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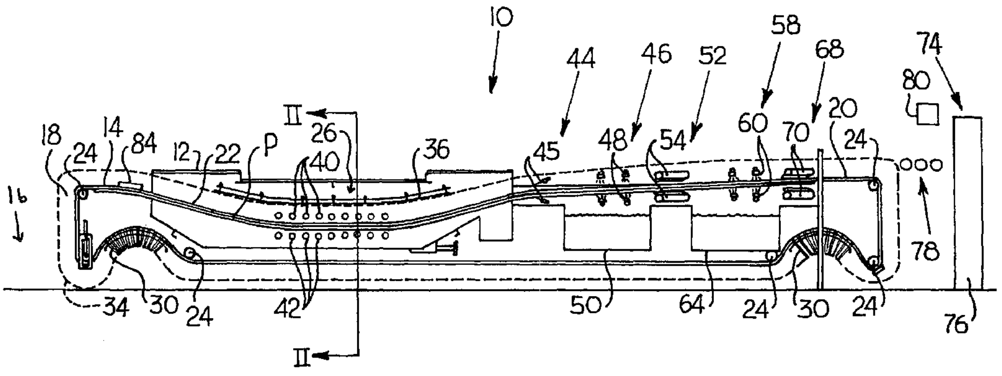
(54) Title: APPARATUS AND METHODS FOR CONTINUOUSLY ELECTROCOATING METAL BLANKS AND/OR COILED METAL SUBSTRATES



(57) **Abstract:** A continuous electrocoat apparatus is provided for applying a coating onto a substantially flat substrate, e.g., an electroconductive substrate in coil or blank form. In one embodiment, the apparatus includes a first electrocoat tank having a coating region and a non-conductive conveyor extending at least partially into the first electrocoat tank and defining a conveyor path. A plurality of electrically conductive supports are carried on the conveyor. A connecting system is configured to selectively place at least a portion of the supports in electrical contact with an electrical power source when the selected supports are in the coating region of the first electrocoat tank.

APPARATUS AND METHODS FOR CONTINUOUSLY ELECTROCOATING METAL BLANKS AND/OR COILED METAL SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is related to U.S. Patent Application Serial No. 09/798,627, entitled "Process for Electrocoating Metal Blanks and Coiled Metal Substrates" of Donald Emmonds et al. and filed concurrently herewith, which related application is herein incorporated by reference in its entirety.

1. Field of the Invention

[0002] The present invention relates generally to electrodeposition apparatus and methods and, more particularly, to apparatus and methods for continuously electrocoating a metal substrate in blank or coil form.

2. Technical Considerations

[0003] Throughout many industrial fields, metal substrates are coated, cut, and treated to form a variety of metal parts. For example, in the fields of appliance fabrication and automotive fabrication, metal substrates in the form of metal coils are processed and shaped into blanks. The term "blank" conventionally refers to a flat or substantially flat metal piece, e.g., a metal piece sheared from a coil, which has been cut to form a particular flat shape. The flat blanks are shaped or pressed into three-dimensional parts, such as front and side panels for appliances, e.g., refrigerators, washers and dryers, metal office furniture, e.g., filing cabinets and desks, and architectural products, e.g., fluorescent lighting fixtures.

[0004] In the past, such metal blanks were typically "post-painted", i.e. first shaped by bending, welding, pressing, etc. into a final three-dimensional form before applying a coating to prevent damaging the coating during the shaping process. The coating could be applied to the shaped part by wet-painting, powder painting, or electrocoating techniques. In a typical wet-painting process, a solvent-borne coating is applied to the shaped part, e.g., by spraying or rolling and then cured. However, increasingly stringent environmental regulations make storage and disposal of coating solvents, particularly volatile organic compounds, more expensive and the cure times for these solvent-borne coatings are relatively long. Further, such wet-painting techniques are typically wasteful of the coating composition and only allow the application of a very thin coating thickness. In a powder coating process, an electrostatically charged powder coating composition having only a fraction of the volatile solvents associated with wet paints is applied onto the metal part, e.g., by spraying, and then heated to melt and cure the coating through a crosslinking process. This technique is also wasteful of the coating composition. In electrocoating techniques, a coating is applied onto a conductive substrate under the influence of an applied electrical potential. Electrocoating generally offers increased paint utilization and lower environmental contamination. While generally acceptable for producing coated parts, "post-painting" is manpower and time intensive and typically requires a separate painting facility. Additionally, the formed or shaped three dimensional parts are more difficult to store and transport than the flat blanks from which they are formed.

[0005] In order to reduce the storage and transport drawbacks of post-painting the blanks, "pre-painting" techniques for coating the coils or blanks by wet painting or powder painting processes prior to shaping were developed. Examples of wet painting processes are disclosed in U.S. Patent Nos. 3,887,720 and 5,271,144. Examples of powder painting processes are disclosed in U.S. Patent Nos. 4,104,416; 5,264,254; and 5,439,704. For Example, U.S. Patent No. 5,439,704 teaches a combined coil and blank powder coating line in which, due to the necessity of placing the blanks on a horizontal support surface for transport, only the topside of the blank can be powder coated, thus leaving the underside uncoated.

[0006] While these wet and powder pre-painting processes provide advantages over the previous post-painting procedures, e.g., more advantageous storage and transport, they are, nonetheless, typically wasteful of the coating material, e.g., due to overspray, and are environmentally unfriendly. To date, no electrodeposition pre-painting methods have proved commercially viable, e.g., have not proved commercially acceptable and/or have not produced electrodeposited coatings mar resistant and flexible enough to withstand the stresses involved during the subsequent shaping process without fracturing or losing adhesion of the coating.

[0007] It would be advantageous to provide an apparatus and/or method for electrocoating, e.g., pre-painting, one or more coatings onto a blank or coil metal substrate to provide efficient paint utilization and faster cure times while also providing sufficient durability and flexibility to withstand post coating shaping of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a side, schematic view (not to scale) of an exemplary electrocoating apparatus incorporating features of the invention;

[0009] Fig. 2 is a sectional view of the electrocoating apparatus of Fig. 1 taken along the line II-II;

[0010] Fig. 3 is an enlarged view of an exemplary connecting system of the electrocoating apparatus shown in Fig. 1; and

[0011] Fig. 4 is a flow chart of an exemplary electrocoating method incorporating features of the invention.

SUMMARY OF THE INVENTION

[0012] A continuous electrocoat apparatus is provided for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces. The apparatus comprises a first electrocoat tank with at least one first electrode spaced from at least one second electrode and defining a first coating region to apply a first aqueous electrodepositable coating composition onto both major surfaces of the substrate between the first and second electrodes. The apparatus further includes a second electrocoat tank located downstream of the first electrocoat tank with at least one third electrode located in the second electrocoat tank and defining a second coating region adjacent the third electrode to apply a second aqueous electrodepositable coating composition onto substantially one major surface of the substrate.

[0013] Another continuous electrocoat apparatus is provided for applying a coating onto a substantially flat substrate, e.g., an electroconductive substrate in coil or blank form. The apparatus comprises a first electrocoat tank having a coating region and a non-conductive conveyor extending at least partially into the first electrocoat tank and defining a conveyor path. A plurality of electrically conductive supports are carried on the conveyor. A connecting system is configured to selectively place at least a portion of the supports in electrical contact with an electrical power source when the selected supports are in the coating region of the first electrocoat tank. A plurality of first electrodes are positioned in the first electrocoat tank, with the first electrodes located on a first side of the conveyor path.

[0014] Another continuous electrocoat apparatus of the invention comprises a first electrocoat tank having a coating region with a non-conductive conveyor extending at least partly into the first electrocoat tank and defining a conveyor path. The conveyor comprises a plurality of laterally spaced, non-conductive chains movably mounted on rotatable sprockets such that the chains move at substantially the same speed. A plurality of electrically conductive supports are carried on each chain to form a support surface of the conveyor. A plurality of grounding bars are carried on the conveyor, with each grounding bar connected to at least one support. A bus bar is located adjacent the electrocoat tank, with the bus bar configured to contact one or more grounding bars carried on a portion of the conveyor in the coating region of the first electrocoat tank.

[0015] A method is provided for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces. The method comprises the steps of conveying the substrate between at least one first electrode and at least one second electrode in a first coating region to apply a first aqueous electrodepositable coating composition onto both major surfaces of the substrate; and conveying the substrate adjacent at least one third electrode located in a second coating region to apply a second aqueous electrodepositable coating composition onto substantially one major surface of the substrate.

[0016] A further method is provided for electrocoating a substantially substrate having two major surfaces. The method comprises the steps of placing the substrate onto a non-conductive conveyor having a plurality of conductive supports defining a support surface, with the conveyor defining a conveyor path through a coating region of an electrocoat bath. An electric potential is applied to the substrate when the substrate is in the coating region. The substrate is conveyed through the coating region adjacent at least one electrode to apply an aqueous electrodepositable coating composition onto at least one major surface of the substrate. The coated substrate is dried and/or cured at a drying station located downstream of the electrocoat bath.

DESCRIPTION OF THE INVENTION

[0017] As used herein, spatial or directional terms, such as "left", "right", "inner", "outer", "above", "below", "top", "bottom", and the like, relate to the invention as it is shown in the drawing figures. However, it is to be understood that the invention may assume various alternative orientations and, accordingly, such terms are not to be considered as limiting. Further, as used herein, all numbers expressing dimensions, physical characteristics, processing parameters, quantities of ingredients, reaction conditions, and the like used in the specification and claims are to be understood as being modified in all instances by the term "about". Accordingly, unless indicated to the contrary, the numerical values set forth in the following specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical value should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Moreover, all ranges disclosed herein are to be understood to encompass any and all subranges subsumed therein. For example, a stated range of "1 to 10" should be considered to include any and all subranges between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges beginning with a minimum value of 1 or more and ending with a maximum value of 10 or less, e.g., 5.5 to 10. Molecular weight quantities used herein, whether Mn or Mw, are those determinable from gel permeation chromatography using polystyrene as a standard. Also, as used herein, the term "polymer" is meant to refer to oligomers, homopolymers, and copolymers. The terms "flat" or "substantially flat substrate " refer to a substrate that is substantially planar in form, that is a primarily level substrate lying in a geometric plane, which, as would be understood by one skilled in the art, can include slight bends, projections, or depressions therein.

[0018] The structural components of an exemplary electrocoating apparatus incorporating features of the invention will first be described and then the use of the electrocoating apparatus to practice an exemplary method of the invention will be described. It is to be understood that the specifically disclosed apparatus and method are presented simply to explain the general concepts of the invention and that the invention is not limited to these specific embodiments.

[0019] With reference to Fig. 1, an electrocoating apparatus 10 of the invention includes an electrocoat tank 12 (first electrocoat tank) with a conveyor 14 extending at least partly into the interior of the tank 12. The electrocoat tank 12 may be of any conventional type and size to accommodate the substrates being coated. The dimensions and capacity of the tank 12 can vary depending upon the size, e.g., length, width, etc., of the substrate. In one non-limiting embodiment, the tank 12 has a capacity of 1,000 gallons to 20,000 gallons (3,800 liters to 76,000 liters), such as 1,000 gallons to 10,000 gallons (3,800 liters to 38,000 liters), e.g., 2,000 gallons to 5,000 gallons (7,600 liters to 19,000 liters). In one non-limiting exemplary embodiment, the tank 12 can have a length of 5 feet to 50 feet (1.5 m to 15 m), such as 15 feet to 20 feet (4.5 m to 6 m), e.g., 17 feet (5.1 m); a width of 5 feet to 50 feet (1.5 m to 15 m), such as 5 feet to 10 feet (1.5 m to 3 m), e.g., 7 feet to 8 feet (2.1 m to 2.4 m); and a depth of 2 feet to 20 feet (0.6 m to 6 m), such as 4 feet to 10 feet (1.2 m to 3 m), e.g., 5 feet to 6 feet (1.5 m to 1.8 m).

[0020] As discussed in more detail below, the tank 12 is configured to contain an electrodepositable coating composition. The interior of the tank 12 can be in flow communication with a conventional recycling system, e.g., through conduits or pipes, having a pump that recirculates at least a portion of the coating composition located in the tank 12 to prevent solids in the coating composition from settling to the bottom of the tank 12. Additionally, the tank 12 can be in flow communication with a conventional heat exchanger, such as an electric heater, in any conventional manner, such as through pipes or conduits, to control the temperature of the coating composition in the tank 12. Further, the interior of the tank 12 may be in flow communication with a conventional ultrafiltration system to remove soluble impurities from the coating composition and to recycle the filtered material back into the electrodeposition tank 12.

[0021] In an ultrafiltration system, the coating composition flows over a membrane permeable to water and small particles, e.g., those less than 1,000 Mw, such as salts. The ultrafiltrate or "permeate", i.e., the portion of the coating composition which passes through the membrane, can be used in rinsing operations as described below and a portion of the permeate, e.g., 20 weight percent, is typically discarded. The "non-permeate" portion of the coating composition is directed back to the tank 12, e.g., through one or more conduits or pipes. The structure and operation of conventional recycling, heat exchanger, and ultrafiltration systems will be well understood by one of ordinary skill in the art and, hence, such systems will not be described in detail herein. Examples of such conventional systems and conventional electrocoat tanks are disclosed, for example but not to be considered as limiting, in U.S. Patent Nos. 4,333,807 and 4,259,163, herein incorporated by reference.

[0022] As shown on the left side of Fig. 1, a load area 16 is defined adjacent one end of the conveyor 14. The load area 16 can be defined, for example, by an area 5 feet to 10 feet (1.5 m to 3 m) long extending the width of the tank 12 and having sufficient free space to permit unhindered loading of substrates to be coated, whether in blank or coil form, onto the conveyor 14 as described in more detail below.

[0023] The conveyor 14 of the invention has an inlet end 18 and an outlet end 20. For coating blanks, the conveyor 14 may be of any convenient type, such as, but not limited to, a belt conveyor, a chain conveyor, a platform conveyor, and the like. However, the conveyor 14 is typically composed primarily of non-conductive material so as not to attract electrodepositable coating material during the coating process. In the exemplary embodiment of the apparatus 10 shown in Figs. 1-3, the conveyor 14 is an endless or "closed-loop" conveyor formed from a plurality of mutually spaced, movable and deformable or flexible members defining an outer conveyor surface facing away from the apparatus 10 and an inner conveyor surface facing the interior of the apparatus 10. As will be appreciated by one of ordinary skill in the art, the exemplary endless conveyor 14 shown in Fig. 1 provides an upper portion or leg to transport substrates during the coating process and a lower or return portion. Examples of materials suitable for the flexible members include polymeric material, e.g., plastic material, or non-conductive metals, such as aluminum or poly-steel chains such as those commercially available from Tsubaki Corp. of Japan. For example, as shown in Figs. 1 and 2, the conveyor 14 may be formed by a plurality, e.g., 5, spaced, non-conductive chains 22 each movably mounted on rotatable wheels, rollers, or sprockets 24 and supported on guide devices, such as guide rails, to define a conveyor path P into and out of the electrocoat tank 12. In the exemplary embodiment shown in Figs. 1-3, the non-conductive chains 22 are laterally spaced 1″ to 24″ (2.5 cm to 61 cm) apart, typically 5″ to 11″ (13 cm to 28 cm) apart.

[0024] In order to help maintain a substrate on the conveyor 14 during the coating process, a plurality of holding devices can be carried on the conveyor 14. For example, as shown in Fig. 3 a plurality of magnets 25 can be carried on or attached to or between the chains 22. In one embodiment of the present invention, the magnets 25 are located at or near the inner surface of the conveyor 14 and do not extend above the top or outer surface of the conveyor 14 such that the magnets do not contact a substrate located on the conveyor 14. Alternatively, the magnets 25 can be located on the guide rails over which the conveyor 14 travels.

[0025] In order to electrocoat a substrate, the substrate should be under the influence of an applied electric potential. Therefore, a connecting system 26 is provided to connect the substrate to be coated to an electrical source (not shown) during the coating process. In the exemplary embodiment shown in Figs. 1-3, the connecting system 26 includes a plurality of spaced, electrically conductive supports 28 (Fig. 3) carried on the chains 22 and extending above the top or outer surface of the conveyor 14 to support and contact a metal substrate during the coating process as described below. For example, the supports 28 can be carried on or attached to each chain 22 at evenly spaced intervals, e.g., 6 inch to 12 inch (15 cm to 31 cm) intervals, on the chain 22. The supports 28 on adjacent chains 22 can be aligned to form spaced rows of supports 28 extending across the width of the conveyor 14. A timing shaft (not shown) can be attached to the sprockets 24 so that the chains 22 move at substantially the same speed to maintain the supports 28 in rows. Examples of suitable supports 28 for the practice of the invention include K-1 electrical connectors commercially available from 3I Engineering of Evansville, Indiana. Of course, the invention is not limited to forming such rows of supports 28. The supports 28 on adjacent chains 22 can be offset from one another, if desired.

[0026] In order to provide the electric potential, the supports 28 can be connected to one or more electrically conductive connectors. For example, the connectors can be solid, metal, electrically conductive grounding bars 30 (Figs. 2 and 3), each connected to one or more of the supports 28. The grounding bars 30 can be carried on the chains 22 to move when the chains 22 move. For example, one grounding bar 30 can be connected to each of the adjacent supports 28 of a row as described above. Each grounding bar 30 may have an outer end 32, e.g., extending above the outer surface of the conveyor 14. So as not to clutter the figures, only a portion of the total number of grounding bars 30 are shown in Fig. 1. The outer ends 32 of the grounding bars 30 define a path 34 shown in dashed lines in Fig. 1 as the conveyor 14 moves. As described below, the grounding bars 30 act to place one or more selected supports 28 in electrical contact with the electrical power source to apply an electric potential to a substrate carried on the selected supports 28 when the selected supports 28 supporting the substrate are adjacent to or in the tank 12, particularly in a coating region of the tank 12, as described in more detail below.

[0027] The grounding bars 30, e.g., the outer ends 32 of the grounding bars 30, are configured to contact an electrical bus bar 36 mounted adjacent, e.g., above, the electrocoat tank 12. As shown in Fig 1, the bus bar 36 is shaped, e.g., curved, such that, as described in more detail below, the outer end 32 of a grounding bar 30 contacts the bus bar 36 when the supports 28 to which the grounding bar 30 is connected are positioned in or adjacent the electrocoating composition in the tank 12 but loses contact with the bus bar 30 when the supports 28 connected to the grounding bar 30 pass out of the electrocoating composition or out of the coating region of the tank 12.

[0028] As will be appreciated by one of ordinary skill in the art, the invention is not limited to connecting systems having the grounding bar and bus bar structure described above. For example, the connecting system 26 could be formed by a plurality of electrically conductive driven contact wheels forming part of the conveyor or by opposed contact clamps configured to engage the substrate when located in the tank 12. Non-limiting examples of suitable alternative connecting systems are disclosed in U.S. Patent Nos. 4,385,967 and 4,755,271, herein incorporated by reference.

[0029] At least one and typically a plurality of first electrodes 40 are located in the electrocoat tank 12 on one side of the conveyor path, e.g., above the conveyor path as shown in Fig. 1. The first electrodes 40 can be located less than 10″ (25 cm) from the top of the conveyor 14, i.e., the side of the upper leg of the conveyor 14 closest the first electrodes 40, are often less than 5″ (12.5 cm) from the top of the conveyor 14, and usually are less than 1″ to 2″ (2.5 cm to 5 cm) from the top of the conveyor 14. The first electrodes 40 can be attached to or carried on a vertically movable support (not shown) such that the distance between one or more of the first electrodes 40 and the top of the conveyor

14 can be adjusted. The first electrodes 40 are disposed in the tank 12 transverse to the conveyor path. The electrodes 40 are connected to a power source (not shown) in any suitable manner, such as by cables. The electrodes 40 are made of electrically conductive material, such as copper, and may be configured as copper bars extending across the width of the conveyor 14 in the tank 12.

[0030] As described more fully below, one or more optional second electrodes 42 can be located in the electrocoat tank 12 below the upper leg of the conveyor path P, e.g., opposite the first electrodes 40. If present, the second electrodes 42 are typically located 1" to 10" (2.5 cm to 25 cm) from the bottom of the upper leg of the conveyor 14. The second electrodes 42 also can be attached to or carried on one or more movable supports such that the distance between one or more of the second electrodes 42 and the bottom of the upper conveyor 14 portion can be adjusted.

[0031] An exit rinse station 44 can be located at or near a discharge end of the tank 12. The rinse station 44 can comprise one or more spray applicators 45 in flow communication with a source of rinsing fluid, e.g., one or more applicators located above the conveyor path P of the upper portion of the conveyor 14 and one or more applicators 45 below the upper portion of the conveyor 14. For example, the spray applicators 45 can be in flow communication with the ultrafiltration system to provide permeate to the rinse applicators 45. Excess rinse fluid can be directed into the tank 12, e.g., by a sloped shelf located under the rinse applicators 45 and sloping toward the tank 12.

[0032] A first rinse station 46 is located downstream (with respect to a direction of movement of the conveyor) of the electrocoat tank 12, e.g., downstream of the exit rinse station 44. The first rinse station 46 can comprise any conventional rinse applicators but, in the exemplary embodiment under discussion, includes one or more spray applicators 48 located above and in flow communication with a first rinse tank 50, e.g., by a pump and conduits to supply rinse fluid from the first rinse tank 50 to the spray applicators 48. The first rinse tank 50 may also be in flow communication with a conventional recirculation system having a recirculation pump (not shown). As shown in Fig 1, one or more of the applicators 48 can be located above the upper portion of the conveyor 14 (and directed toward the outer surface of the conveyor 14) and one or more other of the applicators 48 can be located below the upper portion of the conveyor 14 (and directed toward the inner surface of the conveyor 14).

[0033] A first drain station 52 is located downstream of the first rinse station 46 to remove at least some of the excess rinse composition from the surfaces of the substrate being coated. The first drain station 52 can include one or more fluid removal devices, such as an air knife or squeegee rolls. In the exemplary embodiment shown in Fig. 1, the first drain station 52 includes two air knives 54, with one air knife 54 located above the conveyor path and another air knife 54 located below the conveyor path. The air knives 54 are configured to direct or blow at least some of the excess rinse composition back into the first rinse tank 46.

[0034] A second rinse station 58 is located downstream of the first rinse station 46. The second rinse station 58 can comprise any conventional rinsing applicators but, in the exemplary embodiment under discussion, includes one or more spray applicators 60 located above and in flow communication with a second rinse tank 64, e.g., by a pump and conduits to supply rinse fluid from the second rinse tank 64 to the spray applicators 60 in similar manner as in the first rinse station 46. The second rinse tank 64 may be in flow communication with a conventional recirculation system having a recirculation pump (not shown).

[0035] A second drain station 68 is located downstream of the second rinse station 58 to remove at least some of the excess rinse composition from the substrate. The second drain station 68 includes at least one fluid removal device, such as one air knife 70 located above the conveyor path and another air knife 70 located below the conveyor path. The air knives 70 are configured to direct at least some of the excess rinse composition back into the second rinse tank 64.

[0036] A drying station 74 having a dryer 76 is located downstream of the second rinse tank 64 to dry and/or cure the applied coating. As used herein, the term "dry" means the almost complete absence of water from the coating and the term "cure" means that the majority, preferably all, of any crosslinkable components of the applied coating material are crosslinked. The dryer 76 can include any conventional drying oven or drying apparatus, such as an infra-red radiation oven, an electric oven, a gas oven, a hot air convection oven, and the like. In one exemplary embodiment, the dryer 76 is a high velocity gas oven commercially available from Gruenwald Corp. of Germany.

[0037] A dryer conveyor 78 extends between the discharge end of the conveyor 14 and the entrance to the dryer 76. The dryer conveyor 78 can be of any conventional type, such as a belt conveyor, roller conveyor, skate-wheel conveyor, and the like.

[0038] An optional induction heater 80 can be located around at least a portion of the dryer conveyor 78 prior to the entrance to the dryer 76. The induction heater 80 preferably surrounds the dryer conveyor 78 and induces a field that induces a current that generates heat.

[0039] Having described the structural components of an exemplary electrocoat apparatus 10, an exemplary method of priming and topcoating a substrate by a continuous electrocoating process utilizing one or more apparatus 10 in accordance with the invention will now be described. By "continuous electrocoating process" is meant that the substrate is in continuous movement throughout the coating process. Although the process can be practiced on substrates in blank or coil form, the following exemplary method will first be discussed with reference to electrocoating blanks with a primer coating on both major surfaces and then a subsequent electrodeposited topcoat primarily on one major surface.

[0040] The substrates used in the practice of the present invention typically are metallic substrates and can include ferrous metals and non-ferrous metals. Suitable ferrous metals include iron, steel, and alloys thereof. Non-limiting examples of useful steel materials include cold-rolled steel, galvanized (zinc coated) steel, electrogalvanized steel, stainless steel, pickled steel, GALVANNEAL®, GALVALUME®, and GALVAN® zinc-aluminum alloys coated upon steel, and combinations thereof. Useful non-ferrous metals include aluminum, zinc, magnesium and alloys thereof. Combinations or composites of ferrous and non-ferrous metals can also be used.

[0041] As shown in Fig. 4, the metal substrate can be cut or punched to form a flat metal blank of a desired configuration and/or cleaned, degreased, and/or a corrosion resistant coating applied at one or more pretreatment stations 82. Before depositing coatings upon the surface of the metallic substrate, it is preferred to remove foreign matter from the metal surface by thoroughly cleaning and/or degreasing the substrate surface. As used herein, the terms "deposited upon", "applied onto", and "provided upon" a substrate mean deposited or provided above or over but not necessarily adjacent to the surface of the substrate. For example, a coating "deposited upon" a substrate can be deposited directly on the substrate or one or more other coatings can be located therebetween.

[0042] The surface of the metallic substrate can be cleaned by physical or chemical means, such as mechanically abrading the surface or, as is preferred, cleaning/degreasing with commercially available alkaline or acidic cleaning agents which are well known to those skilled in the art, such as sodium metasilicate and sodium hydroxide. Non-limiting examples of preferred cleaning agents include CHEMKLEEN® 163 and CHEMKLEEN® 177 phosphate cleaners, both of which are commercially available from PPG Industries, Inc. of Pittsburgh, Pennsylvania.

[0043] Following the cleaning step, the surface of the metallic substrate may be rinsed with water, typically deionized water, in order to remove any residue. Optionally, the metal surface can be rinsed with an aqueous acidic solution after cleaning with the alkaline cleaners. Examples of rinse solutions include mild or strong acidic cleaners such as the dilute nitric acid solutions commercially available and conventionally used in metal pretreatment processes. The metallic substrate can be air-dried using an air knife, by flashing off the water by brief exposure of the substrate to a high temperature, or by passing the substrate between squeegee rolls.

[0044] Optionally, a phosphate-based pretreatment or conversion coating can be applied to the metallic substrate. Suitable phosphate conversion coating compositions include those known in the art, such as zinc phosphate, optionally modified with nickel, iron, manganese, calcium, magnesium or cobalt. Useful phosphating compositions are described in U.S. Patent Nos. 4,793,867 and 5,588,989; 4,941,930; 5,238,506 and 5,653,790.

[0045] With reference to Figs. 1 and 4, pretreated metal blanks 84 are loaded onto the inlet end 18 of the conveyor 14 at the load area 16. The blanks 84 can be supplied to the load area 16 in any desired manner, such as by a conveyor, a fork lift truck, on pallets, by overhead crane, etc., and then placed on the conveyor 14 by a worker or directly by the supply device. Because the supports 28 protrude above the top of the conveyor 14, e.g., above the outer or top surface of the chains 22, the blank 84 is supported totally on the supports 28 and does not contact the chains 22 themselves. The top portion of the supports 28 are tapered or pointed to minimize the area of contact between the bottom of the blank 84 and the top of the supports 28 on which it rests. The supports 28 should be sufficiently tapered or pointed to minimize the contact area with the bottom of the blank 84 but should not be so pointed that the points damage the bottom surface of the blank 84 or damage any previous coatings which may have been applied to the blank 84.

[0046] In the exemplary embodiment of Figs. 1 and 4, the conveyor 14 conveys the blank 84 to the right toward the tank 12. As the blank 84 is moved from the load area 16 toward the electrocoat tank 12, the supports 28 on which the blank rests are typically not in contact with a source of electrical potential. In the exemplary embodiment under discussion, this is because the outer ends 32 of the grounding bars 30 connected to the supports 28 on which the blank 84 rests are not in contact with the bus bar 36. When the conveyor 14, and hence the blank 84, begins to descend into the electrocoat composition in the tank 12 (into the first coating region), the forward most (right most) grounding bar 30 connected to the forward most (right most) supports 28 carrying the blank 84 contacts the left end of the bus bar 36 to electrically ground the forward most supports 28, and hence the blank 84 resting thereon, to the bus bar 30. Electrical current is conducted through the grounding bar 30 and the supports 28 to the blank 84 to apply an electrical potential to the blank 84. As shown in Figs. 2 and 3, the outer end 32 of the grounding bar 30 can be bent or have an "L-shaped" contact region 86 which contacts and slides along the bus bar 36 to maintain the electrical connection as the conveyor 14 continues to move. As the conveyor 14 moves to the right in Fig. 1, the subsequent grounding bars 30 connected to the supports 28 on which the blank 84 rests sequentially come into contact with the bus bar 36 in similar manner as described above to apply an electric potential to the supports 28 connected thereto and, hence, to the blank 84 carried thereon. In the electrocoating process of the invention, the blank 84 serves as an electrode, e.g., a cathode, in an electrical circuit comprising the blank (electrode) and the electrodes 40 and/or

42 (counter-electrodes) immersed in the coating composition as described below.

[0047] Assuming a coating, e.g., a primer coating, is to be applied to both major surfaces of the blank 84, both the first and second electrodes 40, 42 are energized during the coating process. The electrodes 40, 42 are preferably positioned to be less than 1″ to 5″ (2.5 cm to 12.5 cm) from the respective top and bottom major surfaces of the blank 84, such as less than 1″ (2.5 cm) during the coating process. As the conveyor 14 moves the charged blank 84 between the electrodes 40, 42 in the first coating region, the electrodepositable coating composition in the tank 14 is deposited over both major surfaces and the edges of the blank 84.

[0048] As will be appreciated by one of ordinary skill in the art, in the process of applying the first electrodepositable coating, the aqueous dispersion of the electrodepositable composition is placed in contact with an electrically conductive anode and cathode. Upon passage of an electric current between the anode and cathode, an adherent film of the electrodepositable composition will deposit in a substantially continuous manner on the substrate serving as either the anode or the cathode depending on whether the composition is anionically or cationically electrodepositable. Electrodeposition is usually carried out at a constant voltage ranging from 1 volt to 7,000 volts, and typically between 50 and 500 volts. Current density is usually between 1.0 ampere and 15 amperes per square foot (10.8 to 161.5 amperes per square meter).

[0049] As will be appreciated by one of skill in the art, the amount of the coating composition applied to the blank 84 depends on several factors, such as the throwpower of the coating composition, the temperature of the coating composition, the voltage applied to the electrodes, and the dwell time of the blank in the coating composition. As used herein, the term "dwell time" refers to the length of time the charged substrate is positioned in the tank 12 adjacent one or more of the electrodes 40 and/or 42 (i.e. in the coating region). In one exemplary embodiment, the coating composition can have a temperature of 70°F to 100°F (21°C to 38°C), e.g., 80°F to 90°F (27°C to 32°C), an applied voltage of 1V to 450V, such as 1V to 300V, and a conveyor speed sufficient to provide a dwell time of 10 secs to 30 secs, e.g., 15 secs. In one exemplary embodiment, the apparatus 10 is configured such that a conveyor speed of 20 feet per minute (FPM) (6 meters per minute (MPM)) provides a dwell time of 15 secs. Assuming the applied coating is a primer coating, the deposition conditions are set to provide a dried primer coating thickness of 0.15 mil to 0.25 mil (0.004 mm to 0.006 mm) on both major surfaces of the blank 84. In another exemplary embodiment, the conveyor speed can be in the range of 50 ft/min to 1000 ft/min (15 meters/min to 305 meters/min).

[0050] An exemplary electrodeposition bath composition useful in the practice of the present invention comprises a resinous phase dispersed in an aqueous medium. The resinous phase includes a film-forming organic component which can comprise an anionic electrodepositable coating composition, or, as is preferred, a cationic electrodepositable coating composition. The electrodepositable coating composition typically comprises an active hydrogen group-containing ionic resin and a curing agent having functional groups reactive with the active hydrogens of the ionic resin. As used herein, the term "reactive" refers to a functional group that forms a covalent bond with another functional group under suitable reaction conditions.

[0051] Non-limiting examples of anionic electrodepositable coating compositions include those comprising an ungelled, water-dispersible electrodepositable anionic film-forming resin. Examples of film-forming resins suitable for use in anionic electrodeposition coating compositions are base-solubilized, carboxylic acid containing polymers, such as the reaction product or adduct of a drying oil or semi-drying fatty acid ester with a dicarboxylic acid or anhydride; and the reaction product of a fatty acid ester, unsaturated acid or anhydride and any additional unsaturated modifying materials which are further reacted with polyol. Also suitable are the at least partially neutralized interpolymers of hydroxy-alkyl esters of unsaturated carboxylic acids, unsaturated carboxylic acid and at least one other ethylenically unsaturated monomer. Yet another suitable electrodepositable anionic resin comprises an alkyd-aminoplast vehicle, i.e., a vehicle containing an alkyd resin and an amine-aldehyde resin. Yet another anionic electrodepositable resin composition comprises mixed esters of a resinous polyol. These compositions are described in detail in U.S. Pat. No. 3,749,657 at col. 9, lines 1 to 75 and col. 10, lines 1 to 13.. Other acid functional polymers can also be used such as phosphatized polyepoxide or phosphatized acrylic polymers as are well known to those skilled in the art.

[0052] By "ungelled" is meant that the polymer is substantially free of crosslinking and has an intrinsic viscosity when dissolved in a suitable solvent. The intrinsic viscosity of a polymer is an indication of its molecular weight. A gelled polymer, on the other hand, since it is of essentially infinitely high molecular weight, will have an intrinsic viscosity too high to measure.

[0053] With reference to the cationic resin, a wide variety of cationic polymers are known and can be used in the compositions of the invention so long as the polymers are "water dispersible," i.e., adapted to be solubilized, dispersed or emulsified in water. The water dispersible resin is cationic in nature, that is, the polymer contains cationic functional groups to impart a positive charge. The cationic resin may also contain active hydrogen groups.

[0054] Examples of cationic resins suitable include onium salt group-containing resins such as ternary sulfonium salt group-containing resins and quaternary phosphonium salt-group containing resins, for example, those described in U.S. Patent Nos. 3,793,278 and 3,984,922, respectively. Other suitable onium salt group-containing resins include quaternary ammonium salt group-containing resins, for example, those which are formed from reacting an organic polyepoxide with a tertiary amine salt. Such resins are described in U.S. Patent Nos. 3,962,165; 3,975,346; and 4,001,101. Also suitable are the amine salt group-containing resins such as the acid-solubilized reaction products of polyepoxides and primary or secondary amines such as those described in U.S. Patent Nos. 3,663,389; 3,984,299; 3,947,338 and 3,947,339.

[0055] Usually, the above-described salt group-containing resins described above are used in combination with a blocked isocyanate curing agent. The isocyanate can be fully blocked as described in the aforementioned U.S. Patent No. 3,984,299 or the isocyanate can be partially blocked and reacted with the resin backbone such as is described in U.S. Patent No. 3,947,338.

[0056] Also, one-component compositions as described in U.S. Patent No. 4,134,866 and DE-OS No. 2,707,405 can be used as the cationic resin. Besides the epoxy-amine reaction products, resins can also be selected from cationic acrylic resins such as those described in U.S. Patent Nos. 3,455,806 and 3,928,157. Also, cationic resins which cure via transesterification such as described in European Application No. 12463 can be used. Further, cationic compositions prepared from Mannich bases such as described in U.S. Patent No. 4,134,932 can be used. Also useful in the electrodepositable coating compositions of the present invention are those positively charged resins which contain primary and/or secondary amine groups. Such resins are described in U.S. Patent Nos. 3,663,389; 3,947,339; and 4,115,900. U.S. Patent No. 3,947,339 describes a polyketimine derivative of a polyamine such as diethylenetriamine or triethylenetetraamine with the excess polyamine vacuum stripped from the reaction mixture. Such products are described in U.S. Patent Nos. 3,663,389 and 4,116,900.

[0057] In one embodiment of the present invention, the cationic resins suitable for inclusion in the electrodepositable coating compositions useful in the methods of the present invention are onium salt group-containing acrylic resins.

[0058] The cationic resin described immediately above is typically present in the electrodepositable coating compositions in amounts of 1 to 60 weight percent, such as 5 to 25 weight percent based on total weight of the composition.

[0059] As previously discussed, the electrodepositable coating compositions which are useful in the methods of the present invention typically further comprise a curing agent which contains functional groups which are reactive with the active hydrogen groups of the ionic resin.

[0060] Aminoplast resins, which are the preferred curing agents for anionic electrodeposition, are the condensation products of amines or amides with aldehydes. Examples of suitable amine or amides are melamine, benzoguanamine, urea and similar compounds. Generally, the aldehyde employed is formaldehyde, although products can be made from other aldehydes such as acetaldehyde and furfural. The condensation products contain methylol groups or similar alkylol groups depending on the particular aldehyde employed. These methylol groups can be etherified by reaction with an alcohol. Various alcohols employed include monohydric alcohols containing from 1 to 4 carbon atoms such as methanol, ethanol, isopropanol, and n-butanol, with methanol being preferred. Aminoplast resins are commercially available from American Cyanamid Co. under the trademark CYMEL® and from Monsanto Chemical Co. under the trademark RESIMENE®.

[0061] The aminoplast curing agents are typically utilized in conjunction with the active hydrogen containing anionic electrodepositable resin in amounts ranging from 5 percent to 60 percent by weight, such as from 20 percent to 40 percent by weight, the percentages based on the total weight of the resin solids in the electrodeposition bath.

[0062] The preferred curing agents for cationic electrodepositable coating compositions are blocked organic polyisocyanates. The polyisocyanates can be fully blocked as described in U.S. Patent No. 3,984,299 column 1 lines 1 to 68, column 2 and column 3 lines 1 to 15, or partially blocked and reacted with the polymer backbone as described in U.S. Patent No. 3,947,338 column 2 lines 65 to 68, column 3 and column 4 lines 1 to 30.. By "blocked" is meant that the isocyanate groups have been reacted with a compound so that the resultant blocked isocyanate group is stable to active hydrogens at ambient temperature but reactive with active hydrogens in the film forming polymer at elevated temperatures, usually between 90°C and 200°C.

[0063] Suitable polyisocyanates include aromatic and aliphatic polyisocyanates, including cycloaliphatic polyisocyanates and representative examples include diphenylmethane-4,4'-diisocyanate (MDI), 2,4- or 2,6-toluene diisocyanate (TDI), including mixtures thereof, p-phenylene diisocyanate, tetramethylene and hexamethylene diisocyanates, dicyclohexylmethane-4,4'-diisocyanate, isophorone diisocyanate, mixtures of phenylmethane-4,4'-diisocyanate and polymethylene polyphenylisocyanate. Higher polyisocyanates such as triisocyanates can be used. An example would include triphenylmethane-4,4',4"-triisocyanate. Isocyanate prepolymers with polyols such as neopentyl glycol and trimethylolpropane and with polymeric polyols such as polycaprolactone diols and triols (NCO/OH equivalent ratio greater than 1) can also be used.

[0064] The polyisocyanate curing agents are typically utilized in conjunction with the cationic resin in amounts ranging from 1 weight percent to 65 weight percent, such as from 5 weight percent to 45 weight percent, based on the weight of the total resin solids present composition.

[0065] The aqueous compositions of the present invention are in the form of an aqueous dispersion. The term "dispersion" is believed to be a two-phase transparent, translucent or opaque resinous system in which the resin is in the dispersed phase and the water is in the continuous phase. The average particle size of the resinous phase is generally less than 1.0 and usually less than 0.5 microns, such as less than 0.15 micron.

[0066] The concentration of the resinous phase in the aqueous medium is at least 1 and usually from 2 to 60 percent by weight based on total weight of the aqueous dispersion. When the compositions of the present invention are in the form of resin concentrates, they generally have a resin solids content of 20 to 60 percent by weight based on weight of the aqueous dispersion.

[0067] Electrodeposition compositions useful in the methods of the present invention are typically supplied as two components: (1) a clear resin feed, which includes generally the active hydrogen-containing ionic electrodepositable resin, i.e., the main film-forming polymer, the curing agent, and any additional water-dispersible, non-pigmented components; and (2) a pigment paste, which generally includes one or more pigments, a water-dispersible grind resin which can be the same or different from the main-film forming polymer, and, optionally, additives such as wetting or dispersing aids. Electrodeposition bath components (1) and (2) are dispersed in an aqueous medium which comprises water and, usually, coalescing solvents.

[0068] The electrodeposition composition of the present invention has a resin solids content usually within the range of 5 to 25 percent by weight based on total weight of the electrodeposition composition.

[0069] As aforementioned, besides water, the aqueous medium may contain a coalescing solvent. Useful coalescing solvents include hydrocarbons, alcohols, esters, ethers and ketones. The preferred coalescing solvents include alcohols, polyols and ketones. Specific coalescing solvents include isopropanol, butanol, 2-ethylhexanol, isophorone, 2-

methoxypentanone, ethylene and propylene glycol and the monoethyl, monobutyl and monohexyl ethers of ethylene glycol. The amount of coalescing solvent is generally between 0.01 and 25 percent and when used, such as from 0.05 to 5 percent by weight based on total weight of the aqueous medium.

[0070] As discussed above, a pigment composition and, if desired, various additives such as surfactants, wetting agents or catalyst can be included in the dispersion. The pigment composition may be of the conventional type comprising pigments, for example, iron oxides, strontium chromate, carbon black, coal dust, titanium dioxide, talc, barium sulfate, as well as color pigments such as cadmium yellow, cadmium red, chromium yellow and the like.

[0071] The pigment content of the dispersion is usually expressed as a pigment-to-resin ratio. In the practice of the invention, when pigment is employed, the pigment-to-resin ratio is usually within the range of 0.02 to 1:1. The other additives mentioned above are usually in the dispersion in amounts of 0.01 to 3 percent by weight based on weight of resin solids.

[0072] As will be understood from Figs. 1-3, as the blank 84 moves through the electrocoat tank 12 on the conveyor 14, the supports 28 supporting the blank 84 are in contact with the bus bar 38 through the grounding bar 30 when the blank 84 is between and/or adjacent the electrodes 40 and/or 42 (i.e. in the first coating region), thus supplying electrical current to the blank 84 during the coating process. As the conveyor 14 continues to move to the right, the grounding bars 30 connected to the supports 28 supporting the right end (forward end) of the blank 84 slide off of and no longer contact the bus bar 38, thus no electrical power is supplied to those supports 28. As the blank 84 continues to move to the right on the conveyor 14, the remaining grounding bars 30 connected to the supports 28 carrying the blank 84 continue to lose contact with the bus bar 36 until eventually all of the supports 28 supporting the blank 84 are no longer in contact with the bus bar 38 and the blank 84 emerges from the electrocoating composition.

[0073] Upon emergence, the coated blank 84 may undergo a surface rinse, e.g., with water or permeate at the exit rinse station 46, to rinse non-adhered electrocoat material back into the electrocoat tank 12.

[0074] As the conveyor 14 continues to move to the right, the blank 84 is conveyed into the first rinse station 46 where an aqueous rinse composition is sprayed onto the coated blank 84 by the spray applicators 48. Excess rinse composition, e.g., water or permeate, drains back into the first rinse tank 50 located below the applicators 48 to be recirculated for further rinsing operations. In a currently preferred embodiment, the apparatus 10 is configured such that at a conveyor speed of 20 feet per minute (FPM) (6 meters per minute (MPM)) the blank 84 is in the first rinse station 46 for 5 sec to 20 sec, such as 10 sec to 15 sec, e.g., 12 sec.

[0075] As the conveyor 14 moves to the right, the blank 84 is transported into the first drain station 52 between the first set of air knives 54 to help remove excess rinse composition. The air knives 54 direct air toward the blank 84. The air knives 54 are positioned to blow excess rinse composition back into the first rinse tank 50.

[0076] The blank 84 is then moved through the second rinse station 58 and the second drain station 68 where the coated blank 84 is rinsed and drained in similar manner as described above.

[0077] As the conveyor 14 continues to move to the right, the blank 84 is transferred from the conveyor 14 at the outlet end 18 onto the dryer conveyor 78 for transport into the dryer 76 to dry and/or cure the electrodeposited coating as the blank 84 passes through the dryer 76. In one embodiment of the present invention, after the coating has been applied by electrodeposition, it is cured, usually by baking, at elevated temperatures ranging from 90°C to 430°C for a period ranging from 60 to 1200 seconds. The dryer can be any of a variety of curing ovens, both electric and gas powered, that are well known in the art for use on coating lines. Alternatively, the coating can be cured using infrared curing techniques as are well known in the art, typically for a period ranging from 45 to 240 seconds or a time sufficient to obtain a peak metal temperature ranging from 300° to 700°F (148.9° to 371.1°C). In a preferred embodiment of the present invention, the dryer 76 has a temperature of 150°F to 800°F (82°C to 426°C), e.g., 600°F to 750°F (315°C to 398°C), such as 650°F (343°C), and the dryer conveyor 78 has a speed such that the blank 84 is located in the dryer 76 for 20 sec to 60 sec, such as 40 sec to 50 sec, e.g., 45 sec. In one embodiment, the electrodeposited coating is dried by driving substantially all the solvent and/or water from the coating either by evaporation at ambient temperature or by forced drying at elevated temperatures.

[0078] For curable coating compositions, the coating on the blank 84 is cured or at least partially cured in the dryer 76. In certain embodiments of the present invention, the crosslink density of the crosslinkable components, i.e., the degree of crosslinking, ranges from 5% to 100% of complete crosslinking. In other embodiments, the crosslink density ranges from 35% to 85% of full crosslinking. In other embodiments, the crosslink density ranges from 50% to 85% of full crosslinking. One skilled in the art will understand that the presence and degree of crosslinking, i.e., the crosslink density, can be determined by a variety of methods, such as dynamic mechanical thermal analysis (DMTA) using a Polymer Laboratories MK III DMTA analyzer conducted under nitrogen. This method determines the glass transition temperature and crosslink density of free films of coatings or polymers. These physical properties of a cured material are related to the structure of the crosslinked network.

[0079] According to this method, the length, width, and thickness of a sample to be analyzed are first measured, the sample is tightly mounted to the Polymer Laboratories MK III apparatus, and the dimensional measurements are entered into the apparatus. A thermal scan is run at a heating rate of 3°C/min, a frequency of 1 Hz, a strain of 120%, and a static force of 0.01N, and sample measurements occur every two seconds. The mode of deformation, glass transition temperature, and crosslink density of the sample can be determined according to this method. Higher crosslink density values indicate a higher degree of crosslinking in the coating.

[0080] In the method described immediately above, the electrodeposition composition in the tank 12 of the apparatus 10 (i.e., the primer composition) comprises an electrodepositable coating composition which forms an electroconductive coating on both major surfaces and the sheared edges of the blank 84. This electrodepositable coating composition can be an anionic composition or, as is preferred, a cationic composition. The electrodepositable coating composition from which the electroconductive coating is electrodeposited onto both surfaces of the blank 84 can be a substantially unpigmented coating composition (i.e., a clearcoat composition) or a pigmented coating composition.

[0081] Generally, the electrodepositable coating compositions which are useful in the methods of the present invention are applied under conditions such that a substantially continuous coating having a dried film-thickness ranging from 0.1 to 1.8 mils (2.54 to 45.72 micrometers), usually from 0.15 to 1.6 mils (30.48 to 40.64 micrometers) is formed upon both major surfaces of the metal blank.

[0082] It should be understood that the coating applied by the method described immediately above can be an electrocoating primer suitable as a primary coating for subsequent application of a non-electrophoretic coating. Alternatively, the electrocoating can be an appearance-enhancing electrodeposited top coating. In the case of a primer coating, the electrodepositable coating composition is such that a substantially continuous primer coating having a dried film-thickness ranging from 0.1 to 0.4 mils (2.54 to 81.28 micrometers), usually from 0.15 to 2.5 mils (30.48 to 50.8 micrometers) is formed upon both major surfaces of the metal blank. In the case of an appearance-enhancing top coat, the electrodepositable coating composition is applied such that a substantially continuous top coating having a dried film-thickness ranging from 0.8 to 1.8 mils (20.32 to 45.72 micrometers), usually from 1.0 to 1.6 mils (25.4 to 40.6 micrometers) is formed upon both major surfaces of the metal blank.

[0083] In one embodiment, the electrodepositable coating composition from which the electroconductive coating is deposited onto both surfaces of the blank 84 comprises (a) an electrodepositable ionic resin, and (b) one or more electrically conductive pigments. Non-limiting examples of electrodepositable ionic resins suitable for use in the electrodepositable coating composition include the anionic and cationic film-forming polymers described in detail above, as well as the corresponding curing agents for such ionic polymers.

[0084] The electrodepositable compositions can further comprise one or more electroconductive pigments to render the resultant coating electroconductive. Suitable electroconductive pigments include electrically conductive carbon black pigments. Generally the carbon blacks can be any one or a blend of carbon blacks ranging from those that are known as higher conductive carbon blacks, i.e. those with a BET surface area greater than 500 m^2 /gram and DBP adsorption number (determined in accordance with ASTM D2414-93) of 200 to 600 ml/100 g. to those with lower DBP numbers on the order of 30 to 120 ml/100 gram such as those with DBP numbers of 40 to 80 ml/100 grams.

[0085] Examples of commercially available carbon blacks include Cabot Monarch™ 1300, Cabot XC-72R, Black Pearls 2000 and Vulcan XC 72 sold by Cabot Corporation; Acheson Electrodag™ 230 sold by Acheson Colloids Co.; Columbian

Raven™ 3500 sold by Columbian Carbon Co.; and Printex™ XE 2, Printex 200, Printex L and Printex L6 sold by DeGussa Corporation, Pigments Group. Suitable carbon blacks are also described in U.S. Pat No. 5,733,962.

[0086] Also, electrically conductive silica pigments may be used. Examples include AEROSIL 200 sold by Japan Aerosil Co., Ltd., and SYLOID® 161, SYLOID® 244, SYLOID® 308, SYLOID® 404 and SYLOID® 978 all available from Fuji Davison Co., Ltd.

[0087] Other electrically conductive pigments can be used, for example, metal powders such as aluminum, copper or special steel, molybdenum disulphide, iron oxide, e.g., black iron oxide, antimony-doped titanium dioxide and nickel doped titanium dioxide.

[0088] Also useful are particles coated with metals such as cobalt, copper, nickel, iron, tin, zinc, and combinations of thereof. Suitable particles which can be coated with the aforementioned metals include alumina, aluminum, aromatic polyester, boron nitride, chromium, graphite, iron, molydenum, neodymim/iron/boron, samarium cobalt, silicon carbide, stainless steel, titanium diboride, tungsten, tungsten carbide, and zirconia particles. Such metal-coated particles are commercially available from Advanced Ceramics Corp.

[0089] Other metal-coated particles which may be used advantageously in the electrodepositable coating composition from which the conductive coating is deposited include ceramic microballoons, chopped glass fibers, graphite powder and flake, boron nitride, mica flake, copper powder and flake, nickel powder and flake, aluminum coated with metals such as carbon, copper, nickel, palladium, silicon, silver and titanium coatings. These particles are typically metal-coated using fluidized bed chemical vacuum deposition techniques. Such metal-coated particles are commercially available from Powdermet, Inc.

[0090] Mixtures of different electroconductive pigments can be used.

[0091] The conductive pigment is present in the electrodepositable coating composition in an amount sufficient to provide a conductive coating having a sufficiently low specific resistance such that a second electrodepositable coating (topcoat) may be formed over the conductive coating as described above. The amount of electroconductive pigment in the electrodepositable composition can vary depending on the particular type of pigment that is used, but the level needs to be effective to provide an electrodeposited coating with a conductivity of greater than or equal to 10^{-12} Ohms/centimeter, more typically greater than or equal to $10-^{10}$ Ohms centimeter, and usually greater than or equal to $10-^{10}$ Ohms (centimeter).

[0092] In other words, the conductive pigment typically is present in the first electrodepositable coating composition (apparatus 10) in an amount sufficient to provide an at least partially dried (or cured) coating having a specific resistance of less than 10^{10}, typically ranging from 10^2 to 10^{10} Ohms centimeter, such as from 10^3 to 10^8 Ohms centimeter, e.g., from 10^4 to 10^6 Ohms centimeter.

[0093] As discussed above, the electrodepositable coating composition typically also contains other pigments to provide corrosion resistance, hiding, or as fillers and additives such surfactants, flow additives and crater control agents.

[0094] With reference to Fig. 4, after drying and/or curing in the dryer 76, the coated blank 84 can be stored for further coating or, more typically, the coated blank 84 can be directed to one of a plurality of electrocoat topcoat stations by a conveyor system 88 so that a topcoat can be electrodeposited onto the blank 84, e.g., over substantially one of the major surfaces. As shown in Fig. 4, a plurality of topcoat stations 90, 92, 94 can be positioned downstream of the dryer 76. Each topcoat station 90, 92, 94 can have an electrocoat apparatus 96, 98, 100 substantially the same as the apparatus 10 described above for applying the first, e.g., primer, coating but, as described below, the topcoat electrocoat apparatus 96, 98, 100 can be slightly modified to apply a continuous topcoat primarily onto substantially one major surface of the blank 84. The electrocoat tank of each topcoat station 90, 92, 94 can be supplied with the same or a different, e.g., differently colored, (second) coating composition. For example, one topcoat station 90 may include an electrocoat tank having a blue coating composition, another topcoat station 92 can have a red coating composition, and a third topcoat station 94 can have a green coating composition.

[0095] For the purposes of explanation only and not to be considered as limiting, assuming a red topcoat is to be applied to the blank 84 coated as described above, after exiting the dryer 76 the blank 84 is directed by the conveyor system 88 to the first topcoat station 90. Since the electrocoat apparatus 96 of the topcoat station 90 is substantially the same as the apparatus 10 described above, reference will again be made to Fig. 1 to describe the topcoating procedure conducted at the topcoating station. The first topcoat station 90 includes an electrocoat tank 12' and an electrocoat composition (second composition) as described above. However, to apply a topcoat onto a major surface of the blank 84, only one set of electrodes, e.g., only the first or top set of electrodes 40, need be present at the second coating region. If the second set of electrodes 42 are present, they are may be deenergized during the topcoating process described below.

[0096] In the topcoating process, the blank 84 is loaded onto the conveyor 14 and conveyed into the electrocoat tank 12 in similar manner as described above. However, during the topcoating procedure only the first set of electrodes 40 are present or energized so that the second coating, e.g., a topcoat, is applied onto substantially one major surface, i.e. the top major surface, of the blank 84, i.e., the surface adjacent the first electrodes 40 in the second coating region. By the phrase "applied onto substantially one major surface" is meant that a substantially continuous coating is deposited upon one major surface while the majority of the other major surface does not receive the coating. However, as will be understood by one of ordinary skill in the art, some of the second coating composition may "wrap around" the sides and onto the bottom major surface of the blank 84 during topcoating. As discussed above, this wrap around effect depends upon several factors, such as the throwpower of the particular coating composition, the temperature of the coating composition, the impressed voltage and the dwell time of the blank in the electrodeposition bath. As a general rule, as the throwpower, temperature, voltage, and/or dwell time increases, the coverage of the topcoated composition on the bottom side of the blank 84 will generally increase. In a preferred embodiment, the deposition parameters are controlled to deposit a substantially continuous topcoat having a thickness of 0.5 mil to 2 mil (0.013 mm to 0.05 mm), such as 0.95 mil to 1.3 mil (0.02 mm to 0.03 mm) onto the top major surface of the blank 84. The top major surface, therefore, has a total coating thickness (primer plus topcoat) of 1 mil to 1.5 mil (0.025 mm to 0.04 mm).

[0097] The topcoated blank 84 can then be directed through one or more rinse stations 46, 58, drain stations 52, 68, and drying stations 74 in similar manner as described above to dry and/or cure the applied topcoat composition. After drying, the topcoated blank can then be stacked or stored until ready to be shaped into a final, three-dimensional shape, such as a washer or dryer front panel.

[0098] In an alternative embodiment of the invention, the first conductive coating (primer coating) applied by the apparatus 10 is not dried or cured and the second electrodepositable coating composition (applied at one of the topcoat stations 90, 92, 94) is applied directly to the non-dried first coating on one major surface of the blank. This is generally referred to as a wet-on-wet ("WOW") application. A wet-on-wet application is typically used where the first electrodepositable coating is a transparent or clear coating which is substantially free of pigment.

[0099] In the embodiment described above, pre-cut, flat metal blanks 84 were the substrates being coated. However, the invention is not limited to use with metal blanks. Metal coils can also be coated using the apparatus and methods described above. However, to coat metal coils, a conveyor 14 as described above is not required. Rather, the coil itself can function as the conveyor. For example, the coil can be guided by guide devices, such as wheels or rollers, through the first and/or second coating regions to follow the same path described above with respect to coating metal blanks. For coating the coil, the coil can be grounded, i.e., connected to the electrical power source, outside of the tank 12 in any conventional manner rather than by an in tank connecting system 26 as described above.

[0100] Upon discharge from the dryer 76, the coil can optionally be sheared into blanks at a shearing station 104 (Fig. 4) and the blanks transported to one or more of the topcoat stations as described above. Alternatively, the coil discharged from the dryer 76 can be directed to an inline topcoat station (station 92 in Fig. 4) where a topcoat can be applied primarily onto one major surface of the coil as described above. The coil can then be sheared into blanks after the topcoat is dried or cured. However, if the coil is first primed and topcoated and then sheared, the blanks will have sheared edges devoid of any protective coating. Hence, the method optionally can comprise the additional steps of applying a conventional corrosion inhibitor such as yttrium acetate, to the sheared edges. Alternatively still, if a topcoat (rather than a primer and a topcoat as described above) is desired to be applied onto the substrate, the substrate (whether blank or coil) can be directed to a topcoat station as described above without having a primer applied in a first electrocoat tank.

[0101] As aforementioned, metal blanks coated by the methods of the present invention are "post-formed" into parts to be assembled into various end-products, for example, front, side and back panels for appliances such as washers, dryers and refrigerators. The post-forming processes (e.g., punching and bending) require that the coatings (including the multi-layer composite coatings) which are applied to the blanks be particularly adherent and flexible.

[0102] In one embodiment of the present invention, the electrodepositable coating composition provides a post-formable coating capable of providing a T-bend flexibility rating of less than 6T, often ranging from 0T to 6T, and usually ranging from 2T to 4T as determined in accordance with ASTM-D4145. In another embodiment of the present invention, the electrodepositable coating composition provides a post-formable multi-layer composite coating capable of providing a T-bend flexibility rating of less than 6T, such as ranging from 0T to 6T, e.g., from 2T to 4T as determined in accordance with ASTM-D4145.

[0103] Illustrating the invention are the following examples which are not to be considered as limiting the invention to their details. Unless otherwise indicated, all parts and percentages in the following examples, as well as throughout the specification, are by weight.

EXAMPLES

[0104] It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications that are within the spirit and scope of the invention, as defined by the appended claims.

EXAMPLES A through B

[0105] The following Examples A and B describe the preparation of cationic electrodepositable conductive primer compositions useful in the processes of the present invention. Example A describes the preparation of pigmented electrodepositable conductive primer coating composition and Example B describes the preparation of an unpigmented electrodepositable conductive primer coating composition. Each conductive primer composition is in the form of an electrodeposition bath. Each of the electrodeposition bath compositions was prepared by blending under mild agitation the following ingredients:

Ingredients	**Example A (parts by weight)**	**Example B (parts by weight)**
CR661[1]	1326.33	1500.00
CP639[2]	445.82	---
Deionized Water	2027.85	2100.00

[1] Electrocoating resin component available from PPG Industries, Inc.

[2] Electrocoating pigment paste component available from PPG Industries, Inc.

[0106] The electrodeposition bath composition of Example A had a pigment-to-binder ratio ("p/b") of 0.15 and a total solids content of 17.0 percent based on total weight of the respective electrodeposition bath compositions. The electrodeposition bath composition of Example B had a total solids content of 15.0 percent based on total weight of the electrodeposition bath.

EXAMPLE 1

[0107] This example describes the preparation of an electrodepositable top coating composition for application over conductive electrodepositable primer compositions in the processes of the present invention. The electrodepositable top coating composition is in the form of an electrodeposition bath composition. The electrodeposition bath composition was prepared by blending under mild agitation the following ingredients:

INGREDIENTS	**PARTS BY WEIGHT (grams)**
CR940B[1]	1352.07
CP436[2]	375.88
Deionized water	2072.05

[1] Electrocoating resin component available from PPG Industries, Inc.

[2] Electrocoating pigment paste component available from PPG Industries, Inc.

The resulting electrodepositable top coating bath composition had a total solids content of 15.0 percent based on total bath weight and a p/b of 0.53.

EXAMPLE 2

[0108] This example describes the powder top coating composition for application over conductive electrodepositable primer compositions in the processes of the present invention. The powder top coating composition is a dry powder coating composition, PCT80139W, commercially available from PPG Industries, Inc. of Pittsburgh, Pennsylvania.

COMPARATIVE EXAMPLE 3

[0109] This comparative example describes application of a conventional liquid coating system. The liquid coating system was comprised of a liquid urethane primer coating, APPPY 3020, with subsequent application of a conventional liquid polyester topcoat, APTW 3952. Both the APPPY 3020 and the APTW 3952 are commercially available from PPG Industries, Inc. of Pittsburgh, PA. The conventional liquid coating compositions were used as the control series to be evaluated versus the electrodepositable coating compositions applied by the methods of the present invention.

TEST PANEL PREPARATION:

[0110] Each of the above-described electrodepositable conductive primer bath compositions (Examples 1 and 2) was applied to cold rolled steel ("CRS") test panels, which had been pretreated with CF710 CS20®, a zinc phosphate pretreatment composition commercially available from PPG Industries, Inc. The pigmented primer coating of Example A was electrodeposited at 15 seconds / 1.75 Amps / 175 volts onto the zinc phosphated CRS, the non-pigmented coating Example B was electrodeposited at 60 seconds / 1.0 Amps / 100 Volts. Each primer coating composition was electrodeposited at film builds ranging from 0.15 mils to 0.35 mils (3.75 to 8.75 micrometers) dry film thickness.

[0111] The electrocoated test panels for Example A were baked at a temperature of 400°F (204°C) for 20 minutes to cure the conductive primer thereon. The electrocoated test panels for Example B were then "flashed" for 5 minutes at room temperature to allow dehydration to occur.

[0112] The electrodepositable top coating composition of Example 1 was then applied to the primed test panels prepared as described immediately above. For Example A, (cured conductive primer), and Example B, (air-dried conductive clear coat), the electrodepositable top coating composition of Example 1 was electrodeposited at 90 seconds / 1.2 Amps / 125 Volts. The top coated panels thus prepared were then baked at a temperature of 350°F (177°C) for 20 minutes to cure the electrodepositable top coating composition. The cured top coating compositions had a dry film thickness ranging from 1.20 to 1.4 mils (30 to 35 micrometers).

[0113] The powder top coating composition of Example 2 was then applied to the primed test panels. For Example A (cured conductive primer), and Example B (air-dried conductive clear coat), the powder topcoat composition of Example 2 was applied by electrostatic spray. The top coated panels thus prepared were then baked at a temperature of 400°F (204°C) for 10 minutes to cure the powder topcoat. The cured powder topcoat composition had a dry film thickness ranging from 1.20 to 2.20 mils (30 to 55 micrometers).

[0114] With respect to the conventional liquid coating system of Example 3, the primer APPY 3020 was roll applied to zinc phosphate treated galvanized steel substrate, then cured at a temperature of 400°F (204°C) for 10 minutes. A dry film thickness of 0.2 mils (5 micrometers) was achieved. The liquid topcoat was then spray applied to the primed substrate and cured at a temperature of 400°F (204°C) for 10 minutes to form a topcoat having a dry film thickness of 0.8 mils (20.3 micrometers).

[0115] The test panels thus prepared were evaluated for corrosion resistance by salt spray testing in accordance with ASTM B17; detergent resistance in accordance with ASTM D2248; and flexibility by T Bend testing in accordance with ASTM D4145 (where 0T = best; np represents no coating pick off; and nc represents no chipping.)

[0116] Test results are reported below in the following TABLE 1.

TABLE 1

Conductive Primer	Flexible Top Coat	Salt Spray Corrosion Resistance	Detergent Resistance	Flexibility
Example A	Example 1	1.5mm total scribe creepage	No blisters	2T np 3T nc
Example B	Example 1	3.0mm total scribe creepage	Few #8 blisters	3T np/nc
Example A	Example 2	0.5mm total scribe creepage	No blisters	3T np/nc
Example B	Example 2	0.5mm total scribe creepage	Medium #8 blisters	2T np/nc
Not applicable	Example 3 (comparative)	2mm total scribe creepage	< few #8 blisters	4T np/nc

[0117] The data presented in Table 1 illustrate that the two coat process of the present invention provides flexibility properties, 2T np and 1T nc better than the comparative prepaint control system applied by conventional processes. The two coat systems of the present invention using Example A as the primer and Examples 1 and 2 as the flexible topcoats provides better detergent and salt spray performance than Example 3, the comparative prepaint system applied by conventional processes.

[0118] It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications which are within the spirit and scope of the invention, as defined by the appended claims.

WE CLAIM:

1. A continuous electrocoat apparatus for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces, the apparatus comprising:

a first electrocoat tank;

at least one first electrode spaced from at least one second electrode and defining a first coating region to apply a first aqueous electrodepositable coating composition onto both major surfaces of the substrate between the first and second electrodes;

a second electrocoat tank located downstream of the first electrocoat tank; and

at least one third electrode located in the second electrocoat tank and defining a second coating region adjacent the third electrode to apply a second aqueous electrodepositable coating composition onto substantially one major surface of the substrate.

2. The apparatus as claimed in claim 1, including a conveyor extending through the first coating region and defining a first conveyor path, with the first and second electrodes located on opposed sides of the first conveyor path.

3. The apparatus as claimed in claim 2, including a connecting system configured to apply an electric potential to the substrate in the coating region.

4. The apparatus as claimed in claim 3, wherein the conveyor comprises a plurality of electrically conductive supports configured to contact the substrate and the connecting system is configured to provide electricity to at least a selected portion of the supports in the first coating region.

5. The apparatus as claimed in claim 4, wherein the conveyor comprises a plurality of non-conductive members, with the supports carried on the non-conductive members.

6. The apparatus as claimed in claim 1, wherein the substrate is a metal coil and the apparatus includes a guide device to guide the coil through the first coating region.

7. The apparatus as claimed in claim 2, wherein the conveyor includes at least one holding element configured to bias the substrate toward the conveyor.

8. The apparatus as claimed in claim 6, wherein the guide device includes a roller.

9. The apparatus as claimed in claim 4, wherein the connecting system includes:

a bus bar located adjacent the first electrocoat tank; and

a plurality of grounding bars carried on the conveyer, with each grounding bar connected to at least one support, and with each grounding bar having an outer and configured to contact the bus bar when the grounding bar is in the coating region.

10. The apparatus as claimed in claim 1, wherein the first coating composition is different than the second coating composition.

11. The apparatus as claimed in claim 10, wherein the first coating composition is a corrosive-resistant coating composition.

12. The apparatus as claimed in claim 10, wherein the second coating composition is an appearance enhancing coating composition.

13. The apparatus as claimed in claim 1, wherein the coating formed by the first and second coating compositions has a T-bend rating in the range of 0 to 6T.

14. A continuous electrocoat apparatus for applying a coating onto at least a portion of a substantially flat substrate, the apparatus comprising:

a first electrocoat tank having a coating region;

a non-conductive conveyor extending at least partially into the first electrocoat tank and defining a conveyor path;

a plurality of electrically conductive supports carried on the conveyor;

a connecting system configured to provide an electric potential to at least a selected portion of the supports when the selected portion of the supports are in the coating region of the first electrocoat tank; and

a plurality of first electrodes positioned in the first electrocoat tank, with the first electrodes located on a first side of the conveyor path.

15. The apparatus of claim 14, wherein the conveyor is a closed-loop conveyor.

16. The apparatus of claim 14, wherein the conveyor comprises a plurality of non-conductive chains.

17. The apparatus of claim 14, wherein the conveyor includes holding elements configured to bias the substrate toward the conveyor.

18. The apparatus of claim 17, wherein the holding elements comprise magnets spaced from an outer surface of the conveyor.

19. The apparatus of claim 14, wherein the supports extend beyond an outer surface of the conveyor.

20. The apparatus of claim 14, wherein the supports are tapered.

21. The apparatus of claim 16, wherein the chains are laterally spaced from one another and the supports on adjacent chains are aligned to define rows of supports on the conveyor.

22. The apparatus of claim 21, wherein each chain moves at substantially the same speed to maintain the rows of supports as the conveyor moves.

23. The apparatus of claim 14, including a connecting system configured to connect the supports in the coating region with an electrical power source.

24. The apparatus of claim 23, wherein the connecting system includes a bus bar located adjacent the electrocoat tank.

25. The apparatus of claim 24, wherein the bus bar is located above the electrocoat tank.

26. The apparatus of claim 24, wherein the connecting system includes a plurality of grounding bars, with each grounding bar connected to at least one support, and with each grounding bar having an outer end configured to contact the bus bar when the supports to which the grounding bar are connected are in the coating region.

27. The apparatus of claim 14, wherein the first electrodes are located above the conveyor path in the electrocoat tank.

28. The apparatus of claim 14, including a plurality of second electrodes located on a side of the conveyor path opposite to the first electrodes.

29. The apparatus of claim 28, including at least one second electrocoat tank located downstream of the first electrocoat tank and having a second electrocoat conveyor extending at least partially into the second electrocoat tank and defining a second conveyor path, wherein the second tank includes a plurality of third electrodes located on one side of the second conveyor path.

30. The apparatus of claim 29, wherein the second electrocoat tank includes a plurality of fourth electrodes located on a side of the conveyor path opposite to the third electrodes.

31. A continuous electrocoat apparatus for applying a coating over at least a portion of a substantially flat substrate, the apparatus comprising:

a first electrocoat tank having a coating region;

a non-conductive conveyor extending at least partly into the first electrocoat tank and defining a conveyor path, the conveyor comprising a plurality of laterally spaced, non-conductive chains movably mounted on rotatable members such that the chains move at substantially the same speed;

a plurality of electrically conductive supports carried on each chain to form a support surface of the conveyor;

a plurality of grounding bars carried on the conveyor, with each grounding bar connected to at least one support;

a bus bar located adjacent the electrocoat tank, wherein the bus bar is configured to contact one or more grounding bars carried on a portion of the conveyor in the coating region of the first electrocoat tank.

32. A method for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces, comprising the steps of:

(a) conveying the substrate between at least one first electrode and at least one second electrode in a first coating region to apply a first aqueous electrodepositable coating composition onto both major surfaces of the substrate;

(b) conveying the substrate adjacent at least one third electrode located in a second coating region to apply a second aqueous electrodepositable coating composition onto substantially one major surface of the substrate.

33. A method as claimed in claim 32, including drying the coating applied in step (a) before applying the coating of step (b).

34. A method as claimed in claim 32, wherein the substrate is a metal blank.

35. A method as claimed in claim 32, wherein the substrate is a metal coil.

36. A method as claimed in claim 32, wherein the first coating composition is different from the second coating composition.

37. A method as claimed in claim 36, wherein the first coating composition is a primer composition.

38. A method as claimed in claim 36, wherein the second coating composition is an appearance enhancing composition.

39. A method of electrocoating a substantially flat substrate having two major surfaces, comprising the steps of:

placing the substrate onto a non-conductive conveyor having a plurality of conductive supports defining a support surface, the conveyor defining a conveyor path through a coating region of an electrocoat bath;

applying an electric potential to the substrate when the substrate is in the coating region;

conveying the substrate through the coating region adjacent at least one electrode to apply an aqueous electrodepositable coating composition onto at least one major surface of the substrate; and

drying the coated substrate at a drying station located downstream of the electrocoat bath.

40. The method of claim 39, wherein the electrocoat bath includes at least one first electrode located on one side of the conveyor path and at least one second electrode located on an opposite side of the conveyor path and the method includes moving the substrate between the first and second electrode to apply the coating composition to both major surfaces of the substrate.

41. The method of claim 40, including moving the substrate at a speed such that the substrate has a dwell time of 5 secs to 30 secs in the coating region.

42. The method of claim 39, wherein the electrical potential is applied to the substrate by supplying electrical power to the conveyor supports in the coating region.

43. The method of claim 42, wherein the electrical power is supplied by contacting a grounding bar attached to at least one support in the coating region with a bus bar located adjacent the coating tank.

44. The method of claim 40, including applying the coating composition such that the dried coating has a thickness of 0.004 mm to 0.006 mm on both major surfaces of the substrate.

45. The method of claim 40, including directing the coated substrate to a topcoat station having a second electrocoat bath with a second conveyor defining a second conveyor path through a coating region of the second electrocoat bath, wherein the second electrocoat bath includes at least one third electrode located on one side of the second conveyor path and the method includes moving the coated substrate past the third electrode to apply a topcoat composition onto a major surface of the substrate.

46. The method of claim 45, including drying the topcoat composition.

47. The method of claim 46, including applying the topcoat composition such that the dried topcoat has a thickness of 0.02 mm to 0.03 mm.

48. A continuous electrocoat apparatus for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces, the apparatus comprising:

means for conveying the substrate between at least one first electrode and at least one second electrode in a first coating region to apply a first aqueous electrodepositable coating composition onto both major surfaces of the substrate; and

means for conveying the substrate adjacent at least one third electrode located in a second coating region to apply a second aqueous electrodepositable coating composition onto substantially one major surface of the substrate.

49. A continuous electrocoat apparatus for applying a coating onto at least a portion of a substantially flat substrate having two major surfaces, the apparatus comprising:

means for placing the substrate onto a non-conductive conveyor having a plurality of conductive supports defining a support surface, the conveyor defining a conveyor path through a coating region of an electrocoat bath;

means for applying an electric potential to the substrate when the substrate is in the coating region;

means for conveying the substrate through the coating region adjacent at least one electrode to apply an aqueous electrodepositable coating composition onto at least one major surface of the substrate; and

means for drying the coated substrate at a drying station located downstream of the electrocoat bath.

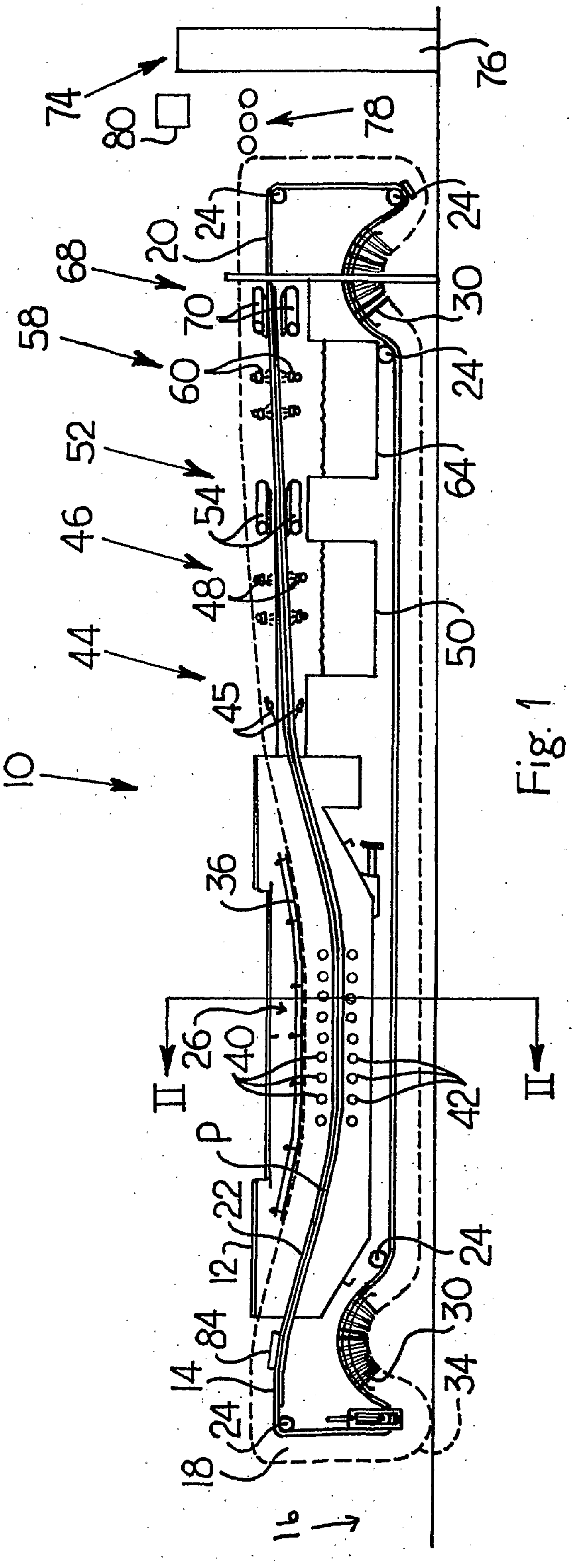

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Fig. 1

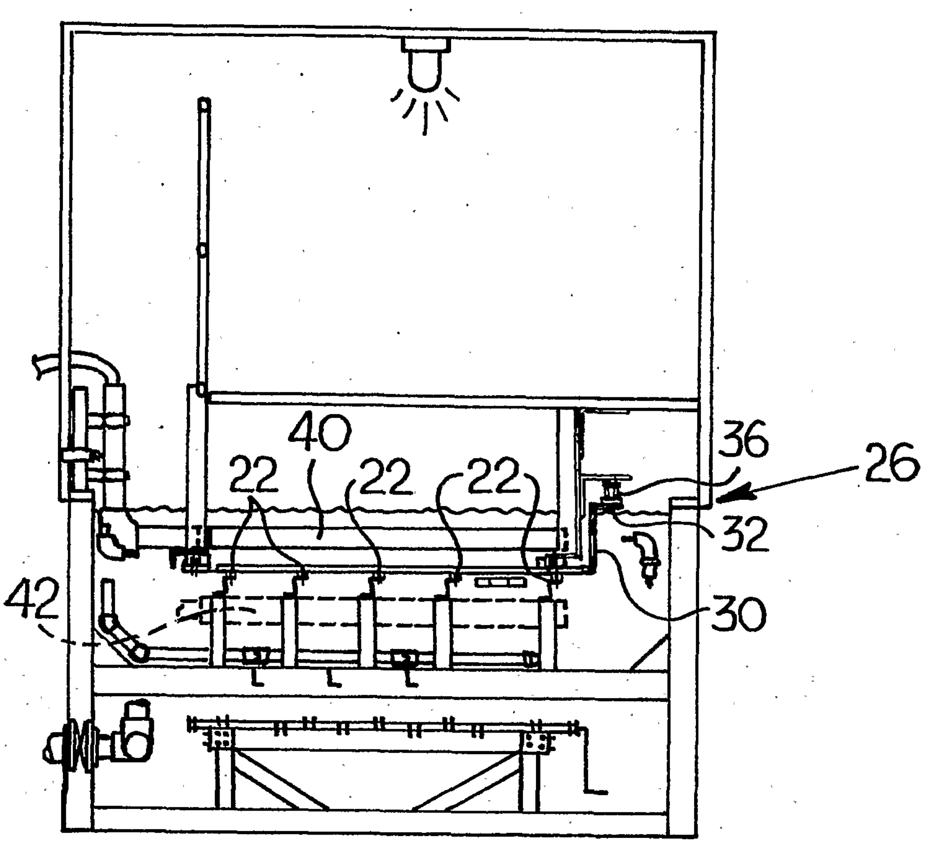
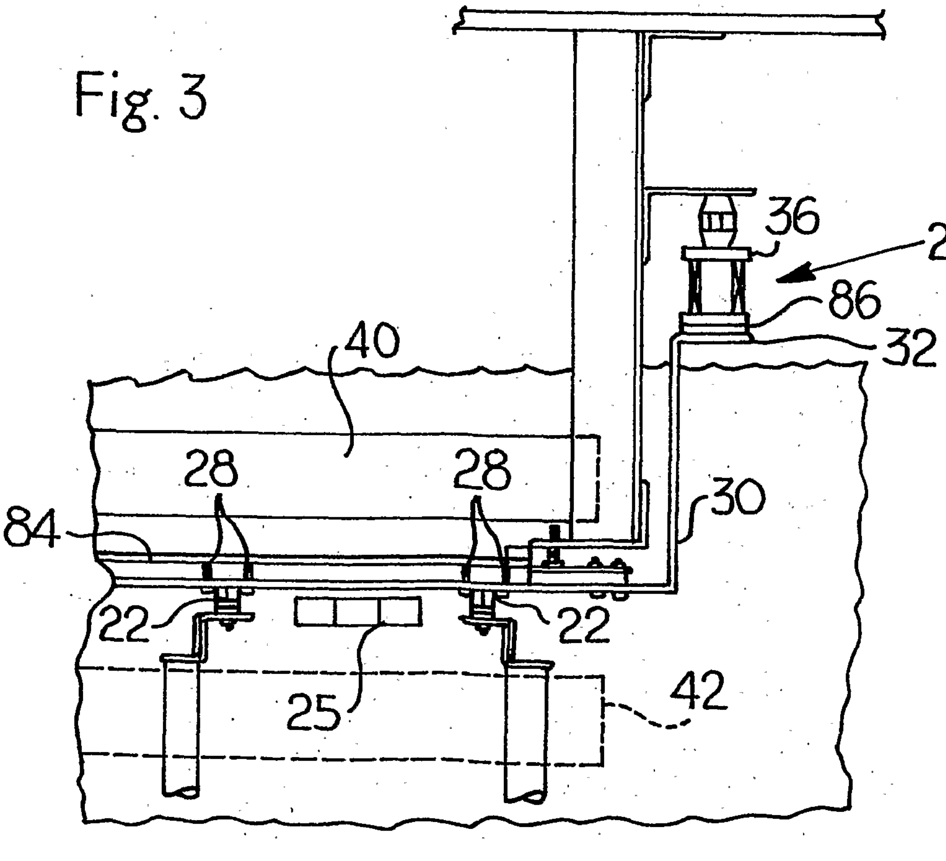


Fig. 2

Fig. 3



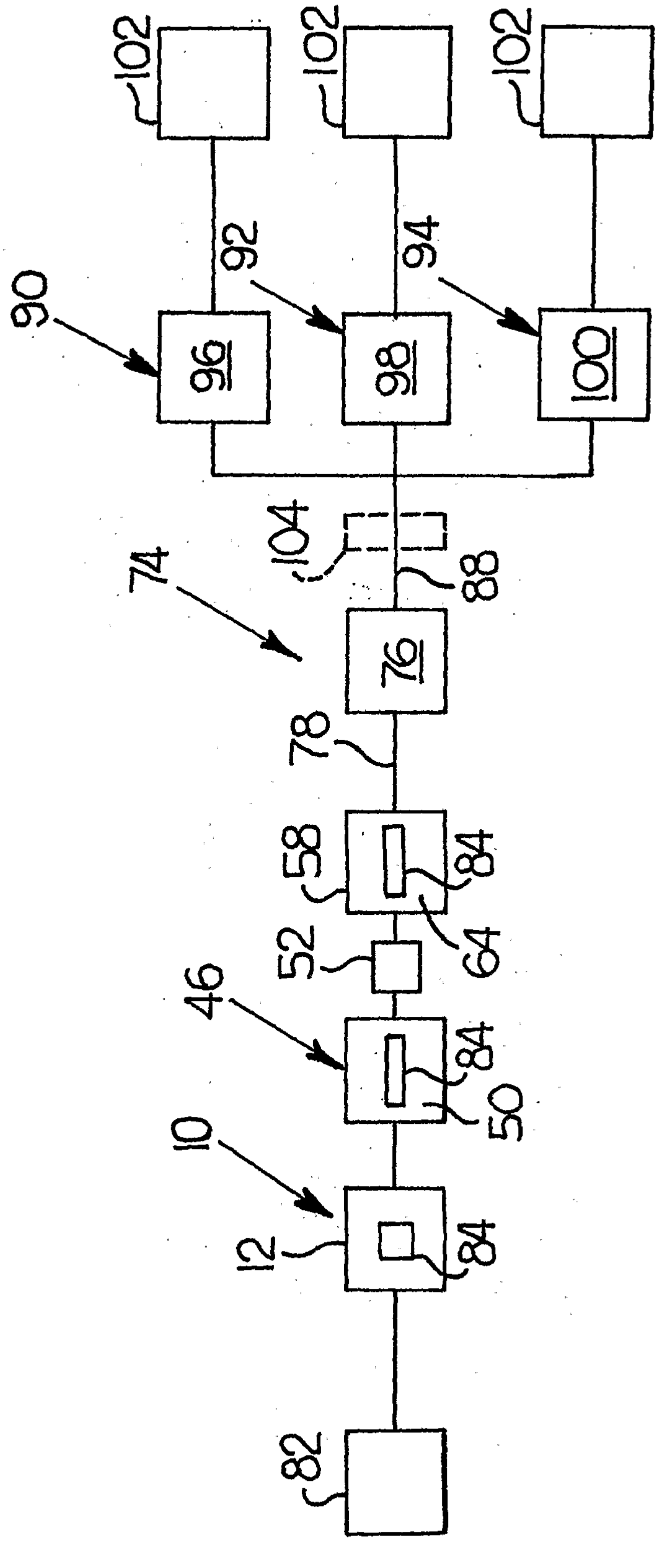

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Fig. 4