Nov. 17, 1953 P. HAMPE 2,659,841

MEANS FOR ELECTRIFYING PULVERULENT MATERIALS

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Fig. 1.

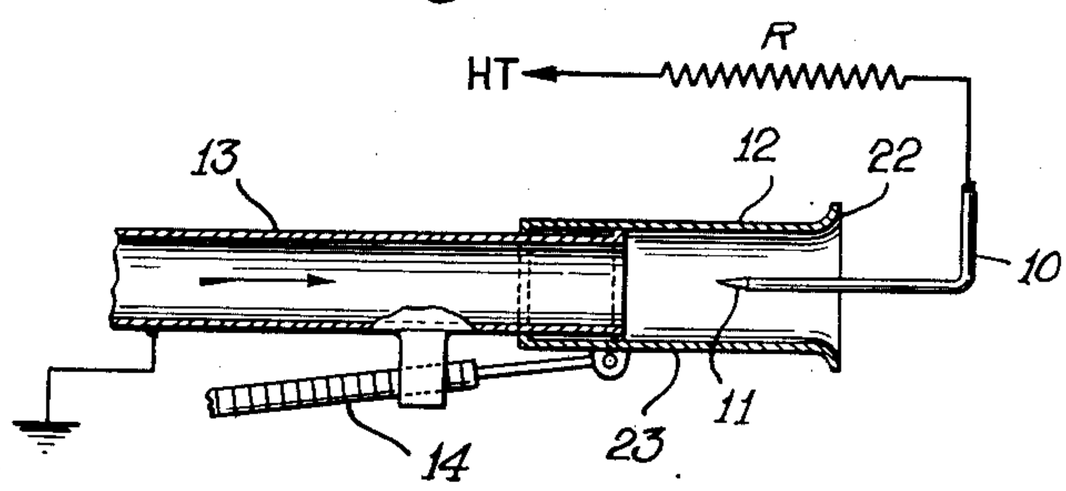


Fig. 2.

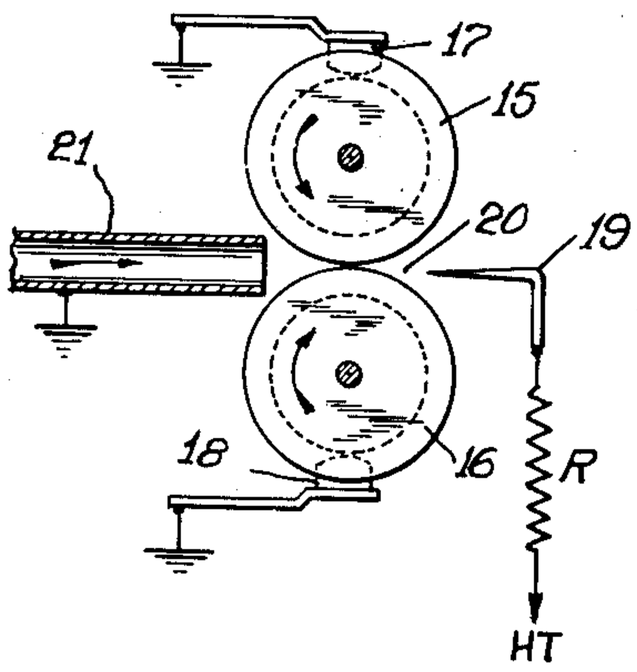
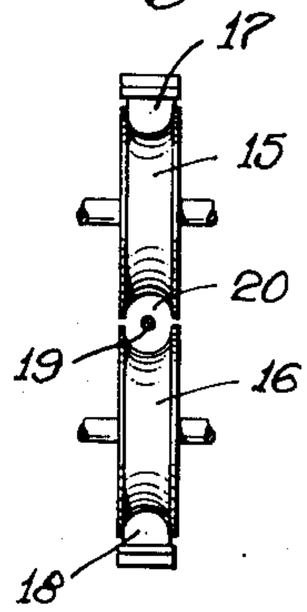


Fig. 3.



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MEANS FOR ELECTRIFYING PULVERULENT MATERIALS

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7 Claims. (Cl. 317—3)

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This invention relates to apparatus for imparting an electrical charge to particles of a pulverulent material suspended in a gaseous medium and is more particularly concerned with apparatus of the character indicated, adapted for providing electrified particles for agricultural and industrial powder spraying, for example, the spray dusting of plants.

Various devices have heretofore been proposed for producing electrified powder particles and for setting up an electrical field which serves to direct the particles to the surface to be covered. These prior devices have been used for the dusting of plant life and for various industrial purposes.

The known devices make use of a direct current of very high voltage between electrodes of the devices, generally of the order of 25,000 to 100,000 volts. The handling of such high voltages presents various serious practical problems. These high voltages have heretofore been considered essential, however, for the reason that known electrifying apparatus did not provide satisfactory results with low voltages and the high voltage permitted the setting up of an electrical field around the plants or surfaces to be dusted, as a result of the arrangement of the electrodes and the transmission of ions through the electrodes. The cloud of electrified powder may contribute to the production of the electrical field but in minor and relatively insignificant degree.

It is the principal object of the present invention to provide apparatus for effectively electrifying particles of pulverulent material by means of relatively low voltages.

The apparatus of my invention, in contrast to such prior devices, permits the electrification of powder particles with lower voltages, of the order of 3,000 volts, for example, and permits the electrification to be effected in such manner that the cloud of dust particles is effective in itself to produce a strong electrical field. In my apparatus, the necessary voltage may be provided by easily supported relatively small generating equipment.

When the electrical field is produced by a live electrode as in the prior devices, the field has its greatest effect upon the surface of the article to be dusted that is nearest the electrode and as a result the opposite side of the article is not adequately dusted. In contrast, the electrical field which is set up by the cloud of electrical particles passes around the various articles in a much more efficient manner and effects a better distribution of the particles on the surfaces treated. Furthermore, when charged electrodes are used for ionizing the gas surrounding the articles to be dusted, if the articles are insulated or of an insulating nature they become electrified and repel the electrified powder particles. When using the apparatus of the invention, however, wherein the electrical field is set up solely by the cloud of electrified particles, even insulating surfaces may be dusted.

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If E represents the electrical field surrounding the article to be dusted and Q the charge of an electrified particle, the force which directs the particle toward the article to be dusted is EQ. When the field is produced solely by the cloud of electrified particles, the strength of the field E is obviously in proportion to the charge Q of each particle. The intensity of the force directing the particles is then in proportion to Q^2 and it is of advantage to have the value of Q as high as possible. I have found that a very high charge Q may be obtained by employing relatively low voltages, i. e. voltages of the order of 2,500 to 8,000 volts.

In accordance with the invention, I provide apparatus comprising a live electrode in the form of a wire or tip, i. e. having a tapering pointed end, to produce an electrical discharge and a second electrode having a larger surface disposed adjacent the first electrode and more or less surrounding it. The second electrode is grounded and acts as a receiver of the ions from the live electrode. The distance between the two electrodes is proportional to the voltage employed and the powder particles are electrified by being passed through the gap between the two electrodes. For this purpose I provide a flow channel for the particle carrying gas stream to direct it through the electrode gap.

The charge Q of the powder particles may not exceed a limiting value determined by the equation

$$Q=PEoa^2$$

where P is a coefficient, a is the radius of the powder particle and Eo is the electrical field between the two electrodes. It is advantageous, therefore, to make Eo as large as possible, i. e. to provide a maximum voltage between the electrodes. The voltage, however, gives rise to the phenomenon of sparking between the electrodes which occurs when the potential difference approximates 1000 volts per millimeter of distance. However, it is well known that high voltages give longer sparks than do relatively low voltages. An ionizing or electrifying apparatus of small size using a voltage of the order of 3,000 volts is less subject to sparking than a large apparatus em-

ploying high voltages which may, for example, carry voltages of the order of 1,500 to 2,000 volts per millimeter of distance between electrodes.

It is a feature of the invention that full advantage may be taken of low voltage operation. In my apparatus, the sparking hazard may be lessened by the provision of a high resistance in the feed circuit positioned just ahead of the discharge electrode. Such a resistance not only serves to prevent sparking but prevents glowing discharges that may either damage the electrode or ignite the powder particles. Furthermore, my apparatus is advantageously provided with several nozzles, each nozzle being provided with a resistance, this arrangement thus serving to divide the discharge of the generator between the various nozzles and to reduce the risk of injury should an operator touch one of the nozzles.

I also advantageously reduce sparking by imparting a high speed to the current of particle-carrying gas conducted through the electrifying zone between the electrodes. Alternately I provide means for operating my apparatus at a super-atmospheric gas pressure. For a given voltage, the sparking length is inversely proportional to the pressure. A small size ionizer in accordance with the invention is particularly adapted for taking advantage of the aforementioned conditions which are conducive to efficient electrification. Furthermore, in an ionizer in which there is a relatively small clearance between the electrodes, the time required for the charging of a powder particle is proportionately small. In fact, the time required for obtaining a given proportion of the maximum charge is inversely proportional to the concentration P of the charges in the ionized gas. Thus, the formula

$$P=\frac{E}{4\pi R}$$

shows that the concentration is proportional to the field E and in inverse proportion to the distance R to the electrode.

In apparatus according to the invention, E may reach a value three times as great as that possible in heretofore known ionizers and R may be ten times less, e. g. two millimeters instead of twenty millimeters. Thus, a charging period sixty times smaller is possible and the length of the ionizer may, accordingly, be reduced. In view of this fact, it has been possible in accordance with the invention to replace the standard fine wire electrode by a tip, an arrangement which has not been satisfactory in known ionizers of larger size. On the other hand, the high value of the charge on the particles enables the ionizer to be fed with gas that is more heavily charged with powder particles without damage of clogging the apparatus. I have found that in addition to the above mentioned measures taken for avoiding sparking, certain other precautionary measures should also be taken. In a small ionizer, such as an apparatus made in accordance with the invention, the two electrodes are more symmetrical than in larger ionizers. Consequently, the strong field that prevails between the electrodes has a tendency to cause eddy currents to appear on the electrode of larger surface. These electrical discharges of opposite polarity discharge the powder and they are created if the electrode becomes covered with powder, particularly if the powder is of an insulating nature. In practice, the strong field which is set up by the ionizer has a tendency to create a strongly attractive deposit that even a rapid current of gas is not effective to prevent.

Accordingly, one of the features of the apparatus of the invention is the prevention of the formation of such deposits on the electrodes. There are several means for advantageously preventing these deposits.

One means comprises the addition to the powder to be electrified of an abrasive such as alumina or quartz. In addition, the nozzle of the ionizer may be shaped to facilitate the cleaning process by insuring that no portion of the surface is sheltered from impacts of the flowing gas. The above mentioned means are particularly effective for insuring that the smaller electrode will be kept clean. Other means are particularly suitable for cleaning the large surface electrode. Thus, in one embodiment of the invention, the larger surface electrode may be arranged to slide in such a way that its inner surface is cleaned by a fixed surface or the larger electrode may take the form of a revolving member which is cleaned by a fixed brush, constantly in engagement with its surface. The cleaning means is located out of the space between the closest portions of the electrodes so that they do not cause arc-overs.

In order to increase the electrical field in the apparatus and to provide the particles with a higher charge, it is advantageous to cause the charge to take place in the presence of compressed gas. In accordance with one embodiment of the invention, therefore, means are provided for feeding the apparatus with gas at a pressure up to several atmospheres, the larger surface electrode being advantageously formed in such manner that the pressure is maintained during the movement of the particle carrying gas through the electrical field. For creating high gas pressures, I advantageously provide compressors, diaphragm pumps and the like in place of the fan blades which have been used in prior ionizer apparatus.

The objects, characteristics and advantages of the invention will be more fully understood from the following description and claims in conjunction with the accompanying drawings, in which:

Fig. 1 is a longitudinal section of an ionizer in accordance with the invention in which an end portion of the nozzle is slidable relative to a fixed portion to keep the nozzle clean during operation of the apparatus.

Fig. 2 is a side elevation, partially in section, of an ionizer in which the larger surface electrode is formed by rotating members.

Fig. 3 is a front view of the arrangement shown in Fig. 2.

The apparatus illustrated in Fig. 1 comprises a central electrode **10** which is shown as a pointed wire electrode having a sharp point **11**. The pointed electrode **10** is connected through a high resistance R to a direct current voltage supply HT the voltage of which is preferably in the range of 3,000 to 6,000 volts. A second electrode **12** surrounds the tip portion **11** of the central electrode **10** and comprises a section of tubing that is coaxial with the central electrode. The tubing section **12** is telescopically slidable on the end portion of a fixed tube **13** through which a stream of air or other gas carrying the particles of pulverulent material to be charged is supplied. The tubing **12, 13** is connected to ground, as indicated at G. Thus, an electric field is produced between the tip portion of the central electrode **10** and the inner surface of the tubing section **12** forming the outer electrode. This inner surface may thus be referred to as the active surface of the electrode **12**. The stream of gas carrying the pulverulent material to be

charged flows through the tubing 12, 13 in the direction indicated by the arrow and thus flows through the field between the electrodes 10 and 12, being thereupon discharged into the atmosphere. The discharge end of the tubing 12 is preferably flared outwardly, as indicated at 22.

In order to clean the active inner surface of the tubular electrode 12 during operation of the apparatus and thereby keep it clear of particles of the material being charged, provision is made for reciprocating the movable tubing section 12 relative to the fixed tubing 13. For example, as illustrated in the drawings, the tubing section 12 is reciprocated by a flexible cable or Bowden wire 14. As the tubing section 12 is reciprocated, its inner surface rubs on the outer end 23 of the fixed tube 13 so as to dislodge any material that may have collected on the inner surface of the tubing section 12. It will be seen that the end edge 23 of the tubing 13 which constitutes cleaning means for the inner surface of the tubular electrode 12 is disposed outside of the direct field between the closest portions of the electrode 12 and the central electrode 10. Hence, the cleaning means does not reduce the gap between the electrodes or tend to cause any arc-over between the electrodes.

In Figs. 2 and 3, there is shown a preferred form of apparatus in accordance with the invention in which the outer electrode comprises two grooved pulleys 15 and 16 rotatable about spaced parallel axes so that the peripheries of the pulleys are close to one another. The grooves in the peripheries of the pulleys 15, 16 are approximately semi-circular in cross section so as to provide a space 20 of approximately circular cross section between the two pulleys. A pointed central electrode 19 projects into, and is concentric with, this circular space so as to be at least partially surrounded by the outer electrode composed of the grooved pulleys 15, 16. As in the foregoing embodiment, the central electrode 19 is connected through a resistance R with a direct current high voltage source to provide an electric field between the pulleys 15, 16 and the pointed central electrode 19. A tube 21 blows a powder-loaded air stream through the space 20 between the pulleys 15, 16 and thus through the above mentioned electrical field.

During operation of the apparatus, the grooved pulleys 15 and 16 are rotated in the directions indicated by the arrows by any suitable driving means. Contact brushes 17 and 18 engage the grooved peripheries of the pulleys and keep the grooves clean as the pulleys are rotated. The pulleys 15, 16, contact brushes 17, 18 and supply tube 20 are grounded as indicated at G.

As a modification, a single pulley may be used instead of two, this pulley being cleaned in similar manner by a grounded contact brush.

It will be seen that, in the embodiment of Figs. 2 and 3, as in that of Fig. 1, the outer electrode is movable relative to fixed cleaning means to keep the active surface of said electrode clean during operation of the apparatus. By thus keeping this surface clean, much closer spacing of the electrodes can be used than would otherwise be possible. Since the cleaning means is located outside the direct field between the closest portions of the inner and outer electrodes, it does not in any way interfere with the desirable small electrode gap.

In addition to keeping the active surface of the outer electrode clean, as described above, it is also important to keep the central electrode clean.

Best results have been obtained by having the central electrode point in a direction opposite to that of the flow of the gaseous current. In this way, the central electrode is kept clean and there has also been found to be a more desirable distribution of the ions in gradually charging the powder during the short length of time it takes to pass through the ionizer. Cleaning of the central electrode is also improved by drawing out the tip to a very fine point and by using a hard non-oxidizable metal such as tungsten, nickel, chromium, etc.

It is also absolutely necessary to protect the point against sparking between the point and the surface of the outer electrode. Such sparking is inhibited by the use of a resistance between the central electrode and the voltage supply.

In order to assure the satisfactory working of the apparatus, it is desirable for the air current to travel at a high speed. This is achieved by supplying the ionizer with air compressed to a suitable pressure. For example, it has been found that good results are obtained with pressures of 20 to 40 grams per square centimeter. Previous devices employing a fan or blower have operated with only 1 to 5 grams per square centimeter pressure. With a view to increasing the voltage of the electrical field in the ionizer and thereby transmit to the powders a higher charge, devices in accordance with the invention may operate with an air compressed up to several atmospheres, the discharge opening or nozzle being restricted so as to provide superatmospheric pressure at the point where electrification takes place.

Apparatus in accordance with the present invention preferably uses direct current with a voltage of the order of 3,000 to 6,000 volts and an output per unit of about 100 microamperes. The required voltage may be supplied by a small generator. Especially suitable are induction coil or transformer generators provided with electronic, copper oxide or rotating commutator rectifiers, the primary current being supplied by a small alternator or by a battery. In this way, dusting equipment is obtained that is easy to carry and is especially suitable for agricultural purposes. The weight of the electric generator required is of the order of one kilogram and the electric power requirement is less than one watt.

It will be understood that the apparatus shown in the drawings is merely by way of example and that the invention is not limited to the specific apparatus herein particularly shown and described.

In the claims:

1. In apparatus for projecting highly electrified particles of pulverulent material, an outer electrode comprising a pair of grooved pulleys rotatable about spaced axes and having their peripheries close to one another, peripheral grooves in said pulleys forming a space of approximately circular cross-section between said pulleys, an inner electrode comprising a pointed wire disposed between said pulleys and means for directing a jet of gas carrying said particles around said inner electrode and between said grooved pulleys.

2. In apparatus for projecting highly electrified particles of pulverulent material, an outer electrode comprising a pair of grooved pulleys rotatable about spaced axes and having their peripheries close to one another, peripheral grooves in said pulleys forming a space of approximately circular cross-section between said

pulleys, an inner electrode comprising a pointed wire disposed between said pulleys, means for directing a jet of gas carrying said particles around said inner electrode and between said grooved pulleys and means for cleaning the grooved peripheries of said pulleys as they rotate.

3. Apparatus for projecting highly electrified particles of pulverulent material into the atmosphere, comprising a pointed wire electrode and a second electrode having an active surface of materially large area facing and at least partially surrounding the pointed electrode, the distance between the electrodes being of the order of a few millimeters, means for producing an electric field between the pointed electrode and said active surface of the large-surface electrode, the potential between said electrodes being of the order of 2500 to 8000 volts, means for directing a stream of gas carrying said particles through the electric field between said electrodes and into the atmosphere, and fixed rubbing means engaging said active surface of said large-surface electrode, said large-surface electrode being movable relative to said fixed rubbing means during the electrification and projection of said particles to bring substantially the entire area of said active surface into engagement with said rubbing means and thereby keep said active surface clear of said particles, said rubbing means being disposed out of the direct electric field between the closest portions of said electrodes.

4. Apparatus according to claim 3, in which said pointed wire electrode points in a direction opposite to the direction of flow of said stream of gas.

5. Apparatus for projecting highly electrified particles of pulverulent material into the atmosphere, comprising a pointed wire electrode and a second electrode having an active surface of substantially larger area facing and at least partially surrounding said pointed electrode, said active surface being a surface of revolution and the distance between said electrodes being of the order of a few millimeters, means for producing an electric field between the pointed electrode and said active surface of the large surface electrode, the potential between said electrodes being of the order of 2500 to 8000 volts, means for directing a stream of gas carrying said particles through the electric field between said electrodes and into the atmosphere, and means for cleaning particles of material from said active surface, said large-surface electrode being rotatable about the axis of said surface of revolution during the electrification and projection of said particles to bring substantially the entire area of said active surface progressively into engagement with said cleaning means to keep said surface clear of said particles, said cleaning means being disposed out of the space between the closest portions of said electrodes.

6. Apparatus for projecting highly electrified particles of pulverulent material into the atmosphere, comprising a pointed wire electrode and a second electrode comprising a pair of rotatable members having active surfaces of substantially

larger area facing and at least partially surrounding said pointed electrode, said active surfaces being surfaces of revolution and the distance between said surfaces and the pointed electrode being of the order of a few millimeters, means for producing an electric field between the pointed electrode and said active surfaces of said second electrode, the potential between said electrodes being of the order of 2500 to 8000 volts, means for directing a stream of gas carrying said particles through the electric field between said electrodes and into the atmosphere, and means for cleaning particles of material from said active surfaces, said rotatable members being rotated during the electrification and projection of said particles to bring substantially the entire area of said active surfaces progressively into engagement with said cleaning means to keep said surfaces clear of said particles, said cleaning means being disposed out of the space between the closest portions of said electrodes.

7. Apparatus for projecting highly electrified particles of pulverulent material into the atmosphere, comprising a pointed wire electrode and a second electrode having an active surface of substantially larger area facing and at least partially surrounding the pointed electrode, the distance between the electrodes being of the order of a few millimeters, means for producing an electric field between the pointed electrode and said active surface of the large-surface electrode, the potential between said electrodes being of the order of 2500 to 8000 volts, means for directing a stream of gas carrying said particles through the electric field between said electrodes and into the atmosphere, means for cleaning particles of material from said active surface, said second electrode being reciprocable relative to the pointed electrode and said cleaning means, and means for reciprocating said second electrode during the electrification and projection of said particles to bring substantially the entire area of said active surface into engagement with said cleaning means to keep said surface clear of said particles, said cleaning means being spaced from said pointed electrode in the direction of reciprocation of said second electrode so as to be disposed out of the space between the closest portions of said electrodes.

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