United States Patent

[11] 3,566,833

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[54] **CONTINUOUS COATING APPARATUS**
3 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **118/634,** 118/304, 118/405
[51] **Int. Cl.** **B05b 5/00**
[50] **Field of Search** ..... 118/637, 623, 624, 629, 630, 634; 117/(Inquired), 17, 17.5, 16+

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ABSTRACT: A magnet wire is prepared by first passing a copper wire through a dense cloud of electrostatically charged and finely divided plastic particles such as epoxy powder held within a confined chamber and being created by a spray gun positioned within the chamber and below the elongated member and in combination with a fluidized bed of a similar or a different plastic powder and then passing the electrostatically coated wire through an oven maintained at a temperature sufficiently high to fuse the electrostatically deposited plastic particles thereon to form an insulation film on the wire.

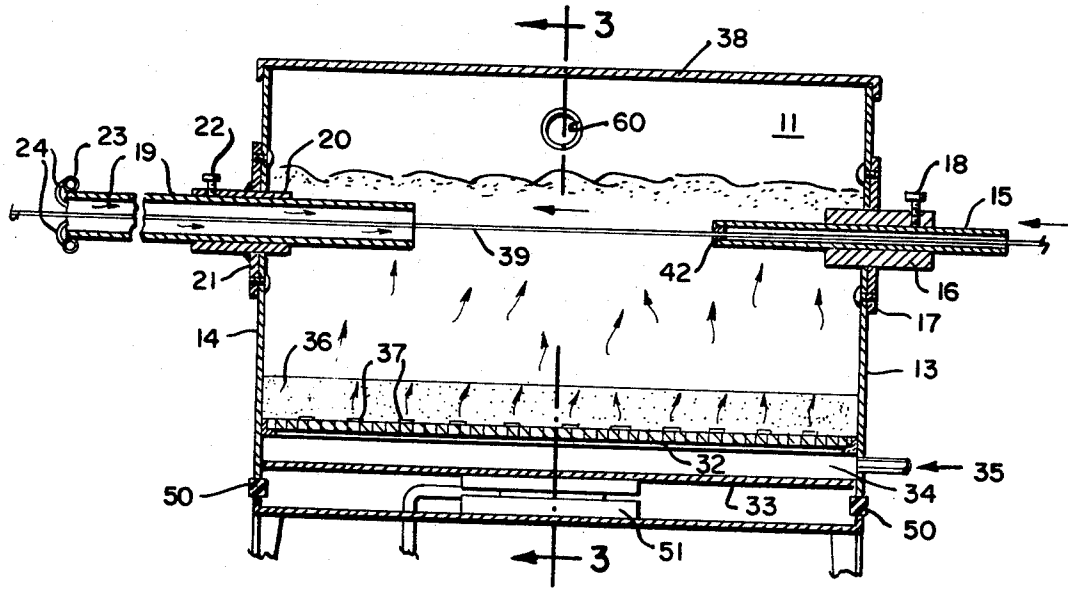


FIG. 1

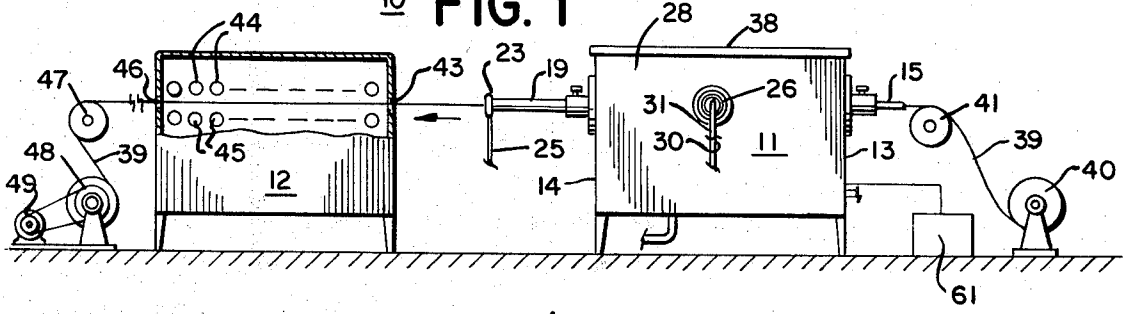


FIG. 2

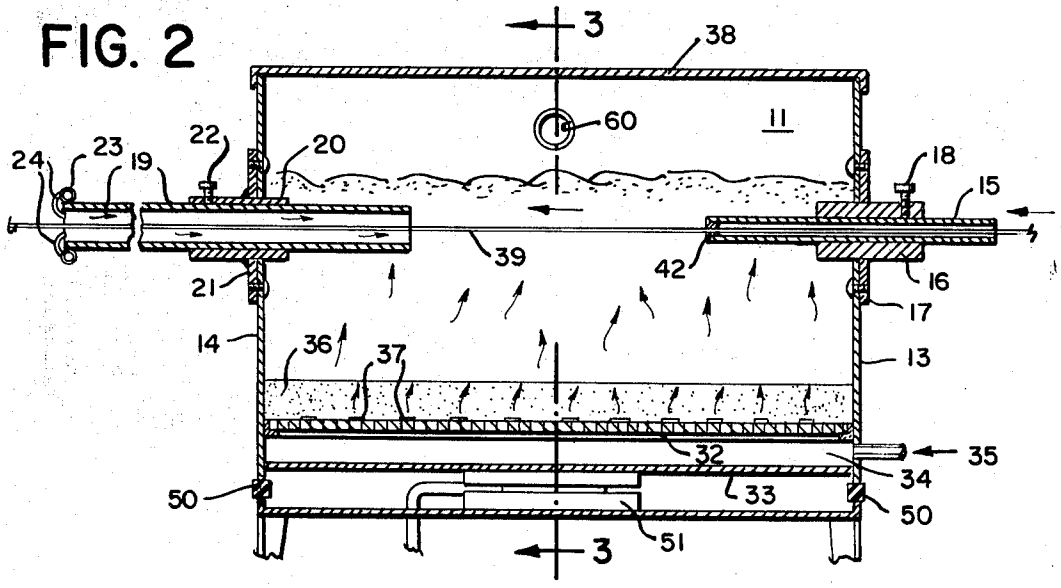
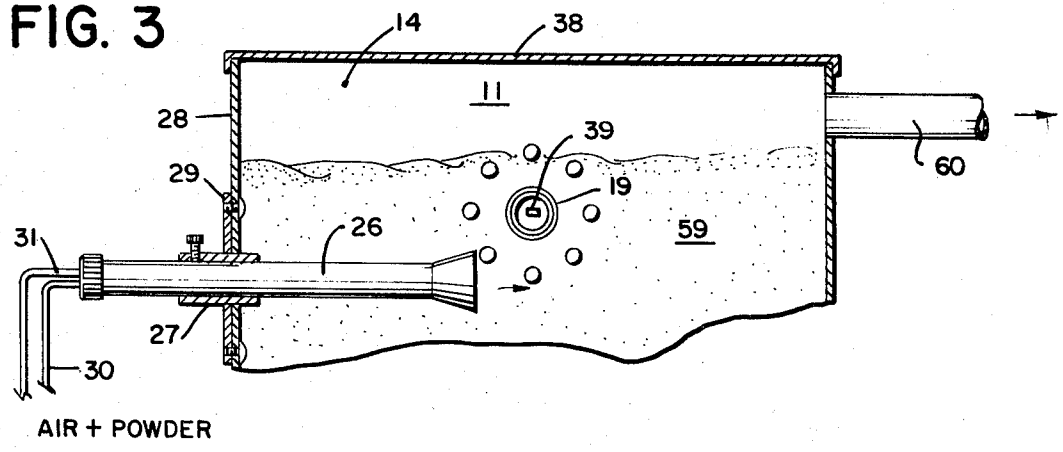


FIG. 3



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CONTINUOUS COATING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an apparatus for continuously coating elongated metallic members and more specifically to the manufacturing of magnet wires.

2. Description of the Prior Art

Electrostatic coating has been widely used to provide a coating of plastic on a substrate using apparatuses such as those described in U.S. Pat. No. 2,893,893, and U.S. Pat. No. 2,893,894 to Crouse and to Ransburg, respectively. These apparatuses electrostatically atomize finely divided discrete particles of liquid as a spray and electrostatically disperse and deposit the particles on the substrate while still in a liquid state. Alternatively, plastic in the form of finely divided solid particles has also been successfully electrostatically coated on a substrate by dipping the substrate into a fluidized bed of charged and finely divided plastic powder. An example of the solid electrostatic coating method is described in U.S. Pat. No. 3,019,126 to Bartholomew. Electrostatic coating methods described above, however, cannot be controlled readily for coating a very thin and even deposition of plastic on a substrate such as that required in the manufacturing of magnet wires.

To improve the deposition, a modified fluid bed electrostatic coating method has been recently developed which uses a DC high voltage supply to create a potential within the chamber sufficient to create a cloud of charged particles above the fluid bed of charged plastic powder and to deposit the powder evenly on the wire passing through the charged cloud. This method and the apparatus for practicing the same are described in U.S. Pat. application Ser. No. 588,511, filed on Oct. 21, 1966, now U.S. Pat. No. 3,396,699, and assigned to Anaconda Wire and Cable Company, the assignee of this application. Magnet wires manufactured by this modified fluid bed electrostatic coating method are acceptable for commercial application. The insulation thereon, however, lacks the smoothness when compared with magnet wires prepared by the more conventional dip-coating method using an enamel solution.

SUMMARY OF THE INVENTION

We have discovered quite unexpectedly that the smoothness of the insulation on the magnet wire can be substantially improved by using an electrostatic spray gun either alone or in combination with a fluid bed to generate an electrostatic cloud of a plastic powder in a modified electrostatic coating apparatus similar to the aforesaid copending application. Broadly stated, the apparatus comprises an enclosed chamber having an inlet and an outlet for the metallic member such as a wire to pass therethrough. Associated with the coating chamber, is an electrostatic spray gun which has at least one spray nozzle positioned within the chamber and spaced apart from but adjacent to the metallic member passing through the chamber. The spray gun is connected to a DC high voltage supply source for generating a high electrical potential within the chamber and is also connected to a source of plastic coating material. The spray gun has pressure means for delivering the plastic coating material to the nozzle and for projecting the material into the chamber in the form of finely divided charged particles.

Preferably, there is a plurality of electrodes which are positioned within the chamber and are also connected to a DC high voltage supply source for generating a high electrical potential within the chamber. The apparatus has means for continuously feeding the metallic member into the chamber through its inlet and withdrawing the metallic member therefrom through the outlet at a predetermined rate. While passing through the enclosed chamber, the metallic member is surrounded by the cloud of the electrostatically charged particles created by the high electrical potential generated by the spray gun or in combination with the electrodes. The metallic member is advantageously grounded to create a potential difference between the charged particles and the metallic member to cause the finely divided and charged coating particles to deposit evenly thereon.

An oven which also has an inlet and an outlet is positioned adjacent to the coating chamber. Through the inlet, the oven receives the coated metallic member from the coating chamber. The oven has a temperature sufficiently high to fuse the coated plastic particles onto the metallic member. Means are provided in the oven for continuously feeding and withdrawing the coated metallic member through the oven at a predetermined rate sufficient to allow the coating thereon to fuse into a smooth and continuous layer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view, partly in section, of the apparatus of this invention;

FIG. 2 is a cross-sectional view of the coating chamber; and

FIG. 3 is a partial cross section taken along line 3–3 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The continuous coating apparatus **10** of this invention as shown in FIG. **1** comprises an enclosed coating chamber **11** and an oven **12**. The coating chamber **11** is generally in the form of a rectangular box having an upstream wall **13** and a downstream wall **14** as shown more clearly in FIG. **2**. A wire inlet **15** in the form of a tube is provided on the upstream wall **13**. The tubular wire inlet **15** is slidably mounted on a bushing **16** which in turn is bolted to the upstream wall **13** by a reinforcing plate **17**. The tubular wire inlet **15** can be locked into place by a thumb screw **18**.

Similar to the wire inlet **15**, the outlet **19** is also in the form of a tube with a slightly larger diameter than the inlet about 5 to 10 times the diameter or the maximum width of the member and is slidably mounted on a bushing **20** bolted to the downstream wall **14** by a reinforcing plate **21**. It is also locked into place by a thumb screw **22**. Mounted on the downstream of the wire outlet **19**, there is a hollow ring **23** with a plurality of jet nozzles **24** directed inwardly into the tube. The hollow ring **23** is connected to an air supply (not shown) by an air hose **25**. The function of the hollow ring and the inwardly directed jets will be described in more detail hereinbelow.

Secured to one of the sidewalls **28** of the coating chamber **11** is an electrostatic spray gun **26** whose spray nozzle protrudes into the coating chamber **11** as shown more clearly in FIG. **3**. Similar to the inlet and outlet tubes, the spray gun is advantageously slidably mounted on a bushing **27** which, in turn, is bolted to the sidewall **28** by a reinforcing plate **29**. Connected to the spray gun are an air- and powdered-coating-material-supply line **30** and an electrical wire **31** connected to a high DC voltage source (not shown). A number of electrostatic spray guns available commercially are suitable for the apparatus of this invention. These guns are capable of spraying finely divided particles, such as plastic powder, by initially mixing the powder with a gas, such as air, and then delivering the powder and air mixture to the spray nozzle. One of such electrostatic spray guns that we found to be eminently suitable is Ransburg Electropowder Gun REP Model 322AB, manufactured by Ransburg Electro-Coating Corp.

As shown in FIG. **2** the coating chamber **11** has a gas permeable false bottom **32** formed of a sheet of porous ceramic, and an impermeable plate **33** spaced apart from the false bottom **32** to form a gas passage **34** into which dried air is blown through a pipe **35** connected to a pressurized air supply (not shown). Above the porous plate **32** is a fluid bed **36** of dielectric powder coating material which may be similar to the coating material from the spray gun **26** and is maintained in the fluidized state by the air through the porous bottom **32**. Embedded in the plate **32** are a large number of electrodes **37** which are evenly distributed and spaced apart over the entire

upper surface of the plate **32**. The electrodes **37** are all electrically connected to a high voltage generator **61** (see FIG. **1**) which supplies a high negative DC voltage to the electrodes in the order to 40—100 kilovolts. The application of the high electrical potential causes the formation of a dense charged cloud of the dielectric powder from the electrostatic spray gun and from the fluid bed which is above the fluidized bed and is sufficiently high to surround the wire coming into the chamber through the inlet tube **15**. The charged cloud is prevented from escaping from the coating chamber by a cover **38**.

Since the coating chamber is enclosed by the cover **38**, an air outlet **60** is provided thereon to release the pressure buildup caused by the air admitted into the chamber from the spray gun and from the fluid bed. The air outlet **60** is preferably positioned at or adjacent to the top above the charged cloud **59** to avoid the removal of an excess amount of charged powder. A certain amount of powder will escape through the air outlet **60** which may be recovered by a filter connected to the air outlet. The recovered powder may be recycled to the coating material supply for reintroduction into the chamber.

The elongated metallic member **39**, which when used for the preparation of magnet wires may be a copper wire, is paid off from a supply reel **40** over a supporting sheave **41** through the inlet tube **15** and into the coating chamber **11**. At the downstream of the inlet tube **15** there is a felt plug **42** which allows the wire **39** to pass therethrough but seals the tube to avoid the leakage of the coating powder. The copper wire **39** exits the coating chamber **11** through the outlet tube **19** which is aligned with the inlet tube **15** and into the oven **12** through inlet **43**. After passing through a bank of heating elements **44** and **45** which may be infrared lamps, the coated copper wire exits through an oven outlet **46**, over a supporting sheave **47** onto a takeup reel **48** which is driven by a motor **49**.

Once the wire enters into the coating chamber it is free from any contact until it leaves the oven **12**. It is, therefore, apparent that inlets and outlets of the oven and the coating chamber must be properly aligned and that the sagging of the wire is controlled by adjusting the tension between the two sheaves **41** and **47**.

Since the coating chamber is enclosed, particles that collect on the top plate **38** may fall on the wire causing loosely deposited particles thereon. These loosely held particles are removed by the jets **24** directed inwardly into the chamber **11**.

The chamber **11** is mounted on rubber or other flexible footing **50** and is vibrated by a vibrator **51** which can be of a number of known types such as air or electric vibrators. The speed and amplitude of the vibrators **51** are preferably variable and are set to establish optimum conditions for a fluid bed which are determined by trial.

The infrared lamps **44** and **45** should be sufficient in number to provide a temperature high enough to thoroughly fuse the coating on the wire. The sheave **47** should be spaced downstream of the oven **12** at a distance long enough to allow the coating to cool to a substantially nontacky state before passing thereover.

Although in the apparatus just described a fluid bed is used to assist the electrostatic spray gun to create a charged cloud for electrostatic coating, it should be understood that such a fluid bed is not essential for the success of the coating operation. When the fluid bed is not used we prefer to use the electrodes **37** to control the charged cloud. In general we found a DC voltage applied to the electrodes **37** should be higher than the voltage applied to the spray gun. The coating thickness of the magnet wire is controlled by a number of variables which include the amount of powder sprayed into the chamber, the magnitude of the potential applied to the spray gun and on the electrodes **37** and the air velocity through the porous plate **32** which affect the density of the cloud **52**, the speed of the wire **39**, and the relative positions of tubes **15** and **19**. The speed of the wire **39** in commercial practice should be maintained as high as the oven **12** can satisfactorily fuse the resultant coated wire. The voltages of the electrodes and of the spray gun have a definite upper limit determined by the capacity of the high voltage generator and the danger of arcing between the electrodes and the wire, and a lower limit below which the cloud **52** will be irregular and will not completely surround the wire.

The proper conditions for obtaining the most effective cloud should be experimentally determined for each type of powder to be applied. However, we have found that a most delicate control of the effective length of the chamber **11** is obtainable by means of the tubes **15** and **19** which can be separated or brought together to determine the length of the wire **39** exposed to the cloud **52**. This exposure could be controlled by adjusting only one of the tubes **15** and **19** but we have found that when both tubes are adjustable it is possible to select an optimum portion of the cloud formation for exposure of the wire **39**. The tubes allow much higher voltages resulting in higher cloud densities which permit the application of denser coatings.

We have found also that although the powder deposit on the wire **39** which is, at least temporarily, adherent due to the electrostatic charge, is uniformly distributed on the wire, there are, in addition, loose particles, such as agglomerates which may fall from the wall or cover, which if they are permitted to remain on the wire, would fuse into an uneven, lumpy coating in the oven **12**. An air current generally will remove these excess particles and lumps, and still will not disturb the desired coating layer. By placing the air ring **23** at the downstream end of the tube **19**, it serves the triple purposes of removing the loose aggregate, of freeing the tube **19** from any deposits of powder, and of controlling the cloud of charged particles.

When a continuous wire is passed through the cloud **52** access to the top of the wire is available only from the sides, not from the back and front as when an individual article is dipped into the cloud. Yet we have found that flat wires held in a horizontal plane can be satisfactorily coated in our apparatus, and we have coated thousands of pounds of copper wire .065 to .31 inches with an epoxy powder.

The wire **39** may be fed at a speed from 10 to 50 feet per minute to apply a coating 0.0005 to .0025 inches thick. This speed is many times faster than the speed used for coating by wet methods with multiple passes. To achieve this speed the oven **12** is preferably about 9 feet long. Since the oven uses infrared energy sources (the lamps **44** and **45**) the actual air temperature in the oven is not the important factor in fusing the coating.

In the preferred operating conditions, the fluid bed is maintained between about 2—5 inches deep and the wire **39** is passed 15 to 18 inches above the porous plate **32** and the spray gun is positioned below the wire and about 6 to 10 inches away from the wire. The volume of the fluid bed should not be much greater, possibly 20 percent, than the volume occupied by the powder in an unfluidized condition. In the absence of fluidization, the electrodes **37** and applied voltage would be used for the purpose of generating the cloud **59** from the spray gun. The length of wire exposed to the cloud **59** can be from 6 inches to about 2 feet.

In the application of epoxy resin to copper wire hereinabove described to provide a coating thickness of 0.0015—0.0018 inches in one pass, the applied potential on the electrodes **37** was 100 kilovolts and on the spray gun was 50 kilovolts. The wire **39** and oven **12** and all external parts of the chamber **11** were grounded.

The epoxy powder used has particle size distribution determined by sieve analysis as follows:

Mesh size:	Percent on screen
140	11.9
170	17.4
200	19.0
230	19.0
270	20.7
325	8.9
Through 325	3.1

Testing this powder using a standard test for comparison shows that the powder will fuse and flow out adhering to a wire in 31 seconds at 230° C. In practice, a higher temperature may be used leading to a shorter duration for fusing. We found a temperature in the range between 300°—350° C. to be particularly suitable. At this high temperature range the fusing period is shortened to about 10 to 12 seconds.

We claim:

1. An apparatus for coating an insulating film on a continuously travelling elongated metallic member which apparatus comprises:

an enclosed chamber having an inlet and an outlet for said metallic member to pass therethrough;

an electrostatic gun having at least one spray nozzle positioned within the chamber and spaced apart from but adjacent to the metallic member passing through the chamber, said spray gun being connected to a source of plastic coating material and having pressure means for delivering the plastic coating material to the nozzle and projecting said material into the chamber in the form of finely divided particles and being connected to a high voltage supply source to create a high electrical potential within said chamber and to electrostatically charge the finely divided coating particles thereby creating a dense cloud of said charged particles within the chamber;

means for forming and maintaining a fluidized bed of finely divided coating particles within the coating chamber and wherein electrodes are provided and are connected to a high voltage supply source to create a high electrical potential within the chamber and to electrostatically charge the finely divided coating particles;

means for continuously feeding the metallic member into the chamber through its inlet and withdrawing the metallic member therefrom through the outlet at a predetermined rate and passing through said cloud fluidized bed;

means for grounding the metallic member to create a potential difference between the charged particles and the metallic member while it passes through the chamber thereby causing the finely divided and charged coating particles to deposit evenly thereon;

an oven positioned next to the chamber and having an inlet and an outlet for receiving the coated metallic member from the chamber, said oven being maintained at a temperature sufficient to cause the fusing of the coating on the metallic member to form said insulating film; and

means for continuously feeding and withdrawing the coated metallic member through the oven at a predetermined rate sufficient to allow the coating to fuse into the said insulating film.

2. An apparatus according to claim 1 wherein the spray nozzle is positioned just below the metallic member.

3. An apparatus according to claim 2 wherein the inlet and the outlet of the chamber each is in the form of an elongated tube slidably mounted on the wall of the chamber and protruding thereinto, said tubes being adjustable to increase or to decrease the exposure of the metallic member within the chamber thereby controlling the thickness of the charged particles deposited on the metallic member.