

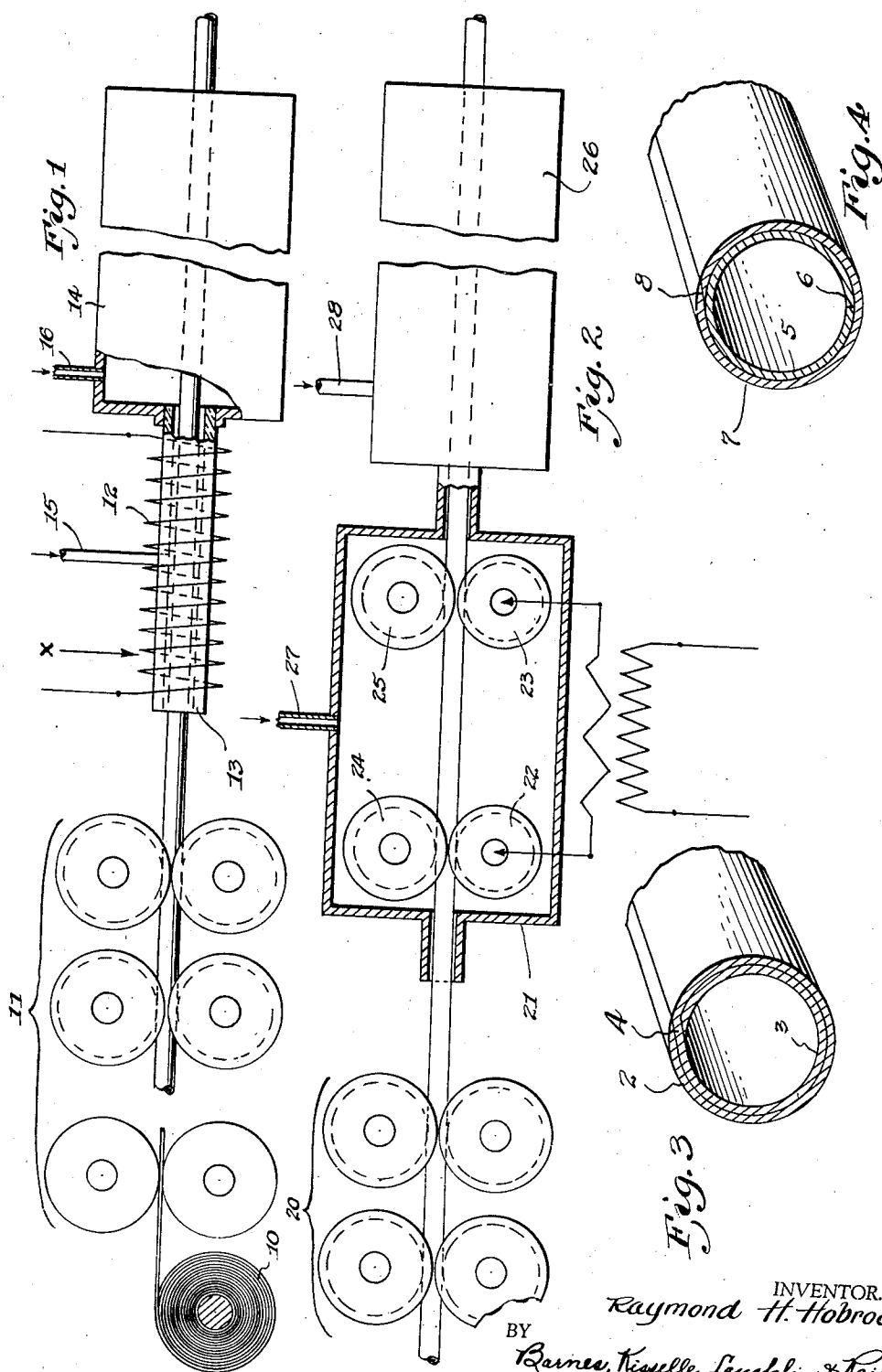
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R. H. HOBROCK

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TUBING

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INVENTOR.
Raymond H. Hobrock
BY
Barney, Kesselle, Laughlin & Kesselle
Attorneys.

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TUBING

Raymond H. Hobrock, Grosse Pointe, Mich., assignor to Bundy Tubing Company, Detroit, Mich., a corporation of Michigan

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This invention relates to tubing, and it has to do particularly with tubing having corrosion resisting properties, tubing capable of being subjected to severe cold working operations, and to the method of making the tubing.

The principal object of the invention is to provide a tube and method of making the tube, wherein the tube is fashioned from strip stock, some or all of which is a copper-nickel alloy, and wherein juxta-positioned parts of the stock, such as parts in a seam or seams or plies, are united by the use of copper or a cuprous metal, which is rendered molten in the process. It is appreciated by those skilled in the metal art that nickel and copper very readily alloy with each other, and this fact presents a difficult problem where it is desired to seal or bond together, by the use of copper, two bodies of metal or two portions of a body of metal, at least one of which comprises a nickel-copper alloy.

In accordance with the invention the amount of copper employed is relatively small as compared with the amount of metal in the copper-nickel strip. If the metals are heated in a furnace where, for example, even a minute or two is required to raise the metals to copper melting temperature, the copper is completely absorbed by the nickel with the result that there is no sealing or joining of the juxta-positioned parts. This may occur by a diffusion of the metals in the solid state without the copper having become molten, or it may occur with the copper in a melted state. The situation is a dynamic one, in that once the copper is rendered molten a rapid alloying of the copper and nickel takes place, resulting in an ever-increasing melting point and requiring an increase in temperature to maintain the molten state. Yet the temperature must not exceed the melting point of the copper-nickel strip stock. If the temperature is not increased after the copper becomes molten, the absorption of the nickel by the copper results in the formation of a nickel-copper alloy which freezes as its melting point reaches or exceeds the temperature, and this prevents the proper flowing or migration of the copper into the seam or between plies, and the failure to unite the juxta-positioned metal bodies or portions.

Accordingly, the invention contemplates and provides a method wherein the rate of increase in the temperature, in the range above the melting point of copper and below the maximum temperature attained, is such that the increasing temperature is higher than the increasing freezing point. Thus it may be said that the average rate of increase in the temperature is greater than the average rate of elevation of the freezing point of the copper-nickel alloy formed by the solution of nickel into the copper.

The rate does not have to be uniform throughout the range so long as the temperature is maintained above the raising freezing point of the forming alloy. Also, the invention contemplates and provides a method wherein the temperature is increased with such rapidity throughout the temperature range below copper melting temperature as to prevent complete diffusion of the copper and nickel in a solid state.

To this end, it is preferable that the metals be heated by generation of heat within the metals as distinguished from the heating of the metals by radiation, although furnaces may be developed, such as the radiant tube furnace, which will provide a sufficient temperature gradient to effect heat transfer to the tube in a manner sufficient for the purpose.

A copper-nickel alloy which has the proportions of copper and nickel as are present in the metal known as Monel, has certain characteristics which are higher or more favorable than the characteristics of a copper-nickel alloy having a higher or lower percentage of nickel and a corresponding variation of copper. These characteristics include the yield strength, the ultimate strength, the working ability and corrosion-resisting characteristics of the metal. Such a metal has about 67% to 70% of nickel and the remainder of copper, except for impurities which may include a small percentage of iron. Accordingly, for some purposes, it is preferable to provide a tube of Monel metal, or in other words, a copper-nickel tube where the percentages of copper and nickel approximate the percentages found in Monel. The tube need not be wholly made of copper-nickel strip but may have an inner ply or an outer ply formed by the copper-nickel strip and an outer ply or inner ply respectively of cheaper or strength-giving metal such as steel or other ferrous metal. In order to give such a tube the desired characteristics of having a high yield strength, ultimate strength, working ability, corrosion resisting characteristics, etc., it is necessary that the bond between the juxta-positioned parts have similar characteristics. To this end the invention contemplates a tube and method of making a tube wherein the copper which is employed for effecting the bond is so diffused with nickel that the seam itself or the interfacial areas between the juxta-positioned parts in a seam or seams, or between plies, is a copper-nickel alloy approximating that of the strip.

In carrying out the invention, commercially pure copper can be employed, although cuprous metals such as brazing brasses and brazing bronzes may be employed for tubes which are to be used under less severe working conditions and less severe conditions of use.

The accompanying drawing illustrates the method and shows illustrations of the tubing.

Fig. 1 is a diagrammatic illustration showing the method where the tube is heated by electrical induction.

Fig. 2 is a diagrammatic illustration showing the tube heated by electrical resistance.

Fig. 3 is a view partly in section showing an example of one form of tube which can be made by the method.

Fig. 4 is a view similar to Fig. 3 showing another example of tube which can be made by the method.

In Fig. 3 the tube is made from a single strip of stock fashioned through substantially 720°, thus providing an outer ply 2 and an inner ply 3. The edges of the stock are beveled and abut against an off-set 4 in the stock which connects the inner and outer plies. Thus the off-set is at a non-abrupt angle with the beveled edges in juxtaposition to opposite sides thereof. This general form of tube and the manner of making it is fully disclosed in the B. L. Quarstrom Patent No. 2,014,982 of September 17, 1935. In Fig. 4 a tube made from two strips is shown. One strip forms an inner ply 5 with its edges abutting in a seam 6; the other strip forms an outer ply 7 and its edges are preferably scarfed and overlapped in a seam at 8.

In Fig. 1 the strip may be drawn from a supply roll 10 and may be passed through a tube mill having rolls illustrated at 11 in which the strip is fashioned into tubular form. The illustration in Fig. 1 shows the tube made from a single strip, but the induction heating arrangement shown in Fig. 1 can be employed for the double strip tube shown in Fig. 4. As the tube passes from the tube mill, it enters a heating zone, shown in Fig. 1 as being in the form of a high frequency induction coil 12. Within the coil is a quartz pipe 13 through which the tube passes, and after the tube passes through the heating zone it may pass through a cooling chamber 14. Where desired, a suitable atmosphere, such as a reducing or non-oxidizing atmosphere, may be maintained by introducing the gas into the quartz tube through an inlet pipe 15 and into the cooler through an inlet pipe 16.

In Fig. 2 the final rolls of a tube mill are shown at 20 from which the formed tube passes into a chamber 21 where the tube is engaged by electrodes 22 and 23 which may be opposed by idler rollers 24 and 25. The electric current thus passes lengthwise through the tube between the electrode rollers 22 and 23 and the tube is heated by electrical resistance. As the tube leaves the chamber 21 it may pass through a cooling chamber 26. A suitable non-oxidizing or reducing atmosphere may be maintained by introducing a suitable gas into chamber 21 and cooler 26 through inlet pipes 27 and 28.

The tubes shown in Figs. 3 and 4 are merely exemplary of a good many tube structures which can be made. The single strip of Fig. 3 will, of course, be of the copper-nickel alloy. The tube of Fig. 4 may be made with the inner ply of nickel-copper alloy and an outer ply of a cheaper metal such as a ferrous metal. On the other hand, the tube shown in Fig. 4 may have the outer ply of the nickel-copper alloy and the inner ply of the cheaper ferrous metal. The use to which the tube is to be put may determine whether the copper-nickel alloy is on the inside or the outside.

As the tube moves through the high frequency electrical induction heating zone of Fig. 1, it is

heated so that its temperature is raised to above copper melting temperature with such rapidity as to prevent a substantial diffusion of the copper and nickel in a solid state. In this connection,

it is thought to be advisable to cite a given exemplary situation. This example is as follows: The copper-nickel strip employed was known as Monel metal having the proportions of copper and nickel as given above, and had a thickness of about .0145 inch so that when fashioned into double ply tubing the wall thickness was about .028 inch. This copper-nickel strip was coated on both sides with copper, and the amount of copper was within the range of .15 to .5 ounce for two square feet of surface. The copper was applied to the strip by electrodeposition. It will be seen that with the tube thus fashioned there will be a layer of copper on the outside of the tube and on the inside of the tube and between the plies and in the seam 4. This tube was moved at a rate of about 20 feet per minute, while the induction coil had a total length of about 8 inches. The temperature of the tube was raised rapidly and reached or exceeded copper melting temperature at about the point indicated at X. This point was about two inches from the end of the induction coil. It will be seen, therefore, that the temperature was raised from room temperature to or exceeding copper melting temperature in about one-half a second, and that the temperature was maintained above copper melting temperature at about two seconds, as this is the time required for a given point on the tube to move through the inductor.

Now in the case of Monel metal, the temperature at which the same begins to get soft or mushy is about 1315° C., whereas copper melting temperature is about 1084° C. It will be seen, therefore, that it is essential not to subject the tube to a temperature higher than that which would melt the strip, but it must be considerably higher than copper melting temperature, due to the dynamic nature of the situation. It is preferable, therefore, that the tube be heated rapidly to a point safely below 1315° C. or say about 1300° C. However, it has been found that a satisfactory tube can be made where the temperature is in the vicinity of 1225° C. Thus the temperature is raised from copper melting temperature to the maximum temperature attained at an average rate greater than the rate of elevation of the freezing point of the copper-nickel alloy formed as the copper and nickel enter into solution. Accordingly, temperatures considerably higher than copper melting temperature must be employed, and yet this temperature must not exceed the melting point of the copper-nickel alloy constituting the strip.

The form of tube shown in Fig. 4 requires the same rapid heating and temperature conditions since the copper and the nickel of the inner or outer ply diffuse with each other. In the Fig. 4 form, either the ferrous metal strip or the copper-nickel strip, or both, can be coated with copper. However, it appears to be preferable to copper coat the ferrous metal strip, as the coating protects the ferrous metal while it is in strip form and being handled in the shop, and because of a preliminary bond between the copper and the ferrous strip.

The tube preferably has a metal composition or alloy at the interfaces in the seam or seams and between plies which approximates that of the metal of the strip. For example, a tube having maximum working properties and the other de-

sirable characteristics of a Monel tube should be made of a copper-nickel strip having the percentages of copper and nickel which approximates that of Monel and likewise the metal in the seam or seams and between plies should approximate the same percentages of copper and nickel. Otherwise, the seam or interfacial areas might be ruptured upon the working of the tube. Under the conditions above recited, the copper and the nickel in the interfacial areas so diffused with each other that, according to the best available tests which can be made at present, the copper and nickel proportions were within about 2% of that of the original strip. In the making of the tube, the nickel in the strip at the interfacial areas alloys with the copper, and this results in a bond between the parts or plies composed of a metal substantially like that of the strip. Accordingly, the finished tube, where it is made entirely from copper-nickel strip, has a substantially homogeneous characteristic. A tube structure like that of Fig. 3 made originally with an outside diameter of about one-fourth or three-eighths of an inch has been drawn down to such a small size as to have a hole of about .0075 inch and a wall thickness of .002 inch without rupture either of the metal of the strip or the metal in the seams or plies.

The all nickel-copper tube has a large number of uses where corrosion resisting tubes are desired as, for example, in the chemical and dairy industries, cooling devices for beverages, radio antennas, particularly for automotive vehicles and boats, and heat exchange devices of various types. Since the tube can be reduced to such a small size, it can be used in various places for control purposes as, for example, in thermostats or other heat sensitive devices and for the so-called capillary tubes for refrigerating mechanism.

In the making of the composite tube as shown in Fig. 4, the copper fills in the butt joint at 6 to unite the steel interfaces where the inner ply is of steel, and to alloy with and unite the copper-nickel interfaces where the inner strip is of the copper-nickel alloy. Also, the interfaces between the inner and outer plies are effectively united and the scarfed seam 8 is united where the outer ply is of steel or copper-nickel alloy. In this tube, it is preferable that the copper so diffuse with the nickel from the strip that the resultant composites of the metal at the interfaces approximates the proportions of the copper and nickel in the original strip. This composite tube may be employed where it is unnecessary to have corrosion resisting characteristics on both the inner and outer surfaces of the tube. The composite tube can also be drawn down to very small sizes and can be effectively employed for the purpose set forth above where it is necessary to have the corrosion resisting metal only on one side of the tube.

Where a copper coated, copper-nickel alloy strip forms an outer ply, the exposed outer surface may have a somewhat spotty or roughened appearance, but with the usual whitish appearance of the metal of the strip. With the composite tube as shown in Fig. 4, the finished tube may have the copper coating intact on the exposed surfaces of the steel regardless of whether or not the surfaces are on the outside or on the inside of the tube.

In the claims appended hereto the term "copper" is used in reference to the metal which is supplied for sealing purposes. This is to be con-

strued to cover commercially pure copper and cuprous metals including the brazing brasses and bronzes.

I claim:

1. A tube comprising metal stock having the geometric shape of elongated strip with opposite edges, some of said metal stock being a copper-nickel alloy, said metal stock being of hollow cross-sectional form having parts, including the opposite edges, disposed in interfacial relationship forming a seam or ply structure so that the hollow form is closed and a bond zone consisting entirely of an alloy of copper and the strip stock metal co-extensive with the interfaces and integral therewith, said bond zone and the interface of the copper-nickel strip having copper-nickel proportions substantially corresponding to the copper-nickel proportions of the copper-nickel strip, whereby the proportions of copper and nickel throughout the body of the copper-nickel strip and the bond zone are substantially uniform.
2. A tube comprising, copper-nickel alloy stock having the geometric shape of the elongated strip with opposite edges, said metal stock being of hollow cross-sectional form having parts, including the opposite edges, disposed in interfacial relationship forming a seam or ply structure to provide a closed tubular wall and a bond zone consisting entirely of copper-nickel alloy co-extensive with the interfaces and integral therewith, said bond zone and the interfaces having copper-nickel proportions substantially corresponding to the copper-nickel proportions of the metal stock, whereby the copper-nickel proportions throughout the thickness of the tubular wall are substantially uniform.
3. A tube comprising, metal stock having the geometric shape of elongated strip with opposite edges, said metal stock having copper and nickel proportions corresponding to those proportions in Monel metal, said metal stock being of hollow cross-sectional form having parts, including the opposite edges of the strip and the opposite surfaces of the strip, disposed in interfacial relationship providing a seam and inner and outer ply structures to form a closed tubular wall and a bond zone consisting entirely of copper-nickel alloy co-extensive with the interfaces and integral therewith, said bond zone and the interfaces having copper-nickel proportions substantially corresponding to the copper-nickel proportions of the metal strip, whereby the copper-nickel proportions throughout the thickness of the tubular wall are substantially uniform.
4. A tube comprising, metal stock having the geometric shape of elongated strip with opposite edges, some of the metal stock being of copper-nickel alloy and some being of ferrous metal, said metal stock being of hollow cross-sectional form having parts, including the opposite edges of the strip stock and surfaces thereof, disposed in interfacial relationship to provide a seam and an inner and an outer ply structure to form a closed tubular wall and a bond zone consisting entirely of copper-nickel-ferrous alloy co-extensive with the interfaces and integral therewith, said bond zone and the interface of the copper-nickel strip having copper-nickel proportions substantially corresponding to the copper-nickel proportions of the copper-nickel strip, whereby the copper and nickel proportions in the copper-nickel ply of the tube wall are substantially uniform.

RAYMOND H. HOBROCK.