Aug. 22, 1950 N. FELICI 2,519,554

ELECTROSTATIC MACHINE

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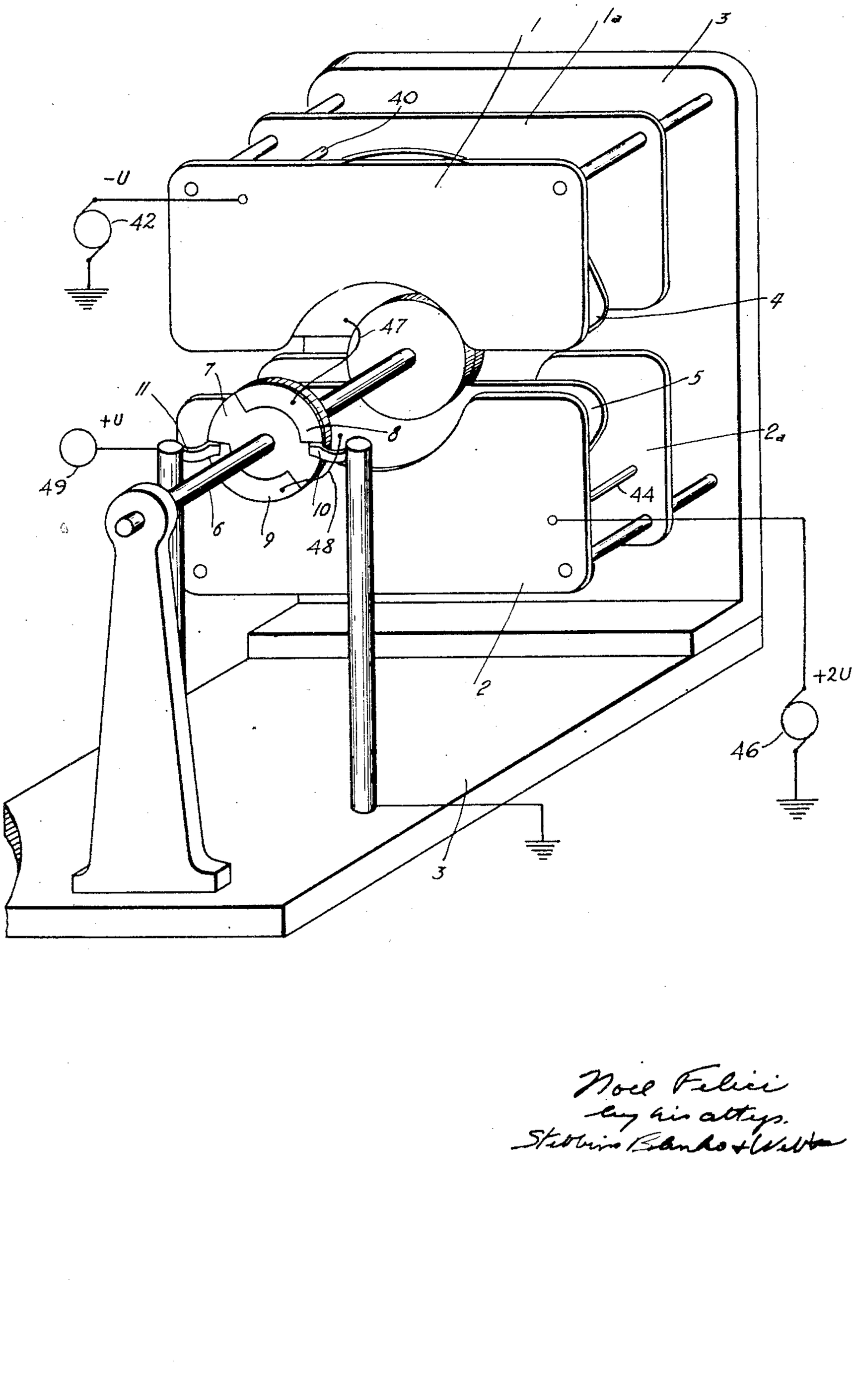
Fig. 1



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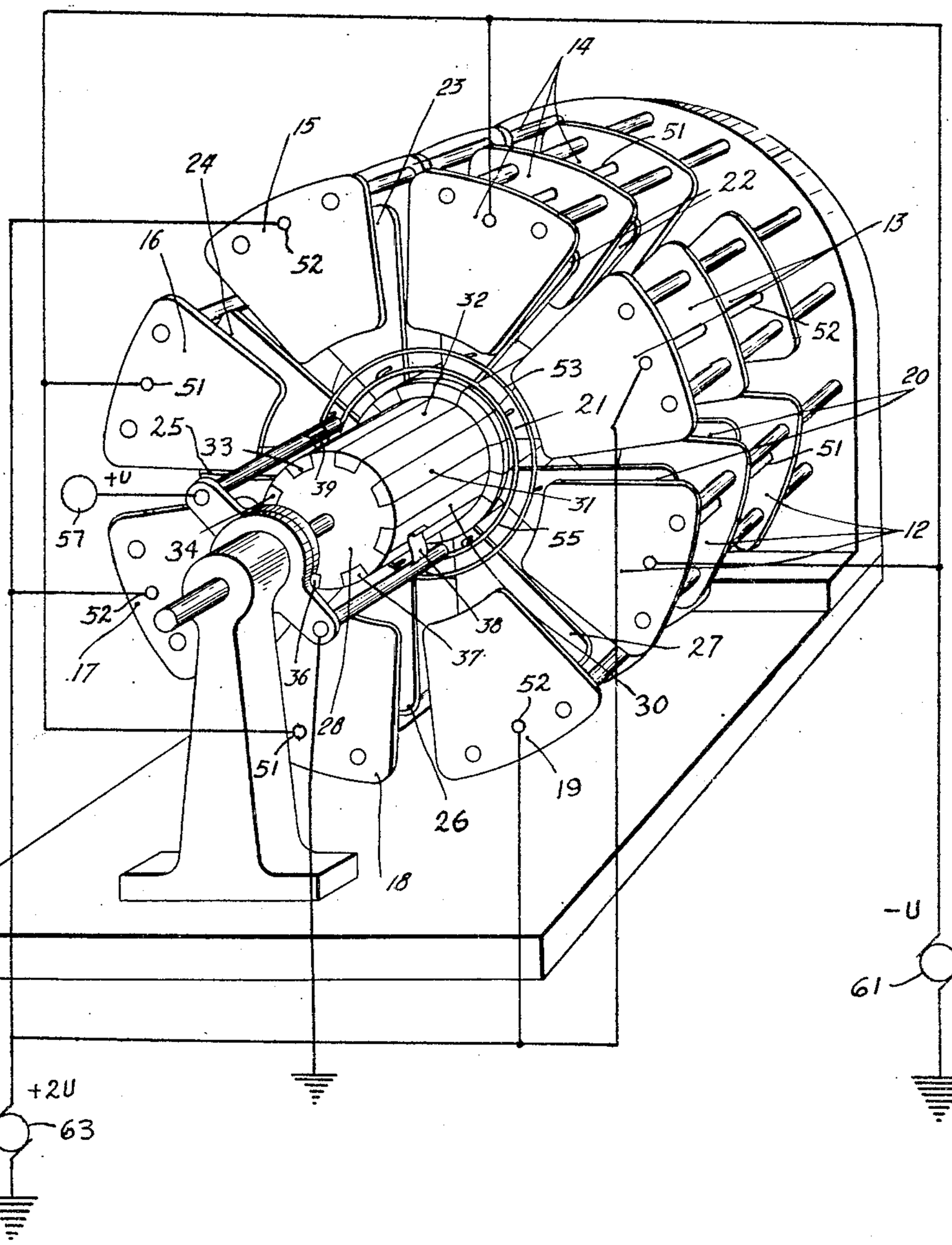
Filed Jan. 23, 1947 2 Sheets-Sheet 2

Fig. 2



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ELECTROSTATIC MACHINE

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14 Claims. (Cl. 171—329)

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The present invention relates to electrostatic machines having movable conducting members, and more particularly to machines of the Toepler type.

In the following description the term "producers" or the term "inductors" stands for stationary or movable members of an electrostatic machine of the above mentioned type which, during the operation of said machine, are brought to a given potential by means of one or more external sources of electricity, said members co-operating with "conveyors" or "carriers" supported for relative movement with respect to the inductors, these carriers being conductive members.

It is known to increase the output of electrostatic machines of the insulating conveyer type such as the Carre and Van De Graaf machines, by causing a conveyer not only to supply electricity with a certain sign to the collector or output terminal of the machine but also to deprive it of a comparable quantity of electricity with the opposite sign, said quantity being removed and conveyed to the other terminal of the machine. This results in an important increase of the intensity and, consequently, of the power supplied by the machine.

The present invention has for its object to provide means making it possible to apply this principle to electrostatic machines having movable conductive members and more particularly to machines of the Toepler type.

According to the invention not only does a conveyor or carrier supply electricity with a given sign to the collector or output terminal which may be connected to the load but it also deprives it of a comparable quantity of electricity with the opposite sign, by the arrangement—in addition to the producers brought to a given potential, the electric influence of which is exerted upon the conveyer members while the latter are connected with the terminal of the machine other than the collector—of one or more auxiliary producer or inductor members the electric influence of which is exerted upon said conveyers while the latter are connected with the collector of the machine, said auxiliary producer members being brought to a potential the sign and valve of which are such that said producers, through the influence which they exert upon the conveyers, attract electricity with the sign opposite to that of the electricity delivered by the machine to the output terminal or collector.

Two machines of the Toepler type made according to the invention are shown diagrammatically in the appended drawings. In said drawings:

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Fig. 1 is a perspective view of one of such machines, and

Fig. 2 is a modified view of a similar machine having a larger number of producers and conveyers.

The machine shown in Fig. 1 comprises two producer or inductor groups 1—1*a* and 2—2*a* each formed of two parallel conductive blades secured in an insulating manner to the frame 3 of the machine and two conductive conveyers 4 and 5 mounted in an insulating manner upon the shaft 6. The groups 1—1*a* and 2—2*a* are arranged in succession about the axis of the shaft 6. The producer blades 1 and 1*a* which correspond to the usual blades of a machine of the type under consideration are connected together electrically by connectors 40 and are connected to a source of electricity, such as the direct current generator 42, capable of bringing them to a given potential such as, say, potential —U, if the maximum potential difference which can exist during the operation of the machine between a producer and a conveyer without discharge therebetween is equal to 2U. The producer blades 2 and 2*a* are connected together electrically by connector 44 and are also connected to a source of electricity, such as generator 46, capable of bringing their potential to a given value the sign of which is contrary to that of the potential imported to the blades 1 and 1*a* and equal, for instance, to +2U in the above mentioned case.

On shaft 6 is also mounted an insulating disc 7 carrying two conducting segments or conductors 8 and 9 electrically connected to conveyers 4 and 5, respectively, by connectors 47, 48 and co-operating with brushes 10 and 11 insulated from the frame 3 of the machine. Brush 10 is grounded and brush 11 is connected with the collector or output terminal 49 of the machine.

The operation of the machine when working as a generator is as follows:

The movable pieces, viz.: shaft 6 with conveyers 4 and 5 and disc 7 are rotated counterclockwise by any motor, not shown. When a conveyer, for instance conveyer 4, engages between the blades 1 and 1*a* of the normal producer, which are brought to the potential —U, it is grounded through the medium of the corresponding segment 8 and of brush 10. This conveyor now takes a charge +Q which is approximately equal to C.U, C being the maximum capacity of the condenser unit formed of conveyer 4 and producer 1—1*a*.

When conveyer 4 begins to move out from between blades 1—1*a* of the normal producer at potential —U its connection with the ground is interrupted since the length of segment 8 was calculated accordingly and the potential of conveyor 4 rises, the increase being promoted by the engagement of the conveyer between blades 2—2*a* of the auxiliary producer, which are brought to the potential +2U. When the potential of conveyor 4 reaches +U segment 8 engages brush 11, the conveyer being thus connected with the collector and this connection lasts as long as the capacity formed of conveyer 4 and producer 2—2*a* increases. Owing to the presence of the auxiliary producer 2—2*a* with the potential +2U the quantity of electricity carried by conveyer 4 when segment 8 leaves brush 11 is equal to —Q. The quantity of electricity discharged into the output terminal by said conveyer is therefore equal to 2Q instead of Q in the case of a similar machine made according to the usual methods and having no auxiliary producer.

During the further rotation of the machine, conveyer 4, which is thus charged with a quantity of electricity equal to —Q and is insulated, engages again between the blades of producer 1—1*a* which is still at the potential —U. The potential of conveyer 4 decreases accordingly. The latter is then grounded again through the medium of segment 8 and brush 10 and transmits its charge —Q to the ground, then receives a charge +Q as previously and the cycle is repeated.

Conveyor 5 behaves in an indentical manner, its presence making it possible to ensure the continuity of the output of the machine.

The energization of both producers 1—1*a* and 2—2*a* respectively to the potentials —U and +2U may be obtained by any known means. For this purpose, two auxiliary generators may be used, for instance, which can be two electrostatic machines of the Toepler type of small output. One of said machines should then yield a potential —U with respect to the ground while the other may yield either the potential +2U directly, as shown in Fig. 1, or only a potential difference U which when added to the potential +U supplied by the main machine yields the necessary potential +2U.

Instead of applying potentials —U and +2U respectively to the producers it is possible to apply to these producers potentials differing from —U and +2U by the addition of one and the same constant value. If said constant is —U the machine terminal to which brush 10 is connected has a negative potential —U and the terminal to which brush 11 is connected has the potential of the ground. If said constant is —½U the terminals of the machine have symmetrical potentials —½U and +½U. If the constant has any other value the terminals have asymmetrical potentials of a different absolute value.

The machine shown in Fig. 2 comprises eight producers each formed of three parallel conducting blades electrically connected together by connectors 51, 52 and mounted in an insulating manner on the frame of the machine, these producers being referred to under numerals 12 to 19. Alternate producers also are connected together electrically so as to form two groups one of which comprises the producers 12, 14, 16, 18 respectively positioned in the succession in interspersed relation to the producers 13, 15, 17, 19 of the other group.

The conveyers are formed of eight pairs of

blades referred to under numerals 20 to 27 the blades of each pair being electrically connected together and to a common conductive segment carried by an insulating cylinder 28 keyed on the shaft of the machine, each of said segments which are designated by the numerals 30 to 37, covering on said cylinder an arc of a circle which is usually smaller than the angle or arcuate extent of the corresponding conveyer. Alternate conveyers in the arcuate succession are also electrically connected together by ring connectors 53, 55 so as to form two groups one of which comprises the conveyers 20, 22, 24 and 26 and the other the conveyers 21, 23, 25 and 27.

The segments 30 to 37 co-operate with two brushes 38 and 39, brush 38 being grounded while brush 39 is connected with the collector or output terminal 57 of the machine. The brushes 38, 39 are arranged so that the conveyers of one and the same group, for instance the group of even number, 20, 22, 24 and 26, all are connected by one of the corresponding conducting segments 30, 32, 34 or 36 with brush 38 when these conveyers engage the producers of group 12, 14, 16, 18 and correspondingly so that brush 39 engages one of the segments 31, 33, 35 or 37 connected to the conveyers of odd number 21, 23, 25 and 27 shortly after the penetration of these odd conveyers into the producers of the group 13, 15, 17, 19. Similar connections respectively to the brushes 38, 39 are established of the odd and even conveyers upon further movement of the conveyers into and out of face to face relation with the producers.

The operation of said machine is similar to that of the machine shown in Fig. 1.

2U being the maximum potential difference which can exist between a conveyer and a producer without discharge therebetween, the group of producers 12, 14, 16, 18 is brought to the potential —U, by being connected to generator 61 capable of maintaining a potential of —U with respect to ground and the group of producers 13, 15, 17, 19 similarly are brought to the potential +2U by generator 63. The four conveyers, for instance 20, 22, 24 and 26 which simultaneously engage between the blades of the producers of the first group are grounded. When this penetration is completed, that is when the conveyers respectively are in full face to face relation to the producers, these conveyers have a charge +Q which is approximately equal to C.U., C being the maximum capacity of the unit formed of the four producers and the four conveyers. When the same conveyers, on further rotating, begin to engage between the blades of the producers of the group 13, 15, 17, 19 which are brought to the potential +2U, their connection with the ground is interrupted and their potential rises. When this potential reaches the value +U they are connected with the collector or output terminal 57 through the medium of brush 39, the position of the latter being determined for this purpose and said connection being maintained as long as the capacity between the conveyers under consideration and the producers of odd number increases. The conveyers 20, 22, 24, 26 have therefore finally a charge which is substantially equal to —Q and they have discharged a quantity of electricity 2Q into the collector or output terminal. When the same four conveyers begin to penetrate again into the producers of the group 12, 14, 16, 18 their connection with the collector 57 is interrupted, their potential decreases and they are grounded again through the medium of brush 38, where-

upon the cycle is repeated. The same action in the meantime is carried out by the conveyers or carriers 21, 23, 25, 27 in cooperation with the producers.

Of course, the machine may be operated under the same conditions as those provided for with respect to the machine shown in Fig. 1.

The invention is also applicable to machines having a number of conveyers which is different from that of the producers, for example, larger than the latter.

Finally, it is possible to make the conveyers and the producers with other surface portions than a plane, for example with portions of a cylinder, a cone or other surfaces of revolution.

The following examples show the advantages obtained with the application of the invention to an electrostatic machine working as a generator and to a similar machine working as a motor.

Example 1

A rationally designed machine of the Toepler type had four sets of producers each formed of six parallel blades, these blades each having an extent of about 45° about the axis of rotation. The rotatable member was formed of eight sets of conveyers each comprising five parallel blades in interplaced relation to the producer blades. The outer diameter of the whole is twenty four centimetres. In air compressed up to 30 atmospheres the machine yielded, at the speed of 1400 R. P. M., 4.5 milli-amperes under 52 kilovolts or 255 watts. By adding, according to the invention, four other sets of producers at the potential of 120 kilovolts the current became 10.2 milli-amperes under the same voltage of 52 kilovolts at the same speed, or an output of 550 watts. The output was, therefore, more than doubled because the prejudicial effect of interfering capacities is reduced by the introduction of the supplementary producers.

The present invention is applicable not only to generator electrostatic machines with conductive conveyers or carriers but also to any driving electrostatic machine or motor with conductive conveyers while making it possible to increase the driving output considerably without changing the speed. It is possible, for instance, to cause the machine shown in Fig. 1 to work as a motor by bringing the producers 1—1*a* and 2—2*a* to the potentials —U and +2U as previously described and feeding the insulated or terminal brush 11 by means of a source supplying a potential difference +U with the ground. The machine then works as a motor while rotating in the direction contrary to the preceding one when it worked as a generator. The presence of the supplementary producer 2—2*a*, in which presence the application of the invention resides, has for its effect that both conveyers are subjected simultaneously to the same electrostatic forces. The driving torque is thus doubled. The absorbed current is, of course, also doubled owing to the fact that when a conveyer is connected with the source having a potential +U it brings a charge which is approximately equal to —CU instead of a charge which is approximately zero when no supplemental producer is used. When the connection with the source is interrupted the conveyer carries away a charge +CU so that the source has supplied 2CU instead of CU.

In a general manner, all the features of application of the invention indicated for generator machines such as, for instance, the values of the potentials, the number of the conveyers and of the producers, are valid for driving machines or motors.

Example 2

A rationally constructed machine of the Toepler type was provided with four producers and eight conveyers. When working as a motor in air compressed up to 30 atmospheres this machine absorbed, at the speed of 1300 R. P. M., a current of 4.4 milli-amperes under 50 kilovolts or 220 watts. Since the friction of the air absorbed 95 watts and solid friction absorbed 15 watts the useful driving power was 220—110=110 watts, the electric efficiency being practically equal to unity. By adding, according to the invention, four other producers with a potential of 120 kilovolts the absorbed current becomes 10.0 milli-amperes under the same voltage of 50 kilovolts at the same speed. The absorbed power becomes 500 watts and the useful driving power is 500—110=390 watts. The useful driving power was more than trebled because the losses, which are due only to friction, remained constant.

What I claim is:

1. An induction electrostatic machine comprising an even number of inductors each formed of at least one fixed electrode and arranged in succession in spaced relation to each other, the odd and even inductor members being respectively connected to means capable of bringing the potentials of the former to $-U+M$ and of the latter to $2U+M$, 2U being substantially the maximum difference of potential which may exist between an inductor and a carrier of the machine without discharge therebetween and M an algebraic constant which may be zero, and as many movable conductive carriers as there are inductors in said succession, said carriers being supported for movement relative to and arranged to be electrically influenced in succession by said inductor members, the alternate carriers being respectively connected to two groups of conductors cooperating with two fixed brushes, said brushes being connected, one to the output terminal of the machine, and the other to a terminal of the machine other than said output terminal, the said conductors and brushes being arranged so that contact of the carriers is established with the first above mentioned brush at a point of the movement of said carrier at which said carriers respectively at least partly engage the inductors of even range and is maintained substantially until the capacity between said carriers and even inductors begins to decrease, said conductors and brushes also being arranged so that contact of said carriers is established with the second above mentioned brush of the machine at a point of said movement at which the carrier members respectively at least partly engage the inductors of odd range and is maintained substantially until the capacity between said carriers and odd inductors begins to decrease.

2. An induction electrostatic machine as claimed in claim 1, in which the odd and even inductors are respectively connected to two external sources of electricity capable of bringing the potentials of the former to $-U+M$ and of the latter to $2U+M$; 2U and M having the meanings set forth in claim 1.

3. An induction electrostatic machine as claimed in claim 1, in which the odd and even

inductors are respectively connected to two external sources of electricity capable of yielding, the first, a potential —U with respect to the ground and the second a potential +2U with respect to the ground.

4. An induction electrostatic machine as claimed in claim 1, in which the odd and even inductors are respectively connected to two external sources of electricity capable of yielding, the first, a potential —U with respect to the ground and the second a potential difference U, the latter source being connected to the corresponding inductors in series with the output terminal of the machine itself so as to produce a potential on said inductors of +2U.

5. An induction electrostatic machine comprising an even number of conductive inductors arranged in succession in spaced relation to each other, means for maintaining the odd inductors of said succession at a predetermined potential, means for maintaining the even inductors at a potential higher than the potential of said odd inductors by a predetermined difference, movable conductive carriers in number equal to the total number of inductors in said succession, means for supporting said carriers for movement in succession in inductive relation to said odd and even inductors from positions of maximum capacity with said odd inductors through positions of equal capacity with the odd and even inductors to positions of maximum capacity with said even inductors, the odd conductive carriers being electrically connected together so as to be at the same potential, the even conductive carriers being electrically connected together so as to be at the same potential, an output terminal of the machine, a brush electrically connected to said output terminal, means for establishing in succession electrical connection to said brush of said two sets of odd and even conductive carriers in the movement thereof, said means for establishing electrical connection of said conductive carriers to said brush being adapted to initiate said connection at a point of said movement at which the capacity between the odd inductors and the respective movable carriers which are in inductive relation to the odd inductors has substantially decreased from said maximum capacity so that the potential of said carriers correspondingly is increased, a second brush, means for establishing in succession electrical connection between said second brush and said two sets of odd and even carriers and in spaced relation to said connection thereof to said output terminal brush in the direction of movement of said carriers, means for maintaining said second brush at a potential intermediate between the potential of said output terminal brush and the potential of said odd inductors, said means for establishing electrical connection between said second brush and said carriers being adapted to initiate said connection as the capacity between said movable carriers and said odd inductors is being increased.

6. An induction electrostatic machine as defined in claim 5 in which said inductors are arranged in said odd and even succession about an axis of rotation, and means for supporting said odd and even movable inductive carriers in circumferentially spaced relation about and for rotation thereof upon said axis of rotation.

7. An induction electrostatic machine as defined in claim 6 in which said means for establishing electrical connections of said movable conductive carriers to said brushes comprise conductive segments respectively electrically connected to said odd and even carriers and supported for rotation therewith and adapted to make contact in succession with said brushes, said segments each having such an arcuate extent and being so arranged with respect to the respective conductive carriers as to maintain said electrical connection of said brushes to the respective carriers throughout a predetermined portion of the movement of said carriers in relation to said odd and even inductors.

8. An induction electrostatic machine comprising conductive inductor members and conductive carrier members supported and arranged for relative movement of said inductor members and said carrier members with respect to each other in a predetermined path into and out of inductive relation to each other, an output terminal for said machine, said inductor members being arranged in succession in spaced relation to each other in the direction parallel to said path of movement and respectively having a substantial extent in said direction of movement, said carrier members being arranged in succession in spaced relation to each other in the direction parallel to said path and respectively having an extent in said direction greater than the space between said inductor members, means for maintaining alternate inductor members at a common predetermined potential lower than the desired output potential of the machine, means for maintaining the intermediate inductor members at a common potential higher than said desired output potential of said machine, means for initially determining the potential of each carrier member at a point in said relative movement at which said carrier member is at least in part in face to face inductive relation to an inductor member which is at said predetermined potential at a potential greater than said predetermined potential and less than said output terminal potential, and means for connecting said carrier members in succession to said output terminal of said machine at a point in said relative movement at which said carrier members respectively are at least in part in face to face inductive relation to said intermediate inductor members.

9. In an electrostatic machine the combination with a primary conductive inductor member, a plurality of conductive carrier members movable in a predetermined path of movement and in succession into and out of inductive relation to said primary inductor member, and an output terminal of the machine, of an auxiliary conductive inductor member in insulated relation to said primary conductive inductor member and in spaced relation thereto in the direction parallel to said path of movement of said carrier members so that said carrier members are movable in succession into and out of inductive relation thereto, said inductor members having an extent in said direction parallel to said path substantially greater than the spacing therebetween, means for supporting said movable conductive carrier members in spaced relation to each other in the direction of movement thereof and with alternate carrier members insulated from the intervening carrier members, said carrier members having an extent in said direction of movement substantially greater than the spacing between said inductor members in said direction, means for maintaining said primary inductor member at a predetermined potential less than the desired output terminal potential of the machine, means for maintaining said auxiliary inductor

member at a potential higher than the desired output terminal potential of said machine, means for initially determining the potential of each movable carrier member at a point in said movement thereof at which said carrier member is at least in part in lapping inductive relation to said primary inductor member at a potential greater than the potential of said primary inductor member and less than said output terminal potential, and means for connecting said movable carrier members in succession to said output terminal at a point in said movement at which said carrier members respectively are in part in lapping relation to said primary inductor members and in part in lapping inductive relation to said auxiliary inductor member.

10. An induction electrostatic machine as defined in claim 5 in which said inductors and said carriers respectively have an extent in the direction of said movement of said carriers greater than the space between said inductors, said means for establishing electrical connection of said carriers to said brush which is electrically connected to said output terminal being adapted to effect said connection to said brush at a point in said movement at which the capacity between the odd inductors and the respective carriers which are moving out of inductive relation to said odd inductors has decreased from said maximum capacity and the capacity between the even inductors and said carriers correspondingly has increased so that the potential of said carriers is substantially the potential of said output terminal, said means for establishing said electrical connection between said second brush and said carriers being adapted to effect said connection to said second brush at a point in said movement of said carriers at which the capacity between said odd inductors and the carriers which are moving into inductive relation to said odd inductors has increased and the capacity between said even inductors and said carriers correspondingly has decreased so that the potential of said carriers substantially is the potential of said second brush.

11. An induction electrostatic machine as defined in claim 8 in which said means for connecting said carrier members in succession to said output terminal of said machine is adapted to effect said connection at a point in said relative movement at which the capacity between the intermediate inductor members and the respective carriers which are moving into inductive relation to said intermediate inductor members has increased and the capacity between the other inductor members at said predetermined potential and the respective carriers which are moving out of inductive relation to said other inductor members correspondingly has decreased so that said capacities substantially are equal.

12. An induction electrostatic machine comprising an even number of conductive inductors arranged in succession in spaced relation to each other, means for maintaining the odd inductors of said succession at a predetermined potential, means for maintaining the even inductors at a potential higher than the potential of said odd inductors by a predetermined difference, conductive carriers in number equal to the total number of inductors in said succession, means for supporting said inductors and said carriers for relative movement thereof with respect to each other to bring said carriers in succession into and out of inductive relation to said odd and even inductors to positions of maximum capacity with said odd inductors and from said positions through positions of equal capacity with the odd and even inductors to positions of maximum capacity with said even inductors, the odd conductive carriers being electrically connected together so as to be at the same potential, the even conductive carriers being electrically connected so as to be at the same potential, an output terminal of the machine, a brush electrically connected to said output terminal, means for establishing in succession electrical connection to said brush of said two sets of odd and even conductive carriers in the relative movement of said inductors and said carriers with respect to each other, said means for establishing electrical connection of said conductive carriers to said brush being adapted to initiate said connection at a point in said relative movement at which the capacity between the odd inductors and the respective carriers which are in inductive relation to said odd inductors has substantially decreased from said maximum capacity so that the potential of said carriers correspondingly is increased, a second brush, means for establishing in succession electrical connection between said second brush and said two sets of odd and even carriers and in spaced relation to said connection thereof to said output terminal brush in the direction in which said carriers move with respect to said inductors, means for maintaining said second brush at a potential intermediate between the potential of said output terminal brush and the potential of said odd inductors, said means for establishing electrical connection between said second brush and said carriers being adapted to initiate said connection as the capacity between said carriers and said odd inductors is being increased.

13. An induction electrostatic machine comprising conductive inductor members and conductive carrier members supported and arranged for relative movement between said inductor members and said carrier members in a predetermined path into and out of inductive relation to each other, said inductor members being arranged in succession in spaced relation to each other in the direction parallel to said path of movement, said carrier members being arranged in succession in spaced relation to each other in the direction parallel to said path and respectively having an extent greater than the space between said inductor members, means for maintaining adjacent inductor members which are in said spaced relation to each other at different potentials, a given one of said potentials being lower than the desired output potential of the machine and the other of said potentials being higher than said output potential of said machine, a pair of terminals, means for maintaining one of said terminals at a potential intermediate between said output potential and the potential of said given inductor member, and means for connecting each carrier member in succession to each of said terminals in succession and adapted to establish said connections respectively at points at which said carrier is in part in lapping inductive relation to an inductor member at said higher potential and in part in lapping inductive relation to an inductor member of said lower potential, whereby an electric charge is delivered to the other terminal substantially at the desired output potential.

14. An electrostatic machine comprising conductive inductor members and conductive carrier members supported and arranged for relative

movement between said inductor members and said carrier members in a predetermined path into and out of inductive relation to each other, said inductor members being arranged in succession in spaced relation to each other in the direction parallel to said path of movement, said carrier members being arranged in succession in spaced relation to each other in the direction parallel to said path, means for maintaining a given one of said inductor members at a predetermined potential lower than the desired output potential of the machine, means for maintaining another of said inductor members spaced along said path from said given inductor member at a potential higher than said desired output potential of said machine, means for initially determining the potential of each carrier member at a point in said relative movement at which it is at least in part in face to face inductive relation to said given inductor member which is at

said predetermined potential at a potential greater than said predetermined potential and less than said output potential, an output terminal of said machine, and means for connecting said carrier members in succession to said output terminal at a point in said relative movement at which said carrier members respectively are at least in part in face to face inductive relation to said other inductor member.

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