United States Patent

[11] **3,612,919**

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[54] **HIGH-VOLTAGE ELECTROSTATIC GENERATOR**
24 Claims, 14 Drawing Figs.

[52] **U.S. Cl.** **310/6**
[51] **Int. Cl.** **H02n 1/00**
[50] **Field of Search** 310/5, 6, 7; 322/2.1; 339/9

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ABSTRACT: A high voltage is developed by conveying electrostatic charges to a high-voltage electrode, by means of an endless conveyor chain comprising conductive links alternating with insulating links. The conductive links comprise cylindrical pellets with cylindrical openings extending axially therein. The insulating links have enlarged spherically rounded end portions swingably received in the cylindrical openings. Pivot pins extend between the enlarged end portions and the cylindrical pellets. The conveyor is trained around wheels having spring contactors thereon for transferring charges to and from the pellets. Channel-shaped induction electrodes are positioned opposite the conveyor where it makes and breaks contact with the wheels. Operating voltages for some of the induction electrodes are obtained by idler pulleys contacting the conveyor. Each idler pulley preferably has one or more spring contactors thereon for engaging the pellets. Additional induction electrodes are preferably provided opposite the idler pulleys.

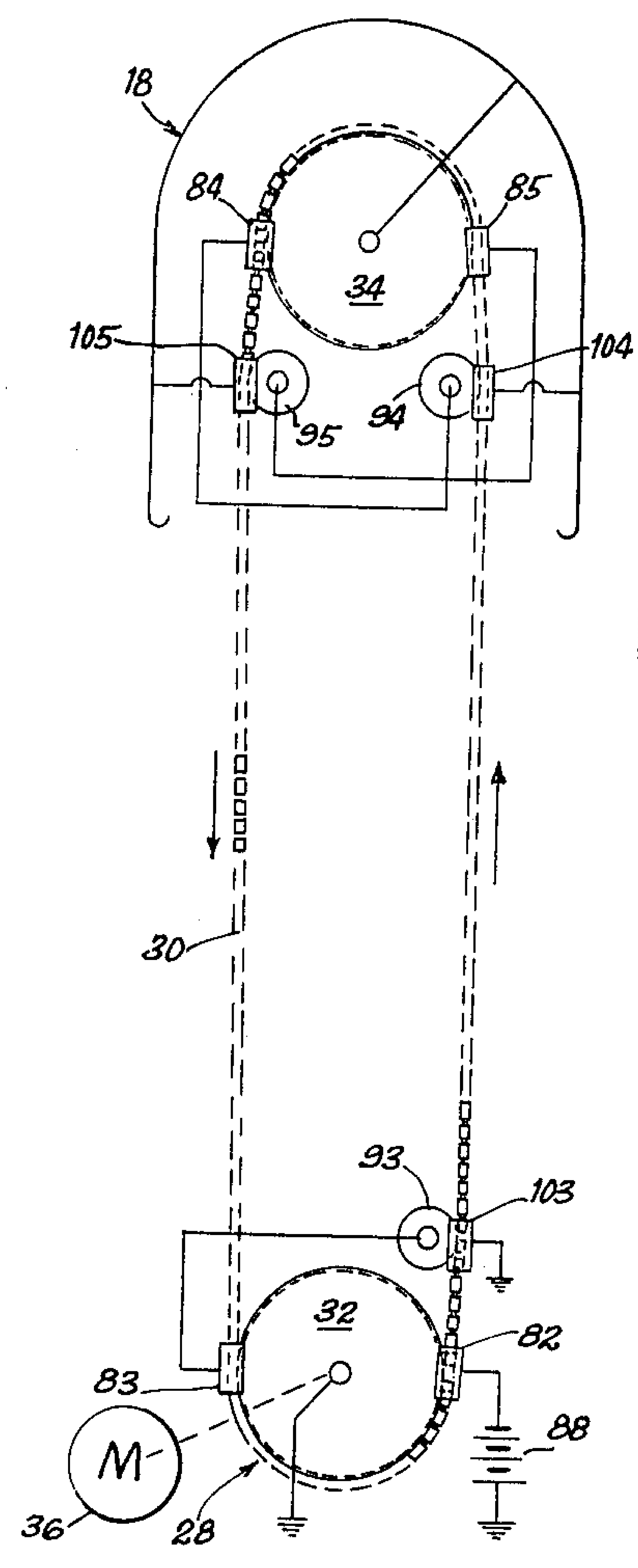

FIG. 1

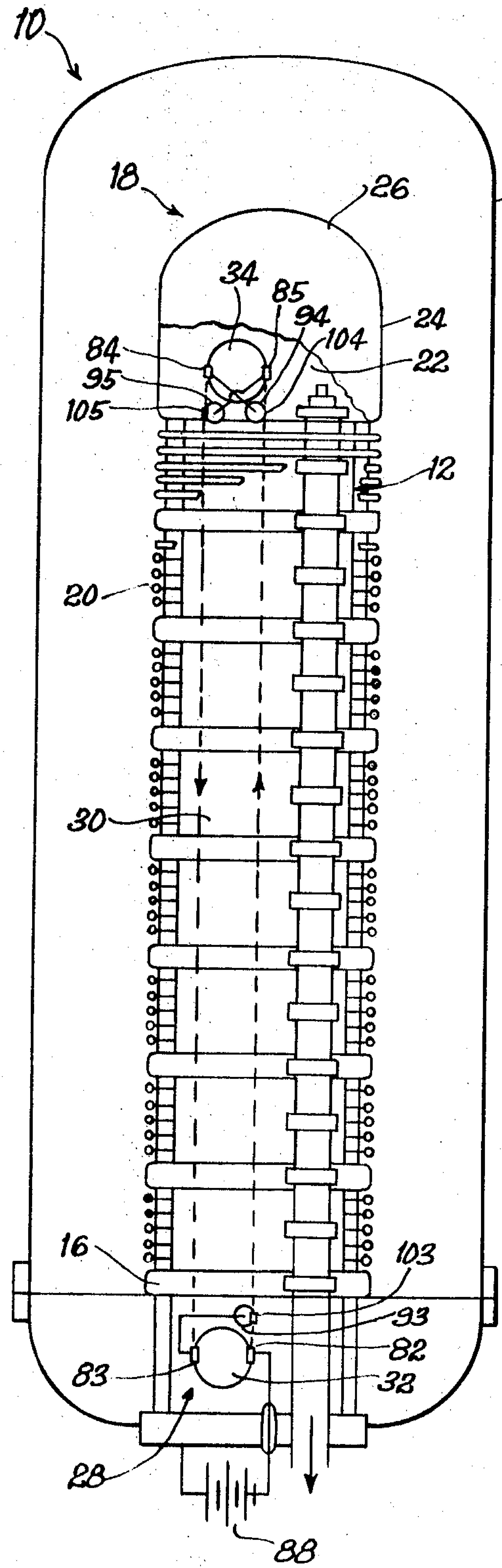

FIG. 2

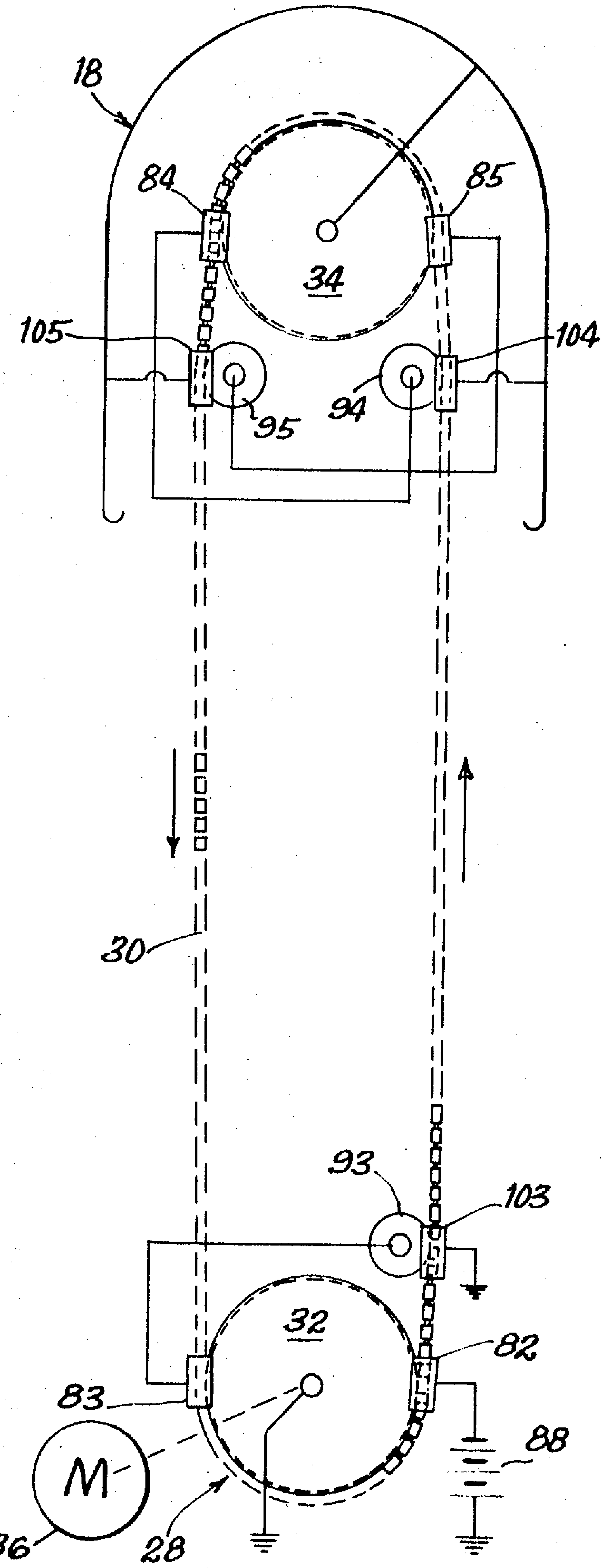

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FIG. 3

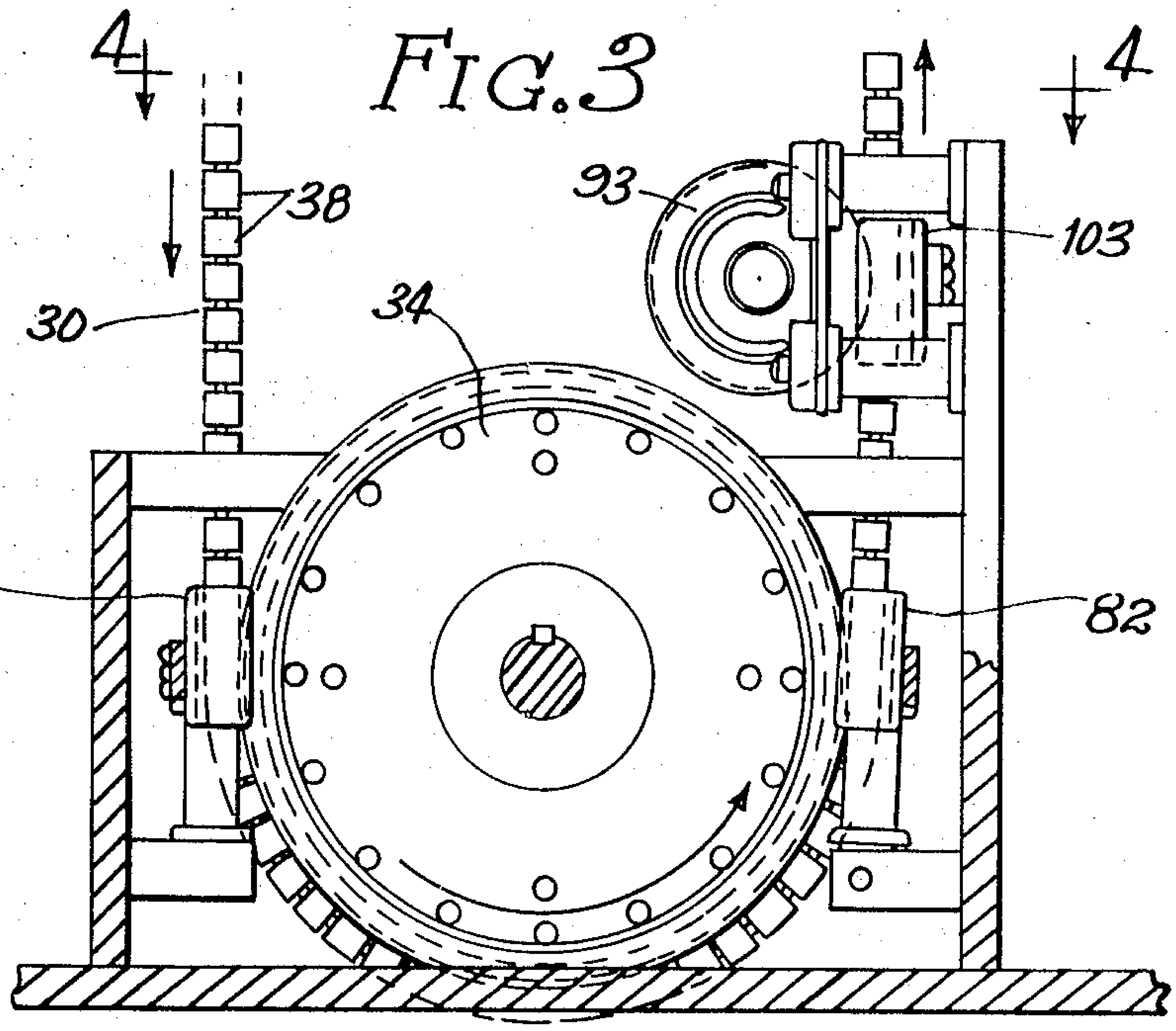
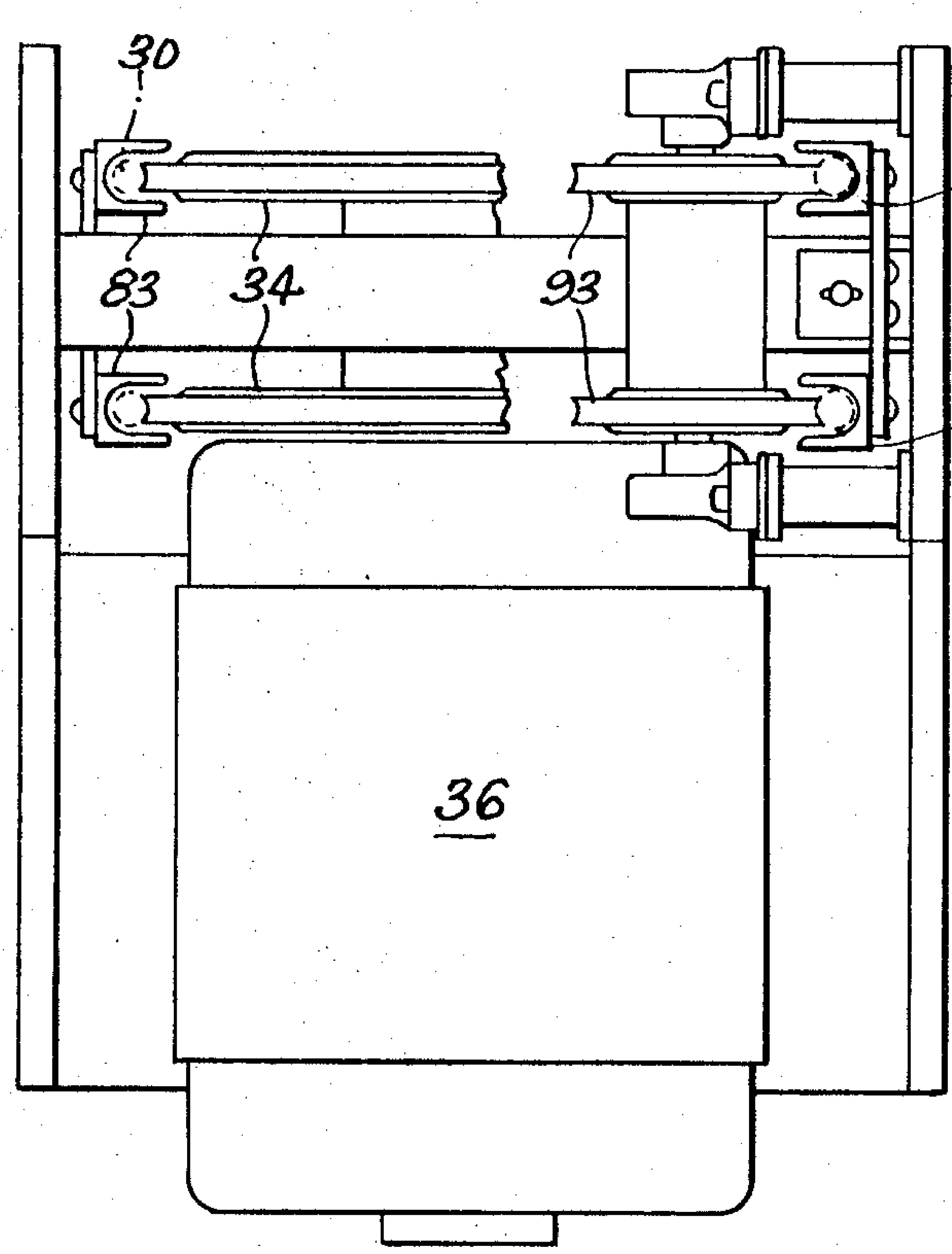


FIG. 4



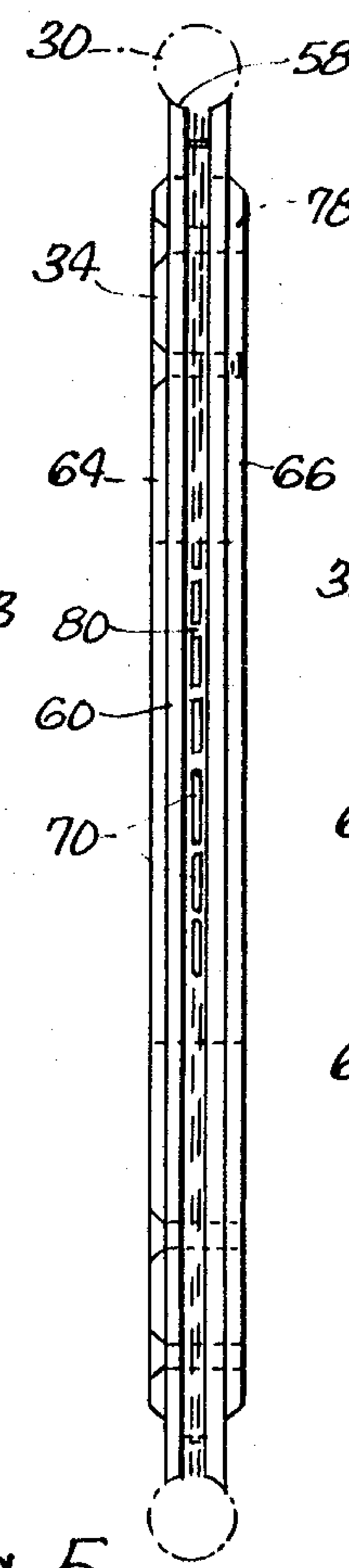


FIG. 5

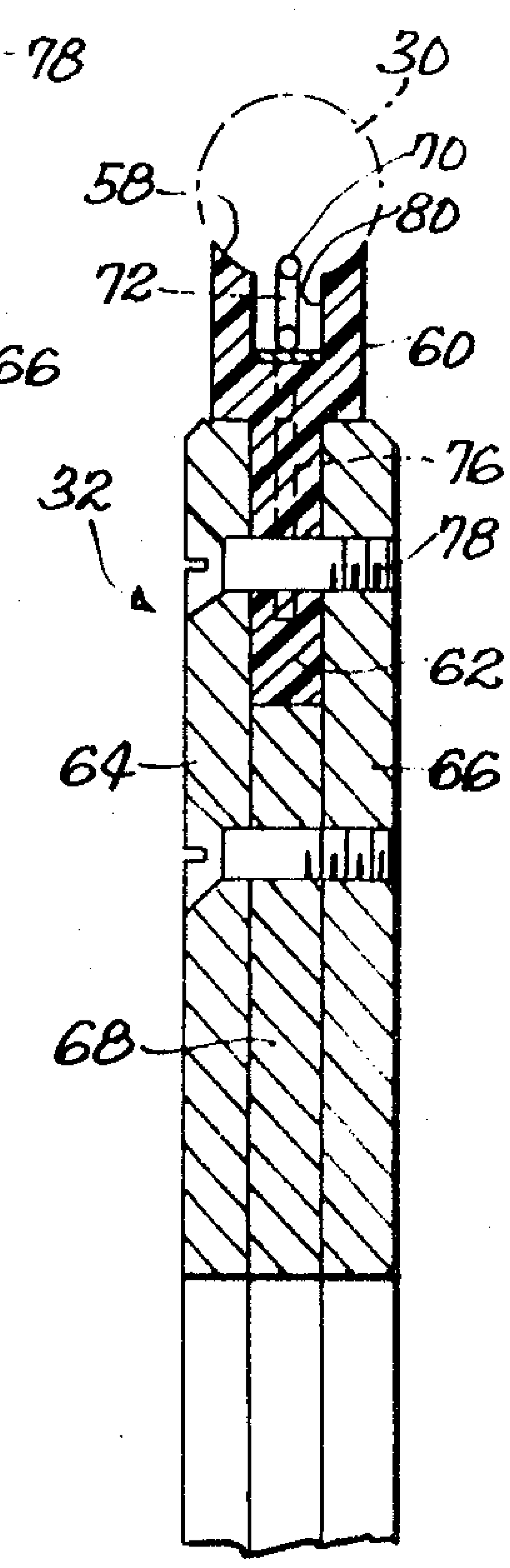


FIG. 6

FIG. 7

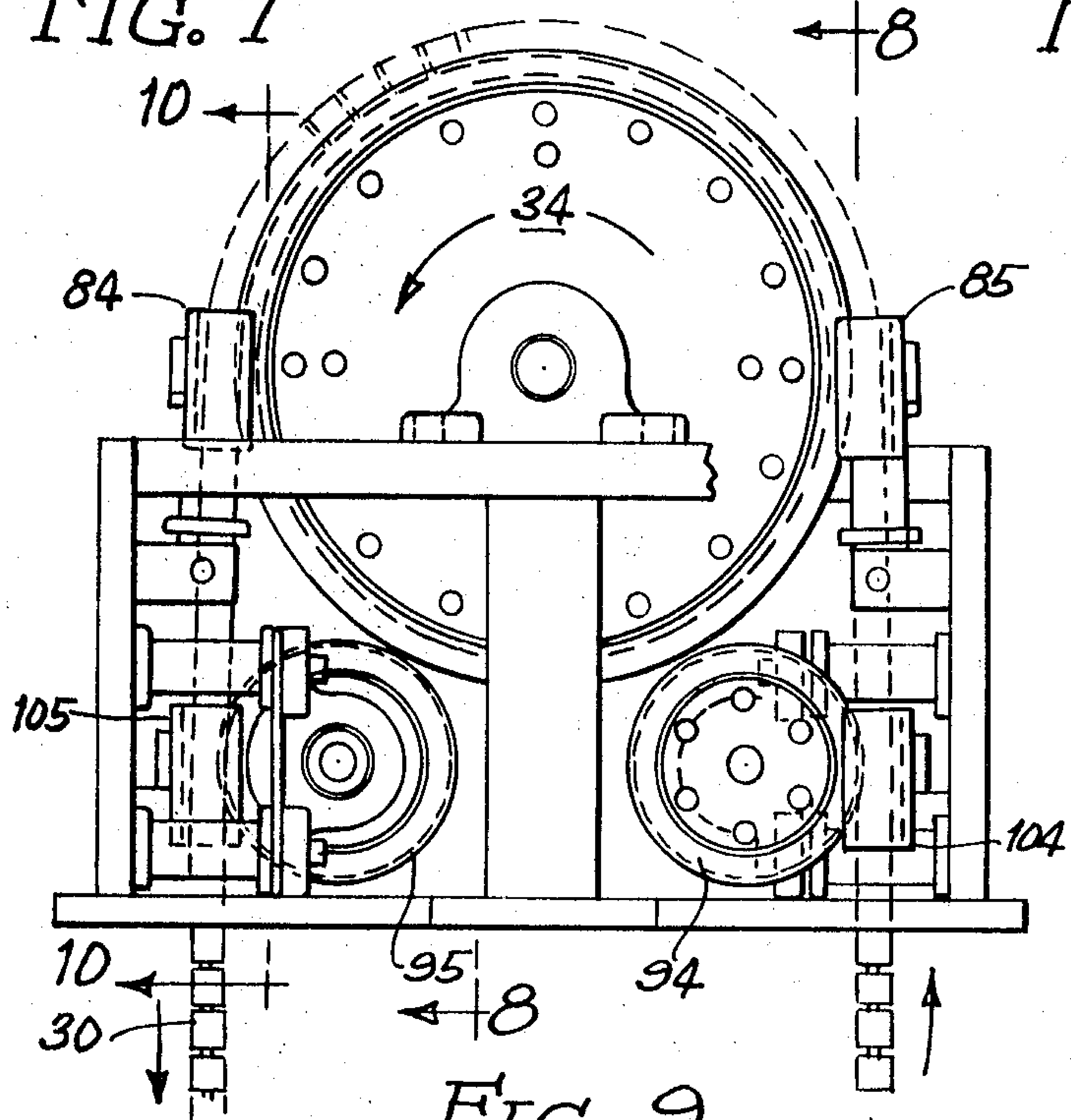


FIG. 8

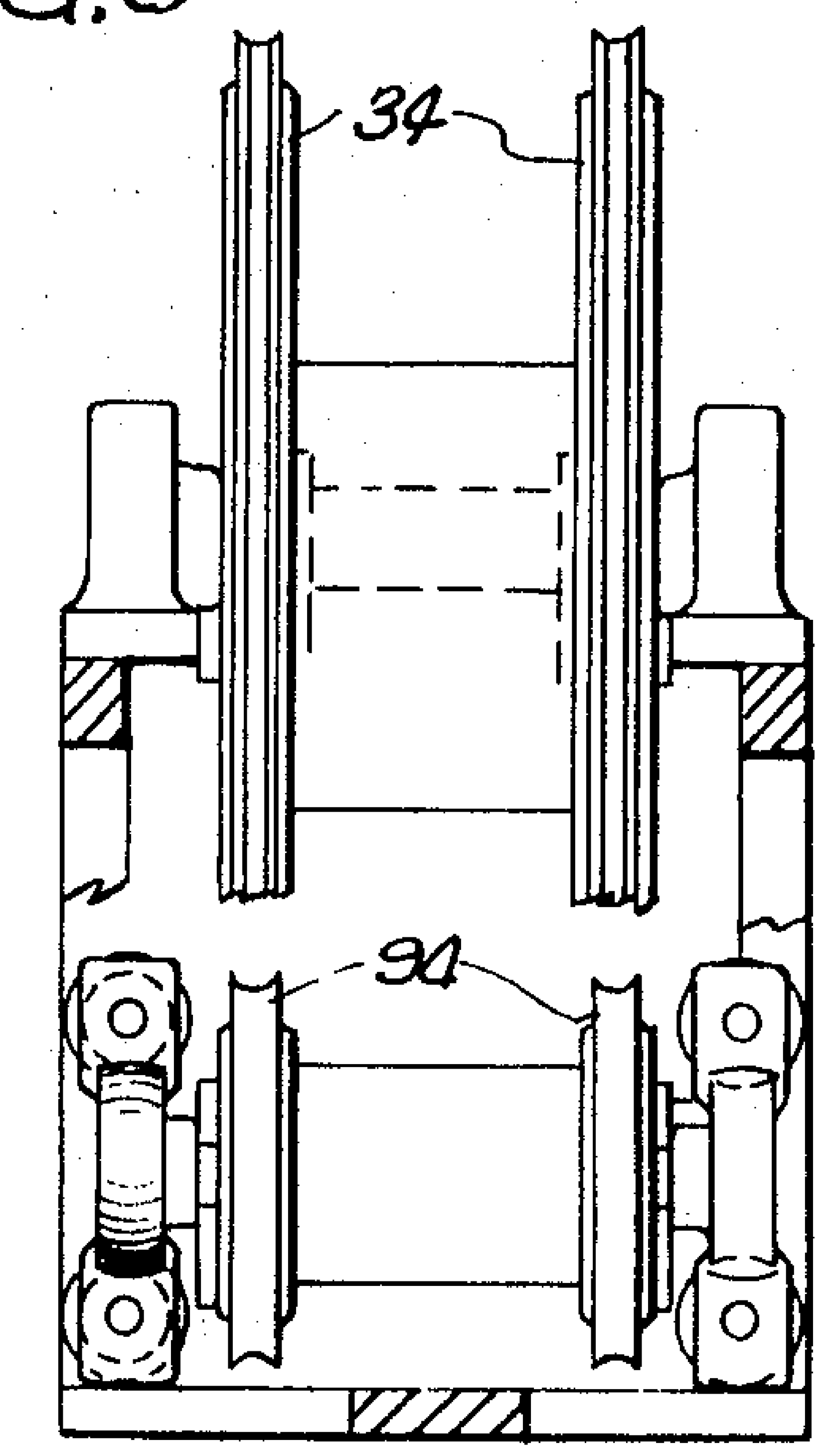


FIG. 9

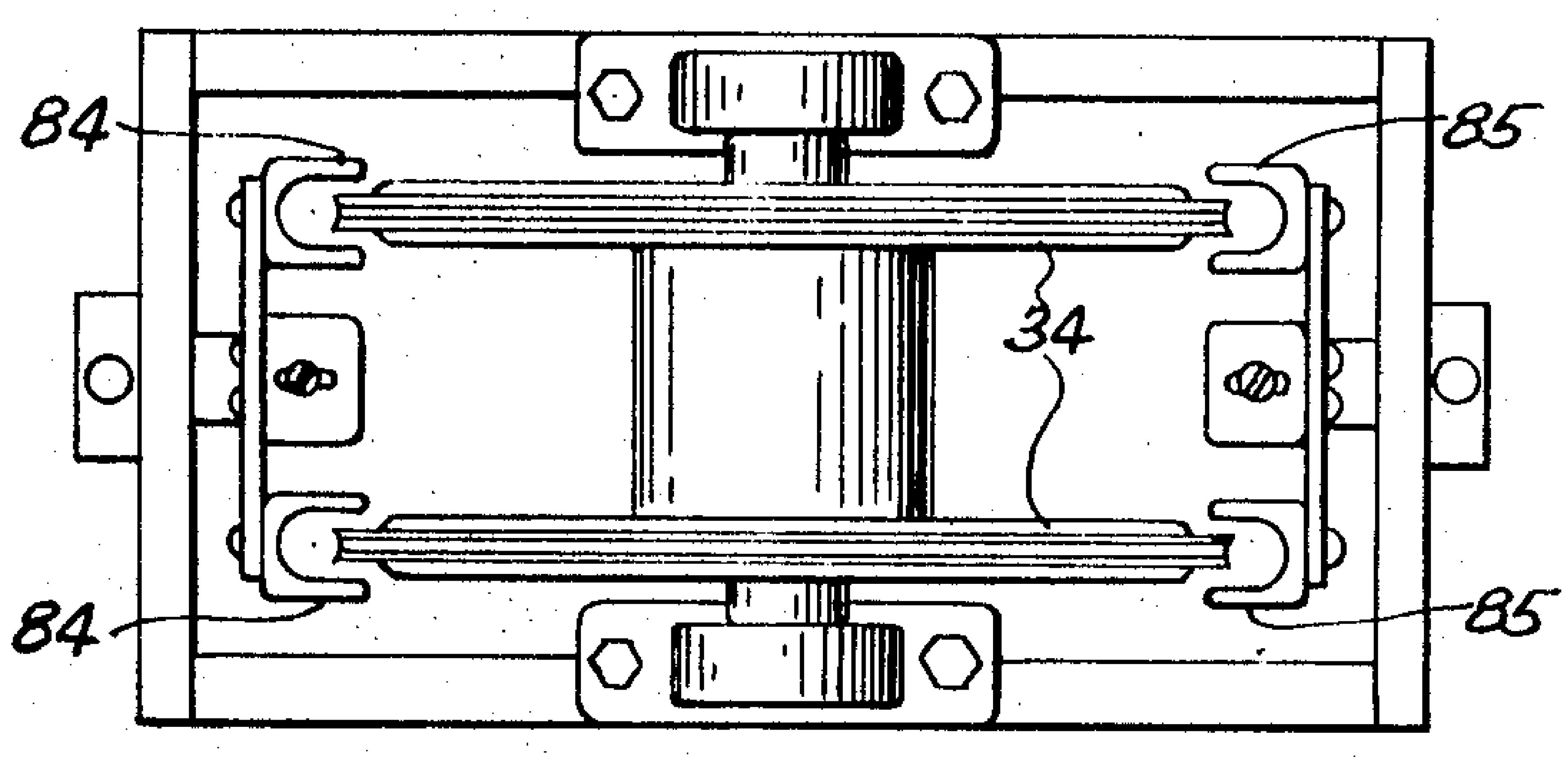


FIG. 10

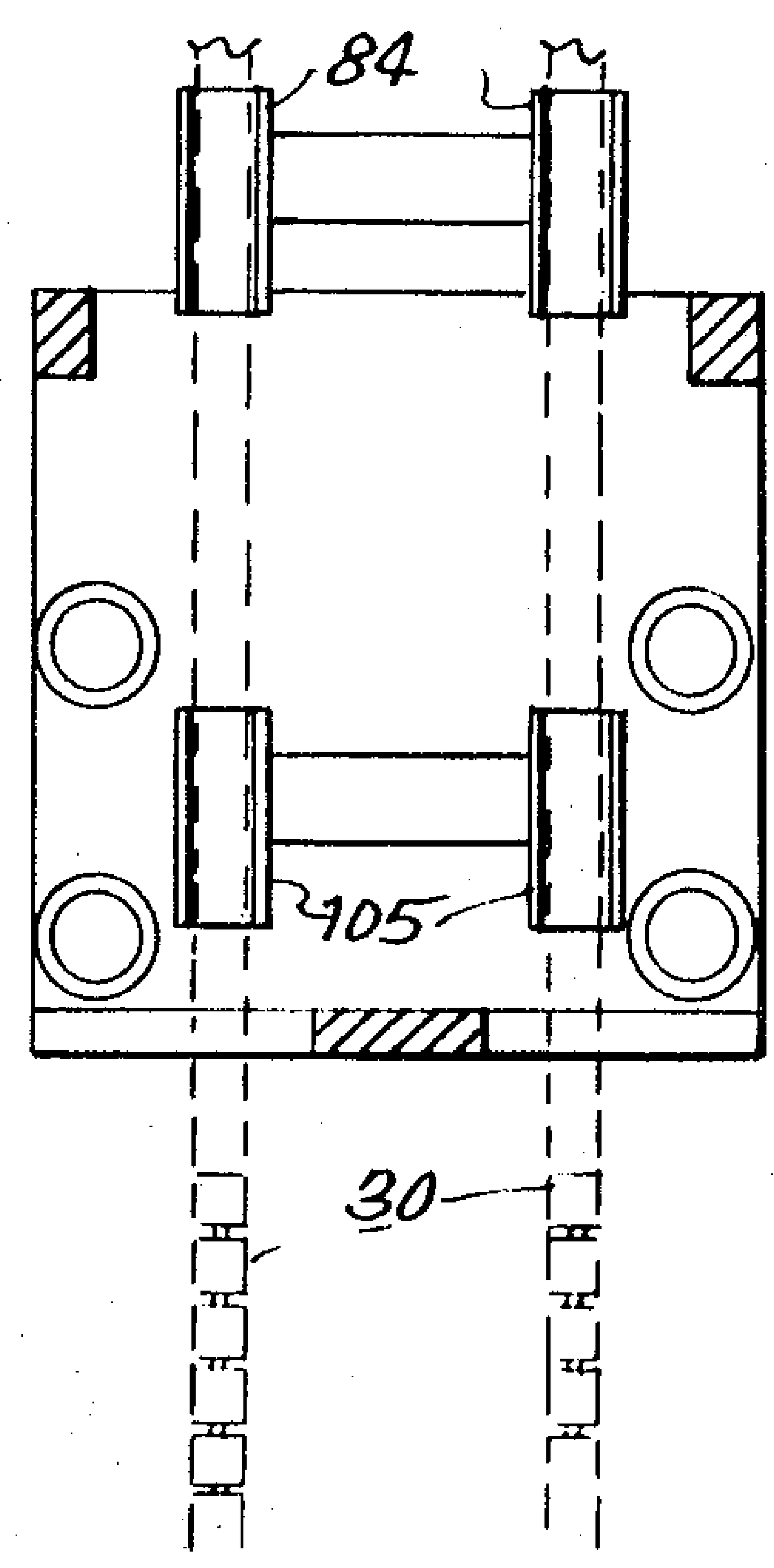


FIG. 11

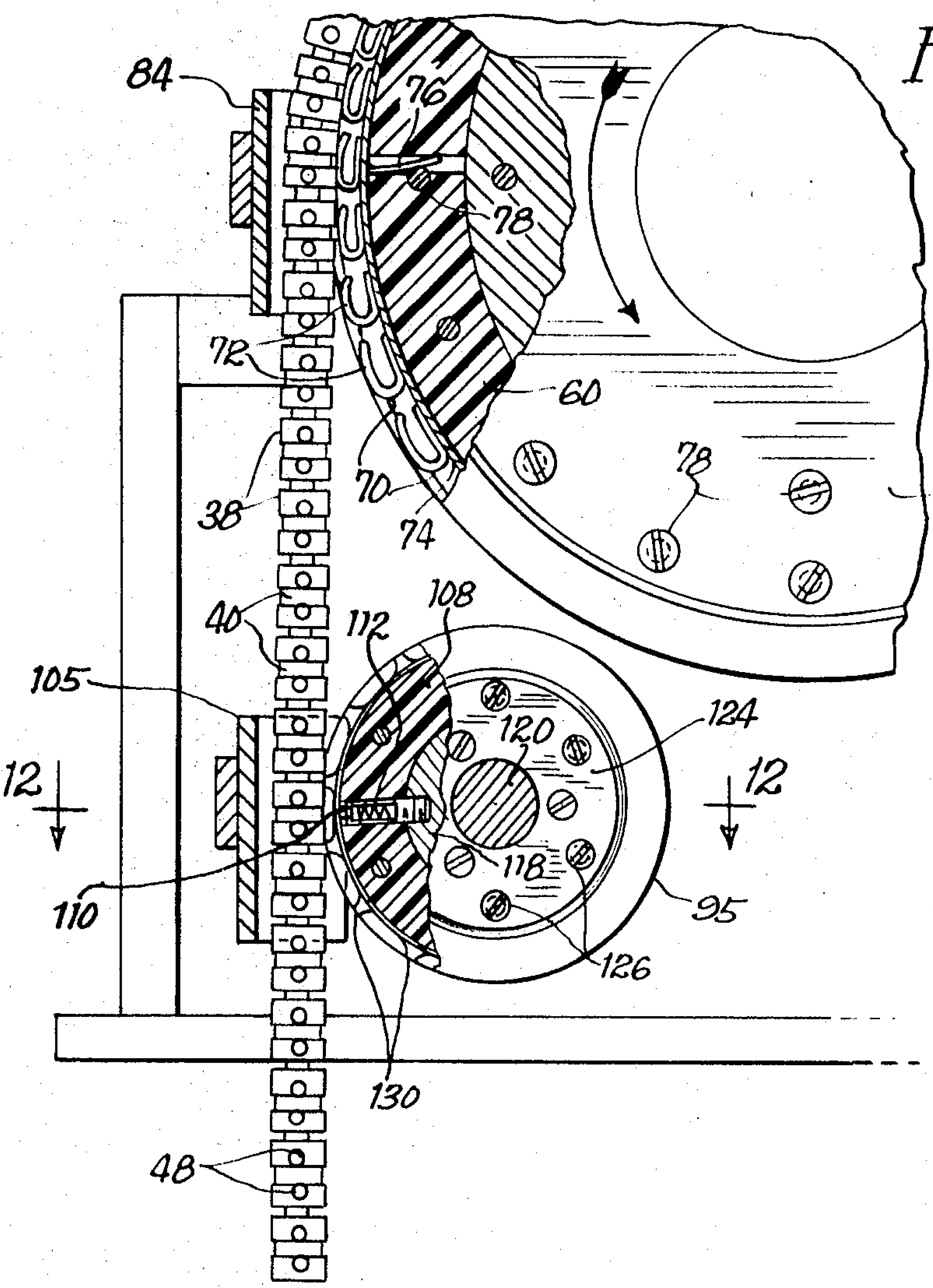


FIG. 13

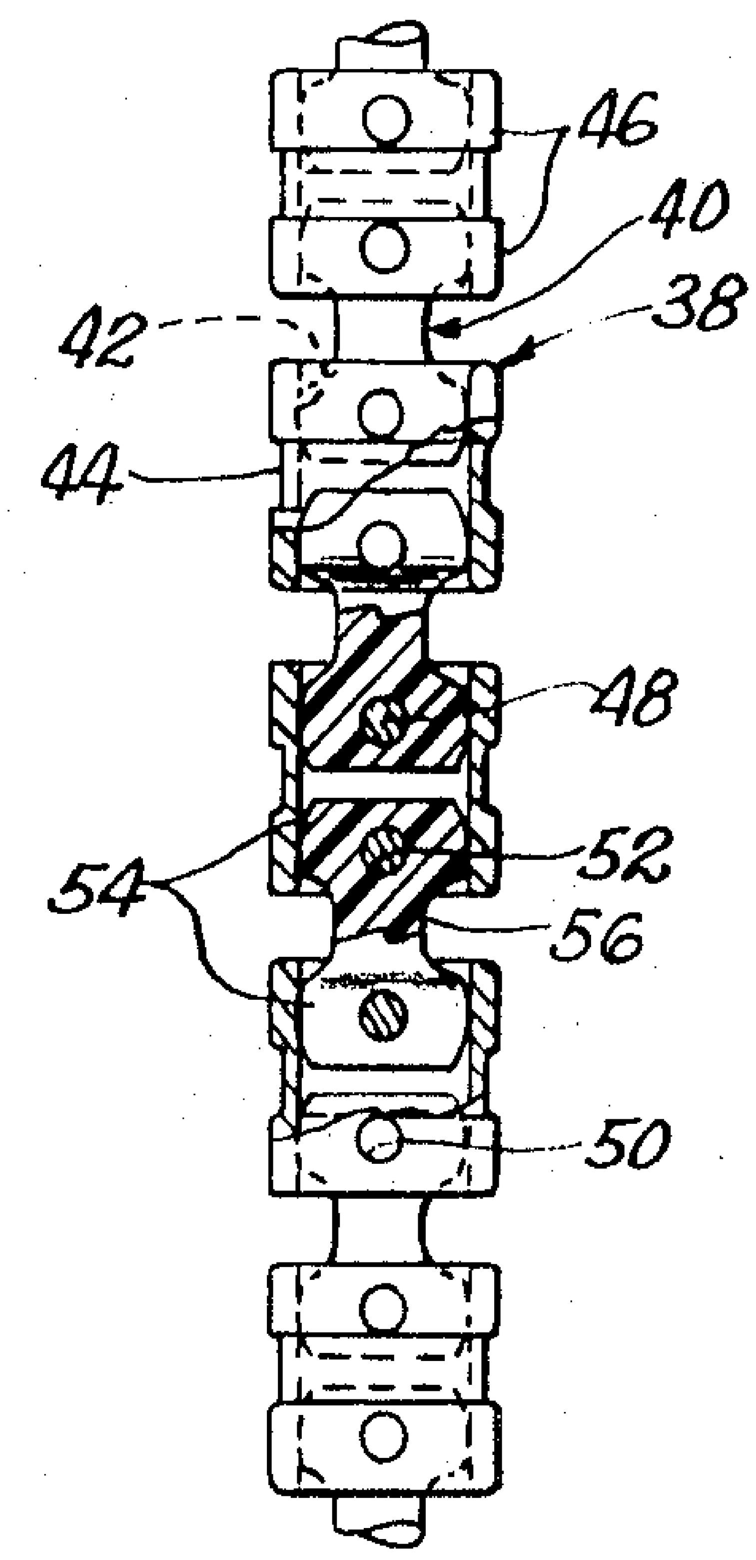


FIG. 12

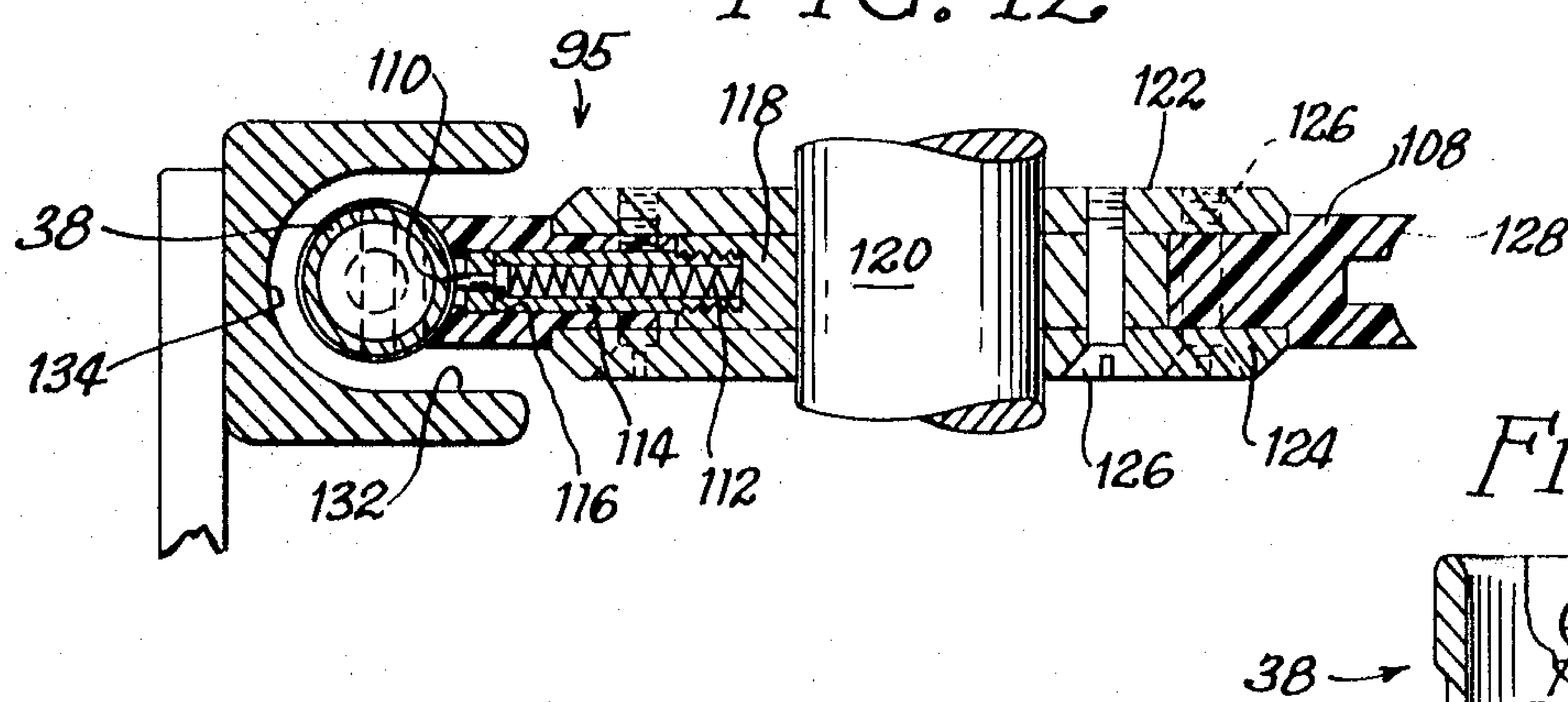
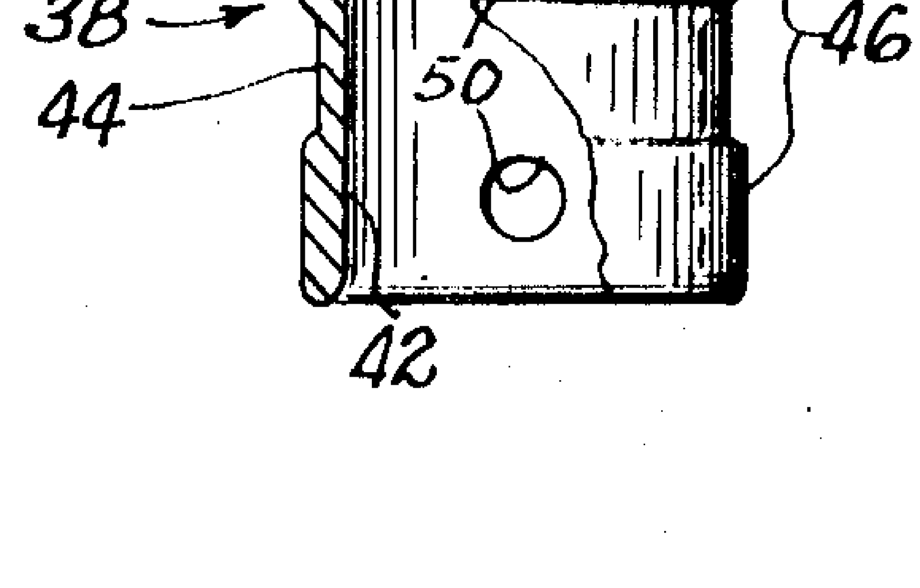


FIG. 14



HIGH-VOLTAGE ELECTROSTATIC GENERATOR

This invention relates to high-voltage electrostatic generators of the type in which an extremely high voltage is produced by conveying electrostatic charges to a high-voltage electrode on which the charges are accumulated.

One object of the present invention is to provide a high-voltage electrostatic generator having a new and improved charge carrying conveyor which has a high-charge-carrying capacity, is capable of operating at high speeds, and is invulnerable to damage due to possible sparking or flashovers along the conveyor.

Thus, the present invention preferably utilizes an endless charge carrying conveyor comprising a chain having electrically conductive links alternating with electrically insulating links. Pivot means are provided between the links. The electrically conductive links are preferably in the form of cylindrical pellets having axially disposed cylindrical openings therein. The electrically insulating links are swingably mounted within the cylindrical openings by means of pivot pins. Preferably, the electrically insulating links comprise enlarged spherically rounded end portions swingably received in the cylindrical openings. The pellets are preferably made of metal while the insulating links are made of nylon or other suitable plastic material. The insulating links may also be made of a ceramic material.

A further object is to provide a high-voltage electrostatic generator having improved systems for transferring charges to and from the pellets, with maximum efficiency and virtually no sparking.

Thus, the invention preferably utilizes an endless conveyor having conductive pellets with insulating elements therebetween. The conveyor is trained around main wheels having edge portions with grooves therein for receiving the conveyor. The edge portion of each wheel is preferably made of nylon or other suitable plastic material to minimize noise and wear. The charges are transferred to and from the pellets by means of contactors on the wheels. The contactors project into the groove on each wheel to engage the pellets. Preferably, the contactors are in the form of contact springs or other resiliently biased elements to provide spring pressure between the contactors and the pellets.

Induction electrodes are preferably provided where the pellets make and break contact with the wheels. The operating voltages for at least some of the induction electrodes are provided by idler pulleys which contact the pellets at points spaced from the main wheels. Each idler pulley preferably has a rim portion made of nylon or other suitable plastic material for quiet running and minimum wear. At least one resilient contactor is preferably provided on each idler pulley to engage the pellets. Additional induction electrodes are preferably provided opposite the idler pulleys.

The induction electrodes substantially prevent sparking between the pellets and the pulleys and also between the pellets and the main wheels. Thus, the erosion of the pellets due to sparking is virtually eliminated. The elimination of sparking also increases the maximum voltage capacity of the generator.

Further objects, advantages and features of the present invention will appear from the following description, taken with the accompanying drawings, in which:

FIG. 1 is a diagrammatic elevational section of a high voltage electrostatic generator, to be described as an illustrative embodiment of the present invention.

FIG. 2 is a diagrammatic elevation of the charge-transporting system for the generator.

FIG. 3 is a fragment elevational section corresponding to the lower portion of FIG. 2 and showing additional details of the charge-transporting system.

FIG. 4 is a sectional plan view taken generally along the line 4—4 in FIG. 3.

FIG. 5 is an edge view of one of the main wheels shown in FIGS. 3 and 4.

FIG. 6 is an enlarged fragmentary section taken through the main wheel of FIG. 5.

FIG. 7 is a fragmentary elevation corresponding to the upper portion of FIG. 2.

FIG. 8 is an elevational section taken generally along the line 8—8 in FIG. 7.

FIG. 9 is a top view of the assembly shown in FIG. 7.

FIG. 10 is an elevational section taken generally along the line 10—10 in FIG. 7.

FIG. 11 is a fragmentary enlarged sectional view corresponding to the left-hand portion of FIG. 7.

FIG. 12 is a fragmentary enlarged section taken generally along the line 12—12 in FIG. 11.

FIG. 13 is an enlarged elevational section of the endless pellet chain employed in the high-voltage generator.

FIG. 14 is an enlarged elevational section of one of the conductive pellets.

As already indicated, FIG. 1 illustrates a high-voltage electrostatic generator 10 which will find many applications, but is especially well adapted to provide an extremely high voltage for accelerating charged particles in an evacuated accelerating tube 12, to carry out studies in nuclear physics or to generate high-energy x-rays. The high-voltage generator 10 is preferably housed within a pressure tank or casing 14. In this way, the generator 10 may be surrounded by a high-pressure atmosphere, so as to provide greatly improved resistance to high-voltage flashovers. Accordingly, the high-voltage generator 10 may be operated at a much higher voltage than would be possible in air at normal atmospheric pressure. While high-pressure air may be employed within the tank 14, it is preferred to provide an atmosphere comprising a gas having an extremely high dielectric strength, such as sulfur hexafluoride, for example. The sulfur hexafluoride may be mixed with air but the use of pure sulfur hexafluoride is preferred. Other known or suitable gases may also be employed to increase the insulating value of the atmosphere around the high-voltage generator. The tank 14 is usually made of steel or other metal and is maintained at ground potential.

Within the tank 14, the high-voltage generator 10 comprises a grounded supporting frame or member 16, mounted on one end of the tank 14. A high-voltage electrode 18 is disposed in the tank 14 near the opposite end thereof and is connected to the frame 16 by a plurality of insulator assemblies 20. The high voltage electrode 18 is hollow and thus is formed with a chamber 22 therein. All of the surfaces of the high-voltage electrode 18 are smoothly curved and rounded to avoid any undue concentration of the electric field around the high-voltage electrode. The illustrated high-voltage electrode 18 has a cylindrical wall portion 24 which merges smoothly into a spherically curved end portion 26. The construction of the high-voltage electrode 18 is such that the possibility of sparking between the high-voltage electrode and the tank 14 is minimized.

The high-voltage electrode 18 is capable of accumulating electrical charges to an extremely high voltage. The insulator assemblies 20 are capable of withstanding the high voltage. It will be seen that the accelerating tube 12 extends between the high-voltage electrode 18 and the grounded tank 14.

A charge-transporting system 28 is provided to carry successive electrical charges to the high-voltage electrode 18. These charges are accumulated on the high-voltage electrode 18 so that the voltage thereon builds up to an extremely high value.

It will be seen that the charge-transporting system 28 comprises one or more endless conveyors 30, each of which is threaded around at least two main wheels or pulleys 32 and 34. While a single endless conveyor could be employed, the illustrated machine utilizes two parallel conveyors, to double the charge-carrying capacity of the charge-transporting system 28, as will be seen from FIG. 4.

As shown in FIGS. 1 and 2, the first supporting wheel 32 for each conveyor 30 is mounted on the grounded frame 16 while the second wheel 34 is mounted within the high-voltage electrode 18. The wheel 32 is suitably driven, preferably by an electric motor 36.

The details of each endless conveyor 30 are shown to best advantage in FIGS. 13 and 14. The conveyor 30 comprises conductive elements 38 alternating with electrically insulating elements 40. The conductive elements 38 are preferably in the form of metal pellets, connected into an endless string by the insulating elements 40. As shown, the conductive elements or pellets 38 are circular in cross section and are preferably of a generally cylindrical shape. The pellets 38 have rounded ends to avoid any sharp edges which might cause a high concentration of the electric field around the pellets. In this way, the possibility of sparking along the pellets is minimized.

The illustrated pellets 38 have cylindrical openings 42, axially disposed therein. While the openings 42 are illustrated as extending completely through the pellets, they could extend only part way into each end.

Each pellet 38 has a generally cylindrical exterior. However, to improve the running of the pellets around the wheels 32 and 34, each pellet 38 is preferably formed with a circumferential groove 44 around its midsection. The pellet 38 has cylindrical surfaces 46 at opposite sides of the groove 44.

The electrically insulating elements 40 may assume a variety of forms, as long as they provide flexible interconnections between the pellets 38. However, the insulating elements 40 are preferably in the form of links made of plastic, ceramic or other insulating materials. One preferred plastic material is nylon, which provides the advantages of high strength, low wear and self-lubrication, as well as good electrical insulation.

Pivot elements 48 are preferably provided between the insulating elements or links 40 and the conductive pellets 38 so that the elements 38 and 40 form the alternate links of a continuous chain. The illustrated pivot elements 48 are in the form of pins extending through openings 50 and 52 in the elements 38 and 40. The pins 50 are preferably press fitted into place so that they are securely retained.

The insulating links 40 are preferably formed with enlarged spherically rounded end portions 54 which are swingable within the cylindrical openings 42 in the pellets 38. Each of the illustrated links 40 has a reduced midsection 56 between the enlarged end portions 54. The main wheels or pulleys 32 and 34 may be essentially the same in construction. The details of the wheels are shown to best advantage in FIGS. 6 and 11. It will be seen that each of the wheels 32 and 34 is formed with a peripheral groove 58 to receive and retain the pellets 38 of the corresponding endless conveyor 30. The groove 58 is preferably rounded in cross section, to correspond with the cylindrical shape of the pellets 38.

To afford low noise and wear, each of the wheels 32 and 34 is preferably provided with a plastic peripheral rim portion 60, made of nylon or other suitable material. The peripheral groove 58 is formed in the rim portion 60. To secure the illustrated rim portion 60 to the wheel, the illustrated rim portion is formed with an inwardly projecting flange 62 of reduced thickness, adapted to be clamped between metal plates 64 and 66, forming the main body of the wheel. Another metal plate 68 is clamped between the inner portions of the plates 64 and 66.

While it is highly advantageous to employ a plastic material for the rim portion 60 of the wheel, the plastic material does not provide an electrical connection between the pellets 38 and the metal parts 64, 66 and 68 of the wheel. Such electrical connection is necessary to provide for electrical charge transfers, to and from the pellets. In the case of the wheel 32, charges are transferred by way of the wheel from the grounded frame 16 to the pellets 38. In the case of the wheel 34, charges are transferred by way of the wheel from the pellets 38 to the high-voltage electrode 18.

To provide for such charge transfers, each of the wheels 34 and 36 is provided with one or more contactors 70 which engage the pellets 38 and are connected electrically to the metal parts of the wheel. The illustrated wheels are provided with a series of such contactors 70 spaced around the periphery of each wheel. The contactors 70 preferably project into the peripheral groove 58 so as to engage the pellets 38. Moreover, the mounting of the contactors 70 is preferably resilient so that they exert spring pressure against the pellets. The illustrated contactors 70 are formed as the outer portions of U-shaped wire springs 72 having their inner portions welded or otherwise secured to a metal band 74, extending around the periphery of the wheel. The metal band 74 is connected electrically to the metal plates 64, 66 and 68 by suitable means, illustrated as comprising one or more spring arms 76 projecting inwardly from the band and engaging clamping screws 78 which extend through the plates 64 and 66. The curved guide groove 58 for the pellets 38 is formed with a deeper central groove 80 to receive the band 74 and the springs 72. It will be seen from FIG. 6 that the contactors 70, constituting the outer portions of the springs 72, extend outwardly from the groove 80, into the groove 58.

As shown to best advantage in FIG. 2, the charge-transporting system 28 preferably comprises two induction electrodes 82 and 83, opposite the main wheel 32, and two more induction electrodes 84 and 85, opposite the other wheel 34. The induction electrodes 82–85 are located at the points where the endless conveyor 30 makes and breaks contact with the wheels 32 and 34.

The induction electrodes 82–85 are employed to charge and discharge the pellets 38 with a minimum of sparking. As shown, the induction electrode 82 is maintained at a fairly high voltage by a direct-current power supply 88. Typically, the power supply 88 delivers 10 to 50 kilovolts. The induction electrode 82 induces charges on the pellets 38 as they depart from the wheel 32. The actual flow of the charges to the pellets occurs before the pellets part company from the wheel 32, so that there is virtually no sparking between the pellets and the wheel.

The pellets 38 carry the charges to the second wheel 34, through which they are transferred to the high-voltage electrode 18. The induction electrode 85 is maintained at a fairly high voltage relative to the high-voltage electrode 18 so that the induction electrode 85 is able to bind the charges on the pellets 38 until after the pellets make contact with the wheel 84. Thus, the induction electrode 85 prevents sparking between the pellets and the wheel 34.

The induction electrode 84 is located opposite the wheel 34 at the point where the return flight of the conveyor 30 parts company from the wheel. The induction electrode 84 is provided with a high voltage relative to the high-voltage electrode 18 so that charges are induced on the pellets 38 as they depart from the wheel 34 in their return flight to the wheel 32. The charges induced on the returning pellets are of the opposite sign from the charges carried to the high-voltage electrode 18 by the incoming pellets. Thus, the polarity of the voltage on the induction electrode 84, relative to the high-voltage electrode 18, is opposite to the polarity of the voltage on the induction electrode 85. For example, if the high-voltage electrode 18 is to be charged positively, the charges on the incoming pellets will be positive, and the voltage on the induction electrode 85 will be less positive than that on the high-voltage electrode. The voltage on the induction electrode 84 will be more positive than that on the high-voltage electrode 18, so that negative charges will be carried away from the high-voltage electrode by the returning pellets.

The charges on the returning pellets are discharged to ground through the wheel 32. The induction electrode 83 is located opposite the wheel 32, where the returning pellets engage the wheel. This induction electrode is operated at a high voltage so as to bind the charges on the returning pellets until they actually engage the wheel 32. In this way, sparking is prevented. The polarity of the voltage on the induction electrode 83 is opposite to that on the induction electrode 82.

When the main high-voltage electrode or dome 18 is to be positively charged, the voltage relationships will be as follows:

	Potential
High voltage electrode 18	V_d
Induction electrode 82	$-V$
Induction electrode 83	$+V$
Induction electrode 84	V_d+V
Induction electrode 85	V_d-V

For negative charging of the high-voltage electrode 18, the signs of all voltages will be reversed from those given in the above table.

In order to provide the operating voltages for the induction electrodes 83, 84 and 85, it is preferred to employ idler pulleys 93, 94 and 95 to engage the conveyor 30 at points near the wheels 32 and 34. The pulley 93 is connected to the induction electrode 83 and is positioned to engage the pellets 38 near the beginning of their outward flight between the wheels 32 and 34. Thus, the charged pellets maintain the pulley 93 and the induction electrode 83 in a charged condition. An additional electrode 103 is disposed so as to influence the pellets 38 as they engage the pulley 93. The induction electrode 103 is grounded and thus is at zero voltage.

The pulley 94 is connected to the induction electrode 84 and is positioned to engage the incoming pellets 38 shortly before they arrive at the wheel 34. Thus, the pulley 94 and the induction electrode 84 are maintained in a charged condition by the pellets. If the pellets are positively charged, the pulley 94 and the induction electrode 84 are charged with a voltage which is more positive then that on the high-voltage electrode 18. Another induction electrode 104 is preferably positioned so as to influence the pellets as they engage the pulley 94. The induction electrode 104 is connected to the high-voltage electrode 18 and thus is kept at the same voltage existing thereon.

The pulley 95 is connected to the induction electrode 85 and is positioned to engage the pellets, shortly after they leave the wheel 34. If the high voltage electrode 18 is positively charged, the pellets at this point are negatively charged, so that the pulley 95 and the induction electrode 85 are charged with a voltage which is less positive than that on the high-voltage electrode 18. Still another induction electrode 105 is disposed opposite the pulley 95 and is connected to the high-voltage electrode 18 so as to be maintained at the voltage thereof.

The idler pulleys 93, 94 and 95 may all be of the same construction. They may be made of metal so as to be totally conductive, but it is preferred to provide each pulley with a peripheral or rim portion 103 (FIGS. 11 and 12) made of nylon or other suitable plastic material, to afford the advantages of quiet operation and extremely long life. The plastic material is electrically nonconductive, but contact is made with the pellets 38 by means of one or more spring contactors 110. The spring contactors 110 could be of the same construction as employed on the main pulleys or wheels 32 and 34. However, as shown in FIGS. 11 and 12, each contactor 110 is in the form of a plunger or pin biased outwardly by a coil spring 112. The contactor 110 and the spring 112 are mounted in a tubular housing 114 which extends through an opening 116 in the plastic rim portion 108. Each of the pulleys 93–95 has a central portion 118 which is also engaged by the housing 114. The central portion 118 and the housing 114 are preferably made of metal or other electrically conductive material. In this way, the contactor 110 is connected to the central portion 118 of the pulley and thence to the shaft 120 on which the pulley is mounted.

The plastic rim portion 108 is suitably secured to the central portion 118, as by means of clamping plates 122 and 124, for example. Screws 126 may be employed to secure the plates 122 and 124 to the central portion 118 and the plastic rim portion 108.

A peripheral groove 128 is preferably provided in the plastic rim portion 108 to receive and retain the pellets 38 of the conveyor 30. The contactor 110 projects into the groove 128 so as to be engageable with the pellets 38.

To improve the traction between the conveyor 30 and the idler pulleys 93–95, it is preferred to provide the rim portion 108 of each pulley with a plurality of angularly spaced teeth or ribs 130, projecting into the peripheral groove 128. The teeth 13 are spaced so as to be readily receivable in the spaces between the pellets 38 on the conveyor 30.

All of the various induction electrodes 82–85 and 103–105 may be of substantially the same construction. As shown to best advantage in FIGS. 11 and 12, each induction electrode may be formed with a U-shaped channel 132, wider than the pellets 38 and adapted to embrace the rim portions of the various pulleys 32, 34, 93, 94 and 95, with ample clearance between the induction electrodes and the pulleys. The U-shaped channel 132 has a cylindrically curved bottom portion 134 adapted to be positioned opposite the pellets 38 of the conveyor 30.

In operation, the conveyor 30 carries electrostatic charges in both directions between the wheels 32 and 34, on the grounded frame 16 and the high-voltage electrode 18. The conductive pellets 38 of the conveyor 30 are charged by the voltage on the induction electrode 82, as the pellets depart from the wheel 32. If the voltage on the electrode 82 is negative, the charges on the pellets will be positive, and vice versa.

The charges on the outbound pellets are coupled to the induction electrode 83 by the idler pulley 93, so that the electrode 83 is maintained at an operating voltage which is opposite in polarity to the voltage impressed on the induction electrode 82 by the power supply 88. The induction electrode 83 prevents sparking between the returning pellets and the wheel 32.

The charged outbound pellets are conveyed across the high voltage which exists between the high-voltage electrode 18 and the grounded frame 16, and are discharged to the high-voltage electrode through the wheel 34. The induction electrode 85 prevents sparking between the incoming pellets and the wheel 34.

The returning pellets are given charges of opposite sign high-voltage depart from the wheel 34. These charges are induced by the electrode 84 which derives its operating voltage from the idler pulley 94. The charges on the incoming pellets are conducted to the pulley 94 and the electrode 84 until these elements are at the same voltage as the pellets, which is higher than the voltage on the high-voltage electrode 18.

The operating voltage for the induction electrode 85 is derived from the returning pellets by way of the idler pulley 95.

The charges on the returning pellets are transferred to ground by the wheel 32. The charges on the returning pellets are opposite in polarity to the charges on the outbound pellets.

The resilient contactors 70 on the main wheels 32 and 34 insure that the pellets 38 are conductively connected to the wheels, and thence to the grounded frame 16 and the high-voltage electrode 18. Similarly, the resilient contactors 110 on the idler pulleys 93–95 insure the electrical connections will be established between the pellets and the idler pulleys.

The charging of the pellets 38 is brought about by the energization of the power supply 88, so as to apply a high-voltage to the induction electrode 82. When the applied voltage is negative, the voltage developed on the high-voltage electrode 18 will be positive and vice versa. For the case in which the voltage developed on the high-voltage electrode or dome 18 is positive, the voltage relationships are as follows:

	Potential
High voltage electrode or dome 18	V_d
Induction electrode 82	$-V$
Induction electrode 83 and pulley 93	$+V$
Induction electrode 84 and pulley 94	V_d+V
Induction electrode 85 and pulley 95	V_d-V
Induction electrode 103	O
Induction electrodes 104 and 105	V_d

The voltage on the induction electrode 82 is stabilized and maintained by the power supply 88. The voltages on the other main induction electrodes 83, 84 and 85 will be held accurately at the desired potentials by charge transfer to or from the pellets 38, only if these additional induction electrodes conform in shape and positioning, relative to the respective pulleys 32 and 34, so that the combination of each induction electrode and the corresponding pulley is electrostatically equivalent to the combination of the induction electrode **82** and the pulley **32**.

The charging rate is determined by the potential applied to the induction electrode **82** by the power supply **88**. During normal operation, the charge on each of the pulleys **93, 94** and **95** is substantially constant, so that there is no appreciable flow of charge. It is only when the charging rate is being changed that there is an appreciable flow of charges to the pulleys **93, 94** and **95**. This flow persists only long enough to change the potentials on the induction electrodes **83, 84** and **85** relative to the corresponding pulleys, so that these potentials are kept equal in magnitude to the applied potential on the induction electrode **82**, but with the appropriate sign.

The induction electrode arrangement achieves two important advantages. First, the returning pellets, on the downcoming run of the pellet chain, are given charges equal in magnitude but opposite in sign to the charges on the outgoing pellets. Thus, the total charging current is maximized, yet is readily subject to control by the operator. Second, the arrangement of the induction electrodes brings about the transfer of charges between the pellets **38** and the pulleys **32** and **34** without sparking.

The action of the induction electrode **82** may be taken as an example. Each pellet **38** is in contact with the pulley **32** as the pellet moves into the U-shaped opening of the induction electrode. The negative potential on the induction electrode **82** causes a positive charge to flow to the pellet. As the pellet moves more deeply into the induction electrode, a greater positive charge is induced upon its surface. This charge flows to the pellet without sparking, because the contact between the pellet and the pulley is maintained. The pellet moves to its maximum depth within the induction electrode before the pellet breaks contact with the pulley. As the pellet is leaving the pulley, constant depth is maintained, so that the induced charge on the pellet is maintained constant. Thus, the current flow to the pellet drops to zero just before the contact break. Accordingly, there is no sparking between the pellet and the pulley. By the time the pellet is leaving the induction electrode **82**, the pellet is far from the pulley, so that the charge can no longer escape.

The positive charge remains on each pellet **38** as it passes upwardly into the high-voltage electrode or dome **18**. There is no charge transfer when the pellet touches the pulley **94** because the charge is bound on the pellet by the induction electrode **104**. The pellet now enters the induction electrode **85** which also binds the positive charge on the pellet. At the moment of contact with the pulley **34**, there is no current flow, because of this charge binding action of the induction electrode **85**. The charge flows from the pellet **38** to the pulley **34** as the pellet is leaving the influence of the induction electrode **85**. The charge flows smoothly while the pellet is in contact with the pulley **34**. Thus, there is no sparking and no energy loss.

The details of the charge transfer as each pellet **38** leaves the pulley **34** are the same as previously described, except for the sign of the charges, which are negative rather than positive. When the returning pellets arrive at the grounded pulley **32**, the charge transfer is again accomplished without sparking, in the same manner as when the pellets arrive at the pulley **34**.

To prevent sparking, all of the induction electrodes **82–85** should be identical in shape and should be positioned identically with respect to the pellet chain and the main pulleys **32** and **34**. The electrostatic field conditions around the various induction electrodes should be closely matched, so that different field conditions will not penetrate within the induction electrodes to any appreciable extent. If the induction electrodes are properly matched, the bound charge on each pellet at the instant of contact or contact break with each pulley will be the same in all four cases.

Under normal operating conditions, the charge on each of the pulleys **93, 94** and **95** is maintained constant so that there is no appreciable current flow and no sparking. It is only when the charging rate is being changed that there is any appreciable charge transfer to or from the pulleys, and even this current is transitory and of small magnitude.

The elimination of sparking under steady state conditions obviates the dust and corrosion problems that are associated with sparking. Moreover, the elimination of sparking obviates the energy loss that is associated with sparking. Accordingly, the charging system is highly efficient.

The pellet conveyor **30** can be operated at extremely high speeds, so that the charge carrying capacity of the conveyor will be high. The conveyor operates quietly and efficiently. The conductive pellets **38** are freely articulated on the insulating links **40** so that the conveyor has a high degree of flexibility.

Sparking does not normally occur along the conveyor **30**, but any accidental sparking between the pellets **38** will not damage the conveyor in any way. Even a full scale flashover along the conveyor will not damage the pellets **38** or the insulating links **40**. Thus, the machine can be kept in normal operation after any such flashover.

It will be evident that the high-voltage electrostatic generator of the present invention is capable of developing and maintaining a higher voltage, even with a higher load current than heretofore. The machine runs quietly even at extremely high speeds. If a flashover should occur along the conveyor, no damage will occur to the conveyor. Thus, there will be no need to shut down the machine for repairs.

Various other modifications, alternative constructions and equivalents may be employed, as will be understood by those skilled in the art.

We claim:

1. A charge-carrying conveyor for a high-voltage electrostatic generator,

comprising an endless chain having electrically conductive links alternating with electrically insulating links,

said electrically conductive links being generally cylindrical and having cylindrical openings extending axially therein,

said electrically insulating links being swingably received in said cylindrical openings,

and means forming pivot connections between the successive electrically conductive and electrically insulating links.

2. A charge-carrying conveyor according to claim **1**,

in which each of said electrically conductive links has a generally cylindrical exterior portion.

3. A charge-carrying conveyor according to claim **2**,

in which said generally cylindrical exterior portion is formed with a circumferential groove.

4. A charge-carrying conveyor according to claim **1**,

in which said last-mentioned means comprise pivot pin elements extending between said electrically conductive and electrically insulating links.

5. A charge-carrying conveyor according to claim **4**,

in which said pivot pin elements comprise pivot pins extending through openings in said links.

6. A charge-carrying conveyor according to claim **1**,

in which each of said electrically insulating links is formed with enlarged end portions received in said cylindrical openings for rocking movement.

7. A charge-carrying conveyor according to claim **6**,

in which each of said electrically insulating links has a reduced midportion between said enlarged end portions.

8. A charge-carrying conveyor according to claim **1**,

in which each of said electrically insulating links is formed with rounded end portions rockably received in said cylindrical openings.

9. A charge-carrying conveyor according to claim **8**,

in which said rounded end portions are spherically curved.

10. A charge-carrying conveyor according to claim **1**,

in which each of said electrically insulating links is formed with enlarged spherically rounded end portions rockably received in said cylindrical openings.

11. A charge-carrying conveyor according to claim **1**, in which said last-mentioned means comprise two pivot elements extending between said electrically insulating and electrically conductive links,

said electrically insulating links having enlarged spherically rounded end portions received in said cylindrical openings,

said pivot elements extending between said enlarged end portions and said electrically conductive links.

12. In a high-voltage electrostatic generator, the combination comprising an endless charge-carrying conveyor including electrically conductive pellets with electrically insulating elements therebetween,

a wheel having an edge portion with a circumferential groove for receiving and guiding said endless conveyor,

and at least one contactor mounted on said wheel and projecting into said groove for electrically contacting said conductive pellets.

13. A combination according to claim 12, in which said edge portion is made of electrically insulating material.

14. A combination according to claim 12, in which said contactor is provided with resilient mounting means between said contactor and said wheel whereby spring pressure is applied between said contactor and the corresponding conductive pellets.

15. A combination according to claim 12, including a plurality of such contactors mounted on said wheel and projecting into said groove for electrically contacting said pellets.

16. A combination according to claim 12, in which said contactor comprises a flexible conductive spring mounted on said wheel.

17. A combination according to claim 15,

in which said contractors comprise flexible conductive springs mounted on said wheel and spaced around the periphery thereof.

18. A combination according to claim 12,

in which said contactor comprises a radially movable plunger,

and a spring biasing said plunger into said groove.

19. In a high-voltage electrostatic generator,

the combination comprising an endless charge-carrying conveyor including a plurality of electrically conductive pellets with electrically insulating elements disposed therebetween,

a pair of wheel for supporting and circulating said conveyor,

and a charging system including at least one pulley having means thereon for electrically contacting said pellets,

said endless conveyor having a longitudinal axis,

said pellets having substantially larger radial dimensions from said axis than the radial dimensions of said insulating elements,

said pellets being engageable with said pulley for holding said insulating elements away from said pulley to provide gaps between said pulley and said insulating elements.

20. A combination according to claim 19,

in which said last-mentioned means include an electrically conductive portion of said pulley.

21. A combination according to claim 19,

in which said last-mentioned means comprise a contactor mounted on said pulley for contacting said pellets.

22. In a high-voltage electrostatic generator,

the combination comprising an endless charge-carrying conveyor including a plurality of electrically conductive pellets with electrically insulating elements disposed therebetween,

a pair of wheels for supporting and circulating said conveyor,

and a charging system including at least one pulley having means thereon for electrically contacting said pellets,

said pulley including an electrically insulating rim portion for engaging and guiding said conveyor,

said last-mentioned means including a conductive contactor mounted on said pulley and projecting from said insulating rim portion to engage said pellets.

23. A combination according to claim 19, including an induction electrode disposed opposite said pulley in a position such that said pellets are influenced by said electrode when said pellets are engaging said pulley.

24. A combination according to claim 23,

in which said induction electrode is shaped to provide a channel through which said pellets are caused to travel when said pellets are engaging said pulley.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,612,919 **Dated** October 12, 1971

Inventor(s) Raymond G. Herb and James A. Ferry

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 72, "13" should be --130--.

Column 6, line 31, "high voltage" should be --as they--.

Signed and sealed this 14th day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents