Fig. 1.  

Fig. 2.  

Fig. 3.  

Fig. 4.  

Fig. 5.  

Fig. 6.  

Inventor  
David Basch,  
Mark M. Hennessey,  
by Charles V. Lucero  
Their Attorney.
Our invention relates to a particular method of joining or compacting the individual parts of a stranded conductor into what appears to be the naked eye as a homogeneous structure but which, under the microscope is shown to consist of the individual parts deformed relatively to one another so that their adjacent surfaces are closely interlocked, and joined to one another by a thin film of alloy which completely covers each of the contacting surfaces. The above operation is performed through the application of a pressure and temperature greater than normally used or necessary in performing soldering or brazing operations and we have consequently designated our improved process as “pressure brazing”.

Our invention also comprises articles produced by our process of pressure brazing.

More particularly, our invention relates to an improved terminal lug and the assembly resulting from joining this lug to a stranded conductor by means of our pressure brazing process whereby a joint of high mechanical strength, even at elevated temperatures, and low electrical resistance may be secured.

An object of our invention is to make it possible to produce in the field as well as in the shop with tools accessible to the ordinary construction gangs joints between the individual strands of a conductor and between a terminal to be attached to the conductor that are free of air spaces, oxides, and flux, that are readily machinable without fission and that will not open up under elevated temperatures, thereby differing from such assemblies previously made by soldering, cold squeezing and cold hammering.

For connecting electrical conductors to one another and to permanent contacts it is customary to provide the conductors with terminal lugs by means of which a bolted or screw connection may be made. The most common form of terminal lug presently used is made from tubular stock by flattening one end of a short section of the stock and punching this section for the reception of the fastening bolt or screw. Terminals thus made are then placed over the ends of conductors and secured thereto by means of solder poured in and around the conductor inserted in the tubular portion of the lug. These lugs have their limitations and the method of securing them to the conductors is objectionable for several reasons. With regard to the tube terminal itself it is to be noted that there is a definite relationship between the width of the flattened portion of the terminal and the diameter and thickness of the tube from which the terminal is made which makes it very difficult to obtain a terminal which will properly fit certain fixed contacts to which the terminal is to be connected and at the same time carry the desired amount of current. The principal objections to the above method of securing the terminal lugs to conductors arise from the difficulty of obtaining joints of minimum and unvarying contact resistance and high mechanical and thermal strength, and the danger of embrittlement of the wire during the soldering operation, especially in small cables or strands where the soldering operation is performed by means of a flame where a flux is used during the operation.

According to our invention we employ a particular form of lug, the parts of which may assume any desired dimensions, and attach this lug to the conductor and consolidate it therewith into an integral whole by heating the parts by passing an electric current therethrough and simultaneously applying mechanical pressure to the same. In order to make it possible to insert the cable or conductor in its natural form into the lug without difficulty and afterwards to compress the joint consisting of lug and conductor into a much smaller solid area without leaving protruding fins and in order to force the heating current from the lug directly in and through the conductor by breaking up the short circuiting path of the continuous lug wall that portion of the lug which encircles the conductor is slotted or grooved. Sufficient current is passed through the lug and conductor to heat the same to a forging temperature at which the tin coating on the strands of the conductor, placed there as a protective covering, alloys with and is dissipated in the material of the conductor.

Insulated copper conductors are usually manufactured with a thin coating or film of tin which is intended to prevent the copper from being corroded by the materials in the insulating coating. This coating of tin is very thin, generally being less than half a thousandths of an inch. If, however, the strands of the conductor are not so coated with a film of tin they should be so coated before performing the electric pressure brazing operation by means of which the improved joint of the present invention is obtained. The lug itself may also be provided with a thin coating of tin. Either tin or tin alloy may be used. If a tin alloy is used the amount of tin in the alloy should be more than that of the alloy. It is essential that only a small
amount of tin be present so that there will not be left in the joint after the electric pressure brazing operation any appreciable amount of free stannous material and so that the penetration of the tin into the copper of the conductor be limited so as not to embrittle the conductor. On very thin strands it may become advisable to dilute the tin with some other element such as lead which does not alloy with copper or cupreous material in order to decrease the penetration of the available tin at the temperature required for the deformation. The stannous metal is used only to wet the contacting surfaces at the joint and to form a binding alloy between the component parts after they have been rendered plastic and brought closely into contact with each other through the application of pressure.

The rate of diffusion of tin into copper is a function of time and temperature, varying practically exponentially with the temperature, and consequently when tin or tin alloys are used, the higher the temperature the quicker and deeper is the diffusion of the tin into the copper and the less the damage on the insulation of the conductor at the joint. It is essential that the heating cycle does not damage the insulation beyond the joint. The quicker the diffusion of the alloying binder into the conductor body can be brought about and the quicker the heat can be shut off, the less will be the damaging effect on the insulation near the joint. On the other hand, the higher the heat the shorter will be the life of the forming dies and the deeper the penetration of the tin into the body metal of the conductor, thereby impairing the ductility and flexibility of the conductor, especially when it is small. Therefore, it is necessary so to adjust the temperature and quantity of alloying binder that in the shortest possible time and at the lowest possible temperature all available alloying binder metal is entirely diffused into the surface metal of the strands of the conductor without penetrating too deeply in the structure. The application of pressure while the body metal is plastic and the binder metal in the molten condition assists in driving the alloying metal into the surface of the conductor, in addition to forcing the individual members into the closest physical proximity, and thus makes it possible to obtain the same results with less heat in the same time. We have found that we obtain the best all around results by bringing the material of the lug and the conductor to a temperature of 600 to 700° C. at which it is quite plastic and yields to pressures that can be exerted through field machines or even hand or tool operated devices.

The particular form of lug which we employ is made from a blank formed of two similar parts adapted to register with each other when bent about a central line. These terminals can be made cheaper than terminals formed of tubing and there is no limit as to the size of the flattened portion of the terminal as in terminals made of tubing. Furthermore, it is somewhat difficult to obtain high conductivity tubing for terminals since manufacturers prefer to use, because of the ease of working it, so-called phosphorized copper which has a lower conductivity. With our improved terminal, however, it is possible to use high conductivity sheet material of copper or cupreous metal, and thus secure a terminal lug of higher conductivity than it is possible generally to secure for punched tube terminal lugs.

A further object of our invention is to provide a terminal lug having ample space within its conductor enclosing portion for the reception of a conductor before consolidation therewith during a pressure brazing operation, which is so constructed that the heating current used for performing the brazing operation is forced to flow from the lug into and through the portion of the conductor enclosed therein, which may be consolidated with the conductor into a much smaller solid area without leaving protruding fins on its surface, which is cheap to manufacture and which has good conductivity and high mechanical and thermal strength.

A further object of our invention is to provide an improved method of operation by which a joint of great mechanical and thermal strength and of constant low contact resistance may be produced in the factory or in the field without embrittling the conductor or corroding it during the operation of forming the joint.

Our invention will be better understood from the following description taken in connection with the accompanying drawing and its claims.

This application is a continuation in part of our application Serial No. 323,130, filed December 1, 1928, all of the disclosure in the same being embodied in this application together with additional matter.

In the drawing Fig. 1 represents a plan view of a blank from which our improved terminal lug is formed: Fig. 2 represents a plan view of the blank shown in Fig. 1 after the same has been shaped and before it has been inserted into the completed terminal lug shown in Figs. 3 to 5 diagrammatically illustrates the method of uniting the terminal lug to the conductor; Fig. 5 shows a side view of the resulting assembly with parts thereof shown in section; and Fig. 6 shows a punched tube terminal the cylindrical portion of which has been slotted in the fiel

The lug shown in Fig. 3 may be made by cutting from sheet material a blank such as shown in Fig. 1 which is then shaped as shown in Fig. 2, and finally creased and folded along its longitudinal center line into the lug illustrated. It is obvious however that the method of forming the lug may be carried out in as many different steps and with as many dies as may be found convenient without departing from the spirit of our invention.

The finished terminal lug illustrated is thus seen to be made up of two complementary members having flattened portions 1 and 2 and dished portions 3 and 4, formed integral with the flattened portions and lying to one side of the plane of the flattened portions. The flattened portions it will be noted are joined to one another along one of their edges and the dished portions form when assembled a slotted chamber for the reception of the end of the conductor to which the terminal lug is to be fastened. The flattened portions are provided with screw or bolt holes.

In forming the union between the end of a conductor and the terminal lug above described, the end of the conductor 6 is inserted in the opening of the terminal lug 3, 4 and both the lug and conductor are placed in dies 7 and 8, which by reason of their connection to a source of current constitute electrodes. The arrangement is diagrammatically illustrated in Fig. 4. If the open end of the conductor have not already been provided in manufacture with a thin coating of tin they are coated with tin or a suitable stannous material.
at the point where it is intended to make the joint before they are placed in the dies. As has been pointed out above, it is essential that the coating be a thin coating and in order to limit the penetration of tin into the copper of the strands so that the strands do not become brittle, the smaller the conductor the smaller the amount of tin or stannous metal being used. A sufficient amount of current to heat the parts and cause the tin to penetrate into the metal of the conductor is then passed through the electrodes 7 and 8 which are also used to transmit sufficient pressure to consolidate the terminal lug with the conductor into an integral structure. Generally, pressures between 1500 and 2000 pounds per square inch and temperatures from 600° to 750° C. are sufficient to accomplish this result.

The purpose of slotting the conductor enclosing portion of the terminal lug will become apparent from the details of Fig. 4. If the lug were not thus prepared most of the welding current would flow directly from the electrode 7 to the electrode 8, through the walls of the terminal lug in a path about the conductor 6 and only a small part of the current would flow through the lug and the conductor in the desired paths to heat the terminal lug and the conductor. Furthermore, it is necessary when applying the conductor to stranded cable, such as illustrated, to have the diameter of the conductor enclosing portion of the terminal lug, ten to twenty per cent greater than the diameter of the conductor after assembly and consolidation, since in the process of compacting the end of the conductor there is such a take-up in the conductor, and unless the lug were slotted to remove about ten to twenty per cent of the excess metal from the walls of the conductor enclosing portion of the lug would interfere with the consolidating process.

The electrodes 7 and 8 may be placed in any suitable machine but where the electric pressure braising equipment is to be portable for use in the field in general assembly shops we mount them in tongs, screw-jacks, or other hinged or toggled operating jaws. For conductors and lugs up to about 500,000 c. m. the electrodes 7 and 8 are made of a high temperature resisting steel or other materials resisting high temperature and pressure such as disclosed and claimed in Patent 1,539,810 to Robert G. Gillette, dated May 26, 1925, and assigned to the same assignee as the present application but for larger lugs and conductors to be joined in the field where the current required to heat the joint is of the proper temperature within the allotted short time would necessitate connecting cables of too large a size to lend themselves to easy handling and transportation. For this reason it may be advisable to form the electrodes of carbon or graphite or some other material of very high electrical resistance and electrical resistance temperature coefficient so that sufficient heat may be generated in the electrodes by a lower current to act as a sort of external furnace to heat the joint instead of relying solely on the internal heat generated electrically inside the joint. This method, however, requires higher temperatures in order to make the conductor material yield physically to the lower pressure which can be withstood by the carbon, bonaceous die material and longer time in order to soak the external heat into and all through the joint and to prevent cracking of the die from too sudden heating, thereby increasing the labor cost and making the problem of preserving the insulation near the joint much more difficult.

Steel electrodes or electrodes having a composition similar to that disclosed in the above-referred to Gillette patent may be used for both large and small conductors in stationary machines. They may even be used with less heat in the joint for large conductors in portable outfits but under such conditions only a good grade soldering job can be effected of electrical, physical and thermal qualities much superior to the ordinary soldering job but not as good as a joint or union produced by electric pressure brazing according to our invention. It is possible to adopt this procedure in view of the fact that there is not the same necessity for heavy cable joints resisting quite as high heat and mechanical stresses as light cable joints because in the case of the large conductors the short circuit overload is proportionately much less.

If during the operation of uniting the conductor with the terminals by the application of heat and pressure it is found that the flattened portions 1, 2 of the lug become unduly heated this shows that too much current is being sent around through these portions and not enough current is being sent through the portions 3 and 4 of the lug and through the conductor 6 inserted therebetween. In order to rectify this difficulty additional pressure should be applied to the parts 3 and 4 of the lug encircling the conductor in order to send more current through the path desired in order to perform the heating and consolidating operation.

The resulting assembly of terminal lug and conductor is shown in Fig. 5. The left-hand portion of the assembly has been shown in section in order to show how the individual wires of the conductor 6 have been consolidated with the walls 3 and 4 of the terminal lug. It is this compacting and close union of the individual strands which decreases the resistance of the joint.

In Fig. 6 we have shown a pressed tube terminal conductor enclosing portion 9 of which has been slotted in order to render it available for use in forming a terminal connection according to our invention. As has been stated above, it is necessary to increase in some such manner the resistance to the flow of electric current through the walls of the terminal lug enclosing the conductor in order to force the current from the lug through the conductor. At the same time it is necessary to make some provision for take-up in the conductor enclosing portion of the lug in view of the decrease in size of the conductor enclosing portion of the lug occurring during the heating and forming operation. It will be found advisable to bell or flange out the conductor enclosing portion of the lug as illustrated in the drawing for small stranded conductors to give a radius for the small strands to bend on rather than a sharp edge and thus prevent breaking of the strands. Lugs for rope core conductors should be large enough to take the conductor with the core in it but before consolidating the core should be drilled out and a solid lug of tinned copper or its equivalent of approximately the same diameter as the core should be inserted in its place. If it is found necessary to unite two conductors to end to end this may be done by our method by using lugs as illustrated and bolting these lugs together, or by using a single lug having no flattened portion whose interior encloses the ends of both conductors which may be, and preferably are, spliced by interstanding when formed of a plurality of individual strands.
Our invention is applicable to single wire or multiple wire conductors. We find that with our method it is not necessary to clean the conductors or use fluxes. By compacting under electric heat loose cable aggregates we obtain with moderate pressures, within the range of a portable tool, a structure practically free from air spaces without damaging or cutting the conductor, or the elements from which it is made or insulated during the operation. It is by reason of the compact structure obtained by our method that a connection of constant low electrical resistance and high mechanical and thermal strength is obtained.

The particular form of terminal lug illustrated and described above is not limited in its application to operations involving pressure brazeing. It may be used wherever joints are made by welding, brazing or soldering by the electric resistance method and although illustrated and described in connection with the operation of forming a pressure brazed joint it is to be understood that its use is not limited to this single operation. While we have shown and described certain particular embodiments of our invention, such modifications and variations are contemplated as fall within the scope of our invention which is set forth in the appended claims.

Letters Patent of the United States is:

1. The method of uniting the component parts of a stranded conductor of cuprous material which comprises completely covering the contacting surfaces of each of the strands of said conductor at the point where the joint is intended to be made with a coating less than half a thousandth of an inch in thickness of a lead tin alloy more than half of which is tin and thereupon heating the strands thus prepared to a temperature between 600° and 750° C. and simultaneously applying sufficient pressure to deform the several strands relative to one another and bring the surfaces of the several strands into close contact with one another.

2. The method of uniting a terminal lug of cuprous material to the ends of a stranded conductor of cuprous material which comprises completely covering the contacting surfaces of the ends of each of the strands of the conductor with a coating less than half a thousandth of an inch in thickness of a lead tin alloy more than half of which is composed of tin, slotting the conductor enclosing portion of the lug at a plurality of places, placing the slotted portion of the lug over the end of the conductor, heating the slotted portion of the lug and the end of the conductor to a temperature between 600° and 750° C. and simultaneously applying pressure to deform the several strands of the conductor relative to one another and to consolidate the lug and conductor into an integral structure.

3. The method of uniting an enclosing casing to a conductor which comprises slotting the wire enclosing portion of the casing in order to divide it into a plurality of segments, placing the casing about the conductor and applying electric current and mechanical pressure to the segments and the conductor to unite the parts into a consolidated structure.

4. The method of uniting a terminal lug to the end of a stranded conductor which comprises slotting the conductor enclosing portion of the lug at a plurality of places, placing the slotted portion over the conductor, heating the slotted portion of the lug and the conductor by sending electric current therethrough and at the same time applying pressure to the outside of said conductor enclosing portion in order to consolidate the lug and conductor into an integral structure.

5. The method of uniting a terminal lug to a tin coated conductor which comprises slotting the wire enclosing portion of the lug at a plurality of places along its length, placing the slotted portion of the lug over the conductor and applying current and pressure to the outside of said lug to close the slots and consolidate the lug and conductor into an integral structure.

6. A terminal lug having a flattened end portion formed integrally with a tubular portion adapted for consolidation with a stranded conductor, said tubular portion being divided longitudinally into a plurality of segments by slots extending along the tubular portion the total width of said slots being greater than 10% of the circumference of the tubular portion of said lug.

7. A terminal lug having a flattened end portion formed integrally with a tubular portion divided longitudinally by slots extending along said tubular portion comprising two complementary members having flattened portions and dished portions formed integrally with the flattened portions and lying to one side of the plane of the flattened portions, said members being joined to each other along one edge of their flattened portions and assembled with the flattened portions folded into contact with each other and the side edges of the dished portions opposite and spaced from one another to form the flattened and slotted tubular portions of said lug.

DAVID BASCH.
MARK M. HENNESSY.