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## WARP DETECTION IN TRAVELING CORRUGATED PRODUCT

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### Abstract

An apparatus for use in producing a multi-layer product includes a flotation column for supporting the multi-layer product at a variable height above the flotation column on a cushion of air. The apparatus further includes a warp detection apparatus for detecting an amount of warp in the multi-layer product supported by the flotation column.

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### Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] This application is a continuation of U.S. patent application Ser. No. 18/367,558, filed Sep. 13, 2023, which claims the benefit of U.S. Provisional Patent Application Ser. No. 63/406,433, filed Sep. 14, 2022, the contents of which are incorporated herein in their entirety by reference.

## TECHNICAL FIELD

[0002] The application relates generally to the production of corrugated board, and more particularly, to a corrugated board manufacturing system that uses a shape measurement and defect detection apparatus during the production of corrugated board.

## BACKGROUND

[0003] The production of corrugated board products is well known. Briefly, in its simplest form a conventional corrugated board structure is made by gluing two flat sheets of web material (called 'liners') to the opposing flute crests of an intermediate, fluted or corrugated sheet of web material (called 'medium'). Often this is done by applying lines of glue, which can be an aqueous starch-based adhesive, to the flute crests of the corrugated sheet and then joining those glue-applied crests to the respective liner in a continuous process. First, a single-face construction is made by joining the first liner to the flute crests at one side of the corrugated sheet in a single-facer. Then the resulting single-face composite is delivered to a double-backer where the second liner is joined to the opposing flute crests to yield a three-layer corrugated board structure. The corrugated board structure is further cut by a rotary shear, transferred to a slitter scorer to perform slitting and creasing of the corrugated board, further cut to form pieces of corrugated board, and then the pieces are stacked. Such processes are well known, as described for example in U.S. Pat. No. 8,398,802, the contents of which are incorporated herein by reference.

[0004] The quality of the produced corrugated board product can be measured by determining flatness or the amount of warp. Whether a corrugated board product contains warp is dependent on many factors during the manufacturing process and subsequent storage. Factors can include, for example, paper supply, adhesive supply, machine tensioning and forces, moisture levels, heating steps, environmental and storage conditions. All of these variables affect the dimensional stability of the final board product on both the hygroexpansion and hydroexpansion levels.

[0005] Detection of warp is accomplished by systems that utilize cameras and lasers. The warp detection equipment is mounted well above cut or scored corrugated board product in a manufacturing system. Cut edges and scoring is detected by warp systems and must be both tracked and accounted for when determining warp and what adjustments should be made to the manufacturing system. This adds complexity to the warp calculations. When mounted above the corrugated board product, the warp detection system cannot see the printed surface facing downward thereby no quality assessments of the printing-side of the corrugated board can be achieved while measuring warp.

[0006] The corrugated board product also travels along conveyors and stationary surfaces during manufacturing and can be under tension and frictional forces from rollers and the stationary surfaces as the detection of warp is carried out. In addition to the tension and frictional forces that can pull a corrugated board product temporarily flat, the corrugated board product also tends to flatten under its own weight when not under tension as it travels on conveyors or is stacked at the end of a manufacturing process. Such additional forces, such as friction, tension and gravity, can alter the degree of warp that is detected and cause warp corrections to be imprecise. Friction, tension and gravity forces can hide warp that would otherwise be detectable and addressed by upstream adjustments to the manufacturing system. The undetected or hidden warp appears later downstream in the process and during storage of the corrugated board product and cannot be easily corrected post-manufacturing. This leads to waste and disposal of warped corrugated board product that increases the overall costs and time for producing quality corrugated board product.

[0007] The inventor has now discovered an efficient way to use a warp detection apparatus to

analyze a truer version of a corrugated board product that is not under or significantly experiencing friction, tension, gravitational weight, or a combination thereof, thus making detection of and quantifying warp more accurate. The inventor's solutions disclosed herein also dispense with the drawbacks noted above that limit the position of warp detection equipment designed to be mounted above cut or scored corrugated board product. Not only are the current warp detection solutions complex by having to account for applied cuts and scoring, as well as attempting to compensate for other flattening forces, but they have exhibited problems with post-manufacturing outcomes of unwanted warped product.

## SUMMARY

[0008] In accordance with one aspect of the present invention, an apparatus for producing a multi-layer product is disclosed. The apparatus includes a flotation column that is operable to support the multi-layer product at a variable height above the flotation column on a cushion of air. The apparatus further includes a warp detection apparatus that detects an amount of warp in the multi-layer product that is supported by the flotation column.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a top-level schematic block diagram illustrating example process steps and associated equipment for methods of making composite corrugated board.

[0010] FIG. 2 is a top-level schematic block diagram illustrating example process steps and associated equipment for methods of making composite corrugated board.

[0011] FIG. 3 is a side view of an example flotation column apparatus and warp detection apparatus that can be used in a corrugated board manufacturing system.

[0012] FIG. 4 is a perspective view of a portion of the flotation column apparatus and warp detection apparatus of FIG. 3.

[0013] FIG. 5 is a cross-section view of a portion of the flotation column apparatus and warp detection apparatus of FIG. 3.

### DETAILED DESCRIPTION

[0014] As used herein, when a range such as 5-25 or >5 up to 25 is given, this means preferably at least or more than 5 or preferably >5, and separately and independently, preferably not more or less than 25.

[0015] It has been determined that by suspending or floating a corrugated board product on a cushion or stream of air that one or more forces that conventionally act on the corrugated board product to mask, hide or alter the degree of warp can be significantly reduced and/or eliminated. For instance, tension and gravity forces can be minimized or eliminated by the flotation of a corrugated board product. The flotation of a corrugated board product can be combined with a warp detection apparatus that is used to detect an amount of warp of the corrugated board product as it travels along and is temporarily floated in a portion of a corrugated manufacturing process. The warp detection apparatus can be selectively positioned to monitor one or more surfaces of the corrugated board product that is suspended on the cushion of air to assess the amount of warp without having to account for other forces that would otherwise mask, hide or alter the degree of warp in the product.

[0016] Flotation of a corrugated board product in a corrugated manufacturing system is achieved by one or more flotation columns. A corrugated board product can be fed or transferred to move across an outer surface of the one or more flotation columns that have an opening or plurality of openings in the outer surface. An air source is used to supply a volumetric flow of air to the flotation columns which is then emitted from the outer surface of the flotation column through the openings to form a stream or cushion of pressurized air for supporting the corrugated board product

traveling across the outer surface while floating on a cushion of air. Air, as used herein, can include any gas mixture and is not limited to a certain gaseous composition. The floating, air-supported corrugated board product can continue to travel and be exposed to a warp detection region that includes a warp detection apparatus for analyzing the floating product. The combination of the one or more flotation columns and warp detection apparatus can be positioned at one or more points along a corrugated manufacturing system. An example position is disclosed to briefly show how the combination can be utilized. The use of the combination is not limited to the example position or to only one location in a corrugated manufacturing system. Multiple combinations of flotation columns and warp detection apparatus can be used in a corrugated manufacturing system to closely monitor and analyze warp and for making adjustments in the manufacturing system to correct detected warp. To understand potential placement points for the combination, first a basic understanding of how paper webs are assembled will be helpful.

[0017] An example corrugator setup will now be briefly described. A block diagram of an example corrugating apparatus **1000** is shown schematically in FIG. **1**. In the illustrated embodiment, corrugating apparatus **1000** includes a moisture conditioning apparatus **100** (FIG. **2**), a web heating arrangement **200**, a single-facer **300**, a glue machine **400**, and a double-backer or double-facer **500**. These components (**100-500**) are arranged in the illustrated and recited order relative to the machine direction of a web of medium material **10** as it travels along a machine path through corrugating apparatus **1000** to produce a finished corrugated board product **40** exiting double-backer **500**. As will become apparent, the medium material **10** will become the corrugated web to which the opposing first and second face-sheet webs **18** and **19** will be adhered to produce the finished corrugated board product **40**. The corrugator setup described and illustrated here with respect to FIG. **1** is substantially the same as that described in detail in U.S. Pat. No. 8,398,802 incorporated by reference above. The same setup having similar and alternative features and as described in the '802 patent can be utilized in the methods disclosed herein. Specifically, the same moisture conditioning apparatus **100** (including a thin-film metering device **130**) described in the '802 patent (where it is used to condition paper webs to 6-9 wt. % total moisture) can be used to apply the excess of moisture to the bonding surfaces of the medium and liners (and web if desired) as described herein.

[0018] The first face-sheet web **18** in FIG. **1** will supply the first liner for the finished corrugated board product **40** on exiting the corrugator. Prior to applying the first face-sheet web **18** to the corrugated medium material **10** as in the conventional process (e.g. disclosed in the '802 patent), it is conditioned to adjust its moisture content to achieve the combined effects described above of: protecting fiber-bound water to prevent over drying, reducing magnitude of hygroexpansivity, and stress-relieving the face-sheet web **18**; all of which can be achieved via drying under restraint (i.e. under tension) against hot plates or heated rollers once the required excess-moisture layer has been applied.

[0019] The moisture adjustment can be achieved by applying a substantially continuous thin film of water to the first face-sheet **18** to adjust its overall moisture content to yield a substantial excess of moisture within the desired range as herein disclosed. The water layer can be applied to the side of the web **18** that will be down to (i.e., directly contact) a heat source prior to contacting flutes of the web of medium material **10**, on which glue has been applied, for bonding thereto in the single-facer **300**.

[0020] The resulting single-faced web **20** (composed of the web of medium material **10** adhered to the first-face sheet **18**, preferably both of which by now have been moisture conditioned) exits the single-facer **300** and enters the glue machine **400** where glue is applied to the remaining exposed flute crests in order that the second face-sheet web **19** can be applied and adhered thereto in the double-backer **500**.

[0021] The single-faced web **20**, having glue applied to the exposed flute crests, enters the double-backer **500** where the second face-sheet web **19** is applied and adhered to the exposed flute crests

and the resulting double-faced corrugated assembly is pressed together.

[0022] Prior to entering the double-backer **500**, the second face-sheet web **19**, which will supply the second liner to the finished corrugated board product **40**, is conditioned similarly as the first face-sheet web **18** described above to apply a metered thin film of moisture to achieve a substantial excess moisture content. Preferably this layer of moisture is applied to the bonding surface of the second face-sheet web **19**, which will be bonded to the exposed flute crests of the web of medium material **10** via glue or suitable adhesive.

[0023] The finished corrugated board product **40** can be further processed, for instance, as briefly shown in FIG. **2**. Prior to downstream processing, finished corrugated board product **40** is a continuous formed sheet free of cuts, scoring and slits present in a stacked final product. Thus, finished corrugated board product **40** represents a product form, prior to downstream operations, that a warp detection apparatus can analyze without adjusting for product features that can appear as warp like scores, cuts, slits, etc. resulting from such downstream operations. Once finished corrugated board product **40** is further processed, warp detection can become more complex as various surface features and treatments must be appropriately accounted for to determine the accurate degree of warp in a corrugated board product.

[0024] From the double-backer **500**, the corrugated board product **40** is transferred to a slitter scorer **600** to slit and/or score the finished corrugated board product **40** fabricated by the double-backer **500**. The slit and/or scored corrugated board product **50** is moved through a cutter device **700** to produce corrugated product boards or sheets **60** at desired dimensions by cutting the corrugated board **50**. The corrugated product boards or sheets **60** can be aggregated or shingled together and sequentially stacked by a stacker **800** in order of fabrication.

[0025] As noted above, the one or more flotation columns can be arranged at various points in the corrugated manufacturing system. FIG. **3** illustrates an example arrangement, in a cross-section view, of a first flotation column **901** spaced apart from a second flotation column **902**. Flotation columns **901**, **902** can be optionally secured together to provide structural integrity and ensure the columns are stationary, for example, by attaching a support bracket **905** to each column to prevent movement during operation. Flotation columns **901**, **902** are shown as rectangular columns but any desirable column shape can be used such that an outer surface (e.g., flat plane) of the column is arranged to face corrugated board product **40** for supporting product **40** as it travels over and parallel to the outer surface of the one or more column.

[0026] As shown, corrugated product **40** is fed across the top outer surface **901a** of flotation column **901** as indicated by the downstream travel direction arrow for product **40**. Corrugated board product **40** travels across flotation column **901** and over an open area **903** before reaching the adjacent top outer surface **902a** of flotation column **902**. As shown, corrugated board product **40** is supported and suspended above the top outer surfaces **901a**, **902a** of flotation columns **901**, **902**, and likewise over open area **903** between the columns, on a stream or cushion or air emitted from the columns. The height of supported corrugated product **40** over the top outer surfaces **901a**, **902a** of columns **901**, **902** can be varied, for example, in the range of 5 to 20 mm or any desired height, by adjusting air flow into and out of the columns. Corrugated board product **40** travels over both columns **901**, **902** and open area **903** without contacting another solid surface thereby reducing additional forces (e.g., friction) that can act on and/or alter detectable warp in the product. The top outer surfaces of the columns can be described as a zero-contact surfaces since the corrugated board product is supported directly above and not in contact with such surfaces. It is not meant to imply that there can never be any contact between any flotation column surface and the corrugated board product. Contact may occur, for example, due to transient or momentary fluctuations during operation.

[0027] To support corrugated board product **40**, columns **901**, **902** are hollow for receiving a flow of air from a pressurized air source. FIG. **4** illustrates flotation column **902** having a hollow center portion with multiple openings **913** along the bottom outer surface **902b** for receiving a volumetric

flow of air from a pressurized air source. Columns **901**, **902** can alternatively receive pressurized air from a single inlet into the column positioned at any suitable location (e.g., a bottom outer surface or column end surface). Air flows into flotation column **902** and is emitted out of the column through openings **911** in outer surface **902a** of column **902**. The volume or flowrate of pressurized air being fed to flotation column **902** can be varied depending on the desired flotation or support height of corrugated board product **40** above outer surface **902a**. An air source preferably supplies compressed or pressurized air to columns **901**, **902** and the pressurized air can be transferred to the columns as known in the art, for instance, by an air handling unit, pump, compressor or transfer blower. FIG. 5 shows an example air flow system for providing pressurized air to the flotation columns. A primary supply header **960** can be in fluid connection with a pressurized air supply. Primary supply header **960** is arranged to position a volumetric flow of pressurized air in proximity to flotation columns **901**, **902**. Header **960** can have one or more supply channels **961**, **962** extending outward from the primary supply header to route or direct the pressurized air to inlet openings **913** to fill columns **901**, **902** with pressurized air for floating product **40** on a constant stream of emitted air.

[0028] The top outer surfaces **901a**, **902a** of flotation columns **901**, **902** can include one or more openings **910**, **911** such as a plurality of openings for emitting air from inside the columns to form a cushion of flowing pressurized air above surfaces **901a**, **902a**. Openings **910**, **911** can be arranged along the top outer surfaces to cover the entire area that corrugated board product **40** will travel over at the top outer surfaces. For example, corrugated board product traveling through a manufacturing system can have a width in the range of 2 to 3.5 meters and thus the flotation columns can include openings that span substantially all or the entire width of the traveling corrugated board product to ensure it is sufficiently supported on a cushion of air. As shown, a plurality of small openings **910**, **911** are uniformly arranged in an array on the top outer surfaces **901a**, **902a** of the columns, although any pattern and size of openings can be used. Any number of openings can be used to support corrugated product **40** wherein the number of openings and air flowrate through the openings can be adjusted to achieve flotation of corrugated board product **40** above the top outer surfaces.

[0029] The flotation columns can be used with a warp detection apparatus. The warp detection apparatus is able to detect a degree of warp of a surface, for instance, whether the corrugated board product (e.g., continuous corrugated product, corrugated sheets in the cut, slit or scored form) are at least partially warped or non-warped along the length and/or width thereof as it travels on a cushion of air formed by the flotation columns. The warp detection apparatus components are known in the industry.

[0030] It is preferred that the warp detection apparatus is positioned at a distance away from the corrugated board product such that the warp detection apparatus is not in direct contact with the product. The warp detection apparatus detects and measures the distance from and/or profile of the air-suspended and traveling corrugated board product, preferably across the entire width and/or length thereof. In one example, the warp detection apparatus can be configured to include a laser distance detection or line profile detection device **925**.

[0031] In another example, the warp detection apparatus can include an imaging device, either alone or in combination with a laser as shown in FIGS. 3-5. To detect the amount of surface variation or warping a corrugated board product the apparatus can include an imaging device for performing a scan of the product surface to provide imaging data so that image analysis can be carried out to analyze surface variation amounts based on collected imaging data from the imaging device. For instance, the imaging device can be a camera. Once an amount of surface variation is determined relative to the travel direction of the corrugated board product, the amount of warp can be calculated in said direction. The calculated amount of warp enables correction adjustments to be executed upstream, downstream, or a combination of both of the warp detection apparatus in the corrugated manufacturing system to prevent or reduce a degree of warp in future corrugated board

product as compared to the analyzed product. Corrective warp measures or adjustments can be carried out by an operator without requiring time-consuming and costly manual inspection of corrugated board product. The warp detection apparatus can communicate with an information processing device or system that can change or correct one or more variables in the corrugated manufacturing system. Such variables can include, but are not limited to, a preheating or heating temperature of a roller, a face sheet, a web of material or corrugated product, a steam supply or temperature thereof, a water film amount applied to a face sheet or surface of a corrugated product, a glue amount, and the like.

[0032] Further surface and property data about the corrugated board product can be made at or near the point of warp detection by the warp detection apparatus. For example, a moisture sensor can be mounted directly upstream or downstream of the warp detection apparatus to convey the present moisture content of one or more layers of the corrugated board product in real time during manufacturing. The moisture data of the corrugated board product can be used to give an operator additional data for making warp adjustments to a corrugated product or individual component or surface thereof. As shown in FIG. 3, a moisture sensor **950** is positioned directly downstream of warp detection apparatus **920**, **925** to determine moisture content of the layers of corrugated board product **40**. The calculated moisture content will further assist an operator in determining, if applicable, the amount of moisture to apply to the corrugated board product or to a specific layer or surface of the product.

[0033] FIG. 3 illustrates an example arrangement of a warp detection apparatus relative to a traveling corrugated board product **40** supported on a cushion of air provided by flotation columns. As shown, camera **920** and laser **925** are mounted below the supported corrugated board product to analyze the bottom surface of the product facing the flotation columns. In an example arrangement, camera **920** and laser **925** positioned in between spaced-apart flotation columns **901**, **902**.

Depending on the distance or open height between the top surface of flotation columns **901**, **902** and first surface of corrugated board product **40** facing columns **901**, **902**, there may not be sufficient space to position components of the warp detection apparatus over the top surface of the columns. Rather, the open space **903** between columns **901**, **902** forms a warp detection zone in which the warp detection apparatus components can evaluate the surface of floating or air-suspended corrugated board product **40** facing downward, for example, a bottom outer surface having printed indicia. The warp detection apparatus components **920**, **925** can be mounted at any suitable distance from corrugated board product **40**. The shown arrangement provides components **920**, **925** to be mounted close to product **40** and can improve the accuracy of warp detection. In one example, the warp detection apparatus is mounted less than 1 meter, less than 0.5 meters, less than 0.2 meters or less than 0.1 meters from an outer surface of corrugated board product **40**. In another example, the warp detection apparatus is mounted relative to the corrugated board product such that it is capable of detecting warp or surface variations in the corrugated board product of 100  $\mu\text{m}$  or less, 50  $\mu\text{m}$  or less, or 25  $\mu\text{m}$  or less.

[0034] The warp detection apparatus components **920**, **925** can be mounted on or around support bracket **905**, or any alternative suitable support surface including a side surface of one or both of columns **901**, **902**. One or more openings or slots can be provided in support bracket **905** to accommodate camera views or lasers being generated below bracket **905** by components for targeting surfaces of corrugated board product **40**. For example, FIG. 4 shows multiple through openings in support bracket **905** to permit camera **920** views and laser contact of the bottom surface of corrugated board product **40**.

[0035] Although not shown, a warp detection apparatus can be mounted above the corrugated board product supported by emitted pressurized air from a flotation column (e.g., flotation columns **901**, **902**). Being mounted above supported corrugated board product **40**, a warp detection apparatus need not be arranged between flotation columns **901**, **902**, but rather can be mounted over one of the columns or in any other suitable arrangement that can also include areas upstream

and downstream of the columns and areas between the columns. In other examples, two or more warp detection apparatuses can be used to detect warp in a supported corrugated board product. A warp detection apparatus can be mounted above the supported corrugated board product supported by a flotation column while a separate warp detection apparatus can be mounted below the same corrugated board product as depicted in FIG. 3.

[0036] The one or more warp detection apparatuses can be positioned, along with the one or more flotation columns, at any point in a corrugated manufacturing system for determining the amount of warp in a corrugated board product. In one example, a warp detection apparatus is positioned upstream of a slitter, scorer or cutter and work in conjunction with one or more flotation columns to analyze warp of a corrugated board product supported on a cushion of air. The warp detection apparatus can also be positioned downstream of a double-facer as described in FIG. 1. In yet another example, one or more warp detection apparatuses can be positioned, either below, above or both relative to a corrugated board product, between a double-facer and a slitter or scorer.

[0037] The invention has been described with reference to the example embodiments described above. Modifications and alterations will occur to others upon a reading and understanding of this specification. Example embodiments incorporating one or more aspects of the invention are intended to include all such modifications and alterations insofar as they come within the scope of the appended claims and their equivalents.

## Claims

1. An apparatus for producing a multi-layer product, comprising: a flotation column operable to support the multi-layer product at a variable height above the flotation column on a cushion of air; and a warp detection apparatus for detecting an amount of warp in the multi-layer product supported by the flotation column.
2. The apparatus of claim 1, wherein the flotation column is a first flotation column and the apparatus further comprises a second flotation column.
3. The apparatus of claim 2, wherein the first and second flotation columns are operable to support the multi-layer product at a variable height above respective outer surfaces of the first and second flotation columns on a cushion of pressurized air that is emitted from openings in the respective outer surfaces.
4. The apparatus of claim 3, wherein the respective outer surfaces of the first and second flotation columns are coplanar.
5. The apparatus of claim 2, wherein the warp detection apparatus is positioned between the first flotation column and the second flotation column in a travel direction of the multi-layer product.
6. The apparatus of claim 1, wherein the multi-layer product supported by the flotation column has opposite first and second surfaces, wherein the first surface faces the flotation column, and wherein the warp detection apparatus faces the first surface.
7. The apparatus of claim 1, wherein the multi-layer product supported by the flotation column has opposite first and second surfaces, wherein the first surface faces the flotation column, and wherein the warp detection apparatus faces the second surface.
8. The apparatus of claim 1, wherein the flotation column is a stationary column positioned adjacent the multi-layer product.
9. The apparatus of claim 1, wherein a distance between the multi-layer product and the flotation column is in a range of 5 mm to 50 mm.
10. The apparatus of claim 1, wherein the warp detection apparatus comprises an imaging device.
11. The apparatus of claim 1, wherein the warp detection apparatus comprises a laser.
12. The apparatus of claim 1, wherein the warp detection apparatus is capable of detecting warp in the multi-layer product of 100  $\mu\text{m}$  or less.
13. The apparatus of claim 1, wherein the warp detection apparatus is arranged to detect the amount



of warp in the multi-layer product when the multi-layer product is not in contact with a solid surface.

**14.** The apparatus of claim 1, wherein the warp detection apparatus comprises an imaging device and a laser device, and wherein the laser device emits a laser beam that intersects a field of view of the imaging device.

**15.** The apparatus of claim 1, further comprising a moisture sensor positioned downstream of the warp detection apparatus and configured to determine a moisture content of the multi-layer product.

**16.** The apparatus of claim 15, wherein the multi-layer product supported by the flotation column has opposite first and second surfaces, wherein the warp detection apparatus faces the first surface, and wherein the moisture sensor faces the second surface.

**17.** The apparatus of claim 16, wherein the first surface faces the flotation column.

**18.** The apparatus of claim 1, further comprising a bracket attached to the flotation column, wherein the bracket has an aperture formed therein, and wherein the warp detection apparatus has a field of view of a surface of the multi-layer product, through the aperture, in use.

**19.** The apparatus of claim 1, wherein the multi-layer product is an uncut, unscored double-faced corrugated board product.

**20.** The apparatus of claim 19, wherein the corrugated board product supported by the cushion of air is discharged from an upstream double facer prior to traveling over the flotation column arranged downstream of the double facer.

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