March 6, 1962 R. A. BERGAN ET AL 3,024,407

BELT CHARGING MEANS FOR BOREHOLE ELECTROSTATIC GENERATORS

Filed Aug. 20, 1959 2 Sheets-Sheet 1

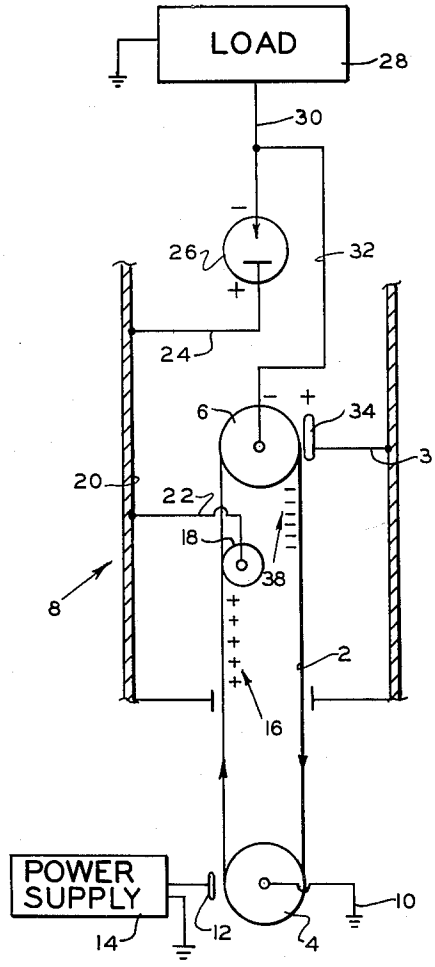


Fig. 1

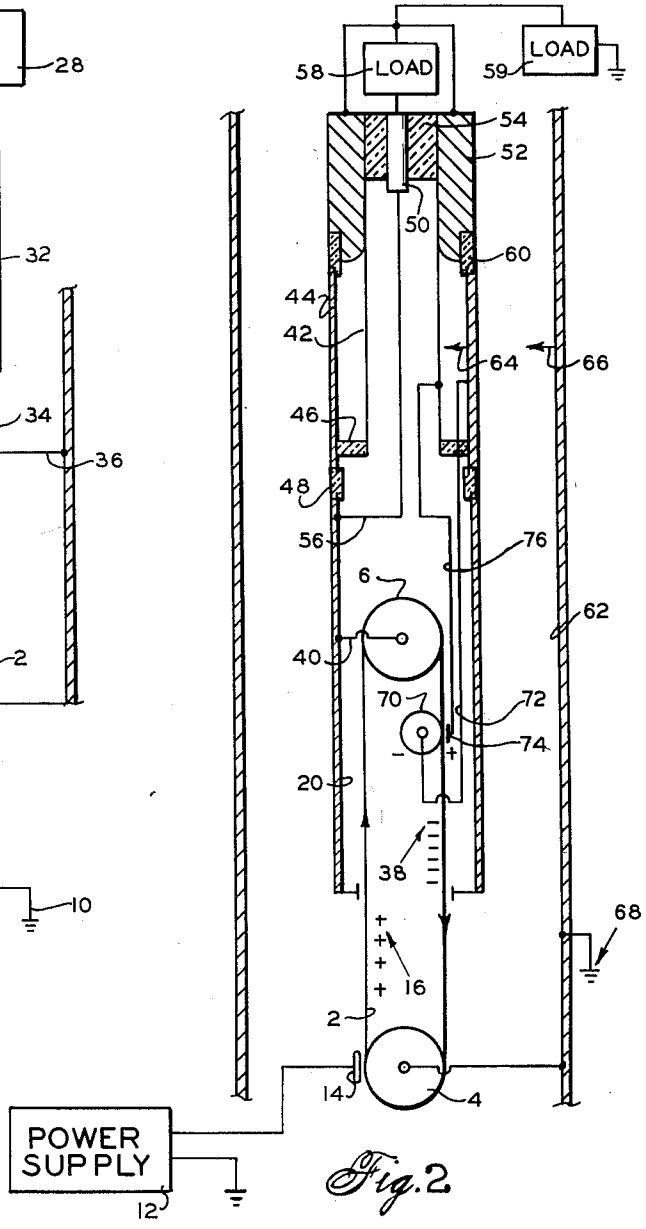


Fig. 2

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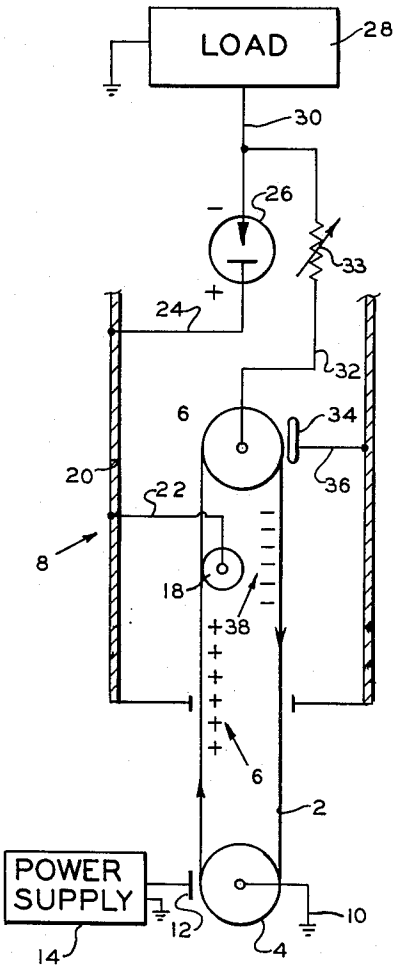


Fig. 3

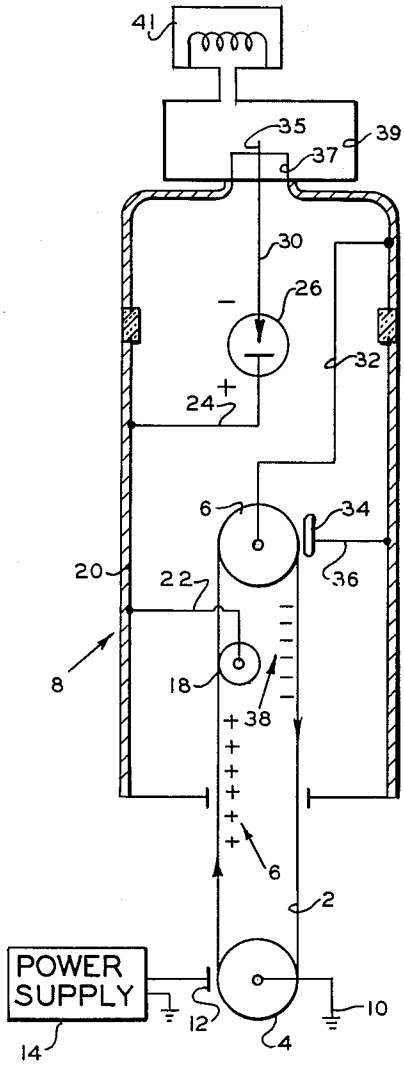


Fig. 4

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BELT CHARGING MEANS FOR BOREHOLE ELECTROSTATIC GENERATORS

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This invention relates to belt-type electrostatic generators and particularly to novel methods and apparatus for charging the belt of a belt-type electrostatic generator.

In a belt-type electrostatic generator, such as a Van de Graaff generator, an electrically insulating belt is driven about a pair of spaced pulleys. Electrical charges of one polarity are applied to the belt adjacent one pulley. Adjacent the other pulley, the charges are removed from the belt at a point within a high voltage terminal where they are accumulated to develop and maintain the required high voltage. The charge per unit time which can be carried by the belt to the high voltage terminal is dependent upon a number of variables. However, for any particular belt, at a particular linear velocity, and under a given set of conditions, a maximum charging rate exists. Should one wish to increase the charging rate beyond this point, it has been found that the charging rate can be substantially doubled by making the belt carry charges of one polarity to the high voltage terminal on its upward travel and carry charges of the opposite polarity away from the high voltage terminal on its downward travel. In order to accomplish this, it is necessary to provide some means inside of the high voltage terminal not only for removing charges of one polarity from the belt, but also applying charges of the other polarity to the belt for transport to ground potential.

Particularly because of severe space limitations, this problem is especially acute in electrostatic generators which are intended for use in subsurface instruments, such as those employed in nuclear well logging. Such borehole generators have been limited to the charging rates obtainable when only the upward travel of the belt is charged. At the same time, the power available to energize borehole generators is greatly restricted by such problems as transmission over the supporting cable which may be several miles long, borehole temperatures which may be as high as 400 degrees Fahrenheit, and portability of the logging apparatus. Consequently, the added efficiency obtainable by charging the downward travel of the belt is sorely needed in borehole generators.

These disadvantages of the prior art are overcome with the present invention and novel means are provided for charging the downward travel of the belt of an electrostatic generator in a regulated manner and for independently controlling the charging of the downward travel of the belt. Moreover, the apparatus of the present invention is sufficiently compact to permit its use in borehole electrostatic generators.

The advantages of the present invention are preferably attained by developing a potential difference across a voltage dropping device, such as a resistor, vacuum tube or corona gap, within the high voltage terminal of a belt-type electrostatic generator and connecting the opposite sides of the voltage dropping device to suitable electrodes to induce a charge of appropriate polarity on the downward travel of the belt. This can easily be accomplished, the inventors have discovered, even in the limited space available in a bore hole generator and permits regulated charging of the downward travel of the belt. As noted above, such charging of the downward travel of the belt substantially doubles the charging current capacity of belt-type electrostatic generators. In particular, in those instances where the generator is employed to energize an ion acceleration tube, as in a borehole accelerator neutron source, the voltage drop across the ion source of the acceleration tube may be employed as the voltage dropping device. This permits charging of the downward travel of the belt to be conveniently controlled by controlling the gas pressure in the acceleration tube.

Accordingly, it is an object of the present invention to provide novel means for charging the belt of a belt-type electrostatic generator.

Another object of the present invention is to provide novel means for applying a regulated charge to the downward travel of the belt of a belt-type electrostatic generator.

A further object of the present invention is to provide novel means for charging the belt of a belt-type electrostatic generator which means is sufficiently compact to permit its use in borehole generators.

An additional object of the present invention is to provide novel methods and apparatus for controlling the charging of the downward travel of the belt of a belt-type electrostatic generator.

A specific object of the present invention is to provide novel means for charging the belt of a belt-type electrostatic generator, said means comprising a voltage dropping device located within the high voltage electrode of said generator, means developing a potential difference across said voltage dropping device, and means connecting the opposite sides of said voltage dropping device to suitable electrodes to induce a charge on the downward travel of the belt of said generator.

These and other objects and features of the present invention will be apparent from the following detailed description wherein reference is made to the figures of the accompanying drawings.

In the drawings:

FIG. 1 is a view, partly in section, of a typical belt-type electrostatic generator embodying the present invention;

FIG. 2 is a view, partly in section, of the high voltage terminal of the generator of FIG. 1 embodying a modified form of the present invention;

FIG. 3 is a view, partly in section, of a modified form of the apparatus of FIG. 1; and

FIG. 4 is a view partly in section, of a further modified form of the apparatus of FIG. 1.

In those forms of the invention chosen for purposes of illustration in the drawings, FIG. 1 shows a typical belt-type electrostatic generator having a non-conductive belt **2** formed with conductive stripes normal to the belt travel and located on the inside of the belt. The belt **2** is driven by motor driven lower pulley **4** and passes about upper pulley **6** mounted inside the high voltage terminal **8**. Any of several conventional means may be employed to charge the belt adjacent the lower pulley **4**. As shown, the lower pulley **4** is grounded by conductor **10** and charges are induced on the belt **2** by induction plate **12** which is energized by a suitable power supply **14**. Induction plate **12** may obviously be made to induce either

positive or negative charges on the belt 2. For the sake of description, it is assumed that in this instance the charge induced on the belt is positive, as indicated at 16 in FIG. 1. Grounding of the lower pulley 4 also serves to remove charges from the downward travel of the belt.

An idler pulley 18 engages the belt 2 inside of the high voltage terminal 20 and allows charges to flow from the belt 2 through conductor 22 to the high voltage terminal 20. A second conductor 24 connects the high voltage terminal 20 to one side of a voltage dropping device 26, which is shown in FIG. 1 as a corona regulator tube, but which may be a resistor, vacuum tube or other suitable device. The other side of the voltage dropping device is connected to a suitable load 28 by conductor 30 and to the upper pulley 6 by conductor 32. Because of the potential drop across the voltage dropping device 26, the upper pulley 6 is maintained at a lower potential than the high voltage electrode 20. Thus, by placing an induction plate 34 near the upper pulley 6 adjacent the upper end of the downward travel of the belt 2 and connecting the induction plate 34 to the high voltage electrode 20 by conductor 36, a charge may be induced on the downward travel of the belt 2, as indicated at 38. Upon reaching the lower pulley 4, these charges pass through conductor 10 to ground.

FIG. 2 illustrates a modified form of apparatus for charging the downward travel of the belt of a belt-type electrostatic generator. As in FIG. 1, the belt 2 is shown carrying a positive charge, indicated at 16, during its upward travel and passing over an upper pulley 6 within the high voltage terminal 20. In this form of the invention, the charge carried by the belt 2 during its upward travel is removed by the upper pulley 6 and passes through conductor 40 to the high voltage terminal 20. At the upper end of the high voltage terminal 20 are mounted a pair of concentric sleeves 42 and 44 which are isolated from each other, by insulator 46, and from the high voltage terminal 20, by insulator 48. A pair of electrodes 50 and 52 are mounted above the sleeves 42 and 44 and are insulated from each other by insulator 54. Electrode 50 is the high voltage electrode and is connected by conductor 56 to the high voltage terminal 20 to provide a high voltage for the loads 58 and 59 which are connected between electrode 50 and ground. Electrode 52 is the "return" or low voltage electrode for the load 58. As shown, electrode 52 is isolated from sleeve 44 by insulator 60 but makes contact with sleeve 42. A cylindrical tank 62 surrounds the generator assembly and corona points 64 and 66 are provided to establish predetermined voltage drops between sleves 42 and 44 and between sleeve 44 and the tank 62 which is grounded, as shown at 68.

It will be seen that in the apparatus of FIG. 2, sleeves 42 and 44 are maintained at different potentials by reason of the corona gap formed by sleeve 42 and corona point 64 mounted on sleeve 44. This potential difference may be employed to induce charges on the downward travel of the belt 2. To accomplish this, an idler pulley 70 is positioned to engage the downward travel of the belt 2 adjacent, but separated from, the upper pulley 6. The idler pulley is connected to sleeve 44 by conductor 72. In addition, an induction plate 74 is mounted adjacent the idler pulley 70 on the opposite side of the downward travel of belt 2 and is connected by conductor 76 to sleeve 42. Thus, idler pulley 70 and induction plate 74 are maintained at the potentials of sleeves 44 and 42 respectively and charges are induced on the downward travel of the belt 2, as indicated at 38.

In those forms of the invention shown in FIGS. 1 and 2, it will be seen that the charge applied to the downward travel of the belt depends on the voltage difference between the induction plate and the adjacent pulley. Where the voltage dropping device 26 is a resistor, this will vary somewhat with the charge carried by the upward travel of the belt. Thus, the charging rate of the downward travel of the belt may be to some extent controlled by controlling the charging rate of the upward travel of the belt. This may be accomplished in any convenient manner, such as those disclosed in the copending application of Eric C. Hopkinson, Serial No. 752,701, filed August 4, 1958, entitled "Control System for Artificial Sources of Radiation" and Robert L. Tucker, Serial No. 771,624, filed November 3, 1958, entitled "Apparatus for Regulating Belt-Type Electrostatic Generators." Moreover, the belt speed may be controlled by varying the speed of the driving motor. This may be accomplished in any convenient manner and many ways of controlling the motor speed are well known in the art. This also determines the rate at which charge is carried between the high voltage electrode and ground.

While these forms of the invention permit control of the charging of the belt, it will be seen that in each form of the invention hereinabove described the charging of the downward travel of the belt cannot be controlled independently of the charging of the upward travel of the belt. In some instances, it may be desirable to control the charging of the downward travel of the belt independently of the charging of the upward travel of the belt. This may be accomplished in several different ways, as hereinafter described. In each of the forms of the invention shown in FIGS.. 1 and 2, a potential difference is developed across a suitable voltage dropping device. While the voltage dropping device has been shown for convenience in the drawings as comprising a corona gap, it has been noted that other voltage dropping devices, such as resistors or vacuum tubes, may also be employed. Furthermore, if the voltage dropping device is variable, the charge applied to the downward travel of the belt may be controlled by varying the electrical impedance of the votlage dropping device and such control will, obviously, be independent of the charging of the upward travel of the belt.

Charging of the downward travel of the belt may be controlled independently of the charging of the upward travel of the belt by connecting a variable resistance device in series between the low voltage side of the voltage dropping device and the electrode which applies the charge to the downward travel of the belt, as shown in FIG. 3. The apparatus of FIG. 3 is substantially identical to that of FIG. 1 and operates in a similar manner. However, a variable resistance 33 is connected in conductor 32 between the low voltage side of the corona tube 26 and the upper pulley 6. The variable resistance 33 may be any suitable device and may be controlled in any appropriate manner to control the voltage applied to pulley 6.

In some instances, the potential drop across the load may be employed as the variable resistance to control the charging of the downward travel of the belt independently of the charging of the upward travel of the belt. An example of this type of control is shown in FIG. 4. The apparatus of FIG. 4 is similar to that of FIG. 1. However, the load 28 of FIG. 1 is shown in FIG. 4 as an ion source having an anode 35 and cathode 37, such as is employed in the acceleration tube 39 of an accelerator-type neutron source for nuclear well logging instruments, such as disclosed in the patent to Arthur H. Youmans, Patent No. 2,689,918, issued September 21, 1954. It has been found that the electrical impedance between the anode 35 and cathode 37 is a function of the gas pressure in the acceleration tube 39. Moreover, the gas pressure may be controlled by suitable means, such as pressure control element 41, as described in the copending application of Arthur H. Youmans, Serial No. 804,360, filed April 6, 1959, entitled "Control of Pressure in a Static Atmosphere Ion Accelerator." Thus, by controlling the pressure of the gas in the acceleration tube 39, the potential between the anode 35 and cathode 37 of the ion source may be regulated. This variable potential serves as a variable

resistance to control the current in conductor 32 and, thus, controls the charging current supplied to upper pulley 6 to charge the downward travel of the belt 2.

The invention has been shown and described as employing induction charging of the belt. However, it will be apparent that the invention is equally useful with other types of charging, such as spray charging. Moreover, where the specification refers to putting positive charges on the belt, this is intended to include removal of negative charges from the belt.

In addition, numerous other variations and modifications may obviously be made without departing from the invention. Accordingly, it should be clearly understood that those forms of the invention described above and shown in the figures of the accompanying drawings are illustrative only and are not intended to limit the scope of the invention.

We claim:

1. A belt-type electrostatic generator comprising a moving belt capable of carrying electrical charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said pulleys for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means at the other of said pulleys for removing said first charges from said belt, a high voltage terminal, means for applying charges removed from said belt to said high voltage terminal, a load circuit connected to said high voltage terminal, voltage dropping means included in said load circuit, second charging means located at said other pulley and spaced in the direction of belt movement from said first charge removing means, said second charging means utilizing the voltage developed across said voltage dropping means to charge the other travel of said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

2. A belt-type electrostatic generator comprising a moving belt capable of carrying electrical charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said pulleys for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means at the other of said pulleys for removing said first charges from said belt, a high voltage terminal, means for applying charges removed from said belt to said high voltage terminal, a load circuit connected to said high voltage terminal, corona discharge means included in said load circuit, second charging means located at said other pulley and spaced in the direction of belt movement from said first charge removing means, said second charging means utilizing the voltage developed across said corona discharge means to charge the other travel of said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

3. A belt-type electrostatic generator comprising a moving belt capable of carrying electrical charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said pulleys for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means adjacent the other of said pulleys for removing said first charges from said belt, a high voltage terminal, means for applying charges removed from said belt to said high voltage terminal, a voltage dropping device connected to said high voltage terminal, a reference potential, a load circuit connected in series between said voltage dropping device and said reference potential, means connecting said other pulley to the low voltage side of said voltage dropping device, an induction plate mounted adjacent said other pulley outside of said belt, and means connecting said induction plate to said high voltage terminal to charge the other travel of said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

4. A belt-type electrostatic generator comprising a moving belt capable of carrying electrical charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said pulleys for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means adjacent the other of said pulleys for removing said first charges from said belt, a high voltage terminal, means for applying charges removed from said belt to said high voltage terminal, a voltage dropping device connected to said high voltage terminal, a reference potential, a load circuit connected in series between said voltage dropping device and said reference potential, variable resistance means connecting said other pulley to the low voltage side of said voltage dropping device, an induction plate mounted adjacent said other pulleys outside said belt, and means connecting said induction plate to said high voltage terminal to charge the other travel of said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

5. A belt-type electrostatic generator comprising a moving belt formed of electrically insulating material, a pair of spaced pulleys supported said belt for revolution about said pulleys, first charging means located at one of said pulleys for charging one travel of said belt with first electrical charges of a first polarity, a high voltage terminal, means connecting the other of said pulleys to said high voltage terminal to transmit said first charges from said belt to said high voltage terminal, a pair of concentric sleeves mounted adjacent one end of said high voltage terminal and electrically insulated from each other and from said high voltage terminal, a load connected between said high voltage terminal and the inner one of said sleeves, a first corona point mounted on the outer one of said sleeves and forming a first corona gap with the inner one of said sleeves, a grounded tank encircling said generator, a second corona point mounted on said tank and forming a second corona gap with the outer one of said sleeves, an idler pulley engaging said belt at a point spaced from said other pulley in the direction of belt movement, means connecting said idler pulley to the outer one of said sleeves, an induction plate mounted adjacent said idler pulley, means connecting said induction plate to the inner one of said sleeves to cause said induction plate to induce second electrical charges of a second polarity on the other travel of said belt, and means at said one pulley for removing said second charges from said belt.

6. A belt-type electrostatic generator comprising a moving belt capable of carrying electrical charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said pulleys, for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means at the other of said pulleys for removing said first charges from said belt, a high voltage terminal, a gas filled acceleration tube including an ion source having an anode and a cathode, means connecting the anode of said ion source to said high voltage terminal, means connecting said other pulley to the cathode of said ion source, means for controlling the gas pressure in said acceleration tube to control the voltage drop across said ion source, an induction plate mounted adjacent said other pulley outside said belt, means connecting said induction plate to said high voltage terminal for charging said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

7. A belt-type electrostatic generator comprising a moving belt capable of carrying electric charge, a pair of spaced pulleys supporting said belt for revolution about said pulleys, first charging means located at one of said

pulleys for charging one travel of said belt with first electrical charges of a first polarity, first charge removing means adjacent the other of said pulleys for removing said first charges from said belt, a high voltage terminal, means for applying charges removed from said belt to said high voltage terminal, an acceleration tube including an ion source having an anode and a cathode, a voltage dropping device connected in series between said anode and said high voltage terminal, second charging means located at said other pulley and spaced in the direction of belt movement from said first charge removing means,

said second charging means utilizing the voltage developed across said voltage dropping device to charge the other travel of said belt with second electrical charges of second polarity, and second charge removing means at said one pulley for removing said second charges from said belt.

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2,883,606	Gale et al.	Apr. 21, 1959

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

March 6, 1962

Patent No. 3,024,407

Reuben A. Bergan et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 2, for "bore hole" read -- borehole --; column 3, line 51, for "sleves" read -- sleeves --; column 4, line 36, for "votlage" read -- voltage --; column 6, line 18, for "pulleys" read -- pulley --; line 26, for "supported" read -- supporting --.

Signed and sealed this 19th day of June 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents