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(54) Electric circuit connecting devices.

(57) A connecting device for one or a large multiple of electric circuits comprises two dissimilar cooperating parts. Each circuit line to be interconnected requires one electrically conductive prong (10) and one stand of electric conductors (12) arranged substantially parallel to each other for permitting the prong (10) to be inserted between at least two of the conductors (12) and forcing a wiping contact between the prong (10) and the conductors (12). On inserting the prong between the conductors wiping contact is made between the conductors and the prong along the longitudinal axis of the two components. The required force for insertion is minimized in a structural relationship wherein the conductors are substantially elongated cylinders of conductive material and the prong is a figure of revolution, having a surface lying along a line defined by the equation of a uniformly loaded cantilever beam as represented by one of the conductors in wiping contact with the prong. This can be expressed by the equation

$$Y = (WX^2/24EI)\ (X^2 - 4LX + 6L^2)$$

where
X is the dimension along said longitudinal axis,
Y is the distance from that axis to a point lying on the curve,
W is the constant force per unit length along said prong,
E is Young's Modulus of said conductors,
I is the sectional moment of inertia of said conductors, and
L is the length of said conductors alongside said prong.

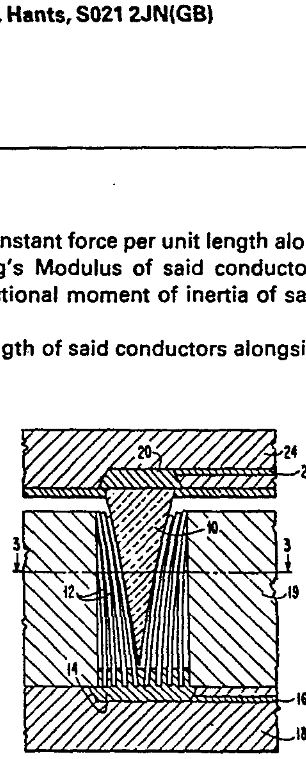

FIG. 1

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Croydon Printing Company Ltd.

ELECTRIC CIRCUIT CONNECTING DEVICES

Field

The invention relates to devices for interconnecting two parts of an electric circuit, and is particularly, but not exclusively concerned with such devices that are ganged for interconnecting a multiple of electric circuits.

Background

The development of electric circuit connecting devices has a long history. A great number of different mechanisms for interconnecting electric circuits have been devised and used. As electric circuit arts have advanced, new requirements have been imposed on the circuit connecting devices. One of the vexing problems prior to this invention is that of providing a satisfactory coupling device for interconnecting a multiple of electric circuits simultaneously by means of a simple manually operated device. As an example, a device is needed for interconnecting hundreds or thousands of individual electric circuits with little effort by use of a two-dimensional array of connectors.

Summary

In accordance with the invention, a connecting device for one or a large multiple of electric circuits comprises two dissimilar but complementary parts. Each circuit to be interconnected requires one electrically conductive prong and one stand of electric conductors arranged substantially parallel to each other, and preferably spaced apart a short distance, for permitting the prong to be inserted between at least two of the conductors and forcing a wiping contact between the prong and the conductors. On inserting the prong between the conductors the wiping contact is made between the conductors and the prong along the longitudinal axis of the two components. On extraction the elastic conductors return to their original positions. It is contemplated that many re-insertions are possible since the elastic limits of the conductors are not exceeded during insertion. The required force for insertion is minimized in a structural relationship wherein the conductors are substantially elongated cylinders of conductive material and the prong is a figure of revolution, having a concave surface. In a preferred embodiment, the surface lies along a line defined by the equation

$$Y = (WX^2/24EI)\ (X^2 - 4LX + 6L^2), \qquad (1)$$

where X is the dimension along the axis of the prong,
Y is the distance from that axis of a point on the curve,
W is the constant force per unit length along the prong,
E is Young's Modulus of the conductors in the stand,
I is the sectional moment of inertia of the conductors, and
L is the length of the conductors.

The curve will be seen to be that of one of the conductors in the form of a uniformly loaded cantilever beam. In addition to permitting contact with the minimum amount of insertion force, the wiping action occurring also provides a most efficacious interconnection for low electric contact resistance. An interconnecting device is comprised of a multiplicity of such conductors in contact with a single prong.

It is contemplated that this interconnecting device be but one of a large multiple of such devices arranged conveniently in "plug and socket" relationship and manually operable in such manner. For example, a cable terminated in a plug having a two-dimensional matrix of conductive prongs for mating into a similar matrix of stands of conductors arranged in a socket or behind a panel of a machine.

Prior Art

Although the inventors are not aware of any prior art arrangements coming within the definition of the electric circuit-connecting device defined in the appended claims, some of the structural features thereof, taken out of context of course, are to be found in the following US patents:

RE11,968	2/1902	Greil et al	-
663,750	12/1900	Greil et al	-
2,156,272	5/1939	Bell	174/94
2,969,520	1/1961	Waldo	339/105
3,427,551	2/1969	Oshima	339/47
3,560,909	2/1971	Wyatt et al	339/100
3,725,844	4/1973	McKeown et al	339/49R
4,050,773	9/1977	Newell	339/224

In the European patented art:

1,045,735	10/1966	Chandler	Great Britain
1,224,281	6/1960	Bergner	France
1,387,274	12/1964	Amp (Co.)	France

The two patents to Greil and Audiger disclose electric circuit connecting devices comprising two parts similar in some respects to the parts of the invention. A bundle of elongated conductors is arranged in a well, and a relatively large diameter convex conductive prong is inserted into the bundle of conductors for completing the contact between two parts of an electric circuit. The convex prongs require considerable pressure to insert into a bundle of conductors, and there is no suggestion of a concave prong as contemplated by the instant invention.

The patent to Bell, and that to Newell as well, discloses a conical conductive prong for insertion into an end of a length of stranded electric wire. The same disadvantages apply and there is no suggestion of a concave prong as contemplated by the invention.

The patent to Waldo is directed to a strain relief but also shows a conductive conical prong and stranded wire connecting arrangement such that some displacement can be tolerated. The patent to Wyatt and Wright discloses an arrangement similar to that of Waldo. These arrangements do not use a concave prong as contemplated according to the invention.

The Oskima and McKeown et al patents each show mating electric conductors having wiping contact areas of considerable length. Oskima is concerned with rather inflexible contactors, and McKeown et al join a number of fine flexible beryllium copper wires (as in a pair of stranded wires) by directly interlaying. The concept of a concave tapered conductor inserted into a bundle of elastic wires is absent.

The Bergner (French) patent is not particularly pertinent other than for the use of one tapered sleeve placed over one conductor of a group for expanding the bundle in a surrounding cylindrical sleeve. Likewise the connector shown in the French patent to the AMP Co. discloses little more than the use of a conical wedge, which may even be an insulator, for expanding the ends of a stranded wire against the inside wall of a conical conductive tube to obtain a permanent connection. In the instant invention a temporary, reusable connection is contemplated. Furthermore, no showing of a concave pronglike wedge is seen.

Not only does the prior art as listed fail to show a concave conductive prong in and of itself, but there is no suggestion of any kind that the curve defining the prong be in any way related to the deformation of the several conductors in the stand as is the case with the connector according to the invention as will be described hereinafter.

Accordingly the invention provides an electric circuit connecting device comprising a stand of elongated electric conductors each having one end connected in common to one part of said electric circuit and extending substantially parallel to one another, and an electrically conductive prong having one end thereof electrically connected to another part of said electric circuit to be connected and having the other end thereof of reduced diameter for inserting said prong into said stand of conductors for completing said electric circuit, characterised by said prong having a configuration comprising a surface of revolution about the longitudinal axis defined by said ends of said prong, said surface of revolution being defined by a curve concave with respect to said axis and progressing from substantially zero at said other end to the maximum dimension at said one end.

The invention also provides an electric circuit connecting device comprising a stand of electric conductors electrically connected to one part of said electric circuit to be connected and an electrically conductive prong connected to another part of said electric circuit for inserting into said stand of conductors and making electric contact with a plurality of said conductors, characterised by said prong having a peripheral contour in the form of a surface of revolution about the longitudinal axis lying in the curve

$$Y = (WX^2/24EI)\ (X^2 - 4LX + 6L^2)$$

where X is the dimension along said axis,
Y is the distance from that axis to a point on the curve,
W is the constant force per unit length along said prong,
E is Young's Modulus of said conductors in the stand,
I is the sectional moment of inertia of said conductors, and
L is the length of said conductors.

The invention will now be further described with reference to the accompanying drawings, in which:-

FIG. 1 is a cross-sectional side view of a pair of complementary electric circuit connecting members according to the invention;

FIG. 2 is a cross-sectional side view of a stand of conductors according to the invention;

FIG. 3 is a plan view of an array of stands of conductors as contemplated for use in a connector and illus ating different conditions of alignment according to the invention;

FIG. 4 -- sections (a), (b), and (c) being taken together -- is a schematic diagram illustrating the fundamental concepts of a complementary prong and conductors according to the invention in comparison with prior art structures;

FIG. 5 -- sections (a), (b), and (c) being taken together -- is an illustration of one particular condition occurring in use of the connecting members according to the invention; and

FIG. 6 is a graphical representation of force v. insertion depth useful in an understanding of the invention.

Description

A side-view in cross-section of cooperating complementary and dissimilar counterpart electric circuit connecting members according to the invention is shown in FIG. 1. The members comprise a substantially rigid conductive prong 10 and a multiple of substantially flexible conductors 12 into a stand of which the prong 10 is inserted. Two or more of the conductors 12 will wipe along the surface of the prong 10 as shown. The conductors 12 are imbedded in a pad 14 to which an electric circuit conductor, usually in the form of a printed circuit wiring trace 16, is attached. A stand of conductors 12 is held in place by an insulating member 18 and protected by an insulating member 19, the latter members forming no part of the invention in and of themselves. Similarly, the conductive prong 10 is fitted with a head 20 to which a conductor 22, also usually in the form of a printed circuit wiring trace, is fitted, and the prong is mechanically and electrically connected to the above printed wiring structure 24. FIG. 2 shows a stand of conductors 12 prior to the insertion of a prong. Preferably, the conductors 12 are spaced apart at a center-to-center distance of the order of twice the diameter of the conductors.

A plan view of an array of multiple stands of conductors is shown in FIG. 3. As will be seen hereinafter, the connection according to the invention is especially advantageous in large arrays. The simplicity of the connector makes small dimensions possible, allowing a large number of connections per unit area. A stand 30 is a cross-section top view of the stand shown in elevation in FIG. 2. A similar stand 32 is shown with a prong 10 inserted corresponding to the cross-section along the line 3-3 as shown in cross-section in FIG. 1. A slightly different situation is shown wherein a stand 34 has inserted therein a prong 10, which is considerably off-center due to misalignment for one reason or another. Thus it is seen that the connector is highly tolerant to dimensional variations. The insulating member 19 acts as a stop for the insertion of the prong 10, and also protects the conductors 12 from damage. It is also contemplated for some applications, that a plug having a multiple of prongs 10 be fitted with a telescoping sleeve to protect the prongs when the plug is not in a socket. A pair of pins, or like indexing means, longer than the prongs are arranged in the plug for inserting into bores 36 and 38 for guiding the plug into the socket. This feature is not otherwise illustrated as it is believed to be well known in the art.

The mating action of the components of the connector is shown in FIG. 1. For low resistance contacts and flexibility, the conductors 12 in each stand are made of phosphor bronze or a beryllium copper alloy or like material. The material should have a high Young's modulus and high yield strength to provide the required spring action without permanent deformation. The conductor is preferably plated with gold or palladium or other suitable material for good contact properties.

The conductors 12 are preferably fabricated with 0.00635-0.00762 cm. (0.0025 to 0.0030 inch) diameter Neyoro-G wire having a composition of 71.5% gold, 14.5% copper, 8.5% platinum, 4.5% silver and 1.0% zinc. The conductors may be joined by welding, brazing or soldering one end of each to a pad 14 on a mother board. Mechanical crimping within a cylindrical tube or a one-piece forming operation is also contemplated. The length of the conductors 12 is 0.15 to 0.20 cm. (or 0.060 to 0.080 inch). These dimensions allow an array of connects to be spaced on a 0.12 cm. (or 0.050 inch) square grid as shown in FIG. 3.

The conductive prong 10 is mechanically formed to the required shape to produce a low force, low contact angle "parting" action upon insertion. The shape of the prong 10 derives from the elastic line equation for the uniformly loaded cantilever beam hereinbefore given by equation (1).

The coordinates for the curve defined by equation (1) are based on an origin at the point of the prong 10 for X_o and substantially at the fixed end of the conductors 12 for Y_o as shown in FIG. 4. The X-Y coordinates are oriented for agreement with the more conventional orientation for depicting the bending of cantilever beams. In the context of the connector, a mating prong of this shape will cause the conductor in the stand to be uniformly loaded as shown in FIG. 4, which is a graphical representation of a plot of prong radius against the distance from the point for an arbitrary fixed set of parameters. The preferred shape is shown in FIG. 4(c). The shape is that of a surface of revolution formed by revolving the quartic curve of Equation (1) about the x axis, which is also the longitudinal axis of the prong 10. The curvature is such as to provide a large contact area and a long wiping length. As the connector becomes fully engaged, a larger number of conductors contact the prong and each other providing additional electric pathways tending toward a reliable low resistance connection.

The advantages of the quartic prong 10 over the conical 50 or ogive 40 configurations is that it allows the maximum insertion depth to be realized and therefore minimizing connector inductance. Conductors in the stands are uniformly stressed for a longer connect-disconnect cycle life. The stress per unit length along the conductors is low, thereby minimizing the thickness of precious metal plating used. The wiped length of the conductors remains stressed and in contact with the prong, providing a high tolerance to contamination.

FIG. 4 graphically illustrates the mating action for these three types of prongs. In the case of the ogive 40, there is a concentrated stress and wire splaying which interferes with adjacent conductors in the stand. For the straight cone 50, the conductors remain in contact with the prong but there are no contact forces above the rather small curved contact region. For the quartic prong 10, according to the invention, there is a uniform stress along the entire length of the conductors.

There is some possibility, especially in multiconnector arrays, of one or more prongs abutting a conductor as shown in FIG. 5. This is minimized by using as small a conductor diameter as possible. With the ends of the conductors rounded or pointed as by an etching process, there is less of a problem here. Also, a high aspect ratio and springy conductors have a tendency to help move the members into place.

A graphical representation of the insertion force required for inserting a prong according to the invention into a stand of conductors and a comparison with prongs of other configuration is made in FIG. 6. A curve 60 depicts the force required with a prong of ogive shape 40 as indicated. Another curve 62 depicts the force required by a substantially conical prong 50, while a further curve 64 represents the force required with a concave prong 10 according to the invention. The latter curve indicates a lower insertion force which is a distinct advantage in using the concave prong 10 in multiple circuit plugs and sockets.

While the invention has been described in terms of express embodiments, and alternatives have been suggested, it should be recognized that those skilled in the art will suggest other changes without departing from the spirit and scope of the invention as defined in the appended claims.

CLAIMS

1. An electric circuit connecting device comprising a stand of elongated electric conductors (12) each having one end connected in common to one part (16) of said electric circuit and extending substantially parallel to one another, and an electrically conductive prong (10) having one end thereof electrically connected to another part (22) of said electric circuit to be connected and having the other end thereof of reduced diameter for inserting said prong (10) into said stand of conductors (12) for completing said electric circuit, characterized by

said prong (10) having a configuration comprising a surface of revolution about the longitudinal axis defined by said ends of said prong, said surface of revolution being defined by a curve concave with respect to said axis and progressing from substantially zero at said other end to the maximum dimension at said one end.

2. An electric circuit connecting device as claimed in claim 1, further characterised in that said prong has a configuration comprising a surface of revolution about the longitudinal axis conforming to the longitudinal shape assumed by a said conductor when deformed as a uniformly loaded cantilever beam anchored substantially at the undisplaced end.

3. An electric circuit connecting device as claimed in claim 1 or 2, further characterised in that said prong has a peripheral contour in the form of a surface of revolution about the longitudinal axis lying in the curve

$$Y = (WX^2/24EI)(X^2 - 4XL + 6L^2)$$

where X is the dimension along said axis,
Y is the distance from that axis to a point on said curve,
W is the constant force per unit length along said prong,
E is Young's Modulus of said conductors,
I is the sectional moment of intertia of said conductors, and
L is the length of said conductors.

4. An electric circuit connecting device comprising a stand of electric conductors (12) electrically connected to one part (16) of said electric circuit to be connected and an electrically conductive prong (10) connected to another part (22) of said electric circuit for inserting into said stand of conductors and making electric contact with a plurality of said conductors, characterised by said prong having a peripheral contour in the form of a surface of revolution about the longitudinal axis lying in the curve

$$Y = (WX^2/24EI)(X^2 - 4LX + 6L^2)$$

where X is the dimension along said axis,
Y is the distance from that axis to a point on the curve,
W is the constant force per unit length along said prong,
E is Young's Modulus of said conductors in the stand,
I is the sectional moment of inertia of said conductors, and
L is the length of said conductors.

5. An electrically conductive prong for use in an electric circuit as claimed in claim 4, said prong being characterised by having a peripheral contour in the form of a surface of revolution about its longitudinal axis lying on a curve expressed by the equation:

$$Y = (WX^2/24EI)(X^2 - 4LX + 6L^2)$$

where X is the dimension along said longitudinal axis,
Y is the distance from that axis to a point lying on the curve,
W is the constant force per unit length along said prong,
E is Young's Modulus of said conductors,
I is the sectional moment of inertia of said conductors, and
L is the length of said conductors alongside said prong.

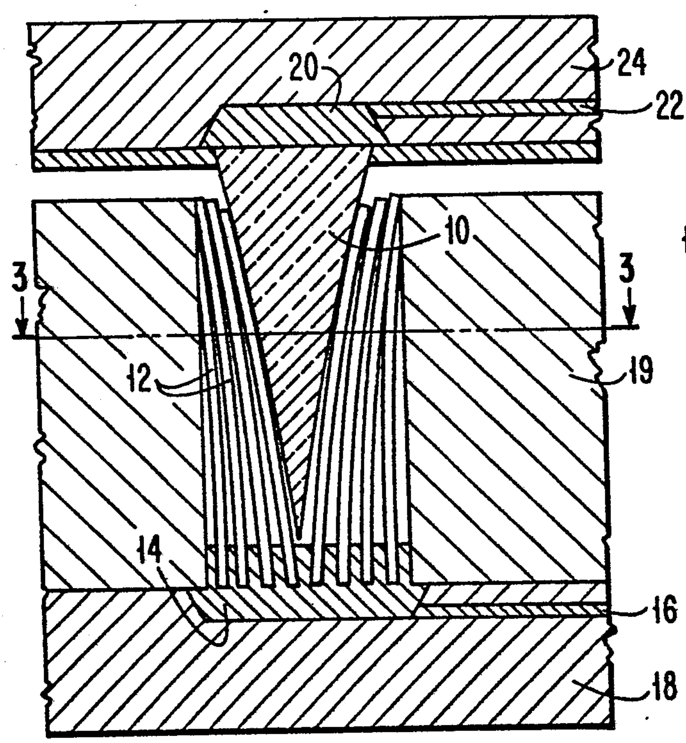

FIG. 1

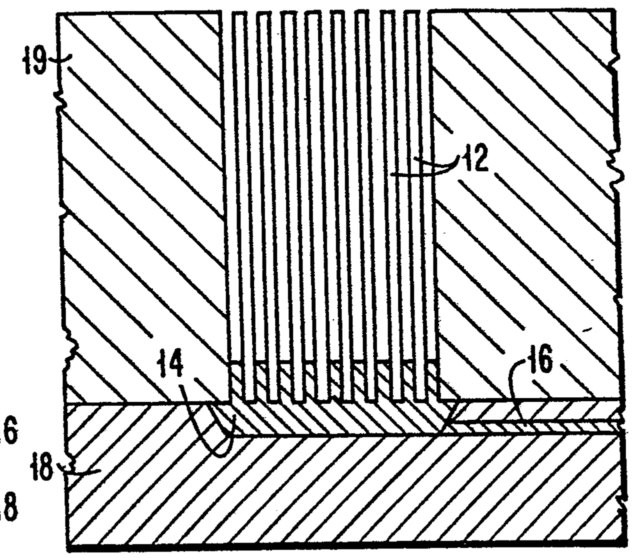

FIG. 2

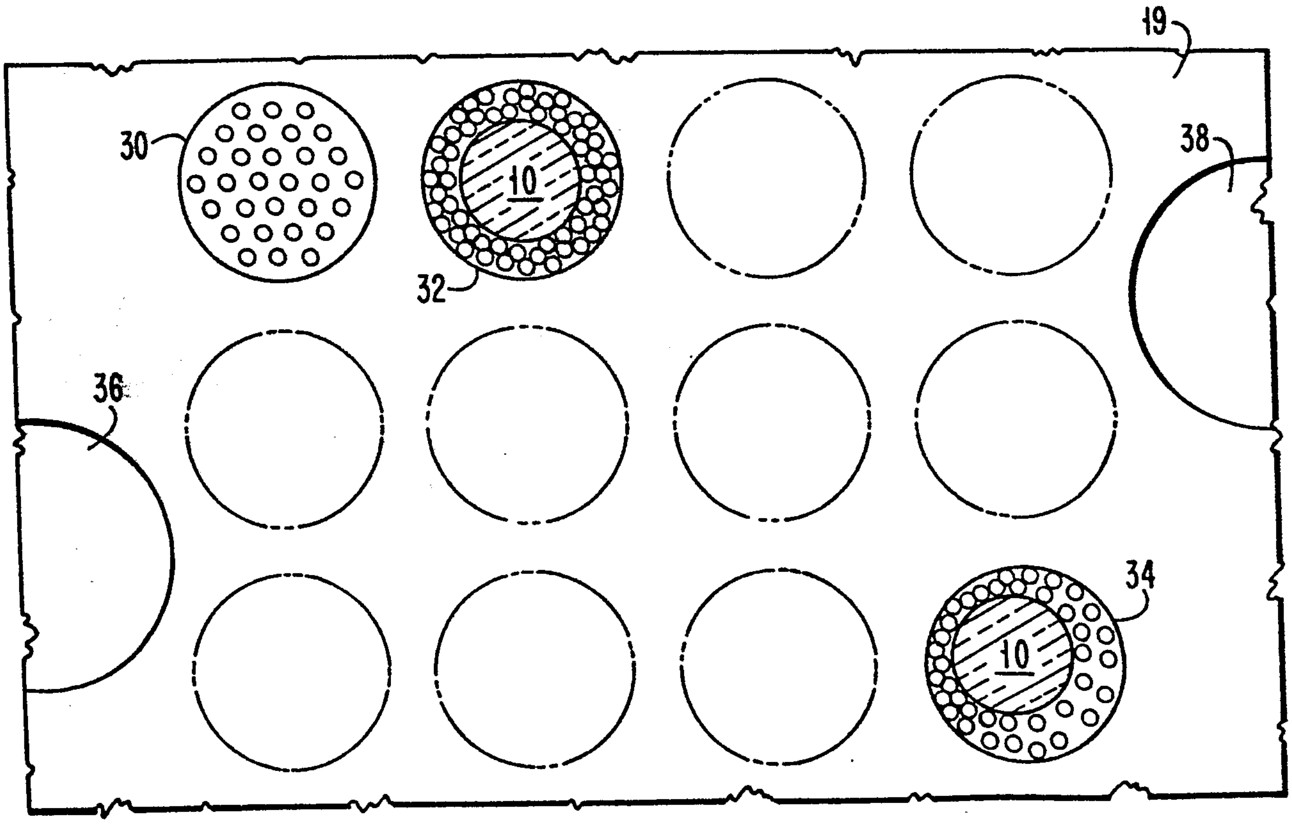

FIG. 3

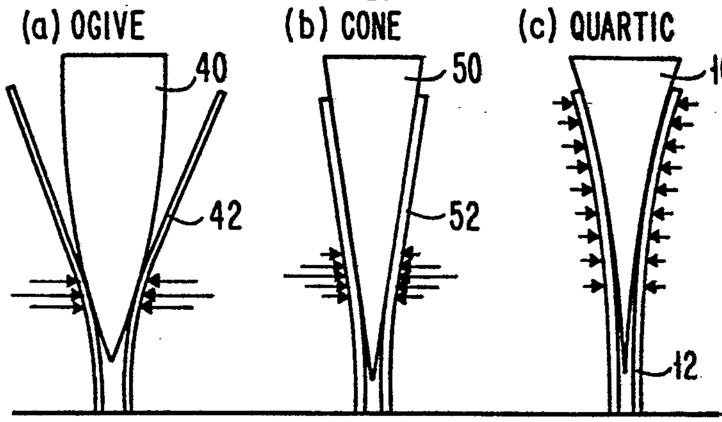

FIG. 4

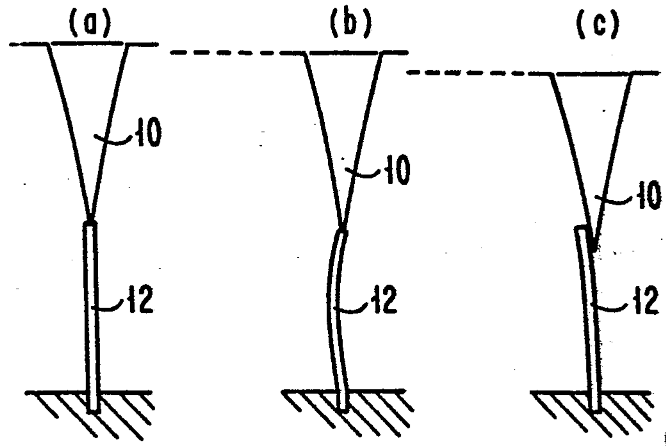

FIG. 5

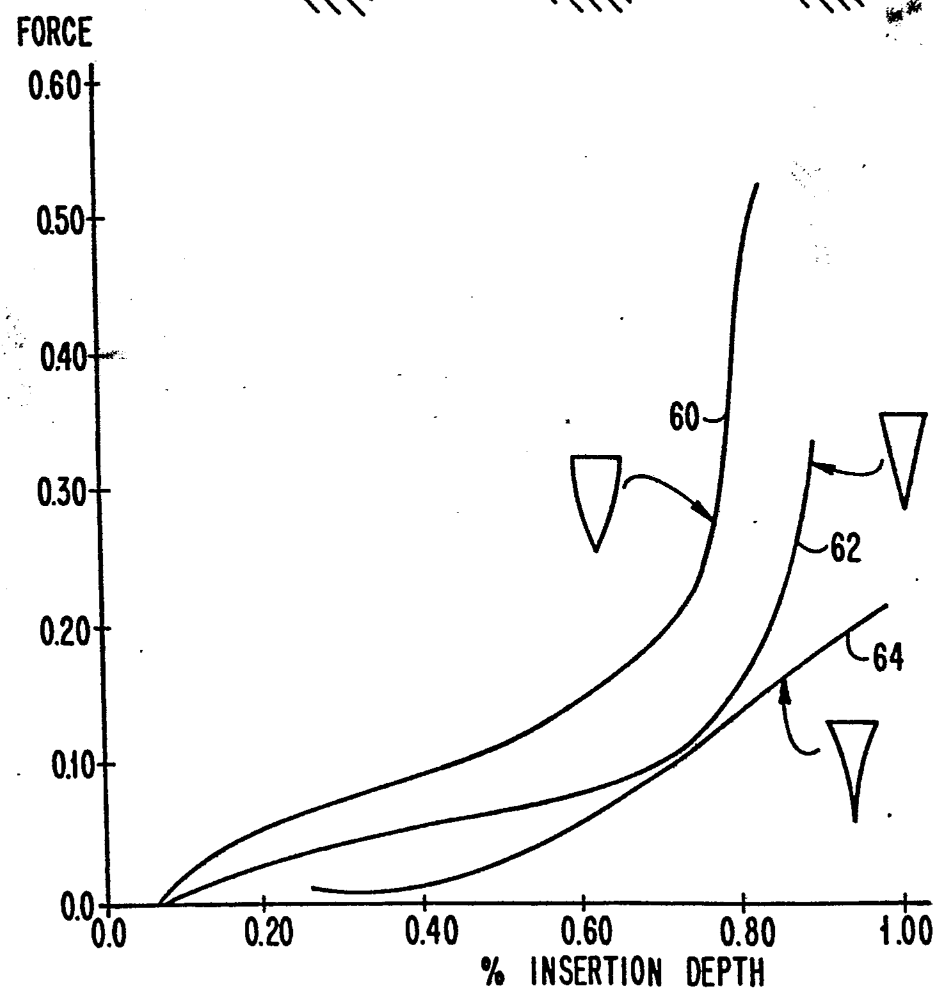

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

0069212

Application number

EP 82 10 3885

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
D,Y	US-E- 11 968 (GREIL et al.) * Whole document * ---	1	H 01 R 13/33
Y	GB-A- 214 525 (ELLA MARTIN) * Figures * ---	1	
A	FR-A- 361 525 (GOURJU) * Page 1, line 54 - page 2, line 4; figure 4 * ---	1	
A,D	US-A-2 969 520 (WALDO) * Figures * ---	1	
A	GB-A-2 026 786 (BENDIX) * Page 2, lines 30-36; figures * ---	1	
A	GB-A-1 007 718 (FITCH) * Page 2, lines 18-36; figures * -----	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 3) H 01 R 13 H 01 R 9 H 01 R 4

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18-10-1982	RAMBOER P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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