March 10, 1970 J. T. MAYHEW 3,499,418

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

Filed Dec. 1, 1966 5 Sheets-Sheet 1

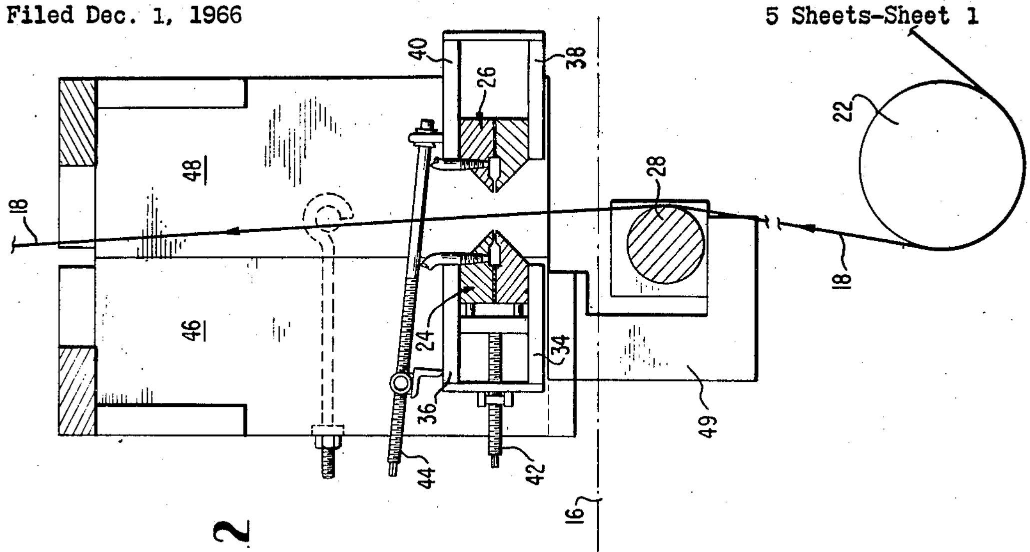


FIG.2

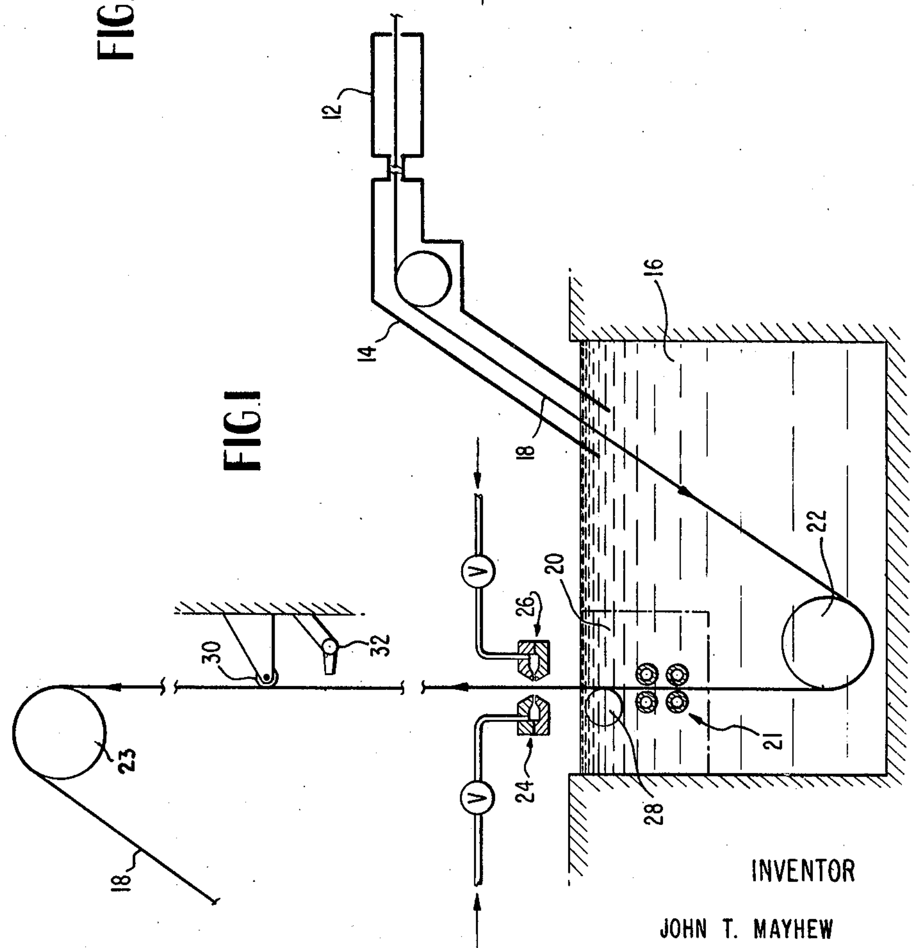


FIG.1

INVENTOR

JOHN T. MAYHEW

BY Shanley & O'Neil

ATTORNEYS

March 10, 1970 J. T. MAYHEW 3,499,418

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

Filed Dec. 1, 1966 5 Sheets-Sheet 2

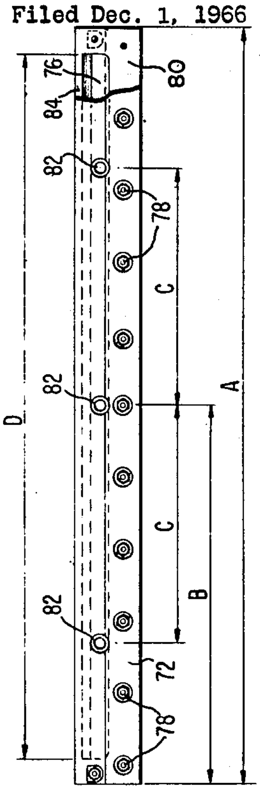


FIG.5

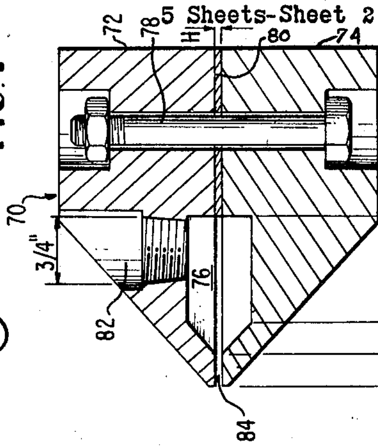


FIG.4

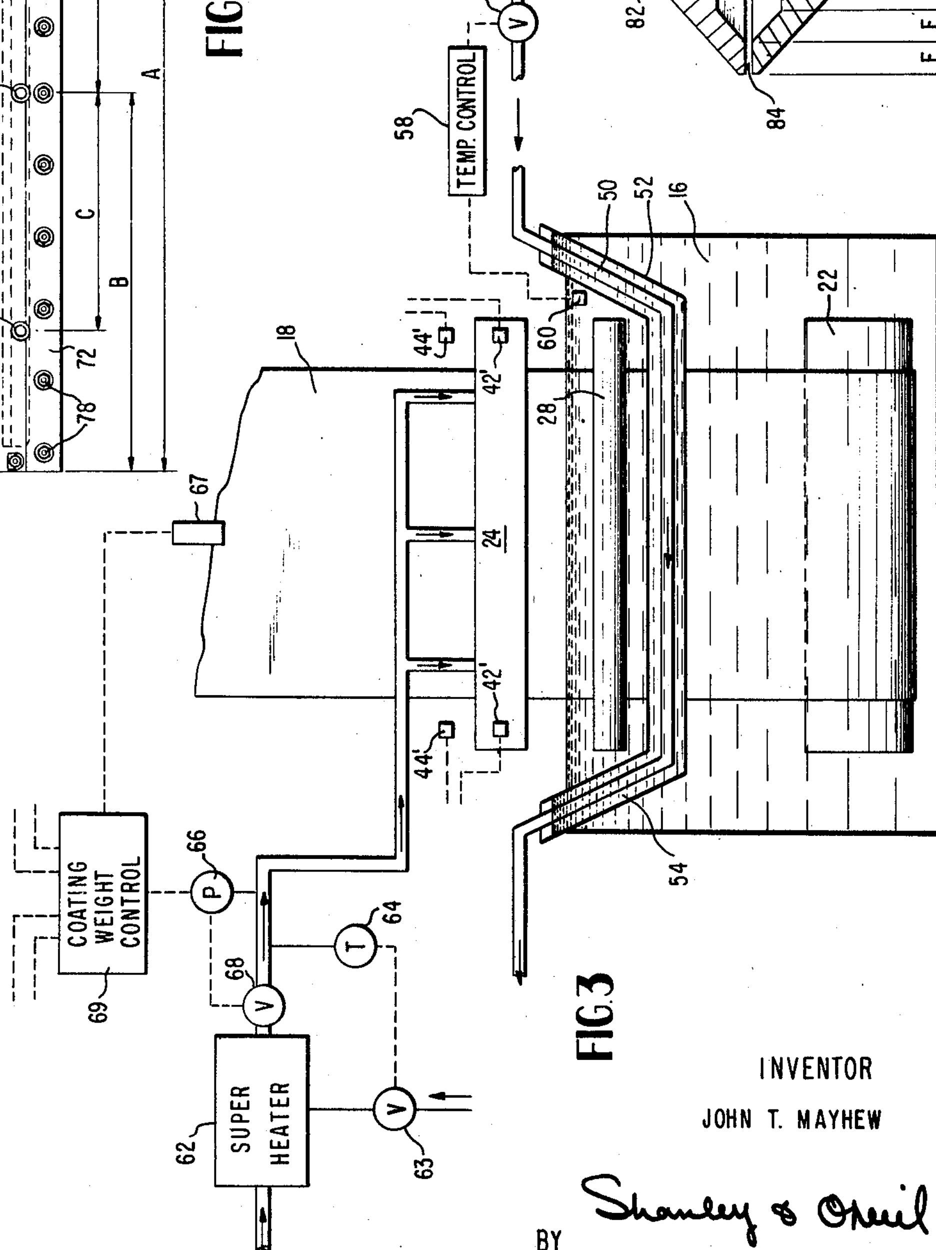


FIG.3

INVENTOR

JOHN T. MAYHEW

BY Shanley & O'Neil

ATTORNEYS

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

Filed Dec. 1, 1966 5 Sheets-Sheet 3

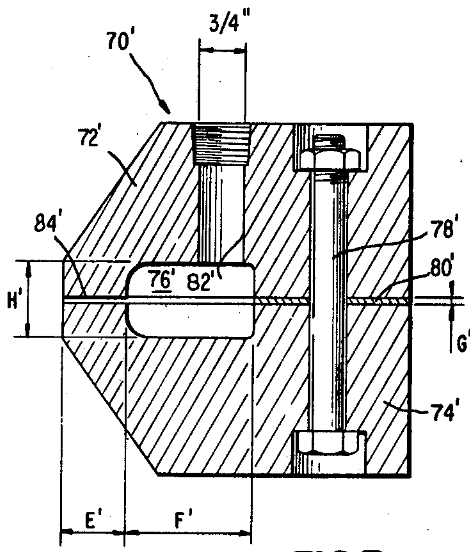


FIG. 7

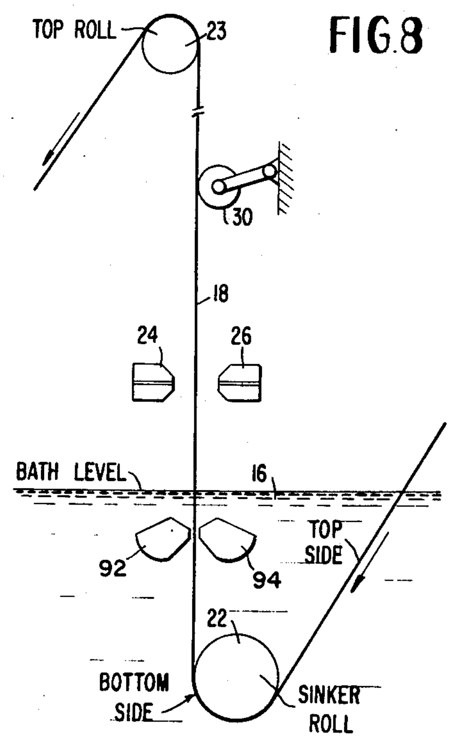


FIG. 8

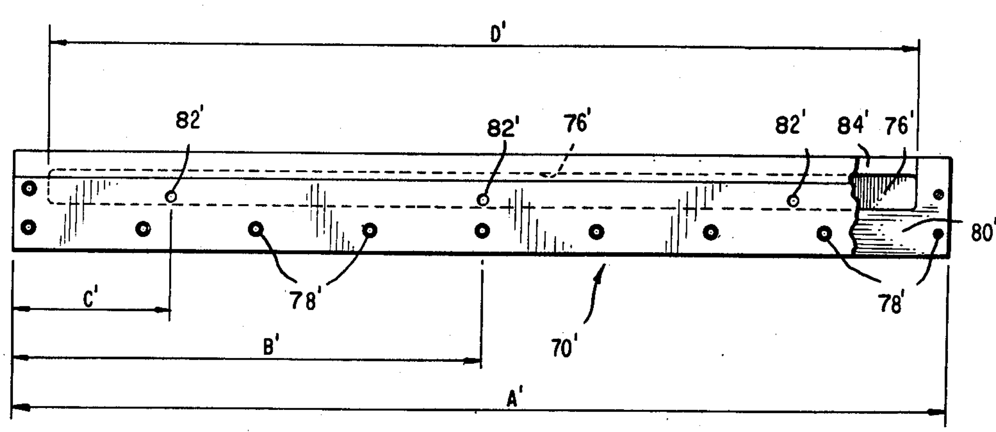


FIG. 6

INVENTOR.
JOHN T. MAYHEW
BY Shanley & O'Neil
ATTORNEYS

March 10, 1970 J. T. MAYHEW 3,499,418

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

Filed Dec. 1, 1966 5 Sheets-Sheet 4

FIG. 10

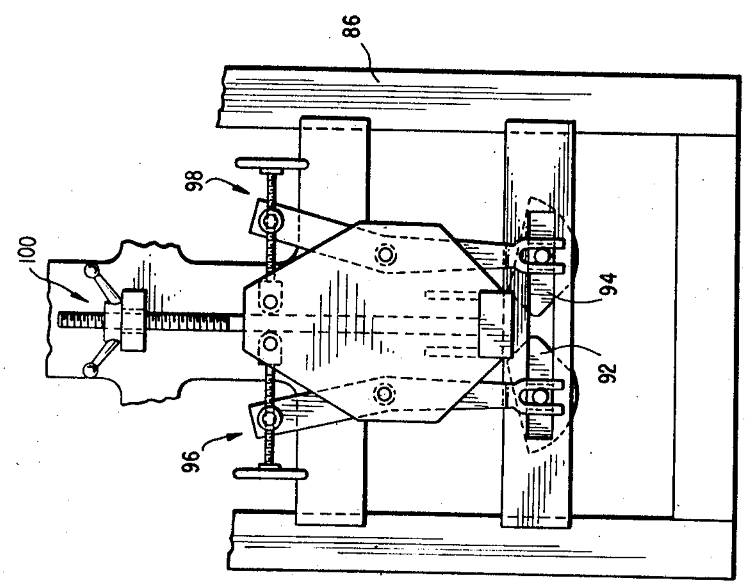
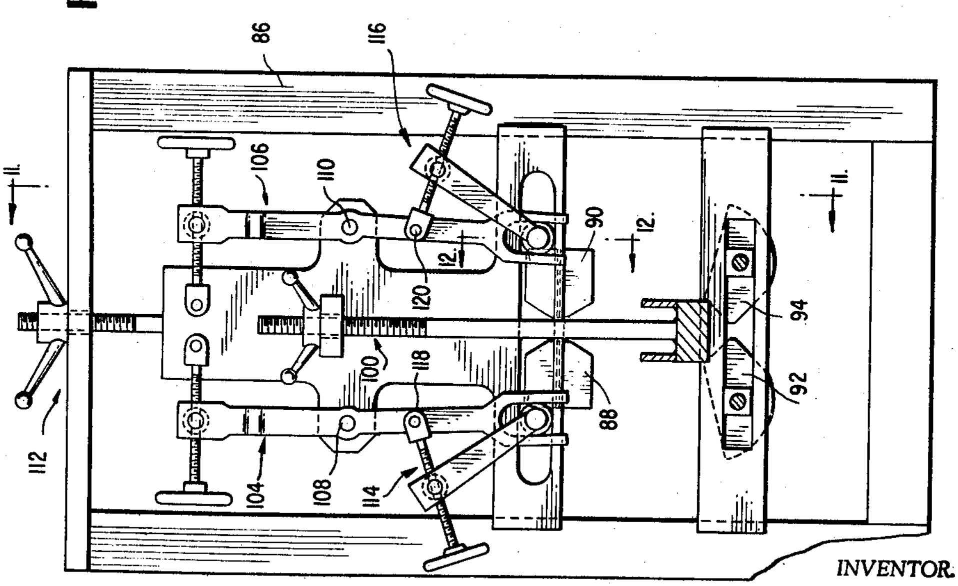


FIG. 9



INVENTOR.
JOHN T. MAYHEW
BY Shanley & O'Neil
ATTORNEYS

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

Filed Dec. 1, 1966 5 Sheets-Sheet 5

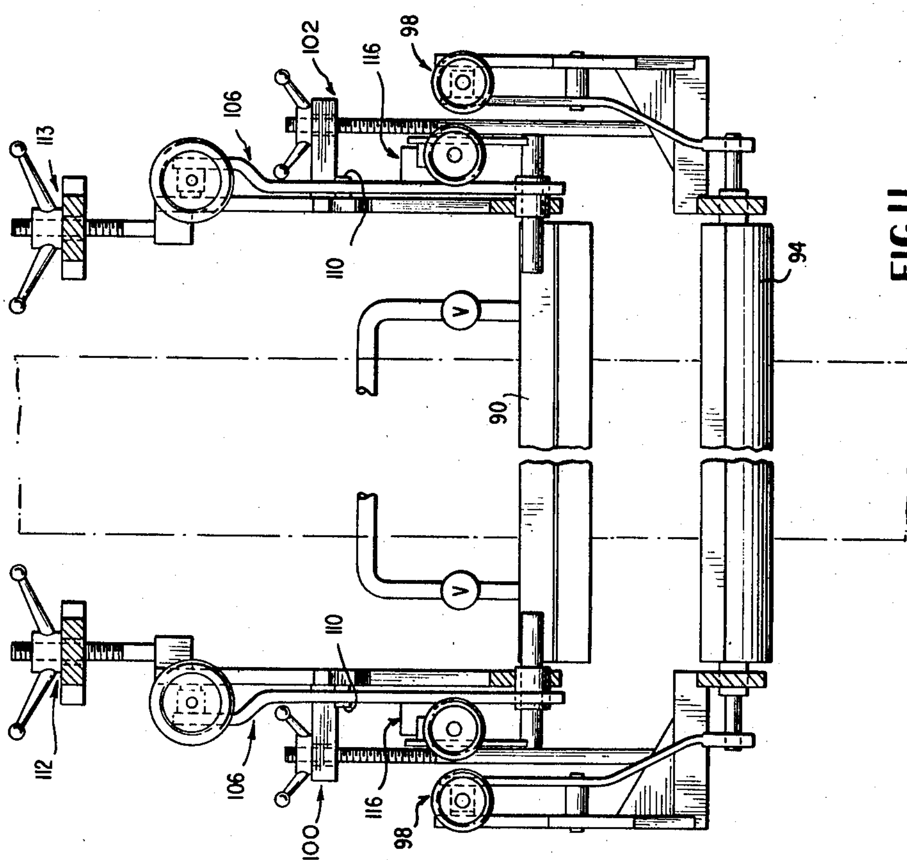


FIG 11

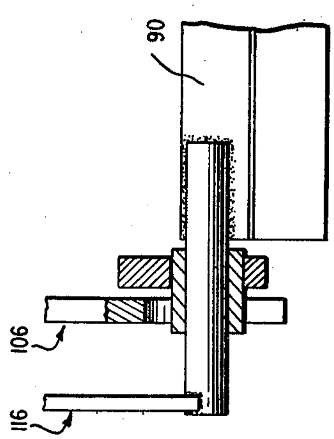


FIG 12

INVENTOR
JOHN T. MAYHEW

BY Shanley & O'Neil

ATTORNEYS

3,499,418

CONTINUOUS METALLIC STRIP HOT-DIP METAL COATING APPARATUS

John T. Mayhew, Toronto, Ohio, assignor to National Steel Corporation, a corporation of Delaware

Continuation-in-part of applications Ser. No. 282,474, May 22, 1963, and Ser. No. 409,053, Nov. 5, 1964. This application Dec. 1, 1966, Ser. No. 598,380
Int. Cl. B05c *11/10, 3/02*
U.S. Cl. 118—4 6 Claims

ABSTRACT OF THE DISCLOSURE

(a) Continuous metal strip hot dip metal coating apparatus in which the conventional finishing rolls are eliminated and the coating weight is controlled by streams of hot gas impinged against continuous metal strip emerging from a molten coating metal bath, the gas being impinged against the strip at a point very close to the surface of the molten coating metal bath and at an angle to the strip at or near the perpendicular.

(b) Continuous metallic strip hot dip metal coating apparatus in which the conventional finishing rolls are eliminated and the coating weight is controlled by streams of hot gas impinged against continuous metal strip emerging from a molten coating metal bath, the gas being impinged against the strip at a point very close to the surface of the molten coating metal bath in conjunction with a guide means submerged in the bath very close to the surface acting to prevent flutter of the strip as it passes the streams of hot gas.

(c) Nozzle means for controlling the coating weight of molten metal coating on a continuous metallic strip, the nozzle orifice being shaped to deliver a concentrated, thin stream of hot gas against the strip across the width of the strip with a major component of motion of the stream of gas being perpendicular to the strip.

(d) Means for controlling the temperature of a portion of the molten coating metal bath adjacent the exit point of continuous metallic strip being coated in connection with the use of streams of gas instead of finishing rolls for controlling the coating weight on the strip to thereby obtain better control of the coating weight.

(e) Means for controlling the coating weight of molten metal coating on continuous metallic strip in response to an indication of the coating weight in conjunction with coating weight control by streams of gas.

This application is a continuation-in-part of application Ser. No. 282,474, filed May 22, 1963 and application Ser. No. 409,053, filed Nov. 5, 1964, both now abandoned.

This invention is concerned with molten metal coating of metal sheet material and in particular relates to novel apparatus which provide faster and more efficient production, better product control and improved product.

Although there have been many highly productive improvements in metal coating operations over the last twenty-five years, molten metal coating itself, especially control of coating weight, has remained essentially the same. Prior to this invention, molten metal coating operations, have relied on mechanical contact with strip at the exit side of a coating bath. This has been a slow cumbersome process, making coating weight control one of the biggest drawbacks and bottlenecks, especially in continuous strip practice.

Since hot dip zinc and zinc alloy coating, herein termed galvanizing, is the commonest form of molten metal coating operations, the invention will be described in this environment.

The invention makes a radical departure from prior

art practice by providing a coating control apparatus which accurately determines coating weight in continuous strip galvanizing operations. The coating control apparatus of the invention leaves the strip free from the marks and damage occasioned by coating rolls, and the like, eliminates changing and cleaning of such mechanical contact devices, and provides numerous unexpected advantages such as increased line speeds, better operational control, a choice of manual or automatic coating weight control, smoother finish, more uniform coatings, and better corrosion protection with less consumption of coating metal.

There are pronounced contrasts between the teachings of the invention and past theories on wiping coating advanced for hot-dip tinplating. For example, the U.S. patents to Steele 850,548, Sebell 2,370,495, Sherman 2,390,007, and the British patent specification 588,281 disclose use of a liquid or equate use of a liquid and compressed gas in tinplating. There are similar contrasts between the teachings of the invention and the wiping action of a high velocity stream of steam passing between a coated surface and internal surfaces of a throat to blow excess metal from the surfaces of a material as disclosed in the U.S. patents to Underwood 2,080,518, 2,095,537 and Reissue 19,758. Such theories have no application in the galvanizing industry and in fact none of these prior art theoretical disclosures is known to have found practical application in hot-dip metal coating of any kind. In practice, coating rolls, despite their many shortcomings and difficulties, remain in use throughout the strip steel galvanizing industry.

The present invention overcomes these problems by controlling coating with what is herein termed a gaseous barrier. Coating control by gaseous barrier leaves the strip free from the marks and damage occasioned by coating rolls, eliminates changing of rolls and other mechanical problems and provides numerous unexpected advantages such as increased line speeds, better operational control, smoother finish, and so forth, which will be discussed below.

Sustained, high-yield, hot-dip galvanizing operations are made possible in the present invention by critical control of a number of factors. The strip is guided from the bath and passes into a coating control zone with its travel path determined and with strip travel limited to longitudinal movement. The strip is shaped to a desired cross-sectional configuration and coating metal on the strip is in excess of desired final coating weight. A linearly extended, thin stream of compressed and heated gas is impinged substantially perpendicularly against the moving strip. The compressed gas is at a minimum desired pressure which will establish a gaseous barrier to passage of a quantity of molten coating metal greater than desired final coating thickness. With this apparatus excess coating metal is returned without turbulence to the coating bath and the final coating on the strip is uniform, smooth, and free from surface imperfections.

Just before leaving the bath and coming into a coating control zone, the strip is led through a portion of the bath in which the metal is held at a controlled temperature so that the temperature of coating metal carried from the bath on exiting strip is substantially uniform regardless of changes in strip width or gage and line speed. Applicant has discovered that this uniformity in coating metal temperature eliminates difficulties encountered in maintaining desired coating weight and quality which stem from variations in coating metal viscosity and the compressibility factor of a gaseous barrier.

In further description of the invention, reference will be had to the accompanying drawings wherein like numbers are used to denote like parts wherever possible:

FIGURE 1 is a schematic drawing of apparatus embodying the invention;

FIGURE 2 is a sectional view of typical coating apparatus of the invention;

FIGURE 3 is a schematic front elevational view of apparatus embodying the invention with some of the parts shown in section;

FIGURE 4 is an enlarged sectional view of nozzle structure of the invention;

FIGURE 5 is a reduced plan view of the structure of FIGURE 4;

FIGURE 6 is is a plan view of a modified nozzle structure embodying the invention with a part broken away for clarity;

FIGURE 7 is a view in section of the modified nozzle structure of FIGURE 6;

FIGURE 8 is a schematic side elevational view of structure embodying a modification of the invention;

FIGURE 9 is a side elevational view of gas barrier coating control apparatus embodying the invention;

FIGURE 10 is another side elevational view of gas barrier coating control apparatus embodying the invention;

FIGURE 11 is a view in section of the apparatus of FIGURE 8, taken along the line **11—11**; and

FIGURE 12 is an enlarged sectional view of a portion of the apparatus of FIGURE 8, taken along the line **12—12**.

In carrying out the invention steel strip is prepared for hot-dip coating with cleaning and/or annealing apparatus **12** shown diagrammatically in FIGURE 1. After preparation, the strip is delivered through controlled atmosphere chute **14** into coating bath **16** where molten coating in excess of desired final coating weight adheres to the strip. The temperature of strip **18** is ordinarily elevated several hundred degrees above atmospheric temperature and heat is added to coating bath **16** by strip **18** or in another practice the coating bath adds heat to the strip. In either situation, with different gages and widths of strip, with changing temperature of the strip itself due to differing heat treatment requirements, and with different strip speeds, which are all part of every day galvanizing conditions, bath temperature tends to fluctuate widely, with the changing masses of strip entering the bath. Compensation for these differences has been difficult and ordinarily required manipulation of strip temperature or speed to the detriment of efficient operation of a line.

Therefore, in accordance with one embodiment of the invention, a portion **20** of the coating bath is maintained at a substantially constant temperature by submerged temperature regulator tubes **21**, regardless of changes in sensible heat effects due to changes in strip steel width, gage, temperature and/or line speed. Strip **18**, after passage around sink roll **22**, passes upwardly through this controlled temperature portion **20** of the bath **16** toward top roll **23**. Thus the temperature of the coating metal on strip **18** as the strip exits from the bath is determined by controlled temperature portion **20** and is held substantially constant at a desired level.

After exit from the coating bath the strip passes through a coating control zone where a gaseous barrier established by superheated steam jets from nozzles **24** and **26** determines the final coating weight. The steam or other heated gas is made to impinge uniformly across the full width of the strip and is confined to a thin stream (five to fifteen-thousandths inch) in the direction of strip travel.

For proper coating metal removal nozzles **24** and **26** must be positioned to impinge the steam against the strip while the coating metal is molten and at proper temperature. These and other considerations can require the nozzles to be positioned in close proximity, about four to five inches, above the coating bath. Yet, applicant has discovered that to obtain a satisfactory smooth coating finish, the surface of the coating bath must be relatively free of turbulence at the strip exist area of the bath. Downwardly inclined nozzles and particularly the higher pressures which downwardly inclined nozzles require must be avoided. Thus the angle of impingement becomes critical if a relatively placid bath surface is to be achieved. When nozzles **24** and **26** are properly positioned molten coating, held back by the gaseous barrier, returns in the form of a smoothly flowing curtain without turbulence to the bath. This result is obtained with substantially perpendicular gas impingement.

Several factors contribute to the advantages of substantially perpendicular gas impingement. For one thing the nozzles **24** and **26** can be positioned closer to the strip and the distance traveled by the steam from nozzle to coated strip can be substantially reduced; in practice a distance around one-half inch and less than about one inch is preferred. This is not practicable with suitable nozzles positioned at a substantial angle with the perpendicular. The increased distance traveled by the steam and the component of force in the steam parallel to the strip resulting from an angled nozzle, require an increase in steam pressure for proper coating removal. For example, with an angle of impingement of 10° from normal with superheated steam being directed downwardly in a direction opposite to strip travel, and a travel path for the steam of one inch, an average steam pressure of forty-two pounds per square inch was required to be delivered to the nozzle structure to produce an ounce and a quarter coating at a line speed of two hundred forty feet per minute. With substantially perpendicular steam impingement, a steam travel path of approximately one-half inch, and a line speed of two hundred thirty feet per minute, an average steam pressure, as delivered to the nozzle structure, of thirty-six pounds per square inch produces an average coating weight of six-tenths ounce per square foot.

Such a reduction in required steam pressure is typical throughout the full range of desired coating weights and line speeds encountered. More important is the fact that the lower pressure has a significant effect on the smoothness of the coating on the product. Still further the bath surface is maintained placid by the perpendicular jet. Coating metal held back by an angled nozzle cascades toward the bath and gives a fluffy appearance as if gas is entrained in the metal. The bath surface near the exiting strip is depressed and is generally turbulent over an area extending to one foot and beyond from the depression surrounding the strip. The drag out of coating metal on the strip between the bath and the jets is decreased by the angled nozzle and the coating metal at the bath surface can be described as "aerated." As a result small particles of solidified metal, referred to as "crumbs," accumulate on the coated surface and are not removed from the strip surface, especially near the edges, by the gaseous jets. The result is a roughened surface on the finished product.

Coating metal held back by the substantially perpendicular gaseous barrier of the present invention returns in a smooth "curtain" to the bath, the bath surface is relatively placid, and there is an increase in drag out of coating metal by the strip. These effects stem in part from an interrelation of substantially perpendicular disposition and lower pressure.

With a downward angle of impingement it appears that a downward component of force in the steam fluffs the coating metal and causes bath turbulence. With substantially perpendicular impingement any downward component of force presented by deflected steam after impingement appears to be dissipated in overcoming the upward component of force represented by the mass of upwardly moving coating metal being held back.

In practice it is not possible to maintain true perpendicular impingement of a heated gas at all points across a strip because of slight variations in strip contour resulting from earlier steel rolling steps. Also while a perpendicular disposition is desirable, slight variations of a few degrees, say at the most 5° in a direction toward the bath, are acceptable as introducing a minimum of difficulties. Also, the invention teaches that in some situations a slight angle upward (in the direction of strip travel) gives results comparable to perpendicular disposition. Also more uniform edge coating can sometimes be obtained with a perpendicularly or upwardly angled nozzle. Therefore, the term "substantially perpendicular" as used herein, includes impingement within the range of a few degrees, above and below the perpendicular with the limitation on the upwardly angled nozzle not being as critical as the downwardly inclined nozzle limitation. These teachings on impingement encompass day-to-day operations on today's galvanizing lines which operate at varying speeds up to four hundred feet per minute. Line speeds can be limited by a number of associated operations. With the present invention, however, the coating control operation will no longer limit line speeds, and new lines should be considerably faster than four hundred feet per minute.

Another important teaching of the invention provides for positioning the moving strip as it passes through the coating control zone. The strip is constrained to purely longitudinal movement by eliminating any lateral vibrating or transverse swaying of the strip during its upward travel. The strip should be shaped to minimize buckles and wavy edges in the strip as much as possible. Also the strip is positioned so that each surface of the strip is uniformly spaced across its width from its respective adjacent nozzle.

To obtain desired conformation, movement, and spacing in the coating control zone, roll guides are specially positioned as close as possible to the coating control zone. Referring to FIGURE 1, guide roll **28** contacts the strip below but adjacent the bath surface and applies a force to the strip which may cooperate with an upper guide roll **30** to control positioning of the strip.

Guide roll **28** is preferably freely rotatable and not driven. Both guide rolls **28** and **30** make contact with the strip as close as possible to the coating control zone without interfering with the coating operation and the coated surface, respectively. In the latter case, with roll **30**, heat is removed from the strip after exit from the coating control zone. Cooling air or wet steam from spout **32** is used to solidify the coating before contact with guide roll **30**. An important discovery of applicant, reasons for which are not fully known, is that upper roll **30** can be positioned closer to the bath with the jet process of the present invention than is possible with coating control rolls. For example when wet steam is discharged from spout **32** to minimize spangle formation by rapidly solidifying the coating the spout can be positioned about five to six feet above the bath rather than the customary eight to twelve feet above the bath used with coating control rolls. Guide roll **30**, which is positioned a short distance (one to three feet) above spout **32**, can then be correspondingly closer to the bath. Because of this, roll **30** is more effective in obtaining the desired strip placement in the coating control zone.

The shaft of guide roll **28** is positioned as close to nozzles **24** and **26** as possible without disturbing coating weight control; for example, seven or eight inches below nozzles **24** and **26**, with the top of the roll submerged about two to three inches beneath the coating bath surface has been found to be optimum in a coil galvanizing line of present design.

A coating control machine in accordance with the invention is shown in more detail in FIGURE 2. The strip **18** passes upwardly from sink roll **22** in contact with guide roll **28** and between nozzles **24** and **26**. The nozzles are supported in slides **34**, **36**, **38** and **40**, which permit the nozzles to move toward and away from the strip. Adjustment gearing **42** and **44** which may be operable by motors **42'**, **44'** (see FIGURE 3) is connected to each nozzle for selection of spacing between each nozzle and its adjacent surface of strip **18**. The adjustment means are

mounted on both longitudinal ends of the nozzles, are calibrated and are adjustable from the same side of the machine. The nozzles and slides are supported by frame members **46** and **48** which are separable to permit installation of the machine without cutting the continuous strip. Frame member **46** also supports arm **49** which holds the bearing for guide roll **28**. The lateral displacement of strip **18** between sink roll **22** and guide roll **28** is exaggerated in the FIGURE 2 showing. In practice, a shaping and placement force is applied to strip **18** by a lateral displacement of strip **18** of around three inches between sink roll **22** and guide roll **28**. An oppositely directed force may be applied at roll **30**. Strip **18** moves upwardly along a substantially vertical path since any lateral offsetting is minor compared to the overall length of the longitudinal path between the sink roll **22** and top roll **23**, usually forty to sixty feet, or more.

Guide roll **28** is spaced seven and one-half inches from nozzles **24** and **26** in the machine shown. This spacing can be fifteen inches or more above roll **28** dependent on a number of conditions. However, the object is to position nozzles **24** and **26** as close to guide roll **28** as possible in order to take advantage of the planar configuration of the strip imposed by roll **28**. In positioning the nozzles however, turbulence of the bath and return of coating metal to the bath must be considered.

The coating metal on the strip should preferably be above 800° F. at the time of contact with the coating control jet. Composition of the galvanizing spelter may affect this; conventional galvanizing spelter includes aluminum additions and impurity level percentages of lead, antimony, cadmium, etc., and has a melting temperature in the neighborhood of 790° F. The temperature of zone **20** is maintained in a range of roughly 800° F. to 860° F. dependent on product and stabilized to avoid changes greater than roughly 10° to 20°; e.g. around 825° F. to 840° F. is preferred for most of today's flat rolled steel galvanized products. In stabilizing the temperature of zone **20**, a temperature differential up to 30° or higher may exist between zone **20** and the remainder of the bath.

FIGURE 3 shows a front elevation, partially in section, of coating apparatus in which a fluid coolant tube **50** is submerged in coating bath **16**. In practice a plurality of such tubes can be used to define a zone of temperature regulated cooled spelter. For safety purposes tube **50** may be surrounded by conduit **52** containing a heat conductive material **54**, such as molten lead. Flow of fluid in tube **50** is controlled by valve **56** and may be responsive to temperature control apparatus **58** which receives signals from temperature measuring device **60**. Water is a preferred coolant.

Superheater **62** controls the temperature of a heated gas, such as superheated steam or air. Temperature of the heated gas is preferably held substantially constant with varying flow demands. In practice a temperature around 850° F. is preferred but satisfactory operation can be obtained within a range of, roughly, 500° F. to 1500° F. Temperature measurements at indicator **64** can be used to automatically control valve **63** which controls fuel flow to superheater **62** to maintain gas temperature at the desired constant value.

The pressure at nozzle **24** or **26** cannot be conveniently measured without disturbing the coating. Pressure measurements read at control meter **66**, or a similar location, give satisfactory results once relative values for a given installation are established. Valve **68** controls the pressure of the heated gas delivered to nozzle **24** and is responsive to selected pressures at control meter **66**. A similar control is provided for nozzle **26** and substantially equal pressures are used on both surfaces of the strip when equal coating weights on each surface are desired.

For automatic coating weight control, a non-contact coating thickness measurement device, such as beta ray back scattering gage **67** is positioned on each side of strip

18. Thickness measurements from the beta ray gages are delivered to coating weight control apparatus **69** and coordinated with the selected coating weight to vary the pressure delivered to each coating control nozzle or control the spacing between each nozzle and its respective side of the strip **18**. Control signals are delivered over the dotted lines shown to a pressure control meter, such as **66**, for each surface of the strip and to motors **42'**, **44'** for actuation of the spacing controls **42** and **44**.

Details of linearly extended nozzle structure are shown in FIGURES 4 and 5. Nozzle structure **70** includes two die members **72** and **74** which mate to form a linearly extended gas manifold **76**. Die members **72** and **74** are joined by a series of bolts **78**. The separation between members **72** and **74** determines the nozzle opening or passageway **84** and is set by use of shim stock **80**. Spacing means **80** can vary in thickness between .005 and .015 inch. Passageway **84** has an inlet opening into manifold **76** and an outlet facing the strip. Gas is supplied through a plurality of apertures **82**, in order to obtain substantially uniform gas pressures across the full longitudinal length of manifold **76**. The gas exits through linearly extended passageway **84**. It is to be noted that the angle of entry of the gas with respect to the plane of the exit is shown as 90° but the invention is not limited to 90°; however, a substantial angular relationship is desired in order to obtain uniform gas dispersal and exit velocity across the linearly extended nozzle opening **84**. Typical dimensions for nozzle structure used in obtaining data for the examples presented are:

	Inches
A	57¾
B	28⅞
C	18
D	54
E	½
F	½
G	1½
H	.015

Details of a slightly modified form of nozzle structure embodying the present invention are shown in FIGURES 6 and 7 wherein identical reference numerals are used corresponding to those used in FIGURES 4 and 5 but in this case are primed. The reference letters indicating the dimensions in FIGURES 6 and 7 differ in part from those used in FIGURES 4 and 5 because of the slightly different shape of the nozzle structure but again are primed to distinguish from the earlier described modification.

Typical dimensions for the nozzle structure illustrated in FIGURES 6 and 7 are as follows:

	Inches
A'	53⅞
B'	26$\frac{15}{16}$
C'	8$\frac{13}{16}$
D'	49⅞
E'	1"
F'	2"
G'	.005–.015
H'	1+G

One of the primary objects of nozzle structure used in gas barrier coating control of strip is a linearly extended gaseous stream of uniform gas pressure across the strip. The thickness of the gaseous barrier in a direction parallel to the strip motion is dependent on the nozzle opening which will give proper flow. Larger nozzle openings give greater gas mass and permit a greater mass of molten coating to be held back. Larger openings also avoid clogging by foreign matter; openings of .015 inch have been found satisfactory for mill use in this latter regard.

As pointed out above, the thickness of the stream of gas contacting the strip, measured in a direction parallel to strip motion, is dependent on the nozzle opening. It will be evident from this and an inspection of the drawings that a stream of gas, under a pressure in the range disclosed, issuing from either of the restricted orifices formed by passageways **84** or **84'** will not be substantially divergent in form and in the short distance between nozzle outlet and line of impingment against the strip will be in the form of a thin sheet having a thickness dimension not substantially greater than the width dimension of the passageway.

FIGURE 8 discloses a modification of the means for presenting the strip to the nozzles **24** and **26** in planar form and constrained against loose movement, i.e., fluttering as it passes between the nozzles. Instead of the guide roll **28** on one side of the strip, two fixed guide members **92**, **94** are positioned under the surface of the bath, one on either side of the strip. The submerged guide members **92**, **94** can assist in the bonding of the zinc to the strip by providing an "ironing" effect on the spelter; that is, some pressure can be exerted on the spelter during passage through guide means **92**, **94**. Also, they provide a near turbulence-free pocket of metal for the strip to pass through before reaching the surface of the bath. In practice, they have been found to function well when submerged several inches beneath the surface of a hot dip galvanizing bath and therefore coating for long periods can take place without additions to the bath. The guide members shown diagrammatically in FIGURE 8 are held fast in the submerged position, as described in more detail below, but the principle of the invention does not exclude a pair of rolls for this purpose.

FIGURES 9 through 12 show details of hot dip, gas barriers apparatus including means for adjusting angle of impingement of the gas, height of impingement above the bath, depth of submerged guide members which guide or constrain strip in a particular bath, the gap between gas nozzles, and the gap between the guide members. Where pairs of identical adjustment means exist on the same side of the strip, the same numbers have been used to identify each member of the pair.

Framework **86** supports the entire apparatus. Nozzle structures **88**, **90** are positioned above guide members **92**, **94** which guide the strip into the coating control zone with substantially planar configuration. Referring in particular to FIGURES 10 and 11, guide member **92** is adjusted by linkages **96** and guide member **94** by linkages **98**. Vertical location of bracing members **92**, **94** is adjusted by screw mechanisms **100** and **102**.

Referring to FIGURE 9 in particular, the gap between the nozzle structures **88** and **90** is adjusted by linkages **104** and **106** which pivot at **108** and **110**, respectively. Linkages **104**, **106** are adjustable by the gearing shown which may be motorized and automated as described above in respect to gearing **42**, **44**. The angles of nozzles **88** and **90** can be adjusted to substantial perpendicularity by linkages **114** and **116** pivoted at **118** and **120**, respectively. The nozzle structures, guide members and their respective adjustment means are moved upwardly or downwardly with respect to the framework **86** by height adjustment means **112**, **113**.

In the gas barrier principle, as taught by the present invention, the mass of the gas impinging against the molten coating is a dominant factor. The effect of mass can be seen from a culvert stock example where approximately 1090 pounds of steam per hour at a line speed of 110 feet per minute produced two and one-half ounce per square foot coating while at a line speed of 130 feet per minute approximately 2200 pounds per hour produced light commercial coating near .6 ounce per square foot.

From an operational point of view, pressure change can be used for changing the mass of the superheated steam or other gas used. For example, with increasing line speeds the mass of coating to be held back to maintain constant coating weight increases. This increase in mass can be achieved by increasing gas pressure. Alternatively, the mass of the gas can be increased by increasing the area of the nozzle slot without increasing the gas pressure.

Speed of the line is an important factor; it has been observed that on a continuous galvanizing line, under similar operating conditions of nozzle location and superheated steam pressure, a speed of one hundred (100) feet per minute produced a "light commercial coat" while two hundred (200) feet per minute produced a commercial ounce and a quarter coating. Line speed could be used to control coating weight but, in practice, an operator would run a line at a maximum speed for a particular gage material as determined by other factors. The gas barrier could be set at the optimum height above the bath, the optimum gas opening, the gas pressure or nozzle spacing or both being then varied to control the coating weight.

Final coating weight at a given line speed can be controlled by either gas pressure or proximity of the linearly extended nozzles to the strip, or both. As described above the temperature of the coating metal applied to the strip is held substantially constant. Briefly, higher strip speeds, lower impinging gas pressure, and greater distances between nozzle and strip produce heavier coating weights; lower strip speeds, higher impinging gas pressure, and lower distances between the nozzle and the strip produce lighter coating weights. Generally the strip speed is selected based on other limiting factors, e.g., the annealing capacity of the line, and the line is ordinarily run at the maximum speed available considering such limitation factors. It is desirable to maintain a minimum steam pressure regardless of other related coating control factors although to meet variations in required coating weight either steam pressure or nozzle spacing can be changed. In practice changing of nozzle spacing is preferred because of the desire to maintain a minimum gas pressure and to avoid over or under correcting when gas pressure controls are employed. With automatic controls either spacing or pressures can be changed readily to meet coating requirements within a selected low pressure range. Typical production examples are included below.

Continuous-strip galvanizing with nozzles 4½" to 5½" above bath level, coating metal at exit side of bath held at or near 825° F., nozzle opening of .015", substantially perpendicular impingement, superheated steam temperature about 840° F., spacing between each nozzle and its adjacent strip surface about ½".

TABLE I

Run	1	2	3	4
Strip thickness (inches)	.020	.0183	.018	.0172
Strip width (inches)	36 9/16	28	24½	27 13/16
Topside pressure (lb./in.^{2})	35	30	37	32
Bottomside pressure (lb./in.^{2})	34	30	38	31
Speed of line (f.p.m.)	170	220	230	230
Coating weight (oz./ft.^{2}) (total of both surfaces)	.59	.82	.59	.99

Continuous-strip galvanizing with nozzles 4½" to 5½" above bath level, coating metal temperature at exit side of bath held at or near 825° F., nozzle opening .015", substantially perpendicular impingement, superheated steam temperature about 840° F., spacing between each nozzle and its adjacent strip surface about ¾".

TABLE II

Run	5	6	7	8
Strip thickness (inches)	.018	.0217	.021	.0157
Strip width (inches)	36	36	23¼	24
Topside pressure (lb./in.^{2})	38	29	42	42
Bottomside pressure (lb./in.^{2})	40	29	41	41
Speed of line (f.p.m.)	200	200	210	230
Coating weight (oz./ft.^{2})	.54	.76	.53	.56

The following differing products were run over a three hour period on the same line with the nozzles 4½ to 5½" above bath level, nozzle opening .015", substantially perpendicular impingement, and spacing between each nozzle and its adjacent strip surface about ¾". The coating metal temperature at the exit side of the bath was

held at or near 825° F. despite wide changes in strip heat added to pot by changes in steel mass introduced and varying line speeds.

TABLE III

Run	9	10	11
Strip thickness (inches)	.018	.0157	.0187.
Strip width (inches)	30	30	35.
Topside pressure (lb./in.^{2})	32	26	28.
Bottomside pressure (lb./in.^{2})	32	26	28.
Speed of line (f.p.m.)	230	130	180.
Coating weight (oz./ft.^{2})	.94	.94	.97.
Product form	Coils	Sheets	Coils.
Use	Pipes	Warehouse stock.	Roofing.

Differential-coat is readily produced by controlling gas pressure on each surface. From observation of production of differential-coat on a continuous galvanizing line, the light side coating is controlled more effectively by the gas barrier method than with any known apparatus. Imperfections in the strip on the light side of the strip are not a problem with the gas barrier apparatus and a smoother light side coating results. Differential galvanized product having less than 0.1 ounce per square foot on the light side and more than .03 ounce per square foot on the heavy side was produced using 55 pounds per square inch steam pressure on the bottom side manifold (light side of the differential coat) and 45 pounds per square inch steam pressure on the top side manifold.

In producing product with equal coating weight on both surfaces, the strip is ordinarily passed midway between the coating control nozzles and the steam pressure on each nozzle is about the same. In order to make differential coat product, the nozzle on the light coating side of the strip can be moved closer to the strip or the steam pressure can be increased or both. In practice, changing the spacing of the nozzles is preferred as shown in the following table.

With perpendicular disposition of the nozzles, drawing quality stock, .0503" gage, 37⅜" width, was produced at a line speed of 80 feet per minute with the following settings:

TABLE IV

	Nozzle Spacing (in.)	Pressure (lb./in.^{2})	Coating weight (lb./ft.^{2})
Light side	¼	25	.19
Heavy side	1¼	22	.48

Adjusting in spacing between nozzles to change coating weight is an advantage of the substantially perpendicular impingement concept which is not readily available with angled impingement. Spacing of angled nozzles cannot be changed without changing the point of impact of the gas with the strip. Therefore the point of the impact for one nozzle may be readily offset from the other with an angled disposition. One result can be an edge buildup of coating metal. With the nozzles disposed substantially perpendicularly to the strip this problem does not exist and a new means of adjusting coating weight, by adjusting nozzle spacing is available to the operator.

With the present invention, high strip speed is not a limiting factor whereas, with mechanical contact methods, coating control was one of the major speed limiting factors. Other operations such as annealing or coiling, etc., may place some limit on a particular line but, with the present invention, the coating operation itself will not limit line speeds with present day molten metal coating lines of any type. In fact, it has been found that the gas barrier principle of this invention produces smoother finishes at higher speeds.

Some of the advantages of the gas barrier principle of coating control include increased production, improved quality and more economic production. Increased production results from the faster line speeds available with this invention over those with the prior art practice; also, less down time for a line since there is no necessity to change coating rolls, etc. Improved quality results from the avoidance of coating roll marks and the smoother finish produced by the gas barrier method. Improved economy results from the increased production referred to above, increased percentage yields, and elimination of a number of post coating treatments to improve coating surface.

I claim:

1. Continuous metallic strip hot-dip metal coating apparatus comprising:

(a) molten coating metal bath means having the upper surface of the molten coating metal of the bath means exposed to a gaseous atmosphere,

(b) roll means defining a travel path for continuous metallic strip through a portion of the molten coating metal of the bath means, thence through a coating weight control zone and upwardly to a point where the molten coating metal applied to the strip in the bath has solidified, the coating weight control zone extending upwardly from the exposed surface of the molten coating metal through the portion of the travel path in which the weight of the still molten coating metal applied to the strip in the bath can be controlled, the roll means comprising a first roll submerged in the molten coating metal and a second roll positioned above the bath means at a point where the molten coating metal applied to the strip in the bath means has solidified, the travel path of the strip including no mechanical means contacting the strip between a point under the upper surface of the molten coating metal and a point above the coating weight control zone,

(c) nozzle means having two linearly extended, narrow gas outlet means, each gas outlet means having a length greater than about 23" and at least equal to the width of the strip, each gas outlet means being shaped to deliver a concentrated stream of gas under pressure of shape and mass along the length of the gas outlet means to give uniform coating weight across the width of the continuous metallic strip,

(d) means for supplying gas under pressure to the nozzle means,

(e) support means for positioning the nozzle means in the coating weight control zone with each linearly extended gas outlet means parallel to and facing an opposite planar surface of the strip and spaced above the upper surface of the bath, with each gas outlet means positioned to direct a stream of gas under pressure against the strip and across the width thereof in a direction substantially perpendicular to the opposed planar surface of the strip to form a gaseous barrier to molten coating metal on the opposed planar surface of the strip,

(f) means for continuously controlling the mass of gas under pressure supplied to the nozzle means, and

(g) support means (e) positioning each gas outlet means to direct a stream of gas under pressure against the strip in substantially direct opposition to and so as to impinge against the associated planar surface of the strip in substantially the same plane as the stream of gas under pressure from the other gas outlet means.

2. Continuous metallic strip hot-dip metal coating apparatus comprising:

(a) molten coating metal bath means having the upper surface of the molten coating metal of the bath means exposed to a gaseous atmosphere,

(b) roll means defining a travel path for continuous metallic strip through a portion of the molten coating metal of the bath means, thence through a coating weight control zone and upwardly to a point where the molten coating metal applied to the strip in the bath has solidified, the coating weight control zone extending upwardly from the exposed surface of the molten coating metal through the portion of the travel path in which the weight of the still molten coating metal applied to the strip in the bath can be controlled, the roll means comprising a first roll submerged in the molten coating metal and a second roll positioned above the bath means at a point where the molten coating metal applied to the strip in the bath means has solidified, the travel path of the strip including no mechanical means contacting the strip between a point under the upper surface of the molten coating metal and a point above the coating weight control zone,

(c) nozzle means having two linearly extended, narrow gas outlet means, each gas outlet means having a length greater than about 23" and at least equal to the width of the strip, each gas outlet means being shaped to deliver a concentrated stream of gas under pressure of shape and mass along the length of the gas outlet means to give uniform coating weight across the width of the continuous metallic strip,

(d) means for supplying gas under pressure to the nozzle means,

(e) support means for positioning the nozzle means in the coating weight control zone with each linearly extended gas outlet means parallel to and facing an opposite planar surface of the strip and spaced above the upper surface of the bath with each gas outlet means positioned to direct a stream of gas under pressure against the strip and across the width thereof with the major component of motion of the stream of gas perpendicular to the opposed planar surface of the strip,

(f) means for continuously controlling the mass of gas supplied to the nozzle means, and

(g) means for adjusting the distance between at least one gas outlet means and the associated planar surface of the strip while maintaining unchanged the direction of the stream of gas under pressure relative to the strip.

3. The apparatus of claim 2 further comprising:

(h) means associated with means (g) for maintaining said one gas outlet means in a position to direct the stream of gas under pressure against said associated planar surface of the strip at a given distance above the upper surface of the bath for any adjustment of the distance of said one gas outlet means from the strip.

4. Continuous metallic strip hot-dip metal coating apparatus comprising:

(a) molten coating metal bath means having the upper surface of the molten coating metal of the bath means exposed to a gaseous atmosphere,

(b) roll means defining a travel path for continuous metallic strip through a portion of the molten coating metal of the bath means, thence through a coating weight control zone and upwardly to a point where the molten coating metal applied to the strip in the bath has solidified, the coating weight control zone extending upwardly from the exposed surface of the molten coating metal through the portion of the travel path in which the weight of the still molten coating metal applied to the strip in the bath can be controlled, the roll means comprising a first roll submerged in the molten coating metal and a second roll positioned above the bath means at a point where the molten coating metal applied to the strip in the bath means has solidified, the travel path of the strip including no mechanical means contacting the strip between a point under the upper surface of the molten coating metal and a point above the coating weight control zone,

(c) nozzle means having two linearly extended, narrow gas outlet means, each gas outlet means having a length greater than about 23" and at least equal to the width of the strip, each gas outlet means being shaped to deliver a concentrated stream of gas under pressure of shape and mass along the length of the gas outlet means to give uniform coating weight across the width of the continuous metallic strip,

(d) means for supplying gas under pressure to the nozzle means,

(e) support means for positioning the nozzle means in the coating weight control zone with each linearly extended gas outlet means parallel to and facing an opposite planar surface of the strip and spaced above the upper surface of the bath, with each gas outlet means positioned to direct a stream of gas under pressure against the strip with the major component of motion of the stream of gas perpendicular to the opposed planar surface of the strip,

(f) means for continuously controlling the mass of gas under pressure supplied to the nozzle means, and

(g) strip guide means in the molten coating metal of the bath means for making substantially continuous contact with the coating on the strip and for exerting pressure on the strip across the width of the strip above the first roll means and entirely below but closely adjacent to the upper surface of the molten coating metal of the bath means, the substantially continuous contact including a straight line of contact about 23″ long, the pressure exerted by the strip guide means on the strip being sufficient to thereby impart a planar configuration to the strip passing through the upper surface of the molten coating metal into the coating weight control zone.

5. The apparatus of claim **4** further including means for adjusting the vertical spacing between the nozzle means and the strip guide means.

6. The apparatus of claim **4** in which the nozzle means and the strip guide means are positioned so that the distance between the line of contact of the strip guide means with one planar surface of the strip and the line of contact of a stream of gas under pressure from the nozzle means with the corresponding planar surface of the strip is between seven inches and fifteen inches.

References Cited

UNITED STATES PATENTS

287,076	10/1883	Young	117—102
811,854	2/1906	Lee	117—102
1,672,526	6/1928	Hawkins	117—114
2,160,864	6/1939	Hill et al.	117—64
2,390,007	11/1945	Sherman	118—63
2,950,991	8/1960	Seymour	117—114
3,148,080	9/1964	Mayhew	117—114

ALFRED L. LEAVITT, Primary Examiner

J. R. BATTEN, Jr., Assistant Examiner

U.S. Cl. X.R.

117—102, 114; 118—9, 63, 419, 428, 429; 239—589

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,499,418 Dated March 10, 1970

Inventor(s) JOHN T. MAYHEW

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

Col. 4, line 1, "exist" should be -- exit --.
Col. 10, line 18, "method" should be-apparatus --
line 23, ".03" should be -- .3 --.

SIGNED AND
SEALED
AUG 4 - 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents