

May 26, 1970

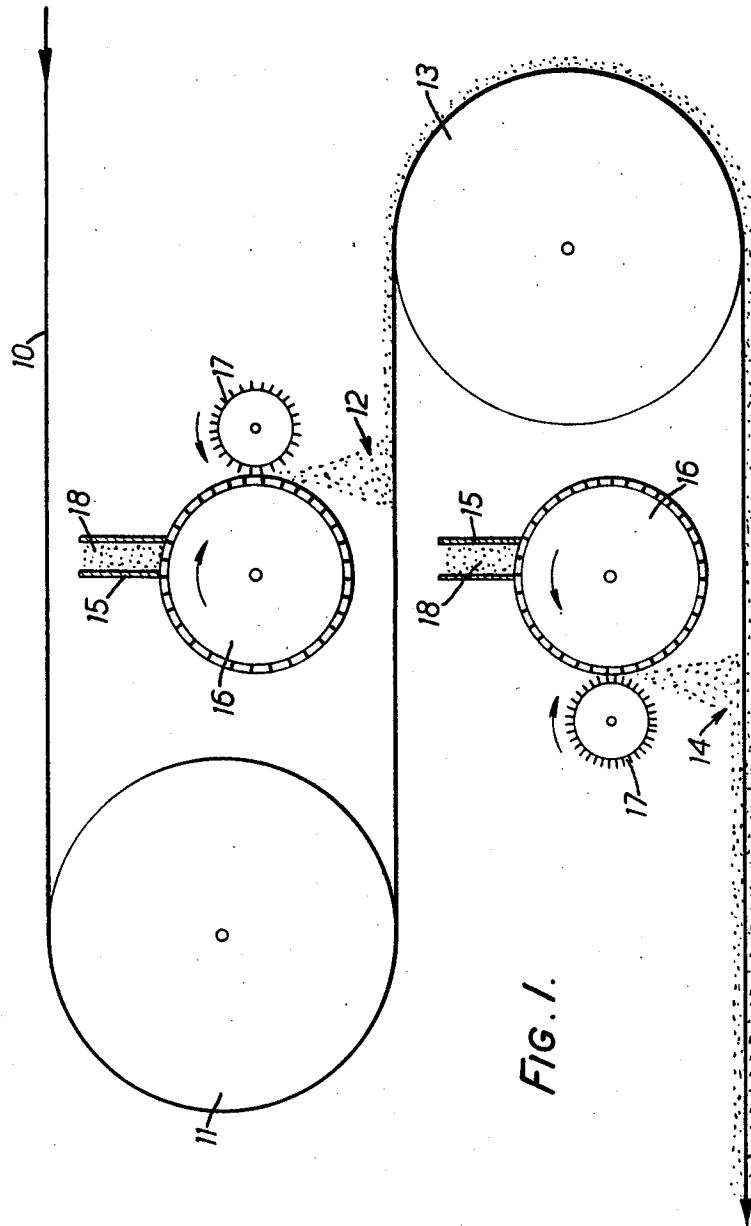
A. E. JACKSON

3,513,810

FORMATION OF COATINGS

Filed June 8, 1964

4 Sheets-Sheet 1



INVENTOR
A. E. JACKSON
BY
Holcombe, Wetkeill & Bricebois
ATTORNEYS

May 26, 1970

A. E. JACKSON
FORMATION OF COATINGS

3,513,810

Filed June 8, 1964

4 Sheets-Sheet 2

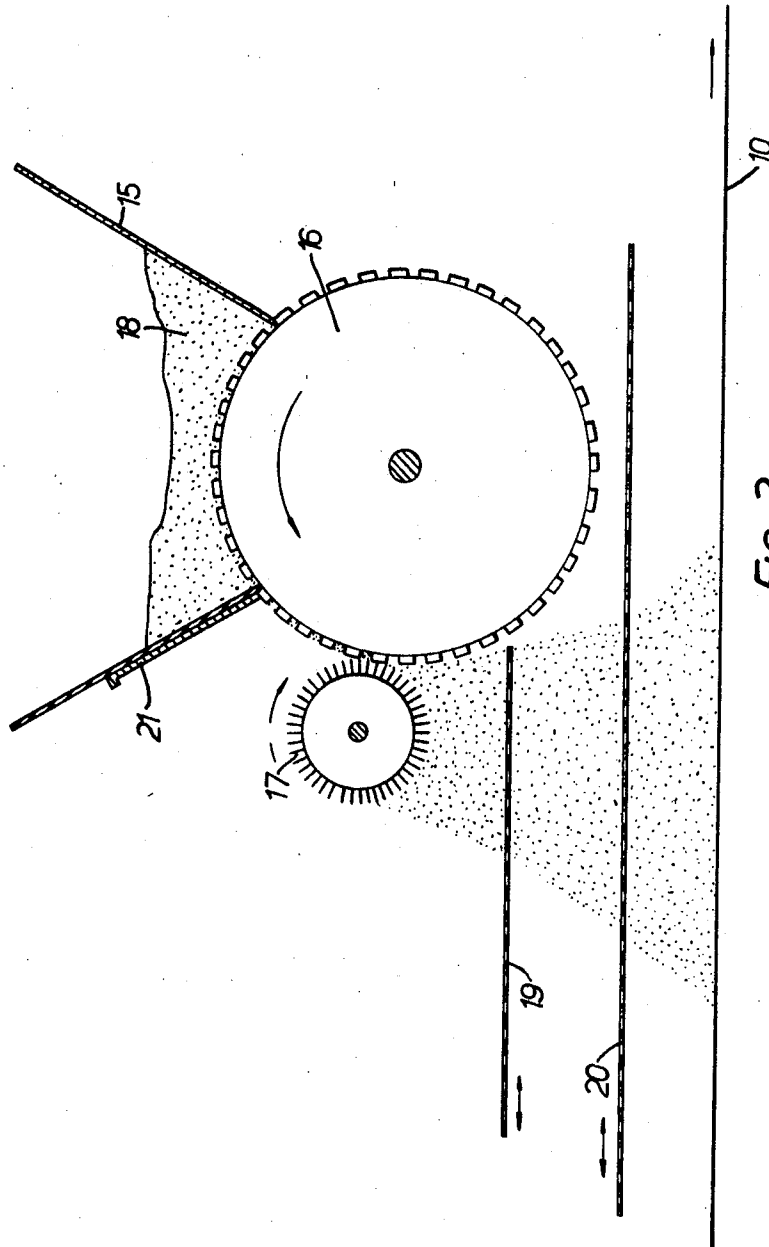


FIG. 2.

INVENTOR
A. E. JACKSON
BY
Halcone, Wetzel & Brinkman
ATTORNEYS

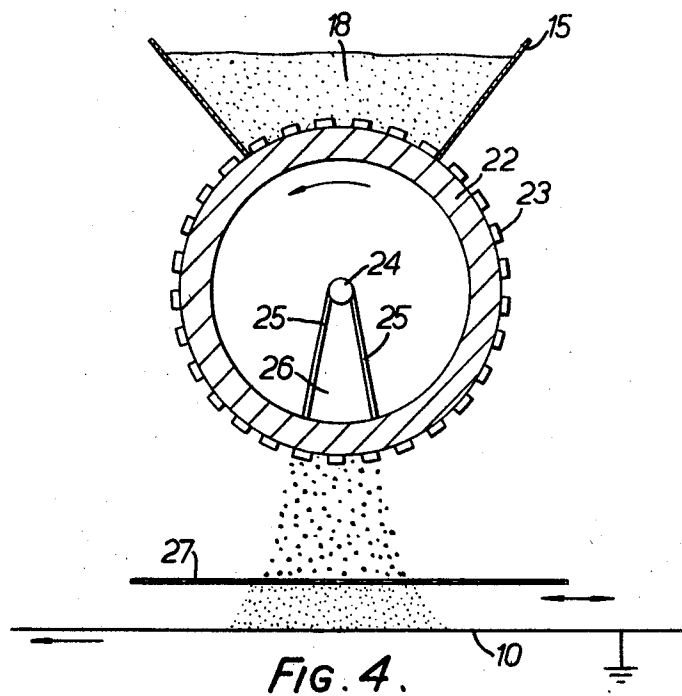
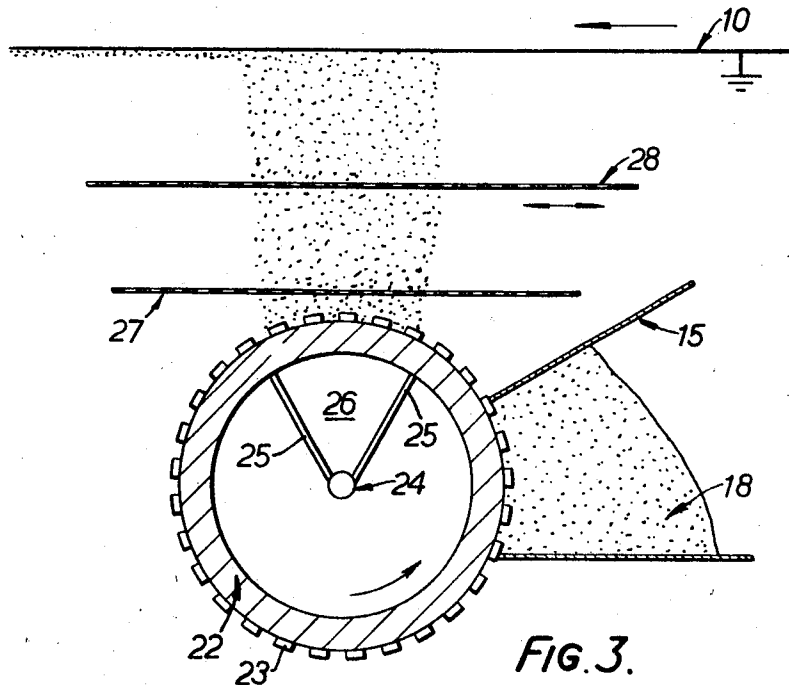
May 26, 1970

A. E. JACKSON
FORMATION OF COATINGS

3,513,810

Filed June 8, 1964

4 Sheets-Sheet 3



INVENTOR
A. E. JACKSON
BY
Holcombe, Wetherill & Briscoe
ATTORNEYS

May 26, 1970

A. E. JACKSON
FORMATION OF COATINGS

3,513,810

Filed June 8, 1964

4 Sheets-Sheet 4

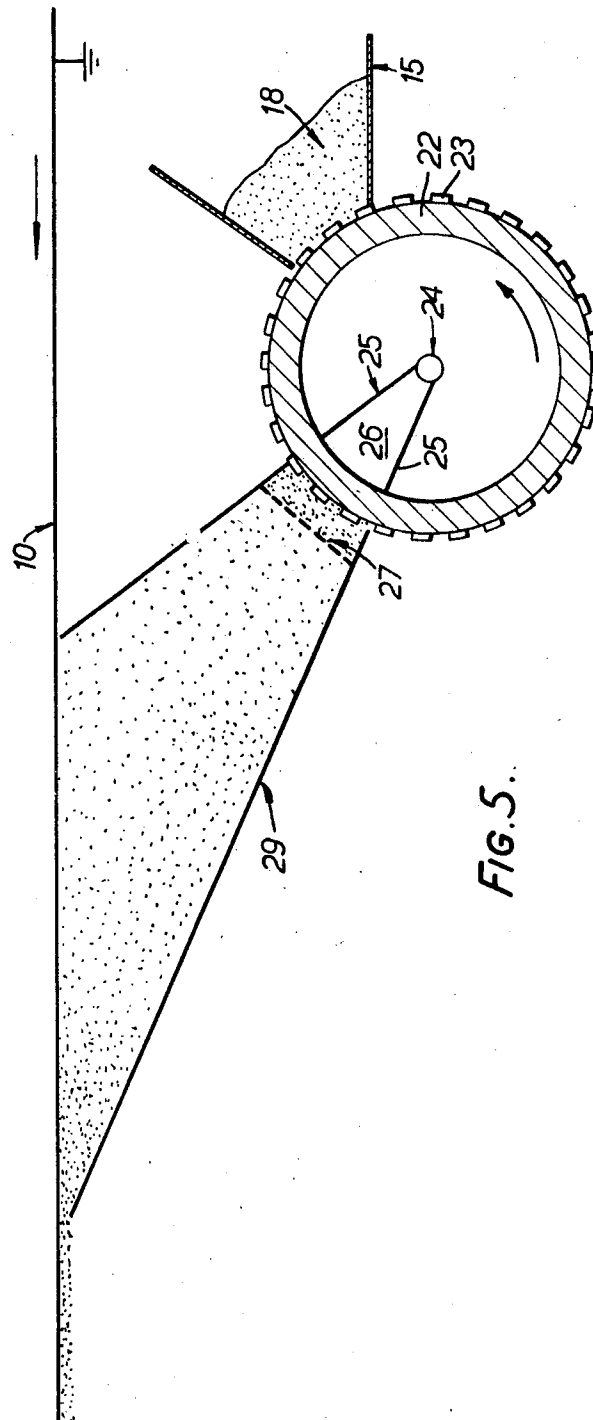


FIG. 5.

INVENTOR
A. E. JACKSON
BY
Holcombe, Westkott & Bricebois
ATTORNEYS

1

3,513,810

FORMATION OF COATINGS

Albert Edward Jackson, Killay, Swansea, Wales, assignor
to The British Iron and Steel Research Association

Filed June 8, 1964, Ser. No. 373,282

Int. Cl. B05b 5/00

U.S. Cl. 118—629

6 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for depositing a coating of a powder onto a moving metal strip comprising a metering roll, a powder container for supplying powder to the metering roll, a pressurized gas outlet in the interior of the roll for blowing gas through the roll to remove powder from the depression in the roll and direct it towards the strip to be coated and a screen which can be electrically charged with respect to the strip positioned in the path of the powder passing from the metering roll to the strip.

This invention is concerned with the formation of coatings by powder deposition on a substrate.

Metal sheet materials having a coating on one or both surfaces thereof of another metal or alloy, a metal oxide or a plastics material are required for many purposes. The present invention is concerned with a process for the production of such coated metal sheet materials in which a layer of powdered material, which is to form the eventual coating, is deposited on a metal strip and is subsequently rendered coherent in itself and adherent to the metal strip, for example by compaction followed by sintering. In order to obtain satisfactory coatings by such a process it is essential that the powder coating should be substantially completely uniform, i.e. in terms of weight of powder per unit area of the surface of the substrate and the devices at present available for applying powder coatings to strip materials do not enable powder coatings of a satisfactory degree of uniformity to be obtained.

It is therefore an object of the present invention to provide an improved apparatus for depositing a coating of a powder on a moving strip.

According to the present invention we provide apparatus for depositing a coating of a powder on a moving metal strip, which comprises a rotatable metering roll having a length at least equal to the width of the strip to be coated and provided, on its curved surface, with depressions which are uniformly distributed over said surface, a container for powder having a powder outlet arranged to supply powder to said depressions along the length of the roll, means for removing powder from the curved surface of the roll surrounding the depressions, and means for removing the powder from the depressions in the roll and depositing it on the surface of the metal strip.

The uniformity of the powder coating obtainable by use of this apparatus is due to the uniform distribution of the depressions on the curved surface of the metering rolls and while these depressions can be formed by machining, it is preferred to use a metering roll which consists of a smooth surfaced roll, the curved surface of which is covered with a conforming sheet of uniformly perforated metal, such as perforated zinc, the perforations forming the depressions in the metering roll.

The particle size of the powder deposited with this apparatus will depend upon the coating thickness required and for a given apparatus, the range of particle sizes which can be handled will depend on the size of the depressions, that is the perforations where perforated metal forms the surface of the metering roll. By way of example, powder having a particle size range of from 5 to 50

2

microns can be successfully handled with a metering roll covered with perforated zinc having 2 mm. diameter perforations and nine perforations to the inch.

The powder container is preferably a hopper of conventional construction having two long walls, the lower (or inner) edges of which extend along and bear against the curved surface of the metering roll and define the powder outlet. The lower edge of the downstream hopper wall (downstream, that is, in terms of the direction of rotation of the metering roll, in operation) acts as a wiper to remove powder from the curved surface of the metering roll which surrounds the depressions therein. To facilitate the removal of powder from the roll surface, said lower edge may be formed of or covered with a material having a low coefficient of friction with the roll, such as polytetrafluoroethylene. Alternatively a separate wiper extending the length of the roll and position adjacent or contiguous the downstream hopper wall, and preferably formed of such a material, may be provided.

In one embodiment of the invention, the means for removing the powder from the depressions in the metering roll is a rotatable cylindrical brush, the axis of which is parallel to that of the metering roll and separated therefrom a distance such that the bristles of the brush can just reach the bottom of the depressions.

In another embodiment, the metering roll is a hollow cylinder formed of a material which is permeable to gas, but not to the powder, such as sintered bronze, and the interior of the metering roll is provided with an inlet for gas under pressure and with stationary baffles which bear against the interior surface of the cylinder and which are so positioned as to direct a gas stream emanating from the gas inlet through only a part of the curved surface of the cylinder and towards the strip to be coated, and at least one screen which can be electrically charged with respect to the strip, i.e. so that there is a potential difference between the screen and the strip, is positioned in the path of powder passing from the metering roll to the strip. On passing through the screen, the powder particles become electrostatically charged and are directed towards the strip. With this arrangement, the strip is conveniently earthed and the screen is charged with a positive or negative potential. The metering roll may be either charged or earthed; in the former case, the metering roll should be charged to a higher potential than the screen and if there is more than one screen, there should be a progressive decrease in the potential to which each screen is charged so that the screen nearest the strip (which is earthed) is at the lowest potential.

Where both the strip and the metering roll are earthed, the screen or screens should be nearer the strip than the metering roll so that the field strength between the screen(s) and the strip will be higher than that between the screen(s) and the metering roll; this has the effect of minimising the tendency for the powder particles to deposit on the metering roll once they have been charged by the screen.

The embodiment using a gas stream and electrostatic charging to remove the powder from the depressions in the metering roll and to deposit it on the strip has the advantage of being somewhat more compact than the embodiment which includes a rotatable brush and is also preferred where the powder to be deposited tends to agglomerate. Agglomeration of the ultimate particles of the powder to form larger particles or agglomerates may be caused by a variety of physical phenomena and is commonly due to the presence of a small amount of moisture in the powder which, in turn, may be due to the powder absorbing water vapour from the atmosphere. In the case of powders of this type, the agglomerates disintegrate into the ultimate particles as the powder passes

3

through the charged screen. It is not, therefore, necessary to dry the powder thoroughly when using this embodiment of the invention.

We have found that a further improvement in the uniformity of the coating can be obtained by passing the powder through one or more vibrating screens positioned between the metering roll and the strip. In the case of the embodiment including an electrically charged screen, the latter can be vibrated.

In order that the invention may be more fully understood, some preferred embodiments of powder depositing apparatus will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic vertical section through a first embodiment;

FIG. 2 is a similar view of a second embodiment;

FIG. 3 is a similar view of a third embodiment;

FIG. 4 is a similar view of a fourth embodiment; and

FIG. 5 is a similar view of a fifth embodiment.

FIG. 1 shows an arrangement for forming a powder coating on both sides of a metal strip. The strip 10 is passed round a deflector roll 11 which deflects the strip through an angle of 180° and is then passed to the first powder deposition station indicated generally by the reference 12. The coated strip is then passed round a further deflector roll 13 which deflects the strip through an angle of 180° and the other side of the strip is then coated at a second powder deposition station indicated generally by the reference 14.

In the arrangement shown the strip is arranged to pass horizontally through each powder deposition station and the deflector rolls are employed in a manner which avoids contact between the coating and the deflector rolls.

Each powder deposition assembly comprises a powder hopper 15, a metering roll 16 and a cylindrical brush 17. An amount of powder 18 is introduced to the hopper 15 and the metering roll 16 is rotated at a speed which is dependent upon the quantity of powder which is to be deposited upon the strip 10. The metering roll consists of a smooth surfaced roll, the curved surface of which is covered with a closely conforming sheet of uniformly perforated metal, such as perforated zinc. The lower edge of the downstream wall of the hopper 15 serves as a wiper to remove powder from the surface of the metering roll surrounding the holes in the perforated metal.

The brush 17 is rotated in the opposite sense to the rotation of the metering roll and serves to remove the powder from the perforations in the material covering the metering roll and to propel it, under the influence of gravity, towards the strip.

The apparatus shown in FIG. 1 has been found particularly suitable for depositing aluminium and nickel powders, although it would be suitable for depositing other powders. The apparatus may be used for depositing powdered plastics material and, in this case, the perforations in the surface of the metering roll should be made larger and deeper to take account of the larger particle size of the powder.

The apparatus described above employing perforated zinc on the metering rolls 16 was found to give excellent uniformity of distribution of powder across the width of a 5 inch strip and the variation in the powder delivery rate per revolution on the metering roll varied by only 8%. We have found that powder coatings up to 0.002 inch thick of aluminium are sufficiently adherent to remain on the underside of the strip even when the strip is subjected to a moderate amount of vibration.

An improvement in the uniformity of the powder coating can be obtained by using the apparatus shown in FIG. 2. This is generally similar to that shown in FIG. 1, but comprises a separate wiper 21, preferably formed of polytetrafluoroethylene, to keep the metering roll surface clean, and also comprises two screens 19 and 20 which are provided with means for vibrating them in their own

4

planes. These screens are suitably 15 mesh, i.e. have 15 openings to the inch.

A further embodiment, arranged for the coating of the underside of a metal strip, is shown in FIG. 3. In this case the metering roll consists of a hollow cylinder 22 formed of a material which is permeable to gas, but not to the powder, such as sintered bronze, the curved surface of which is covered with a closely conforming sheet of uniformly perforated metal 23. Bearing on the metering roll is a hopper 15 containing powder 18 as in the previously described embodiments. Axially positioned within the cylinder 22 is an apertured pipe 24 connected to a source of compressed air and extending from the pipe 24 to the interior surface of the cylinder are stationary baffles 25 which define a sector of the cross-section of the cylinder which constitutes an air chamber 26. Positioned between the metering roll and the strip 10 are screens 27 and 28, the screen 28 being provided with means for vibrating it in its own plane. The metering roll and the screens 27 and 28 are electrically connected so that there is a potential difference between them and the strip, which is earthed (the charge on the roll and the screens may be positive or negative but must, of course, be of the same sign for all three). There is a progressive decrease in potential from the metering roll to the screen 28; a preferred graduation of the potential is for the metering roll to be at a potential of x kv., the screen 27 a potential of $\frac{4}{5}x$ kv., and the screen 28 a potential of $\frac{1}{5}x$ kv. Suitable values for x will depend upon the separation between the screen 28 and the earthed strip; by way of example when the distance from the screen 28 to the strip was 1.5 cms., suitable potentials for the metering roll were from 15 to 20 kv., the corresponding values for the screens 27 and 28 being, respectively, from 12 to 16 kv. and from 3 to 4 kv.

In operation, as the metering roll rotates through the hopper of powder, the perforations become filled and any excess is removed by the lower edge of the downstream hopper wall. As the roll passes over the air chamber 26, the powder is blown out of the perforations by the air stream emanating from the pipe 24 and on striking the electrically charged screen 27 immediately above the roll, disintegrates into discrete particles. Under the influence of the electrostatic field applied between the earthed strip and the screens 27 and 28, the particles pass up through the vibrating screen 28 and deposit as individual particles on to the strip.

Because of its very compact nature, the apparatus shown in FIG. 3 is particularly suitable where there are to be several metering rolls depositing on the same side of the strip. This would be the case where stratified or ply coatings, i.e. coatings made up of layers of different materials, are being applied or even when depositing different particle size power of the same material.

It will be apparent that this apparatus can equally well be used where the strip is passing under the metering roll, i.e. the air chamber can be positioned at the bottom of the metering roll. This arrangement is advantageous where a mixed powder of widely differing densities is to be deposited from a single metering roll to form an alloy coating.

An apparatus arranged to operate in this way is shown in FIG. 4; this apparatus is generally similar to that shown in FIG. 3 but comprises only one screen, 27, which is vibrated in its own plane. The electrical connections are also different; both the metering roll and the strip are earthed and the screen 27 is at a positive or negative potential with respect to the metering roll and the strip. The distance between the screen 27 and the strip is less than the distance between the screen and the metering roll so that the field strength between the screen and the strip is higher than that between the metering roll and the screen.

The following description of a typical coating process

5

carried out with apparatus as shown in FIG. 4 is given by way of illustration only.

The strip to be coated was low carbon steel strip 5 inches wide which was passed at a rate of 20 ft./minute beneath the powder depositing apparatus. The metering roll of the apparatus consisted of a sintered bronze cylinder with an average pore size of 12 microns, the curved surface of which was covered with a closely conforming sheet of perforated zinc having 2 mm. diameter round holes spaced so as to give nine perforations to the inch. The power to be deposited was aluminium powder having a particle size range of from 5 to 50 microns.

The screen was 15 mesh and was vibrated in its own plane. It was charged to a potential of 20 kv., while the metering roll and the strip were both earthed. The distance between the metering roll and the screen was 13 cm. and that between the screen and the strip was 4 cm., so that the field strength between the roll and the screen was 1.5 kv./cm. and the field strength between the screen and the strip was 5 kv./cm.

The metering roll was rotated at 3 r.p.m. and the perforations were completely cleared of powder by supplying air to the chamber 26 at a rate of 0.6 cu. ft./minute and a pressure of 40 lbs./sq. in. An aluminium coating of 0.001 inch thickness was formed on the strip.

When it is desired to deposit very thin coatings using a fine powder, that is one having a particle size of 10 microns or less, the air suspension of the powder passing towards the strip must be much more dilute than when a coating of greater thickness is formed. Because of the dilution and the small particle size, there is a greater tendency for the powder particles to escape from the electrostatic field and in the embodiment shown in FIG. 5, which is designed for the deposition of thin coatings of fine powders, the powder particles are physically restrained from escaping the electrostatic field.

The embodiment shown in FIG. 5 is generally similar to that shown in FIG. 3 but additionally comprises a hood 29 which extends from the metering roll to the strip 10. One end of the hood bears against the metering roll and has an opening corresponding in size to the air chamber 26, whilst the other end is closely adjacent, but does not touch, the under surface of the strip 10. A single charged screen, 27, is used in this case, the screen being positioned within the hood 29.

The apparatus according to the invention can, of course, be employed for the deposition of powder mixtures which can subsequently be treated to form alloy coatings; in this respect the invention enables coatings to be formed which cannot be formed by electrodeposition.

In addition to the application of powder mixtures to provide alloy coatings, it is also possible to arrange a number of deposition stations in cascade so that two or more layers of powder of different compositions can be deposited. Examples of the application of such a cascade arrangement are the deposition of a layer of alumina or oxide pigment particles on a primary coating of aluminium, zinc, tin or nickel, for example, in order to impart colour or scratch resistance. Also, layers of different metal powders can be applied, such as a thin layer of aluminium applied to a steel substrate followed by zinc and then alumina or aluminium, the aluminium coating adjacent the steel substrate preventing the growth of iron zinc alloy which would establish a weak plane in the coating.

A convenient way of compacting the powder is by means of vibration and in this connection it is desirable to deposit mixtures of powders of selected particle size which will give the greatest density. A cascade arrangement of deposition stations is particularly suitable. It has been shown that a mixture of spheres of diameter ratios 1.7:38:316 and a corresponding volume composition 6.1:10.2:23.0:60.7% will pack to a density of 95.1% of solid when vibrated.

After the powder has been deposited and the coating, if

6

desired, compacted, for example, by vibration, the coated substrate may be passed to a compacting mill. The apparatus described is particularly suitable for arranging in line with a compacting mill.

It is advantageous in some cases, for example where nickel or a nickel alloy, such as a Fe/Ni or Fe/Ni/Cr alloy, is being deposited, to heat the strip after depositing powder on it and to effect compaction of the powder coating by rolling while the coated strip is still at an elevated temperature. The coated strip is suitably heated to a temperature of from 100° to 150° C. for this purpose and rolling is suitably carried out while the strip is within this temperature range.

As an example of effecting compaction with the coated strip at an elevated temperature, annealed low carbon steel strip was coated with nickel powder, heated to a temperature of 150° C., and passed through compacting rolls which applied a load of 15 tons/inch width. The compacted nickel coating had a thickness of 0.00275 inch. The coated steel was then coiled and the coating sintered at a temperature of 700° C. for 5 hours to given an extremely adherent coating. By effecting the compaction at elevated temperature it was found that there was no tendency for the nickel coating to delaminate either as the coated strip came away from the compacting rolls or when the strip was coiled.

As has been indicated above, the treatment of the coated strip after the powder has been deposited thereon in order to render the coating coherent in itself and adherent to the strip will, in general, comprise the steps of hot or cold rolling and sintering, compaction by vibration and/or heating being optionally effected before rolling. Suitable rolling pressure will, of course, depend on the nature of the coating. For nickel and nickel alloy coatings, rolling loads of from 12 to 15 tons per inch width are suitable and loads of about 4 tons per inch width are suitable for aluminium and zinc coatings. Suitable sintering temperatures will also depend on the nature of the coating; in the case of metal and metal oxide coatings there will usually be the choice of a long sintering treatment at a relatively low temperature or a short treatment at a higher temperature. For example, nickel and nickel alloy coatings can be sintered at 700° C. in 5 hours or at 1000° C. in 2 minutes; aluminium coatings can be sintered at 250° C. in from 10-15 hours, at 500° C. in 30 minutes or at 600-650° C. in a few seconds; and zinc coatings can be sintered at 350° C. in about 30 minutes. If a sufficiently high sintering temperature is employed, the sintering time can be kept sufficiently short for sintering in line to be economically justified; in this case the whole of the process from uncoated substrate material to the finished coated material ready to use can be carried out continuously.

What is claimed is:

1. Apparatus for depositing a coating of a powder on a moving metal strip, which comprises:

(A) a rotatable metering roll which is a hollow cylinder formed of a material which is permeable to gas, but not to the powder, the roll having a length at least equal to the width of the strip to be coated and being provided, on its curved surface, with depressions which are uniformly distributed over said surface;

(B) a container for powder having a powder outlet arranged to supply powder to said depression along the length of the roll;

(C) means extending along and bearing against the curved surface of the metering roll for removing powder from the curved surface of the roll surrounding the depressions;

(D) an inlet means for gas under pressure in the interior of the metering roll and stationary baffles which bear against the interior surface of the cylinder and which are so positioned as to direct a gas stream emanating from the gas inlet through only a part of

7

the curved surface of the cylinder to thereby remove a part of the powder material from the depressions and to direct it towards the strip to be coated; and

(E) at least one screen which has a mesh size large enough to allow the powder to pass therethrough, which reduces the powder striking it to discrete particles and which can be electrically charged with respect to the strip, said screen being positioned in the path of the powder passing from the metering roll to the strip.

2. Apparatus according to claim 1, in which said metering roll consists of a smooth surfaced roll, the curved surface of which is covered with a conforming sheet of perforated metal, the perforations in said perforated sheet forming the depressions of the metering roll.

3. Apparatus according to claim 1, in which the gas inlet is an apertured pipe extending along the axis of the cylinder and the stationary baffles extend from the pipe to the interior surface of the cylinder defining a sector of the cross-section of the cylinder.

4. Apparatus according to claim 1, which comprises at least two screens, each having a mesh size large enough to allow the powder to pass therethrough, the screens being positioned in sequence in the path of the powder passing from the metering roll to the strip such that one screen is nearer the strip than the other or others, and means for vibrating the screen which is nearest to the strip in its own plane.

5. Apparatus according to claim 1, which comprises a single screen having a mesh size large enough to allow

8

the powder to pass therethrough and means for vibrating said screen in its own plane.

6. Apparatus according to claim 1, in which the space between the metering roll and the strip through which powder passes from the metering roll to the strip is enclosed by a hood having an opening at each end, one end of the hood bearing against the metering roll and the other being closely adjacent, but not touching, the strip surface to be coated.

References Cited

UNITED STATES PATENTS

351,483	10/1886	Baldwin	222—225
2,057,548	10/1936	Wallach et al.	117—16
2,613,633	10/1952	Dressen	118—308
2,675,330	4/1954	Schwartz et al.	117—17
2,757,635	8/1956	Lipsuis	118—308 X
2,976,839	3/1961	Okma et al.	118—624
3,085,548	4/1963	Sheehan	117—16 X
3,108,560	10/1963	Bowne	118—301 X
3,114,482	12/1963	Dunaway	222—328
3,163,553	12/1964	Commanday et al.	117—22
3,269,356	8/1966	Friderici	118—640

25 WILLIAM D. MARTIN, Primary Examiner

P. F. ATTAGUILE, Assistant Examiner

U.S. Cl. X.R.

30 117—16, 17, 22; 118—308, 636, 638

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,513,810

Dated May 26, 1970

Inventor(s) ALBERT EDWARD JACKSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading insert:

--Claims priority, application Great Britain, June 7, 1963,
22769/63--

SIGNED AND
SEALED
SEP 22 1970

(SEAL)

Attest

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents