Aug. 1, 1972 TSUYOSHI OHAMA ET AL 3,681,118

METHOD OF REMOVING EXCESS MOLTEN METAL COATINGS BY EMPLOYING LOW PRESSURE GAS STREAMS

Filed Feb. 26, 1970 4 Sheets-Sheet 1

FIG. 3

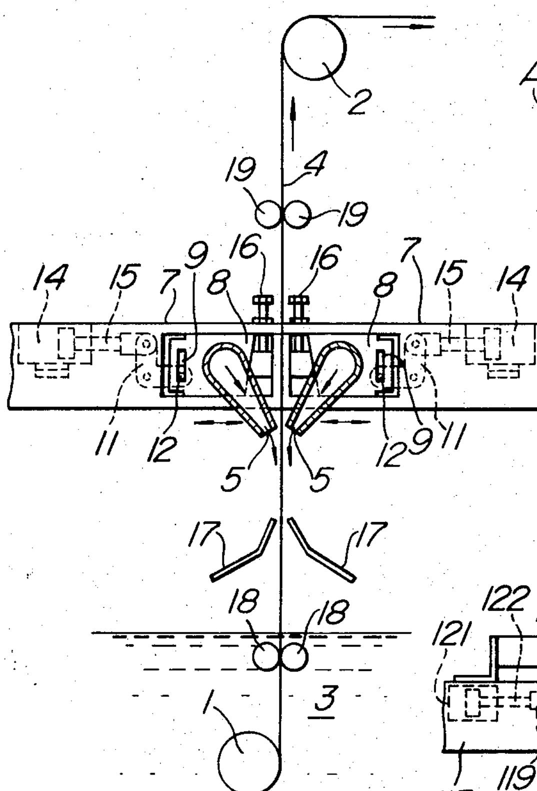

FIG. 1
PRIOR ART

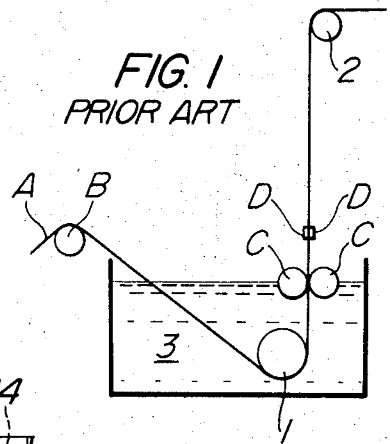

FIG. 5

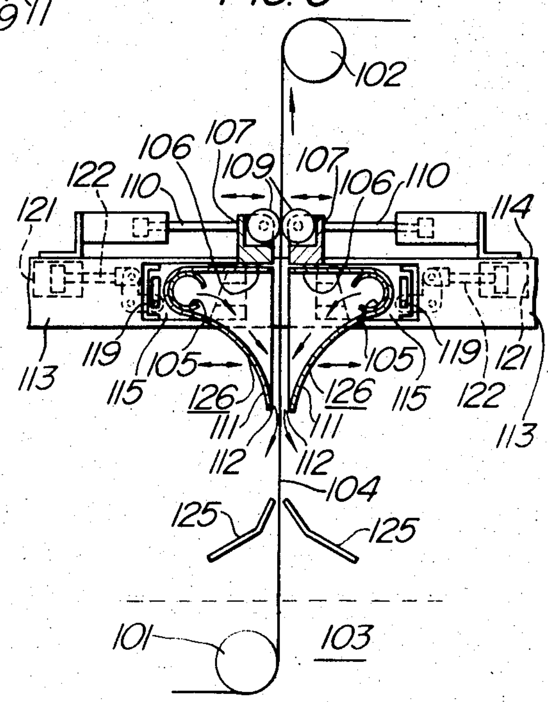

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FIG. 2

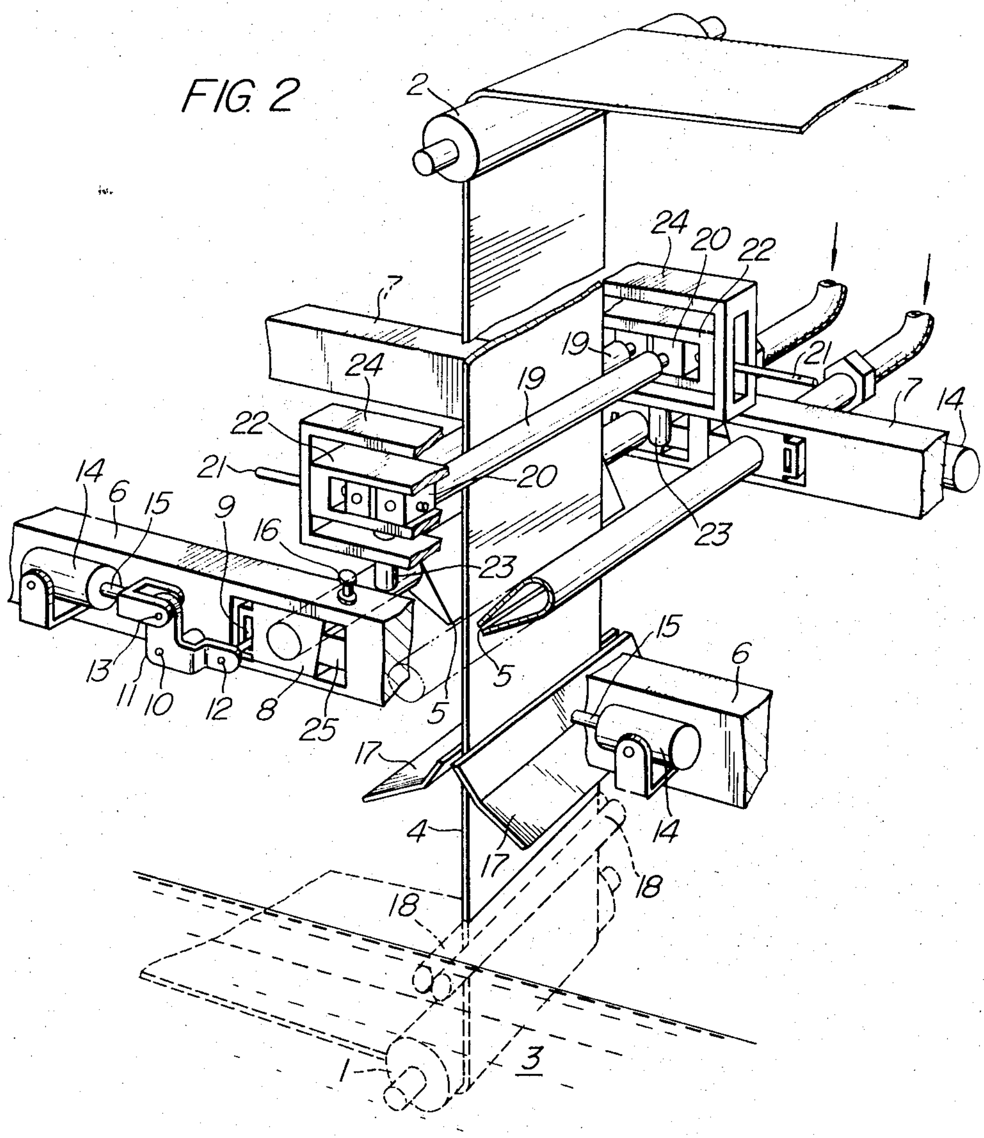

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FIG. 4

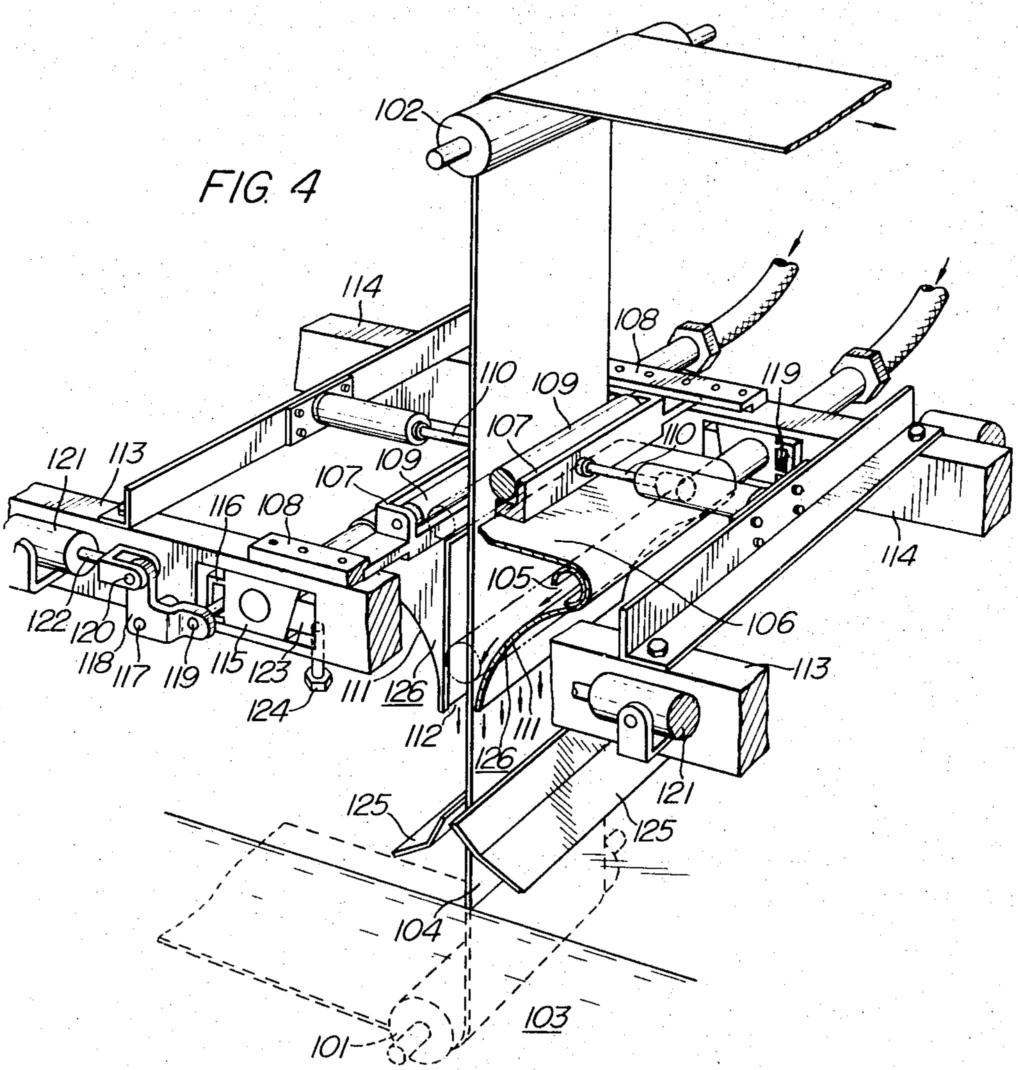

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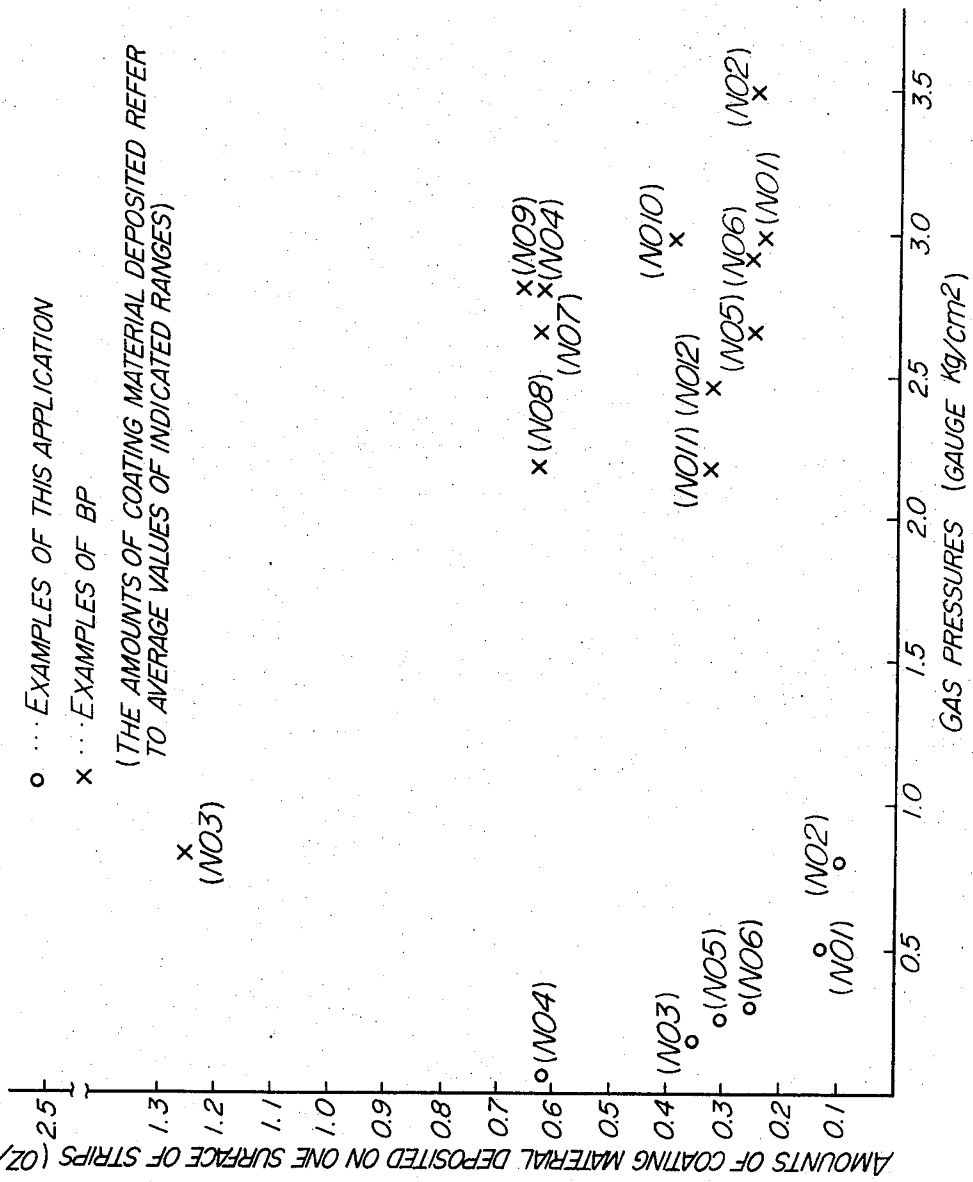
FIG. 6



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METHOD OF REMOVING EXCESS MOLTEN METAL COATINGS BY EMPLOYING LOW PRESSURE GAS STREAMS

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Continuation-in-part of application Ser. No. 696,907, Jan. 10, 1968, which is a continuation-in-part of application Ser. No. 518,154, Jan. 3, 1966. This application Feb. 26, 1970, Ser. No. 14,491

Claims priority, application Japan, June 8, 1965, 40/34,244; June 9, 1965, 40/34,555

Int. Cl. B05c *11/06;* C23c *1/00*

U.S. Cl. 117—102 M 12 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for continuous hot dip metal coating of a metal strip without using coating rolls, wherein gas under pressure is directed onto opposite faces of the metal strip during its continuous upward movement out of a molten coating metal bath. The pressurized gas blows away any excess coated metal while the coating is still in its non-solidified state.

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part application of the applicants' earlier U.S. Ser. No. 696,907 filed on Jan. 10, 1968 which is a continuation-in-part application of the applicants' earlier application U.S. Ser. No. 518,154 filed on Jan. 3, 1968, both now abandoned.

BACKGROUND OF THE INVENTION

(1) Field of the invention

The present invention relates to a method and apparatus for continuous hot dip metal coating wherein compressed gas is directed onto opposite faces of a metal strip, e.g. steel, continuously drawn out of a molten coating metal bath. The pressurized gas blows away any excess metal from the deposited metal film.

(2) Description of the prior art

Continuous hot-dip galvanizing of a steel strip according to prior practice has been affected in such a way that a moving steel strip is fed through a molten zinc bath by being guided by a feed roll and a bottom roll and, while being directed upwardly away from the bath by a deflector roll, the strip is coated with zinc by a pair of coating rolls disposed at the zinc bath surface.

In the prior practice described above, the amount of metal coating has generally been controlled by suitably selecting the diameter and peripheral velocity of coating rolls, the shape and pitch of grooves provided on the coating rolls, the height between the center of coating rolls and the coating metal bath surface, the fluidity of molten metal in the coating metal bath, the moving velocity of the steel strip, and other factors.

There have been considerable variations in coating thicknesses with known processes. In one example of a known process employing the coating rolls, a zinc coat-

ing in an amount of 0.6 ounce per square foot has been obtained on a steel strip, while in another example in which increased squeezing pressure is imparted by the coating rolls, a coating of 0.4 ounce per square foot could have been obtained. This coating could have been further reduced to 0.1 to 0.2 ounce per square foot by providing asbestos wipers directly above the molten zinc bath to wipe away the coated zinc while it is still in its non-solidified state. In this case, where the steel strip moves at a relatively slow velocity, the zinc coating can be controlled to a uniform amount. However, by increasing the moving velocity of the steel strip, variations occur in the amount of molten metal applied, thereby forming a pool or meniscus existing between the coating rolls carried by the steel strip passing through the coating rolls, with the result that the steel strip portions which correspond to the groove portions of the coating rolls are coated to an amount which is about 20 to 40% less than the amount of the coating on the other portions. Conversely, the opposite edge portions of the steel strip are coated to an amount which is about 20 to 30% thicker than is desired. Such non-uniformity of the coating has necessarily impaired corrosion resistance, workability and feasibility of painting of coated products.

Another defect involved in the prior method has been the inclusion of oxides in the coated metal film by the coating rolls. This oxide inclusion results in poorly finished surfaces of a coated steel strip and also provides restriction in the coating speed. This prior method has been also defective in that, although a relatively thin coating can be obtained as described previously, by wiping the coated film with the asbestos wipers while it is still in its nonsolidified state, any wear of the asbestos causes an unsatisfactory wiping operation which results in the appearance of streaks due to the presence of excess metal on the coated film. This leads to a loss of the desirable external appearance, workability and the feasibility of painting. The prior method exhibits further shortcomings in that a time of several hours to several days is wasted in exchanging the coating rolls when surface roughness develops thereon. Also, the rolls must be changed to deal with the requirements for variation of thickness of the coating.

In an attempt to regulate the thickness and weight of coated metal film, a method has been proposed wherein an air flow is directed toward a molten metal meniscus or pool disposed between coating rolls and the surfaces of a steel strip in order to restrict the amount of molten metal carried away, upwardly, by the moving steel strip from the molten metal pool or meniscus while the steel strip passes through the coating rolls. The above step is disclosed, for example, in the specification of British Pat. No. 935,516. This method, however, can not eliminate the defects inherent in the use of coating rolls, such as the non-uniformity of the coated metal film and the limitations in the coating velocity due to the fact that the coating rolls are used therein.

As an alternative to the conventional methods referred to hereinabove, a method has been proposed in which a medium, such as a liquid, a gas or heated steam is ejected in a direction opposite to the direction of movement of a steel strip as the strip is moved vertically upwardly away from the coating metal bath. The medium blows off excess coating material from the opposite faces of the steel strip. This method has been conducted experimentally in laboratories but no commercially effective processes have ever been developed as a result of these experiments.

In recent years, this method has been carried into practice experimentally or made available for public inspection as inventions. However, the examples of this method use relatively high pressures ranging from 2 to 5 kg./cm.^{2} for applying the medium to the surfaces of the coated metal strip. The use of high pressures produces inherent disadvantages in that it is impossible to effect adjustments of the amount of coating material to be deposited on the steel strips by varying the pressure under which the medium is ejected through nozzles. In addition, high pressures are liable to cause the formation of ripples (subsequently to be described in detail) on the surfaces of coated steel strips and also cause splashing of the molten coating metal in the bath on the surfaces of said strips.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved method and apparatus for continuous hot dip metal coating, which provides not only the production of a higher quality steel strip of uniform coating thickness having no oxide inclusion, but also eliminates various defects inherent in the prior art methods of using coating rolls, such as, the difficulty in controlling the coating thickness, loss of the plating metal, oxide inclusion, time loss in exchanging the coating rolls and the unavoidable limitation in coating velocity.

According to the present invention, a metal strip, for example, steel, is moved through a coating metal bath and then in the upwardly direction away from said bath while the excess coating metal is blown away from the strip by a gas under pressure, preferably at a low pressure, while the coating is still in a non-solidified state.

As mentioned above, no such solid means such as the coating rolls of the prior method is used in the present invention. Thus substantially all the drawbacks encountered in the prior art have been eliminated and coated metal strips, advantageously coated steel strips of a higher grade quality, can be manufactured together with improved economical advantages such as for example, more workability, less material loss of the coating metal, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic side elevational view of a prior apparatus for continuously coating by hot dipping;

FIG. 2 is a partly cut-away perspective view of an apparatus for continuously coating by hot dipping embodying the method and apparatus according to the present invention;

FIG. 3 is a side elevational view of the apparatus of FIG. 2;

FIG. 4 is a partly cut-away perspective view of another embodiment of the apparatus embodying the method according to the present invention;

FIG. 5 is a side elevational view of the apparatus of FIG. 4; and

FIG. 6 is a diagram showing the relation between the gas pressures and the amount of coating material deposited on one surface of the steel strip representing the results of adjusting the coating thickness achieved by varying gas pressures.

DETAILED DESCRIPTION OF THE INVENTION

According to one aspect of the present invention there is provided a method and apparatus for hot dip coating comprising moving a continuous metal strip through a bath containing a coating material and then upwardly away from said bath. During its upward movement and while the coating is still in its non-solidified state, a gas is directed under pressure onto either side of the coated metal strip in a direction opposite to the direction of movement of the metal strip, to remove excess coating material from the coated strip.

According to a further embodiment of the present invention there is provided a method and apparatus for continuously coating a metal strip by hot dipping, without the use of coating rolls, comprising moving a continuous steel strip through a coating metal bath and then upwardly away from said bath. A pair of nozzles is disposed on opposite sides of the coated steel strip in a manner such that their openings are directed in a direction opposite to the advancing direction of the steel strip and extend transversely of the steel strip. Said openings have a size of about 0.3 to 3 millimeters and are adjustably spaced from the steel strip at a distance of about 3 to 20 millimeters. A gas at a pressure of about 0.05 to 1 kilogram per square centimeter gauge is directed onto the steel strip faces at an angle of about 3 to 45 degrees with respect to the normal to the steel strip faces while the coated metal films are still in the non-solidified state, thereby blowing away any excess metal from the metal films. Thus, metal films of any desired thickness can be formed on the opposite faces of the steel strip.

Apparatus for carrying out the above method may comprise a bath for the coating material, means for moving a continuous metal strip through the bath and guiding it upwardly away from the bath and gas directing means including nozzles located such that in the operation of the apparatus, gas, under pressure, is directed from the nozzles onto either side of the metal strip during its upward movement while the coating is still in its non-solidified state. The gas is directed opposite to the direction of movement of the metal strip to remove any excess coating maerial from the strip.

The present invention is advantageous in that the thickness of coated films on opposite faces of a metal strip such as steel can accurately and freely be controlled by the use of a gas at a low pressure. It is possible to eliminate every defect previously encountered in the use of solid means such as coating rolls, for example, the occurrence of nonuniformity in the coated film thickness including excessively thick coatings on opposite edge portions of the steel strip, and the lowering of the coating efficiency due to the time required for exchanging the coating rolls. The present invention provides further advantages in that an extremely thin coating such as that which can be obtained by electroplating can be obtained more readily and at a higher speed than with the prior methods. Thus a coated steel strip of good quality which is suitable for multiple purposes can be manufactured at an extremely low cost. A further advantage derivable from the present invention is that damage on the coated film due to contact by nozzles or the closing of the nozzle openings by the moving strip can readily be avoided.

The above and other objects, advantages and features of the present invention will become apparent from the following description with reference to the accompanying drawings.

Before giving detailed description of the method and apparatus of the present invention, a prior method of continuously coating by hot dipping will first be described with reference to FIG. 1 so that the invention can be clearly understood. According to the prior method of continuous hot-dip galvanizing as shown in FIG. 1, a moving steel strip A is continuously conveyed through a molten zinc bath 3, being guided therethrough by a feed roll B and a bottom roll 1. The strip is coated with zinc by the action of a pair of coating rolls C, C disposed at the molten zinc bath surface while the strip A is moved upwardly away from the bath 3. The strip is guided in its upward movement by a deflector roll 2. A pair of asbestos wipers D, D are disposed directly above the molten zinc bath 3 to wipe away any excess metal while the zinc coating is still in its non-solidified state. This prior art method contains many defects previously described.

The method according to the present invention eliminates all of the defects encountered with the prior method and will be described in detail with reference to FIGS. 2 to 5 of the drawings.

In FIGS. 2 and 3, a steel strip 4 is continuously moved upwardly through a zinc coating bath 3 by being guided by a bottom roll 1 and a deflector roll 2. Adjacent the opposite sides of the coated strip 4 as it moves in the upward direction away from the coating bath 3, there are disposed an opposing pair of stationary frame members 6 and 7, positioned at right angles with respect to the moving direction of the strip 4. These frame members 6 and 7 are provided with hollow spaces which are adapted to slidably receive slider means 8. Nozzles 5, 5 are swingably mounted at opposite ends in the opposite sliders 8, 8 so that the gas ejection angle of the nozzles 5 with respect to the strip faces can be freely selected within a range of about 3 to 45°. The nozzles 5, 5 are disposed on opposite sides of the steel strip 4 and have a similar mounting structure therefor. A slot 9 is provided in each slider 8 and receives therein a pin 12 extending from one end of a bellcrank 11 pivotally mounted on a pivot 10 provided on the external face of the corresponding frame member 6. A pin 13 extending from the other end of the bellcrank 11 is connected to a piston rod 15 extending from a hydraulic cylinder 14 secured on the same external face of the frame member. The nozzles 5 can thus be moved toward and away from the strip faces independently of each other by suitably supplying a fluid at pressure to the hydraulic cylinders 14 and discharging the fluid therefrom.

The face of each slider means 8, which is opposite to the steel strip 4, is slope-shaped, and a wedge 25 is disposed in the hollow space in a manner so as to engage this sloped face of the slider means 8. A screw 16 is provided on the wedge 25 to cause vertical movement of the latter by vertical movement of the former so that the slider means 8 can be slightly moved in either direction, thereby effecting close adjustment of the spacing between the nozzles 5, 5 and the steel strip 4.

Baffle plates 17, 17 are disposed below the respective nozzles 5, 5 to prevent any turbulence of the plating bath due to gas streams ejected from the nozzles 5, 5. A pair of lower holding rolls 18, 18 disposed below the coating bath surface and a pair of upper holding rolls 19, 19 disposed above the gas ejection nozzles 5, 5 are freely rotated by the force of frictional contact with the steel strip 4 and are operative to prevent any swinging movement of the steel strip 4, thereby maintaining the rectilinearity of the steel strip 4 during its passage between the nozzles 5. Opposite ends of each upper holding roll 19 are each fixed to a slider 20 which is laterally slidable by the action of a rod 21 actuated as by a servomotor. The two sliders 20, 20 on the same side are received in a slider 22 which is connected to a rod 23 for providing a vertical sliding movement. Sliders 20 and 22 are received in a frame member 24.

Although no problem whatsoever arises from frictional contact between the lower holding rolls 18, 18 and the steel strip 4, strong frictional contact between the upper holding rolls 19, 19 and the steel strip 4 would result in damage of the coating metal films, and therefore some means must be provided to inhibit such strong frictional contact from occurring. Accordingly, resilient means such as an elastic liquid or a spring may be employed to impart to the rolls 19, 19 a suitable pressure which does not develop any strong frictional contact between the rolls 19, 19 and the steel strip 4. Furthermore, a good result may be obtained by adapting the upper holding rolls 19, 19 in such a manner that they can follow any movement of the steel strip 4 in its transverse direction.

According to the experimental results of this embodiment of the present invention, the opening of the nozzles 5, 5 of about 0.3 to 3 millimeters, the space between the nozzle opening and the steel strip 4 of about 3 to 20 millimeters, a gas ejection pressure of about 0.5 to 1 kilogram per square centimeter gauge, preferably a low pressure of about 0.1 to 0.5 kilogram per square centimeter gauge, and a gas ejection angle of about 3 to 45 degrees with respect to the normal to the steel strip faces, preferably an angle of about 3 to 15 degrees have been found to be very effective in eliminating the problems experienced by the prior art methods and apparatus.

Gas wiping of excess coating material have been put into practical use on a commercial scale using the teachings of British Pat. No. 1,071,572. A comparison between the various process and apparatus parameters used in the British patent when compared to the present invention are as follows:

TABLE 1

	Present application	British Patent No. 1,071,572
Size of nozzle openings (mm.).	0.3 to 3.0 (0.5 to 1 preferred).	0.127 to 0.381.
Nozzle spacing (mm.)	6 to 40 (10 to 30 preferred).	50.8 to 101.6.
Pressure at which gas is ejected (kg./cm.^{2} gauge).	0.05 to 1 (0.1 to 0.5 preferred).	0.84 to 4.56.
Nozzle angle (degree)	3 to 45 (3 to 15 preferred).	10 to 45 (0 to 15 preferred).
Gas temperature, ° C.	200 to 500	287.8 to 454.

As is clear from this table, the present application and the British patent, although somewhat agreeing with each other in the nozzle angle and gas temperature, substantially differ from each other in the nozzle spacing and the size of nozzle openings as well as the pressure of gas ejected.

(A) Size of the nozzle openings

The size of the nozzle openings in the British patent is very small, that is, in a range of 0.127 to 0.381 millimeter as compared with a nozzle opening of about 0.3 to 3 millimeter as compared with a nozzle opening of about 0.3 to 3 millimeters as defined by the present invention. This makes it necessary to rely on highly skilled workman to manufacture nozzles having a uniform opening throughout the entire length along the width of the strip. Changes inevitably caused by high temperature heat, even if the change itself is small, would greatly influence the size of the nozzle openings, which give rise to large variations in the amount of the air streams ejected through the nozzle which in turn prevent deposition of a uniform quantity of the coating metal across the width of the strip. This phenomenon can be pronounced, particularly when the pressure at which the gas is ejected is increased to reduce the quantity of coating metal deposited on the steel strip. Moreover, because of the small nozzle opening size the nozzles may become obstructed. When the nozzle openings are below about 0.3 millimeter in size, the jet stream ejected therethrough is in a thin-blade-like shape when it impinges on the coated surfaces of the steel strip. The smallness of area in which the impingement occurs in this instance causes the jet stream to act excessively on the coated surfaces, resulting in the occurrences of a stripe-pattern as described hereafter. On the other hand, the use of nozzle openings larger in size than about 3 millimeters involves the ejection of a jet stream greater in quantity than is required to attain the object. This practice is not only uneconomical but also has a deleterious effect on the coated faces because the wiping energy grows larger than is required as a result of an increased quantity of gas ejected. It has been found that the preferred size of the nozzle openings is in the range from 0.5 to 1 millimeter. These disadvantages are obviated in the present application which is characterized by a large nozzle opening size.

(B) Nozzle spacing

The nozzle spacing in the British patent is very large that is, in a range from 50.8 to 101.6 millimeters as compared with a nozzle spacing of about 6 to 40 millimeters as defined in the present invention. With such a large nozzle spacing, that is, greater than 20 mm. between the nozzle and the strip or 40 mm. between nozzles, it is necessary to use a proportionally high gas ejection pressure in order to obtain the end of throttling the gas stream as desired. This inevitably results in a lowering of the temperature near the nozzle openings and a production of turbulent flow of air in the neighborhood of the nozzle openings which interfers with the streams of gas ejected through the nozzles. The temperature decrease of the gas occurs unevenly along the entire width of the strip resulting in a lack of uniformity on the wiping effect. This makes it impossible to obtain satisfactory finished coated surfaces. Moreover, since the distance between the nozzles and opposite faces of the steel strip is large, the atmosphere in the operation chamber exerts a greater influence on the control of the quantity of coating metal applied to the opposite faces of the steel strip than in the case where a smaller nozzle to steel strip distance, is utilized, as in the present invention. Thus the control of the quantity of coating material can only be effected in an unstable manner when large nozzle to strip distances are utilized. When the spacing between the nozzle openings and the steel strip is below about 3 millimeters flaws and lack of uniformity are liable to occur on the coated faces due to minute vibrations of the steel strip. In addition, frequent occurrences of nozzle blacking result. The preferred spacing has been found to be in the range of 5 to 15 millimeters.

Generally, the quantity of coating metal applied to the opposite faces of the steel strip can be controlled mainly by varying the pressure at which the gas is ejected, the nozzle spacing, and the size of the nozzle openings which define the amount of flow of gas, as well as by varying the angle at which the gas is ejected and the temperature of the gas. When the pressure at which the gas is ejected through the nozzles is increased, the control of the quantity of coating material applied to the opposite faces of the steel strip is effected greatly by various factors as stated above and it becomes impossible to effect accurate and precise adjustments of the quantity of coating material. This causes variations in the quality of the products produced. This is substantiated by a comparison made between the present application and the British patent in operation conditions and the quantity of coating metal deposited on the steel strip, as will be subsequently described.

If the distance between the nozzles and opposite faces of the steel strip is maintained in a range of about 3 to 20 millimeters (the spacing between nozzles is 6 to 40 millimeters) which is characteristic of the present application, the gas can be ejected at a low pressure which greatly reduces the factors which make the operation unstable, as mentioned above. Thus, the present invention provides an effective and stable control of the coating process and results in the production of products which are free from variations in quality.

(C) Gas ejection pressure

It is noted that the gas is ejected at a pressure of 0.84 to 4.56 kilograms per square centimeter gauge in the British patent, whereas a pressure range of 0.05 to 1.0 kilogram per square centimeters gauge is used in the present invention, preferably 0.1 to 0.5.

When an air stream ejected through a nozzle against a steel strip face at an effective angle strikes the face of the steel strip, said air stream branches into an upwardly directly air substream and a downwardly directed air substream. This upwardly directed air substream causes ripples to occur on the unsolidified metal coating applied to the face of the steel strip just as a wind causes a ripple to occur on the smooth surface of water. When the gas is ejected at a higher pressure, a greater force is exerted on the metal coating, so that surges of the ripple run high. In addition, this great force is exerted on the metal coating at a point slightly short of the position where said metal coating becomes solidified. Thus, the ripples produced cannot be removed before the metal coating becomes solidified, with the result that the product obtained has a strip pattern (ripples) over the entire area of the coated surface.

On the other hand, the downwardly directed air substream tends to cause splashing of the molten coating metal from the surface of the molten metal coating bath, thereby causing obstruction of the nozzles or enhancement of the phenomenon of oxidation of the bath surface. However, if the gas is ejected at a low pressure in a range of about 0.05 to 1.0 kilogram per square centimeter gauge, which is characteristic of the present invention, it is possible to achieve a splendid wiping effect. That is, the use of a low pressure entirely eliminates ripples and inherently causes a reduction in the pressure of the downwardly directed air substream, so that occurrences of splashes of the metal coating from the surface of the molten coating metal bath are greatly reduced. This feature avoids abstruction of the nozzles which poses a problem when a pressure of over 1.0 kilogram per centimeter gauge is used. It also eliminates any possible oxidation of the surface of the molten metal bath coating. The pressure ranges of the present application and those of the British patent overlap each other. It is noted that 0.83 kilogram per centimeter gauge is the lower limit of the range in the British patent and that the quantity of coating metal deposited on the steel strip is at a maximum when the gas is ejected at this pressure level. However, in the invention, 1.0 kilogram per square centimeter gauge is the upper gas pressure limit and the quantity of coating metal deposited is at a minimum at this pressure. It is thus evident that there is a clear distincition between the British patent and the present invention.

Table 2 shows the comparison between the present application and the British patent with reference to the size of nozzle openings, the nozzle spacing and the gas ejection pressure stated hereinabove.

TABLE 2

	Present application	British Patent No. 1,071,572
Swirling of ejected gas steam	Little	Liable to occur.
Drawing in of atmosphere (temperature differential).	Small	Great.
Changes of nozzle openings in section (rate of deformation due to heat).	do	Do.
Fluctuations in the quantity of applied metal coating.	do	Do.
Occurrences of ripples (ejection pressure).	None	Liable to occur.
Obturation of nozzles (section of the nozzle openings).	do	Do.
Splashes from the bath surface (ejection pressure).	Almost none	Markedly liable to occur.
Ejected gas (nozzle spacing)	Low pressure is sufficient.	High pressure is required.
Fabrication of nozzles (precision of nozzle openings).	Easy	Requires a highly advanced skill.
Oxidation of molten coating metal bath surface.	Little	Pronounced.

As described in detail above, the present application can achieve far better results than the British patent. It should also be noted that the present application is superior to the British patent in controlling the quantity of coating metal applied to a steel strip.

More specifically, the quantity of coating metal applied to a steel strip can be controlled by adjusting the gas ejection pressure, the nozzle spacing and the size of the nozzle openings as aforementioned. In the present application, adjustments of each of these factors can bring about a variation in the quantity of coating metal applied to the steel strip in a precise and orderly manner. By adjusting these factors in combination, the present application permits the continuous variation in the thickness of a coating material in small steps over a wide range from a very thin gauge coating to a thick coating in a stable manner which is beyond the scope of a coating process using rolls. As subsequently to be described, it can be presumed that the British patent does not permit process control in the manner described above and cannot effect control of the quantity of coating material in a stable manner, much less produce a very thin gauge coating product.

The comparison between the control features of the present invention when compared to the British patent is tabulated in Tables 3 and 4 and shown graphically in FIG. 6.

Comparison tables between examples of British Pat. No. 1,071,572 (Table 3) and the present invention (Table 4).

TABLE 3

Examples of British Pat. No. 1,071,572

Examples, operation number	Gas pressure, lb./in.^{2}	Spacing between nozzles, in.	Gas directing angle, degrees	Distance from liquid level in the bath, in.	Nozzle opening, in.	Gas temperature, ° F.	Rate of strip movement, f.p.m.	Amounts of deposited coating material (on opposite faces) oz./ft.^{2}
1	41	4	10	6-8	0.01	850	80	0.4-0.6
2	50	4	10	6-8	0.01	850	140	0.4-0.6
3	12	4	10	6-8	0.01	850	110	2.5
4	40	4	10	6-8	0.01	850	220	1.25
5	38	2	10	6-8	0.01	850	90	0.4-0.8
6	42	2	10	6-8	0.01	850	130	0.4-0.8
7	38	2	10	6-8	0.01	850	240	1.25
8	31	2	10	6-8	0.01	850	200	1.25
9	40	3	15	8	0.01	650	200	1.25
10	42	3	45	8	0.005	650	220	0.79-0.87
11	31	3	30	10	0.007	550-850	220-250	0.5-0.8
12	35	3	10	6-7	0.01	650	160	0.5-0.8

TABLE 4.—EXAMPLES OF THE PRESENT APPLICATION

Examples, operation number	Gas pressures, kg./cm.^{2}	Spacing between nozzles, mm.	Gas directing angles, degrees	Distance from liquid level in the bath, mm.	Nozzle opening, mm.	Gas temperature, ° C.	Rate of strip movement, M./min.	Amounts of deposited coating material (on one face), oz./ft.^{2}
1	0.5	10	30	250	0.9	500	30	0.175
2	1	14	15	250	1	400	100	0.075
3	0.18	20	8	250	0.6	450	25	0.35
4	0.06	40	10	160	0.9	460	40	0.615
5	0.25	16	5	200	0.85	440	70	0.3
6	0.3	22	5	160	0.9	450	60	0.25

As can be clearly seen from FIG. 6 wherein the quantities of metal coating applied are plotted as ordinates against the pressures at which the gas is ejected as abscissae, the embodiments of the present application and the British patent are compared. As can be readily seen the quantities of coating metal applied in the present application vary at a constant rate but variations in the British patent cannot be followed to any logical conclusion. The fact that variations in the quantities of coating metal applied in the British patent cannot be followed clearly can be shown by the following description which is based on Table 3 (which shows the embodiments of the British patent).

In reference to Table 3, it should be noted that there is a contradiction in the quantity of metal coating applied to the steel strip between the two operations.

More specifically, the nozzle spacing in operation 8 is 2 inches which is smaller than the nozzle spacing of 3 inches in operation 11, so that quantity of metal coating would be reduced to a larger extent in the former than in the latter. Moreover, the ejection angle, the height from the bath surface, the size of nozzle openings, the temperature of steam and the line rate all indicate that the quantity of metal coating applied in operation 8 would be reduced below that applied in operation 11. And yet, the actual results are reversed that is, the quantity of coating metal applied is from 0.5 to 0.8 oz./ft.^{2} in operation 11 and from 1.25 oz./ft.^{2} in operation 8.

A comparison between the operation conditions of operation 11 and operation 9 of the British patent also shows that the results achieved by these operations in the quantity of coating metal applied to the steel strip are also contradictory. More specifically, the bottom pressure in operation 9 is 40 lb./in.^{2} which is higher than 31 lb./in.^{2} in operation 11 so that the quantity of coating metal applied in the former would be reduced to a larger extent than in the latter. Moreover, the ejection angle, the height from the bath surface, the size of nozzle openings, the temperature of the steam and the line rate all indicate that the quantity of metal coating applied in operation 9 would be reduced below that applied in operation 11. However, the actual results are reversed, that is, the quantity of coating metal supplied is 1.25 oz./ft.^{2} in operation 9 and from 0.5 to 0.8 oz./ft.^{2} in operation 11. The results actually achieved by the British patent show that the pressure at which the gas is ejected which causes fluctuations in the quantity of coating metal applied in the present application does not appreciably affect the quantity of coating metal applied in the British patent.

In perusing the operating conditions of operation 12 and operation 5 in the British patent it is noted that the bottom pressure, the nozzle opening, the temperature of steam, and the line rate all indicate that the quantity of coating metal applied in operation 5 would be reduced (other values being equal to those of operation 12). Actually, however, the quantities of coating metal applied in both operations are substantially the same, that is, 0.4 to 0.8 oz./ft.^{2} in operation 5 and 0.5 to 0.8 oz./ft.^{2} in operation 12. This fails to clearly show what is the dominating factor which contributes most to the control of the quantity of coating metal applied to a steel strip.

In considering the operating conditions of operation 6 and operation 10 in the British patent it can be seen that the nozzle opening, the ejection angle, the size of nozzle opening and the temperature of steam all indicate that the quantity of coating metal applied in operation 6 would be reduced over that applied in operation 10 (other values being equal). And yet, the quantities of coating metal applied in both operations are substantially similar, that is, 0.4 to 0.8 oz./ft.^{2} in operation 6 and 0.79 to 0.87 oz./ft.^{2} in operation 10, although there are some differences in the lower limit. This fails to clearly show what factor exerts the greatest controlling influences on the quantity of coating metal applied to a steel strip.

In the operating conditions of operation 1 and operation 6, the line rate of operation 1 is 80 f.p.m. which is lower than 130 f.p.m. in operation 6, indicating that the quantity of coating metal applied in operation 1 would be lower than that applied in operation 6. On the other hand, the pressure and the nozzle spacing indicate that the quantity of coating metal applied in operation 6 would be lower than that applied in operation 1. It appears that these factors combined to produce the result that the quantities of coating metal applied in operation 1 and operation 6 are substantially equal.

It should be noted here that whereas a variation in the line rate is not deemed to be a substantial factor in bringing about a difference in the quantity of coating metal applied to a steel strip in considering operation 6 and operation 10 in relation to each other, the line rate is deemed to affect the quantity of coating metal applied to a steel strip in considering operation 1 and operation 6 in relation to each other.

The conclusions drawn from consideration of the five examples stated above are as follows:

(1) There could be no single factor which plays a decisive role in effectively controlling the quantity of coating metal applied to a steel strip;

(2) Even if all the factors are combined to the fullest extent, the results achieved in controlling the quantity of coating material applied to a steel strip would be minimal; and

(3) The results achieved in controlling the quantity of coating metal applied to a steel strip might be contradictory to what would apparently be considered to be produced, depending on the combination of the factors involved.

Accordingly, it would appear that in view of what can be judged from the embodiments of the British patent, it is difficult for the British patent to effect control of the quantity of coating material applied to a steel strip and to carry on the operation in a stable manner.

On the contrary, the present invention provides a stable metal coating operation. As can be clearly seen, it appears that the gas ejection pressure, the size of the nozzle opening and the nozzle spacing are main factors in controlling the quantity of coating metal applied to a steel strip, and that the temperature of ejected gas, the angle of ejection and the rate of movement of the steel strip play subordinate roles. The present invention defines the ranges of values of the three principal factors, that is, the gas ejection pressure, the size of the nozzle openings and the nozzle spacing, which, in combination, produce unobvious results as contrasted to the results achieved by the British patent. The results achieved by the combination of features of the present invention are as follows:

(1) The quantity of coating metal applied to a steel strip can be controlled in a stable manner as desired, and the thickness of a coating applied to the steel strip can be varied easily from a very thin gauge to a thick gauge over a wide range;

(2) The use of a low pressure at which the gas is ejected produces products with very smooth surfaces and no ripples;

(3) It is possible to obviate obstruction of nozzles, splashings of the molten coating metal, and oxidation of the surface of the molten coating metal bath during operation; and

(4) The use of low pressure takes advantage of small size apparatus and equipment in hot dip metal coating processes and thus performs a hot-dip coating operation economically with reduced noises and danger during the operation, thereby paving the way to the fully automatic operation of hot-dip metal coating.

Samples A and B have been prepared to show the difference of surface smoothness due to the operating conditions according to Table 5. Sample A was formed by the method of the British patent and Sample B was produced by the method of the present invention. The two specimens were compared by viewing their surface at an oblique angle under a strong light. Sample A exhibited a small crystal structure with many irregular dark patches and particularly parallel rippling lines. However, Sample B contained a bright, calender-looking surface with higher reflectivity. A large dendritic crystal structure could be observed with a noted absence of irregular dark areas and/or ripping lines. The results of these tests are shown in Table 5 below.

TABLE 5.—OPERATING CONDITIONS OF GAS WIPING APPLIED AND QUANTITY OF COATED METAL

	Sample A	Sample B
Operating conditions:		
Line speed, M./min	50	60
Temperature of zinc bath, ° C	455	450
Nozzle opening, mm	0.1	0.5
Nozzle spacing (from the surface of strip to the nozzle opening), mm	25	14
Angle of ejection, degree	5	7.5
Height of nozzle (from the bath surface), mm	150	150
Gas pressure, gauge kg./cm.²	2	0.15
Gas temperature, ° C	450–465	418–430
Quantity of coated metal, oz./ft.²:		
At driving side	0.74	0.64
At center	0.69	0.65
At working side	0.71	0.62
Average	0.71	0.64
Remarks	(1)	(2)

[1] Observed ripples and whiskers.
[2] Whiskers of minor degree.

Once the effective gas pressure range was established, it was then possible to set the optimum ranges of the size of the nozzle openings, the spacing between the nozzle openings and the metal strip, and the angle at which the gas is directed against the metal strip.

It will be evident from the following examples described hereinafter that, as illustrated in FIG. 6, which shows the relation between the gas pressures and the amount of coating material deposited on one surface of the steel strips, the use of low gas pressures according to the present invention makes it possible to achieve marked results in effecting adjustments of the coating thickness of the steel strips in a controlled manner.

EXAMPLE 1

A steel strip 2.3 millimeters thick and 1000 millimeters wide was conveyed at a rate of 30 meters per minute for providing a zinc coating thereon. Nozzles having an opening of 0.9 millimeter were disposed at an ejection angle of 30 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 250 millimeters and each nozzle was spaced 5 millimeters from the strip face. Combustion gas at a temperature of 500° C. and at a pressure of 0.5 kilogram per square centimeter gauge was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection, a uniform zinc coating could be attained with a coating on each face of 0.175 ounce per square foot.

EXAMPLE 2

A steel strip 0.5 millimeter thick and 1000 millimeters wide was conveyed at a rate of 100 meters per minute for providing a zinc-aluminum coating thereon. Nozzles having an opening of 1 millimeter were disposed at an ejection angle of 15 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 250 millimeters and each nozzle was spaced 7 millimeters from the strip face. Combustion gas at a temperature of 400° C. and at a pressure of 1 kilogram per square centimeter gauge was directed towards the steep strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection, a uniform zinc-aluminum coating could be attained with a coating on each face of 0.075 ounce per square foot.

EXAMPLE 3

A steel strip 1.5 millimeters thick and 1000 millimeters wide was conveyed at a rate of 25 meters per minute for providing a zinc coating thereon. Nozzles having an opening of 0.6 millimeter were disposed at an ejecting angle of 8 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 250 millimeters and each nozzle **5** was spaced 10 millimeters from the strip face. Combustion gas at a temperature of 450° C. and at a pressure of 0.18 kilogram per square centimeter gauge was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection a uniform zinc coating could be attained on each face of 0.35 ounce per square foot.

EXAMPLE 4

A steel strip 0.8 millimeter thick and 1000 millimeters wide was fed at a rate of 40 meters per minute for providing a zinc-aluminum coating thereon. Nozzles having an opening of 0.9 millimeter were disposed at an ejecting angle of 10 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 160 millimeters and each nozzle **5** was spaced 20 millimeters from the strip face. Combustion gas at a temperature of 460° C. and at a pressure of 0.06 kilogram per square centimeter gauge was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection a uniform zinc coating could be attained with a coating on each face of 0.615 ounce per square foot.

EXAMPLE 5

A steel strip 0.3 millimeter thick and 1000 millimeters wide was fed at a rate of 70 meters per minute for providing a zinc coating thereon. Nozzles having an opening of 0.85 millimeter were disposed at an ejecting angle of 5 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 200 millimeters and each nozzle was spaced 8 millimeters from the strip face. Combustion gas at a temperature of 440° C. and at a pressure of 0.25 kilogram per square centimeter gauge was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection a uniform zinc coating could be attained with a coating on each face of 0.3 ounce per square foot.

EXAMPLE 6

A steel strip 0.4 millimeter thick and 1000 millimeters wide was conveyed at a rate of 60 meters per minute for providing a zinc coating thereon. The nozzles having an opening of 0.9 millimeter were disposed at an ejecting angle of 5 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating was 160 millimeters and each nozzle **5** was spaced 11 millimeters from the strip face. Combustion gas at a temperature of 450° C. and at a pressure of 0.3 kilogram per square centimeter guage was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection a uniform zinc coating could be attained with a coating on each face of 0.25 ounce per square foot.

EXAMPLE 7

A steel strip of 0.6 millimeter thick and 1000 millimeters wide was introduced at a rate of 50 meters per minute for providing a zinc coating thereon. The nozzles having an opening of 0.3 millimeter were disposed at an ejecting angle of 7.5 degrees with respect to the normal to the faces of the steel strip. The height of the nozzles above the coating bath was 200 millimeters and each nozzle **5** was spaced by 10 millimeters from the strip face. Combustion gas at a temperature of 470° C. and at a pressure of 1.5 kilograms per square centimeter gauge was directed towards the steel strip faces in a direction opposite to the advancing direction of the steel strip. As a result of this gas ejection an almost uniform zinc coating could be attained with a coating on each face of 0.4 ounce per square foot. However, there was observed the occurrence of "ripples" on the surface thereof.

Another embodiment of the present invention will next be described with reference to FIGS. 4 and 5. A steel strip **104** is continuously moved upwardly through a coating bath **103** by being guided by a bottom roll **101** and a deflector roll **102**. Adjacent the opposite edges of the steel strip **104** moving upwardly away from the coating bath **103**, there are disposed opposed pairs of stationary frame members **113** and **114** at right angles with respect to the moving direction of the strip **104**. These frame members **113** and **114** are provided with hollow spaces therein in each of which is slider **115** is slidably received. Compressed gas supply pipes **105, 105** each having an opening directed towards the strip face are disposed on opposite sides of the steel strip **104** in parallel relation therewith and are swingably mounted at opposite ends in the opposite sliders **115, 115**. An apron-like member **126, 126** is mounted on each gas supply pipe **105** so that these apron-like members **126, 126** are disposed on opposite sides of the steel strip **104** to define gas spaces between them and the strip **104**. Each apron-like member **126, 126** has a substantially horizontal upper wall **106** and a parabolically sloped lower wall **111** defining a throat **112** between it and the opposite steel strip face. Roll-like or plate-like sealing members **109, 109** of soft, resilient and heat resisting material such as asbestos or glass fiber are disposed in parallel on opposite sides of the steel strip **104** in sealing contact therewith and are each rotatably or fixedly mounted on a support frame **107** which is slidable on guides **108, 108** provided on the opposite frame members **113** and **114**. A piston rod **110** is connected at one end thereof to the center of each support frame **107** at right angles therewith and is connected at the other end to a piston received in a hydraulic cylinder fixedly mounted on a support bar bridging the opposite frame members **113** and **114**. Accordingly, by supplying a fluid at pressure into the hydraulic cylinders and discharging it therefrom, the sealing members **109, 109** are moved toward and away from the steel strip **104** to make sealing contact with the strip face and relieve the sealing contact. A slot **116** is provided in each slider **115** and receives therein a pin **119** extending from one end of a link **118** pivotally mounted on a pivot **117** provided on the external face of the corresponding frame member **113**, while a pin **120** extending from the other end of the link **118** is connected to a piston rod **122** of a piston received in hydraulic cylinder **121** secured on the same external face of the frame member **113**. Thus, the compressed gas supply pipes **105, 105** can be moved towards and away from the strip faces in unitary relation with the apron-like members **126, 126** and the throats can be made wider or narrower as desired by supplying a fluid at pressure into the cylinders **121, 121** and discharging it therefrom.

That face of each slider **115** which is opposite to the steel strip **104** is slope-shaped, and a wedge **123** is disposed in the hollow space in a manner to engage with this sloped face of the slider **115**. A screw **124** is provided under the wedge **123** to cause vertical movement of the latter by vertical movement of the former so that close adjustment of the positions of the compressed gas supply pipes **105, 105** and the apron-like members **126, 126** can thereby be effected. When therefore a compressed gas, for example, compressed air, inert gas such as nitrogen gas, or exhaust gas of combustion is supplied at room temperature or in a heated state from the gas supply pipes **105, 105** while the deposited film on the coated steel strip **104** moving upwardly away from the coating bath **103** is still in its non-solidified state, jet streams of gas caused by the throats **112, 112** flow downwardly along steel strip faces to blow away any excess metal from the coated films on the plated steel strip **104**. Further, the sealing members **109** are operative to correct any non-uniformity in the film thickness and to prevent any vibration of the steel strip **104** during the coating operation, with the result that the coated film of excellent quality can be obtained. Baffle plates **125, 125** are disposed below the respective throats **112, 112** in order to avoid turbulence of the coating bath **103** due to the jet streams of gas.

Although the above embodiment of the present invention has referred to a case of utilization of combustion, gas, similar effects can be obtained by use of nitrogen gas, air or steam. As for the gas temperature to be employed for the zinc or zinc-aluminum coating, room temperature may be acceptable but the optimum temperature is from about 200° to 500° C. It will easily be understood that the present invention is also applicable to the coating of steel strips with tin, tin-lead or aluminum as well as coating other metal strips with various metal coatings.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the present invention, and all such modifications as would be apparent to one skilled in the art are intended to be included.

We claim:

1. A method of continuous hot-dip coating of a metal strip which comprises conveying a continuous metal strip through a coating metal bath, removing the coated metal strip from the bath, directing streams of a gas from a pair of gas-distributing means having apertures of about 0.3 to 3 millimeters, in a direction opposite to the direction of movement of the metal strip at an angle of about 3 to 30 degrees with respect to the normal to the metal strip faces and under a pressure of about 0.05 to 1.0 kg./cm.^{2} gauge to opposite faces of the coated metal strip, said gas streams being directed at the metal strip at a distance of about 3 to 20 millimeters from the faces of said strip and while said metal coating is still in an unsolidified state, to remove excess coating metal from the coated metal strip, whereby coatings of any desired thickness can be formed on the opposite faces of the metal strip.

2. The method of continuous hot-dip coating of a metal strip according to claim **1**, wherein the metal strip is held at a predetermined position between the gas-distributing means to maintain the rectilinearity of the metal strip moving between said gas-distributing means.

3. The method of continuous hot-dip coating of a metal strip according to claim **1**, wherein the distances between the distributing gas means and each face of the metal strip are independently controlled.

4. The method of continuous hot-dip coating of a metal strip according to claim **1**, wherein the metal strip is steel and the coating metal is selected from the group consisting of tin, zinc, aluminum, zinc-aluminum and tin-lead.

5. The method of continuous hot-dip coating of a metal strip according to claim **1**, wherein the distributing gas is combustion gas and is maintained at a predetermined temperature.

6. The method of continuous hot-dip coating of a metal strip according to claim **1**, wherein the size of the apertures through which the gas streams are distributed, the pressure of the ejected gas, the angle of ejection and the distance between the distributing gas means and the faces of the metal strip are adjusted to provide any desired difference between the thickness of the coating on one face of the metal strip and the thickness of the coating on the other face of the metal strip.

7. A method of continuous hot-dip coating of a metal strip which comprises conveying a continuous metal strip through a coating metal bath, removing the coated metal strip from the bath, directing streams of a gas from a pair of gas-distributing means having apertures about 0.3 to 3 millimeters, in a direction opposite to the directioa of movement of the metal strip at an angle of about 3 to 30 degrees with respect to the normal to the metal strip faces and under a pressure of about 0.1 to 0.5 kg./cm.^{2} gauge to opposite faces of the coated metal strip, said gas streams being directed at the metal strip at a distance of about 3 to 20 millimeters from the faces of said strip and while said metal coating is still in an unsolidified state, to remove excess coating metal from the coated metal strip, whereby coatings of any desired thickness can be formed on the opposite faces of the metal strip.

8. The method of continuous hot-dip coating of a metal strip according to claim **7**, wherein the metal strip is held at a predetermined position between the gas-distributing means to maintain the rectilinearity of the metal strip moving between said gas-distributing means.

9. The method of continuous hot-dip coating of a metal strip according to claim **7**, wherein the distances between the distributing gas means and each face of the metal strip are independently controlled.

10. The method of continuous hot-dip coating of a metal strip according to claim **7**, wherein the metal strip is steel and the coating metal is selected from the group consisting of zinc, tin, aluminum, zinc-aluminum and tin-lead.

11. The method of continuous hot-dip coating of a metal strip according to claim **7**, wherein the distributing gas is combustion gas and is maintained at a predetermined temperature.

12. The method of continuous hot-dip coating of a metal strip according to claim **7**, wherein the size of the apertures through which the gas streams are distributed, the pressure of the ejected gas, the angle of ejection and the distance between the distributing gas means and the faces of the metal strip are adjusted to provide any desired difference between the thickness of the coating on one face of the metal strip and the thickness of the coating on the other face of the metal strip.

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