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14

(54) HEAT-RECOVERABLE COUPLING

(71) We, RAYCHEM LIMITED, a British Company, of Moor House, London Wall, London, E.C.2, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to connectors, especially for making electrical connections and terminations.

The field of electrical connection and termination has, until recently, largely depended upon traditional methods such as soldering and crimping to effect the connection and termination of, for example, conductors and cable screens. In simple applications both of these traditional methods are quite satisfactory, but there are many other applications, for example, when the connection or termination must be made in a cramped environment or when one or more associated components are fragile or vulnerable to heat, when a highly skilled operator is need to obtain successful results.

More recently, it has been proposed to utilise the properties of so-called "memory metals" (sometimes called heat-recoverable metals) to form connections. Such memory metals and their properties are described, for example, in British Patents Nos. 1,202,404; 1,327,441; 1,327,442 and 1,338,278 and in U.S. Patents Nos. 3,174,851 and 3,351,463. Basically, these memory metals are alloys which are capable, like certain plastics materials, of having the property of heat recoverability imparted to them by virtue of their different properties in their martensitic (low temperature) and austenitic (high temperature) states. Thus an article made from such a memory metal can be deformed whilst in the martensitic state to a heat-unstable configuration in which it will remain whilst kept in the martensitic state. When it is warmed through the transition temperature, (which, in practice, is usually a small temperature range) to the austenitic state, however, it will recover towards its original form.

As disclosed in British Patent No. 1,327,441, such memory metals can be used to form

useful heat-shrinkable connecting members, especially tubular connecting members with inner teeth.

As disclosed in British Patent No. 1,327,442, some of the recovery can be made reversible by imparting further secondary or non-thermally recoverable deformation to the article. Thus when a heat-shrunk memory metal connector is once again cooled to its martensitic state a small degree of re-expansion may occur. However, the degree of reversibility is generally rather small (i.e. not greater than 3% compared to a recovery of about 8%) and, in some applications, is not sufficient on its own to facilitate removal and re-use of the connector.

In co-pending British Patent No. 1,395,601 there is described and claimed a re-usable connector comprising a heat-recoverable metal member (e.g. a band) in conjunction with a resilient connecting member (e.g. a longitudinally slotted cylindrical element positioned inside the band). When the temperature is above the transition temperature the recovery force of the recoverable metal band dominates and a connection is made on to an underlying object. When, on the other hand, the band is cooled to its weaker martensitic state, the resilient forces of the tines of the connecting member are dominant and the band is forced to expand, thus releasing any connection which has been made. In an alternative form of connector the heat-recoverable metal member may be employed to force the tines of the resilient connecting member apart on recovery, thus enabling a different type of connection to be made (or broken) at the higher temperature. The connectors described and claimed in British Patent No. 1,395,601 have wide application and have proved very successful in solving several different types of problems traditionally encountered in the general field of connection and termination but there are nevertheless some applications where their use is not suitable.

One example of a situation in which the use of a connector as described and claimed in British Patent No. 1,395,601 may not always be suitable is when the requirements

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of the connection or termination are such that no resilient connector member could be used because the resilience of the member could not be accommodated by other components associated with the connection. Another example is when the other requirements of the metal of the connector, such as coefficient of thermal expansion, thermoelectric properties and solderability, are not compatible with the necessary degree of resilience. In this respect it is to be noted that commonly used resilient alloys tend to have large coefficients of expansion.

The present invention provides a re-usable connector which comprises a first connector member at least part of which is substantially non-resilient (as hereinafter defined) and deformable and a second member made from a memory metal, the arrangement of said members being such that at a temperature below the transition temperature of the memory metal the non-resilient deformable part of the first member and the second member can be deformed from their existing configuration and that when the connector is then raised to a temperature above the transition temperature, the recovery of the second member towards its original configuration will force the deformable part of the first connector member back towards its original configuration.

The present invention also provides a method of making a connection, especially an electrical connection, wherein at least one object which is to be connected is brought into position with a re-usable connector as described above whilst the connector is at a temperature below the transition temperature of the memory metal and wherein the temperature is then raised above the transition temperature so that the second member recovers and forces the deformable part of the first connector member back towards its original configuration to make firm connection with the object.

By "substantially non-resilient" is herein meant that the first connector member (unlike the similar, but resilient connector member described in British Patent No. 1,396,601) is not sufficiently resilient that, on cooling below the transition temperature, it will by its resilience deform the memory metal member.

In some cases it will be advantageous if the object to be connected is itself used to deform the re-usable connector whilst the latter is in its low temperature state. This can be done, for example, by forcing the object into the connector whilst the latter is in its low temperature state.

However, when the object to be connected is small, for example is a small connector pin made from nickel/iron, it may be difficult to dimension it sufficiently accurately, especially if it is to be manufactured with a

bulge or other radial protuberance, that it can properly itself deform the re-usable connector of the present invention. In other cases, the object may be relatively inaccessible or fragile or may be associated with other fragile components. Accordingly, in general it will be more convenient to deform the connector by using a separate mandrel or other similar means which is generally sized to conform with the dimensions of the object to be connected. In such cases the connector may be expanded with a mandrel, e.g. a pin having a tapered end, whilst the connector is in its low temperature state and may then immediately be positioned about the object to be connected before the connector has had time to warm above the transition temperature of the memory metal. Another possibility is to expand the connector at the time of manufacture or at some other time prior to installation with a suitable mandrel and then to fit it with a keeper or temporary mandrel (which may, in some cases, be the mandrel used for deformation), which preferably is slightly bigger than the object, e.g. the connector pin, to which it will ultimately be fitted. The connector with the keeper in position can then be stored at room temperature. On installation, it can once again be cooled below the transition temperature whereupon it will slacken its grip upon the keeper which can then be removed whereupon the connector is quickly placed in position about the object to be connected before it has had time to warm above the transition temperature.

In a preferred form of connector according to the present invention, the first connector member comprises a longitudinally slotted tubular portion, preferably having at least two tines, at least the tines being substantially non-resilient and deformable, and the heat-recoverable metal member is a band, preferably a continuous ring, positioned around the tines. Because (contrary to the arrangement in the similar resilient connector described in British Patent 1,395,601) there is substantially no interaction between the tines and the band, it may be preferable to provide the first connector member with means, e.g. a peripheral shoulder, to facilitate proper positioning of the band on said member.

The object to be connected, e.g. a connector pin, can be forced into such a connector whilst the latter is in its low temperature state, simultaneously forcing the tines outwardly and expanding the metal band. When the temperature is then raised above the transition temperature the heat-recoverable band recovers and forces the deformable tines around and into firm connection with the object. However, as is discussed above, it will in most cases be preferable

to use a separate suitably sized mandrel to deform the connector.

5 The object preferably has a portion of slightly greater size, e.g. of greater outer diameter. For example, a connector pin may be provided with a small bulge along its length or may be slightly tapered away from its end. This serves two purposes. First of all, upon recovery, the pull-out strength of the connection made will be increased, especially if the heat-recoverable metal member has shrunk over a smaller sized portion of the object and must be pulled over the larger sized portion, e.g. the bulge, before the connection can be broken. Secondly, when it is desired intentionally to break the connection for modification or repair purposes and the connection is cooled again to a temperature below the transition temperature of the memory metal, the portion of larger size will deform the connector as it passes over it and thereby facilitate subsequent disconnection. In the case where the heat-recoverable metal member must be passed over this portion to break the connection it will be deformed in its low temperature state and will thus again be capable of heat-recovery. This may obviate the need for further expansion, e.g. by a mandrel, before the connector is replaced or otherwise re-used. It will be appreciated that in some cases it may be convenient to obtain a similar effect by providing the deformable first connector member, e.g. the tines thereof, with an inner protuberance, e.g. an annular bulge, which co-operates with a recess, e.g. an annular groove, in the object, e.g. the connector pin.

10 The connectors according to the present invention may be provided with other means for making connections. For example, a connector as described above may be provided with a band and tines at one end for making contact with a connector pin, in accordance with the present invention, and may be provided at its other end with means for connecting a conductor wire or another connector pin. Such means may, for example, simply comprise another deformable portion which can be crimped to the wire or pin. Alternatively, it may comprise a solder pot for a soldered connection. It will be appreciated, of course, that the connectors according to the present invention may comprise more than one heat-recoverable metal member, e.g. that the same type of connection may be made at both ends of the connector.

15 Because the tines are non-resilient the connector can be made slimmer than, for example, a connector as described in British Patent 1,395,601. This is obviously a considerable advantage.

20 The memory metals used in the connectors of the present invention may, for example, be chosen from those disclosed in the above-mentioned patents. The particular memory

metal chosen will depend on the field of application of the connector, especially with regard to its transition temperature. To avoid the connection made being accidentally broken it is important that the transition temperature of the memory metal lies below the lowest temperature likely to be encountered. In general, the connector will be required to operate at temperatures from -40°C upwards, but possibly as low as -75°C , and suitable alloys are those containing approximately equiatomic proportions of titanium and nickel optionally with small proportions of other metals. The connectors may readily be lowered to their transition temperature by spraying with liquid nitrogen or by using commercially available cooling tools.

The deformable member will, in general, be made from a metal and amongst especially suitable metals there may be mentioned the thermocouple metals, chromel and Alumel (Registered Trade Mark).

One form of connector in accordance with the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 represents, in cross-section, one form of standard circular military connector;

Fig. 2 represents, in cross-section, a second form of standard circular military connector;

Fig. 3 shows the crimped connection of a wire to a connector pin suitable for use with the military connector of Fig. 2;

Fig. 4 represents, in cross-section, a third form of standard circular military connector;

Fig. 5 shows in part a modification of the military connector of Fig. 4;

Fig. 6 shows, in cross-section, a connector in accordance with the present invention;

Fig. 7 is an exploded view of the connector of Fig. 6;

Fig. 8 shows the use of the connector of Figs. 6 and 7 to make a connection with a connector as shown in Fig. 5; and

Fig. 9 shows the finished connection.

Referring to the accompanying drawings, there is shown in Fig. 1 a standard circular military connector of an early type comprising a plurality of pins or sockets 1 embedded in an insulating plastics moulded block 2, which is in turn mounted within an outer metal shell 3 which provides the necessary alignment for correct mating and the locking means necessary to hold the connection together under conditions of vibration. Each pin or socket 1 is provided with a solder pot 4 for making a soft solder connection to a wire 6. The pins or socket member 1 are fixed within the insulator block 2 and the connection of the wires 6 is limited to some extent by the accessibility of the solder pots 4.

Referring now to Fig. 2, this shows a modified form of circular connector in which

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the pins or socket members 1 are removably mounted within a resilient insulating block 2 of rubber or a similar material. This has the great advantage that the pins or sockets 1 can form a crimped connection 7 with the wires 6 and then be inserted into the block 2.

However, the use of demountable pins or sockets is not always possible and one type of circular connector which still utilises fixed pins or sockets 1 is shown in Fig. 4. This is a hermetically sealed high temperature connector where the pins 1 are fixed within the metal shell 3 by glass-to-metal seals 8.

This type of connector is very expensive and is often made with its pins or sockets 1 made from thermocouple metals so that it can be used in the temperature sensing systems found in aircraft engines and nuclear power installations. To date no satisfactory method of forming a crimped connection to such a connector has been found and, as the high service temperature of this type of connector precludes soft soldering, it has been necessary to employ silver soldering or brazing necessitating the use of a jeweller's blow-pipe. Apart from the problems of accessibility, such operations require high skill and much care is required to avoid damaging heat-sensitive components, such as wire insulation.

One typical application requiring the use of a hermetically sealed connector is the thermocouple system used for temperature sensing on an aircraft gas turbine engine. Insulated wires leading from the thermocouple element themselves (those wires comprising stranded conductors made from thermocouple metals) are joined to a connector mounted on a pressure-proof bulkhead at the point where the wiring leaves the unpressurized engine area and enters the pressurized cabin area of the aircraft. The mating half of the connector is joined to a similar group of wires, also having thermocouple metal conductors, leading away to the instrumentation, where the electrical signals, representing temperature, are processed for engine control purposes. The pins and sockets in the two connector halves are themselves made of the same thermocouple metals, for example, chromel and alumel, which are not springy. The conditions met in this application fix the characteristics of the inter-connection system as follows:

1. The electrical circuit must be in thermocouple metal throughout.
2. The connections must be vibration proof.
3. The method of attaching the wires to the rear ends of the connector pins/sockets must be compact enough to fit within the pin spacings of the connector.

4. The method of attachment and removal of the wires should not involve the use of a flame, or require a great deal or skill.

Figs. 5 to 9 of the drawings show how, with a modified form of hermetically sealed military connector, the present invention provides a simple and relatively inexpensive method of making a demountable connection suitable for this purpose.

Fig. 5 shows a modified form of a hermetically sealed military connector wherein the pins or sockets 1 have, at their rear ends, a pin with a small bulge 10 in place of a solder pot. Figs. 6 and 7 show a connector 11 in accordance with the present invention comprising a non-resilient connector member 12 and an associated memory metal ring 13. The connector member 11 is provided with a shoulder 14 for positioning the ring 13 and is slotted longitudinally at this end to form two non-resilient tines 15. At its rear end it is provided with a slot or aperture 16 for forming a crimped connection with a wire 6.

Fig. 8 shows the making of the connection. The connector 11 has been cooled to its low temperature form and has been forced over the bulge 10 in the rear end of pin or socket 1 causing it to expand as shown. (However, as discussed above, it will, in many cases be preferable to deform the connector 11 by using a suitably sized mandrel). The wire 6 has previously been crimped to the other end of the connector 11 and, for this purpose, a separate crimping ferrule 17, made, for example, from copper, may have been utilized.

Fig. 9 shows the final connection made upon warming above the transition temperature. The ring 13 has shrunk to its original size and, in doing so, has deformed the tines 15 of the connector 11 so that a secure connection is made about the bulge 10. Because the ring 13 shrinks behind the bulge 10 (i.e. remote from the end of the pin) it will again be deformed when the connector 11 is frozen to the low temperature form and pulled away from the pin or socket 1. The connector member 12 may, for this purpose, be provided with an annular groove or similar means for co-operating with the jaws of a hand tool, e.g. pliers, provided for pulling the connector 11 away from the pin or socket 1.

The present invention has been described with particular reference to the making of connections with hermetically sealed components. However, it will be appreciated that it will find use in many other applications, especially those in which the objects to be connected are, by virtue of close packing, virtually inaccessible for the purposes of conventional connection methods, such as soldering.



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WHAT WE CLAIM IS:—

1. A connector which comprises a first connector member at least part of which is substantially non-resilient (as hereinbefore defined) and deformable and a second member made from a memory metal, the arrangement of said members being such that a temperature below the transition temperature of the memory metal the non-resilient deformable part of the first member and the second member can be deformed from their existing configuration and that when the connector is then raised to a temperature above the transition temperature, the recovery of the second member towards its original configuration will force the deformable part of the first connector member back towards its original configuration.

2. A connector as claimed in claim 1, wherein the first connector member comprises a longitudinally slotted tubular portion having at least two tines, at least the tines being substantially non-resilient and deformable.

3. A connector as claimed in claim 2, wherein the heat-recoverable metal member is a band positioned around said tines.

4. A connector as claimed in claim 3, wherein the band is a continuous ring.

5. A connector as claimed in any one of claims 2 to 4, wherein the first connector member is provided with means to facilitate proper positioning of the heat-recoverable metal member with respect to said first connector member.

6. A connector as claimed in claim 5, wherein said means comprises a peripheral shoulder.

7. A connector as claimed in any one of claims 1 to 6, wherein the heat-recoverable metal member is made from an alloy having a transition temperature lower than -40°C .

8. A connector as claimed in claim 7, wherein the heat-recoverable metal member is made from an alloy having a transition temperature lower than -75°C .

9. A connector as claimed in any one of claims 1 to 8, wherein the heat-recoverable metal member is made from an alloy containing approximately equiatomic proportions of titanium and nickel.

10. A connector as claimed in any one of claims 1 to 9, wherein the first connector member is provided with further means for making a connection.

11. A connector as claimed in any one of claims 1 to 10, which has been deformed at a temperature below the transition temperature using a mandrel and which has been maintained in its deformed state by the provision of a temporary mandrel.

12. A method of making a connection, which comprises bringing at least one object to be connected into position relative to the first connector member of a connector as claimed in any one of claims 1 to 11 whilst the latter is in its deformed state at a temperature below the transition temperature of the memory metal and then warming said connector, or allowing said connector to warm to a temperature above the transition temperature so that the heat-recoverable member recovers and forces the first connector member into firm connection with said object.

13. A method as claimed in claim 12, wherein the connector is brought into its deformed state by using an appropriately sized mandrel or similar means.

14. A method as claimed in claim 13, wherein the connector has been maintained in its deformed state at a temperature above the transition temperature by means of a keeper which has subsequently been removed at a temperature below the transition temperature to leave the connector in its deformed condition.

15. A method as claimed in claim 12, wherein the connector has been brought into its deformed state by using the object to be connected.

16. A method as claimed in any one of claims 12 to 15, wherein the object is a pin having a bulge along its length.

17. A connector as claimed in claim 1, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

18. A method as claimed in claim 12, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

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