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TUBING AND METHOD OF MAKING COATED TUBING

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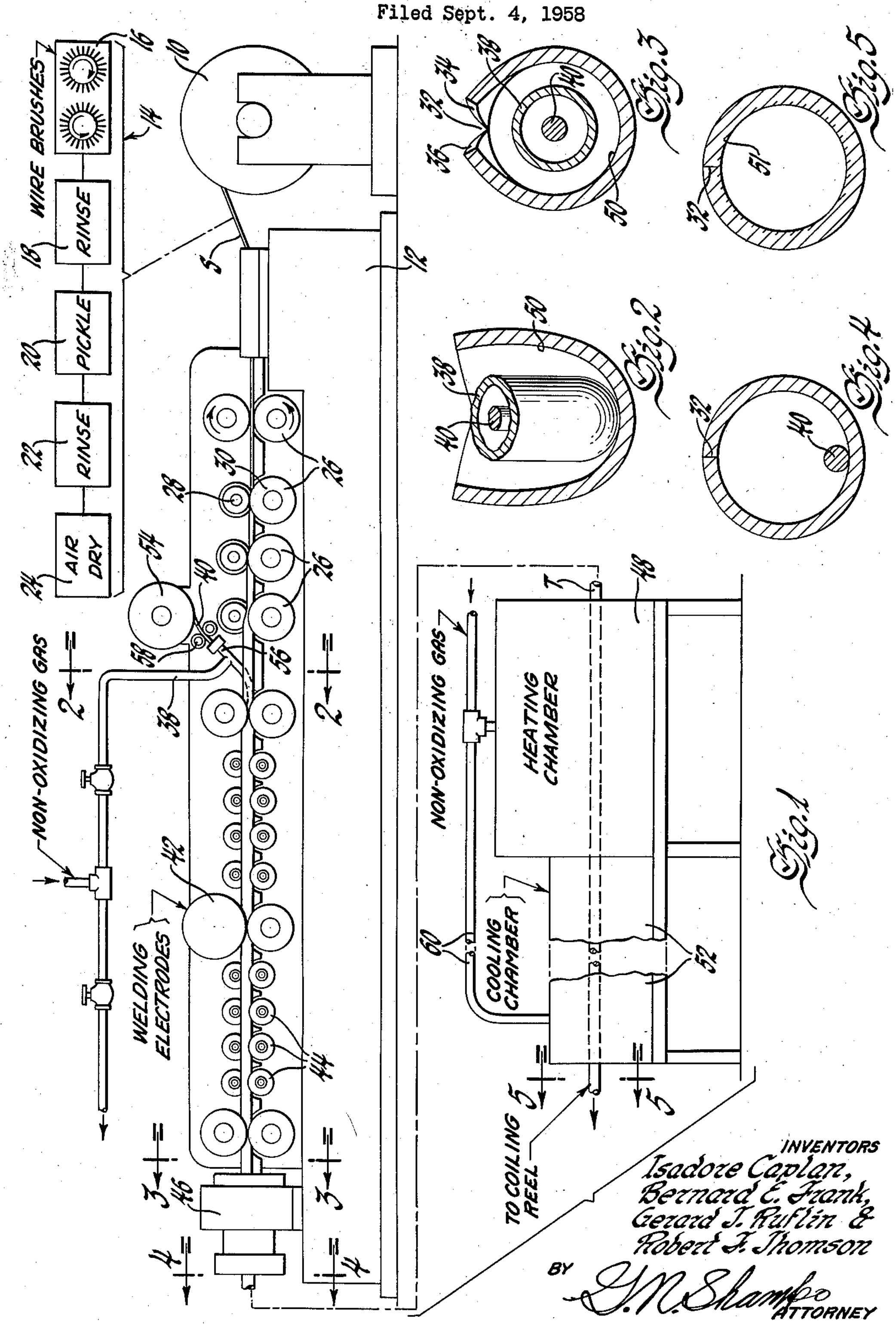

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TUBING AND METHOD OF MAKING COATED TUBING

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This invention relates to the manufacture of interiorly coated welded steel tubing. A primary object of the invention is to provide a method of making welded steel tubing while simultaneously coating the inner surface thereof with a permanent coating of an aluminum-zinc alloy which is securely bonded to the surface of the tubing.

The invention comprehends making steel tubing from a cleaned flat strip of steel which is continuously moved longitudinally through a tube-forming mill. The tube-forming mill transversely bends the strip of steel into a tubular configuration. An alloy of aluminum and zinc is progressively introduced into the tubing during its formation. Prior to the complete formation of the tubing and about at the same point on the tube-forming mill where the aluminum-zinc alloy is introduced into the tubing, the small diameter pipe which discharges a non-oxidizing gas enters the tubing and extends longitudinally therein. After the alloy is introduced into the interior of the tubing the formation of the tubing is completed and the tubing is passed through a suitable welding device. It is subsequently passed through sizing means which impart the desired finish cross-sectional configuration of the tubing. After the tubing has been sized, it is passed through a heating means where the temperature of the tubing is raised sufficiently to vaporize the aluminum-zinc alloy. The vaporized alloy diffuses homogeneously throughout the tubing, to some extent, penetrating the inner surface of the tubing. The hot tubing is then passed through a cooling device which causes the vaporized alloy to condense as a uniform coating on the inner surface of the tubing. If desired, the tubing can then be given a suitable coating on its outer surface, resized, and cut to useful lengths for storage or coiled on reels for storage.

Further objects, features and advantages of the present invention will become more apparent through the following descripton of preferred embodiments thereof and from the drawing, in which:

Figure 1 is a diagrammatic view showing a tube-forming mill provided with suitable apparatus for carrying out the present invention;

Figure 2 is an enlarged sectional view on the line 2—2 of Figure 1;

Figure 3 is another enlarged sectional view on the line 3—3 of Figure 1;

Figure 4 is a similar view on the line 4—4 of Figure 1; and

Figure 5 is another enlarged sectional view along the line 5—5 of Figure 1.

As shown in Figure 1 the tubing T is formed from a flat steel strip S of AISI 1010, AISI 1020, AISI 1008 steel or the like, which is coiled on a reel 10 positioned adjacent one end of a tube-forming mill 12. Between the reel 10 and the tube-forming mill 12 there preferably is a cleaning unit 14 which prepares the surface of the strip S immediately prior to passing into the tube-forming mill 12. The cleaning unit 14 includes a pair of contra-rotating circular wire brushes 16 which are flooded with a suitable cleaning compound, a rinse 18, a pickling bath 20 and a subsequent rinse 22. After passing through the cleaning unit 14, the strip S is dried by an air blow-off 24 and directed into the tube-forming mill 12.

The tube-forming mill 12 is composed of a group of forming devices 26, each of which includes a pair of rolls 28 and 30. A sufficient number of forming devices 26 are included in the forming mill to impart the desired circular cross-sectional configuration to the flat steel strip S. The forming devices progressively bend the flat steel strip S into a tube T having an open seam 32 at the top where edges 34 and 36 of the strip abut.

Prior to the complete formation of the tube T, a small diameter pipe 38 for conveying a non-oxidizing gas is introduced into the tubing interior as shown more clearly in Figure 2. An aluminum-zinc alloy may also be introduced into the tubing at this point as a wire 40 through the small diameter pipe 38. The formed tube T then passes between welding rolls 42 or other suitable welding apparatus to close the seam 32 formed by the abutting edges 34 and 36 of the steel strip S. The formed tube then passes between sizing rolls 44 which further impart desired cross-sectional configuration of the tubing and then through a swaging device 46 for a final sizing operation.

From the mill 12 the formed tubing T passes into a suitable heating chamber 48 where the aluminum-zinc alloy which was placed in the tubing is vaporized. The vaporized alloy penetrates the inner surface 50 of the tubing and forms a strong alloy bond therewith. The specific construction of the means by which the tubing is heated is not material to this invention. It may be of any construction which will sufficiently raise the tubing to a temperature which is sufficient to vaporize the aluminum-zinc alloy and preferably simultaneously anneal the tubing. Although the annealing operation can take place after the vaporization operation, it is generally preferred to accomplish both simultaneously. Satisfactory results have been obtained using annealing rolls such as are described in the United States Patent No. 2,822,291, Rea J. Hahn, patent February 4, 1958, and which is assigned to the assignee of the present invention.

From the heating chamber 48 the tubing T passes through a cooling chamber 52 which serves to solidify the vaporized alloy to form a coating 51 on the inner surface of the tubing. Continuously circulated cooling water in a jacket (not shown) which surrounds the tubing is one effective means by which the vaporized coating metal can rapidly be converted into the solid state. Similarly, a jacket having a suitable number of cooling fins thereon for transferring heat directly to the atmosphere can also be used. When the tubing is cooled in this manner, the alloy coating 51 solidifies so rapidly that there is substantially no tendency for the coating metal to run toward the bottom of the tubing. It has been observed that the alloy coating formed by this invention has an insignificant difference in thickness at the top and bottom of the tubing with the thickness at the bottom being only negligibly greater.

A protective atmosphere is preferably maintained around the outside of the tubing when it is in a heated condition to prevent oxidation of the outer surface of the tubing and to insure against oxidation within the tubing. Accordingly, the heating and cooling means are preferably housed in the closed chambers 48 and 52 to facilitate this end. After cooling, the tubing can then be resized, if desired, and cut into whatever lengths are desired. If cut into extremely long lengths, the tubing is coiled onto long reels but it can be cut into short lengths and stored in straight pieces, if desired.

Prior to entering the tube mill the flat steel strip S is preferably continuously cleaned of all dirt, steel, oxides, oils or other materials by the cleaning unit **14**, shown in the drawing. The cleaning unit consists of two motor driven contra-rotating wire brushes **16** which scrub the side of the strip which is to form the inner surface **50** of the tubing T. The brushes **16** of the cleaning unit are flooded with a hot alkaline cleaning compound to carry away the loosened soil. One such alkaline cleaning solution which may be used is an aqueous solution which is saturated with sodium silicate and sodium hydroxide. The steel strip then passes under a water spray or rinse **18** to remove any cleaning compound which may be adhering to its surface. After rinsing, the steel strip can be passed through a pickling bath **20**, such as an aqueous solution containing 30%, by volume, hydrochloric acid. After the pickling treatment, the strip is passed through the rinse **22** to remove any traces of the pickling solution which may be adhering to its surface after the pickling treatment, and is then subjected to an air blow-off **24** to dry it.

Other methods of cleaning, such as sand blasting, spray washing, electrolytic cleaning, etc., may be used in some instances to prepare the steel strip for use in accordance with the invention. However, we have found that the hereinbefore described method of cleaning provides especially beneficial results when used in combination with the coating method of the invention. The internal coatings applied to tubing surfaces which are cleaned in this manner are particularly more adherent and permanent.

The coating metal can be introduced into the interior of the hollow and annular cylindrical tubing T in any convenient form. Our invention is especially more conveniently practiced, however, if the coating metal is introduced into the tubing in a wire form **40**, as shown in the drawing. Generally it is preferred to introduce the coating metal into the tubing immediately before it is fully formed. The wire **40** may be coiled on a roll **54** mounted on the tube-forming mill **12** and fed through a directing tube **56** into the interior of the tubing by means of a pair of driving rolls **58**. As shown in the drawing, the aluminum-zinc alloy wire **40** can be introduced within the tubing through the small diameter pipe **38** which is used to introduce the protective atmosphere into the interior of the tubing. The specific construction of this mechanism is not a part of this invention and any suitable device can be used to introduce the coating metal at a substantially uniform rate. The particular rate at which the metal is introduced is variable to some extent and is governed by the size and speed of movement of the tubing being formed.

As shown in United States Patent No. 2,771,669, filed in the names of J. W. Armstrong, R. W. Spears and R. D. Williams and which is assigned to the assignee of the present invention, particles of metal such as zinc can also be uniformly introduced into the interior of the tubing employing a suitable hopper or funnel having a narrow outlet which extends into the tubing prior to its complete formation.

Obviously, in order to provide a uniform coating, the amount of aluminum-zinc alloy which is introduced into the interior of the tubing must vary in direct proportion with both the size and speed of movement of the tubing which is to be alloy coated. Moreover, coating compositions of varying proportions can be produced by varying the amount of coating material introduced into the interior of the tubing. In general, highly satisfactory results are obtained if the coating metal is introduced as a wire which moves at the same speed as the tubing. Tubing is generally formed at speeds of approximately 75 feet per minute to 200 feet per minute. Satisfactory alloy coatings are obtained by using a sufficient amount of the alloy to produce a deposit on the inner surface of the tubing which is between 0.0005 inch and 0.002 inch in thickness. In most instances, the coating of approximately 0.001 inch in thickness is preferred.

As a specific example, steel tubing having an outer diameter of approximately 5⁄16 inch and a wall thickness of approximately 0.028 inch can be successfully coated using an aluminum-zinc alloy wire, approximately 0.032 inch in diameter, which is moving at the speed of the tubing being formed. Similarly one can use an aluminum-zinc wire, approximately 0.047 inch in diameter, which is moving at the speed of the tubing to coat tubing having an outer diameter of approximately 5⁄8 inch and a wall thickness of about 0.035 inch. In general, highly satisfactory results are obtained when a weight of approximately 0.0025 pound per foot of tubing and 0.0053 pound per foot of tubing are, respectively, used.

A non-oxidizing gas from a suitable reservoir (not shown) passes through the small diameter pipe **38** which is introduced into the tubing at approximately the same point on the tube-forming mill where the coating metal is introduced into the tubing. As shown in the drawing, this small diameter pipe **38** has a part (not shown) which extends axially within the interior of the tubing towards the swaging device to a point where the tubing is completely formed. The discharge end of the pipe is located at a point where the tubing is completely formed so that the reducing atmosphere emitted therefrom will be substantially contained within the interior of the tubing. Thus, a protective atmosphere is established within the tubing as it moves along the various following operations.

It is also desirable to employ a protective atmosphere outside the tubing in the operation following tube formation. Heating the tubing in an oxidizing atmosphere may cause a deleterious corrosion and spalling of the outer surface which is detrimental to subsequent outer coating operations. Thus, as shown in Figure 1, the heating and cooling of the tubing can be done within closed chambers in which a protective atmosphere is established. The non-oxidizing gas can be introduced into the chambers by means of additional piping **60** from the source of supply (not shown).

A gas which protects the interior and exterior of the tubing is preferably 20% to 25% reducing in nature. For example, highly satisfactory results are obtained with a gas which has the following analysis: 10% carbon monoxide, 18% hydrogen, 4½ carbon dioxide, 1% methane and the balance nitrogen, all proportions by volume. However, substantially pure mixtures of hydrogen, carbon monoxide, nitrogen, helium, argon, can also be used.

From the swaging device or sizing device the tubing passes into the heating chamber where it is heated above the vaporization temperature of the aluminum-zinc alloy which was deposited within the tubing during its formation. The vaporization of the aluminum-zinc alloy permits the alloy to penetrate the inner surface of the tubing to some extent to produce an exceedingly uniform tenacious alloy coating. The vaporization of the alloy and the annealing of the steel tubing can be accomplished simultaneously, if desired, and in such instance the tubing should be heated to a temperature which is not only sufficient to vaporize the zinc but also to anneal the tubing. It has been found that satisfactory alloy coatings are obtained when the tubing is heated to a temperature beween 1700° F. and 2400° F. In general, highly satisfactory annealing and coating results are obtainable in the temperature range of approximately 2000° F. to 2400° F.

After the tubing has been cooled, if desired, it may be coated on its outer diameter and subsequently passed through a pull-out unit to resize the outside of the tubing. In some instances the various coating and heat treatments to which the tubing is subjected may affect the outer dimensions of the tubing so that resizing is required. Should resizing be required, the tubing can be passed through a pull-out unit which is, in general, similar to the final sizing devices employed on the tube mill which impart the final cross-sectional configuration to the tubing.

United States Patent No. 2,771,669 Armstrong et al., which was patented November 27, 1956, and which is assigned to the assignee of the present invention describes a method of vaporizing a zinc coating onto the inner surface of steel tubing during its manufacture.

For some applications steel tubing coated with pure zinc has proved to be only partially satisfactory. For example, steel tubing which is to be used in automobile gas lines must be highly corrosion resistant and must not produce the white corrosion products of a pure zinc coating which would spall or flake from the surface and subsequently deleteriously affect the fuel system. Moreover, steel tubing which is used to convey especially corrosive materials must be correspondingly of especially high corrosion resistance.

It has been found that when vaporizing pure zinc metal in accordance with the method set forth in the aforementioned Armstrong et al. patent, the zinc metal forms dendritic structures on the inner surface of the tubing with pure base metal exposed therebetween. Thus, the coating formed, unlike an immersion coating, is somewhat discontinuous and contains pinholes at which corrosion can occur. The galvanic or sacrificial properties of the zinc will protect these bare spots to some extent but over extended periods of time the corrosion resistance of the coating is seriously affected.

Moreover, due to the dendritic structure and the formation of ferro-zinc intermetallic compounds, the pure zinc coating tends to be undesirably brittle for some applications. Where the tubing is subjected to an excessive amount of bending, the harder and more brittle zinc coating is not sufficiently ductile to resist cracking and delamination and therefore exhibits especially poor corrosion resistance.

It has now been found that by adding rather large amounts of aluminum to zinc an especially satisfactory coating can be formed that is bright, ductile and more corrosion resistant. By vaporizing an aluminum-zinc alloy wire onto the inner surface of the tubing no dendritic structure is formed and an exceptionally smoother, uniform, bright and shiny coating is obtained. Since substantially no dendritic structure is present in the aluminum-zinc coating, there are no pinholes present to expose the base metal. Moreover, the addition of the aluminum minimizes the formation of the brittle ferro-zinc intermetallic compounds which contribute to the brittleness of the coating.

A further advantage of the coating formed with the aluminum-zinc alloy in the method hereinbefore described is that it contains a thin overlay of an aluminum-rich alloy which virtually eliminates the white corrosion products common to a pure zinc coating. This thin aluminum-rich overlay provides the coating with an exceptionally higher corrosion resistance than that even obtained under a hot dip process employing a similar aluminum-zinc alloy. In addition to the more ductile and continuous characteristics of the coating, this invention further provides corrosion protection by means of its fine sacrificial properties.

The ductile, continuous, highly corrosion-resistant coating obtained using an aluminum-zinc alloy is not only better than that obtained with pure zinc but is also better than that obtained with pure aluminum. When attempting to form a pure aluminum coating in a manner hereinbefore described it has been found that aluminum will not even wet the surface onto which it is to be deposited and that it merely melts without even alloying to the surface of the steel. We have found especially satisfactory results are obtainable when forming a coating in accordance with the present invention with a zinc base alloy containing, by weight, about 10% to 20% aluminum and 80% to 90% zinc. However, in some instances, it is preferable to employ a zinc base alloy containing aluminum in quantities as low as about 5%, by weight, and as high as 30%, by weight. In general, highly satisfactory coatings can be obtained employing a zinc base alloy wire containing approximately 18%, by weight, aluminum and the balance zinc.

We have also found that highly satisfactory coatings are obtained with a sodium-aluminum-zinc alloy in which the sodium content is about 0.08% to 0.12%, by weight. The addition of the sodium increases the fluidity of the aluminum-zinc alloy and contributes to the formation of an exceptionally adherent and more ductile coating. In general, we have found that zinc base alloys containing 0.08% to 0.12%, by weight, sodium and about 12% to 18%, by weight, aluminum and the balance zinc will provide highly satisfactory results. In some instances, however, satisfactory coatings may be formed with the abovementioned amount of sodium in zinc base alloys containing as low as 5%, by weight, aluminum and as high as 30%, by weight, aluminum.

We have found that sodium in combination with aluminum and zinc provides a highly satisfactory smooth, bright and ductile alloy coating. However, in some instances alloys containing another alkali metal, particularly lithium and potassium, may also be used in place of a portion or even the entirety of sodium in the alloy described above to obtain highly satisfactory vaporized coatings. Moreover, it is also contemplated that in certain instances the alkaline earth metals, particularly calcium, can be used in place of a portion or all of the sodium in the aluminum-sodium-zinc alloy described above.

It is to be understood that the term "abutment" is used herein in its primary meaning; i.e. indicating touching or contacting. Thus, overlapping edges of a lap seam is also comprehended within the phrase "abutting edges" as well as non-overlapping contacting edges, such as shown in the drawing. Our invention therefore encompasses making tubing having abutting edges from a metal strip having scarfed longitudinal edges, the surfaces thereof being non-perpendicular to the major surface of the steel strip, as well as from a steel strip having its longitudinal edges perpendicular to the major surface of the strip.

It is to be further understood that the term "zinc base alloys" as used herein, refers to those alloys which contain zinc in greater proportions than 50%, by weight.

Although our invention has been described in connection with single wall tubing and other certain specific examples thereof, no limitation is intended thereby except as defined in the appended claims.

We claim:

1. A method of coating the interior of steel tubing with an adherent, uniform alloy coating during formation of said tubing from a steel strip, said method comprising the steps of longitudinally moving a substantially flat steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing an alloy containing aluminum and zinc into the interior of the tubing, after it is completely formed heating the tubing to a degree sufficient to vaporize said alloy within the tubing and thereafter cooling the tubing sufficiently to cause said alloy to solidify so as to form a smooth and ductile alloy coating on the interior of the tubing.

2. The method of coating the interior of steel tubing with an adherent, uniform alloy coating during formation of said tubing from a steel strip, said method comprising the steps of longitudinally moving a steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing a zinc base alloy containing approximately 5% to 30% by weight aluminum into the interior of the tubing, after it is completely formed heating the tubing to a degree sufficient to vaporize said alloy within the tubing and thereafter cooling the tubing sufficiently to cause said alloy to solidify so as to form a smooth and ductile alloy coating on the interior of the tubing.

3. A method of coating the interior of steel tubing

with an adherent, uniform alloy coating during formation of said tubing from a steel strip, said method comprising the steps of longitudinally moving a steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing an alloy containing about 5% to 30% by weight of aluminum and 70% to 95% by weight of zinc into the interior of the tubing, after it is completely formed heating the tubing to a temperature of approximately 1700° F. to 2400° F. to vaporize said alloy within the tubing, and thereafter cooling the tubing sufficiently to cause said alloy to solidify so as to form a smooth and ductile alloy coating on the interior of the tubing.

4. A method of coating the interior of steel tubing with an adherent, uniform alloy coating during formation of said tubing from a steel strip, said method comprising the steps of longitudinally moving a steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing a zinc base alloy containing aluminum and a metal from the class consisting of alkali and alkaline earth metals into the interior of the tubing, after it is completely formed heating the tubing to a degree sufficient to vaporize said alloy within the tubing, and thereafter cooling the tubing sufficiently to cause the alloy to solidify so as to form a smooth and ductile alloy coating on the interior of the tubing.

5. The method of coating the interior of steel tubing with an adherent, uniform alloy coating during formation of said tubing from a steel strip, said method comprising the steps of longitudinally moving a steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing an alloy containing, by weight, about 12% to 18% aluminum, about 0.08% to 0.12% sodium and the balance substantially zinc into the interior of the tubing, after it is completely formed heating the tubing to a temperature of approximately 1700° F. to 2400° F. to vaporize said alloy within the tubing, and thereafter cooling the tubing sufficiently to cause the alloy to solidify so as to form a smooth and ductile coating on the interior of the tubing.

6. The method of coating the interior of steel tubing with an adherent, uniform alloy coating during formation of said tubing from a substantially flat steel strip, said method comprising the steps of longituldinally moving a substantially flat steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, continuously introducing a wire of an alloy containing about 5% to 30%, by weight, aluminum and about 70% to 95%, by weight, zinc into the interior of said tubing prior to the complete shaping thereof, discharging a non-oxidizing gas into the interior of the tubing at a point where it is substantially completely formed, after the tubing is completely formed heating the tubing to a temperature of about 1700° F. to 2400° F. to vaporize said alloy within the tubing, and thereafter cooling the tubing to cause said alloy to solidify so as to form a smooth and ductile coating on the interior of said tubing.

7. An article of manufacture comprising a steel tube having an inner surface, a coating on said inner surface of a vaporized zinc base alloy containing approximately 5% to 30% by weight of aluminum.

8. An article of manufacture comprising a steel tube having an inner surface, a coating on said inner surface of a vaporized alloy consisting essentially of approximately 5% to 30% by weight of aluminum and about 70% to 95% by weight of zinc.

9. An article of manufacture having a smooth and ductile zinc base alloy coating thereon comprising a steel tube and an interior coating on said tube of a vaporized alloy containing, by weight, about 5% to 30% aluminum and about 70% to 95% zinc, said coating being especially high in aluminum content at its outer surface.

10. An article of manufacture having a smooth ductile zinc base alloy coating thereon comprising a steel tube and an interior coating on said tube of a vaporized alloy containing, by weight, about 5% to 30% aluminum, about 70% to 95% zinc and about 0.08% to 0.12% sodium, said coating being especially high in aluminum content at its outer surface.

11. An article of manufacture having a smooth ductile zinc base alloy coating thereon comprising a steel tube and an interior coating on said tube of a vaporized alloy containing, by weight, about 5% to 30% aluminum, about 70% to 95% zinc and about 0.08% to 0.12% of a metal from the class consisting of alkali and alkaline earth metals, said coating being especially high in aluminum content at its outer surface.

References Cited in the file of this patent

UNITED STATES PATENTS

2,771,669 Armstrong ------------- Nov. 27, 1956