

Feb. 1, 1966

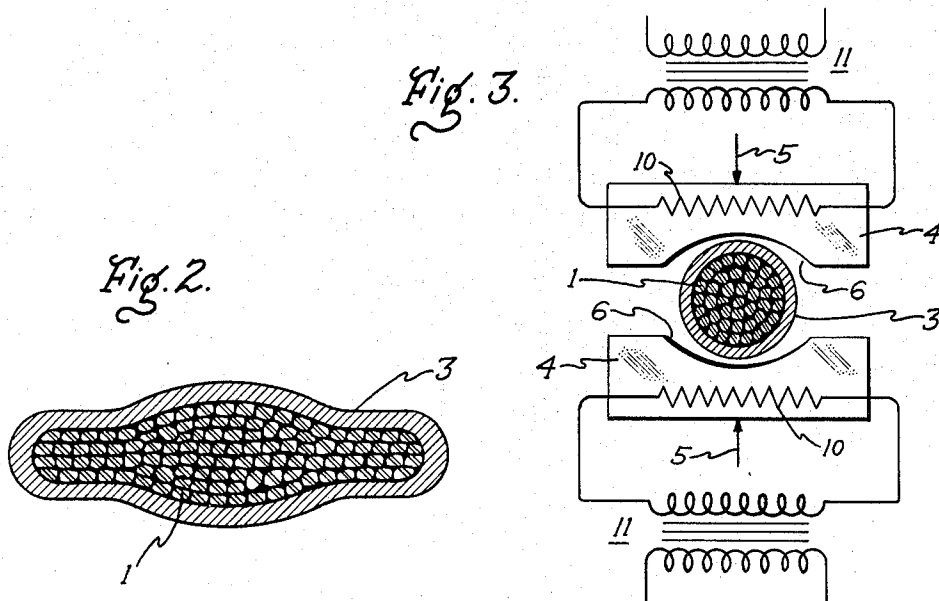
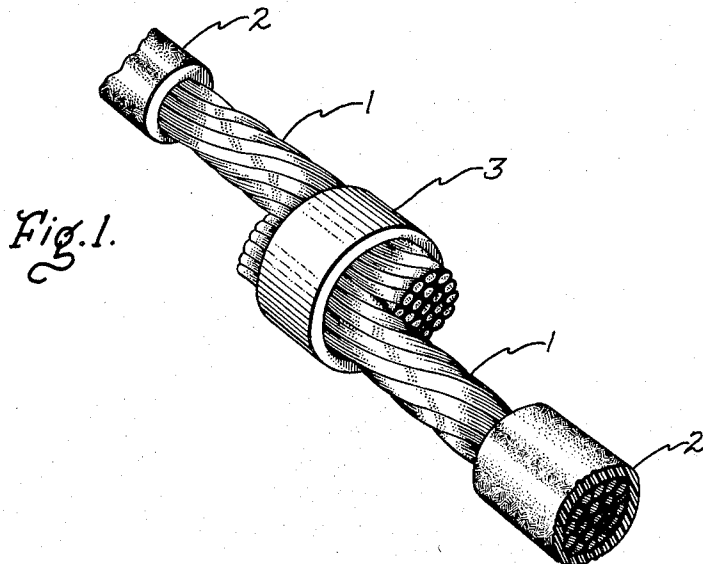
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3,231,964

METHOD OF MAKING AN ELECTRICAL CONNECTION

Filed June 19, 1961

2 Sheets-Sheet 1



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Fig. 4.

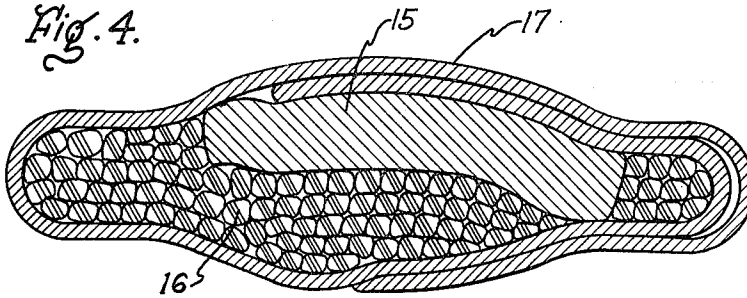


Fig. 6.

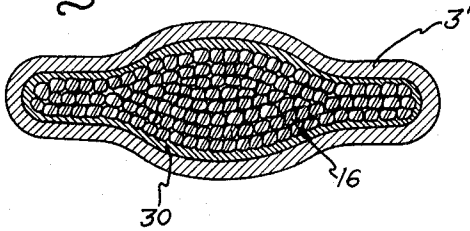


Fig. 5.

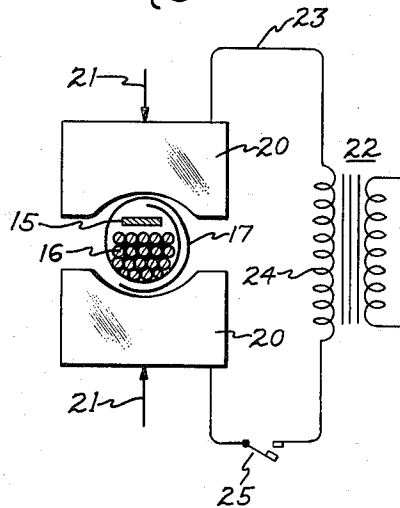
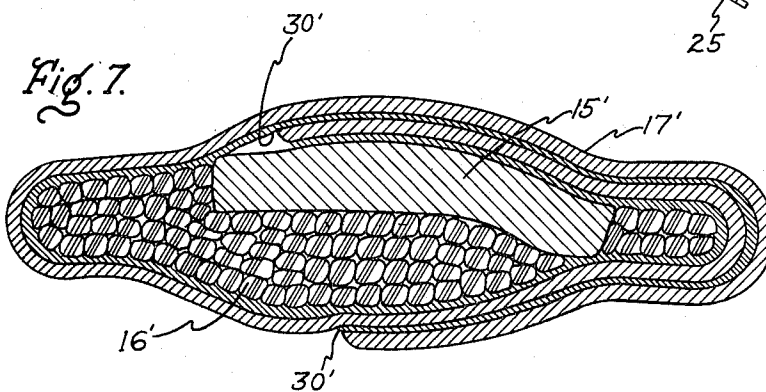


Fig. 7.



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3,231,964

METHOD OF MAKING AN ELECTRICAL CONNECTION

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3 Claims. (Cl. 29—155.5)

This application is a continuation-in-part of application Serial No. 824,623, filed July 2, 1959, now abandoned, in the name of the present inventor and assigned to the same assignee as this application.

This invention relates to an improved electrical connection and an improved method and improved apparatus for making the improved electrical connection.

In the prior art it is well known to connect two electrical leads together by placing them in a metallic sleeve or the like and indenting the sleeve into the two leads. In this type of electrical connection the strength of the joint is dependent upon a mechanical interlocking of the parts with respect to each other. It has several disadvantages. For one thing, inasmuch as the joint is obtained solely by mechanical forces high pressures have to be used to obtain a firm connection of the parts with respect to each other. High pressures require large apparatus for accomplishing the job, and this is particularly true where the members which are to be connected together are large such as bus bars or heavy cable.

The above mentioned type of prior art electrical connection has the further disadvantage that cold working of the sleeve results in residual stresses in the sleeve after it has been indented or the like. The residual stresses in the cold worked sleeve may result in eventual relaxation of the joint which makes for a poor electrical connection. Also, cold working of the sleeve is apt to cause embrittlement or cracking of the same.

It is an object of this invention to provide an improved electrical connection and an improved method and apparatus for making the same which will overcome the above discussed and other disadvantages of the prior art.

In my invention a sleeve or wrap-around element is used about the connected members but the success of the connection is not dependent upon an indentation or other mechanical interlocking of the parts with respect to each other. In the invention a sound electrical connection is obtained by mere compression of the sleeve or wrap-around element about the electrical conductors. The sleeve or other element which surrounds the joined electrical conductors is not cold worked or cold pressed. Instead, when the element is being compressed heat is applied to it. This application of heat has several advantages. For one thing, it assists in deformation or compression of the sleeve or other element which is used to surround the joined electrical conductors. This means that the pressures required to compress the element can be reduced. In some instances the pressures which would be required to compress the element can be reduced as much as 97%. Accordingly the invention makes it possible to reduce the size and cost of the apparatus, device or tool which is used to make the electrical connection.

Making the electrical connection with heat as well as pressure provides the further advantage that stresses in the surrounding sleeve or wrap-around element are relieved. Accordingly, there will be very little likelihood of embrittlement or cracking of the element as is true in cold working of the element, and since there are no residual stresses in the compressed element it will not relax and result in a poor electrical and mechanical connection.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention, it is believed the inven-

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tion will be better understood from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of two electrical conductors during the initial method step of surrounding the ends of the conductors with a deformable connector element,

FIG. 2 is a cross sectional view of the finished product or joint,

FIG. 3 is a diagrammatic illustration of one form of apparatus which can be used in practicing the invention,

FIG. 4 is a cross sectional view of another form of electrical connection,

FIG. 5 is a diagrammatic illustration of another form of apparatus for practicing the invention,

FIG. 6 is a cross sectional view of another form of electrical connection, and

FIG. 7 is a cross sectional view of still another form of electrical connection.

In the drawings like reference numerals will be used throughout the various figures to indicate similar parts, and in the drawings the real dimensions of various parts have been exaggerated for purposes of clarity.

Referring now to FIG. 1, illustrated therein are two stranded copper leads 1 which are stripped of their electrical insulation 2 at their ends. The insulation stripped ends of the conductors 1 are surrounded by a deformable sleeve or other suitable element 3 which can be made from copper or other appropriate material.

Although in FIG. 1 the electrical conductors 1 are indicated as being lapped at their end it will be appreciated that the ends of conductors 1 can be butted up against each other end to end or even spaced with respect to each other. Additionally the invention is not restricted to the particular materials indicated with respect to FIG. 1. For instance one of the conductors 1 could be made from a material different than copper such as aluminum. The conductors do not necessarily have to be stranded. The invention is also applicable to joining non-metallic members as well as members which are solid or laminated in cross section such as bus bars, tap straps or the like. The invention can also be utilized in joining members which have an electrical insulation coating thereon, and also in joining members for other than electrical purposes. Furthermore, it is possible to connect together more than two members or solely an end fitting or the like to a single member. Accordingly, it will be appreciated by those skilled in the art that the drawings are illustrative of the invention and not restrictive.

FIG. 2 is a cross sectional view taken through the sleeve 3 of FIG. 1 after it has been compressed around the ends of the electrical conductors by heat and pressure. The invention is not necessarily restricted to any particular configuration for the joint. That is to say, the element 3 of FIG. 1 can be square or oval shaped or have other shapes. The same is true with respect to the final shape illustrated in FIG. 2. The shape illustrated in FIG. 2 illustrates that there has been no indentation of the parts with respect to each other in order to obtain a mechanical interlocking of the parts with respect to each other. In the invention it is sufficient merely to compact the two parts of the joined conductors and compress the element 3 about the two compacted parts of the electrical conductors. However, it is possible to also indent the parts with respect to each other if this is desirable for some particular reason although the invention does not require it for a sound electrical and mechanical connection.

Referring now to FIG. 3, the improved apparatus for practicing the method of the invention and obtaining the final product of the invention comprises a pair of forming or pressing elements or dies 4. These elements are

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adapted for movement with respect to each other under pressure as indicated by the arrows 5. The facing surfaces 6 of the elements 4 will have a configuration which will be dictated by the shape which is to be imparted to the finished product. In FIG. 3 the surfaces 6 are indicated as being concave in order to obtain the finished shape illustrated in FIG. 2. That is to say, the concave surfaces 6 will flatten the element 3 and the inserted electrical conductors 1 into a shape which is oval, with opposite ends of the oval being somewhat flattened or pinched.

Means is provided for heating the element 3 as it is being pressed. The means for heating the element 3 can comprise a heating element 10 in either, but preferably both of the dies 4. Each of the heating elements 10 can be heated by means such as transformers 11. It will be obvious to those skilled in the art that the electrical apparatus illustrated in FIG. 3 can comprise a portable and hand-operated tool in the case of relatively small electrical connections.

Referring now to FIG. 4, this form of the invention comprises a solid element 15 and a stranded or braided element 16 which are connected with respect to each other by a surrounding element 17 which is in the form of a spiral metal strip having about one and one-half turns. Of course the strip 17 can have additional turns. However, it will be appreciated that if less than one full turn is utilized the strip 17 will be more apt to unravel or spring apart and therefore some lapping of the strip on itself is preferred and I have found that a lap of about one-half of a turn is satisfactory.

The apparatus illustrated in FIG. 3 can be used to make the electrical connection of FIG. 4. However, other forms of electrical apparatus which provide for compressing of the surrounding element as well as heating it during its pressing can be used as shown by the device illustrated in FIG. 5 which will now be described. The device in FIG. 5 comprises two elements 20 which are adapted to receive the pair of electrical conductors and surrounding element therebetween. The elements 20 can be moved with respect to each other under pressure as indicated by arrows 21. In this form of the invention a source of electrical energy as indicated by transformer 22 is connected to the forming elements 20 which also serve as contactors or electrodes for completing the electrical circuit when in engagement with the element 17. That is to say, current will flow from the secondary transformer lead 23 to the upper electrode 20, and then through the element 17 to the lower electrode 20 and then back to the other end of the secondary winding 24 of the transformer 22. Preferably means such as a timed switch 25 is provided to delay closing of the electrical circuit until the electrodes 20 have made firm electrical contact with the element 17. This is to avoid arcing between the electrodes 20 and element 17 and consequent burning of the element 17.

In the invention it is not the purpose of the thermal energy which is put into the surrounding element such as part 17 to melt the parts 15, 16 and 17 so as to fuse or weld them together. This would result in a solidification of these parts with respect to each other and I have found that this is not necessary to obtain a successful electrical and mechanical connection. Instead, in the invention the thermal energy or heat which is put into the surrounding element such as part 17 is essentially only sufficient to help deform the element in order to reduce the pressures required to compress it and also to relieve the stresses which are induced in the surrounding element. In the case of a surrounding element such as the spiral 17 of FIG. 5 it is desirable that the thermal energy which is applied to the joint during the pressing operation be also sufficient to obtain a slight softening or melting of the turns of the element 17 so that they will become bonded with respect to each other. Such bonding of the lapped turns of element 17 with respect to each other will help in keeping

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the turns from unravelling. However, this additional input of heat is not absolutely necessary inasmuch as the element 17 can be coated with a fuseable element which will melt and bond the turns with respect to each other solely with the heat which is required essentially only to help deform the surrounding element and relieve the stresses therein. This will be more fully described hereinafter in connection with FIG. 7.

When connecting members, such as wire conductors 1 in FIGURE 1, which have an electrical insulation coated thereon, it will be obvious that the heat to be applied to form the desired connection, must be sufficient to melt the layer of insulation coated on such conductors. Since this invention does not require the fusing of the conductors and the connector, it is not necessary that the temperature used to form the connection be raised to the melting point of either the conductors or the connector. However, as above stated, it is desired that the temperature be sufficient to relieve the stresses built up in the connector due to the forming of the connection.

The following is an example, considering the connection of FIGURE 1, where the conductors 1 are copper wire having a coating of phenolic modified polyvinyl formal insulation thereon and the sleeve 3 is a copper ferrule. Under such conditions the connection would be formed at a temperature of approximately 1750° F. (approximately 950° C.). This temperature is of course, substantially the annealing temperature of copper, and will thus relieve any stresses of the ferrule 3. It will be understood that this temperature is sufficient to melt the phenolic modified polyvinyl formal insulation on the conductors 1. Obviously, the temperature used to form the connection must be sufficient to melt the insulation and relieve the stresses of the connector or sleeve. This temperature will, of course, depend on the material forming the insulation and the material of the connector or sleeve.

As earlier indicated, the use of heat in forming a connection reduces the pressures required to deform the connector while at the same time relieving the stresses which are induced in the connector means due to such compression. As an example of the reduction in pressure which is obtained over prior cold forming practices, the following is cited. Two stranded copper conductors, such as AWG No. 10, are placed side by side within a copper ferrule approximately $\frac{3}{8}$ " long and $\frac{1}{32}$ " thick and having an inside diameter of approximately $\frac{1}{4}$ ". The connection is positioned within a device such as shown in FIGURE 5. The jaws 20 are closed, applying a force of approximately 1600 pounds per square inch to the connection. At the same time the connection is heated to a temperature of approximately 1750° F. After heating for a short period, generally a very few seconds, switch 25 is opened and the connection allowed to cool. The same connection made by cold forming, requires a pressure of approximately 30 tons per square inch. The substantial reduction in pressure, approximately 97%, is obtained due to the addition of the heat to the connection. Of course, it will be understood, that the above example is for illustrative purposes and should not be considered a limitation of the invention. Obviously, a strip member, such as 17, would perform equally well in the foregoing example.

It has been found that maintaining the pressure on the connection for a few seconds, as the connection cools, insures the obtaining of a sound connection, preventing any separation as the parts of the connection contract in cooling. This maintenance of pressure during cooling is especially helpful when the connection comprises materials having different rates of thermal expansion, for example copper and aluminum.

Referring now to FIGURE 6, this form of the invention is similar to that of FIGURE 2, except that the inside of the surrounding element 3' has been coated with a fuseable metal 30. Fuseable metal 30 can comprise a

soldering or brazing compound. However, inasmuch as brazing compounds require higher temperatures to cause them to flow preferably metallic compound 30 is a low temperature solder which will melt solely by heat which is utilized in the method to assist in deformation of the surrounding element 3' and relieve the stresses induced therein. When the fuseable metal 30 melts the strands of the electrical conductors will be bonded to the surrounding element 3'. Additionally, some of the fuseable metal 30 may penetrate the strands to fuse the strands of the different conductors to each other.

In the form of the invention illustrated in FIGURE 7 the wrap-around element 17' has been coated with fuseable metal 30'. The heat which assists in compression of the element 17' about the electrical conductors 15' and 16' as well as relieve the stresses induced in element 17' is sufficient to melt the fuseable metal 30'. When the fuseable metal 30' melts the turns of the spiral element 17' will be bonded with respect to each other as well as to the solid conductor 15' and the stranded or braided conductor 16'. Additionally, some of the fuseable metal may penetrate or flow through and between the electrical conductors 15' and 16' to also bond them with respect to each other.

In the forms of the invention illustrated in FIGURES 6 and 7 the fuseable material 30 and 30' need not necessarily be deposited in the form of a coating on the inside of elements 3' and 17'. The fuseable material can be incorporated into the connection in other ways. For instance, a small portion of a fuseable material can be inserted inside the elements 3' and 17' along with the electrical conductors prior to squeezing of the elements 3' and 17' about the electrical conductors. It is also possible to dip the ends of the electrical conductors into a fuseable material.

The invention is not restricted to an apparatus, method or product in which the heat or thermal energy is added by electrical means. For instance, it is possible to add heat by gas burners or the like playing on the forming elements or the surrounding connector element for the electrical joint. However, electrical means has the advantage of providing accurate control of the timing and amount of heat input as well as other advantages.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and therefore, it is intended by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of forming a substantially stress relieved electrical connection which comprises: surrounding a portion of a plurality of electrical conductor members, at least one of which initially includes a relatively thin coating of insulating material, with a deformable connector member having an annealing temperature at least as high as the melting point of said insulating material; compressing said connector member into intimate engagement with said conductor members with a relatively low pressure, and applying heat thereto to heat the conductor members below their respective melting points but above the melting point of said coating and to heat the connector member within its annealing temperature range thereby bonding said members together into a compact

electrical conductive mass; discontinuing the application of heat to said members, maintaining pressure on said members as said members partially cool; and finally relieving the pressure on the formed connection.

2. The method of forming a substantially stress relieved electrical connection which comprises: surrounding a portion of a plurality of electrical conductor members, at least one of which initially includes a relatively thin coating of insulating material, with an electrical conductive deformable connector member having an annealing temperature at least as high as the melting point of said insulating material, and with at least one of said members being composed of a different material than the other members; compressing said connector member into intimate engagement with said conductor members with a relatively low pressure, and applying heat thereto to heat the conductor members below their respective melting points but above the melting point of said coating and to heat the connector member within its annealing temperature range thereby bonding said members together into a compact electrical conductive mass; discontinuing the application of heat to said members; maintaining pressure on said members for a predetermined period of time to insure the intimate engagement of said members as they partially cool; and finally relieving the pressure on the formed connection.

3. The method of forming a substantially stress relieved electrical connection which comprises: surrounding a portion of a plurality of electrical copper conductor members, at least one of which initially includes a relatively thin coating of insulating material, with an electrical conductive deformable copper connector member, compressing said connector member into intimate engagement with said conductor members with a relatively low pressure, and applying heat thereto at approximately 1750° F. to heat the conductor members below their respective melting points but above the melting point of said coating and to heat the connector member within its annealing temperature range thereby bonding said members together into a compact electrical conductive mass; said heat relieving any stress in said connector due to said compressing of said connector; discontinuing the application of heat to said members; maintaining pressure on said members for a predetermined period of time to insure the intimate engagement of said members as they partially cool; and finally relieving the pressure on the formed connection.

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