Feb. 13, 1934. C. A. NICKLE 1,947,220

ELECTROSTATIC MACHINE

Filed March 2, 1932

Fig. 2.

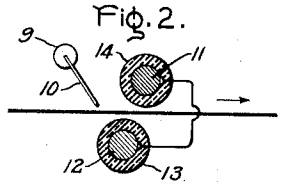


Fig. 1.

Fig. 3.

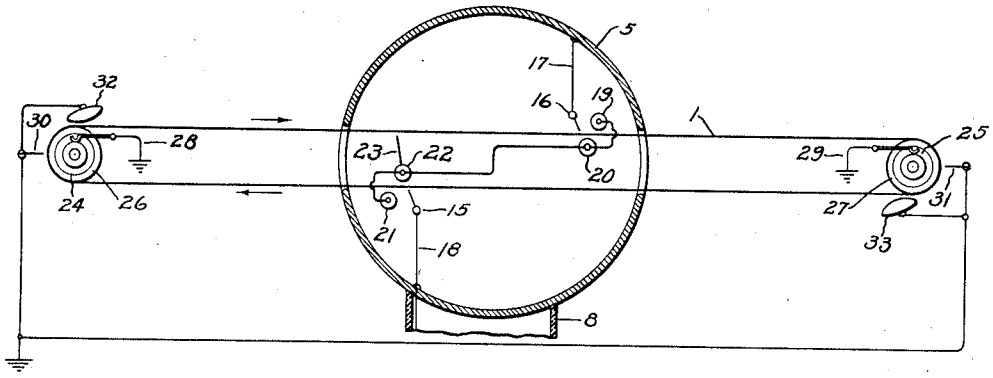


Fig. 4.

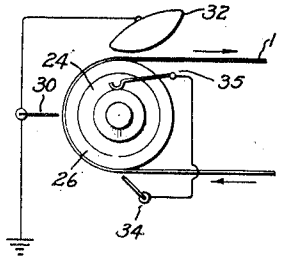
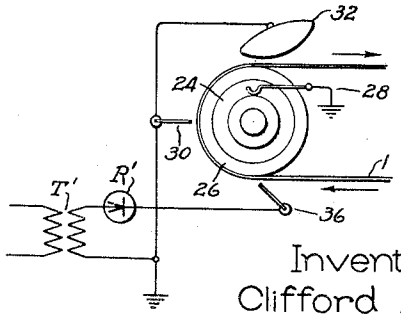


Fig. 5.



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1,947,220

ELECTROSTATIC MACHINE

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Application March 2, 1932. Serial No. 596,187

27 Claims. (Cl. 171—329)

My invention relates to electrostatic machines.

A source of high voltage of the order of a million volts is frequently required for electrical testing, or exciting electric discharge devices, such as X-ray tubes. The high voltage required for these purposes has generally been obtained heretofore by the use of transformers, or induction coils. The large number of turns required in the windings of these devices to obtain such high voltage, and the difficulties involved in adequately insulating the windings makes their construction expensive. Moreover, if the winding or winding insulation breaks down electrically it is impracticable to repair it.

Electrostatic machines, on the other hand, are of simple construction, but machines of this kind proposed heretofore for producing high voltage have had too low current output for most purposes.

In endless belt type electrostatic machines, unless the electrical charge on the portion of the belt excited is of high intensity, the width of the belt necessary to obtain high current output from the machine is so great that it is difficult to construct the machine, and the floor space required for its installation would ordinarily make its use prohibitive.

In exciting the belt in a machine of this type the amount of charge that can be imparted to the belt is limited by the intensity of the electric field of the exciting device and the portion of the belt moving therefrom. In machines, as heretofore constructed, if the intensity of this field is increased to increase the charge on the belt, the air between the exciting device and the portion of the belt moving therefrom will become ionized, and conducting, so that the electrical charge on the belt will leak off to the exciting device, and in this way limit the charge that can be imparted to the belt.

An object of my invention is to obtain a distribution of the electric field between a belt, or other moving element, and the devices employed for exciting it, which will permit a great increase in the electrical charge that can be imparted to the belt, or moving element.

Another object of my invention is to provide an electrostatic machine of the endless belt type having a charge accumulating body arranged entirely about the belt between its supports, so that the construction of the machine will be simplified.

Another object of my invention is to provide an electrostatic machine including a belt, a charge accumulating body associated therewith, and an improved belt exciting device for utilizing the charge carried into the body by the belt to electrically charge the belt moving therefrom.

Another object of my invention is to provide a self-excited endless belt type of electrostatic machine having a belt supported on a roller and excited, or charged, by friction between the belt and the roller, and an arrangement for stabilizing the operation of the machine.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterized my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawing, Fig. 1 is a diagrammatic perspective view of an endless belt type separately excited electrostatic machine embodying my invention; Fig. 2 is an enlarged sectional view of the field pieces and collector which are employed for increasing the charge that can be imparted to the belt; Fig. 3 is a diagrammatic view partly in section of an endless belt type electrostatic machine similar to that shown in Fig. 1, but of the self-excited type; Fig. 4 is a fragmentary view of a portion of a self-excited electrostatic machine, similar to that shown in Fig. 3, having an arrangement for stabilizing the operation of the machine, and Fig. 5 is a fragmentary view of an electrostatic machine like that shown in Fig. 3 having an improved arrangement for separately exciting the machine.

Referring to Fig. 1 of the drawing, the electrostatic machine which I have illustrated is of the separately excited type, and includes an endless belt, 1 of paper, or other suitable material, which is supported in the form of an elongated loop on rollers 2 and 3. These rollers are adapted to be mounted in bearing supports, and the belt is driven by an electric motor 4 suitably connected to the roller 2. A spherical charge accumulating body 5 is arranged about the belt-loop intermediate the ends thereof, and is provided with openings 6 and 7 through which the belt-loop extends. The spherical body 5 is supported on an insulating column 8 of sufficient height to withstand the high voltage of the electric charge accumulated on the sphere. The insulating belt-loop is made long enough to separate the rollers 2 and 3 sufficiently from the spherical body 5 to prevent any direct electrical discharge, or leakage, from the sphere to the part of the construction associated with the rollers. The belt offers sufficient resistance to the flow of any charge on the sphere to prevent any substantial loss of

charge therefrom. If desired, the spherical body may be charged to obtain several million volts and the voltage obtained depends upon the size of the body and the general design of the machine.

The high voltage charge accumulated on the spherical body 5 may be withdrawn therefrom to supply any suitable load for testing purposes, or exciting an electric discharge device, such as an X-ray tube, in any convenient manner. It will be understood that this connection for withdrawing the charge from the spherical body 5 should be constructed in such manner as to avoid excessive leakage of the charge into the surrounding air. This may be accomplished by suitably connecting a sphere, which is insulated from ground, to the load device, and arranging this sphere in contact with the spherical body 5. When the machine is utilized to excite an electric discharge device, the charge may be supplied directly thereto by supporting the device adjacent the spherical body 5.

In this construction, the portions of the belt-loop moving from the rollers 2 and 3 toward the spherical body 5 are electrically charged, and this charge is conveyed on these portions of the belt into the spherical body where it is collected and transferred to the outer surface of the body. In order to utilize fully substantially the entire length of the belt-loop 1, I also electrically charge the portions of the belt-loop moving from the spherical body toward the rollers in such manner as to increase the charge on the spherical body, and remove this charge from the belt at the rollers.

The arrangement which I employ for charging the belt, may be used for charging a moving charge conveying element of other types of machines. In the construction illustrated, the belt-loop 1 is charged adjacent the rollers 2 and 3, by a collector 9 and field pieces 11 and 12 which are connected across a high voltage source of supply. The collector 9 is arranged adjacent the surface of the belt, and has a number of sharp points 10 extending closely adjacent the surface of the belt across the entire width thereof, so as to facilitate the flow of an electrical charge between the points and the belt. The field pieces 11 and 12 have a covering thereon, indicated at 13 and 14 in Fig. 2, which is semi-conducting. These field pieces are arranged adjacent opposite sides of the belt 1 and adjacent the collector 9. The collector 9 and the field pieces 11 and 12 may be connected across a high voltage source of supply in any suitable manner to establish an electric field between the field pieces and the collector. This electric field charges the belt 1 as it passes between the field pieces and toward the spherical body 5. As shown in Fig. 1, the field pieces 11 and 12 and the collectors 9 are connected across a source of high voltage by grounding the collectors and one terminal of a transformer T, and connecting the other terminal of the transformer to the field pieces through rectifying devices R.

In an arrangement for exciting a belt in this manner the amount of charge which can be imparted to the belt is limited by the intensity of the electric field established between the exciting devices and the belt. As the charge on the belt is increased, the intensity of this electric field is increased and when the intensity of this electric field is great enough to ionize the air between the exciting devices and the belt, the air becomes conducting, and the charge leaks off the belt to the exciting devices. By providing electrically connected field pieces arranged on opposite sides of the belt adjacent the collector, I obtain a distribution of the electric field between the exciting devices and the belt, which will permit a large increase in the electrical charge which can be imparted to the belt. In this way, I have already obtained approximately sixty-six per cent increase in output of the machine, and theoretical considerations indicate that, by the use of this arrangement, I will be able to double the current output of the machine.

When the source of high voltage supply is connected across the collector 9 and the field pieces 11 and 12, the belt will be charged in passing between the field pieces. If a direct electrical discharge takes place between the collector 9 and the field pieces 11 and 12, the belt 1 will no longer receive any charge, and the supply of current to the load will be interrupted. When this direct electrical discharge occurs between the collector 9 and the field piece 12 the belt will be punctured. In order to reduce the duration of any direct electrical discharge in this way, I make the covering 13 and 14 on the field pieces 11 and 12 of a semi-conducting material, such as a fabric impregnated with a phenolic resinous condensation product, varnished cambric, dry wood, or other ordinary insulating material having an insulating value comparable with these materials. I have found that this construction considerably reduces the duration of any direct electrical discharge between the field pieces and the collector. This is apparently due to the fact that as long as there is no direct electrical discharge between the collector 9 and the field pieces 11 and 12, the voltage on the outer surfaces of the covering on the field pieces is substantially the same as that on the conducting cores thereof. As soon as the direct electrical discharge occurs, a surge of current takes place between the collector and the field pieces, and the resultant voltage drop across the semi-conducting covering on the field pieces greatly diminishes the difference in voltage between the outer surface of the field pieces and points of the collector, so as to stop the flow of current between the field pieces and the points of the collector.

In order to convey to the spherical body the electrical charge carried into the same by the belt, I provide collectors 15 and 16 inside of the sphere having a plurality of points extending in close proximity to the surface of the belt and across the entire width thereof, which are connected to the inside of the sphere as indicated at 17 and 18. It is well known that the inside of a charge accumulating body of this kind is at zero potential and that any charge conveyed into the same will immediately flow in any conducting path provided to the outer surface of the body.

The portion of the belt passing from the collectors 15 and 16 to the rollers 2 and 3 is charged oppositely to the charge on the spherical body 5, so as to increase the charge thereon by arranging electrically connected field pieces 19, 20, 21 and 22 adjacent the belt and the collectors 15 and 16. These field pieces are constructed like the field pieces 11 and 12 shown in Fig. 2, which have been previously described. I prefer to utilize a portion of the charge carried into the spherical body 5 by the belt 1 for exciting these field pieces, and I accomplish this by providing a collector 23 on the field piece 22, which extends adjacent the inner surface of the belt. In this

way a portion of the charge carried into the spherical body 5 on the belt 1 passes to the field pieces 19, 20, 21 and 22, and raises their potential sufficiently to establish an electric field between the field pieces and the collectors 15 and 16, so as to charge the portion of the belt passing from the collectors toward the rollers 2 and 3 oppositely to the charge on the spherical body, and in this way increase the charge on the spherical body. The charge on the spherical body 5 is increased by this arrangement because part of the charge carried on the belt 1 into the spherical body from adjacent the roller 2 passes to the collector 23 so as to raise the electrical potential of the electrically connected field pieces 19, 20, 21, and 22 sufficiently to establish an electric field between the field pieces and their adjacent collectors 15 and 16. It will be understood that the charge on these field pieces is of the same sign as the charge conveyed into the spherical body to the collector 23 on the belt-loop 1. If the charge carried into the sphere from adjacent the rollers 2 and 3 is positive, the collectors 15 and 16 will collect this positive charge so that it passes to the spherical body 5. At the same time a portion of this positive charge will pass to the collector 23 and charge the field pieces 19, 20, 21, and 22 positively, and as these pairs of field pieces are adjacent opposite sides of the upper and lower sides of the belt-loop 1, the portion of the belt passing from the collector 16 out of the sphere will be acted upon by the electric field produced by the field pieces 19 and 20 so as to bind negative charges to the belt 1 and repel positive charges from this portion of the belt so that they pass to the collector 16 and increase the charge on the spherical body 5. The portion of the belt-loop passing from the field pieces 19 and 20 toward the roller 3 will therefore pass out of the spherical body 5 with a negative charge or a charge opposite to the charge on the spherical body 5. Similarly, the portion of the belt-loop 1 passing from the collectors 21 and 22 toward the roller 2 will be acted upon by the electrical field established by the positively charged field pieces 21 and 22 so as to bind the negative charge on the belt and repel the positive charge so that it passes from the belt to the collector 15. The portion of the belt-loop passing from the field pieces 21 and 22 toward roller 2 will also be negatively charged, so that the portions of the belt-loop 1 passing from the field pieces 19 and 20 to the roller 3 and passing from the field pieces 21 and 22 toward the roller 2 are utilized to increase the charge on the spherical body 5. If the charge conveyed into the spherical body 5 by the portions of the belt-loop 1 passing from the rollers 2 and 3 toward the spherical body are negatively charged by an action similar to that above described, the portions of the belt-loop passing from the collectors 19 and 20 to the roller 3 and passing from the field pieces 21 and 22 toward the roller 2 will also be positively charged so that these portions of the belt-loop will be utilized to increase the negative charge on the spherical body 5. The electrical charge carried from the spherical body in this way is removed from the belt by the collector 9.

In Fig. 3 of the drawing, I have shown a self-excited type of electrostatic machine similar to that shown in Fig. 1, and it also includes an endless belt 1 supported in the form of an elongated loop on rollers 24 and 25, and a spherical charge accumulating body 5 is arranged about this belt-loop intermediate the ends thereof. In this construction, the charge carried into the spherical body on the belt 1 from the rollers 24 and 25 is transferred to the spherical body, and the charge carried into the spherical body on the belt is utilized to charge the portion of the belt moving from the collectors toward the rollers 24 and 25 oppositely to the charge on the spherical body to increase the charge thereon, in the same manner that this is accomplished in the construction shown in Fig. 1. In this machine the roller 24 or 25 is driven by a motor as for example an electric motor, and the belt is electrified by the friction on hard rubber faces 26 and 27 of the rollers. The rollers are also provided with conducting cores, which are grounded at 28, 29. The friction between the hard rubber faces 26 and 27 of the rollers and the belt binds the negative charge on the inside of the belt, and repels the positive charge to the outer surface of the belt. In order to electrify the belt, interconnected grounded collectors 30 and 31 are arranged adjacent the opposite ends of the belt-loop adjacent the surface of the belt, so that the positive charge is drawn from the belt to neutralize the outer surfaces of the belt and the belt then passes from the rollers with a negative charge. The collectors 30 and 31 also remove the charge from the belt which is carried from the spherical body to the rollers 24 and 25.

In a machine of this type the charge which can be imparted to the belt by the rollers is limited by the intensity of the electric field produced between rollers and the portion of the belt moving from the rollers toward the spherical body 5. When the intensity of this electric field is increased above a certain value the air between the surface of the roller and this portion of this belt becomes conducting so that the charge leaks off the belt to the roller. I have found that the amount of charge which can be imparted to the belt by the rollers can be greatly increased by providing field pieces 32 and 33 adjacent the portion of the belt moving from the roller to the spherical body and having a surface which diverges from the outer surface of the belt. It will be noted, that in this construction the conducting core of the roller 24 and the field pieces 32, which are electrically connected together through ground, distribute the electric field about the belt in the same manner that the field pieces 11 and 12, shown in Figs. 1 and 2, distribute the electric field about the belt to increase the charge carrying capacity thereof.

In an electrostatic machine of the construction shown in Fig. 3, I have found that the output of the machine is sometimes unstable, in that the potential will not build up on the spherical body 5 when the machine is started, or that the voltage suddenly decreases, and sometimes to zero, when the machine is in operation. The operation of the machine can be stabilized by arranging a collector 34 closely adjacent the point where the portion of the belt moving toward the roller 24 comes in contact therewith, and connecting this collector, as indicated at 35, to the conducting core of the roller 24. It will be understood, of course, that in modifying the machine in this way the roller 25 shown in Fig. 3 will also be provided with a collector arranged and connected as shown in Fig. 4.

The machine shown in Fig. 3 may be separately excited, as shown in Fig. 5 of the drawing, by arranging a collector 36 adjacent the point where the belt 1 moving toward the roller 24 initially

comes in contact therewith, and connecting this collector and the conducting core of the roller 24 across a high voltage source of supply. In this construction the collector and the conducting core of the roller are connected across the secondary of a transformer T', by grounding the core of the roller at 28 and one terminal of the transformer, and connecting the collector 36 to the other terminal of the transformer through a rectifying device R'.

I have disclosed several embodiments of my invention, but I do not desire to be limited to the particular arrangements set forth, and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding both sides of said belt-loop intermediate the ends thereof, means for driving said belt, and means utilizing both ends of said belt-loop for charging said body.

2. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding both sides of said belt-loop intermediate the ends thereof, means for driving said belt, and means utilizing substantially the entire length of said belt for charging said body.

3. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding both sides of said belt-loop intermediate the ends thereof, means for driving said belt, means for electrically charging the portions of the said belt-loop moving towards said body at both ends of said belt-loop, and means within said body for transferring from said belt to said body the electrical charge carried from the ends of said belt-loop into said body.

4. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding both sides of said belt-loop intermediate the ends thereof, means for driving said belt, means for electrically charging the portions of said belt-loop moving toward said body at both ends of said belt-loop, means within said body for transferring from said belt to said body the electrical charge carried from the ends of said belt-loop into said body, and means within said body utilizing the portions of said belt passing from said body to the opposite ends of said belt-loop for increasing the electrical charge on said body.

5. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding both sides of said belt-loop intermediate the ends thereof, means for driving said belt, and means including a collector adjacent said belt and electrically connected field pieces arranged on opposite sides of said belt and adjacent said collector for electrically charging said belt.

6. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding said belt-loop, means for driving said belt, means remote from said body for electrically charging the portion of said belt-loop moving toward said body, means within said body for transferring the charge on said belt to said body, means within said body and including electrically connected field pieces arranged adjacent opposite sides of the portion of said belt moving out of said body for electrically charging the outwardly moving portion of said belt oppositely to the charge on the portion of said belt moving toward said body to increase the electrical charge on said body.

7. An electrostatic machine having an insulating belt, means for supporting said belt in the form of an elongated loop, a charge accumulating body surrounding said belt-loop, means for driving said belt, means remote from said body for electically charging the portion of said belt-loop moving toward said body, means within said body for transferring the charge on said belt to said body, means within said body and including electrically connected field pieces arranged adjacent opposite sides of the portion of said belt moving out of said body for electrically charging the outwardly moving portion of said belt oppositely to the charge on the portion of said belt moving toward said body to increase the electrical charge on said body, and means for electrically charging said field pieces from said belt.

8. An electrostatic machine having a moving element for conveying an electrical charge, field pieces having a conducting core and a semi-conducting covering thereon and arranged adjacent opposite sides of said element, and means including an electrical connection between the conducting cores of said field pieces for electrically charging said element.

9. An electrostatic machine having a moving element for conveying an electrical charge, a collector arranged adjacent said moving element, field pieces having a conducting core and a semi-conducting covering thereon and arranged adjacent opposite sides of said element, and means for electrically charging said element including a source of voltage supply connected across said collector and the conducting cores of said field pieces.

10. An electrostatic machine having an insulating belt, means for driving said belt, and means including field pieces electrically connected together and arranged adjacent opposite sides of said belt for electrically charging said belt.

11. An electrostatic machine having an insulating belt, means for driving said belt, and means including field pieces electrically connected together and arranged adjacent opposite sides of said belt for electrically charging said belt, said field pieces having a semi-conducting covering thereon.

12. An electrostatic machine having an insulating belt, means for driving said belt, a collector adjacent said belt, field pieces electrically connected together and arranged adjacent opposite sides of said belt and said collector, and means including a source of voltage supply connected across said field pieces and said collector for charging said belt.

13. An electrostatic machine having an insulating belt, means for driving said belt, and means for electrically charging said belt, said means including a collector adjacent said belt and field pieces electrically connected together and arranged adjacent opposite sides of said belt and said collector.

14. An electrostatic machine having an insulating belt, means for driving said belt, a collector adjacent said belt, conducting field pieces

electrically connected together and arranged adjacent opposite sides of said belt and said collector, said field pieces having a semi-conducting covering thereon to reduce the duration of any direct electrical discharge between said field pieces and said collector, and means for establishing a difference in potential between said collector and said field pieces to charge said belt.

15. An electrostatic machine having an insulating belt, means for driving said belt, means including a roller engaging said belt for electrically charging the same, and means for reducing the intensity of the electric field between the portion of said belt moving from said roller and said roller to increase the electrical charge carrying capacity of said belt, said means including a field piece adjacent the portion of said belt moving from said roller and having a surface diverging from the surface of said belt in the direction of motion thereof.

16. An electrostatic machine having an insulating belt, means for driving said belt, means including a roller engaging said belt for electrically charging the same, and means including a field piece adjacent the portion of said belt extending from said roller for reducing the intensity of the electric field between said roller and the portion of said belt extending therefrom to increase the electrical charge carrying capacity of said belt.

17. An electrostatic machine having an insulating belt, means for driving said belt, means including a roller engaging said belt for electrically charging the same by friction on said roller, and means including a field piece adjacent the portion of said belt moving from said roller for reducing the intensity of the electric field between said roller and the portion of said belt extending therefrom to increase the electrical charge carrying capacity of said belt.

18. An electrostatic machine having an insulating belt, means including a roller having a conducting core and semi-conducting face engaging said belt for charging the same, means including a field piece adjacent the portion of said belt moving from said roller and electrically connected to the core of said roller for reducing the intensity of the electric field between the portion of said belt moving from said roller and said roller so as to increase the electrical charge carrying capacity of said belt.

19. An electrostatic machine having an insulating belt, means including a roller for supporting said belt and for electrifying the same by friction on said roller, means for neutralizing a portion of said belt to charge the same, and means including a field piece adjacent the portion of said belt moving from said roller for reducing the intensity of the electric field between said roller and the portion of said belt extending therefrom so as to increase the electrical charge carrying capacity of said belt.

20. An electrostatic machine having an insulating belt, means including a roller having a conducting core and an insulating face for supporting said belt and for electrifying the same by friction on said roller, a collector adjacent the portion of said belt on said roller, means including a connection between the conducting core of said roller and said collector for neutralizing a portion of said belt on said roller to charge said belt, and means including a field piece connected to said collector and said conducting core and arranged adjacent the portion of said belt moving from said roller for reducing the intensity of the electrical field between said roller and the portion of said belt extending therefrom so as to increase the electrical charge carrying capacity of said belt.

21. An electrostatic machine having an insulating belt, means including a roller having a conducting core for supporting said belt and for electrifying said belt by friction on said roller, a collector adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith, and a connection between said collector and the core of said roller to stabilize the operation of said machine.

22. An electrostatic machine having an insulating belt, means including a roller having a conducting core for supporting said belt and for electrifying said belt by friction on said roller, a collector adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith, a connection between said collector and the core of said roller to stabilize the operation of said machine, and means for neutralizing a portion of said belt on said roller to charge said belt.

23. An electrostatic machine having an insulating belt, means including a roller having a conducting core for supporting said belt and for electrifying said belt by friction on said roller, a collector adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith, a connection between said collector and the core of said roller to stabilize the operation of said machine, means for neutralizing a portion of said belt on said roller to charge said belt, and means including a field piece adjacent the portion of said belt moving from said roller for reducing the intensity of the electric field between said roller and the portion of said belt moving therefrom.

24. An electrostatic machine having an insulating belt, means including a roller having an insulating face for supporting said belt, and means for establishing an electric field adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith to electrify said belt.

25. An electrostatic machine having an insulating belt, means including a roller having an insulating face for supporting said belt, means for establishing an electric field adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith to electrify said belt, and means for neutralizing a portion of said belt on said roller to charge said belt.

26. An electrostatic machine having an insulating belt, means including a roller having an insulating face for supporting said belt, means for establishing an electric field adjacent the point where the portion of said belt moving toward said roller initially comes into contact therewith to electrify said belt, means for neutralizing a portion of said belt on said roller to charge said belt, and means including a field piece adjacent the portion of said belt moving from said roller for reducing the intensity of the electric field between said roller and the portion of said belt moving therefrom.

27. An electrostatic machine having a paper belt, and means including a roller having a hard rubber face for supporting said belt and for electrifying the same by friction on the face of said roller.

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