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(54) **Connecting device**

(57) A connecting device comprises a body of shape memory metal 10 capable of reversing between a martensitic and an austenitic state, the body comprising at least two arms 14, 16 cantilevered to form a support means 18 which joins the arms. The arms 14, 16 are deformable with low force when the body is in its martensitic state and the arms revert

towards their undeformed state when the body is in its austenitic state.

Preferably the arms 14, 16 are deformable away from each other and converge to grip a substrate when the body is in its austenitic state, and may have two arms 46, 48 which grip a resilient body having two arms which are normally biased apart and are closed when the body of shape memory metal is in its austenitic state.

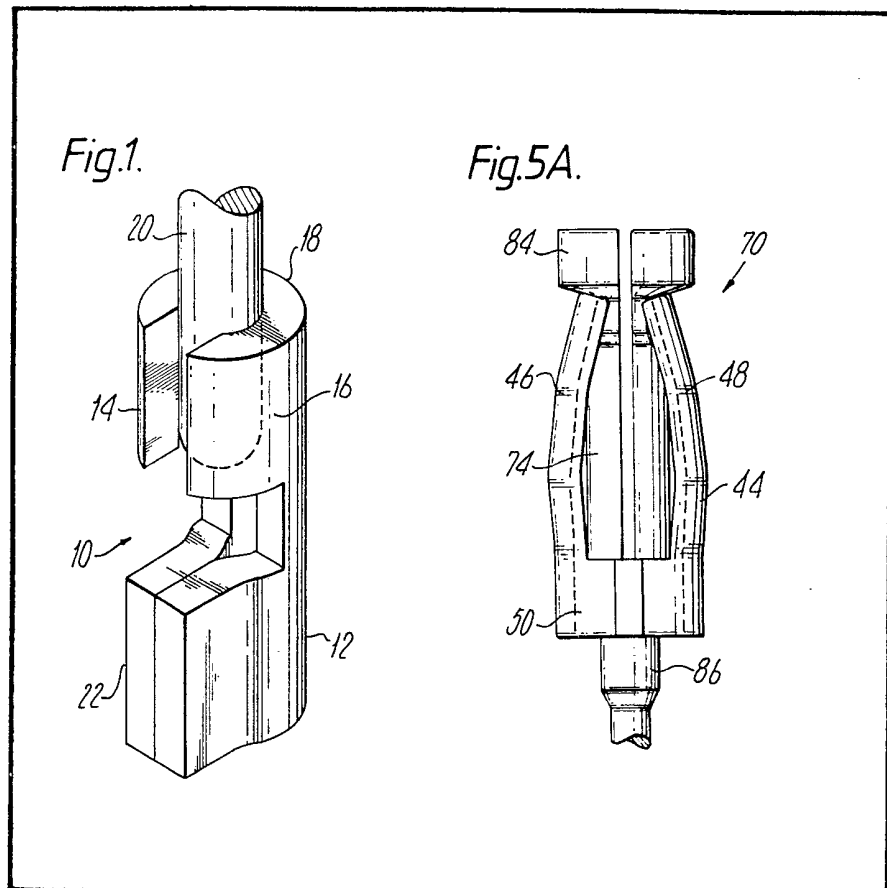


Fig.1.

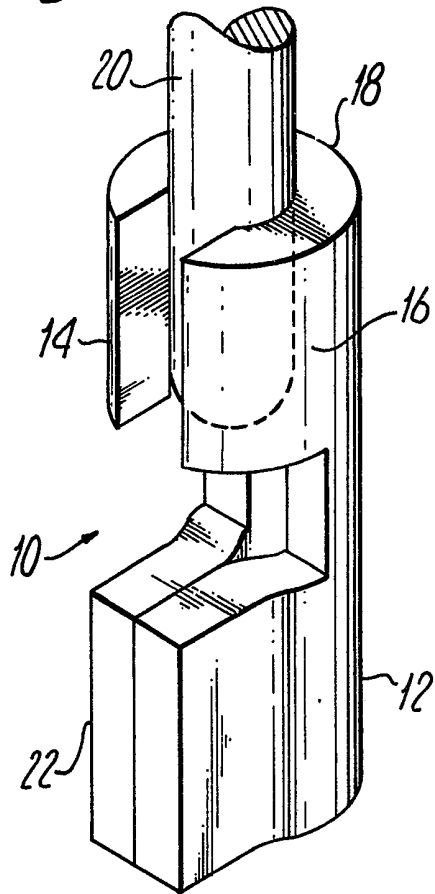


Fig.2.

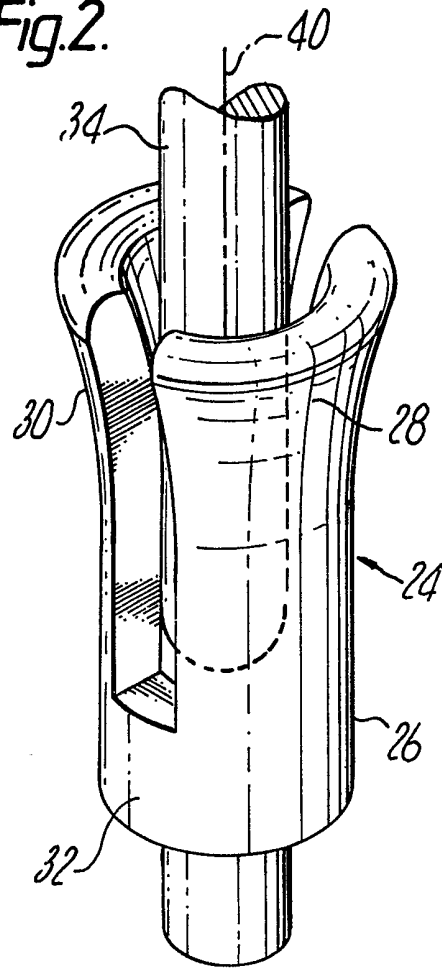


Fig.3.

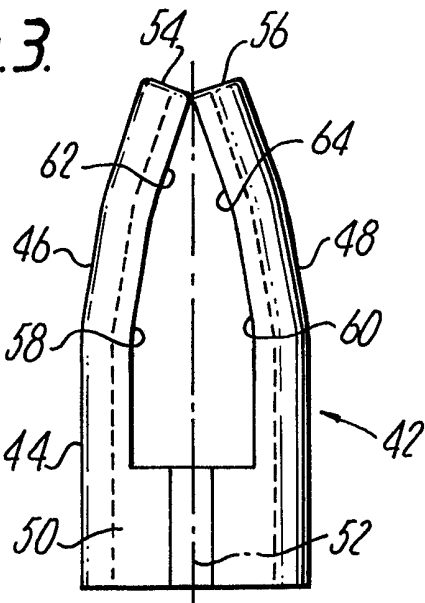


Fig.4A.

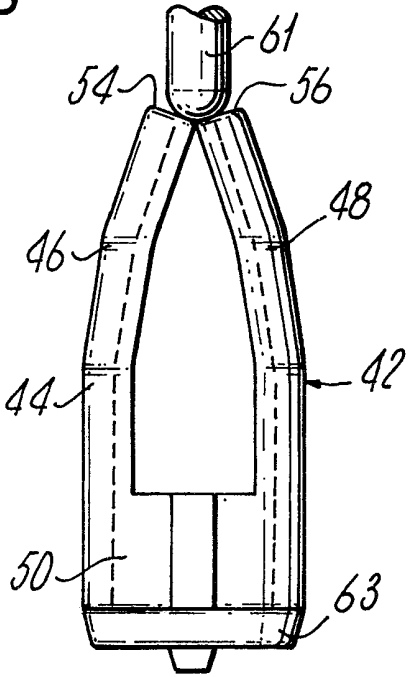


Fig.4B.

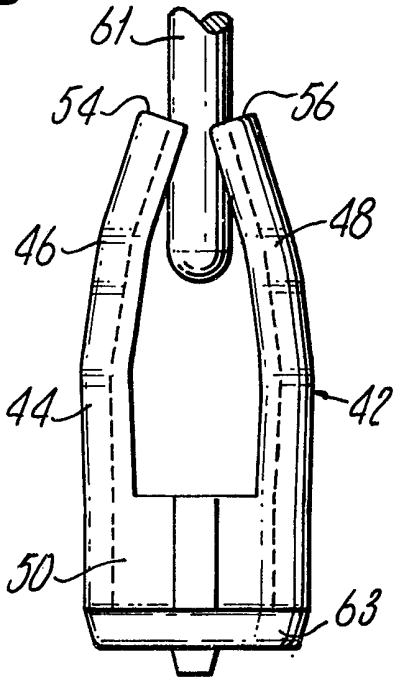


Fig.5A.

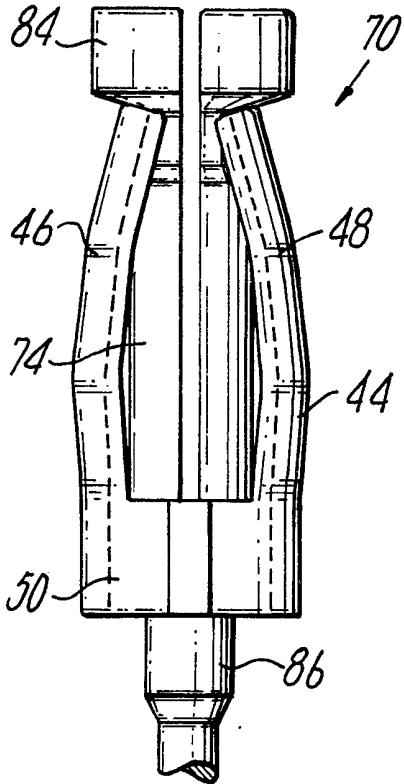


Fig.5B.

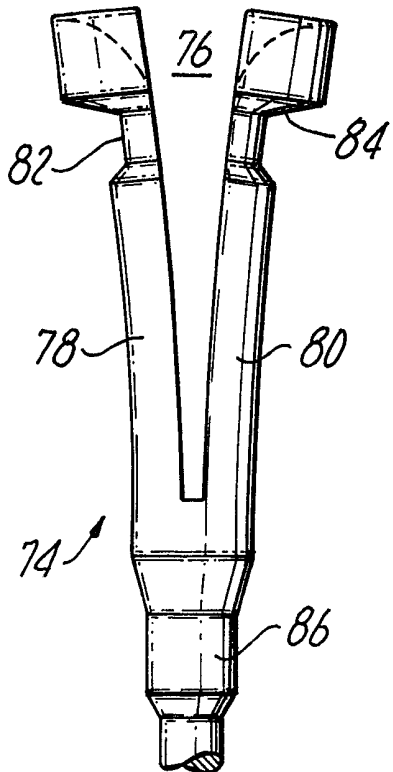


Fig. 6.

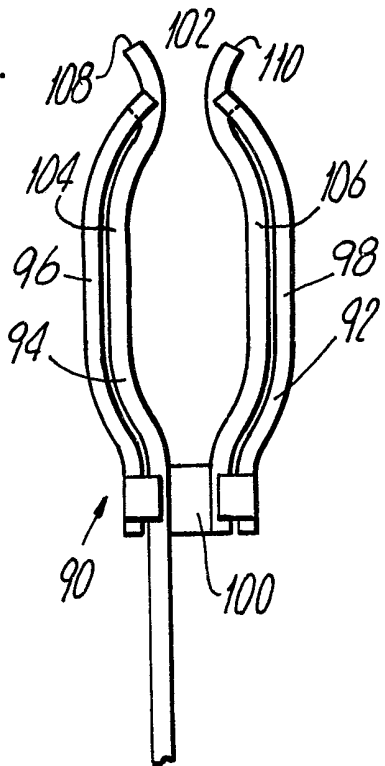


Fig. 8.

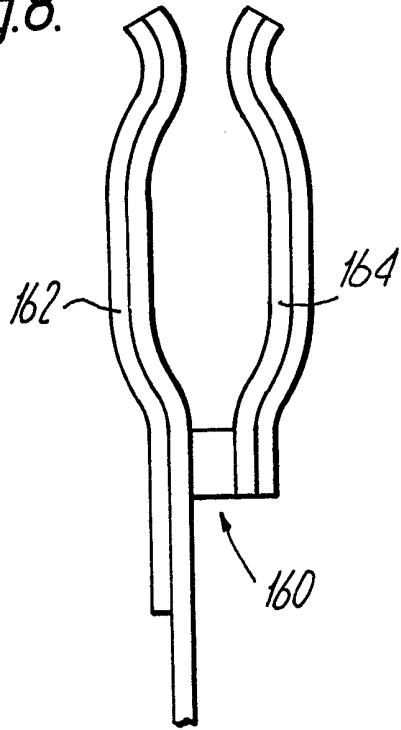


Fig. 7A.

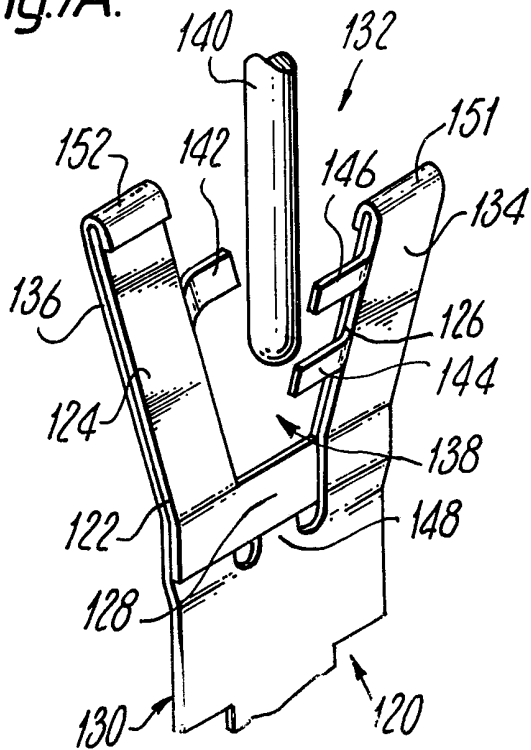
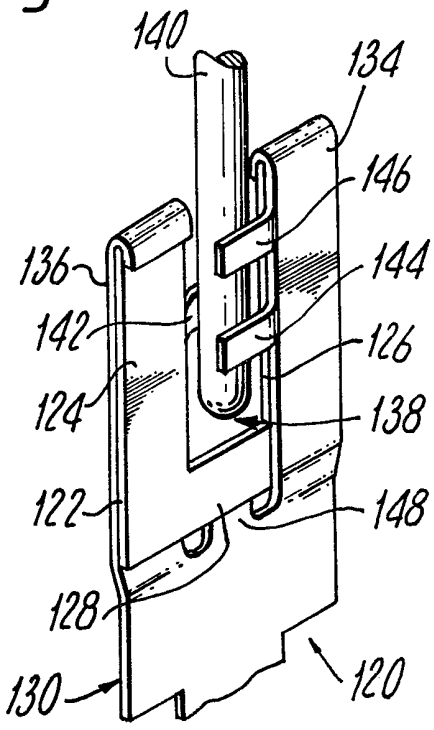


Fig. 7B.



SPECIFICATION
Connecting device

This invention relates to a connecting device and to a method of making such a device.

5 Connecting devices are used, for example, in making terminations and connections for electronic packages such as pin grid array packages (PGAP). Current electronic packages often include sixty-four or more pins. The pins
10 may be inserted into sockets in a printed wiring board (PWB) or printed circuit boards (PCB) and then wave soldered for connection therewith.

Prospective users of such boards are concerned that it will be difficult to remove such
15 electronic packages from the board because of the increasing number of pins which are being used. There is certain amount of force required to insert and remove a pin from a standard socket. With the high count of pins on current electronic
20 packages, the insertion and removal forces can be quite high. In fact, the number of pins may be so great that the electronic package itself may become damaged during insertion or removal. In order to avoid damaging the electronic package, it
25 is desirable to have pins which can be attached or removed from sockets with low or zero force.

One example of a zero insertion force connector currently available, is described in U.S. Patent 3,740,839 (Otte et al). This connector
30 comprises a ring which is made from material capable of reversing between austenitic and martensitic states and a second member encircled by the ring. The second member deforms the ring when the ring is in its martensitic state and is deformed by the ring when the ring is
35 in its austenitic state. The ring increases and decreases in diameter for releasing or engaging a substrate inserted within the second member. A more detailed description of the above mentioned phenomena may be found in U.S. Letters Patents
40 Nos. Re. 29,904; 3,740,830; and 4,022,519.

Although the above described connectors are particularly effective, one disadvantage is that the ring construction has inherent tolerance and
45 manufacturing problems.

The device of the present invention on the other hand, may, inter alia, be made by an easier manufacturing process.

The present invention provides a connecting
50 device comprising a body of shape-memory metal capable of reversing between a martensitic and an austenitic state, the body comprising at least two arms cantilevered from a support means which joins the arms, the arms being deformable
55 with low force when the body is in its martensitic state and the arms reverting towards their undeformed state when the body is in its austenitic state.

The term "low force" is understood in the art and means any force sufficient to deform the
60 arms away from each other substantially without damaging the arms.

Shape memory metals, sometimes also called "Memory Alloys", are metallic materials which

65 exhibit changes in strength and configurational characteristics on passing through a transition temperature, in most cases the transition temperature between the martensitic and austenitic states, and can be used to make heat-recoverable articles by deforming an article made
70 from them whilst the metal is in its martensitic, low temperature state. The article will retain its deformed configuration until it is warmed above the transition temperature to the austenitic state when it will return or attempt to return towards its original configuration. It will be understood that the heat-recoverable article is capable of
75 returning towards its original configuration without the further applications of outside force. The deformation used to place the material in the heat-unstable configuration is commonly referred to as thermally recoverable plastic deformation and can also, in certain cases, be imparted by
80 introducing strains into the article above the transition temperature, whereupon the article assumes the deformed configuration on cooling through the transition temperature. It should be understood that the transition temperature may be a temperature range and that, as hysteresis usually occurs, the precise temperature at which
85 transition occurs may depend on whether the temperature is rising or falling. Furthermore, the transition temperature is a function of other parameters, including the stress applied to the material, the temperatures rising with increasing stress.

Amongst such memory metals there may especially mentioned various alloys of titanium and nickel which are described for example in U.S. Patents Nos. 3,174,851, 3,351,463, 3,753,700, 3,759,552, British Patents Nos. 1,327,441 and 1,327,441 and 1,327,442 and NASA Publication SP 110, "55-Nitinol-The Alloy with a Memory, etc" (U.S. Government Printing Office,
100 Washington, D.C. 1972). The property of heat-recoverability has not, however, been solely confined to such titanium-nickel alloys. Thus, for example, various beta-brass alloys have been demonstrated to exhibit this property in, e.g. N. Nakanishi et al, *Scripta Metallurgica* 5 433—440 (Pergamon Press 1971), U.S. Patents Nos. 3,783,037, 4,019,925, 4,144,104, 4,146,392 and 4,166,739, and such materials may be doped to lower their transition temperature to
115 cryogenic regimes by known techniques. Similarly, 304 stainless steels have been shown to enjoy such characteristics E. Enami et al, id, at pp.663—68.

In general these memory metals have a transition temperature within the range of from -196°C to +135°C, especially from -196°C to -70°C (this being the lowest temperature they are liable to encounter during everyday use), and thus may be brought into their martensitic state
120 by immersion into liquid nitrogen. However, more recently, it has been found possible to "pre-condition" memory metals so as transiently to raise their transition temperature. This enables the articles made from such alloys to be kept at

room temperature prior to use, when they can be recovered by heating. Such preconditioning methods, which eliminate the need for liquid nitrogen during storage and transportation, are described, for example in U.S. Patents Nos. 4,036,669, 4,067,752 and 4,095,999. A further method of treating such alloys in order to raise their effective transition temperature is described and claimed in U.S. Patent No. 4,149,911.

As indicated above by application of a preconditioning process to a memory metal its transition temperature can be elevated. However, once recovery has been brought about by heating the article through its new transition temperature, the memory metals response to temperature change reverts to that it possessed prior to preconditioning. Accordingly, it remains austenitic until cooled to the temperature at which transition to martensite normally occurs, typically chosen to be at 0°C or below depending upon the temperature environment likely to be encountered.

According to the present invention, the arms may be deformed away or towards each other when the body is in its martensitic state. The following discussion is directed to the case where the arms are deformed away from each other, but it is intended that the same points and ideas apply to the case where the arms are deformed towards each other.

The low force to provide the deformation may be provided by insertion of a substrate, such as a contact pin, between the arms. In this case the arms may be arranged such that transformation of the material to its austenitic state causes the arms to engage directly the inserted substrate. In this case, where the low force to deform the arms is provided by insertion of the substrate itself, the device is a low insertion force device (hereinafter LIF device). Alternatively, a second member may be installed on the memory metal body prior to insertion of the substrate. The second member is preferably resiliently biased to provide the low force to deform the memory metal arms when it is in its martensitic state, but allowing the arms to revert to their undeformed state when the body is in its austenitic state. In this case either the memory metal body or the second body or both may engage directly the substrate when it is inserted in use. Advantageously the second member is arranged to deform the arms to an extent that a substrate may be inserted without further deforming the arms of the memory metal body at all. In this case the device is a zero insertion force (ZIF) device.

The arms are cantilevered, that is to say, they are fixed at one end and free at the other, to create the maximum amount of articulation as the device transforms from one state to another. In its martensitic state the arms of the body are sufficiently weakened allowing a substrate to be inserted therein with low insertion force or allowing a second member to deform the arms a sufficient amount to allow a substrate to be inserted with zero force. After insertion of a

substrate, the body may be warmed (or the cooling force merely removed) to return to the body to its austenitic state wherein the arms articulate to become closely spaced for engaging a substrate inserted therein.

Especially important is that the device in accordance with this invention may be advantageously made by an economical stamping process. When the device is made by a stamping process, the support structure for joining the arms is of split construction. The support structure may also be flat.

The LIF connecting device which is stamped preferably includes arms which, when in the austenitic state, are bent and then folded to confront each other. With the arms so bent and then folded, greater pressure can be exerted by the arms on a substrate inserted therein, thereby providing better contact of the device with the substrate, which is especially important in electrical applications. Even in the non-stamped version, the arms may be over-bent such that they make pressing contact with at least one other arm, preferably along the vertical center line of the body. By over-bending is meant bending the arms such that if one arm were removed, its confronting arm would bend over the vertical center line of the body. This additional bending causes preloading of the arms which ensures even better contact of a substrate with the device because of the additional pressure exerted by the arms on the substrate.

Where the connecting device comprises a second member, the memory metal body acts as a driver member in conjunction with the second member. The second member has at least one female end which is arranged to normally diverge to an open condition capable receiving a substrate. The female end is capable of being deformed to a closed condition. Advantageously, the female end of the second member sufficiently forces open the arms of the memory metal member (driver member) when it is in its martensitic state, to a sufficient extent to allow a substrate to be inserted therein with zero force. The arms, with the driver member is in its austenitic state, force the female end of the second member to its closed condition, sufficiently, for the device to engage a substrate inserted therein.

In one embodiment, the driver member surrounds the second member. In this embodiment the female end includes at least two legs which push open the arms, with the driver in its martensitic state, to allow a substrate to be inserted therein. As the driver member approaches the austenitic state, the arms push the legs of the female end to its closed condition to engage a substrate therein.

The above described embodiment of a connecting device preferably includes a female end having at least two normally diverging spread apart resilient legs. The legs preferably include a terminus defining an enlarged end zone for receiving and properly locating a substrate therein. The end

zone advantageously includes an outer surface having an annular recess defining a gripping means for securely connecting the driver and the second member.

5 In another embodiment the arms of the driver member are connected to the inside surface of a corresponding leg of the female end. In this embodiment, the driver member preferably has two arms and the female end of the second member has two legs. By necessity, in this 10 embodiment, there must be a corresponding number of legs and arms. The arms are bent, with the driver member in its austenitic state, to diverge the arms from one another. The arms are thereafter reverse bent, with the driver member in its martensitic state, to again diverge the arms from one another, but this time with the arms in the opposite relative position. Each arm of the driver member is connected to its corresponding 20 leg of the second member with the driver member in its martensitic state. Each leg member advantageously includes means for such connection. In this embodiment, the legs pull the arms open, with the driver member in its martensitic state, and the arms pull the legs to a closed condition, with the driver member in its austenitic state, precisely the reverse of the earlier described embodiment.

In any of the LIF or ZIF devices described above 30 or below, one end of the driver member, the body or the second member advantageously includes a male end which is adapted for connection to a printed circuit or printed wiring board.

Cantilevered arms have much greater 35 articulation (a larger percentage of deformation) from austenitic to martensitic states and vice versa than the earlier described connector ring of U.S. Patent No. 3,740,839 (Otte). In other words, the amount of deformation caused by a shift from 40 martensitic to austenitic states and vice versa is much greater in the present invention than in the earlier known connector. The greater deformation reduces the narrow tolerance limits for making heat recoverable connecting devices of memory metal thereby greatly reducing the cost of 45 manufacture. Additionally there is greater flexibility in making a particularly shaped device than previously possible. For example, a connecting device made in accordance with this invention comprising a second member in 50 combination with a memory metal member may be made to accommodate the standard JEDEC pin having tolerance limits of plus or minus 1.27×10^{-3} cm (.0005 inches).

55 Additionally, the heat recoverable connecting device in accordance with this invention is preferably made by a process which includes a sizing operation further reducing the need for narrow tolerance limits.

60 Furthermore the present invention may preferably be made by a stamping process, a far less expensive process than is currently used for making memory metal connecting devices. Additionally, the present invention may be made 65 from drawn Tinel™ tuning, also a less expensive

process than is currently used for making such devices.

70 The present invention also provides a method for making a connecting device in accordance with the present invention which includes the steps of providing a sheet of shape memory metal capable of reversing between a martensitic and an austenitic state, stamping a blank from the sheet, forming the blank into a body having at 75 least two arms cantilevered from a support means for joining the arms, and folding the arms with the body in its austenitic state, such that when a substrate is inserted therein it contacts the arms. In the preferred method, the arms are bent so that they are spaced apart a distance no greater than 80 the cross sectional width of such a substrate, and preferably less than that dimension, with the body in its austenitic state. The preferred method additionally includes the step of severely bending the arms to preload the arms, with the body in its austenitic state.

85 The present invention also includes a method for making connecting devices in accordance with the present invention which include a second member in combination with the memory metal member, the method including the steps of providing a sheet of shape-memory metal capable of reversing between a martensitic state and an austenitic state, stamping a blank from the sheet 90 and forming from the blank a driver member having at least two arms cantilevered from a support means for joining the arms. Thereafter, folding the above formed arms, with the driver member in its austenitic state, such that the arms are a distance apart no greater than the cross 95 sectional width of a substrate to be inserted therein with the driver member in its austenitic state. Thereafter, connecting a second member to the driver member. The second member includes 100 a normally diverging female end having sufficient diverging strength to spread apart the arms, with the driver member in its martensitic state a distant at least equal the cross sectional width of a substrate inserted therein and the female end 105 being deformable to a closed condition by the arms, with the driver member in its austenitic state, such that the device contacts such a substrate. The method preferably includes diverging the arms of the driver member in one 110 direction, with the driver member in its austenitic state, and thereafter reverse bending the arms of the driver member in the martensitic state so that the arms again diverge from each other, but this time in the opposite direction. Thereafter, 115 connecting the driver member to the inside of an appropriately stamped second member.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

120 Figure 1 illustrates, in perspective, a low insertion force connecting device in accordance with this invention;

125 Figure 2 illustrates, in perspective, another embodiment of a low insertion force connecting device in accordance with this invention;

130

Figure 3 illustrates a third embodiment of a low insertion force connecting device in accordance with this invention;

Figures 4A and 4B illustrate the operation of a stamped low insertion force connecting device in accordance with this invention;

Figures 5A and 5B illustrate one embodiment of a zero insertion force connecting device in accordance with this invention;

Figure 6 illustrates another embodiment of a zero insertion force connecting device in accordance with this invention;

Figures 7A and 7B illustrate a third embodiment of a zero insertion force connecting device in accordance with this invention;

Figure 8 illustrates a laminate embodiment of a zero insertion force connecting device in accordance with this invention;

With reference to the Drawings, and referring particularly to Figure 1, shows a heat recoverable connecting device generally denoted by the reference numeral 10. The device includes a body 12 made from shape-memory metal material capable of reversing between martensitic and austenitic states. The body is made from Tinel™; however, any shape-memory alloys having the properties discussed in U.S. Patent 3,740,839 (Otte) can be used.

The body has two arms 14 and 16 cantilevered from a support 18 which joins the arms. The body 12 is formed by a stamping process and the arms 14 and 16 are folded at the support 18 until the arms 14 and 16 are in confronting relation with each other with the body 12 in its austenitic state. The arms are spaced apart from one another, in the austenitic state, a distance not greater than the cross sectional width of a substrate to be inserted therein. For the purposes of this invention, the cross sectional width refers to that dimension of a substrate which contacts the arms of the body (or driver or second member as will be appreciated more fully hereinafter). It will be appreciated that this dimension could be a substrate's width where the substrate is a rectangular or its diameter where it is cylindrical, as is the case with substrate 20 shown in Figure 1 or it may be an undefinable dimension in the case of an irregularly shaped substrate. In any case, the arms 14 and 16 are spaced so that when the body 12 is in its austenitic state, they contact the substrate. The arms 14 and 16 are advantageously spaced apart a distance less than the cross sectional width of the substrates 20 to ensure secure engagement of the substrate 20 with the device 12, which is especially important in electrical connections.

As is understood and as is explained in more detail in U.S. Patents 3,740,830; 4,022,519 and Reissued Patent 29,904, which are all incorporated herein by reference, when a shape-memory metal body is in its martensitic state, the body is in a weakened condition.

Hence, with the body 12 in its martensitic state, the substrate 20 easily (with low force) spreads apart the arms 14 and 16 as it is inserted

therein. Upon the body 12 returning to its austenitic state, the arms 14 and 16 attempt to return to their position where they were spaced apart a distance less than the cross sectional width (diameter) of substrate 20. However, since the substrate 20 has been inserted between the arms 14 and 16, the original austenitic position is not possible. Thereby, the confronting arms 14 and 16 exert a continuous force against the substrate 20 securely engaging the substrate 20 to device 10 with the body 12 in its austenitic state.

It will be appreciated that support 18 need not exert any force to engage the substrate 20. However, where the support is curved as shown in Figure 1, the support will exert a small force against a substrate with the body 12 in its austenitic state.

The connecting device 10 also includes a male end 22 which is adapted for connection with a printed circuit board.

With particular reference to Figure 2, there is shown another embodiment of a heat recoverable LIF connecting device generally indicated by the reference numeral 24, formed by a screw machine operation. As in the previous embodiment 10, the embodiment 24 includes a body 26 having at least two arms 28 and 30 cantilevered from a support 32 which joins the arms. Similarly, the body 26 is made from the same material as recited above with respect to device 10. Similarly, the support 32 does not necessarily act to engage substrate 34 which is inserted between arms 28 and 30, rather the arms 28 and 30 provide the necessary force for engaging substrate 34. The arms 28 and 30 are formed about vertical axis 40 and are bent inwardly, with the body 26 in its austenitic state, to create a force by the arms against the substrate 34 for securely engaging it to device 24.

With particular reference to Figure 3, there is shown a third embodiment of a heat recoverable LIF connecting device generally indicated by the reference numeral 42. As in the earlier described embodiments, the device 42 has a body 44 having two arms 46 and 48 cantilevered from a support 50 which joins the arms. The embodiment 42 is stamped, which allows the arms to be severely bent before being folded to confront one another. The arms 46 and 48 are over-bent, with the body 12 in its austenitic state, and then folded to confront one another. The bend is such that if arm 46 were removed, confronting arm 48 would bend over vertical center line 52. The arms 46 and 48 are bent, with the body 12 in its austenitic state, to achieve equilibrium along the vertical center line 52 with the ends 54 and 56 of the arms 46 and 48, respectively, in pressing contact thereby pre-loading the arms.

The arms 46 and 48 are bent by a multi-step process while the body is in its austenitic state. The first bend is made at points 58 and 60 of each of the arms 46 and 48, respectively, approximately at the one third point of each of the

arms. A second bend is made at points 62 and 64 of each of the arms 46 and 48, respectively, approximately at the two thirds point of the arms. The bending is made with a mandrel (not shown) while the driver is still a sheet.

With particular reference to Figures 4A and 4B, there is shown the operation of connecting a substrate 61 to a heat recoverable LIF connecting device in accordance with this invention. The LIF device 42 of the present invention is used herein for discussion purposes only. It will be appreciated that the operation of connecting a substrate to any LIF connecting device in accordance with this invention is generally the same.

The LIF connecting device 42 is cooled to its martensitic state by appropriate means, including cryogenic means which are described in Reissued patent 29,904 (Fischer et al) With the body in its martensitic state, the arms are in a weakened condition. As the substrate 61 is inserted into the LIF connecting device 42, ends 54 and 56 are spread apart. The force required for such spreading is low due to the weakened condition of the arms. The exact insertion force is dependent upon the materials used for making the device and the substrate. The exact insertion force (F) necessary to insert a substrate between the arms of a LIF connecting device in accordance with this invention equals twice the coefficient of friction (μ) of the material used for making the arms, times the normal force (N) exerted by the arms. It will be appreciated that the normal force (N) exerted by the arms is increased by bending of the arms and especially increased where the arms are preloaded as in device 42.

After insertion of the substrate 61 within the arms 46 and 48, the body 44 is recovered to its austenitic state by applying heat or merely removing the cooling force. The arms 46 and 48 tend to recover to their original condition with the ends 54 and 56 in pressing contact. Instead, the ends 54 and 56 exert a normal force (N) against the substrate 61 for securely engaging the substrate to the device 42. Good contact between substrate and device is especially important in electrical connections. Since the arms never fully recover, a normal force (N) is constantly exerted by the arms 46 and 48 against the substrate with the body 44 in its austenitic state. This constant normal force assures good electrical contact between the device 42 and substrate 61.

The preferred LIF connecting device 42 includes a male end 63 which is suitable for connection with a printed circuit board or the like.

It will be appreciated that any of the above described LIF connecting devices could be adapted to engage a superstrate having an opening. The arms of the LIF device are bent so that in the martensitic state, the device is inserted within the opening of the superstrate with low force. Upon transformation to its austenitic state the arms articulate as earlier described, and engage the opening of the superstrate.

With particular reference to Figures 5 to 8,

there are shown various preferred embodiments of a zero insertion force (ZIF) connecting device in accordance with this invention. The operation of the ZIF connecting device is similar to that of the LIF connecting device above described. However, unlike the previously described LIF connecting device, the ZIF connecting device includes a second member which spreads apart the arms of the earlier described body (now defining a driver member), with the body in its martensitic state. With the arms of the device in a spread apart condition prior to insertion of a substrate, the ZIF connecting device may receive a substrate with zero insertion force. The second member must, of course, be of sufficient strength to diverge the arms, with the driver in its martensitic state. As will be appreciated, the arms and the diverged end of the second member must be diverged or opened at least as great as the cross sectional width of a substrate, to enable such a substrate to be inserted therein with zero insertion force.

With particular reference to Figures 5A and 5B there is shown one embodiment of a ZIF connecting device generally indicated by the numeral 70. With particular reference to Figure 5B, there is shown the preferred form of the second member generally indicated at 74. The second member 74 defines a socket having a female end 76. It will be appreciated that the second member 74 could have a female end at either end in another embodiment. The female end 76 is bifurcated by cutting longitudinal slots therein. The female end 76 normally diverges to an open condition shown in Figure 5B. The female end 76 is made of resilient material which is deformable so that the female end 76 can be converged or collapsed to a closed condition by a driver member.

The female end 76 has two normally diverging legs 78 and 80. It will be appreciated that legs 78 and 80 must have sufficient diverging strength to spread apart the arms of a driver member with the driver member in its martensitic state, to achieve an open condition wherein the legs are apart a distance at least as great as the cross sectional width of a substrate to be inserted therein. In the device 70, the body 44 is used as the driver member. The legs 78 and 80 of the second member 76 spread apart the arms 46 and 48, respectively, with the driver in its martensitic state. With the legs 78 and 80 in this open condition, a substrate may be inserted therein with zero force.

The driver member 44 is connected to the second member 74 with the driver member 44 in its martensitic state. The second member 74 has a male end 80, which is inserted through legs 46 and 48 of the driver member, with the driver member in its martensitic state, in the manner previously described with respect to connecting a substrate to an LIF connecting device. The driver member may then be warmed to its austenitic state whereupon the driver member securely engages the second member 74.

The second member 74 has an enlarged end

zone 84 with an outside surface having an annular recess 82. As the driver shifts to its austenitic state, the ends 54 and 56 of arms 46 and 48, respectively, engage the recess 82, assuring secure connection between the driver member and second member 74. It will be appreciated that such a recess is not necessary since the arms 46 and 48 will engage the female end legs 78 and 80, anyway. The recess 82 defines a gripping means for properly locating and assuring secure engagement between driver and second members 44 and 74, respectively. The enlarged end zone 84 of the female end 76 encourages correct entry and positioning of a substrate therein.

The female end 76 is deformable to a closed position. When the driver member shifts to its austenitic state, the arms 46 and 48 force the legs 78 and 80 of female end 76 to close about a substrate inserted therein. The arms 46 and 48 attempt to recover to their austenitic position, but are prevented from doing so because legs 78 and 80 and a substrate inserted therein are between the arms. The arms 46 and 48 with the driver member in its austenitic state, possesses sufficient strength to converge the legs to their closed condition, wherein the legs contact the substrate. As a result of the preloading, described earlier, a constant normal force (N) is exerted by arms 46 and 48 upon the legs 78 and 80, which creates good contact between the second member 74 and the substrate inserted therein. The other end of the second member 74 is a male end 86 which is sized and shaped compatible for connection with a printed circuit board.

With particular reference to Figure 6 there is shown another embodiment of a ZIF connecting device generally indicated by the reference numeral 90. As in the earlier described embodiment of the ZIF connecting device 70, the device 90 includes two members, a driver member 92 of heat recoverable memory metal capable of reversing between a martensitic and an austenitic state and a second member 94 which is suitable for connection with a substrate and the driver member 92.

The driver member 92 includes two arms 96 and 98 which are cantilevered from a support 100 which joins the arms. As will be appreciated from earlier discussion, it is not necessary for the support 100 to grip either a substrate or in this case the second member 94 for the device 90 to function properly. Rather, the support 100 supports and joins the cantilevered arms 96 and 98 which articulate upon temperature change similar to previously described body 44 and the driver member of device 70.

Also, similar to earlier described second member 74, second member 94 includes a diverging female end 102. The female end 102 includes two diverging legs 104 and 106 which have outwardly turned ends 108 and 110, respectively. The outwardly turned ends serve the purpose similar to that served by the enlarged end zone 84 previously discussed, namely for

correctly positioning a substrate upon entry and thereafter between legs 104 and 106.

As will be appreciated the embodiment 90 shown in Figure 6 works in exactly the same manner as described earlier with reference to device 70. However, it will be appreciated from viewing Figure 6 that the second member 94 is stamped instead of machined or screw turned as would be the case in the earlier discussed embodiment 74. Thus, the device 90 shown in Figure 6 is particularly advantageous since it will perform precisely the same functions as described earlier, however, the members 92 and 94 are more efficiently manufactured by a stamping process. Additionally, the arms 96 and 98 are severely bent for preloading in the same manner described with reference to body 44 (Figure 3).

With particular reference to Figures 7A and 7B, there is shown a third embodiment of a ZIF connecting device generally indicated by the reference numeral 120. The operation and structure of this connecting device is similar to the earlier discussed embodiment 90 with the exception that a driver member is on the inside of a second member. The driver member pulls the connecting device 120 closed in its austenitic state, while the second member pulls the connecting device 120 open in the martensitic state, precisely opposite of the earlier discussed ZIF connecting devices 70 and 90. Additionally, the legs of the driver and second members are not in line with one another as in the earlier discussed embodiment.

The ZIF connecting device 120 includes two members, a driver member 122 made from shape-memory metal capable of reversing between austenitic and martensitic states. Similar to the earlier discussed embodiment 90, the driver member 122 includes cantilevered arms 124 and 126 joined by a support 128. In this embodiment, the arms 124 and 126 are stamped from a blank and are then bent to an austenitic position where the arms diverge from one another. The driver member 122 is then cooled to its martensitic state and the arms are bent in the reverse direction with the arms 124 and 126 again diverging from one another, but this time with arms in the opposite position. With the arms in this reverse bent martensitic position, the driver 122 is installed on the second member 130.

The second member 130 is similar to earlier discussed second member 94 and includes a female end 132. The female end 132 has diverging legs 134 and 136 with sufficient diverging strength to hold open arms 124 and 126 respectively, in the reverse martensitic bent position. After a substrate 140 is inserted between legs 134 and 136, the driver member 122 is warmed to its austenitic state for securely engaging a substrate inserted therein as shown in Figure 7B.

The second member 130 includes engagement means 138 for contacting the female end 132 with the substrate 140. Of course, the driver member 122 could include additional means for

contacting the substrate or, in fact the sole means for contacting the substrate or, in fact the sole means for doing same as will be explained more fully hereinafter. The engagement means 138 includes inwardly extending teeth 142, 144 and 146. Leg 134 includes teeth 144 and 146 appropriately spaced apart. Leg 136 includes a single tooth 142 which is positioned so that, with the female end 132 in the closed position, tooth 142 is situated between teeth 144 and 146, as shown. The driver member 122 exerts a constant force in its austenitic state upon the female end 132 and substrate 140, assuring good contact therebetween.

The second member 130 includes an abutment shoulder 148 along the surface which joins the diverging legs 134 and 136. The abutment shoulder 148 is used for positioning of the driver member 122 for connection to the second member 130. Additionally, support 128 which joins the arms 124 and 126 defines a means for stopping a substrate inserted therein. The driver member 122 is connected to the second member 130 with the support 128 contacting the abutment shoulder 148, thereby correctly positioning the members with respect to one another. Using the support 128 as a stop means, a substrate inserted therein is correctly positioned in device 120.

Legs 134 and 136 of the second member 130 have inwardly turned ends 151 and 152, respectively, for capturing the driver member 122. The ends 151 and 152 are turned inwardly and spaced from the inside surface of their respective legs 134 and 136, a distance approximately equal to the thickness of the driver member 122. Of course, other means for connecting the members 122 and 130 are possible.

In operation, the diverging female end 132 is of sufficient strength to pull the arms 124 and 126 open with the driver in its martensitic state. The legs 134 and 136 spread the arms 124 and 126 apart a distance greater than the cross sectional width of a substrate so that same is inserted therein with zero insertion force. Additionally, the female end 132 is deformable by the driver member 122 so that as the driver member warms to its austenitic state, the substrate 140 inserted therein is engaged by teeth 142, 144 and 146.

With particular reference to Figure 8, there is shown a laminate version of a ZIF connecting device in accordance with this invention generally indicated at 160. As in the earlier described device 90, the device 160 includes a driver member 162 and a second member 164. The operation of the devices 90 and 160 is identical. The structure of the devices 90 and 160 is generally the same except device 160 has its driver member 162 laminated to its second member 164.

The above described ZIF connecting device in accordance with this invention include a second member having a male end suitable for

connection with a printed circuit (PC) board or the like. As is known, Tinel™ material, as well as other shape-memory metals, do not solder particularly well. Therefore, it is preferred to make the second member with the male end. However, Tinel™ material does conduct electricity and could be specially soldered to a PC board. Also, as will be understood, no male end is necessary for the broad purposes of the instant invention.

It will be appreciated that any of the above described ZIF connecting devices could be adapted to engage a superstrate having an opening. The legs of the second member holds the arms of the driver such that in the martensitic state, the device is inserted within the opening of the superstrate with zero force. Upon shifting to its austenitic state the arms articulate as earlier described, and the device engages the opening of the superstrate.

85 Claims

1. A connecting device comprising a body of shape-memory metal capable of reversing between a martensitic and an austenitic state, the body comprising at least two arms cantilevered from a support means which joins the arms, the arms being deformable with low force when the body is in its martensitic state and the arms reverting towards their deformed state when the body is in its austenitic state.

2. A connecting device according to Claim 1, wherein the arms are deformable away from each other and converge when the body is in its austenitic state.

3. A connecting device according to Claim 2, wherein the arms are adapted such that the low force to deform said arms can be provided by insertion of a substrate and wherein the arms are adapted to engage the substrate inserted, in use, therein when the body is in its austenitic state.

4. A connecting device according to Claim 2 or 3, wherein the arms confront each other when the body is in its austenitic state.

5. A connecting device according to any one of claims 2 to 4, wherein an end of each arm is inwardly overbent (as hereinbefore defined) so that it is in touching contact with at least one other arm thereby preloading the arms to enhance engagement of the arms with a substrate inserted, in use, between the arms.

6. A connecting device according to any preceding Claim, wherein the support means comprises a split ring.

7. A connecting device according to any one of claims 2 to 6, wherein said body of shape-memory metal defines a driver member, the device further comprising a second member having at least one female end, which is normally diverging to an open condition and which is deformable to a closed condition; the driver member being connected to the second member; and the female end spreading apart the arms, with the driver member in its martensitic state, sufficiently to allow a substrate to be inserted, in use, therein, and the arms, with the driver

member in its austenitic state, forcing the female end to its closed condition for engaging a substrate inserted, in use, therein.

8. A connecting device according to Claim 7, wherein the female end of the second member sufficiently spreads apart the arms, with the driver member in its martensitic state, a distance greater than the cross sectional width of a substrate to be inserted therein, such that a substrate can be inserted in the device with zero insertion force.

9. A connecting device according to Claim 7 or 8, wherein the female end of the second member has at least two spread apart normally diverging resilient legs.

10. A connecting device according to Claim 7, 8 or 9, wherein the driver member surrounds the second member.

11. A connecting device according to any one of Claims 7 to 10, wherein the female end includes a terminus having an enlarged end zone for receiving and locating a substrate therein, and wherein the female end has an outer surface on the enlarged end zone having an annular recess defining a gripping means for securely connecting the driver and second member.

12. A connecting device according to any one of Claims 7 to 11 wherein each of the legs of the second member has an inside surface and wherein each arm of the driver member is connected to its corresponding leg member on the inside surface thereof.

13. A connecting device according to Claim 12, wherein the female end defines an abutment means for positioning the driver member correctly with respect to the second member and wherein the support means of the driver member contacts the abutment means.

14. A connecting device according to Claim 11, wherein two arms of the driver member are bent, with the driver member in its austenitic state, to diverge from one another, and wherein the arms are reverse bent, with the driver member in its martensitic state, to diverge from one another in the opposite way, and wherein the second member female end has two legs and each leg includes means for connecting its respective driver member arms thereto, and each arm is connected to its respective leg with the driver member in its martensitic state.

15. A connecting device according to claim 1, wherein the arms are adapted to be inserted within a superstrate when the body is in its martensitic state and wherein the arms are adapted to diverge to engage the superstrate when the body is in its austenitic state.

16. A connecting device, according to claim 15, comprising a second member having at least one female end, which is normally converging to a closed condition and which is deformable to an open condition; the driver member being connected to the second member; and the female end compressing the arms together, with the driver member in its martensitic state, sufficiently to allow the device to be inserted within a

superstrate, and the arms, with the driver member in its austenitic state, forcing the female end to its open condition for engaging a superstrate.

17. A connecting device according to Claim 16, wherein the female end of the second member sufficiently compresses the arms, with the driver member in its martensitic state to a closed condition such that the device may be inserted in a superstrate with zero insertion force.

18. A method for making a connecting device, comprising:

providing a sheet of shape-memory metal capable of reversing between a martensitic and an austenitic state;

stamping a blank from the sheet;

forming the blank into a body having at least two arms cantilevered from a support means for joining the arms; and

folding the above formed arms with the body in its austenitic state so the arms are a distance no further apart than the cross sectional width of a substrate to be inserted therein.

19. A method according to Claim 18, comprising further folding arms, with the body in its austenitic state, at the support means so that the arms are in confronting relation to one another.

20. A method according to Claim 18 or 19, which includes over bending (as hereinbefore defined) the arms when forming the body, with the body in its austenitic state such that the arms are in pressing contact with at least one other arm thereby providing a preloading force on the arms.

21. A method of making a connecting device according to any one of claims 18 to 20, comprising providing a second member suitable for connection with the driver member, the second member having a female end normally diverging to an open condition and having sufficient diverging strength to spread apart the arms, with the driver member in its martensitic state, such that no force is needed to insert a substrate therein and the female end being deformable to a closed condition by the arms, with the driver member in its austenitic state, such that a substrate inserted therein contacts the device; and connecting the driver member to the second member.

22. A method of making a connecting device according to claim 21, wherein the driver and second members are connected by the steps of: cooling the driver member to its martensitic state; and then inserting the second member between the arms of the driver member.

23. A method of making a connecting device, according to claim 21, wherein prior to connecting the driver member to the second member each arm of the driver member is reverse bent in its martensitic state so that the arms diverge from one other but this time with the arms in the opposite position to that in the austenitic state and wherein the driver member is connected in its reverse bent martensitic position to the second member with each of the arms of

the driver member positioned on one inside surface of the legs, of the second member such that when the driver member transform to its austenitic state, the arms recover to their
5 austenitic position deforming the legs to the closed condition for engaging a substrate therein.

24. A connecting device whenever made by a method according to any one of claims 18 to 23.

10 25. A connecting device substantially as hereinbefore described with reference to the accompanying drawings.