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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in Metal Coating methods and apparatus

We, NATIONAL STEEL CORPORATION, a Corporation organised under the laws 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:—

This invention is concerned with molten metal coating of metal sheet material.

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, e.g. hot-dip coating of steel with tin, lead, zinc, aluminum, cadmium, and their alloys, 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.

Prior patents in continuous-strip hot-dip galvanizing highlight the serious problems encountered in controlling molten metal coating and the efforts that have been made to overcome these problems. Grooved rolls, as shown in Sommer, United States Patent No. 1,980,961 and British Patent No. 764,364, have ordinarily been used to control coating weight. Coating rolls present a cleaning problem for which scrapers, such as are provided in Sommer, or other provision must be made. It is also necessary to change the rolls periodically because of roll wear and to change the rolls for certain products. Changing coating rolls requires shutting down the line and is a laborious and expensive process. Alternatives to coating rolls also rely on mechanical contact, e.g. a plurality of blades contacting the

strip at the bath surface. In the cable and wire art, it has been proposed to pass a strand of wire or a multi-strand cable through a throat in which the wiping action of a high velocity stream of steam passing between the internal surfaces of the throat and the surface of the wire or the surfaces of the cable acts to blow excess molten metal off these surfaces. Such a method and apparatus have had no application nor utility in the sheet metal coating art where the necessary apparatus and the method involved would present insurmountable practical difficulties.

Coating rolls, even though considered about the best the art could offer, wear unevenly and develop rough surfaces causing uneven coating application and marring of strip finish. Coating rolls also cause uneven edge coating, often referred to as edge build-up. Various teachings to overcome the latter problem have been disclosed in the patent art, for example United States patents to Inglesfield, No. 2,708,171, Nicman et al, No. 2,888,901, and Mayhew, No. 2,967,114.

Further, to prevent accumulation of coating above the nip of the coating rolls when attempting to coat lightly, it has been suggested that hot blasts be blown against metal in the nip of coating rolls; this process is described in British patent No. 935,516.

Numerous other patents and patent applications deal with marks in strip finishes, elimination of roll deposited stringers and chunks of metal, and with other problems created when dealing with mechanical contact coating control.

According to one aspect of the present invention, continuous metallic strip hot-dip metal coating apparatus comprises a hot dip bath containing molten coating metal having its upper surface exposed to a gaseous atmosphere, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal in the bath, then through a

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coating weight control zone located immediately above the exposed upper surface of 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 exposed upper surface of 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, the metallic strip being 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, 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 uniform, concentrated, narrow-width stream of heated gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to the stream from the other gas outlet with the heated gas impinging against the strip at an angle of incidence between zero and fifteen degrees above the perpendicular, inclusive, to prevent passage of molten coating metal in excess of desired coating weight, means for supplying heated gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by continuously controlling the rate of supply of heated gas to the nozzle arrangement.

Another aspect of the present invention is 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 substantially parallel to 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.

The invention includes metallic strip when coated in the above apparatus and by the above method.

The invention is further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic view in front elevation, partially in section, of one embodiment of metal coating apparatus constructed in accordance with the invention and for carrying out the method of the invention;

Figure 2 is a schematic side elevational view of the embodiment of apparatus of Figure 1 with added top roll;

Figure 3 is a schematic side elevational view of a second embodiment of metal coating apparatus for carrying out the method of the invention;

Figure 4 is a schematic side elevational view, partially in section, of a third embodiment of metal coating apparatus for carrying out the method of the invention;

Figure 5 is a top plan view, partially cut away, of a nozzle structure for the metal coating apparatus of the invention;

Figure 6 is a side view in section of the nozzle structure of Figure 5;

Figure 7 is a schematic view in elevation of yet another embodiment of metal coating apparatus for carrying out the method of the invention;

Figure 8 is a side elevational view of one embodiment of gas barrier coating control equipment for metal coating apparatus constructed in accordance with the invention;

Figure 9 is another side elevational view of another embodiment of gas barrier coating control equipment;

Figure 10 is a view in front elevation of the equipment of Figure 8, taken along the line 10—10; and

Figure 11 is an enlarged sectional view of a portion of the equipment of Figure 8, taken along the line 11—11.

The so-called modern continuous-strip hot dip galvanizing operation requires grooved rolls, edge build-up prevention means, numerous flame jets, and other paraphernalia about the pot in order to meet coating weight specifications. A clear contrast will be apparent in a comparison of the apparatus of Figures 1 and 2 with such prior art. In Figures 1 and 2, existing strip 24 is guided upwardly by a sinker roll 25 and a top roll 26 between gas barrier nozzles 28 and 29 disposed in a coating weight control zone immediately above the exposed upper surface of the molten metal in the bath. A heated gas, such as superheated steam, is provided through lines 30, 32 under the control of valves 34, 36. The superheated steam, or other heated gas, creates a barrier for a portion of the coated metal, causing

return of molten coating metal 37 to the bath and leaving a smooth controlled coating weight on the strip. The crowding of structures, flame jets, etc., often working at cross purposes, is eliminated and the complicated easily-disrupted process of the prior art is replaced with a simplified, stable process. There is no mechanical contact with the strip 24 between the exposed upper surface of the bath and the top roll 26 above the coating weight control zone.

In continuous-strip gas barrier coating control, it is important to present the strip to the barrier gas stream in substantially planar form in order to achieve uniform coating removal. Also, the strip should be uniformly spaced from the nozzles on either side of the strip or adjustment of the gas pressure may be necessary dependent on product specifications. Also, the strip should not be moving loosely, i.e. wobbling, nor be buckled, when passing between the nozzles. If a sinker roll and top roll, as shown in Figure 2, are not sufficient to constrain the strip to the desired configuration, additional guide means can be provided such as the submerged bracing means 40 and 41 and/or roll means 42, of Figure 3, which help present the strip to the gas barrier in a substantially planar configuration. The guide roll means 42 contact the strip after coating solidification which can be accelerated by fluid cooling jets (not shown).

The submerged guide means 40 and 41 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 the guide means 40 and 41. Also, they provide a near turbulence-free pocket of metal for the strip to pass through before reaching the exposed 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 coating for long periods can take place without additions to the bath. Those shown are held fast in the submerged position but the principal of the invention does not exclude driven rolls used for the purpose of

presenting the strip in planar form to the coating control means.

In describing the invention further, specific examples of its application in continuous-strip hot-dip galvanizing will be presented. Figures 3 and 4 show some of the terms which will be used in these examples such as: height of gas nozzle above the bath, angle of impingement of heated gas with the strip, etc. Note that the pressure reading, from a gauge 44, is the pressure of the superheated steam or other gas in the line, entering the nozzle structure. Dimensions for the nozzle structure used in these examples will be given for fluid dynamics purposes; pressure readings in the examples are in pounds per square inch gauge. Steam temperature read at a gauge 46 is approximately the same as the temperature of the steam exiting from the nozzle. Also, the top and bottom sides of strip referred to in coating practice are designated; the top side contacts the sinker roll and the bottom side is opposite thereto.

With the present invention, it has been found that 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.

Specific examples of gas barrier production of continuous-strip galvanized are given in Tables I to III.

TABLE I.

Continuous-strip galvanizing with nozzles located 6" to 8" above bath level, nozzle opening of 0.010", angle of impingement 10° above normal to the strip, superheated steam temperature 850° F., gap between nozzles 4" with the bottom side of the strip closer to adjacent nozzle at approximately 1½".

	RUN 1	RUN 2	RUN 3*	RUN 4
Strip Gage	16	19	16	24
Strip Width (inches)	31	24	27-1/2	30, 29
Bottom Pressure (lb/in. ²)	41	50	12	40
Top Pressure (lb/in. ²)	57	54	17	65
Speed of Line (fpm)	80	140	110	220
Coating Weight (oz/ft ²)	Light Commercial .4 to .6		2-1/2 oz. Culvert Stock	1-1/4 oz. Commercial

* Culvert stock coating up to 3 oz/ft² which ordinarily would require a non-dragging treatment with coating roll application; non-dragging treatment not required with gas barrier principle.

TABLE II.

Continuous-strip galvanizing with nozzles located 6" to 8" above bath level, nozzle opening of 0.010", angle of impingement 10°

above normal to the strip, superheated steam temperature 850° F., gap between nozzles 2" with bottom side closer to adjacent nozzle at approximately 5/6".

	RUN 5	RUN 6	RUN 7	RUN 8
Strip Gage	17	21	24	24
Strip Width (inches)	37-3/4	36	34-5/8	34-5/8
Bottom Pressure (lb/in. ²)	38	42	38	31
Top Pressure (lb/in. ²)	43	42	47	35
Speed of Line (fpm)	90	130	240	200
Coating Weight (oz/ft ²)	Light Commercial .4 to .8		1-1/4 oz. Commercial	

TABLE III

	RUN 9	RUN 10	RUN 11	RUN 12
Strip Gage	24	24	24	24
Strip Width (inches)	33-1/2	33-1/2	30	36
Steam Temperature °F.	650°	650°	550°-850°	650°
Steam Pressure (lb/in. ²)				
Bottom Side	40	42	31	35
Top Side	50	50	36	40
Angle of Impingement of Steam Above Normal	15°	45°	30°	10°
Height Above Bath Surface (inches)	8+	8+	10	6-7
Nozzle Opening (inches)	.010	.005	.007	.010
Gap between Nozzles (inches)	3	3	3	3
Speed of Line (fpm)	200	220	220-250	160
Coating Thickness	Commercial 1-1/4 oz.	.79-.87	Light Commercial .5 to .8 oz.	Light Commercial
Bath Temperature °F.	870°	850°-890°	860°	860°

- 10 The above and other examples of production runs of hot-dip galvanized strip using a gas barrier to control coating weight bring out a number of factors which can be utilized to control coating weight, such as angle of gas impingement, nozzle gap or distance from nozzle slot to strip, speed of the strip, and
- 15

gas flow variations. The last includes interrelation of gas pressure, nozzle opening, and gas temperature, to the extent temperature may affect mass and kinetic energy values of the gas in the coating control zone.

With the use of a gas barrier to control coating weight, the mass of the gas impinging

against the molten coating is a dominant factor. Considering the above and similar runs, 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 0.6 ounce per square foot.

At current continuous-galvanizing line speeds and an angle of impingement of the gas with the strip of 45° above the perpendicular, a rough coating results. With the angle of impingement drastically reduced, to 0° to 15° above the perpendicular and preferably not more than 10° above the perpendicular, a superior, smooth finish results. Moreover, with the major component of motion of the gas perpendicular to the strip, a desirable pressure range for selective coating control of a large number of products is available. The operator can accurately control or change coating weight at a given line speed by selection of the proper pressure. The interrelation of line speed, gas mass, angle of improvement, and desired coating weight are such that the operation can be automated.

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 gauge material as determined by other factors. The gas barrier could be set at the optimum height above the bath, the optimum gas opening, and at the optimum angle, the gas pressure being then varied to control the coating weight.

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 method. Imperfections in the strip on the light side of the strip are not a problem with the gas barrier method and a smoother light side coating results. Differential galvanized having less than 0.1 ounce per square foot on the light side and more than 0.3 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.

Use of superheated steam does not affect spangle formation in producing a galvanized product. It has been found that spangle can be minimized by blowing wet steam onto the strip later in its travel above the nozzle as disclosed in applicant's copending Application No. 14207/64 (Serial No. 1,057,533).

Details of nozzle structure used in obtaining the results shown in the specific examples presented above are shown in Figures 5 and 6. 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 strip motion is dependent on the nozzle opening which will give proper flow. Larger nozzle openings give greater gas mass flow and permit a greater mass of molten coating to be held back. Larger openings also avoid clogging by foreign matter; openings of 0.015" have been found satisfactory for mill use in this latter regard.

The nozzle structure 50 of Figures 5 and 6 includes pieces 52 and 54 which mate to form a linearly extended gas manifold cavity 56. The pieces 52 and 54 are joined by a series of bolts 58. The separation between the pieces 52 and 54 determines the width of the nozzle opening or passage 64 whose inlet end communicates with the cavity 56 and this separation is set by use of shim-stock 60. Gas is supplied through apertures 62 and exits through the linearly extended passage 64 which is of uniform width from its inlet end to its outlet end. Note the angle of entry of the gas with respect to the plane of the exit, as shown it is 90° but the invention is not so limited; however, a substantial angular relationship is desired in order to obtain uniform gas dispersal and exit pressure across the linearly extended nozzle opening 64. Typical dimensions for the nozzle structure used in obtaining the data for Tables I—III are as follows:

A	53-7/8"	E	1"
B	26-15/16"	F	2"
C	8-13/16"	G	0.005" to 0.015"
D	49-7/8"	H	1" + G

Thus it will be seen that the preferred nozzle opening G lies between five thousandths and one sixty-seventh of the nozzle dimension E, which is measured in the direction of gas flow.

Figure 7 shows an arrangement for supplying heated gas to a nozzle and providing auxiliary blowers if needed. From superheater 72 heated gas is fed through conduit 74 to distribution pipes 76, 78 and 80 leading to the manifold of nozzle structure 50. Each of the distribution pipes may include a valve as shown to control flow. The number of distribution pipes used can be chosen and positioned as required to give uniform gas barrier pressure across the strip width.

Auxiliary blowers 82 and 84 can be used along strip edges or as needed. With uniform gas dispersal and at angles near perpendicular to the strip, they are not needed. A similar arrangement of hot gas piping is made on the opposite side of the strip.

Figures 8 to 11 show details of hot-dip, gas barrier equipment including means for adjusting angle of impingement of the gas, height of impingement above the bath, depth of the submerged braces which guide or constrain strip in a particular path, the gap between the gas nozzles, and the gap between the braces. Where pairs of identical adjustment means exist on the same side of the strip, the same numbers have used to identify each member of the pair.

A framework 86 supports the entire equipment. Nozzle structures 88, 90 are positioned above bracing means 92, 94 which guide or constrain the strip into the coating control zone with a substantially planar configuration. Referring in particular to Figures 9 and 10, the bracing means 92 are adjusted by linkages 96 and the bracing means 94 by linkages 98. Vertical location of the bracing means 92, 94 is adjusted by screw mechanisms 100 and 102.

Referring to Figure 8 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. The angles of inclination of the nozzles 88 and 90 are adjusted by linkages 114 and 116 pivoted at 118 and 120, respectively.

The nozzle structures, the bracing means, their respective adjustment means are moved upwardly or downwardly with respect to the framework 86 by height adjustment means 112, 113.

Some of the advantages of the gas barrier method 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 is required 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.

WHAT WE CLAIM IS:—

1. Continuous metallic strip hot-dip metal coating apparatus comprising a hot dip bath containing molten coating metal having its upper surface exposed to a gaseous atmosphere, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal in the bath, then through a coating weight control zone located immediately above the exposed upper surface of 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 exposed upper surface of 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, the metallic strip being 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, 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 uniform, concentrated, narrow-width stream of heated gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to the stream from the other gas outlet with the heated gas impinging against the strip at an angle of incidence between zero and fifteen degrees above the perpendicular, inclusive, to prevent passage of molten coating metal in excess of desired coating weight, means for supplying heated gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by continuously controlling the rate of supply of heated gas to the nozzle arrangement.

2. Apparatus as claimed in claim 1 in which the gas outlets are disposed to direct the streams of gas with an angle of incidence of gas impingement against the strip of not more than ten degrees above the perpendicular.

3. Apparatus as claimed in claim 1 or 2 including strip guide means submerged in the molten coating metal of the bath means adjacent is 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

Thus it will be seen that the preferred nozzle opening G lies between five thousandths and one sixty-seventh of the nozzle dimension E, which is measured in the direction of gas flow.

Figure 7 shows an arrangement for supplying heated gas to a nozzle and providing auxiliary blowers if needed. From superheater 72 heated gas is fed through conduit 74 to distribution pipes 76, 78 and 80 leading to the manifold of nozzle structure 50. Each of the distribution pipes may include a valve as shown to control flow. The number of distribution pipes used can be chosen and positioned as required to give uniform gas barrier pressure across the strip width.

Auxiliary blowers 82 and 84 can be used along strip edges or as needed. With uniform gas dispersal and at angles near perpendicular to the strip, they are not needed. A similar arrangement of hot gas piping is made on the opposite side of the strip.

Figures 8 to 11 show details of hot-dip, gas barrier equipment including means for adjusting angle of impingement of the gas, height of impingement above the bath, depth of the submerged braces which guide or constrain strip in a particular path, the gap between the gas nozzles, and the gap between the braces. Where pairs of identical adjustment means exist on the same side of the strip, the same numbers have used to identify each member of the pair.

A framework 86 supports the entire equipment. Nozzle structures 88, 90 are positioned above bracing means 92, 94 which guide or constrain the strip into the coating control zone with a substantially planar configuration. Referring in particular to Figures 9 and 10, the bracing means 92 are adjusted by linkages 96 and the bracing means 94 by linkages 98. Vertical location of the bracing means 92, 94 is adjusted by screw mechanisms 100 and 102.

Referring to Figure 8 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. The angles of inclination of the nozzles 88 and 90 are adjusted by linkages 114 and 116 pivoted at 118 and 120, respectively.

The nozzle structures, the bracing means, their respective adjustment means are moved upwardly or downwardly with respect to the framework 86 by height adjustment means 112, 113.

Some of the advantages of the gas barrier method 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 is required 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.

WHAT WE CLAIM IS:—

1. Continuous metallic strip hot-dip metal coating apparatus comprising a hot dip bath containing molten coating metal having its upper surface exposed to a gaseous atmosphere, guide rolls defining a travel path for longitudinal movement of the continuous metallic strip through a portion of the molten coating metal in the bath, then through a coating weight control zone located immediately above the exposed upper surface of 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 exposed upper surface of 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, the metallic strip being 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, a nozzle arrangement positioned in the coating weight 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 uniform, concentrated, narrow-width stream of heated gas and being disposed to direct said stream of gas against a respective side of the strip in substantially direct opposition to the stream from the other gas outlet with the heated gas impinging against the strip at an angle of incidence between zero and fifteen degrees above the perpendicular, inclusive, to prevent passage of molten coating metal in excess of desired coating weight, means for supplying heated gas under pressure to the nozzle arrangement and means for obtaining a desired coating weight remaining on the strip by continuously controlling the rate of supply of heated gas to the nozzle arrangement.

2. Apparatus as claimed in claim 1 in which the gas outlets are disposed to direct the streams of gas with an angle of incidence of gas impingement against the strip of not more than ten degrees above the perpendicular.

3. Apparatus as claimed in claim 1 or 2 including strip guide means submerged in the molten coating metal of the bath means adjacent is 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 heated gas from the gas outlets in the coating weight control zone.

4. Apparatus as claimed in claim 3 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 exposed upper surface of the bath.

5. 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 to thereby control the coating weight remaining on the strip.

6. Apparatus as claimed in any preceding claim in which the height of the nozzle arrangement above the exposed upper surface of the molten coating metal is adjustable.

7. 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, transverse to the direction of gas flow.

8. Apparatus as claimed in any preceding claim in which each gas outlet has a dimension in the direction of gas flow of one inch.

9. Apparatus as claimed in any preceding claim in which each gas outlet has a uniform width dimension transverse to the direction of gas flow of between five thousandths and one sixtyseventh of its dimension in the direction of gas flow.

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

11. Apparatus as claimed in claim 10 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.

12. Apparatus as claimed in claim 11 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.

13. Apparatus as claimed in any of claims 10 to 12 in which each manifold has several gas supply conduits connected thereto at points spaced apart along the length of that manifold for supplying 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.

14. Apparatus as claimed in claim 13 in which the direction of entry of the gas supply

conduits into the respective manifold is perpendicular to the direction of gas discharge.

15. Apparatus as claimed in any preceding claim in which the means for supplying heated gas to the nozzle arrangement includes a steam superheater.

16. Apparatus as claimed in any preceding claim in which the molten coating metal is molten zinc.

17. Continuous metallic strip hot-dip metal coating apparatus as claimed in claim 1 and constructed and adapted to operate substantially as herein described with reference to and as illustrated in Figs. 1 and 2 of the accompanying drawings.

18. Continuous metallic strip hot-dip metal coating apparatus as claimed in claim 1 and constructed, arranged and adapted to operate substantially as herein described with reference to and as illustrated in Fig. 3 of the accompanying drawings.

19. Apparatus as claimed in any of claims 1 to 18 and having the nozzle structure substantially as herein described with reference to and as illustrated in Figs. 4 to 7 of the accompanying drawings.

20. Apparatus as claimed in any of claims 1 to 19 and having the nozzle support means and sheet metal guide means constructed substantially as herein described with reference to and as illustrated in Figs. 8 to 11 of the accompanying drawings.

21. Metallic strip when metal coated in the apparatus of any of claims 1 to 20.

22. 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.

23. A process as claimed in claim 22 in

which the angle of incidence of gas impingement against the strip is not more than ten degrees above the perpendicular.

5 24. A process as claimed in claim 22 or 23 wherein the temperature of the heated gas in each of said streams is controlled.

10 25. A process as claimed in any of claims 22 to 24 in which two streams of heated gas are impinged against the strip in substantially opposed relationship.

15 26. A process as claimed in any of claims 22 to 25 in which the mass rate of flow of heated gas in one stream is greater than the mass rate of flow of heated gas in the other stream to thereby produce different coating weights on the opposite sides of the strip.

20 27. A process as claimed in any of claims 22 to 26 in which each stream of heated gas under pressure is directed against the strip from a nozzle and control of the weight of coating metal remaining on the strip at a desired strip speed is achieved by adjusting the distances of the nozzles from the strip.

25 28. A process as claimed in claim 27 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.

29. A process as claimed in any of claims

30 22 to 28 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 35 through the upper surface of the molten coating bath.

30. A process as claimed in any of claims 22 to 29 in which the heated gas is superheated steam. 40

31. A process as claimed in any of claims 22 to 30 in which the coating metal is zinc.

32. A process as claimed in claim 31 in which the temperature of the hot gas is between 45 550°F and 850°F, inclusive.

33. A process as claimed in any of claims 22 to 32 in which the metallic strip is steel strip.

34. A continuous metallic strip hot-dip metal coating process as claimed in claim 22 and substantially as herein described with reference to the accompanying drawings. 50

35. Metallic strip when metal coated by the process claimed in any of claims 22 to 34. 55

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