

March 27, 1956

J. S. COONEY

2,739,369

METHOD OF MAKING ELECTRICAL CONTACTS

Filed March 28, 1952

3 Sheets-Sheet 1

Fig. 3.

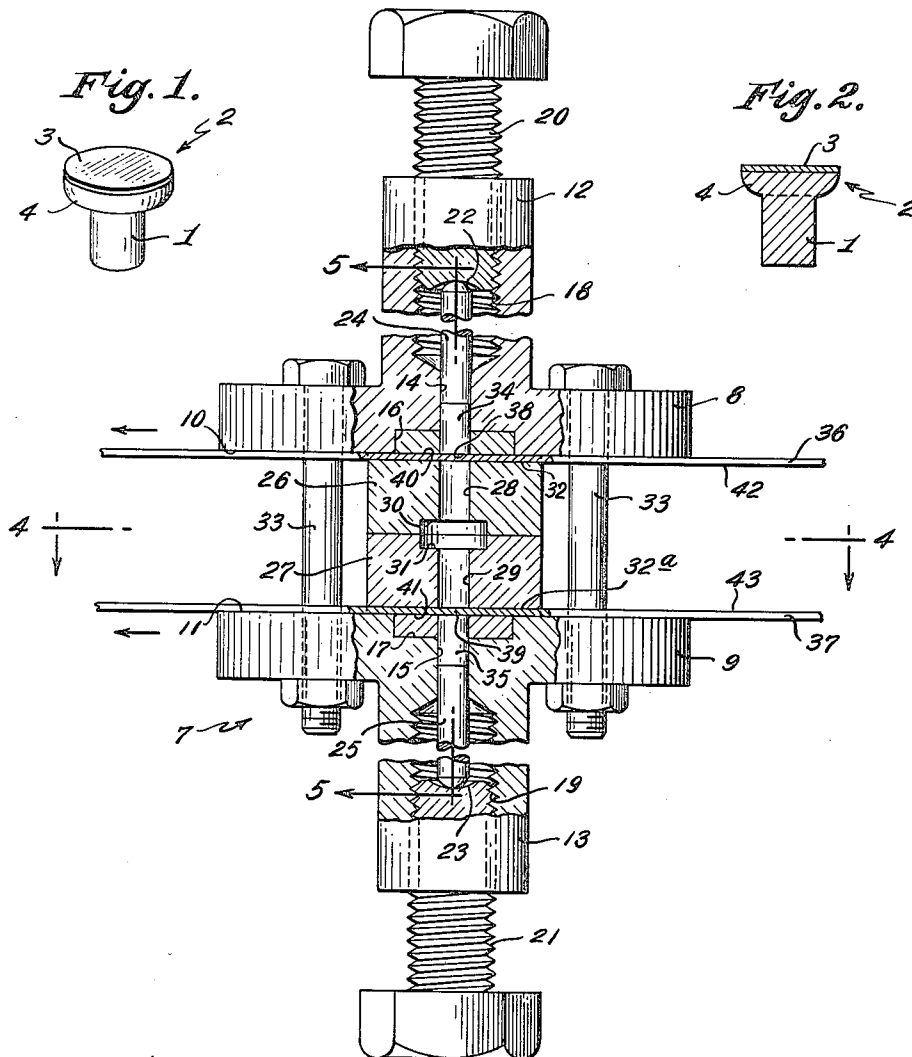
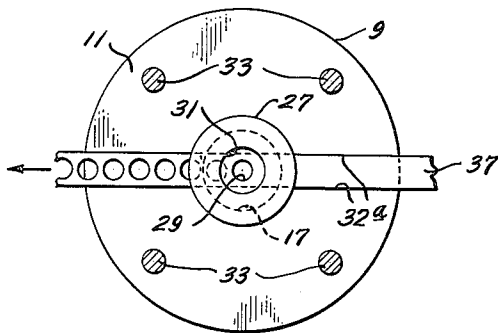


Fig. 4.



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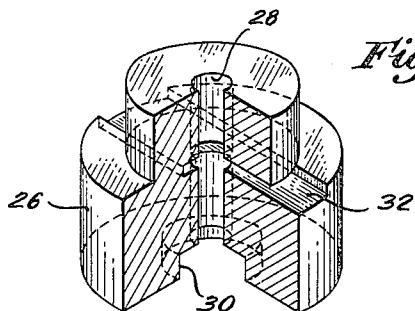
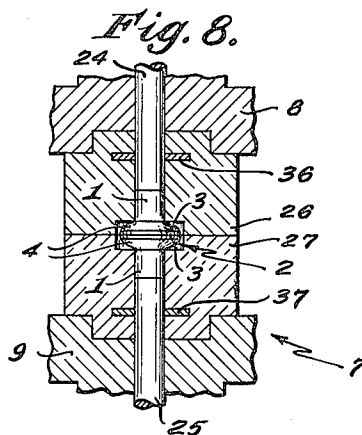
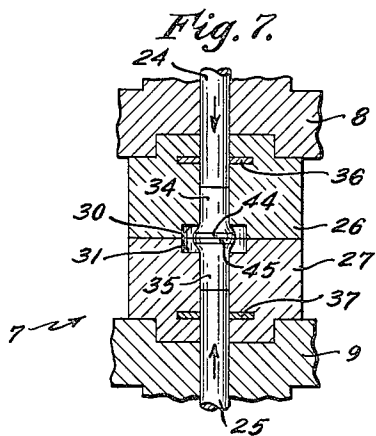
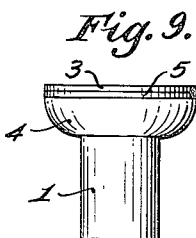
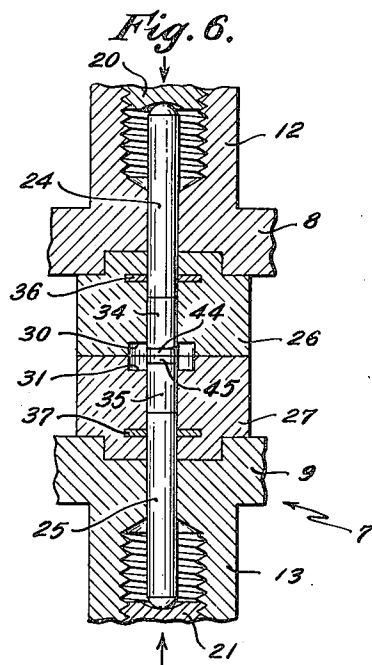
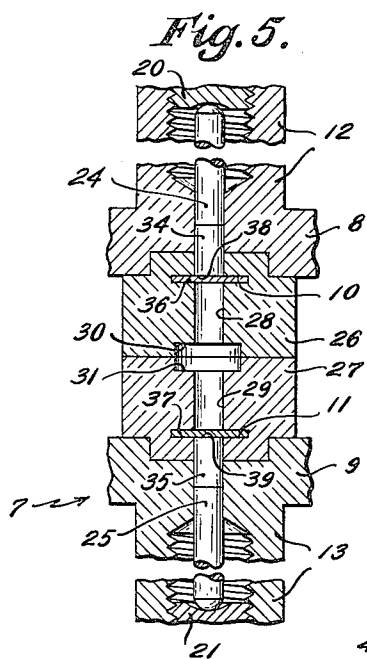
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METHOD OF MAKING ELECTRICAL CONTACTS

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3 Sheets-Sheet 2



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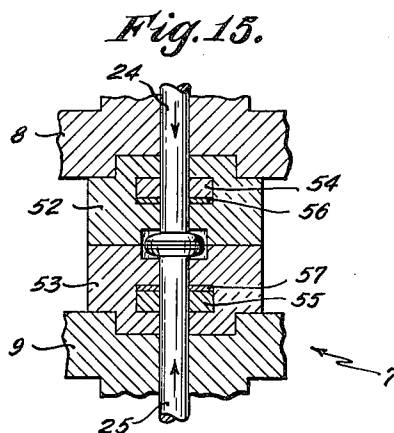
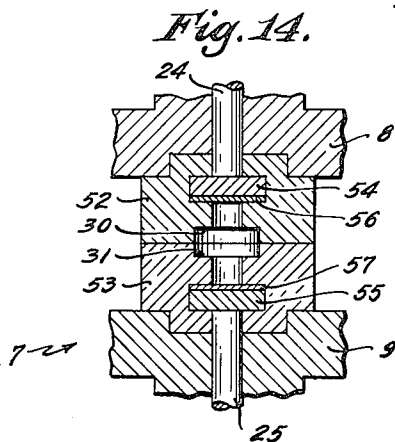
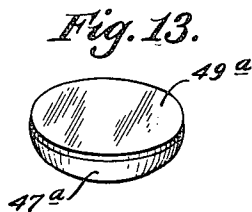
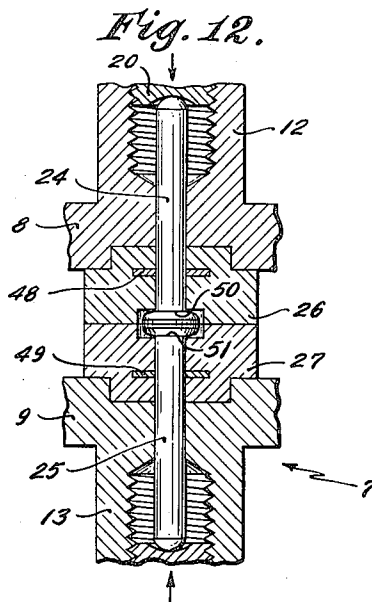
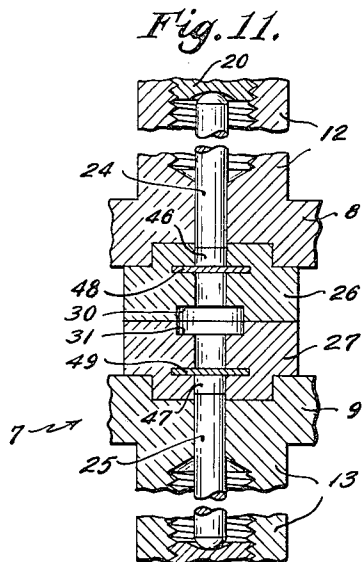
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METHOD OF MAKING ELECTRICAL CONTACTS

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3 Sheets-Sheet 3



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METHOD OF MAKING ELECTRICAL CONTACTS

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Application March 28, 1952, Serial No. 279,122

12 Claims. (Cl. 29—155.55)

This invention relates in general to the making of electrical contacts, and in particular to an improved solid phase bonding method of making composite electrical contacts.

Among the several objects of the invention may be noted an improved method for making composite electrical contacts from metals and alloys by a cold solid phase bonding operation; the provision of methods for making electrical contacts in pairs by a cold solid phase bonding operation which combines an upsetting operation as well as a bonding operation; the provision of methods of the last-named class in which each of the contacts acts as an anvil to permit the upsetting of the other of the contacts being simultaneously made; the provision of making composite electrical contacts in which the material used as a part of the composite contact forms one of the operational elements involved in punching out the contact face material from sheet stock; the provision of a method of making composite electrical contacts in which the materials are unbonded prior to a forming operation but are bonded after the forming operation; and the provision of methods of making composite electrical contacts of the above classes which are simple and economical.

Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the ingredients, the combinations of ingredients, the proportions thereof, steps and sequence of steps, and features of composition and manipulation which will be exemplified in the products and methods hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which certain features of various possible embodiments of the invention are shown:

Fig. 1 is a perspective view of an electrical contact made by the method of this invention;

Fig. 2 is a cross section in elevation of the contact of Fig. 1;

Fig. 3 is an elevation, partly in cross section, of a hand tool which serves to illustrate the steps of the methods of the present invention;

Fig. 4 is a plan view in cross section of the Fig. 3 tool taken in the direction of sight lines 4—4;

Fig. 5 is an elevation, partly in cross section, of a portion of the Fig. 3 tool, taken in the direction of sight lines 5—5, and showing an initial stage in the use of the tool in the manufacture of a rivet-type contact;

Fig. 6 is a view similar to Fig. 5 but showing a second stage in the manufacture of the contact;

Fig. 7 is a view similar to Fig. 5 but showing a third stage in the manufacture of the contact;

Fig. 8 is a view similar to Fig. 5 but showing the contact in its final stage still within the tool of Fig. 3;

Fig. 9 is a view similar to Fig. 1 but showing a rivet-

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type contact in which the contact face has been made from composite laminated sheet material;

Fig. 10 is a perspective view partly in section of a component part of the hand tool illustrated in Fig. 3;

Fig. 11 is a view similar to the view of Fig. 5, but illustrating an initial stage in a second embodiment of the invention;

Fig. 12 is a view similar to Fig. 11 but serving to illustrate the final stage in the embodiment of Fig. 11;

Fig. 13 is a perspective view of the electrical contact made by the steps of the Figs. 11 and 12 embodiment;

Fig. 14 is a view similar to Fig. 5, but serving to illustrate a third embodiment of the invention in its initial stage; and

Fig. 15 is a view similar to Fig. 14 but showing the final stage in the making of the contact by the third embodiment.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

In the several drawings, the relative thicknesses of certain components have been exaggerated for the purpose of clarity in the illustrations.

Since this invention has peculiar adaptability to the making of rivet-type contacts, the description of the invention will be set forth as applied to this type of contact. The basic steps involved are, however, applicable to so-called button-type contacts.

In the manufacture of electrical contacts of the rivet type, it is oftentimes desirable to have the head of the rivet-type contact comprise two or more layers instead of being single layered, one of these layers being the contact face metal and the other being a backing metal which may or may not be of the same metal as the shank of the rivet. (By "metal" herein is meant pure metal or its alloys). Hitherto, such laminated heads have been made by a soldering operation, in which either a headed rivet of one metal is first provided and a contact face disc of other metal is fastened thereto by soldering; or a composite laminated head, which has been blanked from composite laminated metal, is soldered to a shank to form a rivet. Where such soldering needs to be done, the heat of the soldering sometimes tends to anneal the metal of both the head and the shank of the rivet. In many cases this is not desirable. Furthermore, in the soldering operation, control of the solder as to amount and flow is sometimes difficult, especially where thin heads are being manufactured. In addition, the operation of making such a contact is a relatively slow process. These difficulties may be overcome by the methods of the present invention, whereby each of the contacts may be made from a combination of two lengths of wire, or from a length of wire and a sheet of solid or laminated contact head material, or from two sheet stock blanks; in all instances, the lengths of wire and/or sheet can be long lengths suitable for feeding automatic machinery. In addition, the composite contacts may be made from these metals at room temperature, that is, from cold metals as compared to hot metals of prior processes. Since no soldering operation is required, the contacts as formed, and particularly the head of the rivet, are in a substantially work-hardened condition with attendant longer life.

By following my invention, I have found that it is possible to bond together the metals comprising the rivet-type contact in a solid phase bonding operation without the necessity of heating the metals, while at the same time forming the desired shape of rivet. In other instances, while I may prefer to subject the metals to a heat treating operation for the purpose of improving the bond strength, which heat treating operation may tend to soften the materials, nevertheless the speed of making the contact is not thereby diminished.

Furthermore, in the practice of my invention, I make use of the invention described and claimed in my copending application, Serial No. 279,123, filed concurrently herewith, in that I form the contacts in pairs with the eventual head of one of the contacts acting as the heading tool or anvil for the other contact to form against, so that as each contact head is formed, the expansion will take place at the faces of the contacts, thus facilitating the expansion of certain metal surfaces, as will be described below.

Referring now to the drawings, in Figs. 1 and 2, respectively, are shown a perspective view and a cross sectional elevation of one embodiment of a contact made by my invention. The contact of Fig. 1 comprises a shank 1 and a head portion indicated generally by numeral 2. As indicated, head portion 2 comprises a contact face layer 3 and an underneath head portion 4 which is formed from the metal of shank 1 during the operation of making the contact. I have shown this contact as a preferred embodiment, but it should be realized that head 2 can instead comprise three or more layers. This is shown in Fig. 9, in which the top layer is the contact face material 3, an intermediate top layer 5 is another metal, and the underneath head portion 4 is formed from the metal of the shank during the operation of making the contact.

The contact of Fig. 1 is made from a piece of wire which supplies the shank of the finished contact and part of the head, and the contact face portion 3 is made from sheet metal. The wire of the shank portion is preferably round in cross-section, but may have other shapes in cross section, such as square, pentagonal, hexagonal, etc.

Referring now to Fig. 3, there is shown a tool (indicated generally by numeral 7) which may be used to produce the Fig. 1 contact. Tool 7 is not a part of this invention, but a description of it will now be given in order to describe more adequately the steps of my invention. It will be understood that the basic operational steps used in tool 7 are the same basic steps that may be used in high speed automatic machinery in practicing my invention. Tool 7 is therefore used for illustrative purposes herein, because with it the steps of the invention may clearly be followed.

Tool 7 comprises the co-operating dies 8 and 9. For the purpose of illustrating this embodiment of the invention, dies 8 and 9 are made identical, and are of steel. Each of dies 8 and 9 has, respectively, the opposing faces 10 and 11, and integral therewith, the upstanding hubs 12 and 13. Each die is provided axially with bores 14 and 15 and is provided with recesses 16 and 17, respectively, in faces 10 and 11. Upstanding hubs 12 and 13 are each provided, respectively, with internally threaded bores 18 and 19. All of the said bores and recesses are axially aligned. Bores 18 and 19 are preferably larger than bores 14 and 15. Recesses 16 and 17 are also larger than bores 14 and 15. Pressure screws 20 and 21 are threadably fitted into bores 18 and 19, respectively, and their inner ends are provided with recesses 22 and 23, as shown, for non-slipping engagement with the ends of plungers 24 and 25 (described below). Recesses 16 and 17 are snugly fitted with die blocks 26 and 27 as indicated and which are preferably made of steel. Die blocks 26 and 27 are respectively provided with bores 28 and 29 which are axially aligned with and have the same size and cross-sectional shape as bores 14 and 15. The opposing faces of dies 26 and 27 are provided with enlarged recesses 30 and 31, axially aligned with bores 28 and 29, and the purpose of which will be described hereinafter.

As shown in Fig. 10, each of die blocks 26 and 27 has a slot 32 and 32a, respectively, traversing the die block at right angles to bore 28 and through which, as will be described later, is to be fed the sheet material from which the contact face 3 will be formed.

Fitting snugly but slidably in each of bores 14 and 15 (and therefore also bores 28 and 29) are plungers 24 and 25 respectively. Plungers 24 and 25 correspond in shape

with the cross-sectional shapes of bores 14 and 15 respectively, and 28 and 29 respectively, and are preferably made of steel.

Holes are provided in each of face plates 8 and 9 whereby said face plates may be fastened together in face to face relationship as shown by means of bolts 33, the face plates being clamped together so that the opposing faces of die blocks 26 and 27 are pressed together firmly.

The method of making a rivet-type contact with this tool will now be described: Prior to clamping together the dies 8 and 9 as described above, bore 14 is loaded with a length of wire 34 which is to comprise the shank and a portion of the head of the electrical contact, wire 34 corresponding in shape to the cross sectional shape of bore 14 and slidably fitting therein. Similarly, a length of wire 35 is loaded into bore 15, wire 35 comprising the shank and a portion of the head of the other of the pair of contacts that are to be made by this tool. After the loading of wires 34 and 35 is done, a sheet of contact face material 36 is fed via slot 32 through die block 26, and similarly another sheet of contact material 37 is fed via slot 32a in die block 27. Materials 36 and 37 can be, for example, pure silver, or coin silver, or other silver alloys or other contact materials such as gold, gold alloys, or platinum, for example.

Prior to the loading of wires 34 and 35 into their respective bores, the ends 38 and 39 respectively of wires 34 and 35 are cleaned as by scratch brushing to remove grease and other films of extraneous matter, such as oxide layers, sulphide layers, and adsorbed water films. It is essential to maintain these surfaces free from oxide films or other deleterious films until the squeezing operation described below is done. This can be accomplished by doing the cleaning just prior to the squeezing operation described below, or by maintaining the metals in protective atmospheres between the time they are cleaned and the time they are bonded by said squeezing operation. Similarly, surfaces 40 and 41 of materials 36 and 37, respectively, are cleaned of foreign matter. A trace of oil or some other foreign material, such as lead oxide, or lacquer, which will be hereinafter referred to as parting material, is placed on or is left (if already present) on the opposing surfaces 42 and 43 of materials 36 and 37, respectively, which later come in contact with each other.

The above-mentioned squeezing operation will now be described: The dies 8 and 9 are now clamped together with bolts 33, to bring dies 26 and 27 firmly together. Screws 20 and 21 are then turned so that they bear against plungers 24 and 25 to force these plungers towards each other. As plungers 24 and 25 are forced towards each other, they respectively force wires 34 and 35 against the corresponding sheet materials 36 and 37. As the inward motion is continued, wires 34 and 35 act as punches to punch out of the respective sheets 36 and 37 discs 44 and 45 of material the same cross sectional shape as wires 34 and 35. (Due to the slight burring action encountered in each of the dies, a burr from each of these discs will be drawn backward against its respective punching wire so as to hold the punched-out disc to the end of the respective wire.)

This motion inward is continued until the position of the wires 34 and 35 with their respective discs 44 and 45 is that shown in Fig. 6, that is, discs 44 and 45 meet approximately in the center space provided between die blocks 26 and 27 by the recesses 30 and 31 respectively. At this point, it will be observed that between wire 34 and disc 44 there is nothing but thoroughly cleaned surfaces (as described above), and that the same situation exists between the wire 35 and disc 45; but that between the opposing faces of discs 44 and 45, there is at least one layer of parting material as described above. The purpose of this parting material is to prevent the opposing surfaces of discs 44 and 45 from bonding together during the subsequent bonding operation of each wire to its respective disc, now to be described.

The inward motion of screw 20 and 21 and thus

plungers 24 and 25 is continued. As this is done, it will be observed that the contact face material discs 44 and 45, together with the abutting respective ends of wires 34 and 35, begin to expand outwardly as shown in Fig. 7. This expansion is the beginning of both the forming of the head of the contact and the bonding of each wire to its respective disc which forms the contact face of the finished electrical contact. As described in my said copending application, it will be observed that as, for example, disc 44 expands outwardly, the anvil against which it is expanding is the corresponding disc 45 and that disc 45 is also expanding outwardly. The expansion of two discs will be approximately the same if the discs are made of the same material and the two materials have approximately the same ductility. Since the outward motions are approximately the same, the face portion of each contact is not hindered in its outward flow, and hence expansion will take place at the face.

The inward motion of plungers 24 and 25 is continued further until the outward flowing of discs 44 and 45 and the inner ends of wires 34 and 35 is brought to a completion in the final form of the contact as shown in Fig. 8.

The importance in this invention of permitting the relatively free outward expansion of discs 44 and 45, and also the concurrent expansion of the ends of wires 34 and 35 adjacent thereto is apparent when it is realized that one of the criteria for successful cold solid phase bonding is that the surfaces to be bonded together be allowed to increase in area. By such increase in area, virgin metal surfaces are created which, upon being pressed firmly together, bond to each other in many spots in true atomic bonding. These metallurgically bonded spots I call nucleal bonds, since they serve as nuclei from which larger bonds grow with proper heat treatment, as will be described below. In addition, the expansion of the surfaces also serves to attenuate any residual tenacious films to the point where they do not prevent the formation of nucleal bonds; and if brittle oxides are present (as in the case of some metals, such as aluminum), the expansion will break apart the oxide films to expose virgin metal surfaces.

At this point, the dies are separated and the two formed contacts (as shown in Fig. 1) are removed from the die blocks 26 and 27.

If it is desired to utilize the mutual expansion step described above plus the bonding, but with wires substituted for the sheet metals 32 and 32a, all that is necessary is to load each of the dies with the proper lengths of wire to be used as the contact faces, and thereafter follow the above described forming operations.

Referring now to Fig. 9, there is shown a contact in which the head comprises two metals, and the shank may be a third metal; that is, the face 3 may be of silver, the layer 5 may be of copper, with the shank 1 and shank head 4 being of steel. In the manufacture of this contact, the procedure to be followed may be that described above to make the Fig. 1 contact, except that layers 36 and 37 will now be composite layers comprising silver bonded to copper, for example, the bonding being done by any of well-known prior art means. Or, if desired, layers 36 and 37 may each, respectively, comprise a layer of silver superimposed on, but not bonded to, a layer of copper. When the continuous surfaces of these metals have been carefully cleaned, as described above, it will be found that the punched out discs of silver and copper will bond together and the copper will bond to the metal of the shank, all as described above for the case where layers 36 and 37 are single layers.

Referring now to Figs. 11, 12 and 13, there is illustrated the making of button-type contacts using the steps described above, and the contact produced thereby. In this instance, the wires 46 and 47 which will comprise the backs of the respective buttons are made shorter than the wires used for making the rivet-type contacts. The sheet materials 48 and 49 used for the contact face materials may be the same materials as specified for the rivet-

type contacts. The same cleaning operations as described above are used. Fig. 11 illustrates the materials loaded in the dies prior to any punching or forming operations, a parting layer being used as described above for the Fig. 1 embodiment. Fig. 12 shows the contact button in its finished stage but still within the dies, the materials having been expanded and bonded by the inward motions of plungers 24 and 25 as described above. In this instance, it will be observed that the inner ends 50 and 51 of plungers 24 and 25 are brought to rest in a position such that the surfaces formed on the copper (used, for example, as the backs of the contacts) by these inner ends will approximate a continuation of the rest of the copper surfaces of the contacts. If desired, the inner ends of plungers 24 and 25 may be shaped to impart a given shape to the contacts. Fig. 13 shows the contact produced by the above operations, layer 49a being, for example, silver and the back of the contact 47a being, for example, copper.

Referring now to Figs. 14 and 15, there is illustrated another embodiment of the invention in which sheet materials are used for making button-type contacts instead of the combination of sheet and wire. Referring to Fig. 14 specifically, dies 8 and 9 correspond to the dies already described. Die blocks 52 and 53 are similar to die blocks 26 and 27, except that the blocks are made a little bit thicker in order to accommodate the additional sheet material as described below. Die block 52 is loaded with sheet materials 54 and 56 and similarly, die block 53 is loaded with sheet materials 55 and 57. Materials 56 and 57 correspond to the sheet materials 48 and 49 of Figs. 11 and 12. Sheet materials 54 and 55 take the place of wire lengths 46 and 47. It is to be noticed that sheet 54 is not bonded to sheet 56, and sheet 55 is not bonded to sheet 57, and this emphasizes the fact that all bonding is done in the squeezing operation.

Prior to the loading of sheets 54, 55, 56 and 57 into the respective die blocks, the surfaces of sheets 54 and 56 which touch each other are first carefully cleaned as described above, and similarly the touching surfaces of sheets 55 and 57 are carefully cleaned. A parting layer is placed on at least one of the inner surfaces of sheets 56 and 57 for the purpose described above in connection with the Fig. 1 embodiment.

With the materials thus loaded, plungers 24 and 25 are forced together by means of screws 20 and 21 toward the center of the die cavity provided between die blocks 52 and 53. As they come together, plunger 24 punches two discs from the sheets 54 and 56 and similarly plunger 25 punches two discs from sheets 55 and 57. Each set of discs therefore consists of the paired components for a contact. The inward motion of plungers 24 and 25 is continued (while maintaining the paired components together) until the inner opposing faces of sheets 56 and 57 meet at approximately the center of cavity provided by the die blocks. The inward motion is then further continued to cause the above-described lateral expansion of the respective contact materials, to produce the contact button shown in Fig. 15 in its formed state. The finished contact button is similar to that illustrated in Fig. 13.

In regard to the amount of cold flowing outwardly that is necessary to obtain the bond between, for example, the end of wire 34 and disc 44, I have found that if the flowing is continued until the diameter of the expanded portion of the wire 34 and disc 44 at the interface therebetween is such that the area of the interfacial junction is at least approximately $3\frac{1}{2}$ to 4 times the original abutting area of whichever of the two elements (34 or 44) has expanded the less, then it will be found that across the interfacial area between the wire 34 and disc 44, there will be a true metallic bond, the nature of which will be described hereinafter.

If it is not desired to cold flow the materials to the extent indicated above, or in cases where it is found that some metals will not give a sufficient bond strength with

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the above indicated amount of cold flowing, then the formed contact may be heat treated to improve the original bond so formed.

The $3\frac{1}{2}$ to 4 times area increase specified above is primarily adapted for operations where no heat treating is to be thereafter done. If heat treating is not objectionable, it will be found that a lateral expansion such that the final interfacial area is approximately $2\frac{1}{2}$ to 3 times the initial abutting area of the material which has expanded the less, will produce a satisfactory commercial bond if it is followed by the heat treating operation. The heat treatment should be above the minimum recrystallization temperature of that material which has the lowest recrystallization temperature.

The nucleal bond is, as stated above, a true metal-to-metal bond wherein the atoms of one of the metals are within range of the atomic attraction of the atoms of the other metal. This engagement of atoms occurs in randomly distributed spots over the interface between the metals, the number of spots being determined by the nature of the metals, the amount of expansion of the interface from the original areas indicated in Fig. 3 to the final interfacial area in the contact, and the force with which the two metals are squeezed together. For some metals, the nucleal spots are sufficiently numerous and extensive that the bond is strong enough for commercial usage as it is made in the tool without any subsequent heat treating. For other metals, I prefer to use a heat-treating operation to increase the extent of the interfacial bond and therefore its strength. By heat treatment I mean subjecting the formed contact to a temperature which is above the lowest recrystallization temperature of the metal having the lower recrystallization temperature. By such a heat treatment, the nucleal bonds formed by the above-described cold-working operation are caused to grow laterally so as to increase the area of true atomic bond between the metals comprising the contact.

In the practice of my invention, I have found it necessary carefully to clean the butting surfaces of the metals prior to the bonding operation. I prefer to use abrasive methods for this, and in practice I have found that filing or scratch brushing the surfaces is adequate to remove any films that would tend to prevent the nucleal bond from forming. Oils, greases, oxide films, and other gross contaminants should be carefully avoided, films of contaminants should be carefully avoided, and films of contaminating material of molecular thicknesses should also be removed. In the case of wires, instead of filing, a portion of the end of each wire may be sheared off cleanly just prior to bonding, thus presenting new virgin surfaces for bonding. In all cases of cleaning, it is desirable to remove gross contaminants from the sides of the materials also, in order to prevent gross contaminants from being dragged across the ends of the wires during the cleaning operations.

The following examples will illustrate the operation of the invention in practice:

Example 1

Two wires of copper, each approximately .093 inch in diameter, having a Vickers hardness of 55, were used for wires 34 and 35. Each wire was approximately $\frac{3}{16}$ inch long. Sheet material of fine silver, approximately .012 inch in thickness, having a Vickers hardness of approximately 45, was used for contact face materials 36 and 37. This material was approximately $\frac{1}{8}$ inch wide. The aforesaid wires and sheet materials were inserted in the respective dies in the manner described above, and the dies were then clamped together as aforesaid. (Prior to the respective insertions and clamping together, the materials were cleaned as described above, and a parting layer of lacquer was placed on the opposing surfaces of the silver sheet material.) In the clamped together condition, the cavity formed by the die blocks 26 and 27 was approximately $\frac{3}{16}$ inch in diameter and approxi-

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mately .090 inch high. Screws 20 and 21 were then turned to force the copper wires against their respective sheet materials and punch therefrom silver discs as described above. The inward motion of the screws was continued until the silver discs were brought into opposition bearing against each other approximately in the center of the die cavity, and then the inward motion was further continued until the ratio of the area of the expanded junction to the cross sectional area of the copper wire used was approximately four to one. A good bond, commercially satisfactory, was obtained. Using the same metals and the same procedure, the test was repeated but this time with an area increase of only three times, and a relatively poor bond was obtained. However, this relatively poor bond was then changed to a good bond by the heat treatment described above, the temperature used being approximately 850° F.

Example 2

In a manner similar to that described above, another test was made using a combination of copper wires and platinum sheet. Each of the wires 34 and 35 was the same as described in Example 1. The platinum was used as the sheet material for the contact face, and was approximately .010 inch thick by $\frac{1}{8}$ inch wide. Its Vickers hardness was approximately 45. Again, the cleaning operations described above in connection with Example 1, were performed and a lacquer parting layer was used. Again, the motion of screws 20 and 21 was continued to cause the copper wires to punch from the platinum sheets the platinum discs later to comprise the contact faces, and having brought the opposing platinum discs together in approximately the center of the die cavity formed between die blocks 26 and 27, the inward motion was continued until the ratio of the area of the expanded junction to the cross sectional area of the copper wire used was approximately four to one. The finished contacts were then heat treated and a commercially satisfactory bond was obtained, the heat treating operation being at approximately 900° F.

Example 3

Again wires 34 and 35 in each case comprised copper wires approximately .093 inch in diameter, each having a Vickers hardness of approximately 55. The length of each wire in the tool was approximately $\frac{3}{16}$ inch. The material for the contact faces, in this instance, was sheets of composite laminated stock, the two laminations being silver and copper. This latter material was first made by firmly bonding the component layers together in any manner well known to the trade, and the material was then rolled down until it was approximately .010 inch overall thickness, each component being approximately .005 inch in thickness. The material was then slit to give a strip approximately $\frac{1}{8}$ inch wide. The copper wires were inserted in the tools in the manner described above, and the composite sheet materials of copper and silver were inserted in the respective dies with the silver side facing, in each instance, the respective die cavities 30 and 31. That is, the ends of the copper wires 34 and 35 were in abutment with the copper sides of the composite sheet material. As before, the cleaning operations and additions of the parting layers were carried out, prior to the clamping together of the dies. Again the same motions of screws 20 and 21 and plungers 24 and 25 were caused so that the copper wires first punched out discs from the composite sheet materials, and then the component parts were brought together and expanded, all as described above. In this instance, the area increase ratio used was three to one, and thereafter the contacts were heat treated at approximately 900° F. The bond produced was a commercially satisfactory bond.

Example 4

In this example, a button type contact was made, as

follows: For the back of each contact, a copper wire was used for wires 34 and 35. Each wire was approximately .093 inch in diameter and approximately .080 inch long. The sheet materials to be used for the contact faces was in each instance silver approximately .012 inch thick and approximately 1/8 inch wide. These materials were loaded in the dies as aforesaid and were squeezed together until essentially all of the copper wires had expanded to permit the inner ends of plungers 24 and 25 to form the back faces (copper) of the finished buttons. In this case, the expansion ratio was four to one, and the finished buttons were heat treated at approximately 850° F. A commercially satisfactory bond was obtained.

Several things influence the formation of a nuclear bond using the above techniques, such as the individual hardness of the metals being used, the relative hardness of the two metals, and the amount of cold working performed in the process.

In regard to the hardness of each of the metals, each must be of a hardness such that within the limits of the particular apparatus used to expand the metals at the joint, sufficient force can be applied so that the joint will be expanded to give an area increase of approximately 3 1/2 to 4 for a good bond without heat treatment, and an area increase of approximately 2 1/2 to 3 for a good bond to be obtained with heat treatment. Preferably, the relative hardnesses of the metals should be such that the amount of cold flow occurring in each piece is approximately the same. If this is not possible, then it is necessary that the metal that flows the less does flow sufficiently so that its expanded area bears a relation to its original cross sectional area as indicated above.

In regard to the ductility of the metals, both metals preferably should be ductile enough to permit cold flow to the above indicated extent without deleterious cracking at the perimeter of that portion which cold flows. (For example, a free machining brass has a tendency to crack extensively at the perimeter, thus relieving to some extent the forces involved and resulting in a poor bond if the above ratios are observed.)

After the above bonding operations, it may be desirable to coin the finished contact face or shank to smooth or shape it. If the materials of discs 44 and 45 are fairly close in their ductility, the interface between discs 44 and 45 which is maintained as a separable interface by the layer of parting material, will be found to be substantially flat. It may be desired, therefore, to change the shape of this flat face to some other shape suitable for the particular purpose to which the contact is to be put. Where the above bonding operation will produce a good bond without heat treatment adequate to withstand such coining operation, I propose to perform the coining immediately after the above operation. In those cases where the combination of metals is such as to make it desirable to heat treat if no coining is to be done, I have found in some cases that if a coining operation is performed which increases the expanded area to the proper amount, then no heat treatment is needed. Therefore, my invention includes, as a step in some cases, the substitution of a coining operation for further expansion instead of the heat treatment step, as well as a coining operation for the above-mentioned smoothing, sizing or shaping.

While I have illustrated the steps of the invention by means of what may be referred to as a hand-tool, or a hand-operated set of forming dies, it is manifest that the invention may be carried out by means of fully automatic heading machines to obtain high speed manufacture of electrical contacts. The basic steps of the invention would thus be utilized: (1) providing metals which are to form the shank (or backing) of the contact and the contact face; (2) cleaning surfaces of the materials; (3) forcing the cleaned surfaces of the materials together under pressure to cause an expansion in area of the mated, cleaned surfaces of the materials sufficiently to cause the formation of nuclear bonding; and (4) an optional coin-

ing and/or heat treatment of the contact to increase the strength of the bond. Such operations can be readily accomplished on automatic heading machines and since the details of such machines are not a part of this invention, no further details pertaining thereto need be given here.

In view of the above, it will be seen that the several objects and advantages of the invention are achieved and other advantageous results attained. As many changes could be made in carrying out the above steps of the methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact face metal having a cleaned surface and providing a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and providing a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together to form a pair, and placing said cleaned surfaces of the second contact face metal and the second backing metal together to form another pair; placing one of the remaining exposed faces of one pair in opposition to one of the remaining exposed faces of the other pair with a parting layer therebetween; and thereafter forcing said pairs toward each other along a common axis to cause an outward flowing of said contact face metals and said backing metals at the junctions of said cleaned surfaces until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots.

2. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact face metal having a cleaned surface and providing a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and providing a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together, and placing said cleaned surfaces of the second contact face metal and the second backing metal together; placing the other faces of said contact face metals in opposition to each other with a parting layer therebetween; and thereafter forcing said backing metals towards each other along a common axis to cause an outward flowing of said contact face metals and said backing metals at the junctions of said cleaned surfaces until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots.

3. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact face metal having a cleaned surface and providing a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and providing a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together to form a pair, and placing said cleaned surfaces of the second contact face metal and the second backing metal together to form a pair; coating a remaining exposed surface of at least one of said pair with a parting layer and placing said coated surface against a remaining exposed surface of the other pair; and thereafter forcing said pairs toward each other along a common axis to cause an outward flowing of said contact face metals and said backing metals at the junctions of said cleaned surfaces, thereby to cause an inter-

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facial area increase of said cleaned surfaces sufficient to permit the formation of many discrete bonds at the interface between said first contact base metal and its backing metal, and between said second contact face metal and its backing metal, said outward flowing being continued until the area of the interfacial junctions of said pairs of metals is at least $3\frac{1}{2}$ times the original abutting area of that cleaned surface which has flowed the less.

4. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact face metal having a cleaned surface and providing a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and providing a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together to form a pair, and placing said cleaned surfaces of the second contact face metal and the second backing metal together to form a pair; coating a remaining exposed surface of at least one of said pairs with a parting layer and placing said coated surface against a remaining exposed surface of said other pair; and thereafter forcing said pairs towards each other along a common axis to cause an outward flowing of said contact face metals and said backing metals at the junctions of said cleaned surfaces, thereby to cause an interfacial area increase of said cleaned surfaces sufficient to permit the formation of nucleal bonds at the interface between said first contact base metal and its backing metal, and between said second contact face metal and its backing metal, said outward flowing being continued until the area of the interfacial junction of each of said pairs of contacts is at least $2\frac{1}{2}$ times the original abutting area of that cleaned surface which has flowed the less; and thereafter heat treating the composite contacts at a sufficient temperature and for a sufficient length of time to cause said nucleal bonds to grow laterally.

5. The method of forming a rivet type composite electrical contact having a contact face metal portion united to a shank portion, comprising providing a piece of malleable contact face metal having a cleaned surface, providing a length of malleable shank wire having a cleaned end, and bringing said cleaned end and surface together; providing a second piece of malleable contact face metal having a cleaned surface and a second length of malleable shank wire having a cleaned end, and bringing said cleaned end and surface together; coaxially aligning said shank wires with said contact face metals therebetween in opposition to each other with a parting layer therebetween; and forcing said shank wires together coaxially to cause the cleaned end of each of said wires and the cleaned surface of each of said contact face metals to flow outwardly until the cleaned surface of each contact face metal becomes cold welded to the cleaned end of its mating shank wire in many discrete spots while simultaneously forming each set of contact metal and shank wire into a headed structure.

6. The method of claim 5, wherein said flowing is continued until the area of the interfacial junction between the flowed portions of said contact face metals and said shank wires is at least $2\frac{1}{2}$ times the original abutting area of that material which flows the less, whereby nucleal bonds are formed between said contact face metals and the respective shank wires, and thereafter heat treating the composite nucleal bonded contact at a sufficient temperature and for a sufficient time to cause said nucleal bonds to grow laterally.

7. The method of making a composite rivet type electrical contact having a face metal portion united to a backing metal portion, comprising providing a first predetermined length of wire of malleable backing metal having a cleaned end, using the cleaned end of said first wire to punch out from cleaned sheet metal a first disc of malleable contact face metal substantially the diameter of said first wire; providing a second predetermined length

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of wire of malleable backing metal having a cleaned end and using said cleaned end of said second wire to punch out from cleaned sheet metal a second disc of malleable contact face metal substantially the diameter of said second wire; placing said discs in opposition to each other with a parting layer therebetween with said backing metal wires aligned therewith coaxially; and thereafter forcing said wires together coaxially to cause said contact face disc and said backing metal of each combination of face metal and backing metal to flow outwardly against the contact face metal and backing metal of the other combination; said flowing being continued until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots.

8. The method of claim 7, wherein said flowing is continued until the area of the interfacial junction is at least $2\frac{1}{2}$ times the original abutting area of that cleaned surface which has flowed the less, and thereafter heat treating the composite nucleal-bonded contact at a sufficient temperature and for a sufficient time to cause said discrete spots to grow laterally.

9. The method of forming composite electrical contacts having a contact face metal portion joined to a backing metal portion, including providing a pair of dies spaced apart in opposition to each other, each die being provided with a bore axially aligned with the bore in the opposite die; providing a sheet of first malleable metal in each of said dies arranged at right angles to the bore of the respective die, with that surface of each of said sheets being cleaned which is remote from the other sheet, and at least one of the adjacent surfaces of said sheets being covered with a layer of parting material; providing a length of malleable metal wire in the bore of each die adjacent to the cleaned surface of each of said sheets of first metal, with the ends of said wires adjacent to the cleaned surfaces of said first metal also being cleaned; and causing each of said wires to move towards the other in its respective bores with a force sufficient to penetrate the adjacent sheet of said first metal and punch there from a disc of first metal; moving said wires to bring the opposing surfaces of said discs together with the parting layer therebetween; and thereafter moving said wires toward each other sufficiently to cause the cleaned ends of said wires and said discs to expand outwardly, said moving being continued until the interfacial area of the expanded portions is such that the expanded area of that metal which has expanded the least is at least $2\frac{1}{2}$ times the original area of that metal whereby bonds are formed in many discrete spots between the cleaned surfaces of each of the first metals and its corresponding length of metal wire; and thereafter heat treating the composite contact at a sufficient temperature and for a sufficient length of time to cause said discrete spots to grow laterally.

10. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact face metal having a cleaned surface and providing a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and providing a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together to form a pair, and placing said cleaned surfaces of the second contact face metal and the second backing metal together to form another pair; positioning said backing metals with the said contact face metals therebetween and with a parting layer between the butting surfaces of the said contact face metals; and thereafter forcing said backing metals toward each other to cause an outward flowing of the contact face metal and backing metal at the junctions of said cleaned surfaces until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots, each of said pairs

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acting as an expanding anvil to permit lateral expansion of the other pair.

11. The method of making a composite button-type electrical contact having a face metal component united to a backing metal component, comprising providing a first sheet of malleable backing metal having a cleaned surface, and providing a first sheet of malleable contact face metal having a cleaned surface; providing a second sheet of malleable backing metal having a cleaned surface, and providing a second sheet of malleable contact face metal having a cleaned surface; placing the cleaned surfaces of said first sheet of backing metal and first contact face metal together; placing the cleaned surfaces of said second sheet of backing metal and second contact face metal together; punching paired components from each combination of backing metal and contact face metal while maintaining said paired components together; bringing said paired components together in surface abutment with a parting layer therebetween; and thereafter forcing said paired components together along a common axis to cause the contact face metal and backing metal of each set of paired components to flow outwardly against the contact face metal and backing metal of the other paired components, said flowing being continued until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots.

12. The method of forming composite electrical contacts having a contact face metal united to a backing metal, which comprises providing a first malleable contact

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face metal having a cleaned surface and a first malleable backing metal therefor having a cleaned surface; providing a second malleable contact face metal having a cleaned surface and a second malleable backing metal therefor having a cleaned surface; placing the cleaned surfaces of said first contact face metal and said first backing metal together to form a pair, and placing the cleaned surfaces of the second contact face metal and the second backing metal together to form a pair; positioning said backing metals with the said contact face metals therebetween and with a parting layer between the butting surfaces of the said contact face metals; and thereafter forcing said backing metals towards each other to cause an outward flowing of said contact face metals and said backing metals at the junctions of said cleaned surfaces until the cleaned surface of each contact face metal becomes cold welded to the cleaned surface of its mating backing metal in many discrete spots, and thereafter coining the bonded composite contacts to increase further said interfacial area and thereby to strengthen said bond.

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