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## PATENT SPECIFICATION

DRAWINGS ATTACHED

1127831

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### COMPLETE SPECIFICATION

#### Improvements relating to the coating of metals

We, NATIONAL STEEL CORPORATION, a Corporation of the State of Delaware, United States of America, of 2800, Grant Building, Pittsburgh 19, Pennsylvania, United States of America (Assignee of JOHN THOMAS MAYHEW), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention is concerned with continuous strip hot-dip metal coating of metal sheet material.

Prior art hot-dip strip molten metal coating operations have relied on mechanical contact with strip at the exit side of a coating bath for coating weight control. As a result difficulties inherent in mechanical contact have been one of the major limiting factors in the efficiency of continuous-strip hot-dip molten metal coating.

In British Patent Specification No. 20966/64 (Ser. No. 1,071,572), there is described a continuous metallic strip hot-dip metal coating process in which molten coating metal in excess of desired coating weight is applied to the continuous metallic strip by passing the strip longitudinally through a bath of molten coating metal having an upper surface which is exposed to a gaseous atmosphere and the continuous strip is passed in planar configuration from the molten coating metal bath through a coating weight control zone located above the upper surface of the molten coating metal bath, in which zone the molten coating metal applied to the strip in the bath remains molten and there is no mechanical contact with the coated strip, and in which a linearly extended narrow stream of heated gas is impinged against each of the opposite planar sides of the coated strip in the coating weight control zone uniformly across the full width of the strip in a line uniformly spaced from the upper surface of the bath, with each stream of heated gas impinging against the strip at an angle of incidence

between zero and fifteen degrees above the perpendicular, inclusive, and the rate of mass flow of the heated gas impinging against each side of the strip in the coating weight control zone is controlled to obtain a desired weight of coating metal remaining on the strip leaving the coating weight control zone. This coating weight control process leaves the strip substantially free from the marks and damage occasioned by coating rolls, and the like, eliminates changing and cleaning of such mechanical contact devices, and can provide 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.

In making a departure from conventional mechanical contact coating control processes difficulties were encountered in obtaining a smooth finish and in maintaining a uniform coating over sustained periods, with an impingement angle of ten to fifteen degrees above the perpendicular. These difficulties were encountered even though recognized variables in the process were maintained within normal ranges.

According to the present invention, a continuous metallic strip hot-dip metal coating apparatus comprises a hot-dip bath for containing molten coating metal, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal, then through a coating weight control zone located immediately above the molten coating metal, and then upwardly to a point where coating metal applied to the strip has solidified, the coating weight control zone extending upwardly from the molten coating metal through a portion of the travel path of the continuous metallic strip in which the weight of the molten coating metal applied to the strip in the bath can be controlled, a nozzle arrangement positioned in the coating weight control zone and having

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two opposed linearly extended, narrow-width, gas outlets, each gas outlet having a length at least equal to the transverse edge to edge dimension of the metallic strip to be coated and each gas outlet being shaped to deliver a concentrated, narrow-width stream of hot gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to and in substantially the same plane as the stream of gas from the other gas outlet with the hot gas impinging substantially perpendicularly (as hereinafter defined) against the strip to prevent passage of molten coating metal in excess of desired coating weight and to provide a substantially uniform coating weight on the continuous metallic strip, means for supplying hot gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by controlling the flow of hot gas to the nozzle arrangement.

The present invention also provides a continuous metallic strip hot-dip metal coating process in which molten coating metal in excess of desired coating weight is applied to the continuous metallic strip by passing the strip longitudinally through a bath of molten coating metal having an upper surface which is exposed to a gaseous atmosphere and the continuous strip is passed in planar configuration from the molten coating metal bath through a coating weight control zone located above the upper surface of the molten coating metal bath, in which zone the molten coating metal applied to strip in the bath remains molten and there is no mechanical contact with the coated strip, and in which a linearly extended narrow stream of hot gas is impinged against each of the opposite planar sides of the coated strip in the coating weight control zone across the full width of the strip in a line uniformly spaced from the upper surface of the bath, with each stream of hot gas impinging substantially perpendicularly (as hereinafter defined) against the strip, and the rate of mass flow of the hot gas impinging against each side of the strip in the coating weight control zone is controlled to obtain a desired uniform weight of coating metal remaining on the strip leaving the coating weight control zone.

There are pronounced contrasts between the present invention and past theories on wiping coating advanced for hot-dip tinning. For example, the U.S. Patents to Sebell, No. 2,370,495, and to Sherman, No. 2,390,007, and British Patent Specification No. 588,281 describe the use of a liquid or equate use of a liquid and compressed air in tinning. There are similar contrasts between the present 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 described in the U.S. Patents

to Underwood Nos. 2,080,518, 2,095,537, and Reissue No. 19,758.

The invention is further described, by way of example, with reference to the accompanying drawings wherein like numbers are used to denote like parts wherever possible and wherein:—

Figure 1 is a schematic view of hot-dip coating apparatus constructed in accordance with the invention;

Figure 2 is a sectional view, to a larger scale, of part of the coating apparatus;

Figure 3 is a schematic front elevational view of the coating apparatus, with some of the parts shown in section;

Figure 4 is an enlarged sectional view of one of the nozzles of the apparatus; and

Figure 5 is a plan view, to a smaller scale, of the nozzle of Figure 4.

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 a controlled-atmosphere chute 14 into a coating bath 16 where molten coating in excess of desired final coating weight adheres to the strip. The temperature of the strip 18 is ordinarily elevated several hundred degrees above atmospheric temperature and heat is added to the coating bath 16 by the strip 18 or in another practice the coating bath adds heat to the strip. In either situation, with different gauges 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 everyday 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.

Close control of the coating metal temperature at the strip exit zone of the bath is important for sustained uniformity when controlling coating weight with the gaseous barrier process in accordance with the invention. The temperature of the coating metal at the strip exit zone of the bath influences both coating weight control and the behaviour of the bath surface below the coating control apparatus. Therefore, 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, gauge, temperature and/or line speed. The strip 18, after passage around a sink roll 22, passes upwardly through this controlled temperature portion 20 of the bath 16 towards a top roll 23. Thus the temperature of the coating metal on the strip 16 as the strip exits from the bath is determined by the controlled

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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 is made to impinge upon both sides of the strip uniformly across the full width of the strip in two opposed streams and each stream is confined to a narrow stream (five- to fifteen-thousandths inch) in the direction of strip travel.

For proper coating metal removal, the nozzles 24 and 26 must be positioned to impinge the steam against the strip while the coating metal is molten and at a 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, to obtain a satisfactory smooth coating finish, the surface of the coating bath should be relatively free of turbulence at the strip exit area of the bath. Substantially 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 the nozzles 24 and 26 are properly positioned, the molten coating, held back by the gaseous barrier, returns in the form of a smoothly flowing curtain without turbulence to the bath. This result has been obtained with substantially perpendicular gas impingement (as hereinafter defined).

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 travelled by the steam from the gas outlet of the nozzles to the coated strip can be substantially reduced; in practice a distance around one-half inch and less than about one inch is preferred. Thus the distance between the opposed gas outlets is preferably not more than two inches. This is not practicable with nozzles positioned at a substantial angle to the perpendicular. The increased distance travelled 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 (as hereinafter defined), 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 towards 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.

The effect of regulating coating metal temperature on uniformity of coating and reduction of bath turbulence becomes more clear when the interrelation of temperature and fluidity are considered. As the temperature of the molten metal in the coating pot rises the fluidity of the coating metal increases and less coating metal is dragged from the bath, more coating metal is held back by the gaseous barrier and the bath surface is more easily disturbed.

The importance of substantially constant coating metal temperature and resulting constant viscosity at the strip exit area is especially important using the gaseous barrier coating weight control method. Unlike the rigid

nature of the prior art finishing rolls the gaseous barrier, constituting a barrier to the passage of undesired coating metal, is of a yielding nature. Final coating weight is determined by the amount of coating metal encountering the gas barrier and its resistance to flow, or viscosity. Therefore, with other factors constant, a uniform viscosity which affects both drag out of coating metal and action of the gas barrier is required if coating weight remaining on the strip is to remain constant. Stabilizing coating metal temperature in the strip exit zone of the bath stabilizes the drag out of metal and the viscosity of the molten metal meeting the barrier, other factors being constant. In practice such temperature stabilization is preferably carried out by selective cooling of a portion of the bath as shown in Figure 1 and as described more fully in co-pending British Patent application No. 25063/65 (Serial No. 1,116,221). However, certain cold strip type lines with borderline bath heating capacity may require selective heating of that portion of the bath in order to maintain a desired temperature level for the coating metal.

Uniformity of temperature of the coating metal on the exiting strip is usually important where sustained, uniform coating weight production is desired. Other reasons which have not been fully explained at this time may exist for this importance. Additionally, it has been found that more uniform, smoother finish coating results when there is a substantial excess of coating metal to be held back by the gaseous barrier. Of course if less than desired final coating weight were to be dragged out because of excessive fluidity, the need for regulating the coating metal temperature to obtain proper drag out of coating metal would be clear. However, the smoother finish referred to is achieved by virtue of acting on a substantial excess of coating metal over and above the minimal required merely to meet coating weight specifications by holding back some coating metal.

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, at the most 5° above the perpendicular, are acceptable as introducing a minimum of difficulties. Also, in some situations a slight angle below the perpendicular (in the direction of strip travel) gives results comparable to perpendicular disposition. Also more uniform edge coating can sometimes be obtained with a nozzle perpendicular to or slightly inclined below the perpendicular to the direction of strip travel. Therefore, the term "substantially perpendicular" as used herein to denote the angle of impingement, includes impingement within the range

of at the most five degrees, above and below the perpendicular with the limitation on the upwardly angled nozzle not being as critical as the downwardly inclined nozzle limitation. The present invention is applicable to 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. Therefore an important aspect to consider in relation to future, faster galvanizing line is selection of an angle of impingement (within the limits mentioned above) and gas pressure which will hold back the desired weight of coating metal without creating the difficulties described above.

Another important aspect of the invention is the positioning of 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 planar configuration, 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, a 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.

The 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 coating surface, respectively. In the latter case, with the roll 30, heat is removed from the strip after exit from the coating control zone. Cooling air or wet steam from a spout 32 is used to solidify the coating before contact with the guide roll 30. An important feature, 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 the spout 32 to minimize spangle formation by rapidly solidifying the coating, as described in British Patent Application No. 14207/64 (Ser. No. 1,057,533), 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. The guide roll 30, which is

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positioned a short distance (one to three feet) above the spout 32, can then be correspondingly closer to the bath. Because of this, the roll 30 is more effective in obtaining the desired strip placement in the coating weight control zone.

The shaft of the guide roll 28 is positioned as close to the nozzles 24 and 26 as possible without disturbing coating weight control; for example, seven or eight inches below the 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 coal galvanizing line of present design.

The coating weight control equipment is shown in more detail in Figure 2. The strip 18 passes upwardly from the sink roll 22 in contact with the guide roll 28 and between the nozzles 24 and 26. The nozzles are supported in slides 34, 36, 38 and 40, which permit the nozzles to move towards and away from the strip. Adjustment gearing 42 and 44 is connected to each nozzle for selection of spacing between each nozzle and the adjacent surface of the 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 equipment. The nozzles and slides are supported by frame members 46 and 48 which are separable to permit installation of the equipment without cutting the continuous strip. The frame member 46 also supports an arm 49 which holds the bearing for the guide roll 28. The lateral movement of the strip 18 between the sink roll 22 and the guide roll 28 is exaggerated in Figure 2. In practice, a shaping and placement force is applied to the strip 18 by a lateral movement of the strip 18 of around three inches between the sink roll 22 and the guide roll 28. An oppositely directed force may be applied at the roll 30. The strip 18 moves upwardly along a substantially vertical path since any lateral offsetting is minor compared with the overall length of the longitudinal path between the sink roll 22 and the top roll 23, usually forty to sixty feet, or more.

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

Molten galvanize coating 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 effect this; con-

ventional galvanizing spelter includes aluminum additions and impurity level percentages of lead, antimony, cadmium, etc., and has a melting temperature in the neighbourhood of 790°F. The temperature of zone 20 is maintained in a range of roughly 800°F. to 860°F., dependent on the product, and is 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 the zone 20, a temperature differential up to 30° or higher may exist between the 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 the 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 the tube 50 may be surrounded by a conduit 52 containing a heat conductive material 54, such as molten lead. Flow of fluid in the tube 50 is controlled by a valve 56 and may be responsive to temperature control apparatus 58 which receives signals from a temperature measuring device 60. Water is a preferred coolant.

A 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 an indicator 64 can be used to automatically control fuel flow to the superheater 62 to maintain the gas temperature at the desired constant value.

The pressure at the nozzle 24 or 26 cannot be conveniently measured without disturbing the coating. Pressure measurements read at a control meter 66, or a similar location, give satisfactory results once relative values for a given installation are established. A valve 68 controls the pressure of the heated gas delivered to the nozzle 24 and is responsive to selected pressures at the control meter 66. A similar control is provided for the 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 a beta ray back scattering gauge 67 is positioned on each side of the strip 18. Thickness measurements from the beta ray gauges are delivered to coating weight control apparatus 69 and coordinated with the selected coating weight to vary the pressure delivered to each coating weight 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 the meter 66, for each surface of the strip and to motors (not shown) for actuation of the spacing adjustment gearing 42 and 44.

Details of the 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. The die members 72 and 74 are joined by a series of bolts 78. The separation between the members 72 and 74 determines the nozzle opening or slot and is set by use of shim stock 80. Gas is supplied through a plurality of apertures 82 spaced apart along the length of the manifold 76, in order to obtain a substantially uniform gas pressure across the full longitudinal length of the manifold 76. The gas is discharged

through the linearly extended gas outlet slot 84. The slot 84 comprises a passageway which is substantially uniform in length and width throughout its dimension in the direction of gas flow. The inlet end of this passageway communicates with the manifold 76 whilst its outlet end faces towards the strip. The manifold 76 is substantially co-extensive with the slot 84 and opens throughout its length into the slot. It is to be noted that the angle of entry of the gas with respect to the plane of the exit is shown at 90° but the invention is not limited to 90°; however, a substantial angular relationship is desired in order to obtain uniform gas dispersal and discharge velocity across the linearly extended nozzle outlet slot 84. Typical dimensions for nozzle structure used in obtaining data for the examples presented are:

|   |         |   |        |
|---|---------|---|--------|
| A | 57—3/4" | E | 1/2"   |
| B | 28—7/8" | F | 1/2"   |
| C | 18"     | G | 1—1/2" |
| D | 54"     | H | 0.015" |

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 selection of the strip speed is 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 manual 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.

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TABLE I

Continuous-strip galvanizing with nozzles 4—1/2" to 5—1/2" above bath level, coating metal at exit side of bath held at or near 825° F., nozzle opening of 0.015", substantially perpendicular impingement, superheated steam temperature about 840° F., spacing between each nozzle and its adjacent strip surface about 1/2".

|                                                                       | Run 1   | Run 2  | Run 3  | Run 4    |
|-----------------------------------------------------------------------|---------|--------|--------|----------|
| Strip Thickness<br>(inches)                                           | 0.020   | 0.0183 | 0.018  | 0.0172   |
| Strip Width<br>(inches)                                               | 36—9/16 | 28     | 24—1/2 | 27—13/16 |
| Topside Steam Pressure<br>(lb./in. <sup>2</sup> )                     | 35      | 30     | 37     | 32       |
| Bottomside Steam Pressure<br>(lb./in. <sup>2</sup> )                  | 34      | 30     | 38     | 31       |
| Speed of line (fpm)                                                   | 170     | 220    | 230    | 230      |
| Coating Weight<br>(oz./ft. <sup>2</sup> )<br>(total of both surfaces) | 0.59    | 0.82   | 0.59   | 0.99     |

TABLE II

Continuous-strip galvanizing with nozzles 4—1/2" to 5—1/2" above bath level, coating metal temperature at exit side of bath held at or near 825° F., nozzle opening 0.015", substantially perpendicular impingement, superheated steam temperature about 840° F., spacing between each nozzle and its adjacent strip surface about 3/4".

|                                                      | Run 5 | Run 6  | Run 7  | Run 8  |
|------------------------------------------------------|-------|--------|--------|--------|
| Strip Thickness<br>(inches)                          | 0.018 | 0.0217 | 0.021  | 0.0157 |
| Strip Width<br>(inches)                              | 36    | 36     | 23—1/4 | 24     |
| Topside Steam Pressure<br>(lb./in. <sup>2</sup> )    | 38    | 29     | 42     | 42     |
| Bottomside Steam Pressure<br>(lb./in. <sup>2</sup> ) | 40    | 29     | 41     | 41     |
| Speed of Line (fpm)                                  | 200   | 200    | 210    | 230    |
| Coating Weight<br>(oz./ft. <sup>2</sup> )            | 0.54  | 0.76   | 0.53   | 0.56   |

TABLE III

The following differing products were run over a three hour period on the same line with the nozzles 4—1/2" to 5—1/2" above bath level, nozzle opening 0.015", substantially perpendicular impingement, and spacing between each nozzle and its adjacent strip surface about 3/4". The coating metal temperatures 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.

|                                                   | Run 9 | Run 10          | Run 11  |
|---------------------------------------------------|-------|-----------------|---------|
| Strip Thickness (inches)                          | 0.018 | 0.0157          | 0.0187  |
| Strip Width (inches)                              | 30    | 30              | 35      |
| Topside Steam Pressure (lb./in. <sup>2</sup> )    | 32    | 26              | 28      |
| Bottomside Steam Pressure (lb./in. <sup>2</sup> ) | 32    | 26              | 28      |
| Speed of Line (fpm)                               | 230   | 130             | 180     |
| Coating Weight (oz./ft. <sup>2</sup> )            | 0.94  | 0.94            | 0.97    |
| Product Form                                      | Coils | Sheets          | Coils   |
| Use                                               | Pipes | Warehouse Stock | Roofing |

In producing products 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 differentially coated products, 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.

TABLE IV

With perpendicular disposition of the nozzles, drawing quality stock, 0.0503" gauge, 37—3/8" width, was produced at a line speed of 80 feet per minute with the following settings:

|            | Nozzle Spacing | Pressure (lb./in. <sup>2</sup> ) | Coating Weight (lb./ft. <sup>2</sup> ) |
|------------|----------------|----------------------------------|----------------------------------------|
| Light Side | 1/4"           | 25                               | .19                                    |
| Heavy Side | 1—1/4"         | 22                               | .48                                    |

Adjustment in the spacing between the 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 impact for one nozzle may be readily offset from the

other with 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 convenient means of adjusting coating weight, by adjusting nozzle opening, is available to the operator.

If desired, the nozzle opening H can be reduced by replacing the shim stock 80 by

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a thinner stock, the preferred thickness range being 0.005" to 0.015". This gives a nozzle opening H lying between one hundredth and one thirtythird of the nozzle dimension E, which is measured in the direction of gas flow.

Attention is drawn to co-pending Patent Application No. 10308/68 (Ser. No. 1,127,832) which is directed to the combination of a controlled temperature zone in the coating bath and gaseous barrier coating weight control.

Attention is also drawn to co-pending Patent Application No. 10309/68 (Ser. No. 1,127,833) which is directed to the automatic continuous control of the coating weight utilizing a gas barrier coating weight control zone.

#### WHAT WE CLAIM IS:—

1. Continuous metallic strip hot-dip metal coating apparatus comprising a hot-dip bath for containing molten coating metal, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal, then through a coating weight control zone located immediately above the molten coating metal, and then upwardly to a point where coating metal applied to the strip has solidified, the coating weight control zone extending upwardly from the molten coating metal through a portion of the travel path of the continuous metallic strip in which the weight of the molten coating metal applied to the strip in the bath can be controlled, a nozzle arrangement positioned in the coating weight control zone and having two opposed linearly extended, narrow-width, gas outlets, each gas outlet having a length at least equal to the transverse edge to edge dimension of the metallic strip to be coated and each gas outlet being shaped to deliver a concentrated, narrow-width stream of hot gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to and in substantially the same plane as the stream of gas from the other gas outlet with the hot gas impinging substantially perpendicularly (as hereinbefore defined) against the strip to prevent passage of molten coating metal in excess of desired coating weight and to provide a substantially uniform coating weight on the continuous metallic strip, means for supplying hot gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by controlling the flow of hot gas to the nozzle arrangement.

2. Apparatus as claimed in claim 1 in which the hot-dip bath contains a molten metal whose upper surface is exposed to a gaseous atmosphere so that the metallic strip is free of mechanical contact between a point below the upper surface of the molten coating metal

and a point above the coating weight control zone.

3. Apparatus as claimed in claim 2 including strip guide means submerged in the molten coating metal of the bath adjacent its exposed upper surface and making substantially continuous contact with the strip transversely from edge to edge of the strip entirely below the exposed upper surface of the molten coating metal, this substantially continuous contact including a straight line contact to impart a planar configuration to the strip during passage through the exposed upper surface of the molten coating metal, and during impingement by each stream of hot gas from the nozzle gas outlets in the coating weight control zone.

4. Apparatus as claimed in claim 1 or 2 in which said guide rolls include a first guide roll submerged just below the coating metal surface level and a second guide roll above said coating weight control zone at a point at which coating metal applied to the strip will have solidified, to impart a planar configuration to the strip during passage through the upper surface of the molten coating metal and through the coating weight control zone.

5. Apparatus as claimed in claim 3 or 4 in which each linearly extended gas outlet is positioned to face an opposite planar surface of the strip and is uniformly spaced from the strip and from the upper surface level of the bath.

6. Apparatus as claimed in any preceding claim in which said opposed gas outlets are not more than two inches apart.

7. Apparatus as claimed in any preceding claim in which the spacing between each gas outlet and the coated strip in the coating weight control zone is adjustable during impingement of the strip by the hot gas to thereby control the coating weight remaining on the strip.

8. Apparatus as claimed in claim 7 in which the means for obtaining a desired coating weight includes means for continuously measuring the coating weight remaining on at least one side of the strip, after it has left coating weight control zone, and means for continuously controlling the distance of the respective gas outlet from the strip responsively to the coating weight so measured to maintain the coating weight substantially constant at that side.

9. Apparatus as claimed in any of claims 1 to 7 in which the means for obtaining a desired coating weight includes means for continuously measuring the coating weight remaining on at least one side of the strip, after it has left the coating weight control zone, and for continuously controlling the rate of supply of hot gas to the gas outlet at the respective side of the strip to maintain the coating weight substantially constant at that side.

10. Apparatus as claimed in any preceding



a thinner stock, the preferred thickness range being 0.005" to 0.015". This gives a nozzle opening H lying between one hundredth and one thirtythird of the nozzle dimension E, which is measured in the direction of gas flow.

Attention is drawn to co-pending Patent Application No. 10308/68 (Ser. No. 1,127,832) which is directed to the combination of a controlled temperature zone in the coating bath and gaseous barrier coating weight control.

Attention is also drawn to co-pending Patent Application No. 10309/68 (Ser. No. 1,127,833) which is directed to the automatic continuous control of the coating weight utilizing a gas barrier coating weight control zone.

#### WHAT WE CLAIM IS:—

1. Continuous metallic strip hot-dip metal coating apparatus comprising a hot-dip bath for containing molten coating metal, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal, then through a coating weight control zone located immediately above the molten coating metal, and then upwardly to a point where coating metal applied to the strip has solidified, the coating weight control zone extending upwardly from the molten coating metal through a portion of the travel path of the continuous metallic strip in which the weight of the molten coating metal applied to the strip in the bath can be controlled, a nozzle arrangement positioned in the coating weight control zone and having two opposed linearly extended, narrow-width, gas outlets, each gas outlet having a length at least equal to the transverse edge to edge dimension of the metallic strip to be coated and each gas outlet being shaped to deliver a concentrated, narrow-width stream of hot gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to and in substantially the same plane as the stream of gas from the other gas outlet with the hot gas impinging substantially perpendicularly (as hereinbefore defined) against the strip to prevent passage of molten coating metal in excess of desired coating weight and to provide a substantially uniform coating weight on the continuous metallic strip, means for supplying hot gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by controlling the flow of hot gas to the nozzle arrangement.

2. Apparatus as claimed in claim 1 in which the hot-dip bath contains a molten metal whose upper surface is exposed to a gaseous atmosphere so that the metallic strip is free of mechanical contact between a point below the upper surface of the molten coating metal

and a point above the coating weight control zone.

3. Apparatus as claimed in claim 2 including strip guide means submerged in the molten coating metal of the bath adjacent its exposed upper surface and making substantially continuous contact with the strip transversely from edge to edge of the strip entirely below the exposed upper surface of the molten coating metal, this substantially continuous contact including a straight line contact to impart a planar configuration to the strip during passage through the exposed upper surface of the molten coating metal, and during impingement by each stream of hot gas from the nozzle gas outlets in the coating weight control zone.

4. Apparatus as claimed in claim 1 or 2 in which said guide rolls include a first guide roll submerged just below the coating metal surface level and a second guide roll above said coating weight control zone at a point at which coating metal applied to the strip will have solidified, to impart a planar configuration to the strip during passage through the upper surface of the molten coating metal and through the coating weight control zone.

5. Apparatus as claimed in claim 3 or 4 in which each linearly extended gas outlet is positioned to face an opposite planar surface of the strip and is uniformly spaced from the strip and from the upper surface level of the bath.

6. Apparatus as claimed in any preceding claim in which said opposed gas outlets are not more than two inches apart.

7. Apparatus as claimed in any preceding claim in which the spacing between each gas outlet and the coated strip in the coating weight control zone is adjustable during impingement of the strip by the hot gas to thereby control the coating weight remaining on the strip.

8. Apparatus as claimed in claim 7 in which the means for obtaining a desired coating weight includes means for continuously measuring the coating weight remaining on at least one side of the strip, after it has left coating weight control zone, and means for continuously controlling the distance of the respective gas outlet from the strip responsively to the coating weight so measured to maintain the coating weight substantially constant at that side.

9. Apparatus as claimed in any of claims 1 to 7 in which the means for obtaining a desired coating weight includes means for continuously measuring the coating weight remaining on at least one side of the strip, after it has left the coating weight control zone, and for continuously controlling the rate of supply of hot gas to the gas outlet at the respective side of the strip to maintain the coating weight substantially constant at that side.

10. Apparatus as claimed in any preceding



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claim in which the height of the nozzle arrangement above the upper surface level of the bath is adjustable.

11. Apparatus as claimed in any preceding claim in which the means for supplying hot gas under pressure is adapted for continuously measuring and thereby continuously controlling the temperature of the hot gas so supplied.

12. Apparatus as claimed in any preceding claim including a device disposed for heat exchange with molten coating metal in the bath for establishing a zone of controlled temperature coating metal in the bath contiguous to the travel path of the strip through the molten coating metal as the strip approaches the upper surface level of the bath.

13. Apparatus as claimed in any preceding claim in which each linearly extended narrow-width gas outlet defines a nozzle opening having a uniform width dimension of between 0.005" and 0.015", inclusive, measured transversely to the direction of gas flow.

14. Apparatus as claimed in any preceding claim in which each gas outlet comprises a passageway having a width dimension which is uniform along the passageway in the direction of gas flow and a dimension of one half inch measured in the direction of gas flow.

15. Apparatus as claimed in any preceding claim in which each gas outlet has a uniform width dimension measured transverse to the direction of gas flow of between one hundredth and one thirtythird of its dimension measured in the direction of gas flow.

16. Apparatus as claimed in any preceding claim in which the nozzle arrangement includes two linearly extended manifolds substantially co-extensive with and opening throughout the length thereof into a respective one of the linearly extended gas outlets.

17. Apparatus as claimed in claim 16 in which each gas outlet comprises a passageway having an outlet end facing towards the strip and an inlet end in the internal cavity, the outlet and inlet ends of said passageway having the same uniform width dimension.

18. Apparatus as claimed in claim 17 in which the passageway has throughout its dimension in the direction of gas flow a substantially uniform width dimension corresponding to the width dimension of the outlet and inlet ends.

19. Apparatus as claimed in any of claims 16 to 18 in which each manifold has several gas supply conduits connected thereto at points spaced apart along the length of that manifold for supplying hot gas thereto, the gas supply conduits having a direction of entry into the respective manifold transverse to the direction of gas discharge through the gas outlet.

20. Apparatus as claimed in claim 19 in which the direction of entry of the gas supply conduits into the respective manifold is perpendicular to the direction of gas discharge.

21. Apparatus as claimed in any preceding

claim in which the means for supply hot gas to the nozzle arrangement includes a steam superheater.

22. Apparatus as claimed in any preceding claim in which the bath contains molten zinc.

23. Continuous metallic strip hot-dip metal coating apparatus constructed and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

24. Metallic strip when metal coated in the apparatus of any of claims 1 to 23.

25. A continuous metallic strip hot-dip metal coating process in which molten coating metal in excess of desired coating weight is applied to the continuous metallic strip by passing the strip longitudinally through a bath of molten coating metal having an upper surface which is exposed to a gaseous atmosphere and the continuous strip is passed in planar configuration from the molten coating metal bath through a coating weight control zone located above the upper surface of the molten coating metal bath, in which zone the molten coating metal applied to the strip in the bath remains molten and there is no mechanical contact with the coated strip, and in which a linearly extended narrow stream of hot gas is impinged against each of the opposite planar sides of the coated strip in the coating weight control zone across the full width of the strip in a line uniformly spaced from the upper surface of the bath, with each stream of hot gas impinging substantially perpendicularly (as hereinbefore defined) against the strip, and the rate of mass flow of the hot gas impinging against each side of the strip in the coating weight control zone is controlled to obtain a desired uniform weight of coating metal remaining on the strip leaving the coating weight control zone.

26. A process as claimed in claim 25 in which the temperature of the hot gas in each of said streams is continuously measured and controlled to maintain said temperature substantially constant.

27. A process as claimed in claim 25 or 26 in which two streams of hot gas are impinged against the strip in substantially opposed relationship.

28. A process as claimed in any of claims 25 to 27 in which the mass rate of flow of hot gas in one stream is greater than the mass rate of flow of hot gas in the other stream to thereby produce different coating weights on the opposite sides of the strip.

29. A process as claimed in any of claims 25 to 28 in which each stream of hot gas under pressure is directed against the strip from a nozzle and the distance between the gas outlets from the nozzles is not more than two inches.

30. A process as claimed in claim 29 in which control of the weight of coating metal remaining on the strip at a desired strip speed

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is achieved by adjusting the distances of the nozzles from the strip.

31. A process as claimed in claim 30 in which one nozzle is positioned closer to the strip than the other nozzle to thereby produce different coating weights on the opposite sides of the strip.

32. A process as claimed in claim 30 or 31 in which the coating weight remaining on at least one side of the strip, after it has left the coating weight control zone, is continuously measured and the distance of the respective nozzle from the strip is continuously controlled to maintain the coating weight substantially constant at that side of the strip.

33. A process as claimed in any of claims 25 to 31 in which the coating weight remaining on at least one side of the strip, after it has left the coating weight control zone, is continuously measured and the rate of supply of the gas to the respective stream of gas impinging on the strip is continuously controlled to maintain the coating weight substantially constant at that side of the strip.

34. A process as claimed in any of claims 25 to 33 in which a substantially planar configuration is imparted to the strip entering the coating weight control zone by mechanically contacting the strip while the strip is submerged in the molten metal coating bath immediately prior to passage of the strip through the upper surface of the molten coating bath.

35. A process as claimed in claim 34 in which the strip is contacted by a first guide roll submerged just below the coating metal surface and by a second guide roll above the coating weight control zone and above the point at which the coating metal has solidified.

36. A process as claimed in any of claims 25 to 35 in which a zone of controlled temperature is maintained in the bath of molten coating metal contiguous to the strip as the strip approaches the exposed upper surface of the bath.

37. A process as claimed in any of claims 25 to 36 in which the hot gas is superheated steam.

38. A process as claimed in any of claims 25 to 37 in which the coating metal is zinc.

39. A process as claimed in claim 38 in which the temperature of the hot gas is between 500°F and 1500°F, inclusive.

40. A process as claimed in any of claims 25 to 39 in which the metallic strip is steel strip.

41. A continuous metallic strip hot-dip metal coating process substantially as herein described with reference to the accompanying drawings.

42. Metallic strip when metal coated by the process claimed in any of claims 25 to 41.

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