The Air Press for Improved Dewatering

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Abstract
An Air Press system has been developed for improved dewatering of paper webs. A moist paper web can be dewatered to consistency levels not previously thought possible at industrially useful speeds without thermal dewatering. The air press has an air plenum and a vacuum collection device, each on opposite sides of two support fabrics that sandwich the paper web. Cross machine sealing blades impinge upon the support fabrics in a sealing zone formed between two vacuum box elements. Deckles are sealed using a sealing member formed of deformable material. The air plenum and vacuum collection device are movable relative to one another so that the sealing blade and deformable sealing member form a seal in the operating position of the air press.

Introduction

Manufacturers of many paper grades have long sought for improved methods of dewatering a wet web after formation. For many grades, high levels of wet pressing are inadequate solutions, and standard dewatering aids such as vacuum boxes are severely limited in the solids level that can be achieved at practical speeds. Regardless of how a web is finally dried, there is often a need to increase the dryness of the web prior to the drying step or prior to wet pressing.

Many efforts have been made to improve water removal with vacuum elements, but these are ultimately limited to a pressure differential across the web of less than one atmosphere. Air jets and nozzles have been used to varying degrees, but these have not proven effective in terms of water removal or energy efficiency. Unless the air is heated, as it is in many dryers, the applied air generally does little to dewater a wet web, at least not with good energy efficiency.

Other previously proposed improvements in dewatering is displacement dewatering, in which a gas phase is used to drive out the liquid phase. Displacement dewatering has been touted for its potential to increase water removal in a moist web at relatively low applied loads to the web and without the energy cost of evaporative drying. Displacement dewatering has been used in pilot operations in Poland, as reported in a variety of articles by Kawka et al.[1-3] No patents and limited journal articles result from work done by Kawka, and no reports exist of actual commercial mill trials resulting from his work. It is assumed that technical or economic difficulties prevented his work from reaching the commercial stage. The potential of displacement dewatering was further explored experimentally and theoretically by Lindsay[4,5], who noted the challenge of creating a good seal between a pressurized source and a moving web as a major challenge for commercialization of improved dewatering technology.

To date, a successful method for maintaining a good seal between a pressurized plenum and a moist moving web has not been available for industrial use. The problem of maintaining effective seals between a pressurized plenum and a moving web has been a particularly severe challenge. Now new air press technology has been developed which solves many of the problems that hindered effective displacement dewatering in the past. Though initially developed with low-basis weight grades products in mind, a variety of paper and pulp products may benefit from the improved technology, including board grades for packaging, fluff pulp and market pulp, newsprint, and a variety of grades where high densification is undesirable.

The Air Press

A new dewatering device has been developed which allows higher solids levels to be achieved in a web prior to wet pressing or evaporative dewatering. The device, known as the Air Press, can improve dewatering without substantial increases in densification, with solids levels over 30% being demonstrated prior to wet pressing. The increased solids levels can lead to many benefits, such as improved speed, reduced energy cost, reduced sheet breaks, improved operation of subsequent mechanical processes, and so forth. The Air Press can operate at high speeds characteristic of industrial papermaking.

In general, the air press applies gas pressure in a central pressurized plenum to a wet web between two moving fabrics the web and fabrics pass over a vacuum box. Machine direction seal elements run along the sides of the fabrics in the air press, and cross-direction seal elements prevent leakage from the exit and entry regions of the air press. The cross-direction seal descends into the fabric over a recess such that the face of the seal element is flush with the fabric, without compressing the web. The cross-direction seals and the machine-direction seals combine to form a complete seal between the pressurized chamber and the top surface of the upper supporting fabric. Many innovations were required to develop the system and especially the seals that enabled good performance, resulting in a variety of patents. [6-13]

Figures 1-5 below are taken from US Patent No. 6,143,135 (Hada et al.)[6]. Figure 1 depicts a side view of the Air Press operating on a wet web. Label numbers in the figures will be used to describe the corresponding component.

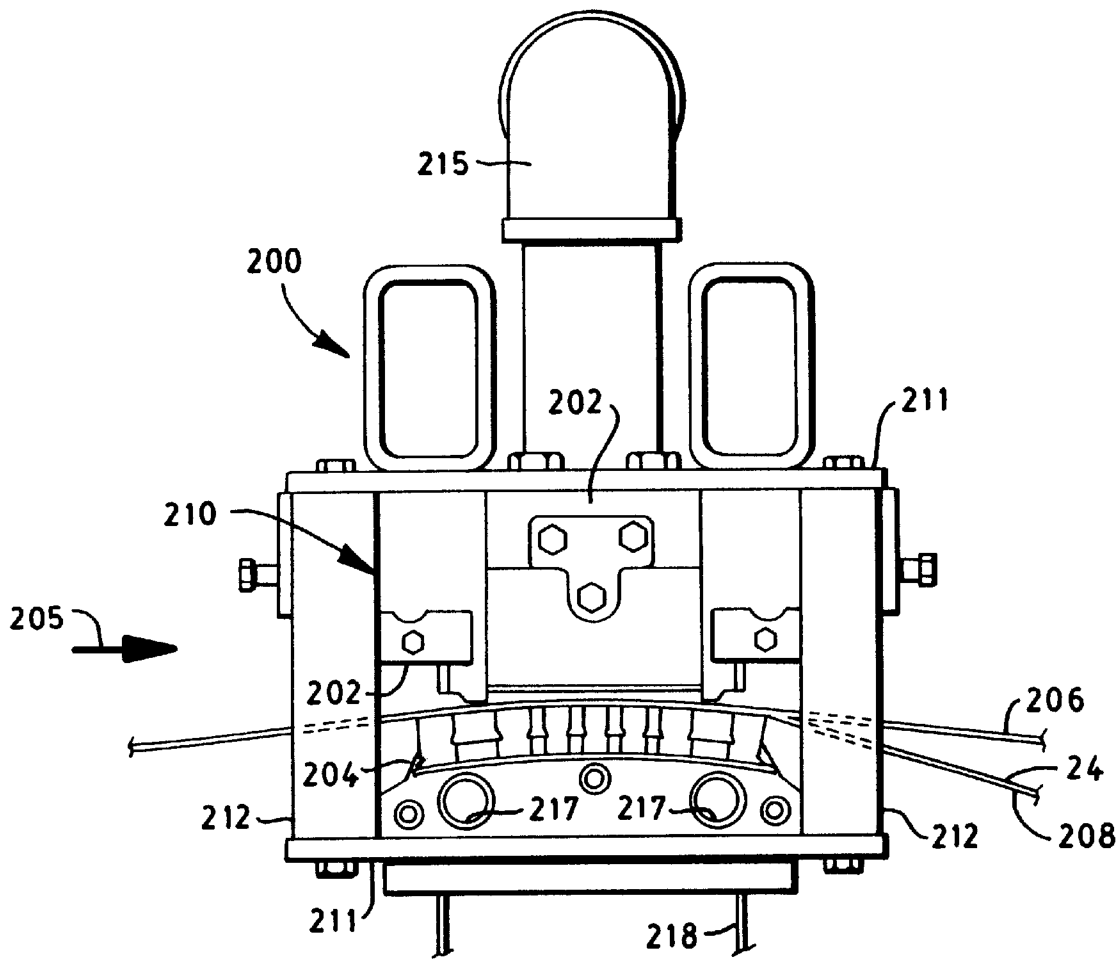

Figure 1. Side View of the Air Press.

As shown in Figure 1, the air press has an upper air plenum 202 in combination with a lower vacuum box 204. The wet web 24 travels in the machine direction between the air plenum and vacuum box while sandwiched between an upper support fabric 206 and a lower support fabric 208. The air plenum and vacuum box allow pressurized fluid supplied to the air plenum to travel through the wet web and be evacuated through the vacuum box.

The illustrated air plenum and vacuum box are mounted within a frame structure 210. The air plenum allows pressurized fluid to flow through one or more air conduits 215 connected to a pressurized fluid source (not shown). Correspondingly, the vacuum box 204 can have multiple vacuum chambers connected to low and high vacuum sources (not shown) by fluid conduits 217 and 218, respectively. The water removed from the wet web is separated from the air streams.

An end view of the air press spanning the width of the wet web is shown in Figure 2. In both Figures 1 and 2, several components of the air plenum are illustrated in a raised or retracted position relative to the wet web and vacuum box. In the retracted position, effective sealing of pressurized fluid is not possible.

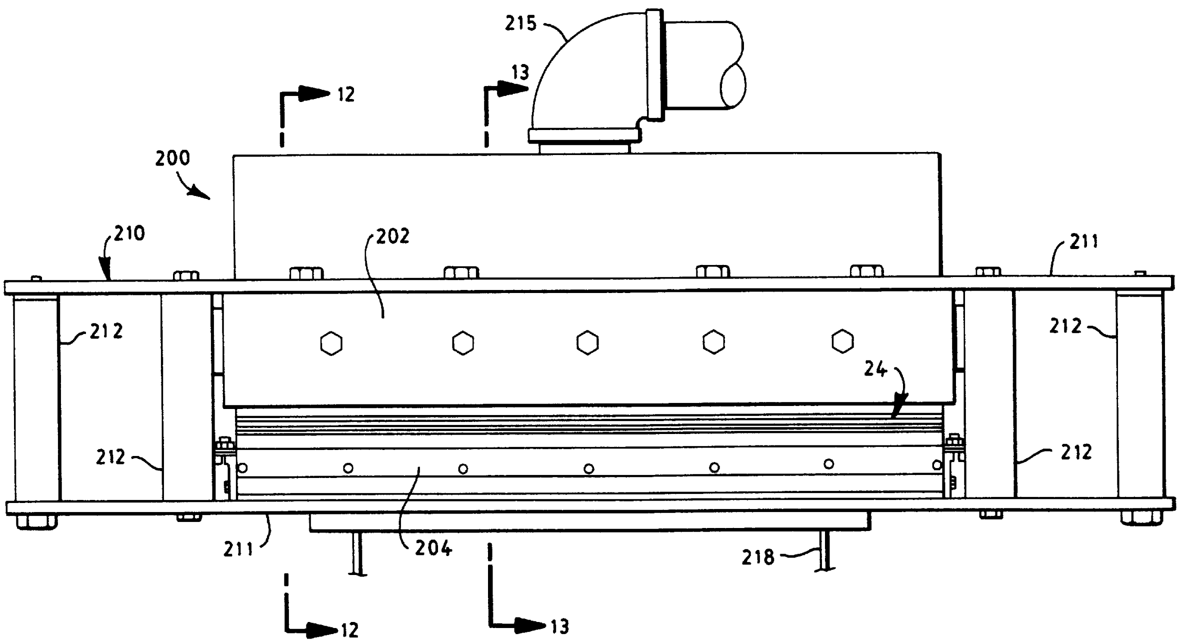

Figure 2. End View of the Air Press.

Enlarged section views of the air press are shown in FIGS. 3 and 4. The air press is shown in an operating position with components of the air plenum lowered to impinge the wet web and support fabrics. The degree of impingement can be optimized for proper sealing with low contact force and therefore reduced fabric wear.

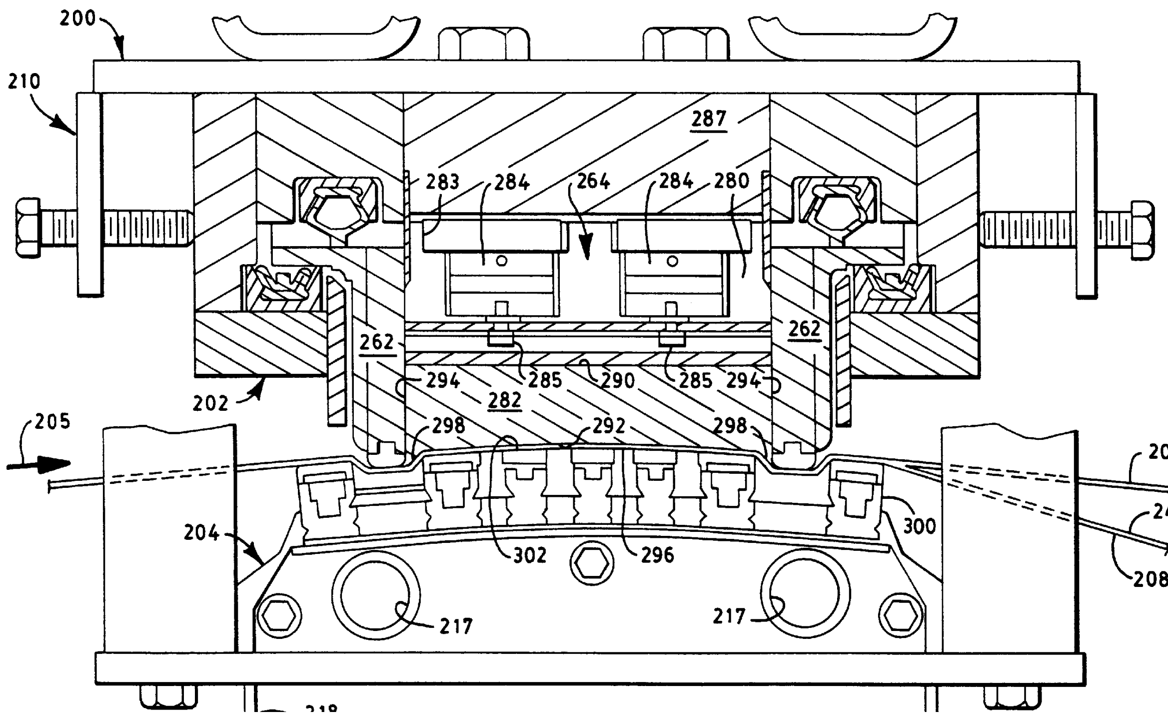

Figure 3. Detailed Side View of the Air Press.

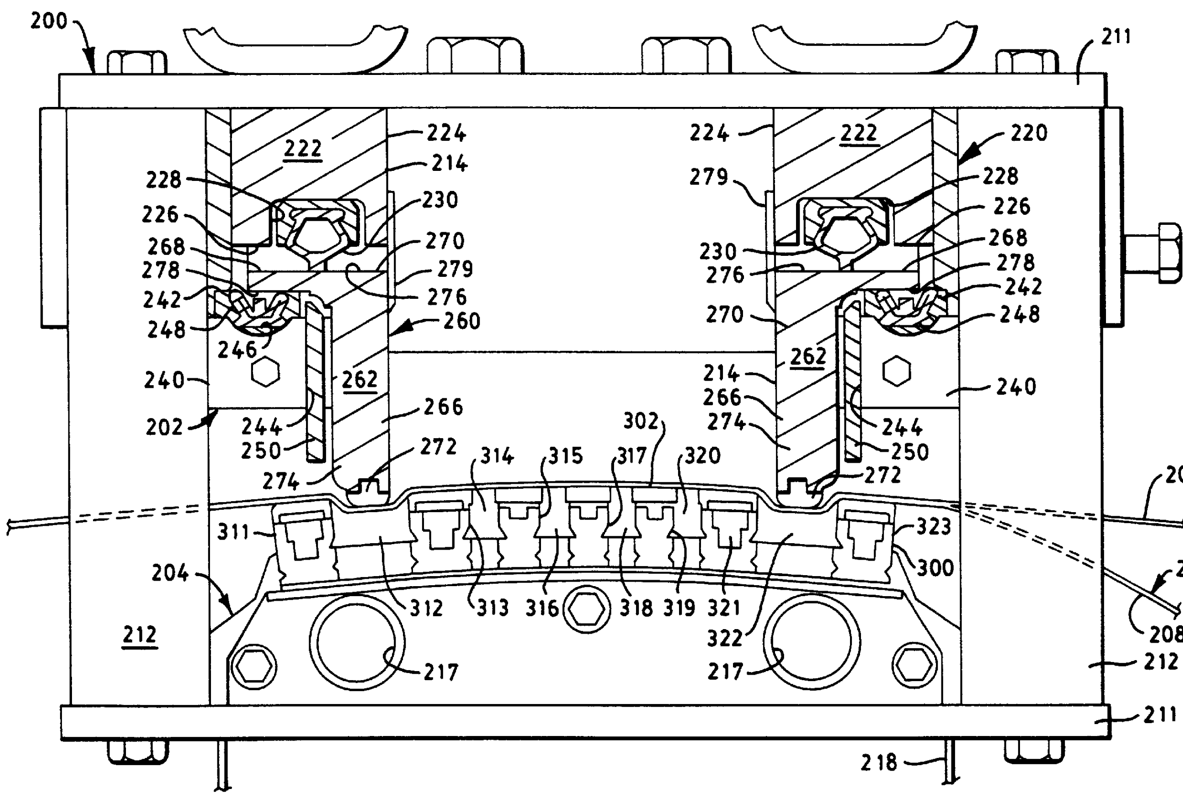

Figure 4. Detailed Side View of the Air Press Showing the Central Chamber.

The air plenum has stationary components 220 that are mounted to the frame structure and a sealing assembly 260 that is mounted relative to the frame structure and the wet web.

In Figure 4, the stationary components of the air plenum include a pair of upper support assemblies 222 positioned beneath the upper support plate 211. The upper support assemblies provide facing surfaces 224 that partially define the plenum chamber 214. The upper support assemblies also have bottom surfaces 226 facing the vacuum box 204. Here, each bottom surface has an elongated recess 228 in which an upper pneumatic loading tube 230 is mounted. The upper pneumatic loading tubes generally extend over the full width of the wet web.

The stationary components of the air plenum also include a pair of lower support assemblies 240 with top surfaces 242 and facing surfaces 244. The top surfaces are directed toward the bottom surfaces of the upper support assemblies and, as illustrated, provide recesses 246 in which lower pneumatic loading tubes 248 are mounted. The lower pneumatic loading tubes are centered in the cross-machine direction and extend over about 50 to 100 percent of the width of the wet web. Lateral support plates 250 are attached to the facing surfaces 244 of the lower support assemblies and function to stabilize vertical movement of the sealing assembly 260.

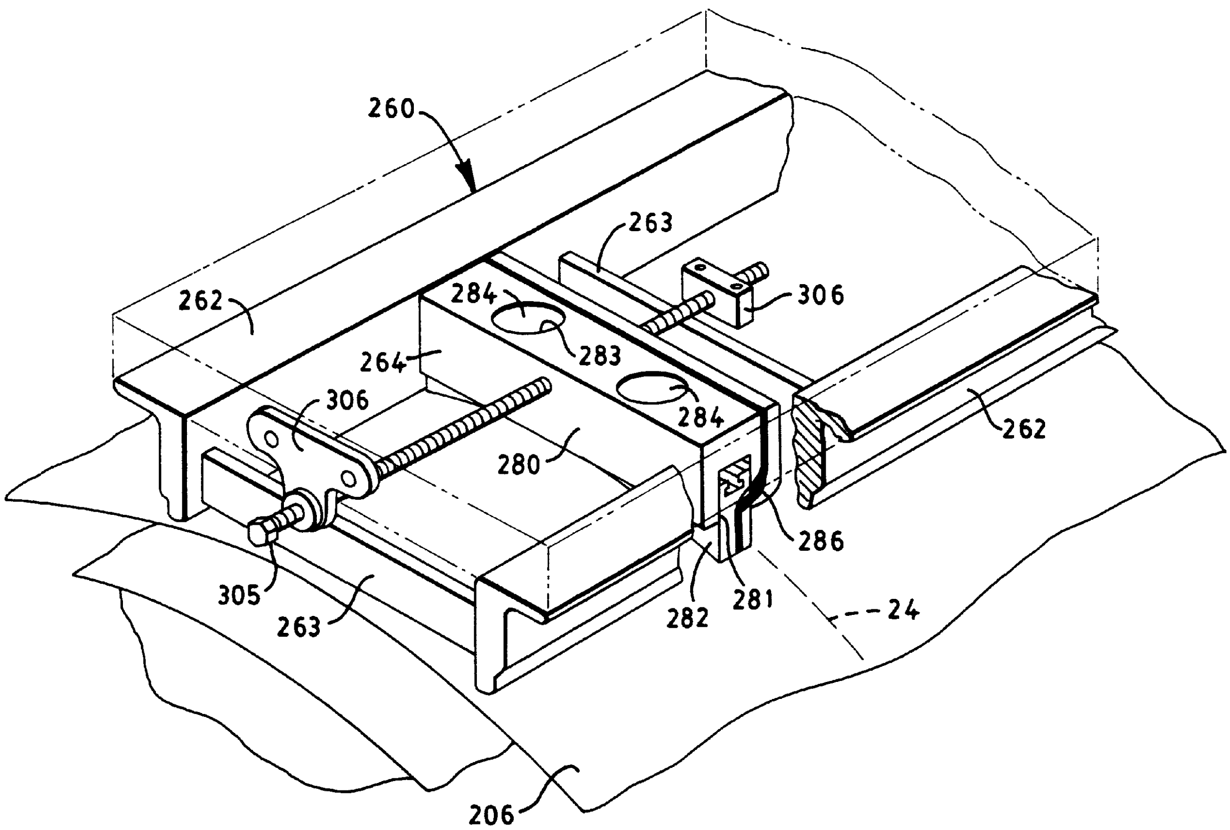

Figure 5. Air Plenum Sealing Assembly Positioned Against the Fabrics.

Also in Figure 5, the sealing assembly 260 has a pair of cross-machine direction sealing members referred to as CD sealing members 262, braces 263 that connect the CD sealing members, and a pair of MD sealing members 264. The braces 263 are attached to the CD sealing members to provide structural support. In the machine direction, the MD sealing members 264 are placed between the upper support assemblies 222 and between the CD sealing members 262. In the cross-machine direction, the MD sealing members are positioned near the edges of the wet web. The MD sealing members are moveable in the cross-machine direction in order to accommodate a range of possible wet web widths.

The vertical position of the transverse flanges 268 and thus the CD sealing members 262 is controlled by activation of the pneumatic loading tubes 230 and 248. Activation of the upper loading tubes creates a downward force on the upper control surfaces of the CD sealing members resulting in a downward movement of the flanges until they contact the top surfaces 242 of the lower support assemblies 240 or are stopped by an upward force caused by the lower loading tubes or the fabric tension. Retraction of the CD sealing members is achieved by activation of the lower loading tubes and deactivation of the upper loading tubes. In this case, the lower loading tubes press upwardly on the lower control surfaces and cause the flanges to move toward the bottom surfaces of the upper support assemblies. Of course, the upper and lower loading tubes can be operated at differential pressures to establish movement of the CD sealing members.

The sealing blades 272 function together with other features of the air press to minimize the escape of pressurized fluid between the air plenum and the wet web in the machine direction. The sealing blades are can be shaped and formed in a manner that reduces the amount of fabric wear. The sealing blades may be formed of resilient plastic compounds, ceramic, coated metal substrates, or the like.

In FIGS. 3 and 5, the MD sealing members 264 prevent the loss of pressurized fluid along the side edges of the air press. FIGS. 3 and 5 each show one of the MD sealing members, which are positioned in the cross-machine direction near the edge of the wet web. As illustrated, each MD sealing member has a transverse support member 280, an end deckle strip 282 connected to the transverse support member, and actuators 284 for moving the end deckle strip relative to the transverse support member. The transverse support members are normally positioned near the side edges of the wet web and are generally located between the CD sealing members. As illustrated, each transverse support member defines a downwardly directed channel 281 (Figure 5) in which an end deckle strip is mounted. Additionally, each transverse support member defines circular apertures 283 in which the actuators 284 are mounted.

The end deckle strips are vertically moveable relative to the transverse support members 280 due to the cylindrical actuators 284. As shown in Figure 5, both the transverse support members 280 and the end deckle strips 282 define slots to house a fluid impermeable sealing strip 286, such as O-ring material or the like. The sealing strip helps seal the air chamber of the air press from leaks.

A bridge plate 287 (Figure 3) is positioned between the MD sealing members 264 and the upper support plate 211 and mounted to the upper support plate. Sealing means such as a fluid impervious gasketing material can be positioned between the bridge plate and the MD sealing members to permit relative movement therebetween and to prevent the loss of pressurized fluid.

The degree of impingement of the CD sealing members into the upper support fabric uniformly across the width of the wet web has been found to be a significant factor in creating an effective seal across the web. The requisite degree of impingement has been found to be a function of the maximum tension of the upper and lower support fabrics and, the pressure differential across the web and in this case between the air plenum chamber and the sealing vacuum zones 312 and 322, and the gap between the CD sealing members 262 and the vacuum box cover 300.

With reference to the diagram of the trailing sealing section of the air press shown in Figure 6 (taken from US Patent No. 6,083,346[9]), the minimum desirable amount of impingement of the CD sealing member into the upper support fabric 206, *h(min)*, has been found to be represented by the following equation:

$$h(\min) = \frac{T}{W}\left(\cosh\left(\frac{Wd}{T}\right) - 1\right);$$

where: T is the tension of the fabrics measured in pounds per inch; W is the pressure differential across the web measured in psi; and d is the gap in the machine direction measured in inches.

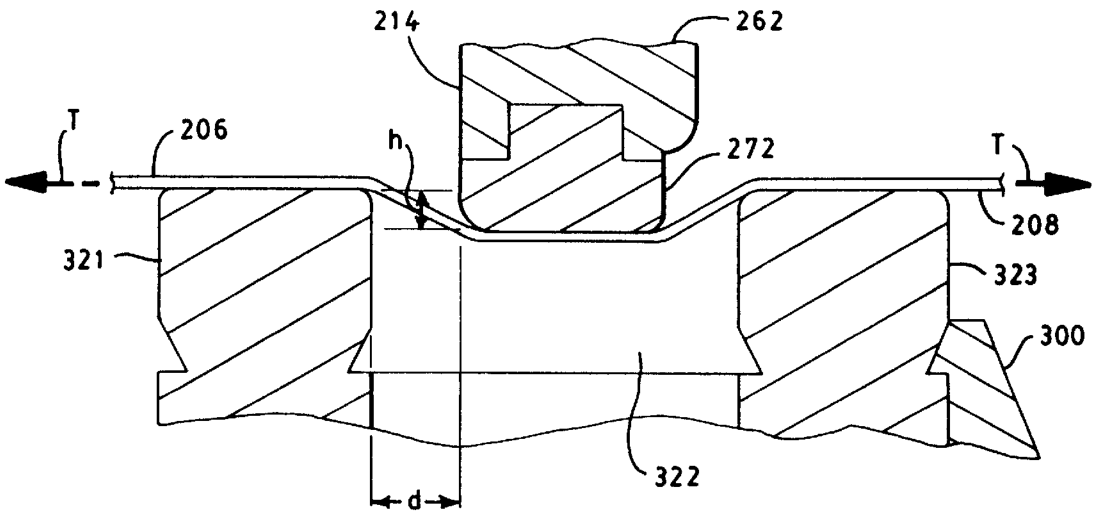

Figure 6. Detail of CD Seal Impinging the Web and Fabrics.

Figure 6 shows the trailing CD sealing member 262 deflecting the upper support fabric 206 by an amount represented by the arrow labeled "h". The maximum tension of the upper and lower support fabrics 206 and 208 is represented by the arrow labeled "T". Fabric tension can be measured by a model tensometer available from Huyck Corporation or other methods. The gap between the sealing blade 272 of the CD sealing member and the second interior sealing shoe 321 measured in the machine direction is represented by the arrow labeled "*d*". The gap *d* of significance for determining impingement is the gap on the higher pressure differential side of the sealing blade, that is, toward the plenum chamber 214, because the pressure differential on that side has the most effect on the position of the fabrics and web. The gap between the sealing blade and the second exterior shoe 323 may be about the same or less than the gap *d*.

Adjusting the vertical placement of the CD sealing members to the minimum degree of impingement as defined above is a determinative factor in the effectiveness of the CD seal. The loading force applied to the sealing assembly 260 plays a lesser role in determining the effectiveness of the seal, and need only be set to the amount needed to maintain the requisite degree of impingement. Of course, the amount of fabric wear will impact the commercial usefulness of the air press. To achieve effective sealing without substantial fabric wear, the degree of impingement is desirably equal to or only slightly greater than the minimum degree of impingement as defined above. To minimize the variability of fabric wear across the width of the fabrics, the force applied to the fabric is desirably kept constant over the cross machine direction. This can be accomplished with either controlled and uniform loading of the CD sealing members or controlled position of the CD sealing members and uniform geometry of the impingement of the CD sealing members.

In use, a control system causes the sealing assembly of the air plenum to be lowered into an operating position. First, the CD sealing members are lowered so that the sealing blades 272 impinge upon the upper support fabric to the degree described above. More particularly, the pressures in the upper and lower loading tubes and are adjusted to cause downward movement of the CD sealing members until movement is halted by the transverse flanges 268 contacting the lower support assemblies 240 or until balanced by fabric tension. Second, the end deckle strips 282 of the MD sealing members 264 are lowered into contact with or close proximity to the upper support fabric. Consequently, the air plenum and vacuum box are both sealed against the wet web to prevent the escape of pressurized fluid.

The air press is then activated so that pressurized fluid fills the air plenum and an air flow is established through the web. The resulting pressure differential across the wet web and resulting air flow through the web provide for efficient dewatering of the web.

A number of structural and operating features of the air press contribute to very little pressurized fluid being allowed to escape in combination with a relatively low amount of fabric wear. Initially, the air press uses CD sealing members that impinge upon the fabrics and the wet web. The degree of impingement is determined to maximize the effectiveness of the CD seal. In one embodiment, the air press utilizes the sealing vacuum zones 312 and 322 to create an ambient air flow into the air press across the width of the wet web. In another embodiment, deformable sealing members 330 are disposed in the sealing vacuum zones 312 and 322 opposite the CD sealing members. In either case, the CD sealing members can be located at least partly in passageways of the vacuum box cover 300 in order to minimize the need for precise alignment of mating surfaces between the air plenum and the vacuum box. Further, the sealing assembly can be loaded against a stationary component such as the lower support assemblies that are connected to the frame. As a result, the loading force for the air press is independent of the pressurized fluid pressure within the air plenum. Fabric wear is also minimized due to the use of low fabric wear materials and lubrication systems. Suitable lubrication systems may include chemical lubricants such as emulsified oils, debonders or other like chemicals, or water. Typical lubricant application methods include a spray of diluted lubricant applied in a uniform manner in the cross machine direction, an hydraulically or air atomized solution, a felt wipe of a more concentrated solution, or other methods well known in spraying system applications.

Observations have shown that the ability to run at higher plenum pressures depends on the ability to prevent leaks. The presence of a leak can be detected from excessive air flows relative to previous or expected operation, additional operating noise, sprays of moisture, and in extreme cases, regular or random defects in the wet web including holes and lines. Leaks can be repaired by the alignment or adjustment of the air press sealing components.

In the air press, uniform air flows in the cross-machine direction are desirable to provide uniform dewatering of a web. Cross-machine direction flow uniformity may be improved with mechanisms such as tapered ductwork on the pressure and vacuum sides, shaped using computational fluid dynamic modeling. Because web basis weight and moisture content may not be uniform in the cross-machine direction, is may be desirably to employ additional means to obtain uniform air flow in the cross-machine direction, such as independently-controlled zones with dampers on the pressure or vacuum sides to vary the air flow based on sheet properties, a baffle plate to take a significant pressure drop in the flow before the wet web, or other direct means. Alternative methods to control CD dewatering uniformity may also include external devices, such as zoned controlled steam showers such as a Devronizer steam shower available from Honeywell-Measurex Systems Inc. of Dublin, Ohio.

Energy Efficiency and Economic Considerations

An important benefit of the Air Press for some grades is improved energy efficiency. The "water retention consistency" of a pulp specimen, referred to herein as WRC, can be calculated from the well known Water Retention Value (WRV) according to the following equation:

$$WRC = \left(\frac{1}{1 + WRV}\right) \times 100.$$

The term WRC is used herein because it represents the maximum consistency obtainable using non-thermal means for a pulp specimen having a given WRV.

The term "Energy Efficiency" (EE) refers to post-dewatering consistency divided by WRC for a given horsepower per inch (Hp/in) of sheet width. The non-thermal, non-compressive dewatering process based on the Air Press provides improved Energy Efficiencies compared to conventional mechanisms such as vacuum dewatering, blow boxes, and so forth. Further, the energy requirements of non-thermal, noncompressive dewatering with the Air Press are significantly improved relative to throughdrying. For example, noncompressive dewatering can be achieved at significantly lower total energy consumption than the theoretical minimum of 1000 BTU/pound required for throughdrying, such as about 500 BTU/per pound of water removed or lower.

The relationship between energy efficiency and various dewatering methods is explored in US Patent No. 6,096,169[7], which shows that the use of compressed air for dewatering with the Air Press can be substantially more energy efficient than using vacuum generated by vacuum pumps to remove water. The economic benefits of an air press depend on the nature of the papermaking process. If a machine is dryer limited, the air press has the potential to directly increase production with a payback time that could range from a few months to two years. As a rough example, suppose a paper machine is drying limited and an air press is installed increasing the capacity by 10%. If the original machine could produce 100,000 MT/yr and now can produce an additional 10,000 MT/yr at a profit of $400/MT, the increased profit would be $4 million/year. If the installed air press cost between $3,000,000 and $6,000,000 the payback could be significantly less than 2 years. In other cases, if the primary benefit is energy savings rather than increased production, payback times could be longer.

Experimental Results

A wide variety of trials point to the ability of the Air Press to give significant benefits in dewatering of paper webs at speeds of practical importance, without excessive fabric wear or runnability problems.

Example 1

In one trial, paper was produced on a pilot machine with an Air Press. Using a furnish made from an unrefined 50:50 fiber blend of bleached kraft northern softwood fibers and bleached kraft eucalyptus fibers, a 12-inch wide embryonic wet web was produced by injecting the slurry between two 22-inch-wide forming fabrics traveling at 1000 feet per minute (fpm). The web was formed using a stratified, three-layer headbox with the slurry being deposited from each stratum to form a blended sheet having a nominal basis weight of 19 gsm. The embryonic web was transported over four vacuum boxes operating with respective vacuum pressures of approximately 11, 14, 13 and 19 inches of mercury vacuum. The embryonic web, still contained between the two forming fabrics, passed through an air press including an air plenum and a collection box that were integrally sealed with one another. The air plenum was pressurized with air at approximately 150 degrees Fahrenheit to 15 pounds per square inch gauge, and the collection box was operated at 11 inches of mercury vacuum. The sheet was exposed to the resulting pressure differential of approximately 41.5 inches of mercury and air flow of 68 SCFM per square inch for a dwell time of 7.5 milliseconds over four slots, each with 3/8" length. The consistency of the web was approximately 30 percent just prior to the air press and 39 percent upon exiting. The web was then dried with a drum dryer.

Examples 2 and 3

A sheet was formed using a fiber blend of 50:50 bleached kraft northern softwood and bleached kraft eucalyptus using the forming equipment of Example 1, but with a machine speed of 2500 fpm. The resulting sheet, at an approximate basis weight of 20 pounds/2880 ft^2, was passed through four vacuum boxes at 19.8, 19.8, 22.6, and 23.6 inches of mercury, respectively. The resulting sheet was then sent through the additional integrally-sealed dewatering system also described in Example 1. The air press was set at a pressure of 15 psig in the plenum and pre- and post-air press samples were taken for consistency measurement, giving values of 26.8% and 34.2% solids, respectively. The experiment was then repeated, but the air press was reconfigured to eliminate the integral seal between the air press plenum and the associated collection box. Specifically, the sealing load and hence the impingement of the cross-machine sealing blades was reduced until a leak between the plenum and the collection box became apparent. At this point, the air press plenum/collection box arrangement was set to a nominal 0.1 inch gap, though it was not possible to actually see the spacing between the plenum and the box as it was occupied by the fabrics and the sheet. Air flow to the plenum increased to the maximum obtainable from the compressor and a post dewatering consistency sample taken, yielding a solids level of 32.1%, showing the importance of preventing leakage for good dewatering results. Specifically, approximately 25% less water was removed (0.61 pounds of water per pound of web versus 0.81) when the integral seal was lost, even though the plenum and collection box were still in apparent contact with the fabrics. The associated 2% loss in post dewatering consistency would translate to approximately a 10% reduction in machine speed on a machine that was speed limited due to drying limitations. Such a limitation would be expected on a wet-pressed machine that was converted to the configuration of this invention.

The previous experiment with an air leak was an attempt to illustrate the best possible result that might be obtained using known technologies, such as that described by Andersson and Hellner [14]. In actual practice, it is unlikely the equipment could even be operated as described above due to the excessive noise generated during the experiment and the jet of air issuing from the non-integrally sealed dewatering equipment. Though not specified, in actual practice, it is thought that the equipment described by Andersson and Hellner would be operated with a gap of 1 inch or more, a condition under which significantly more dewatering would be lost and much greater air consumption would result. In practical terms, such inefficiency leads to so much additional energy consumption and reduced speed as to render such technology unsuitable for commercial equipment. Thus, the improved sealing systems associated with the development of the Air Press are believed to be vital for successful implementation of displacement dewatering. Further concepts for the application of Air Press sealing technology and associated control systems for the use of the air press across broad webs are described in Lindsay et al.[13]

Example 4

A 50/50 blend of northern softwood kraft and eucalyptus pulp was pulped for 30 minutes at 4 percent consistency. The water retention value of the furnish blend was 1.37, yielding a WRC of 42.19. The fiber blend was formed into a sheet on a Lindsay 2164B forming fabric traveling at 2500 feet per minute. The resulting sheets, at basis weights of approximately 10 and 20 pounds/2880 ft^2 (17 gsm and 34 gsm, respectively) and a consistency of approximately 9 to 13 percent, were then further dewatered using vacuum. Test results obtained for Example 4 are shown below in Table 1 and are designated with a lower case "a."

Table 1.

ID	Basis Weight, lb/2880 ft^2	Total Energy (HP/in of sheet width)	Post Dewatering Consistency (%)	Post Dewatering Consistency/ WRC
a	10	7.6	23.5	0.56
a	20	8.3	25.8	0.61
a	20	7.4	26.2	0.61
a	10	8.1	23.2	0.55
A	10	32.4	33.8	0.80
A	10	18.7	29.5	0.70
A	10	19.1	31.8	0.75
A	10	16.9	30.1	0.71
A	20	23.5	35.5	0.84
A	20	21.3	35.8	0.85
A	20	24.0	34.9	0.83
A	20	10.6	32.1	0.76

Example 5

The experiments of Example 4 were repeated with an air press added to the system to augment and/or replace a portion of the vacuum dewatering system. A support fabric identical to the forming fabric was used to sandwich the web through the air press. The air plenum of the air press was pressurized with air at approximately 150 degrees Fahrenheit to 15 or 23 pounds per square inch gauge, and the vacuum box was operated at a constant 15 inches of mercury vacuum. The sheet was exposed to the resulting pressure differentials of 45 and 62 inches of mercury and air flows ranging from 58 to 135 SCFM per square inch of sheet width for dwell times of 0.75 or 2.25 milliseconds. The air press increased the consistency of the web by about 5-10% percent depending on the experimental conditions. Test results obtained for Example 5 are shown above in Table 1 and are designated with an upper case "A".

Example 6

Paper was made on an experimental paper machine using 100 percent recycled fiber (tissue deinked market pulp from Fox River Fiber in DePere, Wisconsin), which had been pulped for 30 minutes at 4 percent consistency. The water retention value of the furnish was 1.72, yielding a WRC of 36.76. The fiber was formed into a sheet on a Lindsay 2164B forming fabric traveling at 2500 feet per minute. The resulting sheets, at basis weights of approximately 10 and 20 pounds/2880 ft^2 (17 gsm and 34 gsm, respectively) and a consistency of approximately 9 to 13 percent, were then further dewatered using vacuum. Test results obtained for Example 6 are shown below in Table 2 and are designated with a lower case "c."

Example 7

The experiments of Example 6 were repeated with an air press added to the system to augment and/or replace a portion of the vacuum dewatering system. A support fabric identical to the forming fabric was used to sandwich the web through the air press. The air plenum of the air press was pressurized with air at approximately 150° Fahrenheit to 15 and 23 pounds per square inch gauge, and the vacuum box was operated at a constant 15 inches of mercury vacuum. The sheet was exposed to the resulting pressure differentials of 45 and 62 inches of mercury and air flows of 43 to 124 SCFM per square inch for dwell times of 0.75 and 2.25 milliseconds. The air press increased the consistency of the web by about 2 to 8 percent. Test results obtained for Example 7 are shown below in Table 2 and are designated with an upper case "C."

Table 2.

ID	Basis Weight, lb/2880 ft^2	Total Energy (HP/in of sheet width)	Post Dewatering Consistency (%)	Post Dewatering Consistency/ WRC
c	10	10.0	23.3	0.64
c	20	9.5	24.4	0.67
c	10	9.6	23.0	0.63
c	20	9.6	24.5	0.67
C	20	7.7	30.7	0.84
C	20	16.4	31.1	0.85
C	20	17.3	32.2	0.88
C	20	4.5	29.0	0.79
C	10	8.7	26.2	0.71
C	10	23.4	31.6	0.86
C	10	8.6	29.4	0.80
C	10	14.1	28.7	0.78

Figure 7 represents a graph of total energy to dewater the web versus the post dewatering consistency for this example. This graph illustrates that for the recycled fiber furnish, the air press was able to achieve approximately 5 percent higher consistency than vacuum dewatering at a comparable energy input. Stated differently, based on the data of Table 2, the air press was able to dewater the furnish to 70-85% of the WRC, while vacuum dewatering was only able achieve roughly 60-70% of the WRC at a similar energy input.

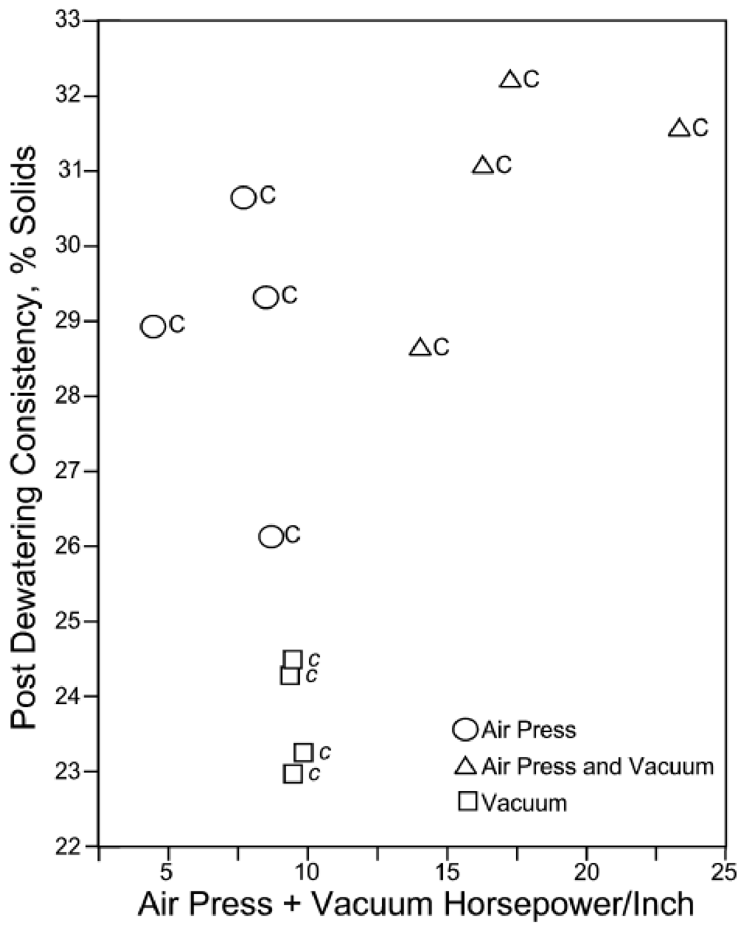

Figure 7. Total Energy versus Post-Dewatering Consistency.

Fabric Wear Testing
Fabric wear was examined during development of the air press. During one series of trials, fabric wear was measured starting with a new fabric using air press dewatering. A subsequent trial measured fabric wear using conventional dewatering, also starting with a new fabric. This allowed fabric wear rates to be determined for air press dewatering and conventional vacuum dewatering. Fabric wear was measured in terms of the change in fabric thickness that occurred during operation. The wear rate was obtained as the slope of the fabric thickness change versus the square root of the number of cycles through the machine (generally a straight line relationship when so plotted). Fabric wear can then be considered as a function of the gain in consistency caused by the dewatering operation. For vacuum dewatering in typical experimental trials, the consistency increase is taken as about 13% (e.g., increasing the consistency of the embryonic web from 12% to 25%), while for air press dewatering, the consistency increase is about 28% (e.g., increasing the consistency of the embryonic web from 12% to 40%). The results are shown in Figure 8, which indicate that fabric wear was higher with the air press, as expected, but appears to be a linear function of the consistency increase over the dewatering unit. Approximately doubling the consistency increase resulted in doubling the fabric wear.

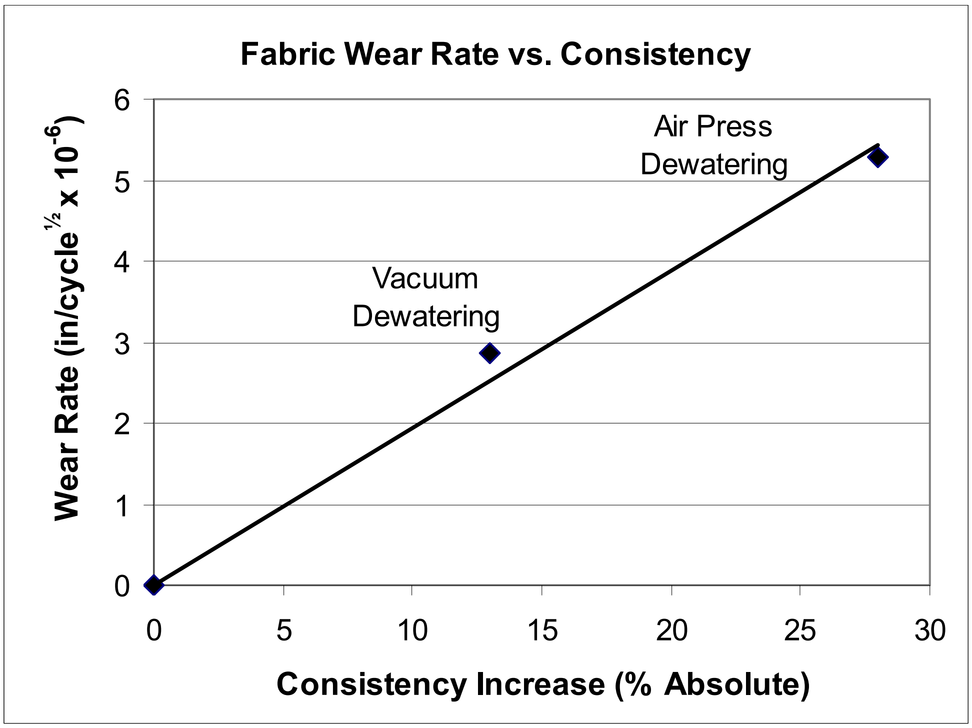

Figure 8. Fabric Wear Rate versus Consistency Increase.

Discussion and Conclusions
High energy efficiency and good dewatering capacity can be achieved with a relatively non-compressive process employing the Air Press concept. The capital and operating costs of the system can be more than compensated by improvements in productivity and other benefits described more fully in the published patents. Though initially developed for low basis weight applications, other paper grades can benefit as well from Air Press technology, especially when good dewatering without high web densification is desired. For example, one candidate could be fluff pulp board that is intended to be fiberized for use in absorbent articles. Excessive densification of fluff pulp can cause problems in fiberization, so efforts are made to maintain good bulk in the product during dewatering. Displacement dewatering with an air press operating at high pressure may improve dewatering without undesirable compaction of the web.

Other particular advantages of the Air Press are for paper mills at high altitude, where the ability to create vacuum is limited by local atmospheric pressure and has high energy costs. Another advantage is for grades of paper that are particularly difficult to dewater such as grades containing high levels of slush pulp, recycled fiber or grades with a high basis weight.

The paper web that is dewatered by the Air Press can be subsequently treated with any known papermaking technology. For example, the dewatered web can be coated, pattern densified, imprinted against a drum dryer, embossed, printed, and so forth. The critical issue is that higher solids can be achieved prior to other water removal technologies or other unit operations for improved processing and energy efficiency.

Advances in sealing technology for have been at the heart of the Air Press, allowing at least part of the dream of efficient displacement dewatering to be realized for a high-speed papermaking operation.

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