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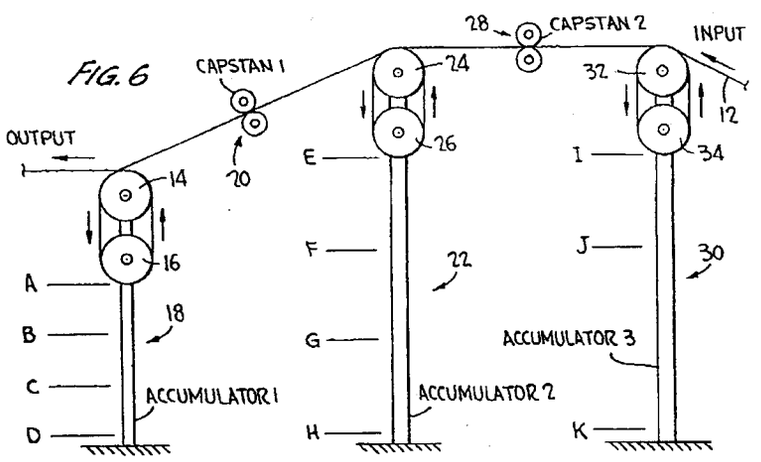
(54) Winding accumulator system.

(57) A winding accumulator system for controlling the transfer of filamentary material between a source and a winding receptacle comprises serially interconnected accumulator units (18,22,30) each storing an additional amount of material stored by the preceding unit, material may be moved between adjacent units by means including a capstan motor (20,28). A programmed controller controls the motors between adjacent units in order to maintain proper line tensions as filamentary material is moved from one unit to another.



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This invention is directed to method and apparatus for accumulator systems for maintaining proper line tension during the winding of filamentary material such as wire or cable from a primary source of filamentary material such as the apparatus for making the filamentary material or a secondary source such as a spool of filamentary material, and more particularly to such apparatus and method using a plurality of serially connected active accumulator elements which are interdependently controlled from a programmed controller.

Related Art

U.S. Patent No. 3,282,488 issued to Bauer et al. November 1, 1966, discloses a web conveying apparatus using an overrunning clutch assembly geared to a dancer roll to power the vertical descent of the dancer roll and limit its descent speed in a system employing a plurality of rotary transport rolls engageable with a web to be transported.

U.S. Patent No. 3,540,641 issued to Besnyo November 17, 1970, relates to a web accumulator for maintaining a substantially uniform web tension in which a pair of opposed arms are mounted for swinging movement at opposite ends of a frame. A plurality of rollers are located at spaced intervals along the arms and the web is conducted alternately over a roller at the outer end of one arm and a roller at the inner end of the other arm and progressively back and forth over the rollers of both arms and then off the frame at the opposite end. The arms swing in coordinated relation to provide wide variation of spacing and the arms are powered to swing when the tension in the web changes.

U.S. Patent No. 3,692,251 issued to Melead September 19, 1972, discloses a tensioning apparatus used with winding and unwinding apparatus for thread-like filamentary material in which a roller is mounted for rotation in members disposed at the ends of the roller and supported by pivot arms, thereby enabling horizontal movement of the roller. The moving filamentary material engages the roller to apply a horizontal force opposite to a pre-determined desired horizontal force. Changes in the tension of the filamentary material cause horizontal motion of the roller and that motion adjusts tensions by changing the speed of the filamentary material.

U.S. Patent No. 3,871,205 issued to Fenton March 18, 1975, relates to apparatus for the length stabilization of armored well logging cable wherein the cable is passed from a payoff reel over hold-back sheaves, a series of fixed sheaves, a movable sheave, and haul-off sheaves to a take-up reel. A hydraulic system controls the movable sheave to place the cable under tension. A second hydraulic system cyclically varies the effect of the hold-back sheaves to vary the cable tension.

U.S. Patent No. 4,202,476 issued to Martin May 13, 1980, discloses web-tensioning apparatus in which fixed web-driving rollers and idler rollers are suspended from the web. A first drive sets the surface velocity of a web-driving roller and a second drive sets the the surface velocities of the other web-driving rollers in response to the positions of the idler rollers to maintain substantially uniform web tension.

There are essentially five different types of large capacity accumulators presently being used for winding filamentary material, and all of them have similar drawbacks or disadvantages, namely poor regulation of tension during acceleration and deceleration of the moving filamentary material. This is caused by the large moving mass of the accumulator, unresponsive air regulators, the time the volume of air requires to flow into the hydraulic cylinders and the inertia of the pulleys or sheaves.

The horizontally opening accumulator schematically shown in Figures 1A, 1B and 1C is normally mounted overhead and as the filamentary material slackens it becomes a safety hazard for the operators of the accumulator.

The vertical accumulator opening down as schematically shown in Figures 2A, 2B and 2C has a minimum tension during static conditions, i.e. when the movable block is stationary or the output speed of the filamentary material is equal to the input speed. Minimum tension is based upon gravity applying a force on the movable block. While this may be an advantage when the accumulator is filling with filamenatary material because gravity accelerates the block downward, it is also a disadvantage when filamentary material is being pulled out faster than it is being put in. Line tension increases during this dynamic change because the filamentary material must accelerate the movable block in the opposite direction of the gravitational force. Under static conditions the minimum tension of the filamentary material equals the weight of the movable block divided by the number of wraps. The vertical accumulator opening up schematically shown in Figures 3A and 3B has one advantage in that it allows the operator to easily string the accumulator with the filamentary material. However, the tensioning system must also operate against gravity and when low tensions are desired there is not enough force to open the accumulator during filling of the filamentary material. This means complete failure of the accumulator. To close the accumulator the line tension must increase to move the block.

In the rotary type of accumulator schematically illustrated in Figures 4A and 4B, the inertia of the accumulator is its greatest disadvantage. During

any speed change of the filamentary material, the material either becomes slack or high line tensions are applied.

The round accumulator that spreads open, which is schematically shown in Figures 5A and 5B, has a large mass so that it also has the same difficulties with controlling line tension as do the other accumulator types mentioned, supra.

In accordance with the invention, the accumulator system comprises a plurality of serially interconnected accumulator units and a programmed controller. The filamentary material capacity of each successive accumulator unit is double that of a preceding accumulator unit. Thus, in an accumulator system using three accumulator units, the first accumulator unit comprises a buffer/dancer, an accumulator and a motor-driven capstan with a total capacity of, for example, forty feet. The second accumulator unit comprises an accumulator, a motor- driven capstan and a twisted rod and potentiometer control with a total capacity of eighty feet. The third accumulator unit is essentially the same as the second accumulator unit but without a motor-driven capstan and with a total capacity of one hundred-sixty feet.

The primary object of the present invention is to provide an accumulator system which maintains proper line tensions and prevents problems induced by sluggish response to sudden starts, stops, accelerations and decelerations during the movement of filamentary material, and in particular during the winding of such material. With large capacity accumulators, for example 300 feet of filamentary material, sudden changes in line speed may cause excessive tension or cause the filamentary material to jump from the accumulator sheaves and tangle.

The above objects, features and advantages of the invention are essentially accomplished by the sequential action of a number of serially connected accumulator units. This enables the mass of the sheaves and blocks to be distributed over the number of accumulator units rather than being massed into one accumulator unit, thereby increasing the response time of these movable sheaves and blocks. A motor-driven capstan located between each series connected accumulator units controls the amount of filamentary material in a particular accumulator with which it is associated, and in turn is controlled by a programmed controller. The individual motor-driven capstans are controlled to minimize the movable block accelerations, which relates to tension in the filamentary material. The vertical accumulator opening down type has been chosen because it affords the best response to changes in the movement of the filamentary material after eliminating all the weight possible in the moving block and driving system.

The above advantages, objects and features of the invention are believed to be apparent from the following description of an embodiment illustrative of the best mode of carrying out the invention when taken in conjunction with the drawings, wherein:

Figures 1A, 1B and 1C illustrate a horizontal type accumulator of the prior art;

Figures 2A, 2B and 2C illustrate a vertical opening down type accumulator of the prior art;

Figures 3A and 3B show a vertical opening up type accumulator of the prior art;

Figures 4A and 4B show a rotary type accumulator of the prior art;

Figures 5A and 5B illustrate a round that spreads open type accumulator of the prior art;

Figure 6 is a side view of the layout of a winding accumulator control system with three accumulator units in accordance with the invention;

Figures 7 and 8 illustrate graphs of the position of the accumulators of Figure 6 with respect to time to explain the operation of the winding control system of the invention;

Figures 9A and 9B show the sheaves of a typical accumulator unit for demonstrating the effects of inertia on the movement of the sheaves within an accumulator unit;

Figures 10 A and 10B are combined schematics and block diagrams showing the interconnection of the accumulator units of a second preferred embodiment of the invention and the controller circuitry;

Figure 10 C is a diagrammatic representation of the pnuematic circuitry for controlling the position of the cable cylinders and sheaves of each of the accumulator units; and

Figure 11 shows a combined block and schematic of the capstan controller circuitry.

The primary principle of the present invention is that, for example, an accumulator for holding three hundred feet of filamentary material, such as cable or wire, is divided into a number of interconnected and interdependent units. This results in a significant lowering of the mass of each of the individual accumulator units, thereby reducing inertia and enabling quicker response of the moving sheaves of the individual accumulators. The following description is taken with respect to an exemplary accumulator control system employing three accumulators, it being understood that the principle of the invention is applicable to any number of cascaded accumulator units.

With reference to Figure 6, the structure and operation of the three unit accumulator will be described from the output to the input. The first accumulator unit 18 comprises a three foot tall spring-loaded) buffer/dancer (not shown) with a total of five Derlin sheaves (three over two), an output

guide (not shown), plus a six foot tall air-loaded accumulator 18 consisting of a stationary block 14 and a movable block 16, with a total of nine, nine inch aluminum sheaves (five over four), and a nine inch motor driven capstan 20. The filamentary material 12, such as wire or cable, is input from a source of filamentary material, such as a cable or wire spool, or directly from the line from which the filamentary material is manufactured, to stationary block 14 of first accumulator 18. The filamentary material is wound around the individual sheaves of stationary block 14 and moving block 16. Assuming the accumulator system is to have a total capacity of 300 feet of filamentary material, the capacity of the first accumulator unit 18 is forty feet.

In the foregoing description, the buffer/dancer is not essential and can be employed, for example, in an application in which the accumulator system of the invention is used in conjunction with a winding apparatus having a reciprocating traverse, such as disclosed in U.S. Patent Nos. 4,406,419 and 4,477,033, both assigned to the same assignee as the subject invention. The buffer/dancer then provides a suitable buffer for feeding the filamentary material to the traverse mechanism of the winding apparatus. For applications other than the winding or re-winding of filamentary material the buffer/dancer is not necessary. The operation of such a buffer/dancer is conventional and known to those skilled in the art of winding filamentary material such that no further description of its structure is necessary for the purposes of this invention.

The second accumulator unit 22 comprises a ten foot tall accumulator, with an eight foot air-loaded cable cylinder with a stationary block 24 and movable block 26 with a total of fourteen, nine inch aluminum sheaves (seven over seven) and a nine inch motor driven capstan 28. The stationary block 24 and the sheaves therein are air piston-locked in position except during string-up when they can be lowered to simplify that operation. A string-up technique forming part of the present invention will be described hereinafter. The movable block 26 and sheaves are active using both gravity and the cable cylinder. The accumulator unit 22 has a total capacity of eighty feet of filamentary material.

Third accumulator unit 30, comprising stationary block 32 and movable block 34, is approximately 10 feet tall and the same as the second accumulator unit 22, with the exception that there are twenty seven, nine inch aluminum sheaves (fourteen over thirteen). The third accumulator unit 30 has a total capacity of one hundred sixty feet. The filamentary material enters the third accumulator 30 from a source of filamentary material such as wire or cable spool, or the production line which actually produces the filamentary material.

In practice, the second and third accumulator units 22 and 30 are preferably mounted on one ten foot tall steel channel. However, in some applications, for example where there is a long distance between the source of filamentary material and the third accumulator unit, the accumulator units may be spread out and separated as indicated in Figure 6. The potentiometer controls for the motor driven capstans are preferably wall mounted or mounted in a separate control cabinet.

The operation of the accumulator system of the invention is as follows. After the individual accumulators have been strung-up, the first accumulator 18 is at position A, the second accumulator 22 is at position E and the third accumulator 30 is at position I. All of the line speeds are the same at all points, namely the output, input capstan 20 and capstan 28 speed. Assume that the filamentary material line speed is one thousand ft/min., and if the output goes to zero, capstans 20 and 28 still operate at one thousand ft/min. Thus the first accumulator 18 starts to fill until it is at a position B, then capstan 20 decelerates and stops when the first accumulator 18 is at position D. As capstan 20 starts to decelerate, the second accumulator 22 starts to to fill. When the second accumulator 22 reaches position F, capstan 28 decelerates and the second accumulator 30 starts to fill. When the second accumulator 22 is at position H capstan 28 is stopped. The third accumulator 30 is now taking up the filamentary material at one thousand ft/min. which is equal to the input of filamentary material at the first accumulator unit 18. The output of filamentary material must begin before the third accumulator unit 30 is at position K. As the output of filamentary material increases to more than one thousand ft/min., the first accumulator unit 18 empties. As this occurs, the first capstan 20 accelerates to more than one thousand ft/min. The first accumulator 18 stops emptying at position C. The second accumulator unit 22 empties and the second capstan 28 starts feeding cable into the second accumulator 22. The third accumulator unit 30 decelerates and stops as capstan 28 reaches one thousand ft/min. The second accumulator unit 22 will be at position G when capstan 28 is driven at one thousand ft/min. As soon as the second accumulator unit 22 goes above position G, capstan 28 will go over one thousand ft/min., which causes the third accumulator unit 30 to start closing. When the third accumulator unit 30 reaches position J, capstan 28 is decelerated to one thousand ft/min. When the third accumulator 30 is back to position I, capstan 28 is going at one thousand ft/min. and the second accumulator unit 22 will finish emptying. When the second accumulator 22 is at position E, capstan 20 is going at one thousand ft/min. Therefore, the first accumulator 18 finishes emptying

until it reaches position A and the operation of the accumulator system is back to where it started. It is noted that the device taking up the cable at the output of the accumulator system is controlled by the position of the first accumulator 18, as that accumulator unit empties the takeup to match line speed.

The significant advantages of the above structure and operation is as follows. The first accumulator unit 18 accelerates to speed in approximately one second as is shown in Figure 7 as it has the lightest weight. As shown in Figure 8, the second accumulator unit 22 accelerates to one thousand ft/min. in 2 seconds as it is heavier than the first accumulator unit 18. The third accumulator unit 30 accelerates to the required speed of one thousand ft/min. in four seconds. Therefore the tension during dynamic changes in the accumulator system is controlled. It is to be noted that the decelerations of the first and second accumulator units 22 and 30 are exponential.

The inertia of the sheaves is another aspect of accumulator operation that has not been fully addressed by the prior art accumulator systems. With respect to Figures 9A and 9B, if no cable is entering the accumulator 36 and the output is not accelerating, sheave E must rotationally accelerate with the output. Sheave A will not rotate, so no acceleration occurs. Sheave B will accelerate at 1/4 the rate of acceleration of sheave E. Sheave C will accelerate at 1/2 the rate of acceleration of sheave E and sheave D will accelerate at 3/4 the rate of acceleration of sheave E. The tension will therefore be different for each wrap of the material. The cable from sheave A to B will be different from that of B to C, etc. Each sheave is accelerated at a different rate. If the sheaves have high inertia, then two stands can hold the entire weight of the blocks for a short duration of time. This creates a high tension impulse on the cable which may damage it. Such an effect is compounded by the addition of more sheaves. The aforementioned effects can be decreased by using sheaves with the lowest inertia available.

In a preferred embodiment of the invention, the second and third accumulators are constructed on one support beam as shown in Figure 10A . As mentioned, supra., such a construction is useful when there is a relatively short distance between the source of the filamentary material and the input to the accumulator system. But if there is such a distance between the source of filamentary material and the input of the accumulator system that the filamentary system sags, then the configuration of Figure 6 is preferred where the second and third accumulator units are mounted on separate supports. Long spans of filamentary material that result in sagging tend to produce undesired oscillations in the system.

In the accumulator system of Figure 10A, the second and third accumulators 40 are mounted on the same beam 42 in side-by-side relationship as is clear from Figure 10B, which is a top view of the individual accumulator units with the accumulator controller 44, take-up unit 46 and take-up controller 48 also illustrated. The take-up unit 46 and take-up controller 48 form no part of the present invention and therefore no further description of their respective structure and operation is necessary for the purposes of this invention. The filamentary material 50 is strung on the individual sheaves 52, 54 of accumulator units 2 and 3 and motor driven capstan 56 and then to motor driven capstan 58 and then strung around the individual sheaves 60 of the first accumulator unit 62, through footage counter wheel 64 and then strung around the buffer/dancer unit 66. The buffer/dancer 66 enables the accumulator system to adjust to the reciprocating motion of a traverse on a rewinding apparatus, and thus the configuration of the accumulator system shown in Figure 10A is suitable for operation with a rewinding apparatus such as that disclosed in U.S Patent Nos. 4,406,419 and 4,477,033, both assigned to the same assignee as the present invention.

The accumlator systems of Figures 6 and 10A are strung up by lowering the lower sheaves 26 and 34 of accumulator units 22 and 30 (Figure 6) and lowers sheaves 43 and 63 of Figure 10A by depression of a "String-Up" button on the controller. This automatically raises the cable cylinder cables to the topmost position, thus preventing free fall of the upper sheaves 24 and 32 of Figure 6 and 45 and 65 of Figure 1-A. The dead-bolt locks (not shown) that hold the top sheaves in their normal operating position are released. The top sheaves 24 and 32 of Figure 6 and 45 and 65 of Figure 10A are slowly lowered by bleeding air out of the air cylinder (to be described more fully hereinafter) until the top sheave block is resting on the bottom sheave block. After the filamentary material, such as cable or wire, has been strung up, the top sheaves are returned to their normal operating positions by the cable cylinders, the dead bolts are locked in place and the cable cylinder cables are returned to the bottom so that they can exert downward force on the lower sheaves. Figure 10C is a block diagram representation of the pneumatic system for controlling the cable cylinders 70, 72.

Figure 11 illustrates, in combined schematic and block diagrammatic format, the essential circuitry for controlling the motor driven capstans to feed the filamentary material through the accumulator system of the invention. The respective first, second and third accumlator unit potentiometers 80, 82 and 84 provide information as to the position

(height) of the movable blocks in each of the accumulator units, which information is input to respective summing and compensation circuits 86, 88 and 90. Each of the summing and compensation circuits 86, 88 and 90 provide properly compensated error signals for the references of the first and second capstans and the final take up by using the settings of each of the accumulator potentiometers 80, 82 and 84 and the respective associated height adjust potentiometers 92, 94 and 96. The respective reference clamping circuits 98, 100 and 102 adjust the output of each of the summing and compensation circuits 86, 88 and 90 to the capstans when certain conditions are met as described above in the operation of the accumulator system. For example, even though the reference signal H from summing and compensation circuit 88 is calling for a speed of nine hundred ft/min., reference clamping circuit 98 may be reducing that speed because the position of the first accumulator is no longer near its normal running height because the take up is stopped. This would cause the second accumulator to begin falling because reference clamping circuit 98 is controlling the first motor driven capstan to go slower. And, even though the third accumlator is at its normal running height providing a reference signal I for 900 ft/min., reference clamping circuit 100 will begin reducing signal I because the second accumulator unit is no longer in place. Additional cascaded circuits can be provided for additional accumulator units if necessary, such that the accumulator control system of the invention is not limited to the three accumulator units described herein for purposes of explaining the structure and operation of the accumulator control system.

Thus, the invention is not intended to be limited by the foregoing description, but by the following claims and the equivalents to which the claimed subject matter is entitled.

Claims

1. A winding accumulator system for controlling the storage of filamentary material between a source of such material and a winding receptacle, comprising:

a plurality of serially interconnected accumulator units (18,22,30) each including means for storing filamentary material with the first accumulator unit receiving filamentary material from said source and storing a given amount of filamentary material and each succeeding accumulator unit storing an integral additional amount of filamentary material stored by a preceding accumulator unit, each of the accumulator units including a stationary block (14,24,32) and a movable block (16,26,34), whereby movement of said movable block away from and toward said stationary block respectively increases or decreases the amount of filamentary material stored in the respective accumulator unit;

means for varying the movement of said filamentary material between adjacent accumulator units and including a capstan motor (20,28) between each successive accumulator unit; and

means for controlling said means for varying to limit the change in tension of said filamentary material with changes in the acceleration or deceleration of said filamentary material caused by a change in the input or output of filamentary material to or from the accumulator system, and further including means (80,82,84) for determining the direction of movement of each said movable block from the relative speed of movement of filamentary material into and out of the respective accumulator unit, means (80,82,84) for sensing the amount of filamentary material stored in each of said accumulator units, means (92,94,96) for indicating a desired reference amount of filamentary material to be stored in each of said accumulator units; means (86,88,90) for comparing the stored and reference amount of filamentary material in each accumulator unit to generate respective capstan motor control signals and further including means (98,100,102) for combining the respective capstan motor control signals from two adjacent accumulator units to control the capstan motor immediately upstream of said two adjacent accumulator units.

2. The winding accumulator system as set forth in claim 1, further comprising buffer/dancer means for receiving the filamentary material output from the last of the accumulator units to enable adjustment of the accumulator system to changes in the input of filamentary material in the winding receptacle.

3. The winding accumulator system as set forth in claim 2, wherein said means for controlling further includes respective means (80,81,82) for determining the position of the movable block in each of the accumulator units, respective summing and compensation circuits (86,88,90) responsive to the respective position determining means for generating respective compensated error signals, and respective reference clamping circuits (98,100,102) for adjusting the output of a respective summing and compensation circuit in accordance with the position of the movable block of an adjacent upstream accumulator unit.

FIG. 1A
(PRIOR ART)

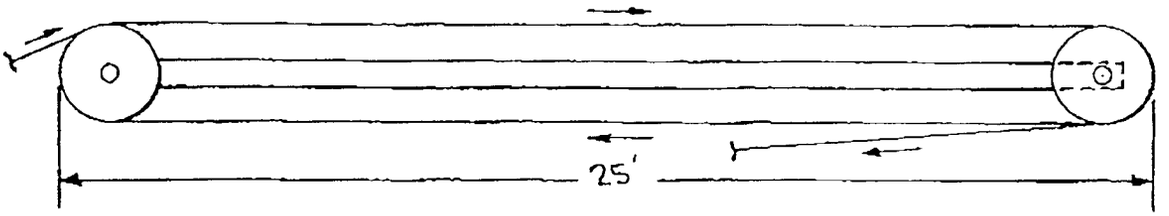


FIG. 1B
(PRIOR ART)

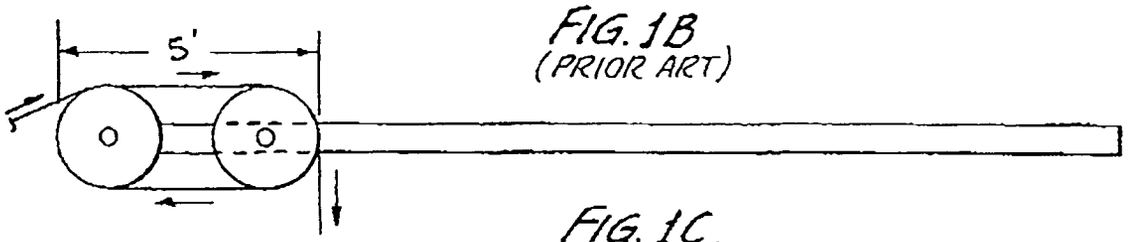


FIG. 1C
(PRIOR ART)

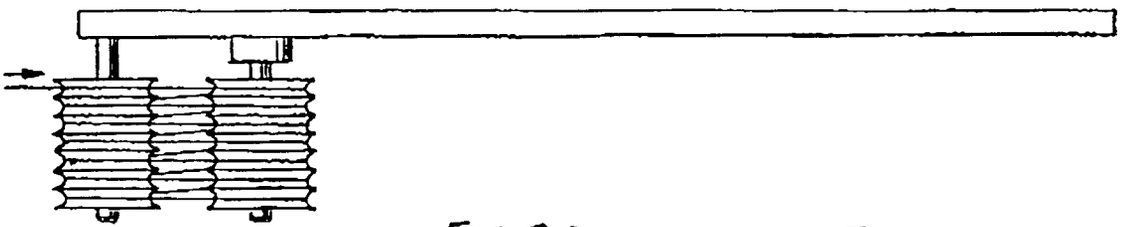


FIG. 2A
(PRIOR ART)

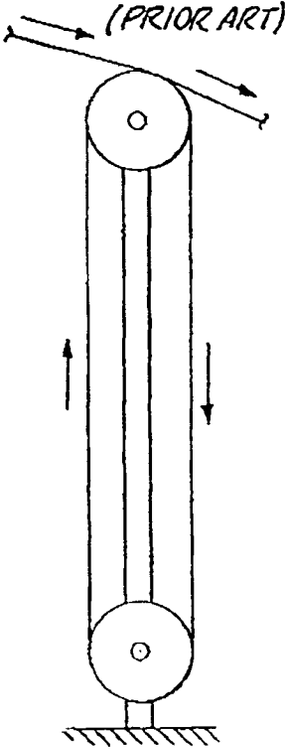


FIG. 2B
(PRIOR ART)

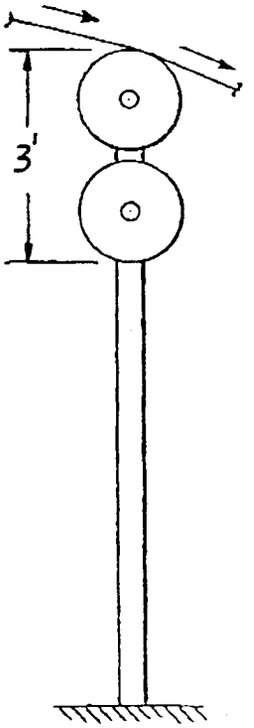


FIG. 2C
(PRIOR ART)

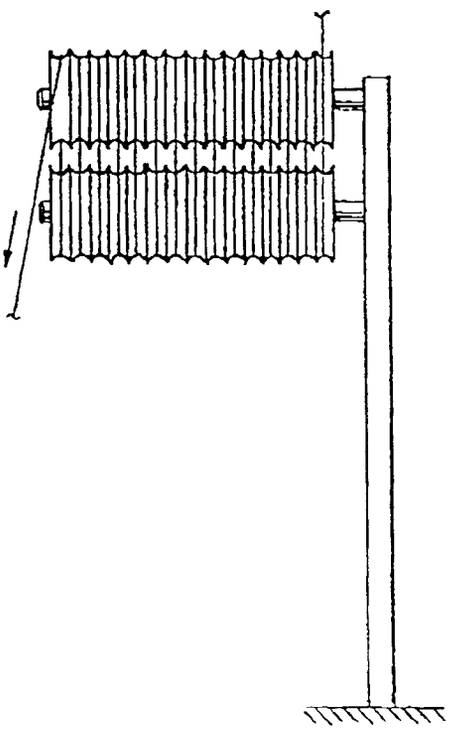


FIG. 3A
(PRIOR ART)

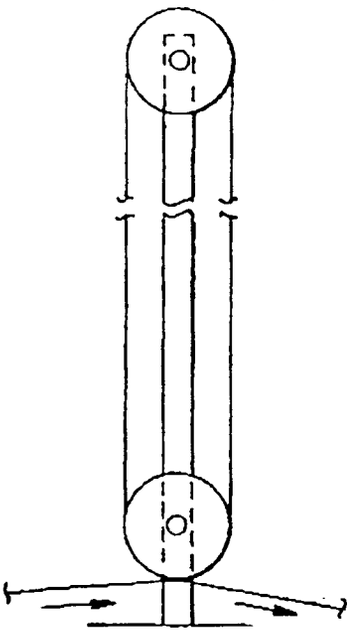


FIG. 3B
(PRIOR ART)

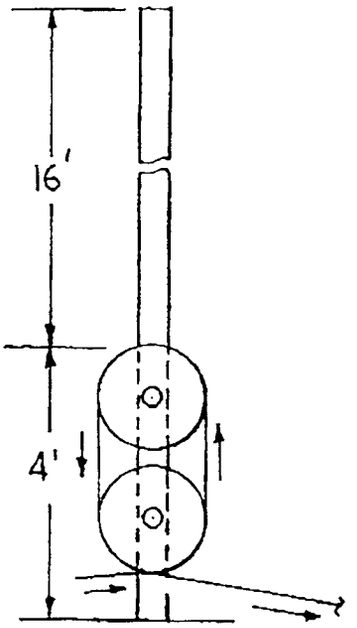


FIG. 5A
(PRIOR ART)

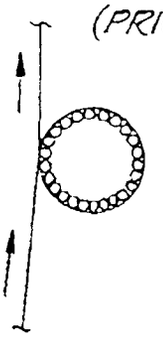


FIG. 5B
(PRIOR ART)

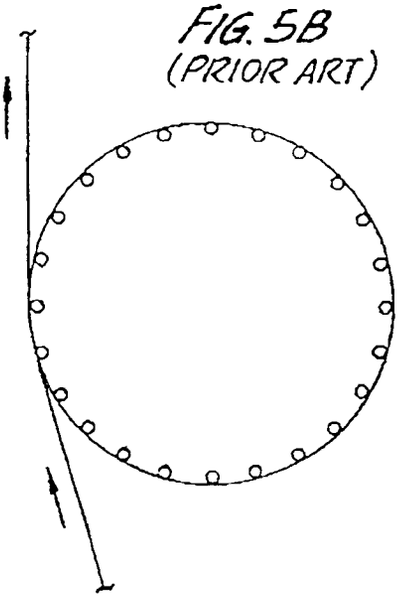


FIG. 4A
(PRIOR ART)

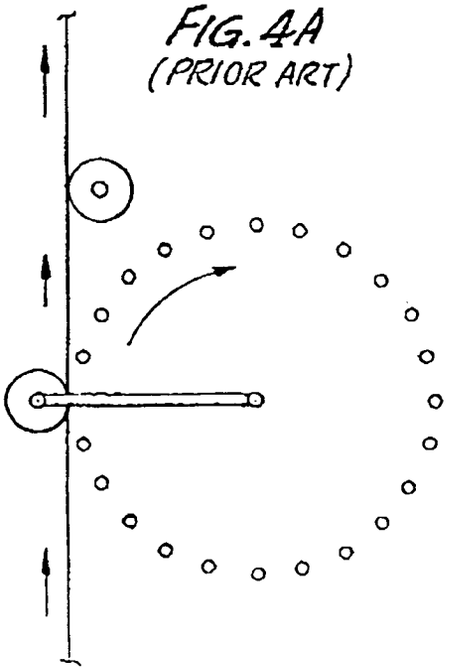


FIG. 4B
(PRIOR ART)

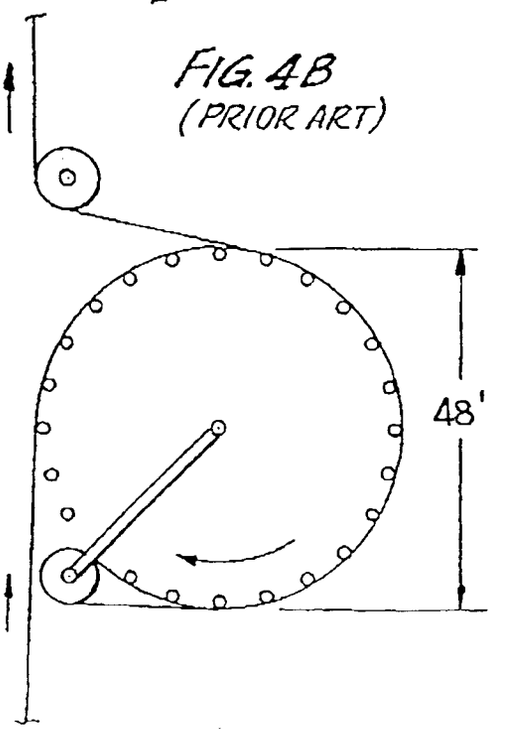


FIG. 6

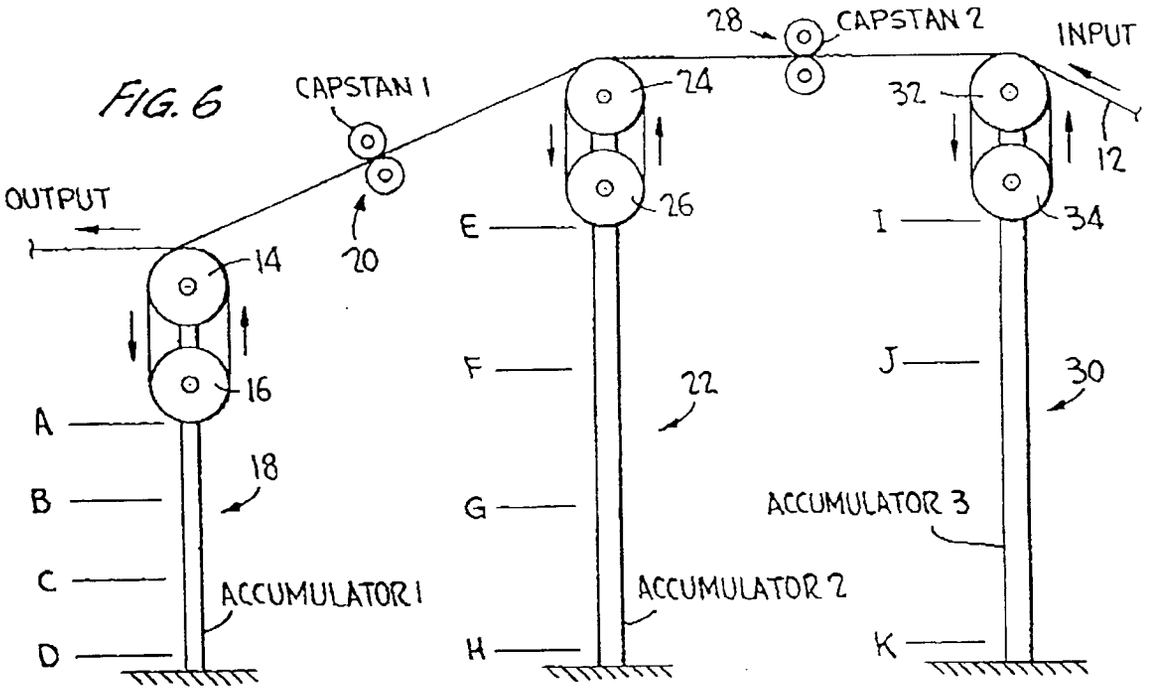


FIG. 7

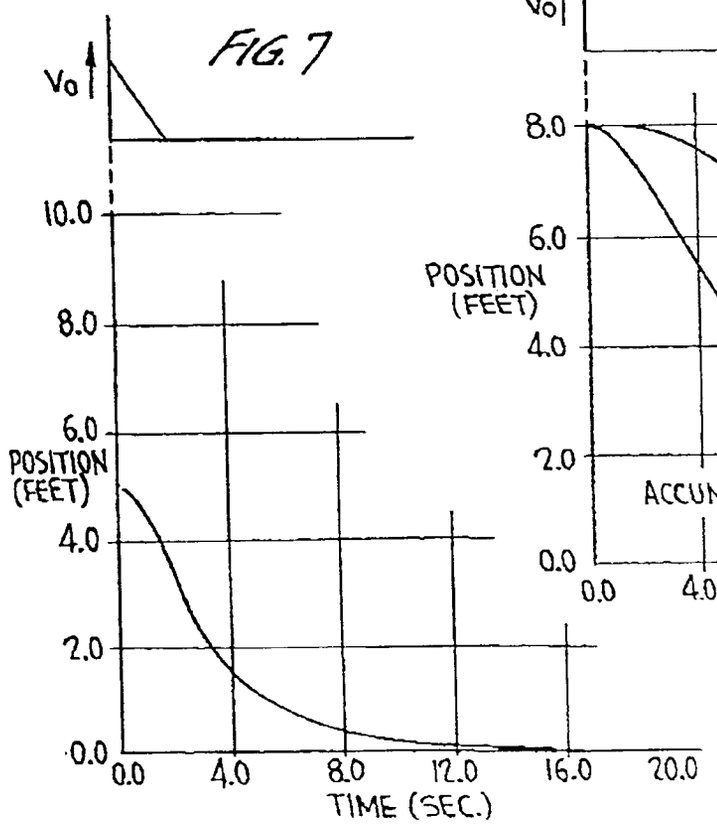


FIG. 8

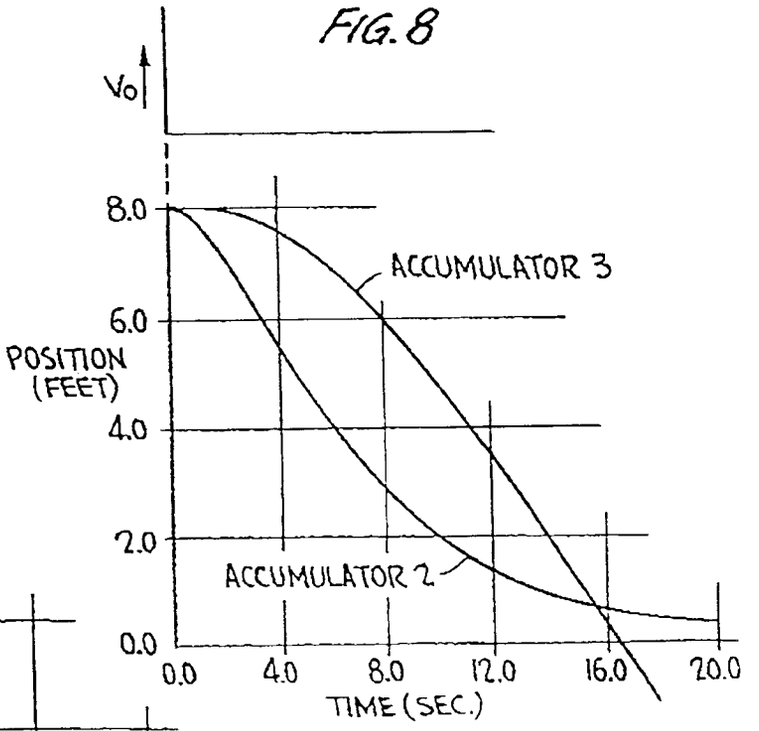


FIG. 10 C

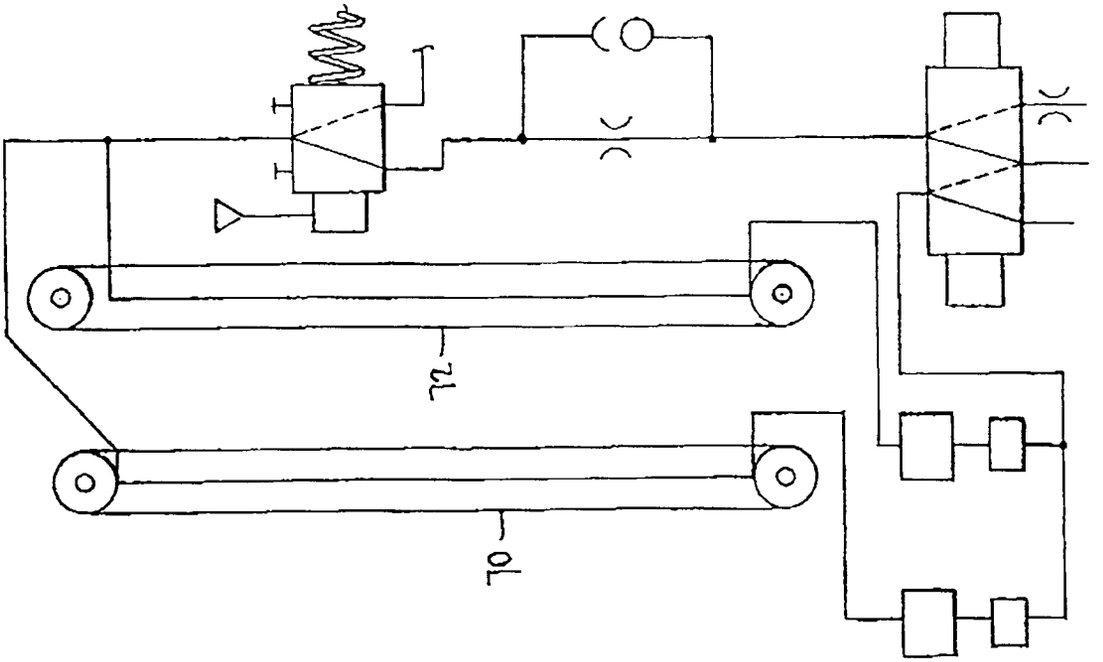


FIG. 9B

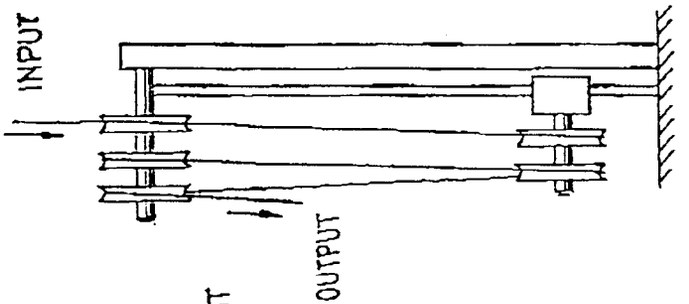
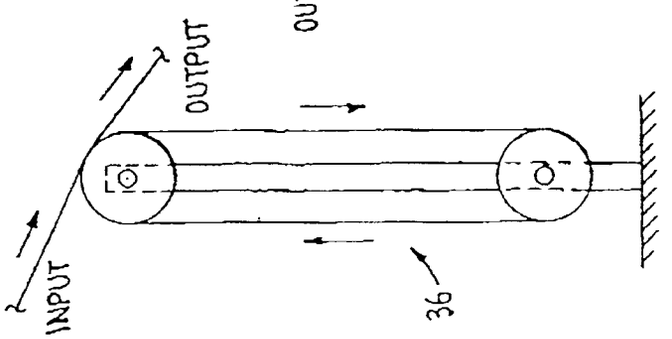


FIG. 9A



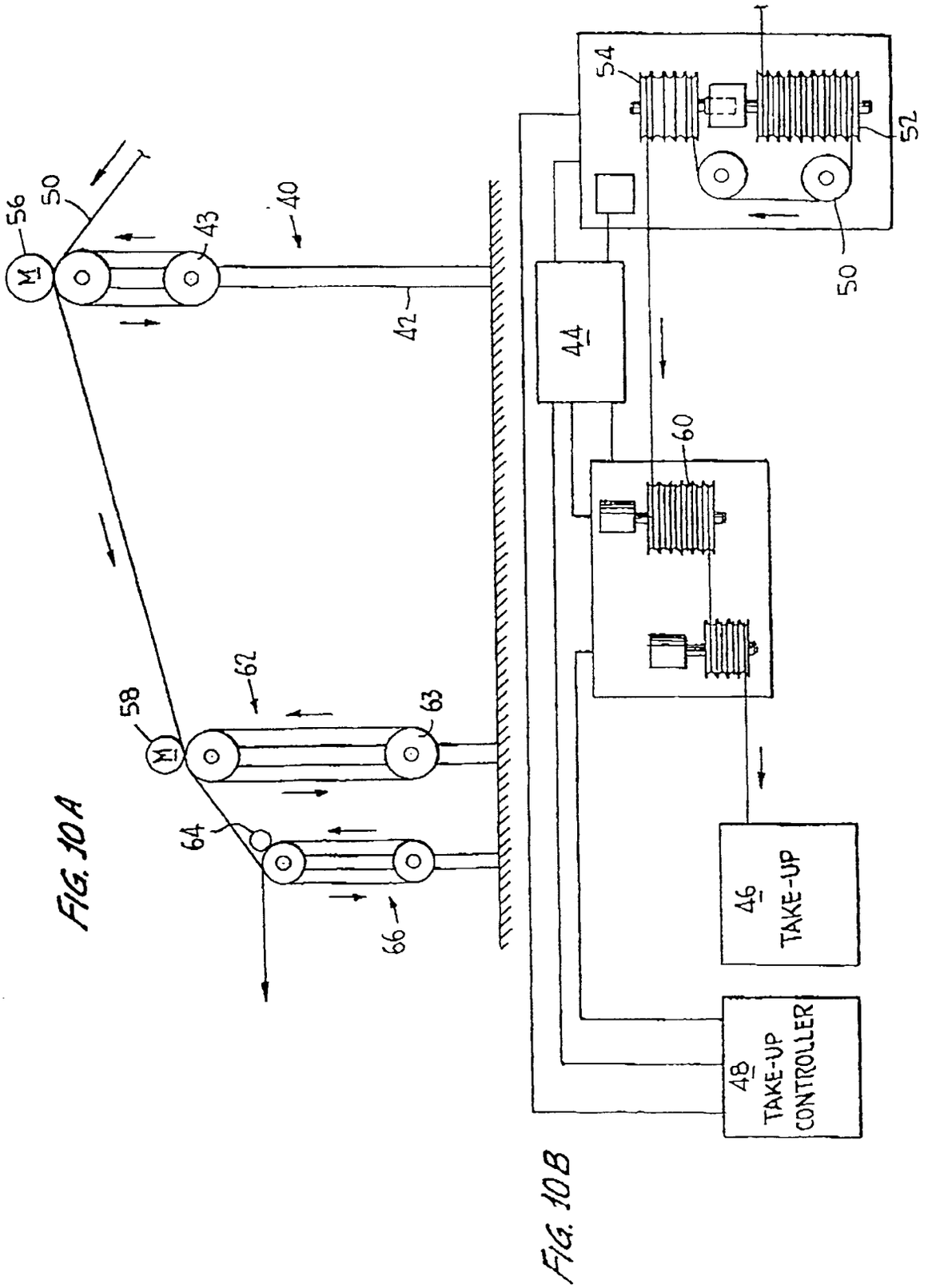
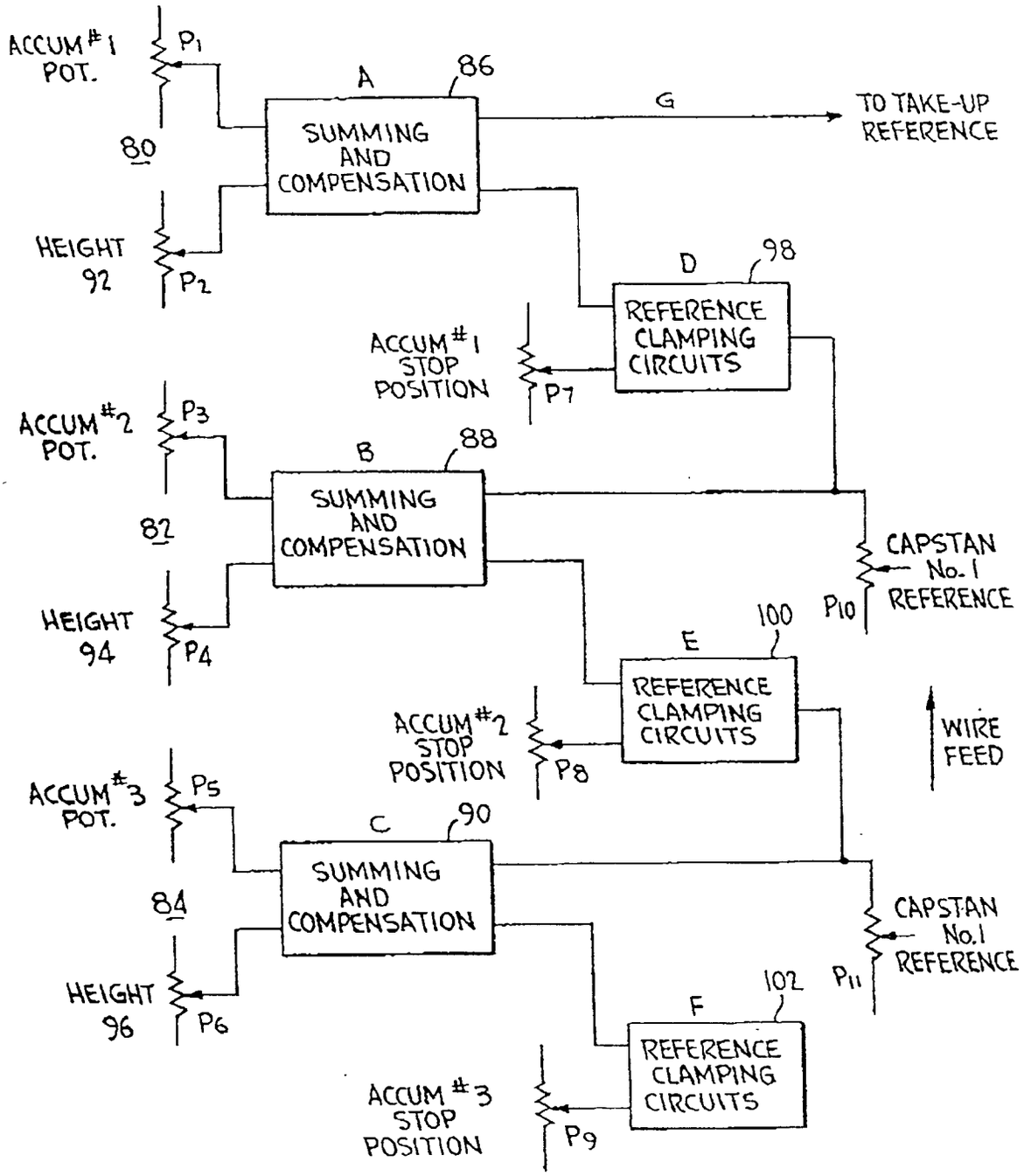


FIG. 10A

FIG. 10B

FIG. 11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P1
80
A
86
SUMMING AND COMPENSATION
G
TO TAKE-UP REFERENCE
HEIGHT 92
P2
D
98
REFERENCE CLAMPING CIRCUITS
ACCUM # 1 STOP POSITION
P7
ACCUM # 2 POT.
P3
B
88
SUMMING AND COMPENSATION
82
CAPSTAN No. 1 REFERENCE
P10
HEIGHT 94
P4
100
E
REFERENCE CLAMPING CIRCUITS
ACCUM # 2 STOP POSITION
P8
WIRE FEED
ACCUM # 3 POT.
P5
C
90
SUMMING AND COMPENSATION
84
CAPSTAN No. 1 REFERENCE
P11
HEIGHT 96
P6
102
F
REFERENCE CLAMPING CIRCUITS
ACCUM # 3 STOP POSITION
P9

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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 3348

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	FR-A-1 052 863 (W.T.GLOVER & CO. LTD.) * page 3, column 1, line 3 - column 2, line 8 *	1	B65H51/20
A	EP-A-0 287 802 (STATOMAT-GLOBE MASCHINENFABRIK GMBH) * column 5, line 58 - column 8, line 26 *	1	
A	US-A-2 929 569 (J.N.DETRICK; C.R.HOFFMAN) * column 2, line 30 - line 63 *	2	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

B65H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 October 1993	GOODALL, C

CATEGORY OF CITED DOCUMENTS

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