INVENTOR
CHARLES K. GRAVLEY
BY
S. G. Christensen
ATTORNEY
This invention relates to a method and apparatus for coating articles with paint, varnish, lacquer or other coating materials.

An object of this invention is to provide an improved method for coating articles.

A more specific object is to provide a method for obtaining an improved distribution of coating material on the coated article.

A further object of this invention is to provide a method for removing the drop or drops of coating material that usually accumulate at the bottom of an article in the coating process.

Another object of this invention is to provide a method for obtaining a heavier coating at corners and edges of an article.

A further object is to provide apparatus for obtaining the above objects.

The invention is applicable to the coating of articles of various kinds, sizes and shapes wherein the coating is applied in the liquid state and subsequently dries or sets. It has been developed in connection with the coating of piezoelectric units and will be described chiefly in connection with the coating of such units, but it should be understood that the invention is merely illustrated by this application, and is not restricted thereto.

Piezoelectric units, especially of the Rochelle salt type such as are used in microphones, phonograph pickups, etc., may be adversely affected by such atmospheric conditions as very high or very low humidity, high temperatures, etc., and for this reason are usually coated with a protective material such as lacquer or shellac. Two difficulties have been encountered in coating such units by the usual dipping or spraying methods. Firstly, part of the coating material tends to run to the lowermost part of the unit and collect there in a large drop. If this drop is not removed it subsequently hardens into a lump which is unsightly and may interfere with the mounting of the unit or the attachment thereto of a part such as a phonograph stylus holder. Such drops have heretofore been removed by a wiping process which could not be practiced effectively with automatic coating machinery. The second difficulty has been to obtain satisfactory coating thickness on sharp corners and edges. Most coating materials tend to favor flat surfaces by drawing away from the corners and edges. Consequently the coating material is thinnest at the locations which are most easily damaged.

I have discovered that the above difficulties can be greatly reduced and a desirable distribution of coating material obtained by subjecting the coated article to the influence of an electrostatic force while the coating material is in a wet state. For example, the article after being coated by spraying or dipping may be supported between metal electrodes, or above an electrode, or both. I usually prefer to use the article itself as one electrode and establish a difference of potential on the order of a few hundred to several thousand volts between the article and the adjacent electrodes. The resulting electrostatic force causes the excess coating material to leave the object and produces a more uniform distribution of the coating material which remains.

The excess material may be removed in one or two large drops or in a large number of fine drops or even in a practically atomized state, depending on the nature of the material and the voltage used. In general, a higher voltage tends to remove the material in smaller drops or particles. It has been observed that the material leaves an article from sharp points such as the lowermost corners.

By thus using electrostatic force to remove the excess coating material it is possible to obtain a more uniform distribution of material than if gravity alone is relied on. I have also observed that the distribution of coating material which remains on the article is improved in another respect by the action of the electrostatic field, this improvement resulting from the tendency of the material to build up in thickness at sharp corners and edges. When the additional protection which is afforded by this increased thickness is desired, it may be secured by keeping the coated article under the influence of the electrostatic field until after the coating material has become set; that is, until after the material has reached that state or condition wherein it will henceforth hold its shape while drying. This provides additional protection at the regions most subject to damage.

When the coating material in a wet state is a reasonably good conductor of electricity and when the material is conductively connected to the source of high potential such as is the case when the coated article is of metal and connected to a high potential source, the source may be of either alternating or direct current. When the coating material is a very poor conductor, better results are obtained by the use of direct current. It appears that for poor conductors the conductivity between the electrode and the outer parts of the coating is so poor that said outer parts do not have time to become...
charged to a sufficient potential before the cycle has reversed, whereas with the direct current there is no reversal of the potential and therefore considerable time may be allowed for a suitable charge to reach the outer portions. In the interest of safety for the operator, it is usually desirable to use a direct current source although this requires somewhat more elaborate equipment. The reason for this is that when a direct current source is used a very large protective resistance may be built into the power supply, which resistance makes it impossible for a fatal amount of current to flow through a person's body if he should accidentally come in contact with the electrodes. On the other hand, if alternating current is used, the alternating current necessary to charge the electrodes may in some cases cause so great a voltage drop in the series protective resistance that sufficient potential may not be obtained at the electrodes.

To further explain the invention I will now describe a practical form of automatic apparatus suitable for carrying out the new method in connection with the coating of small objects, such as piezoelectric units.

Referring to the drawings,

Fig. 1 is a front elevation of a portion of a conveyor system and associated apparatus suitable for use with my improved method.

Fig. 2 is a sectional view taken on line 2, 2 of Fig. 1.

Fig. 3 is a front elevation of a portion of the conveyor holding a piezoelectric unit which has been coated by my new method.

Fig. 4 is an end elevation of the part shown in Fig. 3.

Figs. 5 and 6 are front and side elevations respectively of a piezoelectric unit as it appears when coated without benefit of my improved method, or as it appears before being subjected to the influence of the high-voltage electrostatic force.

Fig. 7 is an enlarged fragmentary sectional view of a portion of the piezoelectric unit of Fig. 5 and taken on line 7, 7.

Fig. 8 is an enlarged fragmentary sectional view of a portion of the piezoelectric unit of Fig. 3 and taken on line 8, 8.

Referring to the figures, the conveyor comprises a roller chain 1 which is guided in the direction of arrows 2 and 3 by sprockets 4, 5, 6 and 7, and is kept in motion by a suitable motor and reduction gear not shown.

At intervals along its length the conveyor chain is provided with extended pins 8, 8 which carry spring clips 9, 9, each provided with an enlarged handle portion 9a and a rubber compression pad 9b. The clips are free to rotate on pins 8 and are held in place by collars 10, 10. The leads 11a, 11a of the piezoelectric units 11, 11, are clipped into the clips by an operator positioned somewhat to the left of sprockets 4 and 5.

Below sprocket 5 is located a double tank comprising reservoir 12 containing an inner level-controlling tank 13. A motor-driven pump 14 pumps the liquid coating material 15 out of reservoir tank 12 through pipe 16 and into level-controlling tank 13 through pipe 17, so that tank 13 continuously overflows at 13a back into main tank 12, thus maintaining a constant level of liquid as determined by the lower edge of cut out 13a in tank 13.

As the conveyor progresses in the direction indicated by the arrows 2 and 3, each piezoelectric unit 11 is successively dipped in the tank and then withdrawn. As the units are withdrawn from the tank the excess coating material tends to accumulate at the lower portions of the units under the action of gravity as indicated at 18 in Figs. 5 and 6.

To prevent accumulation of excess coating material at the bottom of the units and to assist in coating the edges and corners, I provide electrodes 19, 19 and a source of high voltage 20 connected to the electrodes and to the conveyor. Electrodes 19 are removably supported by angle members 21, 21 which are carried by high-voltage insulators 22, 22. A frame 23 supports the insulators and is constructed to permit adjustment of the height and spacing of the electrodes. The high potential terminal 24 of the power supply 20 is connected by conductors 25, 25 to angle members 21 which are in contact with the electrodes. The low potential terminal 26 of the power supply is connected to ground and to the conveyor system by conductor 21 and therefore is also connected to the conductive coating of the piezoelectric unit.

As the coated piezoelectric units 11 approach the electrodes 19 the electrostatic forces established by the high potential causes the excess coating material 18 to be drawn off to the electrodes usually in a fine stream or spray. The excess continues to be drawn off until the coating material which remains on the article has reached a condition where it no longer flows in response to the electrostatic force. The material is then in such condition that it will henceforth hold its shape without forming drips, and hence has become set. Figs. 3 and 4 show the element after the coating material has thus become set while subjected to the action of the high voltage. The high potential field also tends to force the coating material to edges and corners. This is illustrated by Figs. 7 and 8 which are enlarged sectional views of the elements of Figs. 5 and 3 respectively, showing in exaggerated detail the distribution of coating material at the edges of the unit before and after the treatment with the electrostatic field. It will be observed (Fig. 7) that prior to application of the high voltage field the coating material tends to pull away from the edges leaving a very thin coating in the region that should have the greatest protection. However, when the electrostatic field is applied the coating material is caused to build up at the edges, thus providing the desired additional thickness at those regions, as shown in exaggerated form in Fig. 8. The electrodes 19, 19 of course are long enough to permit the coating material to become set in this built-up condition before the units pass beyond their influence. The units are then carried back and forth by the conveyor through a drying chamber (not shown) to permit more thorough drying and then pass to successive dipping tanks and removing electrodes where additional coats are applied. After the last coating applied to the units has become dry, the units are removed from the clips by another operator and are ready for final test and use.

It has been found that a plurality of thin layers of coating material provides more satisfactory protection for piezoelectric units than a single thick layer. It is, therefore, expensive to apply a plurality of coats because each coat has been applied by hand and the excess coating material wiped off after each coating step. My invention eliminates the necessity for handling the units individually each time a coating layer is applied, and thus permits the appli-
cation of a plurality of layers without additional cost. A further advantage of the use of a plurality of coats is that the different kinds of coating material may be used for the different layers. For example, it has been found that the vinyl chloride composition known to the trade as Korolac is an excellent moistureproofing material but does not adhere well to piezoelectric units. Black shellac has good adhering properties but is not as effective in protecting the units. By using shellac for the first coat and then by using a coat of two of Korolac, very effective protection is obtained. Without the aid of my invention such a composite, built-up protective coating would be excessively expensive.

The voltage required for satisfactory operation of the invention depends on a number of factors of which the surface tension of the coating material and the spacing of the coated object from the electrodes are perhaps most important. In general, the greater the surface tension of the coating material, the greater the required voltage becomes. Also, the greater the spacing between the coated article and the electrodes, the greater the voltage required. For the electrode arrangement shown in Figs. 1 and 2, with the electrodes spaced about 2" from the coated article, a voltage in the order of 10,000 to 20,000 volts is desirable when thin black shellac is the coating material. The effect of this voltage may be markedly increased by adding materials like acetonil acetone to the shellac for the purpose of reducing its surface tension.

Approximately the same results may be obtained with lower voltage and closer electrode spacing but the possibility of short circuits occurring due to swinging of the coated units over to an electrode becomes more serious. Voltages which produce a visible or audible discharge should be avoided.

It will be understood that many other arrangements of parts may be employed. For example, in lieu of the pair of vertical electrodes 19, 19, a single horizontal electrode may be placed beneath the conveyor. This arrangement provides for satisfactory removal of excess material but has the disadvantages, when used for coating piezoelectric units, that the effective electrode spacing depends on the length of the units being treated. Another arrangement is to use the tank of coating material as an electrode. With this arrangement, if the coating material is a conductor, the system is short circuited every time an article is dipped and it is necessary to arrange the spacing of the units on the conveyor so that a dipped unit is removed from the tank and subjected to the removal action of the high potential before the next unit enters the tank. This arrangement is hazardous when used with inflammable coating material, but the hazard may be avoided effectively by maintaining an inert atmosphere around the coating tank.

I prefer to use the coated article as one electrode of the system whenever this is possible because I have had best results with this arrangement. When it is desired to use a coated non-conducting article as one electrode, this may be accomplished, for example, by suspending the non-conducting article from a wire or hook which is connected to one side of the voltage source, the other side thereof being connected to an adjacent electrode. With this arrangement, a coating material should be used which is a conductor when in a wet state. The dipping step should then be conducted in such manner that the hook or wire contacts the coating material. The conductive coating on the article will then function as an electrode.

It should be understood that it is not essential that the coated article be connected to the high-voltage source, since it has been found that the coated article, whether a conductor or not, may be treated by merely introducing it in an electrostatic field which is maintained between two electrodes of opposite polarity.

The high voltage supply, 20, as shown comprises a step-up transformer, 28, two thermionic rectifiers, 25, 29, and condensers, 30, 30, connected in a voltage doubling circuit. Resistance, 31, in the order of 20 megohms is connected in series with the high potential side to limit short circuit currents to a safe value. This high resistance cooperates with the capacity of the electrodes and wiring to provide smoothing or filtering action.

Other types of high voltage supplies may, of course, be used. For example, the thermionic rectifiers may be replaced by mechanical rectifiers, or the complete supply, 20, may be replaced by an electrostatic generator. Furthermore, in many cases an alternating current supply may be used comprising simply a step-up transformer. Transformers intended for use with neon signs are comparatively inexpensive and are suitable for this use.

Since various changes may be made in the above construction and different applications of the invention could be made without departing from the scope thereof, it is intended that all matters contained in the above description or shown in the drawings shall be interpreted as illustrative and not in a limiting sense.

Having now explained my invention, what I claim is:

1. The method of treating an article which comprises the steps of coating said article with liquid coating material and thereafter allowing said liquid coating material to become set while under the influence of an electrostatic force.

2. The method of treating an article which comprises the steps of applying liquid coating material to said article, subjecting said coated article to the action of an electrostatic force while said coating material is in a liquid condition to remove the excess therefrom and to redistribute the liquid material which remains and maintaining said article under the influence of said force until the coating becomes set.

3. The method as claimed in claim 2 wherein the said liquid coating material is applied by dipping.

4. The method of increasing the thickness of coating on the edges of a coated article, which comprises the step of subjecting said coated article to an electrostatic force while the coating material is in a liquid condition, and maintaining the article under the influence of said force until the coating material has become set.

5. The method of removing excess liquid coating material from an article coated therewith and for increasing the thickness of coating on the edges of the article, said method comprising the steps of: subjecting the coated article to an electrostatic field while allowing the excess material on said article to drain by gravity to the bottom portions of the article; and maintaining the article in said field until the coating has become set.

6. The method of treating an article, which comprises the steps of: coating said article with
apparatus comprising the combination of: means for establishing an electrostatic field capable of removing drops of excess coating material from said article, and means for subjecting said article to the action of said field while the coating material is still liquid and until it has become set.

13. Apparatus for coating an article with liquid coating material, said apparatus comprising: means for applying the liquid coating material to the article; an electrode; means for establishing an electrostatic field between said article and electrode; and means for disposing said article adjacent said electrode while said coating material thereon is in a liquid state and for maintaining it adjacent said electrode until the liquid coating material has become set.

14. Apparatus for coating an article, which comprises: a bath of liquid coating material; electrode; conveyor means adapted to dip said article into said bath, then to transport said article into a predetermined spaced relationship with respect to said electrode; establishing an electrostatic field between said article and electrode while said coating material is sufficiently liquid to drain by gravity to the bottom portions of the article, and maintaining said field until the coating material which remains on the article has become set.

15. The method of making a coated article which comprises the steps of: dipping said article in liquid coating material, and then subjecting the dipped article to the action of an electrostatic force while the coating thereof is in a liquid state.

16. The method of removing a portion of a coating from an article comprising the steps of: establishing a potential difference in a circuit, connecting one side of the circuit to the article to establish the article and the coating thereon at substantially the same potential, and connecting the other side of the circuit to terminal means spaced relative to said article to cause a portion of the coating to leave the article and move through the space toward the terminal means.

17. The method as claimed in claim 16 in which the article is maintained at substantially ground potential.

18. The method as claimed in claim 16 in which said established potential difference is maintained by a direct current source.

19. The method as claimed in claim 16 in which said coating is a liquid coating.

20. Apparatus for treating an article comprising: liquid coating material; subjecting the coated article to the action of an electrostatic force while the coating material is still liquid; and thereafter allowing said liquid coating material to become set while under the influence of said electrostatic force.

7. The method of removing liquid coating material from an article which is coated with an excess thereof, said method comprising the steps of: bringing the coated article into a spaced relationship with respect to an electrode; establishing an electrostatic field between said article and electrode while said excess coating material is sufficiently liquid to drain by gravity to the bottom portions of the article; and maintaining said field until the coating material which remains on the article has become set.

8. The method of treating an article which comprises the steps of: coating said article with an excess of liquid coating material; causing the excess coating material to flow over the surface of the article and to accumulate on predetermined surface portions thereof; subjecting at least the said predetermined portions to the influence of an electrostatic field while the accumulations of coating material are still liquid; and maintaining the article under the influence of said field until no further accumulations of coating material appear adjacent said predetermined portions.

9. The method of treating an article, which comprises the steps of: coating said article with an excess of liquid coating material; causing the excess coating material to flow over the surface of the article and to accumulate on predetermined surface portions thereof; passing at least the said predetermined portions into an electrostatic field maintained between a pair of electrodes while the accumulations of coating material are still liquid and until it has become set.

10. A method of treating a piezoelectric unit, said method comprising the steps of: coating said unit with an excess of liquid coating material; subjecting the coated unit to the influence of an electrostatic field while the shellac is still liquid and until it has become set; drying said coating of shellac; thereupon coating said unit with an excess of liquid waterproofing vinyl resin; and subjecting the unit to the influence of an electrostatic field while the resin is still liquid and until it has become set.

11. In the process of coating an article with liquid coating material, the method of preventing the accumulation of drops of excess coating material at the bottom portions of said article, which comprises subjecting at least said portions of the coated article to the influence of an electrostatic force while said coating material is in a liquid state and until it has become set.

12. Apparatus for treating an article having a coating of liquid coating material thereon, said apparatus comprising the combination of: means for establishing an electrostatic field between said article and electrode; and means for disposing said article adjacent said electrode while said coating material thereon is in a liquid state and for maintaining it adjacent said electrode until the liquid coating material has become set.

21. Apparatus for coating an article with liquid coating material, said apparatus comprising: means for applying the liquid coating material to the article; an electrode; means for establishing an electrostatic field between said article and electrode; and means for disposing said article adjacent said electrode while said coating material thereon is in a liquid state and for maintaining it adjacent said electrode.
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2,359,476 electrode means; conveyor means adapted to dip said article in said bath, then to transport said dipped article into predetermined spaced relationship with respect to said electrode means while the coating on said article is in a liquid condition, and then to maintain it in said spaced relationship with said electrode; and electrical means for establishing an electrostatic force between said coating and said electrode means capable of removing the excess liquid coating material which drains to the bottom portions of the article.

23. The method of removing surplus coating material from a pre-coated article that comprises, imparting an electric charge to said surplus, and subjecting such charged surplus to an electric field of proper polarity and of sufficient strength to cause the said surplus to leave the article.

24. Apparatus for treating a coated article comprising, in combination, a high potential source, means for connecting one side of said high potential source to the coated article, electrode means spaced from said article, means connecting said electrode means to the other side of said high potential source to establish a steep potential gradient between said electrode means and said article whereby excess coating material is caused to leave said coated article.

25. Apparatus for treating a coated article comprising in combination, a plurality of spaced terminal means, means connected to at least one of the terminal means for establishing a high potential difference between said terminal means, and means for electrically connecting said coated article to one of said terminal means to subject the coating to the electrostatic force established by said potential difference to cause a portion of the coating to leave the article.

26. In an apparatus for treating a coated article; circuit means including a voltage source for establishing a potential difference in said circuit means, means for connecting one side of the voltage source to the article to establish the article and the coating thereon in the circuit and to establish the coating thereon at a certain potential, electrode means spaced from said coated article, and means for connecting the other side of the said voltage source to the said electrode means to establish the electrode means in the circuit and at a potential different from the potential of the coating to cause portions of the coating to leave the article.

27. Apparatus for treating a pre-coated article, comprising in combination a plurality of spaced apart electrodes, means for giving one of said electrodes a high potential with respect to another of said electrodes, and means for disposing a coated article effectively in the electric field between said electrodes and in effective contact with one of said electrodes whereby excess coating material is expelled from said article.

CHARLES K. GRAVLEY.