II. METHOD OF MAKING COATED TUBING

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This invention relates to the manufacture of brazed steel tubing and the primary object of this invention is to provide a method of making brazed steel tubing wherein simultaneously coating the interior surface thereof with a permanent coating of a non-ferrous alloy which is securely bonded to the surface of the tubing.

In forming brazed steel tubing a flat strip of steel is continuously moved longitudinally through a tube-forming mill which transversely bends the strip into a tubular configuration. A non-ferrous metal, such as zinc, is progressively introduced into the tubing while it is being formed. Prior to the complete formation of the tubing and at about the same point on the tube-forming mill where the non-ferrous metal is introduced into the tubing, a small diameter pipe which discharges a non-oxidizing gas enters the tubing and extends longitudinally there-through. After the non-ferrous metal is introduced into the interior of the tubing and the tubing is completely formed, it passes through a sizing device which imparts the desired final cross sectional configuration to the tubing. After the tubing has been sized, it is heated to a suitable temperature to vaporize the metal within the tubing and a molten metal, such as copper, is exteriorly applied to the hot tubing. The exteriorly applied metal migrates between abutting edges of the formed tubing into the interior thereof to combine or alloy with vaporized metal within the tubing. After the exterior application of the molten metal the tubing is passed through a sizing device which causes the hot alloying metals to solidify. Thus the tubing is simultaneously exteriorly coated, brazed and given an interior alloy coating.

Further objects, features and advantages of the present invention will become more apparent from the following detailed description of preferred embodiment thereof and from the drawings, 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 along the line 2—2 of FIGURE 1;

FIGURE 3 is an enlarged sectional view along the line 3—3 of FIGURE 1;

FIGURE 4 is a similar view along 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 clean flat steel strip S which is coiled on a reel 10 positioned at one end of a tube-forming mill 12. The tube-forming mill 12 is composed of a group of forming devices, some of which include a pair of rolls 14. A sufficient number of forming devices are included in the forming mill to impart the desired circular cross sectional configuration to the flat steel strip S. These rolls progressively form the flat steel strip S into a tube T having an open seam 16 at the top where edges 18 and 20 of the steel strip S abut. The formed tube T then passes between suitable sizing rolls 22 which further impart the desired cross sectional configuration to the tubing and then through a swelling device 24 for a final formation operation.

A non-ferrous metal 26 is introduced into the interior of the tubing prior to its complete formation. As shown more clearly in FIGURE 2, means for conveying a non-oxidizing gas from a suitable source 28 may also be introduced into the interior of the tubing at this point by means of a small diameter pipe 30.

From the swaging device 24 the formed tubing T passes into a brazing furnace 32 and the non-ferrous metal 36 which was deposited within the tubing T is vaporized. Within the brazing furnace 32 the heated tubing passes through a molten bath 34 of a second non-ferrous metal which is metallurgically compatible with the metal deposited within the tubing. Molten metal, such as copper, exteriorly applied to the tubing migrates through the open seam 16 between the abutting edges 18 and 20 into the interior of the tubing. The molten metal combines with the non-ferrous previously vaporized metal within the tubing to deposit an alloy coating 36 on the inner surface of the tubing and braze the longitudinal seam 16 on the tubing. The tubing T then passes through a cooling chamber 38 which serves to solidify the alloying metals. A protective atmosphere is also preferably maintained by introducing into the interior of the tubing a reducing gas which is strong adhesion of the alloying metals to the surface of the tubing. Upon cooling, the coating metals solidify and the tubing can then be cut into whatever lengths are desired. If cut in very long lengths, the tubing is rolled on large rollers but it can be cut in short lengths and stored in straight pieces.

Prior to formation of the tubing if necessary the steel strip can be cleaned in the usual manner. The steel can be degreased in any convenient way, as by means of an alkali cleaner or suitable solvents such as trichloroethylene. After degreasing the steel, if it is excessively rusted or scaled, it can be pickled in a water solution of hydrochloric acid in the known and accepted manner for such cleaning.

Our invention is successfully practiced by introducing a suitable non-ferrous alloying metal 26, such as zinc, into the interior of the tubing in any convenient form. Our invention is especially more conveniently practiced if the metal 26 is introduced into the tubing in wire form. Generally, it is preferred to introduce the coating metal into the tubing immediately before it is fully formed and the edges 18 and 20 of the steel strip are brought into abutment. A strand 26 of wire from a coiled roll 40 mounted on the tube-forming mill 12 is fed by means of a pair of driving rolls 42 through a directing tube 44 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. 2,771,659, 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 introduced uniformly into the interior of the tubing employing a suitable hopper or funnel having a narrow outlet which extends into the tubing at a point just prior to its complete formation.

Obviously, in order to provide a uniform coating the amount of zinc or other metal 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 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 this coating metal is introduced as a wire which moves at the same speed as the tubing. To produce a uniform satisfactory brass coating at this speed on ¾ inch tubing, it is desirable to use a zinc wire
having a diameter of 0.03 inch. Similarly, % inch tubing can be effectively brass coated using 0.04 inch diameter zinc wire moving at the same rate as that of the tubing. Of course, in this instance the exteriorly applied coating metal would be copper.

A non-oxidizing gas 28 from a suitable reservoir passes through a small diameter pipe 36 which passes into the tubing T at approximately that point of a tube-forming mill where the tubing metal 36 is introduced. The small diameter pipe 36 has a part 46 which extends axially within the interior of the tubing towards the swaging device 24 to a point where the tubing is completely formed. The discharge end of the pipe is located at a point where the tubing T 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 to the various following operations.

It is also desirable to maintain a protective atmosphere outside the tubing during the following operations. Heating the tubing in an oxidizing atmosphere may cause a deleterious corrosion and spalling of the outer surface. Moreover, oxidation of the outer surface may inhibit satisfactory bonding of the second coating metal to the outer surface. Thus, as shown in FIGURE 1, the non-oxidizing gas can also be introduced into the brazing furnace 32 and cooling chamber 38 by means of additional piping 48 from the source of supply 28.

After the tubing T passes through the swaging device 24 it progresses through the brazing furnace 32 where it is heated above the vaporization temperature of the coating metal 26 within the tubing. The vaporization of this metal permits rapid alloying with the subsequently applied molten second coating metal to produce an exceedingly uniform, tenacious alloy coating 36. Accordingly, when the coating metal within the tubing is zinc, the tubing must be heated to a temperature above about 1650° F., the vaporization temperature of zinc. Since this temperature is generally about the annealing temperature of steel, the tubing can be simultaneously annealed when vaporizing the metal within the tubing. Thus, when coating the inner surface of the tubing with brass, for example, and the metal within the tubing is zinc the tubing can be simultaneously annealed. Satisfactory brass coatings are attained when the zinc is vaporized within the tubing at a temperature of about 1700° F. to 2200° F. Exteriorly applied molten copper migrates into the interior of the tubing and alloys with the zinc to form the brass coating.

At the end of the brazing furnace opposite the entrance thereof the tubing passes through a molten bath 34 of the second alloying metal. The metal molten applied to the outer surface of the tubing is at the open seam 16 so that it not only coats the outside 50 of the tubing but also permeates the open seam. When forming a brass coating, for example, this bath is of molten copper. For commercial applications this bath can be conveniently maintained automatically at a constant level. A spool 52 of copper wire 54 is mounted on the outside wall 56 of the furnace 32. A strand 58 of copper wire 54 extending from the spool extends through an opening 60 in the wall 56 of the furnace 32 into the molten bath 34. The wire can be automatically fed into the bath by a pair of engaging driving rolls 62. Zinc and copper combine in the protective atmosphere within the tubing and uniformly deposit as an adherent brass coating 36 on the inner surface of the tubing as it progresses through the cooling chamber 38.

Alloy coatings of various compositions can be formed by this invention when employing an interiorly applied coating metal, such as zinc, which has a vaporization temperature below the melting point of steel. The exteriorly applied coating metal, of course, must have a lower melting point than that of steel and be metallurgically compatible with the interiorly applied coating metal. By metallurgically compatible, we refer to metals which are mutually soluble in the liquid state and which readily alloy with one another at elevated temperatures, such as copper and zinc, and copper base and zinc base alloys. Accordingly, the terms "copper" and "zinc," for example, are used in the appended claims as respectively including not only the pure metals but, for example, the alloying constituents present in only very minor proportions.

A gas which protects the interior and exterior of the tubing is preferably 20% to 25% reducing. The gas may be, for example, the following gas analysis: 10% monoxide, 18% hydrogen, 4.5% carbon dioxide, 1% methane and the balance nitrogen, all proportions by volume. Other atmospheres which can be employed are those comprising substantially nitrogen, helium, argon, carbon monoxide, etc.

The nature of the coating achieved by our invention is such that it has been found that a superior corrosion-resistant coating is obtained. The heating of the tube as it passes through the furnace or other heating devices at the ordinary speed of operation of a tubing mill is sufficient to effect the desired vaporization of the coating metal so that the speed of operation of the mill does not have to be slowed down to coat the tubing. When the described method is carried out, the interior of the tubing will be coated with a thin film of a corrosion-resistant alloy securely adhered to the interior surface of the steel tubing. In producing a brass coating, for example, the brass vapor enters the minute pores of the surface of the steel tubing in cooling the alloy coating is securely anchored to the inner surface of the tubing to form a continuous, superior non-corrosive coating thereon. Moreover, the coating is not only secured to any of the superior physical adherence to the steel surface but the high temperature of coating metal, for example, additionally effects an alloy bonding of steel.

The term "abutting" is used herein in its primary meaning, i.e., indicating touching or contacting. Thus, the overlapping edges of a lap seam, for example, is also comprehended within the phrase "abutting edges" as well as non-overlapping contacting edges, such as the butt joint 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-parallel. 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 understood that although our invention has been described in connection with single walled brazed tubing and other certain specific examples thereof, no limitation is intended thereby except as defined in the appended claims.

We claim:
1. 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 longitudinally moving a substantially flat steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing a non-ferrous metal having a vaporization point lower than the melting point of metal into the tubing, after it is completely formed heating the tubing to a degree sufficient to vaporize said non-ferrous metal thereby creating and causing it to permeate the pores of the steel on the interior surface of the tubing, applying to the outer surface of the heated tubing a second non-ferrous metal which has a melting point lower than that of steel and which is metallurgically compatible with said first non-ferrous metal, applying said second non-ferrous metal while molten at said seam so as to permit migration of said molten non-ferrous metal between said abutting edges into the interior of the tubing and alloy with said first non-ferrous metal, and finally cooling the
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5 tubing sufficiently to cause said alloying metals to solidify so as to form a continuous alloy coating.

2. The method of coating the interior of steel tubing with a corrosion-resistant brass coating during the formation of said tubing from a substantially flat 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 zinc into the tubing after it is partially formed, heating the tubing to a degree sufficient to vaporize said zinc within the tubing and cause it to permeate the pores of the steel on the inner surface of the tubing, applying molten copper to the outer surface of the tubing so as to permit migration of said molten copper between said abutting edges through said seam into the interior of the tubing and alloy with said zinc, and finally cooling the tubing sufficiently to cause said alloying copper and zinc to solidify so as to form a continuous non-corrosive brass coating.

3. The method of coating the interior of steel tubing with a corrosion-resistant brass coating during the formation of said tubing from a substantially flat steel strip, said method comprising the steps of longitudinally moving a flat steel strip while continuously transversely bending it into a tubular configuration having abutting edges forming a seam, introducing a reducing gas into the tubing after it is fully formed so as to establish a non-oxidizing atmosphere therein, introducing zinc within said tubing, subsequently heating the tubing to a temperature of about 1700° F. to 2200° F. to vaporize said zinc within the tubing and cause it to permeate the pores of the steel on the inner surface of the tubing, applying molten copper to the outer surface of the tubing so as to permit migration of said molten copper between said abutting edges through said seam into the interior of the tubing and alloy with said zinc, and finally cooling the tubing sufficiently to cause said alloying copper and zinc to solidify so as to form a continuous non-corrosive brass coating.

4. A method of making a steel tubing while continuously forming an adherent, uniform alloy coating on the inner surface thereof which comprises the steps of continuously longitudinally moving a flat steel strip while transversely bending it into a tubing having abutting edges which form a longitudinal seam, continuously introducing a non-ferrous metal having a vaporization point lower than the melting point of steel into the interior of the 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, heating the tubing to a sufficient temperature to vaporize said non-ferrous metal and cause it to permeate the pores of the steel on the inner surface of the tubing, applying to the outer surface of said heated tubing a molten second non-ferrous metal which has a melting point lower than that of steel and which is metallurgically compatible with said first non-ferrous metal, applying said second non-ferrous metal at said seam so as to permit migration thereof between said abutting edges into the interior of the tubing and to alloy with said first non-ferrous metal, and finally cooling the tubing to cause said alloying metal to solidify so as to form a continuous uniform alloying coating.

5. A method of making steel tubing while continuously forming a brass coating on the inner surface thereof which comprises the steps of continuously longitudinally moving a flat steel strip while transversely bending it into a tubing having abutting edges which form a longitudinal seam, continuously introducing a zinc into the interior of the tubing when it is partially formed, heating the tubing to a sufficient temperature to vaporize said zinc within the tubing and cause it to permeate the pores of the steel on the inner surface of the tubing, applying molten copper to the outer surface of the tubing at said seam so as to permit migration of said molten copper between said abutting edges into the interior of the tubing and alloy with said zinc, and finally cooling the tubing sufficiently to cause said alloying copper and zinc to solidify so as to form a continuous non-corrosive brass coating.

6. A method of making steel tubing while continuously forming a brass coating on the inner surface thereof which comprises the steps of continuously longitudinally moving a flat steel strip while transversely bending it into a tubing having abutting edges which form a longitudinal seam, continuously introducing zinc into the interior of the tubing when it is partially formed, discharging a non-oxidizing gas into the interior of the tubing at a point where it is substantially completely formed, heating the tubing to a temperature of about 1700° F. to 2200° F. to vaporize said zinc within the tubing and cause it to permeate the pores of the steel on the inner surface of the tubing, applying molten copper to the outer surface of the tubing at said seam so as to permit migration of said molten copper between said abutting edges into the interior of the tubing and alloy with said zinc, and finally cooling the tubing sufficiently to cause said alloying copper and zinc to solidify so as to form a continuous non-corrosive brass coating.

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