June 11, 1968 ŠTĚPÁN FIGAR 3,387,608

ELECTRODE FOR ELECTROMEDICAL MEASUREMENT

Filed Jan. 4, 1965 2 Sheets-Sheet 1

FIG. 2

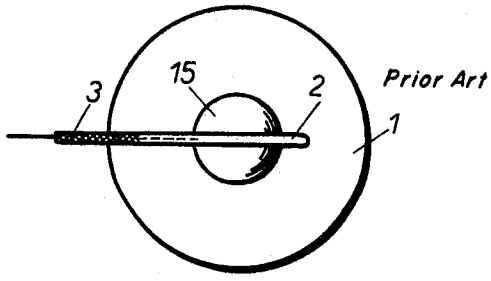


FIG. 3

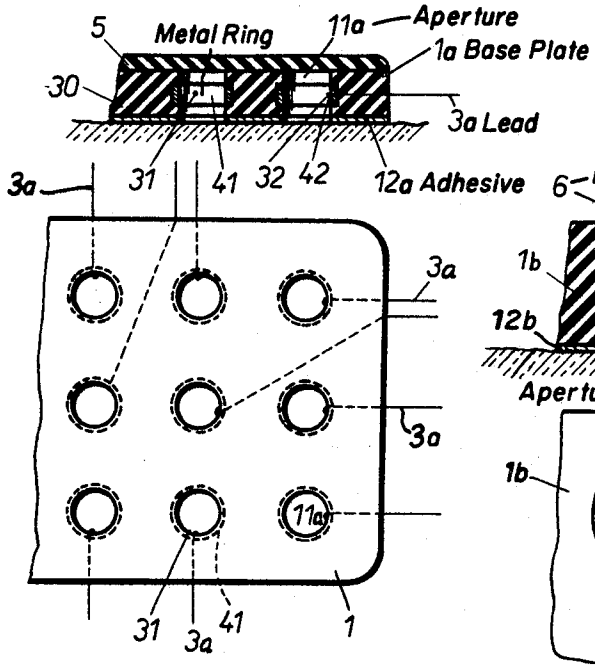


FIG. 4

FIG. 5

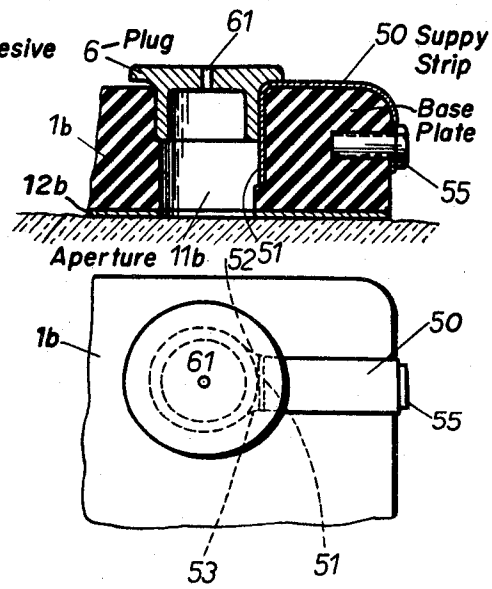


FIG. 6

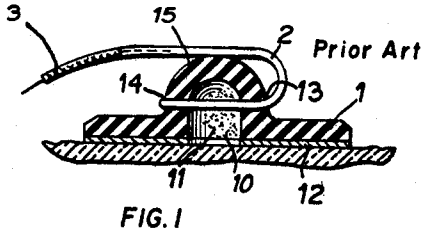


FIG. 1

INVENTOR.
Štěpán Figar
BY
Richard Hurd
Atty

June 11, 1968 ŠTĚPÁN FIGAR 3,387,608

ELECTRODE FOR ELECTROMEDICAL MEASUREMENT

Filed Jan. 4, 1965 2 Sheets-Sheet 2

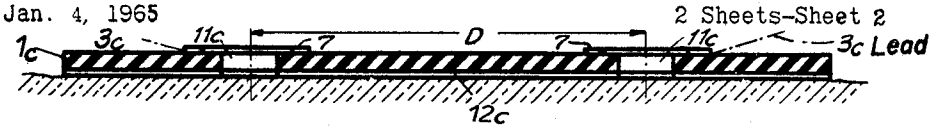


FIG. 7

FIG. 8

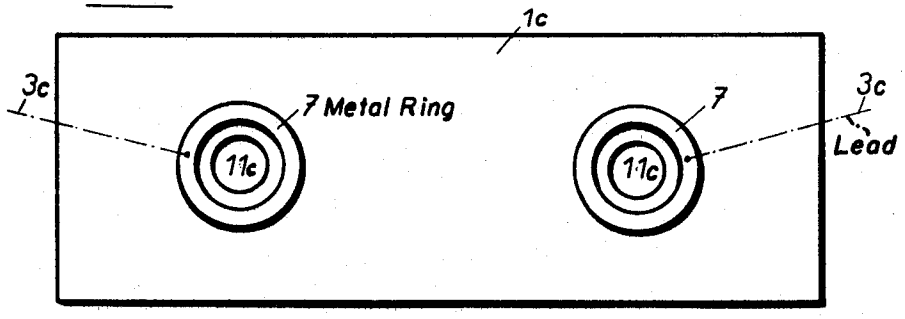


FIG. 9

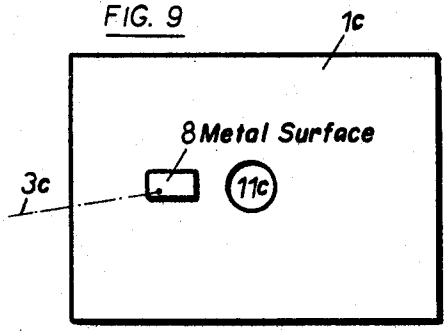


FIG. 10

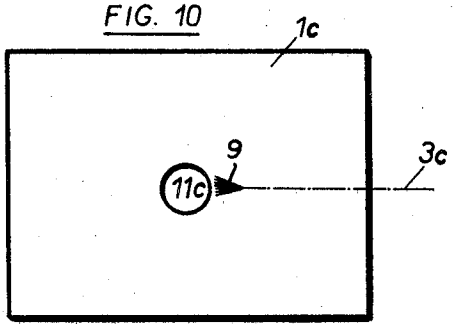
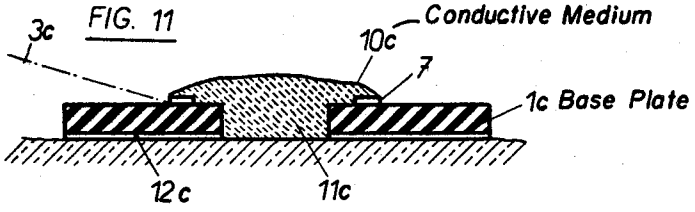


FIG. 11



INVENTOR.
Štěpán Figar
BY
Reland Hurd
Atty

United States Patent Office

3,387,608

Patented June 11, 1968

3,387,608

ELECTRODE FOR ELECTROMEDICAL MEASUREMENT

Štěpán Figar, Prague, Czechoslovakia, assignor to Ceskoslovenska akademie ved, Prague, Czechoslovakia

Filed Jan. 4, 1965, Ser. No. 423,039
Claims priority, application Czechoslovakia, Jan. 7, 1964, 92/64
5 Claims. (Cl. 128—2.06)

ABSTRACT OF THE DISCLOSURE

In an electrode which is to provide electrical connection between animals or humans and an electrical readout apparatus there is a relatively thin plate of a resilient nonconducting material. The front face of the plate contacts the skin of the wearer, the opposite face of the plate being referred to as the reverse face. The plate has at least a single aperture extending throughout the plate, and in one embodiment of the present electrode at least a portion of a conductive element is held within said aperture in a spaced relationship with respect to both said front and said reverse face, and a conductive medium fills the well and establishes electrical connection between the skin and the conductive element. According to another embodiment, a conductive element is held on the reverse face, while the conductive medium fills the aperture fully. In the latter case lead means establish electrical connection between the conductive medium and the conductive element.

The invention relates to an electrode for electromedical measurements, which is intended for establishing an electrically conductive connection with the surface of the human or animal body, more particularly for picking up bioelectrical potentials. The invention also relates to the method of applying the electrode in accordance with the invention to the examined or tested body.

Electrodes of the above mentioned type are particularly useful in electrocardiographic, electromyographic, electroencephalographic and similar examinations, and also for measuring electrical properties of biological tissue, for example, the electrical resistance of skin. The electrode in accordance with the invention also allows application of an electrical voltage to the surface of the human or animal body.

Existing electrodes of the referred to type ordinarily include a flat metal connection piece having mostly the shape of a plate which is directly applied to a certain spot of the surface of the body. In order to secure a low contact resistance the chosen spot is covered with a layer of an electrically conductive paste, and the metal connection piece is placed on this layer. The position of this connection piece is secured by means of a suitable strap or the like. The picked up potentials or the applied voltage are, as a rule, very low, and the conditions prevailing at the place at which the conductive connection is established are therefore very important. There are many factors which have hitherto been neglected in designing and using electrodes, for example, the thickness of the applied layer of the conductive paste decreases quickly by drying, and this affects the measurement to a large extent if it extends over a longer period of time. Another inaccuracy of the measurement is caused by the fact that the size of the area covered by the paste and the conductive cross-section between the surface of the body and the metal connection piece are not exactly defined. Since drying of the conductive paste proceeds from the borders of the metal connection piece or plate, the conductive cross-section decreases in an entirely uncontrollable manner.

Another severe disadvantage of existing electrodes resides in the fact that, as the paste dries, a direct mechanical contact between the connection piece and the surface of the body is created. In many cases the effects of this contact may even endanger the results of the pick-up tests or obstruct them completely. The thus created direct contact between the electrode and the surface of the body impedes the free movement of the body in the seating face of the electrodes. Consequently, immediately below the surface of the body there are created abnormal conditions with respect to the transmission of bioelectrical potentials which, of course, affects their magnitude and time characteristics. If, in consequence of the relative slight movement of the body with respect to the connection piece, there is produced an additional potential, such additional potential is algebraically added to the bioelectrical potential which has to be picked up. Experience has shown that the relative movement between the connection piece and the body produces additional potentials, interference noises, disturbances or artefacts of such magnitude that they exceed many times the value of the bioelectrical potential which has to be picked up or sensed.

It is the primary object of this invention to eliminate the above mentioned drawbacks.

Stated briefly but more specifically, the electrode in accordance with the invention is characterized by the fact that it comprises a conductive element which is positioned in spaced relationship from the surface of the body, that is being examined. This spaced relationship which prevents direct contact between the conductive element and the tested place of the body is achieved by means of a resilient holder which can be applied to the examined surface in a permanent position and over a well defined area.

In a preferred embodiment of the invention, the resilient holder is a base plate made of an electrically nonconductive and resilient material, such as rubber and the like. In this plate is provided at least one aperture opening both in the front face of the base plate, that is, the side which is applied to the examined surface of the body, and in the opposite or reverse face. The opening of the aperture in the reverse face may be covered by a removable closure.

The conductive element of the electrode is constituted by a conductive metal connection piece positioned in spaced relationship from the front face of the base plate so that direct contact between the conductive element of the electrode and the examined surface is safely prevented. Electrically conductive connection between the metal connection piece and the surface of the body is achieved by placing in the referred to aperture an electrically conductive medium, such as, a paste or liquid, which covers the metal connection piece.

The base plate can readily be fastened to the examined surface of the body by means of suitable adhesive material, such as, mastic dissolved in highly volatile ether.

The above mentioned and other features of the invention and its various advantages will be best understood from the following specification to be read in conjunction with the accompanying drawings illustrating examples of carrying out the invention. In the drawings:

FIGS. 1 and 2 illustrate a simple eiectrode in a sectioned elevation and a plan view, respectively, to show a feature of known electrode assemblies;

FIGS. 3 and 4 illustrate a multiple electrode in accordance with the invention similarly in a section and a plan view, respectively, a part being omitted in FIG. 4;

FIGS. 5 and 6 show to enlarged scale a section and a plan view, respectively, of another modification of the electrode;

FIGS. 7 and 8 show to enlarged scale a section and a plan view, respectively, of a twin electrode in accordance with the invention;

FIGS. 9 and 10 illustrate two modifications of the electrodes of FIGS. 7 and 8 in plan views; and

FIG. 11 shows an elevational section of the electrode according to FIGS. 7 and 8, on a larger scale explaining the application of the electrode.

Referring now in greater detail to the drawings, and initially to the construction illustrated in FIGS. 1 and 2, it can be seen that the electrode comprises a base plate **1** made of a resilient and electrically non-conductive material, for example, rubber and the like, which is fastened or stuck to the examined area of the body by means of a layer of adhesive material **12**. The base plate is provided on its reverse side with a projection **15** which defines a hollow **11** opening in the front side, and closed on the reverse side, of the base plate **1**. In the lateral wall of the projection **15** are provided two openings **13** and **14** in two substantially opposite places. A conductive connection piece **2** has the shape of the letter U. The hollow **11** is filled with an electrically conductive paste **10**, and one leg of the connection piece **2** is passed through the two holes **13** and **14** in the wall of the projection **15**, and the other leg of the connection piece is connected with a connection wire or cable **3**. FIG. 1 shows the connection piece **2** assembled with the projection **15** so that the hollow is completely closed after the base plate **1** has been applied to the surface of the body. When the connection piece **2** is inserted in one of the two holes, for example, the hole **13** the opposite opening **14** remains open until the very last moment before the insertion of the connection **2** therethrough. The electrically conductive paste in the hollow **11** secures electrical connection between the surface of the body and the conductive connection piece **2** over an area defined by the opening of the hollow **11** in the front face of the base plate. In FIGS. 1 and 2 an electrode construction is shown which may be referred to as a closed system as distinguished from an open system that involves essential features of the present invention and is shown in FIGS. 2 to 11 and described hereinafter.

The multiple electrode in accordance with FIGS. 3 and 4 is intended for simultaneous testing or picking up of a larger number of spots close to each other on the tested body. In the flat base plate **1***a* are several holes **11***a* extending throughout and in the walls of which are inserted metal rings **41**, **42** to which are connected ends **31**, **32** of connection **3***a*. These connections pass through the flat base plate **1***a* to the metal rings **41**, **42**. The flat base plate **1***a* is covered on its front side with an adhesive layer **12***a* by means of which the plate **1***a* is stuck or attached to the surface of the body. After the plate **1***a* has been thus applied to the tested body and secured to it, the openings **11***a* are filled from outwardly with an electrically conductive paste (not shown). If required, particularly in measurements extending over a longer period of time, the reverse side of the base plate **1***a* is covered with a rubber plate **5** which prevents drying of the conductive paste. This rubber plate which is conveniently secured to the reverse face of the base plate **1***a* by means of mastic dissolved in ether creates an elastic closure of all openings **11***a*. The various terminals of the connection **3***a* may be spliced together to form a single spliced wire terminated by a multi-pole, non-interchangeable plug. This prevents completely any mistake in the location of the various terminals and leads and facilitates handling of the electrode.

In the embodiment according to FIGS. 5 and 6, openings **11***b* are closed by means of hollow metal stoppers or plugs **6**. Into each opening **11***b* extends a bent end **51** of a supply strip **50** whose other end is connected with a jack **55**. If the bent end **51** is flat and inserted into an opening **11***b* having a circular cross-section, the cross-section of the bent end portion **51** becomes deformed as the plug **6** is inserted in the opening. Small ducts **52** and **53** are thus created at both edges of the bent end **51**. Air can now escape from the opening **11***a* through these ducts **52** and **53** while plug **6** is inserted.

The plug **6** is shown to be provided with an air vent **61**. Such vent may supplement the ducts **52**, **53** or may exclusively be provided if, for instance, conductive connections of the kind shown in FIGS. 3 and 4 are used instead of the supply strip **50**. The vent **61** may be closed when the aperture **11***b* has been filled with a conductive paste.

In the embodiments illustrated in FIGS. 7 to 11, conductive connection pieces **3***c* terminate on the reverse side of a flat base plate **1***c* in the vicinity of an opening **11***c*. This termination may be accomplished in various manners, for example, by a flat ring **7** made from a thin metal foil, or a thin metal surface **8**. The conductive connection piece **3***c* is shown at **9**, FIG. 10, to terminate in a plurality of conductors. All types of termination, that is, the flat ring **7**, the thin metal surface **8**, or the various conductors at **9** are secured to the reverse side of the flat plate **1***c* in the vicinity of the respective opening **11***c*.

FIG. 11 shows how the electrically conductive paste **10***c* is filled into the opening **11***c* after the electrode of the above described embodiment according to FIGS. 7 to 10 has been secured to the surface of the body. The conductive paste does not only cover the sharply defined place of the surface of the body, but also the ring **7**, the thin metal surface **8**, or the plurality of conductors **9** on the reverse side of the base plate **1***c*.

In the embodiment according to FIGS. 7 to 11, the base plate **1***c* may be very thin and made, for example, of a thin rubber foil which is highly flexible and expandable in all directions.

The elasticity and flexibility of the base plate **1** permits any movements of the skin and movements of the body. For example, for measuring the electrical resistance of the skin, the embodiments according to FIGS. 7 and 8 may be used. Two apertures are provided in the flat base plate **1***c* at a predetermined distance D. Around each of the openings **11***c* is secured by adhesive a flat ring **7** connected with a conductive connection piece **3***c*. The portion of skin between the two openings **11** is connected in the respective electrical measuring circuit by means of the two connections **3***c*.

It is an advantage of the electrode in accordance with the invention that the pressure at the tested place remains constant which eliminates some disturbing factors associated with existing electrodes of this type, for example, changes in the contact resistance. Direct contact between the metal electrode and the surface of the body is eliminated; eliminates all disadvantages of interfering potentials (artefacts). The sensitivity of the measuring instruments and the overall accuracy of the measurement is increased.

The openings **11***c* form sufficiently large reservoirs for conductive paste which can be applied in a sufficiently strong layer also on the reverse side of the base plate **1***c*, as shown in FIG. 11. The effect of drying of the conductive paste **10***c* on the results of measurement is therefore eliminated.

The electrodes of FIGS. 7 to 11 may also be made to include printed circuitry which can be applied to the base plate **1***c* in curved or meander-shaped formations so as not to diminish the flexibility of the base plate.

It follows from the above that the new electrode for electromechanical measurements ensures the following main technical results:

The possibility of direct contact between the metal connection piece and the surface of the body is eliminated. At the accurately defined tested place a substantially constant contact resistance and pressure are secured. The electrode adapts itself softly to the curvatures of the body, and bioelectrical potentials can be picked up regardless of the movement of the tested object. The small dimensions of the electrode permit the construction of multiple electrodes, and this permits individual picking up or testing on a larger number of places, even if the distance between the various places is small.

In case of measurements extending over a long period

of time, the electrode in accordance with the invention may be arranged so that drying of the electrically conductive paste is prevented.

The electrode in accordance with the invention, regardless of the type of embodiment, does not require special attaching means; it can be simply attached or stuck to the surface of the body. A suitable material for this purpose is mastic dissolved in highly volatile ether which permits this adhesive to dry within a few seconds. Mastic is so intensively soluble in ether that the electrode can be freed from the skin by mere wetting with ether.

What I claim is:

1. An electrode comprising
(a) a thin plate of resilient nonconductive material, having a front face for contacting the surface of a live body, and a reverse face,
(1) said plate being provided with at least a single aperture extending through said plate,
(b) a conductive element held within said aperture, at least a portion of said element being in a spaced relationship with respect to both of said two faces,
(1) said conductive element being formed as a ring positioned so as to line a portion of the wall of said aperture and to extend substantially perpendicular to the skin,
(2) said wall portion being intermediate said front and reverse faces, and
(c) a conductive medium filling said aperture and establishing electrical connection between the skin and said conductive element.

2. An electrode comprising
(a) a thin plate of resilient nonconductive material, having a front face for contacting the surface of a live body, and a reverse face,
(1) said plate being provided with at least a single aperture extending through said plate,
(b) a conductive element formed as a flat strip,
(1) a portion of said strip overlying a portion of said reverse face,
(2) another portion of said strip being bent away to enter said aperture, and
(c) a conductive medium filling said aperture and establishing electrical connection between the skin and said conductive element.

3. The electrode according to claim 2, wherein a plug is removably inserted in said aperture from said reverse face.

4. An electrode comprising
(a) a thin plate of resilient nonconductive material, having a front face for contacting the surface of a live body, and a reverse face,
(1) said plate being provided with at least a single aperture extending through said plate,
(2) said aperture being cylindrical,
(b) a conductive element on said reverse face,
(1) said conductive element being formed as a metal ring on said reverse face and being
(2) concentrically arranged with the opening of said aperture in said reverse face,
(3) the inner diameter of said ring being larger than the diameter of said aperture,
(c) a conductive medium filling said aperture, and
(d) lead means establishing electrical connection between said conductive element and said conductive medium.

5. An electrode comprising
(a) a thin plate of resilient nonconductive material, having a front face for contacting the surface of a live body, and a reverse face,
(1) said plate being provided with at least a single aperture extending through said plate,
(b) a conductive element of said reverse face,
(1) said conductive element being formed as a metallic flat member on said reverse face a distance away from the opening of said aperture in said reverse face,
(c) a conductive medium filling said aperture, and
(d) lead means establishing electrical connection between said conductive element and said conductive medium.

References Cited

UNITED STATES PATENTS

2,493,155	1/1950	McMillan	128—172.1
2,943,628	7/1960	Howell	128—418
3,170,459	2/1965	Phipps et al.	128—2.06
3,187,745	6/1965	Baum et al.	128—2.06
3,295,515	1/1967	Kahn	128—2.06

RICHARD A. GAUDET, *Primary Examiner.*

S. BRODER, *Assistant Examiner.*