

[72] Inventors Takane Tsuchiya
Yokohama-shi;
Tetsuya Ohtani, Yokohami-shi; Akira Sato,
Tokyo; Syoichi Ito, Yokohama-shi, all of
Japan
[21] Appl. No. 882,456
[22] Filed Dec. 5, 1969
[45] Patented Nov. 23, 1971
[73] Assignee Tokai Denki Kabushiki Kaisha
Tokyo, Japan
[32] Priorities Aug. 5, 1969
[33] Japan
[31] 44/61590;
Aug. 7, 1969, Japan, No. 44/62106

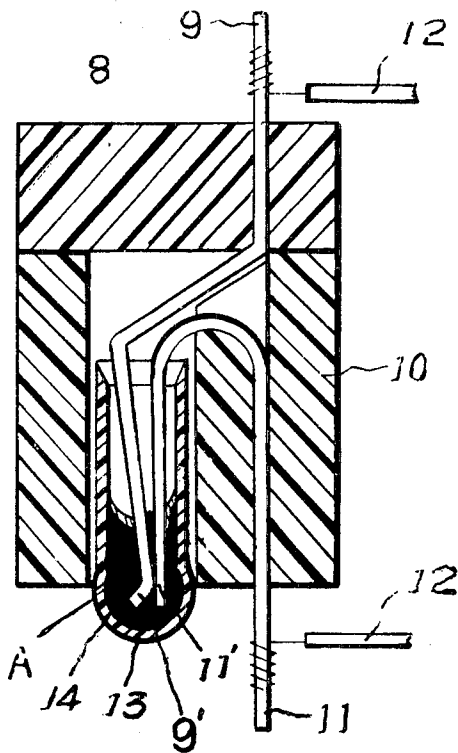
[54] ELECTRICAL CONNECTOR
6 Claims, 14 Drawing Figs.
[52] U.S. Cl. 339/118 R,
339/275 T, 339/278 C
[51] Int. Cl. H01r 3/08

[50] Field of Search..... 339/118,
275, 278; 29/194, 199

[56] References Cited
UNITED STATES PATENTS
3,023,393 2/1962 Oliver..... 339/118
3,184,303 5/1965 Grobin 75/134

Primary Examiner—Joseph H. McGlynn
Attorney—Marshall & Yeasting

ABSTRACT: In this electrical connector, an electrical connection is made through a low melting point alloy consisting essentially of gallium and indium which is liquid at room temperature. In order to retain the low melting point alloy, contact points may be made of a porous solid material impregnated with the low melting point alloy, or may be made of cadmium, bismuth or lead having interfaces between which the low melting alloy is precipitated. In any case, gallium may be provided at one contact point and indium at the other contact point, so that when the two points are brought together the low melting point alloy is formed.



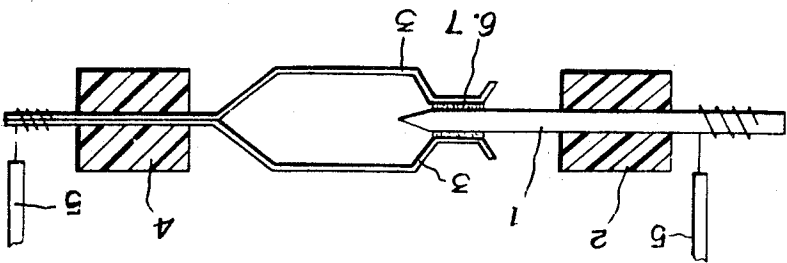


FIG. 3.

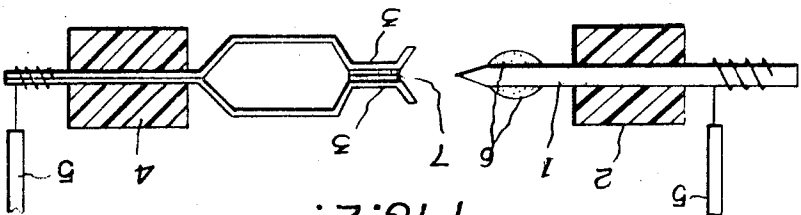


FIG. 2.

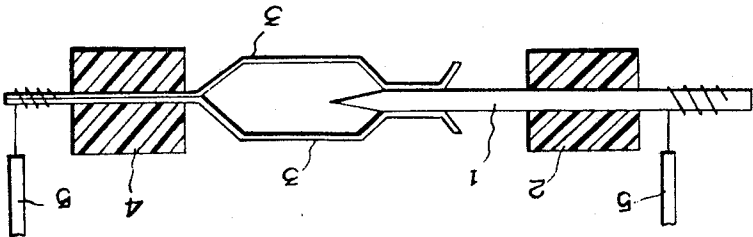


FIG. 1.

FIG. 4.

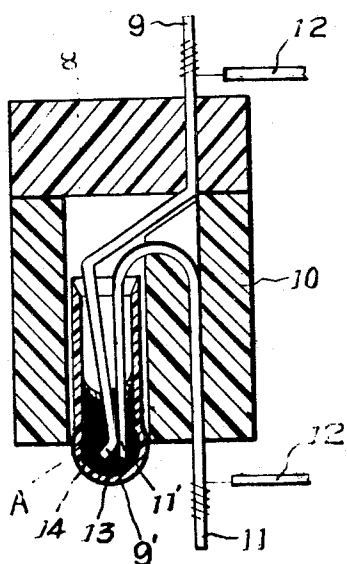


FIG. 5.

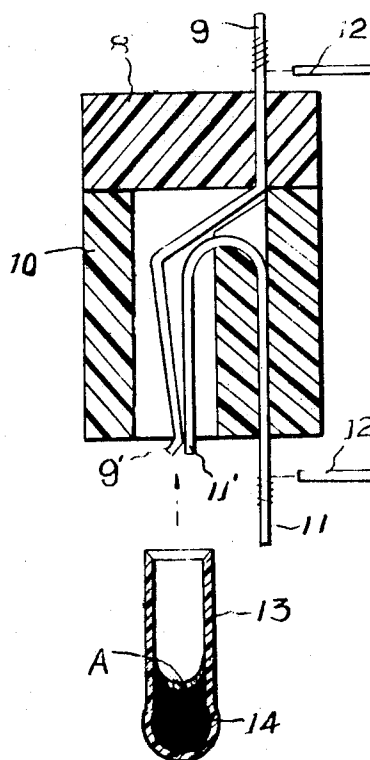


FIG. 6.

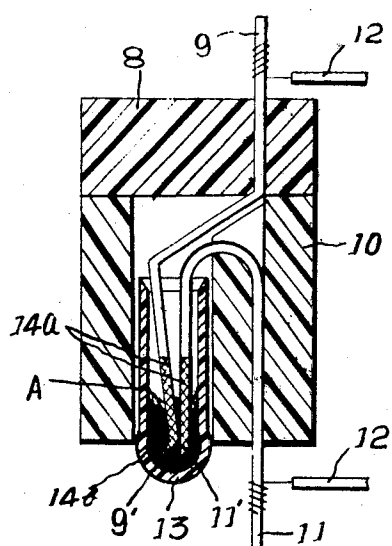


FIG. 7.

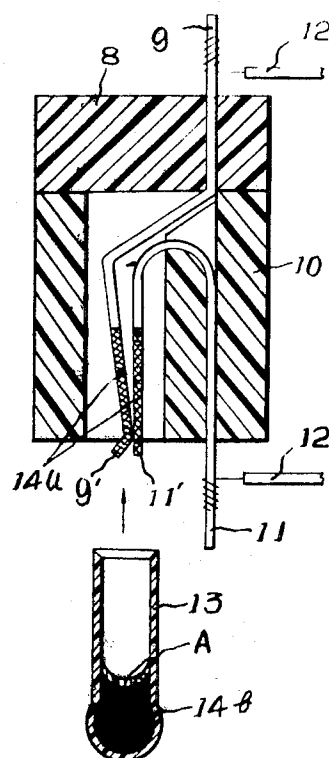


FIG. 8.

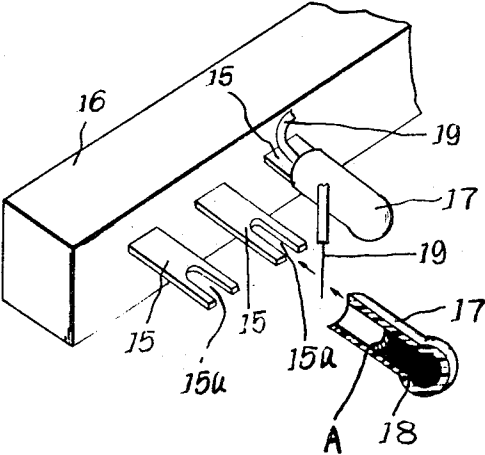


FIG. 9.

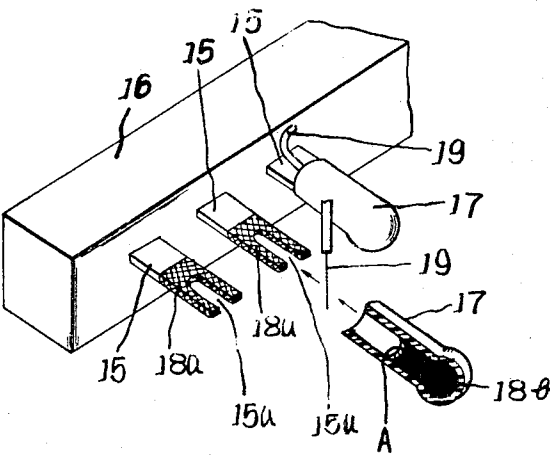


FIG. 10.

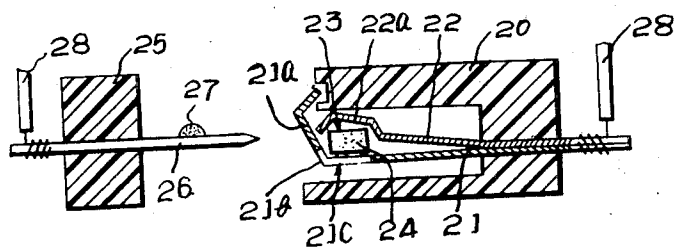
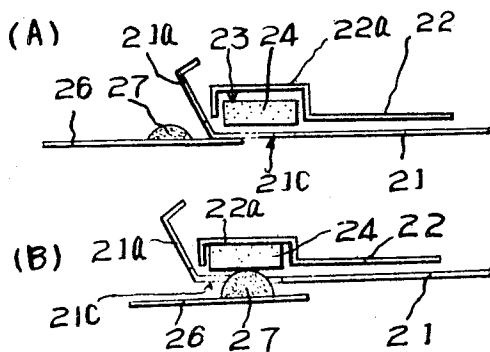
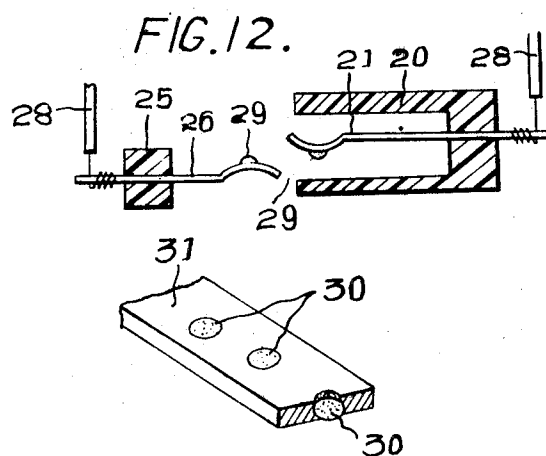
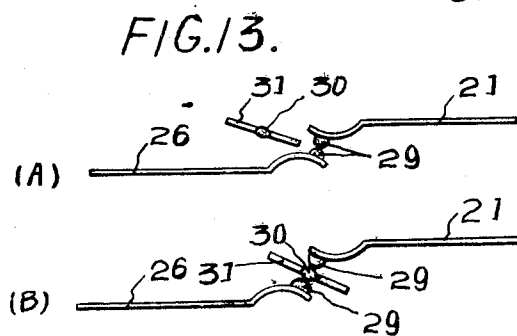
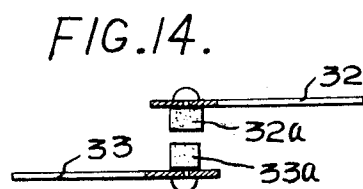


FIG. 11.





ELECTRICAL CONNECTOR

BACKGROUND OF THE INVENTION

This invention relates to an electrical connector which can be used for connecting electrical conductors in various types of electrical apparatus, such as communication equipment, electrical machinery and other electrical equipment.

In the known electrical connectors, it is conventional to form an electrical connection by holding contact surfaces together under pressure.

In such known electrical connectors, the contacting surfaces are gradually corroded or contaminated by the action of the atmosphere, so that the electrical resistance across the connection gradually increases. Under such conditions, the minimum force with which the contacting surfaces must be held together in order to provide a certain minimum resistance across the connection gradually increases. Because of the modern tendency toward miniaturization of electrical apparatus, the contact pressure which can be provided is limited, so that it is not possible to employ high contact pressure in order to maintain the desired low resistance across a pair of contacts.

SUMMARY OF THE INVENTION

The present invention overcomes these and other disadvantages of the known connectors and affords additional advantages. In an electrical connector embodying the present invention, an electrical connection is made through a low melting point alloy consisting essentially of gallium and indium which is a liquid at room temperature. The preferred alloy is a eutectic alloy of gallium and indium.

A primary object of the invention is to provide a low contact resistance by forming an electrical connection through an alloy which is a liquid at room temperature, consisting essentially of gallium and indium, which is present on the contacting surfaces.

A secondary object of the invention is to prevent the gradual increase which takes place in the resistance of the known connectors, so that high contact pressure is not required.

Other objects of the invention are to eliminate the need for periodic cleaning of contacts, to eliminate the need for appreciable contact pressures, and to make it possible to produce perfect and permanent electrical connections by mere assembly without the use of complicated operations such as soldering. A permanent, solid connection may be achieved in the practice of the present invention, by providing, in contact with the indium-gallium alloy which is a liquid at room temperature, a metal which diffuses there into and thereby converts the low melting point alloy into a solid alloy. Such conversion of the normally liquid alloy into a solid alloy is a gradual process, so that the electrical connection may be repeatedly broken and remade during assembly, and the connection does not solidify until sometime after all assembly operations are completed.

Thus the present invention saves labor and makes possible more economical manufacturing methods, in addition to providing a more dependable and lasting electrical connection.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation of a conventional electrical connector in its assembled state.

FIG. 2 is a side elevation of a preferred form of electrical connector embodying the invention, showing its appearance prior to assembly of the connector.

FIG. 3 is a side elevation of the electrical connector of FIG. 2 in its assembled state.

FIG. 4 is a longitudinal section of another connector embodying the invention.

FIG. 5 is a similar section showing the elements of FIG. 4 before assembly.

FIG. 6 is a longitudinal section of a third form of connector embodying the invention.

FIG. 7 is a section similar to FIG. 6, showing the elements of the connector before assembly.

FIG. 8 is a perspective view of a terminal block embodying the invention.

FIG. 9 is a perspective view of another terminal block embodying the invention.

FIG. 10 is a longitudinal section of another connector embodying the invention, showing the parts before assembly.

FIG. 11(A) is a fragmentary diagrammatic view showing the parts of the connector of FIG. 10 assembled to form a temporary connection.

FIG. 11(B) is a fragmentary diagrammatic view showing the parts of the connector of FIG. 10 in their final assembled condition.

FIG. 12 is a longitudinal section of another connector embodying the invention, showing the parts before assembly.

FIG. 13(A) is a fragmentary diagrammatic view showing the parts of the connector of FIG. 12 partially assembled.

FIG. 13(B) is a fragmentary diagrammatic view showing the parts of the connector of FIG. 12 in their final assembled condition.

FIG. 14 is a diagrammatic view of a further connector embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a conventional electrical connector, in which the two contacts consist of a plug 1 fixed in a holder of suitable insulating material and a jack 3,3 fixed in another holder 4 of insulating material. The jack 3,3 is resilient, so that when the plug is inserted into the jack a certain amount of force must be used, and the assembled contacts are then held together under sufficient pressure to provide the necessary low resistance across the connector. A disadvantage of this connector is that the resistance gradually increases because of the action of the atmosphere in corroding or contaminating the connecting surfaces, and the accumulation of dust and dirt upon the contacting surfaces.

In order that the connector may form part of an electrical circuit, connecting members such as the plug 1 and the jack 3,3 are permanently connected to wire leads 5,5.

The low melting alloy used in the practice of the present invention is an alloy consisting essentially of gallium and indium. When gallium is contacted with indium, a liquid alloy is formed at a temperature as low as 16.5° C. If the indium contains zinc or tin, a liquid alloy may be produced by contacting it with gallium at a temperature as low as 9° C.

In the connector embodying the invention shown in FIG. 2, gallium or a eutectic alloy of gallium is applied at 6 to the contact portion of the plug 1, and indium or a eutectic alloy of indium is applied at 7 on the surface of the jack 3,3 which is contacted when the plug 1 is inserted.

As shown in FIG. 3, when the plug 1 is inserted into the jack 3,3, a liquid alloy 6,7 of gallium and indium is formed, and this liquid alloy forms a junction between the contacting surfaces of the plug and the jack.

In a connector embodying the invention, such as that shown in FIG. 3, substantial pressure is not required to form a connection of low resistance, and mere contact between the connecting members which are separated by the liquid alloy is sufficient to provide a contact or electrical connection of low resistance.

The quantity of the liquid alloy which is required in a connector embodying the invention is very small, and the liquid alloy is maintained on the contact surfaces by adhesion and cohesion. In a connector embodying the invention, the electrical connection is not impaired by vibration or shock, because the connecting members are electrically joined by the liquid alloy. Moreover, in a connector embodying the invention there is no danger that the resistance may be increased by the action of gases in the atmosphere or by accumulation of dust or dirt.

In a connector embodying the invention, the connecting members, which are usually made of copper, may be plated

with chromium or titanium. The diffusion of chromium or titanium into a liquid alloy of gallium and indium is very slow so that the liquid form of the alloy is preserved for a very extended period of time when the connecting members are plated with chromium or titanium.

An automatic telephone exchange usually is assembled from a large number of panels or shelves. When these panels are mounted in place, it is necessary to make wire connections between the shelves and the wiring operation is very tedious. In order to expedite the work of wiring the panels in an automatic telephone exchange, attempts to use electrical connectors have been made, but it has been found that electrical connectors which can be provided upon the panels are not reliable.

When the connector shown in FIGS. 2 and 3 is to be used on panels for an automatic telephone exchange, excellent and reliable results can be obtained by making the plug and jack of phosphorous bronze, galvanized with silver or gold. Gallium is applied to the plug at 6, and indium or a eutectic alloy of indium is applied to the jack at 7. In the connector shown in FIG. 2, the gallium at 6 and the indium at 7 are solid materials before the plug is inserted into the jack. As soon as the plug is inserted, a liquid alloy is formed from the gallium and indium between the contacting surfaces of the plug and jack. Gold, silver or copper surfaces on the plug or jack, when in contact with the liquid gallium-indium alloy, diffuse into the liquid alloy and thus gradually convert the liquid alloy into a solid by raising the melting point of the alloy. However, the resulting solid alloy is relatively soft so that the plug can be pulled out of the jack without difficulty, particularly when the connector is warm.

In the connector shown in FIGS. 4 and 5, a plug is formed by a holder 8 of insulating material carrying a resilient contact member 9. A jack is formed of a holder 10 of insulating material provided with a contact member 11 adapted to extend adjacent to the contact member 9. The contact member 11 does not need to be resilient. Lead wires 12 are connected to the contact members 9 and 11. A cylindrical receptacle 13, made of elastic material, is open at the top and contains a low melting point alloy 14 which is a liquid at room temperature and consists essentially of gallium and indium. The alloy 14 is covered with a thin film A, which is made of paraffin, rubber, a plastic material or the like, and which retains the low melting point alloy 14. The contact members 9 and 11 may be made of copper or a copper alloy, and the contact portions 9' and 11' of these contact members may be left bare or may be galvanized with gold or silver. When the receptacle 13 is inserted in place as shown in FIG. 4, the contact portions 9' and 11' puncture the film A and are then surrounded with the gallium-indium alloy in the receptacle, which wets the contact portions 9' and 11' and forms the electrical connection between them. The alloy forms a perfect electrical connection which does not depend upon pressure between the contact members. If the contact portions 9' and 11' have been plated with titanium or chromium, or are made of stainless steel, the alloy will remain liquid at room temperature for an extended period of time. On the other hand, if the surfaces of the contact portions 9' and 11' consist of copper, a copper alloy, gold, silver or the like, gradual diffusion of the metal from the surfaces of the contact portions 9' and 11' into the gallium-indium alloy occurs to produce a eutectic alloy which has a melting point above room temperature, so that a solid connection between the contact portions 9' and 11' is formed after a period of time.

The embodiment shown in FIGS. 4 and 5 is useful in forming a permanent connection as distinguished from a connection which is frequently broken and remade, for example, in wiring a panel. An electrical connection formed in this manner does not deteriorate with age, and a permanent connection is formed which may gradually increase in strength by diffusion of metal into the gallium-indium alloy.

In the embodiment shown in FIGS. 6 and 7, the contact portions 9' and 11' are initially coated with indium or an indium

alloy, while the filling in the receptacle 13 is gallium or a gallium alloy covered with the film A. Alternatively, the coating 14a on the contact portions 9' and 11' may consist of gallium or a gallium alloy, if the filling 14b in the receptacle 13 consists of indium or an indium alloy. In either case, the coating 14a and the filling 14b consist of solid materials. X

When the parts are assembled as shown in FIG. 6, the indium and gallium come into contact, thus forming an alloy having a melting point below room temperature which is normally liquid.

Except as described above, the connector illustrated in FIGS. 6 and 7 functions like the connector illustrated in FIGS. 4 and 5.

FIG. 8 shows how the invention may be embodied in a terminal bar having terminals to be connected with lead wires. In this embodiment, a group of terminals 15 are to be permanently connected to lead wires. The terminals 15 are mounted upon a terminal bar 16 of insulating material. The receptacle 17 is similar to the receptacle 13 of FIGS. 4 and 5, and is filled with a gallium-indium alloy covered with a film A.

The lead wire 19 is placed with its end extending into a notch 15a in a terminal 15, and the receptacle 17 is then telescoped over the terminal 15 so that the terminal 15 and the lead wire 19 become embedded in the liquid alloy 18. The indium-gallium alloy then wets the wire 19 and the terminal 15, to complete an electrical connection between them.

The embodiment of FIG. 9 differs from the embodiment of FIG. 8 in that initially the gallium or gallium alloy is separate from the indium or indium alloy, one of these materials being contained in a coating 18a on each of the terminals 15, and the other of these materials constituting a filling 18b in each of the receptacles 17, covered with a film A. When the embodiment shown in FIG. 9 is assembled as described in connection with the embodiment of FIG. 8, a gallium-indium alloy is formed in each of the receptacles 17 which is a liquid at room temperature. This liquid alloy may be gradually converted into a solid alloy by diffusion of the metal constituting the terminal 15.

The embodiments shown in FIGS. 10 to 14 are designed to protect against escape of the liquid alloy. For this purpose, the gallium which is to be converted into a liquid alloy by contacting it with indium may be present as a precipitate in the interfaces of a body of cadmium, bismuth or lead. Also, the gallium or the liquid alloy itself may be present as an impregnant in a porous body made of glass or a plastic, or made of a metal powder by powder metallurgy techniques. These embodiments are useful not only for retaining the liquid alloy, but also for retaining gallium in cases in which the melting point of gallium (30° C.) may be exceeded.

A solution of gallium in cadmium, bismuth or lead, containing from 10 to 20 percent of gallium by weight, can be produced by heating to several hundred degrees C. Upon cooling, such a solution of gallium becomes supersaturated, and when the solidified material is held at a reduced temperature, particles of gallium precipitate at the interfaces between the crystals of cadmium, bismuth or lead. The size of the gallium particles can be increased by heat treatment. In the resulting system, the gallium is effectively retained and does not escape even when the material is heated above 30° C. When the surface of such a material, having gallium precipitated at the interfaces, is brought into contact with a surface containing indium, a liquid alloy of gallium and indium is produced which forms a good electrical connection by wetting the contacting surfaces.

Gallium or a gallium-indium alloy also may be retained and protected against escape by incorporating it in a porous material as an impregnant. If the porous material is made by powder metallurgy techniques, it should be produced by use of a metal powder of titanium, chromium, tungsten, or another metal which is inert to gallium. The diameter of the pores in such a porous material may be about 50 microns.

The impregnation of the porous material may be carried out by heating the material in a vacuum and then exposing it to

gallium vapor, if desired while subjecting the material to ultrasonic vibration.

Contacts employing the system just described preferably are not subjected to repeated making and breaking, and preferably are used as static or permanent contacts. FIG. 10 and 11 show an embodiment in which ordinary metal-to-metal contacts are provided for temporary use during trials and testing and the gallium-indium alloy connection of the present invention is effected during final assembly of the apparatus after all preliminary tests and checks have been performed.

In FIG. 10 the holder 20 of insulating material contains a resilient plate 22 having its end bent in the shape of an inverted U, and a second resilient plate 21 having a hooked end 21a and a slot 21c. A boxlike space is provided between the bent portion 22a of the member 22 and the hooked portion 21a of the contact member 21. The boxlike space 23 is used to hold a connecting body 24 consisting of cadmium, bismuth or lead having gallium precipitated in the interfaces. The resilient member 22 acts as a keeper, holding the body 24 against the slot 21c. The contact member 21 and the keeper member 22 preferably are plated with nickel, chromium, titanium, or another metal which does not appreciably diffuse into a gallium-indium alloy.

A plug is formed by a holder 25 of insulating material carrying a contact prong 26 for engaging the contact member 21. On the upper surface of the contact prong 26 is provided a connecting surface consisting of indium or an indium alloy. Lead wires 28 are connected to the contact member 21 and the contact prong 26.

FIGS. 11A and 11B illustrate the operation of the connector shown in FIG. 10.

FIG. 11A shows a condition in which the prong 26 is only partially inserted, in order to make a temporary electrical connection without bringing the indium surface 27 in contact with the gallium-containing material 24. In the condition, the electrical connection is by metal-to-metal contact. This is a "primary contact state" in which no liquid alloy is formed. Such partial insertion of the prong 26 is employed during trial assembly, for testing and checking when repeated making and breaking of the connection may occur. After all connections have been checked and found to be correct, the final connection is formed by pressing the parts fully together to insert the prong 26 completely as shown in FIG. 11B. When this is done, the indium-containing material 27 is brought into contact with the gallium-containing material 24 so that a liquid alloy of indium and gallium is formed between the contacting surfaces. This connection is formed through the slot 21c, into which the indium-containing body 27 projects to contact the gallium-containing body 24.

It will be understood that the prong 26 is wider than the slot 21c, so that the prong 26 slides under the corner 21b of the contact member 21 and does not enter the slot 21c.

In the modification shown in FIG. 12, the contact member 21 and the prong 26 are both provided with a coating of an indium-containing material 29. Upon assembly of the elements shown in FIG. 12, as illustrated in FIG. 13A, a temporary electrical connection is made between the indium-containing surfaces 29. When a permanent connection is to be effected, it is necessary to interpose a holder 31 of insulating material which may cooperate with a series of aligned connectors of the type shown in FIG. 12. The holder 31 has a series of holes, each of

which is filled with a connecting material 30 consisting of cadmium, bismuth or lead containing gallium precipitated at the interfaces. The holder 31 is inserted in proper alignment with a series of connectors so that a body of connecting material 30 in one of the holes is brought between the indium-containing surfaces 29 of each connector. In this way, a permanent connection is produced by forming some of the liquid alloy on both of the indium-containing surfaces 29 of each connector.

In the embodiment shown in FIG. 14, the contact members 32 and 33 are provided with contact points 32a and 33a each of which consists of a body of porous metal impregnated with a liquid alloy of gallium and indium. The contact points 32a and 33a perform well with repeated making and breaking, because the liquid alloy in the pores of the porous metal forms a liquid connection when the contact points 32a and 33a are brought together. Whenever these contact points are separated, the liquid alloy is retained in the pores of the porous metal by capillarity.

In the practice of the present invention, an electrical connection is made through an alloy consisting essentially of gallium and indium which is a liquid at room temperature. When the electrical connection is thus formed by a liquid alloy, the resistance across the connector is stable and does not vary with contact pressure or increase upon exposure to the atmosphere.

The liquid alloy consisting essentially of gallium and indium which is used in the practice of the present invention is superior to mercury in that it does not emit a toxic vapor.

We claim:

1. An electrical connector comprising two members which are adapted to be assembled to form an electrical connection, each member having an electrically conducting element which extends adjacent to an electrically conducting element of the other member, and a body of a low melting point alloy consisting essentially of gallium and indium which is a liquid at room temperature, forming a junction between the two elements.

2. An electrical connector according to claim 1 comprising, in contact with the low melting point alloy, a metal which diffuses therein and thereby converts the low melting point alloy into a solid alloy.

3. An electrical connector according to claim 1 wherein each member has an electrically conducting contact which is directly engageable by an electrically conducting contact of the other member to form a temporary connection, and an electrically conducting element which is adapted to be interposed between the two contacts to form a permanent electrical connection between the two contacts through a body of a low melting point alloy consisting essentially of gallium and indium which is a liquid at room temperature.

4. An electrical connector according to claim 1 wherein an electrical connection is made through a porous solid material impregnated with the low melting point alloy.

5. An electrical connector according to claim 1 comprising a connecting member having a surface comprising indium, and a second connecting member having a surface which comprises gallium and is engageable with the surface comprising indium to form an alloy therewith.

6. An electrical connector according to claim 5 wherein the second connecting member has a surface comprising a material of the class consisting of cadmium, bismuth and lead having interfaces between which gallium is precipitated.

* * * * *