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[54] **ELECTROSTATIC COATING OF METAL POWDER ON METAL STRIP**
 13 Claims, 6 Drawing Figs.

[52] **U.S. Cl.**..... **118/634,**
 117/17, 117/19, 117/50, 118/638

[51] **Int. Cl.**..... **B05b 5/02**

[50] **Field of Search**..... 118/630,
 634, 635, 638, 70, 108; 117/17, 18, 22, 31, 19, 50,
 93.4, 93.41

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ABSTRACT: Apparatus for applying a metal coating on continuously moving metallic strip, particularly steel strip, by electrostatically depositing in one or in a plurality of regions a uniform layer of metal powder on the metallic strip and thereafter subjecting the strip and the layer of metal powder to heat treatment and then compaction to effect cohesion of the particles of metal powder and adhesion of the metal powder particles to the strip.

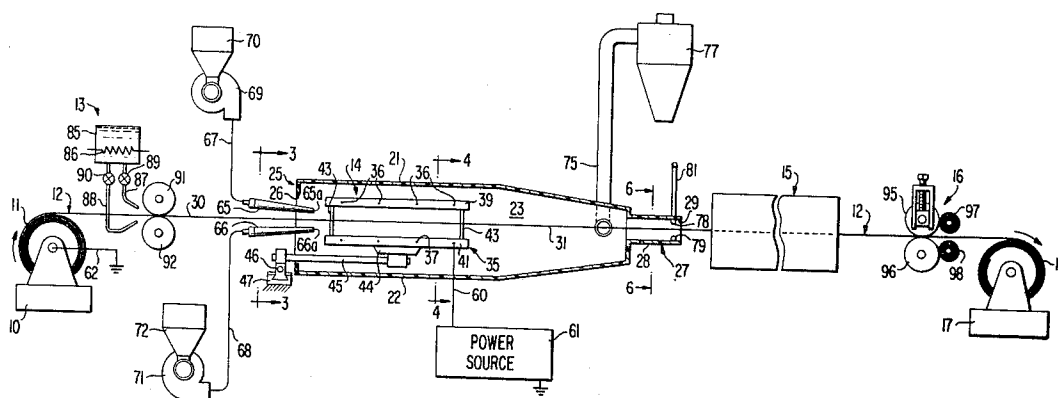


FIG. 1

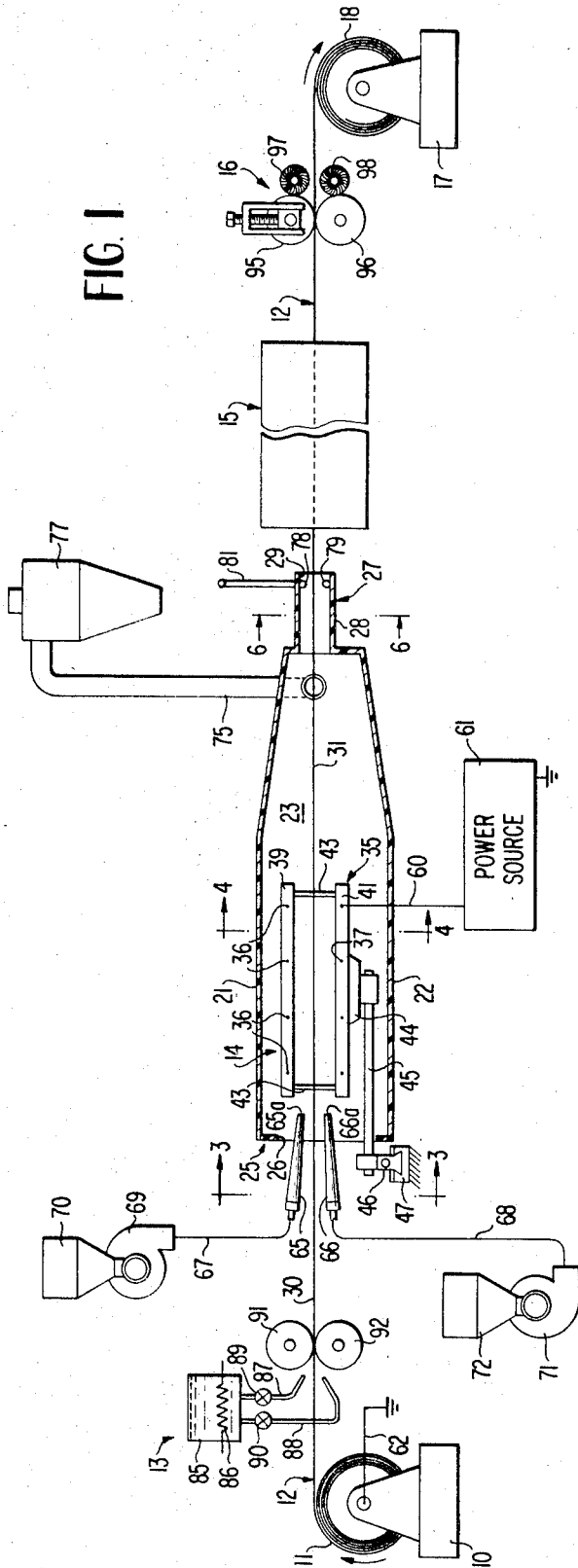
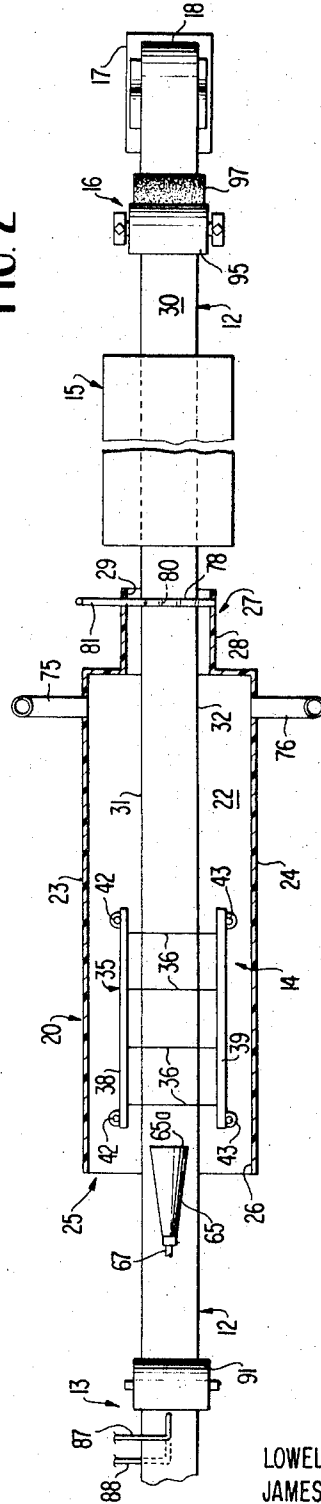


FIG. 2



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FIG. 3

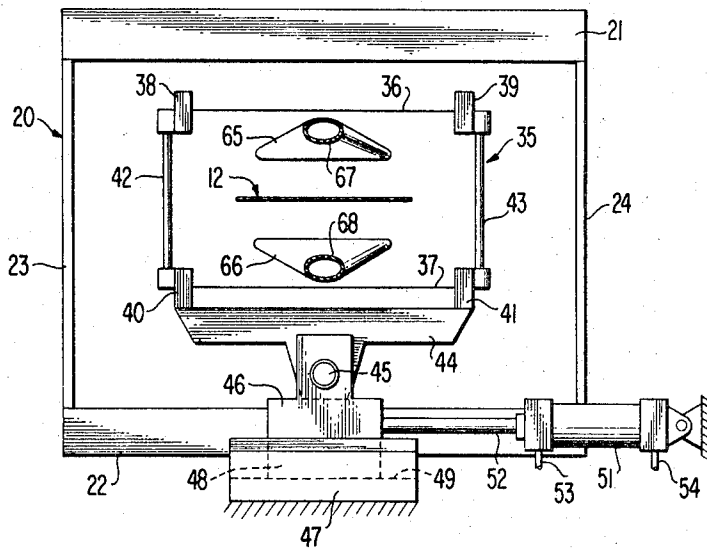


FIG. 4

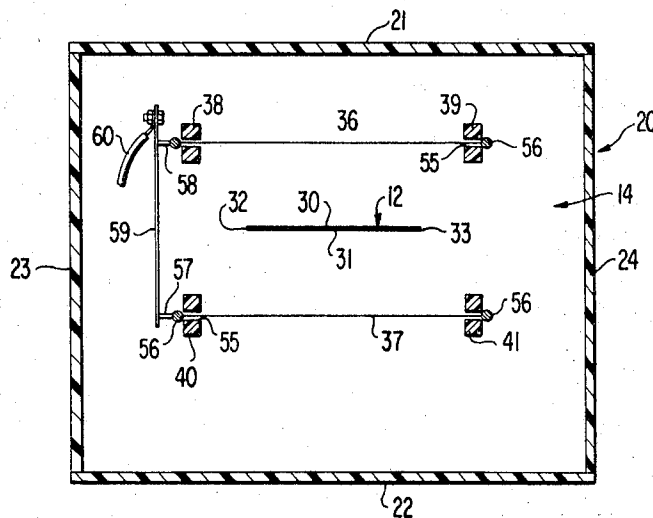


FIG. 5

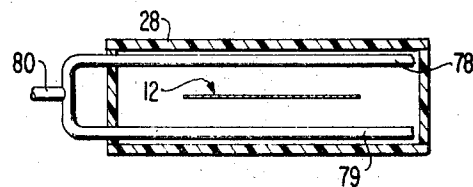
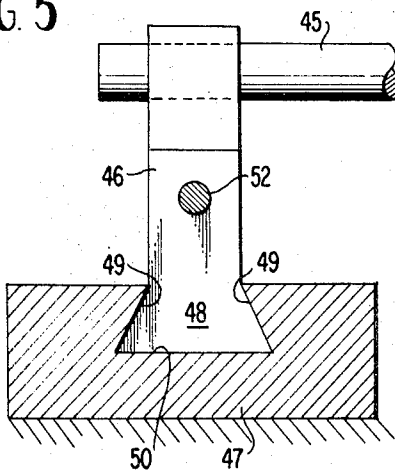
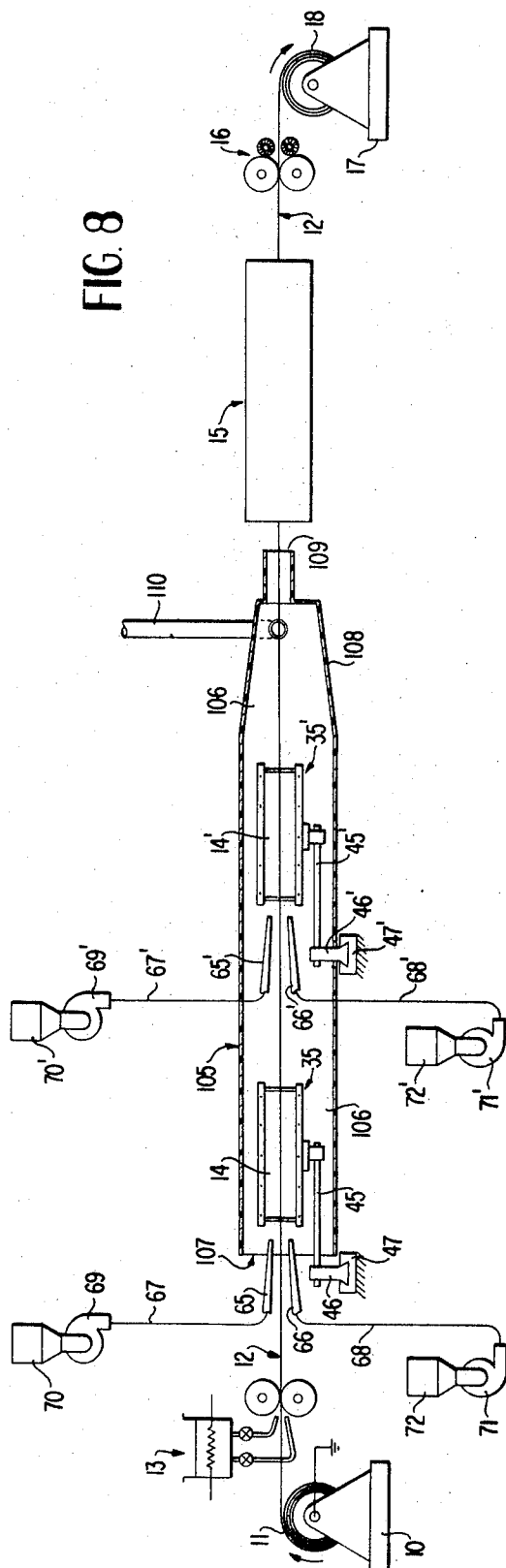
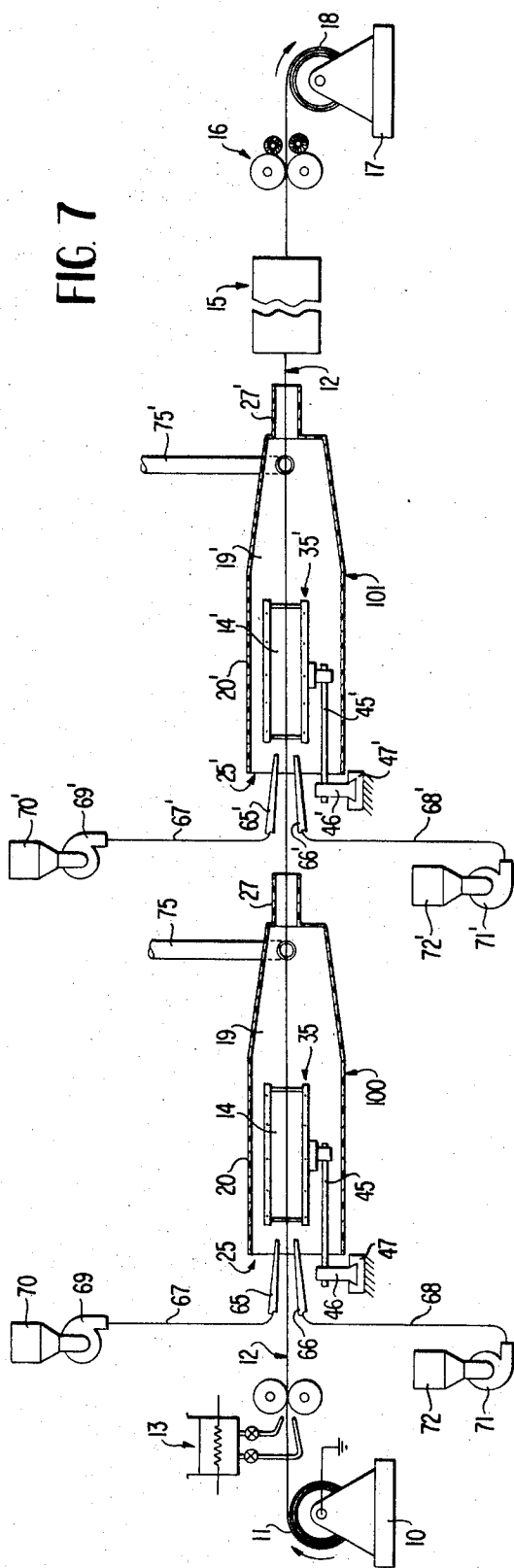


FIG. 6

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ELECTROSTATIC COATING OF METAL POWDER ON METAL STRIP

BACKGROUND OF THE INVENTION

This invention relates to apparatus for applying a metal coating on continuously moving metallic strip by electrostatically depositing metal powder on the strip.

In the past, metallic coating has been applied to metal strip by electrostatically depositing metal powder on the strip and then subjecting the strip with deposited metal powder to heat treatment and then compaction to effect cohesion of the particles of metal powder and adhesion of the metal powder particles to the strip. Such prior process employs charging wires spaced from the surface of the strip and charged with high potential opposite the potential of the strip to provide a corona discharge about the wires, and means for discharging an aerosol of metal powder and gas generally between the strip and the charging wires. The corona about the charging wires results in intensive ionization of gas molecules about the charging wires and produces a large number of ions which charge the particles of metal powder by ion bombardment and metal particles charged to a polarity the same as the charging source move in a direction toward the strip under influence of the electric field established by the charged wires and impinge upon and collect on the surface of the strip. Following heat treatment and compaction, uniform coatings possessing good adherence and coherence may be obtained.

The present invention provides an improvement on such prior process which makes it possible to electrostatically deposit metallic powder on one or both surfaces of metal strip continuously moving at a relatively high speed and, after heat treatment and compaction, to produce metal strip uniformly coated with the material of the powder, the process being capable of producing the product with a degree of reliability required for a commercial operation.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, in which similar reference characters denote similar elements throughout the several views:

FIG. 1 is a diagrammatic view in side elevation and partially in section of a coating apparatus constructed in accordance with one embodiment of the present invention;

FIG. 2 is a diagrammatic view in plan and partially in section of the coating apparatus shown in FIG. 1;

FIG. 3 is a view in section taken along the line 3-3 of FIG. 1;

FIG. 4 is a view in section taken along the line 4-4 of FIG. 1;

FIG. 5 is an enlarged view of a part of the apparatus shown in FIG. 1;

FIG. 6 is a view in section taken along the line 6-6 of FIG. 1;

FIG. 7 is a diagrammatic view, in side elevation, of a coating apparatus constructed in accordance with another embodiment of the present invention; and

FIG. 8 is a diagrammatic view, in side elevation, of a coating apparatus constructed in accordance with still another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference more particularly to FIGS. 1 and 2 of the drawings, a coating apparatus provided by the present invention is shown therein including an uncoiling device 10 supporting a coil 11 of strip material 12 such as steel strip material. The strip material leaves the coil 11 and moves through a strip wetting device 13 which functions to controllably wet both sides of the strip material for a purpose and in a manner described below. The wetted strip material then moves through an electrostatic coating region 14 wherein a coating of metallic powder is deposited on both surfaces of the strip material. The strip material with deposited metal powder then moves through a heat treating furnace 15 and then through a compaction device 16 from which the coated strip material is fed to a coiling device 17 for coiling the coated strip material in coil 18. The uncoiling device 10 and the coiling device 17 may be of conventional construction

capable of moving the strip material through the line at a controlled speed and under the required tension. The strip material is supported upon its movement through the line between the coating zone 14 and the compaction device 16 by a suitable number of strip edge supporting rollers, not shown, of the type mounted for rotation about a vertical axis and having a continuous circumferential groove in its peripheral edge for supportably receiving the edge of the strip. The heat treating furnace 15 also may be of conventional construction and may comprise an electrical furnace.

As more clearly shown in FIGS. 3 and 4, the electrostatic coating region 14 is confined within a chamber or zone 19 defined by an elongated housing 20 having top wall 21, bottom wall 22 and sidewalls 23 and 24 constructed of electrically insulating material. The strip entry end 25 of the housing 20 is provided with an enlarged opening 26, substantially equal to the maximum cross-sectional area of the zone 19, and the strip exit end 27 includes a portion 28 of reduced cross-sectional area having an exit opening 29 of an area substantially less than the area of the entrance opening. As seen from FIGS. 1 and 2, the entrance opening 26 is defined by wall portions spaced from the upper surface 30 and lower surface 31 of the strip and from the edges 32 and 33 of the strip by distances approaching the width of the strip, whereas the exit opening 29 is defined by wall portions spaced closely from the surfaces and edges of the strip.

Located within the housing 20 is a carriage 35 which defines the deposition region 14, the deposition region 14 being located above and below the surfaces of the strip. The carriage 35 supports a plurality of upper charging wires 36 in spaced relation above the upper surface 30 of the strip and supports a plurality of lower charging wires 37 located in spaced relation below the lower surface 31 of the strip, the charging wires comprising the plurality of charging wires 36 and the charging wires comprising the plurality of charging wires 37 being spaced from each other in the direction of movement of the strip 12 through the zone 19. The carriage 35 includes a pair of laterally spaced upper supporting members 38 and 39 for carrying the upper charging wires 36 and a pair of laterally spaced lower supporting members 40 and 41 for carrying the lower charging wires 37. The supporting members 38 and 40 and the supporting members 39 and 41 are rigidly joined together by vertical members 42, 42 and 43, 43, respectively, and the lower supporting members 40 and 41 are rigidly connected by transverse member 44. A rigid rod 45 is connected rigidly to the transverse member 44 and the rod 45 extends longitudinally of the zone 19 through the entrance opening 26 and is rigidly attached to a supporting block 46 located outside the housing 20. For a purpose that will be described below, the block 46 is supported by a fixed member 47 in such a manner as to permit lateral movement of the block 46 and hence the carriage 35 relative to the strip 12. A suitable arrangement for rigidly supporting the block 46 while permitting such lateral movement is illustrated in FIG. 5. As shown, the lower end of the block 46 is provided with an enlarged portion 48 having downwardly and outwardly inclined planar sides 49 disposed in the direction of the lateral movement, and the fixed member 47 is provided with a groove 50 shaped to slideably receive the enlarged portion 48. Transverse movement of the block 46 relative to the fixed member 47 and hence the strip 12 may be accomplished by a double-acting hydraulic cylinder 51 having a driven shaft 52 connected to the block 46 and hydraulic feed conduits 53 and 54 alternately energized through a control system, not shown, to effect reciprocating movement of the block 46 for a purpose that will be described below.

In accordance with the principles of the present invention, the rigid rod 45 is constructed of a material having high electrical resistance, and components forming the carriage 35 including the supporting members 38, 39, 40, and 41, the vertical members 42, 42 and 43, 43, and the transverse member 44, are preferably constructed of similar material. Also, it will be appreciated from the drawings and the

foregoing description that the carriage 35 is supported only by the rigid rod 45, that the rigid rod 45 is supported at one point, i.e., at its connection with the block 46, and that the point of singular support of the rigid rod 45 is located outside the zone 19. This construction minimizes the possibility of shorting currents which possess a high tendency of occurrence due to the presence of metal powder and high voltages required for the electrostatic deposition process and makes it possible to effect coating of the strip material continuously for extended periods as required for commercial operations.

As shown in FIG. 4, the charging wires 36 and 37 may pass through openings 55 formed in respective supporting members 38, 39, 40, and 41 may have enlarged members 56 on their ends to provide a permanent assembly. The plurality of charging wires 36 and the plurality of charging wires 37 are electrically connected by longitudinal electrical conductive members 57 and 58, respectively, and the latter conductive members are electrically connected by conductive member 59 which is connected to a power source 61 by conductor 60. The electrical circuit for the electrostatic coating apparatus is completed by a ground connection 62 to the uncoiling device 10 which connects the strip 12 to ground potential.

It will be seen from FIG. 4 that the plurality of charging wires 36 and the plurality of charging wires 37 lie in substantially common planes parallel to the strip 12 and that the common planes of the charging wires 36 and 37 are respectively spaced from the inner surfaces of the top wall 21 and the bottom wall 22 by distances greater than the spacing between such planes and the top and bottom surfaces of the strip 12. This relationship results in more efficient deposition of metal powder on the strip and reduces the possibility of free powder accumulating in the zone 14 and increases the period of continuous operations.

At the entry end 25 of the housing 20, a pair of discharge nozzles 65 and 66 are positioned above and below the strip 12, respectively. The discharge nozzles 65 and 66 extend through the entrance opening 26 into the zone 19 and preferably are positioned centrally of the longitudinal axis of the strip with their respective discharges directed into the deposition region 14 between the top surface of the strip and the charging wires 36, and between the bottom surface of the strip and the charging wires 37, respectively, generally in the direction of strip movement. As seen from FIGS. 2 and 3, the discharge nozzles 65 and 66 are flared outwardly in the direction of their discharge and their discharge ends 65a and 66a, respectively, have a transverse dimension approaching the width of the strip. The discharge nozzles 65 and 66 are fed by conduits 67 and 68, respectively, with a pressurized aerosol composed of metal powder and air or an inert gas, and emit a cloud of metal powder into the zone 14 between the top and bottom surfaces of the strip and the charging wires 36 and 37. The aerosol may be formed by a blower to which is fed a controlled supply of metal powder and inert gas or air. As shown in FIG. 1, a blower 69 having a metal powder hopper 70 feeds the conduit 67 and a blower 71 having a metal powder hopper 72 feeds the conduit 68.

At the exit end of the housing 20, conduits 75 and 76 communicate with the zone 19 on opposite sides of the strip and with a device 77 which functions to maintain a slight vacuum in the conduits 75 and 76. The device 77 preferably includes powder separating means for recovering excess metal powder withdrawn from the zone 19; the excess metal powder may be recycled to the hoppers 70 and 72 of the aerosol producing means. In the strip exit end 27 of the housing 20, pipes 78 and 79 are located above and below the strip within the portion 28 of reduced cross-sectional area and inwardly of the exit opening 29; the pipes extending transversely of the strip. The pipes 78 and 79 are provided with a plurality of discharge openings 80 extending along their length and each discharge opening faces in a direction toward the strip. The pipes 78 and 79 are fed with gas under pressure by conduit 81 and jets of gas from the discharge openings form a gaseous shield across the exit opening 29 above and below the strip to

minimize the flow of excess metal powder from the zone 19 through the exit opening.

The wetting device 13 includes a container 85 for water provided with a heating element 86. Conduits 87 and 88 communicate with the container and terminate adjacent the top surface 30 and the bottom surface 31 of the strip, respectively, valves 89 and 90 being provided for controlling the quantity of water applied. Downstream of the conduits 87 and 88, relative to the direction of movement of the strip, means, such as rolls 91 and 92, are located above and below the strip 12 for the purpose of removing excess water from both sides of the strip.

The compaction device 16 includes rolls 95 and 96 between which the strip passes. The compaction device may be of conventional construction and designed to effect a slight reduction of the strip material upon passing between the rolls, such as the order of 1 percent—4 percent. For a purpose that will be described below, the present invention provides a novel arrangement including brushes 97 and 98 associated with rolls 95 and 96, respectively. The brushes 97 and 98 are each mounted for rotation about an axis parallel to the axis of rotation of respective rolls 95, 96, and are rotated by means not shown, such as an electric motor, in a direction opposite the direction of rotation of the rolls 95, 96. The brushes 97 and 98 are of the bristle type and contact the rolls 95 and 96 throughout their transverse dimension. The bristles are of nonmetallic material and bristle brushes sold under the trade name "TAMPICO" have been found to be suitable for the purposes of the present invention.

In operation, chemically clean strip material from the coil 11 moves through the line at the desired speed. Upon passing through the wetting device 13, both sides of the strip material are wetted. An aerosol of powdered metal and air or an inert gas is fed by conduits 67 and 68 to the discharge nozzles 65 and 66 and a cloud of powdered metal is discharged into the zone 19, generally in the direction of strip movement, and into the deposition region 14 between the top surface 30 of the strip and the charging wires 36 and between the bottom surface 31 of the strip and the charging wires 37. High potential from the charging source 60 is applied to the charging wires 36 and 37 to produce corona about the charging wires and the resulting intense ionization of gas molecules about the charging wires produces a large number of ions. The ions of a polarity opposite that of the charging source are attracted to the charging wires and are neutralized, while ions of the same polarity as the charging source are repelled from the charging wires. Since the strip 12 is maintained at the opposite potential through the grounded connection 62, the high potential applied to the charging wires establishes an electrical field between the charging wires 36 and the surface 30 of the strip and between the charging wires 37 and the surface 31 of the strip. Ions of the same polarity as that of the charging source are propelled by the electrical fields in directions toward the surfaces of the strip. The particles of metal powder discharged from the nozzles 65 and 66 move into contact with the ions repelled from the charging wires and are charged by ion bombardment. The thus charged metal powder particles are propelled by the electrical fields in a direction toward and impinge upon and collect on the top surface 30 and on the bottom surface 31 of the strip. Such charging of the metal powder particles and deposition of the charged metal particles on the surfaces of the strip occurs substantially throughout the deposition region 14 defined generally by the carriage 35, and the strip, as it leaves the zone 19 through the exit opening 29, has deposited completely over its top surface and over its bottom surface an accumulation of metal powder particles of uniform thickness. The thickness of powder accumulation may be controlled by varying parameters of the process including strip speed and the rate of metal powder fed to the discharge nozzles. Particles of metal powder which are not charged or which are otherwise not deposited on the surfaces of the strip are swept from the zone 19 into the discharge conduits 75 and 76 by the flow of air into the entrance

opening 26 and through the zone 14 as a result of the suction maintained on the conduits 75 and 76. As mentioned above, the device 77 may function to separate particles of metal powder and the separated metal powder particles may be recycled in the system by metal powder conveyor means, not shown, for returning separated metal powder particles from the device 77 to the hoppers 70 and 72. The compressed air or inert gas fed to the conduits 78 and 79 and discharged from the openings 80 forms a gas shield across the exit opening to insure minimum escape of metal powder particles from the zone 19.

The sweeping action of the air which enters the opening 26 and flows through the zone 19 minimizes the accumulations of metal powder particles on the inside surfaces of the top, bottom and sidewalls defining the housing 20, on the carriage 35 and on the charging wires. Such sweeping action substantially completely precludes the formation of conductive paths by accumulation of metal powder particles that would effect shorting of the charging wires and interruption of the charging and deposition processes.

During the foregoing operation, the carriage 35, and hence the charging wires 36 and 37, may be continuously oscillated transversely of the path of movement of the strip 12 by alternately applying fluid pressure through conduits 53 and 54 to opposite sides of the hydraulic cylinder 51. Such transverse oscillating movement of the carriage 35 compensates for the existence of any nonuniformity of the electric field transversely of the strip 12 which could exist should metal powder particles accumulate nonuniformly along the charging wires, and makes it possible to deposit uniformly a predetermined thickness of metal powder particles, transversely and longitudinally of the strip, and eliminate imperfections in the coating surface, such as streaks running longitudinally of the strip. Oscillations at a rate of about 40 to 50 cycles per minute have been found to be adequate for these purposes. Although the arrangement including the block 46 and the fixed member 47 effects movement of the charging wires in a direction perpendicular to strip movement, the same result may be obtained by apparatus effecting oscillatory movement of the carriage about a fixed point.

The strip material carrying a uniform layer of deposited metal powder particles on its top surface 30 and on its bottom surface 31 leaves the zone 19 through the exit opening 29 and then passes through the heat treating furnace 15 wherein a temperature is maintained so that at least moisture is driven off the strip and deposited powder during passage through the furnace. Thereafter, the strip material is passed through the compaction device where the rolls 95 and 96 operate upon the deposited layers of metal powder particles to effect cohesion between the particles of metal powder and adhesion between the metal powder particles and the surfaces of the strip. During compaction, a slight reduction of the order of about 1 percent—2 percent of the metal strip may occur. The strip material leaves the compaction device 16 coated on both of its sides with the material of the metal powder, the coatings being uniform and completely overlying the surfaces of the strip and possessing excellent green strength. The strip may be fed directly to another line for further processing or may be fed to the coiling device 17 and formed in coil 18.

It has been determined from actual operating experience that the manner of effecting the wetting of the strip prior to the strip entering the electrostatic deposition region is critical to the obtaining of a uniform coating on the strip material with the reliability required for a commercial operation. In particular, it has been discovered that, when the strip is not wetted in accordance with the teachings of the present invention, powder metal particles frequently adhere to the rolls 95 and 96 when the strip is passed through the compaction device 16 and adherence of metal powder particles on the compaction rolls is cumulative making impossible the producing of a product with the reliability required for a commercial continuous line operation. In particular, it has been discovered that the quantity of wetting

agent in the water is critical and that, in order to obtain a continuous operation without metal powder adhering to the compaction rolls, the wetting agent should not exceed two grams per liter of water. It has been determined also that at least one-half gram of wetting agent per liter of water is ordinarily necessary and that the preferred range is about one-fourth gram to one gram per liter of water. Any commercially available wetting agents are useable such as sodium alkylarylsulfonate or polyoxyalkyl phenol. A solution of the critical quantity of wetting agent and water is placed in the container 85 and, by means of the heater 86, an adequate temperature is maintained to insure that the wetting agent remains in solution.

The bristle-type cylindrical brushes 97 and 98 function to maintain the surfaces of the compaction rolls 95 and 96 free of dust or extraneous particles which would tend to cause powdered metal particles to be pulled from the strip and adhere to the surfaces of the compaction rolls during the compaction step. The bristle brushes 97 and 98 have particular usefulness in preventing accumulation of powder on the regions of the rolls 95 and 96 adjacent the edges of the strip.

The embodiments of the invention shown in FIGS. 7 and 8 include novel concepts which make it possible to apply coatings of predetermined thickness on the surfaces of the strip material at high strip speeds as compared to the embodiment described above. The novel concepts are based on the discovery that metallic strip may be provided with a metal coating possessing a high order of cohesion and adhesion by electrostatically depositing in a controlled manner metal powder on strip on which there is already deposited a uniform coating of metal powder by electrostatic deposition without the necessity of any intervening process step such as wetting, heat treatment or compaction. Thus, in the embodiments of FIGS. 7 and 8, a plurality of deposition regions are provided through which the strip successively passes. Although in both embodiments two deposition regions are disclosed, it is to be expressly understood that any desired number of deposition regions in excess of two may be employed in each embodiment and, for a given coating thickness, the strip speed may be increased in accordance with the number of deposition regions employed.

The embodiment of FIG. 7 is similar to the embodiment of FIG. 1 except two electrostatic coating devices 100 and 101 are provided. Similar reference characters are used to identify corresponding elements and components of the additional electrostatic coating device are identified by primed reference characters. As seen from the drawing, the second coating device 101 is interposed in the path of movement of the strip between the first coating device 100 and the furnace 15. Thus, the strip 12 moves past the wetting device 13, through the deposition region 14 of the coating device 100, then through the deposition region 14' of the device 101 and on through the furnace 15 and the compaction device 16.

In operation, the coating devices 100 and 101 function in a manner similar to the coating device of FIG. 1 as described above. Thus, as the strip moves through the coating device 100, a first uniform accumulation of metal powder is deposited on both its top and bottom surfaces. Then, as the strip moves through the coating device 101, a second uniform accumulation of metal powder is deposited over the first accumulation, both on the top and bottom surfaces of the strip. The strip with the first and second accumulations of metal powder moves through the furnace 15 wherein a temperature is established to at least dry the strip and is then passed through the compaction device 16. The thickness of the coating may be determined by controlling the parameters of one or more of the charging devices such as by varying the rate of powder feed to the blowers. The final coating possesses the same order of cohesion and adhesion as obtained by the embodiment of FIG. 1 and, for a given coating thickness, the strip moves through the embodiment of FIG. 7 at approximately twice the strip speed of the embodiment of

FIG. 1 and further increases in strip speed may be obtained by employing additional coating devices.

In the embodiment of FIG. 8, the strip material successively moves through a plurality of electrostatic deposition regions; however, the electrostatic deposition regions are located in a common zone provided with an inlet end and an outlet end. As shown, the apparatus includes carriages 35 and 35', similar to the carriage 35 of FIG. 1, providing deposition regions 14 and 14' through which the strip is successively passed in its movement from the wetting device 13 onto the heating furnace 15 and the compaction mill 16. The deposition regions 14 and 14' are fed with an aerosol of metal powder and a carrier gas through nozzles 65, 66 and 65', 66', respectively, and the nozzles are connected to sources of the aerosol in the manner of the FIG. 1 embodiment. The apparatus also includes an elongated housing 105 constructed of electrically insulating material and providing an elongated passageway or zone 106 within which is located the carriages 35 and 35'. The housing 105 has an enlarged entrance opening 107 at the entry end of the strip into the zone 106 and at its exit end beyond the carriage 35' in the direction of strip movement the housing includes a portion 108 of decreasing cross-sectional area terminating in an exit opening 109 of reduced size in the manner of the embodiment of FIG. 1. Conduits 110, only one of which is shown, communicate with the zone 106 on opposite sides of the strip adjacent the exit opening 109 and lead to a vacuum producing means and dust collector, not shown, which may be similar to the device 77 of FIG. 1. The carriages 35 and 35' are supported in a manner similar to the support of the carriage 35 of FIG. 1; an opening 111 being provided in the housing 105 for passage of the support member 46' in out-of-contact relation with the housing to outside the zone 106 into engagement with the block 47'. The opening 111 is of sufficient size and is shaped to permit oscillating movement of the carriage 35' without contact between the housing and the member 46'. If desired, the exit opening may be provided with a gas-type seal similar to the arrangement at the exit end 29 of the housing of FIG. 1.

The embodiment of FIG. 8 operates in a manner similar to the embodiment of FIG. 7, as described above, except with respect to the flow of auxiliary gas and the removal of excess metal powder. The auxiliary gas, i.e., air in the embodiment as shown, enters the entrance opening 107 of the housing 105 and flows in the direction of strip travel substantially throughout the passageway 106, past the carriage 35 and the carriage 35', under the influence of the vacuum produced by the device connected to the conduits 110. Such flow of the auxiliary gas prevents the accumulation of metal powder on the inside wall surfaces of the housing 105 and on the structure of the carriages 35 and 35' and sweeps metal powder that is not deposited on the surfaces of the strip through the passageway 106 and from the passageway 106 through the conduits 110.

Apparatus embodying the principles of the invention in the form of the embodiment of FIGS. 1-6 has been successfully operated to continuously coat steel strip under conditions of a commercial operation in accordance with the following examples:

EXAMPLE I

Powder Aluminum
Powder size Mean mass particle size of 18 micron
Strip gauge 0.013 inch
Strip width 6 inches
Strip speed 10 feet per minute
Powder flow rate:
To top surface of strip 37 grams per minute
To bottom surface of strip 63 grams per minute
Charging potential 20 Kv.
Wetting agent 1 gram per liter of water
Temperature of strip from furnace 250° F.
Reduction at compaction mill 2 percent
Coating thickness after compaction:

Top surface 1.2 mil.
Bottom surface 1.2 mil.

EXAMPLE II

Powder -Chromium
Powder size -200 mesh
Strip gauge 0.02 inch
Strip width 6.75 inches
Strip speed 10 feet per minute
Powder flow rate:
To top surface of strip 175 grams per minute
To bottom surface of strip 200 grams per minute
Charging potential 20 Kv.
Wetting agent 1 gram per liter of water
Temperature of strip from furnace 300° F.
Reduction at compaction mill 2 percent
Coating thickness after compaction:
Top surface 0.6 mil.
Bottom surface 0.6 mil.

EXAMPLE III

Powder Alloy: 70 percent chromium, 30 percent iron
Powder size -150 mesh
Strip gauge 0.020 inch
Strip width 6.75 inches
Strip speed 10 feet per minute
Powder flow rate:
To top surface of strip 175 grams per minute
To bottom surface of strip 200 grams per minute
Charging potential 20 Kv.
Wetting agent 1 gram per liter of water
Temperature of strip from furnace 300° F.
Reduction at compaction mill 2 percent
Coating thickness after compaction:
Top surface 0.6 mil.
Bottom surface 0.6 mil.

EXAMPLE IV

Powder Chromium
Powder size -200 mesh
Strip gauge 0.02 inch
Strip width 6.75 inches
Strip speed 50 feet per minute
Powder flow rate:
To top surface of strip 200 grams per minute
Charging potential 20 Kv.
Wetting agent 1 gram per liter of water
Temperature of strip from furnace 300° F.
Reduction at compaction mill 2 percent
Coating thickness after compaction:
Top surface 0.15 mil.

The coated steel strip produced by each of the foregoing examples was found to possess a coating of the material of the powder possessing good coherence and adherence and of uniform thickness over the strip surface. During operation of the apparatus in accordance with each example, there was no appreciable accumulation of metal powder within the zone defined by the housing or on the carriage means within the zone and the operation was in no way inhibited by electrical shorting of the charging system.

The novel methods and apparatus provided by the present invention may be used with a wide variety of metal powders including, by way of example, aluminum, cadmium, chromium, cobalt, copper, lead, nickel, platinum, titanium, tin, tantalum, tungsten, vanadium, zinc, and zirconium. Additionally, alloys including one or more of the foregoing metals may be used. The alloys may include brass, bronze, stainless steel, Monel, high chromium ferrous alloys such as an alloy containing 70 percent chromium and 30 percent iron, zinc-iron alloys such as an alloy containing 70 percent zinc and 30 percent iron, and aluminum-manganese alloys, such as an alloy containing 10-70 percent manganese and the remainder aluminum together with incidental impurities.

Furthermore, mixtures of powders of one or more of the foregoing metals or alloys may be used. Presently preferred coating metals include aluminum, alloys of aluminum, chromium, and chromium-iron alloys and zinc and zinc-iron alloys, all of which have special utility in the manufacture of container stock. The particle size of the metal powders is sufficiently small as to be suspended in a stream of air or inert gas and deposited on the surface of metallic strip under the influence of an electrostatic field. Particle sizes as great as -150 mesh, comprising a maximum particle size of about 105 microns and a mean mass particle size of from 60 to 80 microns, have been successfully used. Metallic powders of sizes commercially available, of mean mass particle size of from 15 to 80 microns, may be used in practicing the invention.

The coated product produced by the several embodiments of the present invention may be further processed chemically or by heat treatment in a continuous operation directly from the compaction mill or in coil form. The temperature to which the strip is raised by the precompaction heat treating furnace may be increased as may be required for such further processing. Thus, the present invention contemplates processes in which the temperature of the coated strip prior to the compaction step may be raised to temperatures higher than the temperatures necessary to drive off moisture from the strip.

It is to be understood that the gaseous carrier forming the aerosol of metal powder may comprise air or an inert gas. Also, the auxiliary gas flowed into the entrance opening and through the charging zone may comprise air, as described above, or an inert gas. When the auxiliary gas comprises an inert gas, an inert gas supply duct would be attached to the opening 25, 25' or 107 of the housing 20, 20' or 105, respectively, and the discharge nozzles would pass through a wall of the supply duct with its discharge opening located within the supply duct and positioned relative to the entrance opening of the zones generally in the manner shown in the drawings.

Accordingly, it is to be understood that the foregoing description including the specific examples is for the purpose of description only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

We claim:

1. Apparatus for applying a coating of metal on metallic strip comprising:

an elongated housing of nonelectrically conductive means having an entrance opening and an exit opening and defining an elongated passageway extending between the entrance opening and the exit opening,

means for continuously moving metallic strip through the passageway of the housing along a path in a direction from the entrance opening to the exit opening and in out-of-contact relation with the nonelectrically conductive means,

carriage means located in the passageway between the entrance opening and the exit opening and in out-of-contact relation with the nonelectrically conductive means,

support means for supporting the carriage means, the support means being in out-of-contact relation with the nonelectrically conductive means of the housing,

a plurality of charging wires supported by the carriage means, the charging wires being spaced longitudinally of the passageway in the direction of movement of the metallic strip through the passageway and extending transversely of the path of the metallic strip through the passageway,

a charging circuit for the charging wires including the metallic strip and a source of charging potential connected to the charging wires,

means for introducing a cloud of metal powder into the entrance opening of the passageway generally in a

direction of the movement of the strip through the passageway, and

means for withdrawing metal powder at a point contiguous to the exit end of the passageway.

2. Apparatus for applying a coating of metal on metallic strip as defined in claim 1

wherein: the support means for supporting the carriage means is located at a point outside the passageway defined by the elongated housing.

3. Apparatus for applying a coating of metal on metallic strip as defined in claim 1 including:

means for oscillating the carriage means to move the charging wires transversely of the path of movement of the metallic strip through the passageway.

4. Apparatus for applying a coating of metal on metallic strip as defined in claim 1 including:

a compaction mill comprising a pair of metal compacting rolls,

means for passing the metallic strip from the passageway to the compaction mill and between the rolls thereof, and bristle brushes rotating in contact with the rolls.

5. Apparatus for applying a coating of metal on metallic strip including:

means for wetting metallic strip with liquid,

a plurality of carriage means,

support means supporting the plurality of carriage means in successive relationship,

means for continuously moving metallic strip through the wetting means and then successively through the plurality of carriage means,

each carriage means supporting a plurality of charging wires extending transversely of the direction of movement of the metallic strip and spaced from each other in the direction of movement of the metallic strip,

a charging circuit for the charging wires of each carriage means including the metallic strip and a source of potential connected to the charging wires,

means for introducing an aerosol of metal powder and a carrier gas to between the metallic strip and the charging wires of each carriage means generally in the direction of movement of the metallic strip,

a metallic strip heating furnace and a metallic strip compaction mill, and

means for moving the metallic strip from the carriage means through the heating furnace and then through the compaction mill.

6. Apparatus for applying a coating of metal to metallic strip as defined in claim 5 in which the support means includes:

nonelectrically conductive material separately supporting each carriage means at a singular point of support.

7. Apparatus for applying a coating of metal to metallic strip as defined in claim 6 including:

means for oscillating each of the carriage means to move the charging wires transversely of the path of movement of the metallic strip through the carriage means.

8. Apparatus for applying a coating of metal to metallic strip as defined in claim 5 including:

an elongated housing of nonelectrically conductive means defining an elongated passageway enclosing the plurality of carriage means in out-of-contact relation with the carriage means and the metallic strip,

the support means for the carriage means being in out-of-contact relation with the nonelectrically conductive means of the housing,

the elongated housing having an entrance opening and an exit opening and the metallic strip moving through the passageway in a direction from the entrance opening to the exit opening, and

means for withdrawing excess metal powder at a point contiguous to the exit opening of the housing.

9. Apparatus for applying a coating of metal to metallic strip as defined in claim 8 including:

means for introducing auxiliary gas into the entrance opening of the housing, and

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means for withdrawing auxiliary gas at a point contiguous to the exit opening of the housing.

10. Apparatus for applying a coating of metal to metallic strip as defined in claim 8 in which the support means for each of the plurality of carriage means includes:

nonelectrically conductive means in out-of-contact relation with the housing joined to a rigid support located outside the passageway.

11. Apparatus for applying a coating of metal to metallic strip as defined in claim 5 including:

a plurality of elongated housing means of nonelectrically conductive means each having an entrance opening and an exit opening and each defining an elongated passageway extending between the entrance opening and the exit opening,

each elongated housing means enclosing one carriage means in out-of-contact relation with the nonelectrically conductive means,

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the support means for each of the carriage means being in out-of-contact relation with the nonelectrically conductive means of the respective housing means, and means for withdrawing excess metal powder at a point contiguous to the exit opening of each housing means.

12. Apparatus for applying a coating of metal to metallic strip as defined in claim 11 including:

means for introducing auxiliary gas into the entrance opening of each housing means, and

means for withdrawing auxiliary gas at a point contiguous to the exit opening of each housing means.

13. Apparatus for applying a coating of metal to metallic strip as defined in claim 11 in which the support means for each carriage means includes:

nonelectrically conductive means in out-of-contact relation with respective housing means joined to a rigid support located outside the passage of respective housing means.

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