United States Patent

[11] 3,542,116

[72] Inventor **Eugene S. Machlin**
Croton-on-Hudson, New York

[21] Appl. No. **697,765**
[22] Filed **Jan. 15, 1968**
[45] Patented **Nov. 24, 1970**

[73] Assignee **U.S. Smelting Refining & Mining Co.**
New York, New York
a corporation of Maine

---

[54] **METHOD AND APPARATUS FOR THE CONTINUOUS CASTING OF METAL TUBING**
34 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **164/86,** 164/268, 164/276, 164/283; 117/94, 117/97, 117/117; 118/405, 118/408
[51] **Int. Cl.** **B22d 11/00**
[50] **Field of Search** ..... 164/73, 82, 85—87, 268, 275, 276, 283; 118/405, 408 (Pipe and Tube Digest); 117/94, 97, 117

[56] **References Cited**

UNITED STATES PATENTS

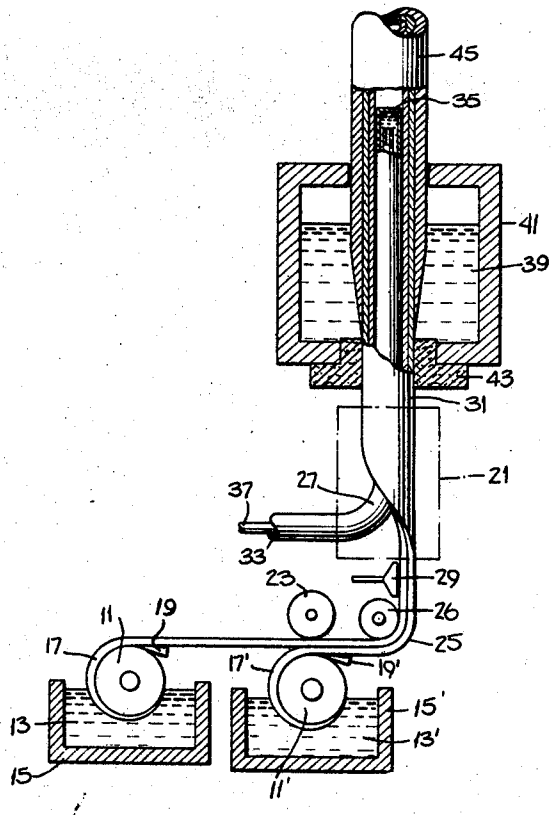
2,692,411	10/1954	Brennan	164/85X
1,025,848	5/1912	Wagner	164/87
2,074,812	3/1937	Sendzimir	164/87
2,569,150	9/1951	Brennan	164/86
2,956,320	10/1960	Pulsifer	164/87
3,164,896	1/1965	Fullman	164/86X

FOREIGN PATENTS

602,912	3/1960	Italy	118/408
108,184	8/1939	Australia	164/278
900,022	9/1944	France	164/278
1,441,374	4/1966	France	164/275

Primary Examiner—J. Spencer Overholser
Assistant Examiner—R. Spencer Annear
Attorney—Kenyon and Kenyon Reilly Carr and Chapin

ABSTRACT: Cast metal tubing is continuously produced by forming metal strip into a tube, passing the tube upwardly through a bath of molten metal in contact with one surface of the tube and causing the solidification of molten metal in contact with one surface of the tube by withdrawing heat through the tube by a heat absorbing body adjacent the surface of the tube opposed to the surface in contact with the molten metal. The tube may form a part of the thus produced tubing, in which case it is formed from strip obtained by casting the strip on a heat-absorbing body and maintaining the strip under an inert atmosphere until solidification of the molten metal on the tube. Alternatively, the tube may be a moving mold which is stripped from the cast tube after the casting operation.



Patented Nov. 24, 1970 3,542,116

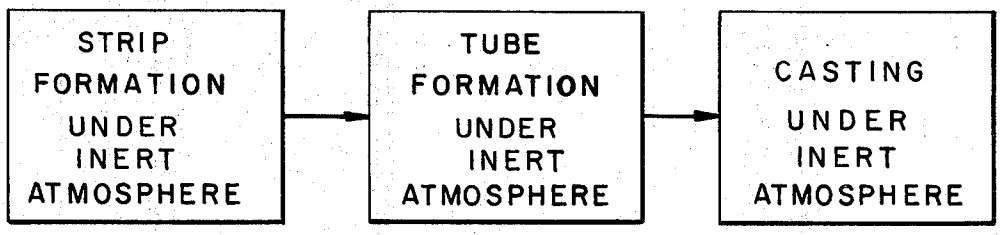


Fig. 1.

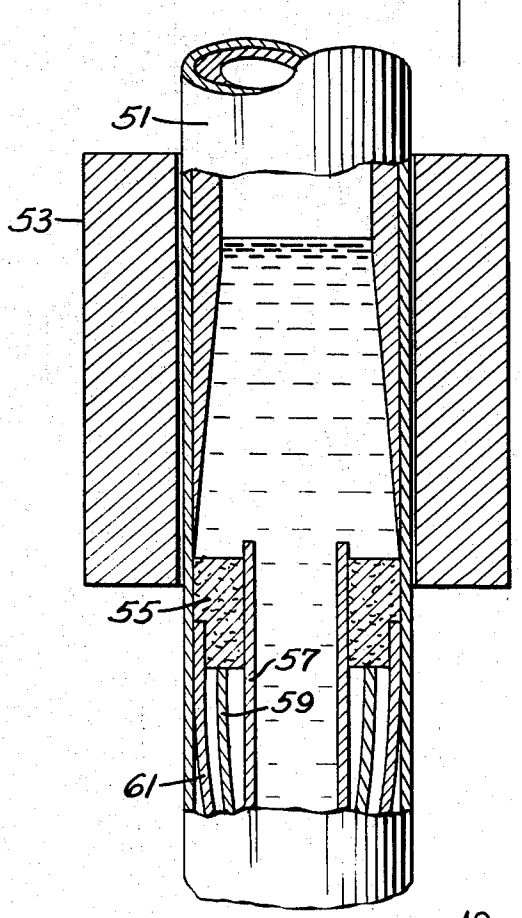
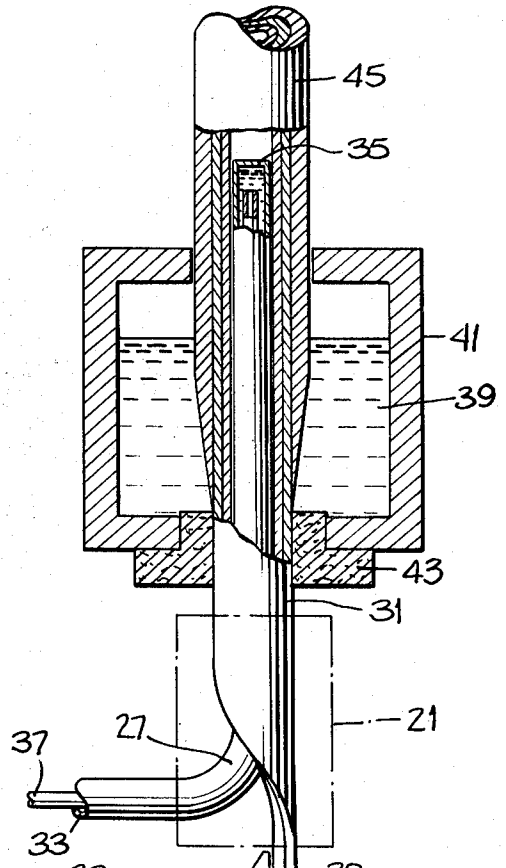


Fig. 3.



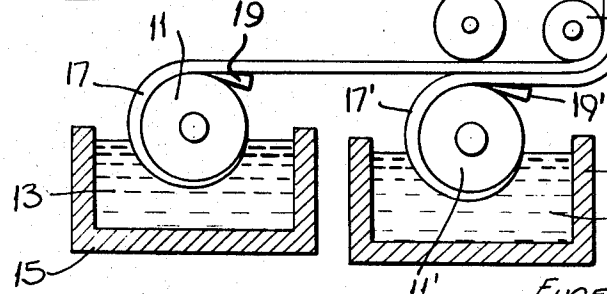


Fig. 2.

INVENTOR.
EUGENE S. MACHLIN
BY
Kenyon & Kenyon
ATTORNEYS

Patented Nov. 24, 1970 3,542,116

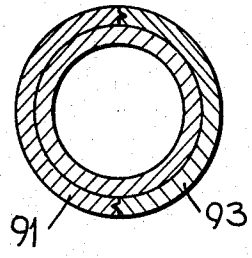


Fig. 6.

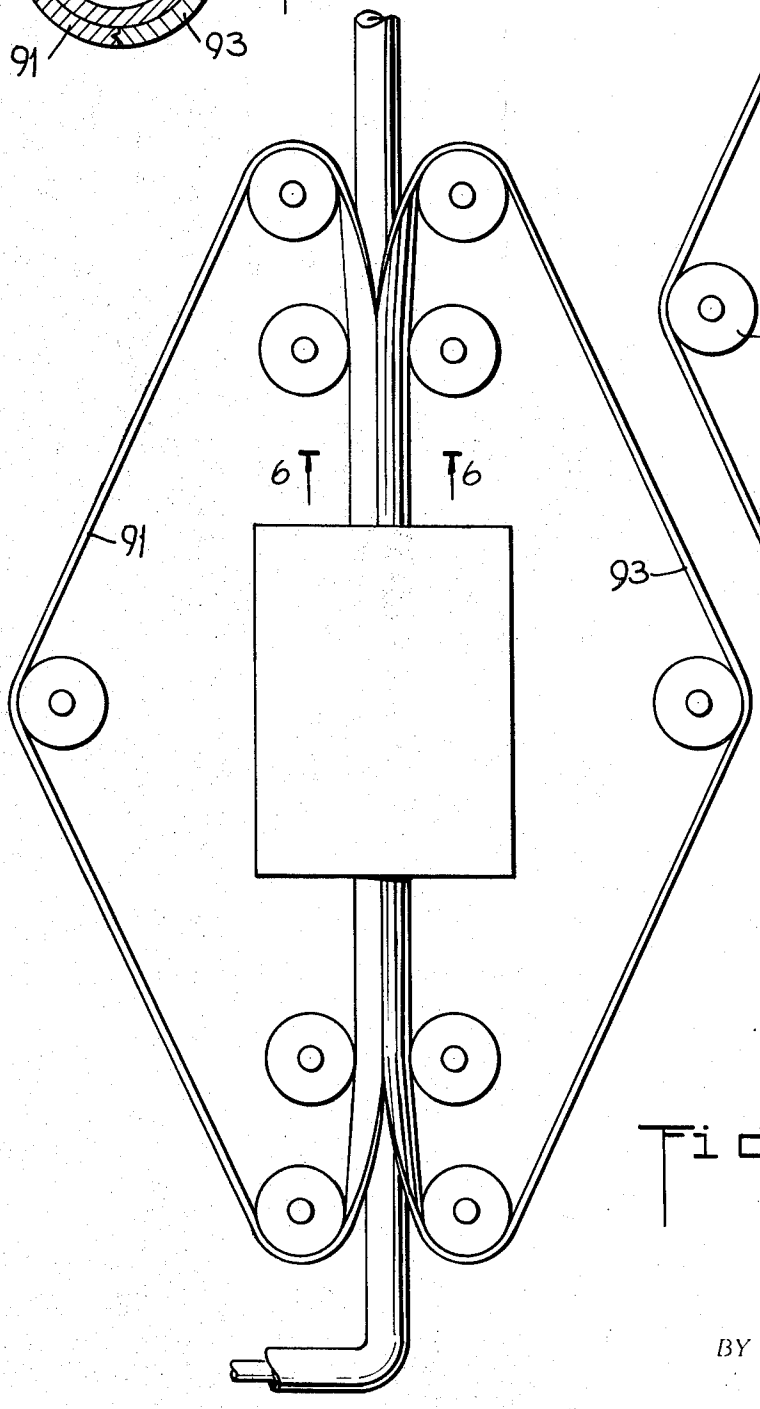


Fig. 5.

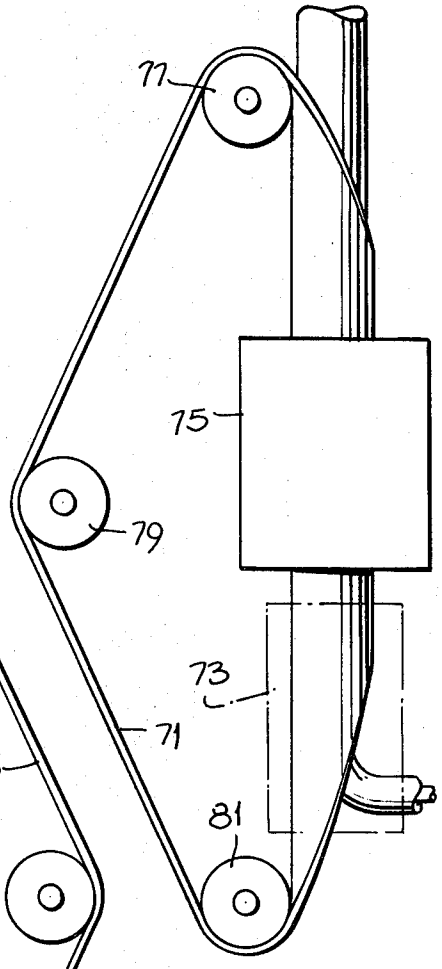


Fig. 4.

INVENTOR.
EUGENE S. MACHLIN

BY

Kenyon & Kenyon
ATTORNEYS

METHOD AND APPARATUS FOR THE CONTINUOUS CASTING OF METAL TUBING

DESCRIPTION OF THE INVENTION

This invention relates to the production of metal tubing. More particularly, this invention is concerned with a method and apparatus for producing tubing on a continuous basis directly from molten metal.

A variety of methods for producing metal tubing have been proposed, but the most widely practiced method comprises forming metal strip into a cylinder, welding the seam and drawing the cylinder through a series of dies to produce tubing of the desired diameter. This technique requires a large amount of space, especially when small diameter tubing is required, and has a rather low production rate. In addition, care must be taken in welding the seam to ensure that a good metallurgical bond is obtained which will not rupture during processing or upon subsequent use. Moreover, the production of clad tubing by this method is quite difficult, in that a uniform bond between the laminae is difficult to achieve.

Various alternatives have been proposed to avoid the problems attending the foregoing technique, but all have suffered from one or more disadvantages. For example, it has been suggested that tubing could be drawn or extruded from a melt, thereby avoiding a seam and the need for the use of a series of reducing dies. But this method has failed because of the difficulty in lubricating the mold surfaces, as well as the fact that the thus formed tubing lacked sufficient strength to enable it to be drawn through the mold at commercially feasible rates without frequent rupture. In addition, the use of the same apparatus to produce tubing of varying diameters and wall thicknesses was impossible without a time-consuming shut down while the mold was replaced. Finally, this method cannot be easily adapted to the production of clad tubing.

A method for producing clad tubing has been proposed whereby an already formed tube, whether formed as described above, or formed from strip metal is passed through a bath of molten metal, whereby metal solidifies on the outer surface of the tube and seals the seam, if present. Although seamless tubing can be continuously produced by this method, variation of the thickness of the inner laminus was not feasible without interrupting the process. Moreover, to ensure a reasonable degree of adhesion of the two laminae a costly cleaning of the tube fed to the bath was required. In addition to the expense, it was found impossible to remove all surface impurities, such as metal oxides and cleaning agents, from the metal surface, with the result that good metallurgical bonds were difficult to achieve, if not impossible.

It is an object of this invention to provide a method and apparatus for continuously producing metal tubing.

It is another object of this invention to provide a method and apparatus for continuously casting tubing at high production rates.

Still another object of this invention is to provide a method and apparatus for producing metal tubing of varying diameters and thicknesses without interrupting the process.

A further object of this invention is to provide a method and apparatus for producing clad metal tubing whereby a good metallurgical bond between the laminae is obtained.

These and other objects of this invention, which will be apparent from the ensuing discussion, attached drawings and appended claims, are generally achieved, at least in part, by forming a cylinder from metal strip, passing the resulting cylinder through a bath of molten metal, withdrawing heat from the molten metal through the metal cylinder by means of a heat absorbing body at the surface of the cylinder opposed to the surface in contact with the molten metal, whereby metal is solidified on the metal cylinder and allowed to build up to the desired thickness.

Various embodiments of this invention are illustrated by the attached drawings of which:

FIG. 1 is a schematic diagram of the basic process steps employed in forming tubing, especially clad tubing, in accordance with this invention;

FIG. 2 illustrates one form of apparatus useful in carrying out the present invention;

FIG. 3 illustrates a modification of the embodiment of FIG. 2;

FIG. 4 illustrates a variation of the embodiment of FIG. 3 which is adapted for the production of nonclad tubing;

FIG. 5 illustrates a preferred form of the embodiment of FIG. 4; and

FIG. 6 represents a cross section of FIG. 5 taken at line 5–5.

With reference to FIG. 1, the process employed in accordance with this invention comprises the continuous steps of (1) forming metal strip from molten metal, (2) forming the strip into a tube, and (3) casting a layer of metal on one side of the tube by passing the tube through a body of molten metal and withdrawing heat from the molten metal through the tube by means of a heat absorbing body disposed adjacent the tube surface opposed to the surface in contact with the molten metal, whereby the molten metal solidifies on the surface of the tube. These steps are conducted under an inert, *i.e.*, nonoxidizing atmosphere, such as a vacuum or an atmosphere of an inert gas, such as nitrogen or argon.

Metal strip is formed from molten metal by contacting a heat absorbing body with a body of molten metal. As heat is withdrawn from the molten metal it solidifies on the surface of the heat absorbing body. After solidified metal of the desired thickness has formed on the heat absorbing body, the body is withdrawn from the molten metal and the solidified metal is removed from the heat absorbing body in sheet form. Thereafter the metal sheet is formed into a tube of a desired diameter. If the sheet is too wide, it is slit to form a strip of the desired width. The resulting strip is continuously formed into a tube. Because the strip is under an inert atmosphere, no oxidation of the metal surface occurs and the sides of the strip are metallurgically clean, *i.e.*, uncontaminated by oxides or other impurities, and will weld together on contact or with only slight pressure.

One surface of the resulting tube, which surface is still maintained under an inert atmosphere, is contacted with a body of molten metal, which may be the same as or different from the metal forming the tube, and heat is withdrawn from the molten metal through the tube by a heat absorbing body adjacent the opposed tube surface, whereby metal solidifies on the tube surface. In a first embodiment, the tube is formed around a cooled mold or mandrel and the outside of the tube is passed through a bath of molten metal. In a second embodiment, the tube is passed through an external cooled mold and contacted with a body of molten metal maintained on the inside of the tube. In either case, a good metallurgical bond between the tube and the deposited metal is obtained because of the clean surface which is preserved by the presence of the inert atmosphere. After completion of the casting operation the tubing is coiled in a conventional manner or cut into desired lengths.

The casting step of this invention is effected by passing the tubing vertically through the molten metal. When the body of molten metal is maintained on the outside of the tube (external casting), the tube can be passed through the molten metal in an upward or downward direction, although an upward direction is preferred. In the case of internal casting, however, the tubing is moved upward past the molten metal.

Suitable apparatus for the continuous production of tubing by the external casting technique is illustrated in FIG. 2, and comprises cooled drum 11 having a horizontal axis of rotation, the cylindrical surface of which is continuously passed through constant level bath of molten metal 13 maintained in container 15. The level of molten metal 13 is maintained by continuously charging molten metal to container 15. Because heat is withdrawn from the molten metal adjacent the surface of drum 11 it solidifies on the surface to form sheet 17. The thickness of sheet 17 can be controlled, in part, by control of the temperatures of molten metal 13 and drum 11. A more practical mode of controlling the thickness of sheet 17 is by controlling the time during which the surface of drum 11 is immersed in molten metal 13, as by controlling the rate of rotation of drum 11 or depth of bath 13.

After formation, sheet 17 is stripped from the surface of drum 11, as by doctor blade 19, and, after being optionally slit to form a strip of narrower width, is formed into a tube by tube forming means 21.

Optionally a second strip 17' may be formed in a similar manner with drum 11'; molten metal bath 13' and container 15'; and doctor blade 19'. Strips 17 and 17' may be superimposed and contacted, desirably under pressure applied by roller 23, whereby strips 17 and 17' are welded together to form composite strip 25.

The thus formed strip is passed around pulley or roller 26 and then upward through tube forming means 21 wherein the strip is formed into tube 31 around cooled internal mold 27. To prevent the strip from adhering to mold 27 it is lubricated on the surface which forms the inside of the tube in a suitable manner, as by oil spray 29. Alternatively, a molten, low melting metal, such as lead may be employed as the lubricant.

Tube forming means 21 comprises a mold which urges the strip into the desired tubular configuration, or a series of rollers which forms tube 31. Mold 27 comprises a coaxial tube of which outer tube 33 is heat conductive and is sealed at its distal end 35, whereas internal tube 37 is a thermal insulator which is open at its distal end and terminates at a point short of the end 35 of outer tube 33. A cooling medium, for example, water, is fed in through the annulus defined by outer tube 33 and inner tube 37, where it is heated by heat withdrawn from molten metal 39 contained in casting chamber 41. Heated cooling medium, *e.g.*, water or steam, is withdrawn through tube 37. Coaxial tube 27 desirably terminates at a point above the level of molten metal 39, and preferably outside chamber 41.

Tube 31 is passed into chamber 41 through packing gland 43 and then through molten metal 39, which solidifies on the outside surface of the tube. The level of molten metal is maintained at a constant level by continuously charging molten metal to chamber 41.

As in the case of the formation of the strip, the thickness of the metal layer formed in casting chamber 41 may be controlled in part by control of the relative temperatures of internal mold 27 and molten metal 39, but preferably by control of the time tube 31 is immersed in bath 39, as by controlling the rate of tube 31 through bath 39 and preferably by controlling the depth of bath 39.

As indicated previously, the steps of strip formation, tube formation and casting are conducted under an inert atmosphere to preserve the purity of the metal surface. As a result an extremely good metallurgical bond is formed between tube 31 and the metal deposited in chamber 41.

After completion of the casting operation the thus produced tube is cooled, as by air or a water spray, not shown, and is then coiled or cut into suitable lengths.

It is readily apparent that the present invention, as illustrated by FIG. 2, possesses numerous advantages over the prior art. The apparatus is compact and, by virtue of the vertical orientation, requires little floor space in comparison with commonly employed apparatus. As noted above, strong metallurgical bonds are obtained without the need for a cleaning step, which bonds are stronger than can be obtained with other casting techniques. Variations in tube thickness can be readily effected without interrupting the process, as by independently varying the bath depths. In addition, the process of this invention enables production of tubing at a higher rate of speed than previous processes.

In an alternative but preferred embodiment, casting chamber 41 is modified to provide the molten metal bath on the inside of the tube, as illustrated in FIG. 3. In this form, tube 51, the outside surface of which is desirably lubricated, is fed up through externally cooled mold 53, which forms the walls of the casting chamber. The lower end of mold 53 is sealed by packing gland 55, through which molten metal is fed by transfer tube 57. Heat loss is prevented by surrounding transfer tube 57 with tube 59 formed of an insulating material, optionally equipped with heating wires, not shown, and maintaining a vacuum in the annulus between tubes 57 and 59. If desired, tube 59 is surrounded by tube 61 and a vacuum is maintained between tubes 59 and 61. An inert atmosphere is maintained between tubes 51 and 61.

This embodiment permits the formation of tubing having smaller inside diameters than the form illustrated in FIG. 2. It will be appreciated that the thickness of the layer cast onto the tube surface is a function of the rate at which heat can be withdrawn from the molten metal by heat absorbing bodies 27 and 53. This does not present a serious problem in the case of external mold 53 of FIG. 3. In the case of internal mold 27, however, there is a minimum cross section which must be maintained to provide sufficient cooling and metal deposition to form an effective coating of cast metal. Even in this second embodiment there is a minimum obtainable inside diameter, which is determined by the rate at which molten metal can be supplied to the internal bath, but this minimum diameter is much less than that encountered in the external casting technique of FIG. 2.

A further modification of the process and apparatus of this invention comprises a variation of the internal casting technique illustrated in FIG. 3. In this modification, cylinder 51, instead of forming a part of the tube product, is employed as a travelling mold, as in illustrated in FIG. 4. The travelling mold is desirably formed from endless belt 71, which, after being formed into a cylinder by cylinder-forming means 73, is passed upwards through externally cooled mold 75. After casting the tube in chamber 75, the mold is removed from the tube and passes around drive pulley 77, tensioning pulley 79, and idler pulley 81, to repeat the process. Endless belt 71 can be a normally flat belt, but desirably has a normally curved configuration to aid in formation of the cylinder in cylinder-forming means 73. It may be constructed of a springlike material to aid in opening of the mold after completion of the casting. In this embodiment, the inside surface of belt 71 is desirably treated with a parting substance, such as graphite, to prevent adherence of the cast tube to the cylinder surface. The use of such a mold allows increased production rates. As will be appreciated, the outer cylinder of the embodiment of FIG. 3 is quite hot and is relatively weak. Thus care must be taken that the tube is not withdrawn at sufficiently high rate to rupture the tube. Because the external travelling mold of FIG. 4 can be formed from a material having better high-temperature strength characteristics than metals which are employed to form the cast tubing, it can bear substantially all of the stress encountered in withdrawing the cast tubing from the casting chamber, thereby permitting higher casting rates.

The technique of FIG. 4 may be further modified by the use of two belts, as in illustrated in FIG. 5. In this form two belts 91 and 93, each of which preferably has a normally semicircular cross section are employed This form has the advantage that the cylinder can be formed or parted over a considerably shorter distance than that permitted by the use of a single endless belt. When a single belt is used, a long transition zone is required to form the cylinder without buckling of the metal. When two belts are employed the transition zone can be reduced to as little as one-third of that required for a single belt.

Still more continuous belts can be employed, but the advantage of the further reduced transition zone is more than offset by the increased complexity and difficulty in controlling the rate of travel of three or more belts. In addition, there will always be a slight burr formed on the tube surface where the belt edges meet, and although it can be minimized by close control of belt dimensions, or by the use of a tongue and groove joint as illustrated in FIG. 6, the difficulty of avoiding burr formation increases as the number of belts increase.

The present invention has been illustrated with reference to the formation of tubing having a circular cross section, but it is obvious that it can be readily adapted to produce tubing of any desired cross section. By the present invention one can continuously produce tubing of a single metal, or one can produce laminated or clad tubing. Although any metal can be employed in the practice of this invention, the present invention

is particularly applicable to the production of copper tubing or ferrous tubing clad with copper. By the term metal is meant alloys, such as brass and the like, as well as pure metals.

I claim:

1. A method for continuously casting metal tubing which comprises the steps of (a) forming a tube from at least one metal strip; (b) passing said tube upwards through a first bath of molten metal whereby the molten metal contacts only one surface of said tube; (c) withdrawing heat from said molten metal through said tube by passing a cooling medium through a heat absorbing body adjacent the tube surface opposed to the surface in contact with the molten metal, whereby molten metal solidifies on the surfaces of said tube; and (d) withdrawing said tube and solidified metal from said bath.

2. A method according to claim 1 wherein the outside surface of said tube is contacted with said molten metal.

3. A method according to claim 2 wherein the metal strip which is employed to form said tube is formed by (a) immersing a heat absorbing body in a second bath of molten metal whereby molten metal solidifies on the surface of said heat absorbing body; (b) removing the solidifies metal from the surface of said heat absorbing body in strip form; and (c) forming said strip into said tube.

4. A method according to claim 3 wherein the steps of forming the strip, forming the strip into a tube and passing the tube through said first bath are all conducted under an inert atmosphere.

5. A method according to claim 4 wherein the heat absorbing body upon which said strip is formed is a drum having a horizontal axis of rotation, the cylindrical surface of which is passed through said second bath.

6. A method according to claim 5 wherein the metals forming said baths are the same.

7. A method according to claim 6 wherein said metal is copper.

8. A method according to claim 5 wherein the metals forming said baths are different.

9. A method according to claim 8 wherein at least one of said metals is copper.

10. A method according to claim 1 wherein the inside surface of said tube is contacted with said molten metal.

11. A method according to claim 10 wherein the metal strip which is employed to form said tube is formed by (a) immersing a heat absorbing body in a second bath of molten metal whereby molten metal solidifies on the surface of said heat absorbing body; (b) removing the solidified metal from the surface of said heat absorbing body in strip form; and (c) forming said strip into said tube.

12. A method according to claim 11 wherein the steps of forming said strip, forming the strip into tubing and passing the tubing through said first bath are all conducted under an inert atmosphere.

13. A method according to claim 12 wherein the heat absorbing body upon which said strip is formed is a drum having a horizontal axis of rotation, the cylindrical surface of which is passed through said second bath.

14. A method according to claim 13 wherein the metals forming said baths are the same.

15. A method according to claim 14 wherein said metal is copper.

16. A method according to claim 13 wherein the metals forming said baths are different.

17. A method according to claim 16 wherein the inside surface of said tube is contacted with said molten metal.

18. A method according to claim 10 wherein said tube is formed from at least one endless belt which, prior to passing through said bath is treated with a parting agent on the inside surface thereof and, after withdrawal from said bath, is separated from the thus produced case tube.

19. A method according to claim 18 wherein said endless belt has a normal, unstressed cross section in the shape of an arc.

20. A method according to claim 18 wherein two endless belts, each having a normal, unstressed cross section in the shape of a semicircle, are employed.

21. A method according to claim 20 wherein said molten metal is copper.

22. Apparatus for continuously forming metal tubing comprising in combination; (a) means for forming metal strip into a tube; (b) a vertically oriented chamber adapted to contain molten metal and having therein vertically oriented heat absorbing means including means for passing cooling medium therethrough and means for supplying molten metal to said chamber; (c) means for feeding said tube upwardly through said chamber, whereby said molten metal is applied to one surface of said tube and said heat absorbing means is in contact with the other surface of said tube; and (d) means for withdrawing said tube from said chamber.

23. Apparatus according to claim 22 including means for forming said metal strip from molten metal comprising; (a) means for containing molten metal; (b) a heat absorbing body which is adapted to contact said molten metal and cause solidification of said metal on the surface of said body; and (c) means for removing said solidified metal from the surface of said body in strip form.

24. Apparatus according to claim 23, wherein said heat absorbing means comprises a mandrel passing through said chamber, whereby said tube is passed up around said mandrel.

25. Apparatus according to claim 24 including means for maintaining an inert atmosphere around said strip from the time of its formation until its introduction into said chamber.

26. Apparatus according to claim 25 wherein the heat absorbing body is a drum having a horizontal axis of rotation and the cylindrical surface of which is adapted to pass through said molten metal.

27. Apparatus according to claim 26 including means for applying lubricant to the surface of said tube in contact with said mandrel.

28. Apparatus according to claim 23 wherein said heat absorbing means comprises the walls of said chamber whereby said tube is passed upward through said chamber, and including means for maintaining a bath of molten metal in the center of said tube.

29. Apparatus according to claim 28 including means for maintaining an inert atmosphere around said strip from the time of its formation until its introduction into said chamber.

30. Apparatus according to claim 29 wherein the heat absorbing body is a drum having a horizontal axis of rotation and the cylindrical surface of which is adapted to pass through said molten metal.

31. Apparatus according to claim 30 including means for applying lubricant to the surface of said tube in contact with said walls.

32. Apparatus according to claim 22 wherein said metal strip is an endless belt, including means to drive said endless belt upwardly through said chamber, and means to apply a parting substance to the surface of said tube, said heat absorbing means comprising the walls of said chamber and including means for maintaining a bath of molten metal in the center of said tube.

33. Apparatus according to claim 32 wherein said endless belt has a normal, unstressed cross section in the form of an arc.

34. Apparatus according to claim 33 including two endless belts having normal, unstressed semicircular cross sections which mate to form a cylinder.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. U.S. 3,542,116 Dated November 24, 1970

Inventor(s) EUGENE S. MACHLIN

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 24, "in" should read --is--; line 49, "in" should read --is--; line 51, after "employed" insert a period (.). Column 5, line 21, "solidifies" should read --solidified--. Column 6, line 1, "case" should read --cast

SIGNED AND
SEALED

FEB 23 1971

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents