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(71) Applicant (*for all designated States except US*): **LANTECH.COM, LLC** [US/US]; 11000 Bluegrass Parkway, Louisville, Kentucky 40299 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **LANCASTER, Peter R, III** [US/US]; 4620 River Road, Louisville, Kentucky 40222 (US). **ELDRIDGE, David E.** [US/US]; 11812 Waterford Road, Fern Creek, Kentucky 40291 (US). **HALL, Willie Martin** [US/US]; 98 Bluegrass Acres Road, Taylorsville, Kentucky 40071 (US). **JOHNSON, Richard L.** [US/US]; 2112 Clearview Drive, Lagrange, Kentucky 40031 (US). **MARTIN, Curtis W.** [US/US]; 8617 John Pectol Road, Georgetown, Kentucky 47122 (US). **MOORE, Phillip R.** [US/US]; 114 Valley Drive, Mount Washington, Kentucky 40047 (US). **NORRIS, Joseph Donald** [US/US]; 1116 Bunk Road, Pleasureville, Kentucky 40057 (US).

(74) Agent: **GARRETT, Arthur S.**; Finnegan, Henderson, Farabow, Garrett & Dunner, Llp, 901 New York Avenue, N.W., Washington, District Of Columbia 20001-4413 (US).

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(54) Title: METHOD AND APPARATUS FOR METERED PRE-STRETCH FILM DELIVERY

(57) Abstract: The present invention provides a method and apparatus for dispensing a predetermined substantially constant length of pre-stretched packaging material based upon load girth. Based upon the girth of the load to be wrapped, an amount of pre-stretched packaging material to be dispensed for each revolution of relative rotation between a packaging material dispenser and the load is determined. A rotational drive system used to provide the relative rotation is linked to a pre-stretch assembly portion of the packaging material dispenser. The linkage may be mechanical or electrical. The linkage controls a ratio of the rotational speed to the pre-stretch assembly dispensing speed, such that the predetermined substantially constant length of pre-stretched packaging material is dispensed for each revolution of the packaging material dispenser relative to the load regardless of the speed of the rotational drive. In the case of a mechanical linkage, the linkage also connects the rotational drive to the pre-stretch assembly portion such that the rotational drive also drives the pre-stretch assembly portion. Good wrapping performance in terms of load containment (wrap force) and optimum packaging material use is obtained by dispensing a length of pre-stretched packaging material that is between approximately 90% and approximately 120% of load girth.

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METHOD AND APPARATUS FOR METERED PRE-STRETCH FILM DELIVERY

[001] This application claims priority under 35 U.S.C. § 119 based on U.S. Provisional Application No. 60/775,779, filed February 23, 2006, the complete disclosure of which is incorporated herein by reference.

Field of the Invention

[002] The present invention relates to an apparatus and a method for wrapping a load with packaging material, and more particularly, stretch wrapping.

Background of the Invention

[003] Various packaging techniques have been used to build a load of unit products and subsequently wrap them for transportation, storage, containment and stabilization, protection and waterproofing. One system uses stretch wrapping machines to stretch, dispense and wrap stretch packaging material around a load. Stretch wrapping can be performed as an inline, automated packaging technique that dispenses and wraps packaging material in a stretch condition around a load on a pallet to cover and contain the load. Pallet stretch wrapping, whether accomplished by a turntable, rotating arm, vertical rotating ring, or horizontal rotating ring, typically covers the four vertical sides of the load with a stretchable packaging material such as polyethylene packaging material. In each of these arrangements, relative rotation is provided between the load and the packaging material dispenser to wrap packaging material about the sides of the load.

[004] Stretch wrapping machines provide relative rotation between a stretch wrap packaging dispenser and a load either by driving the stretch wrap packaging dispenser around a stationary load or rotating the load on a turntable. Upon relative rotation, packaging material is wrapped on the load. Rotating ring style stretch wrappers generally include a roll of packaging material mounted in a dispenser, which rotates about the load on a rotating ring. Wrapping rotating rings are categorized as vertical rotating rings or horizontal rotating rings. Vertical rotating rings move vertically between an upper and lower position to wrap

packaging material around a load. In a vertical rotating ring, as in turntable and rotating wrap arm apparatuses, the four vertical sides of the load are wrapped, along the height of the load. Horizontal rotating rings are stationary and the load moves through the rotating ring, usually on a conveyor, as the packaging material dispenser rotates around the load to wrap packaging material around the load. In the horizontal rotating ring, the length of the load is wrapped. As the load moves through the rotating ring and off the conveyor, the packaging material slides off the conveyor (surface supporting the load) and into contact with the load.

[005] Historically, rotating ring style wrappers have suffered from excessive packaging material breaks and limitations on the amount of containment force applied to the load (as determined in part by the amount of pre-stretch used) due to erratic speed changes required to wrap "non-square" loads, such as narrow, tall loads, short, wide loads, and short, narrow loads. The non-square shape of such loads often results in the supply of excess packaging material during the wrapping cycle, during time periods in which the demand rate for packaging material by the load is exceeded by the supply rate of the packaging material by the packaging material dispenser. This leads to loosely wrapped loads. In addition, when the demand rate for packaging material by the load is greater than the supply rate of the packaging material by the packaging material dispenser, breakage of the packaging material may occur.

[006] When stretch wrapping a typical rectangular load, the demand for packaging material varies, decreasing as the packaging material approaches contact with a corner of the load and increasing after contact with the corner of the load. When wrapping a tall, narrow load or a short load, the variation in the demand rate is even greater than in a typical rectangular load. In vertical rotating rings, high speed rotating arms, and turntable apparatuses, the variation is caused by a difference between the length and the width of the load. In a horizontal rotating ring apparatus, the variation is caused by a difference between the height of the load (distance above the conveyor) and the width of the load.

[007] The amount of force, or pull, that the packaging material exhibits on the load determines how tightly and securely the load is wrapped. Conventionally, this force is controlled by controlling the feed or supply rate of the packaging

material dispensed by the packaging material dispenser with respect to the demand rate of packaging material required by the load. Efforts have been made to supply the packaging material at a constant tension or at a supply rate that increases as the demand rate increases and decreases as the demand rate decreases. However, when variations in the demand rate are large, fluctuations between the feed and demand rates result in loose packaging of the load or breakage of the packaging material during wrapping.

[008] The wrap force of many known commercially available pallet stretch wrapping machines is controlled by sensing changes in demand and attempting to alter supply of packaging material such that relative constant packaging material wrap force is maintained. With the invention of powered pre-stretching devices, sensing force and speed changes was immediately recognized to be critically important. This has been accomplished using feedback mechanisms typically linked to or spring loaded dancer bars and electronic load cells. The changing force on the packaging material caused by rotating a rectangular shaped load is transmitted back through the packaging material to some type of sensing device which attempts to vary the speed of the motor driven pre-stretch dispenser to minimize the force change on the packaging material incurred by the changing packaging material demand. The passage of the corner causes the force on the packaging material to increase. This increase force is typically transmitted back to an electronic load cell, spring-loaded dancer interconnected with a sensing means, or by speed change to a torque control device. After the corner is passed the force on the packaging material reduces as the packaging material demand decreases. This force or speed is transmitted back to some device that in turn reduces the packaging material supply to attempt to maintain a relatively constant wrap force.

[009] With the ever faster wrapping rates demanded by the industry, the rotation speeds have increased significantly to a point where the concept of sensing demand change and altering supply speed is no longer effective. The delay of response has been observed to begin to move out of phase with rotation at approximately 20 RPM. The actual response time for the rotating mass of packaging material roll and rollers approximating 100 lbs must shift from accelerate

to decelerate eight times per revolution that at 20 RPM is a shift more than every ½ sec.

[010] Even more significant is the need to minimize the acceleration and deceleration times for these faster cycles. Initial acceleration must pull against the clamped packaging material, which typically cannot stand a high force especially the high force of rapid acceleration that cannot be maintained by the feedback mechanisms described above. Use of high speed wrapping has therefore been limited to relatively lower wrap forces and pre-stretch levels where the loss of control at high speeds does not produce undesirable packaging material breaks.

[011] Packaging material dispensers mounted on horizontally rotating rings present additional special issues concerning effectively wrapping at high speeds. Many commercially available rotating ring wrappers that are in use depend upon electrically powered motors to drive the pre-stretch packaging material dispensers. The power for these motors must be transmitted to the rotating ring. This is typically done through electric slip rotating rings mounted to the rotating ring with an electrical pick up fingers mounted to the fixed frame. Alternately others have attempted to charge a battery or run a generator during rotation. All of these devices suffer complexity, cost and maintenance issues. But even more importantly they add significant weight to the rotating ring which impacts its ability to accelerate and/or decelerate rapidly.

[012] Packaging material dispensers mounted on vertically rotating rings have the additional problem of gravity forces added to centrifugal forces of high-speed rotation. High-speed wrappers have therefore required expensive and very heavy two part bearings to support the packaging material dispensers. The presence of the outer race on these bearings has made it possible to provide a belt drive to the pre-stretch dispenser. This drive is taken through a clutch type torque device to deliver the variable demand rate required for wrap force desired.

[013] Accordingly, it is an object of the present invention to provide a method and apparatus for regulating the feed of packaging material to produce a secure load for shipment without distorting the top layers of a load, crushing product, or breaking film.

[014] It is another object of the present invention to provide a method and apparatus capable of regulating the packaging material supply rate to maintain a wrapping force below the force that will incur film breaks.

[015] It is an additional object of the present invention to provide a method and apparatus for wrapping loads at faster wrapping rates.

[016] It is an additional object of the present invention to provide a method and apparatus capable of minimizing packaging material dispenser acceleration and deceleration times, in order to obtain faster wrapping cycles.

[017] It is an additional object of the present invention to provide a method and apparatus that reduces the amount of complexity, cost, weight, and maintenance associated with known rotating ring apparatuses.

SUMMARY OF THE INVENTION

[018] In accordance with the invention, a method and apparatus for dispensing a predetermined substantially constant length of pre-stretched packaging material relative to load girth is provided. The method and apparatus include a linkage between a rotational drive system for providing relative rotation between a load and a packaging material dispenser and a pre-stretch assembly portion of the packaging material dispenser. The linkage may be mechanical or electrical. The linkage controls a ratio of the rotational speed to the pre-stretch assembly dispensing speed, such that the predetermined substantially constant length of pre-stretched packaging material is dispensed for each revolution of the packaging material dispenser relative to the load regardless of the speed of the rotational drive. In the case of a mechanical linkage, the linkage also connects the rotational drive to the pre-stretch assembly portion such that the rotational drive also drives the pre-stretch assembly portion.

[019] According to one aspect of the present invention, an apparatus for stretch wrapping a load is provided. The apparatus includes a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly, a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle, and a mechanical input/output ratio

control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser.

[020] According to another aspect of the present, an apparatus for stretch wrapping a load comprises a packaging material dispenser for dispensing a film web, the packaging material dispenser including a pre-stretch assembly, a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle, a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser, and a virtual film accumulator configured to accommodate variations in film demand as the film is dispensed at the predetermined substantially constant length for each revolution.

[021] According to a further aspect of the present invention, an apparatus for stretch wrapping a load comprises a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly, a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle, a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser, and a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a film length extending between the downstream pre-stretch roller and the final roller is at least thirteen inches.

[022] According to yet another aspect of the present invention, an apparatus for stretch wrapping a load, the load having a shortest wrap radius and a longest wrap radius, includes a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly, a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle, a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser, and a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a length of film extending from the second pre-stretch roller to the final roller has a length greater than a difference between the shortest wrap radius and the longest wrap radius of the load.

[023] According to one aspect of the present invention, a method for stretch wrapping a load is provided. The method comprises determining a girth of a load to be wrapped; determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser around the load, dispensing the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser around the load, and rotating the packaging material dispenser around the load at a speed sufficient to wrap the predetermined substantially constant length of pre-stretched packaging material around the load before the pre-stretched packaging material recovers from pre-stretching.

[024] According to another aspect of the present invention, a method for stretch wrapping a load comprises determining a girth of a load to be wrapped, determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser around the load, dispensing the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser around the load, and rotating the packaging material dispenser around the load at a

speed sufficient to permit the predetermined substantially constant length of pre-stretched packaging material of a revolution to conform to at least two successive corners of the load substantially simultaneously.

[025] According to a further aspect of the present invention, a method for stretch wrapping a load includes providing a packaging material including a pre-stretch portion, providing relative rotation between the packaging material dispenser and the load, setting a ratio of relative rotational speed to pre-stretch speed with a mechanical input/output ratio control, driving the pre-stretch assembly through an output of the mechanical input/output ratio control to dispense a predetermined substantially constant length of pre-stretched packaging material during each revolution of the relative rotation between the load and the packaging material dispenser, and compensating for variations in film demand during each revolution of the relative rotation as the dispensed predetermined substantially constant length of pre-stretched packaging material travels from the dispenser to the load.

[026] According to yet another aspect of the present invention, a method for stretch wrapping a load comprises determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser relative to the load, using a rotational drive to provide relative rotation between the packaging material dispenser and the load, setting a ratio of relative rotational speed to pre-stretch speed, driving the pre-stretch portion at the set ratio through a mechanical connection to the rotational drive to dispense the predetermined substantially constant length of pre-stretched packaging material during each revolution of the relative rotation between the load and the packaging material dispenser, and damping variations in forces acting on the dispensed predetermined substantially constant length of pre-stretched packaging material as it travels from the dispenser to the load.

[027] According to one aspect of the present invention, an apparatus for stretch wrapping a load comprises a packaging material dispenser for dispensing a film web, the packaging material dispenser including a powered pre-stretch portion, a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle, and an electronic control configured to

maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle.

[028] According to another aspect of the present invention, an apparatus for stretch wrapping a load includes a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a powered pre-stretch assembly, a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle, an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle, and a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a film length extending between the downstream pre-stretch roller and the final roller is at least thirteen inches.

[029] According to a further aspect of the present invention, an apparatus for stretch wrapping a load comprises a packaging material dispenser for dispensing a film web, the packaging material dispenser including a powered pre-stretch portion, a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle, an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle, wherein the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle, and a virtual film accumulator configured to accommodate variations in film demand as the film is dispensed.

[030] According to yet another aspect of the present invention, an apparatus for stretch wrapping a load includes a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a powered pre-stretch assembly, a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle, an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle, wherein

the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle, and a final roller positioned a predetermined distance from the downstream pre-stretch roller, the predetermined distance being such that at least a portion of a length of film extending between the downstream pre-stretch roller and the final roller acts to dampen variations in forces acting on the pre-stretched packaging material as it travels from the dispenser to the load.

[031] According to one aspect of the present invention, a method for stretch wrapping a load comprises providing a packaging material including a powered pre-stretch portion, providing relative rotation between the packaging material dispenser and the load, setting a ratio of relative rotational speed to pre-stretch speed, electronically maintaining the set ratio during a primary portion of the wrap cycle to dispense pre-stretched packaging material, and electronically varying the set ratio during at least one of an initial acceleration and a final deceleration of the packaging material dispenser relative to the load.

[032] According to another aspect of the present invention, a method for stretch wrapping a load includes providing relative rotation between the packaging material dispenser and the load, setting a ratio of relative rotational speed to pre-stretch speed, electronically maintaining the set ratio during a primary portion of the wrap cycle to dispense the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser relative to the load during the primary portion of the wrap cycle, electronically varying the set ratio upon sensing at least one of a film break and slack film, and damping variations in forces acting on the dispensed predetermined constant length of pre-stretched packaging material as it travels from the dispenser to the load.

[033] Additional objects and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[034] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

[035] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one embodiment of the invention and together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[036] Fig. 1 is an isometric view of a stretch wrapping apparatus for wrapping a load according to one aspect of the present invention;

[037] Fig. 2 is an isometric view of a roll carriage of the stretch wrapping apparatus of Fig. 1, the roll carriage including a packaging material dispenser with a pre-stretch portion, a film drive down portion, a virtual accumulator, and a film metering portion, according to one aspect of the present invention;

[038] Fig. 3A is an isometric view of a roll carriage of the roll carriage including a packaging material dispenser with a pre-stretch portion, a film drive down portion, a virtual accumulator, and a film metering portion of Fig. 2, with certain elements in different positions, according to one aspect of the present invention;

[039] Fig. 3B is an enlarged portion of the isometric view of the roll carriage of Fig. 3A;

[040] Fig. 4 is an isometric view of a lower film roll support on a roll carriage according to one aspect of the present invention;

[041] Fig. 5 is an isometric view of an upper film roll support on a roll carriage according to one aspect of the present invention;

[042] Fig. 6 is an isometric view of a support structure for the rotating ring of a stretch wrapping apparatus according to one aspect of the present invention;

[043] Fig. 7 is a top view of a load being wrapped and illustrating the shortest wrap radius and the longest wrap radius according to one aspect of the present invention;

[044] Fig. 8 is a side view of a rolled portion of packaging material formed into a cable according to one aspect of the present invention;

[045] Fig. 9 is an isometric view of an alternative embodiment of a stretch wrapping apparatus according to one aspect of the present invention;

[046] Fig. 10 is a front cross-sectional view of the stretch wrapping apparatus of Fig. 9;

[047] Fig. 11 is a side view of another alternative embodiment of a stretch wrapping apparatus according to the present invention;

[048] Fig. 12 is a side view of an alternative drive system of the stretch wrapping apparatus of Fig. 11; and

[049] Fig. 13 is a side view of yet another alternative embodiment of a stretch wrapping apparatus according to the present invention.

DESCRIPTION OF THE EMBODIMENTS

[050] Reference will now be made in detail to the present embodiment of the invention, an example of which is illustrated in the accompanying drawings. Examples and descriptions of the invention are also set forth in the Invention Disclosure that is included as part of the provisional application and incorporated herein by reference. In addition, the disclosures of each of U.S. Patent No. 4,418,510, U.S. Patent No. 4,953,336, U.S. Patent No. 4,503,658, U.S. Patent No. 4,676,048, U.S. Patent No. 4,514,995, and U.S. Patent No. 6,748,718 are incorporated herein by reference in their entirety. In addition, U.S. Patent Application No. 11/398,760, filed April 6, 2006, and entitled "Method and Apparatus for Dispensing a Predetermined substantially constant length of Pre-stretched Film Relative to Load Girth," and U.S. Patent Application No. 10/767,863, filed January 30, 2004, and entitled "Method and Apparatus for Rolling a Portion of a Film Web into a Cable" are incorporated by herein by reference in their entirety. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[051] The present invention is related to a method and apparatus for dispensing a predetermined substantially constant length of pre-stretched packaging material per revolution of a packaging material dispenser around a load during a wrapping cycle. The packaging material dispenser may include a pre-stretch portion and a pre-stretch metering assembly. The packaging material

dispenser may be rotated about the load to be wrapped, or the load may be rotated relative to the packaging material dispenser. In each case, a rotational drive system is used to provide the relative rotation. The rotational drive system may include a rotating ring (vertical or horizontal), a turntable, or a rotatable arm. A mechanical linkage may be used to connect the rotational drive system to the pre-stretch portion of the packaging material dispenser to drive the pre-stretch portion. Thus, rotation of the downstream roller of the pre-stretch portion of the packaging material assembly is mechanically linked to the rotational drive, ensuring that a ratio of relative rotational speed to pre-stretch speed may be set such that the pre-stretch portion dispenses a substantially constant length of pre-stretched packaging material during each revolution.

[052] The substantially constant length of pre-stretched packaging material dispensed per revolution of the packaging material dispenser is predetermined based upon the girth of the load to be wrapped. The girth (G) of a load is defined as the length (L) of the load plus the width (W) of the load times two (2) or G = [2 x (L + W)]. Test results have shown that good wrapping performance in terms of load containment (wrap force) and optimum packaging material use (efficiency) is obtained by dispensing a length of pre-stretched packaging material that is between approximately 90% and approximately 130% of load girth, and preferably between approximately 95% and approximately 115% of load girth. The amount of film dispensed divided by the girth of the load is referred to in this application as the payout percentage. For example, a 40 inch x 48 inch load has a girth of (2 x (40 + 48) or 176 inches. To provide a payout percentage of between approximately 95% and approximately 115%, it would be necessary to dispense a length of pre-stretched packaging material that has a length of between approximately 167 inches and approximately 202 inches. Additional testing has shown that a payout percentage equal to approximately 107% of load girth gives best containment and efficiency results. Thus, for the example above, the predetermined amount of pre-stretched packaging material to be dispensed for each revolution of the packaging material dispenser would be approximately 188 inches. However, the optimum payout percentage will vary according to the type of stretch wrap packaging

material used, the level of pre-stretch used (i.e., percentage of elongation), and different load containment (i.e., wrap force) required.

[053] Because a ratio of the relative rotational speed to pre-stretch speed is set and maintained during the wrap cycle, the same amount of pre-stretched packaging material will be dispensed during each revolution of the dispenser relative to the load, regardless of the speed of relative rotation. For example, if approximately 190 inches of packaging material are needed per revolution of the rotating ring/dispenser, one can measure the circumference of the downstream pre-stretch roller, for example 10 inches, and know that each rotation of the downstream pre-stretch roller will dispense 10 inches of pre-stretched packaging material. Therefore, in order to dispense 190 inches of packaging material during one revolution of the rotating ring and dispenser, the downstream pre-stretch roller may rotate 19 times (190 inches/10 inches). Once the necessary number of revolutions of the downstream pre-stretch roller is known, it is possible to set the sprocket to, for example, 19 pre-stretch roller revolutions per one rotating ring rotation. Thus, the length of the pre-stretched packaging material that is dispensed may be between approximately 90% and approximately 120% of girth per rotating ring revolution and the dispensing is mechanically controlled and precisely selectable by establishing a mechanical ratio of a rotational drive (e.g., drive to rotate a rotatable ring, a turntable, or a rotating arm) to pre-stretch roller surface speed (e.g., number of pre-stretch roller revolutions per rotating ring rotation).

[054] Drive components can be arranged for easy change of the amount of pre-stretch of the packaging material or the payout percentage dispensed per revolution of the rotatable ring. For example, in one exemplary embodiment, the packaging material dispenser is mounted on the rotatable ring, and a motor rotates a belt that rotatably drives the rotatable ring. A first portion of a mechanical connection can translate the drive of the motor and rotating belt to drive pre-stretch rollers in the pre-stretch assembly of the packaging material dispenser. A second portion of the mechanical connection controls an input to output ratio so as to set a ratio of the speed of the rotation of the rotatable ring to the speed of the rotation of the pre-stretch rollers in order to obtain the predetermined substantially constant length of film per revolution of the rotatable ring. No electrical slip rings, motor,

control box, or force controls are required because the rotation of the rotatable ring drives the pre-stretch rollers through the mechanical connection.

[055] The dispensing of the predetermined substantially constant length of pre-stretched packaging material per revolution of the packaging material dispenser relative to the load may be independent of the speed of the relative rotation. It is independent of the speed of the relative rotation because a ratio of the relative rotational speed to pre-stretch speed is set and mechanically maintained during the wrap cycle. Thus, regardless of the speed of the relative rotation, the ratio is maintained and thus the pre-stretch speed changes accordingly with the relative rotation speed. The dispensing of the predetermined substantially constant length of pre-stretched packaging material per revolution of the packaging material dispenser relative to the load may also be independent of load girth shape or placement of the load. That is, for each revolution of the packaging material dispenser relative to the load, regardless of the speed of the relative rotation, the pre-stretch roller may complete a fixed number of revolutions. If the speed of the relative rotation increases, the amount of time it takes for the pre-stretch roller to complete the fixed number of revolutions may decrease, but the same fixed number of revolutions will be complete during one revolution of the packaging material dispenser relative to the load. Similarly, if the speed of the relative rotation decreases, the amount of time required for the downstream pre-stretch roller to complete the fixed number of revolutions may increase, but the same fixed number of revolutions may be complete during one revolution of the packaging material dispenser relative to the load. Because the speed of the relative rotation is tied to the speed of the pre-stretch through the mechanical link, the proportion or ratio of the speeds is constant, regardless of what those speeds may be. Thus, during acceleration and deceleration of the relative rotation, the pre-stretch assembly accelerates and decelerates with the rotational drive system.

[056] The ability of the rotational drive system and the pre-stretch assembly to accelerate and decelerate together is a particular advantage when a rotatable ring is the means of providing relative rotation. The rotatable ring may be powered for very rapid acceleration to over 60 rpm with an acceleration period of one second and a deceleration period of one second. Since the packaging material feed (via

the pre-stretch assembly) may be independent of the relative rotational speed as described above, there is no extra force on the packaging material during acceleration or excess packaging material during deceleration.

[057] If a reduced force below optimum wrapping force is required during initial startup, the rotating ring can be reversed to create slack packaging material at the end of the previous cycle. A one-way clutch may be included to prevent any backlash from packaging material feed while the rotating ring is reversed. The slack packaging material may remain well around the first corner of the load until the elasticity of the dispensed packaging material can take it up.

[058] According to one aspect of the invention, a film break sensing roller is provided. The primary purpose of the film break sensing roller is to completely stop film feed as quickly as possible when the film breaks so that the film does not backlash and wind up on the rollers. The film break sensing roller is connected to the mechanical connection which controls the input/output ratio of the speed of the rotational drive to the surface speed of the pre-stretch roller. The film break sensing roller has the ability to shift this ratio such that even though an input is received, the output is zero, effectively stopping the dispensing of film. A secondary purpose of the film break sensing roller is that it senses slack film. As the film break sensing roller moves toward a neutral position, the input/output ratio decreases, slowing the film feed. As the film feed slows and the rotatable ring continues to rotate, the slack is taken up and a new film feed position and input/output ratio are established.

[059] According to one aspect of the present invention, a stretch wrapping apparatus 100 for wrapping a load may include a non-rotating frame, a moveable frame, a rotatable ring, a fixed ring, a rotational drive system, and a packaging material dispenser with a pre-stretch assembly.

[060] As embodied herein and shown in Fig. 1, the apparatus 100 may include the non-rotating frame 110. The non-rotating frame 110 may include four vertical legs, 112a, 112b, 112c, and 112d. The legs 112a, 112b, 112c, and 112d of the non-rotating frame 110 may or may not be positioned over a conveyor (not shown) such that a load 138 to be wrapped may be conveyed into a wrapping space (defined in part by the non-rotating frame 110), wrapped, and then conveyed

away from the wrapping space. The non-rotating frame 110 may also include a plurality of horizontal supports 116a, 116b, 116c, 116d, that connect the vertical legs 112a, 112b, 112c, and 112d, to each other, forming a square or rectangular shape (see Fig. 1). Additional supports may be placed across the square or rectangle formed by the horizontal supports 116a, 116b, 116c, 116d (see Fig. 1). In one exemplary embodiment, the non-rotating frame 110 may have a footprint of 88 inches by 100 inches. The benefit of this particular footprint is that it may allow the stretch wrapping apparatus 100 to fit into an enclosed truck for shipment. Prior art devices may generally have a much larger footprint. Due to their large size, disassembly may be required to transport the prior art devices. Otherwise, shipment on a flatbed may be required. Either of those two scenarios could significantly increase shipping costs.

[061] A vertically movable frame portion 118 may be connected to and movable on the non-rotating frame 110. As embodied herein and shown in Figs. 1, 2, 3A, and 3B, the vertically movable frame portion 118 may include a support portion 120, a rotatable ring 122, and a fixed (i.e., non-rotatable) ring 124. A plurality of rotatable ring supports 126 (see Fig. 6) may extend downwardly from the support portion 120. Each rotatable ring support 126 may have an L-shape and may comprise one or more pieces of material, such as steel, to form the L-shape. It is possible that the rotatable ring supports 126 may have a shape other than an L-shape. Connected to each rotatable ring support 126 may be a roller or wheel 128. Rotatable ring 122 may rest on top of the rollers 128, such that rotatable ring 122 may ride on the rollers 128. Preferably, rotatable ring 122 may be constructed of a very lightweight material. The lightweight nature of the rotatable ring 122 may allow for faster movement of the rotatable ring 122, and thus, faster wrapping cycles. In one exemplary embodiment, the rotatable ring 122 may have an inner diameter of 80 inches, an outer diameter of 88 inches, and may be made of a lightweight composite material. Use of a composite material may reduce the weight of the rotatable ring by approximately 75% when compared to conventional steel or aluminum rotatable rings.

[062] Independent of the rotatable ring 122, the fixed ring 124 may be positioned below and outside of the rotatable ring 122. Fixed ring 124 may be

supported by the support portion 120. A first drive belt 130, driven by a motor 132, may be positioned around an outer circumference of the rotatable ring 122. The motor 132 rotates the first drive belt 130 which in turn rotates the rotatable ring 122. Thus, the motor 132 and the first drive belt 130 form a rotational drive system. A second drive belt 134 may be positioned around the outer circumference of the fixed ring 124. The second drive belt is a fixed belt that does not rotate. This second drive belt 134 may be used as part of a mechanical connection between the rotational drive system of the rotatable ring 122 and a pre-stretch assembly of a packaging material dispenser, as will be discussed below. It is also contemplated that a second motor 136 may be provided to raise and/or lower the movable frame portion 118 on non-rotating frame 110. Alternatively, the rotatable ring 122 can be frictionally driven by suitably surfaced wheel(s) pressed against the outer surface of the rotatable ring 122.

[063] As embodied herein and shown in Figs. 1-3B, the stretch wrapping apparatus 100 may include a packaging material dispenser 140. As shown in Figs. 2, 3A, and 3B, the packaging material dispenser 140 may dispense a sheet of packaging material 142 in a web form. The packaging material dispenser 140 may include a roll carriage 144. As embodied herein and shown in Figs. 2-4, the roll carriage 144 may include a structure for supporting a roll 152 of packaging material 142. A lower support plate 146 includes a lower roll support 148 mounted thereon. It is contemplated that the lower roll support 148 may be configured to engage a core 150 of the roll 152 of packaging material 142, and may rotate as roll 152 rotates. Alternatively, roll 152 may rotate relative to the lower roll support 148. The roll carriage 144 may also include an upper support plate 154. The upper support plate 154 may include a rotatable plate 155 hingedly connected to the upper support plate 154 of the roll carriage 144 and include an upper roll support 156. The upper roll support 156 may be similar to the lower roll support 148 in structure and operation. The upper roll support 156 may be mounted on the rotatable plate 155. When removal of the roll 152 of packaging material 142 is desired, the rotatable plate 155 may be lifted, causing the rotatable plate 155 to rotate about a hinge, moving the upper roll support 156 out of engagement with the top of the core 150 of roll 152 of packaging material. This allows the remainder of the roll 152 to

be easily removed from the lower roll support 148 and from the roll carriage 144. Insertion of a new roll 152 of packaging material 142 into the roll carriage 144 may be accomplished by reversing the steps, e.g., placing the bottom of the core 150 over the lower roll support 148, lifting the rotatable plate 155 to raise the upper roll support 156, sliding the roll 152 into position in the roll carriage 144, and then returning the rotatable plate 155 to its lowered position to allow the upper roll support 156 to engage the top of the core 150.

[064] Preferably, the packaging material dispenser 140 is lightweight, which in combination with the lightweight rotatable ring 122 may allow for faster movement of the rotatable ring 122, and thus, shorter (faster) wrapping cycles. By using the second drive belt 134 to drive a pre-stretch assembly off of the rotational drive system, it is possible to eliminate the conventional motor that drives the packaging material dispenser 140 as well the conventional control box, greatly reducing the weight of the packaging material dispenser 140. By providing an entirely mechanical connection between the rotational drive system and the pre-stretch assembly, the need for placing electrical power sources or connections on the rotatable ring 122 for electrically powering the pre-stretch assembly may be eliminated.

[065] In an exemplary embodiment, the packaging material 142 is stretch wrap packaging material. However, it should be understood that various other packaging materials such as netting, strapping, banding, or tape may be used as well. As used herein, the terms "packaging material," "film," "film web," "web," and "packaging material web" are interchangeable.

[066] The packaging material dispenser 140 and rotatable ring 122 may rotate about a vertical axis 158 (Fig. 1) as the moveable frame 118 moves up and down the non-rotating frame 110 to spirally wrap packaging material 142 about a load 138. The load 138 can be manually placed in the wrapping area or conveyed into the wrapping area by the conveyor 114. As shown in Figs. 1-3B, the packaging material dispenser 140 may be mounted underneath and outboard of the rotatable ring 122, thus maximizing wrapping space.

[067] The packaging material dispenser 140 may include a pre-stretch assembly 160. Pre-stretch assembly 160 may include an upstream pre-stretch

roller 162 and a downstream pre-stretch roller 164. "Upstream" and "downstream," as used in this application, are intended to define the direction of movement relative to the flow of packaging material 142 from the packaging material dispenser 140. Thus, since the packaging material 142 flows from the packaging material dispenser 140, movement toward the packaging material dispenser 140 and against the flow of packaging material 142 from the packaging material dispenser 140 may be defined as "upstream" and movement away from the packaging material dispenser 140 and with the flow of packaging material 142 from the packaging material dispenser 140 may be defined as "downstream."

[068] The surfaces of the upstream and downstream pre-stretch rollers 162 and 164 may either be coated or uncoated depending on the type of application in which the stretch wrapping apparatus 100 is being used. The upstream and downstream pre-stretch rollers 162 and 164 may be mounted on roller shafts 166 and 168, respectively. Sprockets 170 and 172 may be located on the ends of the roller shafts 166 and 168, respectively, and may be configured to provide control over the rotation of the roller shafts 166 and 168 and the upstream and downstream pre-stretch rollers 162 and 164. It is contemplated that the upstream pre-stretch roller 162 and the downstream pre-stretch roller 164 may have different sized sprockets 170 and 172 so that the surface movement of the upstream pre-stretch roller 162 may be at least approximately 40% slower than that of the downstream pre-stretch roller 164. The sprockets 170, 172 may be sized depending on the amount of packaging material elongation desired. Thus, the surface movement of the upstream pre-stretch roller 162 can be about 40%, 75%, 200% or 300% slower than the surface movement of the downstream pre-stretch roller 164 to obtain pre-stretching of 40%, 75%, 200% or 300%. While pre-stretching normally ranges from 40% to 300%, excellent results have been obtained when narrower ranges of pre-stretching are used, such as pre-stretching the material 40% to 75%, 75% to 200%, 200% to 300%, and at least 100%. In certain instances, pre-stretching has been successful at over 300% of pre-stretch. The upstream and downstream pre-stretch rollers 162 and 164 may be operatively connected by a drive chain or belt 174.

[069] Rapid elongation of the packaging material 142 by the pre-stretch rollers 162 and 164, followed by rapid strain relief of the packaging material 142, may cause a "memorization" effect. Due to this "memorization" effect, the packaging material 142 may actually continue to shrink for some time after being wrapped onto the load 138. Over time, the packaging material 142 may significantly increase holding force and conformation to the load 138. This characteristic of the packaging material 142 may allow it to be used for wrapping loads at very close to zero stretch wrapping force, using the memory to build holding force and load conformity. As previously noted, some embodiments of the present invention permit relative rotation between the load and dispenser at approximately 60 rpm. At this speed, the dispensed pre-stretched film has a tendency to billow around the load before contracting/shrinking onto the load such that the film contacts all sides/corners of the load substantially simultaneously. This is particularly beneficial when dealing with light, crushable, or twistable loads.

[070] In one exemplary embodiment, each of the upstream and downstream pre-stretch rollers 162 and 164 may preferably be the same size, and each may have, for example, an outer diameter of approximately 2.5 inches. The upstream and downstream pre-stretch rollers 162 and 164 should have a sufficient length to carry a twenty (20) inch wide web of packaging material 142 along their working lengths, and they may be mounted on the roller shafts 166 and 168, which may include, for example, hex shafts. The upstream and downstream pre-stretch rollers 162 and 164, may be connected to each other through chains to a sprocket idle shaft with the sprockets 170 and 172 selected for the desired pre-stretch level. It is contemplated that, in one exemplary embodiment, rollers used for conventional conveyors may be used to form the upstream and downstream pre-stretch rollers 162 and 164.

[071] As embodied herein and shown in Figs. 2, 3A, and 3B, the pre-stretch assembly 160 may include a midstream idle roller 176 positionable between the upstream and downstream pre-stretch rollers 162 and 164. The midstream idle roller 176 may be the same diameter as or smaller in diameter than the upstream and downstream pre-stretch rollers 162 and 164. Preferably, midstream idle roller 176 is uncoated. In one exemplary embodiment, midstream idle roller 176 may

include an idle roller operatively connected to an upper frame portion 178 of the packaging material dispenser 140. The midstream idle roller 176 may also be a cantilevered roller that is not connected to any additional structure and is unsupported at its base. Although not physically connected at its base or to a base support, the midway idle roller 176 may nest in a U-shaped guard (not shown) that connects the upstream and downstream pre-stretch rollers 162 and 164 as disclosed in U.S. Patent Application No. 11/371,254, filed March 9, 2006, and entitled "Stretch Wrapping Apparatus Having Film Dispenser with Pre-Stretch Assembly," the entire disclosure of which is incorporated herein by reference. Preferably the midstream idle roller 176 may be aligned to provide a pinching action on the upstream pre-stretch roller 162, as disclosed in U.S. Patent No. 5,414,979, the entire disclosure of which is incorporated herein by reference. Additional idle rollers may be provided adjacent the upstream and downstream pre-stretch rollers 162 and 164 as necessary to direct the film path.

[072] According to another aspect of the present invention, the packaging material dispenser 140 may include a final idle roller 180 positioned downstream of the second downstream pre-stretch roller 164. Spacing the final idle roller 180 downstream of the last pre-stretch roller 164 may provide an extra length 182 of packaging material 142 between the downstream pre-stretch roller 164 and the final idle roller 180 mounted on the packaging material dispenser 140. See Fig. 7. The extra length 182 of packaging material 142 may provide the additional elasticity in the pre-stretched packaging material 142 to accommodate the passage of a corner of the load 138 or to accommodate offset and/or off-center loads. The extra length 182 of packaging material 142 provides the same benefits as a film accumulator or a dancer bar without require the usual structure and connections required by such. For this reason, the extra length 182 of packaging material 142 may also be referred to as a "virtual accumulator" 182.

[073] The virtual accumulator 182 may also permit the length of packaging material 142 to the load 138 to always be longer than at least one side of the load 138. Preferably, the final idle roller 180 is positioned to provide an extra length 182 of packaging material 142 that is equal to a length greater than a difference between the shortest wrap radius of a load and the longest wrap radius of a load

138. Fig. 7 illustrates the wrap radii with regard to a rectangular load 138 and shows that the shortest wrap radius 186 can be found along the middle of the side of the load and the longest wrap radius 188 can be found at a corner of the load 138. By providing an extra length 182 of film 142 that is greater than the difference between these two radii, there is sufficient extra film 142 to accommodate movement from the shortest wrapping radius 186 to the longest wrapping radius 188.

[074] Experimentation, and observation of the geometry of the wrap process revealed that the virtual accumulator 182 produces significant dampening of the force variation when the load is relatively centered. A 40 x 48 rectangular load would add approximately 13 inches to the film length. Although less than this will be required where the load does not "fill the ring wrap space" since the film from the final idle roller to the load will be more, testing has shown that a minimum length of 13 inches should be used. Depending on the positioning of the load, a maximum of length of up to about 88 inches of extra film may be used. The optimum length, considering threading and film roll change, has been found to be approximately 29 inches between the downstream pre-stretch roller 164 and the final idle roller 180 mounted to the roll carriage 144. It should be noted that the distance from the final idle roller 180 to the load 138 constantly varies as the corners of the load 138 pass. If the ring is "filled," the passage of a corner of the load 138 may permit only inches of film to the final idle roller 180.

[075] As shown in Figs. 2, 3A, and 3B, the packaging material dispenser 140 may also include a pre-stretch packaging material metering assembly 190. The pre-stretch packaging material metering assembly 190 may include a mechanical input/output ratio control 192, a film break sensing roller 194, and a metering adjustment control 196.

[076] As embodied herein, the second drive belt 134 forms a first part of a mechanical connection between the rotational drive system and the pre-stretch assembly 160. The mechanical input/output ratio control 192 forms the second part of the mechanical connection between the rotational drive system and the pre-stretch assembly 160. As shown in Figs. 2, 3A, and 3B, the mechanical input/output ratio control 192 may be a variable transmission such as, for example,

a hydrostatic transmission 200. One exemplary such hydrostatic transmission is made by Hydrogear, model number BDR-311. The hydrostatic transmission 200 may include a first rotatable input shaft 202 and a second rotatable output shaft 204. A series of hydraulic pumps and valves control the ratio between the input and the output of the hydrostatic transmission 200. This ratio may be set as desired. 1-3B, the second drive belt 134 may engage the rotatable input shaft 202 of the hydrostatic transmission 200 on the roll carriage 144 of the packaging material dispenser 140. During operation of the apparatus 100, the motor 132 drives the first drive belt 130, which in turn rotates the rotatable ring 122 and the packaging material dispenser roll carriage 144 mounted on the rotatable ring 122. As the roll carriage 144 rotates with the ring 122, the second drive belt 134 on fixed ring 124 engages the rotatable input shaft 202 of the hydrostatic transmission 200, causing the input shaft 202 to rotate. Thus, the second drive belt 134 translates the rotational drive from the rotatable ring 122 to the hydrostatic transmission 200. The output of the hydrostatic transmission 200, via the rotatable output shaft 204, drives the downstream roller 164 of the pre-stretch assembly 160, and through the connection 174 between the pre-stretch rollers 162, 164, the upstream pre-stretch roller 164. As the pre-stretch rollers 162, 164 rotate, the packaging material 142 flows downstream from the packaging material roll 152 through the pre-stretch assembly 160, through the pre-stretch packaging material metering assembly 190 and to the load 138, as will be discussed in greater detail below.

[077] As embodied herein, the hydrostatic transmission 200 may include a rotatable input shaft 202 that engages the fixed second drive belt 134 through gear teeth or any other suitable mode of engagement. Accordingly, when the rotatable ring 122 and the roll carriage 144 are rotatably driven by the first drive belt 130 via the motor 132, the movement of the roll carriage 144, including the rotatable input shaft 202, relative to the fixed second drive belt 134 causes rotation of the rotatable input shaft 202. The hydrostatic transmission 200 may be set to control a ratio of the relative rotational speed to pre-stretch speed by controlling a ratio of drive input to drive output. The speed at which the rotatable input shaft 202 rotates, based on the speed at which the rotatable ring 122 and the roll carriage 144 rotate, may be considered the input. The series of pumps and valves contained within the

hydrostatic transmission 200 transmit the input from the input shaft 202 to the output shaft 204, adjusting the rotational speed of the output shaft 204 based on the input/output ratio of the hydrostatic drive 200.

[078] The rotation of the rotatable output shaft 204 drives the downstream pre-stretch roller 164. The connection 174 between the upstream and downstream pre-stretch rollers 162, 164 causes the upstream pre-stretch roller 162 to rotate as the downstream pre-stretch roller 164 rotates, thus dispensing film 142. Engagement between the rotatable output shaft 204 and the downstream pre-stretch roller 164 may include, for example, drive belts, gears, chains, and/or any other suitable devices configured to convert rotation of the rotatable output shaft 204 into rotation of the upstream and downstream pre-stretch rollers 162, 164. In the exemplary embodiment, the hydrostatic transmission 200 may have a ninety degree angle between its rotatable input shaft 202 and its rotatable output shaft 204. Although a hydrostatic drive is used in the exemplary embodiment, any other appropriate mechanical power transmissions may be used to control the input/output ratio. Further, other suitable mechanical controls such as, for example, a split sheave, variable pitch belt sheaves, fixed center and adjustable center sheaves, wider range variable pitch belt drives, cone and ring variable speed drives, rolling ring variable speed drives, and ball and ring variable speed drives may be used to control the input/output ratio. Alternatively, methods such as a moving second ring with the differential between the rings generating the output, using a differential and controlling one output to adjust another output, and an electric motor without load cell feedback.

[079] The input/output ratio of the hydrostatic transmission 200 may be selectively and variably adjusted. As the input/output ratio increases, the relative speed of the output shaft 204 increases, and the rotational speed of the upstream and downstream pre-stretch rollers 162 and 164 increases proportionally. The increased rotational speed of the upstream and downstream pre-stretch rollers 162 and 164 causes an increase in the supply rate of the packaging material 142. If, on the other hand, the input/output ratio decreases, then the speed of the rotational output shaft 204 decreases, and the relative rotational speed of the upstream and downstream pre-stretch rollers 162 and 164 decreases proportionally, resulting in a

decrease in the supply rate of the packaging material 142. Thus, it should be apparent that while the rotatable ring 122 and the rotatable input shaft may rotate at substantially the same speed, the rotational speed of the rotatable output shaft 204, and consequently the rotational speed of the upstream and downstream pre-stretch rollers 162 and 164 may vary depending on the input/output ratio setting of the hydrostatic transmission 200.

[080] A transmission lever 206 may be operatively coupled to the hydrostatic transmission such that the orientation of the transmission lever 206 may affect the input/output ratio of the hydrostatic transmission 200. For example, the transmission lever 206 may be adjusted to a first position, where the transmission lever 206 may set a minimal input/output ratio such that the speed of the rotatable input shaft 202 is much greater than the speed of the rotatable output shaft 204 and thus the downstream pre-stretch roller 164. It is contemplated that in the first position, the transmission lever 206 may prevent input at the rotatable input shaft 202 from being transmitted/translated to the rotatable output shaft 204. This may be accomplished, for example, by controlling a valve positioned between an input pump and an output pump in the hydrostatic transmission. With the transmission lever 206 in such a position, the hydrostatic drive is essentially in neutral. It can accept an input from the rotatable input shaft 202 but does not produce an output through the rotatable output shaft 204. The transmission lever 206 may also be adjusted to a second position, where the transmission lever 206 may allow for a maximum input/output ratio. The transmission lever 206 may be adjusted to virtually any position between the first and second positions, causing changes in the input/output ratio and thus ratio of relative rotational speed to pre-stretch speed. Changes in the input/output ratio and the ratio of relative rotational speed to pre-stretch speed result in changes to the relative speed of the rotatable output shaft 204. Accordingly, the input/output ratio may vary between a maximum ratio and a minimum ratio, depending on the angular orientation of the transmission lever 206 relative to the hydrostatic transmission 200, and the output of the hydrostatic transmission 200. The speed of downstream pre-stretch roller 164, and thus the amount of film dispensed by the pre-stretch assembly 160, varies based on the input/output ratio.

[081] According to one aspect of the present invention, a metering adjustment control 196 may be provided. The metering adjustment control 196 may include, for example, a sliding plate 220 having a slot 222 therein extending through a first surface 224. The sliding plate 220 may also include a second surface 226 extending substantially perpendicularly to the first surface 224. The first surface 224 of the sliding plate 220 may rest on the lower frame portion 216 of the packaging material dispenser 140, and may be configured to slide thereon. The slot 222 in the sliding plate 220 may be arranged such that it at least partially overlaps a slot (not shown) in the lower frame portion 216 of the packaging material dispenser 140. The metering adjustment control 196 may include an adjustment knob 232 and a bolt assembly, including a bolt 234 and a nut 236. The bolt 234 may be inserted through an aperture 238 in the second surface 226 of the sliding plate 220, and may also extend through an aligned aperture 240 in a side frame portion 242 of the packaging material dispenser 140. Rotation of the adjustment knob 232 in a first direction may draw the bolt 234 towards the adjustment knob 232, causing the sliding plate 220 to slide in a first direction. Rotation of the adjustment knob 232 in a second direction (opposite the first direction) may cause the sliding plate 220 to slide away from the adjustment knob 232. Accordingly, an operator may selectively determine the input/output ratio of the hydrostatic transmission 200 by adjusting the adjustment knob 232. The position of the sliding plate 220, through a series of linkages, adjusts the input/output ratio of the hydrostatic transmission 200, and thus, the supply rate of packaging material 142. Thus, by using the adjustment knob 232 to position the sliding plate 220 in a predetermined position, an operator can set the input/output ratio of the hydrostatic transmission 200, thereby setting the rotational speed of the pre-stretch rollers relative to the speed of the rotatable ring 122. This in turn "sets" the pre-stretch rollers 162, 164 to dispense a predetermined substantially constant length of film per revolution of the rotatable ring 122.

[082] In situations when the packaging material apparatus is to be used for loads having different girths, the adjustment knob 232 of the metering adjustment control 196 should be positioned to adjust the payout percentage for the girth of the load and wrap force desired. Setting the payout percentage with knob 232 will set

the input/output ratio of the hydrostatic transmission 200, ultimately determining the amount of packaging material 142 that will be distributed per revolution of the upstream and downstream pre-stretch rollers 162 and 164. Thus, to wrap larger girth loads, more packaging material will be required per revolution and thus the ratio of relative rotational speed to pre-stretch speed should be higher to permit a higher predetermined substantially constant length of packaging material to be distributed for each revolution. On the other hand, if the load has a small girth, less packaging material will be required per revolution and thus the ratio of relative rotational speed to pre-stretch speed should be lower to permit a smaller predetermined substantially constant length of packaging material to be dispensed per revolution of the rotatable ring 122. Thus, adjustment of the metering adjustment control 196 may allow an operator to selectively adjust the input/output ratio of the transmission 200 and thus the rotational speed of the pre-stretch rollers 162 and 164, and the supply rate of the packaging material 142, such that the stretch wrapping apparatus 100 may be used to wrap loads have varying shapes and sizes. Therefore, by adjusting the input/output ratio, an operator is adjusting the speed of the pre-stretch rollers proportional to the rotational ring speed.

[083] According to another aspect of the present invention, a film break sensing roller 194 may be provided. The film break sensing roller 194 may be operatively coupled to the transmission lever 206 through a series of linkages. The film break sensing roller 194 may be mounted to the roll carriage 144 on a shaft 212. The film break sensing roller 194 may have an outer diameter of approximately 2.5 inches, and may have a sufficient length to carry a twenty (20) inch wide web of packaging material 142 along its working length. In one embodiment, bearings for supporting the shaft 212 may be press-fit or welded into each end of the film break sensing roller 194, and the shaft 212 may be placed therethrough, such that the shaft 212 may be centrally and axially mounted through the length of the film break sensing roller 194.

[084] The primary purpose of the film break sensing roller 194 is to completely stop film feed as quickly as possible when the film 142 breaks so that the film 142 does not backlash and wind up on the rollers. During normal operation of the stretch wrap apparatus 100, tension in the packaging material 142 holds the

film break sensing roller 194 in a "full forward" position (i.e., retracted toward pre-stretch assembly 160). When the film break sensing roller 194 moves from the "full forward" position to a "neutral" position due to tension release in the packaging material 142, the film break sensing roller 194 extends away from the pre-stretch assembly 160. The hydrostatic transmission moves to a neutral position, i.e., to a position where the output of the hydrostatic transmission 200 goes to zero even with continued input into the hydrostatic transmission due to the continued rotation of the rotatable ring 122 and the packaging material dispenser 140. A secondary purpose of the film break sensing roller 194 is that it may sense slack film. For example, if the girth of the load 138 is radically reduced (as in a few boxes on the only top layer of the load) the film break sensing roller 194 senses slack film (which feels the same as a film break) and begins to move towards the "neutral" position. As the film break sensing roller 194 moves toward the neutral position, the input/output ratio of the hydrostatic drive decreases, slowing the film feed. As the film feed slows and the rotatable ring continues to rotate, the slack is taken up as the smaller top layer is wrapped and the film break sensing roller 194 remains in the position at which it no longer senses the slack, establishing a new film feed position and input/output ratio where less film/revolution is dispensed.

[085] As embodied herein and shown in Figs. 3A and 3B, the film break sensing roller 194 may be mounted on a shaft 212. A first end of the shaft may extend through a slot 214 in a lower frame portion 216 of the packaging material dispenser 140, and may be pivotally attached to an upper support plate 218 of the packaging material dispenser 140. Additionally, the shaft 212 may be cantilevered, such that a second end of the shaft may hang freely. Consequently, the film break sensing roller 194 may swing back and forth between extended (neutral) and retracted (full forward) positions. The swinging movement of the film break sensing roller 194 may be linked to the rotation of the transmission lever 206 as the film break sensing roller 194 may be coupled to rotate with the transmission lever 206 through a series of linkages.

[086] According to another aspect of the present invention, the stretch wrapping apparatus 100 may be provided with a belted packaging material

clamping and cutting apparatus as disclosed in U.S. Patent No. 4,761,934, the entire disclosure of which is incorporated herein by reference.

[087] The packaging material 142 may be sealed to the layers of wrap on the load 138 by any conventional means such as by heat sealing and by the use of wipe down mechanisms. Further, heated cutting and sealing elements as known in the art may be used. Also, the sealing systems may be automatic, semi-automatic, or manually operated.

[088] According to another aspect of the present invention, the stretch wrapping apparatus 100 may be provided with a film drive down and roping system as disclosed in U.S. Patent Application No. 10/767,863, filed January 30, 2004, and entitled "Method and Apparatus for Rolling a Portion of a Film Web into a Cable" and in U.S. Patent Application No. _______________, filed February 23, 2007, and entitled "Method and Apparatus for Securing a Load to a Pallet with a Roped Film Web," the entire disclosures of which are incorporated herein by reference.

[089] As shown in Figs. 2, 3A, and 3B, the stretch wrap apparatus 100 may include a film drive down assembly 38. The film drive down assembly 38 may include a film drive down roller 40, a film drive down roller support 42, an actuation mechanism 46, a roping apparatus 48, and a latching assembly 50. The film drive down roller support 42 may include a shaft 52, a leg 54 extending substantially alongside the shaft 52, and a lever 56. The lever 56 may extend at an angle from a bottom end of the leg 54. The shaft 52 may rotatably support the film drive down roller 40. The film drive down roller support 42 may be rotatably mounted by a pivot connection 58 on its bottom end either directly or indirectly to the packaging material dispenser 140. The top end of the film drive down roller support 42 may move freely, and thus, the entire film drive down roller support 42 may rotate about an axis extending through the pivot connection 58, allowing the film drive down roller support 42 to move between a relatively vertical position and a tilted film drive down position, shown in Figs. 2 and 3A, respectively. When the film drive down roller 40 is in the tilted film drive down position (Fig. 3A), the film web 142 will enter onto the surface of the film drive down roller 40 at a first height. Due to the tilted orientation of the film drive down roller 40, the film web 142 will be forced

downward as it travels around the film drive down roller 40, coming off of the film drive down roller 40 at a lower height than when film web 142 entered.

[090] Rotation of the film drive down roller support 42 about the pivot connection 58 may be achieved using the actuation mechanism 46 shown in Fig. 3A. The actuation mechanism 46 may selectively engage the lever 56 during certain times in a wrap cycle. The actuation mechanism 46 may include, for example, an air cylinder activated pad, and/or any other suitable mechanical, electrical, or hydraulically powered device configured to project outwardly to abut and drive the lever 56 upwardly, thus causing clockwise rotation of the film drive down roller support 42 and the film drive down roller 40 from the relatively vertical position of Fig. 2 to the tilted film drive down position of Fig. 3A. The film drive down roller 40 may remain in contact with the film web 142 throughout the wrap cycle, whether the film drive down roller 40 is in the relatively vertical position or in the tilted film drive down position.

[091] In one embodiment, the actuation mechanism 46 may cause tilting of the film drive down roller 40 at the start of the wrap cycle, when the packaging material dispenser 140 is in the initial position. After abutting the lever 56, the air cylinder activated pad may retract inwardly out of the path of travel of the packaging material dispenser 140 as relative rotation is provided between the packaging material dispenser 140 and the load 138. Additionally or alternatively, the actuation mechanism 46 may include an abutment, wherein the packaging material dispenser 140 may be lowered while not rotating to bring the abutment into contact with the lever 56 and cause rotation of the film drive down roller support 42. Prior to providing relative rotation between the packaging material dispenser 140 and the load 138, the packaging material dispenser 140 may be moved so as not to be obstructed by the abutment.

[092] The roping apparatus 48 may be configured to engage a least a portion of a bottom edge of the film web 142. The roping apparatus 48 may include, for example, a cable rolling roper element 60, a pulley 62, and a linking cable 64. The cable rolling roping element 60 may be slidably or otherwise moveably mounted either directly or indirectly to the packaging material dispenser 140, such that the cable rolling roping element 60 may move upward and

downward relative to the packaging material dispenser 140. In Figs. 2 and 3A, the cable rolling roping element 60 is shown in lowered and raised positions, respectively. The cable rolling roping element 60 may move in between the lowered and raised positions due to movement of the film drive down roller support 42, which may be operatively connected to the cable rolling roping element 60 by the linking cable 64. In one embodiment, the linking cable 64 may include a first end looped or otherwise attached to the cable rolling roping element 60, and a second end looped or otherwise attached to an upper portion of the film drive down roller support 42. When the film drive down roller support 42 is in the relatively vertical position of Fig. 2, the cable rolling roping element 60 may be in the lowered position. When the film drive down roller support 42 rotates towards the tilted film drive down configuration, it may pull on the linking cable 64. The pulling force may be translated by the pulley 62 into an upward movement of the first end of the linking cable 64, causing the cable rolling roping element 60 to move towards the raised position. As long as film drive down roller support 42 remains in the tilted film drive down configuration, the roping element 60 may remain in the raised position. When the film drive down roller support 42 is released from the tilted film drive down configuration, and moves back to the relatively vertical position, the cable rolling roping element 60 may move back to the lowered position. The cable rolling roping element 60 may be positioned downstream of and adjacent to an upstream idle roller 34.

[093] Preferably, the cable rolling roping element 60 may include low friction materials, for example unpainted steel bars or elements coated with zinc chromate. The cable rolling roping element 60 may have a v-shaped circumferential groove for engaging the film web 142. The cable rolling roping element 60 works with the film drive down roller 40 to create a rolled rope 49 of film that is capable of maintaining its structural integrity as a rope structure during and after wrapping of a load. The cable rolling roping element 60 and film drive down roller 40 may form a "cable rolling means" for rolling a portion of the film web into a cable of film. The cable rolling means rolls an outer edge of the film web inward upon itself and toward the center of the film web. The film is rolled upon itself to form a tightly rolled cable of film, or a high tensile cable of film along an edge of the film web 142. As used

herein, a "cable of film" or a "rolled cable" or a "rolled rope" are intended to denote a specific type of "roped" packaging material, where the film web has been rolled upon itself to create the rolled cable structure. An example is shown in Fig. 8.

[094] Once the film drive down roller support 42 rotates into the position shown in Fig. 3A, it may engage the latching mechanism 50. The latching mechanism 50 may include a catch, configured to receive and hold a bolt member 66 mounted to the top end of the film drive down roller support 42. As long as the bolt member 66 is held in the catch, the film drive down roller support 42 and the film drive down roller 40 may be locked in the tilted film drive down position, and thus, the roping element 60 may be held in the raised position. In order to release the bolt member 66, the latching mechanism 50 may include a release device 68. Actuation of the release device 68 may serve to unlock (release) the catch to allow the bolt member 66 to escape, thus allowing the film drive down roller support 42 and film drive down roller 40 to return to the relatively vertical position of Fig. 2. The release device 68 may include, for example, a spring steel release pad. The spring steel release pad 68 may be configured to engage an abutment 69 mounted on a non-rotating frame 71, such as, for example, a roller or wheel. At a pre-determined point in the wrap cycle, the spring steel release pad 68, may be brought into contact with the abutment 69, causing the spring steel release pad 68 to bend inwardly in the direction of the load. That inward movement of the spring steel release pad 68 may actuate the catch into an unlocking position, allowing the bolt member 66 to escape. Continued movement of the packaging material dispenser 10 may disengage the abutment 69 from the spring steel release pad 68, which may bend back outwardly due to its inherent resiliency. The catch may be returned to the locking position by the outward movement of the spring steel release pad 68 and/or by the force generated by a return spring or other suitable biasing device. The next time in the wrap cycle that the film drive down roller support 42 moves to the tilted film drive down position, the bolt member 66 may once again be received and held by the catch.

[095] According to another aspect of the invention, a method of using the stretch wrapping apparatus 100 will now be described. In operation, the load 138 may be manually placed in the wrapping area or may be conveyed into the

wrapping area by the conveyor 114. The girth of the load 138 may be determined, and a substantially constant length of packaging material 142 to be dispensed for each revolution of the packaging material dispenser 140 and rotatable ring 122 may be subsequently determined based on that girth. The substantially constant length of packaging material 142 to be dispensed per revolution may be between approximately 90% and approximately 130% of the load girth, and preferably may be between approximately 95% and approximately 115% of load girth, and most preferably may be approximately 107% of load girth. Once the substantially constant length of packaging material 142 to be dispensed per revolution of the rotatable ring 122 is known, the mechanical input/output ratio control 192 of the pre-stretch packaging material metering assembly 190 may be set through use of the metering adjustment control 196. The setting of the input/output ratio of the variable transmission (hydrostatic transmission 200) sets the ratio of the relative rotational speed (i.e., speed of the rotatable ring) to the pre-stretch speed (i.e., pre-stretch roller surface speed).

[096] A leading end of the packaging material 142 may be threaded through the upstream and downstream pre-stretch rollers 162 and 164, and around any middle idle rollers 176 of pre-stretch assembly 160. Then, the leading end of the packaging material 142 may be wrapped around the film break sensing roller 194 and a final idle roller 180, and then may be attached to the load 138 using a film clamp, or by tucking the leading end of the packaging material 142 into the load 138. It is noted that if the spacing between the pre-stretch rollers 162, 164 and the film break sensing roller 194 is sufficient to provide the extra length 182 of film 142, a final idle roller 180 may not be used. Additionally, the final idle roller 180 may be located anywhere within the film path between the downstream pre-stretch roller 164 and the load 138 that will provide the desired extra length 182 of film 142.

[097] The first motor 132 may operate to rotate the first drive belt 130 and thus the rotatable ring 122 and the packaging material dispenser 140 around the load 138. As the packaging material dispenser 140 rotates relative to the fixed ring 124, the fixed second drive belt 134 may be picked up by a pulley system 250 mounted to the rotatable ring 122 and move relative to the rotatable input shaft 202 of the hydrostatic transmission 200, causing the rotatable input shaft 202 to rotate.

As the rotatable ring 122 rotates, a tensile force may be created in the length of the packaging material 142 extending between the load 138 and the film break sensing roller 194. That tensile force may tend to pull the film break sensing roller 194 toward its retracted (full forward) position.

[098] Rotation of the input shaft 202 is translated to output shaft 204 according to the set input/output ratio, and the rotation of the output shaft 204 in turn causes rotation of the downstream pre-stretch roller 164 and thus, via the connector and sprockets, the upstream pre-stretch roller 162. As the upstream and downstream pre-stretch rollers 162 and 164 rotate, they may elongate the packaging material 142 and dispense a predetermined substantially constant length of pre-stretched packaging material 142 during each revolution of the rotatable ring 122. The packaging material dispenser 140 may rotate about a vertical axis 158 as the moveable frame 118 moves up and down the non-rotating frame 110 to spirally wrap packaging material 142 about the load 138.

[099] During the wrapping cycle, the film break sensing roller 194 may sense the occurrence of packaging material breaks. For example, if a break occurs in the length of packaging material 142 extending between the load 138 and the film break sensing roller 194, the tensile force holding the film break sensing roller 194 in the full forward position will cease to exist. The film break sensing roller 194 will then rapidly move toward its extended (neutral) position, thus causing the rotational speed of the pre-stretch rollers 162 and 164 and the supply rate of packaging material 142 to rapidly decrease to zero. This rapid decrease coincides with the shifting of the hydrostatic transmission to neutral. Thus, the ring 122 may still be rotating and providing input to the hydrostatic transmission 200, but the hydrostatic transmission 200 provides no output. This ensures that the pre-stretch assembly 160 will not continue to dispense packaging material 142 after a break occurs and thus prevents back lash and winding of the film on the rollers.

[0100] It is also contemplated that a sensor device, such as for example, a photo-cell sensor, may be placed on the packaging material dispenser 140 to detect the orientation of the film break sensing roller 194. The sensor device may be configured to send a signal to a controller to bring the apparatus 100 back to a home position and stop. It may additionally signal an operator that there has been a failure.

[0101] According to another aspect of the present invention, the means for providing relative rotation between the dispenser and the load may be a horizontal rotatable ring as shown in Figs. 9 and 10. For example, the horizontal ring stretch wrapping apparatus 300 may include substantially the same elements as the vertical rotatable ring apparatus described above. The horizontal ring stretch wrapping apparatus may function in substantially the same manner as the vertical rotatable ring apparatus 100 described above, with the exception that the horizontal ring structure is rotated 90 degrees relative to the vertical ring structure.

[0102] As embodied herein and shown in Figs. 9 and 10, a housing 302 of a horizontal ring apparatus 300 may include a central aperture 304 through which a conveyor 306 passes. A load 338 to be wrapped may be conveyed into a wrapping space defined by the central aperture 304, wrapped, and then conveyed away from the wrapping space.

[0103] The horizontal ring apparatus may have a structure similar to that of conventional horizontal ring apparatus as described in U.S. Patent No. 6,748,718, issued on June 15, 2004, and entitled "Method and Apparatus for Wrapping a Load," the entire disclosure of which is incorporated herein by reference. The horizontal ring apparatus may include a packaging material dispenser 340. The packaging material dispenser 340 may include the same or substantially similar components as the packaging material dispenser 140 mounted on the rotatable ring 122 of stretch wrapping apparatus 100. Thus, the descriptions of the packaging material dispenser 140 provided above may be applicable to the packaging material dispenser 340. A mechanical link between the rotation of the roll carriage and the pre-stretch rollers may be provided. The mechanical link may include a hydrostatic transmission carried by the roll carriage. As discussed above, the hydrostatic transmission may provide an input/output ratio control for controlling a relative speed of the rotation of horizontal ring relative to the speed of the pre-stretch rollers to thus ensure that a predetermined substantially constant length of packaging material is dispensed for each revolution of the packaging material dispenser 340 relative to the load 338. The setting of the input/output ratio may be accomplished in the same manner as described above with respect to the stretch wrapping apparatus 100.

[0104] According to another aspect of the invention, the means for providing relative rotation between the dispenser and the load may be a rotatable turntable as shown in Fig. 11. A stretch wrapping apparatus 400 including a rotatable turntable 422, as shown in Fig. 11, may also be configured to dispense a predetermined substantially constant length of pre-stretched packaging material 442 per revolution of a load 438 during a wrapping cycle. The rotating turntable apparatus 400 may include a turntable assembly 420 including a rotatable turntable 422, a mechanical connection 492 between a rotational drive of the turntable assembly 420 and the pre-stretch rollers 462, 464 of a pre-stretch assembly 460, and a packaging material dispenser 440. Embodiments of the rotatable turntable apparatus 400 are shown in Figs. 11 and 12.

[0105] The rotatable turntable assembly 420 may include a load support surface 405 for supporting the load 438. The load support surface 405 may include a flat surface, non-powered conveyor surface with one or more non-powered rollers, or powered conveyor surface with one or more powered rollers. The load support surface 405 may be operatively coupled to a rotational drive system of the turntable assembly 420. The rotational drive system may include, for example, a turntable drive motor 432 and a turntable drive belt or chain 430 configured to convert rotational power generated by the turntable drive motor 432 into rotation of the load support surface 405. The drive belt 430 may engage sprockets or pulleys 434 and 436 mounted on both the load support surface 405 and a first output of the turntable drive motor 432.

[0106] The turntable drive motor 432 may also be operatively coupled at a second output to the power transfer assembly 438 by a drive belt or chain 439. The drive belt 430 may engage sprockets or pulleys 442, 444 mounted on both the turntable drive motor 432 and a rotatable shaft 446 housing in a column 448. Also, a split shive or stacked pulley system 450 may also be provided at or near the turntable drive motor 432 to help control the feed rate of the packaging material. The rotational power generated by the turntable drive motor 432 may drive the drive belt 439, which may in turn cause rotation of the rotatable shaft 446. Rotation of the rotatable shaft 446 may be used to power the packaging material dispenser 440, as will be described in greater detail below.

[0107] A spring clutch 452 may be operatively coupled between the turntable drive motor 432 and the shaft 446. When a break in the packaging material is detected by a switch or sensor, the spring clutch 452 may at least partially disengage the turntable drive motor 432 from the shaft 446 to slow or stop the shaft 446 and the packaging material dispenser 440. This may prevent malfunctions by slowing or stopping the supply rate of packaging material from the packaging material dispenser 440 when breakages occur.

[0108] The power transfer assembly 438 may also include a sprocket drive 454 used to turn rotation of the shaft 446 into power for operating the packaging material dispenser 440. In particular, the sprocket drive 454 may be used to rotate an upstream pre-stretch roller 464 and a downstream pre-stretch roller 464 of a pre-stretch assembly 460 of the packaging material dispenser 440. In one embodiment, the sprocket drive 454 may include two drive chains or belts 456 and 458 operatively coupling the upstream and downstream pre-stretch rollers 462 and 464 to the shaft 446.

[0109] The upstream and downstream pre-stretch rollers 462 and 464 may include packaging material engaging surfaces that may either be coated or uncoated depending on the application in which the stretch wrapping apparatus 400 is being used. The upstream and downstream pre-stretch rollers 462 and 464 may be mounted on roller shafts (not shown). Sprockets 466 and 468 may be located on the ends of the roller shafts, and may be configured to provide control over the rotation of the roller shafts and the upstream and downstream pre-stretch rollers 462 and 464. It is contemplated that the upstream pre-stretch roller 462 and the downstream pre-stretch roller 464 may have different sized sprockets 466 and 468 so that the surface movement of the upstream pre-stretch roller 462 may be at least 40% slower than that of the downstream pre-stretch roller 464. In these and in other ways, the upstream and downstream pre-stretch rollers 466 and 468 may be structurally and operatively similar to the upstream and downstream pre-stretch rollers 162 and 164 of the stretch wrapping apparatus 100.

[0110] The packaging material dispenser 440 may also include a roll carriage 470 and one or more idle rollers, similar to those previously described with respect to the stretch wrapping apparatus 100. The packaging material dispenser 440 may also be driven up and down the column 448 by a vertical drive mechanism (not shown) during a wrapping cycle to spirally wrap packaging material about the load 438.

[0111] According to one aspect of the invention, a corner lock mechanism may be provided. The corner lock mechanism of the rotating turntable apparatus 400 may include a set of programmable controls (not shown), a corner target 472 on the load support surface 405 positioned just before each corner of the load 438 and a corner target sensor 474. Each time that a corner of the load 438 approaches the corner target sensor 474, the corner target sensor 474 senses the corner target 472 associated with that corner of the load 438. The programmable controls may momentarily reduce or stop the feed of pre-stretched film to increase the force on the film as it engages the corner of the load. This could be accomplished mechanically by clutch-brake means. This corner lock mechanism or a similar mechanism may be used with any of the stretch wrapping apparatus embodiments disclosed herein.

[0112] Additionally or alternatively, a spring clutch 552 and/or a split shive or stacked pulley system 550 may be separated from a turntable drive motor 532 as shown in the embodiment of Fig. 12. In this embodiment, a shaft 556 may include two welded rotational fins 457, fixed at locations opposite each other on the surface of the shaft 556. As the shaft 556 is rotated by the turntable drive motor 532, two cam followers 576 on a disc 578 may ride on the rotational fins 457, causing the disc 578 to rotate with the shaft 556. Rotation of the disc 578 may cause rotation of the upstream and downstream pre-stretch rollers 562 and 564 through the engagement of drive belts or chains 556 and 668 to sprockets or pulleys 554 and 555 on the upstream and downstream pre-stretch rollers 562 and 564 and the disc 578.

[0113] According to another aspect of the invention, the means for providing relative rotation between the dispenser and the load may be a rotatable arm as shown in Fig. 13. A rotating arm apparatus 600, shown in Fig. 13, may also be configured to dispense a predetermined fixed amount of pre-stretched packaging material per revolution of a load during a wrapping cycle. The rotating arm apparatus 600 may include a rotating arm assembly 602, packaging material dispenser 604 mounted on the rotating arm assembly 602, and a power transfer assembly 606. An exemplary embodiment of the rotating arm apparatus 600 is shown in Fig. 13.

[0114] The rotating arm assembly 602 may include a horizontal arm 608 cantilevered from a pivot point 610. A column 611 may be cantilevered from the free end of the horizontal arm 608. The packaging material dispenser 604 may be mounted on the column 611, and may be driven by a vertical drive device (not shown), vertically along the length of the column 611. The rotating arm assembly 602 may be rotated by an arm motor 612. Rotation of the rotating arm assembly 602, when coupled with vertical movement of the packaging material dispenser 604, may serve to wrap packaging material spirally about the load.

[0115] The power transfer assembly 606 may include a fixed (i.e., non-rotating) sprocket or pulley wheel 614. The fixed sprocket 614 may be operatively coupled by a drive belt or chain 616 to a split shive or stacked pulley system 618 mounted in the rotating arm assembly 601. The split shive or stacked pulley system 618 may be operatively coupled by a drive belt or chain 620 to a rotatable shaft 622 in the column 611. As the arm motor 612 rotates the rotating arm assembly 602, the engagement of the fixed sprocket 614 to the split shive or stacked pulley system 618 through the drive belt 620 causes the split shive or stacked pulley system 618 to rotate. As the split shive or stacked pulley system 618 rotates, the drive belt 620 is also driven, causing the shaft 622 to rotate. The shaft 622 may include two welded rotational fins 624, fixed at locations opposite each other on the surface of the shaft 622. As the shaft 622 is rotated, two cam followers 626 on a disc 628 may ride on the rotational fins 624, causing the disc 628 to rotate with the shaft 622. Rotation of the disc 628 may power a pre-stretch assembly 630 of the packaging material dispenser. In particular, rotation of the disc 628 may cause rotation of upstream and downstream pre-stretch rollers 632 and 634 through the engagement of drive belts or chains 636 and 638 to sprockets or pulleys 614 and 618 on the upstream and downstream pre-stretch rollers 632 and 634 and the disc 628.

[0116] The split shive or stacked pulley system 618 may also include a spring clutch device 640. When a packaging material break is detected by, for example, a break sensor or switch, the spring clutch device 640 may at least partially disengage the fixed sprocket 614 from the shaft 622 to slow or stop the shaft 622 and the packaging material dispenser. This may prevent malfunctions by slowing or stopping the supply rate of packaging material from the packaging material dispenser when breakages occur.

[0117] According to yet another aspect of the invention, the mechanical connection between the rotational drive system and the pre-stretch assembly may be replaced by an electrical connection. This use of an electrical connection may be used in any of the embodiments of the stretch wrap apparatuses discussed herein. In such embodiments, two separate drives may be provided, a first rotational drive for providing relative rotation between the load and the packaging material dispenser, and a second rotational drive for rotating the pre-stretch rollers of the pre-stretch assembly. The two rotational drives may be electronically linked such that a ratio of the drive speeds remains constant throughout a primary portion of the wrap cycle in order to permit the pre-stretch assembly to dispense a predetermined substantially constant length of film for each revolution of the dispenser relative to the load. A means for providing relative rotation between the load and the dispenser may include any of the systems previously discussed, e.g., vertical or horizontal rings, rotatable arms, and turntables.

[0118] An electrical connection, such follower circuits, for example a tachometer follower, or encoders may be used to link the first rotational drive and the second rotational drive such that a ratio of the drive speeds remains constant throughout a primary portion of the wrap cycle. In this manner, the electronic connection mimics the mechanical connection previously described

[0119] Unlike the mechanical connection, there may be times when it is undesirable for the two drives to be proportionally controlled at the same ratio for the entire wrap cycle. There may be times when it is instead desirable to vary the ratio while continuing to proportionally control the drives. Such times include start of the wrap cycle to accommodate prior art clamping systems and at the end of a wrap cycle to accommodate limitations of prior art film cutting and wiping systems or when one of the rotational drives may be moving in an opposite direction from the other (e.g., backing up the dispenser to provide slack in the film). Additionally there may be other reasons to vary the ratio for special applications such as corner board insertion, securing slip sheet flaps, etc. In addition, should the film break or become slack, it would be undesirable to have the pre-stretch assembly continue to dispense film that wind up the rollers.

[0120] According to an exemplary embodiment of the invention, two AC variable frequency drives, such as Allen-Bradley Power Flex 40 drives, may be used to drive the relative rotation between the load and the dispenser and to drive the pre-stretch rollers. A Control Logix processor may be used to electronically control the speed of the drives relative to one another so as to permit the pre-stretch assembly to dispense a predetermined substantially constant length of film for each revolution of the dispenser relative to the load. Preferably, an interface will be provided that permits the operator to select the payout percentage.

[0121] A corner lock mechanism, such as discussed with regard to the turntable stretch wrap apparatus 400, may be easily incorporated into any of the stretch wrap apparatuses using an electronic control to maintain the ratio of the rotational drive to the pre-stretch drive. The use of a corner lock mechanism is another instance when it may be desirable to vary the ratio while continuing to proportionally control the drives. In such an embodiment, proximity switches would be used to "pulse" the pre-stretch drive off for a precise rotation angle as a flag passes the proximity switches. For example, on a turntable embodiment flags could be positioned immediately prior to each corner of a load and be required to pass two proximity switches adjacent the mast upon which the packaging material dispenser is mounted, a first to pulse the pre-stretch drive off and a second to pulse the pre-stretch drive on again. This would be done four times during a revolution of the packaging material dispenser relative to a square or rectangular load, each time immediately prior to the passage of a corner of the load, in order to lock in a higher wrap force at the corners of the load. Appropriate alternative positioning of the flags and proximity switches for other types of means for providing relative rotation may be used. In addition, for other shapes of loads, the corner lock mechanism may be adapted accordingly.

[0122] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

1. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly;

a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle; and

a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser.

2. The apparatus of claim 1, wherein the mechanical input/output ratio control includes a mechanical transmission.

3. The apparatus of claim 2, further comprising a film break sensing roller operatively connected to the mechanical transmission.

4. The apparatus of claim 3, wherein the film break sensing roller is configured to shift the mechanical transmission into neutral upon sensing a film break.

5. The apparatus of claim 2, wherein the mechanical transmission is a hydrostatic transmission.

6. The apparatus of claim 1, wherein the rotational drive system includes one of a turntable and a rotatable arm.

7. The apparatus of claim 1, further comprising a final roller positioned a predetermined distance from the downstream pre-stretch roller, the predetermined distance being such that at least a portion of a length of film extending between the downstream pre-stretch roller and the final roller acts to dampen variations in forces acting on the predetermined substantially constant length of pre-stretched packaging material as it travels from the dispenser to the load.

8. The apparatus of claim 1, wherein the rotational drive system includes a rotatable ring.

9. The apparatus of claim 1, further comprising a film drive down roller positioned to continuously engage at least a portion of a width of the film web in a film path from the dispenser to the load, the film drive down roller being selectively moveable between a vertical position and a tilted film drive down position.

10. The apparatus of claim 9, further comprising at least one roping element.

11. The apparatus of claim 1, further comprising a film cutting and sealing assembly.

12. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including a pre-stretch assembly;

a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle;

a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser; and

a virtual film accumulator configured to accommodate variations in film demand as the film is dispensed at the predetermined substantially constant length for each revolution.

13. The apparatus of claim 12, wherein the mechanical input/output ratio control includes a mechanical transmission.

14. The apparatus of claim 12, wherein the mechanical input/output ratio control includes a hydrostatic transmission.

15. The apparatus of claim 12, further comprising a film break sensing roller.

16. The apparatus of claim 15, wherein the film break sensing roller is operatively coupled to the mechanical input/output ratio control.

17. The apparatus of claim 16, wherein a connection between the film break sensing roller and the mechanical input/output ratio control prevents output of the mechanical input/output ratio control when a film break is sensed.

18. The apparatus of claim 12, wherein the rotational drive system includes one of a turntable, a rotatable ring, and a rotatable arm.

19. The apparatus of claim 12, wherein the virtual film accumulator includes an arrangement of rollers configured to provide at least thirteen additional inches of film to a film path extending between the dispenser and the load.

20. The apparatus of claim 12, further comprising a film drive down roller positioned to continuously engage at least a portion of a width of the film web in a film path from the dispenser to the load, the film drive down roller being selectively moveable between a vertical position and a tilted film drive down position.

21. The apparatus of claim 20, further comprising at least one roping element.

22. The apparatus of claim 12, further comprising a film cutting and sealing assembly.

23. The apparatus of claim 12, wherein the mechanical input/output ratio control includes an input shaft, and further comprising a mechanical connector connecting the rotational drive system to the input shaft.

24. The apparatus of claim 12, wherein the mechanical input/output ratio control includes a rotatable input shaft and a rotatable output shaft, wherein the rotatable output shaft drives a downstream roller of the pre-stretch assembly.

25. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly;

a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle;

a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser; and

a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a film length extending between the downstream pre-stretch roller and the final roller is at least thirteen inches.

26. An apparatus for stretch wrapping a load, the load having a shortest wrap radius and a longest wrap radius, the apparatus comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a pre-stretch assembly;

a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle;

a mechanical input/output ratio control configured to set a ratio of relative rotation speed to pre-stretch speed, an output of the mechanical input/output ratio control driving the pre-stretch assembly to dispense a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser; and

a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a length of film extending from the second pre-stretch roller to the final roller has a length greater than a difference between the shortest wrap radius and the longest wrap radius of the load.

27. A method for stretch wrapping a load, comprising:

determining a girth of a load to be wrapped;

determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser around the load;

dispensing the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser around the load; and

rotating the packaging material dispenser around the load at a speed sufficient to wrap the predetermined substantially constant length of pre-stretched packaging material around the load before the pre-stretched packaging material recovers from pre-stretching.

28. The method of claim 27, wherein determining a substantially constant length of pre-stretched packaging material to be dispensed includes determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser around the load based on the girth of the load.

29. The method of claim 27, further comprising setting a ratio of relative rotation speed to pre-stretch speed.

30. The method of claim 29, further comprising maintaining the set ratio of rotational speed to pre-stretch speed through a mechanical input/output ratio control.

31. The method of claim 30, further comprising driving the pre-stretch assembly to dispense the predetermined substantially constant length of pre-stretched packaging material with an output of the mechanical input/output ratio control.

32. The method of claim 31, wherein the driving the pre-stretch assembly includes providing an input to the mechanical input/output ratio control from a rotational drive rotating the dispenser.

33. The method of claim 32, wherein driving the pre-stretch assembly further includes providing an input to a pre-stretch roller of the pre-stretch assembly from an output of the mechanical input/output ratio control.

34. The method of claim 29, further comprising maintaining the set ratio of relative rotation speed to pre-stretch speed during a primary portion of a wrap cycle through an electronic control.

35. The method of claim 27, further comprising sensing a break in the film during a wrapping cycle.

36. The method of claim 35, further comprising stopping dispensing the predetermined substantially constant length of pre-stretched packaging material upon sensing the film break.

37. A method for stretch wrapping a load, comprising:

determining a girth of a load to be wrapped;

determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser around the load;

dispensing the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser around the load; and

rotating the packaging material dispenser around the load at a speed sufficient to permit the predetermined substantially constant length of pre-stretched packaging material of a revolution to conform to at least two successive corners of the load substantially simultaneously.

38. The method of claim 37, further comprising setting a ratio of relative rotation speed to pre-stretch speed.

39. The method of claim 38, further comprising maintaining the set ratio of relative rotation speed to pre-stretch speed through a mechanical input/output ratio control.

40. The method of claim 38, further comprising maintaining the set ratio of relative rotation speed to pre-stretch speed during a primary portion of the wrap cycle through an electronic control.

41. The method of claim 39, further comprising driving the pre-stretch assembly to dispense the predetermined substantially constant length of pre-stretched packaging material with an output of the mechanical input/output ratio control.

42. The method of claim 41, wherein driving the pre-stretch assembly includes providing an input to the mechanical input/output ratio control from a rotational drive rotating the packaging material dispenser.

43. The method of claim 42, wherein driving the pre-stretch assembly further includes providing an input to a pre-stretch roller of the pre-stretch assembly from an output of the mechanical input/output ratio control.

44. The method of claim 40, further comprising varying the set ratio of relative rotation speed to pre-stretch speed during one of an initial acceleration and a final deceleration portion of the wrap cycle through an electronic control.

45. A method for stretch wrapping a load, comprising:

providing a packaging material including a pre-stretch portion;

providing relative rotation between the packaging material dispenser and the load;

setting a ratio of relative rotational speed to pre-stretch speed with a mechanical input/output ratio control;

driving the pre-stretch assembly through an output of the mechanical input/output ratio control to dispense a predetermined substantially constant length of pre-stretched packaging material during each revolution of the relative rotation between the load and the packaging material dispenser; and

compensating for variations in film demand during each revolution of the relative rotation as the dispensed predetermined substantially constant length of pre-stretched packaging material travels from the dispenser to the load.

46. The method of claim 45, further comprising continuously engaging the film web in a film path between the dispenser and the load with at least one film drive down roller; and

selectively driving down a portion of the film web in the film path with the at least one film drive down roller.

47. The method of claim 46, further comprising roping a portion of the film web into a cable.

48. The method of claim 47, further comprising wrapping the roped portion of the film web spirally around the load.

49. The method of claim 45, further comprising sealing a final tail of packaging material to the load.

50. The method of claim 49, further comprising severing the final tail of film.

51. A method for stretch wrapping a load, comprising:

determining a substantially constant length of pre-stretched packaging material to be dispensed for each revolution of a packaging material dispenser relative to the load ;

using a rotational drive to provide relative rotation between the packaging material dispenser and the load;

setting a ratio of relative rotational speed to pre-stretch speed;

driving the pre-stretch portion at the set ratio through a mechanical connection to the rotational drive to dispense the predetermined substantially constant length of pre-stretched packaging material during each revolution of the relative rotation between the load and the packaging material dispenser; and

damping variations in forces acting on the dispensed predetermined substantially constant length of pre-stretched packaging material as it travels from the dispenser to the load.

52. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including a powered pre-stretch portion;

a rotational drive system for providing relative rotation between the load and the dispenser during the wrapping cycle; and

an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle.

53. The apparatus of claim 52, wherein the predetermined ratio is set such that the pre-stretch portion dispenses a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser.

54. The apparatus of claim 52, wherein the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle.

55. The apparatus of claim 52, wherein the electronic control is configured to stop the relative rotation upon sensing a film break.

56. The apparatus of claim 52, further comprising a virtual film accumulator configured to accommodate variations in film demand as the film is dispensed.

57. The apparatus of claim 56, wherein the virtual film accumulator includes an arrangement of rollers configured to provide at least thirteen additional inches of film to a film path extending between the dispenser and the load.

58. The apparatus of claim 52, wherein the rotational drive system includes one of a turntable, a rotatable ring, and a rotatable arm.

59. The apparatus of claim 52, further comprising a film drive down roller positioned to continuously engage at least a portion of a width of the film web in a film path from the dispenser to the load, the film drive down roller being selectively moveable between a vertical position and a tilted film drive down position; and

at least one roping element.

60. The apparatus of claim 52, further comprising a film cutting and sealing assembly.

61. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a powered pre-stretch assembly;

a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle;

an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle; and

a final roller positioned a predetermined distance from the downstream pre-stretch roller, wherein a film length extending between the downstream pre-stretch roller and the final roller is at least thirteen inches.

62. The apparatus of claim 61, wherein the predetermined ratio is set such that the pre-stretch portion dispenses a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser.

63. The apparatus of claim 61, wherein the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle.

64. The apparatus of claim 61, further comprising a film break sensing roller.

65. The apparatus of claim 64, wherein the electronic control is configured to stop the relative rotation upon sensing a film break.

66. The apparatus of claim 61, wherein the rotational drive system includes one of a turntable, a rotatable ring, and a rotatable arm.

67. The apparatus of claim 61, further comprising a film drive down roller positioned to continuously engage at least a portion of a width of the film web in a film path from the dispenser to the load, the film drive down roller being selectively moveable between a vertical position and a tilted film drive down position; and

at least one roping element.

68. The apparatus of claim 61, further comprising a film cutting and sealing assembly.

69. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including a powered pre-stretch portion;

a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle;

an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle, wherein the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle; and

a virtual film accumulator configured to accommodate variations in film demand as the film is dispensed.

70. The apparatus of claim 69, wherein the virtual film accumulator includes an arrangement of rollers configured to provide at least thirteen additional inches of film to a film path extending between the dispenser and the load.

71. The apparatus of claim 69, wherein the predetermined ratio is set such that the pre-stretch portion dispenses a predetermined substantially constant length of pre-stretched packaging material for each revolution of the relative rotation between the load and the packaging material dispenser.

72. The apparatus of claim 69, further comprising a film break sensing roller.

73. The apparatus of claim 72, wherein the electronic control is configured to stop the relative rotation upon sensing a film break.

74. The apparatus of claim 69, wherein the rotational drive system includes one of a turntable, a rotatable ring, and a rotatable arm.

75. The apparatus of claim 69, further comprising a film drive down roller positioned to continuously engage at least a portion of a width of the film web in a film path from the dispenser to the load, the film drive down roller being selectively moveable between a vertical position and a tilted film drive down position; and

at least one roping element.

76. The apparatus of claim 69, further comprising a film cutting and sealing assembly.

77. An apparatus for stretch wrapping a load, comprising:

a packaging material dispenser for dispensing a film web, the packaging material dispenser including an upstream pre-stretch roller and a downstream pre-stretch roller within a powered pre-stretch assembly;

a rotational drive system providing relative rotation between the load and the dispenser during the wrapping cycle;

an electronic control configured to maintain a predetermined ratio between a drive powering the pre-stretch portion and the rotational drive system during a primary portion of a wrap cycle, wherein the electronic control is configured to vary the predetermined ratio during at least one of initial acceleration and final deceleration of the wrap cycle; and

a final roller positioned a predetermined distance from the downstream pre-stretch roller, the predetermined distance being such that at least a portion of a length of film extending between the downstream pre-stretch roller and the final roller acts to dampen variations in forces acting on the pre-stretched packaging material as it travels from the dispenser to the load.

78. A method for stretch wrapping a load, comprising:

providing a packaging material including a powered pre-stretch portion;

providing relative rotation between the packaging material dispenser and the load;

setting a ratio of relative rotational speed to pre-stretch speed;

electronically maintaining the set ratio during a primary portion of the wrap cycle to dispense pre-stretched packaging material; and electronically varying the set ratio during at least one of an initial acceleration and a final deceleration of the packaging material dispenser relative to the load.

79. The method of claim 78, further comprising damping variations in forces acting on the dispensed pre-stretched packaging material as it travels from the dispenser to the load.

80. The method of claim 78, further comprising continuously engaging the film web in a film path between the dispenser and the load with at least one film drive down roller; and

selectively driving down a portion of the film web in the film path with the at least one film drive down roller.

81. The method of claim 80, further comprising roping a portion of the film web into a cable.

82. The method of claim 78, further comprising sealing a final tail of packaging material to the load.

83. The method of claim 82, further comprising severing the final tail of film.

84. The method of claim 78, further comprising using a film break sensing roller to sense a break in the film during the wrap cycle.

85. The method of claim 84, further comprising discontinuing dispensing pre-stretched packaging material upon sensing a film break.

86. The method of claim 78, wherein electronically maintaining the set ratio during a primary portion of the wrap cycle to dispense pre-stretched packaging material includes dispensing a predetermined substantially constant length of pre-stretched packaging material per revolution of the dispenser relative to the load.

87. A method for stretch wrapping a load, comprising:

providing relative rotation between the packaging material dispenser and the load;

setting a ratio of relative rotational speed to pre-stretch speed;

electronically maintaining the set ratio during a primary portion of the wrap cycle to dispense the predetermined substantially constant length of pre-stretched packaging material during each revolution of the packaging material dispenser relative to the load during the primary portion of the wrap cycle;

electronically varying the set ratio upon sensing at least one of a film break and slack film; and

and damping variations in forces acting on the dispensed predetermined constant length of pre-stretched packaging material as it travels from the dispenser to the load.

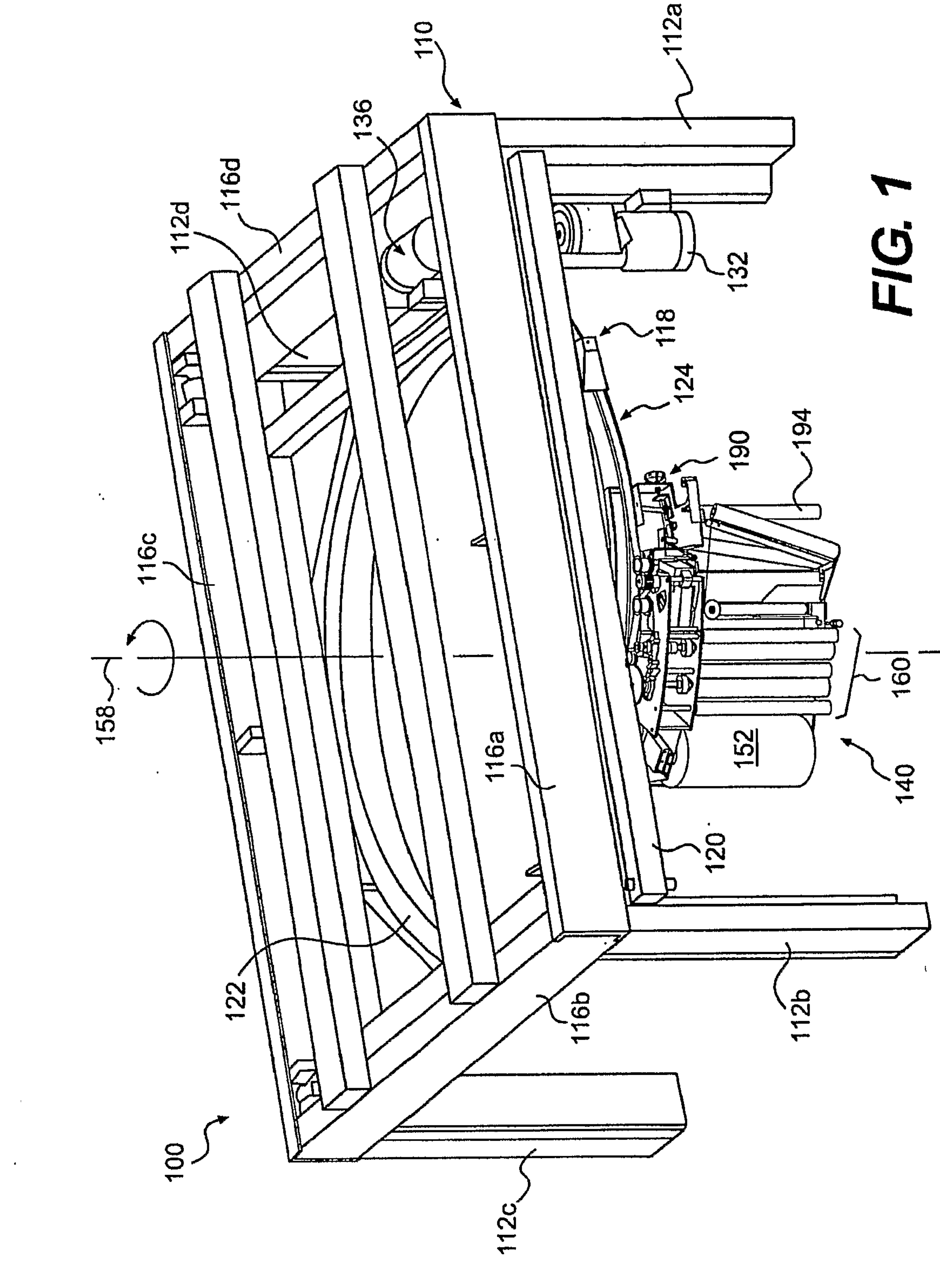
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FIG. 1

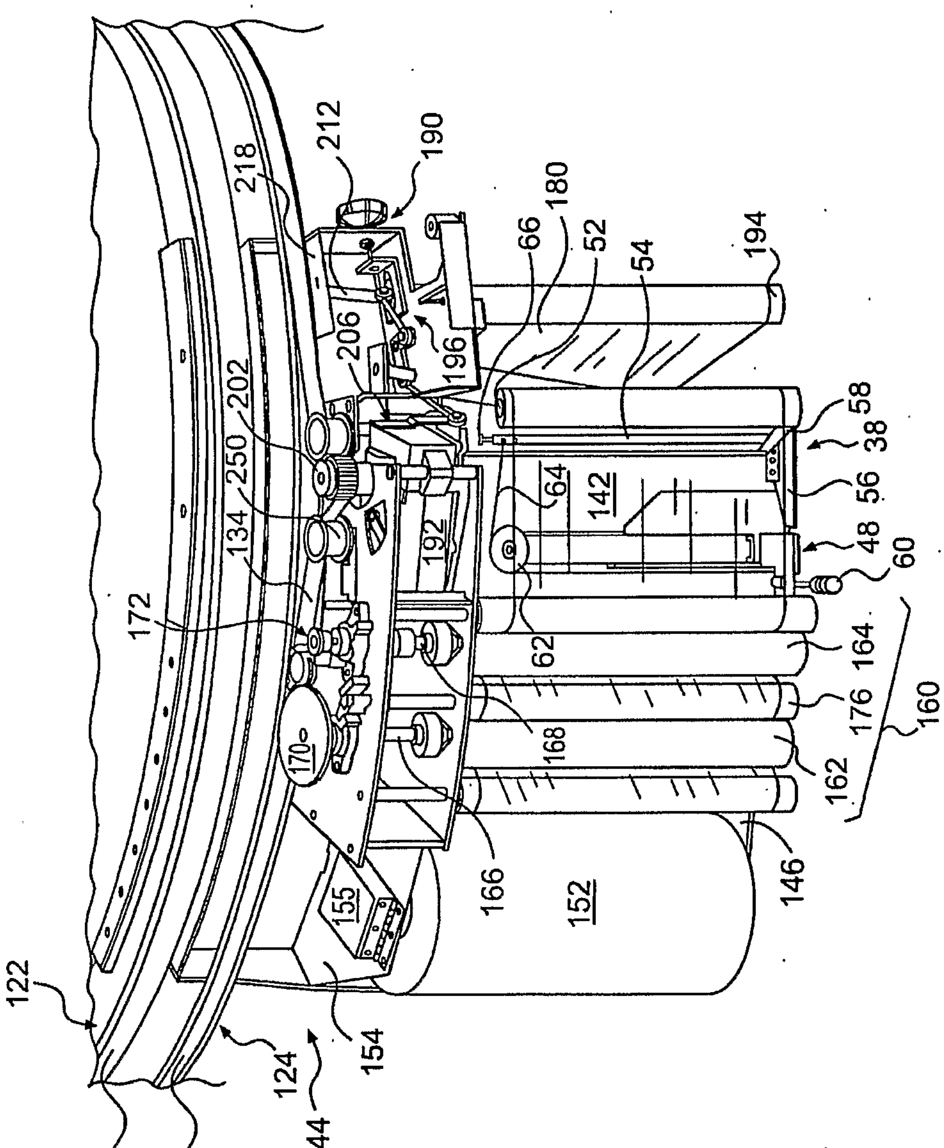
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FIG. 2

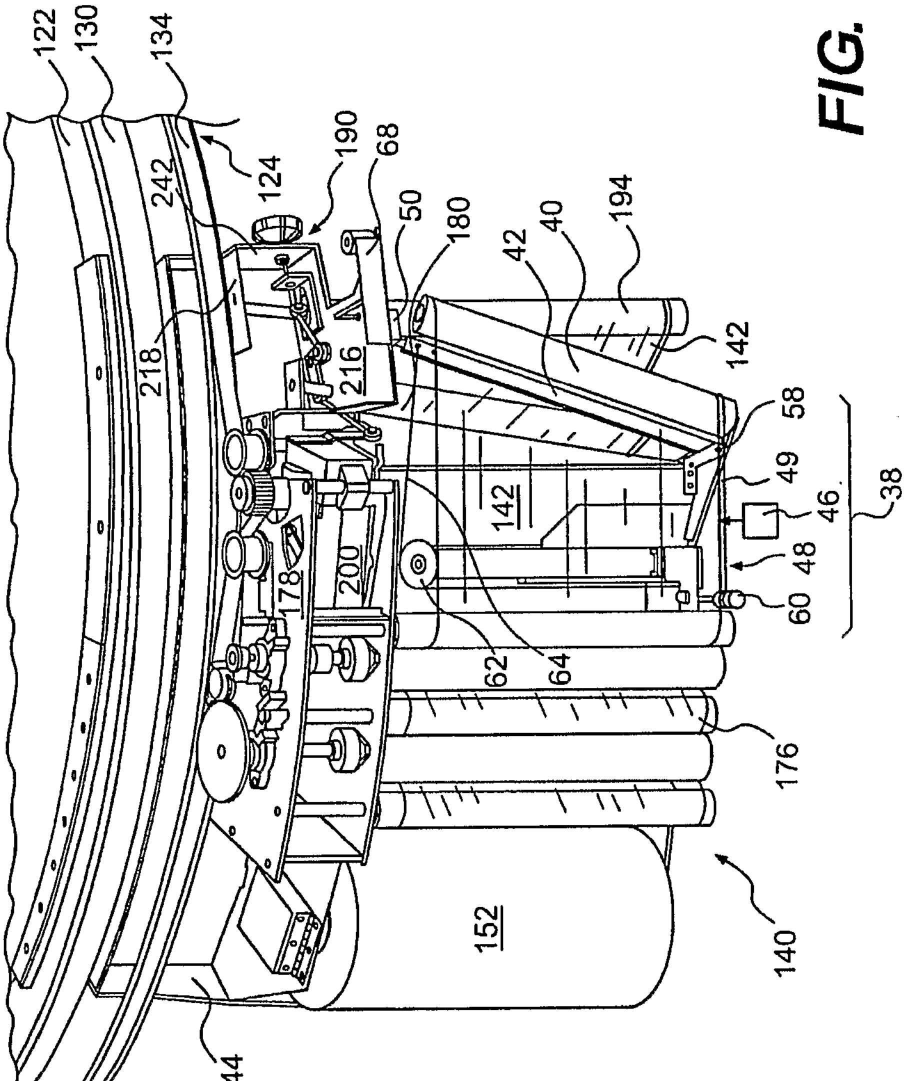
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FIG. 3A

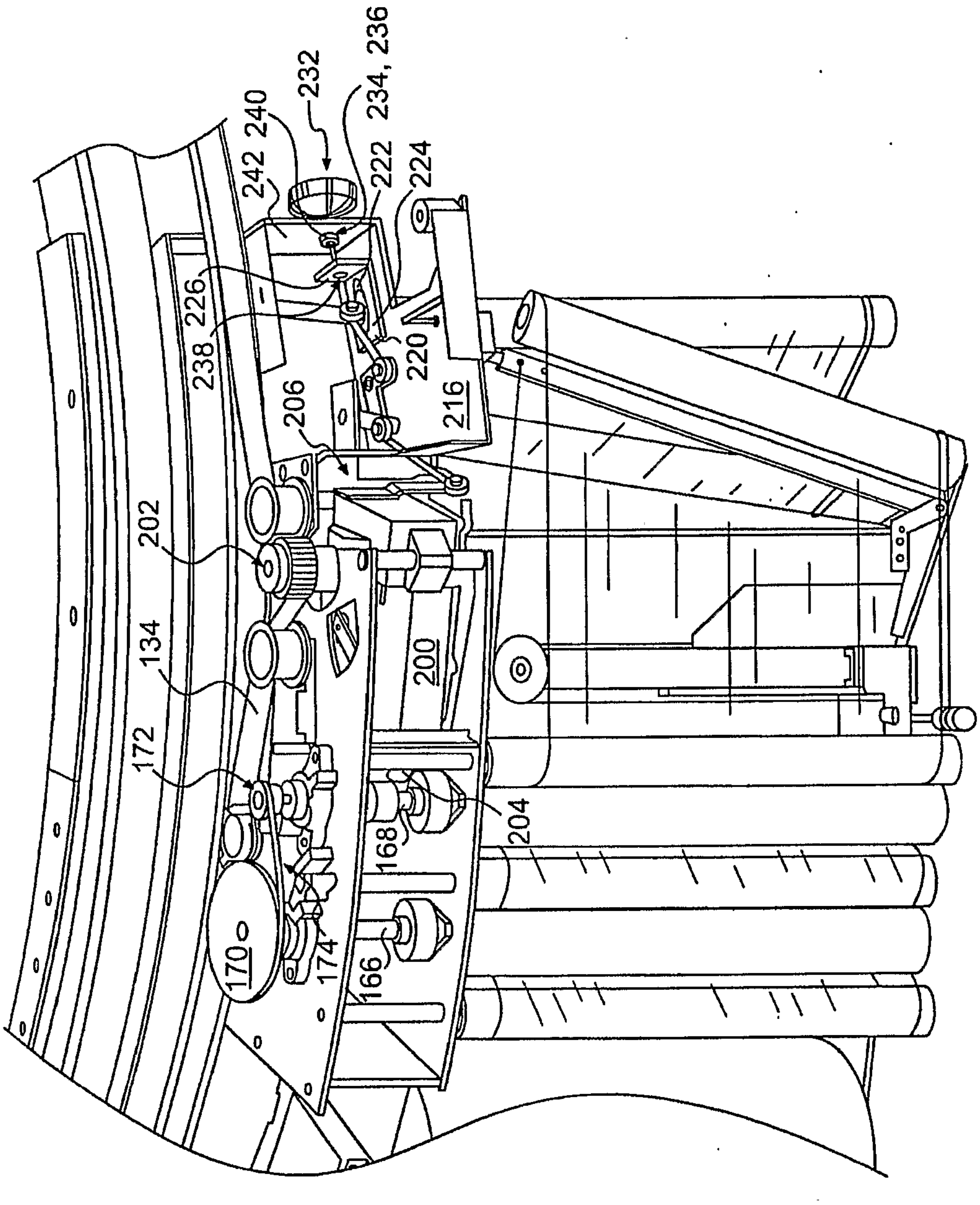
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FIG. 3B

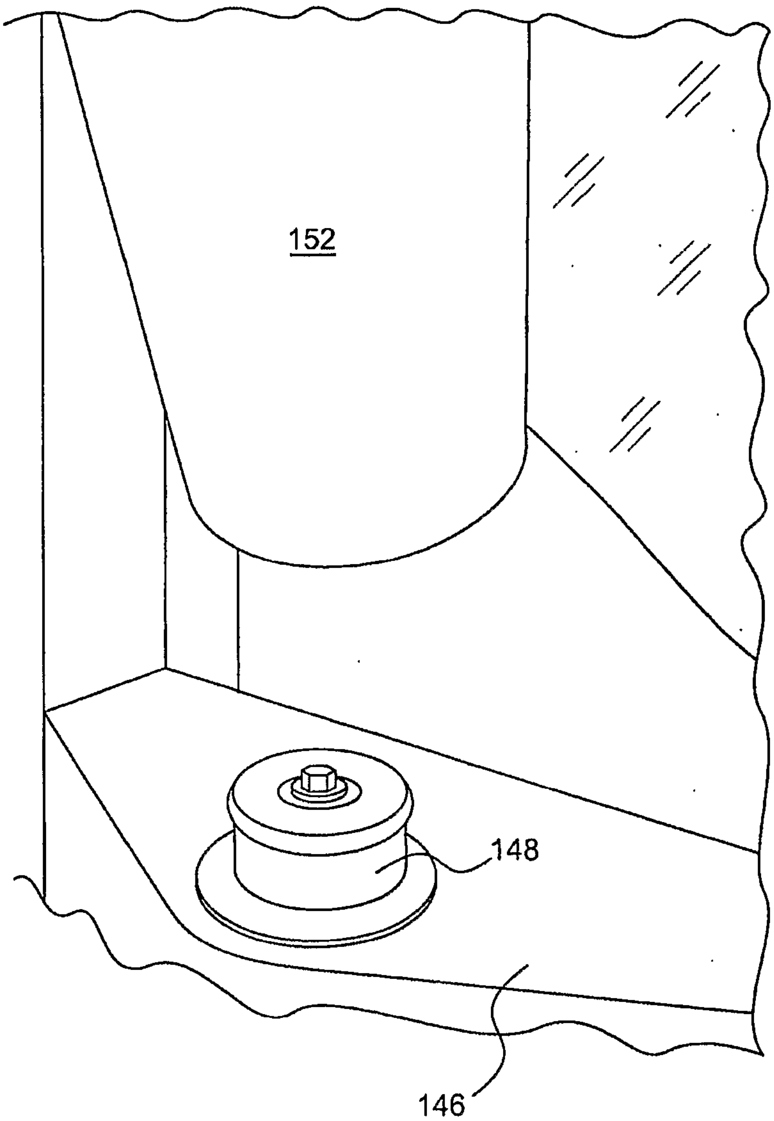


FIG. 4

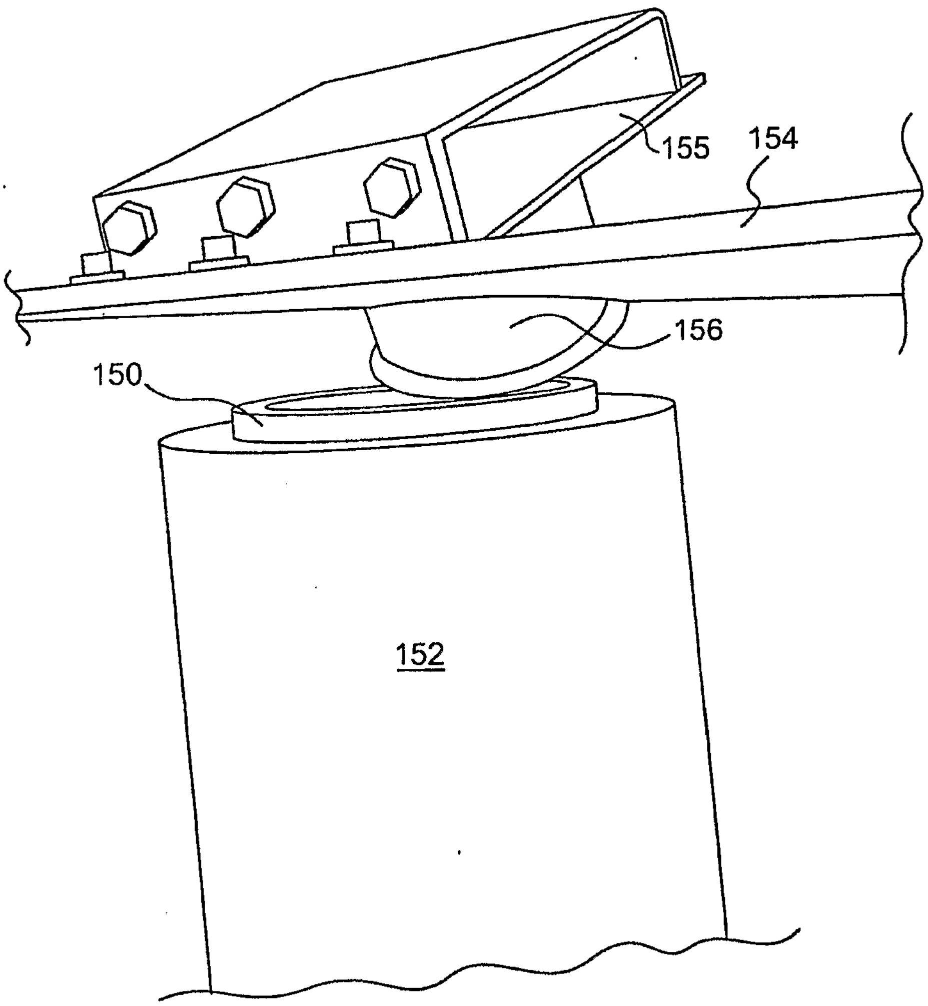
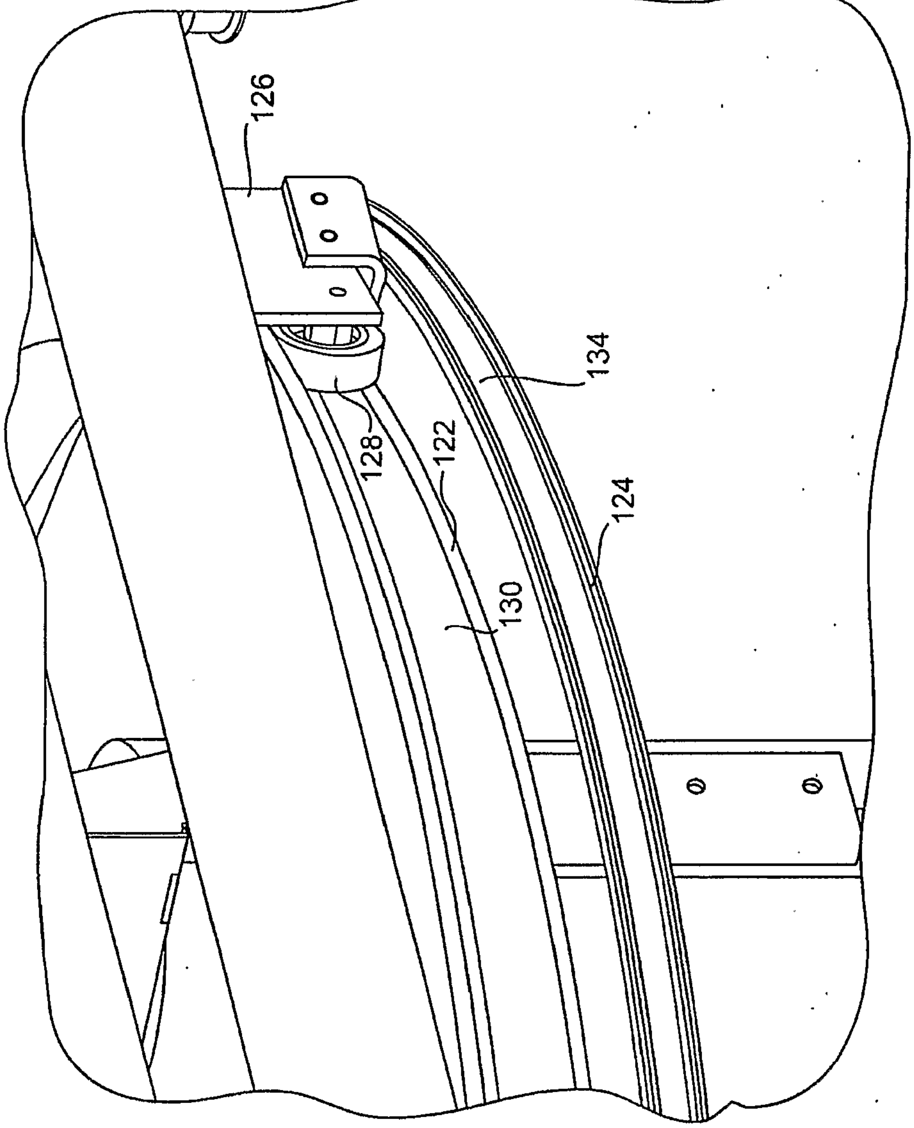


FIG. 5

FIG. 6



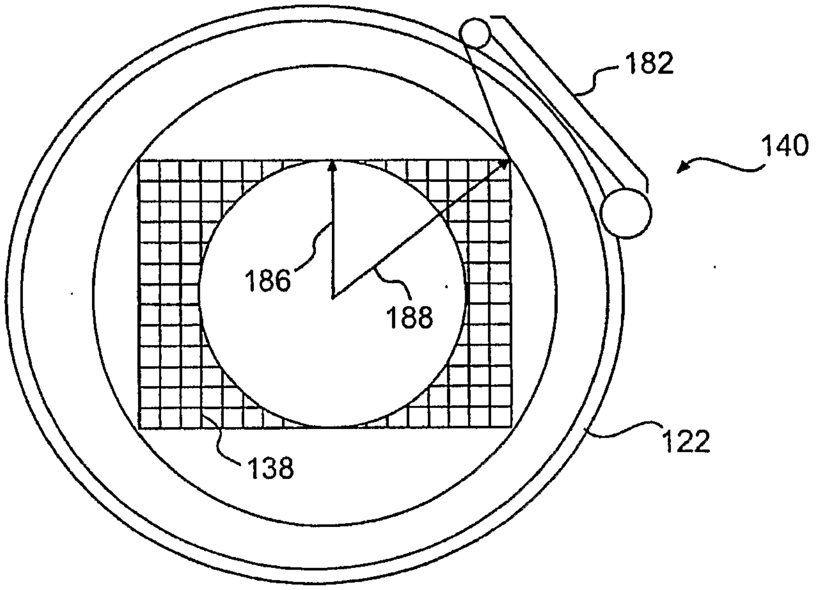


FIG. 7

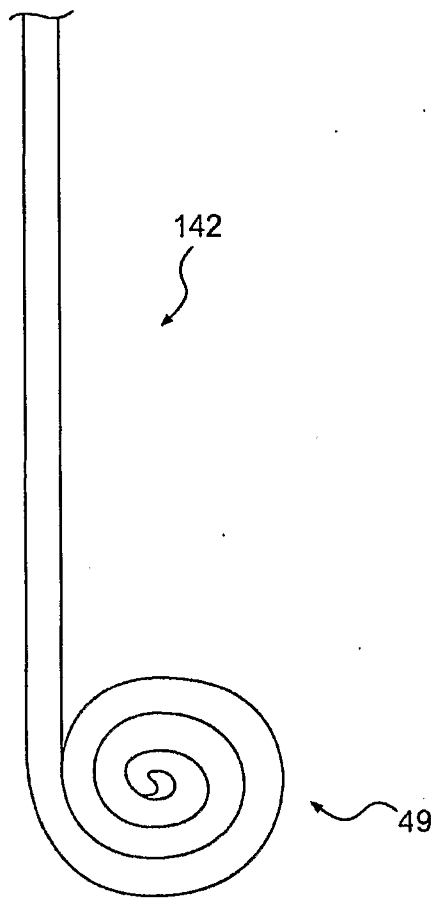


FIG. 8

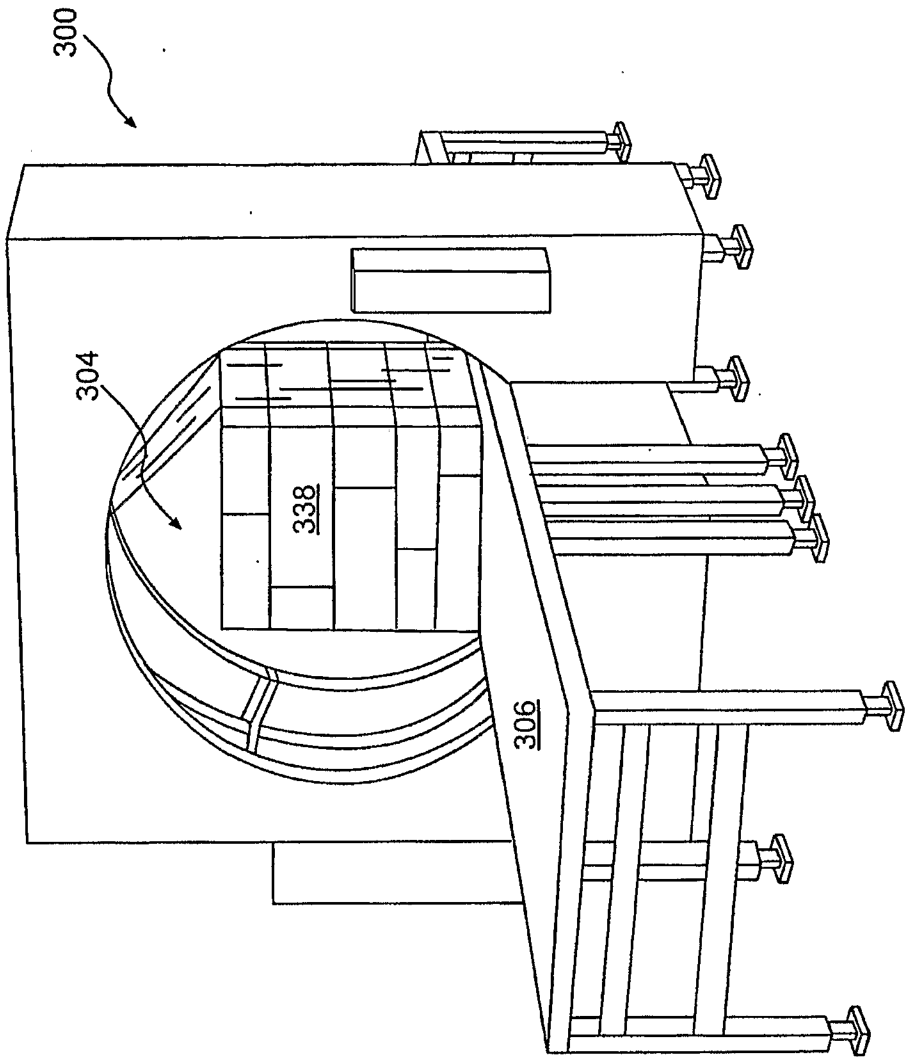


FIG. 9

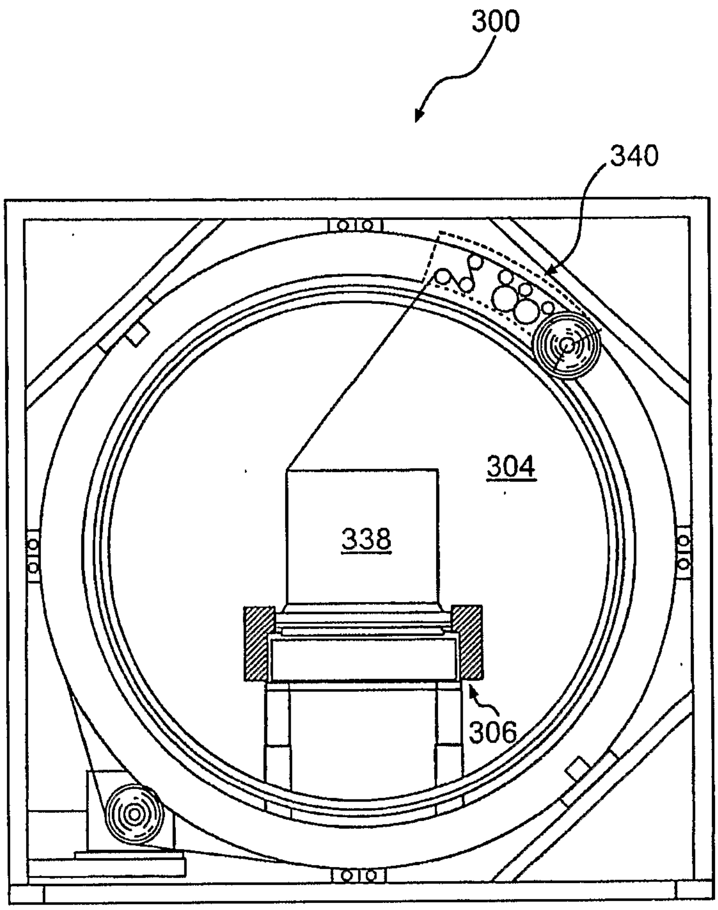


FIG. 10

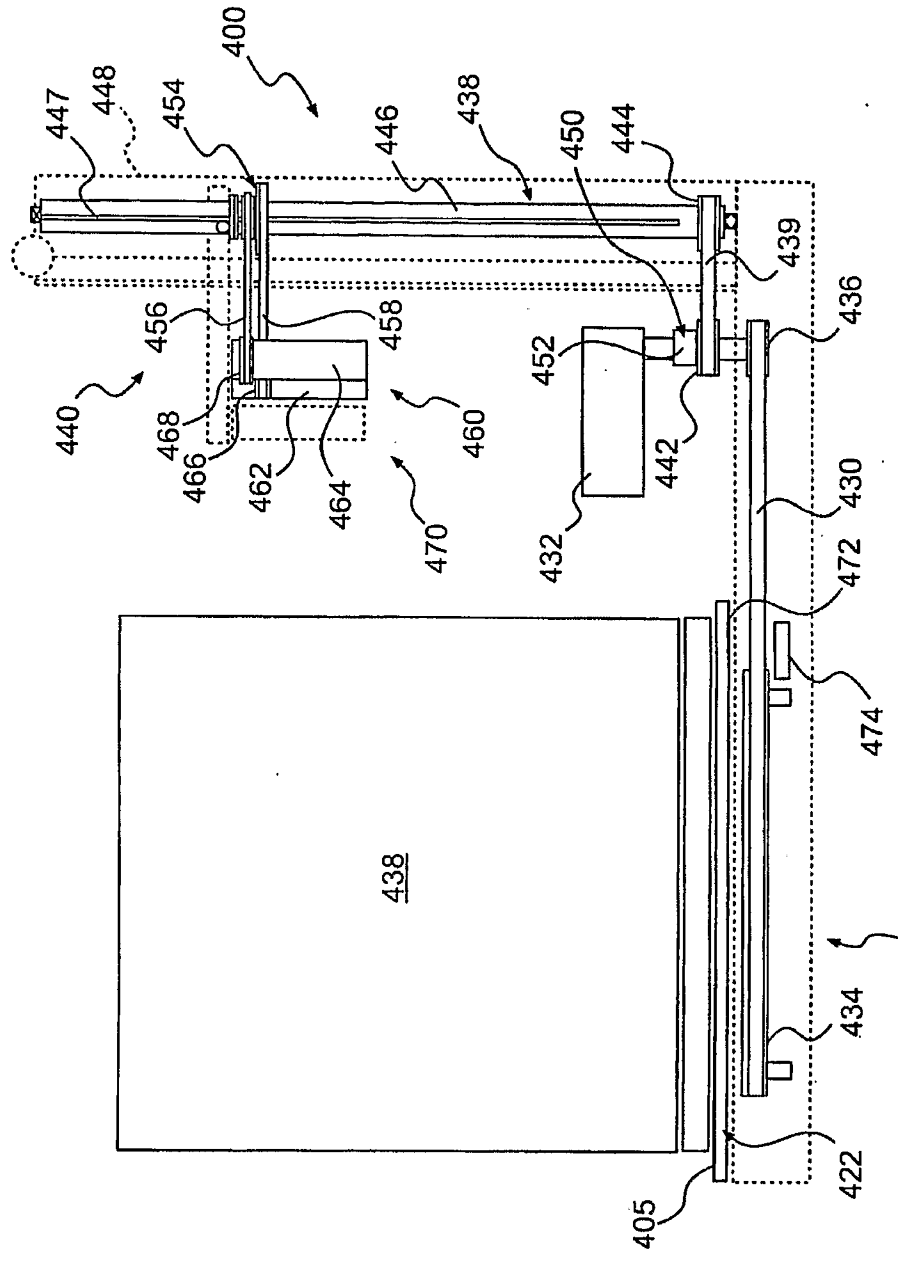

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FIG. 11

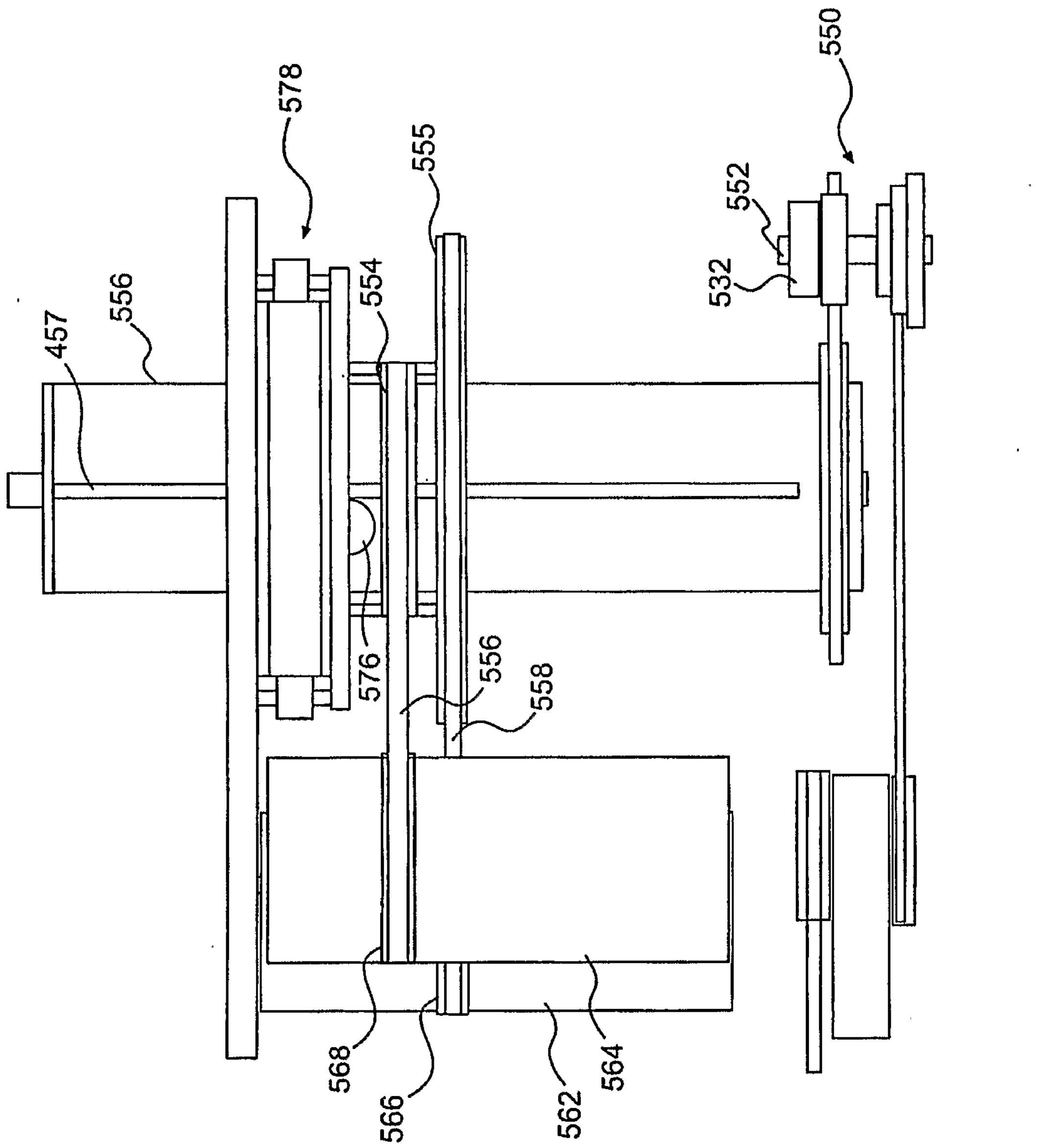

FIG. 12

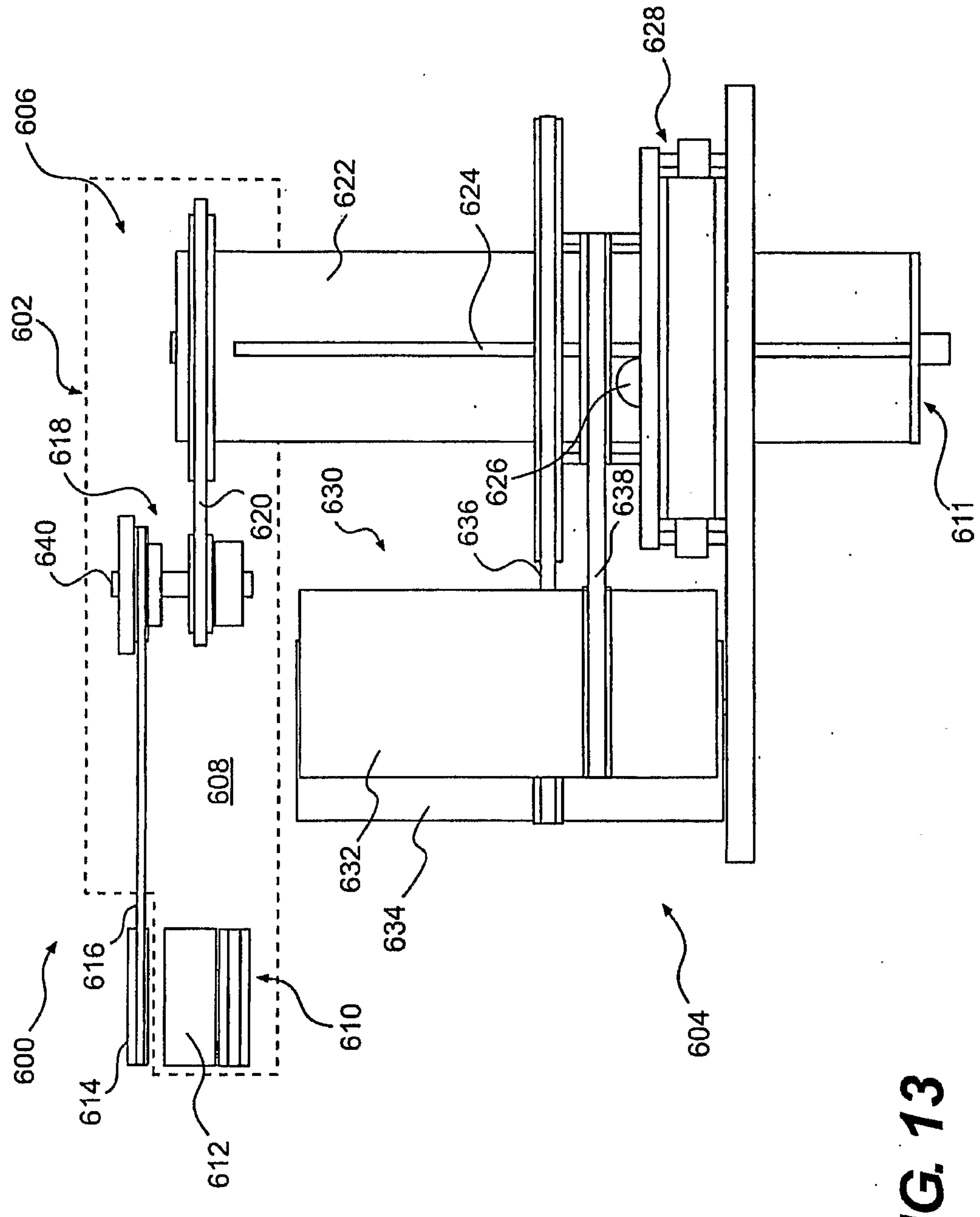
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FIG. 13