

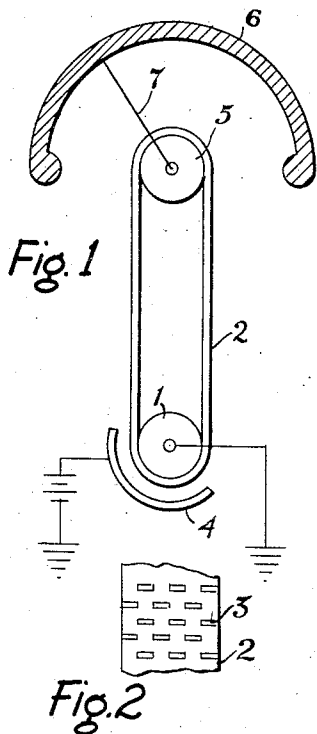
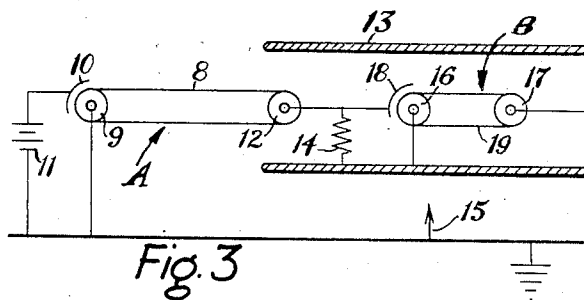
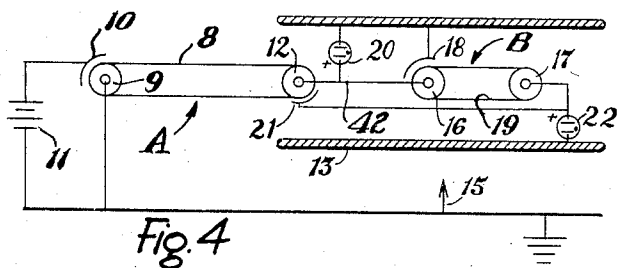
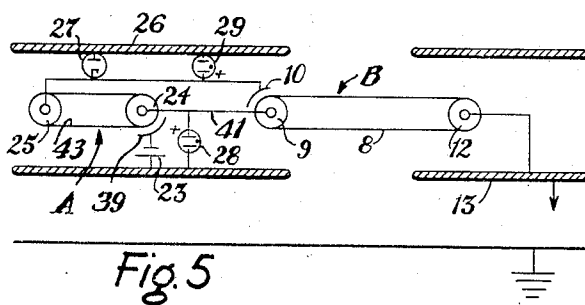
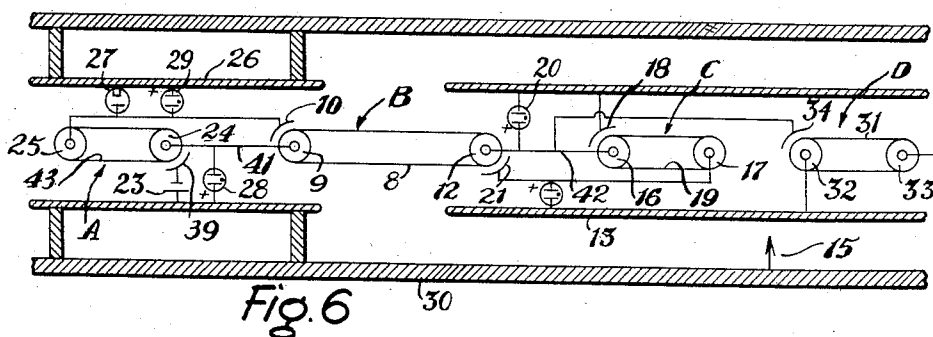
April 21, 1959

A. J. GALE ET AL  
CHARGING SYSTEMS FOR INDUCTION-CONDUCTION  
CHARGED BELT ELECTROSTATIC GENERATORS

2,883,606

Filed May 1, 1957

2 Sheets-Sheet 1



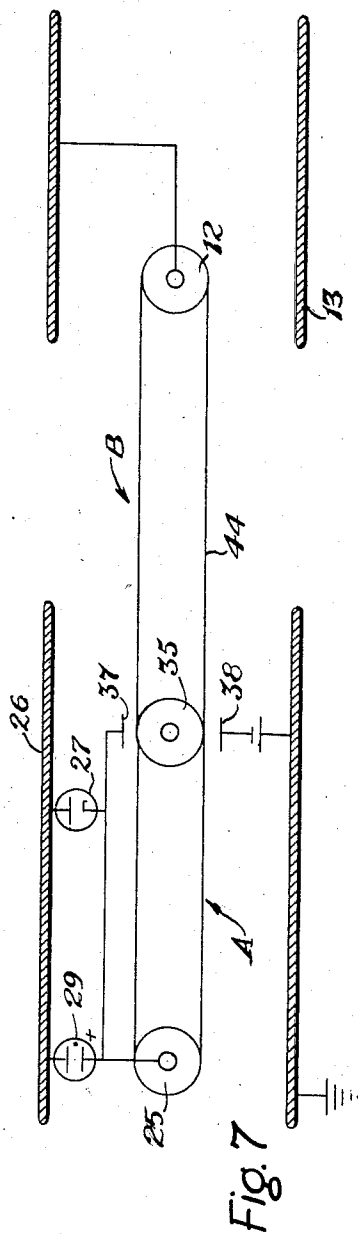
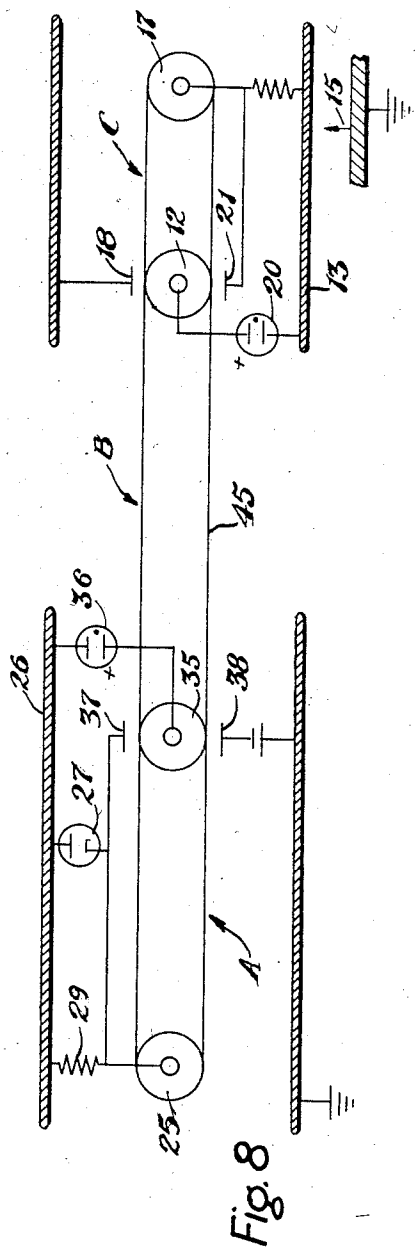
April 21, 1959

A. J. GALE ET AL  
CHARGING SYSTEMS FOR INDUCTION-CONDUCTION  
CHARGED BELT ELECTROSTATIC GENERATORS

2,883,606

Filed May 1, 1957

2 Sheets-Sheet 2



1

2,883,606

## CHARGING SYSTEMS FOR INDUCTION-CONDUCTION CHARGED BELT ELECTROSTATIC GENERATORS

Alfred J. Gale, Lexington, and Charles H. Goldie, Bedford, Mass., assignors to High Voltage Engineering Corporation, Cambridge, Mass., a corporation of Massachusetts

Application May 1, 1957, Serial No. 656,404

14 Claims. (Cl. 322—2)

This invention relates to belt electrostatic generators and in particular to novel methods for charging belt electrostatic generators of the type wherein induction-conduction principles of charge transfer are utilized. In accordance with the invention the exciting voltage necessary for the charging of such generators is provided by at least one auxiliary belt electrostatic generator which is connected to the main generator in a manner to be described in detail hereinafter. The invention may best be understood from the following detailed description thereof having reference to the accompanying drawings in which:

Figure 1 is a diagrammatic view of a belt electrostatic generator of the induction-conduction type;

Figure 2 is a diagrammatic view of the charge-carrying surface of a portion of the belt of the generator shown in Fig. 1;

Figure 3 is a diagram illustrating one embodiment of the invention in which a single power supply is used to excite two generators;

Figure 4 is a diagram similar to that of Figure 3 but showing an embodiment of the invention in which a single power supply is used to charge both the up-run and the down-run of the main generator;

Figure 5 is a diagram similar to that of Figure 3 and shows an embodiment of the invention in which the conventional power supply is replaced by a power supply of much lower voltage;

Figure 6 is a diagram similar to that of Figure 3 showing an embodiment of the invention in which several features thereof are combined in one apparatus;

Figure 7 is a diagram similar to that of Figure 5 and shows an embodiment of the invention in which a single belt is used for the two generators; and

Figure 8 is a diagram similar to that of Figure 6 and shows an embodiment of the invention in which a single belt is used for three generators.

In general there are two methods by which a belt electrostatic generator may be charged. In accordance with one method, which is the method most widely used, charge is sprayed onto an insulating belt from a series of points. This charge transfer is caused to take place by applying a potential difference between the points and one of the pulleys. Such a generator may easily be made self-charging by using insulating pulleys of an appropriate material, so that the required charge transfer is effected by means of the voltage produced by the accumulation of charge on the pulleys due to its interaction with the belt surface.

The second general method of charging the belt of an electrostatic generator is induction-conduction charging, and is shown in Figs. 1 and 2. Referring thereto, electric charge is transferred from one pulley 1, which is conductive, onto the belt 2, which is insulating but has conductive zones 3 on its inner surface. This charge transfer is caused to take place by means of a voltage difference which is applied between the pulley 1 and an inductor plate 4 spaced a short distance therefrom. Upon contact with the other pulley 5, which is conductive, the charge

2

on the inner surface of the belt 2 is collected on the pulley 5 and flows to the high-voltage terminal 6 via a connection 7. Owing to the different charging mechanisms involved, it is difficult to make use of the self-charging principles which have proven successful in connection with point charging methods.

Referring now to Fig. 3, electric charge is deposited on the inner surface of the main belt 8 from a first pulley 9 by means of the potential difference produced between the first pulley 9 and the first inductor plate 10 by a power supply 11. This voltage difference is usually of the order of 10 kilovolts. For simplicity of description, it will be assumed that positive charge is thus deposited on the belt 8. The belt 8 conveys this positive charge to a second pulley 12 and deposits the charge on the second pulley 12. The second pulley is connected to a high voltage hollow electrode 13 through an impedance path such as a resistor 14. The positive charge which accumulates on the high voltage electrode 13 raises the voltage of this electrode 13 to a voltage which may be controlled by means of a corona regulator 15. This voltage will be assumed to be 100 kilovolts. Owing to the resistor 14, the second pulley 12 will be at a higher potential than the electrode 13, say 110 kilovolts. The potential difference across this resistor 14 may then be used as the exciting voltage for another belt electrostatic generator B such as that shown inside the high voltage electrode 13. One pulley 16 of this auxiliary generator B is connected to the high voltage electrode 13 and the other pulley 17 is raised to a voltage different from that of the high voltage electrode 13. The auxiliary generator B may be caused to run positive or negative, and in Fig. 3 the negative connection is shown. The inductor plate 18 opposite the first pulley 16 is connected to the second pulley 12 of the main generator A so that it is at 10 kilovolts with respect to the first pulley 16 of the auxiliary generator B. This voltage difference causes negative charge to be deposited on the belt 19 of the auxiliary generator B, which charge is delivered to the second pulley 17 of the auxiliary generator B.

The auxiliary generator B may be used to excite the down-run of the main generator A, and such a connection is shown in Fig. 4. In this case the auxiliary generator B must be run positive and accordingly the second pulley 12 of the main generator A is connected not to the inductor plate 13 but to the first pulley 16 of the auxiliary generator B by means of a suitable electrical connection 42. In the diagram of Fig. 4, the resistance 14 shown in Fig. 3 is replaced by a corona regulator tube 20. The inductor plate 18 of the auxiliary generator B is connected to the high voltage electrode 13. The second pulley 17 of the auxiliary generator B is connected directly to a second inductor plate 21 of the main generator A and is also connected electrically to the high voltage electrode 13 through a second corona regulator tube 22. The first corona regulating tube 20 is set at 10 kilovolts and the second corona regulator tube 22 is set at 20 kilovolts, so that the second inductor plate 21 of the main generator A is at 10 kilovolts with respect to the second pulley 12 of the main generator A. This potential difference serves to deposit negative charge on the down-run of the main belt 8.

The power supply 11 which, as stated, is generally of the order of 10 kilovolts, may be replaced by a low voltage power supply of the order of 1 kilovolt by means of the embodiment of the invention shown in Fig. 5, wherein a 1-kilovolt power supply 23 is used to excite a small auxiliary generator A which is at the grounded end of the main generator B. The power supply 23 is connected between the inductor plate 39 of the auxiliary generator A and a grounded terminal 26. The belt 43 of this auxiliary generator A transfers positive charge

from a first pulley 24 to a second pulley 25 and from there to the grounded terminal 26 through a corona regulator tube 27 which is adjusted to maintain the second pulley at 19 kilovolts. This 19 kilovolts is applied to the inductor plate 10 of the main generator B, and the low-voltage pulley 9 of the main generator B is connected directly to the first pulley 24 of the auxiliary generator A by means of a suitable electrical connection 41 and to ground through a second corona regulator tube 28 which is set at 9 kilovolts. In order to insure that the low-voltage pulleys 9, 24 will acquire the correct polarity during the initial stages of the operation of the apparatus, a rectifier 29 may be used to by-pass the first corona regulator tube 27 in the proper direction. Thus, in the diagram of Fig. 5 the rectifier 29 prevents the inductor plate 10 of the main generator B from becoming negative with respect to the grounded terminal 26. If the pulleys 9 and 24, which always have the same potential, become positive with respect to ground, then the auxiliary generator A operates immediately at the proper polarity, so that the inductor plate 10 of the main generator B is raised to 19 kilovolts almost at once; and as a result of the transfer of negative charge from the low-voltage pulley 9 of the main generator B to the main belt 8 the resultant positive charge on the low-voltage pulley 9 of the main generator B soon raises its potential to 9 kilovolts. When this negative charge is carried by the main belt 8 to the high voltage pulley 12 of the main generator B, it is transferred from the main belt 8 to the high voltage pulley 12 and thence to the high voltage electrode 13. If, on the other hand, the pulleys 9 and 24 become negative with respect to ground, this negative charge cannot reach the inductor plate 10 so as to cause the main generator B to run positive. If the auxiliary generator A is excited with the wrong polarity, so that it carries negative charge to the pulley 25, this negative charge is immediately drained by the rectifier 29. If, however, the rectifier 29 were omitted, the negative potential created at the inductor plate 10 of the main generator B by even a small amount of negative charge would cause the main generator B to reach its full output immediately, and this output would be of the wrong polarity. This result would occur even if the other impedance 28 were by-passed by a rectifier connected so as to drain negative charge from the pulley 24 to the grounded terminal 26. While such a rectifier serves to drain the pulley 24 in an appropriate manner, unfortunately the pulley 24 is connected to the pulley 9, so that such a rectifier would provide a direct path for current of the wrong polarity to travel from the grounded terminal 26 through the rectifier to the pulley 9 and thence onto the belt 8 of the main generator B. For this reason, if the rectifier 29 is used it should in general be connected to that pulley of the auxiliary generator A which is not connected to the pulley of the main generator B.

Referring now to Fig. 6, therein is shown a device in which various features of the invention are combined in a single apparatus. For example, the apparatus shown in Fig. 6 may be used in connection with a neutron source of the type disclosed in the co-pending application of Gale, Serial Number 515,435, filed June 14, 1955, assigned to the assignee of the present application. In such a neutron source, a main voltage generator is required for the acceleration of positive ions and an auxiliary voltage source is required for the production of the positive ions to be accelerated. In one form of such a neutron source, the source of positive ions is within a hollow electrode, which is maintained at a positive potential of about 100 kilovolts, and within which an auxiliary generator produces a potential difference of several kilovolts for the production of positive ions.

Referring now to Fig. 6, the hollow electrode 13 may be identified with the high voltage terminal of such a neutron source and is accordingly raised to a high positive potential with respect to a grounded metal cas-

ing 30 by carrying positive charge from ground to the hollow electrode 13 by means of the main belt 8. The voltage source A required for depositing positive charge on the belt at its grounded end may be identical to that disclosed in Fig. 5 except that the electrical connections of the voltage source 23, the corona regulator tubes 27 and 28, and the rectifier 29 are reversed. Within the high voltage terminal 13 a circuit such as that disclosed at B in Fig. 4, but which is designated as C in Fig. 6, may be employed in order to charge the down-run of the main belt 8, and an additional generator D may be used as the voltage source for the positive ion source or for other purposes. Said additional voltage source D comprises a belt 31, a pulley 32 which is connected to the electrode 13 and a pulley 33 which is maintained at a potential different from that of the hollow electrode 13 as a result of the charge transfer effected by the belt 31. The charge transfer between the pulley 32 and the belt 31 is produced by means of an inductor plate 34 which is connected to the hollow electrode 13 through the corona regulator tube 20 so that it is at a potential different from that of the pulley 32. If desired, the additional generator D may be eliminated and a single generator C may be used not only to charge the down-run of the main belt 8, but also to supply the power for the ion source. In principle, any number of additional generators may be provided within the hollow electrode 13. The pulleys of the various generators may be interconnected by appropriate gears (not shown) so that a single drive motor at ground potential may suffice to provide mechanical power to all the generators.

Referring to Figs. 4 and 5, it will be observed that in each pair of generators A, B two pulleys are electrically connected together directly. In Fig. 4 the two pulleys are identified at 12 and 16, and in Fig. 5 they are identified at 9 and 24. It is always possible in principle to eliminate one of these pulleys and use a single belt as the charge carrier for both generators A and B, as shown at 44 and 45, respectively, in the diagrams of Figs. 7 and 8, which may be compared with Figs. 5 and 6, respectively. Referring now to Figs. 7 and 8, if the generators are so connected that one generator is withdrawing positive charge from the common pulley 35 (or pair of pulleys, e.g. 9 and 24 in Fig. 5) and the other generator is withdrawing negative charge from the same common pulley 35 and if these two currents are or may be equal, then the common pulley 35 may be disconnected from the rest of the apparatus, as shown in Fig. 7. That is to say, the voltage regulator 36 or other impedance which is connected to the common pulley 35 in the diagram of Fig. 8 may be eliminated in the diagram of Fig. 7. The common pulley 35 will then assume a potential between those of the inductor plates 37, 38, and if the potential difference between the common pulley 35 and one of the inductor plates, such as inductor plate 37 should become too small, the potential difference between the common pulley 35 and the other inductor plate 38 will increase, thereby causing the two currents from the common pulley 35 to differ in such a sense as to increase the potential difference between the common pulley 35 and the first inductor plate 37. Of course, if the two currents should be different, as in the case in the apparatus of Fig. 8, there will be a continuous transfer of charge from the common pulley 35, and so a voltage regulator 36 or other impedance must be provided in order to permit the deficiency to be supplied.

If two generators A and B are connected so that each excites the other, as shown in Figs. 4-8, the current on the belts will tend to increase without limit unless at least one of the impedances, across which exciting voltage is developed, is a voltage regulator. A voltage regulator may be defined as a device such as a corona discharge tube across which the voltage is substantially constant despite wide deviations in current therethrough. Again, if the two generators are connected so as to excite each

5

other, it is possible in principle to eliminate all external voltage sources and also the rectifier 27. If all external voltage sources are eliminated, the excitation voltage is provided by frictional charges caused by the contact of the belt against the pulleys, and the excitation voltage can be made to assume the proper polarity by proper choice of belt and pulley materials. If the polarity of the frictional charges does not always go the right way, the low voltage battery 23 may be added, and this will be sufficient if the frictional charges are not excessive.

In each figure of the drawings, the generator designated as "A" excites the generator designated as "B." In Figures 4-8 the generator B also excites the generator A. In Figure 6 the generator B also excites the generators C and D, while the generator C excites the generator B. In Figure 8, the generator B also excites the generator C, while the generator C excites the generator B. In Figures 3-6 of the drawings the belt of the main generator is designated as "8" and is the one which produces the high voltage. The other belts belong to the auxiliary generators. In Figures 7 and 8 of the drawings there is only one belt, designated as 44 and 45, respectively.

Having thus described the principles of the invention together with several illustrative embodiments thereof, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims:

We claim:

1. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby electric charge is transferred between said second conductive member and said part of said surface; and (3) an impedance through which the second conductive member of said first electrostatic generator is discharged, the voltage source of said second electrostatic generator being derived from the voltage across said impedance.

2. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby electric charge is transferred between said sec-

6

ond conductive member and said part of said surface; (3) a hollow electrode surrounding said second electrostatic generator and the second conductive member of said first electrostatic generator; (4) an impedance connecting said hollow electrode to the second conductive member of said first electrostatic generator, the voltage source of said second electrostatic generator being derived from the voltage across said impedance; and (5) means for discharging said hollow electrode.

3. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby electric charge is transferred between said second conductive member and said part of said surface; (3) a hollow electrode surrounding said second electrostatic generator and the second conductive member of said first electrostatic generator; (4) an impedance connecting said hollow electrode to the second conductive member of said first electrostatic generator; the voltage source of said second electrostatic generator being derived from the voltage across said impedance; (5) a second inductor plate near the second conductive member of said first electrostatic generator but separated therefrom by said moving charge conveyor and insulated from said part of said surface; (6) means for applying, between said second conductive member and said inductor plate, at least part of the voltage generated by said second electrostatic generator, whereby the transfer of electric charge between the second conductive member of said first electrostatic generator and said part of said surface is augmented; (7) means for discharging said hollow electrode; and (8) means for discharging the second conductive member of said second electrostatic generator.

4. Apparatus in accordance with claim 3 wherein said impedance comprises a voltage regulator.

5. Apparatus in accordance with claim 3 wherein said means for discharging the second conductive member of said second electrostatic generator comprises a voltage regulator.

6. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby

7

electric charge is transferred between said second conductive member and said part of said surface; (3) a hollow electrode surrounding said first electrostatic generator and the first conductive member of said second electrostatic generator; (4) a first and a second impedance connecting said hollow electrode to the first conductive member of said second electrostatic generator and to the second conductive member of said first electrostatic generator, respectively; the voltage sources of said first and said second electrostatic generators being derived respectively from the voltages across said first and second impedances; (5) an exciting voltage source of relatively low potential being included in at least one of said voltage sources; and (6) a rectifier connected in parallel with at least one of said impedances.

7. Apparatus in accordance with claim 6 wherein at least one of said impedances comprises a voltage regulator.

8. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby electric charge is transferred between said second conductive member and said part of said surface; (3) a direct connection between the first conductive member of said second electrostatic generator and one of said conductive members of said first electrostatic generator; (4) an impedance through which the second conductive member of said first electrostatic generator is discharged, the voltage source of said second electrostatic generator being derived from the voltage across said impedance.

9. Electrostatic apparatus comprising in combination: (1) a first electrostatic generator and (2) a second electrostatic generator, each of which comprises a moving charge conveyor substantially nonconducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field; a first conductive member adapted to make successive contact with said part of said surface; an inductor plate near said first conductive member but separated therefrom by said moving charge conveyor and insulated from said part of said surface; a voltage source adapted to maintain a potential difference between said first conductive member and said inductor plate, whereby electric charge is transferred between said first conductive member and said part of said surface; a second conductive member adapted to make successive contact with said part of said surface after said part of said surface has made contact with said first conductive member, whereby electric charge is transferred between said second conductive member and said part of said surface; (3) a hollow electrode surrounding said first electrostatic generator and the first conductive member of said second electrostatic generator; (4) an impedance connecting said hollow electrode to the second conductive member of said first electrostatic generator; (5) a direct connection between the first conductive member of said second electrostatic generator and the first conductive member of said first electrostatic generator; the voltage sources of said

8

first and said second electrostatic generators being derived respectively from the voltage between said hollow electrode and said direct connection and the voltage across said impedance; (6) an exciting voltage source of relatively low potential being included in at least one of said voltage sources; and (7) a rectifier connected between said hollow electrode and said direct connection.

10. Electrostatic apparatus comprising in combination: a conductive charging electrode; a first and a second inductor plate near said charging electrode but spaced therefrom; an impedance between said inductor plates; a first and a second conductive charge-collecting electrode; at least one charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field, said charge conveyor being so arranged that said parts of said surface make successive contact with (1) said charging electrode, (2) said first charge-collecting electrode, (3) said charging electrode, and (4) said second charge-collecting electrode; means for discharging said first charge-collecting electrode through said impedance; and means for discharging said second charge-collecting electrode.

11. Apparatus in accordance with claim 10 wherein said charge conveyor comprises an endless belt and wherein each of said electrodes comprises a pulley adapted to support said belt.

12. Electrostatic apparatus comprising in combination: a conductive charging electrode; a first and a second inductor plate near said charging electrode but spaced therefrom; an impedance between said inductor plates; a first and a second conductive charge-collecting electrode; at least two charge conveyors, each substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field, one charge conveyor being so arranged that said parts of said surface make successive contact with (1) said charging electrode and (2) said first charge-collecting electrode, and the other charge conveyor being so arranged that said parts of said surface make successive contact with (1) said charging electrode, and (2) said second charge-collecting electrode; means for discharging said first charge-collecting electrode through said impedance; and means for discharging said second charge-collecting electrode.

13. Apparatus in accordance with claim 12, wherein each of said charge conveyors comprises an endless belt, wherein each of said charge-collecting electrodes comprises a pulley, and wherein said charging electrode includes two pulleys each of which cooperates with one of said charge-collecting pulleys to support each of said belts, respectively.

14. Electrostatic apparatus comprising in combination: a first and a second conductive charging electrode; a first and a second inductor plate near each charging electrode but spaced therefrom; an impedance between each pair of inductor plates; a first and a second conductive charge-collecting electrode; at least one charge conveyor substantially non-conducting along its direction of motion but at least part of at least one surface being adapted to donate or receive electric charge by contact with a conductor in the presence of an electric field, said charge conveyor being so arranged that said parts of said surface make successive contact with (1) said first charging electrode, (2) said first charge-collecting electrode, (3) said first charging electrode, (4) said second charging electrode, (5) said second charge-collecting electrode, and (6) said second charging electrode; means for discharging each charge-collecting electrode through one of said impedances, respectively; and means for discharging each charging electrode.

No references cited.