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(54) COMPRESSIVE TREATMENT OF WEB MATERIALS

(71) I, RICHARD RHODES WALTON, a citizen of the United States of America, of 10 West Hill Place, Boston, Massachusetts, United States of America, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to fine, uniform longitudinal compressive treatment of fibrous webs for changing their physical properties, for example to impart shrink-resistance, stretchiness, increased density, softness, texture, improved filtering action, and other properties to the web.

In U.S. Patent Specification 3260778 I have described a machine for the purpose but this machine can only be used on a limited number of web materials because it includes a stationary feeding shoe which exerts a drag on the web and a retarding blade which is liable to catch fibres and degrade the web. Certain sticky or high friction webs cannot be treated on this machine because of friction with the shoe and certain double layer fabrics and thick webs cannot withstand the shear forces applied between the shoe and the driven roll. It is the object of the present invention to over-come these deficiencies.

The invention accordingly provides a method of imparting longitudinal compressive treatment to a web, comprising advancing the web by a pair of oppositely rotating rolls forming a drive nip and having rigid surfaces, retarding the web on the exit side of the nip between the rolls by a damming effect produced by a retarding member, which presents a frontal surface inclined to the direction of travel of the web and, downstream of the frontal surface, a confinement surface more nearly parallel to the direction of travel of the web than the frontal surface for engagement with a face of the compressed web after the web has passed over said frontal surface, and maintaining the frontal surface of the retarding member in an operational position at a distance downstream from the nip centre line not exceeding 5% of the sum of the diameters of the rolls, said operational position establishing between the roll surfaces and said frontal surface a longitudinal compression cavity that confines a longitudinally compacted moving column of web without coarse pleating or wrinkling of the web and web that is progressively advanced by said drive rolls being compressed against the end of said moving column confined in said cavity. In operation of the method, the web after being advanced by the moving roll surfaces acting on its opposite sides is suddenly placed in the longitudinally compressed state. An unusually high state of pressure is possible because the opposing forces act over the very short distance available in the extremely short compression cavity. Wrinkling and coarse pleating under the pressure conditions are avoided because of the narrow face-wise engagement of the web afforded by the slightly diverging roll surfaces and the narrow exit passage from the compression chamber. Since the web attains the highly compressed state so soon after passage through the roll nip, and due to the diverting effect of the inclined frontal surface of the retarding member, fibres in the web have little tendency to be caught and damaged at the transition from moving to stationary parts of the machine, notwithstanding the high pressure in the compression chamber. The web emerges from the machine without being subjected to shear forces or to frictional drag over a long distance.

The invention includes a machine for performing the above method, comprising a pair of oppositely rotating rolls that have rigid surfaces, a retarding device on the exit side of the nip between the rolls, the retarding device being formed by at least one retarding member which has a frontal surface inclined to the direction of travel of the web and, downstream of said frontal surface, a surface for engagement with the web after it has passed over said frontal surface which is more nearly parallel to the direction of travel of the web than the frontal surface and means for maintaining the frontal surface of the retarding member in an operational position in which it is disposed adjacent one of the rolls downstream from the nip centre line at a distance not exceeding 5% of the sum of the diameters of the rolls.

The method and machine according to the invention are applicable to compaction and shrink-proofing of knitted goods, mechanical softening and compacting of non-woven fabrics including those which are loosely formed, open or thick, and gathering, splaying and otherwise conditioning the fibre assemblage in a web or bat.

The invention is based on the appreciation that the driving rolls, the retarding member, and the material being treated form a dynamic system, in which certain system parameters, if carefully observed, will result in the desired treatment. Specifically it has been established that for the fine treatments being sought, the treatment point at which the web is slowed down and caused to compact longitudinally must be maintained continually inside the actual drive nip, in opposition to forces presented by the moving roll surfaces bounding both sides of the compression cavity, with the inclined frontal surface of the retarding member retained in operation at the above-noted critical distance downstream of the nip centre line; and with the web-engaging surface of the retarding member downstream of the frontal surface disposed more nearly parallel to the direction of travel of the web than the frontal surface.

Preferably the retarding member is maintained in its operational position by a resiliently applied force which opposes the passage of the web through the compression cavity. The retarding member is preferably a thin flexible spring member; but in certain special cases where the treated material presents a compacted column which tends by itself to blossom to greater thickness, sufficient resiliency is provided by the compacted material itself. In maintaining the operational position variations in the balance between the various friction and drag forces and the nature of the constriction offered by the retarding member affect the treatment. In certain preferred embodiments, two drive rolls are employed having the same surface friction characteristics and driven at the same speed, and a pair of retarding members are employed, which in running condition, act in a balanced way upon the material.

Alternatively a single retarding member may be employed which has an upstream part supported next to one of the rolls and a downstream part thereof conforming to the curvature of the opposite roll, the latter roll preferably having a lesser driving force than the other roll. This lesser driving force may be provided by driving the roll at a slower speed, or by providing a surface which is not as rough as that of the other roll. The balance of forces may be adjusted by providing surface roughness on the active surface of the retarding member as by plasma coating with an abrasive material.

Certain embodiments of the invention will now be described, by way of example with reference to the accompanying drawings, in which:—

Figure 1 is an end view of a machine according to the invention and Figure 1*a* is a perspective view thereof;

Figures 2 and 3 are views on a magnified scale of the elements of this machine that form the compression cavity, shown repsectively in starting and running positions; while Figure 4 is a diagrammatic view illustrating action of the material in an intermediate position between the positions of Figures 2 and 3;

Figure 5 is a perspective view of a retarding member used in this embodiment while Figure 5*a* shows an alternative retarding member;

Figures 6, 7 and 8 are views corresponding respectively to Figures 2, 4 and 3, illustrating a machine with a single spring retarding member;

Figure 9 is a view similar to Figure 2 of a machine employing a single retarding member while Figure 10 is a view on an enlarged scale of a variation thereof;

Figures 11-13 are views similar to Figures 6-8 of a machine employing rigid retarding faces; and

Figure 14 is an end view similar to Figure 1 of a machine employing linear adjustment of the retarding members.

The machine shown in Figure 1 includes a roll 12, e.g. of 5 inch diameter, mounted in a bearing 40 supported by a base 42 and a roll 10 of the same diameter mounted in a bearing 44 and resiliently biased against the roll 12 by compression springs 46 bearing against an upper plate 48 held by rods 50 projecting from the base 42. An adjustable stop nut 52 limits downward movement of the roll 10 to establish the starting gap between the rolls. The rolls are of rigid material and are driven in the direction of the arrows by means not shown.

Arms 54 and 56 are pivoted about axes 10*a* and 12*a* at each end of the respective rolls and each arm carries a retarding assembly 29, the details of which will be described later.

A double-acting air cylinder 60 is pivoted to the upper arm 54 at 55 at each side of the machine and an extension 61 of the piston rod of each cylinder is pivoted at 57 to the lower arm 56. Outward movement of the pistons forces arms 54 and 56 apart, causing movement of the upper retarding assembly out of the nip to the rest position shown in Figure 1; inward movement draws the upper assembly toward a minimum spaced working position established by a stop 64. The stops 64 for the two pistons are linked by a chain 65, Figure 1*a*, to have equal movement during adjustment. The linkage provided by the rods 61 ensures that if one retarding assembly moves out of the nip the other tends to move toward the nip. An adjustable lift rod 62, urged by a spring 63, prevents gravity motion of the lower arm, thus making it possible to establish a position in which the lower retarding assembly 29 is inserted more deeply into the nip than the upper retarding assembly, with a predetermined amount of resilience.

For setup of the machine, without the web in place, the stop nuts 52 at each end of the roll assembly are adjusted to establish the starting gap between the rolls at a spacing equal to a desired fraction of the thickness of the particular web selected for treatment. A nut 62*a* on the lift rod 62 is then adjusted to impose a chosen degree of resilient compressive force with which the lower retarding assembly 29 is lifted against gravity and urged into the nip. The stops 64 are then adjusted to establish the desired minimum spacing between the two assemblies. The air presure source for the air cylinders 60 can then be set, to establish the degree of resilient force tending to hold the two assemblies at the minimum spacing set by the stops 64.

With air pressure supplied to the air cylinders 60, the arms 54 and 56 are drawn together, carrying the upper retarding assembly into the nip, the lower retarding assembly retaining approximately its original position. The drive rolls 10, 12 are then set in motion to feed the web toward the retarding device, whose details will now be described.

In the embodiment of Figures 1-4, each of the retarding assemblies 29, see Figure 5, is provided with an initial part forming a dam and is of a two-part construction which incorporates a resilient compensatory action. The parts consist of a spring plate 30, e.g. of blue spring steel, having a bent-down frontal curve at the end 31 converging toward its roll, and a carrier knife blade 32 having a leading part 33 which extends slightly upstream of the end 31 of the plate 30. Both parts extend continuously for the full length of the rolls. The forward end 31 of the spring plate 30 is free, but bears for support on the carrier blade 32, and its other end is fixed in a holder 34 (Figure 5) attached to the carrier blade 32.

As shown, the frontal portion 31 of the plate 30 forms an acute angle α with the path D of the oncoming web within the range of 20° to 60°. The web-contactable surface 35 of the plate 30 downstream of the frontal portion 31 is more closely parallel to the path D.

The operative sequence of the machine is as follows: After actuation of the air cylinders 60 has drawn the arms 54, 56 together, the position of Figure 2 is attained, in which the lower plate 30 assumes a curvature in conformity with the opposite roll 10 before terminating at the forward end 31 which curves toward the adjacent roll 12. As the web 14 is driven forward by the rolls, Figure 2, it is opposed by the dam formed by the forward end 31 of the lower plate 30 which has substantially filled the nip. This resistance to the flow of the material causes a compacted column to extend upstream in the web to a point X, (Figure 4), close to the nip centre line. As this occurs the lower retarding assembly 29, moves to the left against the pressure of the spring 63 under the influence of the leftward compressive force of the material, finally reaching and being maintained in the position shown in Figure 3. Due to the linkage between the retarding assemblies provided by the rods 61, the upper assembly moves simultaneously upstream to the right from the position of Figure 2 to that of Figure 3. Depending upon the forces generated in the material, the resilient air pressure in the cylinders 60 can be overcome to force both assemblies to the left of the position shown in Figure 3 to further separate the assemblies. As the damming forces produced by the lower spring plate 30 oppose the passage of the material, compaction occurs in the nip, in the extremely short passage A between the retarding assembly and the nip centre line. The length of this passage A does not exceed 5% of the sum of the diameters of the rolls, and is usually less than half that amount. An open space S (Figure 4) between the curved end 31 of each plate 30 and its associated carrier blade 32 enables each plate 30 to deflect toward its blade 32 in response to the forces perpendicular to the plane of the web exerted by the compacted web. During this action the relatively abrupt curvature of the initial part of the spring plate prevents its conplete flattening. In this manner a damming quality can be retained during operation.

In an alternative embodiment, Figure 5*a*, a resilient pad 39, e.g. of silicone rubber, extending the full length of the rolls and adhered to the underside of the leading part 31 of the spring plate 30, maintains the angle of inclination α of the leading part during passage of compacted material. As the spring plate 30 of either embodiment tends to deflect from its unstressed to its stressed, more flattened, position, its tip is free to slide upstream, while still bearing upon carrier blade 32, to facilitate this deflection. Also, downstream portions of the carrier blade serve to maintain the corresponding downstream portion 35 of the plate 30 in resilient contact with the compacted web, so that time-dependent processes can occur to set the treated web before it is released by further downstream movement. Opposition to any tendency of the column to spurt over the dam and shift the point X of initial compaction is assisted by this resilient engagement.

Preferably the spring plates have a thickness of .003 to 0.10 inch, are bent to a general radius of curvature of four to five inches, and have a relatively abrupt bend toward the respective roll at a point 1/4 to 1/8 inch from the upstream end of the spring plate.

The mounting of the spring plates permits them to work relatively to the passing compacted material and relatively to one another and even to vibrate, to aid in the smooth passage of the web between them.

By comparison of Figures 2 and 3 it will be seen that the geometry of the compression cavity is self-adjusting in yet another way between start-up and running conditions. The upper roll is resiliently deflected upwardly by the compressed material, thus automatically reducing any crushing tendency commensurate with the continued compaction of the web, a motion revealing that fluid pressure-like compression forces are generated.

The embodiment just described is suitable for use with very thin materials, and with materials which are not resilient when compacted. It is particularly well suited in instances where identity of treatment of both sides of the web is a vital requirement.

Figures 6-8 show a double bladed retarding device. Only one of the blades 32 carries a spring member 30, which, like the lead spring member in Figure 2, dams the cavity at start-up, even to some extent resiliently conforming to the opposite roll as shown in Figure 6. This retarding assembly moves from the start-up position of Figure 6 through the intermediate position of Figure 7 to the operating position of Figure 8. This embodiment may be employed where identity of treatment of both sides of the material is of reduced concern, and in instances in which the web material itself has a certain degree of resiliency in the compacted state. Indeed it is found to give an acceptable uniformity of treatment to both sides of the web in many instances, with the virtue of requiring fewer parts than the embodiment of Figures 1-4.

Figure 9 shows a two-roll machine employing a single retarding member 70. This retarding member is formed of spring steel sheet, and has for example a thickness t = .010 inch in its rearward portion. The forward portion of length L, e.g. ½ inch, is of reduced thickness, t_1 = .005 inch. The rolls 10, 12 and the retarding member 70 extend throughout the width of the material to be treated. The retarding member 70 has a gradual longitudinal upwardly convex curvature in the unstressed condition throughout its thin portion, with a decreased radius of curvature at its forward tip 71. The member 70 is held in the position shown in Figure 9 with the curved tip 71 bearing directly against the surface of the roll 12 and with the portion to the rear thereof conforming to the curvature of the opposite roll 10. As in the previous embodiments, the effect of the retarding member is to produce a compacted column of material extending to the right of the tip of the retarding member to point X, thus defining the compression cavity within the nip. In the embodiment shown, the roll 12 is driven at a velocity V_1 while the roll 10, which engages the compacted material over length L after compaction, is driven at a slower velocity V_2. In this case both rolls 10 and 12 may be provided with a smooth surface finish such as chrome plate over steel. In the embodiment of Figure 10, which is similar to Figure 9, the rolls 10 and 12 are driven at the same velocity V_2 and the retarding member 70′ has a band, extending over distance L_1, of roughened surface, formed by applying a plasma coating of metal carbide to the spring steel member over this distance. The rolls 10, 12 may also be provided with a plasma coating.

Alternatively the roll 12 may be provided with such a coating, and the roll 10 may have a smoother surface. In both Figures 9 and 10 the retarding members are shown in a running condition. The dotted line position in Figure 10 represents the starting position in which the retarding member substantially fills the nip before the material is driven into contact with it.

In the embodiments so far described the retarding member has maintained resilient engagement with the compacted material. However, certain web materials, e.g. certain needled felts, offer sufficient resiliency to enable the material itself to be the source of resilient compensatory action in the presence of varying compressional forces, and it is possible to use a rigid retarding assembly, as shown in Figures 11-13.

As indicated in Figure 11, the drive rolls 10, 12 rotating as shown by the arrows M, M_1, advance the web 14 between opposed rigid retarding members 16, 19. These members are similar in general construction to the blades 32 and may be mounted in similar fashion in the machine. The retarding members 16, 19 have frontal surface parts 17, 20 inclined to the direction of travel of the web and forming dams positioned in the region where the rolls begin to diverge beyond the nip centre line, which frontally oppose the progress of the web.

The frontal surfaces 17 of the retarding members 16, 19 are sloped and then rounded, merging into flat surfaces 18, 21 which diverge gradually relative to the web path. The passage for the web material accordingly reduces in a short convergent passage from the dimension D_1, between the moving drive rolls to the lesser dimension D_2 between the retarding members 16, 19, in which passage retarding forces are abruptly applied, and then expands to ease the flow of the treated material. While under certain circumstances the retarding members may be rigidly held in the operational position, it is preferred that the leading retarding member 19 be mounted so that it is free to respond to forces exerted by the compacted material to move to the left from the initial position in Figure 11, with the leading part 20 continually hugging the roll surface during this movement, against a suitable spring restraining force denoted by double arrow R. For starting the treatment, the frontal surface 20 of the retarder 19 is positioned at distance A very close to the nip centre line, Figure 11, and the action commences by frontal opposition to the web by the leading retarder 19 and its initial movement to the position of Figure 12. By the time the compacted material passes over the leading parts of both of the retarding members, the longitudinal forces increase sufficiently to force the retarder 19 to the operational position of Figure 13, the size of the entrance between the retarding members being thus self-adjusted in a compensatory manner, and with the rolls spread apart in response to the compressive forces of the process.

In certain cases it is advantageous for both retarding members to be resiliently mounted, e.g. by springs or by pneumatic cylinders so that they may move independently, in dependence upon the spring rates of their respective resilient mounts.

The drive rolls are advantageously provided with wear-resistant surfaces, for example an external chrome layer or a plasma coating of a metal carbide over a steel base. Their surfaces may be smooth or may have a selected roughness, depending upon the driving forces employed and the nature of the treatment desired. The retarding members should also be of suitable hard, wear-resistant material and have polished surfaces in most cases.

It will be understood that the retarding members in effect present a leading entry orifice which imposes the main restriction in a resilient manner to the oncoming material, in a way which prevents cutting or shearing by blades as the compressional forces build up, and this orifice shifts in position in a self-adjusting manner as the treatment establishes itself, in the ways shown in the examples, to achieve extremely fine and controllable treatments.

While the pivotal movement of the arms of the embodiment of Figure 1 has advantage in maintaining the desired relationship of the tips of the retarding members to the rolls throughout the range of movement, other arrangements are possible. For instance, in the embodiment of Figure 14 the lower retarding assembly 29 is mounted on a slide 90, downstream movement being resiliently resisted by an adjustable compression spring 92 while the leading part of the retarding assembly is resiliently biased to follow the contour of the roll surface. The upper retarding assembly 29, which is mounted on a slide 90*a* on a pivoted arm 94 and resisted by a compression spring 92*a*, is biased into the nip by a compression spring 96. For purposes of illustration, Figure 14 shows the upper roll held upwardly in a non-operative position, and exaggerates the thickness of the retarding members. The retarding members themselves may be of any of the previously described constructions.

Since the drive rolls are smooth or only slightly rough, the spring plates 30 will wear relatively slowly. In cases where wear does occur, plates can be simply replaced or they may be adjusted relative to their supports to compensate for the wear. The plates may be insulated from their holders in order to assume the temperature of the machine, or separate heaters may be employed in cases where differential temperatures occur to remedy any distortion problems. The plate assemblies can provide steam, hot air or treatment gas distribution chambers, and the resilient plates can be perforated to admit such gases to the fabric both in the compression cavity in advance of the retarding assembly and in the retention passage following the retarding orifice.

To further explain operation according to the invention, during start-up and opposition to advance of the web by the retarding members reference will again be made to Figures 4, 7, 9, 10 and 11. Oncoming material is longitudinally compacted in the confines of the diverging passage defined by the moving rolls, downstream of the nip centre line, and upstream of the retarding members. The retarding forces are thus transmitted upstream through a compacting column of web to a line x, at which the grip of the drive rolls on the material is first overcome. Further oncoming untreated material reaching the line x slips relative to the drive rolls and is longitudinally compacted against the already compacted column, while the column is continuously forced to emerge through the restricted region formed by the leading parts of the retarding members. The line x can shift to the right, toward the nip centre line, if the compacted material forces the rolls apart from their original position. In any event, the retarding members are maintained in a position such that the line x of initial compaction continually remains upstream from them, the material being confined by the gradually diverging, moving roll surfaces as it is longitudinally compacted. The entire action upon the material thus occurs in essentially a straight line across the width of the web with both sides of the material exposed to similar conditions during the driving and retarding stages and with only light crushing forces on the web perpendicular to the web plane.

In machines according to the invention, as previously mentioned, the distance over which the treatment actually occurs is very short. In the case of embodiments employing drive rolls both of 5 inch diameter, for instance, the dimension A, from the nip centre line to the frontal surface of the retarding device may be from 1/10 to 1/2 inch for a range of felt, nonwoven, woven and knitted materials.

For reliable operation in most treatments, the resilient compensatory actions of the retarding members that have been described help to assure uniform flow and treatment, and to ensure positioning of the point of compaction continually in the nip, preceding the retarding members. But, as previously suggested, for instance with certain needled felts, having, for example, an uncompressed thickness of 1/4 to 3/8 inch, the material itself, when longitudinally compacted in the machine, provides the needed resilience to resiliently compact or expand in the direction of its thickness as pressures respectively tend to rise or fall. In such cases an entirely rigid system may be employed.

The following are examples of cavity configurations operable according to the invention.

EXAMPLE I:

A web has an uncompressed thickness of .032 inches and a nipped dimension of .012 inch at the centre-line of the spring-biased 5 inch diameter rolls, under normal driving conditions. The two retarding members, constructed according to Figures 11-13, are steel plates of .050 inch thickness, with the ends hollow ground to match the curvature of the rolls, but each with a leading end portion formed in accordance with Figures 11-13, the dimension G being .008 inch and the angle $\alpha = 55^\circ$. In the running condition the ends of the retarding members are 0.16 and 0.25 inch from the nip centre-line respectively. The dimension D_1 between the roll surfaces immediately preceding the retarding members is larger than the dimension D_2, the minimum dimension between the retarding members.

EXAMPLE II:

Similar to Example I, but with the construction of Figures 6-8, employing a convexly curved blue steel spring plate 30 of .005 inch thickness, rounded with approximately 4 inch radius of curvature, and having its free tip approximately 1/16 inch to the rear of the tip of the blade 32 upon wnich it is mounted, as shown in Figure 5. The curved spring member deflects to the position of Figures 7 and 8 during operation.

EXAMPLE III:

A configuration according to Figures 2-4 in which the blades 32 are each of at least .020 inch thickness, mold steel, with tips hollow ground to points as shown, matching the roll curvature. The spring plates 30, of .003 inch thickness, blue steel, each have a distinct downwardly curved end, with sharp curvature beginning at a point about 3/16 inch from their free tips. With this arrangement at start-up the parts may be forced into the nip in accordance with the position of Figure 2, virtually filling the nip with metal and ensuring that flow of even the thinnest web will be opposed to commence and maintain the compactive action as described.

For treating such materials as tubular knitted webs, the parameters determining the resilient compensatory action are selected to maintain the roll surfaces and the retarding members in intimate supporting contact with the faces of the fabric, supporting the fabric against creping throughout its transit through the machine. For treating double layer materials, the machine surfaces can be adjusted to engage the material identically on both sides to ensure equality of treatment. In cases such as these the relationship of the parts ensures that the material, even at start-up, never escapes past the leading portion of the reatrding assembly without being compacted. The material is confined by the gently diverging hard surfaces of the rolls while the retarding members perform their damming function to create and maintain the compacted column. The column, because of its shortness and denseness, and the angular disposition of the dams, is able to bridge the transition between moving and stationary surfaces at both faces of the web without detrimental snagging, and the material proceeds throughout the machine while intimately engaged and supported on both sides. By this means micro-pleating, without production of gross folds or detrimental crepe, is obtainable.

For treating loosely formed bats of webs, such as filter media, the drive rolls can engage the web with only sufficient force to thrust the material forward without undue crushing of the web in the direction of its thickness. In such a case the machine surfaces may be relaxed to a position to produce a desired crepe of the material to re-orient the fibres as desired, while the initial compaction nevertheless proceeds in advance of the retarding members in the manner described.

WHAT I CLAIM IS:–

1. A method of imparting longitudinal compressive treatment to a web, comprising advancing the web by a pair of oppositely rotating rolls forming a drive nip and having rigid surfaces, retarding the web on the exit side of the nip between the rolls by a damming effect produced by a retarding member, which presents a frontal surface inclined to the direction of travel of the web, and, downstream of the frontal surface, a confinement surface more nearly parallel to the direction of travel of the web than the frontal surface for engagement with a face of the compressed web after the web has passed over said frontal surface, and maintaining the frontal surface of the retarding member in an operational position at a distance downstream from the nip centre-line not exceeding 5% of the sum of the diameters of the rolls, said operational position establishing between the roll surfaces and said frontal surface a longitudinal compression cavity that confines a longitudinally compacted moving column of web without coarse pleating or wrinkling of the web, and web that is progressively advanced by said drive rolls being compressed against the end of said moving column confined in said cavity.

2. A method according to Claim 1, in which the flow of the web through the compression cavity is opposed by a resiliently applied force, effective to maintain the frontal surface of the retarding member in said operational position.

3. A method according to Claim 1 or Claim 2, in which the frontal surface of the retarding member is inclined at 20 - 60° to the direction of travel of the web.

4. A machine for perfoming the method of any one of Claims 1-3, comprising a pair of oppositely rotating rolls that have rigid surfaces, a retarding device on the exit side of the nip between the rolls, the retarding device being formed by at least one retarding member which has a frontal surface inclined to the direction of travel of the web and, downstream of said frontal surface, a surface for engagement with the web after it has passed over said frontal surface which is more nearly parallel to the direction of travel of the web than the frontal surface, and means for maintaining the frontal surface of the retarding member in an operational position in which it is disposed adjacent one of the rolls downstream from the nip centre-line at a distance not exceeding 5% of

the sum of the diameters of the rolls.

5. A machine according to Claim 4, in which the upstream portion of the retarding member is resilient.

6. A machine according to Claim 5, in which the upstream portion of the retarding member includes a web-engaging surface which, in the start-up condition when no web is passing through the nip, is bowed along the direction of travel of the web with its bowed portion bearing against the other roll.

7. A machine according to Claim 5 or Claim 6, in which the retarding member is a spring plate extending generally in the direction of travel of the web and having an upstream end coverging toward the adjacent roll.

8. A machine according to Claim 7, in which the upstream portion of the spring plate is supported on a carrier blade.

9. A machine according to any one of Claims 4 to 8, wherein the retarding member is movable under the pressure of the advancing web to its operational position from a start-up position, in which its frontal surface is nearer to the roll nip.

10. A machine according to Claim 4, in which the retarding device includes retarding members on opposite sides of the web, each retarding member having a surface for engagement with the corresponding face of the web.

11. A machine according to Claim 10, in which the upstream portions of both retarding members are resilient.

12. A machine according to Claim 11, in which both retarding members apply a damming force to the advancing web.

13. The machine according to Claim 12, in which the retarding members are movable from a starting position in which one retarding member has its upstream edge immediately adjacent to the nip centre-line of the rolls and the upstream edge of the other retarding member is spaced a greater distance from the nip centre-line, to the operational position in which the spacings of the retarding members from the nip centre-line are equal.

14. A machine according to Claim 13, in which each of the retarding members is mounted for pivotal movement with respect to its respective roll and which includes a linkage between the retarding members which causes pivoting of one retarding member away from the nip centre-line to cause pivoting of the other retarding member towards the nip centre-line.

15. A machine according to Claim 4, in which the retarding device is formed by a single retarding member, the upstream part of which comprises means defining a resilient nipping surface co-operating with one of the rolls to maintain in position in advance of the retarding device the longitudinally compacted moving column of web.

16. A machine according to Claim 15, in which the retarding member has a portion downstream of said upstream part which generally conforms to the curvature of the other roll and forming with the other roll a passage for the web.

17. A machine according to Claim 16, in which the conforming portion of the retarding member has a roughened surface for imposing drag upon the compressed web passing over it.

18. A machine according to Claim 16 or 17, in which the other roll has a less web drive capability than the roll with which the resilient nipping surface co-operates.

19. A machine according to any one of Claims 4-18, in which the rolls are pressed together by a resilient means permitting them to separate in response to variation of the compressional force in comparison cavity between the retarding member or members and the roll nip.

20. A method according to Claim 1, substantially as herein particularly described with reference to the accompanying drawings.

21. A machine according to Claim 4, constructed and arranged substantially as herein particularly described with reference to the accompanying drawings.

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1591387 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

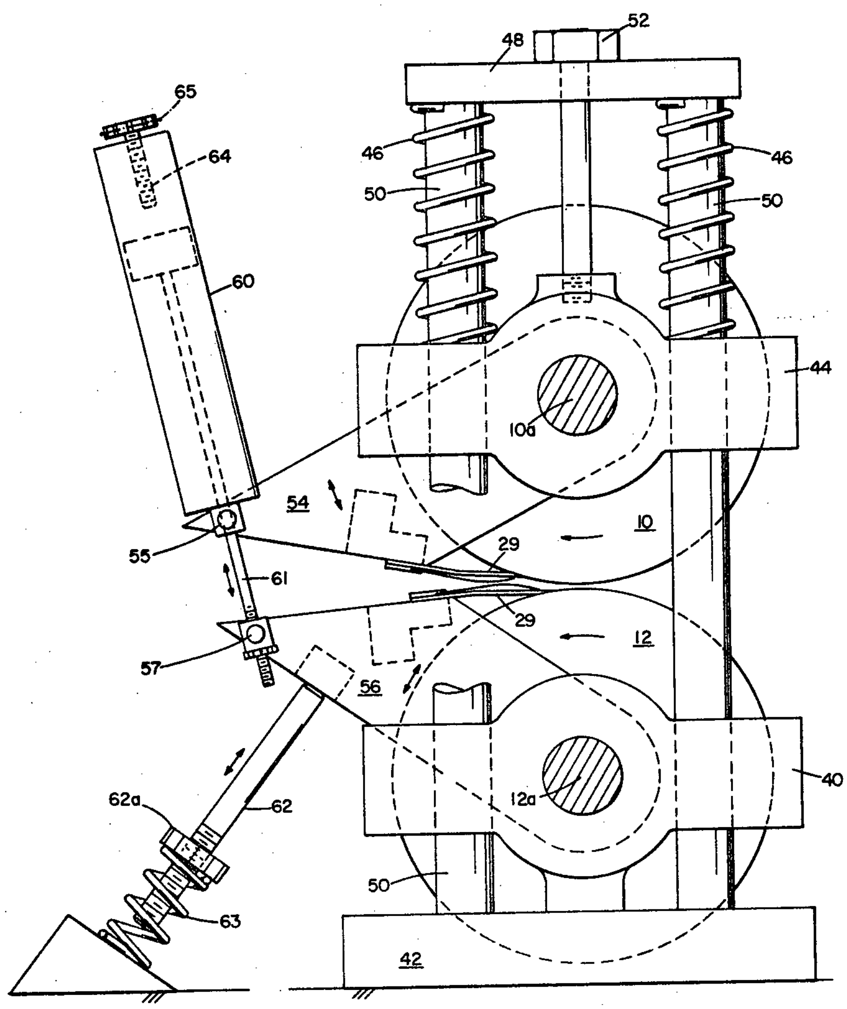
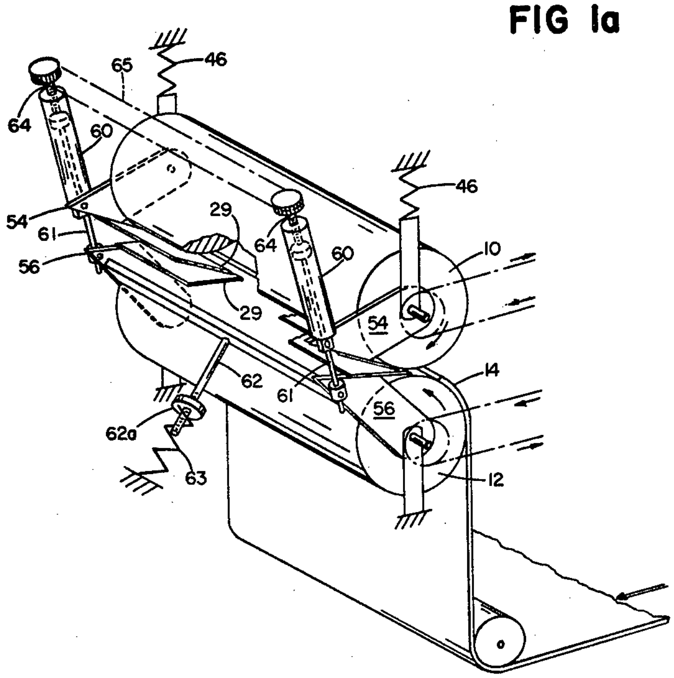


FIG I

FIG 1a



1591387 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

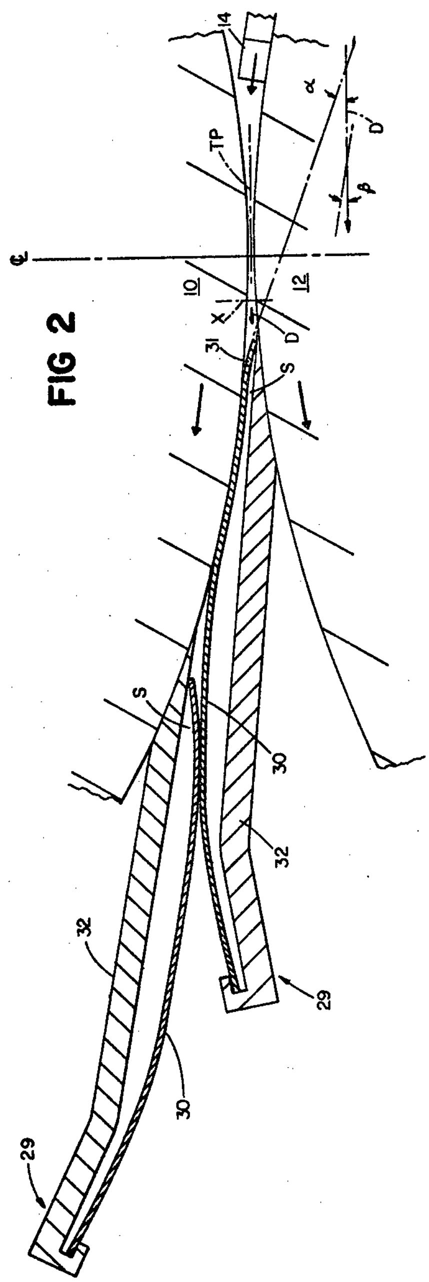


FIG 2

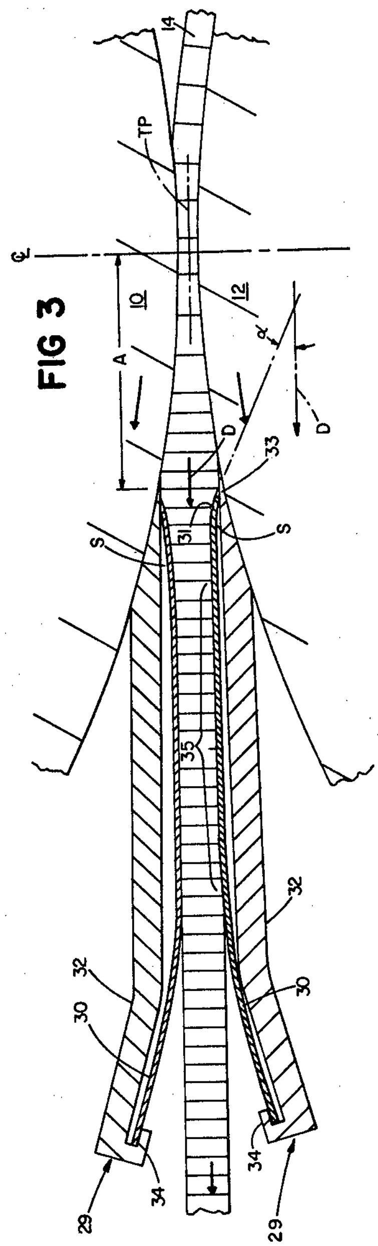
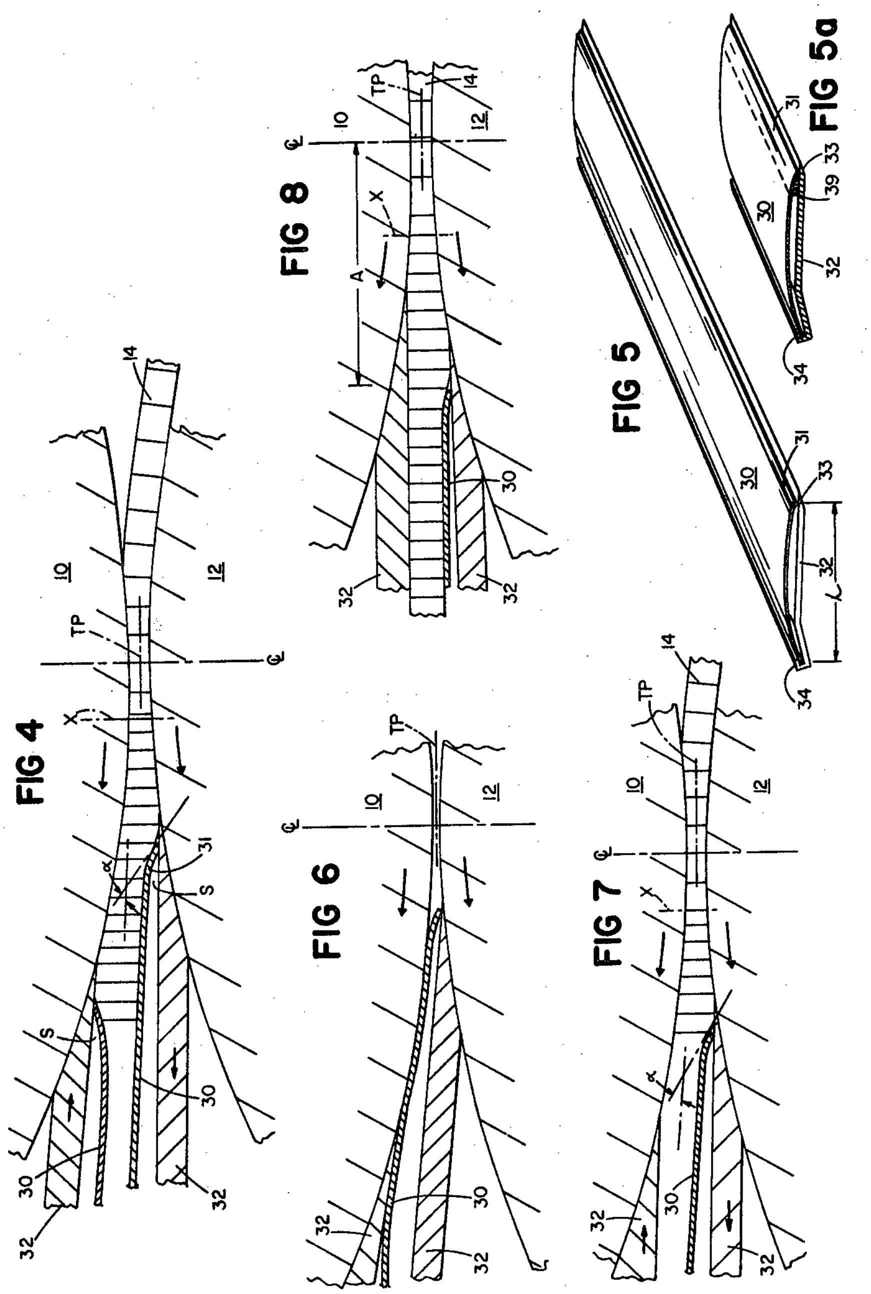


FIG 3

1591387 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4



1591387 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

FIG 9

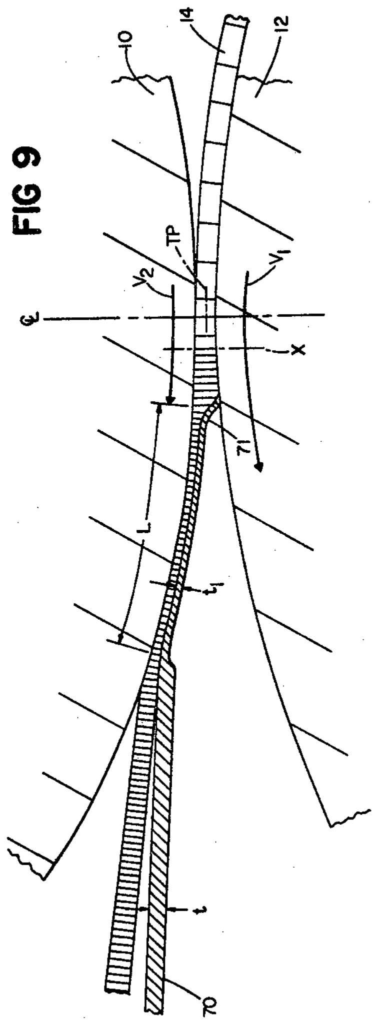
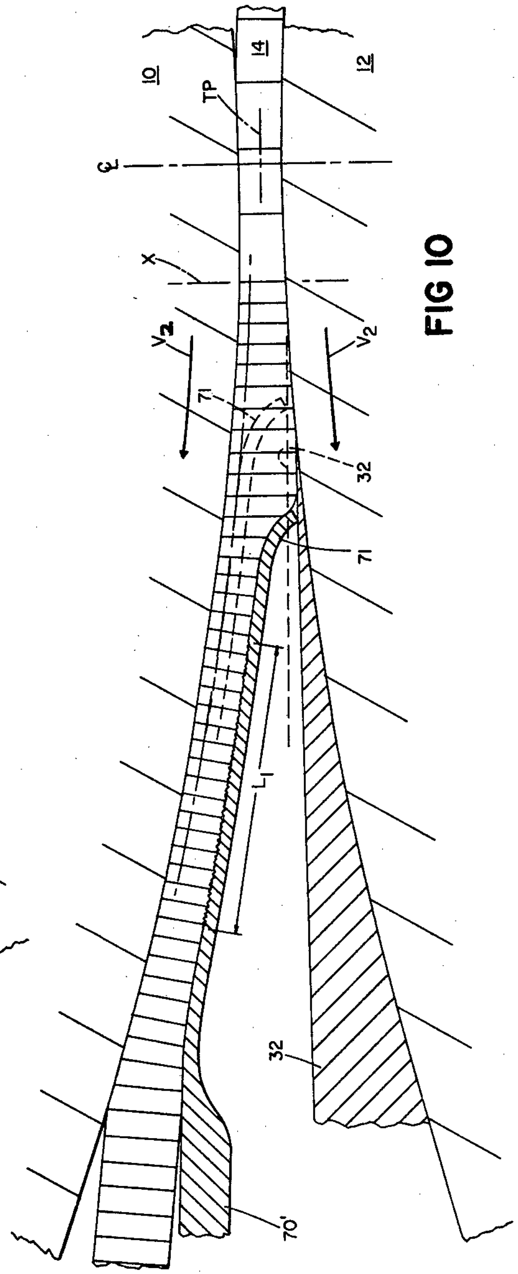


FIG 10



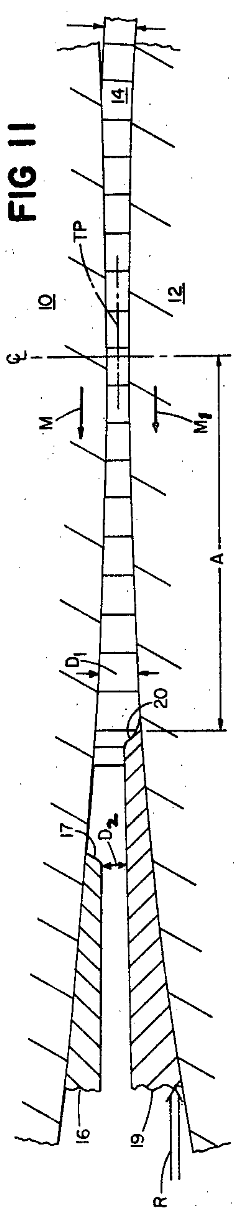


FIG 11
14
TP
10
12
M
M1
A
D1
20
17
D2
16
19
R

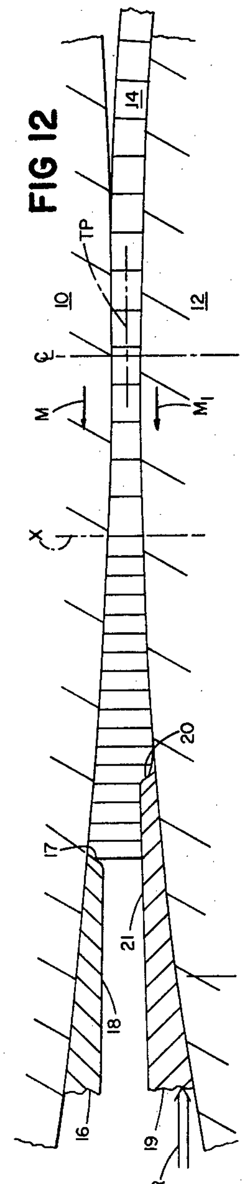


FIG 12
14
TP
10
12
M
M1
X
20
17
21
18
16
19
R

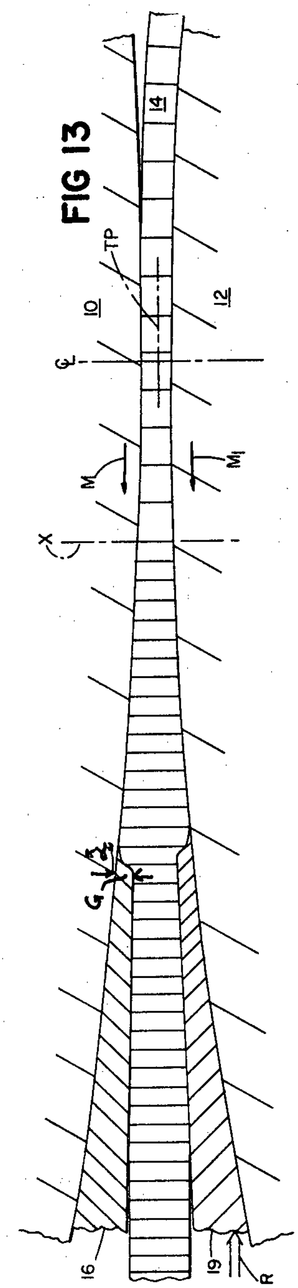


FIG 13
14
TP
10
12
M
M1
X
G
16
19
R

1591387 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 7

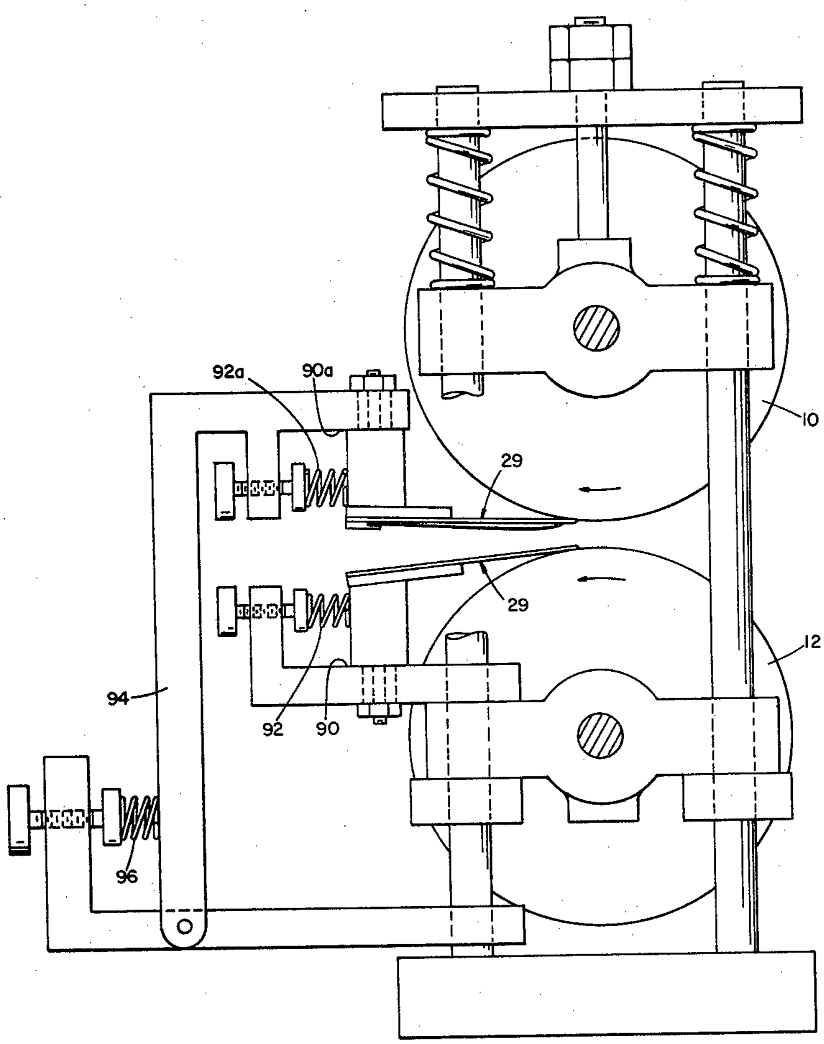


FIG 14