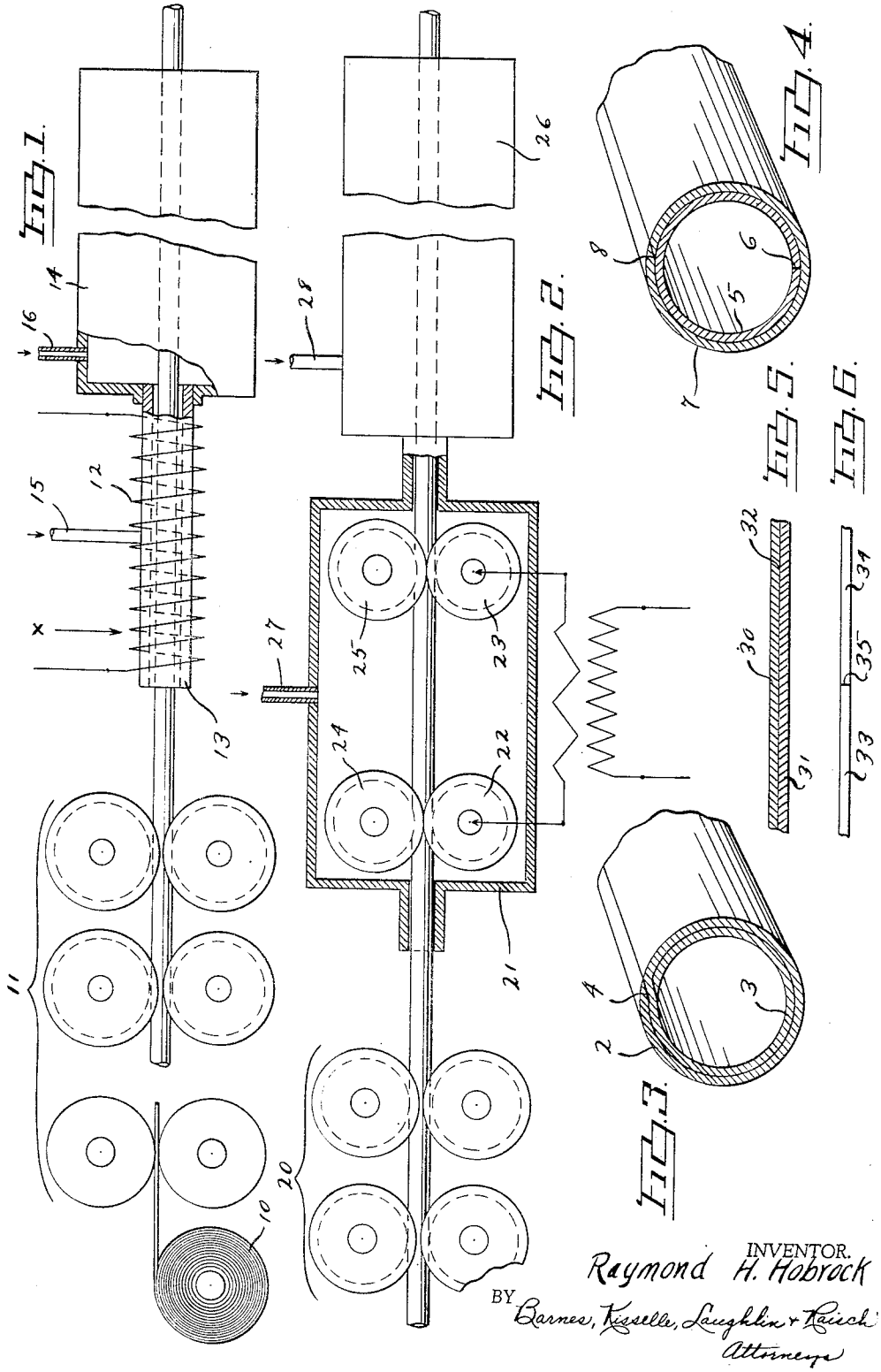
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METHOD OF UNITING METALS

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METHOD OF UNITING METALS

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This invention relates to a method of uniting or bonding together separate bodies of metal or two portions of the same body of metal at least one of which bodies or portions comprises a nickel-copper alloy. More specifically, the invention relates to the forming of a bonding joint or seam between a body of nickel-copper alloy and another body wherein copper is used as the joining medium.

It is to be appreciated that nickel and copper very readily alloy with each other and this fact presents a difficult problem where it is desired to make a joint between metals involving a nickel-copper alloy by the use of copper. The joint or connection of the present invention may be likened to or termed, a weld or a braze, but, however this may be, it is merely termed a joint, bond or connection herein. This application is a continuation in part of my application, Serial No. 391,595, filed May 2, 1941.

In accordance with the invention the amount of copper employed is relatively small as compared with the amount of metal in the copper-nickel body. 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 body. 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 metals 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 finished article comprising the two or more united bodies or portions, wherein one of the bodies is of Monel metal, or in other words, a body having copper-nickel percentages which approximate the percentages found in Monel. This gives the article the favorable characteristics found in Monel. In order to give the article 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 method wherein the copper which is employed for effecting the bond is so diffused with the nickel in the nickel-copper body 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 the copper-nickel proportions in the body.

The invention is applicable to the making of tube from strip stock wherein the juxta-positioned parts of the stock, such as parts in a seam or seams, or plies, are joined or united by the method and it is advantageous to disclose the method in connection with the making of such tube. An article made by the method may include a body or portion of copper-nickel alloy and a body or portion of some other metal, such, for example, as iron or steel. For example a tube may have an inner ply, or an outer ply, formed by the nickel-copper stock and an outer ply or inner ply, respectively, of cheaper or strength giving metal, such as steel or other ferrous metal. A tube or other article made in accordance with the invention, and which has the bond at the interfacial areas between juxtapositioned parts in a seam or seams, or between plies, of a copper-nickel alloy approximating that of Monel, has substantially the above desirable characteristics of the Monel body.

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 drawings illustrate the method and show illustrations of the tubing and other articles.

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.

Fig. 5 is a view illustrating two joined and superimposed bodies of metal in the nature of a bi-metallic element.

Fig. 6 is a view showing the connection of two bodies at their meeting edges.

The following detailed disclosure of the method is made largely by reference to the making of tube.

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. Quarnstrom 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.

In Fig. 5 a structure is shown in the nature of a section of bi-metallic strip or member having a layer or ply 30 and a layer or ply 31 which are united in the same way, the bond or connection being along the intermediate line or interfacial area 32. In Fig. 6 two bodies 33 and 34 are connected at their meeting edges as at 35. Where long lengths of strip, such as shown in Fig. 5, is to be made, the same may be run through a heating zone or furnace after the manner shown in Figs. 1 and 2. Where the bodies are not of strip form or of long length, they may be heated in a manner otherwise than by moving them through the furnace. For example, such articles may be placed in a furnace or heating zone where the same repose stationarily and the heat may be applied to the stationary body. The joint 35 in Fig. 6 is representative of a connection between any two parts or bodies of an article. As is the case with the tube, both or only one of the bodies shown in Figs. 5 and 6 may be of Monel metal. One may be of ferrous metal or other metal including copper-nickel alloy of different proportions than Monel.

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. These observations also apply to Figs. 5 and 6.

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 desirable 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 percentage 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.

What has been said above with respect to tube applies equally well to any other article with a joint thus formed, or a strip or piece of bimetallic metal, or a strip or piece having more than two layers, except, of course, where the characteristic is peculiar to tube alone.

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 construed to cover commercially pure copper and cuprous metals including the brazing brasses and bronzes. The appended claims describe the method as one for uniting two metal bodies; this language is to be construed to cover the uniting of two parts or portions even though at the time they are joined together with one body.

What I claim is:

1. The method of uniting two metal bodies, at least one of which is a copper-nickel alloy, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfacial surfaces, inducing electrical current in the bodies to generate heat within the metal thereof to raise the temperature of the bodies to a temperature between copper melting temperature and the melting temperature of the copper-nickel body at an average rate of temperature increase, in the range from the copper melting temperature to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the copper-nickel body and the copper of the coating, whereby to maintain the alloying metals adjacent the interfaces in a molten state during the time of rising temperature, and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper coating at the interfacial surfaces alloyed with the metal bodies.

2. The method of uniting two metal bodies, at least one of which is a copper-nickel alloy, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfacial surfaces, raising the temperature of the bodies by electrical current in the metal thereof to a temperature between copper melting temperature and the melting temperature of the copper-nickel body at an average rate of temperature increase, in the range from the copper melting temperature to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the copper-nickel body and the copper coating, whereby to maintain the alloying metals adjacent the interfaces in the molten state during the time of rising temperature, and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper coating of the interfacial surfaces alloyed with the metal bodies.

3. The method of uniting two metal bodies, at least one of which is a copper-nickel alloy, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfacial surfaces, heating the bodies to a temperature between copper melting temperature and the melting temperature of the copper-nickel body at an average rate of temperature increase, in the range from the copper melting temperature to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the copper-nickel body and the copper coating, whereby to maintain the alloying metals adjacent the interfaces in the molten state during the time of rising temperature, and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper coating at the interfacial surfaces alloyed with the metal bodies.

4. The method of uniting two metal bodies, at least one of which is a copper-nickel alloy, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfacial surfaces, heating the bodies to raise the temperature thereof to the copper melting point before there is any deleterious diffusion of the copper and nickel in the solid state, and to raise the temperature of the bodies, in the range above copper melting temperature to the maximum temperature attained at an average rate greater than the elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the copper-nickel body and the copper of the coating and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper coating at the interfacial surfaces alloyed with the metal bodies.

5. The method of uniting two metal bodies, at least one of which is copper-nickel alloy having copper-nickel proportions approximating 70 per cent nickel and 30 per cent copper, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfaces, heating the bodies to raise the temperature thereof to from about 1225° C. and about 1300° C. at an average rate of temperature increase, in the range from copper melting temperature to the maximum temperature attained which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of nickel of the copper-nickel body and the copper of the coating, whereby to maintain the alloying metals adjacent the interfaces in the molten state during the time of rising temperature, and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper coating at the interfacial surfaces alloyed with the metal bodies.

6. The method of making tube from strip metal stock, at least some of which strip is a copper-nickel alloy, which comprises coating some of the surface of the strip stock with copper, all of the strip stock having a higher melting point than that of said copper coating, fashioning the strip stock, while in a solid state, into tube form, having parts disposed in interfacial relationship to provide a seam or ply formation with the copper coating constituting one of the interfacial surfaces, heating the tube to a temperature above copper melting temperature and below the melting temperature of the copper-nickel strip at an average rate of temperature increase, in the range from copper melting temperature to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the copper-nickel strip and the copper of the coating, whereby to maintain the alloying metals adjacent the interfaces in a molten state during the time of rising temperature and

then discontinuing raising of the temperature of the tube to cause solidification of the alloyed metals with all of the copper coating at the interfacial surfaces alloyed with the metal strip stock.

7. The method of uniting two metal bodies at least one of which comprises nickel, which comprises placing a coating of copper on a surface of at least one of the bodies, said bodies having melting points above that of the copper coating, disposing the bodies, while in a solid state, in interfacial relationship with the copper coating constituting one of the interfacial surfaces, heating the bodies to raise the temperature thereof to a temperature beween copper melting temperature and the melting temperature of the nickel body at an average rate of temperature increase, in the range from the copper melting temperature to the maximum temperature attained, which is greater than the rate of elevation of the freezing point of the alloy formed adjacent the interfaces by the alloying of the nickel of the body and the copper of the coating, whereby to maintain the alloying metals in a molten state during the time of rising temperature and then discontinuing the raising of the temperature of the bodies to cause solidification of the alloyed metals with all of the copper of the coating alloyed with the metal bodies.

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