July 5, 1966 T. H. KRENGEL ETAL 3,259,148

GALVANIZED STEEL TUBING

Original Filed May 1, 1961 2 Sheets-Sheet 1

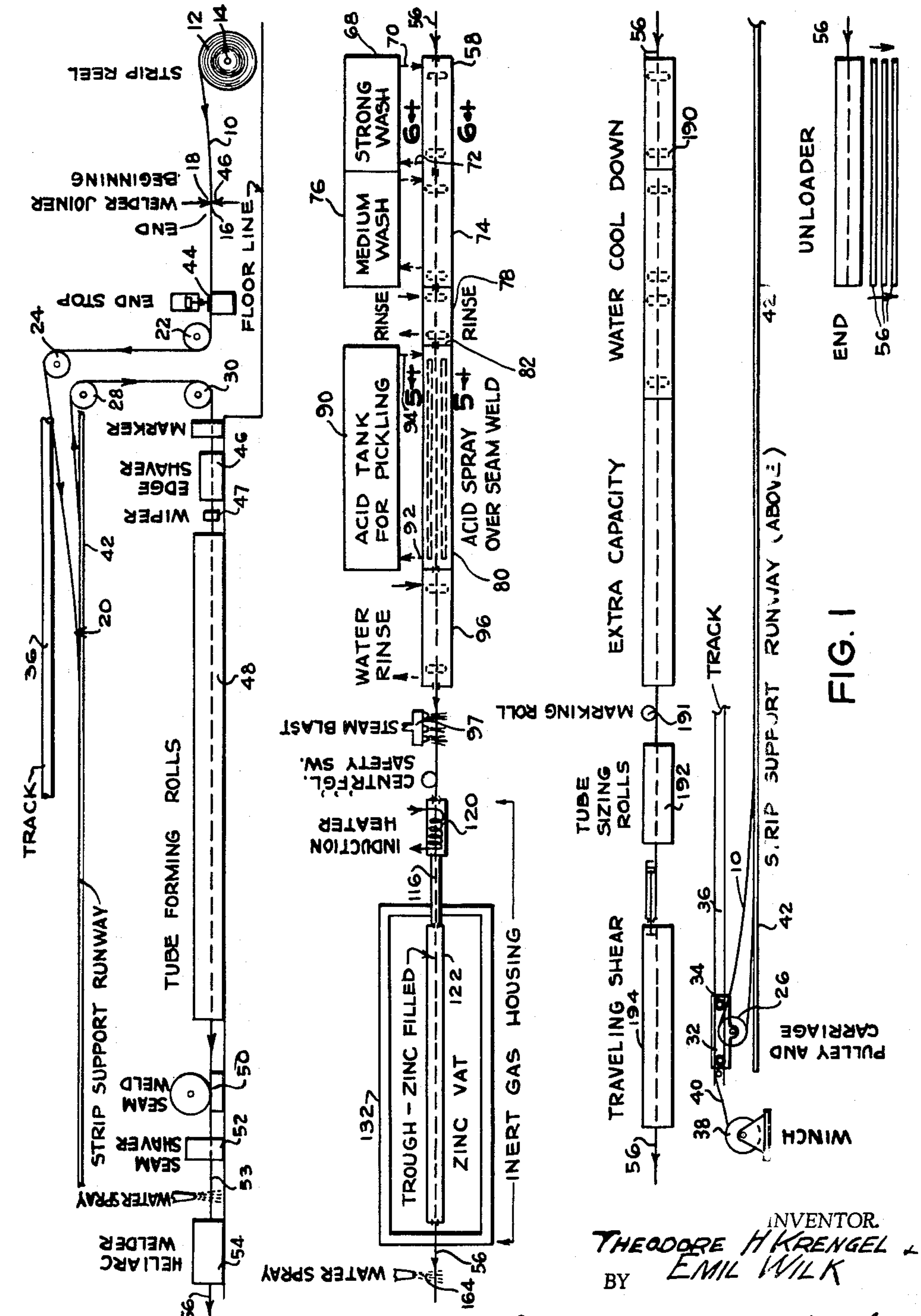

FIG. 1

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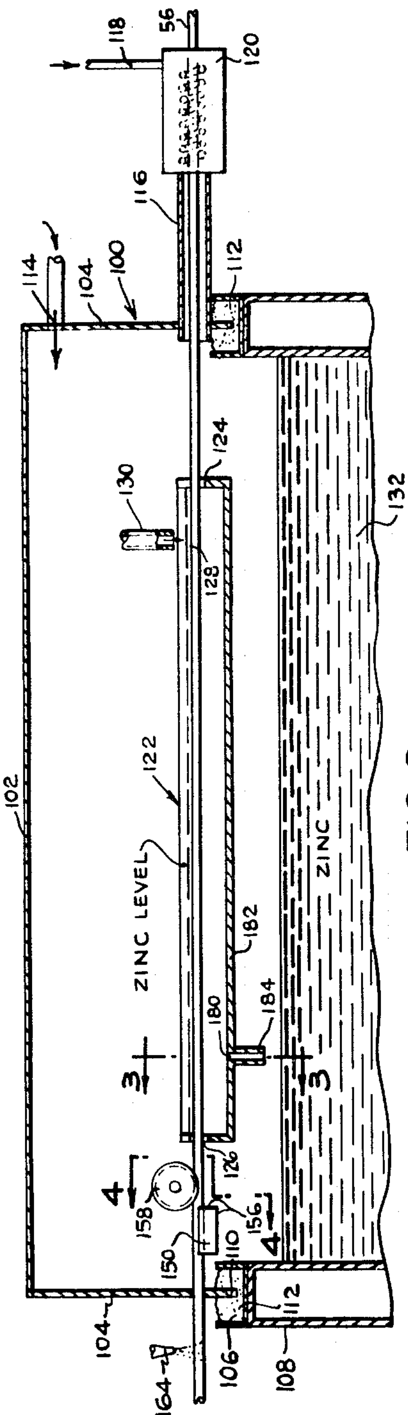

FIG. 2

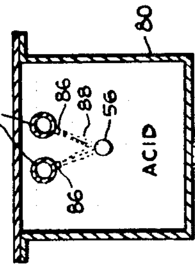

FIG. 5

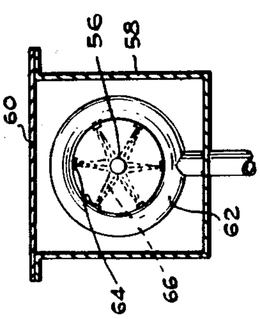

FIG. 6

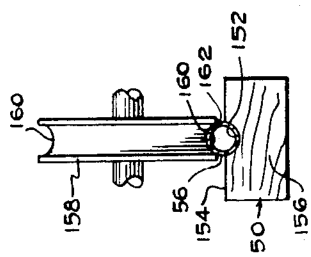

FIG. 4

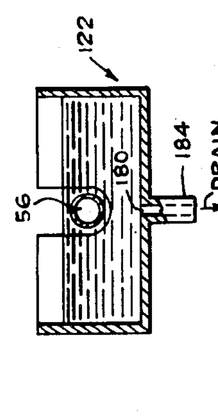

FIG. 3

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3,259,148
GALVANIZED STEEL TUBING

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Original application May 1, 1961, Ser. No. 106,699, now Patent No. 3,122,114, dated Feb. 25, 1964. Divided and this application Dec. 12, 1962, Ser. No. 244,099
5 Claims. (Cl. 138—145)

This is a division of our copending application Ser. No. 106,699, filed May 1, 1965 and entitled "Continuous Tube Forming and Galvanizing," and now Patent No. 3,122,114.

This invention relates to a continuous process for forming and galvenizing tubing of endless strips of steel and to a new and improved galvanized tubing which results from same and it relates more particularly to the production of a new and improved galvanized steel tubing.

It is an object of this invention to provide a new and improved galvanized steel tubing and a process for the continuous forming of tubing from endless lengths of strip steel and for continuous galvanizing of the formed tubing as a continuous operation with the formation of the tubing and it is a related object to produce a new and improved machine for use in the practice of same.

These and other objects and advantages of this invention will hereinafter appear and, for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawings in which—

FIG. 1 is a schematic flow diagram of the continuous forming and galvanizing of tubing in accordance with the practice of this invention;

FIG. 2 is a sectional elevational view of the furnace for the continuous galvanizing of the formed tubing in accordance with the practice of this invention;

FIG. 3 is a sectional view taken substantially along the line 3—3 of FIG. 2;

FIG. 4 is a sectional elevational view taken substantially along the line 4—4 of FIG. 3;

FIG. 5 is a sectional view taken substantially along the line 5—5 of FIG. 1; and

FIG. 6 is a sectional view taken substantially along the line 6—6 of FIG. 1.

Referring now to FIG. 1 of the drawings, the tubing forming mill is fed with strip steel **10** supplied in the form of coils **12** mounted on a pay-out reel **14** for free rotational movement to pay out strip steel as it is required by the continuous tube forming mill. In a continuous mill for forming tubing, the strip steel is processed substantially continuously at a relatively constant rate through the mill. Advancement is effected primarily by engagement between the strip steel and the forming and sizing rolls rotating at relatively constant speed whereby the strip steel is drawn into the mill for processing.

Since the lengths of the steel strip in the coils **12** come to an end after a short period of operation of the mill and since strip is taken up continuously by the mill in its continuous operation, it is essential to provide means for splicing the end of one coil **16** with the leading end **18** of another coil for joinder of the strips into continuous lengths without stoppage of the mill in its continuous operation. For this purpose, a loop **20** is taken in the strip of steel dimensioned to have a length sufficient continuously to feed strip to the mill while the trailing end **16** of the strip is stationarily held for splicing, as by welding, onto the leading edge of the new reel which has been displaced into position of use. The loop is formed by feeding the strip **10** under the roller **22** and over the roller **24** to about the roller **26** and back over the roller **28** and under the roller **30** into the mill. The rollers are each mounted for free rotational movement while the roller **26** is carried by a carriage **32** having wheels **34** rotatably positioned

upon a track **36** for endwise displacement of the carriage in one direction to make strip available to the mill and in the other direction, responsive to the actuation of the winch **38** through the cable **40**, to return the carriage and to reform the loop.

Normally, the carriage is in its retracted position to provide a full loop **20** of strip steel which rests upon a platform **42** overlying the mill and underlying the track. When the end is reached, a portion adjacent the end is locked in a clamping member **44** to hold the end section while the end **16** of the coil is joined, as by welding, to the beginning of the next coil in the joiner **46**. The operation takes but a few seconds. In the meantime, the mill continues to draw its requirements of strip from the loop to displace the carriage **32** in the direction away from the winch as the loop is shortened. When the ends of the coils have been joined, the clamping device **44** is inactivated to free the strip whereby strip can thereafter be supplied from the new coil as the winch **38** and cable **40** are effective to return the carriage to normal retracted position and replenish the loop in preparation for the next splicing operation. It will be apparent that the strip **10** feeds from the coil through the loop to the mill for continuous operation.

Hereafter description will be made of the sequence of operations effected in the mill with the elements in the mill longitudinally aligned for the passage of strip and the tubing formed thereof continuously linearly therethrough. In the preferred practice, the strip **10** is dimensioned to be slightly greater in width than is required to form the tubing so that an edge can be made available from each side to be shaved therefrom in sizing the strip and to provide freshly cut metal in the meeting edges forming the seam thereby to enhance joinder as by a continuous welding opreation to form the closed tubing. From the edge shaver **45** the strip is advanced to wiper **47**, such for example as a pad, which sweeps or otherwise removes chips or other pieces of metal released from the shaving operation. This operation has not heretofore been employed in the continuous formation of galvanized thin wall tubing, yet failure to remove such metal particles from the surface of the metal strip has been found to leave the metal particles where they can become bonded to the surface during subsequent processing steps, such as heating, welding, galvanizing and the like, to constitute an obstruction in the interior of the formed tubing and to provide undesirable surface roughness. Instead of a wiper pad, the loose particles can be removed by a blow-off jet, etc. From the cleaning stage **47**, the strip enters a series of aligned conventional tube forming rolls, identified by the numeral **48**, whereby the strip is deformed from a flat section to a rounded tubing having the freshly cut edges of the strip in abutting relation to form the seam of the tubing.

From the tubing forming roll section **48**, the formed tubing is advanced directly to the seam welder **50** where the abutting free edges of the strip formed to tubular shape are joined by welding, preferably using a continuous resistance welder operated on 360 cycles in order to keep the upset on the inside of the formed tubing at a minimum. Otherwise, it would require the use of a support within the tubing and/or an upset removing tool employed in combination with a water suction device. Since sufficient space is not available in small diameter tubing for housing such support, upset removal tool and water suction means, it has been found to be expedient, in accordance with the practice of this invention, to make use of a continuous welder in the form of a roller operated on 360 cycles and adjusted to effect the major upset on the outside of the tubing where access is available for removal.

It has been conventional practice to apply cooling water to the entry end of the welding operation for cooling the electrode. However, it has been found that the application of cooling water before the seam has been closed enables water to gain access to the interior of the formed tubing where it can raise numerous problems, as during the subsequent galvanizing operations, for example. Thus, as a further improvement in the continuous formation of galvanized thin wall tubing, the coolant is transposed from the leading edge of the trailing end portion of the tubing during the welding operation where the seam has already been closed and water is incapable of escaping into the formed tubing. Cooling of the electrode remains efficient even with the described transformation.

When, as in the practice of this invention, the upset is concentrated on the outside, the upset or flash can be removed by a seam shaving tool **52** which follows immediately after the seam welder. The seam shaver embodies a scarfing tool which shaves the seam to leave a smooth surface on the outer periphery of the formed tubing and whereby the seam would be concealed except for the presence of a heat line indicated by a dark discoloration of metal oxide formed along the weld surface.

By way of a still further improvement in the means and method for the continuous forming of galvanized thin wall tubing, it has been found to be desirable to quench the hot surface of the tubing immediately after the scarfing operation to minimize oxidation of the freshly cut and hot surface. For this purpose, cold water is applied to the surface of the tubing **53** immediately after the scarfing operation with the result that a heat treating effect to produce a blue coloration indicative of a metallic surface free of oxidation is secured, as distinguished from an otherwise formed brownish discoloration on the freshly cut surface, indicative of oxide formation. The minimum film secured by water cooling of the freshly cut hot metal surface can be easily removed by the subsequent cleaning fluids whereas the otherwise formed oxide film is incapable of removal sufficiently cleanly to permit the formation of a desired zinc coating during the subsequent galvanizing step.

To this point, welded tubing is continuously formed of strip steel with the exception of the possible short lengths of formed tubing which remain with an open seam in the event of skidding of the tubing and the machine when the mill is stopped for one reason or another. As a result, in the described continuous processing for forming tubing, an auxiliary welder **54** in the form of a heliarc welder may be employed, where desired, to take over the welding operation whenever the seam welder fails to weld the seam of the formed tubing. When employed, an overlap is effected with the stop and start of the mill continuously to weld the seam and to insure closure of the seam throughout the length of the tubing. In actual practice with good controls, it has been found that the heliarc welder is not essential.

After the tubing has been welded to provide a continuous weld throughout the length thereof, the tubing is advanced from the welders to elements linearly aligned therewith for washing and pickling the outer surfaces of the formed tubing in preparation for continuous galvanizing. The welded tubing **56** is advanced first into a housing **58** having a removable cover **60** for access thereto. The housing is provided with a plurality of axially aligned ring members **62** in the form of headers having a plurality of spray nozzles **64** arranged equally spaced about the inner periphery for directing a spray **66** onto the outer periphery of the tubing **56** advanced axially therebetween. Each spray head is connected to a reservoir **68** of wash water for recirculating the wash water from the reservoir through pipe **70** to the spray head **62** and from the drain in the housing back through pipe **72** for return to the reservoir. In the illustrated modification the reservoir is shown alongside the housing but it may equally be arranged in other positions such as beneath the housing.

A pump means is interposed between the reservoir and the spray heads for displacement of wash water forcibly to spray the wash water onto the exposed surfaces of the tubing as it passes through the housing. For purposes of washing to remove grease and the like, use can be made of an alkali wash which may be represented by a solution of 5 ounces of alkali per gallon of water and it is preferred to heat the wash water to a temperature below the boiling point of the alkali solution, such as to a temperature of 200° F. to accelerate removal of grease from the surface.

From the hot alkali wash, the tubing **56** is advanced continuously into the adjacent section of housing **74** in which the tubing is treated with a dilute alkali wash. The housing **74** is similar to that of the housing **58** for the hot alkali wash including spray heads to direct the dilute alkali wash onto the periphery of the tubing and with a separate reservoir **76** connected to the headers to feed dilute alkali from the reservoir to the headers and connected to the drain in the base of the housing for returning the dilute alkali wash from the housing back to the reservoir. The dilute alkali wash is employed for more complete removal of grease and dirt from the surface of the tubing and the use of the dilute alkali wash following immediately after the strong alkali wash operates to save alkali loss since strong alkali carried on the surface of the tubing from the strong alkali wash will be recovered in the wash with dilute alkali to supply some of the alkali for maintaining the desirable concentration thereof. The dilute alkali wash may be formulated to contain about 2 ounces of alkali per gallon and it may also be heated to an elevated temperature such as to a temperature below boiling, or up to 200° F. more effectively to remove grease and other undesirable material from the surface of the welded tubing.

From the alkali washes, the tubing is advanced into a rinse housing **78** aligned endwise with the alkali wash housing and similarly constructed. The rinse housing is fitted with a number of axially aligned spray heads, similar to the rings employed in the alkali wash systems, from which rinse water is sprayed onto the surface of the tubing as it passes therethrough to rinse remaining alkali from the surface before passing the tubing into the pickling bath. The rinse water is circulated under pressure from a water supply source to the spray heads and the water collected in the bottom of the rinse housing can be released to the drain unless water is at a premium, in which event the water is recirculated with sufficient makeup water to provide for substantial removal of alkali. The rinse water may be used either cold or warm, but it is economically undesirable to invest in warming the water unless the warm water is recirculated between the housing and a water storage reservoir for re-use.

From the rinse, the tubing **56** is advanced directly into a pickling housing **80** of similar construction as the wash and rinse housings and separated therefrom only by a separating wall **82**. The pickling housing is provided with a pair of longitudinally arranged, laterally spaced apart spray pipes **84** arranged in the upper portion of the housing to overlie the tubing **56** which passes linearly through an intermediate portion of the housing beneath the spray pipes to face the weld seam in the direction of the pipes. The pipes are each provided with a plurality of spray nozzles **86** in the underside positioned to direct the spray **88** angularly downwardly to converge on the weld seam positioned uppermost in the tubing passing therethrough. Thus the spray is directed forcefully from the spray nozzles onto the seam to react with the oxides on the surface which are formed at the weld. Use can be made of conventional pickling solutions for removal of the metal oxide, such for example as an acid solution containing about 30 percent by volume RCl dissolved in aqueous medium. For best results, it is desirable to make use of a pickling solution heated to an elevated temperature such as at a temperature of 100–120° F., but a heated pickling solution is not essential.

The solution is stored in a suitable reservoir **90** and is connected with the spray heads through lines **92** and **94** and circulation is effected by means of a displacement pump. The reservoir, pump and housing are all provided with a rubber lining to protect the metal parts from the acids of the pickling solution.

From the pickling housing **80**, the pickled tubing is advanced into an aligned section of housing **96** for rinsing the pickling solution from the surface of the tubing. The rinse housing following pickling is very similar to the rinse housing **76** wherein water is sprayed from spray rings onto surfaces of the tubing passing therethrough to rinse the pickling solution from the surface.

In the aforementioned alkali washes, rinse, pickling and final rinse, the housings can be of a unitary construction subdivided into separate sections by separating walls each of which is provided with aligned openings dimensioned to enable the tubing to pass lengthwise therethrough in and out of the housings. Instead, the housings can be separated members with aligned openings in the end walls for the continuous passage of the tubing from one to another without bending.

An important concept of this invention resides in the means and method for continuously galvanizing the formed tubing as a continuous operation with the described forming, welding and cleaning operations. For this purpose, it is desirable to contact the cleaned surface of the steel tubing with molten zinc for sufficient time to enable the desired reactions to take place to form the desired thickness of galvanize on the surface and it is important to carry out the reactions under non-oxidizing conditions, otherwise undesirable oxides of the metal will form at the elevated temperatures under which the reactions are carried out.

The desired reducing or non-oxidizing atmosphere can be maintained by the enclosure of the galvanizing zone within a sealed housing into which an inert, or reducing gas can be introduced for maintenance of a non-oxidizing atmosphere. This can be accomplished by a sealed enclosure but it is preferable to make use of an enclosure which is capable of removal to gain access to the interior of the galvanizing zone but without interfering with the ability to achieve atmospheric control, when in position of use.

The desired characteristics have been achieved in the construction illustrated in FIG. 2 of the drawings by the use of a rectangular hood **100** having a horizontally disposed top wall **102**, side and end walls **104** which depend perpendicularly downwardly from the edges of the top wall into a trough **106** facing upwardly from a frame **108** which extends all about the galvanizing zone. The bottom edges **110** of the side walls are received within the trough for support of the hood on the bottom wall thereof. The trough is at least partially filled with a pulverulent material **112**, such as fine sand, into which the lower edge of the side walls become embedded to effect a sealing relationship all around which militates against the flow of free gases all around for atmospheric control. One or more inlets **114** for the inert or reducing gas are provided in the walls of the hood for introduction of such inert or reducing gases in amounts to maintain a non-oxidizing atmosphere therein.

It has been found that the galvanizing reactions can be carried out more rapidly with greater uniformity when the tubing is preheated to an elevated temperature, such as to a temperature above the melting point temperature for the zinc, such as at 750° F., before being contacted with the molten zinc, although it is not essential to preheat. When preheating is effected, it is again important to achieve the desired preheat without exposure of the metal surface to oxidizing conditions, otherwise the metal oxides that would form at an accelerated rate while the tubing is heated to an elevated temperature would interfere with the formation of a suitable galvanize on the surface. In the illustrated modification, the preheat section comprises a tubular housing **116** which has its center aligned with the line of travel of the formed tubing through the machine and which communicates with the enclosure **100**. Inert gas is introduced into the tubular housing through an inlet **118** in the forward end of the tubular member for the circulation of the inert or reducing gas lengthwise through the housing into the hood or enclosure **100** to maintain non-oxidizing conditions within the tubular housing during passage of the tubing therethrough.

The tubing can be heated to elevated temperature by the introduction of heat from suitable and conventional internal or external heaters but it is preferred to make use of induction heating means **120** within the tubular housing to accelerate the build-up of temperature within the tubing walls in minimum time thereby to minimize the lengths necessary for the tubular housing.

By way of a still further improvement in the continuous process for forming and galvanizing thin wall tubing, it has been found desirable to effect the removal of moisture from the surface of the tubing prior to entry into the preheat furnace. Moisture otherwise left on the surface from the preceding cleaning and rinsing operations makes oxygen available to the surface at the time that the surface is raised to elevated temperature. Such available oxygen is capable of conversion of the atmosphere from an inert state to a reactive state to cause oxidation of the surface of the heated metal tubing. The presence of such oxides on the surface interferes with the application of uniform zinc coating during the subsequent galvanizing step and thus militates against production of an optimum galvanize on the surface. In accordance with a further concept of this invention, the surface of the formed tubing is subjected to a blast **97** of steam prior to passage of the tubing into the preheat furnace.

Having described the preheat of the tubing and the introduction of the preheated tubing into the inert galvanizing zone maintained to reducing or non-oxidizing conditions, description will now be made of the new and novel means by which the tubing is maintained in contact with a molten bath of zinc as a continuous operation with the tubing forming process.

Referring now more particularly to FIGS. 2 and 3, the galvanizing means comprises an elongate, horizontally disposed housing **122** in the form of a trough aligned axially with the line of travel of the tubing for passage of the tubing axially through an intermediate section of the housing from an inlet **124** at one end to the outlet **126** at the opposite end. The housing is provided with one or more inlets **128** which are connected by a passage **130** to a reservoir **132** of molten zinc with means for displacement of the molten zinc from the reservoir to the inlets at a rate sufficient to maintain the housing substantially filled with molten zinc to cover the tubing advanced therethrough. The inlet **128** is preferably, though not necessarily, located in the portion of the housing adjacent the inlet end **124** through which the tubing is introduced into the housing for concurrent flow of the molten zinc through the housing with the tubing and in position to overlie the tubing so as to direct the stream or streams of molten zinc onto the tubing.

The housing is further provided with a drain opening **180** in the bottom wall **182** of the housing with a downpipe **184** leading from the drain to the reservoir. The drain opening is of small dimension to enable a thin stream of molten zinc constantly to flow therethough but at a rate that is considerably less than the rate of introduction of molten zinc into the housing less the amount that escapes through the openings so that there will be an overflow of molten zinc over the ends of the trough forming the inlet and outlet to the housing but with an amount of molten zinc in the trough to cover the tubing passing therethough. The drain opening **180** is effective in the event of some failure in operation or stoppage of the machine thereby to drain molten zinc from the housing before the zinc has cooled to a temperature below its melting point otherwise the zinc would become solidified within the housing and thereby render the housing unfit for future use until the solidified zinc is passed from the housing or otherwise, with difficulty, removed.

The zinc in the reservoir can be heated by suitable burners or other heating means to maintain the zinc in the bath at a temperature above its melting point temperature of about 750° F. and preferably at a temperature above about 850° F. Access means are provided in the hood **100** for addition of pigs of zinc to the reservoir in amounts corresponding to the zinc that is used or otherwise removed with the tubing.

It is important to provide a sufficient weight of coating of molten zinc onto the surface of the formed tubing but it is undesirable to enable excess molten zinc to be carried off with the tubing thereby to increase the cost of galvanizing and/or prevent bead formation by excess zinc remaining on the outer surface. One means particularly adapted to control the thickness of the zinc coating without bead formation and to provide for removal of excess for return to the reservoir, while in a molten state and while still in a protective atmosphere, comprises an elongate block **150** of stainless steel or the like formed with a groove **152** extending lengthwise across the top wall **154** in which at least the leading edge portion **156** of the block still extends into the trailing end portion of the hood. The groove **152** in the top surface of the block is adapted to correspond in curvature with a hemispherical section of the tubing to engage the lower half thereof during passage of the tubing lengthwise therethrough. In the preferred practice, the groove is formed to a diameter corresponding to that of the tubing or slightly greater.

Cooperating with the block is a roller **158** mounted for rotational movement about an axis crosswise of the line of travel of the tubing with an annular, arcuate recess **160** formed in the periphery of the roller shaped to correspond somewhat to a hemispherical section of the tubing being processed. As in the block, the arcuate recess **160** is dimensioned to have a diameter corresponding to that of the tubing or slightly greater. The roller is positioned with its lower edge **162** in endwise alignment with the top side of the recess **152** to more or less define a circular section therebetween corresponding to the circular section defined by the tubing or slightly greater.

Thus the roller **158** operates to engage the top side of the tubing after it issues from the galvanizing trough to pre-position the tubing both in its travel through the galvanizing system and for its subsequent engagement with the grooved block for wiping excess molten zinc from the surface. Some excess zinc will also be removed by the roller upon engagement.

The cooperation between the roller and the block is believed to make the block effective as a wiper for removal of excess molten zinc from the outer wall of the tubing. Such excess zinc is removed while the tubing is still within the hood thereby to provide premature freezing of the metal while simultaneously protecting the molten metal from oxidation so that the excesses removed can be allowed to flow back into the reservoir for re-use.

The block is effective to still leave a desirable amount of zinc as a coating on the outer wall of the tubing. To prevent flow and bead formation, it is desirable to freeze the metal as soon after wiping as possible. For this purpose, use can be made of a water quench, as in the form of a water spray or flow coat **164** following substantially immediately after the tubing emerges from the hood.

From the galvanizing section, the galvanized tubing is advanced sequentially through a series of water spray sections **190** to cool down the galvanized tubing if the tubing has not otherwise been sufficiently cooled in the freezing step, and, from the cool-down operation, to conventional tube sizing rolls **192**, and from the tube sizing rolls to a traveling shear section **194** where the endless tubing is cut into lengths of predetermined dimension for shipping. The water spray sections are similar to the rinse sections which follow alkali cleaning or acid etch and the tube sizing rolls and flying shear are of conventional construction.

As an alternative, the galvanized tubing, after being cooled, may be processed through a spray housing similar to the alkali cleaning, wherein the galvanized surface is wetted with a chromate and nitric acid solution for reaction to form a surface of zinc chromate whereby still greater resistance to oxidation is secured by comparison with a plain zinc galvanized surface. If a section of the spray housing is devoted to the chromate spray, an additional section should be provided for a water rinse to remove excess chromate solution from the surface.

As another innovation, the tubing is marked, as by means of a marking roll, after galvanizing, as distinguished from the conventional practice of indenting to mark the tubing before galvanizing or even before the formation of the tubing. This is because the marking applied to the surface of the tubing before galvanizing becomes filled with molten zinc so that it would no longer be visible and the marked depressions appeared also to interfere with the proper galvanizing of the tubing surface. Thus the marking roll precedes tube sizing, as indicated by the position **191**.

To the present, the description has been addressed to the method and means for the continuous forming and galvanizing of steel tubing from substantially endless strips of steel. The product formed by the described method and means constitutes a new and improved article of commerce which is characterized by many improvements in properties and characteristics by comparison with galvanized tubing normally produced by processes of the types heretofore employed.

The galvanized steel tubing prepared in accordance with the practice of this invention is characterized by a coating of zinc formed by a hot dip in a molten bath of zinc only on the outside of the formed tubing, leaving the inner surfaces free of zinc. The zinc coating that is formed on the outer wall by the hot dip provides a zinc coating that becomes strongly bonded to the underlying steel surfaces of the tubing by reason of the fact that the hot molten zinc which is brought into contact with the cleaned surface of the freshly formed steel tubing is capable of alloying with the steel to produce a tubing which in cross-section, from the inside out, comprises an inner core of steel which is free of zinc on its inner surface; an intermediate thin layer of an alloy of iron and zinc that is formed in the inner face between the outer layer of zinc and the inner core of steel strongly to bond the outer layer of zinc to the inner core of steel; and finally, the outer layer of zinc. An intermediate alloy layer is formed to a thickness within the range of 0.00001 inch to 0.001 inch and it is preferably maintained to a thickness within the range of 0.00005 inch to 0.0005 inch. The outer layer of zinc is maintained to a thickness within the range of 0.00075 inch to 0.01 inch and preferably within the range of 0.001 inch to 0.0025 inch. A number of advantages flow from the combination described, as will hereinafter be pointed out.

To the present, two processes have been employed in commercial practice for the production of galvanized tubing. One such process, identified as an electrolytic process, deposits a thin coating of zinc on the outer surfaces of the steel tubing by electrolytic means, using the steel tubing as the anode in an electrolytic bath containing an ionizable salt of zinc dissolved in the electrolyte. The electrolytic process is capable of use to deposit only a layer of zinc on the outer surfaces of the formed steel tubing. However, by comparison with the described hot dip coating that is formed in accordance with the practice of this invention, the outer zinc coating that is deposited by the electrolytic process is one in which the coating of zinc has a sharp line of demarcation from the underlying surface of steel such that the resulting structure is substantially free of the alloying layer which is effective strongly to bond the zinc coating to the steel core. Thus the galvanized coating provided by the electrolytic process can be easily chipped or separated from the underlying steel tubing thereby to produce an inferior product.

Aside from the foregoing improvement that is derived by the hot dip outer galvanized coating, the electrolytic plating process is more expensive from the standpoint of the cost of the materials, the power requirements, the labor requirements and equipment.

The other method employed commercially in the preparation of galvanized steel tubing embodies the preparation of steel tubing and the subdivision of the formed steel tubing into lengths which can be handled for separate hot dip galvanizing. This is a batch type of process wherein the lengths of tubing are separately advanced through a molten bath of zinc to zinc coat both the inside of the tubing as well as the outside. Thus the product that is secured is one that is characterized in cross-section from the inside out by an inner layer of zinc; an inner intermediate layer of an alloy of zinc and salt; an iron core; an outer intermediate layer of an alloy of zinc and iron; and an outer layer of zinc. A product of this character is less desirable than the product that is secured by the practice of this invention for various reasons:

(1) When the individual lengths are separately hot dipped to coat both the inside and the outside with zinc, it has been found that the zinc tends to collect as or otherwise form beads on the interior surfaces of the tubing. These beads cannot be removed in forming because of the difficulty to gain free access to the interior of the tubing. Such beads and imperfections constitute surface roughness and imperfections which interfere wtih the optimum use of the tubing and the ability freely to draw the wire through the interior of the tubing.

(2) When zinc is present on the inner surfaces of the tubing, it becomes more difficult to pull the various electrical wires or other elements through the tubing by comparison with tubing that is free of such inner coatings of zinc. It is believed that this difficulty in pulling through wires and the like stems from the greater frictional characteristics of zinc by comparison with steel with the result that the hot dipped tubing having an interior zinc coating exhibits greater frictional resistance to relative movement of other materials thereover by comparison with the steel surface. Such increased resistance to pull-through may also result in part from surface roughness which results from the interior zinc coating that is formed from a hot melt.

(3) It has been found that zinc, when applied as a hot melt, tends to accentuate imperfections in the underlying surface such that any imperfections on the inside of the steel tubing become magnified by the hot dip coating of zinc. While these accentuations can be removed when formed on the outside walls, they often are allowed to remain on the inside because of the inaccessibility. The internal bead constitutes an imperfection which is undesirably accentuated by the zinc coating. The accentuated bead is sufficiently significant in some instances to cut the wires as they are being drawn through the galvanized tubing.

(4) In the conventional hot dip process where both the outer and inner surfaces of the tubing are coated with molten zinc, it is undesirable to effect rapid cooling by quenching because non-uniform cooling in cross-section would have an effect to cause bowing of the length of tubing. As a result, steel tubing galvanized on both sides by a hot dip is not quenched immediately after galvanizing. When the zinc coating is allowed to cool slowly, a spangle is formed on the coating which materially detracts from the appearance of the galvanized tubing. On the other hand, when the tubing is galvanized with a hot dip capable of being applied only on the outside of the tubing, the tubing can be quenched for cooling immediately after contact with the molten zinc. As a result, a smooth and bright galvanize is produced on the outside of the tubing.

(5) The applied zinc coatings are characterized by a hardness which is greater than that of the steel core. When, in accordance with the practice of this invention, the zinc coating is present only as a single layer on the outside of the steel tubing, the increased hardnesss of the outer zinc coating will have little, if any, effect on the bendability or flexure of the galvanized steel tubing. On the other hand, when the zinc coating is formed both on the outer surfaces and the inner surfaces of the steel tubing to constitute spaced hard layers integral with the steel tubes, the spaced hard layers introduce a decided stiffness in the formed tubing which makes it relatively inflexible and more difficult to bend.

(6) Air is introduced into the interior of the tubing before closure of the tubing, during tubing formation, at the final stages of actuation by the tube forming rolls, as described in our copending application Ser. No. 239,432, filed November 23, 1962, and entitled "Continuous Tube Forming and Galvanizing." Such air, which travels continuously through the interior of the closed tubing for purposes of maintaining a desirable atmospheric control and a dried state, has been found also to operate to cause the formation of a blue oxide of iron on the interior surfaces of the formed tubing at the elevated temperatures to which the tubing is exposed during preheat and the galvanizing step. Such blue temper or oxide coating on the interior surface of the formed tubing has been found to be effective to resist corrosion or rust and thereby to protect the interior surfaces of the tubing. It also exhibits low resistance to friction thereby to enhance the pull of the wire or cables through the lengths of the tubing. Additionally, the blue surface or film which forms permanently on the interior of the tubing represents a base to which paint or other organic coating compositions can strongly adhere.

(7) Finally, the layer of zinc that is formed on the inside of the tubing by commercial hot dip processes constitutes a waste of zinc which not only materially increases the cost of the formed tubing but such additional layer takes up space such that it becomes necessary to provide a steel tubing of larger diameter than that produced in accordance with the practice of this invention to end up with a galvanized tubing of the same internal diameter.

It will be understood that changes may be made in the details of construction, arrangement and operation, as well as in materials employed, without departing from the spirit of the invention, especially as defined in the following claims.

We claim:

1. A hollow steel tubing hot dip galvanized on the exposed outer surfaces of the tubing while the interior surfaces of the tubing remain free of galvanize, comprising a steel base having a blue oxide of iron on the inner surfaces and thereby completely free of zinc, and the outer surfaces of which have a galvanize coating consisting solely of an inner portion of an alloy of iron and zinc and an outer portion consisting of zinc with the portions of the galvanized coating strongly bonded one to the other end and with the inner portion strongly bonded to the steel base.

2. Galvanized steel tubing as claimed in claim 1 in which the alloy layer has a thickness within the range of 0.00001 inch to 0.001 inch.

3. Galvanized steel tubing as claimed in claim 1 in which the zinc layer has a thickness within the range of 0.00075 inch to 0.001 inch.

4. Galvanized steel tubing as claimed in claim 1 in which the alloy layer has a thickness within the range of 0.00005 inch to 0.0005 inch.

5. Galvanized steel tubing as claimed in claim 1 in which the zinc layer has a thickness within the range of 0.001 inch to 0.0025 inch.

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