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ELECTROPHORETIC COATING APPARATUS

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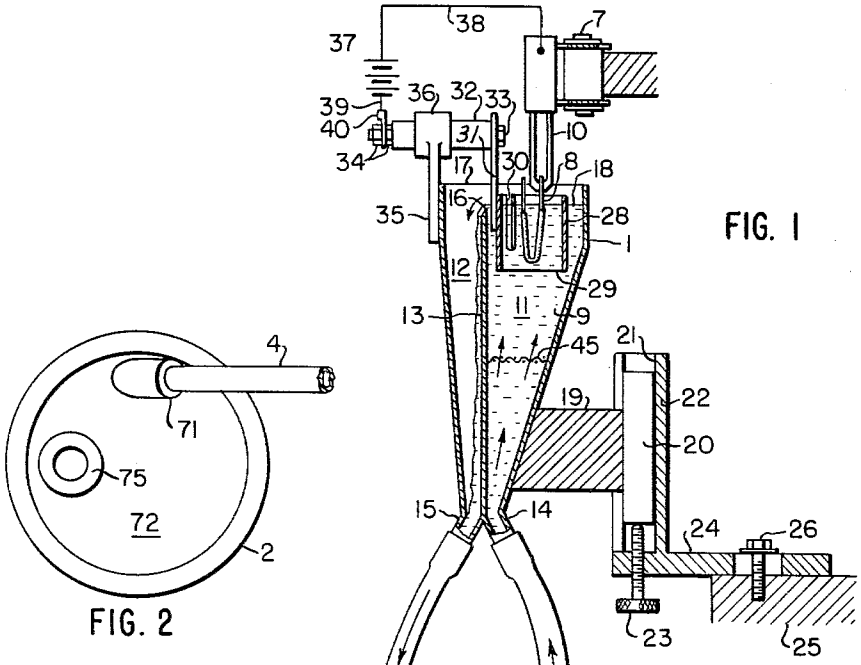
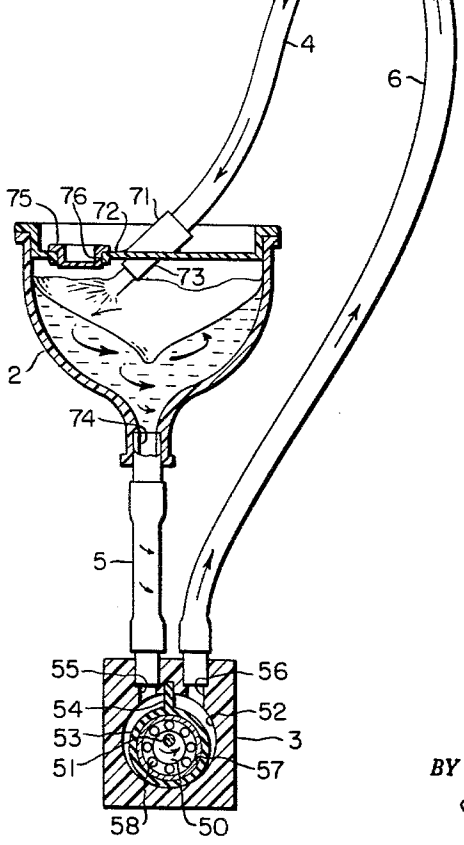


FIG. 1

FIG. 2



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ELECTROPHORETIC COATING APPARATUS

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This invention relates to electrophoretic coating apparatus, and more particularly to an improved apparatus for applying adherent coatings from a liquid suspension of finely divided particles, by an electrophoretic process.

Electrophoretic coating has been utilized for a number of applications, including the formation of latex coatings in the rubber industry, the enameling of tin cans, and the coating of electrical filaments with insulating material. The process involves the sedimentation of fine particles from a suspension in an appropriate liquid medium. The suspension is preferably of a type characterized by stability in a diffuse state of the particles, but by increasing instability with increasing concentration of the particles.

Electrophoretic coating is performed by inducing the sedimentation of particles from a suspension by electrostatic attraction. The articles to be coated is extended into a suspension of the coating material in a suitable liquid medium, and an electric potential is applied through the liquid between the article and an electrode. Opposite polarity to that of the ionized particles is applied to the article, and the particles migrate toward the article, establishing a sedimented layer thereon which is surrounded by a layer of settling particles which are relatively incohesive. Subsequent to coating, the article is rinsed in a suitable solvent to remove the settling layer, leaving the sedimented layer in an adherent coating upon the surface of the article.

Apparatus for carrying out electrophoretic coating is subject to conflicting requirements. A quiescent surface of the coating suspension must be maintained in the region of the coated article, to avoid interference with the settling of particles thereon. At the same time, however, it is necessary to agitate continuously the coating suspension to prevent a gravity-induced sedimentation from clogging the apparatus, and to maintain a desired particle concentration for effective and uniform coating action. In addition to these conflicting requirements, the surface of the coating suspension must be maintained at a predetermined level to permit uniform and repetitive coating of desired portions of a series of like articles.

An electrophoretic coating apparatus for accommodating these requirements is described and claimed in a copending application of Edward D. Parent entitled "Electrophoretic Coating Apparatus," Serial No. 75,834, filed Dec. 14, 1960, now patent No. 3,157,588, granted Nov. 17, 1964. According to that application, a coating apparatus is described which comprises a coating container for affording a quiescent coating suspension surface of controlled level for the coating of articles, a reservoir having means for continuously agitating coating suspension therein, and pumping means; these elements being connected for recirculation of the coating suspension between the container and the reservoir. The coating container is vertically elevated from the reservoir for gravity return of suspension from the coating container to the reservoir, and the pump is arranged to deliver the coating fluid from the reservoir to the container. A suitable electrode is inserted into the surface of the coating suspension at the top of the coating container, and means are provided for dipping articles to be coated into the suspension at a distance from the electrode. Finally, means are provided for applying an electric potential across the electrode and the article to be coated, for inducing electrophoretic coating action.

In the aforementioned copending application, the reservoir is provided with mechanical agitating means positioned to prevent the accumulation of a sedimented layer upon the bottom of the reservoir. While this expedient is quite satisfactory in the great majority of applications, it results in a substantial rate of evaporation and some risk of explosion where extremely volatile liquid suspension media are used, such as acetone, because of the necessity of providing an opening in the top of the reservoir for entry of an impeller shaft, and the use of electrically-driven motive means for the impeller. Additionally, the requirement that the reservoir be the lowermost element of the system may result in vapor-lock of the pump by a highly volatile suspension medium.

It is the primary object of the present invention to feature an improved electrophoretic coating apparatus having means for minimizing the rate of evaporation and the risks of explosion and vapor-lock of a highly volatile suspension medium.

It is a further object of the present invention to feature an improved electrophoretic coating apparatus having means for agitating a coating suspension which do not require the use of a mechanically-actuated impeller, and in which a reservoir may be fully enclosed to minimize evaporation.

Further objects and advantages of our invention will become apparent as the following description proceeds.

Briefly stated, in accordance with a preferred embodiment thereof, we may carry out our invention by providing a coating apparatus which includes an enclosed vortex-flow reservoir, into which a conduit discharges a stream of coating suspension with a component of direction such as to agitate the suspension for the uniform distribution of coating particles therein. The formation of a sedimented layer of particles in the reservoir is thus prevented. The conduit is snugly received through an opening in the reservoir to prevent the escape of evaporated suspension. The reservoir is formed with an outlet at the bottom thereof to accommodate the creation of a vortex flow in suspension draining therefrom.

The improved coating apparatus also includes a pump which is positioned at the lowest elevation in the system because of this location, the agitating action of the pump allows the omission of separate mechanically-actuated agitating means from the system. To prevent clogging and to secure optimum agitation, we prefer to utilize a valveless accentric pump, although this is not essential to the practice of the invention.

A coating container, which may be of the type described by the aforementioned copending application, is connected for a recirculating flow of suspension from the pump and to the reservoir, and is elevated for gravity flow to the latter.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which we regard as our invention, it is believed that the invention will be more clearly understood from the following detailed description of a preferred embodiment thereof, referring to the accompanying drawing, in which:

FIG. 1 is a sectional view in elevation of a coating apparatus made according to the invention; and

FIG. 2 is a plan view of a reservoir forming a portion of the apparatus.

Referring to the drawing, the improved coating apparatus comprises a closed recirculating system including a coating container **1**, a reservoir **2**, a pump **3**, and conduits **4**, **5**, and **6** connecting the elements of the apparatus in serial fluid flow relation. In the embodiment illustrated, the coating apparatus is utilized in conjunction with a chain conveyor **7** of a conventional type arranged to dip a succession of filaments, one of which is

shown at 8, into a supply of coating suspension liquid 9 for applying a coating of insulation to the filaments by electrophoresis. The conveyor carries a series of forceps 10 for gripping the filaments, and is arranged to dip the individual filaments successively into the coating suspension for timed intervals. The conveyor mechanism may be of any conventional type, and no further detailed description thereof is believed necessary.

The coating container 1 is made according to the aforementioned copending application of Edward D. Parent, and in itself forms no part of the present invention; if desired, a container of another configuration may be used, although optimum results might not be obtained thereby. As illustrated, the container has the form of a rectangular-section funnel, whose walls diverge upwardly, and is divided into a coating chamber 11 and an overflow chamber 12 by means of a transversely-extending partition 13. At the lower end of the container, an inlet tube 14 communicates with the coating chamber 11, and an outlet tube 15 communicates with the overflow chamber 12.

The partition 13 is formed with a sharp-edged horizontally-extending weir 16 vertically spaced below the upper end 17 of the container 1. An upwelling flow of coating suspension flows over the weir and downwardly through the overflow chamber 12 to the outlet 15. A surface 18 of the coating suspension is thus established at a uniform level, so that desired portions of the filaments may be uniformly coated.

The coating container is mounted for vertical adjustment by means of an arm 19 having a slide 20 secured thereto and slidably received in a vertically-extending groove 21 of a mounting bracket 22. An adjusting screw 23 is threaded through a base portion 24 of the mounting bracket, and supports the slide 20 in a vertically adjusted position. The mounting bracket is secured to a supporting surface 25 by means of a bolt 26, or in any other suitable fashion. By these means, the container 1 may be vertically adjusted to position the surface 18 at a desired level for coating predetermined portions of filaments of varying forms and dimensions.

The coating material particles and the liquid suspension medium may be of various types, as is well known in the art; however, the apparatus is particularly adapted for use with highly volatile suspension media, such as acetone.

The electrophoretic coating process is carried out by suspending a cylindrical electrode 28 in the surface 18 of the coating suspension and by applying an electric potential between the filament 8 and the electrode. A flow of coating suspension about the filament takes place through an open lower end 29 of the electrode, and an outlet slot 30 thereof. The electrode is secured to a hanger 31 which is supported in an insulator 32 by means of a bolt 33 and nuts 34 threaded thereon. A bracket 35 is soldered or otherwise suitably secured to the container 1, and receives the insulator 32 in an annular boss 36 thereof, to support the electrode assembly upon the container. An electrical potential is supplied across the electrode and the filament by means of a battery 37, one terminal of which is connected to the forceps 10 by means of a conductor 38, and the other terminal of which is connected to the electrode by means of a conductor 39 and a connecter 40 clamped to the bolt 33 by means of the nuts 34. Insertion of a filament into the coating suspension results in a current flow which deposits a sedimentary coating of particles upon the filament.

The formation of an adherent and uniform coating requires that the coating suspension about the filament and in the vicinity of the surface be substantially quiescent. The provision of diverging walls in the container 1 to increase the cross-sectional area of the chamber 11 upwardly has a highly beneficial effect in damping pulsations in the flow of suspension from the pump 3. A screen 45 is mounted within the passage 11, and serves the dual function of aiding in damping pulsations in the flow, and of preventing the passage of sediment to the pump 3. By these means, a quiescent zone is established in the suspension at the surface 18.

While the specific construction of the pump 3 is not critical to the practice of the invention, it is necessary to utilize a pump which provides an agitating action, and preferably one which is resistant to clogging by the accumulation of sedimented material and to wear by the highly abrasive coating particles. In the embodiment shown, a valveless eccentric pump is provided, comprising a rotor 50 eccentrically mounted upon a suitably driven shaft 51 within a cylindrical chamber 52. A flexible gland 53 is received in the chamber and forms a partition 54 closing direct communication between an inlet opening 55 and an outlet opening 56, which are connected to the conduits 5 and 6, respectively. A sleeve 57 is received within the gland and is mounted upon the rotor 50 by means of ball bearings 58. Rotation of the rotor in the direction shown by the arrow affords a pumping action of a pulsating nature from the inlet 55 to the outlet 56, and thus establishes a flow of suspension from the reservoir to the coating container 1. The gland 53 must be formed of a flexible material which will withstand swelling or chemical attack by the suspension medium.

A pump is located at the lowermost point in the system, and therefore is not susceptible to vapor-lock which might otherwise occur upon evaporation of a highly volatile suspension medium. The agitation of the suspension by the pump at this location also maintains a uniform distribution of particles and prevents sedimentation, eliminating the need for a mechanically-actuated impeller.

A vortex reservoir 2 is provided to utilize hydrodynamic action for agitation of the suspension, and is elevated above the pump 3 to form a "bottomless' system which affords no surfaces upon which sedimentation could occur. The reservoir 2 is preferably of circular cross-section in a horizontal plane, and converges downwardly to facilitate the formation of a vortex flow therein. The conduit 4 is supported eccentrically in the reservoir in a boss 71 formed in a cover plate 72. The conduit enters the reservoir with a circumferential component of direction, and terminates in a nozzle 73 which discharges a flow of suspension into the reservoir with a velocity establishing a vortex flow toward an outlet opening 74 communicating the bottom of reservoir with the conduit 5. The vortex flow effectively agitates the suspension to establish a uniform concentration of coating particles without the provision of mechanically-actuated agitating means.

The reservoir is fully enclosed by the cover plate 72, and by a cap 75 removably inserted in an opening 76 therein to prevent evaporation of volatile solvent. As the supply of coating particles in the suspension becomes depleted by the coating of articles, additional amounts may be poured into the opening 76 at suitable intervals.

The overflow of suspension from the coating container continually flows through the conduit 4 into the reservoir 2 to establish a closed recirculating system in which the reservoir and pump afford agitated zones for maintaining a uniform concentration of coating material in the suspension. The coating chamber 11 constitutes a quiescent zone in which a uniform surface level is maintained by the weir 16, and in which pulsations induced by the pump are damped by the divergence of the container walls and by the screen 45. The conflicting requirements of uniform concentration and quiescence which are necessary for the formation of uniform and adherent electrophoretic coatings are thus effectively accommodated.

The apparatus is particularly adapted for use with highly volatile suspension media. It should be noted that the system of the present invention should have a more limited suspension capacity than the system described by the aforementioned copending application of

Edward D. Parent, Jr., in order to secure thorough and effective agitation of the suspension by the vortex-flow reservoir and the pump. It is therefore necessary to add additional suspension at more frequent intervals. However, the present system affords increased protection against evaporation or explosion where highly volatile suspension media are employed.

While we have shown and described preferred embodiments of our improved apparatus by way of illustration, various changes and modifications will occur to those skilled in the art without departing from the true spirit and scope of the invention. We therefore intend to cover all such changes and modifications in the appended claims.

What we desire to claim and secure by Letters Patent of the United States is:

1. In an eletrophoretic coating system, the combination comprising: an internally uninterrupted coating suspension reservoir formed with an outlet at the bottom thereof, the sides of said reservoir converging downwardly towards said outlet, said sides being of a circular cross-section in a horizontal plane, said outlet being axially disposed and at the lowermost end of said reservoir; a container disposed above said reservoir for establishing a suspension surface for electrophoretic coating of articles; means disposed on said container for electrophoretic coating of articles in said suspension; conduit means for conducting a flow of suspension from said container into said reservoir, said conduit being arranged to discharge said flow of suspension with a circumferential component of velocity into said reservoir and to establish an agitated vortical flow of suspension within said reservoir; pumping means disposed below the outlet of said reservoir and as the lowermost element in said system; conduit means connecting said reservoir outlet to the inlet of said pump; conduit means connecting the outlet of said pump to said container, whereby a flow of suspension will flow into said container and out therefrom and thence into said reservoir where it will be discharged therein with a circumferenetial component of velocity and drain outwardly therefrom in an agitated flow and cycle back into said pump thereby flowing through said system without appreciably settling.

2. The system according to claim 1 wherein said reservoir has a cover plate disposed on the top thereof, said reservoir inlet means being disposed through said cover plate near the side thereof and tangentially arranged and pointed towards the side, whereby vortical flow from the suspension flowing therefrom can be established.

3. The system according to claim 1 wherein said pump is a gland pump.

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