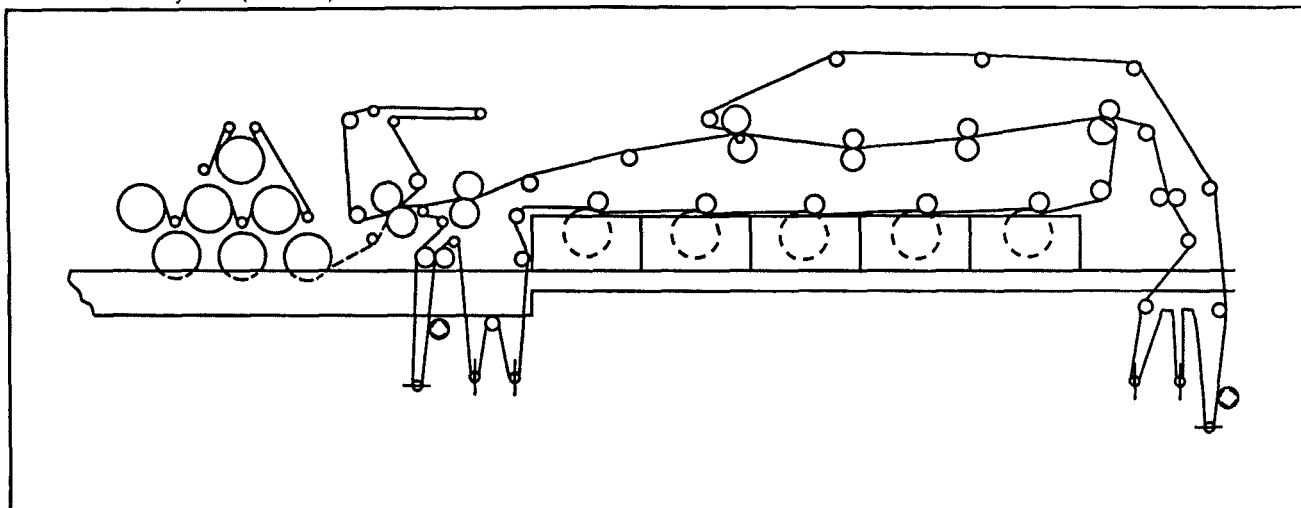
Ultra-former series

This former was developed in Japan to achieve higher

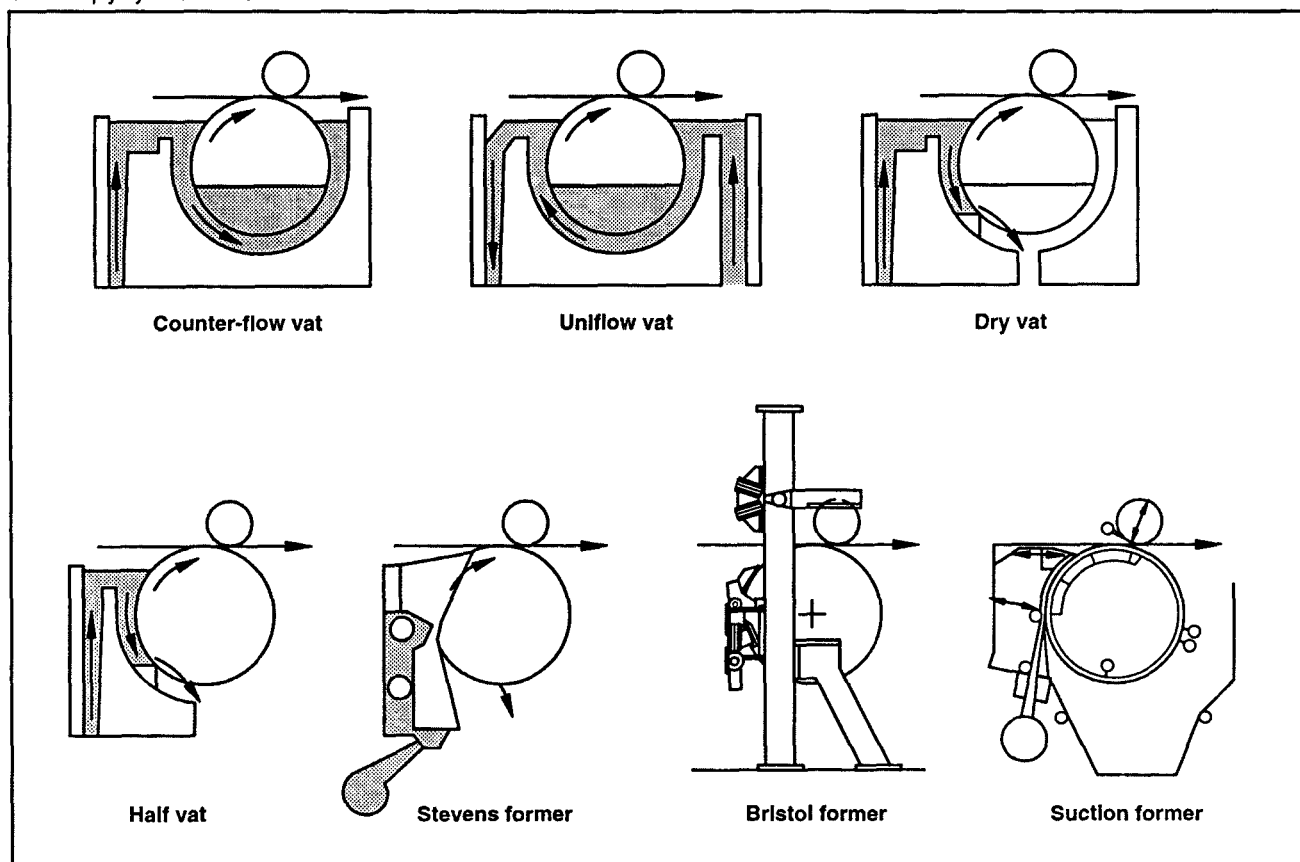
speed while retaining or improving the quality of the board produced by conventional cylinder machines. The sectional cylinder (e.g., half or dry vat) had problems at the higher speeds due to drop offs because the stock is applied beneath the felt. If the stock is applied on the top side of the felt, drop-off never happens — regardless of machine speed.

To realize this idea, the sectional cylinder was turned upside down (Fig. 6). An open-type fourdrinier headbox was located above the cylinder mold, the couch roll was

4. Conventional cylinder (multi-vat) machine



5. Multi-ply cylinder formers



relocated upward, and a roll was added to wrap the cylinder mold with felt. This created the basic design, in which the sheet is formed in a relatively short span on the wire-covered cylinder mold, sandwiched between the felt and the cylinder mold, and transferred on top of the felt.

Top operating speeds range from 150 m/min to 180 m/min (492-590 ft/min). At the higher speed, however, the white water was lifted toward the couch roll nip by

centrifugal force, which disrupts sheet formation. A phalanx of formers then followed, each designed for higher operating speeds. They include:

- High-speed version
350 m/min (1150 ft/min)
- Super ultra version
500 m/min (1650 ft/min)
- Ultra C version

500 m/min (1650 ft/min)

- Ultra twin version
700 m/min (2300 ft/min).

About 600 units are in operation worldwide.

Top-wire formers

The method of forming a layer onto an existing fiber mat is also employed, as in making the top liner on conventional linerboard machines. The stock delivered by the secondary headbox is drained through the base sheet formed on the fourdrinier wire. This gives a very good ply bond, but the method can hardly be applied to the forming of more than one top layer because of the rapidly increasing drainage resistance of the base-sheet layers.

To this end, the major machinery manufacturers have developed several top-wire arrangements from which their customers can choose. These include:

1. Upward draining formers above the bottom wire
2. Top formers above the bottom wire
3. Short or mini fourdrinier(s) above the bottom wire (Fig. 7).

The upward-draining formers are applied to both paper and board grades. They are utilized on the fourdrinier forming table for better formation and improved drainage, for both grades on the base sheet, or used in tandem with a headbox to form a separate web or webs to bond with the base sheet.

Inverform Bel Bond. This top-wire process was designed and patented in 1956 by St. Annes board mill in Bristol, England. The first production machine started up in Bristol in 1958. The standard flat unit at that time consisted of a cellular forming roll, auto-slice, inverted suction boxes, and a rotary vacuum box. This arrangement had serious limitations in drainage capacities. Several design improvements were made to improve capacity, including curved shoes, dipped wires, and inverted suction and open rolls. This unit gained wide acceptance, particularly in Japan, Europe, and Australia, where secondary fiber is widely used to produce multi-ply board. Despite the design changes, drainage or capacity were limiting factors.

Subsequently, it was replaced with a modified arrangement which utilizes a three-chambered, curved, inverted suction box for upward drainage. Greater capacity within broader speed ranges was achieved.

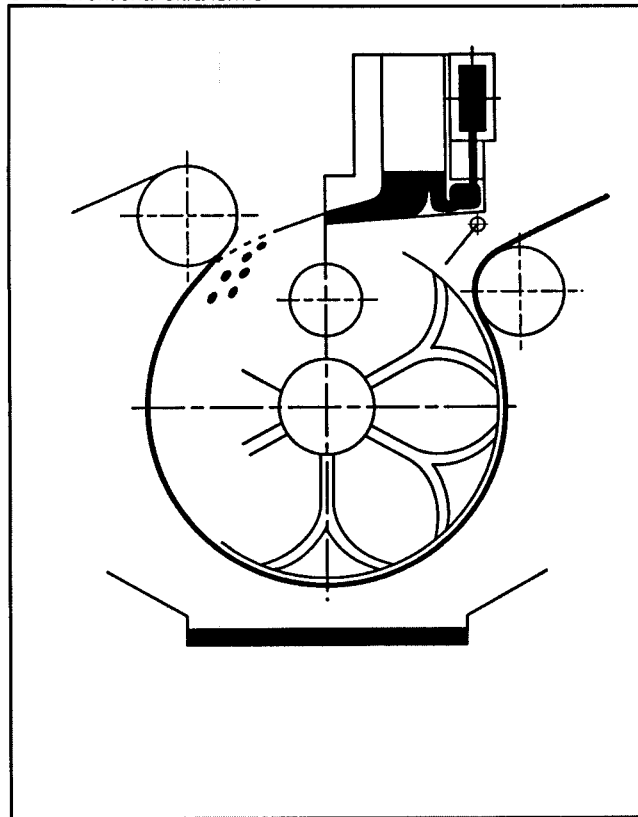
Alform MB. This top-wire unit has individually adjustable low-pressure elements that support the bottom wire to create a self-adjusting dewatering wedge. These elements are centered below the slots of the inverted vacuum boxes.

Duo-Former D. This top-wire unit also has loaded pressure elements under the bottom wire with inverted suction boxes above.

Tamformer S. This former utilizes a large-radius forming shoe located below the bottom wire on the in-going nip, followed by an inverted suction box.

"C" former. This top-wire unit uses adjustable deflector blades below the bottom wire and an open top roll with a close-fitting shield that lifts the water for upward drainage without vacuum.

6. Conventional ultra former



Twin Top N former. The jet from the step diffuser headbox enters a wedge formed by an outer wire and the open forming roll. This is covered by the second wire. Dewatering is through the outer wire (centrifugally) and also through the forming roll. The formed ply is then couched on the fourdrinier base sheet(s).

Top mini fourdrinier

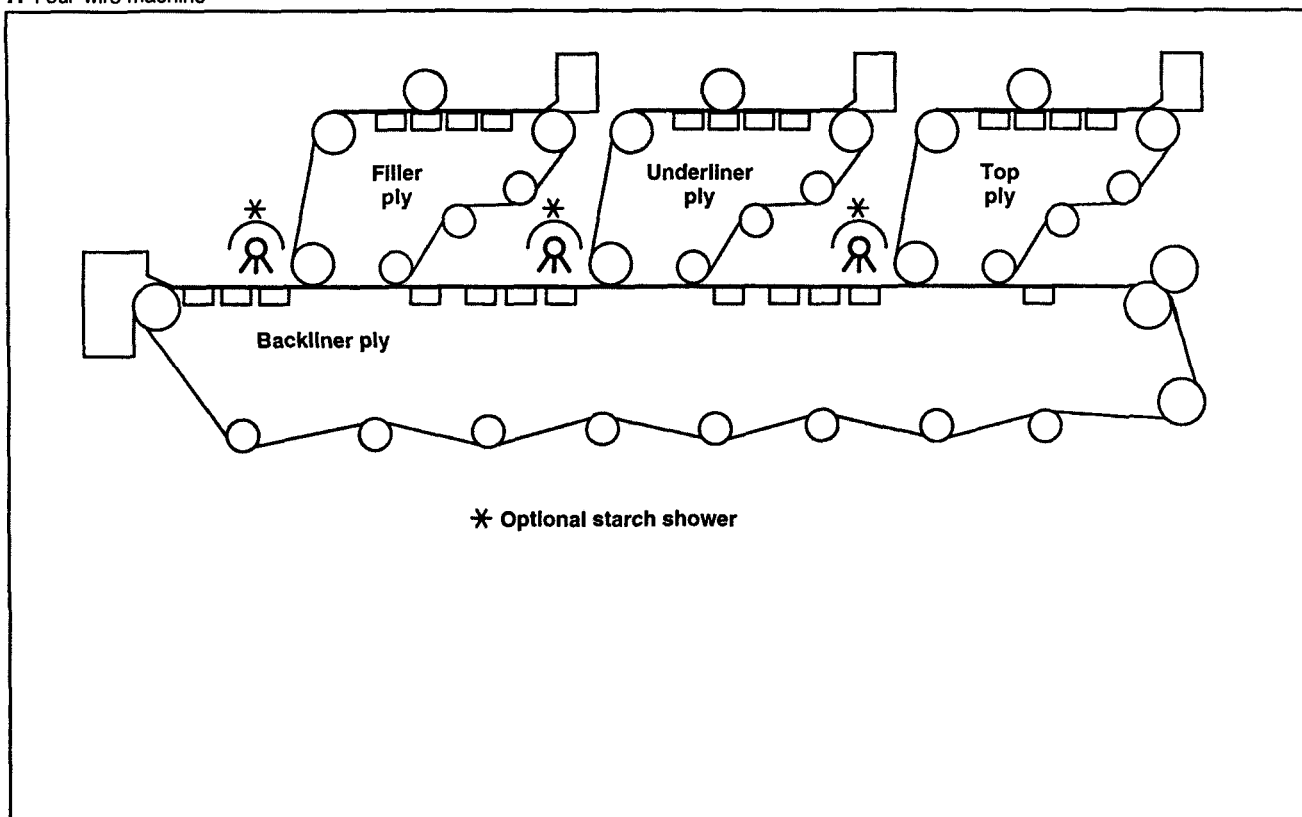
The short or mini fourdrinier has been used for many years, particularly in Europe, for producing various grades of multi-ply board. In some cases, it was not uncommon to have an upper level above the base fourdrinier, which had two or more fourdriniers, or a fourdrinier or a cylinder wet end, or both. Transfer of the webs formed above were accomplished by means of a carrying felt to the main wire below.

Modern multiwire arrangements "couch" the formed plies to other wires and combine these with the main wire with no need for a carrying felt (Fig. 8). The reasons board mills have opted for these top wires are:

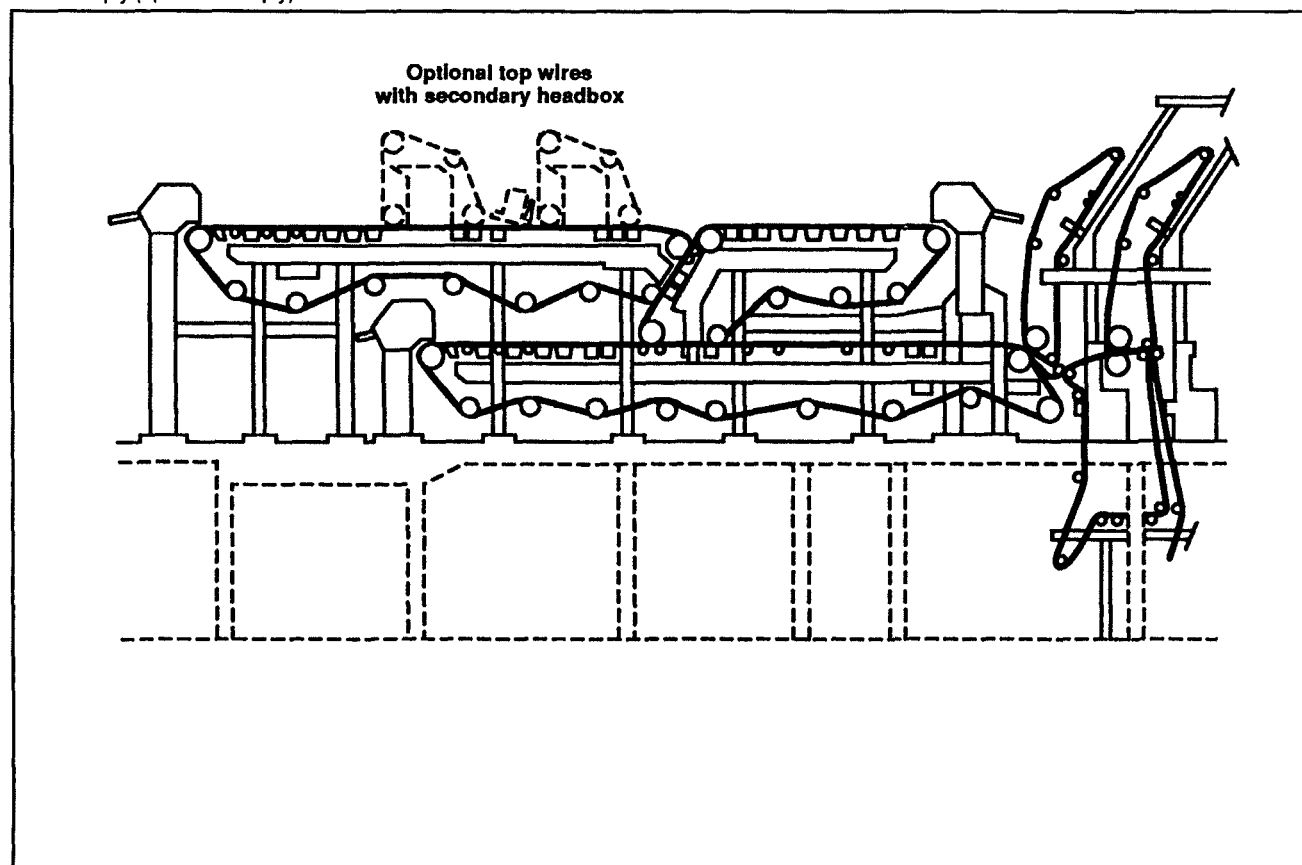
1. Better formation
2. Better test results, including smoothness
3. Separate white water systems. This is an important consideration, particularly if a white top liner is mated with a brown base.

In summary, multi-ply board machines are receiving strong recognition today with the increased use of secondary fiber, particularly on linerboard grades. The objective is the maximum utilization of waste furnish.

7. Four-wire machine



8. Three-ply (optional four-ply) board machine



I. Quality comparison in newsprint

	European mills			U.S. mills	
	Mill 1 100% TMP	Mill 2 75% TMP 24% DIP	Mill 3 55% TMP 45% DIP	Mill 4 100% DIP 100% ONP	Mill 5 100% DIP 100% OMG
Grammage, g/m ²	45.0	45.0	45.0	48.5	45.0
Thickness, μ m	73.9	70.7	69.0	...	66.0
Bulk, cm ³ /g	1.64	1.57	1.53	...	1.47
Brightness (ISO), %	58.6	58.6	58.8	58.9	58.0
Opacity, %	92.4	92.8	93.0	93.6	92.2
Roughness, mL/min	100	81	80	118	150
Porosity, mL/min	328	258	202	...	200
Tensile (MD), Nm/g	52.7	52.4	52.5	...	58.3
Tear (CD), mN·m ² /g	5.69	6.00	5.96	...	8.06
Burst, kPa·m ² /g	1.69	1.67	1.68	1.34	1.84
Ash, %	<0.5	2.5	2.9	...	7.0

TMP = thermomechanical pulp. DIP = deinked paper. ONP = old newsprint. OMG = old magazine.

Paper and tissue grades

Figure 1 shows us that the current costs of deinked newsprint per ton is about 53% of the cost of deinked printing and writing paper. Therefore, it is logical that newsprint made from deinked fiber (either in whole or in part) is gaining acceptance from a standpoint of cost.

Lightweight coated grades (coated groundwood specialties) are also targeted to use more deinked fiber.

The physical makeup of these machines is basically the same as ones producing these grades with virgin fiber. The machines are usually equipped with top-wire formers or gap formers using suction pickup with three or four presses. Dryer sections are designed for good sheet support, closed draws, and to minimize or eliminate sheet fluttering.

Even with the most sophisticated deinking and stock preparation equipment, a certain amount of contaminants will pass through along with fiber fragments. If deposited on the fabric, they will produce holes or weak spots in the web. Headbox cleanliness requires close attention. The headbox should be designed with pivoting sections for easy accessibility for cleaning. Electro-polishing of interior surfaces is also desirable.

Multilayer headboxes have been in existence for a number of years on board and tissue grades. In general, secondary fiber may be applied in the center layer on board grades. On tissue, a three-ply sheet may have stronger fiber in the center and smoother, softer fiber in the outer layers.

The forming section requires close attention with emphasis directed toward:

1. Adequate showering for fabric cleanliness
2. Use of multilayered fabrics for better fabric life and fiber retention
3. Use of chemicals to complement the cleaning action of doctors and showers (this is applicable to the press section as well).

There are a great number of top-wire formers offered

by major paper machinery suppliers today. Many have been retrofitted on existing fourdriniers, while others have been included in the original machine design. Their purpose is to improve drainage, formation, and sheet uniformity.

Gap formers have become almost standard practice for new high-speed machines producing newsprint and tissue grades.

Newsprint machines using deinked waste in their furnish are operating at comparable speeds and quality standards to those having virgin furnish. Table I compares three types of newsprint. Test data compares favorably between virgin and secondary fiber.

One newsprint mill in Finland has been running continuously at 1435 m/min (4706 ft/min) using up to 45% deinked pulp with excellent paper quality.

The age of old newsprint (ONP) affects both fiber strength and bleaching requirements. Additionally, the source of ONP is another factor to consider regarding the resulting test data with deinked newsprint because northern and southern softwoods differ in fiber characteristics (2).

The number of tissue machines using recycled fiber is growing steadily. It is estimated that recycled fiber will make up about 57% of total tissue furnish this year (3). These machines use a wide variety of recycled fibers from old newsprint to high-grade deinked waste. Currently, three of the leading tissue companies use 100% recycled fiber. Others with lesser capacities are also in that category. Still others using virgin fiber either in whole or in part are planning to increase their use of recycled fiber.

The most common forming sections offered today for virgin fiber are also applicable to secondary fiber. They include:

1. "C" wrap twin wires (with plain or suction forming roll)
2. "S" wrap twin wires
3. Crescent formers
4. Inclined fourdriniers with a suction breast roll.

Though hard to imagine, tissue weights (at the wire) which range from 11.4 g/m² to 22.8 g/m² (7-14 lb/3000 ft²) are made in layers. Two-layer and in some cases three-layer headboxes are not uncommon on a modern tissue machine.

The contaminant problem is even more critical on these machines producing lightweight papers at high operating speeds. Operation can falter considerably when the wires and felts are filled, which contributes to holes and spots in the web.

Close attention has been given to recycled white water, showering, and the chemicals that are applied to maintain cleanliness and improve machine efficiency. One tissue mill, for example, has separate collecting pans for shower water used to clean the wires and wire rolls in the twin-wire former. This water is sent to treatment and not mixed with the white water that is directed to the machine silo.

Summary

A great deal of progress has been made in recent years in the processing of secondary fiber, which includes deinking. This has led to a better-quality secondary stock with fewer contaminants.

As greater attention is given to the proper conditioning and cleanliness of the stock prior to reaching the machine chest, the problems on the paper machine will be reduced. Contaminants reduce machine efficiency and paper quality. They increase deposits on clothing and rolls, cause abrasion, and reduce chemical additive efficiency.

Significant developments in multilayer technology have led to more effective use of recycled fiber, particularly in the production of board and tissue.

The pulp and paper industry has benefited by increased knowledge in applying recycled furnish to obtain the properties desired for their products. No doubt problems still exist and more are yet to come, but the challenge to provide solutions will be rewarding to the industry. □

Literature cited

1. Uuetela, E. and Black, N. P., *Tappi J.* 73(7): 50(1990).
2. Young, J., *Pulp & Paper* 64(2): 81(1990).
3. Goodman, J. A., *American Papermaker* 53(12): 41(1990).

The author wishes to acknowledge past reports by former associates Jan Bergstrom, John Peel, and Michael McCormick for material used as reference in this paper.

Received for review July 31, 1991.

Accepted Nov. 19, 1991.

Presented at the TAPPI 1991 Engineering Conference.

Keywords: Board machines, furnish, multiply boards, reclaimed fibers, sheet forming, tissue machines.