Pressure forming developments in multi-ply paperboard forming

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ABSTRACT: Recent developments in pressure forming equipment include a new range of short rotary formers capable of producing high-quality products at speeds up to 400 m/min. One new pressure former operates in conjunction with a short fabric run and a special type of drainage box.

KEYWORDS: Multi-ply boards, pressure forming, paper boards, machine design, rotary machines.

Before the 1950s, paperboard grades were produced mainly by the use of the fourdrinier, the cylinder mold, or a combination of these systems. Since then, detailed studies of web forming have looked at mill operation and pilot plant facilities. Now there is a wide range of methods for producing paperboard grades.

Examples of these methods can be grouped into three categories:

1. Under felt formers
   - Uniflow and contraflow cylinder formers
   - Dry vats
   - Restricted flow vats
   - Hydraulic formers
   - Pressure (short) formers
2. Fourdrinier related formers
   - Fourdriniers with secondary headboxes
   - Multifourdriniers
   - Fourdriniers/multifourdriniers with twin-wire formers
3. Miscellaneous
   - Simultaneous (multichannel) headboxes
   - Ultra formers
   - High consistency forming (middle plies)
   - New generation pressure formers
   - Combination of some of the above.

Under felt forming

Rotary formers (cylinder)

For many years, rotary formers of the uniflow and contraflow type were the main workhorses for the production of a wide range of paperboard grades. The mechanism of forming in uniflow and contraflow vats has been investigated by numerous workers, but probably the most detailed was that carried out by Muller Ridd and Hombsch *(1)*. Using pilot plant equipment, they studied the flow pattern in uniflow and contraflow vats. This work and the work of others led to the development of the dry vat and the restricted flow vat.

Rotary pressure formers

A significant development has been that of the "short" roll former or "pressure" former. The short former is essentially a combination of a well-designed stock inlet with a mixing/dispersing chamber (explosion chamber) which feeds the dispersed fibrous suspension directly into a forming zone.

Pressure forming can be described as a filtering process where drainage and recycling, together with stock dispersion, take place under controlled conditions in an enclosed forming zone.

J. Parker *(2)* stated the following advantages of roll formers over cylinder molds:

1. They can develop and tolerate high levels of turbulence in the initial forming zone because the drainage zone is enclosed. On a cylinder vat machine, the initial forming starts at a free surface.
2. Both high pressure in the free suspension and suction on the underside of the wire (if required) can be applied in the roll former in order to increase the rate of drainage.
3. With a shorter drainage zone, greater advantage is taken of the

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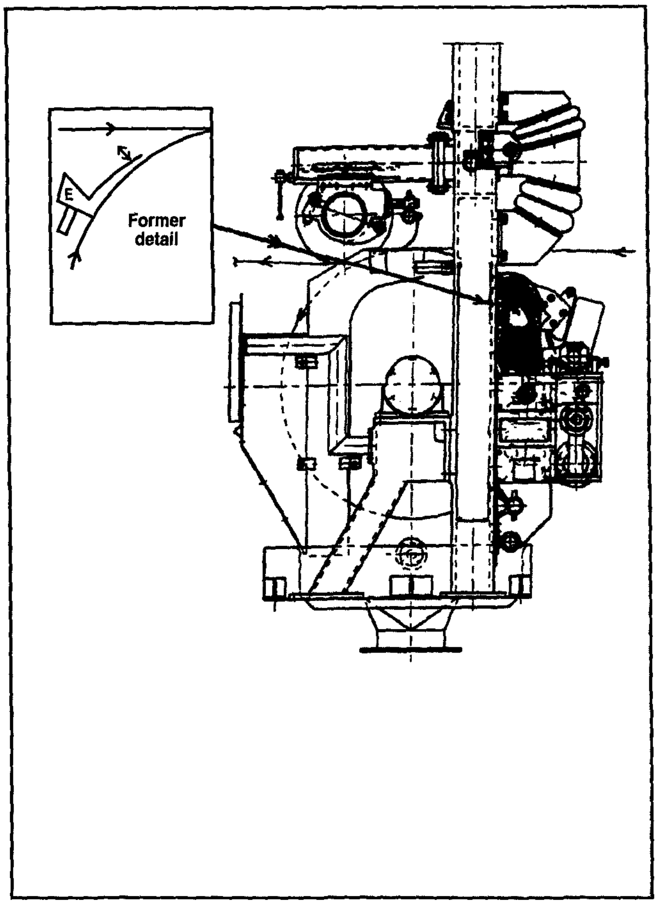
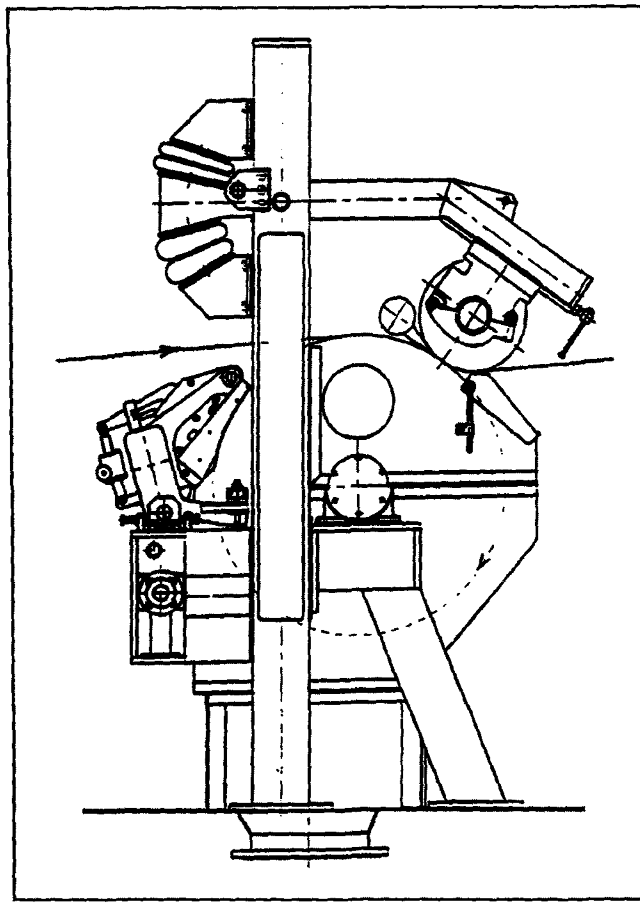
1. Bristol former



2. Bristol super former



increased dispersion in the approach flow; and, further, this increased drainage provides a greater capacity for either sheet weight or dilution of the suspension.

4. A more uniform metering of the flow on the forming wire is obtained by the highly turbulent flow under the precisely machined and positioned, closely spaced contoured roof. Contrast this with conventional cylinder molds, where the final mat forming phase of the cylinder vat process is comprised of the emergence of the formed mat from a relatively stagnant and large pool of stock, which results in uncontrolled and irregular pickup of a layer of poor formation.

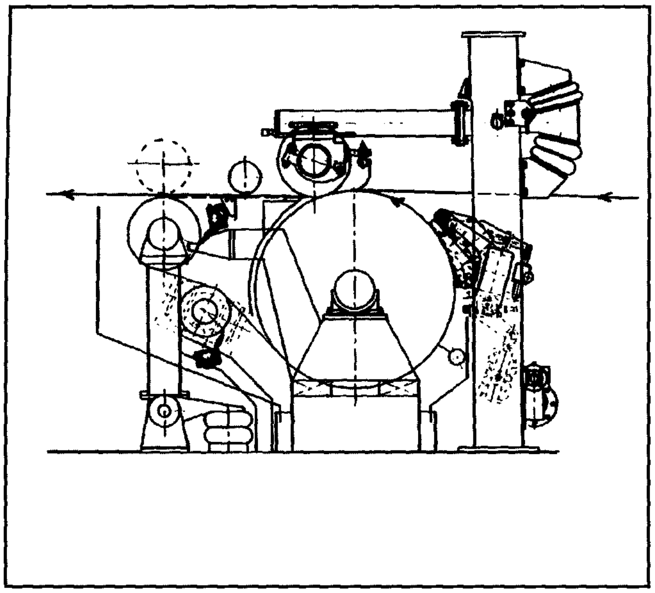
The above reasons are why, with the combination of a scientifically designed inlet system, a fiber dispersion zone (explosion chamber), and an associated lid, the short former can produce well-formed webs at relatively high speeds from a wide range of furnishes.

Recent work relating to the design of the lid and the short length of the forming section has overcome many of the problems encountered when operating in the higher speed range. A typical example of a pressure former is the BRDA St. Anne's former *(3, 4)* which was developed in the 1970s as the result of collaboration between St. Anne's Board Mill (United Kingdom) and BRDA, using pilot facilities at St. Anne's and at Western Michigan University. **Figure 1** shows a typical BRDA/ St. Anne's former, in this case a unit produced by one of the licensees (Black Clawson) and known as the Bristol former.

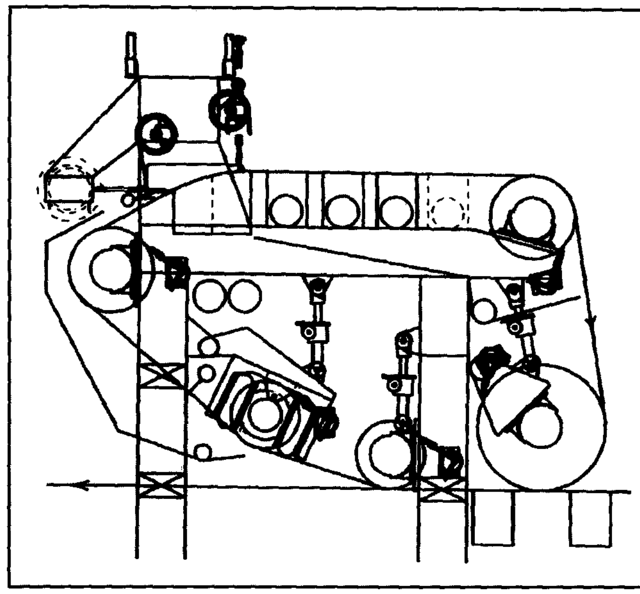
Bristol formers

These formers consist of three main sections: the inlet header, the explosion chamber, and the forming roof (lid). The inlet header is designed to suit the particular needs of a mill and provides good cross machine profile. The fiber suspension passes from the inlet header to the explosion chamber through evenly spaced shear pipes. When the suspension passes through the shear pipes, fiber dispersion takes place. The design of the explosion chamber is the result of numerous pilot plant studies using Plexiglas models.

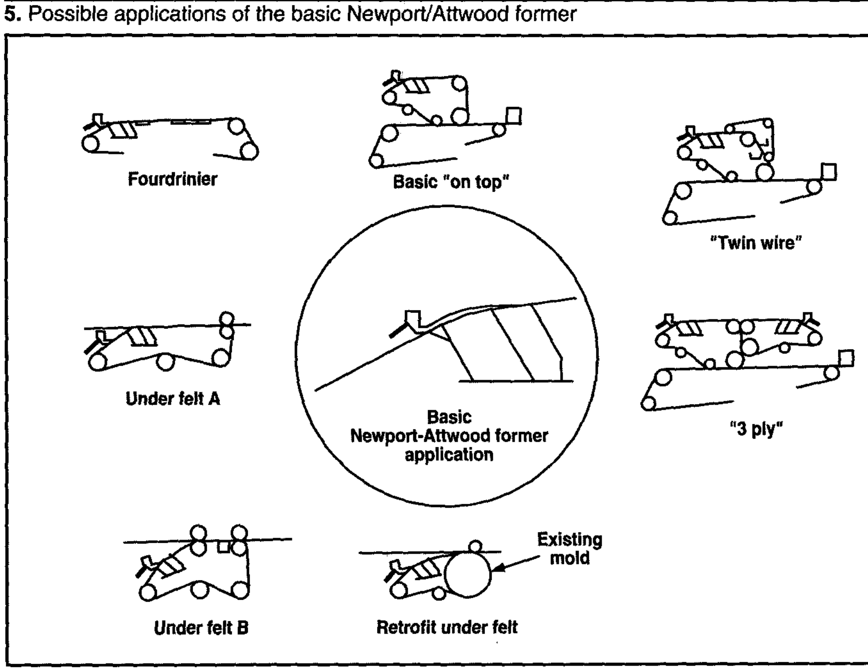
3. Bristol high capacity former



4. Newport/Attwood former



5. Possible applications of the basic Newport/Attwood former



The forming roof can have various configurations, according to the type of product being produced, but it has been found that a normal configuration will operate over a wide range of conditions such as speed, basis weight, forming consistency, etc. Under the forming roof, the web is pressure formed in a relatively short distance, for example, 10–30 cm.

The formers are supplied with a fixed or variable throat which allows control of the throat opening to be carried out on the run. The throat opening influences fiber orientation.

This arrangement has been used on a wide range of board machines, either in the form of retrofits or as complete new forming sections. The former has also been used on ultra former machines, replacing the normal headbox with a pressure former *(5)*.

New developments

Further development has taken place in recent years. The following information indicates this work and the results to date.

The Bristol super former

Commercial experience backed by experimental studies has led to the development of the Bristol super former, which is designed to produce high-quality paperboard grades at speeds up to approximately 350 m/min. It is shown in **Fig. 2.**

A problem of operating rotary formers at speeds over 100 m/min is that of "throw-out" water damaging the fragile web on the underside of the making felt. Studies originally carried out at Western Michigan University showed that if the couch roll was positioned at an angle in excess of 45° over the top dead center position, the throw-out water was thrown downward and away from the fragile web. Similar geometry can be used with the super former.

The result of pilot plant studies has led to the development of a cylinder mold evacuation system incorporating an air-assisted doctor which prevents throw-out water hitting the fragile web on the underside of the making felt.

This former also incorporates step diffusers in the inlet pipes in order to improve dispersion of the fibrous suspension before it reaches the explosion chamber. The result is a well-dispersed fibrous suspension fed to the forming area, allowing operation at higher consistencies.

Bristol HC former

A recent development of the Bristol former system is the Bristol HC (high capacity) former, as illustrated in **Fig. 3.** It consists of a cylinder mold with a relatively short wire run. The pressure former previously described applies the fibrous suspension to a forming wire draped around the cylinder. After forming, the web is brought in contact with the underside of a making felt and while on the forming fabric continues in this state for a distance of a least 1 m.

While in this position the fragile fibrous web:

- Is protected from any throw-out water associated with the forming roll
- Can be further dewatered with a doctor(s) which at the same time can subject the fibrous suspension to shear forces resulting in a degree of reforming
- Can be further dewatered with vacuum boxes
- Is subjected to pressing using either a plain/grooved roll or an extractor roll.

The arrangement can be considered a type of twin-wire forming, where dewatering takes place through the forming screen in a downward direction with the assistance of gravity, as opposed to upward dewatering, as is the case in conventional multi-ply twin-wire forming. Another difference from conventional twin-wire multi-ply forming is that preforming takes place against a forming fabric and not on a previously formed layer.

The equipment is designed to operate, when required, at medium consistency (1.5–2.2%)—for example, when producing middle plies with high individual basis weights (150–180 g/m²). It can operate at high speed (+400 m/min).

The Newport/Attwood system for formers and headboxes

During the early development of the BRDA/St. Anne's formers, preliminary studies took place at St. Anne's where the fibrous suspension was applied not to the curved surface of a cylinder mold but to the flat surface of a fourdrinier wire part. Under the lid of the former was positioned a drainage box. The aim of this work was to modify an Inverform machine by applying this arrangement to existing Inverform top-wire units, converting them, in effect, into "on top" pressure formers. Preliminary studies indicated considerable potential for the development of such an arrangement, but the closure of St. Anne's put this work "on ice."

In recent years, this concept has been further studied and developed, using pilot plant equipment at Black Clawson Kennedy (Watertown). The essential parts of the developed unit (Newport/Attwood System) are a computer-designed tapered inlet; an explosion chamber; a top lid which can either be planar, a combination of planar and curved, or totally curved; and a curved forming drainage box. This unit is shown in **Fig. 4.**

The curved drainage box can be compartmentalized, allowing various degrees of vacuum to be applied where and as necessary. Because the forming wire is pulled under tension over the curved surface, the forming fabric is always level and free of undulations in the critical forming zone.

A wide range of furnishes has been used during experimental studies, and satisfactory operation has been obtained with furnishes ranging from recovered paper to virgin pulps, cotton linters, synthetic fibers, glass fibers, etc. Freeness has ranged from 80-600 CSF. Operating consistencies have ranged from 0.2% to 2.5%. Basis weights have ranged from 20 g/m² (backs and underliner plies) to 800 g/m² (pulp lap). The pilot unit has been operated over a speed range of 80 m/min to 450 m/min, and current work indicates the potential for higher speeds.

The equipment is not complicated and is easy to control and operate. Startup and shutdown time can be extremely short.

The process allows the operator to control a number of web characteristics—for example, tensile ratios. This particular control is carried out by adjusting the throat opening at the point at which the fibrous suspension flows from the explosion chamber onto the moving forming fabric. Studies have shown that ratios ranging from 1.3:1 to 3.0:1 are readily obtainable (samples taken at the couch).

The system can be considered to be a new type of headbox. Among its advantages are that it is relatively small in size, operates over a wide range of conditions, allows draining and forming to be easily controlled, and is less costly than other systems. With the compartmentalized forming box and associated circulating system, it is possible to have a closed system at the point where preliminary forming and high rates of drainage take place.

There can be numerous applications of the development, as illustrated in **Fig. 5.** For example:

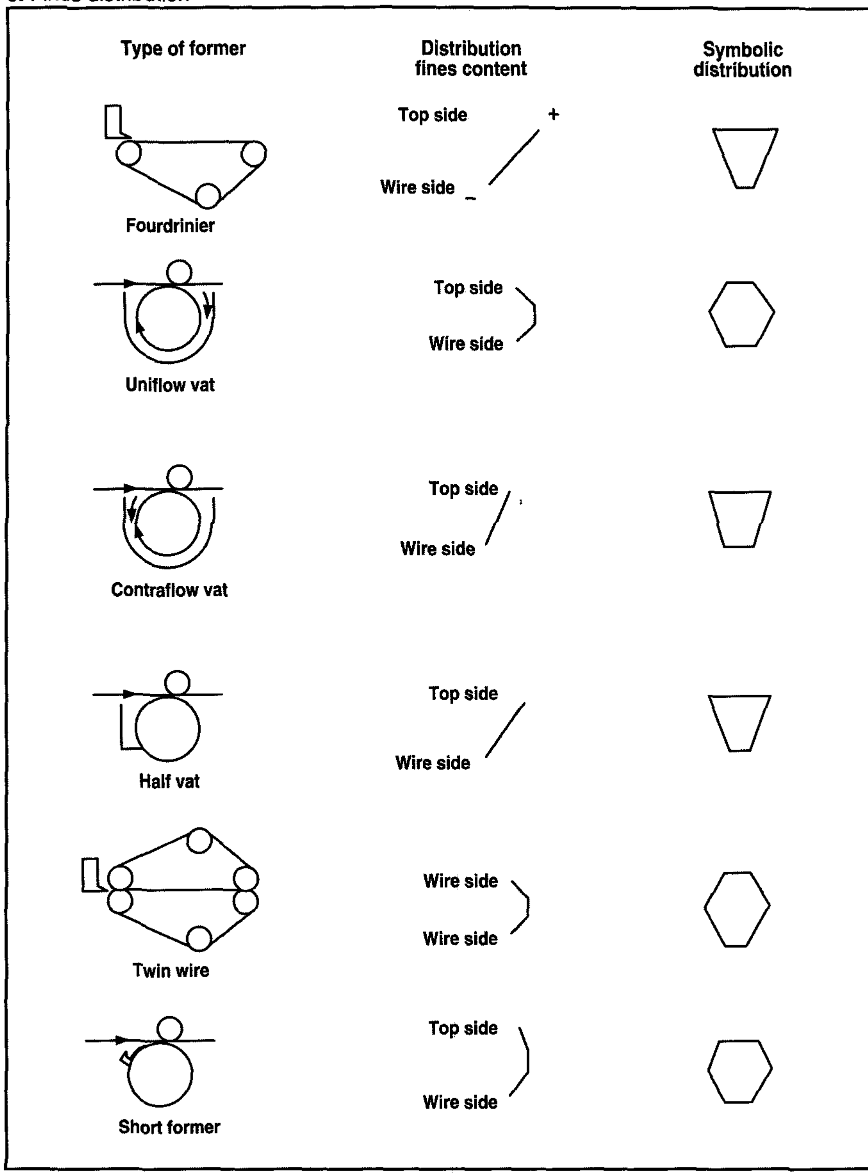
- An underfelt former
- An "on-top" former
- A twin-wire forming system
- A method for producing multilayer webs either from individual plies couched together or by simultaneous forming
- A headbox on a conventional fourdrinier wire pan.

Other work is underway in simultaneous multi-ply forming and high-consistency operation. Previous studies indicated the potential for operation as a "foam" forming unit.

Ply bonding

An examination of the webs produced by various forming methods, using techniques described by Majewski *(6)* and others, shows the distribution of fines through the webs to be approximately as illustrated in **Fig. 6.** The distribution of fines using short formers is one of the reasons why the use of these formers gives acceptable ply bonding levels, with a wide range of furnishes over a wide range of speeds.

6. Fines distribution



Summary

Pressure formers have been developed to operate at higher speeds while maintaining good quality webs. Other developments enable high basis weights (individual plies) to be produced. A new development of the pressure former is the Newport/Attwood System, where a pressure former operates in conjunction with an endless forming fabric and a curved forming box. This arrangement has been proved on pilot facilities to operate at speeds in excess of 450 m/min, and there are indications from current work of the possibility of achieving far higher speeds.

These pressure formers have proved to be versatile and can be used not only in the under felt position but also as on-top formers. They have the potential for use in the manufacture of nonwoven materials using synthetic fibers and mineral fibers and have been shown to have the capability of operating at medium to high consistencies.

Although there are now many ways of producing multi-ply paperboard webs, it is believed that "under felt" forming will remain an important method for many years to come.

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